No. 24-2123 (Lead)
Also Filed In Nos. 24-2215, 24-2225, & 24-2494

UNITED STATES COURT OF APPEALS
FOR THE EIGHTH CIRCUIT

SOUTHWESTERN ELECTRIC POWER COMPANY, et al.,

Petitioners,

v.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY, and MICHAEL S. REGAN, Administrator, United States Environmental Protection Agency,

Respondents,

CLEAN WATER ACTION, SIERRA CLUB, WATERKEEPER ALLIANCE, INC., NATURAL RESOURCES DEFENSE COUNCIL, INC., ENVIRONMENTAL INTEGRITY PROJECT, PENNENVIRONMENT, INC. and PRAIRIE RIVERS NETWORK,

Respondent-Intervenors.

RESPONDENT-INTERVENORS' RESPONSE TO UTILITY AND STATE PETITIONERS' MOTION FOR A STAY PENDING REVIEW

TABLE OF CONTENTS

TABLE OF AUTHORITIES

Page(s)

Cases

Statutes

Regulations

Federal Register

INTRODUCTION

Utility and State Petitioners' Motion for a Stay Pending Review ("Motion") to the Environmental Protection Agency's ("EPA") final rule strengthening effluent limitation guidelines ("ELGs") for steam electric power plants (the "2024 Rule"),[1] fails to satisfy the stringent standards for a stay. *See Nken v. Holder*, 556 U.S. 418, 433–34 (2009). Movants' challenges to the 2024 Rule are unlikely to succeed because EPA's rulemaking record demonstrates that zero-discharge technologies are available and economically achievable, consistent with Clean Water Act ("CWA") requirements. During the rulemaking process, EPA both adequately considered Movants' concerns that EPA had underestimated compliance costs and reasonably explained its cost methodology and conclusion that the costs of the 2024 Rule can be reasonably borne by the industry.

Movants have also not met their burden to show they will suffer irreparable harm before the Court decides their legal challenges. Movants' arguments ignore the 2024 Rule's lengthy compliance timeline while citing inflated and misleading cost estimates and unsupported reliability claims. Finally, the public interest and balance of equities weigh heavily against staying a rule that will prevent more than 660 million pounds of pollutants from entering U.S. waters each year and provide

[1] 89 Fed. Reg. 40,198 (May 9, 2024).

hundreds of millions of dollars per year in public health and environmental benefits.

Petitioners in consolidated case No. 24-2255, Catawba Riverkeeper and Winyah Rivers Alliance, join this response in full.

The stay motion should be denied.

BACKGROUND

The CWA sets a goal of eliminating water pollution. 33 U.S.C. § 1251(a)(1). To help achieve that goal, EPA must establish, and review every five years and revise as appropriate, ELGs setting increasingly stringent limits for categories of industries based on the capabilities of wastewater treatment technologies. 33 U.S.C. § 1311(b), (d). For toxic pollutants such as heavy metals, the CWA required EPA to set initial standards based on best practicable control technology ("BPT"), *id.* § 1311(b)(1)(A), followed by increasingly more stringent standards based on best available technology economically achievable ("BAT"), *id.* § 1311(b)(2)(A).

BAT represents a stringent treatment standard that is "a commitment of the maximum resources economically possible to the ultimate goal of eliminating all polluting discharges," *EPA v. Nat'l Crushed Stone Ass'n*, 449 U.S. 64, 74 (1980), including "requir[ing] the elimination of discharges of all pollutants" if "such elimination is technologically and economically achievable," 33 U.S.C. § 1311(b)(2)(A).

Congress intended BAT standards to be "technology-forcing,"[2] with EPA looking to the best-performing facilities to determine which technologies are available to the industry as a whole.[3] A technology is "available" if it is in use in the industry, even if only by the best-performing plant, or if it can be demonstrated through pilot studies or use in other industries,[4] so long as EPA shows that the technology is transferable to the industry for which it is establishing BAT.[5]

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[2] *See Nat. Res. Def. Council v. EPA*, 808 F.3d 556, 563–64 (2d Cir. 2015) ("Congress designed [BAT] to be technology-forcing, meaning it should force agencies and permit applicants to adopt technologies that achieve the greatest reductions in pollution."); *Nat. Res. Def. Council v. EPA*, 822 F.2d 104, 123 (D.C. Cir. 1987) ("the most salient characteristic of this [CWA] statutory scheme, articulated time and again by its architects and embedded in the statutory language, is that it is technology-forcing").

[3] *Chem. Mfrs. Ass'n v. EPA*, 870 F.2d 177, 226 (5th Cir. 1989); *see also Nat. Res. Def. Council v. EPA*, 863 F.2d 1420, 1426 (9th Cir. 1988); *Kennecott v. EPA*, 780 F.2d 445, 448 (4th Cir. 1985) ("In setting BAT, EPA uses not the average plant, but the optimally operating plant, the pilot plant which acts as a beacon to show what is possible."); *cf. Riverkeeper, Inc. v. EPA*, 475 F.3d 83, 107–08 (2d Cir. 2007) ("The statutory directive requiring facilities to adopt the best technology cannot be construed to permit a facility to take measures that produce second-best results . . . especially given the technology-forcing imperative behind the Act . . . .") (citations omitted), *rev'd on other grounds sub nom. Entergy Corp. v. Riverkeeper, Inc.*, 556 U.S. 208 (2009).

[4] *See Chem. Mfrs. Ass'n*, 870 F.2d at 226; *Am. Petroleum Inst. v. EPA*, 858 F.2d 261, 265 (5th Cir. 1988) (BAT need not be "in use" to be "deemed 'available'"); *Kennecott*, 780 F.2d at 448; *FMC Corp. v. Train*, 539 F.2d 973, 983–84 (4th Cir. 1976) (EPA justified in setting BAT based on performance data from a single pilot plant).

[5] *Kennecott*, 780 F.2d at 453 ("Progress would be slowed if EPA were invariably limited to treatment schemes already in force at the plants which are the subject of the rulemaking."); *see also Reynolds Metals Co. v. EPA*, 760 F.2d 549, 562 (4th Cir. 1985).

Congress intended BAT to "push[] industries toward the goal of zero discharge as quickly as possible."[6]

A technology is economically achievable if the "costs can be reasonably borne by the industry."[7] EPA determines BAT for industrial categories, rather than plant by plant,[8] and therefore considers costs to the industry as a whole.[9] In determining BAT, costs are to be given less importance than for the less stringent BPT standards. Congress underscored this by requiring EPA to balance costs against benefits for BPT but omitting any cost-benefit analysis from BAT requirements.[10] Accordingly, courts have consistently held that EPA is precluded from basing a BAT determination on cost-benefit analysis.[11]

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[6] *Kennecott*, 780 F.2d at 448.
[7] *Waterkeeper All., Inc. v. EPA*, 399 F.3d 486, 516 (2d Cir. 2005); *Rybachek v. EPA*, 904 F.2d 1276, 1290–91 (9th Cir. 1990) (discussing this standard).
[8] *E.I. du Pont de Nemours & Co. v. Train*, 430 U.S. 112, 127 (1977).
[9] *See Am. Iron & Steel Inst. v. EPA*, 526 F.2d 1027, 1051 (3d Cir. 1975) (cost must be considered "on a class or category basis, rather than [on] a plant-by-plant basis").
[10] *Compare* 33 U.S.C. § 1314(b)(1)(B) *with id.* § 1314(b)(2)(B).
[11] *See, e.g.*, *Entergy Corp.*, 556 U.S. at 222 (affirming that only certain CWA standards "authorize cost-benefit analysis" and that BAT is not one of them); *Nat'l Crushed Stone*, 449 U.S. at 71 ("[I]n assessing BAT total cost is no longer to be considered in comparison to effluent reduction benefits."); *Am. Iron & Steel Inst.*, 526 F.2d at 1052 n.54 ("cost-benefit analysis is not required at all" for BAT); *CPC Int'l, Inc. v. Train*, 540 F.2d 1329, 1341–42 (8th Cir. 1976) (BAT guidelines are "governed by a standard of reasonableness without the necessity of a thorough cost-benefit analysis"); *Reynolds Metals Co.*, 760 F.2d at 565 ("no balancing is required" for BAT); *Rybachek*, 904 F.2d at 1290–91 (EPA "need not compare [control] cost with the benefits of effluent reduction"); *BP Expl. & Oil, Inc. v.*

The 2024 Rule is EPA's third in a series of rulemakings since 2015 updating the steam electric ELGs. 89 Fed. Reg. at 40,199, 40,203–04. In April 2019, the U.S. Court of Appeals for the Fifth Circuit vacated certain provisions of the 2015 Rule because EPA had purported to determine that "demonstrably outdated and ineffective" surface impoundments were BAT for those waste streams. *Sw. Elec. Power Co. v. EPA*, 920 F.3d 999, 1031 (5th Cir. 2019). This decision reaffirmed the well-established law that ELGs are required to be technology-forcing, and that BAT must be based on the best-performing plant in the industry and the most effective technologies that are available and achievable. *See generally id.* at 1004–07, 1015–33.

The 2024 Rule requires power plants that intend to operate past 2034 to utilize commercially available, affordable treatment technologies to eliminate discharges of toxic pollutants from their three largest toxic waste streams: flue gas

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EPA, 66 F.3d 784, 799–800 (6th Cir. 1995) (rejecting industry demand for cost-benefit analysis because BAT "does not require cost-benefit analysis" and "EPA need only find . . . that the cost of the technology is reasonable"); *Tex. Oil & Gas Ass'n v. EPA*, 161 F.3d 923, 928 (5th Cir. 1998) (underlining that "BAT is the CWA's most stringent standard" and must be set based not on cost-benefit analysis but on "performance of the single best-performing plant in an industrial field"); *Waterkeeper All., Inc.*, 399 F.3d at 516 (BAT can be set to level that can "reasonably be borne by a given industry"); *Am. Paper Inst. v. Train*, 543 F.2d 328, 354 (D.C. Cir. 1976) ("Section 304(b)(2)(B) mandates no [cost-benefit] balancing"); *Ass'n of Pac. Fisheries v. EPA*, 615 F.2d 794, 805 (9th Cir. 1980) ("The conspicuous absence of the comparative language contained in section 304(b)(1)(B) leads us to the conclusion that Congress did not intend the Agency or this court to engage in marginal cost-benefit comparisons [for BAT].").

desulfurization ("scrubber") wastewater, bottom ash transport water, and combustion residual leachate ("leachate"). 40 C.F.R. § 423.13(g)(4), (k)(4), (*l*)(1). The Rule also creates a new subcategory for power plants that commit to retire by 2034 that allows them to avoid the new, more stringent requirements, *id.* § 423.13(g)(4)(iii), (k)(4)(iii), (*l*)(2)(i). Movants request that this Court stay these and other 2024 Rule requirements in their entirety.[12]

ARGUMENT

I. MOVANTS ARE NOT LIKELY TO SUCCEED ON THE MERITS.

A. EPA's BAT Determination Comports with the Well-Established Meaning of "Available."

EPA lawfully determined that BAT for scrubber wastewater and leachate can achieve zero discharge pollutant limits and that membrane filtration and other technology options to meet those limits are available. Movants allege that zero-discharge technology is "not available to actually (and if so reliably) achieve zero discharge limits." Motion at 19. However, Movants erroneously rely upon a general-usage definition of "available" in Merriam-Webster rather than the

[12] Despite this request, Movants' arguments exclusively concern the 2024 Rule's scrubber and "managed" leachate limits, which they claim require membrane and evaporator technologies. *See, e.g.*, Motion at 19 & Motion Ex. 1 (¶¶ 19–26, 37), Ex. 6 (at 5, 91, 157), Ex. 19 (¶ 25), Ex. 20 (¶ 13), Ex. 21 (¶ 12), Ex. 22 (¶ 7). Because limits on other waste streams and other changes to the regulations do not relate to those technologies, Movants offer no basis for staying those limits.

definition determined by the courts applying this statute. Courts have consistently held that BAT technology is "available" if it is in use in the industry, even if only by the best-performing plant, or if it can be demonstrated through pilot studies or use in other industries. *See Chem. Mfrs. Ass'n*, 870 F.2d at 226; *Am. Petroleum Inst.*, 858 F.2d at 265; *Kennecott*, 780 F.2d at 448; *FMC Corp.*, 539 F.2d at 983–84.

Here, EPA did much more than determine that zero-discharge technology is "merely 'possible,'" or "wish[] [it] into existence," as Movants argue. Motion at 20. Rather, the record shows membrane filtration is available because it is being used in "different subcategor[ies] or categor[ies], bench scale or pilot plant studies, [and] foreign plants." 89 Fed. Reg. at 40,202 (citing *Sw. Elec. Power Co.*, 920 F.3d at 1006). EPA completed a "Preliminary Technology Review" of membrane treatment and listed twenty-three industrial categories, including the steam electric industry, that use the technology.[13] EPA also identified at least three domestic plants using membrane filtration[14] and twenty-two domestic pilot applications,[15] as

[13] Ex. 1 at 5, Tbl.2.
[14] *See* Ex. 2 at Tbl.2. This table suggests that there are at least three plants (Cross Generating Station, Monroe Power Plant, and Plant Scherer) that have already purchased and installed membrane filtration systems, two of which are able to meet a zero-discharge standard without any additional investment.
[15] 88 Fed. Reg. 18,824, 18,840 (Mar. 29, 2023).

well as "American-made" zero-discharge systems that have routinely been used in other countries since 2015.[16]

Additionally, there are multiple options other than membrane filtration, which can be used alone or in combination, to meet the zero-discharge limit. *See id.* at 40,208–09. Forty domestic coal plants with wet scrubber systems have already achieved zero-discharge using other technologies, including evaporation systems. *Id.* at 40,216. In fact, more domestic facilities operate, or have operated, zero-discharge systems than the biological treatment systems on which EPA based BAT limits in 2015 and 2020. *Id.*

B. EPA Lawfully Determined That Zero-Discharge Technology Is Economically Achievable.

1. Membrane filtration is economically achievable because the costs can be reasonably borne by the industry.

The record shows that, after updating the analysis and modeling for the final rule, EPA lawfully determined that membrane filtration is economically achievable for the industry. 89 Fed. Reg at 40,219, 40,257–59. EPA also confirmed with new information that membrane filtration is often cheaper than the technology required by the 2020 Rule. *Id.* at 40,213, n.64. Moreover, EPA determined that other zero-discharge technologies are economically achievable and, in some cases, the

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[16] 89 Fed. Reg. at 40,216; *see also* Ex. 3.

cheapest options. *See, e.g.*, 88 Fed. Reg. at 18,843, n.60 (stating that the cost of evaporation treatment is "economically achievable").

Finally, EPA found that the 2024 Rule as a whole—including the zero-discharge scrubber wastewater, bottom ash transport water, and leachate requirements—is economically achievable. EPA usually determines economic achievability based on costs to the industry and subcategory financial conditions. 89 Fed. Reg. at 40,202. A cost-to-revenue ratio of less than one percent suggests that a plant or owner is "unlikely to face economic impacts." *Id.* at 40,264. In this case, EPA identified between 220 and 391 entities owning regulated energy-generating units, and found that less than one percent of those plant owners would incur costs exceeding one percent of revenue. *Id.*; Ex. 4 at 4-5 to 4-9. Thus, the record shows that the costs of eliminating scrubber wastewater using zero-discharge technologies can be "reasonably borne by the industry." *Waterkeeper All., Inc.*, 399 F.3d at 516; *Rybachek*, 904 F.2d at 1290–91.

2. *EPA did not "sidestep" any demonstrated errors in its cost-estimation methodology.*

Movants claim that EPA's BAT determination for scrubber wastewater and leachate was flawed because the Agency arbitrarily "sidestepped" alleged errors in its cost-estimation methodology. Motion at 21–23. Movants acknowledge, however, that in response to EPA's request for performance and cost data, utilities provided "data in the wrong format or with insufficient specificity." *Id.* at 22.

Despite these utility-caused data errors, EPA responded to utilities that provided cost estimates for specific plants, including by revising its cost methodology for membrane filtration, which resulted in higher plant-level estimates. *See* Ex. 5 at 1188, 1192–97.

Movants also claim EPA acted arbitrarily by acknowledging underestimated compliance costs for some plants without questioning its BAT determinations as a result. Motion at 22. But the CWA requires EPA to determine BAT for industrial categories, not plant by plant,[17] based on costs to the industry as a whole.[18] EPA acknowledged it may have underestimated compliance costs for some plants, but noted also that it "likely . . . overestimated costs for other plants," Ex. 5 at 1188, and its "cost estimates do not account for leasing treatment technology equipment and may therefore be overestimated for some plants," *id.* at 1169. Further, there are several ways industry presented its cost estimates, both in comments and the Motion here, that exaggerate the extent to which they appear larger than EPA's cost estimates. *See generally* Ex. 6 (discussing how Movants' costs estimates are based on overdesigned and unnecessarily complex systems, use different scrubber flow optimization approaches, fail to provide underlying calculations or inputs, and

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[17] *E.I. du Pont de Nemours & Co.*, 430 U.S. at 127.
[18] *Am. Iron & Steel Inst.*, 526 F.2d at 1051.

compare estimates from different years using different dollar values).[19] Thus, EPA did not "sidestep" any errors in its cost methodology; rather, the Agency adequately determined that "[o]verall, the EPA's cost estimates provide a reasonable estimate for purposes of determining economic achievability, as required by the CWA." Ex. 5 at 1188; *see also* Ex. 6 at 9 (concluding that "EPA's cost estimating methodology was based on reasonable and prudent engineering practices and cost estimating practices").

3. *EPA adequately considered reliance costs and provided a reasoned explanation for its BAT determination in the 2024 Rule.*

Movants' argument that EPA failed to account for the "substantial costs incurred in reliance on the 2020 Rule," Motion at 23, similarly fails. When an agency takes action that changes prior policy, the agency must provide a "reasoned explanation" for its change in position if "its prior policy has engendered serious reliance interests that must be taken into account." *F.C.C. v. Fox Television Stations, Inc.*, 556 U.S. 502, 515 (2009).

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[19] Although the Court must base its review on the record and not consider extra-record evidence to determine whether Movants are likely to succeed on the merits, *Voyageurs Nat. Park Ass'n v. Norton*, 381 F.3d 759, 766 (8th Cir. 2004), Exhibit 6 (Declaration of Kevin Draganchuk, P.E., BCEE, and attached technical memorandum) summarizes and explains information included in EPA's rulemaking record. To the extent the Court considers Movants' extra-record evidence, it should also consider Exhibit 6. The exhibit is also offered to rebut Movants' arguments that their extra-record evidence demonstrates irreparable harm.

Here, EPA did more than merely demonstrate "awareness" that industry had incurred costs to comply with the 2020 Rule. Motion at 24. In response to industry comments, EPA provided a reasoned explanation for selecting zero-discharge technology as BAT in the 2024 Rule. EPA evaluated both the costs of the 2020 Rule and 2024 Rule in its cost analysis and determined that "even the cumulative cost of the two technologies [required to comply with both rules] is economically achievable." 89 Fed. Reg. at 40,219. As EPA explained, when more stringent technologies are available and economically achievable, "the fact that facilities may have to spend more to supplement or replace existing treatment systems, even relatively new ones, is not a sufficient reason on its own to reject selection of the technology." *Id.* Further, although facilities must meet BAT limitations "as soon as possible," 40 C.F.R. § 423.13(g)(4)(i)(A), EPA accounted for reasonable reliance interests by including a "'no later than' date approximately five-and-a half years following promulgation" of the rule, 89 Fed. Reg. at 40,219. Thus, contrary to Movants' claims, EPA understood and accounted for industry's costs to comply with the 2020 Rule when establishing the 2024 Rule's requirements, while providing a reasoned explanation for its change in position. *See Ohio v. EPA*, 144 S. Ct. 2040, 2054–55 (2024); *Fox Television*, 556 U.S. at 515.

II. MOVANTS FAIL TO SHOW IRREPARABLE HARM.

Movants' speculative claims do not justify the extraordinary remedy of a stay because they fail to demonstrate they "will *in fact*" suffer irreparable harm that is "both certain and great," and "will directly result" from the 2024 Rule during the pendency of this litigation. *Packard Elevator v. I.C.C.*, 782 F.2d 112, 115 (8th Cir. 1986) (quoting *Wis. Gas Co. v. FERC*, 758 F.2d 669, 674 (D.C. Cir. 1985)); *see also Nken*, 556 U.S. at 432–34 ("The party requesting a stay bears the burden of showing that the circumstances justify" the "extraordinary remedy" of a stay.). "[T]heoretical" harm is insufficient; the harm must be "actual" and of "such *imminence* that there is a 'clear and present' need" to stay the 2024 Rule pending judicial review. *Packard Elevator*, 782 F.2d at 115; *see also Morehouse Enters., LLC v. Bureau of Alcohol, Tobacco, Firearms & Explosives*, 78 F.4th 1011, 1018 (8th Cir. 2023) (denying injunction where alleged compliance costs were uncertain and feared to occur at some indefinite time).

A. Movants Do Not Prove They Will in Fact Incur Great Costs Imminently.

Movants claim the 2024 Rule requires utility petitioners to "spend massive sums of money starting right now." Motion at 25. These arguments ignore the 2024 Rule's lengthy compliance timeline while citing inflated and misleading cost estimates and unsupported reliability claims.

The rulemaking record shows utilities can achieve compliance with the 2024 Rule's limits in roughly two years or less, undercutting Movants' claims that they would need to incur significant costs immediately to meet the December 31, 2029 compliance deadline. *See, e.g.*, Ex. 7 at PDF pp. 4, 6, 21, 26, 32. Further, the 2024 Rule's new limits do not apply to utilities until incorporated into facility-specific CWA permits, which are typically renewed no more frequently than every five years. Ex. 5 at 1135. At most, utilities will incur minimal compliance costs in the near term. *See West Virginia v. EPA*, No. 24-1120, 2024 WL 3542546, at *1 (D.C. Cir. July 19, 2024) (denying a motion to stay EPA's greenhouse gas regulations because the "actual compliance deadlines do not commence until 2030 or 2032—years after this case will be resolved.").

Moreover, though this case's schedule is not yet set, the parties have proposed briefing deadlines through March 2025. This case could thus be argued and decided by this Court long before December 2029, and even potentially in advance of the December 2025 deadline for plants to notify EPA if they intend to cease burning coal by 2034 instead of complying with the 2024 Rule's limits. 89 Fed. Reg. at 40,297, 40,304.

Movants' assertions that utilities will incur unrecoverable near-term compliance costs are unsupported. Movants rely on conclusory statements from declarations that lack underlying documentation, meriting little if any weight.

Packard Elevator, 782 F.2d at 115 ("Bare allegations of what is likely to occur are of no value since the court must decide whether the harm will *in fact* occur."). When Movants do provide underlying documentation, they cite unreasonable and unrepresentative examples. For example, Movants point to an estimate for Plant Miller, Motion at 17, that is based on an "overdesigned" and "unnecessarily complex" treatment system and thus is highly inflated. Ex. 6, Attach. A at 1–3; *see also id.* at 4–8 (explaining that EPRI's industry-wide 2024 Rule cost estimates are inflated). Movants also ignore that utilities could reduce compliance costs by leasing, rather than buying, zero-discharge technologies and/or repurposing existing equipment, including technologies installed to comply with the 2020 Rule. *See, e.g.*, Ex. 5 at 1166, 1169.

Although Movants highlight 2020 Rule compliance cost estimates that were larger than EPA's, this is not direct evidence that the 2024 Rule will harm them. *See Packard Elevator*, 782 F.2d at 115. In any event, Movants fail to explain or document how those estimates were developed, leaving no way to evaluate their credibility or ascertain why they were larger than EPA's estimates. *See, e.g.*, Motion, Ex. 5 at 13, 17 (showing only a summary line item for "[scrubber] WWT Capital" for Plant Mitchell); Ex. 6, Attach. A at 3–4. They were also just estimates; utilities' *actual* compliance costs for the 2020 Rule may be far less. For example, two Kentucky utilities recently projected actual compliance costs $132.6 million *lower* than their 2020 estimates for three plants (Ghent, Mill Creek, and Trimble County), Ex. 8 at 1, that Movants rely on to show cost estimates exceeding EPA's, Motion at 15. Similarly, one of Movants' declarants asserts that 2020 Rule compliance costs at three plants totaled $94 million, Motion Ex. 1 ¶ 24, but the utility had previously estimated that the compliance costs *at one plant alone* would be $148.5 million, *see* Ex. 9 at PDF p. 47, and at another plant $48.4 million, *see id.* at PDF p. 48, underscoring how pre-compliance estimates are often far larger than actual compliance costs. Movants also compare EPA's estimates in 2018 dollars to industry estimates that use dollar values from more recent years; by not holding the dollar value constant, this "flawed approach" inflates the appearance of a difference between EPA and industry estimates. Ex. 6, Attach. A at 9.

B. Movants Speculate About Reliability Harms.

The Rule will not trigger any reliability problems, let alone imminently. Ex. 10 ¶¶ 19–21;[20] *contra* Motion at 27. EPA established a December 2029 timeframe for compliance with new limits, and plants that opt to retire or convert to gas can continue operating until 2034 before transitioning. Moreover, retiring plants can operate beyond 2034 if needed for reliability. 89 Fed. Reg. at 40,284, 40,302–03. Because the 2024 Rule includes these flexibilities, there is no basis for assuming

[20] Exhibit 10 (Declaration of Metin Celebi, Ph.D.) is offered to rebut Movants' arguments that their extra-record evidence demonstrates irreparable harm.

the 2024 Rule will "directly result" in plant retirements or reliability problems during this litigation. Movants' repeated invocation of EPA's separate regulation of power plants' greenhouse gas emissions (Motion, Ex. 1 ¶¶ 36, 40–41, Ex. 19 ¶ 44, Ex. 20 ¶ 35)—which is not at issue in this case—underscores their failure to show that any harm to grid reliability would "directly result" from the 2024 Rule itself.

Movants nevertheless claim that a stay is required to maintain reliability. They are mistaken. First, EPA estimates that only thirty-five power plants will incur costs under the 2024 Rule—five percent of the total 688 steam electric power plants in the country—and those costs will be relatively modest. 89 Fed. Reg. at 40,265–66; Ex. 10 ¶¶ 5, 14. EPA modeled the 2024 Rule's impacts and found that, by 2035, only five power plants (0.7% of U.S. generation capacity) might retire earlier than planned. 89 Fed. Reg. at 40,265. Movants provide no evidence that this would certainly and imminently impact reliability during this litigation.

Second, energy market economics, not the 2024 Rule, have been, and will continue to be, the primary driver for coal-plant retirement decisions. Ex. 10 ¶¶ 6–16. Over the past two decades, coal plant retirements have resulted from declining gas prices, the increasing unreliability and cost to operate aging coal plants, and rapid growth in renewables. *Id.*; Ex. 4 at 2-15. These economic and cost factors affect all coal plants, whereas the 2024 Rule affects only a fraction of plants.

Third, the Motion fails to acknowledge that utilities, regulators, and transmission organizations charged with maintaining the grid are already taking steps to ensure grid reliability, including planning for resource adequacy, and have several tools to address reliability impacts if and when they arise. 89 Fed. Reg. at 40,208; Ex. 10 ¶ 20.

Finally, Movants assert only that retirements "*could* undermine reliability." Motion at 27, Ex. 19 at 41, n.7 ("*could* place the reliability of the electric grid in jeopardy") (emphasis added), Ex. 20 ¶ 30 ("potential reliability risks"), Ex. 23 ¶¶ 7–9 ("I have concerns that the Final Rule will undermine [] reliability . . . beginning in 2028 if currently expected generator requirements actually occur."). These speculative harms are insufficient to justify the "extraordinary" remedy of a stay. *Winter v. Nat. Res. Def. Council*, 555 U.S. 7, 22 (2008); *Packard Elevator*, 782 F.2d at 115.

C. Any Near-Term Planning Costs Would Be Minimal.

Movants similarly fail to prove the 2024 Rule will directly result in significant near-term costs to evaluate retrofits or replacement generation. Motion at 25–26. Their vague concerns about resource planning costs are speculative and unquantified, and prudent utility practice inherently entails continuous evaluation of regulatory risks and the costs and benefits of replacement generation. Ex. 11

¶¶ 4, 10.[21] Regulators and grid operators are likewise responsible for continually evaluating resource adequacy, regardless of the 2024 Rule and whether it is stayed. Ex. 10 ¶ 20. Moreover, Movants fail to demonstrate that any engineering costs would be "great" relative to utilities' parent companies' multi-billion-dollar operating revenues. Ex. 11 ¶¶ 33–34; *Packard Elevator*, 782 F.2d at 115. And, for regulated utilities, like some Movants, those planning and engineering costs would be recoverable from customers if prudently incurred. *Id.* ¶¶ 19, 34.

Finally, Movants claim any retirement decision is "effectively irreversible," Motion at 26, but they fail to identify any "certain" or "imminent" retirement decision that must be made before this Court reaches the merits.

In sum, Movants' efforts to show "great," "certain," and "imminent" harm fail.

III. THE PUBLIC INTEREST AND BALANCE OF EQUITIES WEIGH HEAVILY AGAINST A STAY.

The public interest and the balance of equities among interested parties also weigh heavily against a stay. *See Nken*, 556 U.S. at 434.

Coal plants dump large quantities of harmful pollutants into U.S. waterways. *See, e.g.*, Ex. 12 at Tbl.26 (estimating that under a baseline scenario assuming full compliance with the 2020 Rule, power plants will discharge 807 million pounds of

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[21] Exhibit 11 (Declaration of Devi Glick) is offered to rebut Movants' arguments that their extra-record evidence demonstrates irreparable harm.

pollutants per year). Many of these pollutants cause neurological impairment, cancer, and other human health effects, and harm to aquatic life and fish-eating wildlife. Ex. 13 at 3-1 to 3-12. EPA estimates that power plants' discharges negatively affect public water systems supplying drinking water for over 30 million people and the habitats for "over 100 high-vulnerability threatened and endangered species." 89 Fed. Reg. at 40,276. Among other things, EPA projects that under a baseline scenario assuming full 2020 Rule compliance, power plant discharges will continue to make water unsafe for human use in 38 waterbodies and render 777 downstream river miles unsafe for human health or wildlife. Ex. 14 at 32, Tbl.9, 50, Tbl.21.

People who live, work, and recreate downstream from coal plant discharges are concretely harmed by the diminished water quality those facilities cause. *See, e.g.*, Ex. 15. Some impacted waterbodies supply drinking water to communities. *See, e.g.*, Ex. 15 at Hill Decl. ¶¶ 9–11; McKiernan Decl. ¶¶ 5–6. Many community members have reduced or entirely stopped using and enjoying those waterways, due to concerns over the health effects of ingesting or contacting toxic pollutants, or consuming fish caught in those waters. *See, e.g.*, Ex. 15 at McKiernan Decl. ¶ 9; Limbach Decl. ¶¶ 8–9, 11; Sprouse Decl. ¶¶ 6–9, 12–13; Kotcon Decl. ¶¶ 7, 9, 12; Davis Decl. ¶ 6.

If the 2024 Rule were stayed, and any compliance deadlines were subsequently delayed, impacted community members would continue to be harmed and deprived of the health and environmental benefits of improved water quality. According to EPA, the 2024 Rule would prevent the dumping of over 660 million pounds of pollutants into U.S. waterways each year. 89 Fed. Reg. at 40,198, 40,267. EPA's Benefit-Cost Analysis demonstrates that the 2024 Rule's benefits are three to six times greater than its costs—even as EPA acknowledges that a significant portion of the rule's benefits are not quantified or monetized (and therefore undercounted). Ex. 16 at ES-4, Tbl.ES-3. The 2024 Rule's benefits include, among others, avoiding ninety-eight bladder cancer cases and twenty-eight cancer deaths attributable to bromide pollution of drinking water sources from power plant discharges, *id.* at 4-20, Tbl.4-8, and reducing the number of waterbodies that are unsafe for fish-eating wildlife by eighty-five percent, and that present a risk of cancer to humans from eating arsenic-containing fish by seventy-eight percent, Ex. 14 at 5.

Even short delays in water quality improvements caused by a stay of the 2024 Rule and any subsequent delay of compliance deadlines would result in significant harm. For example, short-term human exposure to mercury *in utero* can cause permanent neurological damage and IQ loss. Ex. 16 at 4-26. Similarly, ecological damage from toxic pollutants can occur in short periods of time, "and even short periods of exposure (e.g., less than a year) can cause observable ecological impacts that last for years." Ex. 14 at 2. These significant harms strongly weigh against staying the 2024 Rule.

CONCLUSION

For the reasons set forth above, the Court must deny Utility and State Petitioners' stay motion.

Respectfully submitted this 20th day of August, 2024.

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CERTIFICATE OF COMPLIANCE

Pursuant to Federal Rules of Appellate Procedure 27 and 32(g)(1), the undersigned counsel for Respondent-Intervenors certifies that this response complies with (1) with the type-volume limitation of Federal Rule of Appellate Procedure 27(d)(2)(A) because it contains 5199 words and (2) with the typeface and type-style requirements of Federal Rules of Appellate Procedure 27(d)(1)(E) and 32(a)(5)–(6) because it has been prepared using Microsoft Office Word for Office 365 and is set in Times New Roman font in size equivalent to 14 points or larger.

*<u>/s Thomas Cmar</u>*_______________________
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CERTIFICATE OF SERVICE

I certify that on August 20, 2024, this response to Utility and State Petitioners' stay motion and accompanying attachments were served on all parties via this Court's CM/ECF system.

*/s Thomas Cmar*______________________
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Index of Exhibits

Ex. 1	EPA, Preliminary Technology Review: Membrane Wastewater Treatment, Docket ID No. EPA-HQ-OW-2021-0547-0172 (Sept. 2021).
Ex. 2	EPA, Generating Unit-Level Costs and Loadings Estimates by Regulatory Option for the 2023 Proposed Rule, Docket ID No. EPA-HQ-OW-2009-0819-9686 (Feb. 28, 2023).
Ex. 3	EPA, Technologies for the Treatment of Flue Gas Desulfurization Wastewater, Coal Combustion Residual Leachate, and Pond Dewatering, Docket ID No. EPA-HQ-OW-2009-0819-10358 (Apr. 22, 2024).
Ex. 4	EPA, Regulatory Impact Analysis for Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category, Docket ID No. EPA-HQ-OW-2009-0819-10348 (Apr. 18, 2024).
Ex. 5	EPA, Response to Public Comments for Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category, EPA-HQ-OW-2009-0819-10584 (Apr. 2024).
Ex. 6	Declaration of Kevin Draganchuk, P.E., BCEE (Aug. 13, 2024), and Attachments A and B thereto.
Ex. 7	Compilation of Record Evidence on FGD Treatment Installation Timelines (compiling, in full, Docket ID Nos. EPA-HQ-OW-2009-0819-8191, EPA-HQ-OW-2009-0819-8179, Attach. 18 to EPA-HQ-OW-2009-0819-7617, and EPA-HQ-OW-2009-0819-8887 and, as excerpted, Docket ID No. EPA-HQ-OW-2009-0819-8155).
Ex. 8	Louisville Gas & Electric Company and Kentucky Utilities Company, 2020 ECR Plan Status Update Report, Quarterly Report – Update #15, Case Nos. 2020-00060 & 2020-00061 (Ky. P.S.C. July 30, 2024).
Ex. 9	Direct Testimony of Brian D. Sherrick, Case No. PUR-2022-00001, Petition of Appalachian Power Company for approval of a rate adjustment clause, the E-RAC, for costs to comply with state and federal environmental regulations pursuant to § 56-585.1 A 5 e of the Code of Virginia (Va. State Corp. Comm’n filed Mar. 21, 2022).
Ex. 10	Declaration of Metin Celebi, Ph.D. (Aug. 16, 2024).
Ex. 11	Declaration of Devi Glick (Aug. 20, 2024).

Ex. 12	EPA, Technical Development Document for Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category, Docket ID No. EPA-HQ-OW-2009-0819-10337 (Apr. 2024).
Ex. 13	EPA, Environmental Assessment for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category, Docket ID No. EPA-HQ-OW-2009-0819-6427 (Sept. 2015).
Ex. 14	EPA, Environmental Assessment for Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category, Docket ID No. EPA-HQ-OW-2009-0819-10309 (Apr. 2024).
Ex. 15	Declarations from Staff and Members of Clean Water Action, Sierra Club, Waterkeeper Alliance, Inc., Natural Resources Defense Council, Inc., Environmental Integrity Project, PennEnvironment, Inc., and Prairie Rivers Network, as submitted to the Court in support of their motion to intervene as respondents in Case No. 24-2123 et al. (June 27, 2024).
Ex. 16	EPA, Benefit and Cost Analysis for Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category, Docket ID No. EPA-HQ-OW-2009-0819-10346 (Apr. 18, 2024).

Exhibit 1

Preliminary Technology Review: Membrane Wastewater Treatment

1. Introduction

EPA reviewed information on membrane treatment of wastewater from previous effluent limitations, guidelines, and standards (ELGs) and EPA's Industrial Wastewater Treatment Technology (IWTT, https://www.epa.gov/eg/industrial-wastewater-treatment-technology-database-iwtt) database as of August 2021 to summarize the status in industrial applications, provide an overview of the technology for use in industry studies, and characterize treatment capabilities. Section 2 includes an overview of membrane wastewater treatment and treatment capabilities. Section 3 describes considerations for evaluating this technology as part of an industry study or rulemaking. Section 4 presents references.

2. Technology Overview

A membrane is a barrier that allows certain substances to pass through while blocking others. In wastewater treatment applications, membranes allow water to pass through while preventing unwanted substances from passing through with the water. This occurs when a driving force is applied, such as a pressure differential. Molecules and particles smaller than the pore size, the spaces or voids in the membrane, pass through the membrane to the opposite side while larger matter builds up in a cake layer on the membrane surface. Accumulated material on the membrane surface must be cleaned to maintain membrane performance.

Depending on the pore size and membrane configuration, membranes can be used to treat total suspended solids (TSS), total dissolved solids (TDS), oil and grease, microbes, natural organic matter, and minerals. Key streams generated by membrane treatment include:

- **Permeate** - The treated wastewater stream produced by membrane treatment. This is the water that passes through the membrane pores.
- **Concentrate** – The material that does not pass through the membrane. This can also be referred to as reject. Portions of this stream can be recirculated back to the inlet of the membrane for further treatment, further treated by other technologies, or disposed.
- **Wastewater generated from cleaning operations** – This includes spent cleaning chemicals and material built up on the surface of the membrane.

Membrane systems are often characterized by their percent recovery, which refers to the amount of influent that will be recovered as permeate. This value will vary based on the characteristics of the water being treated and the membrane but is useful to determine the amount of concentrate that will need to be managed. For example, a membrane system with 80 percent recovery that treats a 100 gallon per minute flow will generate in 80 gallons per minute of permeate and 20 gallons per minute of concentrate.

Disposal options for the concentrate stream will depend on the volume and characteristics Potential concentrate management options include:

- Deep-well Injection – Sequestering the concentrate stream deep underground, below drinking water aquifers. This disposal option can be used for smaller amounts of wastewater and depends on wastewater characteristics and the proximity to a well that is able to accept the wastewater.
- Evaporation Pond(s) – Using ponds to evaporate water and isolate solids. This type of disposal option is best suited for plants located in arid climates with a large amount of land available.
- Land Application – Applying the waste stream to soil surfaces. This type of disposal can be limited to those locations near land willing to accept the wastewater.
- Offsite Waste Management – Sending the stream to a centralized waste treatment (CWT) facility, publicly owned treatment works (POTW), or offsite disposal contractor.
- Additional wastewater treatment - Using additional treatment technologies to achieve further reduction in volume or eliminating the water and generating a solid stream. This could include using evaporation/crystallization or other thermal technologies operated to remove all or part of the liquid portion of the stream or filter presses where solids are disposed, and liquid is recycled.

Fouling is the general term for substances present in the wastewater absorbing or depositing on the surface of the membrane. The substances can be inorganic material such as salts, organic matter like fats, oils, or greases, or biofouling from the formation of biofilms on the membrane surface. A declining in the flow through the membrane or an increase in the driving force required to maintain the flow can indicate the need for membrane cleaning and eventually decreases the lifespan of the membrane. Membranes can be cleaned using chemicals or injecting air in the inlet water to create a turbulent environment to flush fouling substances off the membrane surface. Chemical cleaning solutions are generally acidic in nature but can vary based on the membrane material and wastewater characteristics. Spent cleaning wastewater can require neutralization prior to disposal. Depending on the characteristics, spent cleaning wastewater can be combined with membrane concentrate for disposal.

Even with regular cleaning, membranes can still degrade over time. Pores can become clogged, or cleaning operations are unable to clean all the fouling material. Pressure drop across a membrane is regularly monitored as an indicator of when membrane cleaning or replacement is needed. As the pressure drop across the membrane increases, it is becoming more and more difficult for water to pass through the membrane. If cleaning is unable to reduce the drop in pressure it may signal a need to replace the membrane. Studies of membrane life based on membrane replacements suggest a life of approximately eight years, with ceramic membranes expected to last longer (Judd, 2018). However, the timing of cleaning and life of a membrane will vary based on many factors including influent wastewater characteristics, operating pressures, and membrane configuration.

Membrane processes are often distinguished by the pore size and/or the process by which they affect separation. The most common membrane processes used for treatment of industrial wastewater are:

- Microfiltration
- Ultrafiltration
- Nanofiltration
- Reverse osmosis

Microfiltration (MF), ultrafiltration (UF), and nanofiltration (NF) use pressure to help force water through a semi-permeable membrane. Separation occurs based on the size of the pores as the water is pushed through. Reverse osmosis (RO) also uses pressure, but typically a much higher pressure than MF, UF, or NF, and relies on principles of osmosis. Osmosis occurs when a semi-permeable membrane separates two salt solutions of different concentrations. The water will migrate from the weaker solution to the stronger solution, until the two solutions are of the same concentration, because the semi-permeable membrane allows the water to pass through, but not the salt. In reverse osmosis, the two solutions are still separated by a semi-permeable membrane, but pressure is applied to reverse the natural flow of the water. This forces the water to move from the more concentrated solution to the weaker. The contaminants end up on one side of the semi-permeable membrane and the treated water is on the other side. Table 1 compares the most common membrane processes used for industrial wastewater treatment.

Table 1. Membrane Process Comparison

Process	Pore Size	Typical Operating Pressure	Pollutants Removed	Notes
MF	0.1 – 10 µm	< 50 psi	• Suspended solids • Macromolecules • Colloids • Bacteria	• Can be used as stand-alone treatment or prior to RO to reduce system size and fouling potential.
UF	0.001 – 0.1 µm	< 50 psi	• Suspended solids • Proteins • Fatty acids • Pathogens, viruses • Silica	• Can be used as stand-alone treatment or prior to RO to reduce system size and fouling potential.
NF	1-10 nm	50 – 150 psi	• Calcium • Heavy metals • Salts • Dissolved organics	• The basic design guidelines, operational parameters, and process considerations for NF and RO are similar.
RO	<1 nm	125 – 1,200 psi[a]	• Monovalent atoms (e.g., chlorine) • Heavy metals • Trace phosphates • Dissolved organics	• Cost of RO is typically high due to the energy costs of supplying a pressure for filtration to occur. Operating at lower pressures will reduce costs but can reduce removal efficiency.

Abbreviations – micrometers (µm), nanometers (nm)

a – RO systems can be categorized into three different subgroups, low-pressure systems which operate between 125 and 300 psi, standard systems which operate between 350 and 600 psi, and high-pressure systems which operate between 800 and 1,200 psi. High-pressure systems are typically used for seawater applications.

Membranes can be made of different types of materials including polymer-based films or ceramics. These membrane materials can be molded into different shapes (e.g., in a flat sheet or rolled into a tube) and configured in various ways. Membrane configuration, pore size, and membrane material of construction depend on the application, required treatment level, and characteristics of the water being treated. Common membrane configurations include:

- **Hollow fiber systems –** Uses several long, filaments or membrane tubes ranging from less than 1 to 3.5 millimeter in diameter in a PVC shell. As wastewater is pumped through each filament, particles too large to pass through remain inside. Because the filaments are so small, and packed so tightly together, scaling can easily develop as particles are deposited on the filaments or plug the small spaces between the filaments. Irreversible fouling and fiber breakage are the main problems with hollow fiber systems.

- **Plate and frame systems** – Uses membranes and spacers stacked together and held in place with a frame. Because this configuration includes spacers, the membranes are not packed as tightly together, and this configuration can be used for wastewater with higher solids content or higher viscosities since fluid can flow between the membranes without clogging/plugging issues. However, the addition of these spacers also requires a greater footprint than in other membrane configurations to accommodate the same membrane surface area.
- **Spiral-wound systems** – Uses a flat sheet membrane and spacer wrapped around a permeate collection tube to produce flow channels for permeate and feedwater. The feedwater is routed through these spacers, providing a space for water to flow between the membrane surfaces. The layers are wrapped concentrically around the inner tube creating the spiral shape. Water that reaches the center and flows into the inner tube is considered permeate. This design maximizes flow while minimizing the membrane module size. Due to the high packing density, TSS must be reduced to less than 5mg/L in the feed stream to prevent plugging of the membrane.
- **Tubular systems** – Uses several tube-like membranes, typically with a diameter of 2 millimeters or greater, placed within a pipe/shell. As the waste stream is passed through the tubes, it transfers the permeate to the pipe/shell side. These systems are much like hollow fiber systems, but with a lower packing density. The lower packing density allows for a more turbulent flow which can stir up particles that may otherwise scale or foul the membrane. This type of configuration can be used for hard-to-treat streams, such as those with high TDS, TSS, and oils, greases, and fats.

Recent developments in membrane technology have focused on water/wastewater reuse, fouling control, and nutrient control. The applications for membrane systems for wastewater treatment continues to expand and the cost for these systems is decreasing. Membrane systems are being developed to handle streams with higher solids content that have been typically considered too difficult for membranes to treat. Technologies that incorporate vibration, more systematic cleaning, and other methods to decrease fouling are emerging.

3. Considerations for Industry Studies

The versatility of membranes in treating wastewater along with lower costs have broadened their use in industrial treatment systems. More stringent water quality-based effluent limitations for direct dischargers have also contributed to examining new wastewater treatment options. Membranes are used by a variety of industries and can be used for treating the entire wastestream, or for sidestream treatment.

Membrane cleaning and membrane replacement can increase maintenance and operating costs and remain the limiting factor affecting the widespread application of membranes for industrial wastewater treatment.

3.1 Industrial Applications

Membranes are often combined with other chemical, physical, and biological wastewater treatment systems. Membrane filtration is part of the technology basis for BAT or PSES in one industrial point source category, Steam Electric Power Generating (CFR Part 423) (U.S. EPA, ELG Database).

Table 2 lists the regulated categories reporting the use of membrane filtration, as part of a treatment train, from EPA's IWTT database. Table 2 also lists the targeted pollutants for the full treatment train, as identified within IWTT, for papers associated with the industries presented.

Table 2. Regulated Industries Reporting the Use of Membrane Filtration Systems as Part of a Treatment Train in IWTT

Industrial Category	40 CFR Part	Targeted Pollutants for Full Treatment Train
Dairy Products Processing	405	Biochemical Oxygen Demand, Chemical Oxygen Demand, Fats, Total Dissolved Solids, Total Suspended Solids
Canned and Preserved Fruits and Vegetables Processing	407	Chemical Oxygen Demand, Total Dissolved Solids, Total Suspended Solids
Textile Mills	410	Solids
Concentrated Animal Feeding Operations (CAFOs)	412	Chemical Oxygen Demand, Nutrients, Total Suspended Solids
Organic Chemicals, Plastics and Synthetic Fibers (OCPSF)	414	Total Suspended Solids
Petroleum Refining	419	Biochemical Oxygen Demand, Chemical Oxygen Demand, Metals, Nutrients, Oil and Grease, Organics, Phenols, Solids, Total Dissolved Solids
Iron and Steel Manufacturing	420	Metals, Organics
Nonferrous Metals Manufacturing	421	Metals
Steam Electric Power Generating	423	Metals, Nutrients, Total Dissolved Solids, Total Suspended Solids
Ferroalloy Manufacturing	424	Cyanide, Metals, Nutrients, Sulfates, Total Dissolved Solids
Pulp, Paper and Paperboard	430	Biochemical Oxygen Demand, Chemical Oxygen Demand, Nutrients, Total Suspended Solids
Metal Finishing	433	Biochemical Oxygen Demand, Chemical Oxygen Demand, Metals, Nutrients, Oil and Grease, Organics, Solids
Coal Mining	434	Chemical Oxygen Demand, Metals, Nutrients, Organics, Total Dissolved Solids, Total Suspended Solids
Oil and Gas Extraction	435	Biochemical Oxygen Demand, Metals, Nutrients, Oil and Grease, Organics, Phenols, Solids
Mineral Mining and Processing	436	Metals, Nutrients, Organics, Total Dissolved Solids
Pharmaceutical Manufacturing	439	Total Suspended Solids
Transportation Equipment Cleaning	442	Biochemical Oxygen Demand, Chemical Oxygen Demand, Metals, Oil and Grease, Solids
Landfills	445	Biochemical Oxygen Demand, Chemical Oxygen Demand, Nutrients, Phenol, Thiocyanate
Airport Deicing	449	None identified.
Aluminum Forming	467	Biochemical Oxygen Demand, Chemical Oxygen Demand, Metals, Oil and Grease, Solids, Surfactants
Electrical and Electronic Components	469	Chemical Oxygen Demand, Metals, Nutrients, Solids

Table 2. Regulated Industries Reporting the Use of Membrane Filtration Systems as Part of a Treatment Train in IWTT

Industrial Category	40 CFR Part	Targeted Pollutants for Full Treatment Train
Miscellaneous Foods and Beverages	503	Total Suspended Solids
Independent and Stand Alone Labs	507	Metals

Source: U.S. EPA, IWTT.

Note: The targeted pollutants may not all be removed by membrane filtration alone. This table includes any treatment train where membrane filtration was noted, so additional treatment units may be included.

3.2 Applicability Considerations

As described Section 2, wastewater flowrate and characteristics will impact the membrane configuration and pore size. Membrane systems can be used in combination to achieve effective treatment (e.g., using MF or UF prior to RO to optimize RO performance). In all cases, the final destination of the permeate and concentrate streams should be considered when designing a membrane system.

3.3 Cost Considerations

Advances in membrane technology have resulted in lower costs, making membrane systems more viable from an economic standpoint. Membranes may also allow for the reuse of treated wastewater within production processes which decreases the volume discharged and required intake water volumes. System design and overall cost depend on the characteristics of the influent and the desired effluent quality. Costs for RO and NF treatment systems depend on the size of the system, which are impacted by wastewater flow rates and the level of pretreatment prior to membrane filtration. For example, if MF is used as pretreatment upstream of an RO system, the RO system can be smaller and less expensive. Concentrate disposal can be a large percentage of operation and maintenance (O&M) costs depending on the volume and method selected for disposal. Cost components include the following:

Capital Costs

- Purchased equipment
- Site preparation
- Engineering design fees
- Administrative/legal costs
- Inspections
- Contingencies
- Profits and overheads

Treatment system equipment for membrane treatment often includes the following:

- Tanks (equalization, permeate storage, concentrate storage)
- Membrane unit(s)
- Pumps
- Chemical cleaning equipment (tanks, pumps, storage)
- Pretreatment equipment
- Concentrate management equipment

Annual costs

- Chemicals (for cleaning)

- Energy requirements to run the treatment system
- Concentrate disposal
- Labor for operation and maintenance
- Maintenance materials

Membrane systems require routine maintenance for proper operation. Maintenance activities include:

- Membrane replacement.
- Membrane cleaning.
- Calibrating instrumentation and cleaning probes.
- Maintaining pumps (inspection, cleaning, lubrication, replacing seals and packing, replacing check valves, cleaning strainers).
- Monitoring tanks (inspection, cleaning, corrosion prevention).

3.4 Non-Water Quality Environmental Impacts

Non-water quality environmental impacts (NWEQI) from membrane treatment are higher for RO systems than MF or UF systems due to the increased pressure requirements. It can be difficult to compare NWQEI among different membrane systems because these impacts can depend heavily on the method of concentrate disposal (e.g., large energy requirements for thermal systems or large air emissions from hauling). Generally, systems with lower percent recoveries, where more concentrate is generated are also more likely to have higher NWQEI as this larger concentrate stream will need to be manage and disposed.

NWQEI for membrane treatment include:

- Energy required to pressurize the treatment system and pump wastewater.
- Energy requirements for concentrate disposal.
- Air emissions from treatment system and transportation.

4. References

1. U.S. EPA. Effluent Limitations Guidelines and Standards (ELG) Database. Available online at: https://owapps.epa.gov/elg/

2. U.S. EPA. Industrial Wastewater Treatment Technology Database (IWTT). Available online at: https://www.epa.gov/eg/industrial-wastewater-treatment-technology-database-iwtt

3. Judd, Simon. (2020). Membrane ageing – factors determining membrane replacement. Available online at: https://www.thembrsite.com/blog/membrane-ageing-factors-determining-membrane-replacement/.

Exhibit 2

MEMORANDUM

TO: Steam Electric Rulemaking Record - EPA-HQ-OW-2009-0819

FROM: U.S. EPA

DATE: February 28, 2023

SUBJECT: Generating Unit-Level Costs and Loadings Estimates by Regulatory Option for the 2023 Proposed Rule – DCN SE10381

For the 2023 proposed rule, EPA evaluated data on wastewater flow rates, treatment technology costs, and pollutant concentration data from individual power plants, technology vendors, and previous rulemakings to estimate compliance costs and pollutant loadings associated with treating flue gas desulfurization (FGD) wastewater and combustion residual leachate (CRL) from landfills as well as with handling bottom ash (BA) transport water[1]. The methodology for estimating these costs and loadings for each wastestream and regulatory option are presented in the *Technical Development Document for Proposed Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* report (EPA-821-R-23-005). This memorandum presents the treatment technology and estimated costs and pollutant loadings for each generating unit for the regulatory options considered by EPA. The regulatory options for the 2023 proposed rule are shown in Table 1.

Table 1. Main Regulatory Proposed Options

Wastestream	Subcategory	Technology Basis for the BAT/PSES Regulatory Options			
		1	2	3 (Preferred)	4
FGD wastewater	NA	CP+LRTR	Membrane filtration	Membrane filtration	Membrane filtration
	High FGD flow facilities/LUEGUs	Not subcategorized	Not subcategorized	Not subcategorized	Not subcategorized
	EGUs permanently ceasing coal combustion by 2028	Surface impoundments	Surface impoundments	Surface impoundments	Surface impoundments
	Early adopters permanently ceasing coal combustion by 2032	Not subcategorized	CP+LRTR	CP+LRTR	Not subcategorized
BA transport water	NA	High recycle rate systems	High recycle rate systems	Dry handling or closed-loop systems	Dry handling or closed-loop systems
	LUEGUs	Not subcategorized	Not subcategorized	Not subcategorized	Not subcategorized

[1] For legacy wastewater, an additional wastestream considered under this proposed rule, EPA is proposing to not specify a nationwide technology basis. However, EPA estimated wastewater flow rates and corresponding costs and pollutant loadings for facilities to treat legacy wastewater using several technology options, as described in *Legacy Wastewater at CCR Surface Impoundments – Estimated Volumes, Treatment Costs, and Pollutant Loadings* (DCN SE10252).

Table 1. Main Regulatory Proposed Options

Wastestream	Subcategory	Technology Basis for the BAT/PSES Regulatory Options			
		1	2	3 (Preferred)	4
	EGUs permanently ceasing coal combustion by 2028	Surface impoundments	Surface impoundments	Surface impoundments	Surface impoundments
	Early adopters permanently ceasing coal combustion by 2032	Not subcategorized	Not subcategorized	High recycle rate systems	Not subcategorized
CRL	NA	CP	CP	CP	CP

CP+LRTR = chemical precipitation plus low residence time reduction
LUEGU = low utilization electric generating unit
EGU = electric generating unit

The following tables present the costs and loadings estimates for the steam electric industry:

- Table 2: Unit-level costs for FGD wastewater treatment under Regulatory Option 1;
- Table 3: Unit-level costs for FGD wastewater treatment under Regulatory Option 2;
- Table 4: Unit-level costs for FGD wastewater treatment under Regulatory Option 3;
- Table 5: Unit-level costs for FGD wastewater treatment under Regulatory Option 4;
- Table 6: Unit-level costs for BA transport water treatment under Regulatory Option 1;
- Table 7: Unit-level costs for BA transport water treatment under Regulatory Option 2;
- Table 8: Unit-level costs for BA transport water treatment under Regulatory Option 3;
- Table 9: Unit-level costs for BA water treatment under Regulatory Option 4;
- Table 10: Unit-level costs for CRL treatment under all regulatory options;
- Table 11: Unit-level total pollutant loadings for FGD wastewater under baseline and all regulatory options;
- Table 12: Unit-level total pollutant loadings for BA transport water under baseline and all regulatory options; and
- Table 13: Unit-level total pollutant loadings for CRL under baseline and all regulatory options.

EPA estimated potential ranges of bromide and iodine loadings. Given that most coal-fired power plants use bromide additives, total loadings are calculated as the sum of bromide maximum loading and iodine minimum loading. See the *FGD Halogen Loadings from Steam Electric Power Plants* (DCN SE10317) on additional details on halogen loadings estimates.

Table 2. Unit-Level Cost Estimates for FGD Wastewater Treatment Under Regulatory Option 1

Plant Name	Plant ID	Unit ID	Treatment Technology	Capacity (MW)	Capital Cost	Annual O&M Cost	One Time Cost	Recurring O&M Costs		
								5-Year	6-Year	10-Year
W. H. Sammis Plant	103	SE Unit-6	SI	680	$0	$0	$0	NA	NA	NA
W. H. Sammis Plant	103	SE Unit-7	SI	334	$0	$0	$0	NA	NA	NA
W. H. Sammis Plant	103	SE Unit-5	SI	175	$0	$0	$0	NA	NA	NA
Kingston	265	SE Unit-1	SI	175	$0	$0	$0	NA	NA	NA
Kingston	265	SE Unit-2	SI	175	$0	$0	$0	NA	NA	NA
Kingston	265	SE Unit-3	SI	175	$0	$0	$0	NA	NA	NA
Kingston	265	SE Unit-4	SI	200	$0	$0	$0	NA	NA	NA
Kingston	265	SE Unit-5	SI	200	$0	$0	$0	NA	NA	NA
Kingston	265	SE Unit-6	SI	200	$0	$0	$0	NA	NA	NA
Kingston	265	SE Unit-7	SI	200	$0	$0	$0	NA	NA	NA
Kingston	265	SE Unit-8	SI	200	$0	$0	$0	NA	NA	NA
Kingston	265	SE Unit-9	SI	503	$0	$0	$0	NA	NA	NA
J. K. Spruce Power Plant	493	SE Unit-1	CP+LRTR	803	$0	$0	$0	NA	NA	NA
J. K. Spruce Power Plant	493	SE Unit-2	CP+LRTR	217	$0	$0	$0	NA	NA	NA
OVEC - Kyger Creek Station	771	SE Unit-2	CP+LRTR	217	$0	$0	$0	NA	NA	NA
OVEC - Kyger Creek Station	771	SE Unit-3	CP+LRTR	217	$0	$0	$0	NA	NA	NA
OVEC - Kyger Creek Station	771	SE Unit-4	CP+LRTR	217	$0	$0	$0	NA	NA	NA
OVEC - Kyger Creek Station	771	SE Unit-5	CP+LRTR	217	$0	$0	$0	NA	NA	NA
OVEC - Kyger Creek Station	771	SE Unit-1	CP+LRTR	586	$0	$0	$0	NA	NA	NA
Williams Station	864	SE Unit-1	SI	176	$0	$0	$0	NA	NA	NA
Muscatine Power and Water Generating Station	904	SE Unit-4	CP+LRTR	816	$0	$0	$0	NA	NA	NA
Mitchell Plant	1236	SE Unit-1	CP+LRTR	816	$0	$0	$0	NA	NA	NA
Mitchell Plant	1236	SE Unit-2	CP+LRTR	692	$0	$0	$0	NA	NA	NA
EME Homer City Generation L.P.	1381	SE Unit-3	CP+LRTR	706	$0	$0	$0	NA	NA	NA
Plant James H Miller Jr	1493	SE Unit-3	CP+LRTR	706	$0	$0	$0	NA	NA	NA
Plant James H Miller Jr	1493	SE Unit-2	CP+LRTR	706	$0	$0	$0	NA	NA	NA
Plant James H Miller Jr	1493	SE Unit-1	CP+LRTR	706	$0	$0	$0	NA	NA	NA
Plant James H Miller Jr	1493	SE Unit-4	CP+LRTR	566	$0	$0	$0	NA	NA	NA
Trimble County	1674	SE Unit-1	CP+LRTR	738	$0	$0	$0	NA	NA	NA
Trimble County	1674	SE Unit-A	CP+LRTR	952	$0	$0	$0	NA	NA	NA
Georgia Power Company - Plant Bowen	2244	SE Unit-3	CP+LRTR	952	$0	$0	$0	NA	NA	NA

Table 2. Unit-Level Cost Estimates for FGD Wastewater Treatment Under Regulatory Option 1

Plant Name	Plant ID	Unit ID	Treatment Technology	Capacity (MW)	Capital Cost	Annual O&M Cost	One Time Cost	Recurring O&M Costs 5-Year	Recurring O&M Costs 6-Year	Recurring O&M Costs 10-Year
Georgia Power Company - Plant Bowen	2244	SE Unit-4	CP+LRTR	850	$0	$0	$0	NA	NA	NA
Conemaugh	2268	SE Unit-1	SI	850	$0	$0	$0	NA	NA	NA
Conemaugh	2268	SE Unit-2	SI	165	$0	$0	$0	NA	NA	NA
Allen Steam Station	2550	SE Unit-1	SI	165	$0	$0	$0	NA	NA	NA
Allen Steam Station	2550	SE Unit-2	SI	275	$0	$0	$0	NA	NA	NA
Allen Steam Station	2550	SE Unit-4	SI	275	$0	$0	$0	NA	NA	NA
Allen Steam Station	2550	SE Unit-5	SI	557	$0	$0	$0	NA	NA	NA
Ghent	2601	SE Unit-1	CP+LRTR	556	$0	$0	$0	NA	NA	NA
Ghent	2601	SE Unit-4	CP+LRTR	556	$0	$0	$0	NA	NA	NA
Ghent	2601	SE Unit-2	CP+LRTR	557	$0	$0	$0	NA	NA	NA
Ghent	2601	SE Unit-3	CP+LRTR	372	$0	$0	$0	NA	NA	NA
Wateree Station	3087	SE Unit-1	SI	372	$0	$0	$0	NA	NA	NA
Wateree Station	3087	SE Unit-2	SI	591	$0	$0	$0	NA	NA	NA
Cross Generating Station	3235	SE Unit-1	CP+Memb	556	$0	$0	$0	NA	NA	NA
Cross Generating Station	3235	SE Unit-2	CP+Memb	652	$0	$0	$0	NA	NA	NA
Cross Generating Station	3235	SE Unit-3	CP+Memb	652	$0	$0	$0	NA	NA	NA
Cross Generating Station	3235	SE Unit-4	CP+Memb	615	$0	$0	$0	NA	NA	NA
Cardinal	3265	SE Unit-1	SI	615	$0	$0	$0	NA	NA	NA
Cardinal	3265	SE Unit-2	CP+LRTR	650	$0	$0	$0	NA	NA	NA
Cardinal	3265	SE Unit-3	CP+LRTR	385	$0	$0	$0	NA	NA	NA
Lawrence Energy Center	3309	SE Unit-3	CP+LRTR	615	$0	$0	$0	NA	NA	NA
W. A. Parish E.G.S.	3464	SE Unit-8	CP+LRTR	658	$0	$0	$0	NA	NA	NA
Marshall Steam Station	3597	SE Unit-3	CP+LRTR	380	$0	$0	$0	NA	NA	NA
Marshall Steam Station	3597	SE Unit-2	CP+LRTR	380	$0	$0	$0	NA	NA	NA
Marshall Steam Station	3597	SE Unit-1	CP+LRTR	660	$0	$0	$0	NA	NA	NA
Marshall Steam Station	3597	SE Unit-4	CP+LRTR	321	$0	$0	$0	NA	NA	NA
Mill Creek	3604	SE Unit-1	SI	321	$0	$0	$0	NA	NA	NA
Mill Creek	3604	SE Unit-2	SI	411	$0	$0	$0	NA	NA	NA
Mill Creek	3604	SE Unit-3	CP+LRTR	496	$0	$0	$0	NA	NA	NA
Mill Creek	3604	SE Unit-4	CP+LRTR	936	$0	$0	$0	NA	NA	NA
RRI Energy Keystone Generating Station	3831	SE Unit-2	SI	936	$0	$0	$0	NA	NA	NA

Table 2. Unit-Level Cost Estimates for FGD Wastewater Treatment Under Regulatory Option 1

Plant Name	Plant ID	Unit ID	Treatment Technology	Capacity (MW)	Capital Cost	Annual O&M Cost	One Time Cost	Recurring O&M Costs		
								5-Year	6-Year	10-Year
RRI Energy Keystone Generating Station	3831	SE Unit-1	SI	406	$0	$0	$0	NA	NA	NA
PPL Brunner Island	4122	SE Unit-2	SI	347	$0	$0	$0	NA	NA	NA
PPL Brunner Island	4122	SE Unit-1	SI	794	$0	$0	$0	NA	NA	NA
PPL Brunner Island	4122	SE Unit-3	SI	817	$0	$0	$0	NA	NA	NA
Monroe Power Plant	4533	SE Unit-4	CP+Memb	823	$0	$0	$0	NA	NA	NA
Monroe Power Plant	4533	SE Unit-3	CP+Memb	823	$0	$0	$0	NA	NA	NA
Monroe Power Plant	4533	SE Unit-2	CP+Memb	817	$0	$0	$0	NA	NA	NA
Monroe Power Plant	4533	SE Unit-1	CP+Memb	1,300	$0	$0	$0	NA	NA	NA
Mountaineer Plant	4543	SE Unit-1	CP+LRTR	730	$0	$0	$0	NA	NA	NA
TransAlta Centralia Generation, LLC	4547	SE Unit-2	SI	217	$0	$0	$0	NA	NA	NA
Clifty Creek Station	5318	SE Unit-5	CP+LRTR	217	$0	$0	$0	NA	NA	NA
Clifty Creek Station	5318	SE Unit-6	CP+LRTR	217	$0	$0	$0	NA	NA	NA
Clifty Creek Station	5318	SE Unit-4	CP+LRTR	217	$0	$0	$0	NA	NA	NA
Clifty Creek Station	5318	SE Unit-3	CP+LRTR	217	$0	$0	$0	NA	NA	NA
Clifty Creek Station	5318	SE Unit-2	CP+LRTR	217	$0	$0	$0	NA	NA	NA
Clifty Creek Station	5318	SE Unit-1	CP+LRTR	440	$0	$0	$0	NA	NA	NA
Leland Olds Station	6334	SE Unit-2	CP+LRTR	216	$0	$0	$0	NA	NA	NA
Leland Olds Station	6334	SE Unit-1	CP+LRTR	486	$0	$0	$0	NA	NA	NA
Tampa Electric - Big Bend Station	6377	SE Unit-4	CP+LRTR	626	$0	$0	$0	NA	NA	NA
Morgantown Generating Station (f.k.a. Mirant Mid-Atlantic, LLC)	6616	SE Unit-1	SI	626	$0	$0	$0	NA	NA	NA
Morgantown Generating Station (f.k.a. Mirant Mid-Atlantic, LLC)	6616	SE Unit-2	SI	315	$0	$0	$0	NA	NA	NA
Winyah Generating Station	7411	SE Unit-2	SI	315	$0	$0	$0	NA	NA	NA
Winyah Generating Station	7411	SE Unit-1	SI	315	$0	$0	$0	NA	NA	NA
Winyah Generating Station	7411	SE Unit-3	SI	315	$0	$0	$0	NA	NA	NA
Winyah Generating Station	7411	SE Unit-4	SI	715	$0	$0	$0	NA	NA	NA
Seminole Generating Station	7785	SE Unit-1	CP+LRTR	891	$0	$0	$0	NA	NA	NA
Plant Scherer	8179	SE Unit-1	CP+Memb	891	$0	$0	$0	NA	NA	NA
Plant Scherer	8179	SE Unit-2	CP+Memb	684	$0	$0	$0	NA	NA	NA
Pleasants Power Station	8281	SE Unit-1	SI	684	$0	$0	$0	NA	NA	NA
Pleasants Power Station	8281	SE Unit-2	SI	500	$0	$0	$0	NA	NA	NA

Table 2. Unit-Level Cost Estimates for FGD Wastewater Treatment Under Regulatory Option 1

Plant Name	Plant ID	Unit ID	Treatment Technology	Capacity (MW)	Capital Cost	Annual O&M Cost	One Time Cost	Recurring O&M Costs		
								5-Year	6-Year	10-Year
Miami Fort Station	8308	SE Unit-2	SI	500	$0	$0	$0	NA	NA	NA
Miami Fort Station	8308	SE Unit-3	SI	681	$0	$0	$0	NA	NA	NA
Jeffrey Energy Center	8353	SE Unit-1	CP+LRTR	681	$0	$0	$0	NA	NA	NA
Jeffrey Energy Center	8353	SE Unit-2	CP+LRTR	681	$0	$0	$0	NA	NA	NA
Jeffrey Energy Center	8353	SE Unit-3	CP+LRTR	1,110	$0	$0	$0	NA	NA	NA
Belews Creek Steam Station	8661	SE Unit-1	CP+LRTR	1,110	$0	$0	$0	NA	NA	NA
Belews Creek Steam Station	8661	SE Unit-2	CP+LRTR	270	$0	$0	$0	NA	NA	NA
F.B. Culley Generating Station	8965	SE Unit-3	CP+LRTR	816	$0	$0	$0	NA	NA	NA
John E. Amos Plant	9161	SE Unit-2	CP+LRTR	1,300	$0	$0	$0	NA	NA	NA
John E. Amos Plant	9161	SE Unit-3	CP+LRTR	816	$0	$0	$0	NA	NA	NA
John E. Amos Plant	9161	SE Unit-1	CP+LRTR	555	$0	$0	$0	NA	NA	NA
Fort Martin Power Station	9225	SE Unit-2	CP+LRTR	552	$0	$0	$0	NA	NA	NA
Fort Martin Power Station	9225	SE Unit-1	CP+LRTR	411	$0	$0	$0	NA	NA	NA
Roxboro Steam Plant	9391	SE Unit-1	SI	657	$0	$0	$0	NA	NA	NA
Roxboro Steam Plant	9391	SE Unit-2	SI	745	$0	$0	$0	NA	NA	NA
Roxboro Steam Plant	9391	SE Unit-3	SI	745	$0	$0	$0	NA	NA	NA
Roxboro Steam Plant	9391	SE Unit-4	SI	1,300	$0	$0	$0	NA	NA	NA
W H Zimmer Station	9475	SE Unit-1	SI	806	$0	$0	$0	NA	NA	NA
PPL Montour	9805	SE Unit-1	SI	819	$0	$0	$0	NA	NA	NA
PPL Montour	9805	SE Unit-2	SI	230	$0	$0	$0	NA	NA	NA
Dallman	9971	SE Unit-4	CP+LRTR	701	$0	$0	$0	NA	NA	NA
Elm Road Generating Station	56068	SE Unit-B	CP+LRTR	701	$0	$0	$0	NA	NA	NA
Elm Road Generating Station	56068	SE Unit-A	CP+LRTR	680	$0	$0	$0	NA	NA	NA

SI = Surface impoundment
CP+Memb = Chemical precipitation followed by membrane filtration. Indicates an EGU that has opted into the voluntary incentives program (VIP).
NA = Not applicable

Exhibit 3

MEMORANDUM

TO: Steam Electric Rulemaking Record – EPA-HQ-OW-2009-0819

FROM: U.S. EPA

DATE: April 22, 2024

SUBJECT: Technologies for the Treatment of Flue Gas Desulfurization Wastewater, Coal Combustion Residual Leachate, and Pond Dewatering – 2024 Final Rule - DCN SE11695

The U.S. Environmental Protection Agency (EPA), with the support of ERG, collected information on technologies available for the treatment of power plant wastewater, including flue gas desulfurization (FGD) wastewater, combustion residual leachate (CRL), and technologies for pond dewatering. This memorandum is a compilation of treatment technology information gathered since the 2015 rule. Organizationally, this memorandum is a compendium of individual appendix documents, one for each technology and/or vendor. As noted in the *Technical Development Document for Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (TDD), the EPA determined that CRL from landfills and surface impoundments includes similar types of constituents as FGD wastewater, although the concentrations of the constituents in CRL are generally lower than in FGD wastewater (U.S. EPA, 2024). Based on this characterization of the wastewater and knowledge of treatment technologies, the EPA determined that certain treatment technologies identified for FGD wastewater could also be used to treat CRL.

Table 1 lists the treatment technologies summarized in this memorandum. For each technology, the table identifies the relevant appendix name and the wastestreams (FGD wastewater, leachate, or pond dewatering) the technology has been demonstrated to treat to date (as opposed to which wastestreams the technology is capable of treating). For leachate, the table also indicates whether the technology has been demonstrated for CRL and/or for municipal landfill leachate.

Table 1. Treatment Technologies

Vendor and/or Treatment Technology Name	Location of Technology Summary	Wastestreams Treated		
		FGD Wastewater	Leachate	Pond Dewatering
Aquatech Thermal Technology	Appendix A	✓		
BKT FMX Membrane Technology	Appendix B	✓		
Envirogen Technology	Appendix C	✓		
Evoqua Technology	Appendix D	✓		
Frontier Technology	Appendix E	✓		
GE Alstom Spray Dryer Technology	Appendix F	✓		
Heartland Technology	Appendix G	✓	✓ (CRL, municipal landfill leachate)	
HPD Thermal Technology	Appendix H	✓		
KLeenWater Technology	Appendix I	✓	✓ (CRL)	
Mitsubishi Spray Dryer Technology	Appendix J	✓		✓

Table 1. Treatment Technologies

Vendor and/or Treatment Technology Name	Location of Technology Summary	Wastestreams Treated		
		FGD Wastewater	Leachate	Pond Dewatering
New Logic Membrane Technology	Appendix K	✓	✓ (CRL)	
Oasys Forward Osmosis Technology	Appendix L	✓		
Purestream Advanced Vapor Recompression Technology	Appendix M	✓	✓ (CRL)	
Saltworks Technology	Appendix N	✓	✓	
SUEZ ABMet Biological Treatment Technology	Appendix O	✓	✓ (CRL)	
SUEZ Thermal Technology	Appendix P	✓		
Sylvan Source Technology	Appendix Q	✓		
Vacom Technology	Appendix R	✓	✓ (municipal landfill leachate)	
Dupont Technology	Appendix S	✓	✓ (municipal landfill leachate)	
Ljungström Spray Dryer Technology	Appendix T	✓		
MDS Technology	Appendix U		✓ (municipal landfill leachate)	✓
Slurry Management Technology	Appendix V			✓

References

1. U.S. EPA. 2024. U.S. Environmental Protection Agency. *Technical Development Document for Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (TDD). EPA-821-R-24-004. (April) DCN SE11757.

Appendix A - Aquatech Thermal Technology

1. Technology Description

Aquatech is a privately owned, global water treatment technology provider with over 1,500 installations in 60 countries. Primary markets include the oil and gas, petrochemical and refining, power, mining and metals, and infrastructure (i.e., desalination) industries. Aquatech provides options for treatment and discharge as well as complete reuse (i.e., zero liquid discharge (ZLD)). Aquatech designs, builds, and installs treatment systems and offers operation and maintenance services to their customers.

For FGD wastewater treatment, Aquatech primarily markets their falling-film evaporator which uses a proprietary two-stage external mist eliminator with horizontal flow chevrons and a vapor compressor. Aquatech has implemented different FGD wastewater treatment configurations at full scale using the evaporator in conjunction with one or more additional treatment technologies for pretreatment and/or brine concentrate management. Clarification as a pretreatment step is required in all configurations to precipitate metal hydroxides, thereby reducing total suspended solids (TSS) concentration (to 25 parts per million (ppm) or less) and lowering hardness. Additional lime and soda ash softening pretreatment may be required for the full evaporation configurations to efficiently generate salt crystals.

Aquatech advertises four system configurations, shown in Figure 1 and described below in order of least to most expensive capital cost.

2. Partial evaporation: consists of physical/chemical pretreatment for TSS reduction followed by a mechanical vapor compressor (MVC) brine concentrator to produce a distillate and 16 to 18 percent brine concentrate. The plant can recycle distillate for reuse and mix the brine with fly ash for solidification, also referred to as encapsulation. Aquatech believes any coal-fired power plant could treat FGD wastewater using this configuration to a quality that would permit reuse in plant operations for complete zero discharge.
3. Partial evaporation: consists of physical/chemical pretreatment for TSS reduction, MVC brine concentration, and steam driven crystallization. The concentrated brine is sent to a crystallizer for further volume reduction, but the evaporation process in the crystallizer is not operated to produce crystallized salt. Plants can recycle evaporator and crystallizer distillate back to the process for reuse and mix the crystallizer brine with fly ash. This configuration may be appropriate for large FGD flow rates where the brine volume needs to be further reduced for optimal encapsulation with available ash.
4. Full evaporation: consists of physical/chemical pretreatment, softening, MVC brine concentration, and steam-driven crystallization to produce salt crystals instead of a brine. Crystallization salts are dewatered in a filter press before landfill disposal. This system configuration uses the most energy.
5. Full evaporation: consists of physical/chemical pretreatment, softening, and MVC brine crystallization. Crystallization salts can be dewatered with a filter press and landfilled. This configuration is used for smaller systems, specifically those below 30 gallons per minute (gpm). As this system configuration has a standalone crystallizer (without a brine concentrator), it is the most expensive, produces the most sludge, has the highest steam consumption, but uses the least energy per unit volume of water treated, comparatively.

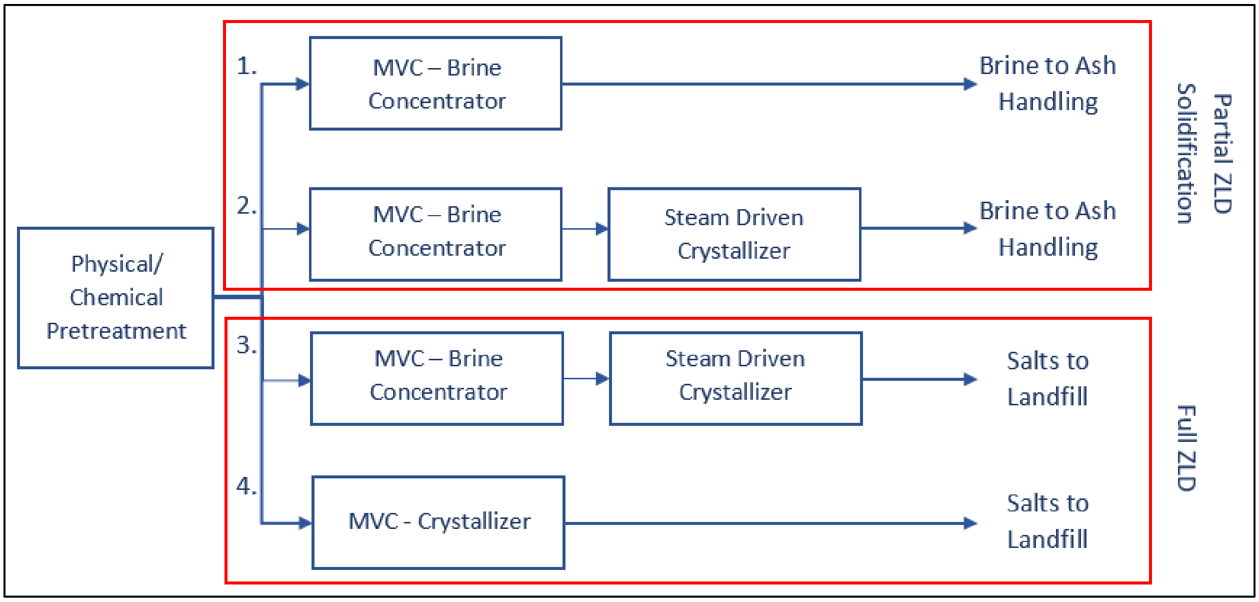

Figure 1. Aquatech ZLD Configurations

Evaporators typically require annual cleaning, with less frequent cleaning required for crystallizers. For example, Enel's Torrevaldaliga Plant cleans their concentrators once every 12 to 18 months and has not needed to clean the crystallizer in five years.

Aquatech stated that two 60 percent treatment trains with a large holding tank would be sufficient redundancy for maintaining a system and would be far less costly than full redundancy (two 100 percent treatment trains). When coal-fired generating units are not operating, the evaporation system can be put in "hot standby" where the system does not produce a distillate stream. When the system is completely shut down, such as during cleaning, plants need to seed the system with gypsum and allow the slurry to mature.

2. Technology Status and Performance

Aquatech has provided design, build, and installation of full-scale thermal ZLD systems for the treatment of FGD wastewater at eight coal-fired power plants in the United States and Italy. The company has conducted one pilot study on FGD wastewater in Germany and is exploring the market in India. An additional power plant in South Korea has commissioned Aquatech to install a ZLD treatment system for FGD wastewater. Aquatech is also bidding on an Eastern Kentucky power plant's FGD wastewater treatment system (Spurlock Generating Station) that will target selenium removal. Some power plants have also expressed interest in coupling reverse osmosis (RO) and thermal technologies for the treatment of FGD wastewater, with some already using a hybrid technology for the treatment of cooling tower blowdown.

Table 2 provides treatment configuration information on the eight full-scale Aquatech installations.

Table 2. Full Scale Aquatech FGD Wastewater Treatment Systems

Plant Name	Location	Treatment Configuration Notes
Brindisi (Enel)	Italy	Two clarifiers, two falling film brine concentrators, crystallizer

Table 2. Full Scale Aquatech FGD Wastewater Treatment Systems

Plant Name	Location	Treatment Configuration Notes
La Spezia (Enel)	Italy	Clarifier, falling film brine concentrator, crystallizer
Fusina (Enel)	Italy	Two clarifiers, two falling film brine concentrators, crystallizer
Sulcis (Enel)	Italy	Clarifier, falling film brine concentrator, crystallizer
Torrevaldaliga (Enel)	Italy	Clarifier, two falling film brine concentrators, two crystallizers
Merrimack (Granite Shore Power (GSP))	New Hampshire	Chemical precipitation, partial softening, falling film evaporator, crystallizer
Dallman (City Water, Light, and Power (CWLP))	Illinois	Two falling film evaporators with mist eliminator and vapor compressor
Iatan (Kansas City Power and Light (KCPL))	Missouri	Clarifier, two brine concentrators, distillate recycle to process, brine mixed with fly ash prior to on-site landfill disposal

2.1 Enel Power Plants (Various locations in Italy)

Changes in environmental regulations led five Enel coal-fired power plants in Italy to install full-scale Aquatech ZLD systems to treat FGD wastewater. All five plants were designed to send FGD purge to pretreatment that includes chemical precipitation with lime and sulfide addition followed by partial softening with soda ash. The wastewater then flows through falling-film brine concentrators/evaporators and forced circulation crystallizers. Evaporator and crystallizer distillate are recycled to plant operations. The crystallizer salts are separated from the concentrate and sent to a belt filter press for dewatering prior to disposal, and remaining brine are mixed with fly ash for disposal in a landfill.

The five Enel power-plants are listed below and range in capacity from 55 gpm to 310 gpm:

- Brindisi Power Plant (2,640 MW)
- La Spezia Power Plant (1,300 MW)
- Fusina Power Plant (975 MW)[1]
- Sulcis Power Plant (585 MW)
- Torrevaldaliga Nord Power Plant (1,980 MW)

Aquatech operated the five systems for approximately two years following installation; following this period, Enel assumed operation for all systems.

As part of the 2015 Rule, the EPA collected effluent data from Brindisi Power Plant. The EPA used a subset of these data to characterize effluent concentrations for power plants treating FGD wastewater with chemical precipitation followed by evaporation. See the *Statistical Support Document: Effluent Limitations for FGD Wastewater, Gasification Wastewater, and Combustion Residual Leachate for the Final Steam Electric Power Generating Effluent Limitations Guidelines and Standards* (DCN SE05733) for detailed information regarding the pollutant removal efficacy of this treatment technology.

[1] As of 2018, Enel is not operating the Fusina ZLD system.

2.2 Iatan Generating Station (Weston, MO)

The Iatan Generating Station, owned by KCPL, operates two coal-fired electric generating units with a total capacity of 1,520 MW. Prior to its replacement with a different treatment system, the wastewater treatment system installed in March 2009 had a design flow rate of 60 gpm. The system contained pretreatment consisting of clarification for suspended solids reduction and metals removal followed by two MVC brine concentrators. Sludge from the clarifier was dewatered with a belt press prior to disposal. The brine concentrators produced a high purity distillate stream with less than 10 ppm TDS that was recycled to the plant's water system. Brine concentrate went to the fly ash silo where it was mixed with fly ash for final disposal in an onsite landfill.

Iatan Generating Station installed a ZLD FGD wastewater treatment system for multiple reasons, including preventing delays in plant project timelines (i.e., the time to receive a discharge permit), improving the environmental footprint of the station, and avoiding the need for a crystallizer and solids removal device.

During the installation and initial troubleshooting of the system, Iatan and Aquatech found high amounts of salt in the system feed water. As a result, the mineral witherite (i.e., barium carbonate) was produced. Witherite concentrations above 15 percent may cause issues in the system. Aquatech noted that an additional brine concentrator on the back end of the system would have been a better design for this plant.

As part of the 2015 Rule, the EPA collected data from the Iatan Generating Station. These data were not used to characterize loads from power plants using evaporation for the 2015 Rule because Iatan's FGD wastewater treatment system did not include chemical precipitation or a softening step. Table 3 provides a summary of Iatan effluent data collected by the EPA.

Table 3. Pollutants Average Data Summary for Iatan FGD Wastewater Treatment System

Analyte	Unit	FGD Scrubber Purge (4-day avg.)	FGD Brine Concentrator Distillate (4-day avg.)
Arsenic	µg/L	87.3	ND (4.00)
Mercury	ng/L	7,470	213
Selenium	µg/L	495	ND (4.00)
Nitrate/nitrate as N	mg/L	230	NQ (0.100)
TDS	mg/L	81,000	<49.0

< - Average Result includes at least one value measured below the quantitation limit. (Calculation uses ½ calculation limit for values below the quantitation limit).

ND – Not detected (number in parentheses is quantitation limit).

NQ – Analyte was measured above the method detection limit, but below the quantitation limit (number shown in parentheses is the quantitation limit).

2.3 Dallman Power Station (Springfield, IL)

Dallman Power Station is owned by CWLP and is located in Springfield, Illinois. The station operates four coal-fired units. The Dallman Power Station acquired Aquatech equipment for a ZLD FGD wastewater treatment system to treat increased boron concentrations in FGD wastewater that were caused by ammonia carryover from Dallman's Selective Catalytic Reduction systems' nitrogen removal process. The treatment system never began operating because a publicly owned treatment works (POTW) agreed to take Springfield's FGD wastewater. Dallman's ZLD FGD wastewater treatment system was designed with a feed preheater, a deaerator, and two falling-film evaporators with mist eliminator and vapor compressor. The mist eliminator was designed to prevent droplets containing concentrated chloride salts from traveling to the vapor compressor, which minimizes corrosion. Aquatech equipment remains onsite at Dallman Power Station.

2.4 Merrimack Station (Bow, NH)

Merrimack Station is located in Bow, New Hampshire. The wastewater treatment system was designed to send FGD purge to pretreatment that includes chemical precipitation with lime and sulfide addition followed by partial softening with soda ash. Resulting sludge is disposed of in a landfill and pretreated wastewater is sent to a 65-gpm capacity evaporator. Evaporator brine is sent through an 8-gpm capacity two-effect crystallizer for further concentration. Evaporator and crystallizer distillate are reused in plant operations. The crystallizer salts are separated from the concentrate and sent to a belt filter press for dewatering prior to beneficial reuse. The salt produced is greater than 95% pure sodium chloride (NaCl). Remaining concentrate is mixed with fly ash for disposal in a landfill.

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Appendix B – BKT FMX Membrane Technology

1. Technology Description

BKT originally started as a company specializing in biological treatment technologies for livestock wastewater but has since developed the FMX system and expanded their applications to the shale gas, food and beverage, biotechnology, and power industries. BKT developed their anti-fouling membrane filtration system in Korea, and this system has now been operating in the U.S. for over ten years.

The FMX membrane system is an advanced membrane filtration system designed for wastewaters containing high total suspended solids (TSS) and total dissolved solids (TDS) and uses vortex-generating blades to minimize fouling of membrane surfaces. Blades are used to generate a vortex that maintains turbulent flows on the membrane surfaces; these eddies serve to reduce deposits on the membrane surface that could lead to fouling or scaling. The blades are made of a lightweight engineered plastic and are resistant to chemicals, corrosion, and heat. The blades are connected to a center drive shaft and positioned between trays of membranes vertically. The center shaft rotates the blades resulting in the turbulence. Depending on the membrane surface area required, the number of membrane/blade stacks and size of the membrane pores can be customized to meet the desired removals.

The FMX system processes wastewater between 50 and 150 liters per square meter per hour (LMH) (or 30 and 88 gallons per square foot per day (GFD)). Depending on the application, microfiltration, ultrafiltration, or nanofiltration membranes can be used in the system. For FGD wastewater applications, BKT recommends using nanofiltration membranes. The FMX system can be operated in conjunction with a downstream conventional RO system. In this configuration, the FMX system reduces the TDS concentrations and total hardness in the FGD wastewater which prevents scaling in the RO system, while the RO system further treats the permeate to reduce the pollutant concentrations to very low levels prior to discharge.

According to BKT, pretreatment prior to entering the FMX system is dependent on the concentration of TSS in the feed. If FGD wastewater undergoes settling (e.g., impoundment, settling tank), only a light particle filter may be needed; however, the FMX cannot receive influent directly from a hydrocyclone without pretreatment. At one half to two percent solids, the concentration is too high for the FMX system and would require either ultrafiltration or a physical/chemical pretreatment system with pH adjustment and coagulation/flocculation to remove solids.

As shown in pilot studies, the FMX system can also be incorporated into an existing treatment train. A treatment system using FMX nanofiltration followed by conventional RO could be used as a treatment process for FGD wastewater. Including pretreatment prior to the FMX system may increase overall process efficiency of the FMX system and help lower the capital and operations and maintenance costs of the FMX portion of the system. Treating FGD wastewater with the FMX system can also be used to achieve significant volume reduction upstream of thermal or brine solidification/encapsulation zero discharge technologies, thereby reducing the size and cost of the thermal or encapsulation equipment. Figure 1 shows an example process flow diagram for FGD wastewater treatment with an FMX system that includes a chemical precipitation pretreatment step using lime addition, the FMX stage, a post-processing RO system, and an evaporator/crystallizer system to handle the concentrate stream.

Industry sources report that the FMX tests summarized in Section 2 demonstrate that anti-fouling technology can enable the use of membrane filtration to treat FGD wastewater and that the FMX/RO treatment train is effective at removing selenium, arsenic, mercury, and nitrate-nitrite to concentrations well below the ELG limitations. These sources also report that the onsite tests demonstrate that the anti-fouling properties of the FMX system enable it to treat FGD wastewater without the need for extensive pretreatment. Additionally, the FMX/RO treatment process has a relatively small footprint and obviates the need for the reaction tanks and much of the other equipment typically included as part of chemical-biological treatment trains.

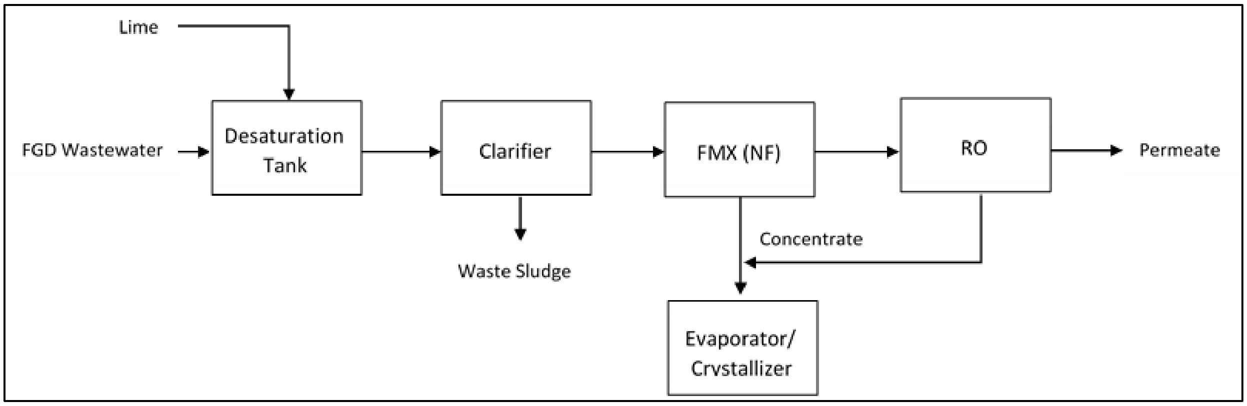

Figure 1. Example Process Flow Diagram for FMX Membrane System with Pretreatment and RO System

Like other membrane systems, the FMX membranes require periodic flushing and chemical cleanings. The FMX system provides the ability to replace membranes without replacing other associated equipment. BKT estimates that the membranes will need to be replaced every one to two years depending on the operation of the system. Chemical cleaning requirements and frequencies for the membranes are variable and dependent on the characteristics of the influent wastewater and treatment system configuration. As demonstrated in one pilot study, permeate from the FMX system treatment process can be further treated and reused to clean the membranes, eliminating the need for implementation of chemical clean-in-place (CIP) procedures. BKT has also indicated that influent characteristics affect the cost of operation of the system, as a high TDS concentration combined with a lower sulfate concentration is less expensive to operate than a lower TDS concentration combined with a higher sulfate concentration due to the impacts on membrane flux.

2. Technology Status and Performance

BKT has conducted at least six onsite pilot-scale studies for the treatment of FGD wastewater from coal-fired power plants using the FMX system. These pilot tests are summarized below.

2.1 Pilot Study #1

A commercial-scale FMX system was tested for three months at a coal-fired power plant to treat FGD wastewater. The FMX module contained nanofiltration membranes and was used in conjunction with a conventional spiral-wound reverse osmosis membrane. The system was operated in batch mode, with the FMX system receiving untreated FGD wastewater from the plant's FGD storage tank. During each batch, the concentrate from the FMX system was returned to the feed tank and the system continued to process the wastewater until the desired recovery was reached (i.e., 70-80 percent of the feed volume passes through the membrane as permeate).

The permeate from the FMX stage was transferred to the RO stage for further treatment and was able to meet the 2015 ELGs for selenium in FGD wastewater. Other than gravity settling in a surface impoundment, no pretreatment of the wastewater was performed prior to the FMX system. Using the combination of FMX and spiral RO, the treatment train consistently met the discharge limits for FGD wastewater established by the 2015 ELGs (in fact, the effluent concentrations were lower than the limits proposed by the EPA in 2013, which were lower than the limits established by the 2015 ELGs). Average pollutant concentrations are shown in Table 1. The pilot test results demonstrated that anti-fouling technology enables the use of membrane filtration to treat FGD wastewater, with no loss of flux and no irreversible fouling or scaling of the membranes over the duration of the study. The pilot test also showed that chemical pretreatment of the wastewater was unnecessary.

Table 1. Pilot Study #1 – Average Pollutant Concentrations

Parameter	Feed	FMX Permeate	RO Permeate
pH	7.2	7.1	6.05
Conductivity (µS/cm)	21,700	13,000	149
Alkalinity (mg/L as CaCO3)	57.6	30	5
Total Dissolved Solids (mg/L)	17,500	8,930	201
Total Suspended Solids (mg/L)	38	19.5	1.5
Total Solids (mg/L)	17,500	8,950	202
Fluoride (mg/L)	7.8	3.35	< 0.039
Chloride (mg/L)	7,250	4,300	< 28.9
Bromide (mg/L)	59.8	36.2	< 0.283
Nitrate-Nitrite (mg/L as N)	< 27.3	< 17.6	< 0.234
Phosphate (mg/L as P)	< 4.56	< 2.93	< 0.039
Sulfate (mg/L)	1,070	252	< 1.75
Beryllium (µg/L)	< 1.7	< 0.75	< 0.5
Boron (µg/L)	120,000	106,000	39,900
Sodium (µg/L)	32,000	30,200	2,750
Magnesium (µg/L)	661,000	293,000	1,780
Aluminum (µg/L)	867	105	< 135
Silicon (µg/L)	24,700	17,500	< 1220
Potassium (µg/L)	14,600	15,000	< 2780
Calcium (µg/L)	3,540,000	2,120,000	14,100
Titanium (µg/L)	< 32.8	< 3	< 3
Chromium (µg/L)	7.7	< 2	< 2
Manganese (µg/L)	8,750	4,780	31.2
Iron (µg/L)	< 476	< 100	< 100
Cobalt (µg/L)	64.1	31.3	< 0.75
Nickel (µg/L)	325	160	< 5
Zinc (µg/L)	1,740	1,250	12.7
Arsenic (µg/L)	< 12.7	< 5.35	< 2
Selenium (µg/L)	219	55.4	< 1
Strontium (µg/L)	1,140	589	4.05
Molybdenum (µg/L)	62.6	15.4	< 0.5
Silver (µg/L)	< 1.5	< 0.5	< 0.5
Cadmium (µg/L)	72.7	56.3	< 0.75
Antimony (µg/L)	7.6	2.65	< 0.5
Barium (µg/L)	496	265	2.4
Tungsten (µg/L)	3.8	1.95	< 0.5
Mercury (ng/L)	2,030	94.7	< 5
Lead (µg/L)	< 2.015	< 0.5	< 0.5
Uranium (µg/L)	24.8	6.08	< 0.5

2.2 Pilot Study #2

BKT conducted a pilot study of the FMX system at a coal-fired power plant, testing two different nanofiltration membranes during the study. Permeate generated from the FMX system was further treated by a conventional RO system.

Both pretreated FGD wastewater, which had been injected with a polymer for coagulation in a clarifier, and untreated FGD wastewater were tested as influent streams to the FMX system. Based on the results of the study, BKT determined that polymers have the potential to coat the membranes and, thereby, decrease the performance of the FMX system. Table 2 presents the average pollutant concentrations feed, FMX permeate, and RO permeate.

Table 2. Average Pollutant Concentrations in the Feed and Permeate for FMX Nanofiltration and RO During Pilot Study #2

Parameter	Feed	FMX Permeate	RO Permeate
Arsenic (Total, µg/L)	2.21	1.14	0.673
Mercury (Total, ng/L)	77.4	7.18	0.81
Selenium (Total, µg/L)	275	96.7	2.13

2.3 Pilot Study #3

BKT conducted an 8-month pilot test of the FMX system using a commercial-scale unit with nanofiltration membranes at a coal-fired power plant. The pilot system treated FGD wastewater in 1,000-gallon batches. Effluent from chemical precipitation treatment was transferred to a feed tank at the head of the FMX system. Wastewater from the feed tank was fed to the FMX nanofiltration system. Permeate from the pilot system was returned to the equalization tank at the front end of the plant's existing full-scale FGD wastewater treatment system; concentrate (i.e., membrane reject) was transferred back to the feed tank. A polishing RO unit was not used in this test to further treat the FMX permeate. Plant staff reported that the permeate from the FMX nanofiltration system was pure enough for reuse in the FGD system. The wastewater was treated in two to three batches per day and the system was drained and flushed with hot water at the end of each day and at the end of each batch cycle. A clean-in-place (CIP) procedure was conducted once per month using hydrochloric acid and sodium hydroxide.

The FMX concentrate was collected so that it could be used to evaluate encapsulation processes. The primary goal of the study was to produce enough brine that could be used to test various cement recipes and evaluate whether the FMX system could be operated as a closed-loop system. Additionally, plant staff determined that the FMX permeate would be fit for reuse in the FGD system and that the closed-loop system recovered 80 percent of the influent wastewater. This means that the volume of wastewater ultimately requiring additional disposal or management (e.g., encapsulation, crystallization, underground injection) was reduced to 20 percent of the original volume. Table 3 presents the average pollutant concentrations measured at the influent and effluent of the FMX system during the testing. Since a polishing RO unit was not included during this test, the data in Table 3 does not show the effluent quality following combined FMX and RO treatment.

Table 3. Average Pollutant Concentrations in the Feed and Permeate for FMX Nanofiltration During Pilot Test #3

Parameter	Feed	FMX Permeate
Arsenic (Total, µg/L)	10	2
Mercury (Total, ng/L)	50	3
Selenium (Total, µg/L)	200	69

The plant intended to conduct an encapsulation study using brine from the FMX nanofiltration system and the plant's fly ash. The encapsulation study had not yet been conducted at the time the EPA obtained information about this test.

2.4 Pilot Study #4

An FMX system with nanofiltration membranes was used for over a year to treat FGD wastewater at a coal-fired power plant. FGD wastewater was transferred directly from the plant's existing holding ponds to the FMX system without any additional pretreatment. Permeate from the FMX system was recirculated back to the holding ponds. The system was set up to treat one batch per day at an 80 percent water recovery rate. During testing, a CIP procedure was performed once per month using the FMX system permeate. Table 4 presents the average pollutant concentrations in the FMX feed and permeate for data collected over approximately six months. Since a polishing RO unit was not included for this pilot test, the data in Table 4 does not show the effluent quality following combined FMX and RO treatment.

Table 4. Pilot Study #4 – Average Pollutant Concentrations

Parameter	Feed	FMX Permeate
Total Suspended Solids (mg/L)	1,360	<10
Total Dissolved Solids (mg/L)	25,400	5,230
Bromide (mg/L)	73	15
Nitrate (as N, mg/L)	27.8	6
Calcium (Dissolved, µg/L)	5,620,000	1,297,000
Arsenic (Total, µg/L)	<5.5	<5.5
Mercury (Total, ng/L)	1,610	334
Selenium (Total, µg/L)	423	30.4

2.5 Pilot Study #5

BKT conducted a 3-month pilot study of the FMX system at a coal-fired power plant. Wastewater from the plant's FGD holding pond was transferred to a feed tank prior to treatment through the FMX system. Permeate from the FMX system was further treated using a conventional RO system and the FMX system concentrate was transferred back to the FGD holding pond.

Based on the results of the study, BKT determined that increasing the speed of the FMX system blades increases flux and reduces the rate of flux decline as more permeate is produced. BKT also determined that introducing an anti-scalant to the feed water reduces the change in flux, which successively reduces CIP needs and increases membrane lifespan. Table 5 presents the average pollutant concentrations in the treatment system influent, the FMX permeate, and the RO permeate.

Table 5. Average Pollutant Concentrations in the Feed and Permeate for FMX Nanofiltration and RO During Pilot Study #5

Parameter	Feed	FMX Permeate	RO Permeate
Total Dissolved Solids (mg/L)	3,890	1,860	192
Sulfate, mg/L	2,380	929	20
Arsenic (Total), µg/L	11.1	8.46	6.09
Mercury (Total), ng/L	240	16.6	< 5
Selenium (Total), µg/L	1,930	726	6.84
Nitrate-Nitrite, mg/L as N	5.6	5.6	1.25

2.6 Pilot Study #6

BKT conducted a pilot study of a 400 gallon per minute (GPM) FMX system in 2018 at a large coal-fired power plant in the Southeastern U.S. The FMX system was set up to be able to function in either a batch or a single pass (SP) mode. Wastewater was drawn from the plant's FGD holding ponds and sent through the FMX system; batch tests were performed with approximately 1,000 gallons of feed. Effluent from the FMX system was also intermittently sent through a RO system in order to assess the performance of a treatment strategy combining the two methods.

BKT found that operating in batch mode results in the lowest operating and maintenance costs, as compared to continuous, single-pass operation and would therefore be the most advantageous operation mode for steam electric plants. BKT also found that combining the FMX system with an RO system resulted in continuous flow rates through the RO membranes, suggesting that FMX treatment successfully prevented scaling. Table 6 presents the average pollutant concentrations in the treatment system influent, the FMX permeate, and the RO permeate over the course of two months of operation.

Table 6. Average Pollutant Concentrations in the Feed and Permeate for FMX Nanofiltration and RO During Pilot Study #6

Parameter	Feed	FMX Permeate	RO Permeate
TSS (ppm)	14.4	0.00	0.00
Alkalinity (ppm)	40.3	34.4	-
Chloride (ppm)	227	209	11.3
Nitrate (ppm)	19.0	19.2	3.5
Sulfate (ppm)	2,350	1,115	12
Phosphate (ppm)	≤ 0.25	≤ 0.25	≤ 0.25
Sodium (ppm)	59	43	4.11
Magnesium (ppm)	231	117	0.84
Aluminum (ppb)	108	≤ 107	≤ 107
Silica (ppm)	15	12	1.07
Calcium (ppm)	501	246	≤ 2.11
Iron (ppb)	166	116	107
Arsenic (ppb)	≤ 8.1	≤ 6.69	≤ 5.73
Selenium (ppb)	2,062	974	8.44
NO_2+NO_3 as N (ppm)	5.54	5.66	1.17
Total Mercury (ppt)	151	≤ 10.2	≤ 12.3
TDS (ppm)	3,995	2,193	224

Note: Underlined average pollutant concentration values include samples below the detection limit.

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Appendix C – Envirogen Technology

1. Technology Description

Envirogen, an environmental technology and process solutions provider, markets a fluidized bed reactor (FBR) system, which consists of attached growth cultures. The FBR is an active, fixed-film bioreactor that fosters the growth of microorganisms on a hydraulically fluidized bed of fine media, usually sand or activated carbon. In this reactor, the wastewater is passed through a granular solid material at velocities sufficient to suspend or fluidize the solid media. The small, fluidized media provide an extremely large active surface area on which a film of microorganisms can grow while treating contaminants thus producing a large inventory of biomass. This high concentration of biomass – typically 5 to 10 times greater than in conventional activated sludge bioreactors – provides the system's high volumetric efficiency. The attached growth process uses a granular activated carbon media in an anaerobic fluidized bed process to reduce selenium. As the biomass increases, the microorganisms grow on the carbon media causing the density of the media to decrease, thus increasing the height of the media in the FBR.

The process biologically reduces selenate to elemental selenium that precipitates out of solution. The process also reduces sulfate to sulfide, forming metal sulfide compounds that precipitate in the wastewater and remove other metals including mercury, cadmium, chromium, copper, and zinc.

Envirogen's FBR operates continuously in an aerobic, anaerobic, or anoxic environment. Anoxic FBR systems are used to treat inorganic constituents, including nitrate and selenium. The reactors are available up to 30 feet tall with diameters ranging from 2 to 18.5 feet. The deep bed design and vertical orientation contributes to the FBR's smaller footprint compared to other biological treatment systems such as packed bed reactors. The FBR distribution system maintains uniform upflow of influent wastewater through the suspended media at a constant hydraulic loading rate.

Envirogen FBRs include patented biomass control systems, which are critical to retaining media and steady-state operation and plug-flow. The FBR system is maintained without backwashing as the treated water (with biomass sheared from the media) overflows from the top of the reactor to the downstream biosolids removal unit. In Envirogen's systems, biomass is removed in a steady-state manner with their patented biomass control devices. These systems allow the FBR to operate with an optimized and consistently high biomass concentration, resulting in reliably high performance. A portion of the wastewater passing through the suspended media is recycled back to the reactor, combining with the influent wastewater stream.

During start-up, the FBR is seeded with heterotrophic bacteria that are suited for nitrate and selenium removal. Electron donor materials and nutrients are pumped into the FBR to promote microbial growth. As microorganisms envelope the media, the fluidized bed height expands. With time, a biofilm develops on the media surface. Nitrate and selenate/selenite reduction occur on this biofilm. Treated water from the FBR system is discharged to a downstream liquid/solid separation system where the biological solids and elemental selenium are separated. Thickened or dewatered bio-solids and elemental selenium are disposed.

For FGD wastewater applications, pretreatment is required prior to entering the bioreactor to soften the water to prevent scaling (dropping hardness levels to where traditional scaling indices, e.g., Langelier and Ryzner, indicate low risk of scaling) and to achieve removal of arsenic and mercury. This may consist of traditional physical/chemical unit operations, such as chemical precipitation. Sand filters may be used following traditional clarification to remove residual solids including particulate arsenic and mercury.

The FBR system requires solids separation post-treatment to remove suspended solids (particulate selenium) and polish wastewater to final permit limits. This may be accomplished with a ballasted sand clarifier, which is in full-scale operation at two mining operations; a multi-media filter, which has been pilot tested at Mill Creek; or with ultrafiltration (UF) membrane treatment, which has been pilot tested at Winyah Generating Station. The UF membrane has proven most effective for solids and selenium removal from final effluent but is also the most prone to upsets related to scaling, especially for FGD wastewaters high in dissolved solids.

2. Technology Status and Performance

Envirogen has either conducted or provided equipment for 12 pilot studies for selenium removal using an FBR in the mining, refinery/petrochemical, and coal-fired power plant industries. Three of these pilots treated FGD wastewater and are listed in Table 1. See the *Supplemental Statistical Support Document: Effluent Limitations for Final Steam Electric Power Generating Effluent Limitations Guidelines and Standards* (DCN SE09642) for detailed information regarding the pollutant removal efficacy of this treatment technology.

Table 1. Pilot Scale Envirogen FBR FGD Wastewater Treatment Systems

Pilot Number	Test Duration
Pilot #1	6 Months
Pilot #2	8 Months
Pilot #3	6 Months

3. References

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Appendix D – Evoqua Technology

1. Technology Description

The underlying technology for Evoqua's Pironox™ system was developed in conjunction with Dr. Yongheng Huang of Texas A&M University. The system is commonly referred to as hybrid zero-valent iron (ZVI), activated iron, or advanced reactive media. It is designed as an add-on system to be used in conjunction with other treatment systems, such as chemical and physical treatment, to target specific inorganics such as selenium, arsenic, nitrate, and mercury.

The principle behind the Pironox™ technology is the mixing of influent wastewater with ZVI, or pure elemental iron, which spontaneously reacts with oxyanions, metal cations, and some organic molecules in the wastewater. A reduction reaction of these pollutants occurs with the ZVI. After the reduction reaction, these pollutants immobilize through surface adsorption to the iron oxide coating on the ZVI. The quantity of ZVI required for treating FGD wastewater depends on multiple factors such as wastewater flow rate and the concentration of selenium and nitrate. For example, for an influent nitrate concentration of 25 milligrams per liter (mg/L), a ZVI dosage rate of 250 to 450 mg/L is expected. If a nitrate removal system is used upstream of the Pironox™ system, ZVI consumption may be reduced by 70 percent.

Figure 1 shows the treatment configuration using the Pironox™ treatment system in an FGD wastewater application. In this configuration, the Pironox™ system treats concentrate from an upstream reverse osmosis (RO) treatment system. The Pironox™ system focuses on reducing selenium and nitrate from the RO concentrate to levels that, when blended back with the RO permeate, is intended to meet 2015 ELG discharge standards. In this example, the Pironox™ system includes three reactors in series with ferric chloride dosed in each reactor to encourage flocculation. Other designs may incorporate four reactors. Having multiple reactors allows the operator to bypass individual units for maintenance or repair without having to take down the entire system. After sodium hydroxide addition for pH adjustment and polymer addition for coagulation, ZVI reactor effluent is further treated through a clarifier before discharge.

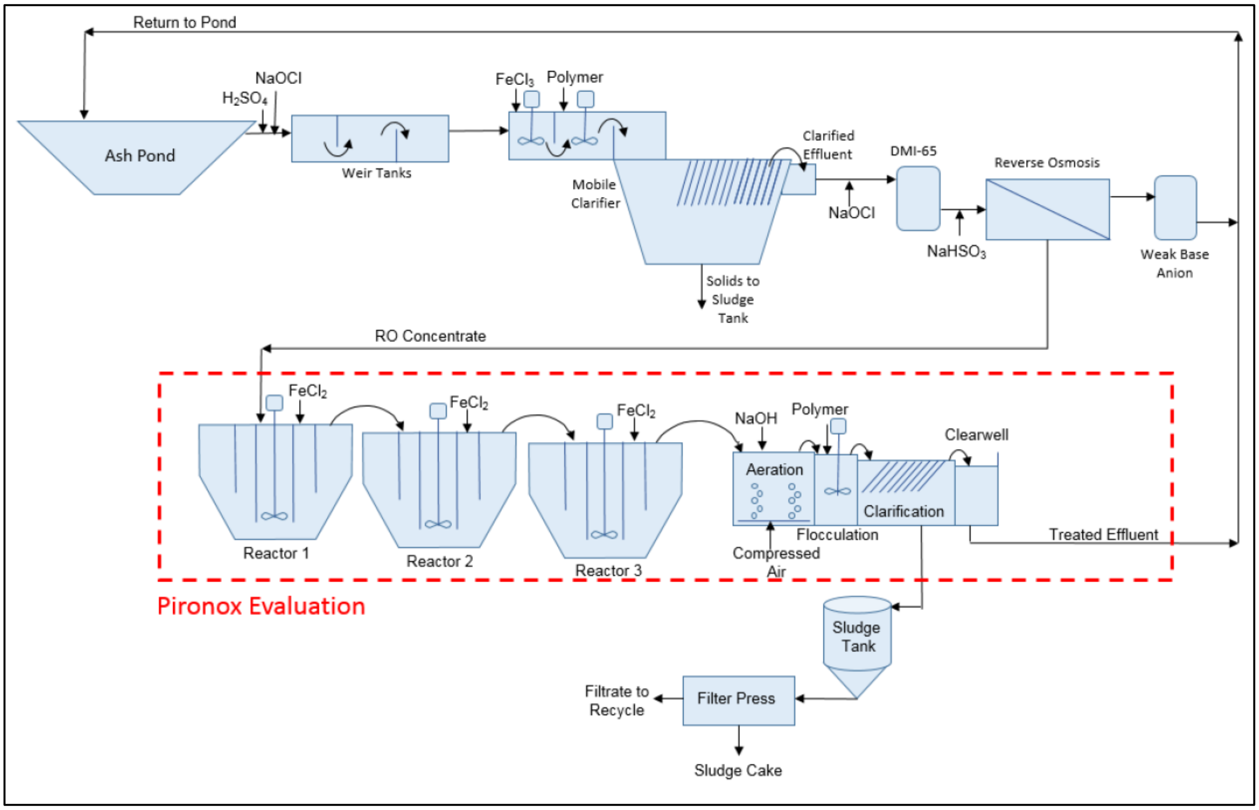

Figure 1. Example Process Flow Diagram for the Pironox™ System

2. Technology Status and Performance

Evoqua has conducted at least eight FGD wastewater pilot tests at seven coal-fired power plants (shown in Table 1). Evoqua's objective in conducting pilot tests has been to demonstrate the long-term stability of metals removal performance and to establish the minimum hydraulic retention time (HRT) of the reactor series. The typical treatment train in the pilots included wastewater pretreatment (e.g., settling ponds or chemical precipitation), multiple ZVI reactors, followed by clarification and filtration (multimedia or sand filtration). The following sections contain details of the seven pilot studies where additional information is available.

Table 1. Pilot Scale Pironox FGD Wastewater Treatment Systems

Pilot Number/Plant Name	Test Dates
Pilot #1 (Section 2.1)	1/17/2011 – 6/22/2011
Pilot #2 (Section 2.2)	9/25/2012 – 11/19/2012
Pilot #3 (Section 2.3)	9/11/2013 – 12/2/2013 and 1/21/2014 – 4/2/2014
Pilot #4 (Section 2.4)	11/2014 – 4/2015
Pilot #5 (Section 2.5)	12/22/2014 – 3/22/2016
Pilot #6 (Section 2.6)	7/20/2015 – 3/31/2016
Pilot #7 (Section 2.7)	9/15/16 – 3/16/17
Pilot #8 [a]	2017

a—No further details available.

2.1 Pilot Study #1

A pilot-scale demonstration continuously treated 1–2 gallons per minute (gpm) of FGD wastewater for five months. After developing the pilot-scale system, the power company used it to conduct longer-term demonstration under various field conditions to evaluate the performance and cost-effectiveness of the hybrid ZVI process for removing nitrates and trace metals, including mercury to less than 14 parts per trillion (ppt) and selenium to less than 10 parts per billion (ppb). The pilot study also evaluated the lower range of hydraulic residence time (HRT) required to achieve the desired removal efficiency.

FGD wastewater from a gypsum pond was pumped into an equalization tank that trapped large particles from the FGD pond; a second pump sent water from the equalization tank to the treatment train, consisting of four ZVI reactors, aeration, clarification, and two sand filtration beds operated in parallel. The reactors operated as a four-stage, single-train system and as a two-stage dual-train system at different points during the study. Water flowed by gravity between the ZVI reactors for a total HRT of 17.4 hours for the single-train operation and 8.7 hours on average for the dual-train operation. Treated effluent from the sand filters was pumped to the plant's ash pond. When operating as a single-train system, the pilot configuration reduced selenium to less than 10 ppb. When operating as a dual-train system at an HRT of 5 hours, mercury was reduced to less than 14 ppt.

2.2 Pilot Study #2

A pilot-scale demonstration continuously treated 1 gpm of FGD wastewater for a period of two months. In addition to meeting 2015 ELG limits for selenium and mercury, the pilot study focused on whether addition of bromide to coal for mercury control affected selenium concentration in FGD wastewater. Blowdown from a gypsum pond overflowed into an equalization pond, where a slipstream was pumped to the treatment train at a rate of 2 gpm. The pilot study evaluation consisted of four ZVI reactors with a retention time of 17.4 hours, aeration, clarification, and sand filtration. The study demonstrated that the technology could reduce selenium to 50 ppb and mercury to less than 10 ppt. Bromide addition did not affect operation of the Pironox reactors.

2.3 Pilot Study #3

The Pironox™ pilot study operated from September 11, 2013, to December 3, 2013 (Phase 1) and again from January 21, 2014, to April 2, 2014 (Phase 2). The pilot-scale system treated effluent from the plant's existing FGD settling ponds. The pilot treatment train consisted of four ZVI reactors, an oxidation step, a clarifier, and a sand filter. Each of the four ZVI reactors was specifically designed to allow for optimum mixing to reduce selenate to selenite, elemental selenium, or selenide and allow the selenite to adsorb to the iron oxyhydroxides generated in the process. Following the fourth reactor, an oxidation step was used to oxidize the ferrous iron that is generated as a by-product during the reaction to ferric iron. Sodium hydroxide and an anionic polymer were added for pH control and to promote settling. The ferric iron was settled out in the clarifier. The overflow from the clarifier was polished using a two-stage sand filter prior to being discharged.

Influent water to the pilot varied considerably during the study. During Phase 1, the FGD wastewater was highly oxidized, had a low pH, and had high concentrations of selenium, mercury, and nitrate. In December 2013, the FGD absorber was removed from service for repair, absorber control points were re-programmed, and the facility changed the quality of coal it burned. As a result, the FGD wastewater treated during Phase 2 exhibited a lower ORP, neutral pH, lower concentrations of selenium, mercury, and nitrate, as well as higher concentrations of manganese and iron. Changing the absorber operation to produce a less oxidizing wastewater reduced the mercury concentration by roughly two orders of magnitude and selenium by one order of magnitude.

2.3.1 Phase 1 (September 11, 2013, to December 3, 2013)

During Phase 1, the pilot was fed with a flow rate of 0.5 gpm (HRT of 26 hours) except for September 29 through October 29 when the feed flow rate was increased to approximately 1 gpm (HRT of 13 hours).

Selenium removal ranged from around 80 percent to 95 percent. Effluent selenium mostly consisted of selenate and the unknown selenium species. After one week of operation, the effluent selenium was 6.14 ppb. After two weeks, it increased to 63 ppb, and to 300 ppb after three weeks. During the remainder of Phase 1, effluent selenium ranged from 92 ppb to 437 ppb, with an average of 261 ppb.

One potential reason for the poor selenium removal during Phase 1 was improper system start-up. Although the system was operated by Evoqua staff for the entirety of the study, anti-passivation reagents were not added to the system until October 2 at which point a definite decrease in selenium was observed. The high levels of oxidant may have resulted in passivation of a significant portion of the media. Evoqua believes that the doses of anti-passivation reagents used at the pilot were not high enough to ensure continuously good selenium removal. A definite decrease in selenium was observed in the following two weekly samples after the anti-passivation reagents were added. A second reason for poor selenium removals was a lack of fresh ZVI media. Evoqua decided to re-use media from a previous pilot test for this study because they felt the media had a sufficient life expectancy. The life expectancy of the ZVI media was further reduced due to higher than expected nitrate and oxidant compounds in the untreated FGD wastewater. In addition to poor start-up procedures, the analytical laboratory used during Phase 1 had long turnaround times, up to 4-5 weeks for selenium analysis. This resulted in poorly timed treatment system improvements; there were several weeks of poor results before operators were even aware of system performance. The pilot study used an alternative analytical lab during Phase 2 with a faster turnaround time.

Over 99.9 percent mercury removal was achieved during the early part of Phase 1 when the influent concentration was greater than 100 micrograms per liter (µg/L). However, during the second half of Phase 1, the mercury concentrations were close to 1 µg/L. Evoqua hypothesizes that the higher mercury concentrations were the result of high levels of oxidants and nitrates in the FGD wastewater that left very little active ZVI media in the reactors.

2.3.2 Phase 2 (January 21, 2014, to April 2, 2014)

By the end of November, the treated effluent contained high concentrations of selenium, so Evoqua decided to remove the ZVI media from the system and re-start the study in 2014. During Phase 2, the pilot treatment system was modified to include a sedimentation step following Reactor 2. Sludge from the sedimentation step was recycled back to the first reactor and overflow was directed to Reactor 3. The FGD wastewater was treated at a rate of 0.5 gpm with an HRT of 26 hours for all of Phase 2. The sedimentation step was added in response to the high levels of nitrate seen in Phase 1. The high nitrates were resulting in higher concentrations of waste sludge. Allowing time for this sludge to settle and recycling of these solids within the ZVI reactors allowed for more complete use of the ZVI. Additionally, a finer grade and higher concentration of ZVI media was used in each reactor.

During the first four weeks of Phase 2, the selenium concentration in the treated effluent was below 10 ppb. On February 21, the flow was increased from 0.5 gpm to 1.0 gpm (HRT was reduced from 24 to 12 hours). Evoqua observed that this increase was done too quickly, and a significant quantity of the ZVI media was washed out of the system as a result. The effluent selenium increased to 12.5 ppb, but it's unknown whether this was the result of media washout or another factor. For the remainder of the study, the effluent selenium ranged from 17 µg/L to 37 µg/L (using the Applied Speciation data) and up to 100 µg/L (EPA 200.7 data). On March 7, Evoqua started experimenting with various doses of anti-passivation reagents, including very low doses. From March 18 through the end of the study, slightly higher selenium concentrations were seen in the treated effluent. It is unclear whether the increase in selenium was due to changes in reagent dose.

Mercury concentrations in the treated effluent were below 100 ng/L for all of Phase 2. However, changes in the operation of the FGD scrubber resulted in lower concentrations of mercury in the untreated FGD wastewater used for Phase 2.

Nitrate plays an important role in the ZVI process because it is chemically reduced along with the selenium. The nitrate present in the untreated FGD wastewater was converted to ammonia within the treatment system.

2.4 Pilot Study #4

Evoqua conducted a pilot-scale demonstration of the Pironox™ system at a power plant from November 2014 to April 2015. The pilot system treated FGD blowdown wastewater at an average flow rate of 12 gpm.[2] The Pironox™ system included four separate reactors followed by aeration, pH adjustment, clarification, and sludge thickening and dewatering. The primary goal of the study was to demonstrate performance of the Pironox™ system over 30 consecutive days of operation. Over a testing period of 106 days, the treatment train met the 2015 ELG limits for arsenic, mercury, selenium, and nitrate-nitrite.

2.5 Pilot Study #5

A Pironox pilot study was conducted at a power plant from December 22, 2014, to March 22, 2016, to determine whether the technology could meet the 2015 ELG limits. The pilot received a slipstream of FGD wastewater from a pond. The treatment train consisted of four ZVI reactors followed by clarification and multimedia filters with flow rates between 12 and 20 gpm. Ultimately, the pilot exhibited unreliable compliance with the ELG limits.

2.6 Pilot Study #6

To evaluate the scalability of the Pironox technology on a mobile platform, a pilot study was conducted from July 20, 2015, to March 31, 2016. A 1 gpm slipstream of FGD wastewater from a pond was treated through a series of four ZVI reactors, a clarifier, and multimedia filters. The pilot study was not scaled to handle a larger flow rate. No performance data were provided with the pilot study documentation.

2.7 Pilot Study #7

To evaluate potential long-term compliance with the 2015 ELG limits, a pilot study was conducted using a 1 gpm slipstream of FGD wastewater at a power plant. The pilot received pretreated effluent from a system consisting of pH adjustment, primary clarification, addition of organosulfide and ferric chloride, and secondary clarification. The pH of the pretreated effluent was adjusted with hydrochloric acid before being pumped to a series of four ZVI reactors. Following ZVI filtration, FGD wastewater was pumped through an aeration tank as well as a mix tank with polymer addition. Finally, precipitated iron was settled in a clarifier prior to discharge. Average performance data collected during the pilot study are presented in Table 2.

Table 2. Performance Data for FGD Wastewater Pilot Study Using Evoqua's Pironox™

Parameter	Average Influent	Average Effluent
Arsenic, µg/L	156	< 5
Bromide, mg/L	57.9	42.6
Chloride, mg/L	1,390	1,220
Mercury, µg/L	53.4	0.00579
Nitrate-Nitrite (as N) mg/L	< 5.15	< 2.37
Selenium, µg/L	789	< 10.1
TDS, mg/L	45,80	4,780

[2] The report includes no information regarding the source of the FGD wastewater and whether the wastewater was pretreated.

3. References

1. EPRI. 2013. Electric Power Research Institute. Pilot-Scale Demonstration of Hybrid Zero-Valent Iron Water Treatment Technology. 1022161. Palo Alto, CA. (April). DCN SE07840.
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Appendix E – Frontier Technology

1. Technology Description

Frontier's SeHAWK is a modular, fixed-film, biological treatment system that is prefabricated and can be delivered directly to a treatment site. Frontier manufactures four sizes based on flow capacity (50 gallons per minute (gpm), 250 gpm, 500 gpm, and 1,000 gpm) so that steam electric facilities may implement several modules of varying sizes to meet the flow rate and retention time needed for treatment.

Frontier recommends installing a physical/chemical pretreatment system prior to the bioreactor. In addition, depending on wastewater characteristics, it may be appropriate to include an additive such as sodium bisulfite prior to the SeHAWK unit to remove oxidants that can inhibit biological performance. The pretreatment system typically includes two reaction tanks with organosulfide and coagulant chemical addition followed by a clarifier with polymer addition. Sludge generated through clarification is dewatered while the process wastewater continues to a gravity filter. The SeHAWK treatment train begins at an equalization tank that receives process wastewater from the gravity filter as well as the filtrate from the dewatering process. If the FGD purge contains a nitrate concentration greater than 50 milligrams per liter (mg/L), wastewater stored in the equalization tank would first need to be sent to a nitrate pre-treatment stage. Following nitrate pre-treatment (if needed), the wastewater would then be transferred to the anoxic, two-stage bioreactor. Water flows by gravity from the first stage upflow bioreactor to the second stage downflow biofilter. The bioreactors reduce selenate and selenite to elemental selenium that then precipitates out of solution. Filtrate from the biofilter is further treated by an ultrafiltration (UF) membrane that removes suspended solids exiting the bioreactor. The bioreactor system also includes oxidation-reduction potential (ORP) monitoring as a process control to optimize nutrient addition (food for microorganisms) and reducing agent dosage when needed. See Figure 1 for a general block flow diagram of the Frontier SeHAWK treatment process for FGD wastewater.

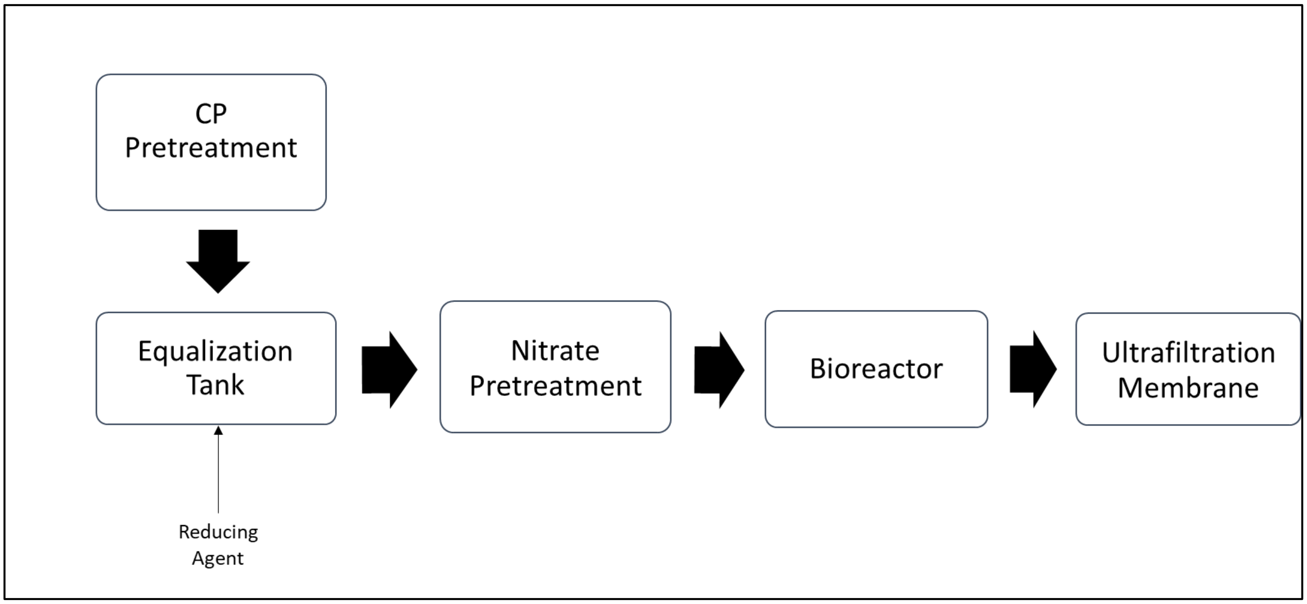

Figure 1. Frontier SeHAWK Biological Treatment Process Flow Diagram

2. Technology Status and Performance

Frontier has conducted 14 FGD wastewater pilot tests at coal-fired power plants in the past six years. Frontier conducts pilot studies to optimize chemical dosages, ultrafiltration efficiency, residuals management for a specific plant's operation, and determine the ideal design criteria to remove FGD wastewater pollutants, including selenium and nitrate nitrogen. In addition to the 14 pilots, Frontier has installed four full-scale SeHAWK treatment systems at coal-fired power plants to treat FGD wastewater to remove selenium, nitrate, and other metals. See the *Supplemental Statistical Support Document: Effluent Limitations for Final Steam Electric Power Generating Effluent Limitations Guidelines and Standards* (DCN SE09642) for detailed information regarding the pollutant removal efficacy of this treatment technology.

Table 2 includes a listing of the pilot demonstrations of the Frontier system on FGD wastewater.

Table 1. Pilot Scale Frontier FGD Wastewater Treatment Systems

Pilot Number	Test Duration (if known)
Pilot #1	3 Months
Pilot #2	7 Months
Pilot #3	5 Months
Pilot #4	2 Months
Pilot #5	2 Months
Pilot #6	5 Months
Pilot #7	Unknown
Pilot #8	5 Months
Pilot #9	4 Months
Pilot #10	1 Month
Pilot #11	8 Months

Table 1. Pilot Scale Frontier FGD Wastewater Treatment Systems

Pilot Number	Test Duration (if known)
Pilot #12	3 Months
Pilot #13	Unknown
Pilot #14	Unknown

The EPA is also aware of four full-scale installations of Frontier's SeHAWK system for treating FGD wastewater. Table 2 includes a list of these full-scale installations.

Table 2. Full Scale Frontier FGD Wastewater Treatment Systems

Plant Name	State
Crystal River	Florida
Marshall	North Carolina
Miller	Alabama
Cliffside	North Carolina

3. References

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Appendix F – GE Alstom Spray Dryer Technology

1. Technology Description

The spray dryer evaporator (SDE) system utilizes a spray dryer to combine wastewater with hot flue gas and evaporate the waste stream, resulting in zero liquid discharge from the system. Wastewaters to be treated, including FGD wastewater and other steam electric wastewaters (e.g., cooling tower blowdown, storm water, coal pile runoff), collect in a holding tank and mix with lime. The lime-rich wastewater is injected into a spray dryer with hot flue gas from the boiler, taken from upstream or downstream of the air heater depending on the plant's configuration. The hot gas is used to evaporate the water and dry the suspended and dissolved solids in the wastewater. The temperature of the gaseous outlet from the spray dryer is controlled to ensure all solids are dried completely.

The lime, added to the untreated wastewater, reacts with acid gases in the flue gas forming additional solid particulate. Particulate collection equipment, a fabric filter or an electrostatic precipitator, can then be used to collect the dried wastewater solids, reacted lime particulate, and fly ash from the flue gas stream.

This SDE technology is currently used by at least one steam electric power plant, in the Midwest, to treat FGD wastewater from two 850-megawatt (MW) coal-fired boilers. The system utilizes a small slipstream of hot flue gas from the boilers to evaporate the wastewater and collect solids in the plant's existing downstream particulate collection device.

2. References

1. Alstom. 2014. GE Alstom Spray Dryer Evaporator Brochure. DCN SE07122.
2. Alstom. 2015. Alstom's first-of-its kind water treatment technology to help utility customer meet EPA guidelines. (July 27). Available online at: https://www.alstom.com/press-releases-news/2015/7/alstoms-first-of-its-kind-water-treatment-technology-to-help-utility-customers-meet-epa-guidelines. DCN SE07123. Accessed: September 23, 2019.

Appendix G – Heartland Technology

1. Technology Description

Heartland developed a proprietary adiabatic evaporator technology called the LM-HT concentrator (i.e., Heartland concentrator). The system uses an evaporation zone, an entrainment separator, and a solid/liquid separator to achieve zero liquid discharge without a crystallizer. First, the system injects wastewater and hot feed gas into the contact chamber evaporation zone to form water vapor and concentrated wastewater. The wastewater is introduced into the heat zone via proprietary mist eliminators that allow water to evaporate before meeting the surface of the vessel. The feed gas for the concentrator may be pulled from processes within a coal-fired power plant (e.g., slip stream from flue gas, engine waste heat, or combustion exhaust from dedicated gas burners) and must be at least 400°F prior to injection. The optimal feed gas temperatures are between 900°F and 1,000°F; cooler gas streams require more surface area, and thus a larger footprint concentrator, to evaporate the same amount of water. Once in the concentrator, the feed gas is maintained between 150°F and 800°F. Any remaining wastewater that is not evaporated collects in a sump and is recirculated back through the concentrator. Typically, the concentrator is fed a wastewater stream that is 80 percent recycle from the sump (wastewater that has already been through the concentrator's heat zone) and 20 percent fresh feed.

The temperature at the top of the concentrator is around 900˚F while the temperature in the bottom of the concentrator (near the sump) is around 150˚F. The cooling in the system is conducted rapidly so that solids build up but do not scale the equipment. The only moving parts of the LM-HT concentrator are the sump and an induced draft fan, which pulls hot gasses through the concentrator.

Effluents from the concentrator include a water vapor stream, which can either be vented to atmosphere or captured and condensed, and a residuals stream. The residuals stream is typically sent to a solid/liquid separator such as a cone bottomed separating tank or a centrifuge. The LM-HT can be operated to produce a liquid effluent (either a saturated brine or high-density slurry), or the concentrated wastewater may be recycled back to the evaporation zone and operated in conjunction with solids handling equipment to produce a solid for disposal. The solids can be disposed of directly in a landfill or the brine/slurry can be mixed with fly ash and sent to a landfill. Figure 1 is a simplified process flow schematic of the Heartland LM-HT when used in conjunction with a dedicated heat source (in this example, propane combustion).

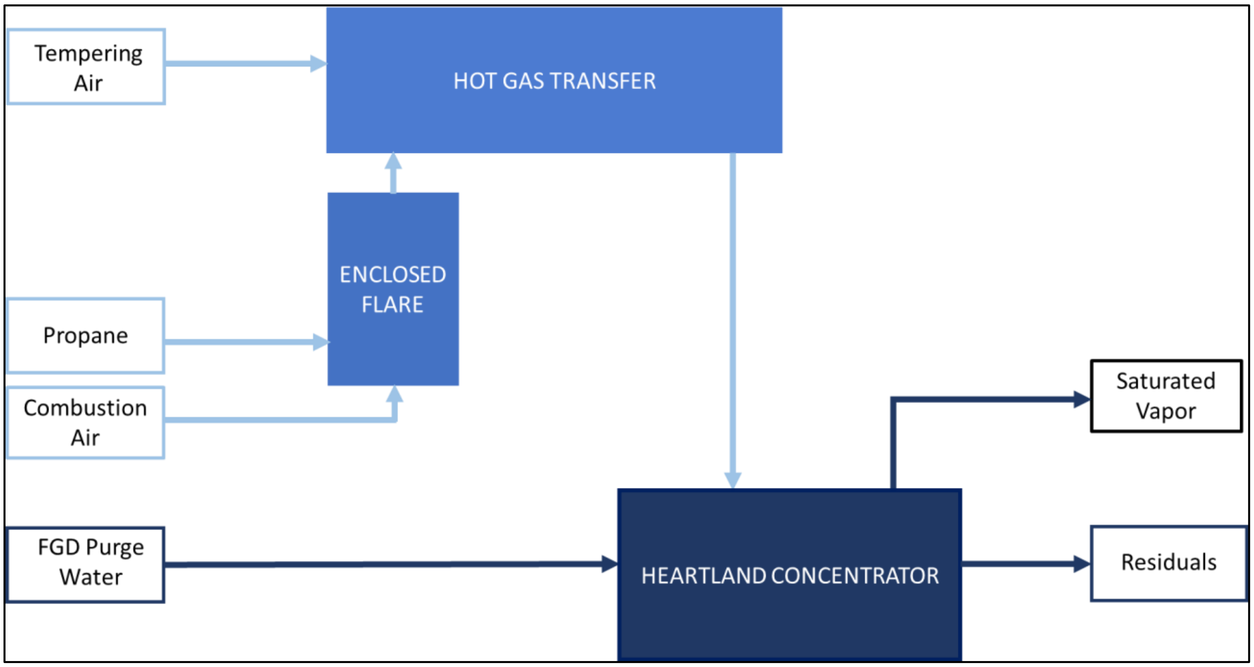

Figure 1. Heartland LM-HT Concentrator Process Flow Diagram (Using Dedicated Gas Burners for Heat Source)

While pretreatment is not required prior to sending FGD purge to the concentrator, if the total suspended solids (TSS) concentration is greater than five percent, a clarifier may be useful in reducing solids produced by the concentrator and would lower concentrator costs. The concentrator can handle up to 200,000 milligrams per liter (mg/L) total dissolved solids (TDS). The maximum chlorides that can be treated using the concentrator is roughly half of TDS, equivalent to 100,000 mg/L.

Each LM-HT concentrator unit is mounted on a pre-packaged skid with an average footprint of 2,500 square feet. The LM-HT requires approximately 1,350 BTUs of heat energy to vaporize one pound of wastewater when operating with optimal feed gas temperatures. Density and temperature are the only process control parameters. Materials of construction include Al6N, a highly corrosion resistant alloy metal for the concentrator, fiberglass for the mist eliminator section of the concentrator, and stainless steel for the induced draft fan.

If the LM-HT uses flue gas from upstream of the air heater as a heat source, the flue gas would be returned to the system at a cooler temperature, downstream of the air heater but upstream of the electrostatic precipitator (ESP). This configuration is similar to a spray dryer. Heartland describes that the difference between their concentrator system and a spray dryer is the location of FGD solids collection. Spray dryers typically rely on the downstream ESP to collect both fly ash and FGD solids. The Heartland concentrator allows the downstream ESP to collect only fly ash solids, as it typically operates, and the FGD solids to be collected from the concentrator's purge stream.

Heartland tested stabilization of produced water concentrate using Portland cement and other additives. Heartland has not conducted similar testing with FGD wastewater yet. Through testing, Heartland has found the key component of encapsulation is the brine consistency, and the most cost-effective solution is evaporation of the brine beyond solids saturation to a slurry solution.

In addition to operating as a stand-alone wastewater treatment option, the LM-HT can be preceded by a membrane filtration system (e.g., reverse osmosis, nanofiltration) to pre-concentrate wastewater.

Maintenance of the LM-HT concentrator involves cleaning the mist eliminator plates every two weeks. During this process, the concentrator is shutdown, and the plates are removed and cleaned with a pressure washer. As an alternative, the plates can be cleaned in place. Shutting down and restarting the concentrator takes as little as 5 minutes. Other maintenance activities include monitoring and managing foaming with occasional addition of an anti-foaming agent. Heartland also advises dosing the entire system once per week with acid to prevent solids from building up in piping. The concentrator unit does not require housing or cover. The life expectancy of the blower and pump equipment is roughly 20 years.

The LM-HT system has been operating at multiple landfill locations for years to treat landfill leachate. In addition, the system previously operated successfully for three years at a power plant to treat FGD wastewater and has been piloted elsewhere.

2. Technology Status and Performance

Heartland has operated a full-scale treatment system for FGD wastewater at Iatan Generating Station (Section 2.1) and a pilot-scale system for FGD wastewater treatment at the Water Research Center's Plant Bowen (Section 2.2). Section 2.3 describes a pilot test using the Heartland system to treat CRL, and Section 2.4 describes the MSW leachate applications.

2.1 Iatan Generating Station Full-Scale System

Iatan Generating Station operated a full-scale Heartland system to treat FGD wastewater for three years starting in 2014. The system treated 40 gallons per minute (GPM) of FGD wastewater with a clarifier as pretreatment for TSS removal. The system used a direct fire burner fueled with propane as the heat source. The LM-HT concentrator was operated to achieve zero liquid discharge, evaporating the wastewater all the way to a salt that was then centrifuged and disposed of in an on-site landfill.

2.2 Water Research Center at Plant Bowen Pilot Study

Heartland, in combination with the Electric Power Research Institute (EPRI), Southern Company, and Georgia Power, conducted a 14-day demonstration project at Plant Bowen to evaluate the capability of the LM-HT concentrator. The test, conducted in September 2014, used flue-gas waste heat as the thermal energy source. The test system operated on Bowen's Unit 3, a 950-megawatt (MW) unit and pulled hot gas from the selective catalytic reduction unit outlet, returning the cooled gas just downstream of the air heater. The test operated 24 hours per day for the duration of the 14-day trial, treating more than 10,000 gallons of FGD wastewater. The concentrator achieved 90-95 percent volume reduction, concentrating wastewater to 40 percent solids.

The 14-day Bowen test also evaluated options for disposing of the concentrated FGD product to assess the feasibility of zero liquid discharge (ZLD) using encapsulation/stabilization. Six different mixtures of brine, fly ash, Portland cement, and iron sulfate heptahydrate (used to immobilize heavy metals) were tested. Table 1 details the different mixtures tested.

Table 1. Encapsulation/Stabilization Test Mixtures

Mix Number	Brine Slurry (Percentage)	Fly Ash (Percentage)	Portland Cement (Percentage)	Iron Sulfate Heptahydrate (Percentage)
1	75	15	10	0
2	70	20	10	0
3	75	20	5	0
4	70	25	5	0
5	75	8.5	10	6.5
6	70	13.5	10	6.5

Heartland also performed a pilot test at Plant Bowen using the LM-HT concentration with membrane pretreatment to preconcentrate the incoming wastewater.

2.3 Coal Combustion Residual Landfill Leachate Pilot Study

Heartland participated in a pilot test with EPRI at a coal-fired power plant, Plant Harrison in West Virginia. The test concentrated landfill leachate using a membrane system and then treated it using the Heartland concentrator. The project reduced more than 100,000 gallons of wastewater to less than 1,000 gallons. The test also evaluated encapsulation of the resulting concentrated brine stream.

2.4 Municipal Landfill Leachate

The Heartland LM-HT concentrator has treated landfill leachate from municipal landfills at 14 locations. Each system treats leachate directly using biogas generated by the landfill as the thermal energy source. The Heartland system also treats leachate at two landfills where leachate is preconcentrated using reverse osmosis (RO) followed by treatment using the LM-HT concentrator.

3. References

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2. EPRI. 2016. Electric Power Research Institute. Landfill Leachate Treatment & Brine Encapsulation Project. (January 1). DCN SE07112A3.
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Appendix H – HPD Thermal Technology

1. Technology Description

Veolia offers a variety of technologies for treating FGD wastewater. The primary system, their HPD® technology treats FGD wastewater with evaporation and crystallization. The evaporation portion of the system includes five components:

1. The feed tank;
2. The deaerator;
3. The falling film evaporator (connected to a compression device);
4. The distillate level tank;
5. And the seed recycle tank.

The evaporation process typically recovers 80 to 90 percent of influent water and can concentrate brine up to 25 percent total dissolved solids (TDS).

For FGD wastewater applications, FGD scrubber purge is first treated with minor chemical addition, then pre-heated to atmospheric boiling temperature. The wastewater is deaerated and chemicals are added to remove bicarbonate alkalinity and prevent scaling. Calcium hardness is removed later during crystallization. Wastewater is then sent to the evaporator vessel. As water evaporates, the vapor passes through mist eliminators and a compression device that increases the pressure. The vapor then returns to the evaporator, where it coats the outer evaporator tube walls and condenses as a distillate. The distillate flows to the distillate level tank and is subsequently pumped through the heat exchanger to transfer heat to incoming feed water.

The evaporator also produces a concentrated brine that is sent to a seed tank. Calcium sulfate seed crystals are added to precipitate low solubility calcium salts and silica. The brine is typically sent to a crystallizer for further concentration but can also be sent offsite for disposal. The evaporator, and crystallizer if present, must be taken offline twice a year for cleaning.

Typically, preconcentration using membranes prior to a crystallizer is not desired because the preconcentration equipment is difficult to operate and entails high operation and maintenance costs. At very high flows, it may be more beneficial to preconcentrate the FGD feed to reduce the crystallizer size, so preconcentration using either membranes or a brine concentrator could be advantageous in specific circumstances.

Veolia's steam-driven crystallizer can be operated downstream of the falling film evaporator. The crystallizer allows the system to achieve ZLD. For treatment trains using a crystallizer, concentrated brine is sent from the evaporator to a crystallizer heater, then circulates to the crystallizer vessel. As water evaporates, crystals form and flow out of the vessel as a slipstream before entering a belt filter press or centrifuge for dewatering. The distillate produced by the crystallizer has a low TDS concentration (<50 ppm) and may be reused in the FGD treatment system or elsewhere in the power plant. However, the crystallizer is less efficient than the brine concentrator, as it requires one pound of steam per pound of evaporated water.

Veolia also manufactures a system known as CoLD® Crystallization. This technology does not require as much chemical pretreatment as typical evaporation/crystallization processes because it operates at lower temperatures and pressures. In the CoLD® Crystallization system, a small amount of lime is first added to the FGD wastewater. The FGD wastewater enters the falling film evaporator with seeded slurry. The concentrated brine produced by the evaporator is pumped to the crystallizer, where calcium chloride and other highly soluble salts crystallize. Solids leave the crystallizer vessel as a slipstream that is sent for dewatering, ultimately creating a wet cake. The distillate stream can be recycled or discharged.

Veolia has documented both full- and pilot-scale installations of its HPD® evaporation and crystallization systems. There are more than 1,000 installations of the traditional falling film evaporator systems at plants worldwide. One of these full-scale installations is at a steam electric power plant in Monfalcone, Italy. Since 2008, this plant has utilized the HPD® falling film evaporation with the ZLD crystallization step. Distillate produced by the treatment system is reused within the plant.

As of August 2019, one steam electric power plant is installing a single train falling film evaporator and steam-driven CoLD® Crystallization treatment system for FGD wastewater. The plant has agreed to install the system under an air emissions consent decree. As designed, the system will not include active pretreatment, but some settling is expected in existing scrubber purge ponds before water enters the evaporator. The plant plans to send residual salts to the landfill and recycle distillate. Veolia anticipates that the treatment train will be operational in late 2019.

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Appendix I – KLeeNwater Technology

1. Technology Description

KLeeNwater is a joint venture between ProChem, Inc. and Environmental Energy Services Corporation (EES). KleeNwater offers three trade-marked technologies for FGD wastewater treatment applications: ProChem's I-MICRO, I-PRO, and B-PRO. I-MICRO is a microfiltration membrane with chemical addition, and I-PRO and B-PRO are reverse osmosis (RO) membranes. The typical application for FGD wastewater treatment consists of pretreatment to reduce suspended solids in the wastewater (using either I-MICRO microfiltration/chemical pretreatment, or physical/chemical pretreatment), followed by the I-PRO and B-PRO RO membranes.

Scale forming ions, including calcium, magnesium, and sulfates, are targeted during pretreatment. When microfiltration is incorporated into the treatment train, KLeeNwater uses ProChem's ceramic microfiltration/chemical pretreatment system (I-MICRO). I-MICRO is designed to remove total suspended solids (TSS) from wastewater containing up to 4 percent (40,000 parts per million) TSS. Solids that are removed from the wastewater by the I-MICRO membrane are typically sent to a filter press. Where chemical precipitation is used for TSS removal in place of the I-MICRO system, KLeeNwater includes a sand filtration system upstream of the I-PRO (downstream of chemical precipitation). After TSS removal with either the I-MICRO or chemical precipitation, KLeeNwater also implements cartridge filters to further protect the I-PRO/B-PRO membranes. The I-PRO system removes contaminants including arsenic, mercury, selenium, nitrates/nitrites, boron, bromides, and chlorides.

I-PRO is designed to handle high concentrations of total dissolved solids (TDS). The technology has a TDS influent limit of 5,000 to 45,000 milligrams per liter (mg/L) and a flow rate range of 15 of 350 gallons per minute (GPM). Multiple membrane systems can be installed in parallel to accommodate larger flows.

KLeeNwater offers its brackish water reverse osmosis system (B-PRO) for further removal of TDS from I-PRO permeate. This polishing step is not needed in all industrial wastewater applications. B-PRO has a TDS influent limit of 10 to 5,000 mg/L and a flow rate range of 10 to 350 GPM; higher flow rates would be managed using additional membrane modules.

Like other membrane systems, KLeeNwater RO membranes require flushing and chemical cleaning. In pilot studies, flushes using system permeate were performed approximately once a day, and chemical cleanings were performed approximately once a week. KLeeNwater estimates the membranes will need to be replaced twice per year.

I-PRO or B-PRO concentrate can be managed using a variety of approaches, including thermal technologies or brine encapsulation or solidification processes to achieve zero liquid discharge. KLeeNwater has tested these technologies for different mixtures (e.g., fly ash, lime, superabsorbent polymer) to improve residual treatment and disposal.

2. Technology Status and Performance

The KLeeNwater system has been tested at coal-fired power plants in both laboratory- and pilot- scale studies. KLeeNwater has conducted at least 23 laboratory-scale studies treating wastewater from coal-fired power plants with at least two of the studies treating FGD wastewater. In addition, the EPA reviewed data for four onsite pilot-scale studies with KLeeNwater systems at steam electric power plants for FGD wastewater treatment; the results consistently show pollutant concentrations in the membrane permeate lower than the limits established by the 2015 ELGs. All pilot systems included I-MICRO, followed by the I-PRO and B-PRO, and were operated using a flow rate of approximately five GPM.

2.1 Pilot Studies #1 and #2

KLeeNwater conducted a 5-week pilot study at a utility to test membrane technology and confirm the results of a previous bench-scale study. The FGD wastewater used for testing had a chlorides concentration of 14,300 ppm.

The pilot system included physical/chemical treatment, I-MICRO, I-PRO, and B-PRO. The treated effluent consistently met ELG and state regulations, and the permeate was considered suitable for re-use within the plant or discharge. Encapsulation tests met regulatory requirements for leachability.

The pilot testing used a different pretreatment strategy during each week of the pilot to evaluate the chemical consumption, system performance, and overall costs of the treatment system. The optimal pretreatment design used the addition of an aluminum-based coagulant and a proprietary scale inhibitor formulation prior to the RO. This specific test was conducted during Week 4 and repeated during Week 5 to confirm the results.

Water recovery data for the Week 4 and 5 trials were consistent, even appearing in line with the recovery achieved in bench-scale laboratory trials. The average recovery was 79.5 percent. Table 1 lists the data obtained from the pilot study.

Table 1. Pilot Test #1 - Average Results

Parameter	FGD Purge	Final Effluent
Arsenic (µg/L)	14.5	1.2
Nitrate-Nitrite as N (mg/L)	70.4	0.16
Selenium (µg/L)	563	2.7
TDS (mg/L)	27,900	86.8

The second pilot study was conducted to validate the results of the first pilot study and to refine the pretreatment process. KLeeNwater successfully validated the results of the first study and further optimized the system's pretreatment in the second study.

2.2 Pilot Study #3

KLeeNwater conducted a six-week pilot-scale study at a coal-fired power plant to treat FGD wastewater. The system typically operated 7 days per week during the first shift, demonstrating the ability of the system to handle demands due to load cycling. For one 5-day period, the system operated 24 hours per day to demonstrate continuous operation.

The FGD wastewater used as influent to the pilot system had a chlorides concentration of 865 ppm. The RO system provided 5 GPM of treated water and achieved an average water recovery of greater than 90 percent. The treated effluent met the 2015 ELG requirements. Table 2 lists the data obtained from the pilot study.

Table 2. Pilot Test #3 - Average Results

Parameter	Pretreatment Influent	Final Effluent
Arsenic (µg/L)	158	5.0
Mercury (ng/L)	53,900	9.7
Nitrate-Nitrite as N (mg/L)	5.15	0.40
Selenium (µg/L)	809	9.5
TDS (mg/L)	4,580	90.2

2.3 Pilot Study #4

KLeeNwater conducted a pilot study for 10 weeks, operating continuously at a coal-fired power plant to treat FGD wastewater. The test objectives were to confirm results of a previous bench-scale test, meet ELGs while reducing I-PRO concentrate volume, assess B-PRO for water reuse applications, compare pretreatment options, and demonstrate long-term feasibility of the technology. The treatment train consisted of chemical pretreatment followed by clarification, microfiltration (I-Micro), and a two-stage RO system (I-PRO/B-PRO). The system yielded on average 85.4 percent recovery. The highest recovery rate achieved was 93 percent while treating 100 percent FGD wastewater; the lowest recovery rate was 69 percent when treating 100 percent brine. Treated effluent consistently met ELG regulations when the B-PRO system was operated; otherwise, B-PRO permeate was of sufficient quality for reuse as scrubber make-up water. Table 3 lists the data obtained from the pilot study.

Table 3. Pilot Test #4 - Average Results

Parameter	Feed Tank Effluent	Final Effluent
Arsenic (µg/L)	18.5	5.0
Mercury (ng/L)	636	0.5
Nitrate-Nitrite as N (mg/L)	294	1.19
Selenium (µg/L)	561	5.0
TDS (mg/L)	19,200	67.1

2.4 Laboratory Scale Treatability Testing

KLeeNwater conducted laboratory-scale treatability testing on samples of FGD wastewater from coal-fired power plants and coal combustion residual (CCR) landfill leachate. Table 4 includes results for FGD wastewater treatment using chemical pretreatment followed by clarification, microfiltration (I-Micro), and a one-stage RO system (I-PRO). KLeeNwater estimates approximately 83 percent recovery could be achieved.

Samples of untreated CCR landfill leachate were tested at the KLeeNwater lab to determine untreated leachate characteristics and evaluate treatment efficacy of the I-PRO/B-PRO system. In the laboratory environment, KLeeNwater simulated physical-chemical treatment to remove solids, I-PRO treatment, and B-PRO treatment simulated. Table 5 provides average wastewater characteristics for untreated leachate, permeate, and concentrate for the I-PRO system.

Table 4. Average Characteristics for FGD Wastewater Treatability Testing

Parameter	Untreated Wastewater	I-PRO Permeate	I-PRO Concentrate
Boron (µg/L)	215	134	604
Nitrate (µg/L)	2,250	0	0
Nitrite (µg/L)	1,622	0	0
Nitrate-Nitrite as N (mg/L)	3,872	0	0
Bromide (µg/L)	114	1.11	236
Chloride (µg/L)	23,178	175	47,687
TDS (mg/L)	38,038	408	72,255

Table 5. Average Characteristics for CCR Landfill Leachate Treatability Testing

Parameter	Untreated Wastewater	I-PRO Permeate	I-PRO Concentrate
Arsenic (µg/L)	0.265	0.05	1.25
Mercury (ng/L)	<400	1.19	<400
Nitrate-Nitrite as N (mg /L)	<1	<10	<10
Selenium (µg/L)	<0.20	<0.10	<0.20
TDS (mg/L)	17,400	440	75,200

2.5 Concentrate Management Pilot Testing

As part of KLeeNwater's pilot tests, the company evaluated options to manage the concentrate (i.e., membrane reject stream) generated by treatment of FGD wastewater. Concentrate encapsulation technologies were evaluated in four different pilot studies to assess their performance. These included:

- Wetting fly ash with concentrate (*fly ash wetting*).
- Wetting FGD gypsum with concentrate (*gypsum wetting*).
- Wetting fly ash samples with lime and concentrate (*hydrated lime encapsulation*).
- Adding super absorbent polymer and lime with concentrate (*super absorbent polymer encapsulation*).

Based on the results of the pilot studies, KLeeNwater states that their treatment technology produces a concentrate that can be encapsulated using these different approaches in compliance with toxicity characteristic leaching procedure (TCLP) testing.

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Appendix J – Mitsubishi Spray Dryer Technology

1. Technology Description

Mitsubishi Power (Mitsubishi) has developed a spray dryer unit (i.e., the wastewater spray dryer (WSD)) that uses a slipstream of flue gas upstream of the air heater as a heat source. The slipstream is typically at a temperature between 650°F and 800°F. The FGD wastewater evaporates in the WSD, and residual solids are carried along with the slipstream as it exits the WSD and recombines with the main flue gas stream. The solids are subsequently removed along with the fly ash through separate particulate removal equipment (i.e., electrostatic precipitator or fabric filter). Alternatively, solids from the slipstream can be removed separately from fly ash through installation of separate particulate filtration technologies to treat the slipstream only. A booster fan is used to propel the flue gas slipstream through the WSD to overcome any pressure drop. The booster fan also enables the operator to have positive control over the flue gas slipstream. The evaporated wastewater (i.e., water vapor) is carried along with the flue gas as it travels through the air pollution control equipment.

There is no theoretical limit on what can be evaporated in the WSD; however, because the slipstream is taken from the flue gas prior to going through the air heater, thus reducing the energy input to the boiler, there is a practical limit when considering the impact on the plant from using flue gas. Mitsubishi has designed WSDs that extract six to seven percent of the total flue gas volume from the air heater and have less than a one percent impact on the plant. The slipstream is then recirculated back to the main flue gas stream at approximately the same temperature as the flue gas exiting the air heater. Figure 1 shows an example process flow diagram for an FGD wastewater treatment system that uses a WSD to achieve zero discharge.

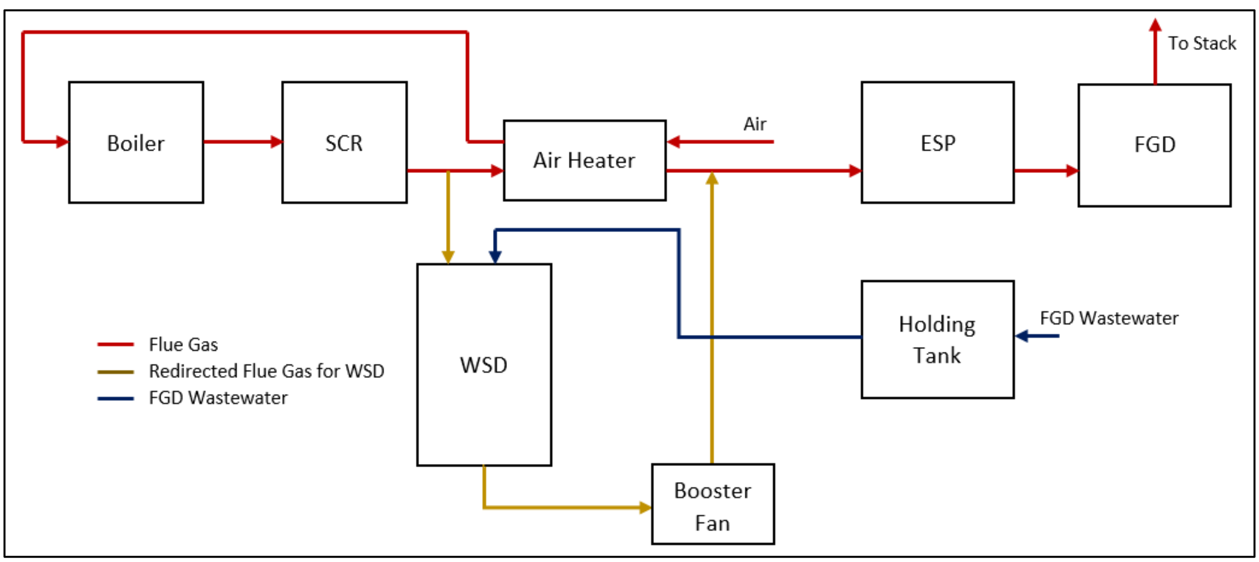

Figure 1. Example Flow Diagram for FGD Wastewater Treatment through WSD

The WSD can either be equipped with dual fluid nozzles or rotary atomizers. Dryers using rotary atomizers are designed to be shorter and wider while dryers using dual fluid nozzles are designed to be taller and thinner based on the spray patterns for each type of atomizer. Each WSD can be equipped with an unlimited number of atomizers. The WSD volume is based on the required volume of flue gas for evaporation, the total volume of wastewater to be treated, and the droplet drying time. The applicable droplet drying time depends on the characteristics of the wastewater inflow. Increased total suspended solids (TSS) concentrations result in reduced total drying times due to the condensation and crystallization of gypsum nuclei. Increased total dissolved solids (TDS) concentrations result in increased total drying times due to the presence of chloride ions. The effects of TSS and TDS on drying time are somewhat offsetting; however, the effects are not linear and not a 1:1 offset. The volume of flue gas required for evaporation can be calculated using the difference in the inlet and outlet flue gas enthalpy.

In a multi-unit plant, the WSD may either be dedicated to individual units or shared between units. When a WSD is dedicated to a single unit, the WSD is off-line during unit outages. When WSDs are shared between units, the WSD typically operates off a single unit but is ducted to multiple units with suitable isolation dampers. This configuration allows the WSD to process wastewater even when individual units are in an outage. Shared operation by multiple units is possible but not recommended by Mitsubishi as it can result in boiler control issues, since the WSD directly affects air heater operation. Even if the units are identical, the units may not be operating at the same load, have the same temperature profile, air heater leakage, or other operational parameters.

Residual solids generated in the dryer can either be commingled with fly ash in the exiting flue gas and collected using existing particulate removal equipment, such as an electrostatic precipitator or fabric filter, or filtered from the treated slipstream prior to commingling with the main flue gas stream. The configuration for solids management employed at a facility may depend on whether the facility sells the fly ash collected from the flue gas stream. Facilities that do not sell fly ash may opt to use existing particulate removal equipment and landfill commingled solids, while facilities that sell fly ash may elect to install separate particulate removal systems dedicated to collecting residual solids from the WSD exhaust gas stream.

Mitsubishi noted that volume reduction using membrane filtration, other treatment technologies, or wastewater management practices, could be paired with the WSD system to achieve zero discharge. Volume reduction may be most economical for wastewater volumes greater than 200 gallons per minute (gpm).

2. Technology Status and Performance

Treatment systems using WSDs are designed to treat FGD wastewater at 25 gpm per 100 megawatts (MW) of capacity; however, if the influent slipstream temperature is cooler than 650°F, the flow limit will be slightly lower. For facilities with FGD wastewater flows exceeding 25 gpm per 100 MW, Mitsubishi recommends implementing operational changes to reduce FGD wastewater flows.

One method for reducing influent flows to the WSD is to install a reverse osmosis (RO) system upstream of the WSD. Concentrate from the RO system can be processed through the WSD to achieve zero discharge. Mitsubishi estimates that the practical influent recovery rate of the combined unit processes is between 80 and 90 percent when wastewater composition is variable. In order to achieve zero discharge, permeate from the RO system needs to be recirculated back into plant operations as process wastewater.

Other methods for reducing the volume of FGD wastewater influent to the WSD may include reconfiguring process flow to exclude non-FGD wastewater from the treatment system (if wastewater is diluted by utility water streams prior to treatment), adjusting the chloride setpoint for FGD purge to up to 80 percent of the design capacity, or increasing the liquid-to-gas ratio of the absorber, which allows reduced blowdown by re-gearing the absorber recycle pumps.

Mitsubishi has conducted pilot-scale studies using the WSD for the treatment of FGD wastewater from coal-fired power plants at the Mitsubishi Heavy Industries, Ltd. Research and Innovation Center in Hiroshima, Japan. The pilot studies were used to develop design parameters necessary to achieve zero discharge based on the volume and characteristics of FGD wastewater to be treated. Based on pilot testing using TSS and TDS as variables, Mitsubishi established a baseline algorithm for calculating total drying time.

Mitsubishi is also working with customers to design a system to treat power plant ash pond water. This system will be designed to operate at flow up to 135 gpm and up to 24 hours per day.

2.1 Linfen Power Station and Other Installations in China

Mitsubishi installed a full-scale WSD system in July 2017 at the Linfen Power Station in China, which operates a single 300-MW generating unit. The treatment system was designed to treat influent FGD wastewater flows up to 35 gpm. The FGD wastewater off the hydrocyclone overflow enters the WSD at an influent flow rate between 20 and 25 gpm. The hydrocyclone overflow is not pretreated prior to entering the WSD. The typical hydrocyclone overflow feed to the WSD is 4.9 percent TSS and 5.8 percent TDS.

Mitsubishi has five other full-scale WSD systems operating or in the process of being installed for FGD wastewater treatment in China. At least three of these systems are in the process of being commissioned, with the original date of service scheduled for the end of 2021 but delayed due to COVID restrictions and other supply chain issues.

2.2 Boswell Energy Center, Minnesota

Mitsubishi installed a spray dryer system at the Boswell Energy Center (Boswell) located in Minnesota. This system is the largest WSD for FGD treatment to date, sized for 145 gpm. The system was brought online in 2022. This system is designed to treat wastewater containing up to 5,000 parts per million chlorides. Boswell will first use the system to dewater a pond that contains FGD wastewater and other miscellaneous wastewater streams. Once pond dewatering is complete, the plant will send FGD wastewater to the WSD, capturing it first in holding tanks that will feed the WSD. Solids generated by the WSD will be collected along with fly ash from the combined flue gas stream.

3. References

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Appendix K – New Logic Membrane Technology

1. Technology Description

The first industrial application of New Logic's VSEP technology was for dewatering kaolin clay for coal mining facilities. Since then, New Logic has expanded the use of the VSEP to other industries, including petrochemical, automotive, food and beverage, pulp and paper, and power generation.

The VSEP system is a new generation membrane filtration system designed for wastewaters containing high total suspended solids (TSS) and total dissolved solids (TDS) and uses vibratory movement to reduce fouling on the membrane surface. The technology works by spinning an eccentric weight bearing, which induces a vibratory action that is translated to the torsion spring and on to the filter pack drive (i.e., the membrane). The filter then oscillates 54 times per second up to an amplitude of ¾ of an inch. The shear created by the rapid change in direction makes it difficult for foulants to attach to the membranes. However, clean water may still pass through the membrane pores.

Early applications of VSEP were configured with microfiltration and ultrafiltration membranes, which mainly removed suspended solids and large organics. Today, New Logic also produces fully automated VSEP systems configured with reverse osmosis (RO) membranes. The RO membranes can separate difficult to treat feed streams including those with high levels of suspended and dissolved solids, oils, metals, and organics. New Logic also provides spiral-wound RO membranes that can be used independently or in conjunction with VSEP. Figure 1 shows an example of a process flow diagram for a combination VSEP and spiral RO treatment system for FGD wastewater. The concentrate from stage one (VSEP) can be disposed of using a variety of onsite and offsite techniques, including thermal treatment, solidification (also referred to as encapsulation), and underground disposal. The concentrate from stage two (RO reject) would typically be combined with the feed entering the VSEP membrane (stage one).

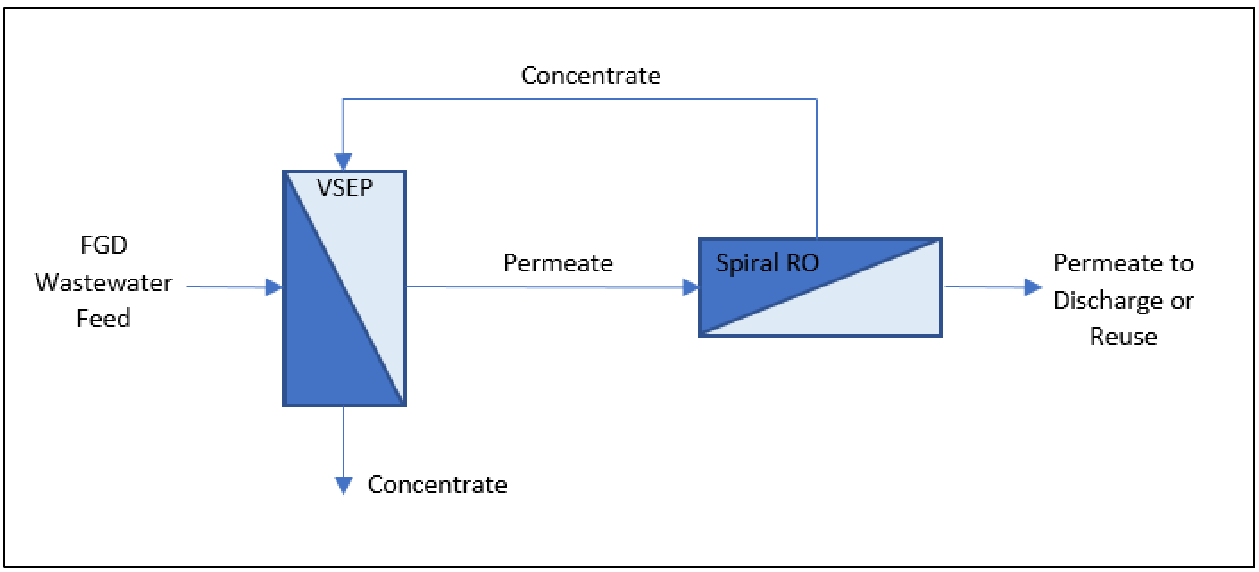

Figure 1. Example Two-Stage VSEP System Process Flow Diagram

Another potential configuration would be a three-stage system with two VSEP RO membrane units followed by a conventional spiral RO membrane to polish the VSEP permeate, as shown in Figure 2. This configuration consists of a low-pressure (500 psi) VSEP RO membrane and a high-pressure (1,000 psi) VSEP RO membrane. Concentrate from the low-pressure VSEP is transferred to a high-pressure VSEP stage, with the permeate from the two VSEP stages becoming the influent to the spiral RO membrane. According to New Logic, the number of VSEP/RO stages is determined by the TDS or osmotic pressure limitations and the desired amount of water recovery (or to reduce the volume of reject requiring disposal).

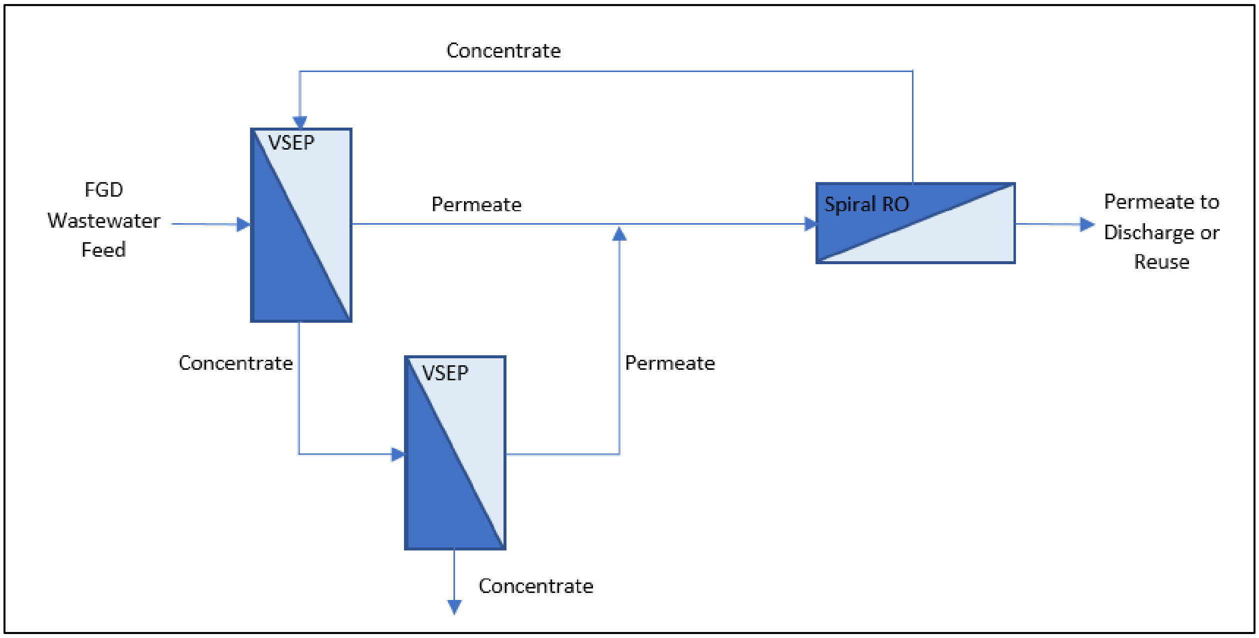

Figure 2. Example Three-Stage VSEP System Process Flow Diagram

New Logic's VSEP modules are available in several sizes. The largest VSEP module currently offered by New Logic is 1,400 ft^2. The capacity of a single 1,400 ft^2 VSEP module will depend on the TDS of the feed, temperature, and recovery rate. But assuming an average flux rate of 18 gallons per square foot per day, which could be considered a typical range, the single module could produce 18,000 gallons per day (GPD) of permeate. Modules of VSEPs can be operated in parallel to meet any flow rate requirements.

Concentration of TSS is not a limiting factor for the VSEP/RO system; however, particle size is. Large particles, those greater than 100 micrometers (µm) in diameter, can cause damage to pumps, valves, and the membrane. Pretreatment of the raw feed water prior to the VSEP/RO technology is necessary for FGD wastewater treatment applications. The raw feed water should be strained or passed through a settling tank to remove grit and large particles, and also treated such that the influent TDS does not exceed 100,000 ppm. As designed, the typical VSEP/RO system includes a basket strainer, but this is not meant as a pretreatment step; it is a secondary measure for large particles or items that may be accidentally dropped (e.g., screwdrivers). It should not be the sole form of pretreatment if the wastewater does contain particles larger than 100 microns. Another pretreatment step that needs to be considered is chemical addition to remove free chlorine and other oxidants. Dechlorination of the feed may be necessary because chlorine damages the polyamide membranes used in the VSEP system, which would result in a lower membrane rejection rate.

Like other membrane systems, the VSEP membranes require periodic flushing and chemical cleanings. These cleanings occur anywhere from once a day to once a month, with once or twice a week being the average. New Logic estimates that the membranes will need to be replaced every one to two years.

Industry sources report that the VSEP tests summarized in Section 2 demonstrate that anti-fouling technology can enable the use of membrane filtration to treat FGD wastewater and that the VSEP/RO treatment train is effective at removing selenium, arsenic, mercury, and nitrate-nitrite to concentrations well below the ELG limitations. These sources also report that the onsite tests demonstrate that the anti-fouling properties of the VSEP system enable it to treat FGD wastewater without the need for extensive pretreatment. Additionally, the VSEP/RO treatment process has a relatively small footprint and obviates the need for the reaction tanks and much of the other equipment typically included as part of chemical-biological treatment trains. Treating FGD wastewater with the VSEP/RO system can achieve significant volume reduction upstream of thermal or encapsulation zero discharge technologies, thereby reducing the size and cost of the thermal/encapsulation equipment.

The EPA met with representatives from New Logic in support of the 2024 final rule to discuss membrane operations. New Logic confirmed that membrane permeate recovery generally decreases with increased TDS concentrations.

2. Technology Status and Performance

New Logic has conducted several on-site, pilot-scale studies for the treatment of wastewater from power plants using the VSEP system. Table 1 provides a summary of several pilots conducted to treat FGD wastewater and fly ash leachate. With the exception of one pilot study where the wastewater was pretreated by softening with lime and soda ash, New Logic confirmed that there was no pretreatment prior to the VSEP system. New Logic also confirmed that all studies included spiral RO polishing in the treatment train.

Table 1. Summary of New Logic Pilot-Scale Studies

Location	Date	Application	Flux Rate (GFD)	Water Recovery	Feed TDS (mg/L)	Concentrate TDS (mg/L)
Pilot Study #1	6/29/09 - 8/14/09	FGD Wastewater	30.0	67.0%	41,200	93,000
Pilot Study #2	10/16/13 - 1/15/14	FGD Wastewater	25.5	83.2%	17,500	63,500
Pilot Study #3	1/10/15 - 1/20/15	FGD Wastewater	24.8	73.0%	24,600	105,200
Pilot Study #4	6/8/15 - 7/17/15	FGD Wastewater	21.6	75.0%	16,000	59,000
Pilot Study #5	5/17/16 - 6/8/16	FGD Wastewater	24.3	78.8%	4,000	14,200
Pilot Study #6	3/1/18 - 3/15/18	Fly Ash Leachate	27.9	93.0%	7,700	57,000
Pilot Study #7	6/2008 – 10/2008	Surface Impoundment Effluent, including FGD Wastewater	Not reported	75.0%	Not reported	Not reported
Pilot Study #8	9/26/18 - 10/10/18	FGD Wastewater	29.5	55.0%	46,800	75,500
Pilot Study #9	Two years (intermittent)	FGD Wastewater	Flow rate: 50 GPM. Other specific details unknown.			
Pilot Study #10	5/18 – 10/18	FGD Wastewater	Flow rate: 1 GPM. Other specific details unknown.			

Table 1. Summary of New Logic Pilot-Scale Studies

Location	Date	Application	Flux Rate (GFD)	Water Recovery	Feed TDS (mg/L)	Concentrate TDS (mg/L)
Pilot Study #11	9/20 – Unknown	FGD Wastewater	Flow rate: 50 GPM. Other specific details unknown.			

Abbreviations: GFD (gallons per square foot per day); GPM (gallons per minute).

The EPA has additional details on three of the on-site, pilot-scale studies for the treatment of FGD wastewater listed in Table 1: Pilot Study #2, #4, and #7. New Logic also provided further information on full-scale VSEP systems installed to treat cooling tower blowdown. The details of these three FGD wastewater pilots and cooling tower blowdown applications are presented further in the subsections below.

2.1 Pilot Study #2

A commercial-scale two-stage VSEP/RO system was tested for three months at a coal-fired power plant to treat FGD wastewater. During the study, the VSEP system was operated in both a batch mode and a single-pass mode, with the VSEP system receiving untreated FGD wastewater from the plant's feed tank. The source of wastewater for the feed tank was the plant's FGD settling pond. Other than gravity settling in a surface impoundment, no pretreatment of the wastewater was performed prior to the VSEP system. During batch mode, a finite volume of FGD wastewater is processed through the system. The permeate was transferred away from the system, while the concentrate stream was recycled back to the feed tank for reprocessing. As the batch continued, the feed to the VSEP system became more concentrated and continued operating until a specified end point was reached, such as a target permeate flow rate. Batch operation such as this can be used to maximize the amount of water recovery, which has the effect of minimizing the volume of concentrate requiring disposal or further treatment. During single-pass mode, the feed enters the VSEP system while the concentrate valve is closed. As the permeate is processed through the system, the concentrate valve is opened when the desired permeate volume has been achieved. The concentrated wastewater (membrane reject) is purged from the system when the concentrate valve is opened. During the study, in both modes of operation, the VSEP permeate was transferred to a conventional spiral RO for polishing. Using the combination of VSEP and spiral RO, the treatment train consistently met the discharge limits for FGD wastewater established by the 2015 ELGs (in fact, the effluent concentrations were lower than the limits proposed by the EPA in 2013, which were lower than the limits established by the 2015 ELGs). The pilot test results demonstrated that anti-fouling technology enables the use of membrane filtration to treat FGD wastewater, with no loss of flux and no irreversible fouling or scaling of the membranes over the duration of the study. The pilot test also showed that chemical pretreatment of the wastewater was unnecessary, although addition of anti-scalant can increase water recovery rates. Table 2 presents the average pollutant concentrations in the influent, the VSEP permeate, and the spiral RO permeate when the system was operated in a single-pass mode. Table 3 presents the average pollutant concentrations in the influent, the VSEP permeate, and the spiral RO permeate when the system was operated in a batch mode.

Table 2. Average Pollutant Concentrations for VSEP Pilot Operating in Single-Pass Mode During Pilot Study #2

Parameter	Feed	VSEP Permeate	Spiral RO Permeate
Alkalinity (mg/L)	56.3	10.8	10.8
TDS (mg/L)	17,400	813	352
TSS (mg/L)	106	2	< 1
Total Solids (mg/L)	17,600	815	353

Table 2. Average Pollutant Concentrations for VSEP Pilot Operating in Single-Pass Mode During Pilot Study #2

Parameter	Feed	VSEP Permeate	Spiral RO Permeate
Fluoride (mg/L)	9.46	< 1.30	< 1.30
Chloride (mg/L)	8,010	254	< 25
Nitrite (mg/L)	4.58	< 1.30	< 1.30
Bromide (mg/L)	61.0	< 3.26	< 3.26
Nitrate (mg/L)	19.2	< 6.51	< 6.51
Nitrate-Nitrite (mg/L)	23.7	0.45	0.07
Phosphate (mg/L)	< 1.30	< 1.30	< 1.30
Sulfate (mg/L)	1,440	< 25	< 25
Beryllium (µg/L)	< 2.5	0.67	< 0.5
Boron (µg/L)	155,000	109,000	81,200
Sodium (µg/L)	52,100	15,900	2,480
Magnesium (µg/L)	646,000	12,500	< 50
Aluminum (µg/L)	< 1,000	< 200	< 200
Silicon (µg/L)	20,900	1,010	< 1,000
Potassium (µg/L)	20,050	10,300	< 2,000
Calcium (µg/L)	2,980,000	72,700	< 2,000
Titanium (µg/L)	21.4	< 2	< 2
Vanadium (µg/L)	< 50	< 10	< 10
Chromium (µg/L)	< 10	< 2	< 2
Manganese (µg/L)	6,430	134	< 4
Iron (µg/L)	< 500	< 100	< 100
Cobalt (µg/L)	34.6	< 0.5	< 0.5
Nickel (µg/L)	178	< 5	< 5
Copper (µg/L)	< 25	< 5	< 5
Zinc (µg/L)	2,010	47.9	< 10
Arsenic (µg/L)	< 5	< 1	< 1
Selenium (µg/L)	191	1.54	< 1
Strontium (µg/L)	912	22.8	< 0.5
Molybdenum (µg/L)	64.6	0.52	< 0.5
Silver (µg/L)	< 2.5	< 0.5	< 0.5
Cadmium (µg/L)	74.2	1.61	< 0.5
Antimony (µg/L)	5.24	< 0.5	< 0.5
Barium (µg/L)	404	11.0	< 0.5
Tungsten (µg/L)	< 2.5	< 0.5	< 0.5
Mercury (ng/L)	1,400	35.4	11.0
Thallium (µg/L)	8.12	9.76	1.19

Table 2. Average Pollutant Concentrations for VSEP Pilot Operating in Single-Pass Mode During Pilot Study #2

Parameter	Feed	VSEP Permeate	Spiral RO Permeate
Lead (µg/L)	< 2.5	< 0.5	< 0.5
Uranium (µg/L)	23.1	< 0.5	< 0.5

Table 3. Average Pollutant Concentrations for VSEP Pilot Operating in Batch Mode During Pilot Study #2

Parameter	Feed	VSEP Permeate	Spiral RO Permeate
Alkalinity (mg/L)	55.0	10.0	10.0
TDS (mg/L)	9,820	544	< 1
TSS (mg/L)	58	< 1	< 1
Total Solids (mg/L)	9,880	544	< 1
Fluoride (mg/L)	6.3	< 1.30	< 0.260
Chloride (mg/L)	4,110	183	< 5
Nitrite (mg/L)	< 5.21	< 1.30	0.5
Bromide (mg/L)	23.3	5.8	< 0.651
Nitrate (mg/L)	< 26.0	< 6.51	< 1.30
Nitrate-Nitrite (mg/L)	13.1	0.75	0.04
Phosphate (mg/L)	< 5.21	< 1.30	< 0.260
Sulfate (mg/L)	1,010	< 25	< 5
Ammonium (µg/L)	< 40	< 20	0.109
Beryllium (µg/L)	0.72	< 20	< 0.5
Boron (µg/L)	97,900	< 0.5	32,400
Sodium (µg/L)	24,800	54,100	881
Magnesium (µg/L)	375,000	5,260	139
Aluminum (µg/L)	< 400	14,000	< 400
Silicon (µg/L)	17,400	< 400	< 1,000
Potassium (µg/L)	13,800	1,000	< 2,000
Calcium (µg/L)	2,120,000	4,650	< 2,000
Titanium (µg/L)	6.08	86,100	< 1
Vanadium (µg/L)	< 10	< 1	< 10
Chromium (µg/L)	< 2	16.2	< 2
Manganese (µg/L)	5,110	< 2	< 2
Iron (µg/L)	< 100	181	< 100
Cobalt (µg/L)	36.4	< 100	< 0.5
Nickel (µg/L)	177	1.32	< 5
Copper (µg/L)	10.8	6.61	< 5

Table 3. Average Pollutant Concentrations for VSEP Pilot Operating in Batch Mode During Pilot Study #2

Parameter	Feed	VSEP Permeate	Spiral RO Permeate
Zinc (µg/L)	1,160	< 5	< 5
Arsenic (µg/L)	2.03	42.9	< 1
Selenium (µg/L)	267	< 1	< 1
Strontium (µg/L)	633	4.24	< 0.5
Molybdenum (µg/L)	31.3	24.7	< 0.5
Silver (µg/L)	< 0.5	0.54	< 0.5
Cadmium (µg/L)	54.4	< 0.5	< 0.5
Antimony (µg/L)	5.02	1.33	< 0.5
Barium (µg/L)	288	< 0.5	< 1
Tungsten (µg/L)	0.65	11.4	< 0.5
Mercury (ng/L)	833	< 0.5	<10
Thallium (µg/L)	6.20	10.3	0.88
Lead (µg/L)	< 0.5	5.46	< 0.5
Uranium (µg/L)	15.1	< 0.5	< 0.5

2.2 Pilot Study #4

New Logic conducted a pilot study at a coal-fired power plant to test the performance of its VSEP system at treating FGD wastewater at a power plant. During the study, the VSEP system was primarily tested in the single-pass mode, but the percent recovery and the use of an anti-scalant pretreatment were varied to find the optimal performance for the system. Additionally, the VSEP permeate was fed through a spiral-wound RO system to improve the quality of the discharge. Three single-pass runs were conducted at 50 percent recovery, and four single-pass runs were conducted at 75 percent recovery. Initial testing demonstrated that anti-scalant typically increased throughput rates, so the majority of testing was performed with anti-scalant. Results from the 50 percent recovery runs are presented in Table 4, and results from the 75 percent recovery runs are presented in Table 5.

Table 4. Single-Pass Pollutant Concentrations Under 50% Permeate Recovery Rate During Pilot Study #4

Run Permeate Recovery Rate	Parameter	Feed	VSEP Permeate	Spiral RO Permeate
50	Mercury (total, ng/L)	110	1.7	0.28[a]
	Arsenic (total, µg/L)	2.5[a]	ND	ND
	Cadmium (total, µg/L)	ND	ND	ND
	Chromium (total, µg/L)	ND	ND	ND
	Copper (total, µg/L)	ND	ND	ND
	Selenium (total, µg/L)	280	6.3	2.3[a]

Table 4. Single-Pass Pollutant Concentrations Under 50% Permeate Recovery Rate During Pilot Study #4

Run Permeate Recovery Rate	Parameter	Feed	VSEP Permeate	Spiral RO Permeate
	Zinc (total, µg/L)	ND	ND	ND
	Nitrate (as N; mg/L)	6.4	0.51	0.02[a]
	TDS (mg/L)	13,000	540	51
	TSS (mg/L)	31	ND	1.6[a]
50	Mercury (total, ng/L)	190	3.5	1.8
	Arsenic (total, µg/L)	2.5[a]	ND	ND
	Cadmium (total, µg/L)	ND	ND	ND
	Chromium (total, µg/L)	ND	ND	ND
	Copper (total, µg/L)	2.2[a]	ND	ND
	Selenium (total, µg/L)	340	6.4	2.8[a]
	Zinc (total, µg/L)	ND	ND	ND
	Nitrate (as N; mg/L)	6.1	1.3	ND
	TDS (mg/L)	16,000	750	230
	TSS (mg/L)	97	1.6[a]	2[a]
50	Mercury (total, ng/L)	69	1.3	1.9
	Arsenic (total, µg/L)	3[a]	ND	ND
	Cadmium (total, µg/L)	ND	ND	ND
	Chromium (total, µg/L)	ND	ND	ND
	Copper (total, µg/L)	1.9[a]	ND	ND
	Selenium (total, µg/L)	240	3.4[a]	1.6[a]
	Zinc (total, µg/L)	ND	ND	ND
	Nitrate (as N; mg/L)	17	1	0.18
	TDS (mg/L)	16,000	620	150
	TSS (mg/L)	29	1.6[a]	6.4

a – Measurement below the quantitation limit, but above the method detection limit.

Table 5. Single-Pass Pollutant Concentrations Under 75% Permeate Recovery Rate During Pilot Study #4

Run Permeate Recovery Rate	Parameter	Feed	VSEP Permeate	Spiral RO Permeate
75	Mercury (total, ng/L)	150	4.2	0.24[a]
	Arsenic (total, µg/L)	1.9[a]	ND	ND
	Cadmium (total, µg/L)	ND	ND	ND
	Chromium (total, µg/L)	ND	ND	ND
	Copper (total, µg/L)	1.4[a]	ND	2.9[a]
	Selenium (total, µg/L)	330	11	3.9[a]
	Zinc (total, µg/L)	ND	ND	ND
	Nitrate (as N; mg/L)	15	3.2	0.025[a]
	TDS (mg/L)	16,000	1,000	240
	TSS (mg/L)	63	1.6[a]	ND
75	Mercury (total, ng/L)	180	2.6	0.44[a]
	Arsenic (total, µg/L)	2[a]	ND	ND
	Cadmium (total, µg/L)	ND	ND	ND
	Chromium (total, µg/L)	ND	ND	ND
	Copper (total, µg/L)	1.7[a]	ND	ND
	Selenium (total, µg/L)	320	10	5
	Zinc (total, µg/L)	ND	ND	ND
	Nitrate (as N; mg/L)	16	2.6	0.06[a]
	TDS (mg/L)	15,000	1,200	260
	TSS (mg/L)	36	3.2[a]	2.8[a]
75	Mercury (total, ng/L)	100	6.5	1.2
	Arsenic (total, µg/L)	1.9[a]	ND	ND
	Cadmium (total, µg/L)	ND	ND	ND
	Chromium (total, µg/L)	ND	ND	ND
	Copper (total, µg/L)	ND	ND	1.7[a]
	Selenium (total, µg/L)	250	7.9	5
	Zinc (total, µg/L)	ND	ND	ND
	Nitrate (as N; mg/L)	17	1.1	0.13
	TDS (mg/L)	16,000	1,100	100
	TSS (mg/L)	170	5.6	7.6

Table 5. Single-Pass Pollutant Concentrations Under 75% Permeate Recovery Rate During Pilot Study #4

Run Permeate Recovery Rate	Parameter	Feed	VSEP Permeate	Spiral RO Permeate
75	Mercury (total, ng/L)	54	2.6	0.82
	Arsenic (total, µg/L)	2.3[a]	ND	ND
	Cadmium (total, µg/L)	ND	ND	ND
	Chromium (total, µg/L)	ND	ND	ND
	Copper (total, µg/L)	ND	ND	ND
	Selenium (total, µg/L)	250	10	3.2[a]
	Zinc (total, µg/L)	ND	ND	ND
	Nitrate (as N; mg/L)	16	3.7	0.23
	TDS (mg/L)	16,000	2,000	110
	TSS (mg/L)	71	2.8[a]	1.6[a]

a – Measurement below the quantitation limit, but above the method detection limit.

2.3 Pilot Study #7

New Logic conducted a pilot study at a power plant to test the performance of the VSEP system at reducing the volume of water stored in a surface impoundment containing FGD wastewater. The plant operates with zero discharge and its storage ponds were beginning to reach a level that could potentially cause issues at the plant. Therefore, the plant was looking for a technology that would allow them to reuse water internally to reduce the amount of raw water entering the plant and reduce the volume of stored water in the ponds. The tested system incorporated five VSEP nanofiltration membrane modules. The addition of spiral RO treatment downstream of the VSEP modules was not tested as part of the original pilot test but was determined to be a viable option for further polishing monovalent ions. The goal of the study was to identify the optimum system operation that allowed for the highest recovery achievable in which the required cleanings were at least five days apart. The pilot test found that 75 percent recovery at 210 psi reduced the conductivity of the feed water from approximately 5,000 µS/cm to 1,400 µS/cm in the permeate. Concentrate from the system averaged approximately 10,500 µS/cm and was routed to one of the on-site evaporation ponds.

2.4 Cooling Tower Blowdown VSEP Installations

New Logic has installed three full-scale VSEP installations to treat cooling tower blowdown. Table 6 provides a summary of these installations including system design flowrate, permeate destination, and concentration destination.

Table 6. Summary of Cooling Tower Blowdown VSEP Installations

Project	Feed Material	Design Flow Rate (GPM)	Permeate Destination	Concentrate Destination
ExxonMobil King Ranch Gas Plant	Cooling Tower Blowdown	161	Reuse as boiler feed and/or cooling tower makeup	Saltwater disposal

Table 6. Summary of Cooling Tower Blowdown VSEP Installations

Project	Feed Material	Design Flow Rate (GPM)	Permeate Destination	Concentrate Destination
Burney Forest Power	Cooling Tower Blowdown	35	Reuse as cooling tower makeup	Brine hauling
Calpine Pastoria	Cooling Tower Blowdown	60	Reuse as cooling tower makeup	Brine concentrator

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Appendix L – Oasys Forward Osmosis Technology

1. Technology Description

Forward osmosis (FO) is a membrane-based process utilizing a draw solution as a high osmotic potential agent to capture fresh water from a saline or contaminated feed stream. FO is driven by an osmotic pressure gradient across a semi-permeable membrane to attain spontaneous and preferential diffusion of water molecules from a wastewater feed into a draw solution. The draw solution pulls out the clean water from the wastewater feed stream and becomes diluted as it flows through the FO membrane system. The result of the FO separation is a highly concentrated wastestream (i.e., brine stream) and a diluted draw solution stream. The diluted draw solution stream is subsequently processed and recycled to re-concentrate the draw solution to full strength for reuse in the FO system and to recover the final high-quality product water.

Oasys has developed a high recovery FO technology platform, the MBC system, which combines a specialized draw solution technology, a highly efficient draw recovery system, and a proprietary FO membrane. Oasys has two MBC system technologies, the ClearFlo MBC system and the ClearFlo Edge MBC system. The ClearFlo MBC can treat influent total dissolved solids (TDS) concentrations of up to 150,000 ppm. Oasys manufactures the ClearFlo MBC Edge for smaller desalination applications, with influent streams containing up to 50,000 ppm TDS.

1.1 FGD Wastewater Treatment – ClearFlo MBC

Oasys developed the ClearFlo MBC system by combining optimization of membrane and draw solution interaction, innovation in draw solution recovery, and refinements to system controls architecture to improve process performance and economics. The Oasys FO membrane is a thin-foam composite (TFC) with a thin polyamide backbone. Treatment only requires one pass through the membrane unit. The MBC utilizes a high osmotic draw solution (6,000 psi) that is highly soluble. The solution contains ammonia carbamate, formed by dissolving ammonia and carbon dioxide gases in water.

Two streams are fed into the FO membrane unit: influent wastewater and the concentrated draw solution (CDS) in a countercurrent orientation. Two streams also leave the FO membrane unit: the diluted draw solution (DDS) and the concentrated brine solution. The DDS is sent to a recovery unit where clean water is stripped and discharged for reuse. The draw solution is thermolytic—as heat is added, the ammonia and carbon dioxide evaporate from solution, leaving behind clean water. The ratio of ammonium salts to other components in the dilute and concentrated draw solution naturally buffers the solution and maintains pH between 9.8 and 10.3. No additional pH control by chemical addition is required, other than making sure the salt ratios are in range. The ammonia and carbon dioxide gases formed in the recovery unit are sent to a condenser absorber (a simple distillation column) for recovery.

The ClearFlow MBC system is operated at atmospheric pressure. The difference between the effective feed pressure of the CDS and the effective draw pressure of the DDS is the driving force for FO. Unlike the conventional reverse osmosis (RO) where the differential osmotic pressure generally decreases as the water flows through the membrane column, FO can maintain an approximately constant differential osmotic pressure through the membrane column. The draw solution is concentrated and polarized at the feed and becomes more dilute as water is naturally pulled from the wastewater to the other side of the membrane, thus creating a concentrated brine solution.

The draw solution system is considered a closed loop. A minimal amount of draw solution does pass into the brine. Over time, makeup draw solution is required due to some loss into the brine and losses due to upsets and sample collection. Draw solution that passes into the brine is stripped out in a brine stripper column, ensuring that draw solution is lost at a very slow rate. Energy used to heat the thermolytic draw solution can be recovered.

RO is sometimes used to pre-concentrate influent that enters the FO membrane. By pre-concentrating the wastewater, the FO system can be smaller and more economical.

Upon exiting the FO unit, the brine concentrate has a TDS concentration of 250,000 ppm or higher. Brine concentrate may then be fed into a crystallizer, a spray dryer, or mixed with fly ash and lime to manufacture a solid for disposal. Oasys does not provide evaporation, crystallizing, or spray drying equipment.

2. Technology Status and Performance

Oasys has installed two full-scale systems for the treatment of FGD wastewater internationally and has conducted one pilot studies in the U.S.

2.1 Changxing Power Station – China

In 2015, Oasys installed a full-scale treatment system at the coal-fired Huaneng Changxing Power Plant the world's first FO-based ZLD solution. The station includes twin 660 MW steam generators and flue gas pollution controls including wet limestone slurry FGD units by Wuhan Kaidi. The treatment train consists of a solids contact clarifier, filter press, multi-media filtration, and weak acid cation (WAC) ion exchange polishing as pretreatment, then into the ClearFlo MBC system (RO pre-concentration and the FO trains). The concentrated brine is then sent to a crystallizer.

The treatment system is designed to handle approximately 160,000 gallons per day. The incoming FGD wastewater has a TDS concentration of 25,000 ppm. Since operation began, the system has consistently achieved product water with a TDS concentration in the range of 35 to 50 ppm.

The FO system at Changxing was designed to treat wastestreams that were pretreated for mineral hardness removal and concentrated using a RO membrane system. Operations have found the FGD wastewater to be generally at a much lower TDS than the design envelope of 25,000 to 40,000 ppm. The low salinity of the raw water leads to a higher total water recovery through the RO and FO systems. The raw feed is rich in sulfate, which is typical of most FGD blowdown. The combination of these factors requires the removal of mineral hardness for extensive water recovery in the RO and FO systems prior to being fed to the crystallizer. Table 1 presents water quality data for the FO system at Changxing.

Table 1. Water Quality of Major Streams of the FO System in Changxing, China

Analyte	Raw FGD Wastewater	Pretreated MBC Feed	FO Feed	MBC Brine/ Crystallizer Feed	MBC Product Water
pH	9.4-10.2	9.5-11.0	9.5-11.6	9.5-9.8	9.9-10.9
Na (mg/L)	1,400-2,000	3,460-6,800	14,000-21,000	57,000-85,000	8.7-19.2
Ca (mg/L)	60-600	< 5.0	< 5.0	< 5.0	< 0.05
Mg (mg/L)	150-650	< 5.0	< 5.0	< 5.0	< 0.05
SiO_2 (mg/L)	10-80	5-37	26-137	200-300	< 0.10
Cl (mg/L)	1,700-3,000	2,600-4,800	8,000-16,000	37,000-59,000	5.5-15.2
SO_4 (mg/L)	1,500-3,500	1,500-3,500	8,000-15,000	33,000-45,000	0.3-1.1
HCO_3 (mg/L)	40-120	210-620	1,000-3,300	7,300-20,800	3.0-10.1
CO_3 (mg/L)	15-45	390-805	2,000-4,200	1,300-6,200	5.5-11.0
TDS (mg/L)	6,500-11,500	8,700-16,000	43,000-64,500	155,000-220,000	36-49

Note: Raw water contains 0.0025 mg/L arsenic, 0.044 mg/L selenium, 19.4 mg/L nitrate nitrogen, and 0.1 mg/L nitrite nitrogen. Mercury was not detected, with a detection limit of 0.0002 mg/L. The product water from the RO and system contains < 0.001 mg/L arsenic, 0.0026 mg/L selenium, 7.3 mg/L nitrate nitrogen, and 0.06 mg/L nitrite nitrogen. Mercury was not detected, with a detection limit of 0.0002 mg/L.

2.2 Shanxi Lujin Wangqu Power Station, Lucheng City, China

At the Shanxi Lujin Wangqu Power Plant, Oasys installed a full-scale MBC system to treat FGD wastewater at a feed rate of 79,000 gallons per day. Pretreatment prior to entering the MBC system consists of softening, multimedia filtration, and weak acid cation exchange. The treatment system was installed in mid-2017. The final brine is combined with bottom ash and fly ash for landfill disposal but is not completely encapsulated. Product water is used as make-up water to an offsite denim plant.

2.3 Water Research Center Pilot Study for FGD Wastewater Treatment

Oasys deployed the ClearFlo MBC technology at the Water Research Center (WRC) at Georgia Power's Plant Bowen Power Station from September to October 2016. The two-month pilot study tested a sidestream of FGD pond effluent and verified MBC system performance, reliability, and safety. Oasys operated a 6-9 gallon per minute system consisting of a physical/chemical treatment system to reduce hardness, metals, silica, and solids (pH adjustment, chemical softening, microfiltration, ion exchange, antiscalant) prior to the MBC system (RO, single-pass FO units, and draw recovery system).

The FO units operated as a single-pass operation and did not require cleaning throughout the duration of the study, which totaled more than 300 hours of continuous operation. Untreated FGD wastewater TDS concentrations ranged from 12,000 to 20,000 ppm and 90-95 percent of the raw water was recovered for potential reuse or discharge with a TDS concentration of less than 250 ppm. Brine concentrate had TDS concentrations of up to 300,000 ppm. Table 2 presents performance data from the WRC pilot study.

Table 2. Summary of Performance Data from WRC Pilot Study

Analyte	Raw FGD Water	MBC Feed Water	MBC Product Water
		Data Based on Oasys Demonstration Pilot	
Arsenic (ppb)	33	29	ND (<5)
Mercury (ppt)	2,920	ND (<200)	ND (<200)
Selenium (ppb)	313	250	3.4
Nitrate-Nitrite (ppm-N)	15	13	0.9
TDS (ppm)	13,300	14,600	<250
Boron (ppm)	187	159	4.4

3. References

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2. Oasys. 2016. Oasys Water Inc. *Forward Osmosis Based Membrane Brine Concentration of Wastewater Stream in Coal-Fired Power Generation: An Update*. International Water Conference Proceedings, 77th Annual Meeting, IWC, 2016. (IWC 16-30). DCN SE08481.

Appendix M – Purestream Advanced Vapor Recompression

1. Technology Description

Purestream is a water services company formed in 2010 with a specialty in developing brine concentration and desalination technology for water reuse in power plants. Purestream's AVARA uses advanced mechanical vapor recompression to remove pollutants from wastewater and generates a reusable distillate stream and concentrated brine stream from wastewater. It can be used in municipal, commercial, and industrial wastewater treatment systems but is intended for power plant waste streams. It is designed as a modular system that could be used in the field to minimize wastewater, reducing or even eliminating the need to transport, treat, or dispose of wastewater elsewhere.

Each commercial AVARA module has a capacity of 35 gallons per minute (GPM), is skid-mounted (50 feet by 12 feet) and can easily be installed. The modular system, after being purchased or leased from Purestream, can be built in 180 days and is deployable within two days of on-site delivery; assembly only requires electrical and plumbing connections be established. Multiple 35 GPM units can operate together to create a larger capacity system. Each self-contained unit can be placed on-site on individual skids (one unit and ancillary equipment per skid), or equipment can be reconfigured (e.g., all compressors on one skid, all heat exchangers on one skid, etc.) for flexible installation. Purestream asserts that if pH, scaling potential, and solids are monitored and kept within an acceptable range, there are not any additional factors that would preclude installation of the system in any plant design. Influent concentrations are typically monitored and controlled at the feed tank prior to the heat exchanger. Figure 1 shows a process flow diagram for a typical AVARA system.

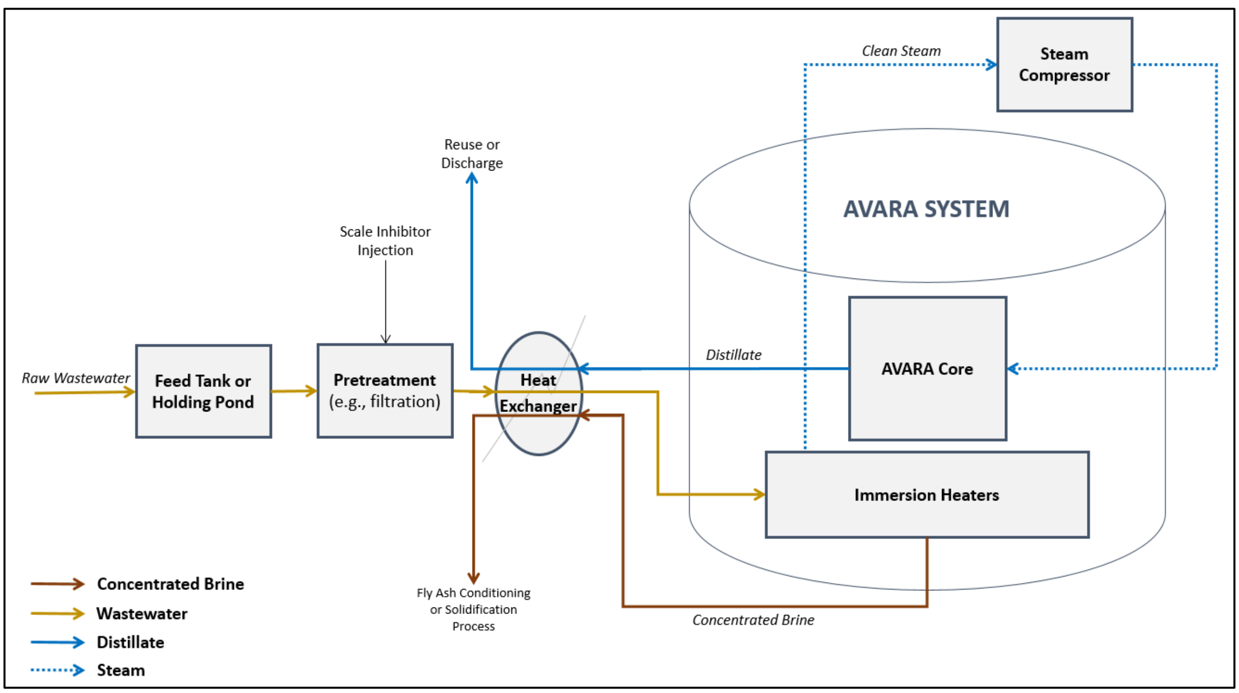

Figure 1. Process Flow Diagram for AVARA Mechanical Vapor Recompression System

FGD wastewater is pumped from a holding pond or tank through an influent filtration system to remove suspended solids; a scale inhibitor is added at the filtration system. To facilitate evaporation, wastewater is initially heated by immersion heaters to the desired temperature. As the wastewater inside the tank boils, steam vents from the top of the tank and passes through a steam compressor, which pushes the steam inside the AVARA cores; the cores are a proprietary design in vertical plate orientation. Heat transfers from steam inside the cores to the brine in the tank, while the steam condenses inside the cores and becomes the "clean" distillate stream. This distillate stream can be discharged or returned to the plant for beneficial reuse; it has a total dissolved solids (TDS) concentration below 300 parts per million (ppm). As wastewater evaporates and steam is generated, the TDS in the brine remaining in the tank becomes concentrated. Once the brine reaches a predetermined TDS set point concentration, not to exceed 200,000 ppm,[3] brine is discharged from the tank in a continuous stream through hydrocyclones. Heat exchangers recover and transfer energy from the hot brine and distillate streams to preheat influent entering the AVARA tank, reducing reliance on the immersion heaters. The concentrated brine may be combined with fly ash for disposal in a landfill or may be used as an ingredient for a solidification process (also referred to as brine encapsulation).

In most FGD wastewater applications, raw FGD wastewater with a total suspended solids (TSS) concentration below 30 ppm can be pumped directly into the AVARA system. Wastewater with higher TSS concentrations may require clarification to lower this influent TSS concentration. However, a settling tank often provides sufficient pretreatment. Chemical addition may also be required to maintain the necessary pH between 5.5 and 6.5. Crystal inhibitors and antiscalants are also added to maintain optimal conditions and to mitigate scaling. The bubbles generated by the boiling liquid create turbulence, which also helps mitigate scaling on the immersed cores. Transducers create ultrasonic bubbles and turbulence in the tank that also prevent scale from building up on the cores. Water circulation within the tank also reduces scaling. The submerged core design leaves little potential for oxidation, so equipment corrosion is typically not an issue.

Conventional reverse osmosis (RO) technology may be used to preconcentrate FGD wastewater prior to the AVARA. This could be a cost-effective zero discharge technology when implemented with brine encapsulation.

The AVARA's modular design allows for simple and quick core replacements and repairs. The cores can be considered akin to cartridges that can be removed and replaced with minimal system downtime. When removed, the cores can be serviced offline (i.e., mechanical or chemical cleaning) without affecting running operation of the system. AVARA can be kept in standby mode during shut-down periods of less than a week. In standby mode, burners are lowered to keep wastewater warm and prevent solids from precipitating. For extended shut-down periods, the system is purged, flushed, and residual steam is blown out. The small volumes of steam released from the vents are not typically scrubbed because this is an infrequent process. The AVARA system is marketed as a turn-key technology that includes operation and service (i.e., Purestream is contracted to operate the system for the facility). The longest system operating in the field has been running intermittently for three years.

The AVARA system typically requires on-site operators, but the system can be managed remotely with proper process controls. One operator can run up to five AVARA modules. When scale builds up and cleaning is required in a multi-unit fleet, one unit can be shut down for cleaning while the others continue operating. Based on a pilot-scale study treating FGD wastewater, Purestream estimates the system can operate a year or more before cleaning to remove scale is required. In testing and full-scale

[3] Above this concentration, the solution becomes saturated, and solids have been observed precipitating out of solution. The system can treat influent with TDS concentrations as high as 120,000 ppm but will see lower recovery rates as the influent TDS concentration approaches the TDS set point.

implementation to date, cores have been pressure washed to remove scale and have not required chemical cleaning.

2. Technology Status and Performance

In 2015, Purestream, in conjunction with the Electric Power Research Institute (EPRI), began exploring the potential for AVARA to manage wastewater from coal-fired power plants. Since that time, Purestream has been piloting AVARA with EPRI and three coal-fired power plants to treat FGD wastewater and other waste streams. In 2017, Purestream conducted another AVARA pilot-scale study to treat FGD wastewater at a coal-fired power plant in Northern Indiana. Each of these pilot-scale studies is summarized in Table 1.

Table 1. Pilot Scale AVARA Treatment Systems

Pilot Number/Plant Name	Test Duration and/or Test Date	Treatment Train	Treated Water	Recovery Rate
Pilot #1 – Springerville Plant (Arizona)	February – September 2016	Storage pond, settling pits, Induced Gas Flotation (IGF), 35 GPM AVARA	Cooling tower blowdown	86%
Pilot #2 – Plant Bowen (Georgia)	May – October 2016	3-GPM AVARA	FGD wastewater and brine concentrate	-
Pilot #3 – Merom Generating Station (Indiana)	October – December 2016	35-GPM AVARA	FGD wastewater	82.5%
Pilot #4 – Plant in Northern Indiana	July – September 2017	Chemical precipitation (first three quarters of study), 35-GPM AVARA	Pond effluent containing leachate and FGD wastewater	91%

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Appendix N – Saltworks Technologies

1. Technology Description

Headquartered in British Columbia, Canada, Saltworks Technologies (STI) was founded in 2008. STI specializes in technological applications for treating high saline, highly variable wastewater. Specific to FGD wastewater, STI markets two products, the Flex Electrodialysis Reversal (EDR) Selective (previously the Salt Splitter) and SaltMaker™ zero liquid discharge (ZLD) wastewater treatment technologies.

The Flex EDR Selective is a hybrid technology built around two common desalination technologies: electrodialysis (ED) and reverse osmosis (RO). The ED system operates upstream of the RO which improves RO reliability by reducing the scaling potential and allowing the RO to operate at a lower pressure. ED is used to electrochemically soften wastewater. The electrochemical process uses monoselective ion exchange membranes to selectively remove chlorides from wastewater. Compared to the traditional softening processes, which involve addition of soda ash, the Flex EDR Selective achieves lower volumes of brine exiting the RO system.

The Flex EDR Selective converts calcium sulfate ($CaSO_4$) to non-scaling sodium sulfate (Na_2SO_4) and calcium chloride ($CaCl_2$). Sodium sulfate and calcium chloride are much more soluble in water than calcium sulfate. Sodium chloride (NaCl) must be added to some FGD wastewater to prevent scaling and allow the ED process to function as designed and maintain the chemistry charge balance in the water. The amount of NaCl required varies by influent chemistry and depends on the concentrations of calcium, sulfate, sodium, and chloride. The Flex EDR Selective technology generates a RO permeate stream, which can be discharged or reused, and two concentrated brine streams, one rich in sodium sulfate and another rich in calcium chloride. Lower TDS concentrations in the untreated wastewater result in higher recovery of water in the RO permeate. The two brine streams can achieve a TDS concentration of 200,000 milligrams per liter (mg/L). Reject from the RO system is recycled back to the Flex EDR Selective feed and reprocessed through the system. Sulfates and multi-valent anions do not pass through the Flex EDR Selective ion exchange membranes and thus are recycled back to the FGD scrubber. Arsenate and selenite also do not pass through the ion exchange membranes.

FGD wastewater requires additional treatment to remove heavy metals and silica. For these pollutants, which cannot be effectively removed by the RO, the pH of the incoming wastewater is raised to 10.5 in order to precipitate out these pollutants prior to the Flex EDR Selective system. When treating FGD wastewater, the treated chloride-reduced wastewater is recycled back to the FGD scrubber. The technology also produces a non-scaling brine, predominantly calcium, sodium, and chloride.

The concentrated brine streams can be sent to a traditional crystallizer, to produce solids that can be landfilled as part of a ZLD configuration, or to STI's SaltMaker™ technology. STI markets their SaltMaker™ technology as an alternative to traditional crystallizers or vapor compression systems. It uses humidification and dehumidification systems to evaporate the water. The technology can produce more concentrated brine streams or achieve true ZLD and generate solids. SaltMaker™ technology operates at temperatures below 95 degrees Celsius and can use low-pressure steam as the thermal energy source. Because the system reuses thermal energy, it uses 20-25% of the energy of typical single effect evaporation systems that are open to atmosphere. In part, due to its self-cleaning functionalities, STI claims their SaltMaker™ technology is more robust, is less likely to foul, and experience lower rates of shutdown as compared to traditional vapor compression systems. The SaltMaker™ is currently operated at full-scale at mining, landfills, smelters, and waste to energy facilities.

Pilot-scale and bench-scale testing has shown the system can successfully treat FGD wastewater. In 2017, a pilot-scale demonstration in China operated for 90 days and treated 50 gallons of wastewater per day. The system included pretreatment to removed silica, transitional metals and ultra/microfiltration. The incoming FGD wastewater had a total dissolved solids concentration of 19,300 mg/l and the system achieved a RO recovery rate of approximately 91-92%; brine (combined flow of both streams) volume was around 8-9%.

From March 24th to May 24th, 2019 , STI also conducted a second pilot study in collaboration with the United States Department of Energy, the Electric Power Research Institute, and Southern Company. The pilot study's goal was to selectively remove chlorides so the FGD wastewater could be reused within the FGD scrubber system. The pilot treated FGD wastewater continuously for 61 days with an average recovery of 93 percent. Influent TDS to the Flex EDR Selective ranged from 7,860 mg/L when the feedwater was untreated FGD wastewater to 35,300 mg/L when the feedwater was membrane filtration reject. Pretreatment consisted of lime and sulfuric acid addition to prevent scaling. The chemicals used during the Flex EDR Selective operation included sodium chloride and sodium sulfate to protect against electrode fouling; and biocide to inhibit biological growth.

2. References

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Appendix O – SUEZ ABMet Biological Treatment Technology

1. Technology Description

The ABMet^{TM} technology utilizes a packed bed, fixed-film biological filter, consisting of anoxic, granular activated carbon (GAC) media bioreactors. The GAC media is inoculated with microorganisms that grow within the GAC bed to create a fixed-film that retains the microorganisms and precipitates solids within the bioreactor. The system uses microorganisms chosen specifically for use in FGD systems because of their hardiness in the extreme water chemistry as well as selenium respiration and reduction abilities. The ABMet^{TM} system is classified as high residence time biological reduction (HRTR); the bioreactor stage is typically designed for a residence time on the order of 10-16 hours or more. The long hydraulic residence time of the HRTR process results in a relatively large footprint for tanks and other equipment. However, SUEZ has stated that their ABMet^{TM} technology can be designed and sized for a continuum of residence times, including shorter than 10 hours.

The ABMet^{TM} system is designed as a plug-flow system to ensure the feed water is evenly distributed and has maximum contact with the microorganisms in the fixed-film. The bioreactor allows for oxidation-reduction potential (ORP) gradational zones in the bioreactors to facilitate denitrification, reduction of selenium to its elemental form, and sulfur reduction, eventually precipitating trace metals. The system maintains a pH level in the bioreactor between 6.0 and 9.0 S.U. because extreme high or low pH levels could affect the performance of the microbes and potentially allow undesirable microbes to propagate.

Figure 1 presents a typical process flow diagram for an anoxic/anaerobic biological treatment system with two stages of bioreactor cells in series. Both stages of bioreactors contain multiple cells in parallel. Plants usually employ multiple bioreactors to provide the necessary residence time to achieve the specified removals.

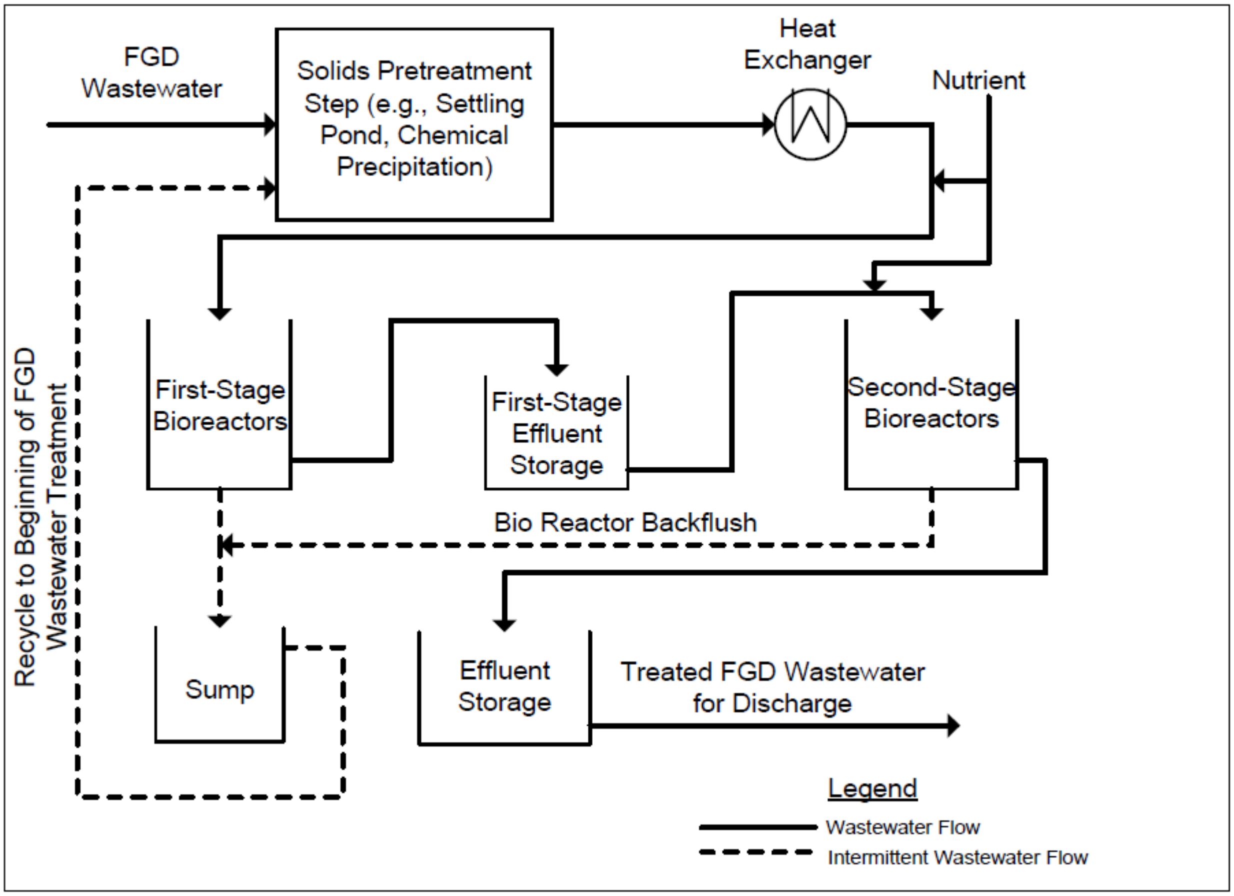

Figure 1. Process Flow Diagram for a Typical Downflow Packed Bed Anoxic/Anaerobic Biological Treatment System

Management of ORP in the bioreactor is important for optimizing removal of nitrate-nitrite and selenium. Nitrate-nitrite and selenium removals are optimized when ORP in the reactor is in range of -300 to -150 mV. These levels are achieved by adding organic carbon to feed microbial growth and sodium bisulfite as needed to reduce free oxidants, and encouraging sequential reduction of oxygen, nitrate, selenate, and sulfate. High concentrations of oxidants have the potential to inhibit the growth and activity of the microorganisms that reduce nitrate-nitrite and selenium. At one pilot test site, the plant was experiencing degraded pollutant removal performance that was determined to be associated with high ORP of the wastewater. The site added reducing agents to remove the oxidants and the wastewater was then able to support microbial growth and activity. The site found that by monitoring the ORP in the wastewater, optimizing pretreatment with chemical precipitation including the addition of reducing agents to pretreat the wastewater, the issues related to the increased ORP levels can be controlled and the biological treatment system is able to function as expected.

The microorganisms in this system are susceptible to temperatures in excess of 105ºF. Because of this susceptibility, some plants cool the FGD wastewater before it enters the biological system using heat exchangers. Based on data from the EPA sampling episodes, these plants generally are in geographic regions with sustained periods of maximum ambient temperatures greater than 90ºF.

When gases or solids build-up in the media, they are periodically backwashed from the system using permeate from the biofilter, effectively removing nitrogen gas, selenium, and other pollutants. Waste solids are collected near the top of the biofilter and flow by gravity to a storage tank, pond, or solids handling system. Some plants send the backflush water to the beginning of the chemical precipitation wastewater treatment system so that the system can remove the solids (and adhered selenium) within the clarifier. Other plants have transferred the backflush water to a surface impoundment where the solids (and adhered selenium) settle out.

2. Technology Status and Performance

As of 2015, full-scale ABMet™ treatment systems were being used to treat gold mining wastewater, coal mining wastewater, precious metal recycling wastewater, FGD wastewater from power plants, and ash leachate from power plants. See the *Statistical Support Document: Effluent Limitations for FGD Wastewater, Gasification Wastewater, and Combustion Residual Leachate for the Final Steam Electric Power Generating Effluent Limitations Guidelines and Standards* (DCN SE05733) for detailed information regarding the pollutant removal efficacy of this treatment technology.

Through communication with GE Water, Suez, and power companies, the EPA is aware of at least 5 full-scale installations of ABMet™ for treating FGD wastewater at coal-fired power plants. These systems were designed to treat either FGD wastewater alone or a combination of FGD wastewater and other wastewater streams (e.g., landfill leachate). Table 1 includes a list of the locations of these full-scale installations.

Table 1. Full Scale ABMet™ FGD Wastewater Treatment Systems

Plant Name	State	Treatment Configuration Notes
Allen Steam Station	North Carolina	Chemical precipitation followed by ABMet™.
Belews Creek Steam Station	North Carolina	Chemical precipitation followed by ABMet™.
Roxboro Steam Plant	North Carolina	Original configuration was pond followed by ABMet™. System has since been upgraded to chemical precipitation followed by ABMet™.
Mayo Electric Generating Plant	North Carolina	Original system was pond followed by ABMet™. Treatment system has since been replaced by a thermal evaporation system.
Mountaineer Plant	West Virginia	Chemical precipitation followed by ABMet™. ABMet™ system treats FGD wastewater and landfill leachate.

The systems operated at Duke Energy Carolinas' Allen Steam Station and Belews Creek Steam Station have two stages of bioreactor cells in series, as shown in Figure 1, but both stages of bioreactors contain multiple cells in parallel. Data from both treatment systems were used to establish the 2015 effluent guidelines for FGD wastewater.

Table 2 includes a listing of the pilot demonstrations of the ABMet™ system on FGD wastewater.

Table 2. Pilot Scale ABMet™ FGD Wastewater Treatment Systems

Pilot Number/Plant Name	Test Duration and/or Test Date
Pilot #1 – North Carolina	2007
Pilot #2 – North Carolina	2007
Pilot #3 – West Virginia	2008
Pilot #4 – Belgium	2009
Pilot #5 – North Carolina (Cliffside)	2011-2012
Pilot #6 – Indiana	2013
Pilot #7 – South Carolina	8 Months (2013-2014)
Pilot #8 – Georgia	2014-2015
Pilot #9 – Wisconsin (Pleasant Prairie)	6 Months (2015-2016)
Pilot #10 – South Carolina (Winyah)	87 Days (2016-2017)
Pilot #11 – Ohio (Cardinal)	5 Months (2017)

3. References

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Appendix P – SUEZ Thermal Technology

1. Technology Description

SUEZ offers a brine concentration treatment option consisting of a vertical tube falling film evaporator and mechanical vapor compressor. SUEZ recommends pretreatment upstream of the brine concentration system to achieve desaturation and solids removal. Depending on the FGD wastewater characteristics, pretreatment may include organosulfide, ferric chloride, and polymer addition, followed by clarification and filtration (in certain cases), for increased metals removal.

The brine concentration technology can recover up to 95 percent of industrial wastewater as high purity distillate that can be used for other plant processes. The remaining five percent is a slurry concentrate. The technology uses a calcium sulfate seeded slurry process to concentrate wastewater and prevent scaling inside the system. Seeds are added at startup, then continuously produced as the system operates. The slurry has the lowest solubility at the heat transfer surface on the evaporator to ensure calcium sulfate precipitates on circulating seed material.

SUEZ doses anti-scaling solution in the brine concentration system feed tank and the system runs at a pH between 5.5 and 6.0 and dissolved oxygen levels less than 50 parts per billion (ppb) to prevent stress corrosion cracking. To bring the brine concentration system online for initial use, an operator seeds the evaporator and circulates the slurry between eight and twelve hours. To put the evaporator offline, an operator enables a "hot standby" where the recirculation pump is running, but no heat input is needed due to the high level of insulation in the system. The brine concentration system can be on standby indefinitely and the only cost incurred during this time is for energy associated with the recirculation pump. After a standby period, the evaporator can be brought back online in about 15 minutes and no re-seeding is needed. This mode of operation is beneficial for peaking plants that only operate between 12 and 14 hours per day. The brine concentration system needs to be brought completely offline for cleaning once per year for a period of three to five days.

To operate the system with no discharge, the brine concentration system can be combined with mixed salt crystallization or pozzolanic solidification/encapsulation. Mixed salt crystallization can reduce brine concentrate to a dry solid. Recovered water can be recycled back to plant processes, while the dry solids produced through the crystallization process can be disposed in a landfill. In the case of mixed salt crystallization, softening pretreatment is required to remove calcium and magnesium sulfates. These compounds are converted to a sodium sulfate and calcium chloride solution exiting the crystallizer, which must be disposed in a landfill.

To create the final pozzolan for disposal, brine, Portland cement, fly ash, and water are combined in a ribbon mixer. Additional lime may be added to the mixture to facilitate partial encapsulation, if desired. The final pozzolan is less permeable and is less likely to leach when disposed in a landfill, compared with the mixed salt crystallization products. SUEZ has conducted both bench-scale and pilot-scale testing to optimize encapsulation mixtures.

If a plant has Class F fly ash, soluble calcium will not be in the brine solution; therefore, more calcium addition would be required for pozzolanic encapsulation, compared to a plant with Class C fly ash. The evaporator concentrate may have considerable concentrations of free calcium. A greater amount of fly ash (per unit of product) is needed to perform fly ash wetting than for a pozzolanic reaction and final disposal.

SUEZ also offers spray dryer evaporator (SDE) with brine concentration as a thermal treatment option. The SDE uses flue gas upstream of an electrostatic precipitator (ESP) or baghouse system to evaporate FGD blowdown. Spray drying without brine concentration is more expensive than spray drying with brine concentration. If a plant has a single power block and a small wastewater flow rate, SUEZ recommends the implementation of an SDE to achieve ZLD. However, for plants with multiple power blocks that are not close in proximity, an SDE may not be an ideal option because the flue gas ducting may not be easily combined.

In addition, SUEZ has examined lime softening plus ultrafiltration followed by crystallization as a zero-discharge option; however, SUEZ emphasized that their falling film evaporator combined with brine encapsulation is a more cost-effective treatment option for FGD wastewater. SUEZ has found that life cycle costs of the crystallizer are typically higher due to high electricity costs.

2. Technology Status and Performance

In the power industry, SUEZ has over 65 full-scale installations of their brine concentration system. There are approximately six installed brine concentration systems treating FGD wastewater alone, including one installed at the Indianapolis Power and Light (IPL) Petersburg Generating Station, or combined with other waste streams. SUEZ plans to install one system in South Africa, two systems in Korea, and is in talks with plants in China and India.

3. References

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2. ERG. 2020. Eastern Research Group, Inc. *Final SUEZ Meeting Notes*. (August). DCN SE08591.

Appendix Q – Sylvan Source

1. Technology Description

The SSI Core technology is a system that combines three different treatment technologies into a single thermal evaporation system to boil wastewater and then condense the steam to create clean water. Figure 1 presents a schematic of the SSI Core technology. The SSI Core combines the following three wastewater treatment technologies:

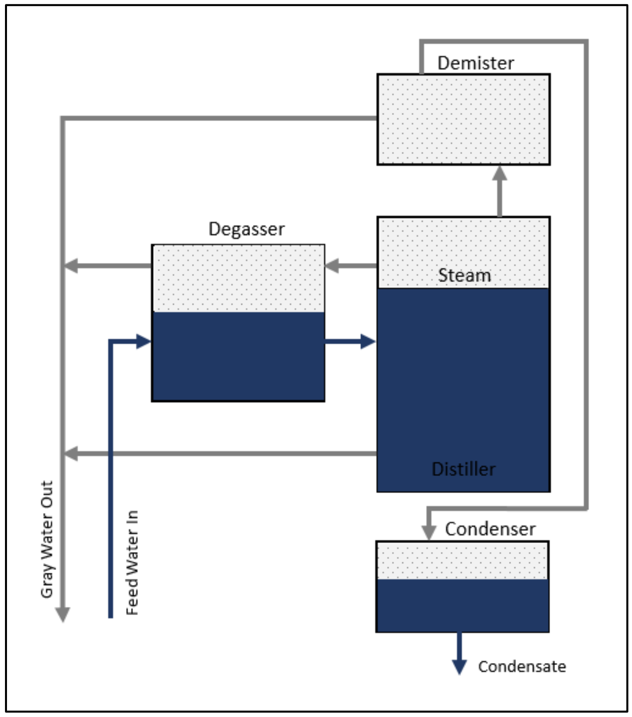

Figure 1. SSI Core Technology Schematic

- Degassing: The wastewater is first sent to a degasser where it is heated to near boiling by the steam leaving the distiller. This allows the dissolved gases and organics to vaporize out of the wastestream and into counterflowing steam from the distiller. The steam, dissolved gases, and organics leave the degasser as a gas and are referred to as "gray steam."
- Distillation: The water stream leaving the degasser flows into the distiller where it is converted to steam. The concentrated brine created in the distiller is removed from the bottom of the vessel and combined with the "gray steam" from the degasser. Some of the steam from distiller flows through the degasser to remove the dissolved gases and organics. The remainder of the steam rises to the demister. The SSI Core operates close to atmospheric pressure, but it is possible to configure with vacuum.
- Demisting: The steam from the distiller enters the demister where SSI's patent-pending process separates the steam from the mist droplets. The droplets are removed from the demister and combined with the "gray steam" and concentrated brine. These combined contaminated streams are condensed and prepared for disposal. The steam, on the other hand, passes through the demister and is then condensed and can be reused or discharged.

The SSI Core system can be operated in multiple stages. For multiple stage operation, the energy to drive the first system can come from a variety of sources, including steam, flue gas, and other forms of waste heat. But for all the subsequent stages, the energy to drive the system comes primarily from the heat of condensation of the steam created in the previous stage.

The SSI Core is capable of concentrating waste streams to a heavy brine that crystallizes when cooled. However, the SSI Core does require the feed water to be pretreated to reduce the magnesium concentration to enable crystallization. A range of standard pretreatment technologies, including ion exchange, pH adjustment, and precipitation, can be used to optimize the SSI Core.

SSI has conducted several pilot studies on various power plant wastewaters, including one pilot-scale study of FGD wastewater from a coal-fired power plant. In 2013, FGD wastewater from a coal-fired power plant was transported to SSI in San Carlos, CA for treatment through their SSI System Pilot Unit. Table 1 presents the FGD feedwater and product water (following proprietary pretreatment and SSI Core system treatment) concentrations for a subset of pollutant.

Table 1. Sample Test Results from 2013 SSI System Pilot Unit Study Using Power Plant FGD Wastewater

Parameter	FGD Feedwater	SSI Product Water
Arsenic	<2 ppb	ND
Mercury	15 ppb	0.086 ppb
Selenium, total	1,221 ppb	ND
TDS	13,200 ppm	33 ppm

2. References

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2. EPRI. 2017a. Electric Power Research Institute. Thermal Evaporation Technologies for Treating Power Plant Wastewater: A Review of Six Technologies. 3002011665. Palo Alto, CA. (September).
3. EPRI. 2017b. Electric Power Research institute. Pilot Evaluation of the Sylvan Source Core Water Treatment System. 3002008683. Palo Alto, CA. (April).
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7. Sylvan Source. 2017c. *Test Results*. Accessed on October 17, 2017. Available online at: https://www.sylvansource.com/test-results.
8. Sylvan Source. 2017d. *Equipment Cost Analysis for FGD Wastewater Treatment Systems*. Accessed October 18, 2017. Available online at: https://docs.wixstatic.com/ugd/930f28_af6567c181f1433ebc7becb62af1973b.pdf.
9. U.S. DOE. 2016. U.S. Department of Energy. Final Report: Heat Recovery – Use Technology Assessments. (September 26). Available online at: https://www.osti.gov/scitech/servlets/purl/1332489
10. U.S. EPA. 2022. U.S. Environmental Protection Agency. *Notes from Vendor Call with Sylvan Source October 25, 2021*. (26 September). DCN SE10294.

Appendix R – Vacom Technology

1. Technology Description

The Vacom VCC One-Step™ Process combines an evaporator and a crystallizer into a single system. Additionally, the process uses turbulent flows to minimize fouling and scaling on the equipment. Figure 1 presents a process flow diagram of the VCC One-Step™ Process.

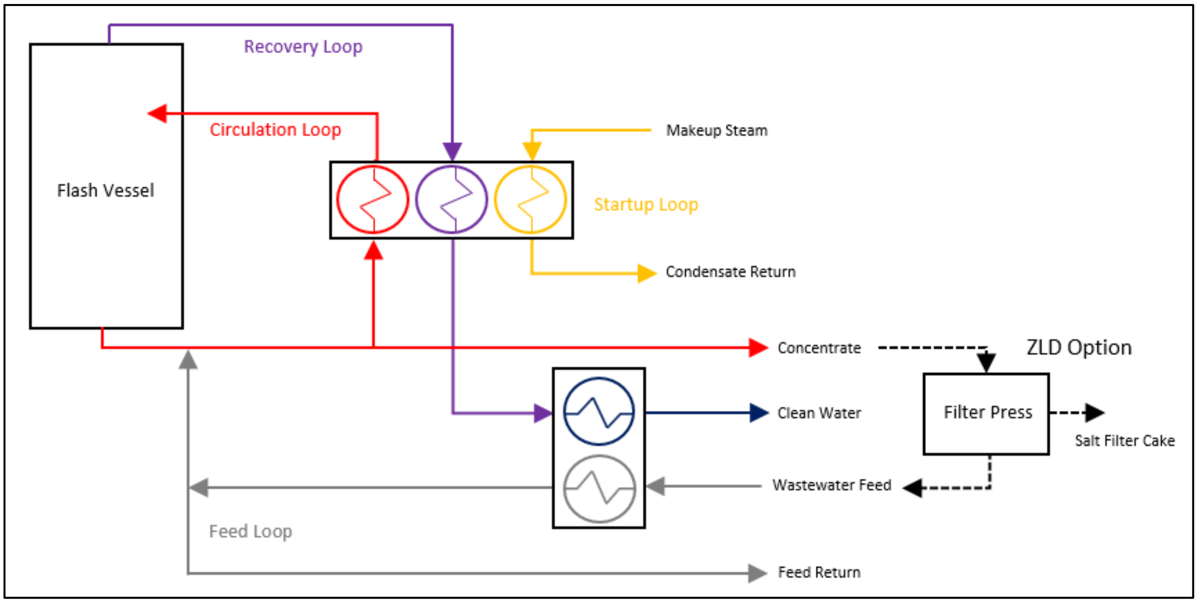

Figure 1. Process Flow Diagram for the Vacom VCC One-Step™ Process

As shown in Figure 1, there are four interconnected loops in the system:

1. The feed loop;
2. The circulation loop;
3. The recovery loop; and
4. The startup loop.

In the feed loop, the raw wastewater entering the VCC One-Step™ Process first passes through a heat exchanger where the heat from the clean distillate stream is used to preheat the feed water. This preheated feed water is then mixed in-line with the circulation loop.

In the circulation loop, the concentrated wastestream leaving the bottom of the flash vessel is mixed with the preheated feed water and circulated back to the flash vessel. But prior to reaching the flash vessel, the wastewater is pumped at high velocities through the primary heat exchanger to heat the wastewater to its boiling point using the heat from the steam generated and removed from the flash vessel. The high velocity of the wastewater in combination with the salt crystals generated in the flash vessel act as scouring agents in the heat exchanger help to clean the tubing and prevent scaling and fouling. The wastewater in the circulation loop is maintained at a temperature and pressure such that evaporation does not occur in the loop, but rather, only occurs in the flash vessel. Once the wastewater reaches the flash vessel, the water is evaporated, exits the vessel through the top and enters the recovery loop. The salts remaining in the vessel are pulled from the bottom of the vessel and enter the circulation loop again.

There is a bleed stream from the circulation loop, referred to as the concentrate, which needs to be disposed.

The steam generated in the flash vessel is removed using a blower that increases the temperature and pressure of the steam. This higher-pressure steam then passes through the primary heat exchanger to heat the circulation loop prior to it entering the flash vessel. Additionally, this condenses the steam in the recovery loop into water. The condensed water then passes through another heat exchanger to heat the raw wastewater feed, which also helps cool the distillate stream.

The start-up loop consists of make up steam that is used in the primary heat exchanger to heat the circulation loop to get the process started. This is necessary because when the process initially begins, there is not any steam generated in the recovery loop that can heat up the circulation loop. Therefore, another source of heat is needed until the process gets started.

As for the concentrate (i.e., salt slurry) generated through the VCC One-Step™ Process, the plant can dewater the salt slurry to generate a dry haulable salt. Potential dewatering devices may include a rotary drum filter or a filter press. Any water removed from the dewatering process would then be combined with the raw wastewater feed and reprocessed in the system.

Vacom has conducted at least one onsite pilot study for the treatment of FGD wastewater from a coal-fired power plant using the VCC One-Step™ Process. The pilot test was conducted at the Water Research Center located at Georgia Power's Plant Bowen. Over a period of approximately 42 days, the pilot system was tested using the following three different variations of FGD wastewater:

1. Chemical precipitation effluent;
2. Raw FGD pond effluent; and
3. Concentrated effluent from a pilot-scale vibratory shear enhanced process membrane provided by New Logic Research, Inc.

2. Technology Status and Performance

Two steam electric power plants in China are using the VCC One-Step™ Process to treat FGD wastewater. The first system, installed in December 2017, treats 100 gallons per minute from four coal-fired generating units. Treatment includes clarifiers to remove suspended calcium sulfate followed by the One-Step™ Process. When the system was designed, the plant had planned to beneficially reuse or sell the calcium sulfate removed in pretreatment, and sodium chloride filtered from the concentrate stream, but has since abandoned these plans due to high costs of chemical addition required for pretreatment (sodium sulfate). Instead, the plant stabilizes the concentrate and disposes of it in a landfill. The second installation in China is identical to the first but included disposal of stabilized concentrate in its original design.

Vacom has also participated in a series of pilot and long-term testing of FGD wastewater treatment at the Water Research Center with the Electric Power Research Institute (EPRI). The testing used the One-Step™ Process in combination with other FGD wastewater treatment technologies, including other membrane filtration technologies.

Vacom also piloted its One-Step™ Process for treatment of municipal landfill leachate in China. This pilot system used a reverse osmosis (RO) membrane with concentrate from the RO membrane further treated using the One-Step™ Process.

3. References

1. EPRI. 2015. Electric Power Research Institute. Evaluation of Vacom One-Step System for Concentrating Flue Gas Desulfurization Wastewater: Pilot Testing at the Water Research Center. 3002007212. Palo Alto, CA. (December).
2. EPRI. 2017. Electric Power Research Institute. Thermal Evaporation Technologies for Treating Power Plant Wastewater: A Review of Six Technologies. 3002011665. Palo Alto, CA. (September).
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Appendix S – DuPont Technologies

1. Technology Description

DuPont markets a combination of two technologies to treat FGD wastewater: minimal liquid discharge (MLD) membrane filtration and zero liquid discharge (ZLD) thermal treatment.

- MLD – Includes chemical precipitation, ultrafiltration, ion exchange softening, and combinations of reverse osmosis (RO), forward osmosis (FO), and/or nanofiltration (NF).
- ZLD – Includes pretreatment, which could be MLD, followed by a brine concentrator and crystallizer.

When combined with a ZLD thermal treatment technology, MLD systems can be more affordable and reduce landfill waste. The MLD-ZLD water reuse process begins with pretreatment using UF to remove suspended solids followed by ion exchange or nanofiltration softening to remove scaling potential. After pretreatment, a combination of primary RO, secondary RO, ultra-high-pressure RO or FO, and/or selective NF generates permeate and a purified sodium chloride brine. The brine is further treated through the ZLD portion of the system, using the brine concentrator and crystallizer. Permeate from the MLD system can be reused.

Pretreatment requirements vary based on the wastewater influent quality. In general, system operation increases in efficiency with greater softening. With DuPont's RO systems, it is ideal to remove close to 100 percent of hardness prior to RO. Instead of a secondary or more robust precipitation softening step, weak acid cation (WAC) exchange is used to ensure a plant can achieve the desired recovery level. The ion exchange regeneration waste can be sent back to a lime and soda softening process for further treatment.

RO treatment is limited by osmotic pressure of the water and the designed pressure limits of the RO system and membrane module. Standard RO systems can be operated up to 1,200 pounds per square inch (psi). When applying 1,200 psi pressure to an RO membrane, water will stop permeating through the membrane when the water osmotic strength approaches 1,200 psi. Depending on the compositions of salts, the maximum concentration of salt achieved by a system operating at 1,200 psi will be approximately eight to 10 percent. Ultra-high-pressure RO systems are designed to operate up to 1,740 psi, producing salt concentrations between 10 to 20 percent depending on the salt composition.

A four-stage, single-pass RO system, using an ultra-high-pressure RO as the final stage, can achieve up to 95 percent water recovery, with booster pumps used between stages to increase pressure. DuPont recommends operating membranes below 35 degrees Celsius to optimize permeate quality such that permeate is suitable for reuse without needing a second pass of RO treatment.

2. Technology Status and Performance

DuPont has installed nine MLD-ZLD systems for FGD wastewater treatment at power plants in China since 2015, shown in Table 1. Detailed information on two of these installations were provided by DuPont, described in Sections 2.1 and 2.2 below.

Table 1. DuPont MLD-ZLD Installations in China

Plant Number	Commission Date	Capacity (cubic meters per hour)
Plant #1	2015	22
Plant #2	2017	36
Plant #3	2018	25
Plant #4	2018	10
Plant #5	2018	15
Plant #6	2018	40
Plant #7	2018	40
Plant #8	2018	6
Plant #9	2019	100

2.1 Changxing Power Plant – China

The ZLD water treatment system at the Changxing Power Plant in Zhejiang Province, China treats FGD wastewater and cooling tower blowdown using lime soda softening to remove most of the hardness, WAC exchange to remove any remaining hardness, two-pass RO to preconcentrate the brine, FO, and a brine concentrator/crystallizer. Recovered water from the treatment train is reused as boiler make-up water. Since operation began in May 2015, the plant has achieved between 70 to 75 percent water recovery. This plant uses two seawater RO systems that produce a concentrate TDS of 60,000 mg/L. Salts generated by the crystallizer, up to 10,000 metric tons per year, are sold to the local chemical industry.

2.2 Hanchuan Power Plant – China

At the Hanchuan Power Plant in Hubei Province, China, DuPont implemented an FGD wastewater treatment system consisting of tubular microfiltration (MF) softening, NF, two-pass RO (seawater and brackish water systems, SWRO and BWRO, respectively), high-pressure RO, and ZLD technologies that generate industrial grade salt, shown in Figure 1 below. Final disposal of the salt product is unknown. Laboratory studies have demonstrated that NF concentrate contains sodium sulfate with some sodium chloride, and the permeate mostly consists of sodium chloride (98.5 percent). This treatment train was originally a pilot study that experienced stable operation for over two months and led to full scale implementation, beginning operation in late 2016.

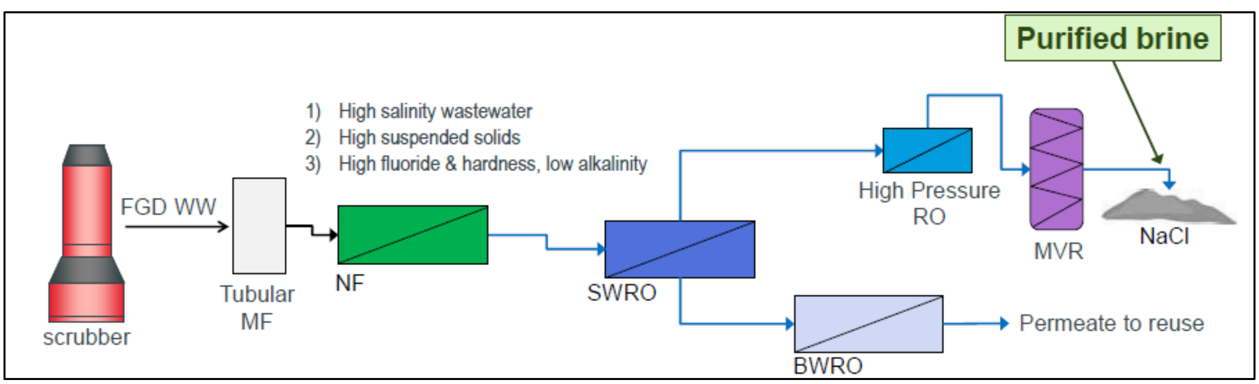

Figure 1. Hanchuan Power Plant FGD Wastewater Treatment System

2.3 Treatment of Landfill Leachate

Dupont noted experience treating leachate from municipal landfills in both Mexico and China. Treatment consists of membrane filtration. Permeate is typically discharged and reject is disposed of in the landfill. Dupont noted, in China, landfill leachate has strict requirements for chemical oxygen demand (COD), biochemical oxygen demand (BOD), total suspended solids (TSS), nitrogen, and color. Typical treatment needed to meet requirements include biological treatment (anaerobic or aerobic) then a membrane bioreactor (typically a tube configuration) followed by a combination of nanofiltration and reverse osmosis.

3. References

1. Dow Water and Process Solutions. 2017. DuPont Notes Appendix C: Case Studies & Analysis of Reverse Osmosis to Treat Flue Gas Desulfurization Wastewater. (November). IWC 17-74. DCN SE08618A3.
2. DuPont. 2020a. Notes from Meeting with DuPont Appendix A: DuPont Presentation to EPA. (15 April). SE08618A1.
3. DuPont. 2020b. Notes from Meeting with DuPont Appendix B: Zero liquid discharge and water reuse at a coal power plant in Changxing County, China. (15 April). S08618A2.
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Appendix T – Ljungström Technology

1. Technology Description

The Ljungström AdvX®-ZLD Technology consists of three major components:

1. Spray dryer evaporator (SDE),
2. Sulfur trioxide (SO_3) control upstream of the air pre-heater, and
3. AdvX® Air preheater upgrade.

Ljungström markets the technology as a potential zero liquid discharge (ZLD) evaporation treatment alternative for the power generation industry. The technology routes a slipstream of flue gas around the boiler air preheater. The hot flue gas is used to evaporate wastewater. In the case of steam electric plants, flue gas desulfurization (FGD) wastewater or other wastestreams are sprayed into the evaporation vessel and mixed with the hot gas. Liquid is evaporated, generating a gas stream and a solid byproduct. The gas stream is reintroduced to the flue gas downstream of the air preheater, which allows entrained solids to be collected via an existing particulate control device, along with fly ash. Ljungström offers a proprietary AdvX® Air preheater upgrade. This upgrade recovers the heat rate loss associated with the flue gas bypass duct around the air preheater, thus reducing or eliminating the corresponding energy cost.

The Ljungström technology is not sensitive to water quality and does not require pretreatment of wastewater. Water quality (such as high chlorides) may require different materials of construction for wastewater holding tanks or piping. Wastewater does not come into contact with the evaporator vessel; therefore, wastewater characteristics do not impact those materials of construction.

There is a practical limit for the flow rate that can be evaporated in the flue gas using this type of technology. Wastewater can only be evaporated until the flue gas reaches saturation. The treatment flow rate threshold is plant specific based on flue gas saturation and/or acid dewpoint and flue gas temperature. The largest system Ljungström has quoted to date is 125 gallons per minute (gpm) per unit; however, it is concievable that AdvX®-ZLD can accommodate higher flow rates.

Operation and maintenance requirements for the Ljungström system include energy, instrument air, water, and spare parts. Power requirements are higher without the AdvX® upgrade to compensate for the higher heat rate loss. No chemicals are needed for the technology, and no additional labor is needed operation and maintenance of the system.

2. Technology Status and Performance

The Ljungström AdvX®-ZLD Technology is used to treat FGD wastewater internationally, at two power plants in Asia.

3. References

1. Ljungström. 2021. CBI Vendor Cost Data for Ljungström. (07 October). DCN SE10370.
2. US EPA. 2022. US Environmental Protection Agency. *Notes from Vendor Call with Ljungström on September 17, 2021*. (02 September). DCN SE10377.

Appendix U – Membrane Development Specialists (MDS) Technology

1. Technology Description

Membrane Development Specialists (MDS) has been developing membrane technologies for industrial applications since 1980. Over the last several years, MDS has developed pilot systems and full-scale installations within various industries, including flue gas desulfurization (FGD) wastewater reuse, cooling tower blowdown, mine wastewater, and municipal landfill leachate.

A typical treatment train for treatment of FGD wastewater using an MDS system includes pretreatment to precipitate gypsum followed by ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO), if needed. Permeate is recycled as scrubber make up water. Concentrate can be managed by an evaporation pond or small evaporators. The hollow fiber UF membranes remove bacteria and suspended solids but are less expensive over time than comparable sand filters. NF removes divalent cations and anions.

The NF portion of the system is considered the most vulnerable. Since this membrane is exposed to saturated sulfates, frequent replacement is required due to fouling from precipitates. However, quality pretreatment can extend the life of the membranes. MDS estimates that with pretreatment, on average, the lifespan of UF, NF, and RO membranes are less than 2 years, 3-5 years, and over 3 years, respectively. The membranes require a suite of pretreatment chemicals to remove fouling.

Typical system monitoring parameters include conductivity, oxidation reduction potential (ORP), pH, temperature, and pressure drop across the membranes. Monitoring for scale forming ions is also important as temperature and pH may impact their solubility.

MDS has partnered with Purestream to test management of membrane concentrate using evaporation. Since the cost of evaporators can drive the cost of overall treatment, plants can alternatively dispose of concentrate as a hazardous waste.

2. Technology Status and Performance

MDS is currently working with a coal-fired power plant in Pennsylvania to consider membranes as an option for treating FGD wastewater.

MDS has worked with European municipal landfills to treat landfill leachate, which can have high concentrations of biochemical oxygen demand (BOD) and TDS, to meet limits acceptable for surface discharge. Some of these landfills use small membrane bioreactors (MBR) following the MDS system to remove organics. Concentrate from these treatment systems is typically disposed of in a hazardous landfill.

MDS is also assisting with projects in Nevada and South America to capture and treat wastewater from mines.

The EPA met with MDS in support of the 2024 final rule to discuss their experience treating wastewaters with similar characteristics to FGD wastewater. The following topics were discussed:

- MDS's timeline to design, build, and commission a 100-gpm treatment system is approximately eight to 12 months.
- Their experience with acid mine drainage is analogous to FGD wastewater, as there is high TDS concentrations and low pH, but with higher concentrations of heavy metals.

3. References

1. ERG. 2022. Eastern Research Group, Inc. *Notes from Meeting with EPA, MDS, and ERG on November 17, 2021.* (February). DCN SE10419.

Appendix V – Slurry Management Systems, LLC (SMS) Technology

1. Technology Description

The Slurry Management Systems, LLC (SMS) technology is a mobile dewatering system. Wastewater from a holding area (e.g., pit, pond, collection tank) is pumped through a filter press to generate a filter cake and filtrate. A shaker screen may be used as pretreatment to remove larger particles prior to the filter press. The shaker screen, feed pumps, controls, holding tank, and filter press are self-contained on a trailer, which can be hauled directly to any site. Automated plate shifters on the filter press allow solids to drop from the end of the trailer directly into a loader or truck. The capacity of a single mobile system is 100-150 gallons per minute (gpm).

The SMS technology is targeted for multiple industries, including concrete plants, oil and gas facilities, ash and flue gas desulfurization (FGD) ponds, mining, and construction.

SMS currently applies their dewatering technology at a wash sand plant where two temporary systems are used to handle wastewater while a site-specific SMS system is designed and installed.

2. References

1. ERG. 2022. Eastern Research Group, Inc. *Notes from Vendor Call with Slurry Management Systems, LLC on November 19, 2021.* (22 December). DCN SE10379.

Exhibit 4

United States Environmental Protection Agency | Office of Water Washington, DC 20460 | EPA-821-R-24-007 April 18, 2024

Regulatory Impact Analysis for Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category

United States Environmental Protection Agency

Regulatory Impact Analysis for Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category

EPA-821-R-24-007

April 18, 2024

U.S. Environmental Protection Agency
Office of Water (4303T)
Engineering and Analysis Division
1200 Pennsylvania Avenue, NW
Washington, DC 20460

Table of Contents

List of Tables

List of Figures

Abbreviations

AEO	Annual Energy Outlook
ASCC	Alaska Systems Coordinating Council
BA	Bottom ash
BAT	Best available technology economically achievable
BCA	Benefit and Cost Analysis
BEA	U.S. Bureau of Economic Analysis
BLS	U.S. Bureau of Labor Statistics
BMP	Best management practice
BPJ	Best professional judgment
BPT	Best practicable control technology currently available
BSER	Best system of emission reduction
CAA	Clean Air Act
CC	Carbon capture
CCI	Construction cost index
CCR	Coal combustion residuals
CCRMU	CCR management units
CCS	Carbon capture and storage
CEMS	Continuous emission monitoring systems
CES	Clean Energy Standards
CFR	Code of Federal Regulations
CP	Chemical precipitation
CPP	Clean Power Plan
CRL	Combustion residual leachate
CSAPR	Cross-State Air Pollution Rule
CWA	Clean Water Act
DOE	Department of Energy
EA	Environmental Assessment
ECI	Employment Cost Index
EGU	Electricity generating units
EIA	Energy Information Administration
EJ	Environmental justice
ELGs	Effluent limitations guidelines and standards
EO	Executive Order
EPA	U.S. Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
FGD	Flue gas desulfurization
FOM	Fixed O&M
fPM	Filterable particulate matter
FR	Federal Register
FRCC	Florida Reliability Coordinating Council
GDP	Gross domestic product
GHG	Greenhouse gas

GW	Gigawatt
GWh	Gigawatt-hour
HICC	Hawaii Coordinating Council
HRI	Heat rate improvement
HRR	High recycle rate
HRTR	High Hydraulic Residence Time Reduction
IBR	Inverter-based resources
IPM	Integrated Planning Model
IRA	Inflation Reduction Act of 2022
ISO	Independent system operator
kWh	Kilowatt-hour
LRTR	Low Hydraulic Residence Time Reduction
MATS	Mercury and Air Toxics Standards
Mcf	Million cubic feet
MDS	Mechanical drag system
MRO	Midwest Reliability Organization
MT	Million short tons
MW	Megawatt
MWh	Megawatt-hour
NAAQS	National ambient air quality standards
NAICS	North American Industry Classification System
NERC	North American Electric Reliability Corporation
NOPP	Notice of planned participation
NPCC	Northeast Power Coordinating Council
NPDES	National Pollutant Discharge Elimination System
NPRM	Notice of proposed rulemaking
NSPS	New Source Performance Standards
NTTAA	National Technology Transfer and Advancement Act
O&M	Operation and maintenance
OMB	Office of Management and Budget
POTW	Publicly owned treatment works
PRA	Paperwork Reduction Act
PSES	Pretreatment Standards for Existing Sources
PSNS	Pretreatment Standards for New Sources
QA	Quality assurance
QC	Quality control
Quad	Quadrillion British thermal units
RCRA	Resource Recovery and Conservation Act
RIA	Regulatory Impact Analysis
RFA	Regulatory Flexibility Act
RF	Reliability First Corporation
RGGI	Regional Greenhouse Gas Initiative
RTO	Regional transmission organization
RULOF	Remaining Useful Life and Other Factors

SBA	Small Business Administration
SBREFA	Small Business Regulatory Enforcement Fairness Act
SDE	Spray dry evaporator
SERC	SERC Reliability Corporation
SISNOSE	Significant impact on a substantial number of small entities
SPP	Southwest Power Pool
TDD	Technical Development Document
TRE	Texas Reliability Entity
TWF	Toxic weighting factor
TWh	Terawatt-hour
TWPE	Toxic weighted pound equivalent
UMRA	Unfunded Mandates Reform Act
USC	Ultra-supercritical coal
VIP	Voluntary Incentive Program
VOM	Variable O&M
WECC	Western Electricity Coordinating Council
WMU	Waste management unit

Executive Summary

The U.S. Environmental Protection Agency (EPA) is finalizing revisions to the technology-based effluent limitations guidelines and standards (ELGs) for the steam electric power generating point source category, 40 CFR part 423, which EPA proposed on March 29, 2023 (88 FR 18824). The final rule revises certain best available technology (BAT) effluent limitations and pretreatment standards established in the rules EPA previously promulgated in November 2015 (80 FR 67838) and October 2020 (85 FR 64650) for existing sources for three wastestreams: flue gas desulfurization (FGD) wastewater, bottom ash (BA) transport water, and combustion residual leachate (CRL). The rule also establishes effluent limitations and pretreatment standards for legacy wastewater.

This action is an economically significant regulatory action that was submitted to the Office for Management and Budget (OMB) for interagency review. This Regulatory Impact Analysis (RIA) presents an assessment of the compliance costs and impacts associated with this final rule and presents analyses to meet various statutory and Executive Order requirements. The accompanying *Benefit and Cost Analysis for Supplemental Revisions to the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (BCA) document presents social costs and benefits of the action, consistent with Executive Orders 12866, 13563 and 14094.

Regulatory Options

For this final rule, EPA evaluated three regulatory options as summarized in Table ES-1. EPA established BAT effluent limitations based on the technologies described in Option B.

Table ES-1: Regulatory Options Analyzed for the Final Rule

Wastestream	Subcategory	Technology Basis for BAT/PSES Regulatory Options[a]			
		2020 Rule (Baseline)	**Option A**	**Option B**	**Option C**
FGD Wastewater	NA (default unless in subcategory)[b]	CP + Bio	ZLD	ZLD	ZLD
	Boilers permanently ceasing the combustion of coal by 2028	SI	SI	SI	SI
	Boilers permanently ceasing the combustion of coal by 2034	NS	CP + Bio	CP + Bio	NS
	High FGD Flow Facilities or Low Utilization Boilers	CP	NS	NS	NS
BA Transport Water	NA (default unless in subcategory)[b]	HRR	ZLD	ZLD	ZLD
	Boilers permanently ceasing the combustion of coal by 2028	SI	SI	SI	SI
	Boilers permanently ceasing the combustion of coal by 2034	NS	HRR	HRR	NS
	Low Utilization Boilers	BMP Plan	NS	NS	NS
CRL	NA (default)[b]	BPJ	CP	ZLD	ZLD
	Discharges of unmanaged CRL	NA	NS	CP	CP
	Boilers permanently ceasing the combustion of coal by 2034	NA	CP	CP	NS
Legacy Wastewater	Operate after 2024	NA	NS	CP	CP

Abbreviations: BMP = Best Management Practice; CP = Chemical Precipitation; HRR = High Recycle Rate Systems; SI = Surface Impoundment; ZLD = Zero Liquid Discharge; NS = Not subcategorized (default technology basis applies); NA = Not applicable

a. See TDD for a description of these technologies (U.S. EPA, 2024e).

b. The table does not present existing subcategories included in the 2015 and 2020 rules as EPA did not reopen the existing subcategorization of oil-fired units or units with a nameplate capacity of 50 MW or less.

Source: U.S. EPA Analysis, 2024

Annualized Compliance Costs

EPA estimates that the regulatory options result in incremental costs to owners and operators of steam electric power plants when compared to the baseline of the 2020 rule (Tables ES-2 and ES-3). On an *after-tax* basis, the final rule (Option B) has estimated incremental annualized compliance costs ranging from $479 million to $956 million.[1]

Table ES-2: Estimated Incremental Annualized After-tax Compliance Costs (Million of 2023$, Discounted to 2024 using 3.76 Percent) - Lower

Regulatory Option	Capital Technology	Other Initial One-Time	Total O&M	Total Costs[a]
Option A	$186	$0.1	$200	$386
Option B	$229	$0.1	$250	$479
Option C	$270	$0.2	$286	$557

a. Costs analyzed over the period 2025-2049.

Source: U.S. EPA Analysis, 2024

Table ES-3: Estimated Incremental Annualized After-tax Compliance Costs (Million of 2023$, Discounted to 2024 using 3.76 Percent) - Upper

Regulatory Option	Capital Technology	Other Initial One-Time	Total O&M	Total Costs[a]
Option A	$372	$0.1	$490	$863
Option B	$415	$0.1	$541	$956
Option C	$456	$0.2	$577	$1,033

a. Costs analyzed over the period 2025-2049.

Source: U.S. EPA Analysis, 2024

This analysis accounts for costs associated with the BA transport water, FGD wastewater, CRL wastestreams (including unmanaged CRL), and legacy wastewater. Costs associated with legacy wastewater limits would be incurred only as plants close and dewater their existing ponds. There is uncertainty on when plants may do so; for the purposes of this analysis, EPA assumed all plants would implement technologies to meet limits for legacy wastewater and incur costs in 2044. EPA believes this could overestimate costs if plants are decommissioned in later years. Similarly, certain plants could incur costs associated with the treatment of unmanaged CRL discharged from landfills, surface impoundments, or other features. These limits would apply only in cases where a permitting authority deems, on a case-by-case basis, that the discharge is functionally equivalent to a direct discharge and requires a permit. Because these discharges are uncertain, EPA assumed that plants incurred costs associated with

1 These costs are the basis for social costs presented in Chapter 11 of the BCA with the main differences being the applied discount rates, the way costs are distributed over the period of analysis, tax considerations, and the annualization period. In the private cost analysis, all costs are annualized over the life of the technology or cost recurrence period (*e.g.*, 1 year, 5 years, 20 years), discounted according to the estimated plant compliance year, and summed over each plant and across plants. After-tax costs are a more meaningful measure of compliance impact on privately owned for-profit plants and incorporate approximate capital depreciation and other relevant tax treatments in the analysis. By contrast, for the social cost analysis, costs are presented on a pre-tax basis and recorded in the year in which they are estimated to be incurred during the analysis period of 2025-2049. The modeled stream of future costs is then discounted back to the estimated rule promulgation year to obtain the total present value, and then annualized over the 25-year analysis period.

unmanaged CRL costs at the same time as they would implement technologies to meet limits for CRL wastestreams. See Section 3.1 for details.

EPA also evaluated whether the New Source Performance Standard (NSPS) requirements of the final rule present a barrier to the entry of new generation. EPA notes that no new coal capacity additions are projected between 2024 and 2050 in AEO2023 (EIA, 2023b) or in the Integrated Planning Model (IPM) detailed in Chapter 5, making the assessment of the relative costs and of any barrier the final ELGs may pose to additional generation hypothetical. Nonetheless, EPA assessed the costs imposed on new plants in relation to the costs for building and operating a new plant and found that the costs for adding treatment technology at a new plant would represent approximately 1 percent of the total annualized costs of building and operating a new plant. Section 3.3 details the analysis.

Impacts on Steam Electric Industry and Electricity Market

EPA assessed the impacts of the regulatory options on the steam electric industry and the electricity market in two ways:

1. A screening-level assessment reflecting historical characteristics of steam electric power plants and with assignment of estimated compliance costs to the plants and their owners. Specifically, EPA calculated cost-to-revenue ratios for individual steam electric power plants and for domestic parent-entities owning these plants to assess the relative impact of compliance outlays. Overall, this screening-level analysis shows that few entities are likely to experience significant changes in compliance costs compared to revenues. See Chapter 4 for details.

2. A broader electricity market-level analysis using the Integrated Planning Model (IPM), which provides a more comprehensive indication of the economic impacts of this final rule, looking specifically at regulatory option B, including an assessment of changes in the operating characteristics of steam electric power plants and other electricity generators resulting from changes in electricity markets under the final rule. See Chapter 5 for details.

Table ES-4 and Table ES-5 summarize IPM results in the baseline (absent Option B) and under Option B (absolute values and changes relative to the baseline). These analyses show that the final rule is estimated to have small impacts on the steam electric power plants, on the entities that own these plants, and on the electricity market as a whole. For example, IPM results for the market show net changes in total generation capacity of 0.4 percent and generation costs of less than 0.2 percent across economic measures for Option B in the model year 2035 after implementation of the revised ELGs (see Table ES-4). The final rule results in a small projected increase in total generation, and a small projected increase in total generation capacity (less than 0.4 percent of the baseline) as the net effect of increases in non-coal generation sources (combination of renewables, natural gas, and energy storage) and decreases in coal-fired generation capacity resulting from early retirements of coal-fired electricity generating units relative to the baseline and already scheduled retirements. The final rule results in a small projected increase in total electricity market costs, the net effect of decreases in fuel costs, variable O&M, and fixed O&M and increases in capital and CCS costs. These projected changes depend on overall changes in capacity, generation mix, and pollutant controls, among other factors (*e.g.*, switch from generating units with higher fixed O&M to units with lower fixed O&M would result in a decrease in total fixed O&M).

Results for steam electric power plants in scope of the final rule (in Table ES-5) also show small impacts, with a net decrease in total capacity under the final rule when compared to the baseline (2.6 percent), and net decreases in total generation by steam electric power plants of 3 percent for the final rule. Projected decreases in fixed O&M and capital costs for steam electric power plants in scope of the final rule reflect projected capacity retirements. The IPM model determines the least cost approach to meeting demand subject to modeled system and operational constraints. Therefore, changes in the national power sector (*e.g.*, generation mix, cost for non-steam electric generation, technology changes, cost for new capacity relative to new coal-steam production costs) affect projected retirements of steam electric capacity.[2] These findings suggest that the final rule will have small economic consequences for the steam electric power generating industry and the electricity market overall.

Looking specifically at plants with estimated incremental compliance costs, the results for the final rule show no change in generation for 1 of the 35 plants with compliance costs, and a slight decrease in generation for another 4 plants. See Chapter 5 for details of these analyses, including results by region and for different model years.

Table ES-4: Modeled Impact of Final Rule on National Electricity Market in the Model Year 2035

Economic Measures[a] (all dollar values in 2023$)	Baseline Value	Option B		
		Value	Difference	% Change
Total Domestic Capacity (GW)	1,712	1,718	6.4	0.4%
Existing			-1.5	-0.1%
New Additions			7.9	0.5%
Early Retirements			1.5	0.1%
Generation (TWh)	5,158	5,160	1.7	0.0%
Costs ($Millions)	$138,325	$138,544	$219	0.2%
Fuel Cost	$39,166	$38,975	-$191	-0.5%
Variable O&M	$5,351	$5,244	-$107	-2.0%
Fixed O&M	$65,915	$65,666	-$249	-0.4%
Capital Cost	$34,149	$34,536	$387	1.1%
CCS Cost[b]	-$6,256	-$5,878	$379	-6.1%
Average Variable Production Cost ($/MWh)	$8.63	$8.57	-$0.06	-0.7%
CO_2 Emissions (Million Metric Tons)	724	713	-11.6	-1.6%
Mercury Emissions (Tons)	2	2	-0.050	-2.0%
NO_X Emissions (Million Tons)	0	0	-0.009	-3.4%
SO_2 Emissions (Million Tons)	0	0	-0.013	-5.3%
HCL Emissions (Million Tons)	0	0	-0.00012	-8.1%

a. See Chapter 5 for a description of the economic measures.

b. "CCS Cost" is the cost of CO_2 transportation and storage and also includes expenses on equipment and pipelines, as well as the total value of 45Q tax credits and enhanced oil recovery (EOR) revenues. In the baseline and under Option B, the total

2 Costs to replace retired capacity are not included in the estimate of compliance costs reported in Table ES-2 and Table ES-3. However, as detailed in Chapter 5, the ELG compliance costs are entered as a fixed cost adder in IPM for units subject to the ELGs and included in the modeled decision of whether to keep generating electricity from that unit or shift to other generators with lower production costs. In cases where the modeled decision is the retirement of a steam electric unit in favor of other generating sources or new capacity, the ELG compliance costs would not be incurred for that unit and the compliance costs reflected in Table ES-2 and Table ES-3 are overestimated. Additionally, the final rule results in projected retirements representing only a fraction of a percent of total capacity, and an even smaller percentage of active capacity.

Table ES-4: Modeled Impact of Final Rule on National Electricity Market in the Model Year 2035

Economic Measures[a] (all dollar values in 2023$)	Baseline Value	Option B Value	Difference	% Change
private costs are negative because the sum of the tax credits and EOR revenues exceed the equipment and pipeline costs of CO_2 storage. Under Option B, total CCS Costs are less negative, and therefore these costs increase relative to the baseline, as the total amount of the 45Q tax credit received by the sector and/or EOR revenues fall due to lower coal generation.				

Source: U.S. EPA Analysis, 2024

Table ES-5: Impact of Final Rule on Plants in the Steam Electric Power Generating Point Source Category, as a Group, in the Model Year 2035

Economic Measures [a]		Option B		
(all dollar values in 2023$)	Baseline Value	Value	Difference	% Change
Total Domestic Capacity (MW)	220,237	214,455	-5,782	-2.6%
Early Retirements – Number of Plants	78	83	5	6.4%
Full & Partial Retirements – Capacity (MW)	104,544	110,326	5,782	5.5%
Generation (GWh)	789,529	765,950	-23,579	-3.0%
Costs ($Millions)	$28,580	$27,740	-$840	-2.9%
Fuel Cost	$13,957	$13,454	-$503	-3.6%
Variable O&M	$1,976	$1,840	-$136	-6.9%
Fixed O&M	$15,419	$15,041	-$378	-2.5%
Capital Cost	$3,202	$3,000	-$202	-6.3%
CCS Cost[b]	-$5,974	-$5,595	$379	-6.3%
Average Variable Production Cost ($/MWh)	$20.18	$19.97	-$0.21	-1.1%

a. See Chapter 5 for a description of the economic measures.

b. The "CCS Cost" is the cost of CO_2 transportation and storage and also includes expenses on equipment and pipelines, as well as the total value of 45Q tax credits and enhanced oil recovery (EOR) revenues. In the baseline and under Option B, the total private costs are negative because the sum of the tax credits and EOR revenues exceed the equipment and pipeline costs of CO_2 storage. Under Option B, total CCS Costs are less negative, and therefore these costs increase relative to the baseline, as the total amount of the 45Q tax credit received by the sector and/or EOR revenues fall due to lower coal generation.

Source: U.S. EPA Analysis, 2024

Potential Impacts on Employment

In addition to addressing the costs and impacts of the regulatory options, EPA discusses the potential impacts of this rulemaking on employment in Chapter 6. EPA estimates a net increase in employment as a result of the final rule (Option B).

Potential Electricity Price Effects

EPA also assessed the estimated impacts of the regulatory options on electricity prices, assuming a worst-case scenario of full cost pass-through of compliance costs in electricity prices. The Agency conducted this analysis in two parts: (1) an assessment of the estimated annual changes in electricity costs per MWh of total electricity sales; and (2) an assessment of the estimated annual changes in household electricity costs. Chapter 7 details these analyses.

Changes in costs per MWh of total electricity sales are small for all regulatory options; the maximum difference in price effect is a fraction of a cent per kWh. Overall, across the United States, the final rule (Option B) results in an average estimated cost increase of between 0.015¢ and 0.030¢ per kWh.

On the national level, the final rule (Option B) results in estimated average compliance costs per residential household of between $1.61 to $3.14 per year.

Potential Impacts on Small Entities

In accordance with the Regulatory Flexibility Act (RFA) requirements, EPA assessed whether the regulatory options would have "a significant impact on a substantial number of small entities" (SISNOSE). The analysis is detailed in Chapter 8.

Under the final rule (Option B), in the lower bound scenario, EPA estimates that 3 small cooperatives, 4 small nonutilities, and 3 small municipalities owning steam electric power plants would incur costs exceeding one percent of revenue. On a *percentage* basis, small entities represent approximately 5 to 8.5 percent of the total number of small entities owning steam electric power plants (12 to 16 percent of small cooperatives, 3 to 7 percent of small nonutilities, and 10 to 14 percent of small municipalities). In the upper bound scenario, EPA estimates that 4 small cooperatives, 5 small nonutilities, and 3 small municipalities owning steam electric power plants would incur costs exceeding one percent of revenue. On a *percentage* basis, small entities represent approximately 6 to 10 percent of the total number of small entities owning steam electric power plants. (16 to 21 percent of small cooperatives, 4 to 9 percent of small nonutilities, and 10 to 14 percent of small municipalities).

In the lower bound scenario, the analysis shows that 2 small cooperatives, 2 small nonutilities, and 1 small municipality owning steam electric power plants would incur costs greater than three percent of revenue. In the upper bound scenario, the analysis shows that 3 small cooperatives, 2 small nonutilities, and 2 small municipalities owning steam electric power plants would incur costs greater than three percent of revenue. Overall, this screening-level analysis suggests that the analyzed regulatory options are unlikely to have a significant economic impact on a substantial number of small entities.

Unfunded Mandate Reform Act

Under Title II of the Unfunded Mandates Reform Act (UMRA) of 1995 section 202, EPA generally must prepare a written statement, including a cost-benefit analysis, for final and final rules with "Federal mandates" that might result in expenditures by State, local, and Tribal governments, in the aggregate, or by the private sector, of $100 million (adjusted annually for inflation) or more in any one year (*i.e.*, $198 million in 2023 dollars).

EPA estimates that the final rule (Option B) would result in expenditures of at least $198 million for State and local government entities under the upper bound scenario, in the aggregate, in any one year, but not in the lower bound scenario. The Agency does estimate that the private sector would incur expenditures greater than $198 million, in the aggregate, in any one year. For the final rule (Option B), the maximum compliance costs incurred by the private sector in any one year are between $1,380 and $3,156 million in 2028, whereas total annualized compliance costs for plants owned by private sector entities are between $603 and $1,207 million. The implementation period built into the final rule is one way that EPA accounted for the site-specific needs of steam electric power plants.

Other Administrative Requirements

EPA conducted analyses to address other administrative requirements. Key findings, which are discussed further in Chapter 10, include:

- **Executive Order 12866: Regulatory Planning and Review, Executive Order 13563: Improving Regulation and Regulatory Review, and Executive Order 14094 Modernizing Regulatory Review:** Pursuant to the terms of Executive Orders 12866, 13563, and 14094, this action is a "significant regulatory action" because the action is likely to have an annual effect on the economy of $200 million or more. As such, the action is subject to review by the OMB. Any changes made during this period of review will be documented in the docket for this action. EPA prepared an analysis of the estimated benefits and costs associated with this action; this analysis is detailed in Chapter 13 of the BCA (U.S. EPA, 2024a).

- **Executive Order 13211: Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution, or Use:** EPA's analyses show that the final rule will not have a significant adverse effect at a national or regional level under Executive Order 13211. Specifically, the Agency's analyses found that the final rule would not reduce electricity production in excess of 1 billion kilowatt hours per year or in excess of 500 megawatts of installed capacity, nor that it would increase U.S. dependence on foreign supply of energy.

- **Executive Orders 12898: Federal Actions to Address Environmental Justice (EJ) in Minority Populations and Low-Income Populations; and Executive Order 14008: Tackling the Climate Crisis at Home and Abroad**: EPA examined whether the benefits from the regulatory options may be differentially distributed among population subgroups in the affected areas. This analysis is detailed in the accompanying *Environmental Justice Analysis for Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (EJA) document (U.S. EPA, 2024c). The analysis showed that the human health or environmental risk addressed by this final action will not have potential disproportionately high and adverse human health or environmental effects on minority, low-income, or indigenous populations.

- **Executive Order 13045: Protection of Children from Environmental Health Risks and Safety Risks:** As described in Section 10.3 and detailed in the BCA (U.S. EPA, 2024a), EPA identified several ways in which the final rule could benefit children by reducing health risk from exposure to pollutants present in steam electric power plant discharges, including neurological effects from exposure to lead and mercury.

1 Introduction

1.1 Background

EPA is finalizing a regulation that revises the technology-based effluent limitations guidelines and standards (ELGs) for the steam electric power generating point source category, 40 CFR part 423, which EPA previously proposed on March 29, 2023 (88 FR 18824). The final rule revises certain BAT effluent limitations and pretreatment standards for existing sources previously established in the ELG published in October 2020 (85 FR 64650) for four wastestreams: flue gas desulfurization (FGD) wastewater, bottom ash (BA) transport water, combustion residual leachate (CRL), and legacy wastewater.

This document describes the Agency's analysis of the costs and economic impacts of the regulatory options that were evaluated by EPA. EPA analyzed three regulatory options, including the final rule (Option B). The document also provides information pertinent to meeting several legislative and administrative requirements.

This document complements and builds on information presented separately in other reports, including:

- *Technical Development Document for Supplemental Revisions to the Effluent Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (TDD) (U.S. EPA, 2024e). The TDD provides background on the regulatory options; applicability and summary of the regulatory options; industry description; wastewater characterization and identifying pollutants; and treatment technologies and pollution prevention techniques. It also documents EPA's engineering analyses to support the regulatory options including plant-specific compliance cost estimates, pollutant loadings, and non-water quality environmental impact assessment.

- *Benefit and Cost Analysis for Supplemental Revisions to the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (BCA) (U.S. EPA, 2024a). The BCA summarizes the societal benefits and costs estimated to result from implementation of the regulatory options.

- *Environmental Assessment for Supplemental Revisions to the Effluent Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (EA) (U.S. EPA, 2024b). The EA summarizes the environmental and human health improvements that are estimated to result from implementation of the regulatory options.

- *Environmental Justice Analysis for Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (EJA) (U.S. EPA, 2024c). This report presents a profile of the communities and populations potentially impacted by this final rule, analysis of the distribution of impacts in the baseline and finalized changes, and summary of input from potentially impacted communities that EPA met with prior to the final rule.

The revisions to the ELGs for the Steam Electric Power Generating Point Source Category are based on data generated or obtained in accordance with EPA's Quality Policy and Information Quality Guidelines. EPA's quality assurance (QA) and quality control (QC) activities for this rulemaking include the development, approval and implementation of Quality Assurance Project Plans for the use of environmental data generated or collected from all sampling and analyses, existing databases and literature searches, and for the development of any models which used environmental data. Unless otherwise stated within this document, the data used and associated data analyses were evaluated as described in these quality assurance documents to ensure they are of known and documented quality, meet EPA's requirements for objectivity, integrity and utility, and are appropriate for the intended use.

1.2 Overview of the Costs and Economic Impacts Analysis

This section describes the key components of the analysis framework. The Agency's analysis generally follows the methodology EPA previously used to analyze the 2020 rule and 2023 proposal (see RIA; U.S. EPA, 2020, 2023d). Appendix A describes the principal changes to the regulatory options analysis, as compared to analyses of the 2020 rule and 2023 proposal. These changes include:

- Updating the information on the control and treatment technologies and associated costs for BA transport water, FGD wastewater, CRL, and legacy wastewater (see TDD for details; U.S. EPA, 2024e).
- Updating the universe of steam electric power plants and their wastestreams to account for major changes such as additional retirements, fuel conversions, ash handling system conversions, wastewater treatment system updates and updated information on capacity utilization.
- Accounting for announced unit retirements and repowerings[3] in estimating the stream of expenditures under the baseline and each regulatory option during the period of analysis.
- Updating the baseline used in analyses using the Integrated Planning Model (IPM). IPM incorporates the effects of existing regulations and programs or estimated to be in effect by the time the rule resulting from this final rule is implemented. For the final rule, this baseline includes the 2020 rule, as well as expected effects of provisions in the Inflation Reduction Act of 2022. See Section 2.2 for additional discussion of these regulations and Chapter 5, *Assessment of the Impact of the Final Rule on National and Regional Electricity Markets*, for further description of the analysis using IPM, including a description of the analysis baseline.
- Updating electricity generation, sales, and electricity prices based on the most current data from the Energy Information Administration (*e.g.*, 2016-2021 vs. 2013-2018).
- Updating information about the entities that own steam electric generating units, based on EIA data, and recategorizing these entities as small or large using SBA small business size thresholds.

1.2.1 Main Regulatory Options Presented in the Final Rule

For this final rule, EPA evaluated three regulatory options as shown in Table 1-1. EPA finalized BAT effluent limitations based on the technologies described in Option B.

3 Repowering refers to the replacement of coal generation equipment with non-coal generation equipment.

Table 1-1: Regulatory Options Analyzed for the Final Rule

Wastestream	Subcategory	Technology Basis for BAT/PSES Regulatory Options[a]			
		2020 Rule (Baseline)	Option A	Option B	Option C
FGD Wastewater	NA (default unless in subcategory)[b]	CP + Bio	ZLD	ZLD	ZLD
	Boilers permanently ceasing the combustion of coal by 2028	SI	SI	SI	SI
	Boilers permanently ceasing the combustion of coal by 2034	NS	CP + Bio	CP + Bio	NS
	High FGD Flow Facilities or Low Utilization Boilers	CP	NS	NS	NS
Bottom Ash Transport Water	NA (default unless in subcategory)[b]	HRR	ZLD	ZLD	ZLD
	Boilers permanently ceasing the combustion of coal by 2028	SI	SI	SI	SI
	Boilers permanently ceasing the combustion of coal by 2034	NS	HRR	HRR	NS
	Low Utilization Boilers	BMP Plan	NS	NS	NS
CRL	NA (default)[b]	BPJ	CP	ZLD	ZLD
	Discharges of unmanaged CRL	NA	NS	CP	CP
	Boilers permanently ceasing the combustion of coal by 2034	NA	CP	CP	NR
Legacy Wastewater	Operate after 2024	NA	NS	CP	CP

Abbreviations: BMP = Best Management Practice; CP = Chemical Precipitation; HRR = High Recycle Rate Systems; SI = Surface Impoundment; ZLD = Zero Liquid Discharge; NS = Not subcategorized (default technology basis applies); NA = Not applicable

a. See TDD for a description of these technologies (U.S. EPA, 2024e).

b. The table does not present existing subcategories included in the 2015 and 2020 rules as EPA did not reopen the existing subcategorization of oil-fired units or units with a nameplate capacity of 50 MW or less.

Source: U.S. EPA Analysis, 2024

1.2.2 Baseline

The baseline for the analyses supporting this final rule reflects the 2020 rule requirements. The Agency estimated and presents in this report the incremental compliance costs that plants could incur under each of the three regulatory options presented in Table 1-1 relative to this baseline.

EPA updated baseline information to incorporate major changes in the universe and operational characteristics of steam electric power plants such as additional retirements and fuel conversions since the analysis of the 2020 rule detailed in U.S. EPA (2020). EPA also incorporated updated information on the technologies and other controls that plants employ. The current analysis focuses on four wastestreams for which plants are expected to incur costs during the period of analysis: BA transport water, FGD wastewater, CRL (including unmanaged CRL), and legacy wastewater.

1.2.3 Cost and Economic Analysis Requirements under the Clean Water Act

EPA's effluent limitations guidelines and standards for the steam electric industry are promulgated under the authority of the Clean Water Act (CWA) Sections 301, 304, 306, 307, 308, 402, and 501 (33 U.S.C. 1311, 1314, 1316, 1317, 1318, 1342, and 1361). In establishing national effluent guidelines and pretreatment standards for pollutants, EPA considers the availability and economic achievability of control and treatment technologies, as well as specified statutory factors including "costs." 33 U.S.C. 1311(b)(2)(A), 1314(b)(2)(B).

EPA analyzed economic achievability; the cost and economic impact analysis for this rulemaking also focuses on understanding the magnitude and distribution of compliance costs across the industry, and the broader market impacts. This report also documents analyses required under other legislative (*e.g.*, Regulatory Flexibility Act, Unfunded Mandates Reform Act) and administrative requirements (*e.g.*, Executive Order 12866: Regulatory Planning and Review as supplemented by Executive Order 14094: Modernizing Regulatory Review).

1.2.4 Analyses of the Regulatory Options and Report Organization

This document discusses the following analyses EPA performed in support of the regulatory options as compared to the baseline:

- **Overview of the steam electric industry** (Chapter 2), which focuses on changes to the industry since the 2020 rule.
- **Compliance cost assessment** (Chapter 3), which describes the cost components and calculates the industry-wide incremental compliance costs for the regulatory options relative to the baseline.
- **Cost and economic impact screening analyses** (Chapter 4), which evaluates the incremental impacts of compliance on plants and their owning entities on a cost-to-revenue basis.
- **Assessment of impacts in the context of national electricity markets** (Chapter 5), which analyzes the impacts of the final rule (Option B) using IPM and provides insight into the incremental effects of the final rule on the steam electric power generating industry and on national electricity markets, relative to the baseline.
- **Analysis of employment effects** (Chapter 6), which assesses national-level changes in employment in the steam electric industry, relative to the baseline.

- **Assessment of potential electricity price effects** (Chapter 7), which looks at the incremental impacts of compliance in terms of increased electricity prices for households and for other consumers of electricity.

- **Regulatory Flexibility Act (RFA) analysis** (Chapter 8) which assesses the change in impact of the rule on small entities on the basis of a revenue test, *i.e.*, cost-to-revenue comparison.

- **Unfunded Mandates Reform Act (UMRA) analysis** (Chapter 9) which assesses the change in impact on government entities, in terms of (1) compliance costs to government-owned plants and (2) administrative costs to governments implementing the rule. The UMRA analysis also compares the impacts to small governments with those of large governments and small private entities.

- **Analyses to address other administrative requirements** (Chapter 10), such as Executive Order 13211, which requires EPA to determine if this action would have a significant effect on energy supply, distribution, or use.

These analyses generally follow the same methodology used by EPA for the analysis of the 2015 and 2020 rules and 2023 proposal and the discussion follows a presentation very similar to that in the associated RIA documents (U.S. EPA, 2015, 2020, 2023d).

Chapter 11 provides detailed information on sources cited in the text and three appendices provide supporting information:

- *Appendix A: Summary of Changes to Costs and Economic Impact Analysis* lists the principal changes EPA made to its costs and economic impact analysis for the regulatory options, relative to the methodology used to analyze the 2020 rule.

- *Appendix B: Comparison of Incremental Costs and Pollutant Removals* describes EPA's analysis of the cost-effectiveness of the regulatory options.

- *Appendix C: Total Costs Based on 7 Percent Discount Rate* presents compliance cost estimates for the regulatory options based on a 7 percent discount rate.

2 Overview of the Steam Electric Industry

This section provides a general description of the steam electric industry, focusing on changes to the universe of plants and entities that own the plants as compared to the profile used for the 2015 and 2020 rules (U.S. EPA, 2015, 2020). It also discusses the regulations applicable to the universe of plants subject to this final rule.

2.1 Steam Electric Industry

The final rule revises BAT limitations and pretreatment standards for bottom ash transport water, FGD wastewater, CRL, and legacy wastewater for existing sources in the steam electric industry. The Steam Electric Power Generating Point Source Category covers "discharges resulting from the operation of a generating unit by an establishment whose generation of electricity is the predominant source of revenue or principal reason for operation, and whose generation of electricity results primarily from a process utilizing fossil-type fuel (coal, oil, or gas), fuel derived from fossil fuel (*e.g.*, petroleum coke, synthesis gas), or nuclear fuel in conjunction with a thermal cycle employing the steam water system as the thermodynamic medium." (40 CFR 423.10)

EPA had identified 1,080 steam electric power plants – including plants that operate coal, oil, gas, and nuclear generating units – and used this universe in its analysis of the 2015 rule (U.S. EPA, 2015), based on an industry survey the Agency conducted in 2010.[4] Review of more recent data revealed that some of the plants EPA surveyed in 2010 have since retired their coal steam units, converted to different fuels, or made other changes that affect discharge characteristics. The TDD describes the changes in the steam electric industry population since the 2015 and 2020 rule analyses, including retirements, fuel conversions, ash handling conversions, wastewater treatment updates, and updated information on capacity utilization (U.S. EPA, 2024e).

EPA adjusted the 2015 universe to remove coal steam plants that no longer fit the definition of the Steam Electric Power Generating point source category. As a result of these adjustments, EPA estimates that there are 858 plants in the steam electric power generating industry, based on available EIA data. As presented in Table 2-1, the 858 steam electric power plants represent 6.4 percent of the total number of plants in the power generation sector, but represent 54.4 percent of the national total electric nameplate generating capacity with 674,998 MW.[5]

Of the estimated 858 steam electric power plants in the universe, EPA expects only a subset to incur compliance costs under the final rule: those coal fired power plants that discharge BA transport water, FGD wastewater, or CRL. As presented in Table 2-1, EPA estimated between 141 and 170 plants would incur non-zero compliance costs under the final rule (Option B); these plants represent 1 to 1.3 percent of the total plants reported by EIA in 2021 and 15.4 to 17.5 percent of the total generating capacity.

4 See *Questionnaire for the Steam Electric Power Generating Effluent Guidelines* (Steam Electric Survey; U.S. Environmental Protection Agency. (2010). *Questionnaire for the Steam Electric Power Generating Effluent Limitations Guidelines*.)

5 The total number of plants and electric generating capacity are for 2021. At the time EPA developed the industry profile, 2021 was the most recent calendar year for which EIA had published detailed annual data.

Table 2-1: Steam Electric Industry Share of Total Electric Power Generation Plants and Capacity in 2021

	Total[a]	Steam Electric Industry[b]		Plants with Non-Zero Compliance Costs for Final Rule[c]	
		Number	% of Total	Number	% of Total
Plants	13,455	858	6.4%	141 - 170	1.0% - 1.3%
Capacity (MW)	1,241,578	674,998	54.4%	189,572 – 217,184	15.3% - 17.5%

a. Data for total electric power generation industry are from the 2021 EIA-860 database (EIA, 2022c).

b. Steam electric power plant count and capacity were calculated on a sample-weighted basis.

c. See Chapter 3 for details on compliance cost estimates, including number of plants with non-zero compliance costs under the final rule (Option B) and other analyzed regulatory options. Number of affected plants and capacity are presented to reflect the lower and upper bound cost estimates.

Source: U.S. EPA Analysis, 2024; EIA, 2022c.

The following sections present information on ownership, geographic distribution, and operating characteristics of steam electric power plants.

2.1.1 Owner Type and Size

Entities that own electric power plants can be divided into seven major ownership categories: investor-owned utilities, nonutilities[6], federally-owned utilities, State-owned utilities, municipalities, rural electric cooperatives, and other political subdivisions. These categories are important because EPA has to assess the impact of the final rule on State, local, and tribal governments in accordance with UMRA of 1995 (see Chapter 9, *Unfunded Mandates Reform Act (UMRA) Analysis*).

Table 2-2 reports the number of parent entities, plants, and capacity by ownership type for the 858 steam electric power plants (for details on determination of parent entities for steam electric power plants, see Section 4.3). The plurality of steam electric power plants (37 percent of all steam electric power plants) are owned by investor-owned utilities, while nonutilities make up the second largest category (36 percent of all steam electric power plants). In terms of steam electric nameplate capacity, investor-owned utilities account for the largest share (50 percent) of total steam electric nameplate capacity.

Table 2-2: Existing Steam Electric Power Plants, Their Parent Entities, and Nameplate Capacity by Ownership Type, 2021

Ownership Type	Parent Entities[a,b,c]				Plants[a,b,d]		Capacity (MW)[a,d]	
	Lower Bound		Upper Bound					
	Number	% of Total	Number	% of Total	Number[c]	% of Total	Number[c]	% of Total
Cooperative	22	10.0%	28	7.1%	59	6.9%	39,934	5.9%
Federal	2	0.9%	7	1.7%	23	2.7%	31,154	4.6%
Investor-owned	57	25.9%	88	22.5%	320	37.4%	338,005	50.1%
Municipality	50	22.7%	84	21.5%	111	12.9%	42,882	6.4%
Nonutility	76	34.5%	160	40.9%	308	35.9%	196,559	29.1%
Other political subdivisions	11	5.0%	23	5.8%	33	3.8%	21,474	3.2%
State	2	0.9%	2	0.5%	4	0.5%	4,990	0.7%

6 Nonutilities are entities that own or operate facilities that generate electricity for use by the public but are not public utilities.

Table 2-2: Existing Steam Electric Power Plants, Their Parent Entities, and Nameplate Capacity by Ownership Type, 2021

Ownership Type	Parent Entities [a,b,c]				Plants [a,b,d]		Capacity (MW) [a,d]	
	Lower Bound		Upper Bound					
	Number	% of Total	Number	% of Total	Number[c]	% of Total	Number[c]	% of Total
Total	**220**	**100.0%**	**391**	**100.0%**	**858**	**100.0%**	**674,998**	**100.0%**

a. Numbers may not add up to totals due to independent rounding.

b. Ownership information on steam electric power plants is based on EIA (2022c). Information on parent entities, including type, revenue, and other characteristics, is based on information gathered through Dun and Bradstreet and additional research of publicly available information.

c. Parent entity counts are calculated on a sample-weighted basis and represent the lower and upper bound estimates of the number of entities owning steam electric power plants. For details see Chapter 4.

d. Steam electric power plant count and capacity were calculated on a sample-weighted basis. For details on sample weights, see TDD.

Source: U.S. EPA Analysis, 2024; EIA, 2022c

EPA estimates that between 52 percent and 53 percent of entities owning steam electric power plants are small entities (Table 2-3), according to Small Business Administration (SBA) (SBA, 2023) business size criteria. By definition, states and the federal government are considered large entities.

The size distribution of parent entities owning steam electric power plants varies by ownership type. Under the lower bound estimate, the lowest share of small entities is in the other political subdivision category (18 percent), while small entities make up the largest share of nonutilities and cooperatives (75 percent and 86 percent, respectively). The pattern is similar under the upper bound estimate, but small entities represent 9 percent of other political subdivision entities, 89 percent of cooperatives, and 77 percent of nonutilities.

EPA estimates that, of 858 steam electric power plants, 267 plants (31 percent) are owned by small entities (Table 2-4). Nonutilities represent the majority (50 percent) of plants owned by small entities (134 out of 263 plants), while investor-owned utilities, cooperatives, municipalities, and other political subdivisions[7] make up the remaining 50 percent. For a detailed discussion of the identification and size determination of parent entities of steam electric power plants, see Chapter 4 and Chapter 8.

Table 2-3: Parent Entities of Steam Electric Power Plants by Ownership Type and Size (assuming two different ownership cases)[a,b]

Ownership Type	Lower bound estimate of number of entities owning steam electric power plants				Upper bound estimate of number of entities owning steam electric power plants			
	Small	Large	Total	% Small	Small	Large	Total	% Small
Cooperative	19	3	22	86.4%	25	3	28	89.3%
Federal	0	2	2	0.0%	0	7	7	0.0%
Investor-owned	17	40	57	29.8%	22	66	88	24.6%
Municipality	22	28	50	44.0%	30	54	84	35.6%
Nonutility	57	19	76	75.0%	123	36	160	77.3%
Other political subdivision	2	9	11	18.2%	2	21	23	8.9%
State	0	2	2	0.0%	0	2	2	0.0%

7 Other political subdivisions include public power districts and irrigation projects.

Table 2-3: Parent Entities of Steam Electric Power Plants by Ownership Type and Size (assuming two different ownership cases)[a,b]

Ownership Type	Lower bound estimate of number of entities owning steam electric power plants				Upper bound estimate of number of entities owning steam electric power plants			
	Small	Large	Total	% Small	Small	Large	Total	% Small
Total	**117**	**103**	**220**	**53.2%**	**202**	**189**	**391**	**51.7%**

a. Numbers may not add up to totals due to independent rounding.

b. For details on estimates of the number of majority owners of steam electric power plants see Chapter 4 and Chapter 8.

Source: U.S. EPA Analysis, 2024

Table 2-4: Steam Electric Power Plants by Ownership Type and Size

Ownership Type	Number of Steam Electric Power Plants[a,b,c]			
	Small	Large	Total	% Small
Cooperative	52	7	59	88.1%
Federal	0	23	23	0.0%
Investor-owned	44	276	320	13.9%
Municipality	31	80	111	28.0%
Nonutility	134	174	308	43.6%
Other political subdivisions	6	27	33	18.5%
State	0	4	4	0.0%
Total	**267**	**590**	**858**	**31.2%**

a. Numbers may not sum to totals due to independent rounding.

b. Plant counts are sample-weighted estimates.

c. Plant size was determined based on the size of majority owners. In case of multiple owners with equal ownership shares, a plant was assumed to be small if it is owned by at least one small entity.

Source: U.S. EPA Analysis, 2024

2.1.2 Geographic Distribution of Steam Electric Power Plants

The U.S. bulk power system is composed of three major networks, or power grids, subdivided into several smaller North American Electric Reliability Corporation (NERC) regions:

- The *Eastern Interconnection* covers the largest portion of the United States, from the eastern end of the Rocky Mountains and the northern borders to the Gulf of Mexico states (including parts of northern Texas) on to the Atlantic seaboard.

- The *Western Interconnection* covers nearly all areas west of the Rocky Mountains, including the Southwest.

- The *Texas Interconnected System*, the smallest of the three major networks, covers the majority of Texas.

The Texas system is not connected with the other two systems, while the other two have limited interconnection to each other. The Eastern and Western systems are integrated with, or have links to, the Canadian grid system. The Western and Texas systems have links with Mexico.

These major networks contain extra-high voltage connections that allow for power transmission from one part of the network to another. Wholesale transactions can take place within these networks to reduce power costs, increase supply options, and ensure system reliability.

NERC is responsible for the overall reliability, planning, and coordination of the power grids. An independent, not-for-profit organization, it has regulatory authority for ensuring electric reliability in the United States, under the oversight of the Federal Energy Regulatory Commission (FERC). NERC is organized into six regional entities that cover the 48 contiguous States, and two affiliated councils that cover Hawaii, part of Alaska, and portions of Canada and Mexico.[8] These regional organizations are responsible for the overall coordination of bulk power policies that affect their regions' reliability and quality of service. Interconnection *between* the bulk power networks is limited in comparison to the degree of interconnection *within* the major bulk power systems. Further, the degree of interconnection between NERC regions even within the same bulk power network is also limited. Consequently, each NERC region deals with electricity reliability issues in its own region, based on available capacity and transmission constraints. The regional organizations also facilitate the exchange of information among member utilities in each region and between regions. Service areas of the member utilities determine the boundaries of the NERC regions. Though limited by the larger bulk power grids described above, NERC regions do not necessarily follow any State boundaries. Figure 2-1 provides a map of the NERC regions listed in Table 2-5 that EPA used for the analysis of the regulatory options.[9]

Table 2-5: NERC regions

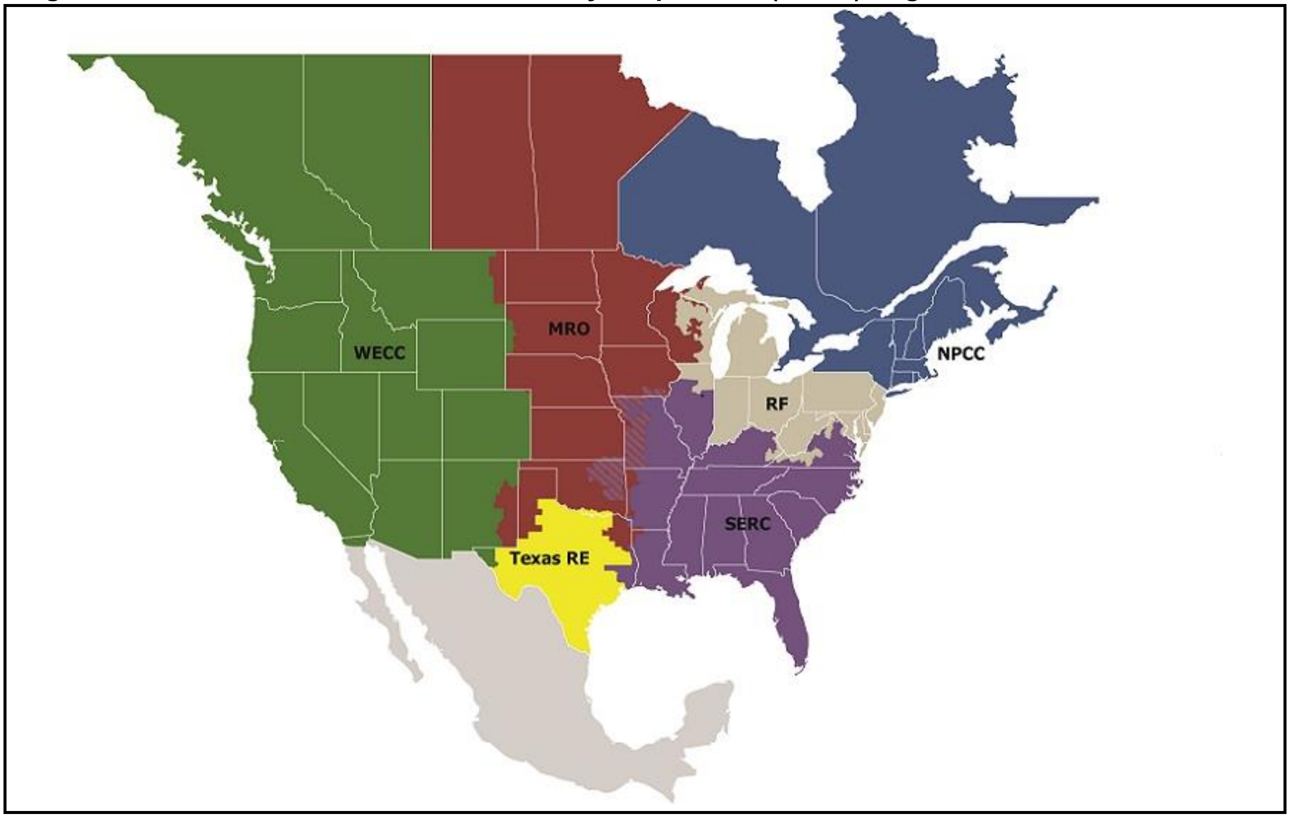
Bulk Power Network	NERC Region	NERC Entity
Eastern Interconnected System	MRO	Midwest Reliability Organization
	NPCC	Northeast Power Coordinating Council (U.S.)
	RF	Reliability First Corporation
	SERC	SERC Reliability Corporation
Western Interconnected System	WECC	Western Electricity Coordinating Council (U.S.)
Texas Interconnected System	TRE	Texas Reliability Entity
	ASCC	Alaska Systems Coordinating Council
	HICC	Hawaii Coordinating Council

Source: NERC, undated

8 Energy concerns in the States of Alaska, Hawaii, the Dominion of Puerto Rico, and the Territories of American Samoa, Guam, and the Virgin Islands are not under reliability oversight by NERC.

9 Some 2023 Annual Energy Outlook (AEO) data were based on an older version of NERC regions which contained regions that are not used in this analysis. EPA used best professional judgement (BPJ) to allocate 2023 AEO data for these regions into the appropriate NERC regions used in this analysis.

Figure 2-1: North American Electric Reliability Corporation (NERC) Regions



Note: The AK and HICC regions are not shown.
Source: NERC, undated.

The evaluated options are estimated to have a different effect on profitability, electricity prices, and other impact measures across NERC regions. This is because of variations in the economic and operational characteristics of steam electric and other power plants across NERC regions, including the share of the region's electricity demand met by steam electric power plants subject to the final rule under the different options. Other factors include the baseline economic characteristics of the NERC regions, together with market segmentation due to limited interconnectedness among NERC regions. To assess the potential reliability impact of the regulatory options, EPA assessed the distribution of steam electric power plants and their capacity across NERC regions.

As reported in Table 2-6, NERC regions differ in terms of both the number of steam electric power plants and their capacity. Steam electric power plants are primarily located in the RF, SERC, and WECC regions (20 percent, 28 percent, and 18 percent of plants, respectively); these three regions also account for a majority of the steam electric nameplate capacity in the United States (23 percent, 38 percent, and 15 percent, respectively).

Table 2-6: Steam Electric Power Plants and Nameplate Capacity by NERC Region, 2021				
NERC Region	Plants[a,b]		Capacity (MW)[a,b]	
	Number	% of Total	MW	% of Total
AK	2	0.2%	120	0.0%
HICC	10	1.2%	1,155	0.2%
MRO	136	15.9%	82,012	12.1%
NPCC	80	9.3%	28,669	4.2%
RF	170	19.8%	151,710	22.5%
SERC	238	27.8%	255,610	37.9%
TRE	66	7.7%	54,407	8.1%
WECC	155	18.1%	101,315	15.0%
TOTAL	**858**	**100.0%**	**674,998**	**100.0%**

a. Numbers may not add up to totals due to independent rounding.

b. The numbers of plants and capacity are calculated on a sample-weighted basis.

Source: U.S. EPA Analysis, 2024; EIA, 2022c

2.1.3 Electricity Generation

Total net electricity generation in the United States for 2021 was 4,110 TWh.[10] The 2021 EIA data was the most recent year of finalized EIA data that was available at the time of analysis. Coal generation accounted for 22 percent of total electricity generation, behind natural gas (38 percent), but ahead of nuclear (19 percent) and renewables (14 percent). Other energy sources accounted for comparatively smaller shares of total generation, with hydropower representing 6 percent and petroleum less than one percent.

As presented in Table 2-7, the 7-year period of 2015 through 2021 saw total net generation increase by approximately 0.8 percent with the 269 TWh increase (89 percent) in generation from renewables and 246 TWh (18 percent) increase in generation from natural gas more than offset the 454 TWh (34 percent) drop in generation from coal-fueled generators.[11]

Between 2015 and 2021, the amount of electricity generated by utilities declined by 4.5 percent while that generated by nonutilities rose by 8 percent. Comparing 2015 and 2021 values, across all fuel-source categories, utilities generated a larger share of their electricity using natural gas (a 26 percent increase) and renewables (a 137 percent increase) even as their overall generation declined. For nonutilities, the largest percent increase in electricity generation (82 percent) occurred for renewables, whereas generation from natural gas increased 12 percent.

10 One terawatt-hour is 10^{12} watt-hours.

11 The decline in 2021 is likely partially driven by the economic effects of the COVID-19 pandemic and relatively warmer winter weather (U.S. Energy Information Administration. (2021d). U.S. energy consumption fell by a record 7% in 2020. *Today in Energy*. https://www.eia.gov/todayinenergy/detail.php?id=47397).

Table 2-7: Net Generation by Energy Source and Ownership Type, 2015-2021 (TWh)

Energy Source	Utilities			Nonutilities			Total		
	2015	2021	% Change	2015	2021	% Change	2015	2021	% Change
Coal	996	672	-32.5%	354	223	-37.0%	1,350	896	-33.6%
Hydropower	226	225	-0.3%	18	22	17.4%	244	246	1.0%
Nuclear	417	431	3.4%	380	349	-8.3%	797	780	-2.2%
Petroleum	18	15	-17.5%	10	5	-51.4%	27	19	-29.5%
Natural Gas	618	777	25.8%	716	802	12.1%	1,333	1,579	18.4%
Other Gases	4	2	-39.6%	13	11	-11.9%	17	14	-18.3%
Renewables[a]	38	89	137.3%	264	482	82.2%	302	571	89.1%
Other[b]	0	0	1.4%	7	4	-36.0%	7	5	-34.0%
Total	**2,315**	**2,212**	**-4.5%**	**1,762**	**1,898**	**8%**	**4,078**	**4,110**	**0.8%**

a. Renewables include wood, black liquor, other wood waste, municipal solid waste, landfill gas, sludge waste, agriculture byproducts, other biomass, geothermal, solar thermal, photovoltaic energy, and wind.

b. Other includes batteries, hydrogen, purchased steam, sulfur, tire-derived fuels and other miscellaneous energy sources.

Source: EIA, 2022d; 2016

2.2 Other Environmental Regulations and Policies

The 2015, 2020 and 2023 RIAs described factors, such as deregulation and environmental regulations and programs, that have affected the steam electric power generating industry, and electrical power generation more generally, over the last decades. See Chapter 2 in U.S. EPA (2015, 2020, 2023d).2015, 2020, 2023d). The sections below provide updated discussions on changes to key environmental regulations since 2020 as well as greenhouse gas (GHG) reduction targets and energy provisions of the Inflation Reduction Act (IRA) of 2022 that may affect the power generating industry.

2.2.1 Coal Combustion Residuals Rule

On April 17, 2015, the Agency promulgated the Disposal of Coal Combustion Residuals from Electric Utilities final rule (2015 CCR rule). This rule finalized national regulations to provide a comprehensive set of requirements for the safe disposal of coal combustion residuals (CCR), commonly referred to as coal ash, from steam electric power plants. The final 2015 CCR rule was the culmination of extensive study on the effects of coal ash on the environment and public health. The rule established technical requirements for CCR landfills and surface impoundments under subtitle D of the Resource Conservation and Recovery Act (RCRA), the nation's primary law for regulating solid waste.

These regulations established requirements for the management of coal ash (including its disposal), including requirements designed to prevent leaking of contaminants into groundwater, blowing of contaminants into the air as dust, and the catastrophic failure of coal ash surface impoundments. Additionally, the 2015 CCR rule set recordkeeping and reporting requirements as well as requirements for each plant to establish and post specific information to a publicly accessible website. The rule also established requirements to distinguish between the beneficial use of CCR from disposal.

As a result of the D.C. Circuit Court decisions in Utility Solid Waste Activities Group v. EPA, 901 F.3d 414 (D.C. Cir. 2018), and Waterkeeper Alliance Inc. et al. v. EPA, No. 18-1289 (D.C. Cir. filed March 13, 2019), the EPA Administrator signed two rules: A Holistic Approach to Closure Part A: Deadline to Initiate Closure and Enhancing Public Access to Information (CCR Part A rule) on July 29, 2020, and A Holistic Approach to Closure Part B: Alternate Liner Demonstration (CCR Part B rule) on October 15, 2020. EPA finalized five amendments to the 2015 CCR rule which are relevant to the management of the wastewaters covered by this ELG because these wastewaters have historically been co-managed with CCR in the same surface impoundments. First, the CCR Part A rule established a new deadline of April 11, 2021, for all unlined surface impoundments in which CCR are managed ("CCR surface impoundments"), as well as CCR surface impoundments that failed the location restriction for placement above the uppermost aquifer, to stop receiving waste and begin closure or retrofit. EPA established this date after evaluating the steps that owners and operators need to take for CCR surface impoundments to stop receiving waste and begin closure, and the timeframes needed for implementation. (This would not affect the ability of plants to install new, composite-lined CCR surface impoundments.) Second, the Part A rule established procedures for plants to obtain approval from EPA for additional time to develop alternative disposal capacity to manage their wastestreams (both CCR and non-CCR) before they must stop receiving waste and begin closing their CCR surface impoundments. Third, the Part A rule changed the classification of compacted-soil-lined and clay-lined surface impoundments from lined to unlined. Fourth, the Part B rule finalized procedures potentially allowing a limited number of facilities to demonstrate to EPA that, based on groundwater data and the design of a particular surface impoundment, the unit ensures there is no reasonable probability of adverse effects to human health and the environment. Should EPA approve such a submission, these CCR surface impoundments would be allowed to continue to operate.

As explained in the 2015 and 2020 ELG rules, the ELGs and CCR rule may affect the same electric generating unit (EGU) or activity at a plant. Therefore, when EPA finalized the ELG and CCR rules in 2015, and as well revisions to both rules in 2020, the Agency coordinated the ELG and CCR rules to minimize the complexity of implementing engineering, financial, and permitting activities. Likewise, EPA considered the interaction of these two rules during the development of this final rule. EPA's analytic baseline includes the final requirements of these rules using the most recent data provided under the CCR rule reporting and recordkeeping requirements. This is further described in the TDD (see Section 3, U.S. EPA, 2024e).[12]

Concurrently with the final ELG, in a separate rulemaking, EPA is also finalizing regulatory requirements for inactive CCR surface impoundments at inactive utilities ("legacy CCR surface impoundment" or "legacy impoundment"). This action is being taken in response to the August 21, 2018, opinion by the U.S. Court of Appeals for the District of Columbia Circuit in the *USWAG* decision that vacated and remanded the provision exempting legacy impoundments from the CCR regulations. This action includes adding a definition for legacy CCR surface impoundments and other terms relevant to this rulemaking. It also requires that legacy CCR surface impoundments comply with certain existing CCR regulations with tailored compliance deadlines.

EPA is also establishing requirements to address the risks from currently exempt solid waste management that involves the direct placement of CCR on the land. EPA is extending a subset of the existing requirements in 40 CFR part 257, subpart D to CCR surface impoundments and landfills that closed prior to the effective date of the 2015 CCR rule, inactive CCR landfills, and other areas where CCR is managed directly on the land. In this action, EPA refers to these as CCR management units, or CCRMU. This rule

12 For more information on the CCR Part A and Part B rules, including information about ongoing implementation of these rules, visit https://www.epa.gov/coalash/coal-ash-rule.

will apply to all existing CCR facilities and all inactive facilities with legacy CCR surface impoundments subject to this final rule.

Finally, EPA is making a number of technical corrections to the existing regulations, such as correcting certain citations and harmonizing definitions.[13]

2.2.2 Air Pollution Rules and Implementation

EPA is taking several actions to regulate a variety of conventional, hazardous, and greenhouse gas (GHG) air pollutants, including actions to regulate the same steam electric plants subject to part 423. In light of these ongoing actions, EPA has worked to consider appropriate flexibilities in this proposed ELG rule to provide certainty to the regulated community while ensuring the statutory objectives of each program are achieved. Furthermore, to the extent that these actions are finalized and already impacting steam electric power plant operations, EPA has accounted for these changed operations in its Integrated Planning Model (IPM) modeling discussed in Chapter 5 of this document**.**

2.2.2.1 The Revised Cross State Air Pollution Rule Update and the Good Neighbor Plan for the 2015 Ozone National Ambient Air Quality Standards

On June 5, 2023, EPA promulgated its final Good Neighbor Plan, which secures significant reductions in ozone-forming emissions of nitrogen oxides (NO_X) from power plants and industrial facilities. 88 FR 36654. The Good Neighbor Plan ensures that 23 states meet the Clean Air Act's (CAA's) "Good Neighbor" requirements by reducing pollution that significantly contributes to problems attaining and maintaining EPA's health-based air quality standard for ground-level ozone (or "smog"), known as the 2015 Ozone National Ambient Air Quality Standards (NAAQS), in downwind states. Further information on this action is available on EPA's website.[14]

As of September 21, 2023, the Good Neighbor Plan's "Group 3" ozone-season NO_X control program for power plants is being implemented in: Illinois, Indiana, Maryland, Michigan, New Jersey, New York, Ohio, Pennsylvania, Virginia, and Wisconsin. Pursuant to court orders staying the Agency's State Implementation Plan disapproval action in the following states, EPA is not currently implementing the Good Neighbor Plan "Group 3" ozone-season NO_X control program for power plants in: Alabama, Arkansas, Kentucky, Louisiana, Minnesota, Mississippi, Missouri, Nevada, Oklahoma, Texas, Utah, and West Virginia.[15]

On January 16, 2024, EPA signed a proposal to partially approve and partially disapprove State Implementation Plan submittals addressing interstate transport for the 2015 ozone NAAQS from Arizona, Iowa, Kansas, New Mexico, and Tennessee and proposed to include these states in the Good Neighbor Plan beginning in 2025.

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13 For further information on the CCR regulations, including information about the CCR Part A and Part B rules' ongoing implementation, visit *www.epa.gov/coalash/coal-ash-rule*

14 *See https://www.epa.gov/csapr/good-neighbor-plan-2015-ozone-naaqs.*

15 Further information on EPA's response to the stay orders can be found online at: *https://www.epa.gov/Cross-State-Air-Pollution/epa-response-judicial-stay-orders.*

On April 30, 2021, EPA published the final Revised Cross-State Air Pollution Rule (CSAPR) Update, 86 FR 23054, which resolved 21 states' good neighbor obligations for the 2008 ozone NAAQS, following the remand of the 2016 CSAPR Update (81 FR 74504) in *Wisconsin v. EPA*, 938 F.3d 308 (D.C. Cir. 2019). Together, these two rules establish the Group 2 and Group 3 market-based emissions trading programs for 22 states in the eastern United States for emissions of NO_X from fossil fuel-fired EGUs during the summer ozone season.[16]

2.2.2.2 Clean Air Act Section 111 Proposed Rule

Concurrently with the final ELG, EPA is finalizing the repeal of the Affordable Clean Energy Rule, establishing Best System of Emissions Reduction (BSER) determinations and emission guidelines for existing fossil fuel-fired EGUs, and establishing BSER determinations and accompanying standards of performance for GHG emissions from new and reconstructed fossil fuel-fired stationary combustion turbines and modified fossil fuel-fired EGUs. Specifically, for coal-fired EGUs, EPA is establishing final standards based on carbon capture and storage/sequestration with 90 percent capture with a compliance date of January 1, 2032. For coal-fired EGUs retiring by January 1, 2039, EPA is establishing final standards based on 40 percent natural gas co-firing with a compliance date of January 1, 2030.

While four subcategories for coal-fired EGUs were proposed, EPA is finalizing just the two subcategories for coal-fired EGUs as described in the preceding paragraph. Consistent with 40 CFR 60.24a(e) and the Agency's explanation in the proposal, states have the ability to consider, *inter alia*, a particular source's remaining useful life when applying a standard of performance to that source.[17]

In addition, EPA is creating an option for states to provide for a compliance date extension for existing sources of up to one year under certain circumstances for sources that are installing control technologies to comply with their standards of performance. States may also provide, by inclusion in their state plans, a reliability assurance mechanism of up to one year that under limited circumstances would allow existing EGUs that had planned to cease operating by a certain date to temporarily remain available to support reliability. Any extensions exceeding 1-year must be addressed through a state plan revision.[18]

2.2.2.3 Mercury and Air Toxics Standards Final Rule

On March 6, 2023, EPA published a final rule which reaffirmed that it remains appropriate and necessary to regulate hazardous air pollutants (HAP), including mercury, from power plants after considering cost. This action revoked a 2020 finding that it was not appropriate and necessary to regulate coal- and oil-fired power plants under CAA section 112, which covers toxic air pollutants. EPA reviewed the 2020 finding and considered updated information on both the public health burden associated with HAP emissions from coal- and oil-fired power plants, as well as the costs associated with reducing those emissions under the Mercury and Air Toxics Standards (MATS). After weighing the public risks these emissions pose to

16 *See www.epa.gov/csapr/good-neighbor-plan-2015-ozone-naaqs*.

17 See 88 FR 33383 (invoking Remaining Useful Life and Other Factors (RULOF) based on a particular coal-fired EGU's remaining useful life "is not prohibited under these emission guidelines").

18 Further information about the CAA section 111 rule is available online at *https://www.epa.gov/stationary-sources-air-pollution/greenhouse-gas-standards-and-guidelines-fossil-fuel-fired-power*. https://www.epa.gov/stationary-sources-air-pollution/greenhouse-gas-standards-and-guidelines-fossil-fuel-fired-power.

all Americans (and particularly exposed and sensitive populations) against the costs of reducing this harmful pollution, EPA concluded that it remains appropriate and necessary to regulate these emissions. This action ensures that coal- and oil-fired power plants continue to control emissions of hazardous air pollution and that the Agency properly interprets the CAA to protect the public from hazardous air emissions.

Concurrently with the final ELG, EPA is finalizing an update to the National Emission Standards for Hazardous Air Pollutants for Coal- and Oil-Fired EGUs, commonly known as the Mercury and Air Toxics Standards (MATS) for power plants, to reflect recent developments in control technologies and the performance of these plants. This final rule includes an important set of improvements and updates to MATS and also fulfills EPA's responsibility under the Clean Air Act to periodically re-evaluate its standards in light of advancements in pollution control technologies to determine whether revisions are necessary. The improvements consist of:

- Further limiting the emission of non-mercury HAP metals from existing coal-fired power plants by significantly reducing the emission standard for filterable particulate matter (fPM), which is designed to control non-mercury HAP metals. EPA is finalizing a two-thirds reduction in the fPM standard;[19]
- Tightening the emission limit for mercury for existing lignite-fired power plants by 70 percent;[20]
- Strengthening emissions monitoring and compliance by requiring coal-and oil-fired EGUs to comply with the fPM standard using PM continuous emission monitoring systems (CEMS);[21]
- Revising the startup requirements in MATS to assure better emissions performance during startup.

Additional information on the final MATS is available on EPA's website.[22]

2.2.2.4 National Ambient Air Quality Standards Rules for Particulate Matter Final Rule

On February 7, 2024, the EPA Administrator signed a final rule strengthening the National Ambient Air Quality Standards for Particulate Matter (PM NAAQS) to protect millions of Americans from harmful and costly health impacts, such as heart attacks and premature death. Particle or soot pollution is one of the most dangerous forms of air pollution, and an extensive body of science links it to a range of serious and in some cases deadly illnesses. EPA set the level of the primary (health-based) annual particulate matter ($PM_{2.5}$) standard at 9.0 micrograms per cubic meter to provide increased public health protection, consistent with the available health science. EPA did not change the current primary and secondary (welfare-based) 24-hour $PM_{2.5}$ standards, the secondary annual $PM_{2.5}$ standard, and the primary and

19 Also, EPA is finalizing the removal of the low-emitting EGU provisions for fPM and non-mercury HAP metals.

20 This level aligns with the mercury standard that other coal-fired power plants have been achieving under the current MATS.

21 PM CEMS provide regulators, the public, and facility owners or operators with cost-effective, accurate, and continuous emission measurements. This real-time, quality-assured feedback can lead to improved control device and power plant operation, which will reduce air pollutant emissions and exposure for local communities.

22 *See https://www.epa.gov/stationary-sources-air-pollution/mercury-and-air-toxics-standards.*

secondary PM10 standards. EPA also revised the Air Quality Index to improve public communications about the risks from $PM_{2.5}$ exposures and made changes to the monitoring network to enhance protection of air quality in communities overburdened by air pollution. More information about this action is available on EPA's website.[23]

2.2.3 Greenhouse Gas Reduction Targets

On April 22, 2021, President Biden announced 2030 GHG reduction targets for the United States.[24] As part of reaching net zero emissions by 2050, the nationally determined contribution submitted to the United Nations Framework Convention on Climate Change includes a 50 percent to 52 percent reduction from 2005 levels by 2030. These reduction targets were developed through the National Climate Task Force and support the commitments of the United States under the Paris Agreement. These policies are anticipated to result in significantly reduced reliance on coal-fired generation.

The steam electric sector is one of the largest contributors of U.S. GHG emissions. EPA estimates that 25 percent of 2021 GHG emissions in the U.S. came from electricity generation (largely comprised of emissions from steam electric power plants).[25] Although this fraction continues to decline, several models looking at plausible pathways to meet the announced 2030 goal have determined that as much as 90 to 100 percent of coal combustion may have to be reduced (Bistline et al., 2022).

2.2.4 Inflation Reduction Act of 2022

On August 16, 2022, President Biden signed into law the Inflation Reduction Act (IRA). The IRA marks the most significant action Congress has taken on clean energy and climate change in the nation's history. The IRA provides tax credits, financing programs, and other incentives, some of which are administered by EPA, that will accelerate the transition to forms of energy that produce little or no greenhouse gas emissions and other water and air pollutants. As such, it includes many provisions that will affect the steam electric power generating industry, causing both direct effects through changes in the production of electricity and indirect effects on electricity demand and changes to fuel markets.

In September 2023 EPA published a report on the effect of the IRA on the electricity sector and on the economy in general (U.S. EPA, 2023c).The report found that the IRA would lead to emission reductions from the electric power sector of 49 to 83 percent below 2005 levels in 2030. The associated shifts from fossil fuel generation would also lead to reductions in water and air pollution from the sector. The study also found that the IRA would lower economy-wide CO_2 emissions, including emissions from electricity generation and use, by 35 percent to 43 percent below 2005 levels in 2030. Across the end-use sectors, the study found that buildings exhibit the greatest reductions from 2005 levels of direct plus indirect CO_2 emissions from electricity, followed by industry and transportation. Though it focuses on changes in climate-forcing emissions (in part attributable to the models it uses), the study also implies important changes in the emissions of other pollutants throughout the economy. EPA used IPM to evaluate the impacts of the final ELG relative to a baseline that reflects impacts from other relevant policies and

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23 *See https://www.epa.gov/pm-pollution/national-ambient-air-quality-standards-naaqs-pm*.

24 See https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/.

25 See https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.

environmental regulations that affect the power sector, including the IRA and other on-the-books federal and state rules (see Chapter 5 for additional information).

2.2.5 Recent Developments in Assuring Electric Reliability and Resource Adequacy

The nature and components of the bulk power sector have been evolving away from older and less efficient legacy fossil generation (mostly coal power plants) towards more decentralized, renewable assets and flexible gas-fired generation. Stakeholders have raised concerns that centralized dispatchable power plants are coming offline faster than new generation can replace the reliability attributes associated with them. However, a combination of technology innovation, revised market signals from the Regional Transmission Organizations (RTOs) and Independent System Operators (ISOs), and reforms recently completed and underway by Federal Energy Regulatory Commission (FERC) are collectively poised to address current reliability challenges associated with the transition along with expected higher load growth and the increasing frequency of extreme weather events.

EPA has continued to learn and engage on reliability issues, particularly as part of the Agency's implementation of the *Joint Memorandum on Interagency Communication and Consultation on Electric Reliability*.[26] As part of this process, EPA has engaged in regular meetings with Department of Energy (DOE), North American Electric Reliability Corporation (NERC), FERC, and the various ISOs/RTOs.

FERC, NERC, RTOs, and ISOs are already taking steps to ensure reliability during this period of asset evolution. Among FERC's actions to help address reliability is Order 2023, or "Improvements to Generator Interconnection Procedures," which will help expedite interconnections for new assets waiting to connect to the grid. This is a very important development to ensure future resource adequacy because interconnection wait times for new energy assets entering energy markets have increased, which is stifling the ability of replacement generation to connect to the grid. FERC's final action on extreme cold weather preparedness will support the new peak demand hours, which have migrated to winter months. New reliability standards issued for inverter-based resources "will help ensure reliability of the grid by accommodating the rapid integration of new power generation technologies, known as inverter-based resources (IBRs), that include solar photovoltaic, wind, fuel cell and battery storage resources…."[27] FERC has also undertaken various transmission-related efforts, from inter-regional transmission capacity efforts to reconductoring and dynamic line rating, that would help bolster reliability by increasing the transmission capacity of existing lines and creating incentives for new, inter-regional transmission. Increasing transmission capacity can enhance reliability by increasing the amount of generation that can access the grid to help meet demand.

Furthermore, there are new technologies coming online that can also help provide reliability attributes. The deployment of many of these technologies has been accelerating due to the incentives in the IRA. The rapid increase in energy storage deployment across the nation is an important part of future grid reliability, particularly as the duration of storage assets expands. Examples of existing and emerging storage resources include various types of fuel cells, batteries, pumped hydro-electric reservoirs, and underground hydrogen caverns. Energy storage can help buttress reliability by storing renewable energy

26 Available online at: https://www.epa.gov/power-sector/electric-reliability-mou.

27 For further information about FERC actions to address IBRs, see *https://www.ferc.gov/news-events/news/ferc-moves-protect-grid-transition-clean-energy-resources.*

for dispatch when demand is high. Improved management of demand response assets, better designed electricity tariff structures, aggregation of distributed resources like roof-top solar panels, and integration of behind-the-meter battery storage can further support balancing peak demand on power grids. For example, programs to manage demand, which have shown value well before the recent energy transition, incentivize customers to shift their demand during periods when there is ample supply, which can help reduce instances when supply is tight.

Despite these concerns, there are also existing procedures in place to ensure electricity system reliability and resource adequacy over both the short and long-term. For example, regional planning organizations typically have incentive or planning procedures to ensure that there is sufficient capacity to meet future demand such as day-ahead reserve and capacity markets and seasonal reserve margins. Furthermore, EPA understands that before a unit implements a retirement decision, the unit's owner will follow the processes put in place by the relevant RTO, balancing authority, or state regulator to protect electric system reliability. These processes typically include analysis of the potential impacts of the proposed EGU retirement on electrical system reliability, identification of options for mitigating any identified adverse impacts, and, in some cases, temporary provision of additional revenues to support the EGU's continued operation until longer-term mitigation measures can be put in place.

2.3 Market Conditions and Trends in the Electric Power Industry

The 34 percent decline in coal-fueled electricity generation summarized in Table 2-7 for the period of 2015 through 2021 exemplifies an ongoing trend over the last decade: the progressive reduction in coal-fired generation capacity as coal units and plants retire. In 2023, EIA reported that retirements of coal generation capacity in the US in 2022 were 11.5 GW, slightly higher than the average of 11 GW per year between 2015 to 2020. Moreover, EIA predicted that coal-fired and natural gas utility-scale power plant retirements in 2023 would account for 58 and 40 percent of total electric generating capacity retirements for that year, corresponding to 8.9 and 6.2 GW respectively (EIA, 2022b; EIA, 2023c). Capacity additions in the same year are predicted to consist primarily of solar (54 percent), natural gas (14 percent), and wind (11 percent).

One factor in the decline in the coal-fueled power generation is the aging fleet of coal-fired power plants. The life expectancy of coal plants is approximately 40 to 50 years, and with the majority of plants being built in the 1970s and 1980s, almost all plants that retired in 2015 were more than 40 years old (Kolstad, 2017; EIA, 2023c). Mills, Wiser and Seel (2017) also found that coal plants that retired between 2010 and 2016 had an average age of 52 years, and plants with stated plans to retire were not younger on average. Coal plant retirements due to aging are likely to continue in the coming years, as the average age of coal plants in operation in the United States as of 2021 is 45 years (EIA, 2021b)

The lower costs of natural gas, as well as technological advances in solar and wind power have also been important market factors. Fell and Kaffine (2018) found negative impacts on coal-fired generation from both lower natural gas prices and increased wind generation, with declining natural gas prices having a stronger effect. In 2019, coal-fired generation dropped to its lowest level since 1976, primarily driven by increased availability of highly efficient, low-cost natural gas generation, which has reduced coal plant utilization and resulted in the retirement of some coal plants (EIA, 2020).

In 2021, EIA reported that coal generation increased for the first time since 2014. However, this was a temporary divergence from a longer-term trend as additional retirements of coal-fired plants and lower natural gas prices caused coal-fired electricity generation to fall once again in 2022 (EIA, 2023d). This 2022 decline was exacerbated by a coal supply shortage, precipitated by diminished electricity demand due to pandemic-related economic impacts, as well as a 9 percent reduction in coal production resulting from declining global coal demand and heightened competition from natural gas (EIA, 2023d).

Russia's 2022 invasion of Ukraine and the subsequent agreement between the United States and European Commission to supply additional liquefied natural gas (LNG) to the European market resulted in increased energy prices. With Russia being a huge supplier of the world's oil and natural gas, cutbacks in supply and geopolitical uncertainty caused higher prices and volatility across global energy markets. While coal was temporarily cost-competitive with natural gas, leading to the observed increases in coal-fired generation, this short-term impact has ceased with natural gas prices falling to their pre-invasion prices, at the start of 2023. (Federal Reserve Bank of St. Louis, 2023; The White House, 2022; Wilson, 2022).

Knittel, Metaxoglou and Trindade (2015) found that utilities invested more in natural gas capacity when the prices dropped as a result of the boom in shale gas production, although the magnitude of their investments differed depending on the structure of the electricity market in which they operated. Additionally, in 2020, renewable electricity generation surpassed coal-fired electricity generation as much of the US's coal-fired generation capacity has been replaced or converted to natural gas-fired generation since 2007 (EIA, 2021c). Furthermore, in 2022, generation from renewable sources – wind, solar, hydro, biomass, and geothermal – surpassed coal-fired generation in the electric power sector for the first time. In the preceding year, 2021, renewables had already outpaced nuclear generation for the first time, and this trend persisted, with renewable sources consistently providing more electricity than nuclear generation throughout the subsequent year (EIA, 2023g).

Changes in electricity generation have had impacts in fuel markets. Coal consumption in the electric power industry declined by about 40 percent between 2005 and 2017, whereas natural gas consumption increased by about 24 percent in the same time period, resulting in natural gas consumption doubling coal consumption in 2017 (EIA, 2018). In 2021, EIA reported that the number of producing coal mines in the United States was 548, representing a 62 percent drop since the most recent peak in 2008 of 1,435 producing mines (EIA, 2019, 2023a). EIA reported that this reduction in producing coal mines reflects reductions in investments in the coal industry and declining international and domestic decline for coal (EIA, 2021a). In 2022, EIA reported that natural gas consumption totaled 33.4 quadrillion British thermal units (quads) and that coal consumption totaled 9.85 quads (EIA, 2023j). Market conditions have also negatively affected nuclear-powered generation, though this final rule has no effect on the nuclear-powered sector, except as it affects relative prices through its impacts on coal-fired generation (EIA, 2022e).

The decline in coal is not independent of environmental regulations affecting coal-fired electricity generation, as power companies have cited regulations promulgated, particularly in the last decade, as reasons for their decision when announcing unit or plant closures, fuel switching, or other operational changes. However, fuel prices and trends toward alternative fuels also appear to be drivers of the shift away from coal for electricity generation. Coglianese, Gerarden and Stock (2020) found that the decrease in natural gas prices accounted for 92 percent of the decline in coal production while environmental regulations accounted for 6 percent. Linn and McCormack (2019) found that while air emissions regulations were responsible for most reductions in nitrogen oxides from the electricity sector, they had only a small effect on profitability and retirement at coal plants.

As the electric power infrastructure adjusts to market trends by moving toward optimal infrastructure and operations to deliver the country's electricity, EPA recognizes that the changes can have negative effects for some communities and positive effects for others.

3 Compliance Costs

In developing the final rule, EPA assessed the costs and economic impacts for three regulatory options summarized in Table 1-1. The options are labeled Option A through Option C in order of the stringency of the effluent limits, relative to the baseline. Key inputs for these analyses include the estimated costs to steam electric power plants (and their business, government, or non-profit owners) for implementing control technologies upon which the final BAT limitations and pretreatment standards are based,[28] and to the state and federal government for administering this rule. This chapter summarizes EPA estimates of the incremental compliance costs attributable to the regulatory options. EPA determined that state and federal governments would not incur significant incremental administrative costs.[29]

EPA applied the same methodology used to analyze the 2015 and 2020 rules, as well as the 2023 proposed rule, to calculate industry-level annualized compliance costs. See Chapter 3 of the respective RIA documents for details (U.S. EPA, 2015, 2020, 2023d). Additionally, EPA estimated that some plants incurred compliance costs for CRL treatment after the expected retirement year.

Costs associated with legacy wastewater limits under Options B and C would be incurred only as plants close and dewater their existing ponds. There is uncertainty on when plants may do so. For the purpose of this analysis, EPA anticipates that pond closures will occur on 2044 for all plants and that plants will incur initial one-time costs (*e.g.*, capital costs) in this year followed by O&M costs in the following years of the analysis (there are no incremental legacy wastewater costs under Option A).[30] Similarly, certain plants could incur costs associated with the treatment of unmanaged CRL discharged from landfills, surface impoundments, or other features in cases where a permitting authority deems, on a case-by-case basis, the discharge to be the functional equivalent of a direct discharge and requiring a permit. The costs associated with treatment of unmanaged CRL are uncertain. As a result, the Agency estimated lower- and upper-bound cost estimates for treating unmanaged CRL. These unmanaged CRL costs are added to the costs associated with CRL treatment incurred by plants. As a result, the total costs for all regulatory options as well as their estimated impacts on plants and entities are estimated using a lower and upper bound of costs.

The TDD describes the control technologies and their respective wastewater treatment performance in greater detail (U.S. EPA, 2024e). The TDD also describes how EPA estimated plant-specific capital and operation and maintenance (O&M) costs for each treatment technology, as well as for BMP plans. The cost analysis uses the 2020 rule as the baseline and incorporates technologies that plants have implemented, or would implement, to meet the 2020 ELGs, in absence of the changes in this final rule.

28 Dischargers are not required to use the technologies specified as the basis for the rule. They are free to identify other perhaps less expensive technologies as long as they meet the BAT limitations and pretreatment standards in the rule.

29 EPA estimates that the final rule will not impose significant additional administrative cost to the State and federal governments. See Section 10.7, *Paperwork Reduction Act of 1995*, for additional discussion.

30 Assuming the same 40-year surface impoundment operating life used in the 2015 CCR rule record and acknowledging that these impoundments could be anywhere in that 40-year lifespan, EPA used the midpoint of 20-years as a reasonable approximation for purposes of ensuring that these costs are included in the main cost analyses of the final rule. To the extent that costs could be incurred before this date at some plants and after this date at other plants, these nationwide costs may either over- or underestimate the site-specific costs at any particular plant.

3.1 Analysis Approach and Inputs

EPA updated estimated costs to plants for meeting the limitations of the regulatory options. There are four principal steps to compliance cost development, the last two of which are the focus of the discussion below:

1. Determining the set of plants potentially implementing compliance technologies for each regulatory option. See TDD for details (U.S. EPA, 2024e).
2. Developing plant-level costs for each wastestream and technology option. See TDD for details.
3. Estimating the year when each steam electric power plant would be required to meet new BAT effluent limits and pretreatment standards. This schedule supports analysis of the timing of compliance costs and benefits for analyses discussed in this document and in the BCA. EPA accounted for any planned unit retirements or units ceasing the combustion of coal but did estimate that some units will incur compliance costs associated with CRL treatment after retirement or ceasing the combustion of coal (see the TDD for details regarding how EPA estimated leachate flow rates for these plants).
4. Estimating *total* industry costs for all plants in the steam electric universe for each of the regulatory options.

EPA reports costs in 2023 dollars and discounts the costs to 2024.

3.1.1 Plant-Specific Costs Approach

As detailed in the TDD (U.S. EPA, 2024e), EPA developed costs for steam electric power plants to implement treatment technologies or process changes to control the wastestreams addressed by the regulatory options.

EPA assessed the operations and treatment system components currently in place at a given unit (or required to be in place to comply with other existing environmental regulations), identified equipment and process changes that plants would likely make to meet each of the regulatory options presented in Table 1-1. EPA developed costs to meet each regulatory option based on current plant equipment, processes, and treatment technologies, accounting for compliance with the 2020 rule in the baseline. Thus, the estimated costs of the regulatory options are additive to the costs of treatment technologies that plants have implemented or would implement to meet the 2020 rule. Plants that do not generate a wastestream or that employ technologies which would already meet the given limitations or standards do not incur incremental costs under the regulatory options.

In cases where several different technology options were available to meet the regulatory option limits, EPA estimated the costs of each possible option and selected the least-cost technology for each plant. For example, as detailed in the TDD, for zero-discharge systems used to meet FGD and CRL limits under

Option B and Option C, EPA generally selected the least cost option between systems using membrane filtration or spray dry evaporators (SDEs).[31]

As noted above, there is uncertainty on which plants may incur costs to meet effluent limits for unmanaged CRL as it will depend on case-by-case findings by future permitting authorities. To account for this uncertainty, EPA developed lower and upper bound scenarios that provide a range of probabilistic cost estimates based on different sets of assumptions regarding which plants may incur costs and the compliance approach. The upper bound scenario is based on probabilistically combining three sets of plant-level cost estimates using equal weights: cost estimates based on (1) each plant's closest waste management unit (WMU; either an impoundment or a landfill), (2) cases of corrective action at the WMU level, and (3) cases of corrective action where surface impoundment flows are combined at the plant level. The lower bound scenario is based on probabilistically combining plant-level costs estimates based on corrective action remedies at the WMU level or at the plant level combined with the share of remedies expected to use pumping and treating of groundwater (either alone or in combination with other remedies with groundwater collection or extraction), which make unmanaged CRL most likely to be subject to the limitations in the final rule and therefore to incur costs. Like for the upper bound scenario, EPA assumed that cost estimates were equally probable in calculating a probabilistic average plant-level cost. U.S. EPA (2024d) provides additional details on the approach used to estimate costs for unmanaged CRL treatment.

3.1.2 Plant-Level Costs

Following the approach used for the analysis of the 2015 and 2020 rules and 2023 proposal (U.S. EPA, 2015, 2020, 2023d), EPA estimated compliance costs for all existing steam electric power plants, estimated to be a total 858 plants for the point source category overall. EPA assessed that only a fraction of the universe of steam electric power plants — 232 plants — generate the wastestreams covered by the regulatory options. Furthermore, out of these plants, only a subset would incur non-zero costs under any of the scenarios analyzed for the regulatory options, based on existing control technologies. This subset of plants that incur non-zero costs varies depending on the regulatory option and cost scenario (Between 139 and 170 plants incur non-zero costs across the three regulatory options and two cost scenarios). The TDD provides additional details on this analysis.

The major components of technology costs are:

- *Capital costs* include the cost of compliance technology equipment, installation, site preparation, construction, and other upfront, non-annually recurring outlays associated with compliance with the regulatory options. EPA generally assumes that plants incur all capital costs in the year when their permit is renewed to incorporate the new limitations or standards (see *Technology Implementation Years* below). As explained in the TDD, all compliance technologies are assumed to have a useful life of 20 years.

31 One exception to this approach is CRL where EPA selected membrane filtration as the basis of the estimated compliance costs for five plants that are projected to cease operation after the period of analysis even though SDEs costs would have been lower. This resulted in the estimated total compliance costs for Option B and Option C presented in Section 3.2 being overstated by approximately $6 million (1.5 percent) on an after-tax basis.

- *Initial one-time costs* (apart from capital costs above), if applicable, include a one-time monitoring and recordkeeping cost in the first year if operation for plants operating membrane filtration system to treat FGD wastewater or CRL wastewater (see TDD for more information).
- *Annual fixed O&M costs*, if applicable, include regular *annual* monitoring. Plants incur these costs each year.
- *Annual variable O&M costs*, if applicable, include annual operating labor, maintenance labor and materials, electricity required to operate wastewater treatment systems, chemicals, combustion residual waste transport and disposal operation and maintenance, and savings from not operating and maintaining ash/FGD pond systems. Plants incur these costs each year.

In addition to these initial one-time and annual outlays, certain other costs are estimated to be incurred on a non-annual, periodic basis:

- *5-Yr fixed O&M costs*, if applicable, include remote MDS chain replacement costs that plants are estimated to incur every five years, beginning five years after the technology implementation year.
- *6-Yr fixed O&M costs*, if applicable, include mercury analyzer operations and maintenance costs that plants are estimated to incur every six years, beginning in the technology implementation year.
- *10-Yr fixed O&M costs*, if applicable, include savings from not needing to periodically maintain ash/FGD pond systems. Plants are estimated to incur savings every 10 years from not needing to purchase earthmoving equipment for the pond systems, beginning 5 years after the technology implementation year.

Based on information in the record concerning the normal downtime of electricity generating units, EPA estimated that plants would be able to coordinate the implementation of wastewater treatment systems during already scheduled downtime.

3.1.3 Technology Implementation Years

The years in which individual steam electric power plants are estimated to implement control technologies are an important input to the time profile of costs that plants would incur due to the regulatory options. This profile is used to estimate the annualized costs to the steam electric industry and society associated with the regulatory options.

EPA envisions that each plant to which the regulatory options would apply would study available technologies and operational measures, and subsequently install, incorporate, and optimize the technology most appropriate for each site. As part of its consideration of the technological availability and economic achievability of the BAT limitations and pretreatment standards in the rule and following the approach the Agency used for the 2015 and 2020 rules as well as the 2023 proposal, EPA considered the magnitude and complexity of process changes and new equipment installations that would be required at plants to meet the requirements of the regulatory options in determining the time plant owners may need to comply with any revised limitations or pretreatment standards. See discussion in the TDD (U.S. EPA, 2024e).

As described in greater detail in the NPRM, EPA is establishing availability timing for BAT limitations that is “as soon as possible” after the effective date of any final rule but “no later than” five years from the effective date (*i.e.*, a 2029 deadline).[32]

The timing decision represents when the technologies are available, accounting for the need to provide sufficient time for plant owners to raise capital, plan and design systems, procure equipment, and construct and then test systems. EPA also considered the time frames needed for appropriate consideration of any plant changes being made in response to other agency rules affecting the steam electric power generating industry. Specifying compliance deadlines in the future enables plants to take advantage of planned shutdown or maintenance periods to install new pollution control technologies. This allows for the coordination of generating unit outages in order to maintain grid reliability and prevent any potential impacts on electricity availability caused by forced outages. It is not possible to predict, for each plant, exactly the date the final rule will be incorporated into permits, for purposes of determining exactly when plants will incur costs to meet the new requirements. Similar to the approach used in analyzing the 2015, 2020, and proposed 2023 rules, EPA generally expects plants to meet the new BAT limitations and pretreatment standards in a somewhat staggered fashion, given that (1) the permitting authority determines the date after considering certain specified factors, and (2) all permits are not re-issued at the same time due to their 5-year permit term. Thus, for the cost and economic impact analyses, EPA assumed implementation over a 5-year period preceding the established “no later than” date.[33, 34]

Costs associated with legacy wastewater limits under Options B and C would be incurred only as plants close and dewater their existing ponds. Given the uncertainty on when plants may do so, for the purpose of this analysis EPA assumed that any pond closures would occur after 2044 and further assumed that costs to comply with the limits would be incurred starting in that year.

Similarly, certain plants could incur costs associated with the treatment of unmanaged CRL discharged from landfills, surface impoundments, or other features in cases where a permitting authority deems, on a case-by-case basis, the discharge to be the functional equivalent of a direct discharge and requiring a permit. Because these discharges are uncertain, EPA assumed plants would incur costs associated with treating unmanaged CRL at the same time as other wastewater treatment technologies.

For the purpose of this analysis, EPA accounted for the timing of announced unit retirements or repowerings in determining the compliance year for the plant. Specifically, in cases where the announced retirement occurs after the default compliance year based on the permit renewal cycle but before the rule compliance deadline, EPA assumed that permit authorities would set the “no later than” compliance date

32 EPA did not estimate costs over different timeframes for indirect dischargers. The CWA mandates that such dischargers meet applicable standards three years from promulgation of final PSES. This timing is consistent with the modeling approach during Period 1 as described in the BCA.

33 For the purpose of the analysis, EPA assigned an estimated compliance year to each of the 232 steam electric power plants analyzed for the final rule based on each plant’s estimated NPDES permit renewal year and, similar to the approach used for the 2015 and 2020 rules and 2023 proposal, the assumption that all permits will be renewed promptly (no administrative continuances). EPA projected future NPDES permit years by assuming permits are renewed every 5 years, *i.e.*, a permit expiring in 2023 would be renewed in 2028 and 2033.

34 EPA initially estimated a compliance year for each plant based on a compliance deadline of 2030. During the analyses, EPA subsequently revised the deadline to 2029 and revised plant-specific compliance years by subtracting one year for each plant rather than re-estimating compliance years only for those plants whose compliance year did not meet the deadline.

to correspond to the retirement date. In these cases, the plant would incur no incremental costs to comply with the final rule.

EPA also accounted for announced unit retirements or repowerings in the social cost analysis, which is discussed and detailed in Chapter 12 of the BCA. Specifically, EPA assumed zero O&M costs for BA transport water and FGD wastewater treatment in all years following a unit's retirement or repowering, but continued O&M costs for CRL since treatment of the CRL wastewater is expected to continue even after a unit ceases to generate electricity.

3.1.4 Total Compliance Costs

EPA used the following methodology and assumptions to aggregate compliance cost components, described in the preceding sections, and develop total plant compliance costs for regulatory options A through C:

- EPA estimated compliance costs (including zero costs) for each of the 232 steam electric power plants with the relevant wastestreams, *i.e.*, coal-fired power plants (see TDD for details). All other plants covered by the steam electric power point source category do not generate wastestreams covered by the regulatory options and therefore incur zero costs.
- EPA restated compliance costs estimated in the preceding step, accounting for the specific years in which each plant is assumed to undertake compliance-related activities and in 2023 dollars, using the Construction Cost Index (CCI) from McGraw Hill Construction (2023), the Employment Cost Index (ECI) published by the Bureau of Labor Statistics (BLS) (2023), and the Gross Domestic Product (GDP) deflator index published by the U.S. Bureau of Economic Analysis (BEA) (2023).[35]
- EPA discounted all cost values to 2024, using a rate of 3.76 percent.[36]

35 Specifically, EPA brought all compliance costs to an estimated technology implementation year using the CCI from McGraw Hill Construction (McGraw Hill Construction Engineering News-Record. (2023). *Construction Cost Index (CCI)*) or the ECI from the Bureau of Labor Statistics (U.S. Department of Labor. Bureau of Labor Statistics. (2023). *Total compensation for All Civilian workers in All industries and occupations, Index*), depending on the cost component. The Agency used the average of the year-to-year changes in the CCI (or ECI) over the most recent ten-year reporting period to bring these values to an estimated compliance year. Because the CCI (or ECI) is a nominal cost adjustment index, the resulting technology cost values are as of the compliance year and in the dollars of the technology implementation year. To restate compliance cost values in 2023 dollars, the Agency deflated the nominal dollar values to 2023 using the average of the year-to-year changes in the GDP deflator index published by the BEA over the most recent ten-year reporting period. As a result, all dollar values reported in this analysis are in constant dollars of the year 2023.

36 Compliance costs are discounted and annualized using a rate of 3.76 percent, which is the estimated weighted average cost of capital for the power sector (see U.S. Environmental Protection Agency. (2023a). *Documentation for EPA's Power Sector Modeling Platform v6 Using the Integrated Planning Model Post-IRA 2022 Reference Case*. Retrieved from **https://www.epa.gov/system/files/documents/2023-03/EPA%20Platform%20v6%20Post-IRA%202022%20Reference%20Case.pdf** for details). This rate differs from the social discount rate of 2 percent used when presenting the social costs and benefits in the BCA, following OMB guidance in Circular A-4 (U.S. Office of Management and Budget. (2023). *Circular A-4: Regulatory Analysis*. Retrieved from https://www.whitehouse.gov/wp-content/uploads/2023/11/CircularA-4.pdf).

- EPA annualized one-time costs and costs recurring on other than an annual basis over a specific useful life, implementation, and/or event recurrence period, using a rate of 3.76 percent: [37]
  - Capital costs of each compliance technology: 20 years
  - Initial one-time costs: 20 years[38]
  - 5-Yr O&M: 5 years
  - 6-Yr O&M: 6 years
  - 10-Yr O&M: 10 years
- EPA added annualized capital, initial one-time costs, and annualized O&M costs recurring on other than an annual basis to the annual O&M costs to derive total annualized compliance costs.

EPA accounted for the timing of announced plant retirements in determining the useful life over which to annualize recurring costs. In cases where a plant's announced retirement year occurs after the first instance of a recurring O&M cost for BA transport water and FGD wastewater treatment but before the second instance, EPA adjusted the useful life of that cost category to be the number of years that the plant is expected to operate after the first instance.

EPA did not adjust the annualization of capital costs to reflect plant-specific considerations. EPA annualized capital costs over 20 years but recognizes that some plants may retire units sooner than the 20-year life of the equipment. EPA determined the 20-year annualization period to be reasonable for this analysis because some regulators may allow utilities to recover the value of undepreciated assets in their rate base on a case-by-case basis.[39]

For the assessment of compliance costs to steam electric power plants, EPA considered costs on both a pre-tax and after-tax basis. Pre-tax costs provide insight on the total expenditures as initially incurred by the plants. After-tax costs are a more meaningful measure of compliance impact on privately owned for-profit plants, and incorporate approximate capital depreciation and other relevant tax treatments in the analysis. EPA calculated the after-tax value of compliance costs by applying combined federal and State tax rates to the pre-tax cost values for privately owned for-profit plants.[40] For this adjustment, EPA used State corporate rates from the Federation of Tax Administrators (2023) combined with a 21 percent federal corporate tax rate. As discussed in the relevant sections of this document, EPA uses either pre- or after-tax compliance costs in different analyses, depending on the concept appropriate to each analysis

37 U.S. Environmental Protection Agency. (2023d). *Regulatory Impact Analysis for Proposed Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category*. (EPA-821-R-23-002).

38 EPA annualized these non-equipment outlays over 20 years to match the estimated performance life of compliance technology components.

39 EPA received public comments on the 2023 proposed rule confirming that a typical depreciation and amortization period is 20+ years. One commenter stated that "typical amortization periods for investments" on the scale of the 2020 Final Rule are 20 years (EPA-HQ-OW-2009-0819-10079). Another commenter described the rate recovery request of a utility to comply with the 2020 Final Rule with a proposed 20-year depreciation and amortization period, though noted that depreciation periods for equipment could be as long as 50 or 60 years (EPA-HQ-OW-2009-0819-10161).

40 Government-owned entities and cooperatives are not subject to income taxes. To distinguish among the government-owned, privately owned, and cooperative ownership categories, EPA relied on the Steam Electric Survey and additional research on parent entities using publicly available information. See *Chapter 4: Cost and Economic Impact Screening Analyses* for further discussion of these determinations.

(*e.g.*, cost-to-revenue screening-level analyses are conducted using after-tax compliance costs). Note that for social costs, which are discussed and detailed in Chapter 12 of the BCA, EPA uses pre-tax costs.[41]

3.1.5 Voluntary Incentive Program

As described in the 2020 rule and 2023 proposed rule, under the voluntary incentive program (VIP), plants that discharge directly to waters can voluntarily commit to meeting more stringent FGD limitations based on a membrane filtration treatment technology instead of limits based on CP+LRTR technology. VIP participants had more time – until 2028 – to meet the lower limits based on membrane filtration, as compared to having to meet the limits based on CP+LRTR by 2025. Plants identified as participating in the VIP program in the baseline (*i.e.*, to comply with the 2020 rule) incur zero FGD wastewater treatment costs in this final rule.

3.2 Key Findings for Regulatory Options

3.2.1 Estimated Industry-level Total Compliance Costs

Table 3-1 and Table 3-2 present lower and upper bound compliance cost estimates for the regulatory options.[42]

Table 3-1: Estimated Total Annualized Compliance Costs (in millions, 2023$, at 2024) – Lower Bound

Regulatory Option	Pre-Tax Compliance Costs				After-Tax Compliance Costs			
	Capital Technology	Other Initial One-Time	Total O&M	Total	Capital Technology	Other Initial One-Time	Total O&M	Total
Option A	$232	$0.1	$247	$479	$186	$0.1	$200	$386
Option B	$284	$0.2	$312	$596	$229	$0.1	$250	$479
Option C	$336	$0.2	$359	$695	$270	$0.2	$286	$557

Source: U.S. EPA Analysis, 2024.

41 As described in Chapter 12 of the BCA, EPA used costs incurred by steam electric power plants for the labor, equipment, material, and other economic resources needed to comply with the regulatory options as a proxy for social costs. The social cost analysis considers costs on an as-incurred, year-by-year basis. In the social cost analysis, EPA assumed that the market prices for labor, equipment, material, and other compliance resources represent the opportunity costs to society for use of those resources in regulatory compliance. EPA further assumed that the regulatory options do not affect the aggregate quantity of electricity that would be sold to consumers and, thus, that the rule's social cost would include no changes in consumer and producer surplus *from changes in electricity sales* by the electricity industry in aggregate. Given the small impact of the regulatory options on electricity production cost for the total industry (see *Chapter 5*), this is a reasonable assumption.

42 As discussed in Section 3.1.1 (see footnote 31), EPA did not select the lowest-cost technology for five plants to meet zero-discharge limits for CRL. This resulted in the estimated total compliance costs for Option B and Option C presented in this section being overstated by approximately $6 million (1.5 percent of total costs) on an after-tax basis.

Table 3-2: Estimated Total Annualized Compliance Costs (in millions, 2023$, at 2024) – Upper Bound								
Regulatory Option	Pre-Tax Compliance Costs				After-Tax Compliance Costs			
	Capital Technology	Other Initial One-Time	Total O&M	Total	Capital Technology	Other Initial One-Time	Total O&M	Total
Option A	$453	$0.1	$595	$1,048	$372	$0.1	$490	$863
Option B	$505	$0.2	$659	$1,164	$415	$0.1	$541	$956
Option C	$557	$0.2	$706	$1,263	$456	$0.2	$577	$1,033

Source: U.S. EPA Analysis, 2024.

Table 3-3 and Table 3-4 show the breakout of total upper and lower bound compliance costs for each option by wastestream.[43]

Table 3-3: Estimated Total Annualized Compliance Costs, by Wastestream (in millions, 2023$, at 2024) – Lower Bound										
Regulatory Option	Pre-Tax Compliance Costs					After-Tax Compliance Costs				
	BA Transport Water	FGD Wastewater	CRL	Legacy	Net Total Costs	BA Transport Water	FGD Wastewater	CRL	Legacy	Net Total Costs
Option A	$19	$179	$281	$0	$479	$15	$139	$232	$0	$386
Option B	$19	$179	$370	$28	$596	$15	$139	$302	$23	$479
Option C	$30	$205	$433	$28	$695	$23	$160	$350	$23	$557

Source: U.S. EPA Analysis, 2024.

Table 3-4: Estimated Total Annualized Compliance Costs, by Wastestream (in millions, 2023$, at 2024) – Upper Bound										
Regulatory Option	Pre-Tax Compliance Costs					After-Tax Compliance Costs				
	BA Transport Water	FGD Wastewater	CRL	Legacy	Net Total Costs	BA Transport Water	FGD Wastewater	CRL	Legacy	Net Total Costs
Option A	$19	$179	$849	$0	$1,048	$15	$139	$709	$0	$863
Option B	$19	$179	$939	$28	$1,164	$15	$139	$778	$23	$956
Option C	$30	$205	$1,001	$28	$1,263	$23	$160	$826	$23	$1,033

Source: U.S. EPA Analysis, 2024.

3.2.2 Estimated Regional Distribution of Incremental Compliance Costs

Table 3-5 and Table 3-6 report the estimated lower and upper bound annualized total costs for each regulatory option at the level of a North American Electric Reliability Corporation (NERC) region.[44] As

43 One retired plant incurs legacy costs in the analysis. These costs are reflected in the total cost values in tables in Section 3.2. The costs for this plant are not incorporated in the rest of the RIA analyses because the plant does not have generation revenue or ratepayers.

44 No steam electric power plant is estimated to incur compliance costs in the ASCC and HICC NERC regions and these two regions are therefore omitted from the presentation of results.

explained in Chapter 2 (Overview of the Steam Electric Industry), because of differences in operating characteristics of steam electric power plants across NERC regions, as well as differences in the economic and electric power system regulatory circumstances of the NERC regions themselves, the regulatory options may affect costs, profitability, electricity prices, and other impact measures differently across NERC regions.

Table 3-5: Estimated Annualized Total Compliance Costs by NERC Region (in millions, 2023$, at 2024) – Lower Bound

NERC Region[a]	Pre-Tax Incremental Compliance Costs				After-Tax Incremental Compliance Costs			
	Capital Technology	Other Initial One-Time	Total O&M	Total	Capital Technology	Other Initial One-Time	Total O&M	Total
Option A								
MRO	$29.1	$0.0	$24.9	$54.0	$23.6	$0.0	$20.1	$43.7
NPCC	$3.0	$0.0	$3.0	$6.0	$2.2	$0.0	$2.2	$4.4
RF	$70.3	$0.0	$76.0	$146.3	$54.3	$0.0	$58.7	$113.0
SERC	$111.4	$0.0	$116.7	$228.2	$91.6	$0.0	$97.4	$189.0
TRE	$4.1	$0.0	$3.8	$7.9	$3.6	$0.0	$3.2	$6.8
WECC	$13.5	$0.0	$22.7	$36.2	$10.6	$0.0	$17.9	$28.5
Total	**$231.7**	**$0.1**	**$247.5**	**$479.2**	**$186.1**	**$0.1**	**$199.8**	**$386.0**
Option B								
MRO	$39.5	$0.0	$30.3	$69.8	$32.4	$0.0	$24.3	$56.7
NPCC	$3.3	$0.0	$2.9	$6.1	$2.4	$0.0	$2.1	$4.5
RF	$89.6	$0.1	$118.4	$208.0	$69.0	$0.1	$90.3	$159.3
SERC	$129.3	$0.1	$128.3	$257.7	$106.7	$0.0	$106.9	$213.6
TRE	$5.1	$0.0	$4.1	$9.2	$4.3	$0.0	$3.5	$7.8
WECC	$17.1	$0.0	$27.4	$44.5	$14.0	$0.0	$22.4	$36.5
Total	**$284.1**	**$0.2**	**$311.7**	**$596.0**	**$229.0**	**$0.1**	**$249.8**	**$479.0**
Option C								
MRO	$44.2	$0.0	$32.8	$77.0	$35.8	$0.0	$26.1	$61.9
NPCC	$3.3	$0.0	$2.9	$6.1	$2.4	$0.0	$2.1	$4.5
RF	$103.2	$0.1	$132.0	$235.3	$79.0	$0.1	$100.3	$179.3
SERC	$156.2	$0.1	$150.1	$306.4	$129.1	$0.1	$124.5	$253.6
TRE	$7.7	$0.0	$6.4	$14.1	$6.5	$0.0	$5.4	$11.9
WECC	$21.2	$0.0	$34.4	$55.6	$17.1	$0.0	$27.7	$44.8
Total	**$335.9**	**$0.2**	**$358.9**	**$695.0**	**$270.1**	**$0.2**	**$286.4**	**$556.6**

a. EPA estimated zero ELG compliance costs in the ASCC and HICC regions. These two regions are omitted from the table presentation. This omission does not affect totals.

Source: U.S. EPA Analysis, 2024.

Table 3-6: Estimated Annualized Total Compliance Costs by NERC Region (in millions, 2023$, at 2024) – Upper Bound

NERC Region[a]	Pre-Tax Incremental Compliance Costs				After-Tax Incremental Compliance Costs			
	Capital Technology	Other Initial One-Time	Total O&M	Total	Capital Technology	Other Initial One-Time	Total O&M	Total
Option A								
MRO	$54.8	$0.0	$63.3	$118.2	$43.2	$0.0	$48.6	$91.9
NPCC	$3.2	$0.0	$3.2	$6.4	$2.3	$0.0	$2.3	$4.7
RF	$109.9	$0.0	$135.2	$245.2	$86.4	$0.0	$106.9	$193.3
SERC	$225.3	$0.0	$292.7	$518.1	$192.1	$0.0	$252.3	$444.4
TRE	$8.4	$0.0	$8.3	$16.8	$7.3	$0.0	$7.2	$14.6
WECC	$49.8	$0.0	$90.9	$140.7	$39.4	$0.0	$71.8	$111.3
Total	**$452.6**	**$0.1**	**$595.0**	**$1,047.7**	**$372.0**	**$0.1**	**$490.5**	**$862.6**
Option B								
MRO	$65.3	$0.0	$68.7	$134.0	$52.0	$0.0	$52.8	$104.9
NPCC	$3.5	$0.0	$3.0	$6.5	$2.6	$0.0	$2.2	$4.8
RF	$129.2	$0.1	$177.6	$306.9	$101.1	$0.1	$138.5	$239.6
SERC	$243.2	$0.1	$304.3	$547.6	$207.2	$0.0	$261.9	$469.1
TRE	$9.4	$0.0	$8.7	$18.0	$8.1	$0.0	$7.5	$15.6
WECC	$53.4	$0.0	$95.6	$149.0	$42.9	$0.0	$76.4	$119.2
Total	**$505.1**	**$0.2**	**$659.2**	**$1,164.4**	**$414.9**	**$0.1**	**$540.5**	**$955.6**
Option C								
MRO	$69.9	$0.0	$71.2	$141.1	$55.4	$0.0	$54.6	$110.1
NPCC	$3.5	$0.0	$3.0	$6.5	$2.6	$0.0	$2.2	$4.8
RF	$142.8	$0.1	$191.3	$334.2	$111.0	$0.1	$148.5	$259.6
SERC	$270.0	$0.1	$326.1	$596.2	$229.6	$0.1	$279.5	$509.1
TRE	$12.0	$0.0	$11.0	$23.0	$10.3	$0.0	$9.4	$19.7
WECC	$57.5	$0.0	$102.5	$160.0	$46.0	$0.0	$81.6	$127.5
Total	**$556.9**	**$0.2**	**$706.4**	**$1,263.5**	**$456.0**	**$0.2**	**$577.1**	**$1,033.3**

a. EPA estimated zero ELG compliance costs in the ASCC and HICC regions. These two regions are omitted from the table presentation. This omission does not affect totals.

Source: U.S. EPA Analysis, 2024.

3.2.3 Key Uncertainties and Limitations

Economic analyses are not perfect predictions and thus, like all such analyses, this analysis has some uncertainties and limitations.

- The compliance costs used in this analysis for the regulatory options reflect unit retirements, conversions, and repowerings that have occurred or have been announced and are scheduled to occur by the end of 2029. For details, see TDD (U.S. EPA, 2024e). To the extent that actual unit retirements, conversions, and repowerings at steam electric power plants differ from announced changes, estimated annualized compliance costs of the regulatory options may differ from actual costs.

- EPA assumed that the equipment installed to meet any new limitations could reasonably be estimated to operate for 20 years or more, based on a review of reported performance characteristics of the equipment components. EPA also determined the 20-year annualization period to be reasonable for this analysis because some regulators may allow utilities to recover the value of undepreciated assets in their rate base on a case-by-case basis. EPA thus used 20 years as the basis for the cost and economic impact analyses that account for the estimated operating life of compliance technology. To the extent that the actual service life is longer or shorter than 20 years, costs presented on annual equivalent basis would be over- or under-stated. This includes cases where a plant upgrades treatment technologies to comply with the ELGs but ceases operating before the 20-year life of the equipment.

- Annualized compliance costs depend on the assumed technology implementation year. For the purpose of the cost and economic impact analyses, EPA determined years in which technology implementation would reasonably be estimated to occur across the universe of steam electric power plants, based on plant-specific information about existing NPDES permits and extrapolating future permit issuance dates assuming permits are renewed every five years. To the extent that compliance costs are incurred in an earlier or later year, the annualized values presented in this section may under or overstate the annualized total costs of the regulatory options.

- Plants may incur compliance costs associated with meeting legacy wastewater limits when they close and dewater their existing ponds. As there are no requirements for the ponds to be closed, there is uncertainty on whether and when operators may incur such costs. EPA assumed that pond closures will occur in 2044 at which time plants would incur initial one-time costs associated with treatment of legacy wastewater. As a result, this analysis may under or overstate compliance costs in cases where plants choose to close their ponds before or after 2044.

- Plants may incur compliance costs to comply with unmanaged CRL discharged from landfills, surface impoundments, or other features in cases where a permitting authority deems, on a case-by-case basis, the discharge to be the functional equivalent of a direct discharge and requiring a permit. Because these discharges are uncertain, EPA developed lower and upper bound analyses scenarios that rely on probabilistic estimates of plants that may be subject to the limits, compliance approach, and associated costs. See Section 3.1.1 for a description of these scenarios. Additionally, EPA assumed plants would incur these costs at the same time as they would incur costs associated with other treatment technologies. This may under or overstate the costs of unmanaged CRL treatment if plants incur these costs before or after the assumed compliance year in the analysis.

3.3 Costs to New Sources

Electric power generating plants that meet the definition of a “new source” will be required to achieve the final NSPS, in the case of direct dischargers, or Pretreatment Standards for New Sources (PSNS), in the case of indirect dischargers. This section summarizes the data and methodology used to estimate compliance costs for new steam electric power plants (for a more detailed description of the methodology, see TDD, U.S. EPA, 2024e). The section also assesses the relative magnitude of the compliance costs by comparing them to the costs of new coal steam generation. EPA’s final rule is based on the suite of technologies identified for Option B. EPA’s approach to assess costs to new sources and the potential barrier to entry for new plants is based on the same methodology used for the 2015 rule (U.S. EPA, 2015).

3.3.1 Analysis Approach and Inputs

EPA developed compliance costs for new plants using a methodology similar to the one used to develop compliance costs for existing plants (see TDD for details). EPA did not have information about which entities will construct new plants, the exact characteristics of such plants, or the timing of new plant construction. As a result, EPA calculated and analyzed compliance costs for a hypothetical plant. The Agency treated the incurrence of costs in this analysis as though new plants would be constructed, and additional wastewater treatment costs incurred, as of the rule promulgation, (*i.e.*, 2024). This is a conservative assumption since new sources would not incur costs until there is an NPDES permit applying the NSPS to them.

Compliance costs for new plants under the final NSPS (Option B) include capital costs, initial one-time costs, and annual O&M costs. EPA made the same adjustments to the plant-specific costs for new plants described in the TDD, as those made to develop total compliance costs for existing plants:

- First, EPA brought all compliance costs to 2024 using CCI (or ECI) and restated in 2023 dollars using GDP Deflator.
- EPA then annualized each non-annual cost component over the expected useful life of the technology/processes it represents (capital cost and initial one-time costs over 20 years) using 3.76 percent as the assumed cost of capital.
- Finally, EPA added these annualized capital, initial one-time, and O&M costs.

Table 3-7 presents estimated new plant compliance costs under the final rule (Option B) for new sources. The Agency estimated costs for a new 650 MW coal-fired steam electric power plant. Per MW, EPA estimated that a new plant will cost $4,916 per MW. For more details on the methodology used to estimate compliance costs for new plants, see the TDD (U.S. EPA, 2024e).

Table 3-7: Annualized Pre-tax Compliance Costs for a Hypothetical New 650 MW Plant Under Final Rule (2023$, at 2024)

Total Costs				Costs per MW[a]			
Capital Costs	Non-Fuel O&M Costs	One-Time Costs	Total Annualized Costs	Capital Costs	Non-Fuel O&M Costs	One-Time Costs	Total Annualized Costs
$1,482,503	$1,701,998	$11,088	$3,195,589	$2,281	$2,618	$17	$4,916

a. Unit costs are based on capacity of 650 MW.

Source: U.S. EPA analysis, 2024.

3.3.2 Key Findings for Regulatory Options

EPA assessed the effects of the final NSPS requirements under the final rule for new plants by comparing the compliance costs for new plants to the overall cost of *building and operating* new plants, on a per

MW basis. This analysis assesses the requirements and costs imposed on new plants in relation to the costs that would be incurred for building and operating new plant *without the new plant requirements.*[45]

To assess the relative magnitude of compliance costs for new plants, EPA compared the pre-tax costs presented in Section 3.2.1, to the total cost of building and operating a new plant, also on a pre-tax and per MW basis. EPA obtained the overnight capital[46] and O&M costs of building and operating a new plant from EIA (2024). These costs are based on a new ultra-supercritical coal (USC) plant with no carbon capture (CC) technology with a total generation capacity of 650 MW (EIA, 2024). EPA compared the ELG cost estimates for the 650 MW plant presented in Table 3-7 to the costs of a new USC plant without CC.

EPA also estimated annual fuel O&M costs for operating the plant based on an assumed capacity factor of 90 percent, annual heat rate of a new USC without CC from EIA (2024), and weighted average cost of coal delivered to the power sector from EIA (2023h). EPA annualized new USC without CC plant building and operating costs over 40 years using a discount rate of 3.76 percent.[47] EPA then compared the estimated compliance costs for new plants to the costs of constructing and operating new coal steam capacity. Table 3-8 presents the results of this comparison. The Agency estimated that compliance costs for adding treatment technology at a new plant would represent 1.1 percent of the total annualized costs of building and operating a new plant.

Table 3-8: One-Time & O&M costs for a Hypothetical New 650 MW Plant Under Final Rule

Cost Component	Annualized Costs of New Coal-fired Generation (2023$/MW)	Compliance Costs (2023$/MW)	% of New Generation Cost
Capital	$199,936	$2,281	1.1%
Non-Fuel Annual O&M[a]	$112,095	$2,618	1.0%
Fuel Annual O&M	$153,535		
Total Annualized Costs[b]	$465,566	$4,916	1.1%

a. Fuel costs were estimated assuming heat rate of 8,638 Btu/kWh (EIA, 2024) and the cost of coal delivered to the power sector of 2.25 2023$/MMbtu (EIA (2023h) weighted average cost for all coal ranks in 2022 dollars, converted to 2023 dollars using GDP deflator).

b. Includes annualized initial one-time costs.

Source: EIA, 2024; U.S. EPA analysis, 2024.

45 Note that the market analyses described in Chapter 5 also incorporate costs to new sources as part of inputs to the Integrated Planning Model (IPM). This analysis tests the impact of the new plant requirements in electricity markets accounting for the expected number and timing of new plant installations, and provides additional insight on whether the costs of meeting the standards specified by the final NSPS and PSNS would affect future capacity additions. Since IPM projects no new coal-fired generating plant in the Base Case, however, the market analysis does not offer additional insight on the impacts of the NSPS compliance costs on new generating capacity.

46 Overnight capital costs includes labor and material costs due to installation, mechanical equipment and labor, electrical instrumentation, and indirect management costs according to U.S. Energy Information Administration. (2024). *Capital Cost and Performance Characteristics for Utility-Scale Electric Power Generating Technologies.* Retrieved from https://www.eia.gov/analysis/studies/powerplants/capitalcost/pdf/capital_cost_AEO2025.pdf.

47 The Agency annualized capital costs for a new USC coal unit without CC based on the predicted performance life reported in ibid..

3.3.3 Key Uncertainties and Limitations

Despite EPA's use of the best available information and data available, including information provided to EPA in the industry survey, this analysis has uncertainties and limitations.

- EPA notes that no new coal capacity additions are projected between 2024 and 2050 in AEO2023 (EIA, 2023b), making the assessment of the relative costs and of any barrier the final ELGs may pose to additional generation hypothetical. Similarly, results of the electricity market model using IPM (Chapter 5) shows no additional coal steam capacity being built through 2050 in the Base Case (in the absence of the ELGs) or in the policy case (with the ELGs), and do not offer a basis for determining, using IPM, whether the ELGs present a cost barrier to new coal generation. However, as discussed in Chapter 5, the IPM results demonstrate that the ELGs do not pose a barrier to new electricity generation overall; the model shows increases new capacity projected in IPM under the final rule option.

- Second, EPA made assumptions about plant characteristics in the absence of the final rule. These assumptions affect the types of wastestreams that a plant would generate and changes needed to meet the final limitations and standards. To the extent that the characteristics of new plants differ from EPA's assumed characteristics, the costs may be under or overstated.

- Finally, the costs of implementing and operating compliance technology vary based on the size of the generating plant and plant configuration. To the extent that the size and configuration of a potential new coal plant is different from assumptions that underlay new capacity costs, the relative magnitude of the compliance costs for new steam electric capacity may be under- or over-estimated. For instance, EPA used data from EIA on the cost of additional capacity based on a new 650 MW USC without CC plant (EIA, 2024). The cost of building new capacity for a smaller or larger plant may be smaller or larger on a per MW basis than those of a 650 MW plant.

4 Cost and Economic Impact Screening Analyses

4.1 Analysis Overview

Following the same methodology used for the 2015, 2020 and proposed 2023 rule analyses (U.S. EPA, 2015, 2020, 2023d), EPA assessed the costs and economic impacts of the regulatory options in two ways:

1. A screening-level assessment reflecting current operating characteristics of steam electric power plants and with assignment of estimated compliance costs to those plants. This analysis assumes no changes in operating characteristics — *e.g.*, quantity of generated electricity and revenue — as a result of the regulatory options. This screening-level assessment, which is documented in this chapter, includes two specific analyses:

   – A cost-to-revenue screening analysis to assess the impact of compliance outlays on individual steam electric power plants (Section 4.2)
   – A cost-to-revenue screening analysis to assess the impact of compliance outlays on domestic parent-entities owning steam electric power plants (Section 4.3)

2. A broader electricity market-level analysis based on IPM (the Market Model Analysis). This analysis, which provides a more comprehensive indication of the economic achievability of the final rule, including an assessment of incremental plant closures (or avoided closures), is discussed in Chapter 5. Unlike the preceding analysis discussed in this chapter, the Market Model Analysis accounts for estimated changes in the operating characteristics of plants from both estimated changes in electricity markets and operating characteristics of plants independent of, and as a result of, the regulatory options.

4.2 Cost-to-Revenue Analysis: Plant-Level Screening Analysis

The cost-to-revenue measure compares the cost of implementing and operating compliance technologies with the plant's operating revenue and provides a screening-level assessment of the impact that might be estimated of the regulatory options. As discussed in U.S. EPA (2015; see Chapter 2), the majority of steam electric power plants operate in states with regulated electricity markets. EPA estimates that plants located in these states may be able to recover compliance cost-based increases in their production costs through increased electricity prices, depending on the business operation model of the plant owner(s), the ownership and operating structure of the plant itself, and the role of market mechanisms used to sell electricity. In contrast, in states in which electric power generation has been deregulated, cost recovery is not guaranteed. While plants operating within deregulated electricity markets *may be* able to recover some of their additional production costs through increased revenue, it is not possible to determine the extent of cost recovery ability for each plant.[48]

In assessing the cost impact of the regulatory options on steam electric power plants in this screening-level analysis, the Agency assumed that the plants would not be able to pass any of the change in their

48 While the regulatory status in a given state affects the ability of electric power plants and their parent entities to recover electricity generation costs, it is not the only factor and should not be used solely as the basis for cost-pass-through determination.

production costs to consumers (zero cost pass-through). This assumption is used for analytic convenience and provides a *worst-case* scenario of regulatory impacts to steam electric power plants.[49]

4.2.1 Analysis Approach and Data Inputs

As described in Chapter 1, EPA estimates all steam electric power plants to meet any new requirements for bottom ash transport water, FGD wastewater, and CRL between 2026 and 2030. The Agency used the same approach from the 2015 rule, 2020 rule, and 2023 proposed rule to conduct the analysis of the final rule's regulatory options A through C.

EPA updated the approach used for the 2015 and 2020 rules and 2023 proposal to incorporate more recent data. For the current analysis, EPA used 2024 as the basis for comparing after-tax compliance costs (see Chapter 3) to revenue at the plant level.[50] For this comparison, EPA developed plant-level revenue values for all steam electric power plants using data from the Department of Energy's Energy Information Administration (EIA) on electricity generation by prime mover, and utility/operator-level electricity prices and disposition. Specifically, EPA multiplied the 6-year average of electricity generation values over the period 2016 to 2021 from the EIA-923 database by 6-year average electricity prices over the period 2016 to 2021 from the EIA-861 database (EIA, 2022a, 2022d).[51, 52] EPA estimated compliance costs in 2023 dollars. To provide cost and revenue comparisons on a consistent analysis-year (2024) and dollar-year (2023) basis, EPA adjusted the EIA electricity price data, which are reported in nominal dollars of each year.

Cost-to-revenue ratios are used to describe impacts to entities because they provide screening-level indicators of potential economic impacts. Just as for the plants owned by small entities under guidance in U.S. EPA (2006), and the approach EPA has used previously in previous regulatory analyses (U.S. EPA, 2015, 2020, 2023d), EPA assesses plants incurring costs below one percent of revenue as unlikely to face material economic impacts, plants with costs of at least one percent but less than three percent of revenue

49 Even though the majority of steam electric power plants may be able to pass increases in production costs to consumers through increased electricity prices, it is difficult to determine exactly which plants would be able to do so. Consequently, EPA concluded that assuming zero cost pass-through is appropriate as a screening-level, upper bound estimate of the potential impact of compliance expenditures on steam electric power plants and their parent entities. The analysis, while helpful to understand potential cost impact, does not generally indicate whether profitability is jeopardized, cash flow is affected, or risk of financial distress is increased.

50 For private, tax-paying entities, *after-tax costs* are a more relevant measure of potential private cost burden than *pre-tax costs*. For non-tax-paying entities (*e.g.*, State government and municipality owners of steam electric power plants), the estimated costs used in this calculation include no adjustment for taxes.

51 In using the year-by-year revenue values to develop an average over the data years, EPA set aside from the average calculation any generation values that are anomalously low. Such low generating output likely results from temporary disruption in operation, such as a generating unit being out of service for maintenance.

52 EPA's first step in calculating plant revenue was to restate electricity prices in 2023 dollars using the Gross Domestic Product (GDP) deflator index published by the U.S. Bureau of Economic Analysis (BEA) (U.S. Bureau of Economic Analysis. (2023). *Table 1.1.9 Implicit Price Deflators for Gross Domestic Product (GDP Deflator)*. Retrieved from https://apps.bea.gov/iTable/?reqid=19&step=3&isuri=1&1921=survey&1903=11). These individual yearly values were then averaged and brought forward to 2024 using electricity price projections from the Annual Energy Outlook publication for 2023 (AEO2023) (U.S. Energy Information Administration. (2023b). *Annual Energy Outlook 2023*. Retrieved from https://www.eia.gov/outlooks/aeo/). AEO2023 contains projections and analysis of U.S. energy supply, demand, and prices through 2050. AEO2023 electricity price projections are in constant dollars; therefore, these adjustments yield 2024 revenue values in dollars of the year 2023 (converted from 2022 dollars to 2023 dollars).

as having a higher chance of facing material economic impacts, and plants incurring costs of at least three percent of revenue as having a still higher probability of material economic impacts.

4.2.2 Key Findings for Regulatory Options

Table 4-1 and Table 4-2 present the lower and upper bound cost-to-revenue analysis results for each of the regulatory options. Under all regulatory options analyzed, most plants would not experience compliance costs exceeding one or three percent of revenue.

Table 4-1: Plant-Level Cost-to-Revenue Analysis Results by Owner Type and Regulatory Option – Lower Bound

Owner Type	Total Number of Plants[a]	Number of Plants with a Ratio of			
		0%[a,b]	≠0 and <1%	≥1 and 3%	≥3%
Option A					
Cooperative	59	44	10	3	2
Federal	23	17	4	2	0
Investor-owned	320	238	63	14	5
Municipality	111	100	4	2	5
Nonutility	308	289	15	1	3
Political Subdivision	33	29	3	0	1
State	4	2	2	0	0
Total	**858**	**719**	**101**	**22**	**16**
Option B					
Cooperative	59	44	8	5	2
Federal	23	17	4	2	0
Investor-owned	320	237	59	17	7
Municipality	111	100	2	4	5
Nonutility	308	288	14	3	3
Political Subdivision	33	29	3	0	1
State	4	2	1	1	0
Total	**858**	**717**	**91**	**32**	**18**
Option C					
Cooperative	59	44	8	5	2
Federal	23	17	4	2	0
Investor-owned	320	237	53	23	7
Municipality	111	100	2	4	5
Nonutility	308	288	14	3	3
Political Subdivision	33	29	3	0	1
State	4	2	1	0	1
Total	**858**	**717**	**85**	**37**	**19**

a. Plant counts are weighted estimates.

b. These plants already meet discharge requirements for the wastestreams controlled by a given regulatory option and therefore are not estimated to incur compliance costs.

Source: U.S. EPA Analysis, 2024.

Table 4-2: Plant-Level Cost-to-Revenue Analysis Results by Owner Type and Regulatory Option – Upper Bound

Owner Type	Total Number of Plants[a]	Number of Plants with a Ratio of			
		0%[a,b]	≠0 and <1%	≥1 and 3%	≥3%
Option A					
Cooperative	59	41	9	4	5
Federal	23	14	6	2	1
Investor-owned	320	224	64	19	13
Municipality	111	97	5	3	6
Nonutility	308	284	17	4	3
Political Subdivision	33	27	5	0	1
State	4	2	1	1	0
Total	**858**	**688**	**107**	**33**	**29**
Option B					
Cooperative	59	41	7	6	5
Federal	23	14	5	3	1
Investor-owned	320	223	62	20	15
Municipality	111	97	3	5	6
Nonutility	308	284	15	6	3
Political Subdivision	33	27	5	0	1
State	4	2	1	1	0
Total	**858**	**687**	**98**	**41**	**31**
Option C					
Cooperative	59	41	7	6	5
Federal	23	14	5	2	2
Investor-owned	320	223	57	25	15
Municipality	111	97	3	5	6
Nonutility	308	284	13	8	3
Political Subdivision	33	27	5	0	1
State	4	2	1	0	1
Total	**858**	**687**	**91**	**46**	**33**

a. Plant counts are weighted estimates.

b. These plants already meet discharge requirements for the wastestreams controlled by a given regulatory option and therefore are not estimated to incur compliance costs.

Source: U.S. EPA Analysis, 2024.

4.2.3 Uncertainties and Limitations

Despite EPA's use of the best available information and data, this analysis of plant-level impacts has uncertainties and limitations, including:

- The impact of the regulatory options may be over- or under-estimated as a result of differences between actual 2024 plant revenue and those estimated using EIA databases for 2015 through 2021.

- As noted above, the zero cost pass-through assumption represents a worst-case scenario from the perspective of the plant owner. To the extent that companies are able to pass some compliance costs on to consumers through higher electricity prices, this analysis overstates the potential impact of the regulatory options on steam electric power plants.

- EPA assumes that owners of plants that retire or repower during the period of analysis, but after installing equipment to comply with the final rule, will continue to amortize capital expenses over the 20-year life of the technology. To the extent that plant owners use an accelerated amortization schedule, this analysis may understate the potential impact of the baseline and regulatory options on steam electric power plants.

4.3 Cost-to-Revenue Screening Analysis: Parent Entity-Level Analysis

Following the methodology EPA used for the analysis of the 2015 and 2020 rules and 2023 proposal analyses (U.S. EPA, 2015, 2020, 2023d), EPA also assessed the economic impact of the regulatory options at the parent entity level. The cost-to-revenue screening analysis at the entity level adds particular insight on the impact of compliance requirements on those entities that own multiple plants.

EPA conducted this screening analysis at the *highest* level of *domestic* ownership, referred to as the "domestic parent entity." For this analysis, the Agency considered only entities with the largest share of ownership (*e.g.*, majority owner) in at least one surveyed steam electric power plant.[53,54] The entity-level analysis maintains the worst-case analytical assumption of no pass-through of compliance costs to electricity consumers used for the plant-level cost-to-revenue analysis in Section 4.2.

4.3.1 Analysis Approach and Data Inputs

Following the approach used in the 2015, 2020, and proposed 2023 rule analyses (U.S. EPA, 2015, 2020, 2023d), to assess the entity-level economic/financial impact of compliance requirements, EPA summed plant-level annualized after-tax compliance costs calculated in Section 3.2 to the level of the steam electric power plant owning entity and compared these costs to parent entity revenue.

Similar to the plant-level analysis, EPA used cost-to-revenue ratios of one and three percent as markers of potential impact for this analysis. Also similar to the assumptions made for the plant-level analysis, for this entity-level analysis the Agency assumed that entities incurring costs below one percent of revenue are unlikely to face significant economic impacts, while entities with costs of at least one percent but less than three percent of revenue have a higher chance of facing significant economic impacts, and entities incurring costs of at least three percent of revenue have a still higher probability of significant economic impacts.

Following the approach used in the 2015, 2020, and 2023 rule analyses (U.S. EPA, 2015, 2020, 2023d; see Section 4.3), EPA analyzed two cases that provide approximate upper and lower bound estimates on: (1) the number of entities incurring compliance costs and (2) the costs incurred by any entity owning one or more steam electric power plant.

This entity-level cost-to-revenue analysis involved the following steps: (1) Determining the parent entity; (2) Determining the parent entity revenue; and (3) Estimating compliance costs at the level of the parent

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53 Throughout these analyses, EPA refers to the owner with the largest ownership share as the "majority owner" even when the ownership share is less than 51 percent.

54 When two entities have equal ownership shares in a plant (*e.g.*, 50 percent each), EPA analyzed both entities and allocated plant-level compliance costs to each entity.

entity. The sections below highlight updates to incorporate more recent data than were used for the 2015, 2020, and proposed 2023 rules.

Determining the Parent Entity

EPA used information from the 2021 EIA-860 database which provides owners and the share of ownership in electric generating units (EIA, 2022c) to determine ownership of each coal-fired steam electric power plant and surveyed non-coal steam electric power plants (see U.S. EPA, 2015 for discussion of how non-coal steam electric power plants are incorporated in the analysis). EPA supplemented this information with data from corporate/financial websites and from the Steam Electric Survey to identify the highest-level domestic parent entity for each plant.

Determining Parent Entity Revenue

For each parent entity identified in the preceding step, EPA determined revenue values based on information from corporate or financial websites, if those values were available. EPA tried to obtain revenue for years 2020 and 2021 and used the average of reported values. If revenue values were not reported on corporate/financial websites, the Agency used 2019-2021 average revenue values from the EIA-861 database (EIA, 2022a). Additionally, EPA used entity-level revenue values from Dun and Bradstreet (Dun & Bradstreet, 2021) or Experian (Experian, 2023) if those values were available.

EPA updated entity revenue values to 2023 dollars using the GDP Deflator. For this analysis, the Agency assumed that these average historical revenue values are representative of revenues as of 2024. Although the entity-level revenue values might reasonably be estimated to change by 2024 (*i.e.*, have increased or decreased relative to average historical revenue), EPA was less confident in the reliability of projecting revenue values *at the entity level* than in that of projecting plant-level revenue values to reflect changes in generation. For the entity-level analysis, therefore, EPA did not project or further adjust revenue values developed using the sources and methodology described above but used these values *as is*. In effect, plants and their parent entities are assumed to be the same 'business entities' in terms of constant dollar revenue in 2024 as they were in the year for which revenue were reported.

Estimating Compliance Costs at the Level of the Parent Entity

Following the approach used in the analysis of the 2015 rule, to account for the parent entities of all 858 steam electric power plants, EPA analyzed two approximate bounding cases that provide a range of estimates for the number of entities incurring compliance costs and the costs incurred by any entity owning a steam electric power plant: (1) A lower bound estimate that assumes that the surveyed owners represent all owners, which effectively assumes that any non-surveyed plants are owned by the same surveyed entities and maximizes the number of plants owned by any given entity; and (2) An upper bound estimate that assumes that the non-surveyed owners are different from those surveyed but have similar characteristics, which results in a greater number of owners but minimizes the number of plants owned by each. See Chapter 4 in U.S. EPA (2015) for details.

4.3.2 Key Findings for Regulatory Options

Table 4-3 presents the results from the entity-level impact analysis under the lower bound (Case 1) and upper bound (Case 2) estimates of the number of entities incurring costs for each regulatory option under the lower bound cost scenario. Table 4-4 presents the results for the upper bound cost scenario. The tables show the number of entities that incur costs in four ranges: no cost, and non-zero costs less than one percent of an entity's revenue, at least one percent but less than three percent of revenue, and at least three percent of revenue.

Overall, this screening-level analysis shows that few entities are likely to experience significant changes in cost-to-revenue ratios under any of the regulatory options compared to the baseline.

Table 4-3: Entity-Level Cost-to-Revenue Analysis Results – Lower Bound

Entity Type	Case 1: Lower bound estimate of change in number of firms owning plants that face requirements under the regulatory analysis						Case 2: Upper bound estimate of change in number of firms owning plants that face requirements under the regulatory analysis					
	Total Number of Entities	Number of Entities with a Ratio of					Total Number of Entities	Number of Entities with a Ratio of				
		0%[a]	≠0 and <1%	≥1 and 3%	≥3%	Unknown		0%[a]	≠0 and <1%	≥1 and 3%	≥3%	Unknown
Option A												
Cooperative	22	10	10	0	2	0	28	13	13	0	2	0
Federal	2	1	1	0	0	0	7	3	4	0	0	0
Investor-owned	57	27	29	1	0	0	88	20	67	1	0	0
Municipality	50	39	6	4	1	0	84	71	8	4	1	0
Nonutility	76	65	9	0	2	0	160	139	19	0	2	0
Other[b]	11	9	2	0	0	0	23	20	3	0	0	0
State	2	1	1	0	0	0	2	1	1	0	0	0
Total	**220**	**152**	**58**	**5**	**5**	**0**	**391**	**266**	**115**	**5**	**5**	**0**
Option B												
Cooperative	22	10	9	1	2	0	28	13	12	1	2	0
Federal	2	1	1	0	0	0	7	3	4	0	0	0
Investor-owned	57	27	29	1	0	0	88	20	67	1	0	0
Municipality	50	39	6	3	2	0	84	71	8	3	2	0
Nonutility	76	65	7	2	2	0	160	139	17	2	2	0
Other[b]	11	9	2	0	0	0	23	20	3	0	0	0
State	2	1	1	0	0	0	2	1	1	0	0	0
Total	**220**	**152**	**55**	**7**	**6**	**0**	**391**	**266**	**112**	**7**	**6**	**0**
Option C												
Cooperative	22	10	9	1	2	0	28	13	12	1	2	0
Federal	2	1	1	0	0	0	7	3	4	0	0	0
Investor-owned	57	27	29	1	0	0	88	20	67	1	0	0
Municipality	50	39	6	3	2	0	84	71	8	3	2	0
Nonutility	76	65	7	2	2	0	160	139	17	2	2	0
Other[b]	11	9	2	0	0	0	23	20	3	0	0	0
State	2	1	0	1	0	0	2	1	0	1	0	0
Total	**220**	**152**	**54**	**8**	**6**	**0**	**391**	**266**	**111**	**8**	**6**	**0**

a. These entities own only plants that already meet discharge requirements for the wastestreams addressed by a given regulatory option and are therefore not estimated to incur any compliance technology costs.

b. Other political subdivision.

Source: U.S. EPA Analysis, 2024.

Table 4-4: Entity-Level Cost-to-Revenue Analysis Results – Upper Bound

	Case 1: Lower bound estimate of change in number of firms owning plants that face requirements under the regulatory analysis						Case 2: Upper bound estimate of change in number of firms owning plants that face requirements under the regulatory analysis					
		Number of Entities with a Ratio of						Number of Entities with a Ratio of				
Entity Type	**Total Number of Entities**	**0%[a]**	**≠0 and <1%**	**≥1 and 3%**	**≥3%**	**Unknown**	**Total Number of Entities**	**0%[a]**	**≠0 and <1%**	**≥1 and 3%**	**≥3%**	**Unknown**
Option A												
Cooperative	22	7	12	0	3	0	28	9	16	0	3	0
Federal	2	1	1	0	0	0	7	2	5	0	0	0
Investor-owned	57	24	31	2	0	0	88	11	75	2	0	0
Municipality	50	37	8	1	4	0	84	69	10	1	4	0
Nonutility	76	63	10	1	2	0	160	137	20	1	2	0
Other[b]	11	6	5	0	0	0	23	14	9	0	0	0
State	2	1	1	0	0	0	2	1	1	0	0	0
Total	**220**	**139**	**68**	**4**	**9**	**0**	**391**	**242**	**136**	**4**	**9**	**0**
Option B												
Cooperative	22	7	11	1	3	0	28	9	15	1	3	0
Federal	2	1	1	0	0	0	7	2	5	0	0	0
Investor-owned	57	24	31	2	0	0	88	11	75	2	0	0
Municipality	50	37	8	1	4	0	84	69	10	1	4	0
Nonutility	76	63	8	3	2	0	160	137	18	3	2	0
Other[b]	11	6	5	0	0	0	23	14	9	0	0	0
State	2	1	0	1	0	0	2	1	0	1	0	0
Total	**220**	**139**	**64**	**8**	**9**	**0**	**391**	**242**	**132**	**8**	**9**	**0**
Option C												
Cooperative	22	7	11	1	3	0	28	9	15	1	3	0
Federal	2	1	1	0	0	0	7	2	5	0	0	0
Investor-owned	57	24	31	2	0	0	88	11	75	2	0	0
Municipality	50	37	8	1	4	0	84	69	10	1	4	0
Nonutility	76	63	8	3	2	0	160	137	18	3	2	0
Other[b]	11	6	5	0	0	0	23	14	9	0	0	0
State	2	1	0	1	0	0	2	1	0	1	0	0
Total	**220**	**139**	**64**	**8**	**9**	**0**	**391**	**242**	**132**	**8**	**9**	**0**

a. These entities own only plants that already meet discharge requirements for the wastestreams addressed by a given regulatory option and are therefore not estimated to incur any compliance technology costs.

b. Other political subdivision.

Source: U.S. EPA Analysis, 2024.

4.3.3 Uncertainties and Limitations

Despite EPA's use of the best available information and data, this analysis of entity-level impacts has uncertainties and limitations, including:

- The entity-level revenue values obtained from the corporate and financial websites or EIA databases are for 2019 through 2021. To the extent that actual 2024 entity revenue values are different, on a constant dollar basis, from those estimated using historical data, the cost-to-revenue measure for parent entities of steam electric power plants may be over- or under-estimated.

- The assessment of entity-level impacts relies on approximate upper and lower bound estimates of the number of parent entities and the numbers of steam electric power plants that these entities own. EPA expects that the range of results from these analyses provides appropriate insight into the overall extent of entity-level effects.

- As is the case with the plant-level analysis discussed in Section 4.2, the zero cost pass-through assumption represents a worst-case scenario from the perspective of the plant owner. To the extent that companies are able to pass some compliance costs on to consumers through higher electricity prices, this analysis may overstate the potential impact of the baseline and regulatory options on steam electric power plants. Also, as is the case with the plant-level analysis discussed in Section 4.2, the assumption that owners of plants that retire or repower during the period of analysis, but after installing equipment to comply with the final rule, will continue to amortize capital expenses over the 20-year life of the technology, may understate the potential impact of the baseline and regulatory options on steam electric power plants.

5 Assessment of the Impact of the Final Rule on National and Regional Electricity Markets

Following the approach used to analyze the impacts of the 2015 and 2020 rules and other various regulatory actions affecting the electric power sector over the last decade, EPA used the Integrated Planning Model (IPM®), a comprehensive electricity market optimization model that can evaluate such impacts within the context of regional and national electricity markets. To assess market-level effects of the final rule, EPA used the latest version of this analytic system: Integrated Planning Model Version 6 (IPM v6) Post-IRA 2022 Reference Case (U.S. EPA, 2023a).[55] EPA ran IPM for Option B, excluding costs associated with legacy wastewater limits or the treatment of unmanaged CRL, to evaluate the impacts of the final rule.

This market model analysis is a more comprehensive analysis compared to the screening-level analyses discussed in Chapter 4; it is meant to inform EPA's assessment of whether the proposed rule would result in any capacity retirements (full or partial plant closures)[56] and to provide insight on impacts on the overall electricity market, including to assess whether the proposed rule may significantly affect the energy supply, distribution or use under Executive Order 13211 (see Section 10.6).

In contrast to the screening-level analyses, which are static analyses and do not account for interdependence of electric generating units in supplying power to the electric transmission grid, IPM accounts for potential changes in the generation profile of steam electric and other units and consequent changes in market-level generation costs, as the electric power market responds to changes in generation costs for steam electric units due to the regulatory options. IPM is also dynamic in that it is capable of using forecasts of future conditions to make decisions for the present. Additionally, in contrast to the screening-level analyses in which EPA assumed no pass through of compliance costs, IPM depicts production activity in wholesale electricity markets where some recovery of compliance costs through increased electricity prices is possible but not guaranteed. Finally, IPM incorporates electricity demand growth assumptions from the Department of Energy's *Annual Energy Outlook 2023* (U.S. EIA, 2023b), whereas the screening-level analyses discussed in other chapters of this report assume that plants would generate approximately the same quantity of electricity in 2024 as they did on average during 2015-2020.

Changes in electricity production costs and potential associated changes in electricity output at steam electric power plants can have a range of broader market impacts that extend beyond the effect on steam electric power plants. In addition, the impact of compliance requirements on steam electric power plants may be seen differently when the analysis considers the impact on those plants in the context of the broader electricity market instead of looking at the impact on a standalone, single-plant basis. Therefore, use of a comprehensive, market model analysis system that accounts for interdependence of electric generating units is important in assessing regulatory impacts on the electric power industry as a whole.

55 For more information on IPM, see https://www.epa.gov/airmarkets/clean-air-markets-power-sector-modeling.

56 For the 2015 rule analysis, EPA used IPM to inform assessment of the economic achievability of the ELG options under CWA Sections 301(b)(2)(A) and 304(b)(2) (see U.S. Environmental Protection Agency. (2015). *Regulatory Impact Analysis for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category*. (EPA-821-R-15-004).).

EPA's use of IPM v6 for this analysis is consistent with the intended use of the model to evaluate the effects of changes in electricity production costs, on electricity generation costs, subject to specified demand and emissions constraints. As discussed in greater detail in U.S. EPA (2023a), IPM generates least-cost resource dispatch decisions based on user-specified constraints such as environmental, demand, and other operational constraints. The model can be used to analyze a wide range of electric power market scenarios. Applications of IPM have included capacity planning, environmental policy analysis and compliance planning, wholesale price forecasting, and asset valuation.

IPM uses a long-term dynamic linear programming framework that simulates the dispatch of generating capacity to achieve a demand-supply equilibrium on a seasonal basis and by region. The model computes optimal capacity that combines short-term dispatch decisions with long-term investment decisions. Specifically, IPM seeks the optimal solution to an "objective function," which is the summation of all the costs incurred by the electric power sector, *i.e.*, capital costs, fixed and variable O&M costs, and fuel costs, on a net present value basis over the entire evaluated time horizon. The objective function is minimized subject to a series of supply and demand constraints. Supply-side constraints include capacity constraints, availability of generation resources, plant minimum operating constraints, transmission constraints, fuel supply constraints, and environmental constraints. Demand-side constraints include reserve margin constraints and minimum system-wide load requirements. The assumptions for total electricity demand and demand growth over IPM's period of analysis (see Section 5.1.1) are obtained from the Department of Energy's *Annual Energy Outlook 2023* (EIA, 2023b). IPM runs under the assumption that electricity demand must be met and maintains a consistent expectation of future load. This analysis does not consider the relationship of the price of power on the quantity of electricity demanded (U.S. EPA, 2023a).

The final difference between EPA's electricity market optimization model analysis and the analysis in Chapter 4 is the inclusion of estimated market-level impacts of environmental rules in the analysis baseline. The screening-level analysis estimates the impacts resulting from compliance with the final rule only, relative to a baseline that includes compliance with the 2020 ELG. Though the screening-level analysis and EPA's assumptions regarding baseline operating practices and plant and firm revenue implicitly account for existing environmental rules (*e.g.*, to the extent that these rules affect the status or characteristics of generating units), it does not explicitly estimate the effects of these rules across the entire electricity market over the period of analysis. The IPM analysis, on the other hand, dynamically estimates changes in capacity and generation over the IPM analysis period that account for retrofits and retirements as a result of a broader set of environmental rules. Notably, for the analysis for the final rule, EPA started from an electricity market "reference case" (Summer 2022) that includes the Inflation Reduction Act provisions directed towards electricity generators,[57] the Good Neighbor Plan which addresses transport under the National Ambient Air Quality Standards (NAAQS) for ozone, as well as the requirements of the 2020 ELG, Cross-State Air Pollution Rule (CSAPR and CSAPR Update), Mercury

57 As detailed in U.S. Environmental Protection Agency. (2023a). *Documentation for EPA's Power Sector Modeling Platform v6 Using the Integrated Planning Model Post-IRA 2022 Reference Case*. Retrieved from **https://www.epa.gov/system/files/documents/2023-03/EPA%20Platform%20v6%20Post-IRA%202022%20Reference%20Case.pdf**, the IRA includes tax credit provisions that affect power sector operations. IPM accounts for the Clean Electricity Investment and Production Tax Credits (provisions 48E and 45Y of the IRA), the credit for Carbon Capture and Sequestration (provision 45Q), the impacts from the Zero-Emission Nuclear Power Production Credit (provision 45U), the Credit for the Production of Clean Hydrogen (provision 45V), and the Advanced Manufacturing Production Tax Credit (45X).

and Air Toxics Standards (MATS), CWA section 316(b) rule, and the final 2015 CCR rule and CCR Part A rule, among others (U.S. EPA, 2023a). The reference case also includes the effects of the Regional Greenhouse Gas Initiative (RGGI), California's Global Warming Solutions Act, Renewable Portfolio Standards state-level policies, including recent Clean Energy Standards (CES) in Illinois, Oregon, Delaware, North Carolina, and Massachusetts (U.S. EPA, 2023a).

In analyzing the effect of Option B using IPM v6, EPA specified incremental capital costs[58] and fixed and variable O&M costs that are estimated to be incurred by steam electric power plants and generating units to comply with the final rule requirements for BA transport water, FGD wastewater, and CRL (in the IPM documentation, these costs are referred to as "cost adders".[59] Compliance costs were developed using the same approach described in Chapter 3, based on the technology options and compliance deadlines for this final rule (see Table 1-1 and Section 3.1.3 for the technology basis and compliance deadlines, respectively). As described in Section 3.1.3 for the screening analysis, the IPM analysis assumes an implementation year based on the compliance deadline and each plant's expected permit renewal year. EPA ran IPM to simulate the dispatch of electricity generating units that would meet demand at the lowest costs subject to the same constraints as those present in the analysis baseline. Within this optimization framework, IPM provides generating units the option to retrofit or retire a portion or all of the unit's capacity, depending on the specified unit operating costs, which include ELG compliance costs.

The rest of this chapter is organized as follows:

- Section 5.1 summarizes the key inputs to IPM and the key outputs reviewed as indicators of the effect of the final rule.
- Section 5.2 provides the findings from the market model analysis.
- Section 5.3 discusses the effects of the final rule on new coal capacity.
- Section 5.4 identifies key uncertainties and limitations in the market model analysis.

5.1 Model Analysis Inputs and Outputs

To assess the impact of the final rule, EPA compared the policy run (Option B) to an IPM v6 Baseline projection of electricity markets and plant operations that includes the modeled effects of the 2020 rule, among existing environmental regulations.

5.1.1 Analysis Years

As described in U.S. EPA (2023a), IPM v6 models the electric power market over the 34-year period from 2028 to 2059, breaking this period into the seven representative run years shown in Table 5-1. As discussed in Chapter 1, steam electric power plants are estimated to implement control technologies to meet the regulatory option requirements starting in 2025 and no later than December 2029. This

58 Capital costs are represented as the net present value of levelized stream of annual capital outlays and were specified in terms of the expected useful life of the capital outlay (20 years) using IPM's real discount rate for all expenditures (3.76 percent; see Chapter 10 in the IPM documentation [ibid.] for more information on IPM's financial discount rate).

59 The costs modeled in IPM do not include compliance costs associated with legacy wastewater or CRL discharged via groundwater.

technology implementation window primarily falls within the time period captured by the 2028 run year. The 2050 run year captures the last year in the analysis period (2049).

Table 5-1: IPM Run Years

Run Year	Years Represented
2028	2028
2030	2029-2031
2035	2032-2037
2040	2038-2042
2045	2043-2047
2050	2048-2052
2055	2053-2059

Source: U.S. EPA, 2023a

To assess the effect of the final rule on electricity markets during the period *after* technology implementation by *all* steam electric power plants – the *steady state* post-compliance period – EPA analyzed detailed results reported for the IPM 2035 run year. The Agency also analyzed results summarized at the level of the overall electricity market for the other run years. As discussed in Chapter 3, under the final rule specifications considered for this analysis, this *steady state* period is estimated to begin in the first year following the technology implementation window, *i.e.*, 2030, and continue into the future. Because the model run year 2035 captures decisions made through the end of 2031, by which time all plants will have achieved the revised limitations and standards, EPA determined that 2035 is an appropriate run year to capture steady-state regulatory effects. Effects that may occur during the post-compliance "steady state" include potential *permanent* changes in generating capacity from changes in early retirement (closure) of generating units,[60] *long-term* changes in electricity production costs due to changes in operating expenses, *permanent* changes in electric generating capability and production efficiency at steam electric power plants, and, as described above, changes in dispatches of other generating units resulting from the changes in electric generating capacity.

5.1.2 Key Inputs to IPM V6 for the Market Model Analysis of the Final Rule

5.1.2.1 Existing Plants

The inputs for the electricity market analyses include compliance costs and the technology implementation year. IPM models the entire electric power generating industry using a total of 20,239 generating units at 8,980 plants. EPA estimated that 105 steam electric power plants may incur non-zero compliance costs under Option B, based on the costing methodologies described in the TDD (U.S. EPA, 2024e) and timing of any announced retirements and repowerings relative to compliance deadlines.

EPA input the final rule capital and O&M costs (including costs incurred on a non-annual, periodic basis such as every 5 years or every 10 years) into IPM as capital and fixed O&M (FOM) cost adders that

60 Early retirement of generating units reflects reductions in generating capacity relative to the baseline and relative to any scheduled retirements.

represent an incremental annual charge for operating the relevant EGUs.[61] The capital costs were annualized using IPM's conventional framework for recognizing costs incurred over time, assuming a capital recovery period of 15 years.[62] Annualized capital cost and FOM cost adders are represented in IPM as incremental costs specific to individual model plants and begin in the same technology implementation years discussed in Chapter 3.

5.1.2.2 New Capacity

EPA did not specify ELG compliance costs for new coal capacity. IPM projections include new generating capacity as needed to meet demand. As described below, IPM projects no new coal capacity under the baseline or under Option B.

5.1.3 Key Outputs of the Market Model Analysis Used in Assessing the Effects of the Final Rule

IPM generates a series of outputs at different levels of aggregation (model plant, region, and nation). For this analysis, EPA used a subset of the available IPM output for each model run (baseline and Option B), focusing on metrics that quantify projected changes in capacity (including early retirements[63] and new capacity), generation, production costs, electricity prices, and emissions. See U.S. EPA (2023a) for descriptions of the IPM variables.

EPA compared national-level outputs for IPM run years (2028, 2030, 2035, 2040, 2045, and 2050). EPA then looked at changes in more detailed regional and plant-level outputs for the 2035 run year. Comparison of these outputs for the baseline and Option B provides insight into the incremental effect of the final rule on steam electric power plants and the broader electric power markets.[64]

5.2 Findings from the Market Model Analysis

The impacts of the final rule are assessed as the difference between key economic and operational impact metrics that compare the results for Option B to the baseline. This section presents two sets of analysis:

61 There were no variable O&M (VOM) cost adders for the final rule.

62 IPM seeks to minimize the total, discounted net present value, of the costs of meeting demand, accounting for power operation constraints, and environmental regulations over the entire planning horizon. These costs include the cost of any new plant, pollution control construction, fixed and variable operating and maintenance costs, and fuel costs. As described in the IPM documentation, "*Capital costs in IPM's objective function are represented as the net present value of levelized stream of annual capital outlays, not as a one-time total investment cost. The payment period used in calculating the levelized annual outlays never extends beyond the model's planning horizon: it is either the book life of the investment or the years remaining in the planning horizon, whichever is shorter. This approach avoids presenting artificially lower capital costs for investment decisions taken closer to the model's time horizon boundary simply because some of that cost would typically be serviced in years beyond the model's view. This treatment of capital costs ensures both realism and consistency in accounting for the full cost of each of the investment options in the model.*" (U.S. Environmental Protection Agency. (2023a). *Documentation for EPA's Power Sector Modeling Platform v6 Using the Integrated Planning Model Post-IRA 2022 Reference Case*. Retrieved from **https://www.epa.gov/system/files/documents/2023-03/EPA%20Platform%20v6%20Post-IRA%202022%20Reference%20Case.pdf**, page 2-7).

63 Early retirement refers to the retirement of an EGU before its planned or previously announced retirement year.

64 IPM output also includes total fuel usage, which is not part of the analysis discussed in this Chapter.

- *Analysis of national-level impacts*: EPA compared baseline and Option B IPM results reported for a series of run years to provide insight on the direction and magnitude of market-level changes attributable to the final rule over time.

- *Analysis of long-term regulatory impacts*: As discussed earlier, to assess the long-term impact of the final rule, EPA compared baseline and Option B IPM results reported for 2035. These results provide insight on the effect of the final rule both for the entire electricity market and for steam electric power plants specifically.

5.2.1 National-level Analysis Results for Model Years 2028-2050

Table 5-2 shows baseline values of total system costs, wholesale electricity price, total existing capacity, new capacity, plant retirements, and generation mix at the national-level based on IPM results for the baseline (*i.e.*, without the final rule). The baseline projections show a decline in total coal generation capacity during the period (from 105.8 GW in 2028 to 28.4 GW in 2050; 73 percent reduction) and nuclear generation capacity (from 93.6 GW in 2028 to 45.4 GW in 2050; 51 percent reduction), and increases in generation capacity from renewables and natural gas. These projections are consistent with the market trends discussed in Section 2.3. Table 5-3 provides incremental changes in these measures for Option B relative to the baseline (negative values represent decreases relative to the baseline). Note that while the table includes projections for the 2050 run year, the represented period (2048-2052) includes years 2050-2052 outside of the analysis period EPA used in its analysis of the social costs and benefits, which covers 2025 through 2049.

Table 5-2: Baseline Projections, 2028-2050

Economic Measures	Baseline					
	2028	2030	2035	2040	2045	2050
Total Costs						
Total Costs (million 2023$)	$128,379	$134,505	$138,325	$142,675	$154,477	$164,934
Prices						
National Wholesale Electricity Price (mills/kWh)	34.50	39.71	32.77	31.52	26.46	34.16
Total Capacity (Cumulative GW)						
Renewables[a]	496.5	543.8	805.8	1,055.3	1,344.2	1,368.9
Coal	105.8	85.0	51.6	42.4	29.6	28.4
Nuclear	93.6	90.9	83.7	79.1	64.8	45.4
Natural Gas	471.0	478.6	476.0	516.1	565.6	673.5
Oil/Gas Steam	62.6	64.3	55.3	54.2	53.9	52.3
Other[c]	53.2	65.1	120.1	146.0	182.9	184.0
Grand Total	**1,282.7**	**1,327.7**	**1,592.4**	**1,893.0**	**2,241.2**	**2,352.5**
New Capacity (Cumulative GW)[b]						
Renewables[a]	78.9	126.2	388.4	637.9	926.8	951.5
Coal	0.0	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas	33.8	41.8	41.7	82.6	148.9	268.8
Other[c]	16.6	28.6	83.5	109.4	146.4	147.4
Grand Total	**129.3**	**196.6**	**513.6**	**830.0**	**1,222.1**	**1367.7**
Retirements (Cumulative GW)						
Combined Cycle	0.8	0.8	2.1	2.7	8.7	16.2
Coal	37.8	56.7	83.7	93.0	105.7	106.9

Table 5-2: Baseline Projections, 2028-2050

Economic Measures	Baseline					
	2028	2030	2035	2040	2045	2050
Combustion Turbine	0.5	0.9	2.2	2.4	13.2	17.6
Nuclear	0.0	2.7	9.9	14.5	28.7	48.2
Oil/Gas	12.4	12.4	22.7	23.7	24.0	25.6
Other[c]	3.0	3.0	3.1	3.2	3.2	3.2
Grand Total	**54.4**	**76.5**	**123.7**	**139.4**	**183.4**	**217.7**
Generation Mix (thousand GWh)[d]						
Renewables[a]	1,433.5	1,626.9	2,548.3	3,432.4	4,375.7	4,438.4
Coal	472.4	409.6	235.7	136.8	48.5	99.6
Nuclear	751.1	729.1	667.0	614.4	470.8	351.7
Natural Gas	1,652.0	1,670.3	1,344.4	936.5	616.8	870.7
Oil/Gas Steam	25.5	24.5	7.7	4.9	4.5	4.5
Other[c]	83.4	99.4	178.4	223.1	309.0	315.1
Grand Total	**4,418.0**	**4,559.9**	**4,981.4**	**5,348.1**	**5,825.3**	**6,079.9**

a. Renewables include hydropower and non-hydropower renewables.

b. Reported values for new generation capacity include new modeled capacity and new hardwired capacity.

c. Values for energy storage are reported in the "Other" category.

d. Electricity generation reported in this table does not include generation from distributed solar photovoltaic and differs from generation reported later in Table 5-4, which does include this source.

Source: U.S. EPA Analysis, 2024.

Table 5-3: Incremental National Impact of Final Option B Relative to Baseline, 2028-2050

Economic Measures	Option B Changes Relative to Baseline					
	2028	2030	2035	2040	2045	2050
Total Costs						
Total Costs (million 2023$)	$31	$670	$219	$355	-$16	$47
Prices						
National Wholesale Electricity Price (mills/kWh)	0.08	0.53	0.05	0.00	-0.02	-0.02
Total Capacity (Cumulative GW)						
Renewables[a]	1.8	2.1	2.2	1.1	-0.3	-0.3
Coal	-4.8	-5.6	-5.6	-1.1	-0.1	-0.1
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas	3.6	3.9	4.2	1.1	0.2	0.3
Oil/Gas Steam	-0.2	-0.2	-0.1	-0.1	-0.1	-0.1
Other[c]	0.1	0.1	1.4	0.2	0.0	0.0
Grand Total	**0.5**	**0.3**	**2.1**	**1.1**	**-0.4**	**-0.2**
New Capacity (Cumulative GW)[b]						
Renewables[a]	1.8	2.1	2.2	1.1	-0.3	-0.3
Coal	0.0	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas	3.5	3.9	4.2	1.1	0.2	0.3
Other[c]	0.1	0.1	1.4	0.2	0.0	0.0
Grand Total	**5.4**	**6.0**	**7.9**	**2.3**	**-0.1**	**0.0**
Retirements (GW)						
Combined Cycle	0.0	0.0	0.0	0.0	0.0	0.0

Table 5-3: Incremental National Impact of Final Option B Relative to Baseline, 2028-2050						
Economic Measures	Option B Changes Relative to Baseline					
	2028	2030	2035	2040	2045	2050
Coal	4.8	5.6	6.0	1.5	0.5	0.5
Combustion Turbine	0.0	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0
Oil/Gas	0.2	0.2	0.1	0.1	0.1	0.1
Other[c]	0.0	0.0	0.0	0.0	0.0	0.0
Grand Total	**4.9**	**5.7**	**6.1**	**1.6**	**0.6**	**0.6**
Generation Mix (thousand GWh)						
Renewables[a]	5.8	5.6	6.6	3.6	-0.3	-0.1
Coal	-18.1	-10.6	-21.2	-6.7	-1.1	-0.7
Nuclear	0.0	0.0	0.0	0.4	0.3	0.0
Natural Gas	12.6	6.3	14.9	2.4	1.2	1.0
Oil/Gas Steam	-1.0	-1.7	-0.6	0.0	-0.1	-0.1
Other[c]	0.2	0.2	2.1	0.0	0.0	-0.3
Grand Total	**-0.5**	**-0.3**	**1.7**	**-0.3**	**0.1**	**0.0**

a. Renewables include hydropower and non-hydropower renewables.

b. Reported values for new generation capacity includes new modeled capacity and new hardwired capacity.

c. Values for energy storage are reported in the "Other" category.

Source: U.S. EPA Analysis, 2024.

5.2.1.1 Findings for the Final Rule

Under Option B, total costs to electric power plants are projected to be greater than the baseline from 2028 to 2040. The increases in costs are greatest in the early years of the modeling period (*e.g.*, by $670 million in 2030), which is consistent with the timing of steam electric ELG implementation. IPM projects small increases in wholesale electricity prices in 2028 through 2040 with an increase of 0.53 mills per kWh in 2030 relative to a baseline price of $40 mills/kWh. IPM projects no change or small decreases in wholesale electricity prices in 2040 to 2050 with decreased of 0.02 mills per kWh in 2045 and 2050 relative to the baseline prices of 26 and 34 mills/kWh, respectively.

Looking at results for total capacity by energy source, coal capacity is estimated to decrease for all years from 2028 to 2050, adding to the already significant reductions projected in the baseline. Meanwhile, smaller decreases in capacity from oil/gas steam (0.1 to 0.2 GW), and greater increases in natural gas capacity (0.2 to 4.2 GW) are estimated to occur from 2028 to 2050. Capacity from renewables is estimated to increase during 2028 to 2040 but decrease during 2045 to 2050.

Additional coal retirements are estimated for all years, ranging between 0.5 to 6.0 GW of the 37.8 to 106.9 GW estimated to retire in the baseline. This accounts for most of the incremental retirements in the electric market as a whole (for Option B relative to the baseline), which range between 0.6 to 6.1 GW. Additional oil/gas steam retirements are also estimated for all years, ranging between 0.1 to 0.2 GW above retirements estimated in the baseline.

Lastly, examining results for generation by energy source, generation from coal is estimated to decrease for all years from 2028 to 2050 by 0.7 to 18.1 thousand GWh, with the largest declines occurring in the first few years. These changes are offset in part by an increase in natural gas generation (1.0 to

14.9 thousand GWh increase), nuclear generation (up to 0.4 thousand GWh increase), and generation by renewables, which increases between 2028 and 2040 by 3.6 to 6.6 thousand GWh.

5.2.2 Detailed Analysis Results for Model Year 2035

In the following results which reflect conditions for model year 2035 (2032 through 2037), all plants are estimated to meet the revised BAT limits and pretreatment standards associated with the final rule (Option B). For this more detailed analysis, following the approach used for the 2015, 2020, and proposed 2023 rules (U.S. EPA, 2015, 2020, 2023d), EPA used parsed IPM outputs and considered impact metrics of interest at three levels of aggregation:

- Impact on national and regional electricity markets (Section 5.2.2.1),
- Impact on steam electric power plants as a group (Section 5.2.2.2), and
- Impact on individual steam electric power plants (Section 5.2.2.3).

5.2.2.1 Impact on National and Regional Electricity Markets

The market-level analysis assesses national and regional changes as a result of the regulatory requirements. EPA analyzed six measures:

- *Changes in available capacity*: This measure analyzes changes in the nameplate capacity available to generate electricity. A long-term reduction in available capacity may result from partial or full closures of steam electric power plants. Conversely, increased capacity may result from *avoided* partial or full closure of the plants or the addition of new capacity. Only capacity that is projected to remain operational in the baseline case but is closed in the policy case is considered a closure attributable to the final rule. The model may project partial (*i.e.*, unit) or full plant early retirements (closures) for the final rule. It may also project partial or full avoided closures in which a unit or plant that is estimated to close in the baseline is estimated to continue operation in the policy case. Avoided closures may occur, in particular, when the regulation results in lower costs for a given plant.
- *Changes in the wholesale price of electricity*: This measure represents the change in the annual average energy price (the marginal cost of meeting demand in each time segment, averaged annually) plus any capacity prices associated with maintaining a reserve margin. In the long term, electricity prices may change as a result of changes in generation costs at steam electric power plants or due to generating unit and/or plant closures.
- *Changes in generation*: This measure considers the amount of electricity generated. At a regional level, long-term changes in generation may result from plant closures or a change in the amount of electricity traded between regions. The quantity of electricity demanded does not change between the baseline and the final rule because meeting demand is an exogenous constraint imposed by the model. However, the quantity of electricity demanded for electricity does vary across the modeling horizon according to the model's underlying electricity demand growth assumptions.

- *Changes in costs*: This measure considers changes in the overall cost of generating electricity, including fuel costs, variable and fixed O&M costs, capital costs, and carbon capture and storage (CCS) costs. These costs are not limited to steam electric generating units or to compliance costs of the final rule, but more broadly reflect changes in the cost of generating electricity across all units. Fuel costs and variable O&M costs are production costs that vary with the level of generation. Fuel costs generally account for the single largest share of production costs. Fixed O&M costs and capital costs do not vary with generation. They are fixed in the short-term and therefore do not affect the dispatch decision of a unit (given sufficient demand, a unit will dispatch as long as the price of electricity is at least equal to its per MWh production costs). However, in the long-run, these costs need to be recovered for a unit to remain economically viable.

- *Changes in average variable production costs per MWh*: This measure considers the change in average variable production cost per MWh. Variable production costs are a subset of the costs in the bullet above and include fuel costs and other variable O&M costs but exclude fixed O&M costs and capital costs. Production cost per MWh is a primary determinant of how often a generating unit is dispatched. This measure presents similar information to total fuel and variable O&M costs, but normalized for changes in generation between the baseline and policy case.

- *Changes in CO_2, NOx, SO_2, Hg, and HCL emissions*: This measure considers the change in emissions resulting from electricity generation, for example due to changes in the fuel mix. Compliance with the final rule is estimated to increase generation costs when compared to the baseline and make electricity generated by some steam electric units more expensive compared to that generated at other steam electric or non-steam electric units. These changes may in turn result in changes in air pollutant emissions, depending on the emissions profile of dispatched units. Projected changes in air emissions are used as inputs for the analysis of air-related benefits of the final rule (see Chapter 8 in the BCA (U.S. EPA, 2024a)).

Table 5-4 summarizes IPM results for the final rule at the level of the national market and also for regional electricity markets defined on the basis of NERC regions. All of the impact metrics described above are reported at both the national and NERC level except electricity prices, which are calculated in IPM only at the regional level (*i.e.*, not aggregated to national level). Differences in the relative magnitude of impacts across the NERC regions largely reflect regional differences in the number of plants incurring costs and the magnitude of these costs for the final rule as compared to the baseline and the generation mix.

Table 5-4: Impact of Final Rule on National and Regional Markets in the Year 2035

Economic Measures (all dollar values in 2023$)	Baseline Value	Option B		
		Value	Difference	% Change
National Totals				
Total Domestic Capacity (GW)	1,712	1,718	6.4	0.4%
Existing			-1.5	-0.1%
New Additions			7.9	0.5%
Early Retirements			1.5	0.1%
Wholesale Price ($/MWh)	$32.77	$32.82	$0.05	0.1%
Generation (TWh)	5,158	5,160	1.7	0.0%

Table 5-4: Impact of Final Rule on National and Regional Markets in the Year 2035

Economic Measures (all dollar values in 2023$)	Baseline Value	Option B Value	Option B Difference	Option B % Change
Costs ($Millions)	$138,325	$138,544	$219	0.2%
Fuel Cost	$39,166	$38,975	-$191	-0.5%
Variable O&M	$5,351	$5,244	-$107	-2.0%
Fixed O&M	$65,915	$65,666	-$249	-0.4%
Capital Cost	$34,149	$34,536	$387	1.1%
CCS Cost[b]	-$6,256	-$5,878	$379	-6.1%
Average Variable Production Cost ($/MWh)	$8.63	$8.57	-$0.06	-0.7%
CO_2 Emissions (Million Metric Tons)	724	713	-11.6	-1.6%
Mercury Emissions (Tons)	2	2	-0.050	-2.0%
NO_X Emissions (Million Tons)	0	0	-0.009	-3.4%
SO_2 Emissions (Million Tons)	0	0	-0.013	-5.3%
HCL Emissions (Million Tons)	0	0	-0.00012	-8.1%
Midwest Reliability Organization (MRO)				
Total Domestic Capacity (GW)	224	228	3.9	1.8%
Existing			2.4	1.1%
New Additions			1.5	0.7%
Early Retirements			-2.4	-1.1%
Wholesale Price ($/MWh)	$25.88	$25.83	-$0.05	-0.2%
Generation (TWh)	641	642	1	0.2%
Costs ($Millions)	$11,368	$11,469	$101	0.9%
Fuel Cost	$1,627	$1,578	-$49	-3.0%
Variable O&M	$292	$286	-$6	-1.9%
Fixed O&M	$7,076	$7,137	$61	0.9%
Capital Cost	$3,835	$3,929	$94	2.5%
CCS Cost[b]	-$1,462	-$1,461	$0	0.0%
Average Variable Production Cost ($/MWh)	$2.99	$2.90	-$0.09	-3.0%
CO_2 Emissions (Million Metric Tons)	53	52	-1.526	-2.9%
Mercury Emissions (Tons)	1	1	-0.002	-0.4%
NO_X Emissions (Million Tons)	0	0	-0.001	-2.3%
SO_2 Emissions (Million Tons)	0	0	-0.0004	-0.7%
HCL Emissions (Million Tons)	0	0	-0.000005	-1.4%
Northeast Power Coordinating Council (NPCC)				
Total Domestic Capacity (GW)	128	129	0.9	0.7%
Existing			1.0	0.8%
New Additions			0.0	0.0%
Early Retirements			-1.0	-0.8%
Wholesale Price ($/MWh)	$32.99	$32.91	-$0.086	-0.3%
Generation (TWh)	346	346	0	0.0%
Costs ($Millions)	$11,078	$11,073	-$6	-0.1%
Fuel Cost	$1,682	$1,678	-$4	-0.3%
Variable O&M	$283	$283	$0	-0.1%
Fixed O&M	$5,068	$5,071	$3	0.1%
Capital Cost	$4,044	$4,041	-$3	-0.1%
CCS Cost[b]	$0	$0	$0	NA
Average Variable Production Cost ($/MWh)	$5.68	$5.67	-$0.01	-0.2%
CO_2 Emissions (Million Metric Tons)	33	33	-0.108	-0.3%
Mercury Emissions (Tons)	0	0	0.000	0.0%

Table 5-4: Impact of Final Rule on National and Regional Markets in the Year 2035				
Economic Measures (all dollar values in 2023$)	Baseline Value	Option B		
		Value	Difference	% Change
NO_X Emissions (Million Tons)	0	0	-0.0001	-0.3%
SO_2 Emissions (Million Tons)	0	0	0.000	0.0%
HCL Emissions (Million Tons)	0	0	0.000	0.0%
Reliability First Corporation (RF)				
Total Domestic Capacity (GW)	306	306	0.1	0.0%
Existing			-3.6	-1.2%
New Additions			3.7	1.2%
Early Retirements			3.6	1.2%
Wholesale Price ($/MWh)	$31.99	$32.09	$0.10	0.3%
Generation (TWh)	1,039	1,039	0	0.0%
Costs ($Millions)	$30,899	$30,865	-$34	-0.1%
Fuel Cost	$9,702	$9,647	-$55	-0.6%
Variable O&M	$1,389	$1,318	-$71	-5.1%
Fixed O&M	$14,505	$14,294	-$211	-1.5%
Capital Cost	$6,402	$6,707	$305	4.8%
CCS Cost[b]	-$1,099	-$1,101	-$2	0.2%
Average Variable Production Cost ($/MWh)	$10.67	$10.56	-$0.12	-1.1%
CO_2 Emissions (Million Metric Tons)	192	183	-9.031	-4.7%
Mercury Emissions (Tons)	0	0	-0.027	-8.0%
NO_X Emissions (Million Tons)	0	0	-0.005	-8.5%
SO_2 Emissions (Million Tons)	0	0	-0.008	-13.3%
HCL Emissions (Million Tons)	0	0	-0.00007	-17.5%
Southeast Electric Reliability Council (SERC)				
Total Domestic Capacity (GW)	448	449	1.0	0.2%
Existing			-1.6	-0.3%
New Additions			2.5	0.6%
Early Retirements			1.6	0.3%
Wholesale Price ($/MWh)	$33.14	$33.25	$0.11	0.3%
Generation (TWh)	1,534	1,535	1	0.0%
Costs ($Millions)	$46,339	$46,488	$149	0.3%
Fuel Cost	$17,681	$17,604	-$77	-0.4%
Variable O&M	$2,045	$2,016	-$29	-1.4%
Fixed O&M	$20,546	$20,441	-$105	-0.5%
Capital Cost	$8,656	$8,638	-$17	-0.2%
CCS Cost[b]	-$2,589	-$2,212	$377	-14.6%
Average Variable Production Cost ($/MWh)	$12.86	$12.78	-$0.07	-0.6%
CO_2 Emissions (Million Metric Tons)	267	266	-0.6565	-0.2%
Mercury Emissions (Tons)	0	0	-0.0202	-4.8%
NO_X Emissions (Million Tons)	0	0	-0.0029	-3.3%
SO_2 Emissions (Million Tons)	0	0	-0.0037	-4.7%
HCL Emissions (Million Tons)	0	0	-0.00005	-13.1%
Texas Reliability Entity (TRE)				
Total Domestic Capacity (GW)	201	201	0.04	0.0%
Existing			0.02	0.0%
New Additions			0.03	0.0%
Early Retirements			-0.02	0.0%
Wholesale Price ($/MWh)	$28.02	$28.03	$0.0124	0.0%

Table 5-4: Impact of Final Rule on National and Regional Markets in the Year 2035

Economic Measures (all dollar values in 2023$)	Baseline Value	Option B		
		Value	Difference	% Change
Generation (TWh)	507	507	0.09	0.0%
Costs ($Millions)	$11,258	$11,260	$2	0.0%
Fuel Cost	$1,518	$1,517	-$1	-0.1%
Variable O&M	$194	$193	$0	-0.2%
Fixed O&M	$7,180	$7,181	$1	0.0%
Capital Cost	$2,903	$2,902	-$1	-0.1%
CCS Cost[b]	-$537	-$534	$3	-0.6%
Average Variable Production Cost ($/MWh)	$3.38	$3.37	$0.00	-0.1%
CO_2 Emissions (Million Metric Tons)	37	37	-0.0271	-0.1%
Mercury Emissions (Tons)	0	0	-0.0001	-0.1%
NO_X Emissions (Million Tons)	0.01143	0.01143	0.000007	0.1%
SO_2 Emissions (Million Tons)	0.00861	0.00856	-0.0001	-0.6%
HCL Emissions (Million Tons)	0.00010	0.00010	-0.0000002	-0.2%
Western Electricity Coordinating Council (WECC)				
Total Domestic Capacity (GW)	406	406	0.4	0.1%
Existing			0.3	0.1%
New Additions			0.2	0.0%
Early Retirements			-0.3	-0.1%
Wholesale Price ($/MWh)	$39.03	$39.04	$0.014	0.0%
Generation (TWh)	1,091	1,092	0	0.0%
Costs ($Millions)	$27,383	$27,389	$6	0.0%
Fuel Cost	$6,956	$6,951	-$5	-0.1%
Variable O&M	$1,148	$1,147	-$1	-0.1%
Fixed O&M	$11,539	$11,542	$2	0.0%
Capital Cost	$8,309	$8,319	$10	0.1%
CCS Cost[b]	-$570	-$570	$0	0.0%
Average Variable Production Cost ($/MWh)	$7.43	$7.42	-$0.01	-0.1%
CO_2 Emissions (Million Metric Tons)	142	142	-0.2301	-0.2%
Mercury Emissions (Tons)	1	1	0.0000	0.0%
NO_X Emissions (Million Tons)	0	0	-0.00003	-0.1%
SO_2 Emissions (Million Tons)	0	0	-0.0002	-0.6%
HCL Emissions (Million Tons)	0	0	0.0000	0.0%

a. Numbers may not add up due to rounding.

b. The "CCS Cost" is the cost of CO2 transportation and storage and also includes expenses on equipment and pipelines, as well as the total value of 45Q tax credits and enhanced oil recovery (EOR) revenues. In the baseline and under Option B, the total private costs are negative because the sum of the tax credits and EOR revenues exceed the equipment and pipeline costs of CO2 storage. Under Option B, total CCS Costs are less negative, and therefore these costs increase relative to the baseline, as the total amount of the 45Q tax credit received by the sector and/or EOR revenues fall due to lower coal generation.

Source: U.S. EPA Analysis, 2024.

5.2.2.1.1 Findings for Regulatory Option B

As reported in Table 5-4, the Market Model Analysis indicates that the final rule can be expected to have small effects on the electricity market, relative to the baseline, on both a national and regional sub-market basis, in the year 2035.

At the national level, total annual costs increase by an estimated $219 million (approximately 0.2 percent) relative to the baseline. Total annual costs vary by region and are estimated to increase in the MRO, SERC, and WECC regions and decrease in the NPCC, RF, and TRE. Total costs in the SERC region change by the largest amount with an increase of $149 million (0.5 percent), followed by the MRO region with an increase of $101 million (0.8 percent); changes in estimated total annual costs in the other regions range between $6 million (WECC) and -$34 million (RF). Overall, at the national level, the net change in total capacity, including decreases in existing capacity (which includes early retirements) and reductions in new plants/units, is an increase of approximately 6.4 GW in capacity, which is 0.4 percent of total market capacity. Overall, the final rule is estimated to have a minimal effect on capacity availability and supply reliability across the regions and at the national level. The net capacity increase is a result of an increases in capacity in the SERC region of 1 GW and the MRO region of 3.9 GW (0.2 and 1.8 percent of total market capacity in those regions, respectively) due to greater increases of new capacity additions and existing capacity that more than offset decreases from early retirements. Overall impacts on wholesale electricity prices are similarly minimal. Wholesale electricity prices are estimated to increase in the RF, SERC, TRE, and WECC regions with decreases in the MRO and NPCC regions. Price changes in individual regions range from $0.09 per MWh (0.3 percent) in NPCC to $0.10 per MWh 0.3 percent) in RF. Finally, at the national level, total costs are estimated to increase by $0.05 (approximately 0.1 percent).

At the national level in the year 2035, there are decreases in emissions among all air pollutants modeled. NO_x emissions decrease by 3.4 percent; SO_2 emissions decrease by 5.3 percent; CO_2 emissions decrease by 1.6 percent, mercury emissions decrease by 2 percent; and HCL emissions decrease by 8.1 percent. The impact on emissions varies across regions and by pollutant. Emissions increase in some and decrease in other NERC regions, but the general trend is a decrease in air emissions at the U.S. and regional levels.[65] Furthermore, emission increases modeled in some regions are transient; for example, IPM state-level outputs shows emissions for some pollutants in Texas (part of the TRE NERC region) increasing in some years and decreasing in other years.

5.2.2.2 Impact on Steam Electric Power Plants as a Group

For the analysis of impact on steam electric power plants as a group, EPA used the same IPM v6 results for 2035 used above to analyze the impact on national and regional electricity markets; however, this analysis considers the effect of the final rule on the subset of plants to which the ELGs apply, *i.e.*, steam electric power plants. The purpose of the previously described electricity market-level analysis is to assess the impact of the final rule on the entire electric power sector, *i.e.*, including generators such as combustion turbines, wind or solar to which the ELGs do not apply. By contrast, the purpose of this analysis is to assess the impact of the final rule specifically on steam electric power plants. The analysis results for the group of steam electric power plants overall show a slightly greater impact on a percentage basis than that observed over *all* generating units in the IPM universe (*i.e.*, market-level analysis discussed in the preceding section [*Impact on National and Regional Electricity Markets*]); this is because, at the market level, impacts on steam electric units are offset by changes in capacity and energy production in the non-steam electric units.

65 The changes in emissions only accounts for changes in the profile of electricity generation, and do not include emissions associated with transportation or auxiliary power, which EPA analyzed separately (see TDD for details).

The metrics of interest are largely the same as those presented above in assessing the effect of the final rule on the aggregate of the 688 steam electric power plants explicitly represented in IPM (as opposed to additional steam electric power plants that were not surveyed by EPA in the Steam Electric Survey [see U.S. EPA, 2015]).[66] In addition, a few measures differ: (1) new market-wide capacity additions and prices are not relevant at the level of steam electric power plants, (2) changes in emissions at only the 688 steam electric power plants provide incomplete insight for the overall estimated effect of the rule on emissions and are therefore not presented, and (3) the number of steam electric power plants with projected closure (or avoided closure) is presented.

The following four measures are reported in the analysis of steam electric power plants as a group. In all instances, the measures are tabulated for 688 steam electric power plants explicitly included in EPA's Steam Electric Survey and analyzed in the Market Model Analysis (note that steam electric power plants not included in the tabulation incur no compliance costs for the options EPA analyzed in IPM or are retired and not represented in IPM):

- *Changes in available capacity*: These changes are defined in the same way as in the preceding section (Impact on National and Regional Electricity Markets), with the exception of the units used (MW).
- *Changes in generation*: Long-term changes in generation may result from either changes in available capacity (see discussion above) or in the dispatch of a plant due to changes in production cost resulting from compliance response.
- *Changes in costs*: These changes are defined in the same way as in the preceding section (Impact on National and Regional Electricity Markets).
- *Changes in variable production costs per MWh*: These changes are defined in the same way as in the preceding section (Impact on National and Regional Electricity Markets).

Table 5-5 reports results of the Market Impact Analysis for steam electric power plants, as a group.

The impacts of the final rule on steam electric power plants differ from the total market impacts as these plants become less competitive compared to plants that see no production cost increases under the final rule. As a result, capacity and generation impacts are greater for this set of plants than for the entire electricity market, relative to the baseline, but absolute differences are still small. As described above for the market-level analysis, those impacts vary across the NERC regions.

66 There are 688 steam electric power plants that were surveyed by EPA in the Steam Electric Survey and are represented in IPM. EPA estimates that there are 858 plants in the total steam electric power generating industry, calculated on a sample-weighted basis. For details on sample weights, see TDD.

Table 5-5: Impact of the Final Rule on In-Scope Plants, as a Group, in the Year 2035[a]				
Economic Measures (all dollar values in 2023$)	Baseline Value	Option B		
		Value	Difference	% Change
National Totals				
Total Domestic Capacity (MW)	220,237	214,455	-5,782	-2.6%
Early Retirements – Number of Plants	78	83	5	6.4%
Full & Partial Retirements – Capacity (MW)	104,544	110,326	5,782	5.5%
Generation (GWh)	789,529	765,950	-23,579	-3.0%
Costs ($Millions)	$28,580	$27,740	-$840	-2.9%
Fuel Cost	$13,957	$13,454	-$503	-3.6%
Variable O&M	$1,976	$1,840	-$136	-6.9%
Fixed O&M	$15,419	$15,041	-$378	-2.5%
Capital Cost	$3,202	$3,000	-$202	-6.3%
CCS Cost[b]	-$5,974	-$5,595	$379	-6.3%
Average Variable Production Cost ($/MWh)	$20.18	$19.97	-$0.21	-1.1%
Midwest Reliability Organization (MRO)				
Total Domestic Capacity (MW)	27,018	27,018	0	0.0%
Early Retirements – Number of Plants	25	26	1	4.0%
Full & Partial Retirements – Capacity (MW)	21,954	21,954	0	0.0%
Generation (GWh)	69,410	68,117	-1,293	-1.9%
Costs ($Millions)	$2,400	$2,399	-$1	0.0%
Fuel Cost	$1,156	$1,129	-$27	-2.3%
Variable O&M	$192	$189	-$3	-1.7%
Fixed O&M	$1,671	$1,704	$33	2.0%
Capital Cost	$842	$837	-$4	-0.5%
CCS Cost[b]	-$1,462	-$1,461	$0	0.0%
Average Variable Production Cost ($/MWh)	$19.43	$19.36	-$0.07	-0.4%
Northeast Power Coordinating Council (NPCC)				
Total Domestic Capacity (MW)	7,626	7,626	0	0.0%
Early Retirements – Number of Plants	2	2	0	0.0%
Full & Partial Retirements – Capacity (MW)	2,709	2,709	0	0.0%
Generation (GWh)	18,184	18,131	-53	-0.3%
Costs ($Millions)	$857	$856	-$1	-0.1%
Fuel Cost	$242	$241	-$1	-0.4%
Variable O&M	$24	$24	$0	-0.5%
Fixed O&M	$591	$591	$0	0.0%
Capital Cost	$0	$0	$0	NA
CCS Cost[b]	$0	$0	$0	NA
Average Variable Production Cost ($/MWh)	$14.64	$14.62	-$0.02	-0.1%
ReliabilityFirst Corporation (RF)				
Total Domestic Capacity (MW)	48,588	44,410	-4,178	-8.6%
Early Retirements – Number of Plants	14	17	3	21.4%
Full & Partial Retirements – Capacity (MW)	24,251	28,429	4,178	17.2%
Generation (GWh)	143,716	130,430	-13,286	-9.2%
Costs ($Millions)	$5,996	$5,387	-$610	-10.2%
Fuel Cost	$2,289	$2,043	-$246	-10.8%
Variable O&M	$490	$400	-$90	-18.3%

Table 5-5: Impact of the Final Rule on In-Scope Plants, as a Group, in the Year 2035[a]				
Economic Measures (all dollar values in 2023$)	**Baseline Value**	**Option B**		
		Value	**Difference**	**% Change**
Fixed O&M	$3,737	$3,467	-$271	-7.2%
Capital Cost	$578	$578	-$1	-0.1%
CCS Cost[b]	-$1,099	-$1,101	-$2	0.2%
Average Variable Production Cost ($/MWh)	$19.34	$18.73	-$0.61	-3.1%
Southeast Electric Reliability Council (SERC)				
Total Domestic Capacity (MW)	93,041	91,447	-1,594	-1.7%
Early Retirements – Number of Plants	21	22	1	4.8%
Full & Partial Retirements – Capacity (MW)	38,147	39,741	1,594	4.2%
Generation (GWh)	407,266	398,315	-8,950	-2.2%
Costs ($Millions)	$13,938	$13,706	-$232	-1.7%
Fuel Cost	$7,976	$7,746	-$231	-2.9%
Variable O&M	$939	$896	-$43	-4.6%
Fixed O&M	$6,257	$6,118	-$139	-2.2%
Capital Cost	$1,354	$1,158	-$196	-14.4%
CCS Cost[b]	-$2,589	-$2,212	$377	-14.6%
Average Variable Production Cost ($/MWh)	$21.89	$21.70	-$0.20	-0.9%
Texas Reliability Entity (TRE)				
Total Domestic Capacity (MW)	13,834	13,849	15	0.1%
Early Retirements – Number of Plants	5	5	0	0.0%
Full & Partial Retirements – Capacity (MW)	8,887	8,872	-15	-0.2%
Generation (GWh)	37,973	37,944	-29	-0.1%
Costs ($Millions)	$1,419	$1,420	$1	0.1%
Fuel Cost	$535	$534	-$1	-0.2%
Variable O&M	$70	$70	$0	-0.4%
Fixed O&M	$1,067	$1,068	$1	0.1%
Capital Cost	$282	$281	-$1	-0.4%
CCS Cost[b]	-$537	-$534	$3	-0.6%
Average Variable Production Cost ($/MWh)	$15.95	$15.92	-$0.02	-0.1%
Western Electricity Coordinating Council (WECC)				
Total Domestic Capacity (MW)	30,131	30,105	-26	-0.1%
Early Retirements – Number of Plants	11	11	0	0.0%
Full & Partial Retirements – Capacity (MW)	8,596	8,622	26	0.3%
Generation (GWh)	112,981	113,014	32	0.0%
Costs ($Millions)	$3,971	$3,972	$1	0.0%
Fuel Cost	$1,758	$1,761	$3	0.2%
Variable O&M	$260	$261	$0	0.1%
Fixed O&M	$2,095	$2,093	-$2	-0.1%
Capital Cost	$146	$146	$0	0.0%
CCS Cost[b]	-$288	-$288	$0	0.0%
Average Variable Production Cost ($/MWh)	$17.86	$17.89	$0.03	0.1%

a. Numbers may not add up due to rounding.

b. The "CCS Cost" is the cost of CO_2 transportation and storage and also includes expenses on equipment and pipelines, as well as the total value of 45Q tax credits and enhanced oil recovery (EOR) revenues. In the baseline and under Option B, the total private costs are negative because the sum of the tax credits and EOR revenues exceed the equipment and pipeline costs

Table 5-5: Impact of the Final Rule on In-Scope Plants, as a Group, in the Year 2035[a]

Economic Measures (all dollar values in 2023$)	Baseline Value	Option B		
		Value	Difference	% Change
of CO2 storage. Under Option B, total CCS Costs are less negative, and therefore these costs increase relative to the baseline, as the total amount of the 45Q tax credit received by the sector and/or EOR revenues fall due to lower coal generation.				

Source: U.S. EPA Analysis, 2024.

5.2.2.2.1 Findings for the Final Rule (Regulatory Option B) in the 2035 Model Year

Under the final rule, the steam electric capacity is estimated to decrease approximately 2.6 percent.

For the group of steam electric power plants, total capacity decreases by 5,782 MW or approximately 2.6 percent of the 220,237 MW in baseline capacity. This decrease is largely attributable to net decreases in total capacity of 4,178 MW (8.6 percent) and 1,594 MW (1.7 percent) in the RF and SERC regions, respectively. One plant in SERC, one plant in MRO, and three plants in RF are projected to close under the final rule.

The change in total generation is an indicator of how steam electric power plants fare, relative to the rest of the electricity market. While at the market level there is essentially no projected change in total electricity generation,[67] for steam electric power plants, total generation is estimated to decrease by 23,579 GWh (3 percent). RF is projected to experience the largest decrease in generation from steam electric power plants, 13,286 GWh (9.2 percent), with SERC estimated to experience the second largest decrease in generation from steam electric power plants at 8,950 GWh (2.2 percent). Generation from steam electric power plants is estimated to change in the remaining regions by less than <0.1 to -1.9 percent.

The results for the group of steam electric power plants show a net decrease in total costs of $840 million (2.9 percent). Total costs vary be region with the largest decrease in costs coming from the RF region ($610 million; 10.2 percent) followed by the SERC region ($232; 1.7 percent) and the largest increase[68] in costs coming from the WECC and TRE regions ($1 million; <0.1 percent and $1 million; 0.1 percent, respectively). At the national level, variable production costs for steam electric power plants decrease by $0.21 per MWh (1.1 percent). Effects vary by region, with changes ranging from $0.03 per MWh in WECC and TRE to -$0.61 per MWh in RF.

5.2.2.3 Impact on Individual Steam Electric Power Plants

Results *for the group* of steam electric power plants as a whole may mask shifts in economic performance among *individual* steam electric power plants. To assess potential plant-level effects, EPA analyzed the

67 At the national level, the demand for electricity does not change between the baseline and the analyzed regulatory options (generation within the regions is allowed to vary) because meeting demand is an exogenous constraint imposed by the model.

68 While costs decrease under Option B, this does not mean that plant owners would be undertaking changes on their own in the absence of the rule in order to save costs. The values reported in this table are for in-scope plants only. The negative changes follow from the decline in capacity and generation. Individual plants would not necessarily face lower costs than the rest of the market in the absence of the final rule.

distribution of plant-specific changes between the baseline and the final rule for three metrics: capacity utilization,[69] electricity generation, and variable production costs per MWh.[70]

Table 5-6 presents the estimated number of steam electric power plants with specific degrees of change in operations and financial performance as a result of the final rule. In addition to the category of all plants, the table also reports these metrics for plants that incur costs under Option B and plants that incur no costs under Option B separately. Metrics of greatest interest for assessing the adverse impacts of the final rule on steam electric power plants include the number of plants with reductions in capacity utilization or generation (on the left side of the table), and the number of plants with increases in variable production costs (on the right side of the table).

This table excludes steam electric power plants with modeled significant status changes in 2035 that render these metrics of change not meaningful – *i.e.*, a plant is assessed as either a full, partial, or avoided closure in the IPM results for either the baseline or the regulatory option. The measures presented in Table 5-5, such as *change in electricity generation*, are not meaningful for these plants. For example, for a plant that is projected to close in the baseline but avoids closure under the final rule, the percent change in electricity generation relative to baseline cannot be calculated. On this basis, 382 plants are excluded from assessment of effects on individual steam electric power plants under the final rule. In addition, the change in variable production cost per MWh of generation could not be developed for 58 plants with zero generation in either the baseline or under the final rule (because the divisor, MWh, is zero).[71] For *change in variable production cost per MWh*, these plants are recorded in the "N/A" column.

69 Capacity utilization is defined as generation divided by capacity times 8,760 hours.

70 Variable production costs per MWh is defined as variable O&M cost plus fuel cost divided by net generation projected in IPM.

71 In some cases, non-retired plants will be modeled to have zero generation in 2035. These plants may generate electricity in later years.

Table 5-6: Impact of Final Rule on Individual In-Scope Plants in the Year 2035									
	Reduction				Increase				
Economic Measures	> 3%	≥1% and <3%	<1%	No Change	<1%	≥1% and <3%	≥3%	N/A[b,c]	Total
Steam Electric Power Plants that Incur Costs under Option B									
Change in Capacity Utilization[a]	1	0	1	1	2	0	3	27	35
Change in Generation	3	1	0	1	1	0	2	27	35
Change in Variable Production Costs/MWh	0	0	4	0	4	0	0	27	35
Steam Electric Power Plants that Incur No Costs under Option B									
Change in Capacity Utilization[a]	10	6	45	196	34	3	4	355	653
Change in Generation	16	16	29	196	22	7	12	355	653
Change in Variable Production Costs/MWh	1	11	25	35	164	4	0	413	653
All Steam Electric Power Plants									
Change in Capacity Utilization[a]	11	6	46	197	36	3	7	382	688
Change in Generation	19	17	29	197	23	7	14	382	688
Change in Variable Production Costs/MWh	1	11	29	35	168	4	0	440	688

a. The change in capacity utilization is the difference between the capacity utilization percentages in the baseline and policy cases. For all other measures, the change is expressed as the percentage change between the baseline and policy values.

b. Plants with operating status changes in either baseline or policy scenario have been excluded from general table calculations. Thus, for Option B, “N/A” reports 322 full and 52 partial baseline closures; 5 full closures as a result of the regulatory option; 3 avoided partial closures.

c. The change in variable production cost per MWh could not be developed for 58 plants with zero generation in either the baseline case or Option B policy case.

Source: U.S. EPA Analysis, 2024.

5.2.2.3.1 Findings for the Final Rule (Option B) in Model Year 2035

For the final rule, the analysis of changes in individual plants indicates that most plants experience only slight effects – *i.e.*, no change or less than a one percent reduction or one percent increase. Across the full set of steam electric plants modeled, 36 plants (5 percent) incur a reduction in generation of at least one percent; 17 of these plants (2.5 percent) are also estimated to incur a reduction in capacity utilization of at least one percent. Finally, only 12 plants (2 percent) are estimated incur an increase in variable production costs of at least one percent. For the set of 35 plants that incur costs under Option B, 4 plants incur a decrease in generation and 1 plant is estimated to have no change in generation. Of the plants that incur costs under Option B, three are estimated to increase electricity generation.

5.3 Estimated Effects of the Regulatory Options on New Capacity

IPM results show no new coal-fired capacity projected during the analysis period in the baseline. This continues to be the case for the final rule.

5.4 Uncertainties and Limitations

Despite EPA's use of the best available information and data, EPA's analyses of the electric power market and the overall economic impacts of the final rule involve several sources of uncertainty:

- *Length of capital recovery period.* Some of the EGUs estimated to incur ELG costs during the period of analysis have planned retirement dates in IPM that are less than 15 years after the year in which they are estimated to install wastewater treatment technologies to meet the revised limits. The early retirement of these EGUs in IPM relative to the length of the capital recovery period and the associated truncation of the annual charges results in ELG costs represented in the model that are lower than the total estimated capital costs for meeting ELG limits for these units.[72] Overall, IPM recognizes 87 percent of the estimated capital costs of the final rule. See ICF (2024) for details.

- *Steam electric power plant response to changes in production costs*: IPM includes information about announced retirements only to the extent that there is a high degree of certainty about the future implementation of the announced action (U.S. EPA, 2023a). To the extent that some utilities' business strategy and integrated resource plans call for the retirement of coal generation assets and transition toward other sources of energy such as renewables or natural gas that is separate from the factors modeled in IPM, then IPM may overstate retirements resulting from incremental costs under the final rule.

- *Demand for electricity*: IPM assumes that electricity demand at the national level will not change between the baseline and the final rule (generation within the regions is allowed to vary); this constraint is exogenous to the model. IPM v6 embeds a baseline energy demand forecast that is derived from the Department of Energy's *Annual Energy Outlook 2023* (EIA, 2023b). IPM does not capture changes in demand that may result from electricity price changes associated with the

72 EGUs with a planned retirement date are removed from the inventory of modeled units on that date irrespective of the modeled market conditions. The removal of such units pre-empts IPM from making any further decisions regarding the operational status or configuration of the units. It also stops any operating costs associated with the units.

final rule (*i.e.*, demand is inelastic with respect to price[73]). While this constraint may underestimate total demand in analyses of policy options that have lower compliance costs relative to the baseline, EPA assumes that relaxing the constraint would not affect the results analyzed. As described in Section 5.2.1 and Section 5.2.2, the price changes associated with the final rule in all NERC regions are very small (less than 0.11 $/MWh). EPA therefore concludes that the assumption of inelastic demand-responses over these changes in prices is reasonable.

- *Fuel prices*: Prices of fuels (*e.g.*, natural gas and coal) are determined endogenously within IPM. IPM modeling of fuel prices uses both short- and long-term price signals to balance supply of, and demand in, competitive markets for the fuel across the modeled time horizon. The model relies on AEO2023's electric demand forecast for the US and employs a set of EPA assumptions regarding fuel supplies and the performance and cost of electric generation technologies as well as pollution controls. Differences in actual fuel prices relative to those modeled by IPM, such as lower natural gas prices that may result from increased domestic production or short-term increases in natural gas prices resulting from Russia's invasion of Ukraine, would be estimated to affect the cost of electricity generation and therefore the amount of electricity generated by steam electric power plants, irrespective of the final rule. More generally, differences in fuel prices, and related changes in electricity production costs, can affect the modeled dispatch profiles, planning for new/repowered capacity, and contribute to differences in a number of policy-relevant parameters such as electricity production costs, prices, and emission changes.

- *Electricity imports*: IPM assumes that electricity imports from Canada and Mexico do not change between the baseline and the final rule. Holding international imports fixed potentially understates the impacts of changes in production costs and electricity prices in U.S. domestic markets. EPA does not expect that this assumption materially affects results, however, since IPM projects that only one of the eight NERC regions will import electricity (WECC) in 2035, and the level of imports compared to domestic generation in this region is very small (about 0.3 percent).

73 Electricity demand has been found to be inelastic with respect to price in the short-term. See, for example, Burke, P. J., & Abayasekara, A. (2018). The price elasticity of electricity demand in the United States: A three-dimensional analysis. *The Energy Journal*, *39*(2). and Bernstein, M. A., & Griffin, J. (2005). *Regional Differences in the Price-Elasticity of Demand For Energy*. RAND Corporation. https://www.rand.org/pubs/technical_reports/TR292.html .

6 Assessment of Impacts on Employment

6.1 Background and Context

In addition to addressing the costs and impacts of the regulatory options, EPA estimated the potential impacts of this rulemaking on employment, measured in terms of changes in full-time equivalent (FTE) labor inputs.[74] Evaluation of employment impacts is required by many environmental statutes, including the Clean Water Act (CWA section 507I, 33 U.S.C. § 1367I). This section first provides an overview of the analysis methodology. It then quantitatively presents the Agency's estimates of the potential impacts of the final rule on labor inputs at power plants and other relevant economic sectors.

6.2 Analysis Overview

This section describes the Agency's approach to quantitatively estimate the labor impacts (FTEs) of the final rule.[75] The agency is using an approach outlined in U.S. EPA (2018) to develop a bottom-up analysis that evaluates first order impacts, *i.e.*, the direct changes in the amount of labor needed in the power generation sector and in directly related sectors such as equipment manufacturing and fuel production. This analysis does not account for other indirect and induced effects of the rule on the broader economy due to, for example, changes in forecasted electricity prices. (As discussed in Chapter 7, the potential electricity price effects of the final rule are estimated to be small.)

6.2.1 Quantification of Projected Actions

EPA quantified two categories of actions resulting from the final rule that may affect labor inputs:

- The changes in the profile of electricity generation and in fuel consumption, based on electricity market modeling using IPM, as described in Chapter 5; and
- The ELG compliance technology expenditures (including total capital, initial one-time, and O&M costs) by steam electric power generating plants, as described in Chapter 3.

EPA conducted this analysis for regulatory Option B and the year 2030 to be consistent with the period when plants would comply with the final rule (2025-2029).

Table 6-1 presents the estimated changes in new generation capacity and retirements in 2030 due to Option B relative to the baseline. The Agency calculated the net change in generation capacity by subtracting the projected retirements, in terms of GW of generation capacity, from projected new generation capacity for each generation type. The net change in generation capacity is used in this analysis for determining the required resources of new generation capacity by generation type.

74 One FTE equals 2,080 labor hours per year.

75 Because the employment analysis is based, in part, on electricity market modeling using IPM, this analysis does not include the employment impacts associated with legacy wastewater limits or the treatment of unmanaged CRL.

Table 6-1: Estimated Change in Generating Capacity Under Option B Relative to Baseline in 2030

Generation Type[a]	New Generation (GW)[b]			Retirements (GW)[b]			Net Capacity Change (GW)[c]
	Baseline	Option B	Change	Baseline	Option B	Change	
Solar	11.06	12.05	1.00	0	0	0	1.00
Wind	77.77	78.85	1.08	0	0	0	1.08
Energy Storage	15.19	15.25	0.05	0	0	0	0.05
Combined Cycle (without CCS)	20.35	23.73	3.39	0.80	0.75	-0.04779	3.43
Combustion Turbine	13.91	14.39	0.48	0.95	0.95	0	0.48
Coal steam	0	0	0	56.44	62.05	5.62	-5.62
Oil & Natural Gas Steam	0	0	0	12.39	12.55	0.16	-0.16
Nuclear	0	0	0	2.69	2.69	0.00	0.00
Total	**138.28**	**144.28**	**6.00**	**73.26**	**78.99**	**5.73**	**0.27**

a. Only generation types with non-zero changes in new generation or retirements under Option B relative to the baseline are presented.

b. New generation capacity reported for analysis year 2030 is online in 2030, and retirements reported for analysis year 2030 are offline by 2030.

c. Net capacity change is calculated as new generation less retirements (in GW) under Option B relative to the baseline.

Source: U.S. EPA Analysis, 2024.

EPA also used IPM projections to estimate the quantity of new generation capacity being built in 2030. As described in Chapter 5, IPM outputs are reported for several analysis years, including 2030 and 2035. EPA assumed that the incremental change in new generation capacity between 2030 and 2035 is representative of capacity possibly under construction in 2030. Based on the build duration (years) for each type of generating capacity, EPA estimated the fraction of the incremental change in new capacity that would be under construction in each year. For example, construction for capacity with a build duration of 3 years that is not online by 2030 but is online by 2035 could begin in 2028, 2029, 2030, 2031, or 2032. Of these construction start years, only 2028, 2029, and 2030 would be under construction in 2030. For this example, EPA therefore assumes that 3/5 of the incremental change in new generation capacity would be under construction in 2030. Table 6-2 presents the Agency's estimates of the incremental change in new generation capacity under construction in 2030 for each generation type.

Table 6-2: Incremental Change in New Generation Capacity Under Construction in 2030

Generation Type	Incremental Change in New Generation Capacity (GW)
Solar	<0.01
Wind	0.08
Energy Storage	1.43
Combined Cycle (without CCS)	<0.01
Combustion Turbine	0.15
Total	1.66

Source: U.S. EPA Analysis, 2024.

Table 6-3 presents the estimated changes in consumption of natural gas and coal in 2030 under Option B relative the baseline. EPA calculated the net change in fuel consumption for Option B by subtracting the estimated fuel use under the baseline from the fuel use estimated under Option B in 2030. EPA used these estimates of net fuel consumption to determine the changes in labor inputs in associated sectors due to fuel use changes under the final rule relative to the baseline.

Table 6-3: Estimated Change in Fuel Consumption Under Option B Relative to Baseline in 2030

Fuel Type	Region				
	Appalachia	Interior	Waste	West	All regions
Baseline					
Coal (Million Short Tons)	34.54	34.17	7.15	142.53	218.39
Natural Gas (Trillion Cubic Feet)	N/A	N/A	N/A	N/A	11.70
Option B					
Coal (Million Short Tons)	38.75	35.07	7.15	141.49	222.46
Natural Gas (Trillion Cubic Feet)	N/A	N/A	N/A	N/A	11.70
Change in Fuel Consumption (Option B less Baseline)					
Coal (Million Short Tons)	-4.21	-0.91	0.00	1.04	-4.07
Natural Gas (Trillion Cubic Feet)	N/A	N/A	N/A	N/A	0.00

Source: U.S. EPA Analysis, 2024.

Table 6-4 presents the estimated capital and operating costs associated with installation and operation of the wastewater treatment technology used as basis for the final rule ELGs. EPA used these total cost estimates to determine the associated effects on labor inputs.

Table 6-4: Option B Technology Capital and Operation Costs (millions, 2023$)

Cost Type	Wastestream			
	BA	FGD	CRL	Total
Capital Costs	$165	$1,309	$1,700	$3,173
Pre-Tax Annualized O&M Costs	$8	$91	$113	$212

Source: U.S. EPA Analysis, 2024.

6.2.2 Resource Requirements of Changes in Projected Actions and Treatment Technology

EPA estimated the resource requirements associated with the changes in projected actions and new wastewater treatment technologies used as basis for the final rule in dollars. This section of the analysis is separated in four parts, described below:

1) Construction of new generation capacity;

2) Operation of new generation capacity and retirements;

3) Installation of new treatment technology; and

4) Operation of new wastewater treatment technology.

6.2.2.1 Construction of New Generation Capacity

EPA first estimated the costs associated with construction of new generation capacity for several different cost components *(e.g.*, equipment, materials, construction labor, and engineering services). EPA calculated the annual construction cost ($/year) as the product of the unit capital cost ($/kW) from U.S. EPA (2023b) and the estimated new capacity construction in 2030 (kW/year), as described in Section 6.2.1. EPA then calculated construction costs for specific cost components by multiplying the total capital costs associated with construction of new generation capacity by the estimated percentage of costs that correspond with each cost component based on information from U.S. EPA (2018). EPA further mapped each cost component to the most relevant NAICS sector. Table 6-5 displays the estimated percentage of costs for new generation capacity (for each relevant generation type) that corresponds with each cost component and associated NAICS sector.

Table 6-5: Capital and Labor Components for Construction of New Generation Capacity by Generation Type

Cost Component	NAICS Sector	NAICS Sector Description	Average % of Total Operation Costs		
			Renewables & Biomass	Combined Cycle	Combustion Turbine
Equipment	333	Machinery Manufacturing	54%	65%	65%
Material	33111	Iron and Steel Mills and Ferroalloy Manufacturing	6%	10%	10%
Labor	236210	Industrial Building Construction	31%	18%	18%
Engineering and Construction Management	541330	Engineering Services	9%	7%	7%

Source: U.S. EPA Analysis, 2024; U.S. EPA, 2018.

6.2.2.2 Operation of New Generation Capacity and Retirements

As described in Section 6.2.1, EPA used IPM projections to estimate the incremental quantity of generation capacity in operation in 2030 due to the final rule (see Table 6-1). EPA estimated the annual resource costs for operating new generation capacity, or reduction in resource costs from projected retirements, based on annual fixed operating and maintenance (FOM) costs, as reported in U.S. EPA (2023b). The Agency estimated annual FOM cost ($/year) by multiplying the FOM cost ($/kW-year) by the projected changed in capacity (kW). EPA then matched each generation type in the analysis to its corresponding NAICS electricity generation sector, as shown in Table 6-6.

Table 6-6: NAICS Sectors Associated with Operation of New Generation Capacity

NAICS Sector	NAICS Sector Description	Generation Type
221112	Fossil fuel electric power generation	Combined cycle
		Combustion turbine
		Coal steam
		Oil & natural gas steam
221113	Nuclear electric power generation	Nuclear
221114	Solar electric power generation	Wind
221115	Wind electric power generation	Solar

Source: U.S. EPA Analysis, 2024.

6.2.2.3 Installation of New Wastewater Treatment Technologies

The compliance years for installation of the wastewater treatment technologies used as basis for the final rule are between 2025-2029. As such, EPA does not expect plants to incur compliance costs from installation of new treatment technology in the analysis year of 2030. Thus, EPA estimated that there will be no employment impacts due to installation of new treatment technology in 2030. See Section 6.4 for additional discussion of the effects on labor inputs associated with the installation of new treatment technology prior to 2030.

6.2.2.4 Operation of New Wastewater Treatment Technologies

Plants will incur resource costs for operating and maintaining the wastewater treatment systems to meet the ELGs in the final rule, including operating labor, maintenance labor and materials, energy costs, and chemical purchases. EPA estimated the percentage of total annualized O&M costs that would be required for each of these cost components (Eastern Research Group, 2022). EPA applied these percentages to the total, pre-tax annualized O&M cost for each treatment technology to estimate the costs associated with each cost component. EPA associated each identified cost component with the most relevant NAICS sector. Table 6-7 presents the average percentage of total O&M costs and the relevant NAICS sector associated with each cost component.

Table 6-7: Operation and Labor Components for New Wastewater Treatment Technologies

Cost Component	NAICS Sector	NAICS Sector Description	Average % of Total O&M Costs (All Treatment Technologies)
Chemicals	3251	Basic Chemical Manufacturing	20%
Energy	22111	Electric power generation	5%
Monitoring	22111	Electric power generation	10%
Maintenance Materials	33111	Iron and Steel Mills and Ferroalloy Manufacturing	10%
Operating Labor	221112	Fossil fuel electric power generation	25%
Transportation Operation	484230	Specialized Freight (except Used Goods) Trucking, Long-Distance	5%
Disposal Operation	562211	Hazardous Waste Treatment and Disposal	15%
Maintenance Labor	811310	Commercial and Industrial Machinery and Equipment (except Automotive and Electronic) Repair and Maintenance	10%

Source: U.S. EPA Analysis, 2024; Eastern Research Group, 2022.

6.2.3 Estimation and Aggregation of Labor Impacts

To estimate the total labor impacts of the final rule, EPA converted the estimated resource costs from Section 6.2.2 into FTE estimates using the estimated labor productivity for each economic sector, based on U.S. Census Bureau Economic Census data (U.S. Census Bureau, 2021a; U.S. Census Bureau, 2012). Table 6-8 presents labor productivity estimates based on 2017 Economic Census data for the relevant sectors identified in Section 6.2.2.

Table 6-8: Base Labor Productivity by Relevant Sector

NAICS Sector	NAICS Sector Description	Value of shipments (2023$ Millions) [A] (2017)	Total employees [B] (2017)	Labor productivity [B/A] (2017)	Growth rate (2012-2017)
333	Machinery manufacturing	$410,800	1,029,068	2.51	3.0%
3251	Basic Chemical Manufacturing	$245,653	148,181	0.60	6.4%
22111	Electric power generation	$134,418	138,647	1.03	0.5%
33111	Iron and Steel Mills and Ferroalloy Manufacturing	$98,681	84,792	0.86	2.7%
221111	Hydroelectric power generation	$3,758	3,642	0.97	-3.6%
221112	Fossil fuel electric power generation	$85,041	76,058	0.89	1.5%
221113	Nuclear electric power generation	$32,699	48,521	1.48	0.3%
221114	Solar electric power generation	$2,030	2,163	1.07	-19.0%
221115	Wind electric power generation	$8,748	4,986	0.57	-8.1%
221116	Geothermal electric power generation	$1,097	1,214	1.11	1.3%
221117	Biomass electric power generation	$1,021	1,968	1.93	3.5%
221118	Other electric power generation	$24	95	4.04	-1.0%
236210	Industrial Building Construction	$28,689	71,562	2.49	0.6%
237130	Power and Communication Line and Related Structures Construction	$72,844	232,861	3.20	-5.3%
238910	Site Preparation Contractors	$109,842	385,177	3.51	-3.4%
335911	Storage battery manufacturing	$8,489	25,126	2.96	2.9%
484121	General Freight Trucking, Long-Distance, Truckload	$126,726	519,358	4.10	-0.5%
484230	Specialized Freight (except Used Goods) Trucking, Long-Distance	$46,023	174,571	3.79	-0.2%
541330	Engineering Services	$267,451	1,081,471	4.04	0.7%
562211	Hazardous Waste Treatment and Disposal	$9,819	34,035	3.47	0.3%
562212	Solid Waste Landfill	$8,492	20,525	2.42	-1.4%
811310	Commercial and Industrial Machinery and Equipment (except Automotive and Electronic) Repair and Maintenance	$44,245	202,493	4.58	-2.2%

Source: U.S. Census Bureau, 2012; U.S. Census Bureau, 2021a; U.S. EPA Analysis, 2024.

EPA calculated the compound annual growth rate of labor productivity in each sector using U.S. Census data from a five-year period (2012 to 2017). EPA estimated the labor productivity in 2030 using this calculated growth rate. Due to uncertainty surrounding future labor productivity rates, EPA presents the results of the employment analysis as a range: using the 2017 labor productivity rate, assuming labor productivity remains constant between 2017 and 2030, and using a projected 2030 labor productivity rate assuming labor productivity grows between 2017 and 2030 at the same compound annual growth rate observed from 2012 to 2017. EPA multiplied the estimated costs by NAICS sector (Section 6.2.2) by the estimated labor productivity to estimate employment effects.

To estimate FTE changes associated with fuel consumption (*e.g.*, coal, natural gas), EPA used 2022 regional coal mining productivity estimates from EIA (EIA, 2023i) and 2021 natural gas production and employment estimates from EIA (EIA, 2023f; EIA, 2023e) and U.S. Census Bureau's County Business Patterns (U.S. Census Bureau, 2023), respectively (Table 6-9). EPA divided the projected changes in coal and natural gas use (by region for coal consumption) by the labor productivity estimates for coal and natural gas to obtain the total labor hours required for fuel production. EPA converted labor hours to employees assuming one FTE equals 2,080 labor hours per year. Total employment in the coal mining industry in 2022 was 43,582 (EIA, 2023i). Total employment for the natural gas extraction industry was 28,547, respectively (NAICS code 21113; U.S. Census Bureau, 2023).

Table 6-9: Coal and Natural Gas Labor Productivity Estimates

Resource	Labor productivity	Unit	Data vintage
Coal – Appalachian region	2.7	Short tons per labor hour	2022
Coal – Interior region	5.87	Short tons per labor hour	2022
Coal – Western region	16.04	Short tons per labor hour	2022
Coal – Waste	6.11	Short tons per labor hour	2022
Natural gas	728	Million Btu per labor hour	2021

Source: EIA, 2023e; EIA, 2023f; EIA, 2023i; U.S. Census Bureau, 2023; U.S. EPA Analysis 2024.

6.3 Estimated Impacts of the Final Rule in 2030

6.3.1 New Generation Capacity

Table 6-10 and Table 6-11 present the results of EPA's analysis of the impacts on labor inputs of changes in generation capacity, by generation type and NAICS sector. In each sector identified and for both labor productivity rates, EPA estimated increased FTEs associated with construction of new generation capacity. Using the 2017 and adjusted 2030 labor productivity rates, the storage battery manufacturing sector (NAICS code 335911) is expected to see the second greatest rise in FTE. In total, the Agency estimated an increase of 3,786 to 5,450 FTEs using the 2017 and adjusted 2030 labor productivity rates, respectively.

Table 6-10: Changes in Labor Inputs from Construction of New Generation Capacity in 2030 FTE)

Labor Productivity Rates	NAICS Sector	NAICS Sector Description	Generation Type: Combined Cycle	Wind	Solar	Combustion Turbine	Energy Storage	All Types
2017	333	Machinery Manufacturing	<0.01	37	<0.01	87	0	123
	33111	Iron and Steel Mills and Ferroalloy Manufacturing	<0.01	1	<0.01	5	0	6
	236210	Industrial Building Construction	<0.01	21	<0.01	24	0	45

Table 6-10: Changes in Labor Inputs from Construction of New Generation Capacity in 2030 FTE)

Labor Productivity Rates	NAICS Sector	NAICS Sector Description	Generation Type					
			Combined Cycle	Wind	Solar	Combustion Turbine	Energy Storage	All Types
	335911	Storage Battery Manufacturing	0	0	0	0	3,587	3,587
	541330	Engineering Services	<0.01	10	<0.01	15	0	25
	Total	-	<0.01	69	<0.01	130	3,587	3,786
Adjusted 2030	333	Machinery Manufacturing	<0.01	54	<0.01	127	0	181
	33111	Iron and Steel Mills and Ferroalloy Manufacturing	<0.01	2	<0.01	6	0	8
	236210	Industrial Building Construction	<0.01	23	<0.01	26	0	49
	335911	Storage Battery Manufacturing	0	0	0	0	5,185	5,185
	541330	Engineering Services	<0.01	11	<0.01	17	0	27
	Total	-	<0.01	89	<0.01	176	5,185	5,450

a. Only generation types with non-zero changes in new generation capacity are reported.

Source: U.S. EPA Analysis, 2024.

EPA estimated that overall labor inputs for operation of new generation capacity would decrease by 148 to 247 FTEs using the 2017 and adjusted 2030 labor productivity rates, respectively (Table 6-11). Under both sets of labor productivity rates, labor inputs are expected to increase for certain generation types and decrease for others. FTEs are expected to increase in sectors involved in combined cycle, combustion turbine, wind, and solar. The increases for these generation types are a result of additional generation capacity due to the final rule relative to the baseline. For combined turbine, a minority of increases in FTEs are due to avoided retirements. Using the 2017 labor productivity rate, labor inputs are expected to increase the most for wind and solar generation with 44 and 19 FTEs, respectively. Using the adjusted 2030 labor productivity rate, labor inputs are expected to increase the most for combined cycle and combustion turbine with 14 and 12 FTEs, respectively. By contrast, the analysis shows estimated decreases in FTEs associated with coal steam and oil and natural gas steam generation with the greatest decrease occurring from reduced capacity of coal steam generation. Decreases for coal steam and oil and natural gas steam generation are the result of capacity retirements due to the final rule. The total changes in labor inputs for all generation types are small relative to overall employment in the electric power generation sector (138,647 employees in 2017; see Table 6-8).

Table 6-11: Changes in Labor Inputs from Operation of New Generation Capacity and Retirements in 2030 (# FTEs)

Labor Productivity Rates	Generation Type [a, b]							
	Combined Cycle	Wind	Solar	Combustion Turbine	Coal Steam	Oil & Natural Gas Steam	Nuclear	All Types
2017	12	44	19	10	-228	-4	0	-148
Adjusted 2030	14	3	6	12	-277	-5	0	-247

a. Results are presented as the net employment generated from new generation capacity minus retirements.

b. Only generation types with non-zero changes in employment are reported. Estimated employment impacts from hydro, biomass, geothermal, landfill gas, and energy storage (pumped storage) were zero.

Source: U.S. EPA Analysis, 2024.

6.3.2 New Treatment Technology

Table 6-12 presents the impacts of new wastewater treatment technologies used as basis for the ELGs in the final rule. Estimates of impacts on labor inputs are presented by wastestream and NAICS sectors involved in operation of new treatment technology (see Section 6.4 for construction impacts).

EPA estimated that labor inputs would increase by 371 to 402 FTEs using the 2017 and 2030 adjusted labor productivity rates, respectively due to operation of new treatment technologies, with all NAICS sectors seeing an increase. Operation of CRL treatment technology is estimated to have the greatest increase on labor inputs using either the 2017 and 2030 labor productivity rates (197 and 214 FTEs, respectively) followed by FGD (160 and 173 FTEs, respectively) and BA (14 and 15 FTEs, respectively). Additionally, the sector with the highest associated labor increases under both labor productivity rates is the hazardous waste treatment and disposal sector (NAICS code 562211) with 110 and 114 FTEs, respectively. Using 2017 labor productivity rates, the sector with the second highest increase is the repair and maintenance for commercial and industrial machinery and equipment (except automotive and electronic) sector (NAICS code 811310) with 97 FTEs. Using adjusted 2030 labor productivity rates, the sector with the second highest increase is the electric power generation sector (NAICS code 22111) with 93 FTEs.

Table 6-12: Changes in Labor Inputs from Operation of New Technology in 2030 (# FTEs)

Labor Productivity Rates	NAICS Sector	NAICS Sector Description	Wastestream			
			FGD	BA	CRL	Total
2017	3251	Basic Chemical Manufacturing	11	1	14	26
	22111	Electric Power Generation	35	3	43	80
	33111	Iron and Steel Mills and Ferroalloy Manufacturing	8	1	10	18
	484230	Specialized Freight (except Used Goods) Trucking, Long-Distance	17	2	21	40
	562211	Hazardous Waste Treatment and Disposal	47	4	59	110
	811310	Commercial and Industrial Machinery and Equipment (except Automotive and Electronic) Repair and Maintenance	42	4	52	97
	Total	-	**160**	**14**	**197**	**371**

Table 6-12: Changes in Labor Inputs from Operation of New Technology in 2030 (# FTEs)						
Labor Productivity Rates	NAICS Sector	NAICS Sector Description	Wastestream			
			FGD	BA	CRL	Total
Adjusted 2030	3251	Basic Chemical Manufacturing	25	2	30	57
	22111	Electric Power Generation	40	4	49	93
	33111	Iron and Steel Mills and Ferroalloy Manufacturing	11	1	14	26
	484230	Specialized Freight (except Used Goods) Trucking, Long-Distance	17	1	21	39
	562211	Hazardous Waste Treatment and Disposal	49	4	61	114
	811310	Commercial and Industrial Machinery and Equipment (except Automotive and Electronic) Repair and Maintenance	31	3	39	73
	Total	-	**173**	**15**	**214**	**402**

Source: U.S. EPA Analysis, 2024.

6.3.3 *Fuel Consumption Changes*

Table 6-13 presents the impacts on labor inputs associated with changes in fuel consumption for electricity generation, by region and fuel type. Overall, EPA estimated a net reduction of 793 FTEs. The Appalachia region is estimated to experience the greatest reduction in labor input associated with coal production, followed by the Interior region. EPA estimated a negligible change in labor input associated with coal production in the West region and a negligible change in national labor input associated with natural gas extraction.

Table 6-13: Labor Demand from Fuel Use Changes (# Employees)							
Fuel Type	NAICS Sector	NAICS Sector Description	Coal Region			Waste Coal	Total
			Appalachia	Interior	West		
Coal	2121	Coal Mining	-750	-74	0	31	-793
Natural gas	21113	Natural Gas Extraction	0	0	0	0	<0.01

Source: U.S. EPA Analysis, 2024.

6.3.4 *Total Impacts of the Final Rule by Industry*

Table 6-14 presents the total estimated impacts by NAICS sector. The number of FTEs is expected to increase or remain the same in every relevant sector identified in the analysis except for the coal mining and electric power generation sectors (NAICS codes 2121 and 22111, respectively). The Agency estimated that the coal mining sector will experience a decrease in FTEs due to a decline in fuel consumption for electricity generation. The Agency also estimated that the decrease in FTEs in the electric power generation sector is driven by retirements of coal steam generation. Overall, EPA estimated the final rule to increase labor inputs by 3,218 to 4,813 FTEs using the 2017 and adjusted 2030 labor productivity rates, respectively. The sector with the greatest estimated increase in labor inputs under both labor productivity rates is the storage batter manufacturing sector (NAICS code 335910). Using both labor productivity rates, the sector with the second greatest increase in labor inputs is the machinery manufacturing sector (NAICS code 333) followed by the hazardous waste treatment and disposal sector (NAICS code 562211).

The analysis estimates changes in labor inputs at power generating plants, coal mining, natural gas extraction, and in the sectors involved most directly in generation capacity additions or wastewater treatment technologies. Even though this final rule may affect many sectors, the overall impacts on labor, both positive and negative, are quite small. Furthermore, this impact assessment does not reach a quantitative estimate of the overall effects of the final rule on employment or even whether the net effect will be positive or negative. However, given that the modeled increase in electricity production costs is small (0.5 percent, based on IPM projections of Option B for 2030), the magnitude of all effects combined can also be expected to be small.

Table 6-14: Total Effects on Labor Inputs by NAICS Sector in 2030 (# FTEs)

NAICS Sector[a]	NAICS Sector Description	Labor Productivity Rates	
		2017	Adjusted 2030
333	Machinery Manufacturing	123	181
2121	Coal Mining[a]	-793	-793
3251	Basic Chemical Manufacturing	26	57
21113	Natural Gas Extraction[a]	0	0
22111	Electric Power Generation	-66	-154
33111	Iron and Steel Mills and Ferroalloy Manufacturing	24	34
236210	Industrial Building Construction	45	49
237130	Power and Communication Line and Related Structures Construction	0	0
238910	Site Preparation Contractors	0	0
335911	Storage Battery Manufacturing	3,587	5,185
484121	General Freight Trucking, Long-Distance, Truckload	0	0
484230	Specialized Freight (except Used Goods) Trucking, Long-Distance	40	39
541330	Engineering Services	25	27
562211	Hazardous Waste Treatment and Disposal	110	114
562212	Solid Waste Landfill	0	0
811310	Commercial and Industrial Machinery and Equipment (except Automotive and Electronic) Repair and Maintenance	97	73
Total	-	**3,218**	**4,813**

a. EPA identified NAICS Sector 2121 (coal mining) and 21113 (natural gas extraction) as the relevant sectors that would incur impacts from changes in fuel consumption for electricity generation.

Source: U.S. EPA Analysis, 2024.

6.4 Estimated Impacts from Installation of Wastewater Treatment Technologies

Installation of wastewater treatment technologies used as basis for ELGs in the final rule is projected to occur before the analysis year of 2030. In this section, EPA reports the estimated impacts on labor inputs associated with the installation of each treatment technology during the compliance years of 2025 to 2029.

EPA calculated the resource requirements, in dollars, for different cost components of installation of new treatment technology (*e.g.*, materials, construction labor, engineering services). Table 6-15 presents the average percentage of total capital costs associated with each cost component, applicable to all wastestreams (Eastern Research Group, 2022).

Table 6-15: Capital and Labor Components for New Treatment Technology

Cost Component	NAICS Sector	NAICS Sector Description	Average % of Total Capital Costs
Installation Materials[a]	332	Fabricated Metal Product Manufacturing	43%
Equipment	333	Machinery manufacturing	25%
Indirect Capital Labor (Construction/Installation)	23829	Other Building Equipment Contractors	10%
Indirect Capital Labor (Site Preparation)	238910	Site Preparation Contractors	10%
Indirect capital labor (Engineering Services)	541330	Engineering Services	10%
Disposal Capital Cost	562212	Solid Waste Landfill	2%

a. Installation materials refers to the labor required for the manufacturing of materials required for installation of new treatment technology.

Source: Eastern Research Group, 2022; U.S. EPA Analysis, 2024.

Table 6-16 presents the estimated impacts associated with installation of wastewater treatment technologies in the final rule. These impacts include the employment impacts related to the initial one-time cost incurred by plants to comply with recordkeeping and monitoring under the final rule. Overall, EPA estimated that labor inputs would increase due to installation of new treatment technologies by 10,484 FTEs using the 2017 labor productivity rates and by 11,366 FTEs using the adjusted 2030 labor productivity rates. Under both labor productivity rates, the number of FTEs is estimated to increase the most, by 4,828 to 5,506 FTEs, in the fabricated metal product manufacturing sector (NAICS code 332). The sector with the second greatest increase in labor input is machinery manufacturing (NAICS code 333), followed by the engineering services sector (NAICS code 541330).

Table 6-16: Total FTE Changes from Installation of New Technology

Labor Productivity	NAICS Sector	NAICS Sector Description	Wastestream			
			FGD	BA	CRL	Total
2017	332	Fabricated Metal Product Manufacturing	1,991	250	2,586	4,828
	333	Machinery manufacturing	819	103	1,064	1,987
	23829	Other Building Equipment Contractors	461	58	599	1,118
	221112[a]	Fossil Fuel Electric Power Generation	1	0	2	3
	238910	Site Preparation Contractors	459	58	596	1,113
	484121	General Freight Trucking, Long-Distance, Truckload	0	0	0	0
	541330	Engineering Services	529	67	687	1,283
	562212	Solid Waste Landfill	63	8	82	153
	Total	**-**	**4,324**	**543**	**5,617**	**10,484**
Adjusted 2030	332	Fabricated Metal Product Manufacturing	2,271	285	2,949	5,506
	333	Machinery manufacturing	1,203	151	1,562	2,917
	23829	Other Building Equipment Contractors	285	36	370	691

Table 6-16: Total FTE Changes from Installation of New Technology

Labor Productivity	NAICS Sector	NAICS Sector Description	Wastestream			
			FGD	BA	CRL	Total
	221112[a]	Fossil Fuel Electric Power Generation	1	0	2	4
	238910	Site Preparation Contractors	293	37	381	711
	484121	General Freight Trucking, Long-Distance, Truckload	0	0	0	0
	541330	Engineering Services	582	73	755	1,410
	562212	Solid Waste Landfill	52	7	68	127
	Total	-	**4,688**	**589**	**6,089**	**11,366**

a. EPA estimated impacts related to initial one-time recordkeeping and monitoring costs using the labor productivity rate for the fossil fuel electric power generation sector.

Source: U.S. EPA Analysis, 2024.

6.5 Uncertainties and Limitations

Despite EPA's use of the best available information and data, EPA's analysis of the potential impacts of the final rule on labor input involves several sources of uncertainty:

- EPA used a bottom-up engineering analysis to estimate direct FTE impacts. This analysis does not account for other indirect and induced effects of the rule on the broader economy due to, for example, changes in forecasted electricity prices. However, EPA expects these effects to be small given the relatively small changes in electricity production costs modeled in IPM (see Chapter 5) and small potential electricity price effects (see Chapter 7).

- EPA estimated FTE impacts based on projected changes in electricity generation for a single year (2030) to correspond to the detailed outputs of the market analysis in Chapter 5, but the final rule also has incremental effects in other years.

- Labor productivity in the analysis year 2030 is unknown. To the extent that labor productivity in 2030 diverges from recent trends, this analysis may over- or underestimate employment impacts.

- EPA mapped cost components to the most relevant NAICS sectors, but FTEs in other NAICS sectors may be affected. In addition, if those NAICS sectors have different labor productivity rates, this analysis may over- or underestimate FTE impacts.

7 Assessment of Potential Electricity Price Effects

7.1 Analysis Overview

EPA assessed the potential impacts of regulatory options A through C on electricity prices. Following the methodology EPA used to analyze the 2015 and 2020 rules, and 2023 proposal (U.S. EPA, 2015, 2020, 2023d), the Agency conducted this analysis in two parts:

- An assessment of the potential annual increase in electricity costs per MWh of total electricity sales (Section 7.2)
- An assessment of the potential annual increase in household electricity costs (Section 7.3).

As is the case with the plant-level and parent entity-level cost-to-revenue screening analyses discussed in Chapter 4 (Economic Impact Screening Analyses), this analysis of electricity price effects uses a historical snapshot of electricity generation against which to assess the relative impacts of the regulatory options. However, unlike the plant- and entity-level screening analyses which assume that steam electric power plants and their parent entities would absorb 100 percent of the compliance burden (zero cost pass-through), this electricity price impact assessment assumes the opposite: 100 percent pass-through of compliance costs through electricity prices (*i.e.*, full cost pass-through).

Although this convenient analytical simplification does not reflect actual market conditions,[76] EPA judges this assumption appropriate for two reasons: (1) the majority of steam electric power plants operate under a cost-of-service framework and *may be* able to recover increases in their production costs through increased electricity prices and (2) for plants operating in states where electric power generation has been deregulated, it would not be possible to estimate this consumer price effect at the state level. Thus, this 100 percent cost pass-through assumption represents a "worst-case" impact scenario from the perspective of the electricity consumers. To the extent that all compliance-related costs are *not* passed forward to consumers but are absorbed, at least in part, by electric power generators, this analysis overstates consumer impacts.

It is also important to note that, if the full cost pass-through condition assumed in this analysis were to occur, then the screening analyses assessed in Chapter 4 would overstate the impacts to plants and owners of these plants because the two conditions (full cost pass-through and no cost pass-through) could not simultaneously occur for the same steam electric power plant.

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76 Plants located in states where electricity prices remain regulated under the traditional cost-of-service rate regulation framework may be able to recover compliance cost-based increases in their production costs through increased electricity rates, depending on the business operation model of the plant owner(s), the ownership and operating structure of the plant itself, and the role of market mechanisms used to sell electricity. In contrast, in states in which electric power generation has been deregulated, cost recovery is not guaranteed. While plants operating within deregulated electricity markets *may be* able to recover some of their additional production costs in increased revenue, it is not possible to determine the extent of cost recovery ability for each plant. Moreover, even though individual plants may not be able to recover all of their compliance costs through increased revenues, the market-level effect may still be that consumers would see higher overall electricity prices because of changes in the cost structure of electricity supply and resulting changes in market-clearing prices in deregulated generation markets.

7.2 Assessment of Impact of Compliance Costs on Electricity Prices

EPA assessed the potential increase in electricity prices to the four electricity consumer groups: residential, commercial, industrial, and transportation.

7.2.1 Analysis Approach and Data Inputs

For this analysis, EPA assumed that compliance costs would be fully passed through as increased electricity prices and allocated these costs among consumer groups (residential, commercial, industrial, and transportation) in proportion to the historical quantity of electricity consumed by each group. EPA performed this analysis at the level of the NERC region. Using the NERC region as the basis for this analysis is appropriate given the structure and functioning of sub-national electricity markets, around which NERC regions are defined. The analysis, which uses the exact same approach as used for the 2015 and 2020 rules and 2023 proposal analyses, involves the following steps (for additional details, see Chapter 7 in U.S. EPA, 2015):

- EPA summed weighted pre-tax plant-level annualized compliance costs by NERC region.[77, 78]
- EPA estimated the approximate average price impact per unit of electricity consumption by dividing total annualized compliance costs by the projected total MWh of sales in 2024 by NERC region, from AEO2023 (EIA, 2023b).
- EPA compared the estimated average price effect to the projected electricity price by consumer group and NERC region for 2024 from AEO2023 (EIA, 2023b).

7.2.2 Key Findings for Regulatory Options

As reported in Table 7-1, the compliance costs per unit of sales are very small for all analyzed regulatory options; the maximum cost per kWh is a fraction of a cent. Under all three regulatory options, the regions with the greatest cost per kWh are RF and SERC under both the lower and upper bound scenarios.

Table 7-1: Compliance Cost per KWh Sales by NERC Region and Regulatory Option in 2024 (2023$) – Lower Bound

NERC[a]	Total Electricity Sales (at 2024; MWh)	National Pre-Tax Compliance Costs (at 2024; 2023$)	Costs per Unit of Sales (2023¢/kWh Sales)
Option A			
MRO	456,121,788	$54,026,214	0.012¢
NPCC	253,369,049	$5,992,572	0.002¢
RF	732,859,497	$146,301,472	0.020¢
SERC	1,324,847,581	$228,184,395	0.017¢
TRE	389,170,380	$7,931,750	0.002¢

77 These compliance costs are in 2023 dollars as of a given technology implementation year (2025 through 2029) and discounted to 2024 at 3.76 percent. This analysis accounts for the different years in which plants are estimated to implement the compliance technologies in order to reflect the effect of differences in timing of these electricity price impacts in terms of cost to household ratepayers and society. Costs and ratepayer effects occurring farther in the future (*e.g.*, in the last year of the technology implementation period) have a lower present value of impact than those that occur sooner following rule promulgation. Estimating the cost and ratepayer effect as of the assumed technology implementation year (2025 through 2029) and then discounting these effects to a single analysis year (2024) accounts for this consideration.

78 For this analysis, EPA brought compliance costs forward to a given compliance year using the CCI and ECI.

Table 7-1: Compliance Cost per KWh Sales by NERC Region and Regulatory Option in 2024 (2023$) – Lower Bound

NERC[a]	Total Electricity Sales (at 2024; MWh)	National Pre-Tax Compliance Costs (at 2024; 2023$)	Costs per Unit of Sales (2023¢/kWh Sales)
WECC	691,321,258	$36,218,573	0.005¢
US	**3,868,347,589**	**$479,230,884**	**0.012¢**
		Option B	
MRO	456,121,788	$69,824,715	0.015¢
NPCC	253,369,049	$6,122,629	0.002¢
RF	732,859,497	$208,025,785	0.028¢
SERC	1,324,847,581	$256,608,152	0.019¢
TRE	389,170,380	$9,215,116	0.002¢
WECC	691,321,258	$44,513,228	0.006¢
US	**3,868,347,589**	**$594,885,534**	**0.015¢**
		Option C	
MRO	456,121,788	$76,979,491	0.017¢
NPCC	253,369,049	$6,122,629	0.002¢
RF	732,859,497	$235,300,734	0.032¢
SERC	1,324,847,581	$305,278,400	0.023¢
TRE	389,170,380	$14,139,636	0.004¢
WECC	691,321,258	$55,553,917	0.008¢
US	**3,868,347,589**	**$693,950,715**	**0.018¢**

a. ELG compliance costs are zero in the AK and HICC regions and these regions are therefore omitted from the presentation. Because of this, the sum of electricity sales for all regions do not sum to the total for the United States.

Source: U.S. EPA Analysis, 2024.

Table 7-2: Compliance Cost per KWh Sales by NERC Region and Regulatory Option in 2024 (2023$) – Upper Bound

NERC[a]	Total Electricity Sales (at 2024; MWh)	National Pre-Tax Compliance Costs (at 2024; 2023$)	Costs per Unit of Sales (2023¢/kWh Sales)
		Option A	
MRO	456,121,788	$118,176,904	0.026¢
NPCC	253,369,049	$6,405,553	0.003¢
RF	732,859,497	$245,175,269	0.033¢
SERC	1,324,847,581	$518,050,509	0.039¢
TRE	389,170,380	$16,758,365	0.004¢
WECC	691,321,258	$140,691,334	0.020¢
US	**3,868,347,589**	**$1,047,696,932**	**0.027¢**
		Option B	
MRO	456,121,788	$133,975,405	0.029¢
NPCC	253,369,049	$6,535,610	0.003¢
RF	732,859,497	$306,899,583	0.042¢
SERC	1,324,847,581	$546,474,267	0.041¢
TRE	389,170,380	$18,041,731	0.005¢
WECC	691,321,258	$148,985,988	0.022¢
US	**3,868,347,589**	**$1,163,351,581**	**0.030¢**
		Option C	
MRO	456,121,788	$141,130,180	0.031¢
NPCC	253,369,049	$6,535,610	0.003¢
RF	732,859,497	$334,174,531	0.046¢

Table 7-2: Compliance Cost per KWh Sales by NERC Region and Regulatory Option in 2024 (2023$) – Upper Bound			
NERC[a]	Total Electricity Sales (at 2024; MWh)	National Pre-Tax Compliance Costs (at 2024; 2023$)	Costs per Unit of Sales (2023¢/kWh Sales)
SERC	1,324,847,581	$595,144,514	0.045¢
TRE	389,170,380	$22,966,251	0.006¢
WECC	691,321,258	$160,026,678	0.023¢
US	**3,868,347,589**	**$1,262,416,762**	**0.033¢**

a. ELG compliance costs are zero in the AK and HICC regions and these regions are therefore omitted from the presentation. Because of this, the sum of electricity sales for all regions do not sum to the total for the United States.

Source: U.S. EPA Analysis, 2024.

To determine the relative significance of compliance costs on electricity prices across consumer groups, EPA compared the per kWh compliance cost to retail electricity prices projected by EIA (EIA, 2023b) by consuming group and for the average of the groups. This analysis is presented in Table 7-3 and Table 7-4 for the lower and upper bound scenarios, respectively.

Looking across the four consumer groups and assuming that any price change would apply equally to all consumer groups, under all scenarios industrial consumers are estimated to experience the highest price changes relative to the electricity price basis, while residential consumers are estimated to experience the lowest price changes, shown in Table 7-3. The comparably higher relative price changes to industrial consumers are due to their lower electricity rates and EPA's assumption of uniform changes across all consumer groups; they do not reflect differential distribution of the incremental costs across consumer groups.

Table 7-3: Projected 2024 Price (Cents per kWh of Sales) and Potential Price Increase Due to Compliance Costs by NERC Region and Regulatory Option (2023$) – Lower Bound

NERC[b]	Compliance Costs (2023¢ /kWh)	Residential		Commercial		Industrial		Transportation		All Sectors Average	
		EIA Price Basis (2023¢ /kWh)	% Change[a]	EIA Price Basis (2023¢ /kWh)	% Change[a]	EIA Price Basis (2023¢ /kWh)	% Change[a]	EIA Price Basis (2023¢ /kWh)	% Change[a]	EIA Price Basis (2023¢ /kWh)	% Change[a]
Option A											
MRO	0.012¢	11.58¢	0.10%	9.48¢	0.12%	6.59¢	0.18%	11.00¢	0.11%	9.15¢	0.13%
NPCC	0.002¢	20.94¢	0.01%	17.15¢	0.01%	12.12¢	0.02%	13.96¢	0.02%	17.95¢	0.01%
RF	0.020¢	14.33¢	0.14%	12.07¢	0.17%	8.90¢	0.22%	10.13¢	0.20%	12.05¢	0.17%
SERC	0.017¢	12.42¢	0.14%	10.22¢	0.17%	6.65¢	0.26%	11.45¢	0.15%	10.30¢	0.17%
TRE	0.002¢	12.08¢	0.02%	10.47¢	0.02%	7.59¢	0.03%	9.13¢	0.02%	10.22¢	0.02%
WECC	0.005¢	16.15¢	0.03%	14.34¢	0.04%	9.81¢	0.05%	18.17¢	0.03%	13.91¢	0.04%
US	**0.012¢**	**13.90¢**	**0.09%**	**11.94¢**	**0.10%**	**7.95¢**	**0.16%**	**13.84¢**	**0.09%**	**11.67¢**	**0.11%**
Option B											
MRO	0.015¢	11.58¢	0.13%	9.48¢	0.16%	6.59¢	0.23%	11.00¢	0.14%	9.15¢	0.17%
NPCC	0.002¢	20.94¢	0.01%	17.15¢	0.01%	12.12¢	0.02%	13.96¢	0.02%	17.95¢	0.01%
RF	0.028¢	14.33¢	0.20%	12.07¢	0.24%	8.90¢	0.32%	10.13¢	0.28%	12.05¢	0.24%
SERC	0.019¢	12.42¢	0.16%	10.22¢	0.19%	6.65¢	0.29%	11.45¢	0.17%	10.30¢	0.19%
TRE	0.002¢	12.08¢	0.02%	10.47¢	0.02%	7.59¢	0.03%	9.13¢	0.03%	10.22¢	0.02%

Table 7-3: Projected 2024 Price (Cents per kWh of Sales) and Potential Price Increase Due to Compliance Costs by NERC Region and Regulatory Option (2023$) – Lower Bound

NERC[b]	Compliance Costs (2023¢ /kWh)	Residential EIA Price Basis (2023¢ /kWh)	Residential % Change [a]	Commercial EIA Price Basis (2023¢ /kWh)	Commercial % Change [a]	Industrial EIA Price Basis (2023¢ /kWh)	Industrial % Change [a]	Transportation EIA Price Basis (2023¢ /kWh)	Transportation % Change [a]	All Sectors Average EIA Price Basis (2023¢ /kWh)	All Sectors Average % Change [a]
WECC	0.006¢	16.15¢	0.04%	14.34¢	0.04%	9.81¢	0.07%	18.17¢	0.04%	13.91¢	0.05%
US	**0.015¢**	**13.90¢**	**0.11%**	**11.94¢**	**0.13%**	**7.95¢**	**0.19%**	**13.84¢**	**0.11%**	**11.67¢**	**0.13%**
Option C											
MRO	0.017¢	11.58¢	0.15%	9.48¢	0.18%	6.59¢	0.26%	11.00¢	0.15%	9.15¢	0.18%
NPCC	0.002¢	20.94¢	0.01%	17.15¢	0.01%	12.12¢	0.02%	13.96¢	0.02%	17.95¢	0.01%
RF	0.032¢	14.33¢	0.22%	12.07¢	0.27%	8.90¢	0.36%	10.13¢	0.32%	12.05¢	0.27%
SERC	0.023¢	12.42¢	0.19%	10.22¢	0.23%	6.65¢	0.35%	11.45¢	0.20%	10.30¢	0.22%
TRE	0.004¢	12.08¢	0.03%	10.47¢	0.03%	7.59¢	0.05%	9.13¢	0.04%	10.22¢	0.04%
WECC	0.008¢	16.15¢	0.05%	14.34¢	0.06%	9.81¢	0.08%	18.17¢	0.04%	13.91¢	0.06%
US	**0.018¢**	**13.90¢**	**0.13%**	**11.94¢**	**0.15%**	**7.95¢**	**0.23%**	**13.84¢**	**0.13%**	**11.67¢**	**0.15%**

a. The rate impact analysis assumes full pass-through of all compliance costs to electricity consumers.

b. ELG compliance costs are zero in the AK and HICC regions and these regions are therefore omitted from the presentation.

Sources: U.S. EPA Analysis, 2024; EIA, 2022c, 2023b.

Table 7-4: Projected 2024 Price (Cents per kWh of Sales) and Potential Price Increase Due to Compliance Costs by NERC Region and Regulatory Option (2023$) – Upper Bound

NERC[b]	Compliance Costs (2023¢ /kWh)	Residential EIA Price Basis (2023¢ /kWh)	Residential % Change [a]	Commercial EIA Price Basis (2023¢ /kWh)	Commercial % Change [a]	Industrial EIA Price Basis (2023¢ /kWh)	Industrial % Change [a]	Transportation EIA Price Basis (2023¢ /kWh)	Transportation % Change [a]	All Sectors Average EIA Price Basis (2023¢ /kWh)	All Sectors Average % Change [a]
Option A											
MRO	0.026¢	11.58¢	0.22%	9.48¢	0.27%	6.59¢	0.39%	11.00¢	0.24%	9.15¢	0.28%
NPCC	0.003¢	20.94¢	0.01%	17.15¢	0.01%	12.12¢	0.02%	13.96¢	0.02%	17.95¢	0.01%
RF	0.033¢	14.33¢	0.23%	12.07¢	0.28%	8.90¢	0.38%	10.13¢	0.33%	12.05¢	0.28%
SERC	0.039¢	12.42¢	0.31%	10.22¢	0.38%	6.65¢	0.59%	11.45¢	0.34%	10.30¢	0.38%
TRE	0.004¢	12.08¢	0.04%	10.47¢	0.04%	7.59¢	0.06%	9.13¢	0.05%	10.22¢	0.04%
WECC	0.020¢	16.15¢	0.13%	14.34¢	0.14%	9.81¢	0.21%	18.17¢	0.11%	13.91¢	0.15%
US	**0.027¢**	**13.90¢**	**0.19%**	**11.94¢**	**0.23%**	**7.95¢**	**0.34%**	**13.84¢**	**0.20%**	**11.67¢**	**0.23%**
Option B											
MRO	0.029¢	11.58¢	0.25%	9.48¢	0.31%	6.59¢	0.45%	11.00¢	0.27%	9.15¢	0.32%
NPCC	0.003¢	20.94¢	0.01%	17.15¢	0.02%	12.12¢	0.02%	13.96¢	0.02%	17.95¢	0.01%
RF	0.042¢	14.33¢	0.29%	12.07¢	0.35%	8.90¢	0.47%	10.13¢	0.41%	12.05¢	0.35%
SERC	0.041¢	12.42¢	0.33%	10.22¢	0.40%	6.65¢	0.62%	11.45¢	0.36%	10.30¢	0.40%
TRE	0.005¢	12.08¢	0.04%	10.47¢	0.04%	7.59¢	0.06%	9.13¢	0.05%	10.22¢	0.05%
WECC	0.022¢	16.15¢	0.13%	14.34¢	0.15%	9.81¢	0.22%	18.17¢	0.12%	13.91¢	0.15%
US	**0.030¢**	**13.90¢**	**0.22%**	**11.94¢**	**0.25%**	**7.95¢**	**0.38%**	**13.84¢**	**0.22%**	**11.67¢**	**0.26%**

Table 7-4: Projected 2024 Price (Cents per kWh of Sales) and Potential Price Increase Due to Compliance Costs by NERC Region and Regulatory Option (2023$) – Upper Bound

NERC[b]	Compliance Costs (2023¢ /kWh)	Residential		Commercial		Industrial		Transportation		All Sectors Average	
		EIA Price Basis (2023¢ /kWh)	% Change [a]	EIA Price Basis (2023¢ /kWh)	% Change [a]	EIA Price Basis (2023¢ /kWh)	% Change [a]	EIA Price Basis (2023¢ /kWh)	% Change [a]	EIA Price Basis (2023¢ /kWh)	% Change [a]
Option C											
MRO	0.031¢	11.58¢	0.27%	9.48¢	0.33%	6.59¢	0.47%	11.00¢	0.28%	9.15¢	0.34%
NPCC	0.003¢	20.94¢	0.01%	17.15¢	0.02%	12.12¢	0.02%	13.96¢	0.02%	17.95¢	0.01%
RF	0.046¢	14.33¢	0.32%	12.07¢	0.38%	8.90¢	0.51%	10.13¢	0.45%	12.05¢	0.38%
SERC	0.045¢	12.42¢	0.36%	10.22¢	0.44%	6.65¢	0.68%	11.45¢	0.39%	10.30¢	0.44%
TRE	0.006¢	12.08¢	0.05%	10.47¢	0.06%	7.59¢	0.08%	9.13¢	0.06%	10.22¢	0.06%
WECC	0.023¢	16.15¢	0.14%	14.34¢	0.16%	9.81¢	0.24%	18.17¢	0.13%	13.91¢	0.17%
US	**0.033¢**	**13.90¢**	**0.23%**	**11.94¢**	**0.27%**	**7.95¢**	**0.41%**	**13.84¢**	**0.24%**	**11.67¢**	**0.28%**

a. The rate impact analysis assumes full pass-through of all compliance costs to electricity consumers.

b. ELG compliance costs are zero in the AK and HICC regions and these regions are therefore omitted from the presentation.

Sources: U.S. EPA Analysis, 2024; EIA, 2022c, 2023b.

7.2.3 Uncertainties and Limitations

As noted above, the assumption of 100 percent pass-through of compliance costs to electricity prices represents a worst-case scenario from the perspective of consumers. To the extent that some steam electric power plants do not pass their compliance costs to consumers through higher electricity rates, this analysis may overstate the potential impact of the regulatory options on electricity consumers.

In addition, this analysis assumes that costs would be passed on in the form of a flat-rate price increase per unit of electricity, to be applied equally to all consumer groups. This assumption is appropriate to assess the general magnitude of potential price increases. The allocation of costs to different consumer groups could be higher or lower than estimated by this approach.

7.3 Assessment of Impact of Compliance Costs on Household Electricity Costs

EPA also assessed the potential increases in the cost of electricity to residential households.

7.3.1 Analysis Approach and Data Inputs

For this analysis, EPA again assumed that compliance costs would be fully passed through as increased electricity prices and allocated these costs to residential households in proportion to the baseline electricity consumption. EPA analyzed the potential impact on annual electricity costs at the level of the ‘average’ household, using the estimated household electricity consumption quantity by NERC region. Following the approach used in analyzing the 2015 and 2020 rules and 2023 proposal (U.S. EPA, 2015, 2020, 2023d), the steps in this calculation are as follows:

- As done for the electricity price analysis discussed in Section 7.2, to estimate total annual cost in each NERC region, EPA summed weighted pre-tax, plant-level annualized compliance costs by NERC region.[79]
- As was done for the analysis of impact of compliance costs on electricity prices, EPA divided total compliance costs by the total MWh of sales reported for each NERC region. EPA used electricity sales (in MWh) for 2024 from AEO2023 (EIA, 2023b).[80]
- To calculate average annual electricity sales per household, EPA divided the total quantity of *residential* sales (in MWh) for 2021 in each NERC region by the number of households in that region; the Agency obtained both the quantity of residential sales and the number of households from the 2021 EIA-861 database (EIA, 2022a). For this analysis, EPA assumed that the average quantity of electricity sales per household by NERC region would remain the same in 2024 as in 2021.
- To assess the potential annual cost impact per household, EPA multiplied the estimated average price impact by the average quantity of electricity sales per household in 2021 by NERC region.

7.3.2 Key Findings for Regulatory Options A through C

Table 7-5 and Table 7-6 report the upper and lower bound scenario results of this analysis by NERC region for each regulatory option, and overall for the United States.[81]

Table 7-5: Average Incremental Annual Cost per Household in 2024 by NERC Region and Regulatory Option (2023$) – Lower Bound

NERC[b]	Total Electricity Sales (MWh)	Residential Electricity Sales (MWh)	Number of Households	Residential Sales per Residential Household (MWh/year)	Total Pre-Tax Compliance Costs (at 2024; 2023$/year)	Total Compliance Costs per Unit of Sales (2023$/MWh)	Total Compliance Costs per Residential Household (2023$/year)
Option A							
MRO	456,121,788	119,927,337	10,807,443	11.10	54,026,214	$0.12	$1.31
NPCC	253,369,049	111,525,266	14,886,378	7.49	5,992,572	$0.02	$0.18
RF	732,859,497	320,906,246	32,782,678	9.79	146,301,472	$0.20	$1.95
SERC	1,324,847,581	501,406,381	38,022,008	13.19	228,184,395	$0.17	$2.27
TRE	389,170,380	79,238,157	6,202,682	12.77	7,931,750	$0.02	$0.26
WECC	691,321,258	252,010,889	29,828,524	8.45	36,218,573	$0.05	$0.44
US[b]	**3,861,716,503**	**1,389,584,033**	**133,240,696**	**10.43**	**479,230,884**	**$0.12**	**$1.29**
Option B							
MRO	456,121,788	119,927,337	10,807,443	11.10	69,824,715	$0.15	$1.70
NPCC	253,369,049	111,525,266	14,886,378	7.49	6,122,629	$0.02	$0.18

79 Compliance costs in the ASCC and HICC regions are zero and EPA therefore did not include these regions in its analysis.

80 AEO does not provide information for HICC and ASSC. None of the plants estimated to incur compliance costs as a result of the final ELG, however, are located in these two NERC regions.

81 Average annual cost per residential household is zero in ASCC and HICC for the baseline and the three options and these regions are therefore omitted from the details. They are included in the U.S. totals.

Table 7-5: Average Incremental Annual Cost per Household in 2024 by NERC Region and Regulatory Option (2023$) – Lower Bound

NERC[b]	Total Electricity Sales (MWh)	Residential Electricity Sales (MWh)	Number of Households	Residential Sales per Residential Household (MWh/year)	Total Pre-Tax Compliance Costs (at 2024; 2023$/year)	Total Compliance Costs per Unit of Sales (2023$/MWh)	Total Compliance Costs per Residential Household (2023$/year)
RF	732,859,497	320,906,246	32,782,678	9.79	208,025,785	$0.28	$2.78
SERC	1,324,847,581	501,406,381	38,022,008	13.19	256,608,152	$0.19	$2.55
TRE	389,170,380	79,238,157	6,202,682	12.77	9,215,116	$0.02	$0.30
WECC	691,321,258	252,010,889	29,828,524	8.45	44,513,228	$0.06	$0.54
US[b]	**3,861,716,503**	**1,389,584,033**	**133,240,696**	**10.43**	**594,885,534**	**$0.15**	**$1.61**
			Option C				
MRO	456,121,788	119,927,337	10,807,443	11.10	76,979,491	$0.17	$1.87
NPCC	253,369,049	111,525,266	14,886,378	7.49	6,122,629	$0.02	$0.18
RF	732,859,497	320,906,246	32,782,678	9.79	235,300,734	$0.32	$3.14
SERC	1,324,847,581	501,406,381	38,022,008	13.19	305,278,400	$0.23	$3.04
TRE	389,170,380	79,238,157	6,202,682	12.77	14,139,636	$0.04	$0.46
WECC	691,321,258	252,010,889	29,828,524	8.45	55,553,917	$0.08	$0.68
US[b]	**3,861,716,503**	**1,389,584,033**	**133,240,696**	**10.43**	**693,950,715**	**$0.18**	**$1.87**

a. This analysis assumes full pass-through of all compliance costs to electricity consumers.

b. ELG compliance costs are zero in the AK and HICC regions and these regions are therefore omitted from the presentation. For this reason, electricity sales shown for the United States is greater than the total for NERC regions included in the table.

Sources: U.S. EPA Analysis, 2024; EIA, 2022c, 2023b.

Table 7-6: Average Incremental Annual Cost per Household in 2024 by NERC Region and Regulatory Option (2023$) – Upper Bound

NERC[b]	Total Electricity Sales (MWh)	Residential Electricity Sales (MWh)	Number of Households	Residential Sales per Residential Household (MWh/year)	Total Pre-Tax Compliance Costs (at 2024; 2023$/year)	Total Compliance Costs per Unit of Sales (2023$/MWh)	Total Compliance Costs per Residential Household (2023$/year)
			Option A				
MRO	456,121,788	119,927,337	10,807,443	11.10	118,176,904	$0.26	$2.88
NPCC	253,369,049	111,525,266	14,886,378	7.49	6,405,553	$0.03	$0.19
RF	732,859,497	320,906,246	32,782,678	9.79	245,175,269	$0.33	$3.27
SERC	1,324,847,581	501,406,381	38,022,008	13.19	518,050,509	$0.39	$5.16
TRE	389,170,380	79,238,157	6,202,682	12.77	16,758,365	$0.04	$0.55
WECC	691,321,258	252,010,889	29,828,524	8.45	140,691,334	$0.20	$1.72
US[b]	**3,861,716,503**	**1,389,584,033**	**133,240,696**	**10.43**	**1,047,696,932**	**$0.27**	**$2.83**
			Option B				
MRO	456,121,788	119,927,337	10,807,443	11.10	133,975,405	$0.29	$3.26
NPCC	253,369,049	111,525,266	14,886,378	7.49	6,535,610	$0.03	$0.19
RF	732,859,497	320,906,246	32,782,678	9.79	306,899,583	$0.42	$4.10
SERC	1,324,847,581	501,406,381	38,022,008	13.19	546,474,267	$0.41	$5.44
TRE	389,170,380	79,238,157	6,202,682	12.77	18,041,731	$0.05	$0.59
WECC	691,321,258	252,010,889	29,828,524	8.45	148,985,988	$0.22	$1.82
US[b]	**3,861,716,503**	**1,389,584,033**	**133,240,696**	**10.43**	**1,163,351,581**	**$0.30**	**$3.14**

Table 7-6: Average Incremental Annual Cost per Household in 2024 by NERC Region and Regulatory Option (2023$) – Upper Bound

NERC[b]	Total Electricity Sales (MWh)	Residential Electricity Sales (MWh)	Number of Households	Residential Sales per Residential Household (MWh/year)	Total Pre-Tax Compliance Costs (at 2024; 2023$/year)	Total Compliance Costs per Unit of Sales (2023$/MWh)	Total Compliance Costs per Residential Household (2023$/year)
Option C							
MRO	456,121,788	119,927,337	10,807,443	11.10	141,130,180	$0.31	$3.43
NPCC	253,369,049	111,525,266	14,886,378	7.49	6,535,610	$0.03	$0.19
RF	732,859,497	320,906,246	32,782,678	9.79	334,174,531	$0.46	$4.46
SERC	1,324,847,581	501,406,381	38,022,008	13.19	595,144,514	$0.45	$5.92
TRE	389,170,380	79,238,157	6,202,682	12.77	22,966,251	$0.06	$0.75
WECC	691,321,258	252,010,889	29,828,524	8.45	160,026,678	$0.23	$1.96
US[b]	**3,861,716,503**	**1,389,584,033**	**133,240,696**	**10.43**	**1,262,416,762**	**$0.33**	**$3.41**

a. This analysis assumes full pass-through of all compliance costs to electricity consumers.

b. ELG compliance costs are zero in the AK and HICC regions and these regions are therefore omitted from the presentation. For this reason, electricity sales shown for the United States is greater than the total for NERC regions included in the table.

Sources: U.S. EPA Analysis, 2024; EIA, 2022c, 2023b.

To address concerns that cost increase may affect households served by certain types of operators more than others, the Agency also estimated the potential increases in electricity costs for households by plant ownership type for the final rule. In this analysis, the Agency estimated the potential increase in electricity costs for the average household under each plant ownership type based on the average household electricity sales (10.43 MWh/year) in Table 7-5 and Table 7-6 and the compliance costs per MWh under each plant ownership type.[82] The analysis shows that the compliance costs per average residential consumer are relatively similar under each plant ownership type with an average of $3.57 and $6.48 in the lower and upper bound scenarios, respectively.[83] The compliance costs of the final rule per average residential consumer were greatest for cooperatives (between $6.73 and $19.26) and lowest for federal entities (between $0.62 and $1.63).

7.3.3 Uncertainties and Limitations

As noted above, the assumption of 100 percent pass-through of compliance costs to electricity prices represents a worst-case scenario from the perspective of households. To the extent that some steam electric power plants do not pass their compliance costs to consumers through higher electricity rates, this analysis may overstate the potential impact of the regulatory options on households.

This analysis also assumes that costs would be passed on in the form of a flat-rate price increase per unit of electricity, an assumption EPA concluded is reasonable to characterize the magnitude of compliance

82 The Agency estimated compliance costs per MWh for each plant ownership type by dividing the total compliance costs incurred by plants under each ownership type by the sum of retail sales (MWh) and sales for resale (MWh) for the utilities associated with plants under each ownership type from EIA-861 2021 data (U.S. Energy Information Administration. (2022a). *Annual Electric Power Industry Report, Form EIA-861 detailed data files: Final 2021 Data*).

83 The compliance costs per average residential consumer are different from what is reported in Table 7-5 because only a subset of utilities incurred compliance costs under the final rule (Option B).

costs relative to household electricity consumption. The allocation of costs to the residential class could be higher or lower than estimated by this approach.

7.4 Distribution of Electricity Cost Impact on Household

In general, lower-income households spend less, in the absolute, on energy than do higher-income households, but energy expenditures represent a larger *share* of their income. Therefore, electricity price increases tend to have a relatively larger effect on lower-income households, compared to higher-income households. In analyzing the impacts of the 2015 rule, EPA conducted a distributional analysis of the 2015 rule to assess (1) whether an increase in electricity rates that may occur under the 2015 rule would disproportionately affect lower-income households and (2) whether households would be able to pay for these electricity rate increases without experiencing economic hardship (*i.e.*, whether the increase is affordable). The analysis provided additional insight on the distribution of impacts among residential electricity consumers to help respond to concerns regarding the impacts of the rule on utilities and cooperatives in service areas that include a relatively high proportion of low-income households.

In the 2015 analysis, EPA had concluded that even when looking at a worst-case scenario of 100 percent pass through of the compliance costs, the "incremental economic burden of any final rule based on the regulatory options in the proposal on households is small both relative to income and relative to the baseline energy burden of households in different income ranges. While the incremental burden relative to income is not distributionally neutral, *i.e.*, any increase would affect lower-income households to a greater extent than higher-income households, the small impacts may be further moderated by existing pricing structures (see Section 7.4 in U.S. EPA, 2015)." As presented in the preceding sections, EPA estimates that regulatory options A through C would result in compliance costs for FGD wastewater, BA transport water, and CRL treatment. To the extent that these costs are in turn passed through to electricity consumers in the form of higher prices, the resulting higher electricity prices may have a larger negative effect on lower-income households. However, given the small increase to household electricity costs corresponding to the incremental compliance costs for the rule (between $1.61 and $3.14 per household per year for Option B), EPA finds that the earlier conclusion of small impacts from the 2015 rule still holds given the lower compliance costs of the three regulatory options relative to the 2015 rule.

8 Assessment of Potential Impact of the Regulatory Options on Small Entities – Regulatory Flexibility Act (RFA) Analysis

The Regulatory Flexibility Act (RFA) of 1980, as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA) of 1996, requires federal agencies to consider the impact of their rules on small entities, to analyze alternatives that minimize those impacts,[84] and to make their analyses available for public comments. The RFA is concerned with three types of small entities: small businesses, small nonprofits, and small government jurisdictions.

The RFA describes the regulatory flexibility analyses and procedures that must be completed by federal agencies unless they certify that the rule, if promulgated, would not have a significant economic impact on a substantial number of small entities. This certification must be supported by a statement of factual basis, *e.g.*, addressing the number of small entities affected by the final rule, estimated cost impacts on these entities, and evaluation of the economic impacts.

In accordance with RFA requirements and as it has consistently done in developing effluent limitations guidelines and standards, EPA assessed whether the regulatory options would have "a significant impact on a substantial number of small entities" (SISNOSE). Following the approach used in the analysis of the 2015 and 2020 rules and 2023 proposal (U.S. EPA, 2015, 2020, 2023d), this assessment involved the following steps:

- Identifying the domestic parent entities of steam electric power plants.
- Determining which of those domestic parent entities are small entities, based on SBA size criteria.
- Assessing the change in potential impact of the regulatory options on those small entities by comparing the estimated entity-level annualized compliance cost to entity-level revenue; the cost-to-revenue ratio indicates the magnitude of economic impacts. Following EPA guidance (U.S. EPA, 2006), EPA used threshold compliance costs of one percent or three percent of entity-level revenue to categorize the degree of *significance* of the economic impacts on small entities.
- Assessing the change in whether those small entities incurring potentially significant impacts represent a substantial number of small entities. Following EPA guidance (U.S. EPA, 2006), EPA determined whether the number of small entities impacted is *substantial* based on (1) the estimated *absolute numbers* of small entities incurring potentially significant impacts according to the two cost impact criteria, and (2) the *percentage of small entities* in the relevant entity categories that are estimated to incur these impacts.

EPA performed this assessment for each of the regulatory options. This chapter describes the analytic approach (Section 8.1), summarizes the findings of EPA's RFA assessment (Section 8.2), and reviews

84 Section 603(c) of the RFA provides examples of such alternatives as: (1) the establishment of differing compliance or reporting requirements or timetables that take into account the resources available to small entities; (2) the clarification, consolidation, or simplification of compliance and reporting requirements under the rule for such small entities; (3) the use of performance rather than design standards; and (4) an exemption from coverage of the rule, or any part thereof, for such small entities.

uncertainties and limitations in the analysis (Section 8.3). The chapter also discusses how regulatory options developed by EPA served to mitigate the impact of the regulatory options on small entities (Section 8.4).

8.1 Analysis Approach and Data Inputs

EPA used the same methodology and assumptions used for the analysis of the 2015, 2020, and proposed 2023 rules (U.S. EPA, 2015, 2020, 2023d), but updated input data to reflect more recent information about plant ownership, entity size, and compliance costs as described in the sections below.

8.1.1 Determining Parent Entity of Steam Electric Power Plants

Consistent with the entity-level cost-to-revenue analysis (see Chapter 4), EPA conducted the RFA analysis at the highest level of domestic ownership, referred to as the "domestic parent entity" or "domestic parent firm", including only entities with the largest share of ownership (majority owner)[85] in at least one of the estimated 858 steam electric power plants in the steam electric point source category. As was done for the entity-level cost-to-revenue analysis in Section 4.3, EPA identified the majority owner for each plant using 2022 databases published by EIA (EIA, 2022c), Dun and Bradstreet (Dun & Bradstreet, 2021), Experian (Experian, 2023), corporate and financial websites, information provided in the comments on the 2023 proposed rule, and the Steam Electric Survey (U.S. EPA, 2010).

8.1.2 Determining Whether Parent Entities of Steam Electric Power Plants Are Small

EPA identified the size of each parent entity using the SBA size threshold guidelines in effect as of March 17, 2023 (SBA, 2023). The criteria for entity size determination vary by the organization/operation category of the parent entity, as follows:

- **Privately owned (non-government) entities**: Privately owned entities include investor-owned utilities, nonutility entities, and entities with a primary business other than electric power generation. For entities with electric power generation as a primary business, small entities are those with less than the threshold number of employees specified by SBA for each of the relevant North American Industry Classification System (NAICS) sectors (NAICS 2211) (see *Table 8-1*). For entities with a primary business other than electric power generation, the relevant size criteria are based on revenue or number of employees by NAICS sector.[86]

- **Publicly owned entities**: Publicly owned entities include federal, State, municipal, and other political subdivision entities. The federal and State governments were considered to be large; municipalities and other political units with population less than 50,000 were considered to be small.

85 Throughout the analyses, EPA refers to the owner with the largest ownership share as the "majority owner" even when the ownership share is less than 51 percent.

86 Certain steam electric power plants are owned by entities whose primary business is not electric power generation. EPA determined the NAICS code of each privately owned entity based on Dun and Bradstreet (Dun & Bradstreet. (2021). *Hoovers Data Services* Version [Data set]).).

- **Rural Electric Cooperatives**: Small entities are those with less than the threshold number of employees specified by SBA for each of the relevant NAICS sectors, depending on the type of electricity generation (see *Table 8-1*).

Table 8-1: NAICS Codes and SBA Size Standards for Non-government Majority Owners Entities of Steam Electric Power Plants

NAICS Code[a]	NAICS Description	SBA Size Standard[b]
212114	Surface Coal Mining	1,250 Employees
221111	Hydroelectric Power Generation	750 Employees
221112	Fossil Fuel Electric Power Generation	950 Employees
221113	Nuclear Electric Power Generation	1,150 Employees
221114[c]	Solar Electric Power Generation	250 Employees
221115[c]	Wind Electric Power Generation	250 Employees
221116[c]	Geothermal Electric Power Generation	250 Employees
221117[c]	Biomass Electric Power Generation	250 Employees
221118[c]	Other Electric Power Generation	250 Employees
221121	Electric Bulk Power Transmission and Control	950 Employees
221122	Electric Power Distribution	1,100 Employees
221210	Natural Gas Distribution	1,150 Employees
221310	Water Supply and Irrigation Systems	$41.0 million in revenue
237130	Power and Communication Line and Related Structures Construction	$45.0 million in revenue
332410	Power Boiler and Heat Exchanger Manufacturing	750 Employees
333611	Turbine and Turbine Generator Set Unit Manufacturing	1,500 Employees
523940	Portfolio Management and Investment Advice	$47.0 million in revenue
524113	Direct Life Insurance Carriers	$47.0 million in revenue
524126	Direct Property and Casualty Insurance Carriers	1,500 employees
541614	Process, Physical Distribution and Logistics Consulting Services	$20.0 million in revenue
551112	Offices of Other Holding Companies	$45.5 million in revenue
562219	Other Nonhazardous Waste Treatment and Disposal	$47.0 million in revenue

a. Certain plants affected by this rulemaking are owned by non-government entities whose primary business is not electric power generation.

b. Based on size standards effective at the time EPA conducted this analysis (SBA size standards, effective March 17, 2023).

c. NAICS code used as proxy for determining size threshold for entities categorized in NAICS 221119.

Source: SBA, 2023.

To determine whether a majority owner is a small entity according to these criteria, EPA compared the relevant entity size criterion value estimated for each parent entity to the SBA threshold value. EPA used the following data sources and methodology to estimate the relevant size criterion values for each parent entity:

- **Employment**: EPA used entity-level employment values from Dun and Bradstreet, Experian, or corporate/financial websites, if those values were available.

- **Revenue**: EPA used entity-level revenue values from Dun and Bradstreet, Experian, or corporate/financial website, if those values were available.

- **Population**: Population data for municipalities and other non-state political subdivisions were obtained from the U.S. Census Bureau (estimated population for 2021) (U.S. Census Bureau, 2021b).

Parent entities for which the relevant measure is less than the SBA size criterion were identified as small entities and carried forward in the RFA analysis.

As discussed in Chapter 4, EPA estimated the number of small entities owning steam electric power plants as a range, based on alternative assumptions about the possible ownership of electric power plants that fall within the definition of the point source category. Following the approach used in the analysis of the 2015, 2020, proposed 2023 rules, EPA analyzed two cases that provide a range of estimates for (1) the number of firms incurring compliance costs and (2) the costs incurred by any firm owning a regulated plant (U.S. EPA, 2015, 2020, 2023d).

Table 8-2 presents the total number of entities with steam electric power plants as well as the number and percentage of those entities determined to be small. Table 8-3 presents the distribution of steam electric power plants by ownership type and owner size. Analysis results are presented by ownership type for each of the regulatory options under the lower (Case 1) and upper (Case 2) bound estimates of the number of entities owning steam electric power plants.

As reported in Table 8-2 and Table 8-3, EPA estimates that between 220 and 391 entities own 858 steam electric power plants (for Case 1 and Case 2, respectively).[87] A typical parent entity on average is estimated to own four steam electric power plants (for both Case 1 and Case 2). The Agency estimates that between 117 (53 percent) and 202 (51 percent) parent entities are small (Table 8-2), and these small entities own 267 steam electric power plants (Table 8-3), or approximately 31 percent of all steam electric power plants. Across ownership types, cooperative entities have the largest share of small entities (86 and 89 percent, for Case 1 and Case 2 respectively) and the largest share of steam electric power plants owned by small entities (88 percent).

Table 8-2: Number of Entities by Sector and Size (assuming two different ownership cases)

Ownership Type	Small Entity Size Standard	Case 1: Lower bound estimate of number of entities owning steam electric power plants[a]			Case 2: Upper bound estimate of number of entities owning steam electric power plants[a]		
		Total	Small	% Small	Total	Small	% Small
Cooperative	number of employees	22	19	86.4%	28	25	89.3%
Federal	assumed large	2	0	0.0%	7	0	0.0%
Investor-owned	number of employees[d]	57	17	29.8%	88	22	24.6%
Municipality	50,000 population served	50	22	44.0%	84	30	35.6%
Nonutility	number of employees[d]	76	57	75.0%	160	123	77.3%

87 As described in Chapter 8 in the 2015 RIA (U.S. Environmental Protection Agency. (2015). *Regulatory Impact Analysis for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category*. (EPA-821-R-15-004).), Case 1 assumed that any entity owning a surveyed plant(s) owns the known surveyed plant(s) and all of the sample weight associated with the surveyed plant(s). This case minimizes the count of affected entities, while tending to maximize the potential cost burden to any single entity. Case 2 assumed (1) that an entity owns only the surveyed plant(s) that it is known to own from the Steam Electric Survey and (2) that this pattern of ownership, observed for surveyed plants and their owning entities, extends over the entire plant population. This case minimizes the possibility of multi-plant ownership by a single entity and thus maximizes the count of affected entities, but also minimizes the potential cost burden to any single entity.

Table 8-2: Number of Entities by Sector and Size (assuming two different ownership cases)							
Ownership Type	Small Entity Size Standard	Case 1: Lower bound estimate of number of entities owning steam electric power plants[a]			Case 2: Upper bound estimate of number of entities owning steam electric power plants[a]		
		Total	Small	% Small	Total	Small	% Small
Other Political Subdivision[c]	50,000 population served	11	2	18.2%	23	2	8.9%
State	assumed large	2	0	0.0%	2	0	0.0%
Total[b]		**220**	**117**	**53.2%**	**391**	**202**	**51.7%**

a. Eight plants are owned by a joint venture of two entities.

b. Of these entities, 68 entities, 28 of which are small, own steam electric power plants that are estimated to incur compliance technology costs under Option B under both Case 1 and Case 2 under the lower bound scenario. Under the upper bound scenario, 81 entities, 32 of which are small, own steam electric power plants that are estimated to incur compliance technology costs under Option B under both Case 1 and Case 2.

c. EPA was unable to determine the size of 11 parent entities; for this analysis, these entities are assumed to be small.

d. Entity size may be based on revenue, depending on the NAICS sector (see *Table 8-1*).

Source: U.S. EPA Analysis, 2024.

Table 8-3: Steam Electric Power Plants by Ownership Type and Size				
Ownership Type	Small Entity Size Standard	Number of Steam Electric Power Plants[a,b,c]		
		Total	Small	% Small
Cooperative	number of employees	59	52	88.1%
Federal	assumed large	23	0	0.0%
Investor-owned	number of employees[e]	320	44	13.9%
Municipality	50,000 population served	111	31	28.0%
Nonutility	number of employees[e]	308	134	43.6%
Other Political Subdivisions	50,000 population served	33	6	18.5%
State	assumed large	4	0	0.0%
Total[d]		**858**	**267**	**31.2%**

a. Numbers may not add up to totals due to independent rounding.

b. The number of plants is calculated on a sample-weighted basis.

c. Plant size was determined based on the size of the owner with the largest share in the plant. In case of multiple owners with equal ownership shares (*e.g.*, two entities with 50/50 shares), a plant was assumed to be small if it is owned by at least one small entity.

d. Of these, 142 steam electric power plants are estimated to incur compliance costs under Option B; 33 of the 142 steam electric power plants are owned by small entities under the lower bound. Under the upper bound, 171 steam electric power plants are estimated to incur compliance costs under Option B; 39 of the 171 steam electric power plants are owned by small entities.

e. Entity size may be based on revenue, depending on the NAICS sector (see *Table 8-1*).

Source: U.S. EPA Analysis, 2024.

8.1.3 Significant Impact Test for Small Entities

As outlined in the introduction to this chapter, two criteria are assessed in determining whether the regulatory options would qualify for a no-SISNOSE finding:

- Is the *absolute number* of small entities estimated to incur a potentially significant impact, as described above, *substantial*?

and

- Do these *significant impact* entities represent a *substantial* fraction of small entities in the electric power industry that could potentially be within the scope of a regulation?

A measure of the potential impact of the regulatory options on small entities is the fraction of small entities that have the potential to incur a significant impact. For example, if a high percentage of potentially small entities incur significant impacts *even though the absolute number of significant impact entities is low*, then the rule could represent a substantial burden on small entities.

To assess the extent of economic/financial impact on small entities, EPA compared estimated compliance costs to estimated entity revenue (also referred to as the "sales test"). The analysis is based on the ratio of estimated annualized after-tax compliance costs to annual revenue of the entity. For this analysis, EPA categorized entities according to the magnitude of economic impacts that entities would incur due to the regulatory options. EPA identified entities for which annualized compliance costs are at least one percent and three percent of revenue. EPA then evaluated the absolute number and the percent of entities in each impact category, and by type of ownership. The Agency assumed that entities incurring costs below one percent of revenue are unlikely to face significant economic impacts, while entities with costs of at least one percent of revenue have a higher chance of facing significant economic impacts, and entities incurring costs of at least three percent of revenue have a still higher probability of significant economic impacts. Consistent with the parent-level cost-to-revenue analysis discussed in Chapter 4, EPA assumed that steam electric power plants, and consequently, their parents, would not be able to pass any of the increase in their production costs to consumers (zero cost pass-through). This assumption is used for analytic convenience and provides a worst-case scenario of regulatory impacts to steam electric power plants.

A detailed summary of how EPA developed these entity-level compliance cost and revenue values is presented in Chapter 3 and Chapter 4.

8.2 Key Findings for Regulatory options

As described above, EPA developed estimates of the number of small parent entities in the specified cost-to-revenue impact ranges. Table 8-4 and Table 8-5 summarize the results of the analysis based on lower and upper bound costs. In terms of *number* of entities in each of the impact categories, analysis results for each option are the same under Case 1 and Case 2; however, these numbers represent different percentages of all small entities owning steam electric power plants under each weighting case.

In the lower bound scenario, EPA estimates that 3 small cooperatives, 4 small nonutilities, and 3 small municipalities owning steam electric power plants would incur costs exceeding one percent of revenue (Table 8-4), under the final rule (Option B). On the basis of *percentage*, the 3 small cooperatives represent approximately 12 to 16 percent of the number of small cooperatives owning steam electric power plants. The 4 small nonutilities represent approximately 3 to 7 percent of the number of small nonutilities owning steam electric power plants. The 3 small municipalities represents approximately 10 to 14 percent of the number of small municipalities owning steam electric power plants. These small entities represent approximately 5 to 8.5 percent of the total number of small entities owning steam electric power plants.

In the upper bound scenario, EPA estimates that 4 small cooperatives, 5 small nonutilities, and 3 small municipalities owning steam electric power plants would incur costs exceeding one percent of revenue (Table 8-5), under the final rule (Option B). On the basis of *percentage*, the 4 small cooperatives represent approximately 16 to 21 percent of the number of small cooperatives owning steam electric power plants. The 5 small nonutilities represent approximately 4 to 9 percent of the number of small nonutilities owning steam electric power plants. The 3 small municipalities represents approximately 10 to 14 percent of the number of small municipalities owning steam electric power plants. These small entities represent approximately 6 to 10 percent of the total number of small entities owning steam electric power plants.

In the lower bound scenario, the analysis shows 5 small businesses (2 small cooperatives, 2 small nonutilities, and 1 small municipality) entity incurring costs greater than three percent of revenue under all regulatory options. These small entities represent approximately 2.5 to 4 percent of the small entities owning steam electric power plants. Overall, this worst-case screening-level analysis suggests that the analyzed regulatory options are unlikely to have a significant economic impact on a substantial impact on small entities. In the upper bound scenario, the analysis shows 7 small businesses (3 small cooperatives, 2 small nonutilities, and 2 small municipalities) entity incurring costs greater than three percent of revenue under all regulatory options. These small entities represent approximately 3.5 to 6 percent of the small entities owning steam electric power plants. Overall, this worst-case screening-level analysis suggests that the analyzed regulatory options are unlikely to have a significant economic impact on a substantial impact on small entities under the lower and upper bound scenario.

Table 8-4: Estimated Cost-To-Revenue Impact on Small Parent Entities, by Entity Type and Ownership Category – Lower Bound

Entity Type/Ownership Category	Case 1: Lower bound estimate of number of entities owning steam electric power plants (out of total of 117 small entities)				Case 2: Upper bound estimate of number of entities owning steam electric power plants (out of total of 202 small entities)			
	≥1%		≥3%[a]		≥1%		≥3%[a]	
	Number of small entities	% of all small entities[b]	Number of small entities	% of all small entities[b]	Number of small entities	% of all small entities[b]	Number of small entities	% of all small entities[b]
Option A								
Small Business								
Cooperative	2	10.5%	2	10.5%	2	8.0%	2	8.0%
Investor-Owned	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Nonutility	2	3.5%	2	3.5%	2	1.6%	2	1.6%
Small Government								
Municipality	3	13.6%	1	4.5%	3	10.0%	1	3.3%
Political Subdivision	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total	**7**	**6.0%**	**5**	**4.3%**	**7**	**3.5%**	**5**	**2.5%**
Option B								
Small Business								
Cooperative	3	15.8%	2	10.5%	3	12.0%	2	8.0%
Investor-Owned	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Nonutility	4	7.0%	2	3.5%	4	3.2%	2	1.6%
Small Government								
Municipality	3	13.6%	1	4.5%	3	10.0%	1	3.3%
Political Subdivision	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total	**10**	**8.5%**	**5**	**4.3%**	**10**	**5.0%**	**5**	**2.5%**
Option C								
Small Business								
Cooperative	3	15.8%	2	10.5%	3	12.0%	2	8.0%
Investor-Owned	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Nonutility	4	7.0%	2	3.5%	4	3.2%	2	1.6%
Small Government								
Municipality	3	13.6%	1	4.5%	3	10.0%	1	3.3%
Political Subdivision	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total	**10**	**8.5%**	**5**	**4.3%**	**10**	**5.0%**	**5**	**2.5%**

a. The number of entities with cost-to-revenue impact of at least three percent is a subset of the number of entities with such ratios exceeding one percent.

b. Percentage values were calculated relative to the total of 117 (Case 1) and 202 (Case 2) small entities owning steam electric power plants regardless of whether these plants are estimated to incur compliance technology costs under any of the regulatory options.

Source: U.S. EPA Analysis, 2024.

Table 8-5: Estimated Cost-To-Revenue Impact on Small Parent Entities, by Entity Type and Ownership Category – Upper Bound

Entity Type/Ownership Category	Case 1: Lower bound estimate of number of entities owning steam electric power plants (out of total of 117 small entities)				Case 2: Upper bound estimate of number of entities owning steam electric power plants (out of total of 202 small entities)			
	≥1%		≥3%[a]		≥1%		≥3%[a]	
	Number of small entities	% of all small entities[b]	Number of small entities	% of all small entities[b]	Number of small entities	% of all small entities[b]	Number of small entities	% of all small entities[b]
Option A								
Small Business								
Cooperative	3	15.8%	3	15.8%	3	12.0%	3	12.0%
Investor-Owned	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Nonutility	3	5.3%	2	3.5%	3	2.4%	2	1.6%
Small Government								
Municipality	3	13.6%	2	9.1%	3	10.0%	2	6.7%
Political Subdivision	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total	**9**	**7.7%**	**7**	**6.0%**	**9**	**4.5%**	**7**	**3.5%**
Option B								
Small Business								
Cooperative	4	21.1%	3	15.8%	4	16.0%	3	12.0%
Investor-Owned	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Nonutility	5	8.8%	2	3.5%	5	4.1%	2	1.6%
Small Government								
Municipality	3	13.6%	2	9.1%	3	10.0%	2	6.7%
Political Subdivision	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total	**12**	**10.3%**	**7**	**6.0%**	**12**	**5.9%**	**7**	**3.5%**
Option C								
Small Business								
Cooperative	4	21.1%	3	15.8%	4	16.0%	3	12.0%
Investor-Owned	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Nonutility	5	8.8%	2	3.5%	5	4.1%	2	1.6%
Small Government								
Municipality	3	13.6%	2	9.1%	3	10.0%	2	6.7%
Political Subdivision	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total	**12**	**10.3%**	**7**	**6.0%**	**12**	**5.9%**	**7**	**3.5%**

a. The number of entities with cost-to-revenue impact of at least three percent is a subset of the number of entities with such ratios exceeding one percent.

b. Percentage values were calculated relative to the total of 117 (Case 1) and 202 (Case 2) small entities owning steam electric power plants regardless of whether these plants are estimated to incur compliance technology costs under any of the regulatory options.

Source: U.S. EPA Analysis, 2024.

8.3 Uncertainties and Limitations

Despite EPA's use of the best available information and data, the RFA analysis discussed in this chapter has sources of uncertainty, including:

- None of the sample-weighting approaches used for this analysis accounts precisely for the number of parent-entities and compliance costs assigned to those entities simultaneously. EPA assesses the values presented in this chapter as reasonable estimates of the numbers of small entities that could incur a significant impact according to the cost-to-revenue metric.

- In cases where available information was insufficient to determine the size of an entity, the Agency assumed the entity to be small. EPA was unable to determine the size of nine parent entities and assumed all to be small for this analysis.

- As discussed in Chapter 4, the zero cost pass-through assumption represents a worst-case scenario from the perspective of the plants and parent entities. To the extent that some entities are able to pass at least some compliance costs to consumers through higher electricity prices, this analysis may overstate potential impact of regulatory options A through C on small entities.

8.4 Small Entity Considerations in the Development of Rule Options

As described in the introduction to this chapter, the RFA requires federal agencies to consider the impact of their regulatory actions on small entities and to analyze alternatives that minimize those impacts. As EPA explicitly states in the final rule, the implementation period built into the rule is another way for permit writers to consider the needs of small entities, as these entities may need additional time to plan and finance capital improvements.

9 Unfunded Mandates Reform Act (UMRA) Analysis

Title II of the Unfunded Mandates Reform Act of 1995, Pub. L. 104-4, requires that federal agencies assess the effects of their regulatory actions on State, local, and Tribal governments and the private sector. Under UMRA section 202, EPA generally must prepare a written statement, including a cost-benefit analysis, for proposed and final rules with "Federal mandates" that might result in expenditures by State, local, and Tribal governments, in the aggregate, or by the private sector, of $100 million (adjusted annually for inflation) or more in any one year (*i.e.*, about $198 million in 2023 dollars). Before promulgating a regulation for which a written statement is needed, UMRA section 205 generally requires EPA to "identify and consider a reasonable number of regulatory alternatives and adopt the least costly, most cost-effective, or least burdensome alternative that achieves the objectives of the rule." (2 U.S.C. 1535(a) The provisions of section 205 do not apply when they are inconsistent with applicable law. Moreover, section 205 allows EPA to adopt an alternative other than the least costly, most cost-effective, or least burdensome alternative, if the Administrator publishes with the rule an explanation of why that alternative was not adopted. Before EPA establishes any regulatory requirements that might significantly or uniquely affect small governments, including Tribal governments, it must develop a small government agency plan, under UMRA section 203. The plan must provide for notifying potentially affected small governments, enabling officials of affected small governments to have meaningful and timely input in the development of EPA regulatory proposals with significant intergovernmental mandates, and informing, educating, and advising small governments on compliance with regulatory requirements.

EPA estimated the compliance costs associated with each of the regulatory options for different categories of entities. The Agency estimates that the *maximum* compliance cost *in any one year* to government entities (excluding federal government) range from $155 million under the lower bound cost scenario to $220 million under the upper bound cost scenario.[88,89] The *maximum* compliance cost *in any given year* to the private sector range from $1,380 million under the lower bound cost scenario to $3,156 million under the upper bound cost scenario. From these compliance cost values, EPA determined that the final rule does contain a mandate that may result in expenditures of $198 million (in 2023 dollars) or more for the public (including State, local, and Tribal governments) and private sectors in any one year.

This chapter contains additional information to support the above statements, including information on compliance and administrative costs, and on impacts to small governments. Following the approach used for the analysis of the 2015 and 2020 rules and 2023 proposal (U.S. EPA, 2015, 2020, 2023d; see Chapter 9), the annualized costs presented in this UMRA analysis are calculated using the social cost framework presented in Chapter 12 of the BCA (U.S. EPA, 2024a). Specifically, this analysis uses costs in 2024 stated in 2023 dollars and accounts for costs in the year they are anticipated to be incurred between 2025 and 2049. The discounted stream of costs is then annualized over a 25-year period. As discussed in Chapter 10 (Other Administrative Requirements; see Section 10.7) in this document, the reporting and recordkeeping requirements in this final rule would increase the reporting and recordkeeping burden for the review, oversight, and administration of the rule relative to baseline requirements. NPDES permitting authorities are required to review notices of planned participation (NOPPs), leachate groundwater

88 Maximum costs are costs incurred by the entire universe of steam electric power plants in a given year of occurrence under a given regulatory option.

89 For this analysis, rural electric cooperatives are considered to be a part of the private sector.

information reports (LGIRs), and progress reports associates with EPA's voluntary incentive program (VIP) to administer this rule. Government entities owning steam electric power plants would potentially incur costs as the result of this rule associated with the cost to implement control technologies at power plants they own. For more details on how social costs were developed, see Chapter 12 in the BCA.

9.1 UMRA Analysis of Impact on Government Entities

This part of the UMRA analysis assesses the compliance cost burden to State, local, and Tribal governments that own existing steam electric power plants. The use of the phrase "government entities" in this section does *not* include the federal government, which owns 23 of the 858 steam electric power plants; three of these plants incur compliance costs under the regulatory options. Additionally, in evaluating the magnitude of the impact of the options on government entities, EPA analyzed only *compliance costs* incurred by government entities owning steam electric power plants. EPA estimated that government entities will not incur significant incremental *administrative costs* to implement the rule, regardless of whether or not they own steam electric power plants. As discussed in Section 10.7, EPA estimated some increase in the burden associated with this rule. In the case of plant owners, EPA estimated new reporting burdens from notices of planned participation (NOPPs), annual progress reports, leachate function equivalency reports, annual combustion residual leachate monitoring reports, and website posting of all of these documents.

Table 9-1 summarizes the number of State, local and Tribal government entities and the number of steam electric power plants they own. The determination of owning entities, their type, and their size is detailed in Section 4.3 and Chapter 8 (*Assessment of Potential Impact of the Regulatory Options on Small Entities – Regulatory Flexibility Act (RFA) Analysis*).

Table 9-1: Government-Owned Steam Electric Power Plants and Their Parent Entities

Entity Type	Parent Entities[a]	Steam electric power plants[b]
Municipality	50	111
Other Political Subdivision	11	33
State	2	4
Tribal	0	0
Total	**63**	**148**

a. Counts of entities under weighting Case 1, which provides an upper bound of total compliance costs for any given parent entity. For details see Chapter 8.

b. Plant counts are relative to the estimated 858 plants covered under the point source category.

Source: U.S. EPA Analysis, 2024.

Out of 858 steam electric power plants, 148 are owned by 63 government entities.[90] The majority (75 percent) of these government-owned plants are owned by municipalities, followed by other political subdivisions (22 percent), and State governments (3 percent).

Table 9-2 and Table 9-3 show upper and lower bound compliance costs for government entities owning steam electric power plants. Compliance costs to government entities under the final rule range from

90 Counts exclude federal government entities and steam electric power plants they own. The owning entity is determined based on the entity with the largest ownership share in each plant, as described in Chapter 4.

approximately $40 million to $66 million in the aggregate. Average annualized costs per plant are $0.3 million under the lower bound cost scenario and $0.5 million under the upper bound cost scenario. The maximum annualized compliance costs range from $8.65 million to $12.54 million.

Table 9-2: Estimated Compliance Costs to Government Entities Owning Steam Electric Power Plants (2023$) – Lower Bound

Ownership Type	Number of Steam Electric Power Plants (weighted)[a]	Total Weighted, Annualized Pre-Tax Cost (Millions)[a]	Average Annualized Cost per MW of Capacity[b]	Average Annualized Cost per Plant (Millions)[c]	Maximum Annualized Cost per Plant (Millions)[d]
			Option A		
Municipality	111	$20	$592	$0.2	$7.79
Other Political Subdivision	33	$5	$266	$0.2	$1.93
State	4	$2	$363	$0.4	$1.16
Total	**148**	**$28**	**$462**	**$0.2**	**$7.79**
			Option B		
Municipality	111	$28	$804	$0.3	$8.65
Other Political Subdivision	33	$7	$354	$0.2	$2.48
State	4	$5	$959	$1.2	$2.65
Total	**148**	**$40**	**$663**	**$0.3**	**$8.65**
			Option C		
Municipality	111	$29	$842	$0.3	$8.65
Other Political Subdivision	33	$7	$354	$0.2	$2.48
State	4	$14	$2,936	$3.6	$11.57
Total	**148**	**$51**	**$845**	**$0.3**	**$11.57**

a. Plant counts are relative to the estimated 858 plants covered under the point source category.

b. Average cost per MW values were calculated using total compliance costs and capacity for all steam electric power plants owned by entities in a given ownership category. In case of multiple ownership structure where parent entities of a given plant have equal ownership shares and are in different ownership categories, compliance costs and capacity were allocated to appropriate ownership categories in accordance with ownership shares.

c. Average cost per plant values were calculated using the total number of steam electric power plants owned by entities in a given ownership category.

d. Reflects maximum of un-weighted costs to surveyed plants only.

Source: U.S. EPA Analysis, 2024.

Table 9-3: Estimated Compliance Costs to Government Entities Owning Steam Electric Power Plants (2023$) – Upper Bound

Ownership Type	Number of Steam Electric Power Plants (weighted)[a]	Total Weighted, Annualized Pre-Tax Cost (Millions)[a]	Average Annualized Cost per MW of Capacity[b]	Average Annualized Cost per Plant (Millions)[c]	Maximum Annualized Cost per Plant (Millions)[d]
			Option A		
Municipality	111	$43	$1,261	$0.4	$11.67
Other Political Subdivision	33	$7	$350	$0.2	$1.93
State	4	$4	$795	$1.0	$2.04
Total	**148**	**$54**	**$912**	**$0.4**	**$11.67**

Table 9-3: Estimated Compliance Costs to Government Entities Owning Steam Electric Power Plants (2023$) – Upper Bound

Ownership Type	Number of Steam Electric Power Plants (weighted)[a]	Total Weighted, Annualized Pre-Tax Cost (Millions)[a]	Average Annualized Cost per MW of Capacity[b]	Average Annualized Cost per Plant (Millions)[c]	Maximum Annualized Cost per Plant (Millions)[d]
		Option B			
Municipality	111	$50	$1,472	$0.5	$12.54
Other Political Subdivision	33	$9	$438	$0.3	$2.48
State	4	$7	$1,392	$1.7	$4.09
Total	**148**	**$66**	**$1,113**	**$0.5**	**$12.54**
		Option C			
Municipality	111	$52	$1,511	$0.5	$12.54
Other Political Subdivision	33	$9	$438	$0.3	$2.48
State	4	$16	$3,369	$4.1	$12.23
Total	**148**	**$77**	**$1,295**	**$0.5**	**$12.54**

a. Plant counts are relative to the estimated 858 plants covered under the point source category.

b. Average cost per MW values were calculated using total compliance costs and capacity for all steam electric power plants owned by entities in a given ownership category. In case of multiple ownership structure where parent entities of a given plant have equal ownership shares and are in different ownership categories, compliance costs and capacity were allocated to appropriate ownership categories in accordance with ownership shares.

c. Average cost per plant values were calculated using the total number of steam electric power plants owned by entities in a given ownership category.

d. Reflects maximum of un-weighted costs to surveyed plants only.

Source: U.S. EPA Analysis, 2024.

9.2 UMRA Analysis of Impact on Small Governments

As part of the UMRA analysis, EPA also assessed whether the regulatory options would significantly and uniquely affect small governments. To assess whether the regulatory options would affect small governments in a way that is disproportionately burdensome in comparison to the effect on large governments, EPA compared total incremental costs and costs per plant estimated to be incurred by small governments with those values estimated to be incurred by large governments. EPA also compared the changes in per plant costs incurred for small government-owned plants with those incurred by non-government-owned plants. The Agency evaluated costs per plant on the basis of both average and maximum annualized incremental cost per plant.

Table 9-4 presents the distribution of plants by entity type and size. Out of 148 government-owned steam electric power plants, EPA identified 37 plants that are owned by 24 small government entities. These 37 plants constitute approximately 25 percent of all government-owned plants.[91]

91 Counts exclude federal government entities and steam electric power plants they own.

Table 9-4: Counts of Government-Owned Plants and Their Parent Entities, by Size

Entity Type	Entities[a]			Steam Electric Power Plants[b]		
	Large	Small	Total	Large	Small	Total
Municipality	28	22	50	80	31	111
Other Political Subdivision	9	2	11	27	6	33
State	2	0	2	4	0	4
Total	**39**	**24**	**63**	**111**	**37**	**148**

a. Counts of entities under weighting Case 1, which provides an upper bound of total compliance costs for any given parent entity. For details see Chapter 8.

b. Plant counts are relative to the estimated 858 plants covered under the point source category.

Source: U.S. EPA Analysis, 2024.

As presented in Table 9-5 and Table 9-6, under the final rule, overall compliance costs range from $633 million in the lower bound cost scenario to $1,245 million in the upper bound cost scenario.

Table 9-5: Estimated Incremental Compliance Costs for Electric Generators by Ownership Type and Size (2023$) – Lower Bound

Ownership Type	Entity Size	Number of Plants [a]	Total Annualized Pre-Tax Costs (Millions)[a]	Average Annualized Pre-tax Cost per MW of Capacity[b]	Average Annualized Pre-tax Cost per Plant (Millions)[c]	Maximum Annualized Pre-tax Cost per Plant (Millions)
Option A						
Government (excl. federal)	Small	37	$9	$1,385	$0.24	$2.6
	Large	111	$19	$350	$0.17	$7.8
Private	Small	230	$117	$1,104	$0.51	$40.8
	Large	457	$355	$1,011	$0.78	$42.8
All Plants		**858**	**$509**	**$805**	**$0.59**	**$42.8**
Option B						
Government (excl. federal)	Small	37	$10	$1,566	$0.27	$2.6
	Large	111	$30	$553	$0.27	$8.7
Private	Small	230	$132	$1,245	$0.57	$42.7
	Large	457	$452	$1,285	$0.99	$77.5
All Plants		**858**	**$633**	**$1,001**	**$0.74**	**$77.5**
Option C						
Government (excl. federal)	Small	37	$10	$1,566	$0.27	$2.6
	Large	111	$40	$757	$0.37	$11.6
Private	Small	230	$133	$1,258	$0.58	$42.7
	Large	457	$537	$1,528	$1.18	$77.5
All Plants		**858**	**$734**	**$1,160**	**$0.86**	**$77.5**

a. Plant counts are relative to the estimated 858 plants covered under the point source category.

b. Average cost per MW values were calculated using total compliance costs and capacity for all steam electric power plants owned by entities in a given ownership category, *including plants that incur zero costs*. In case of multiple ownership structure where parent entities of a given plant have equal ownership shares and are in different ownership categories, compliance costs and capacity were allocated to appropriate ownership categories in accordance with ownership shares.

c. Average cost per plant values were calculated using total number of steam electric power plants owned by entities in a given ownership category. As a result, plants with multiple majority owners are represented more than once in the denominator of relevant cost per plant calculations.

Source: U.S. EPA Analysis, 2024.

Table 9-6: Estimated Incremental Compliance Costs for Electric Generators by Ownership Type and Size (2023$) – Upper Bound

Ownership Type	Entity Size	Number of Plants [a]	Total Annualized Pre-Tax Costs (Millions)[a]	Average Annualized Pre-tax Cost per MW of Capacity[b]	Average Annualized Pre-tax Cost per Plant (Millions)[c]	Maximum Annualized Pre-tax Cost per Plant (Millions)
Option A						
Government (excl. federal)	Small	37	$20	$3,046	$0.53	$10.5
	Large	111	$35	$652	$0.31	$11.7
Private	Small	230	$306	$2,884	$1.33	$173.9
	Large	457	$735	$2,090	$1.61	$127.2
All Plants		**858**	**$1,121**	**$1,772**	**$1.31**	**$173.9**
Option B						
Government (excl. federal)	Small	37	$21	$3,227	$0.57	$10.5
	Large	111	$46	$856	$0.41	$12.5
Private	Small	230	$321	$3,025	$1.39	$175.8
	Large	457	$831	$2,364	$1.82	$128.8
All Plants		**858**	**$1,245**	**$1,968**	**$1.45**	**$175.8**
Option C						
Government (excl. federal)	Small	37	$21	$3,227	$0.57	$10.5
	Large	111	$57	$1,060	$0.51	$12.5
Private	Small	230	$322	$3,038	$1.40	$175.8
	Large	457	$917	$2,607	$2.01	$130.6
All Plants		**858**	**$1,346**	**$2,126**	**$1.57**	**$175.8**

a. Plant counts are relative to the estimated 858 plants covered under the point source category.

b. Average cost per MW values were calculated using total compliance costs and capacity for all steam electric power plants owned by entities in a given ownership category, *including plants that incur zero costs*. In case of multiple ownership structure where parent entities of a given plant have equal ownership shares and are in different ownership categories, compliance costs and capacity were allocated to appropriate ownership categories in accordance with ownership shares.

c. Average cost per plant values were calculated using total number of steam electric power plants owned by entities in a given ownership category. As a result, plants with multiple majority owners are represented more than once in the denominator of relevant cost per plant calculations.

Source: U.S. EPA Analysis, 2024.

9.3 UMRA Analysis of Impact on the Private Sector

As the final part of the UMRA analysis, this section reports the compliance costs projected to be incurred by private entities.

Table 9-7 and Table 9-8 summarize the lower and upper bound total annualized costs, maximum one-year costs, and the year when maximum costs are incurred by type of owner. EPA estimates the final rule to have total annualized pre-tax compliance costs for private entities ranging from $603 million under the lower bound cost scenario to $1,207 million under the upper bound cost scenario.

Table 9-7: Compliance Costs for Electric Generators by Ownership Type (2023$) – Lower Bound			
Ownership Type	Total Annualized Costs (Millions)	Maximum One-Year Costs (Millions)	Year of Maximum Costs[a]
Option A			
Government (excl. federal)	$28	$135	2026
Private	$490	$1,096	2028
Option B			
Government (excl. federal)	$40	$155	2026
Private	$603	$1,380	2028
Option C			
Government (excl. federal)	$51	$256	2026
Private	$693	$1,596	2028

a. The year when the maximum cost occurs is driven by the modeled technology implementation schedule and is determined based on the renewal of individual NPDES permits for plants owned by the different categories of entities. See Section 3.1.3 in this report and Chapter 11 in the BCA for more details on the technology implementation years and assumptions on the timing of cost incurrence.

Source: U.S. EPA Analysis, 2024.

Table 9-8: Compliance Costs for Electric Generators by Ownership Type (Millions of 2023$) – Upper Bound			
Ownership Type	Total Annualized Costs (Millions)	Maximum One-Year Costs (Millions)	Year of Maximum Costs[a]
Option A			
Government (excl. federal)	$55	$200	2026
Private	$1,095	$2,872	2028
Option B			
Government (excl. federal)	$67	$220	2026
Private	$1,207	$3,156	2028
Option C			
Government (excl. federal)	$78	$320	2026
Private	$1,298	$3,372	2028

a. The year when the maximum cost occurs is driven by the modeled technology implementation schedule and is determined based on the renewal of individual NPDES permits for plants owned by the different categories of entities. See Section 3.1.3 in this report and Chapter 11 in the BCA for more details on the technology implementation years and assumptions on the timing of cost incurrence.

Source: U.S. EPA Analysis, 2024.

9.4 UMRA Analysis Summary

EPA estimated that State and local government entities would incur expenditures of greater than $198 million, in the aggregate, in any one year under the final rule, Option B, in the upper bound scenario only. Additionally, the Agency estimated that the private sector would incur expenditures of greater than $198 million, in the aggregate, in any one year under all regulatory options, under the upper and lower scenario. Furthermore, as discussed above, neither permitted plants nor permitting authorities are estimated to incur significant additional administrative costs as the result of the regulatory options.

Consistent with Section 205, EPA presents three regulatory options which would all result in compliance costs to governments and the private sector. For Option B, the final rule, the maximum compliance costs incurred by the private sector in any one year range from $1,380 million to $3,156 million in 2028 whereas total annualized compliance costs for plants owned by private sector entities range from $603 million to $1,207 million. The implementation period built into this final rule is one way that EPA accounted for the site-specific needs of steam electric power plants.

10 Other Administrative Requirements

This chapter presents analyses conducted in support of the regulatory options to address the requirements of applicable Executive Orders and Acts. These analyses complement EPA's assessment of the compliance costs, economic impacts, and economic achievability of the final rule, and other analyses done in accordance with the RFA and UMRA, presented in previous chapters.

10.1 Executive Order 12866: Regulatory Planning and Review, Executive Order 13563: Improving Regulation and Regulatory Review, and Executive Order 14094: Modernizing Regulatory Review

Under Executive Order (E.O.) 12866 (58 FR 51735, October 4, 1993), as amended by E.O. 13563 (76 FR 3821, January 21, 2011) and E.O. 14094 (88 FR 21879, April 11, 2023), EPA must determine whether the regulatory action is "significant" and therefore subject to review by the Office of Management and Budget (OMB) and other requirements of the Executive Order. The order defines a "significant regulatory action" as one that is likely to result in a regulation that may:

- Have an annual effect on the economy of $200 million or more (adjusted every 3 years by the Administrator of the Office of Information and Regulatory Affairs (OIRA) for changes in gross domestic product), or adversely affect in a material way the economy, a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or State, local, or Tribal governments or communities; or

- Create a serious inconsistency or otherwise interfere with an action taken or planned by another agency; or

- Materially alter the budgetary impact of entitlements, grants, user fees, or loan programs or the rights and obligations of recipients thereof; or

- Raise novel legal or policy issues for which centralized review would meaningfully further the President's priorities or the principles set forth in the Executive Order, as specifically authorized in a timely manner by the Administrator of OIRA in each case.

Pursuant to the terms of Executive Order 12866, as amended by E.O. 14094, EPA determined that the final rule (Option B) is a "significant regulatory action" because the action is likely to have an annual effect on the economy of $200 million or more. As such, the action is subject to review by OMB. Any changes made during this period of review will be documented in the docket for this action.

EPA prepared an analysis of the potential benefits and costs associated with this action; this analysis is described in Chapter 13 of the BCA (U.S. EPA, 2024a).

As detailed in earlier chapters of this report, EPA also assessed the impacts of the regulatory options on the wholesale price of electricity (Chapter 5: Electricity Market Analyses), retail electricity prices by consumer group (Chapter 7: Electricity Price Effects), and on employment or labor markets (Chapter 6: Employment Effects).

10.2 Executive Order 12898: Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations, Executive Order 14008: Tackling the Climate Crisis at Home and Abroad, and Executive Order 14096: Revitalizing our Nation's Commitment to Environmental Justice for All

E.O. 12898 (59 FR 7629 (Feb. 16, 1994)) establishes federal executive policy on environmental justice. Its main provision directs federal agencies, to the greatest extent practicable and permitted by law, to make environmental justice part of their mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of their programs, policies, and activities on minority populations and low-income populations in the United States. E.O. 14008 (86 FR 7619, February 1, 2021) expands on the policy objectives established in E.O.12898 and directs federal agencies to develop programs, policies, and activities to address the disproportionately high and adverse human health, environmental, climate-related and other cumulative impacts on disadvantaged communities, as well as the accompanying economic challenges of such impacts.

EPA's analysis showed that the human health or environmental risk addressed by this final rule will not have potential disproportionately high and adverse human health or environmental effects on minority, low-income, or indigenous populations. The results of this evaluation are contained in the EJA (U.S. EPA, 2024c).

10.3 Executive Order 13045: Protection of Children from Environmental Health Risks and Safety Risks

E.O. 13045 (62 FR 19885, April 23, 1997) applies to any rule that (1) is determined to be "economically significant" as defined under E.O. 12866 and (2) concerns an environmental health or safety risk that EPA has reason to believe might have a disproportionate effect on children. If the regulatory action meets both criteria, the Agency must evaluate the environmental health and safety effects of the planned rule on children and explain why the planned regulation is preferable to other potentially effective and reasonably feasible alternatives considered by the Agency.

As detailed in the EA and BCA (U.S. EPA, 2024a, 2024b), EPA identified several ways in which the regulatory options would affect children, including by potentially reducing health risk from exposure to pollutants present in steam electric power plant discharges. The reductions are estimated to be relatively small and arise from more stringent limits under the regulatory options as compared to the baseline. EPA quantified neurological changes, as measured by Intellectual Quotient (IQ) points, from lead exposure among pre-school children and from mercury exposure *in-utero* resulting from maternal fish consumption under the regulatory options, as compared to the baseline. EPA also estimated changes in the number of children with very high blood lead concentrations (above 20 ug/dL) and IQs less than 70 who may require compensatory education tailored to their specific needs.

EPA estimated that the final rule could benefit children. The analysis shows relatively small potential changes in lead exposure (from fish consumption) for an average of 1.55 million children annually, and in mercury exposure (from maternal fish consumption) for an average of 201,850 infants born annually. However, EPA estimates the resulting health impacts to be relatively small. EPA estimated that the final rule (Option B) would lead to slight reductions in lead and mercury exposure, decreasing IQ losses by less than 1 point from lead exposure and 1,377 points from mercury exposure over the entire exposed population. The annualized social welfare effects from reduced IQ loss associated with children's exposure to lead and mercury are $2.0 million using a 2 percent discount rate, with most of these benefits associated with reduced mercury exposure. Chapter 5 in the BCA provides further details, including results for the other regulatory options (U.S. EPA, 2024a). EPA did not quantify additional benefits to children from changes in exposure to steam electric pollutant discharges due to data limitations, but discussed them qualitatively. These include changes in the incidence or severity of other health effects from exposure to lead, mercury, and other pollutants including arsenic, boron, cadmium, copper, nickel, selenium, thallium, and zinc. They also include potential effects from reductions in exposure to disinfection byproducts in households served by drinking water systems that use source waters downstream of steam electric power plant outfalls.

10.4 Executive Order 13132: Federalism

E.O. 13132 (64 FR 43255, August 10, 1999) requires EPA to develop an accountable process to ensure "meaningful and timely input by State and local officials in the development of regulatory policies that have federalism implications." Policies that have federalism implications are defined in the Executive Order to include regulations that have "substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government."

Under section 6 of E.O. 13132, EPA may not issue a regulation that has federalism implications, that imposes substantial direct compliance costs, and that is not required by statute unless the federal government provides the funds necessary to pay the direct compliance costs incurred by State and local governments or unless EPA consults with State and local officials early in the process of developing the regulation. EPA also may not issue a regulation that has federalism implications and that preempts State law, unless the Agency consults with State and local officials early in the process of developing the regulation.

EPA has concluded that this action will have federalism implications, because it may impose substantial direct compliance costs on State or local governments, and the Federal government would not provide the funds necessary to pay those costs. As discussed in earlier chapters of this document, EPA anticipates that the final rule will not impose a significant incremental administrative burden on States from issuing, reviewing, and overseeing compliance with discharge requirements.

Specifically, EPA has identified 148 steam electric power plants that are owned by State or local government entities or other political subdivisions. EPA estimates that the maximum compliance cost in any one year to governments (excluding federal government) ranges from $155 million to $220 million under the final rule (Option B) (see Chapter 9, *Unfunded Mandates Reform Act (UMRA)*, for details). Annualized compliance costs incurred by governments are $40 million to $67 million under the final rule (Option B).

10.5 Executive Order 13175: Consultation and Coordination with Indian Tribal Governments

E.O. 13175 (65 FR 67249, November 6, 2000) requires EPA to develop an accountable process to ensure "meaningful and timely input by tribal officials in the development of regulatory policies that have tribal implications." "Policies that have tribal implications" is defined in the Executive Order to include regulations that have "substantial direct effects on one or more Indian Tribes, on the relationship between the Federal government and the Indian Tribes, or on the distribution of power and responsibilities between the federal government and Indian Tribes."

EPA assessed potential tribal implications for the regulatory options arising from three main changes, as described below: (1) direct compliance costs incurred by plants; (2) impacts on drinking water systems downstream from steam electric power plants; and (3) administrative burden on governments that implement the NPDES program.

- Direct compliance costs: EPA's analyses show that no plant estimated to be affected by the regulatory options is owned by tribal governments.

- Impacts on drinking water systems: EPA identified one public water system (PWS) operated by tribal governments that may be affected by bromide and iodine discharges from steam electric power plants.[92] In total, this systems serves approximately 6,800 people. EPA estimated small reductions in bromide and iodine concentrations in the source waters of this PWS under the final rule, providing health benefits to the populations served by the PWS. The analysis is detailed in Chapter 4 of the BCA (U.S. EPA, 2024a). Due to data limitations, EPA was not able to quantify the potential drinking water treatment cost savings for this system in the analysis detailed in Chapter 9 of the BCA (U.S. EPA, 2024a).

- Administrative burden: No tribal governments are currently authorized pursuant to section 402(b) of the CWA to implement the NPDES program.

10.6 Executive Order 13211: Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution, or Use

E.O. 13211 requires Agencies to prepare a Statement of Energy Effects when undertaking certain agency actions. Such Statements of Energy Effects shall describe the effects of certain regulatory actions on energy supply, distribution, or use, notably: (i) any adverse effects on energy supply, distribution, or use (including a shortfall in supply, price increases, and increased use of foreign supplies) should the proposal be implemented, and (ii) reasonable alternatives to the action with adverse energy effects and the estimated effects of such alternatives on energy supply, distribution, and use.

The OMB implementation memorandum for E.O. 13211 outlines specific criteria for assessing whether a regulation constitutes a "significant energy action" and would have a "significant adverse effect on the supply, distribution or use of energy."[93] Those criteria include:

- Reductions in crude oil supply in excess of 10,000 barrels per day;

- Reductions in fuel production in excess of 4,000 barrels per day;

- Reductions in coal production in excess of 5 million tons per year;

92 EPA included public water systems identified in EPA's Safe Drinking Water Information System as having a tribe as the primacy agency and one tribe-operated system with the state of Oklahoma as the primacy agency.

93 Executive Order 13211 was issued May 18, 2002. The OMB later released an Implementation Guidance memorandum on July 13, 2002.

- Reductions in natural gas production in excess of 25 million mcf per year;
- Reductions in electricity production in excess of 1 billion kilowatt-hours per year, or in excess of 500 megawatts of installed capacity;
- Increases in the cost of energy production in excess of 1 percent;
- Increases in the cost of energy distribution in excess of 1 percent;
- Significant increases in dependence on foreign supplies of energy; or
- Having other similar adverse outcomes, particularly unintended ones.

None of the criteria above regarding potential significant adverse effects on the supply, distribution, or use of energy (listed above) apply to this final rule. While the regulatory options might affect (1) the production of electricity, (2) the amount of installed capacity, (3) the cost of energy production, and (4) the dependence on foreign supplies of energy, as described below and demonstrated by the results from the national electricity market analyses conducted for the final rule (see Chapter 5),[94] changes for the first three factors are smaller than the thresholds of concern specified by OMB.

10.6.1 Impact on Electricity Generation

The electricity market analyses (Chapter 5) estimate that the final rule will decrease coal-fired generation, including generation from power plants to which the final rule applies, by 3.8 percent to approximately 0.7 percent in 2028 through 2050, relative to baseline generation. The changes in coal-fired generation would be offset by roughly corresponding changes in production from other plants, resulting in no net decrease in overall production; electricity generated in 2035 increases by 1,693 GWh, which is approximately 0.3 percent of baseline generation. These changes are very small and support EPA's assessment that the final rule does not constitute a "significant energy action" in terms of overall impact on electricity generation.

10.6.2 Impact on Electricity Generating Capacity

As documented in Chapter 5, the Agency's electricity market analysis estimated that the final rule would result in net cumulative capacity decrease of 370 MW of generating capacity by 2045. This is the largest projected decrease in generating capacity in the analysis years.

10.6.3 Cost of Energy Production

Based on the IPM analysis results, EPA estimated that the final rule will not significantly affect the total cost of electricity production. At the national level, total electricity generation costs (fuel, variable O&M, fixed O&M, capital, and CCS) under the final rule are projected to increase by 0.2 percent. At the regional level, the change in electricity generation costs varies. Table 5-4 in Chapter *5* summarizes changes projected in IPM for the 2035 run year and shows range from an increase of 0.9 percent in MRO

94 As described in Chapter 5, this analysis does not consider the costs associated with legacy wastewater limits or the treatment of unmanaged CRL.

to a decrease of 0.1 percent in the RF and NPCC regions under the final rule. None of the NERC regions show increases approaching 1 percent.

Consequently, no region would experience net energy price increases greater than the 1 percent threshold as a result of the final rule in either the short or the long run. This supports EPA's assessment that the final rule does not constitute a "significant energy action" in terms of estimated potential effects on the cost of energy production.

10.6.4 Dependence on Foreign Supply of Energy

EPA's electricity market analyses did not support explicit consideration of the effects of the regulatory options on foreign imports of energy. However, the regulatory options directly affect electric power plants, which generally do not face significant foreign competition. Only Canada and Mexico are connected to the U.S. electricity grid, and transmission losses are substantial when electricity is transmitted over long distances. In addition, the effects on installed capacity and electricity prices are estimated to be small.

Table 10-1 presents IPM projected generating capacity and generation by type in 2035 under the baseline and the final rule. The final rule is estimated to decrease coal-based electricity generation by 9 percent, while generation using several other sources of energy is estimated to either increase (natural gas, wind, solar, and landfill gas), or decrease (*i.e.*, hydro, landfill gas, oil/gas steam). Apart from coal generation and oil/gas steam generation, and natural gas, changes are less than 1 percent across all generation types.

Table 10-1: Total Market-Level Capacity and Generation by Type for the Final Rule in Model Year 2035

Type	Generating Capacity (GW)			Electricity Generation (Thousand GWh)		
	Baseline	Option B	% Change	Baseline	Option B	% Change
Hydro	107.3	107.3	0.00%	319.3	318.7	-0.17%
Biomass	0.2	0.2	0.00%	0.4	0.4	0.00%
Geothermal	3.2	3.2	0.00%	21.3	21.3	0.00%
Landfill Gas	3.0	3.0	0.00%	19.1	19.1	-0.08%
Solar	298.2	299.2	0.33%	705.5	708.0	0.35%
Wind	394.0	395.2	0.31%	1,482.7	1,487.3	0.31%
Coal	51.6	46.0	-10.94%	235.7	214.5	-9.00%
Nuclear	83.7	83.7	0.00%	667.0	667.0	0.00%
Natural Gas	476.0	480.2	0.89%	1,344.4	1,359.3	1.11%
Oil/Gas Steam	55.3	55.1	-0.20%	7.7	7.1	-7.67%
Other[b]	6.5	6.5	0.00%	30.5	30.5	-0.02%
Total[a]	**1,478.9**	**1,479.6**	0.05%	**4,833.5**	**4,833.2**	-0.01%

a. Numbers may not add up due to rounding.

b. Values for energy storage are reported in the "Other" category.

Source: U.S. EPA Analysis, 2024.

Table 10-2 presents the corresponding projections of the quantity of fuel used for power generation. Changes are consistent with changes in generation presented in Table 10-1 with less coal (6.97 percent) and more natural gas (0.83 percent) consumed under the final rule. Changes are less than 1 percent for natural gas, lignite and subbituminous coal. However, bituminous coal consumption decreases by 21.82 percent.

Table 10-2: Total Market-Level Fuel Use by Fuel Type for the Final Rule in Model Year 2035

	Fuel Consumption		
Fuel Type	**Baseline**	**Option B**	**% Change**
Coal (million tons)	141	131	-6.97%
Bituminous Coal (million tons)	42	33	-21.82%
Subbituminous Coal (million tons)	74	74	-0.81%
Lignite (million tons)	24	24	0.07%
Natural Gas (trillion cubic feet)	9	9	0.83%

Source: U.S. EPA Analysis, 2024.

Given the very small changes in coal and other fuels use under the final rule, it is reasonable to assume that any increase in demand for fuel used in electricity generation would be met through domestic supply, thereby not increasing U.S. dependence on foreign supply of energy. Consequently, EPA assesses that the final rule does not constitute a "significant energy action" from the perspective of energy independence.

10.6.5 Overall Executive Order 13211 Finding

From these analyses and the electricity markets analysis in Chapter 5, EPA concludes that the final rule would not have a *significant adverse effect* at a national or regional level under E.O. 13211. Specifically, the Agency's analysis found that the rule would not reduce net electricity production in excess of 1 billion kilowatt hours per year nor or installed capacity in excess of 500 megawatts, nor would the rule increase U.S. dependence on foreign supply of energy. As such, the final rule does not constitute a significant regulatory action under E.O. 13211 and EPA did not prepare a Statement of Energy Effects.

10.7 Paperwork Reduction Act of 1995

The Paperwork Reduction Act of 1995 (PRA) (superseding the PRA of 1980) is implemented by OMB and requires that agencies submit a supporting statement to OMB for any information collection that solicits the same data from more than nine parties. The PRA seeks to ensure that Federal agencies balance their need to collect information with the paperwork burden imposed on the public by the collection.

The definition of "information collection" includes activities required by regulations, such as permit development, monitoring, record keeping, and reporting. The term "burden" refers to the "time, effort, or financial resources" the public expends to provide information to or for a Federal agency, or to otherwise fulfill statutory or regulatory requirements. PRA paperwork burden is measured in terms of annual time and financial resources the public devotes to meet one-time and recurring information requests (44 U.S.C. 3502(2); 5 C.F.R. 1320.3(b)). Information collection activities may include:

- reviewing instructions;
- using technology to collect, process, and disclose information;
- adjusting existing practices to comply with requirements;
- searching data sources;
- completing and reviewing the response; and
- transmitting or disclosing information.

Agencies must provide information to OMB on the parties affected, the annual reporting burden, the annualized cost of responding to the information collection, and whether the request significantly impacts a substantial number of small entities. An agency may not conduct or sponsor, and a person is not required to respond to, an information collection unless it displays a currently valid OMB control number.

OMB has previously approved the information collection requirements contained in the existing regulations 40 CFR part 423 under the provisions of the Paperwork Reduction Act.[95]

EPA is finalizing several changes to the individual reporting and recordkeeping requirements of section 423.19 for specific subcategories of plants and/or plants that have certain types of discharges. EPA is adding reporting and recordkeeping requirements to plants in the permanent cessation of coal combustion by 2034 subcategory and for plants that discharge unmanaged CRL. EPA is also removing reporting and recordkeeping requirements for low-utilization electric generating units and finalizing a new requirement for plants to post reports to a publicly available website. EPA estimates it would take a total annual average of 24,300 hours and $2,540,000 for 236 affected steam electric power plants to collect and report the information in the final rule. These costs are in addition to those detailed in Chapter 3.3 through Chapter 9 of this document.

EPA estimates it would take a total annual average of 3,230 hours and $273,000 for permitting or control authorities to review the information submitted by plants. EPA estimates that there would be no start-up or capital costs associated with the information described above. Here also, these costs are in addition to those detailed in Chapter 3.3 through Chapter 9 of this document.

10.8 National Technology Transfer and Advancement Act

Section 12(d) of the National Technology Transfer and Advancement Act (NTTAA) of 1995, Pub L. No. 104-113, Sec. 12(d) directs EPA to use voluntary consensus standards in its regulatory activities unless doing so would be inconsistent with applicable law or otherwise impractical. Voluntary consensus standards are technical standards (*e.g.*, materials specifications, test methods, sampling procedures, and business practices) that are developed or adopted by voluntary consensus standard bodies. The NTTAA directs EPA to provide Congress, through the OMB, explanations when the Agency decides not to use available and applicable voluntary consensus standards.

The regulatory options do not involve technical standards, for example in the measurement of pollutant loads. Nothing in the regulatory options would prevent the use of voluntary consensus standards for such measurement where available, and EPA encourages permitting authorities and regulated entities to do so. Therefore, EPA did not include any voluntary consensus standards in the final rule.

95 OMB has assigned control number 2040-0281 to the information collection requirements under 40 CFR part 423.

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A Summary of Changes to Costs and Economic Impact Analysis

Table A-1 summarizes the principal methodological changes EPA made to analyses of the costs and economic impacts of this final ELG rule as compared to the analyses of the 2020 rule and the 2023 proposal (U.S. EPA, 2020, 2023d).

Table A-1: Changes to Costs and Economic Impacts Analysis Since 2020 Rule and 2023 Proposed Rule

Cost or Impact Category	Analysis Component (2020 Rule Analysis)	Change from 2020 Rule to 2023 Proposed Rule	Change from 2023 Proposed Rule to 2024 Final Rule
General inputs for screening-level analyses	Compliance costs discounted and annualized (7 percent)	No change	Compliance costs discounted and annualized using a weighted average cost of capital for the power sector of 3.76 percent
	Generation, plant revenue, and estimated electricity prices using EIA-861 and EIA-923 databases; six-year (2013-2018) average values	Updated with data from more current EIA-861 and EIA-923 databases to use more recent six-year [2015-2020] average values	Updated with data from more current EIA-861 and EIA-923 databases to use more recent six-year [2016-2021] average values
	Generating capacity from 2018 EIA-860	Updated using 2020 EIA-860	Updated using 2021 EIA-860
	NERC regions from 2017 EIA-860	Updated using 2020 EIA-860	Updated using 2021 EIA-860
	Electricity revenue, sales, and number of consumers by consumer class (residential, industrial, commercial, and transportation) for ASCC and HICC regions from EIA-861 for [2018]	Updated to use data from EIA-861 for [2020]	Updated to use data from EIA-861 for [2021]
	Electricity revenue, sales, and number of consumers by consumer class (residential, industrial, commercial, and transportation) for NERC regions other than ASCC and HICC regions from [2019] AEO projections	Updated using [2021] AEO projections	Updated using [2023] AEO projections
Industry profile	Total count of plants (914 plants)	Updated universe of 871 plants reflects information on actual, planned, and announced unit retirements through the end of 2028	Updated universe of 858 plants reflects information on actual, planned, and announced unit retirements through the end of 2028
	Industry data (*i.e.*, capacity, generation, number of plants, etc.) from 2018 EIA databases	Updated using 2020 EIA databases	Updated using 2021 EIA databases

Table A-1: Changes to Costs and Economic Impacts Analysis Since 2020 Rule and 2023 Proposed Rule			
Cost or Impact Category	**Analysis Component (2020 Rule Analysis)**	**Change from 2020 Rule to 2023 Proposed Rule**	**Change from 2023 Proposed Rule to 2024 Final Rule**
Screening-level plant impacts	Cost-to-revenue impact indicators (1% and 3%) based on 6-year (2013-2018) average values of electricity generation and electricity prices (to estimate plant-level revenue)	Updated to use average electricity generation and electricity prices for [2015-2020]	Updated to use average electricity generation and electricity prices for [2016-2021]
Market-level impacts (IPM)	The Baseline includes existing regulatory requirements as of January 2020, plus the final CCR Part A rule and an updated representation of the 2015 ELG based on 2020 data.	The Baseline includes existing regulatory requirements as of August 2021 and an updated representation of the 2020 ELG based on 2021 data.	The Baseline includes regulatory requirements as of March 2023 including the Inflation Reduction Act of 2022.
Potential electricity price effects	Projected total electricity sales in [2020] from [AEO 2019]	Projected total electricity sales in [2024] from [AEO 2021]	Projected total electricity sales in [2024] from [AEO 2023]
	Electricity sales data by consumer group from [2018] EIA-860 database	Electricity sales data by consumer group from [2020] EIA-860 database	Electricity sales data by consumer group from [2021] EIA-860 database
Owner-level impacts and RFA/SBREFA	Owners identified in EIA-860 [2018]	Owners identified in EIA-860 [2020]	Owners identified in EIA-860 [2021]
	Small business size determination metrics [Dun and Bradstreet for private entities; Census ACS 2017 for governments]	Small business size determination metrics [Dun and Bradstreet for private entities; Census ACS 2019 for governments]	Small business size determination metrics [Dun and Bradstreet for private entities; Census ACS 2021 for governments]

B Comparison of Incremental Costs and Pollutant Removals

This appendix describes EPA's analysis of the incremental costs and pollutant removals of the regulatory options. The information provides insight into how regulatory options compare to each other in terms of reducing toxic pollutant discharges to surface waters.

B.1 Methodology

Cost-effectiveness is defined as the incremental annualized cost of a pollution control option in an industry or industry subcategory per incremental pound equivalent of pollutant (*i.e.*, pound of pollutant adjusted for toxicity) removed by that control option. The analysis compares removals for pollutants directly regulated by the ELGs and incidentally removed along with regulated pollutants.

As described for the 2015 and 2020 rules and 2023 proposed rule, EPA's cost-effectiveness analysis involves the following steps to generate input data and calculate the desired values (for details, see Appendix F in U.S. EPA, 2015):

1. Determine the pollutants considered for regulation.
2. For each pollutant, obtain relative toxic weights and POTW removal factors.
3. Define the regulatory pollution control options.
4. Calculate pollutant removals and toxic-weighted pollutant removals for each control option and for each of direct and indirect discharges. For indirect dischargers, the calculations include applying a factor that reflects the ability of a POTW or sewage treatment plant to remove pollutants prior to discharge to water. See TDD (U.S. EPA, 2024e) for details.
5. Determine the total annualized compliance cost for each control option and for direct and indirect dischargers.
6. Adjust the cost obtained in step 5 to 1981 dollars.[96]
7. Calculate the cost-effectiveness ratios for each control option and for direct and indirect dischargers.

EPA calculated the cost-effectiveness ratios for the final rule regulatory options, but did not include the costs or loading reductions resulting from the unmanaged CRL limits. EPA only estimated changes in total dissolved solids and total suspended solids for unmanaged CRL discharges. Since these broad parameters cannot be easily translated into toxic pollutants, EPA did not include the costs associated with treatment of unmanaged CRL discharges to be consistent. The next section provides results for steps 1 through 5, where the total annualized compliance costs calculated in step 5 are relative to the 2020 rule baseline.

96 Adjustment of costs to 1981 dollars is a convention to facilitate comparison of cost-effectiveness values across rules. Since EPA is not estimating cost-effectiveness ratios in this analysis, this adjustment was not needed.

B.2 Results

Toxic Weights of Pollutants and POTW Removal

The TDD provides information on the pollutants addressed by the regulatory options (U.S. EPA, 2024e). The pollutants include several metals (*e.g.*, arsenic, mercury, selenium), various non-metal compounds (*e.g.*, chloride, fluoride, sulfate), nutrients, and conventional pollutants (*e.g.*, oil and grease, biochemical oxygen demand.)

The toxic weighted pound equivalent (TWPE) analysis involves multiplying the changes in loadings of each pollutant by a pollutant-specific toxic weighting factor (TWF) that represents the toxic effect level relative to the toxicity of copper. For indirect dischargers, the changes are multiplied by a second factor that reflects the ability of a POTW or sewage treatment plant to remove pollutants prior to discharge to waters.

Evaluated Options

EPA analyzed Options A through C summarized in Table 1-1.

Pollutant Removals and Pound Equivalent Calculations

Table B-1, below, presents estimated annual reduction in the mass loading of pollutant anticipated from direct and indirect dischargers for each regulatory option, relative to the baseline. The toxic weighted removals account for pollutant toxicity and, for indirect dischargers,[97] for POTW removals. The calculations do not account for the removal of pollutants that do not have TWFs, either because data are not available to set a TWF or toxicity is not the pollutant's primary environmental impact (*e.g.*, nutrients contributing to eutrophication, bromide contributing to formation of disinfection byproducts). Furthermore, the pound equivalent pollutant removal analysis does not address routes of potential environmental damage and human exposure, and therefore potential benefits from reducing pollutant exposure.

Annualized Compliance Costs

EPA developed costs for technology controls to address each of the wastestreams present at each steam electric power plant. The TDD provides additional details on the methods used to estimate the costs of meeting the limitations and standards under the baseline and each of the regulatory options (U.S. EPA, 2024e). The method used to calculate the incremental annualized compliance costs is described in greater detail in Chapter 3, *Compliance Costs*. EPA categorized these annualized compliance costs as either direct or indirect based on the discharge associated with each wastestream at each plant. Table B-1 summarizes the annualized compliance costs of the regulatory options relative to the baseline.

Cost Effectiveness

Table B-1 summarizes the cost-effectiveness ratios for the regulatory options, calculated as the annual cost of that option divided by to the pound-equivalents removed by that option. The incremental effectiveness of progressively more stringent regulatory options can be assessed both in comparison to the baseline scenario and to another regulatory option. By convention, EPA presents the cost-effectiveness

97 Plants that discharge pollutants to a POTW.

values in 1981 dollars per pound-equivalent removed. Figure B-1 compares the pollutant removals and costs of the regulatory options graphically.

Table B-1: Estimated Pollutant Removal and Costs of Regulatory Options by Discharger Category

Discharger Category	Option[c]	Total Annual TWF-Weighted Pollutant Removals (lb-eq.)[a]		Total Annual Pre-tax Compliance Costs (million, 2023$)		Cost-Effectiveness (1981$/lb-eq.)[b]	
		Total[d]	Incremental[e]	Total[d]	Incremental[e]	Total[d]	Incremental[e]
Direct	A	199,121	199,121	$317.81	$317.81	$422	$422
	B	247,191	48,070	$432.45	$114.64	$463	$631
	C	271,621	24,430	$529.11	$96.66	$515	$1,047
Indirect	A	2,989	2,989	$9.45	$9.45	$837	$837
	B	3,194	205	$10.15	$0.70	$841	$900
	C	3,214	20	$12.56	$2.41	$1,034	$31,302

a. The Agency estimated zero TWPE but non-zero BA compliance costs for one plant in this analysis. EPA included the costs for this plant in this analysis even though there are no corresponding removals.

b. Compliance costs adjusted to 1981 dollars using the CCI (3,535 / 13,358 = 0.265)

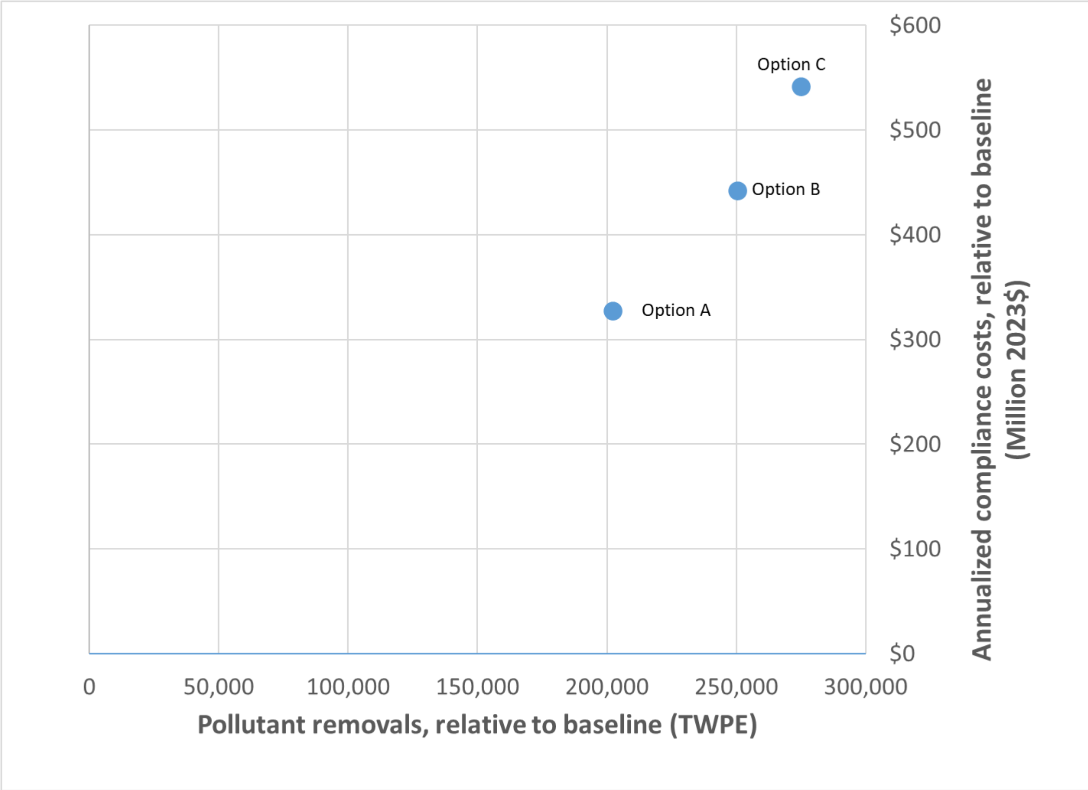
c. Options are listed in increasing order of pollutant removals, relative to the baseline.

d. Total removals and costs are compared to those for the baseline.

e. Incremental removals and costs are compared to those for the next least stringent option in the order listed in the table. For direct dischargers, the incremental removals and costs under Option A are calculated relative to the baseline, the incremental removals and costs for Option B are calculated relative to those of Option A, etc.

Source: U.S. EPA Analysis, 2024

Figure B-1: Estimated Removals and Costs of the Regulatory Options, Relative to Baseline.



Source: U.S. EPA Analysis, 2024.

C Total Costs Based on 7 Percent Discount Rate

Table C-1 and Table C-2 present compliance cost estimates for the regulatory options, and Table and Table C-4 show the breakout of total compliance costs for each option by wastestream, based on the 7 percent discount rate that was previously used for the 2023 proposed rule analysis as representing the private cost of capital (U.S. EPA, 2023d). For comparison, the tables include values from Table 3-1 and Table 3-3 estimated using the 3.76 percent discount rate used as the revised estimate of the private cost of capital.

Table C-1: Estimated Total Annualized Compliance Costs (in millions, 2023$, at 2024) – Lower

Regulatory Option	Pre-Tax Compliance Costs				After-Tax Compliance Costs			
	Capital Technology	Other Initial One-Time	Total O&M	Total	Capital Technology	Other Initial One-Time	Total O&M	Total
3.76% Discount Rate								
Option A	$232	$0.1	$247	$479	$186	$0.1	$200	$386
Option B	$284	$0.2	$312	$596	$229	$0.1	$250	$479
Option C	$336	$0.2	$359	$695	$270	$0.2	$286	$557
7% Discount Rate								
Option A	$271	$0.1	$228	$499	$218	$0.1	$184	$401
Option B	$325	$0.2	$282	$608	$262	$0.2	$226	$488
Option C	$385	$0.2	$325	$711	$310	$0.2	$259	$569

Source: U.S. EPA Analysis, 2024.

Table C-2: Estimated Total Annualized Compliance Costs (in millions, 2023$, at 2024) – Upper

Regulatory Option	Pre-Tax Compliance Costs				After-Tax Compliance Costs			
	Capital Technology	Other Initial One-Time	Total O&M	Total	Capital Technology	Other Initial One-Time	Total O&M	Total
3.76% Discount Rate								
Option A	$453	$0.1	$595	$1,048	$372	$0.1	$490	$863
Option B	$505	$0.2	$659	$1,164	$415	$0.1	$541	$956
Option C	$557	$0.2	$706	$1,263	$456	$0.2	$577	$1,033
7% Discount Rate								
Option A	$526	$0.1	$543	$1,069	$432	$0.1	$447	$878
Option B	$580	$0.2	$597	$1,177	$476	$0.2	$489	$965
Option C	$640	$0.2	$640	$1,281	$524	$0.2	$522	$1,046

Source: U.S. EPA Analysis, 2024.

Table C-3: Estimated Total Annualized Compliance Costs, by Wastestream (in millions, 2023$, at 2024) – Lower

Regulatory Option	Pre-Tax Compliance Costs					After-Tax Compliance Costs				
	BA Transport Water	FGD Wastewater	CRL	Legacy	Net Total Costs	BA Transport Water	FGD Wastewater	CRL	Legacy	Net Total Costs
3.76% Discount Rate										
Option A	$19	$179	$281	$0	$479	$15	$139	$232	$0	$386
Option B	$19	$179	$370	$28	$596	$15	$139	$302	$23	$479
Option C	$30	$205	$433	$28	$695	$23	$160	$350	$23	$557
7% Discount Rate										
Option A	$20	$190	$289	$0	$499	$16	$147	$238	$0	$401
Option B	$20	$190	$381	$17	$608	$16	$147	$310	$14	$488
Option C	$31	$216	$446	$17	$711	$25	$170	$360	$14	$569

Source: U.S. EPA Analysis, 2024.

Table C-4: Estimated Total Annualized Compliance Costs, by Wastestream (in millions, 2023$, at 2024) – Upper

Regulatory Option	Pre-Tax Compliance Costs					After-Tax Compliance Costs				
	BA Transport Water	FGD Wastewater	CRL	Legacy	Net Total Costs	BA Transport Water	FGD Wastewater	CRL	Leg acy	Net Total Costs
3.76% Discount Rate										
Option A	$19	$179	$849	$0	$1,048	$15	$139	$709	$0	$863
Option B	$19	$179	$939	$28	$1,164	$15	$139	$778	$23	$956
Option C	$30	$205	$1,001	$28	$1,263	$23	$160	$826	$23	$1,033
7% Discount Rate										
Option A	$20	$190	$859	$0	$1,069	$16	$147	$715	$0	$878
Option B	$20	$190	$950	$17	$1,177	$16	$147	$787	$14	$965
Option C	$31	$216	$1,016	$17	$1,281	$25	$170	$838	$14	$1,046

Source: U.S. EPA Analysis, 2024.

Exhibit 5

United States
Environmental Protection
Agency

Response to Public Comments for Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category

April 2024

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U.S. Environmental Protection Agency
Office of Water (4303T)
1200 Pennsylvania Avenue, NW
Washington, DC 20460

Docket EPA-HQ-OW-2009-0819
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Contents

Appendices

List of Abbreviations

ACE	Affordable Clean Energy
BA	bottom ash
BAT	best available technology economically achievable
BATW	bottom ash transport water
BCA	Benefit and Cost Analysis
BMP	best management practice
BOD	biochemical oxygen demand
BPJ	best professional judgement
CA	combined ash
CAA	Clean Air Act
CBI	confidential business information
CCR	coal combustion residuals
CFR	Code of Federal Regulations
CH_4	methane
CO_2	carbon dioxide
CP	chemical precipitation
CPP	Clean Power Plan
CRL	combustion residual leachate
CSAPR	Cross-State Air Pollution Rule
CSC	compact submerged conveyor
CUR	capacity utilization rates
CWA	Clean Water Act
CWT	centralized waste treatment
DOE	Department of Energy
EA	Environmental Assessment
EDR	electrodialysis reversal
EGU	electric generating unit
EIA	Energy Information Administration

EJA	Environmental Justice Analysis
ELGs	effluent limitations guidelines and standards
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
FA	fly ash
FBR	fluidized bed reactor
FGD	flue gas desulfurization
FGMC	flue gas mercury control
FO	forward osmosis
gal	gallon
GHG	greenhouse gas
GPD	gallons per day
GPM	gallons per minute
HAP	hazardous air pollutant
HRR	high recycle rate
HRT	hydraulic residence time
HRTR	high residence time reduction
HVAC	heating, ventilation, and air conditioning
ICR	information collection request
IPM	Integrated Planning Model
kWh	kilowatt-hour
L	liter
lb	pound
LRTR	low residence time reduction
LUEGU	low utilization electric generating unit
MATS	Mercury and Air Toxics Standards
MDS	mechanical drag system
mg	milligrams
MGD	million gallons per day

MGY	million gallons per year
mi	mile
µg	micrograms
MW	megawatts
MWh	megawatt-hours
N_2O	nitrous oxide
NA	not applicable
NAAQS	National Ambient Air Quality Standards
NERC	North American Electric Reliability Corporation
NOPP	notice of planned participation
NO_X	oxides of nitrogen
NPDES	National Pollutant Discharge Elimination System
NSPS	new source performance standards
NWQEI	non-water quality environmental impacts
O&M	operation and maintenance
OLEM	Office of Land and Emergency Management
ORCR	Office of Resource Conservation and Recovery
PM	particulate matter
POTW	publicly owned treatment works
PSES	pretreatment standards for existing sources
PSNS	pretreatment standards for new sources
QA	quality assurance
QC	quality control
RCRA	Resource Conservation and Recovery Act
RIA	Regulatory Impact Analysis
RO	reverse osmosis
SDE	spray dryer evaporator
SO_2	sulfur dioxide
TCLP	toxicity characteristic leaching procedure

TDD	Technical Development Document
TDS	total dissolved solids
TMT	trimercapto-s-triazine
TPY	tons per year
TSS	total suspended solids
VIP	Voluntary Incentives Program
WOTUS	Waters of the United States
ZVI	zero valent iron

Introduction

This document provides responses to all significant comments submitted on the EPA's proposed effluent limitations and guidelines rule for the Steam Electric Power Generation Point Source Category. The EPA's proposal was published in the Federal Register on March 29, 2023 (88 FR 18824) and the public comment period closed on May 30, 2023. This includes public comments received during two public hearings held by the EPA during the public comment period (April 20, 2023 and April 25, 2023).[1] The comments received during the public hearings overlap with the comments submitted to the docket and reviewed by the EPA as part of this rulemaking. Therefore, since the comments submitted to the docket that overlap with the comments submitted during the public hearing have been addressed, the EPA considers the public hearing comments to be addressed by this comment response document.

Submitted comments are available electronically through *https://www.regulations.gov* by searching Docket ID No. EPA-HQ-OW-2009-0819 and in hard copy at the EPA Docket Center Public Reading Room. The telephone number for the Public Reading Room is (202) 566-1744. The docket assigned a unique Document Control Number (DCN) to each comment submittal with the following format: EPA-HQ-OW-2009-0819-xxxxx, where the five digit number at the end is unique to that comment submittal. Where a commenter submitted more than one file, the EPA has included an attachment number, for example EPA-HQ-OW-2009-0819-xxxxx-A1 (A2, A3, etc.)

This document is organized into two parts as indicated in the Table of Contents below. To organize the comments and to facilitate the EPA's responses, the EPA classified comment submittals by topic, available in Part 1 of this document. If a specific comment submittal addressed multiple topics, the EPA subdivided the submittal by topic. Comments or portions of comments assigned to specific topics are referred to as "comment excerpts." All of the individual comment excerpts classified to a specific topic are reproduced within the comment code corresponding to that topic. Within a specific comment code, the comment excerpts are often sorted in order of the DCNs. However, comment excerpts may also be ordered within a specific comment code so that similar comment issues are grouped together. The EPA's responses to each comment code topic are available in Part 2 of this document. Similar to comment excerpts, the EPA's responses are organized by comment code. The Table of Contents provides a list of comment topics covered in Part 1 and Part 2 of this document.

To support the reader in finding and understanding the comments and their responses, the EPA has provided the following as part of this document:

- A listing of the major support documents for the rulemaking, referenced throughout the comment responses.
- Comment excerpts by comment topic (located in Part 1).
- Comment responses by comment topic (located in Part 2).
- A list of acronyms used throughout the comment response document.
- A comment submittals index ordered by Affiliate Name (and DCN) with the corresponding list of comment codes identified for topics covered in the comment submittal (Appendix A).

The EPA notes that many commenters raised the same, similar, or related issues. Therefore, the response to a specific code may refer the reader to other responses that provide additional details on a comment topic. While the EPA endeavored to be accurate and consistent in assigning comment excerpts to topics, and in referencing other relevant responses, some excerpts may have content that overlaps multiple topics. Accordingly, readers may find it helpful to read this entire document to obtain the EPA's response

[1] Available documents from each public hearing include the presentations given by the EPA and two transcripts. The documents are available at *https://www.regulations.gov*, see EPA-HQ-OW-2009-0819-10043 and EPA-HQ-OW-2009-0819-10044.

regarding a given general topic. Moreover, in many instances, particular responses presented in this document include references to other portions of the administrative record, including the preamble to the final rule and other major support documents for the rulemaking (see below). Accordingly, this document, together with the preamble and the rest of the administrative record should be considered collectively as the Agency's response to all of the significant comments submitted on the proposed rule.

Due to the volume of comments received, some responses in this document may not reflect the language in the preamble or final rule in every respect. Where the response is in conflict with the preamble or the final rule, the language in the final preamble and rule controls and should be used for purposes of understanding the scope, requirements, and basis of the final rule. Although portions of the preamble to the final rule are paraphrased in this document where useful to add clarity to responses, the preamble itself remains the definitive statement of the rationale for the final rule.

To locate other documents in the record, the reader should use the final rule record index. For information on the final rule record index and how to use it, see the Steam Record Index User's Guide.

The rule is supported, in part, by the following documents:

- Technical Development Document for the Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category (TDD), Document No. EPA-821-R-24-004.
- Environmental Assessment for the Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category (EA), Document No. EPA-821-R-24-005.
- Benefit and Cost Analysis for the Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category (BCA Report), Document No. EPA-821-R-24-006.
- Regulatory Impact Analysis for the Final Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category (RIA), Document No. EPA-821-R-24-007.
- Docket Index for the Revisions to the Steam Electric ELGs.

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current factual record. These findings are within the Agency's expertise: they are the bread and butter of ELGs – for example, determining whether technologies have been sufficiently demonstrated to be deemed "available," whether they are economically achievable as that term is used in the CWA, and whether they have acceptable non-water quality environmental impacts. *See BP Exploration & Oil, Inc. v. EPA*, 66 F.3d 802 (6th Cir. 1995) ("If any entity has the ability to weigh the relative impact of two different environmental harms, it is the EPA.").

The EPA's application of the BAT standard in this regulation is, moreover, as elaborated on in the preamble, consistent with the CWA as a whole, given the technology-forcing nature of the statute. *Southwestern Elec. Power Co. v. EPA*, 920 F.3d 999, 1003 (5th Cir. 2019) ("BAT is the gold standard for controlling water pollution from existing sources. By requiring BAT, the Act forces implementation of increasingly stringent pollution control methods.") (citing *NRDC v. EPA*, 822 F.2d 104, 123 (D.C. Cir. 1987) (describing the Act as "technology-forcing"). This rule does not herald a drastic expansion in regulatory scope, nor is it designed to force a shift in generation away from coal-fired EGUs. *See* Slip Op. at 20 (The "EPA 'claim[ed] to discover in a long-extant statute an unheralded power' representing a 'transformative expansion in [its] regulatory authority.'") (citation omitted). The impacts of this rule are in line with impacts that the EPA has seen in other ELGs. The final rule estimates it will result in a net reduction of 5,782 MW in steam electric generating capacity as of the model year 2035, which corresponds to a net effect of approximately five early plant closures out of 858 steam electric power plants. This is in line with what Congress envisioned would be the impacts of BAT regulations. *See, e.g.*, *Chem. Mfrs. Ass'n v. EPA*, 870 F.2d at 252 n.337 (reviewing cases in which courts have upheld EPA's regulations that projected up to 50 percent closure rates); *Ass'n of Pac. Fisheries v. EPA.*, 615 F.2d 794, 808 (9th Cir. 1980) (recognizing that EPA regulation "result[s] in plant closures" and highlighting other judicially upheld examples); *Nat'l Ass'n of Metal Finishers v. EPA*, 719 F.2d 624, 663 (3d Cir. 1983), *rev'd on other grounds sub nom. Chem. Mfrs. Ass'n v. Nat. Res. Def. Council, Inc*., 470 U.S. 116 (1985) (upholding EPA standard "resulting in the closing of 737 electroplating operations and the loss of 12,584 jobs"). Finally, unlike in *West Virginia v. EPA*, there is no relevant failure by Congress to regulate water pollution from coal-fired power plants, Slip. Op. at 20, and the EPA has not described this action as ground-breaking, Slip Op. at 27 n.4. Rather, the EPA is simply implementing clear authorities that Congress has previously delegated to it.

Response to comments on sufficiency of justification in the rule and consideration of reliance interests

The EPA received a number of comments focused on reliance interests. For example, the EPA received comments from industry stating that the EPA should have stayed the 2020 rule and that, by not doing so, the EPA created reliance interests that the final rule must take into account. Some commenters argued that they are being penalized by having to spend money to comply with the 2020 rule, which is now being changed, causing those investments to be obsolete. One commenter argued that they will be compelled to incur significant costs in reliance on the 2020 rule, then suddenly deprived of the benefits of those expenditures and compelled to incur another layer of substantial costs that renders continued operation of reliable baseload facilities uneconomic. One commenter claimed that the EPA has not appeared to make any effort to investigate costs incurred by facilities who are on track, but have not yet achieved, compliance with the 2020 rule. One commenter cites a Supreme Court decision, *Landgraf v. USI Film Prods*., 511 U.S. 244, 265-66 (1994), for the idea that "settled expectations should not be lightly disrupted." Some commenters claim that, to avoid making investments under the 2020 rule obsolete, the EPA should include additional flexibilities that reflect the good faith efforts that have been undertaken to comply with the 2015 and 2020 rules, as well as consider the costs associated with these continued efforts to comply with those rules. Some commenters stated that the EPA has not adequately considered reliance interests because the proposed early adopter subcategory would only affect some facilities and that the EPA did not consider reliance interests with respect to other facilities. Some commenters claim that the power sector and regulated entities cannot have regulatory certainty when significant rules change course due to a change in political administrations.

The EPA did not stay the 2020 rule because it viewed the pollutant discharge reductions that would be achieved by the 2020 rule as consistent with the requirement under section 301 of the CWA for categories of point sources to achieve limitations that result in reasonable further progress toward the CWA's goal of eliminating the discharge of all pollutants. *See* CWA sections 101 and 301, 33 U.S.C. §§ 1251, 1311. The EPA that had no information to suggest that the technologies on which the 2020 rule were based were not technologically available or economically achievable, and thus staying or postponing the rule and potentially not requiring further control of discharges throughout the duration of the EPA's new rulemaking would be inconsistent with the Act. Moreover, as explained in Section VII.C.7 of the preamble, it is retaining the 2020 rule BAT limitations for FGD wastewater and BA transport water as an interim step in achievement of the more stringent BAT limitations in the final rule. The EPA views these interim limits as in keeping with the technology-forcing nature of the Act and essential for meeting the statutory requirement that BAT result in reasonable further progress toward the CWA's goal of eliminating the discharge of pollutants. *See Nat. Res. Def. Council v. EPA*, 808 F.3d 556, 563-64 (2d Cir. 2015) ("Congress designed this standard to be technology-forcing, meaning it should force agencies and permit applicants to adopt technologies that achieve the greatest reductions in pollution.") (citation omitted). Without these interim limitations, which have a latest applicability date of December 31, 2025, plants could potentially have up to December 31, 2029 (the latest applicability for the zero-discharge requirements in this final rule), before they are required to meet limitations beyond the 1982 limitations based on surface impoundments. *See Southwestern Elec. Power Co. v. EPA*, 920 F.3d 999, 1003-1004 (5th Cir. 2019) (describing the 1982-era regulations as from a "by-gone era" in which limitations were based on the "archaic" technology of surface impoundments, "which are essentially pits where wastewater sits, solids (sometimes) settle out, and toxins leach into groundwater."). The EPA agrees to some extent with one commenter that new rulemakings create some level of uncertainty in the regulated community. The EPA has tried, however, to reduce unnecessary uncertainty where possible from the beginning of this rulemaking by making clear, in the Summer of 2021, that it expected to fully implement the 2020 rule and was examining potentially more advanced treatment technologies as part of a new rulemaking.

The EPA understands that the additional requirements in this final rule may in some cases result in facilities not using the technologies they have installed to meet the 2020 rule limitations for the typical length of time that they would expect to employ treatment technologies. The EPA made attempts to be flexible in this rule to account for these reliance interest, and thus it disagrees with one commenter that this final rule disrupts "settled expectations . . . lightly," as discussed by the Supreme Court in *Landgraf v. USI Film Prods*., 511 U.S. 244, 265-66 (1994). First, the EPA provided a compliance period for the final limitations that provides for compliance no later than December 31, 2029, five-and-a-half years after the rule is promulgated. Moreover, BAT limitations are not self-implementing, which means that they are not applicable until they have been incorporated into NPDES permits, which are issued for 5-year terms. Second, the EPA has finalized a subcategory for EGUs permanently ceasing coal combustion by December 31, 2034, which allows certain plants the ability to continue to use their 2020 rule technologies to meet the rule's limitations until they cease combusting coal. These plants would thus be able to employ their 2020 rule technologies for a longer time and would not be expected to incur costs for more advanced technologies, which would only be operational until the date that the plant permanently ceases combustion of coal. The EPA anticipates that approximately 9 EGUs may be able to avail themselves of this subcategory with respect to FGD wastewater.[7] Finally, the Act requires the EPA to periodically review and revise its ELGs. *See* CWA sections 301(d) and 304(b), 33 U.S.C. §§ 1311, 1314. It is also required to base limitations on the Best Available Technology Economically Achievable, while taking into account certain statutory factors in CWA section 304(b). The EPA's assessment of the best available technology is necessarily informed by technological advancements. *See Southwestern Elec. Power Co. v. EPA*, 920 F.3d at 1018 ("[O]ur court has long recognized that 'Congress intended [BAT] limitations to be based on the performance of the single-best performing plant in an industrial field.'") (citation omitted); *see also NRDC v. EPA*, 863 F.2d 1420, 1433 (9th Cir. 1988) ("Congress has demonstrated its intent to require industry to do as much as possible to control toxic discharges.") (citing 33 U.S.C. section 1331(b)(2)(A)(i)). The final rule incorporates the latest information on pollution control technologies in determining that more

[7] Additional EGUs are projected to participate in this subcategory for BA transport water and CRL.

advanced treatment than was required in 2020 now represents BAT for the industry. Moreover, the costs of the 2020 rule are fully accounted for in this rule, and the EPA has found that the rule is economically achievable, as that term is used in the CWA. As discussed in Sections VII.F and VIII.C of the preamble, the EPA uses IPM to analyze electric sector impacts.[8] IPM shows small impacts across the industry and leads the EPA to the conclusion that even the cumulative cost of the 2020 and 2024 technologies is economically achievable, and potentially would result in incremental capacity retirement of 5,782 MW from the incremental closure of 5 steam electric power plants with a total of 9 EGUs. Where more stringent technologies are available, economically achievable, and have acceptable non-water quality environmental impacts, as the BAT technologies identified in this rule are and do, the fact that facilities may have to spend more to supplement or replace existing treatment systems, even relatively new ones, is not a sufficient reason on its own to reject selection of the technology. This is particularly true given Congress's intent and expectation for technology-based limits based on Best Available Technology Economically Achievable. *Southwestern Elec. Power Co. v. EPA*, 920 F.3d at 1018; *NRDC v. EPA*, 863 F.2d at 1433.

The EPA agrees with some commenters that it should consider the effect of changes on permittees, but the EPA does not believe that an NPDES permittee has certainty of its limitations beyond its 5-year permit term, as reissued permits must incorporate any newly promulgated technology-based limitations as well as potentially more stringent limitations necessary to achieve water quality standards. *See* 40 CFR 122.44(a) & (d). The statute is designed for both technology-based and water quality-based effluent limitations to be revisited in each permit and, when necessary, revised consistent with these provisions and in light of the goal of ultimately eliminating pollutant discharges from point sources into WOTUS. CWA section 101, 33 U.S.C. § 1251.

While some commenters claim that NPDES permits are routinely administratively continued, and the EPA sometimes takes decades to revise certain ELG regulations, the EPA disagrees with commenters that either of those administrative realities justifies an expectation that limits will not change. This is particularly so where there are technologies that are available and achievable and better at meeting Congress's stated goal for the CWA to eliminate the discharge of pollutants. *See* CWA sections 101(a)(1) and 301(b)(2)(A).

The EPA disagrees with some commenters that the costs of this rule will make continued operation of reliable baseload facilities uneconomic. As explained in Section VII of the preamble, the EPA has found that the final rule is economically achievable as required by the Act, and it has acceptable non-water quality environmental impacts (including energy requirements). Indeed, the EPA has established a subcategory for EGUs permanently ceasing coal combustion by December 31, 2034, in part to provide flexibility for the organized retirement or repowering of power plants. This subcategory will help facilities otherwise planning to retire to be able to do so on their already approved, ongoing schedules, thereby helping ensure a reliable energy supply.

The EPA received a number of comments regarding the EPA's basis for deviating from the 2020 rule and whether the rule is adequately justified. Some commenters claim that the EPA has not provided a reasoned basis for revising the 2020 rule under the APA, and that there is no new information to justify changes from 2020. Other commenters claim that the EPA cannot reverse course without providing a detailed justification for the rule, particularly where a rule rests on contradictory factual findings or the prior rule engendered serious reliance interests. The EPA disagrees that it has not provided a reasoned basis for or has not adequately justified the final rule. The EPA has explained in detail and with factual support from the record where it no longer agrees with statements made in 2020, including where its findings are based in part on new information since the 2020 rule. For example, in its finding that zero-discharge technologies are "available," as that term is used in the CWA, for control of flue gas desulfurization wastewater, the EPA explained how its decision-making changed from the 2020 rule on

[8] While this modeling is illustrative as to how the sector may comply with the rule, the EPA notes that the rule does not require any facilities to close.

each major issue cited in the 2020 rule. *See* Section VII.B.1 of the preamble. It explained how the technology-basis for the final rule is different from what the EPA considered for the 2020 rule, and exactly what information, including new information (*e.g.*, *see* discussion of new pilot studies since the 2020 rule), it relied on to show availability of zero-discharge systems, such as use of zero-discharge technologies domestically and abroad, in full-scale applications and pilot projects, and applications on other wastestreams. *Id*. Similarly, in its decision to identify zero-discharge technologies as BAT for control of BA transport water, the EPA explained each technological aspect discussed in the 2020 rule and why those aspects do not warrant a finding that zero discharge is not available for BA transport water. *See* Section VII.B.2 of the preamble. The EPA also discussed how its analysis of process changes happening at plants under the CCR regulations has changed since the 2020 rule; in particular, how the changes happening at plants under the CCR regulations that were cited in the 2020 rule are expected to be complete by the time this final rule's BAT limitations apply to any given plant. *Id*. Thus, the EPA explained how its findings with respect to the CWA consideration factor of process changes has changed since the 2020 rule.

Response to comments on pretreatment standards

The EPA disagrees with a commenter who claimed that the EPA's interpretation of the Act for purposes of establishing pretreatment standards is inconsistent with the statute or contrary to the EPA's regulatory definitions. The EPA has adequate support in the statute and regulations for its view that pretreatment standards are designed to ensure that wastewaters from direct and indirect industrial dischargers are subject to similar levels of treatment. Sections 301 and 307 of the Act call for categorical, technology-based treatment standards reflecting the BAT level of control. Sections 301(b)(1)(A) (BPT) and 301(b)(2)(A) (BAT), after discussing the requirements for direct dischargers, say that "in the case of a discharge into a publicly owned treatment works" or "in the case of the introduction of a pollutant into a publicly owned treatment works which meets the requirements of subparagraph (B) of this paragraph, shall require compliance with any applicable pretreatment requirements and any other requirement under section [307]" of the Act. Section 307 calls for the establishment of categorical pretreatment standards for pollutants that are determined not to be susceptible to treatment by such treatment works or which would interfere with the operation of such treatment works and, as the commenter notes, the EPA's regulations define "pass through" and "interference." However, the EPA interprets this as a condition precedent for regulating a pollutant introduced to a POTW, not as the standard for the regulation.

The EPA's long-standing, reasonable interpretation is that, for purposes of calculating pretreatment standards, a pollutant "passes through" if, on a nationwide basis, the median percent of the pollutant removed by a well-operated POTW achieving secondary treatment is less than the median percentage removed by the model BAT treatment system. *See Chem Mfrs. Ass'n v. EPA*, 870 F.2d 177, 247 (5th Cir. 1989) (rejecting a challenge to an effluent guidelines rule based on the argument that the EPA must take into account the performance of actual POTWs) ("We hold that the EPA's decision to define pass through based on POTW average removal does not violate the CWA."). This reflects that the indirect discharger pays rather than the public for the pollutant removal. *See Chem. Mfrs. Ass'n v. EPA*, 870 F.2d at 244 ("In 1977, when Congress amended the CWA to strengthen the provisions for controlling toxic pollutants, Congress provided that 'an indirect discharger . . . had to 'pretreat' its waste waters so as to achieve, together with the [POTW] that treated the waste before final discharge . . . the same level of toxics removal as was required of a direct discharger.") (citing *NRDC v. EPA*, 790 F.2d 289, 292 (3d Cir. 1986)). Removal credits are available to indirect dischargers to account for the pollutant removal at a POTW, as long as the combined removal of pollutants by the indirect discharger and POTW equals what is required by direct dischargers and revising the standard does not prevent compliance with sludge requirements under CWA section 405. *See* 40 C.F.R. part 403. Because the reference to indirect dischargers, *i.e.*, discharges to pretreatment works, is contained in the subparagraphs of section 301 calling for control at the BPT or BAT level, the EPA interprets the statute to require the same level of control for both direct and indirect dischargers. This interpretation is supported available technology economically achievable. To the extent that specific considerations raised by commenters would already fall under these factors (e.g., consideration of leasing as part of the consideration of the costs factor), no further action by the Agency is necessary. The EPA further clarifies this in Section XIV.B.2 of the preamble.

The EPA agrees in part with the comment regarding closed WMUs. As discussed in Section VII.B.6 of the preamble, the limitations established in this final rule will not apply to previously retired facilities and WMUs; however, the rule will continue to apply to WMUs active as of the effective date even after the facility retires or WMU closes.

To the extent that the limitations could apply to WMUs with site-specific characteristics raised in the comments, the EPA disagrees that the specific considerations discussed in the comment would preclude the Agency from establishing a nationwide BAT. Several of these site-specific considerations related to the ability to successfully implement pump-and-treat operations for unmanaged CRL. These comments incorrectly assume that a facility must use the BAT chemical precipitation BAT basis. Instead, facilities are free to use any technology or process change that meets the final limitations. This could include a range of alternatives such as in situ treatment or impermeable barriers, which do not require pump and treat operations.

The EPA further disagrees that power costs for remote WMUs are not considered. The EPA included these costs in its O&M cost estimates as described in the TDD.

The EPA disagrees that no technology-based effluent limitations are required because the smaller loadings after closure mean there is no reasonable potential for surface water impacts.[17] This comment improperly conflates water quality-based effluent limitations with technology-based effluent limitations.

The EPA disagrees that small, intermittent flows would lead to any different conclusion in selecting BAT. Whether the ultimate discharge is continuous or intermittent, nothing in the record suggests that such a discharge could not meet the effluent limitations established in this final rule. To the contrary, several pilot studies in the record operated on batches of wastewater rather than a continuous, uninterrupted flow. Furthermore, permitting authorities already have the flexibility to tailor monitoring and other requirements for batch discharges.

The EPA disagrees regarding the inability of retired facilities or those without an active FGD system to participate in co-treatment or grandfathering are no longer relevant because the Agency has not finalized either provision. Nevertheless, as described in the preamble, nothing would prevent a facility from co-treating it's FGD wastewater and CRL where co-treatment would meet the final BAT limitations.

The EPA agrees that discharges during stormwater events should be allowed and has finalized a definitional change for such discharges as described in preamble section VII.B.5.

5. Regulatory Options – Compliance Costs Methodology

The EPA has made a reasonable estimate of compliance costs associated with the final rule, and the EPA finds that the final rule is economically achievable. *See* Section VII.F of the preamble, in addition to the Regulatory Impact Analysis for the Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category (RIA), Document No. 821R24007, and Benefit and Cost Analysis for the Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category (BCA Report), Document No. 821R24006, for more information on the EPA's analyses.

[17] To the extent these smaller loadings are the result of decreased flows, the EPA has evaluated this impact in its analyses.

This response addresses comments on the following topics:

- Recovery of Costs from Previous Rulemakings
- General Comments on the EPA's Cost Estimation Methodologies
- Leasing Treatment Technologies

Recovery of Costs from Previous Rulemakings

The EPA is retaining the 2020 rule limitations applicable to FGD wastewater and BA wastewater as interim limitations before the applicability dates of the zero-discharge limitations in this 2024 final rule. The EPA disagrees that it should have halted implementation of the 2020 rule. The EPA found the 2020 rule technologies to be available, economically achievable, and to have acceptable non-water quality environmental impacts. While the EPA agrees that cost recovery periods for the 2020 rule technologies will be curtailed, which commenters claim would divert investment dollars from clean energy projects, the record shows that the total costs of implementing the technologies of both rules under the corresponding timeframes are economically achievable according to the Agency's Integrated Planning Model (IPM), discussed further in Section VIII.C.2 of the preamble.

The EPA also disagrees with comments suggesting it cannot revisit an ELG for seven years. The EPA has revisited many final ELG rules within this time frame, either as the result of a court's vacatur or remand, or as the result of an administrative petition. In fact, the same commenter arguing against the EPA's supplemental rulemaking here submitted administrative petitions for the EPA to reconsider the 2015 rule, and at that time found no procedural problem with the EPA revising a rule before seven years had elapsed.

The EPA views the retention of the 2020 BAT limitations for FGD wastewater and BA wastewater in the interim as in keeping with the technology-forcing nature of the Act and essential for meeting the statutory requirement that BAT result in reasonable further progress toward the CWA's goal of zero discharge of pollutants (*see* Section VII.C.7 and Section XIV.A of the preamble).

Several commenters criticized the EPA for continuing to support implementation of the 2020 rule while simultaneously revising that rule with potentially more stringent limitations. These commenters stated that utilities relied upon materials announcing the Agency's decision to reconsider the 2020 rule and statements in the 2023 proposal which both confirmed that utilities should continue to implement the 2020 rule. Thus, in reliance, utilities claimed that they have continued to install compliant technologies and that such reliance should lead EPA to a decision not to finalize more stringent BAT for these wastewaters. In the alternative, some commenters recommended that such facilities reliance on, and compliance with, the 2020 rule should lead EPA to build in additional flexibility for any more stringent BAT. Suggested flexibilities generally focused on subcategorization or longer timeframes for cost recovery before installation of more stringent technologies.

As stated in Section VII.B.1 of the preamble and in response to comments in Code 1, the EPA:

- Agrees that such reliance interests should be considered. However, the EPA disagrees with commenters who suggested these interests mean the Agency must retain only the 2020 limitations. First, no NPDES permittee has certainty of its limitations beyond its 5-year NPDES permit term, as reissued permits must incorporate any newly promulgated technology-based limitations as well as potentially more stringent limitations necessary to achieve water quality standards (*see* 40 CFR 122.44(a) & (d). The statute is designed for both technology-based and water quality-based effluent limitations to be revisited in each permit and, when necessary, revised consistent with these provisions and in light of the goal of ultimately eliminating pollutant discharges from point sources into WOTUS (CWA section 101, 33 U.S.C. 1251).

- The EPA has included sufficient time for facilities to build in any reasonable reliance interest. As discussed in Section VII.E of the preamble, the Agency is finalizing "no later than" dates for the new FGD wastewater BAT of December 31, 2029. Having a "no later than" date approximately five-and-a-half years following promulgation allows facilities to rely on permitted limits for the remainder of any permit existing as of the effective date of today's final rule. Moreover, BAT limitations are not self-implementing; they must be incorporated into an NPDES permit before they apply to any particular discharger.
- To the extent that the facilities claiming to be most impacted by having to add additional treatment are those that will be permanently ceasing coal combustion by 2034, the EPA has created a new subcategory for these facilities which would allow them to avoid recovering the costs of two treatment systems (e.g., biological treatment and a zero-discharge system) over their short remaining useful life and instead to continue operation of the system designed to meet the standards of the 2020 rule.
- Finally, the Act requires the EPA to periodically review and revise its ELGs. *See* CWA sections 301(d) and 304(b), 33 U.S.C. §§ 1311, 1314. It is also required to base limitations on the Best Available Technology Economically Achievable, while taking into account certain statutory factors in CWA section 304(b). The EPA's assessment of the best available technology is necessarily informed by technological advancements. *See* Southwestern Elec. Power Co. v. EPA, 920 F.3d 999, 1018 (5th Cir. 2019) ("[O]ur court has long recognized that 'Congress intended [BAT] limitations to be based on the performance of the single-best performing plant in an industrial field.'") (citation omitted); *see* also NRDC v. EPA, 863 F.2d 1420, 1433 (9th Cir. 1988) ("Congress has demonstrated its intent to require industry to do as much as possible to control toxic discharges.") (citing 33 U.S.C. section 1331(b)(2)(A)(i)). The final rule incorporates the latest information on pollution controls technologies in determining that more advanced treatment than was required in 2020 now represents BAT for the industry. Moreover, the costs of the 2020 rule are fully accounted for in this rule, and the EPA has found that the rule is economically achievable, as that term is used in the CWA. As discussed in Sections VII.F and VIII.C of the preamble, the EPA uses IPM to analyze electric sector impacts. IPM shows small impacts across the industry and leads the EPA to the conclusion that even the cumulative cost of the 2020 and 2024 technologies is economically achievable, and potentially would result in incremental capacity retirement of 5,782 MW from the incremental closure of 5 steam electric power plants with a total of 9 EGUs. Where more stringent technologies are available, economically achievable, and have acceptable non-water quality environmental impacts, as the BAT technologies identified in this rule are and do, the fact that facilities may have to spend more to supplement or replace existing treatment systems, even relatively new ones, is not a sufficient reason on its own to reject selection of the technology. This is particularly true given Congress's intent and expectation for technology-based limits based on Best Available Technology Economically Achievable. Southwestern Elec. Power Co. v. EPA, 920 F.3d at 1018; NRDC v. EPA, 863 F.2d at 1433.

The EPA acknowledges that some plants have made substantial capital investments to comply with the 2020 rule; however, the EPA disagrees that power companies need a period for recovery of past compliance investments beyond the 2029 proposed compliance date (e.g., until 2040, suggested by a commenter). As one commenter notes, a chemical precipitation system installed for FGD wastewater treatment can be retooled to support meeting the 2024 final rule limitations. Holding tanks, pumps, and other ancillary equipment can also be repurposed. For the 2024 final rule compliance, any BA handling system installed for compliance with the 2020 final rule either already does not discharge BA transport water (e.g., dry handling systems) or is a high recycle rate system (e.g., remote MDS) which plants may supplement with reverse osmosis membrane filtration to meet the zero-discharge limitation, and therefore will not have stranded assets for handling BATW. Since no requirements for legacy wastewater or CRL were included in the 2020 rule, the final rule requirements for these wastestreams would also not cause any stranded assets.

The EPA disagrees that it has ignored the impacts on ratepayers. While the EPA has selected the BAT technologies in the final rule based on the statutory factors, the Agency has also evaluated the impact on residential electricity prices. A summary of these findings are presented in Section VII.H of the preamble. As seen in that section, the marginal price increases resulting from this final rule are small in both relative and absolute terms.

The BAT statutory factors include cost, but not cost recovery. Thus, while it is informative to understand the framework under which the industry recovers costs, it is not required that the costs be borne by the ultimate consumers.

The EPA disagrees with the commenter that stated the "EPAs apparent understanding that coal-fired generating is not cost-competitive is currently incorrect…" The EPA conducted IPM modeling that shows that coal will retire in the future as a less competitive, more costly source of electricity.

General Comments on the EPA's Cost Estimation Methodologies

The EPA disagrees with one commenter that stated the EPA underestimated compliance costs and overstated benefits of implementing treatment technologies for bottom ash transport water and CRL. The EPA disagrees with another commenter that stated the EPA is implementing "unnecessary technologies" and did not fully account for costs for CRL and legacy wastewater. The EPA acknowledges that utilities may need to consider capital investments or retirements in order to comply with the ELG and has accounted for capital investments as part of its compliance cost estimates. The EPA views its cost estimates as reasonable for a nationwide assessment. See also EPA's responses in Comment Code 21 (BATW – Zero Discharge), Comment Code 23 (Leachate – General), and Comment Code 28 (Legacy – General) as well as Comment Code 50 (Benefits).

One commenter questioned the EPA using a 2021 cost year basis in estimating compliance costs and benefits, given current inflation. The EPA used a 2023 cost year basis for the 2024 final rule, a factor of 1.338 to escalate costs, which adequately considers current economic conditions (*see* TDD Section 5).

One commenter, EPRI, provided appendices detailing their own compliance cost methodologies. The commenter presented the capital cost factors used throughout their methodologies and stated that they are "based on common industry standards or a suggested range developed through knowledge accumulated by the engineering industry and refined by professional cost estimators to apply specifically to water treatment." The commenter did not specifically state that the EPA's cost factors were incorrect or misused and this commenter did not offer information to suggest that the EPA's cost factors are unreasonable.

As part of the EPA's compliance cost methodologies, the EPA used cost factors to supplement costs for vendors using standard engineering factors presented in Peters and Timmerhaus' Plant Design and Economics for Chemical Engineers. The EPA's cost factors are the average of those that are standard for a solid plant (e.g., coal briquetting), a solid-fluid plant (e.g., shale oil plant), and a fluid plant (e.g., distillation unit) presented in the table "Ratio factors for estimating capital-investment items based on delivered equipment cost" (Peters and Timmerhaus Table 17, page 183). Similar to development of its indirect cost factor for the 2015 rule and direct and indirect cost factors for the 2020 rule, the EPA determined that averaging these factors is a reasonable approximation for a coal-fired power plant cost estimation.

EPRI's cost factors were the same cost factors presented in EPRI's comments on the EPA's 2019 proposed rule, except for an additional 1 percent added to "Engineering Costs" to account for pilot studies. As part of the Agency's 2019 comment response, the EPA compared these cost factors to the cost factors used in the FGD BAT cost analysis (chemical precipitation plus low residence time reduction) and determined that the EPA's cost factors appropriately contribute to a reasonable industry-level cost estimate. The cost factors included the EPA's cost methodologies (in both the 2020 and 2024 rules) are all based on supplementing vendor data with the Peters and Timmerhaus cost factors (i.e., they are similar for cost methodologies for chemical precipitation, membrane filtration, and zero discharge). The EPA also did not change its cost factors between the 2020 rule and 2024 rule; therefore, the EPA maintains its position, articulated in the 2020 rule, that its cost factors are appropriate and reasonable for an industry-level cost estimate.

The EPA did make changes to its FGD cost methodology, specifically the brine encapsulation methodology and solids handling calculations, see responses to comments in code 14 (FGD Wastewater – Membrane Filtration).

See section 5 of the EPA's Technical Development Document for Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category (2024 TDD), Document No. EPA-821-R-24-004, for more details on the compliance cost estimates.

One commenter submitted their general cost methodology for estimating FGD wastewater and CRL treatment costs, including general O&M cost elements and components. Wastestream-specific responses can be found in Comment Code 11 (FGD Wastewater – General), Comment Code 14 (FGD Wastewater – Membrane Filtration), Comment Code 15 (FGD Wastewater – Spray Evaporation and Thermal), Comment Code 23 (Leachate – General), Comment Code 25 (Leachate – Chemical Precipitation), and Comment Code 27 (Leachate – Other Technologies). As the EPA discusses in these Comment Codes, the EPA disagrees with using peak flow rates to estimate capital costs for FGD wastewater and CRL and average flow rates to estimate FGD wastewater operation and maintenance costs based on information received from industry.

The EPA agrees that consideration of other EPA rules can be relevant as they relate to the timing for any subcategory with a date for permanently ceasing combustion of coal. As described in Section VII.C.3 and 4 of the preamble, the EPA's subcategory for EGUs permanently ceasing coal combustion by 2028 is based in part on harmonization with the CCR regulations. Moreover, the final rule's subcategory for EGUs permanently ceasing coal combustion by 2034 allows for the flexibilities in the CAA section 111 to be utilized, as appropriate.

The EPA acknowledges the transcription errors made in the Generating Unit Level Costs and Loadings Estimates by Regulatory Option for the 2023 Proposed Rule -DCN SE10381 memorandum published at proposal. However, the EPA accounted for correct costs in the proposed rule analyses (as presented in the proposal TDD, RIA, and BCA).

The EPA disagrees with the commenter that stated the EPA "underestimated treatment system capital and O&M costs by tens of millions of dollars at certain facilities" in the last ELG rulemaking and therefore, by not incorporating that evidence into its analyses for this rule, "it is possible that the entire underlying cost-benefit analysis is incorrect." Where commenters provide the detailed data for the EPA to consider in comparison to its costing analyses, the EPA does so and makes updates that are determined to be appropriate. For example, based on public comments, the EPA made updates to the fly ash analysis completed as part of the membrane technology cost estimates (see the EPA's response to code 14). However, the EPA can't simply change plant-specific costs based on general cost estimates provided by industry without specific details to have a record basis to adjust the costs for these plants. The EPA's cost estimates are not intended to be used by a utility to select a technology to install at a particular plant but rather are intended to provide a reasonable estimate of the industry-level impact of the rule. As such, the EPA's estimated compliance costs may, in some cases, under- or overestimate costs at any specific plant, but they still provide a reasonable estimate of the cost to a plant, and thus a reasonable basis for the EPA's analyses. For example, during the 2020 rule, TVA provided public comments showing their FGD cost estimates associated with Cumberland were lower than the EPA's cost estimates. However, the EPA did not make any cost adjustments to Cumberland because TVA's cost estimates lacked specific details.

Leasing Treatment Technologies

The EPA acknowledges that leasing may be similar or greater in cost than purchasing a treatment equipment system when used for a longer period of time. However, the EPA disagrees that leasing treatment equipment is not cost-effective in all cases. One FGD wastewater treatment vendor has stated that lease agreements typically run for 5-6 years and estimated that the cost of leasing a $300,000 (2018$) model of their membrane filtration system would be approximately $40,000 per month (SE08579). In addition, while the EPA considered the availability of leasing, the Agency's primary economic analysis is evaluated assuming outright purchase, the preferred acquisition method for the industry. To the extent that any particular power plant ultimately finds it more affordable, nothing in the final rule would preclude this alternative.

The EPA's cost estimates do not account for leasing treatment technology equipment and may therefore be overestimated for some plants. The EPA maintains the estimates are reasonable for a national assessment and that implementation timing considers plants may change course and continue to operate for a longer period of time than assumed under the EPA's 2024 final rule estimate. Refer to Comment Code 9 (Subcategorization) for EPA's response to comment on the early adopter subcategory.

6. Regulatory Options – Pollutant Loadings Methodology

One commenter suggested that most of the pollutant reduction associated with the steam electric ELG is associated with low toxicity pollutants in FGD wastewater and, therefore, there would only be a "minor" increase in reduction of toxic pollutants as compared with the 2020 rule BAT for FGD wastewater (CP+LRTR).

The EPA partially agrees with the commenter that the highest pollutant removals are associated with FGD wastewater in this final rule. The EPA also agrees that the pollutant removal figure presented by the EPA is a sum of total suspended solids (TSS) and total dissolved solids (TDS) and that "the sum of individual pollutants in the docket documents is less than TDS plus TSS." The EPA uses the sum of TDS and TSS as surrogate to represent the full set of pollutants that may be found in FGD wastewater, recognizing that each parameter has unique impacts to aquatic life and human health. The list of pollutants presented in the docket only represent those that have corresponding analytical data that meet the EPA's data quality criteria.

However, the commenter incorrectly equates the percentage of pollutant loadings with the relative toxicity of a pollutant. Historically the EPA adjusts the estimated pollutant removals by multiplying the estimated removal quantity for each pollutant by a normalizing toxic weight (toxic-weighting factor, or "TWF"). However, this historical weighting scheme has not been updated to account for the toxicity of contemporary pollutants (e.g., PFAS) or pollutants that become significantly more toxic as they are transported to receptors (e.g., bromide releases that lead to the formation of brominated disinfection byproducts). While the EPA continues to present toxicity-weighted pound equivalents in Appendix B of the RIA as a reference, the true impacts of this rule may not be accurately captured by these limited estimates. For more information on the use of TWFs, *see* EPA's response to code 23 (Leachate – General).

In addition, the national goal of the CWA is the elimination of the discharge of all pollutants into the nation's waters (see CWA section 101(a)). Section 301 of the CWA provides that, in setting BAT-based effluent limitations, the EPA "shall require the elimination of discharges of all pollutants" in a wastewater stream if the EPA finds that it is technologically available and economically achievable to do so, after considering the factors specified in section 304(b) of the Act. As described in Section VII.B.1 of the preamble, the EPA is identifying zero-discharge systems as the technology basis for establishing BAT limitations to control pollutants discharged in FGD wastewater. The EPA found that the zero-discharge systems selected as BAT for FGD wastewater for this final rule are technologically available, economically achievable, and have acceptable non-water quality environmental impacts (*see* Section VII.B of the treatment technologies within a permit cycle. Refer to Code 43 (Regulatory Implementation – Timing) for additional information.

Refer to Code 1 (Legal Authority) for the EPA's response to comments reliance interests.

With respect to grid reliability, the EPA does not find that this rule will result in grid reliability concerns as discussed in Section VII.C.4 and VII.F of the preamble.

Refer to Code 5 (Regulatory Options – Compliance Cost Methodology) for the EPA's response to comments on cost recovery.

2020 Rule VIP

As stated in Section XIV.B.1 of the preamble, the EPA did not propose, nor is the Agency finalizing, any changes to the existing 2020 rule VIP. This final rule does not impact dischargers choosing to meet the 2020 rule VIP effluent limitations for FGD wastewater; the date for meeting those limitations is December 31, 2028.

FGD Wastewater High Flow Rate Subcategory

The EPA disagrees with the commenter's assertion that it did not consider higher FGD wastewater flows from once-through or high-flow wet scrubbers to evaluate membrane filtration as BAT. The EPA discussed limitations of the treatment technology with vendors and incorporated cost estimates for a range of membrane flow rates into its costing analyses. As stated previously in this response, the EPA is identifying zero-discharge systems as the technology basis for establishing BAT limitations to control pollutants discharged in FGD wastewater. Specifically, the technology basis is membrane filtration, SDE, and thermal evaporation, alone or in any combination, including any necessary pretreatment (e.g., CP) or post-treatment (e.g., crystallization). The EPA also notes that both Cumberland and Kingston are slated to retire by 2028 and are, therefore, eligible for the EGUs permanently ceasing coal combustion by 2028 subcategory, which contains limits based on surface impoundments (see section VII.C.3 of the preamble).

FGD scrubbers with high purge flows are not fundamentally different from other scrubbers based on the CWA statutory factors, as discussed in the preamble in section VII.C.1s.. As stated in section VII.C.1 of the preamble, the EPA previously based the 2020 high FGD flow subcategory on the supposedly disparately high costs, not other engineering aspects, but this 2024 final rule does not contain a high FGD flow subcategory.

General FGD Wastewater Cost Methodology

See responses to comments in Code 7 (Industry Profile & Plant Operations) related to industry profile changes and incorporating new generating unit retirements into the population of steam electric plants.

Regarding comments on the EPA's FGD wastewater flow methodology, as described earlier in this comment response, the EPA does not use peak flow rates to estimate compliance costs. In addition, the EPA's flow methodology adjusts purge flows at the FGD system level, and the EPA disagrees with the commenter who suggested that FGD wastewater treatment costs do not reduce upon retirement or refueling of EGUs. Where systems service EGUs that are retiring or refueling, the EPA adjusts the system-level FGD purge flow rate to remove the contribution from those EGUs. The unit-level flow rates are then determined by multiplying the system-level purge flow by the ratio of the unit's generating capacity to the sum of generating capacities for all units serviced by the FGD system. Refer to the *Flue Gas Desulfurization Flow Methodology for Compliance Costs and Pollutants Loadings – 2024 Final Rule* (SE11708) for plant-specific details. Where commenters provided purge flow rates that differed from the EPA's estimate, the EPA adjusted the plant's flow rate for the final rule.

The EPA evaluated capital and O&M costs from membrane filtration vendors and ultimately took the average of this range for compliance cost estimation to protect confidential business information (CBI), as one commenter suggests. In response to public comments, the EPA did revise its cost methodology for membrane filtration, resulting in higher plant-level costs. See responses to comments in Code 14 (FGD Wastewater - Membrane Filtration) for additional details on comments specific to the following topics:

- Fly ash required for brine encapsulation, increased transportation and disposal costs, and impacts to beneficial reuse market.
- Estimating O&M costs for membrane filtration using optimized flows.
- Impacts of high chloride and/or TDS.
- Recovery rates of membrane filtration.
- Equipment redundancy.

Commenters state that membrane filtration costs underestimate costs associated with retrofitting. The EPA discusses plant-specific design considerations and how these are factored into the EPA's cost estimates in Code 14 (FGD Wastewater – Membrane Filtration).

One commenter provided their estimate of zero-discharge costs for Cross Generating Station that are based on bids received and noted that the bids were adjusted for submittal to the public docket with "additional estimates of construction cost and risk." The commenter further stated that the zero-discharge costs provided in the Cross estimate would also apply to Winyah Generating Station; however, this plant intends to retire or refuel all generating units by 2031 and, therefore, would qualify for the subcategory for EGUs permanently ceasing coal combustion by 2034 and would not be subject to the zero-discharge limitations of the 2024 final rule. The EPA notes that its final rule costing analyses assumed Cross Generating Station would comply with the 2020 rule VIP (based on a contingent Notice of Planned Participation (NOPP) filed in 2021); the EPA acknowledges this discrepancy in the memorandum *Updates to Estimated Compliance Costs and Pollutant Loadings* (DCN SE11780). In addition, without having the construction cost and risk factors explicitly given, the EPA is unable to make a direct comparison to the commenter's estimates. Another commenter provided their estimate for chemical precipitation and biological treatment costs for Fort Martin Power Station. Chemical precipitation capital and O&M costs or CP+LRTR capital costs are costs incurred as a result of the 2020 rule and are thus represented in the baseline analysis for this rule. The EPA finds that the costs of this rule, over and above costs in the baseline, are economically achievable for the industry, as required by the CWA. The EPA notes that the commenter's estimated biological treatment O&M costs are less than the EPA's CP+LRTR costs, which are considered in the final rule cost estimation and reflected as a cost savings. While the EPA recognizes that it may have underestimated compliance costs for some plants, it is also likely that the EPA overestimated costs for other plants. Overall, the EPA's cost estimates provide a reasonable estimate for purposes of determining economic achievability, as required by the CWA.

Leasing Treatment Equipment

The EPA received comments both for and against leasing equipment for the treatment of FGD wastewater. The EPA conducted an evaluation of leasing equipment in response to comments on the 2019 proposed rule. At that time, data were limited, but the EPA met with one utility that had evaluated leasing of treatment equipment and several vendors that provide this service. The EPA used the information provided about this plant to evaluate leasing in *Cost to Lease Flue Gas Desulfurization Wastewater Treatment* memorandum (DCN SE08633). No new data were provided specific to costs of leasing equipment; therefore, the EPA continues to rely on the analysis completed in support of the 2020 rule. As described in Section VII.B.1 of the preamble, the EPA determined the final rule to be economically achievable, and the EPA expects plants to install technologies within the specified implementation timeline. The final rule does not prohibit industry from leasing wastewater treatment equipment if that is

14. FGD Wastewater – Membrane Filtration

As described in Section VII.B.1 of the preamble, the EPA is identifying zero-discharge systems as the technology basis for establishing BAT limitations to control pollutants discharged in FGD wastewater. More specifically, the technology basis for BAT is membrane filtration, SDE, and thermal evaporation, alone or in any combination, including any necessary pretreatment (e.g., chemical precipitation) or post-treatment (e.g., crystallization).

As part of this rulemaking, the EPA has determined that membrane filtration is technologically available and economically achievable for use by the steam electric industry to control discharges of FGD wastewater. As described in more detail in the preamble, based on the EPA's current record, which contains additional information regarding the application of membrane filtration to FGD wastewater and other wastestreams inside and outside the steam electric industry, the Agency finds that membrane filtration is available to control FGD wastewater discharges, notwithstanding the uncertainties raised in the 2020 rule. Agencies have inherent authority to reconsider past decisions and to revise, replace, or repeal a decision to the extent permitted by law and supported by a reasoned explanation. *FCC v. Fox Television Stations, Inc.,* 556 U.S. 502, 515 (2009); *Motor Vehicle Mfrs. Ass'n* of *U.S. v. State Farm Mut. Auto. Ins. Co.,* 463 U.S. 29, 42 (1983). See Section VII of the preamble for more details.

The EPA received a variety of comments both for and against its inclusion of membrane filtration as part of the BAT technology basis. The EPA has organized comments in this code into six topic areas:

- FGD Membrane Filtration Costs
- FGD Byproducts
- Membrane Filtration – BAT
- Optimization Period
- Pilot Studies and Installations
- 2020 Rule

FGD Membrane Filtration Costs

Several commenters raised concerns about various aspects of the EPA's membrane filtration cost methodology, specifically the options the EPA evaluated for brine disposal, including brine encapsulation, crystallization, and deepwell injection. For the final rule, the EPA also evaluated costs for all plants discharging FGD wastewater to install SDE and thermal evaporation systems. As described in Section 5.1.6 of the Supplemental TDD, in the regulatory option cost estimate, the EPA selected either membrane filtration or SDE for each plant based on the least-cost option. However, each plant is free to choose the treatment technology or combination of technologies that is appropriate for their site and that achieves the final effluent limitations. One commenter provided their independent estimate of membrane filtration and three thermal evaporation technology options; the commenter did not estimate costs for SDE systems and, therefore, the EPA cannot make a direct comparison to its overall estimate. The EPA did estimate costs for thermal evaporation; however, due to claims by technology vendors, plant-level cost estimates are being held as confidential business information (CBI) and are not used in the least-cost estimates prepared using membrane filtration and SDE systems. Refer to Code 15 (FGD Wastewater – Spray Evaporation and Thermal) for more information.

Specific to the EPA's evaluation of brine encapsulation associated with membrane filtration, commenters raised the following issues:

- Plants allegedly not having enough fly ash and concerns over diverting fly ash from beneficial use or revenue from selling this material.

- The EPA's methodology allegedly uses an incorrect mixture of fly ash, brine, and lime.
- Costs for this technology are allegedly underestimated, both capital and operation and maintenance (O&M).

Based on some of these comments, the EPA has revised its methodology. In general, the EPA updated the methodology for estimating the amount of fly ash needed for encapsulation based on available information, including ratios of brine, fly ash, and lime (or other filler materials) and using a mass-based calculation for the solids generated by a membrane, as suggested by one commenter. See *2024 Steam Electric Supplemental Final Rule: Fly Ash Analysis* memorandum (SE11692) for additional details on the truckable brine recipe, as well as plant-specific results of fly ash availability. These changes resulted in increased capital and O&M costs due to the amount of solids that would require transportation and disposal following encapsulation, as well as additional fly ash purchase (as needed). Using this higher fly ash requirement and 2021 plant-specific data from U.S. Energy Information Administration (EIA) on amounts of fly ash generated, the EPA determined that nine out of 26 plants would require more fly ash than produced. Where additional fly ash was required, the EPA assessed O&M costs for the purchase of this material. The EPA did not consider fly ash stored on-site in its calculation of fly ash availability but notes that plants may choose to harvest landfilled ash for encapsulation and begin storing ash in anticipation of installing membrane filtration for FGD wastewater.

This update also resulted in increased non-water quality environmental impacts (NWQEI). Refer to the *Methodology for Estimating NWQEI for the 2024 Final Steam Electric ELGs* for additional details (SE11782). Commenters noted that the EPA had concluded for the 2020 rule revision that there were unacceptable NWQEIs if membrane filtration were to be selected as the BAT technology basis for FGD wastewater, due to diverting fly ash from beneficial reuse and concerns with landfilling the encapsulated material. As the EPA discusses in the preamble (see Sections VII.B.1 and X.C), the amount of fly ash sold for beneficial use fluctuates from year-to-year, but over the last five years, the amount sold would still be less than the amount available for sale even after assuming that every plant uses fly ash to encapsulate brine from an FGD wastewater and/or CRL treatment system. Thus, the EPA does not expect that, under worst-case scenarios, the use of fly ash to encapsulate brine would hamper the fly ash sales market. In addition, the EPA notes that the assumption that all plants will use membrane filtration and generate a brine for encapsulation represents a conservative estimate on fly ash usage. There are other technologies that can achieve zero-discharge limits (i.e., SDE, thermal). Thermal technologies produce much smaller volumes of brine that must be crystallized or encapsulated, and SDE systems generally do not produce any brine (dry byproduct). If plants choose to implement SDE or thermal technologies, which the Agency projects many will do as the least-cost alternative, there will be a smaller potential impact on fly-ash availability and usage.

The EPA received comments on the unknowns with the long-term stability of encapsulated material, stability of the landfill, and infiltration releases. In regards to the stability of the encapsulated brine, the EPA ensured that the brine recipes it used in estimating encapsulation transportation and disposal costs passed the Toxicity Characteristic Leaching Procedure (TCLP) test, paint filter liquids test, and/or the Synthetic Precipitation Leaching Procedure (SPLP) test and does not anticipate issues with landfilling approval; refer to the *2024 Steam Electric Supplemental Final Rule: Fly Ash Analysis* memorandum (SE11692) for additional details. Compared to traditional ash disposal methods, encapsulating the fly ash in brine results in fewer dust emissions (SE08036). With respect to the King George County Landfill leachate blowout, this scenario concerned a municipal solid waste landfill where that waste was mixed with CCR, a scenario that is only possible for facilities that use off-site disposal. While the EPA cost model projected nine facilities would select membrane filtration as the least cost technology, eight have on-site landfills. In addition, if plants have concern with their landfill's stability, they may opt for other brine management options, such as crystallization or deep well injection. See preamble Section VII.B.1 for more information on the EPA's response to comments regarding potential remobilization of pollutants from encapsulated brine and landfill liner compatibility.

The EPA evaluated EIA data to determine the amount of fly ash sold compared to the amount reported as total for the years 2017 through 2021; refer to the *2024 Steam Electric Supplemental Final Rule: Fly Ash Analysis* memorandum (SE11692) for additional details. This analysis again demonstrates variability in fly ash sales from year to year across the industry and within plants. Of the plants that specifically commented on not having sufficient fly ash for encapsulation and/or beneficial reuse, two plants are expected to retire or refuel all generating units by 2028 (and thus would not have to meet more stringent limitations under the 2020 or this 2024 final rule), one plant is expected to retire or refuel all generating units by 2034 (and thus would not have to meet more stringent limitations under this 2024 rule), one plant has sufficient fly ash for encapsulation, and five plants have sufficient fly ash to both encapsulate their brine and meet fly ash sales quotas based on 2021 EIA data (see Table 2 below). For the remaining four plants, the EPA estimated costs to purchase supplemental fly ash (SE11692).

Table 2. Fly Ash Availability for Brine Encapsulation and Beneficial Reuse

ICR ID	Plant Name	Commenter	Sufficient Fly Ash for Brine Encapsulation	Sufficient Fly Ash for Beneficial Reuse
265	Kingston	Tennessee Valley Authority (TVA)	Expected to retire/refuel by 2028	
771	Kyger Creek	Ohio Valley Electric Corporation (OVEC)	Yes	Yes
1236	Mitchell	American Electric Power (AEP)	Yes	Yes
1493	Plant Miller	Southern Company	Yes	Yes
2244	Plant Bowen	Southern Company	No	No
3235	Cross	Santee Cooper	Yes	No
3265	Cardinal	Buckeye Power, Inc.	Yes	Yes
4543	Mountaineer	AEP	Yes	Yes
5318	Clifty Creek	OVEC	No	No
6329	Cumberland	TVA	Expected to retire/refuel by 2028	
7411	Winyah	Santee Cooper	Expected to retire/refuel by 2034	
9161	Amos	AEP	No	No
9971	Dallman	City Water, Light and Power (CWLP), City of Springfield, Illinois	No	No

The demand for fly ash is not guaranteed for a particular location or plant. While there were plants in the EPA's analysis that did not have sufficient ash for beneficial reuse, there were also plants that have a surplus of ash, beyond the amount needed for encapsulation, as well as 2021 EIA fly ash sales; the EPA did not give these plants cost savings for the potential sales from this additional ash. In addition, there is fly ash available to the beneficial reuse market from plants that have "dry" FGD systems (i.e., do not generate slurry blowdown) and, therefore, are already meeting the ELGs. By using fly ash generated on site, plants can avoid the cost of purchasing additives to encapsulate brine. Furthermore, the EPA does not know definitively the amount of fly ash that will be required as it is variable depending on a plant's generation and corresponding flow rate for a given year. While the EPA acknowledges that diverting fly ash from beneficial reuse to membrane filtration brine encapsulation will reduce the amount of fly ash available in the market, the EPA notes that plants may use other materials or technologies to encapsulate the brine or use thermal treatment technologies such as SDEs to meet the zero-discharge standard, as described more in Topic *FGD Byproducts*. Where a plant would need to purchase additional encapsulation materials, such as fly ash, the EPA found that, in all cases, the plant would use an SDE system in its least-cost option estimates and, therefore, would not install a membrane filtration system that might require fly ash for disposal of brine (refer to the Supplemental TDD Section 5.1 for more information on the least-cost option evaluation). Plants can also choose to use different recipes for encapsulating the brine produced by membrane processes that do not include fly ash.

One commenter provided their membrane filtration cost estimates for Plant Miller and Plant Bowen. For the Plant Miller cost estimate, the EPA notes that the commenter included the cost for a thermal evaporation system, in addition to membrane filtration and encapsulation; the EPA assumes this is a likely reason for the cost estimate being higher than the EPA's estimate; however, the commenter did not provide the purchased equipment cost for the membrane filtration equipment vs. the thermal evaporation equipment, so the EPA cannot make a direct comparison. As shown in Table 2, the EPA found that Plant Miller indeed has enough fly ash for membrane filtration brine encapsulation, and the EPA therefore estimated compliance costs for Plant Miller to install membrane filtration (without thermal evaporation). For this final rule, the EPA found that Plant Bowen does not have sufficient fly ash for encapsulation; the EPA found through its least-cost option estimate that membrane filtration was more expensive, and therefore estimated costs for the plant to install SDE. As the commenter did not provide an estimate for the plant to install the SDE technology, the EPA cannot make a direct comparison to its compliance cost estimate.

The EPA disagrees with commenters' assertion that the membrane filtration cost methodology uses an incorrect wastewater flow rate and that the membrane filtration system should include N+1 redundancy. Consistent with the costing approach from the 2020 Rule, the EPA's compliance cost estimates use the FGD average purge flow as the basis for capital costs; this ensures equipment is sized for a higher flow. O&M costs are based on the optimized flow as a closer approximation of costs incurred year to year. This approach sizes equipment for capital costs that incorporate a design capacity. The EPA disagrees that peak flow should be used to size equipment or estimate capital costs, as this would result in overly large equipment and inflate capital costs. Regarding redundancy, the EPA disagrees that N+1 is appropriate, where N is the peak flow. Based on the EPA's record, in practice, plants do not install entirely redundant treatment systems or even entirely redundant power generation equipment. Costs provided by vendors do include costs for redundant pumps. Vendors also noted that membrane systems are modular, so often an entirely redundant system is not required. If one module is taken down for service, either flow can be temporarily reduced, or other modules can take on additional flow temporarily (SE06930). In addition, the EPA supplemented one of the vendor cost estimates with additional flow equalization/storage tanks that may be used while the system is offline for maintenance. The EPA expects that the capacity of the chemical precipitation pre-treatment system will be similar to the design capacity of the membrane filtration system, and again notes that extra storage tanks may be used in times where the flow capacity of the membrane filtration system is exceeded.

The EPA acknowledges general comments that increasing concentration of chloride in the FGD scrubber system may increase total dissolved solids (TDS) concentrations in the blowdown, which could potentially reduce the percentage of treated water the membrane recovery process produces from the wastewater being treated. However, the EPA maintains that the average percentage of treated water produced being used in the EPA compliance cost estimates (70%) is reasonable, since the 70 percent treated recovery value agrees with the industry average value for recovery of treated water cited by one of the commenters. One membrane filtration vendor whose costs are included in the EPA's methodology specifically noted having included metallurgy that is compatible with high chlorides. Refer to Topic *Pilot Studies and Installations* for additional details.

The EPA also disagrees with commenters' statements that the EPA assumed 94.7-99% overall membrane recovery in developing its membrane filtration compliance cost estimates. The EPA's cost methodology

(SE11757) has consistently used an average recovery from treatment vendors of about 70%, as recommended by commenters. This recovery rate is applied to the optimized FGD wastewater flow to estimate the amount of permeate and the amount of brine factored into residuals treatment, disposal costs, and NWQEIs. The EPA acknowledges the special considerations in implementing Flex EDR[23] for treatment of FGD wastewater, such as pretreatment requirements; however, the EPA did not include this particular technology in its BAT technology basis nor its cost methodology. In addition, while constituents such as halogens, nitrate, or boron may lead to lower membrane recovery or boiling point rise in thermal evaporation treatment systems, as one commenter suggests, each plant will have unique wastewater characteristics and may, therefore, want to conduct a pilot study to optimize treatment, as described in Topic 5 *Pilot Studies and Installations*. The EPA did not include the cost for conducting a pilot study in its cost estimates, as none of the technology vendors included pilot testing in their cost estimate and none have stated that pilot studies would be needed; one technology vendor specifically stated that, given their experience to date with pilot testing, it is not required, but it can be conducted if requested by the plant. Merrimack Station, cited by the commenter, still achieves zero discharge of FGD wastewater, according to its 2020 NPDES permit.[24]

One commenter asserted that the EPA has not accounted for the higher annualized costs for plants that will cease coal combustion in less than 20 years. As stated in RIA Section 3.2.3:

> EPA assumed that the equipment installed to meet any new limitations could reasonably be estimated to operate for 20 years or more, based on a review of reported performance characteristics of the equipment components. EPA also determined the 20-year annualization period to be reasonable for this analysis because some regulators may allow utilities to recover the value of undepreciated assets in their rate base on a case-by-case basis. EPA thus used 20 years as the basis for the cost and economic impact analyses that account for the estimated operating life of compliance technology. To the extent that the actual service life is longer or shorter than 20 years, costs presented on annual equivalent basis would be over- or under-stated. This includes cases where a plant upgrades treatment technologies to comply with the ELGs but ceases operating before the 20-year life of the equipment.

Other commenters assert that membrane filtration is not economically achievable due to impact on plant revenue. The EPA determined that zero-discharge limitations are economically achievable, as discussed in Sections VII and VIII of the preamble. See also the *Regulatory Impact Analysis for Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (RIA) (SE11107) for additional details.

The EPA acknowledges the errors in its memorandum *Generating Unit-Level Costs and Loadings Estimates by Regulatory Option for the 2023 Proposed Rule* (SE10381), where several EGUs mistakenly had zero costs; however, the EPA used the correct costs in its engineering, economic, and environmental assessments for both the proposed and final rules, and these errors have been corrected in the final rule memorandum, *Generating Unit-level Costs and Loadings Estimates by Regulatory Option for the 2024 Final Rule* (SE11756).

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[23] Electrodialysis Reversal (EDR), a membrane filtration technology, uses an electrical current passing between electrodes in the water (SE11781). Ion selective membranes between the electrodes allow either positive or negative charged ions to move to the oppositely charged electrodes across the membranes leaving treated water behind. The current is reversed at intervals to minimize scaling problems at the electrodes. Flex EDR is a proprietary technology from Saltworks Technologies that uses membranes that are specific for various ions (SE11695).

[24] After the EPA completed final rule analyses, Granite Shore Power announced that Merrimack Station would voluntarily retire (refer to preamble Section VII.C.2).

Several commenters raised concerns over site-specific scenarios that may result in increased costs. The EPA acknowledges that specific design considerations may be needed on a site-by-site basis. The EPA included contingency costs to cover these types of considerations. The EPA expects that some plants may need the full amount included as contingency costs due to unique site situations, but other plants may not use any contingency costs. The EPA assumes that across the industry, these overestimates and underestimates still result in an overall reasonable estimate of costs to the industry as a whole.

The EPA agrees with commenters' statements that, when evaluating the economic achievability of membrane filtration, the EPA must consider the full costs of membrane filtration technology, including pretreatment, the technology for solidifying and encapsulating the waste, and disposal of the resulting solid waste via landfills. As described in Section 5.1.3 of the Supplemental TDD, the EPA estimated costs for membrane filtration as well as solids-handling costs, which are included in the membrane filtration cost equations; the EPA assumes that plants have already installed chemical precipitation as a result of the 2020 rule limitations, and the cost methodology accounts for this treatment in place. Commenters pointed to specific plants that would incur large retrofit costs, but specific details on these costs are lacking. The EPA disagrees that allegedly "stranded" costs should be factored into its analysis. The economic achievability of a treatment technology is not based on previous or recent investments any plant has or has not made. For the 2024 rule, the EPA estimated the cost for plants to upgrade from existing requirements (the 2020 rule) to the 2024 requirements. The economic achievability of prior ELGs is evaluated specific to those ELGs. Nevertheless, the EPA ran the cumulative costs of both the 2020 rule technologies and the technologies in this final rule through IPM and found the impacts to be economically achievable. The EPA more fully addresses the concept of stranded assets, rate recovery, reliance interests, and compliance with the 2020 rule in Comment Code 5 (Regulatory Options – Compliance Cost Methodology). For more discussion of IPM results, see Section VIII.C.2 of the preamble.

One commenter questioned the EPA's cost estimates for not evaluating thermal evaporation as part of its cost analysis. As part of the final rule, the EPA did evaluate thermal evaporation as part of its cost analyses, see *FGD and CRL Thermal Evaporation Cost Methodology* memorandum (SE11694) and the response to Code 15 (FGD Wastewater - Spray Evaporation and Thermal) for more details. Another commenter expressed concern regarding an alleged loss of $4.3 million annually of revenue due to parasitic power consumption and lost heat rate from thermal treatment technology. The commenter did not provide information regarding how the loss was estimated so the EPA is unable to respond to that specific comment. The EPA does take into consideration the additional cost associated with thermal evaporation for electricity and steam (as needed) for its cost analysis, see the EPA's response to Code 15 (FGD Wastewater – Spray Evaporation and Thermal).

The EPA does not agree with commenters that an option for discharge is needed from FGD wastewater treatment systems as part of normal operations, refer to Topic *Membrane Filtration – BAT*.

FGD Byproducts

The EPA partially agrees with the commenter's assertion that "if there is a market for FGD derived from complete recycle systems, then the product is 'saleable.'" However, the ability to sell the FGD byproducts depends largely on local markets, not just whether the byproduct can be used. The EPA recognizes that it may be cost prohibitive to sell a byproduct if transportation costs overrun the profit of the sale.

The EPA disagrees with commenters that gypsum beneficial reuse would be disrupted by complying with the 2024 final rule ELGs. The commenter has not provided data supporting that cycling up chlorides in FGD scrubber operations would impact gypsum quality. Similar comments were made at the time of the 2020 rule, including that cycling up concentrations of fines could impact gypsum quality in some wet FGD systems. The EPA at the time stated that the commenters did not provide specific data on the FGD systems at plants, including gypsum quality, that would have allowed the EPA to incorporate these other factors into its estimates of flow rates, and this is still the case for this 2024 final rule. Refer to the 2020 rule comment response (EPA-HQ-OW-2009-0819-9015), Comment Code 11 (FGD Wastewater – General).

Exhibit 6

DECLARATION OF KEVIN DRAGANCHUK, P.E., BCEE

I, Kevin Draganchuk, P.E., BCEE declare as follows:

1. I am the President of CEA Engineers, P.C. of Bloomingburg, New York, which is an environmental engineering firm.

2. I hold a Bachelor of Science degree in chemical engineering from Rensselaer Polytechnic Institute of Troy, New York.

3. I am a registered professional engineer in New York, New Jersey, and Florida with more than 17 years of experience in environmental engineering. I am board-certified as an environmental engineer by the American Academy of Environmental Engineers and Scientists, with a specialty in water supply and wastewater. I am certified by the National Association of Sewer Service Companies in its Pipeline, Manhole, and Lateral Assessment Certification Programs. Additionally, I am a member of the Water Environment Federation's Collection System Committee and of the Collection System Committee Technical Practice Group.

4. I was asked by Environmental Integrity Project, Earthjustice, and Sierra Club to review the July 26, 2024, motion to stay, including its attached documents and declarations, and to evaluate its claims regarding the cost of complying with the limits on the discharge of Flue Gas Desulfurization wastewater under the 2020 and 2024 versions of U.S. EPA's final rule entitled "Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category," 89 Fed. Reg. 40,198 (May 9, 2024) ("Steam Electric ELG Rule"). Based on my evaluation, it is my opinion that the motion to stay's cited utility compliance cost estimates are inflated and/or are not direct or accurate comparisons to EPA's compliance cost estimates. Based on my evaluation, EPA's cost estimating methodology was

based on reasonable and prudent engineering practices and reasonable and prudent engineering cost estimating practices, contrary to the criticisms in the motion to stay.

5. I have prepared a technical memorandum that details my opinions, a true and correct copy of which is attached hereto as Attachment A.

6. My opinion, as set forth in my technical memorandum, is informed by my education, training, and professional experience as an engineer. My experience includes analyzing the operation, maintenance, asset management, and design of sanitary and combined sewer systems; analyzing municipal and industrial Wastewater Treatment Plant design, operations, and performance; reviewing National Pollutant Discharge Elimination System permits; and reviewing and evaluating EPA's effluent limitation guidelines ("ELGs"). Specific to the Steam Electric ELG Rule, in May 2023, I prepared a technical memorandum on the 2023 Proposed Rule regarding the adequacy of the Rule's proposed effluent limits and determinations of Best Available Technology for controlling combustion residual leachate and legacy wastewater. *See* Comments of Earthjustice *et al.*, EPA-HQ-OW-2009-0819-10080, Attach. 4 (CEA Engineers Technical Memorandum) (May 30, 2023). I have also provided comments on the 2024 Proposed ELG Rule for the Meat and Poultry Products Point Source Category, and on the adequacy of the existing ELGs for the Organic Chemicals, Plastics, and Synthetic Fibers and Petroleum Refining Point Source Categories with a focus on feedstock conversion processes and plastics production. My qualifications and expert testimony history are provided in my curriculum vitae, attached hereto as Attachment B.

I declare under penalty of perjury under the laws of the United States, pursuant to 28 U.S.C. § 1746, that the foregoing is true and correct to the best of my knowledge.

Executed on this __13__day of August 2024, in Bloomingburg, Orange County, New York.

____
Kevin Draganchuk, P.E., BCEE
President
CEA Engineers, P.C.
25 Dogwood Drive
Bloomingburg, NY 12721

Attachment A

CEA Engineers, P.C.
Kevin Draganchuk, P.E., BCEE
KDraganchuk@ceaengineerspc.com

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Bloomingburg, NY 12721
845-372-9674
https://ceaengineerspc.com/

Technical Memorandum

Date: August 13, 2024

To: Environmental Integrity Project, Earthjustice, and Sierra Club

From: Kevin Draganchuk, P.E., BCEE

Re: Utility and State Petitioners' Motion for a Stay Pending Review for the Steam Electric Power Generating Point Source Category – 2024 Final Rule Compliance Cost Estimates

CEA Engineers, P.C. Job No.: J23-07

At the request of Environmental Integrity Project ("EIP") and EIP's partner organizations, Earthjustice and Sierra Club, CEA Engineers, P.C. ("CEAPC") reviewed the July 26, 2024, Utility and State Petitioners' Motion for a Stay Pending Review ("Motion") to evaluate its claims regarding the costs of complying with United States Environmental Protection Agency's ("EPA") effluent limitations guidelines ("ELGs") for the steam electric power generating point source category. Specifically, this technical memorandum evaluates the Motion's claims about the cost of complying with ELGs on Flue Gas Desulfurization ("FGD") wastewater discharges under the 2020 Steam Electric ELG Reconsideration Rule (promulgated on October 13, 2020, in the Federal Register, Volume 85, Number 198) ("hereafter, "2020 Rule") and 2024 Steam Electric ELG Supplemental Rule (promulgated on May 9, 2024, in the Federal Register, Volume 89, Number 91) (hereafter, "2024 Rule").

Based on CEAPC's evaluation, it is my opinion that the Motion's cited utility compliance cost estimates are inflated and/or not direct or accurate comparisons to EPA's compliance cost estimates. Based on my evaluation, EPA's cost estimating methodology was based on reasonable and prudent engineering practices and engineering cost estimating practices, contrary to the criticisms in the Motion.

Alabama Power Company's Miller Plant Compliance Cost Estimate

The Southern Company received a third-party cost estimate from Westech for conversion of its Alabama Power James H. Miller Plant ("James H. Miller Plant") FGD wastewater treatment system to a zero-discharge facility that totaled $279 million. (Motion, page 17, Ex. 6, page 37 and Appendix A). EPA's compliance cost estimate for conversion of the James H. Miller Plant's wastewater treatment system to achieve zero-discharge through a membrane technology treatment system totaled approximately $25.6 million. (Motion, page 17, Ex. 16).

The proposed zero-discharge wastewater treatment system from Westech ("Westech Proposed System") is unnecessarily complex and overdesigned, speculative in its performance, and includes treatment systems EPA did not include in its compliance cost estimate for the James H. Miller Plant.

EPA's compliance cost estimate for membrane technology included the following primary equipment and treatment units (Ex. 11 (Technical Development Document, pages 37 – 38)):

- Reuse of existing chemical precipitation ("CP") system
- Membrane pretreatment (reuse of existing ultrafiltration if feasible)
- Reverse osmosis ("RO")
- Brine encapsulation with purchase of additional fly ash as needed
- Transportation and disposal of solids in a landfill

The Westech Proposed System included the following primary equipment and treatment units (Ex. 6, App. A, pages 27 – 31):

- Reuse of existing CP system and ultrafiltration (if feasible) for pretreatment
- 2 Vibratory Shear Enhanced Processing ("VSEP") pretreatment systems
    - In its response to EPA's information request for development of the 2024 Rule, The Southern Company stated that "VSEP is not a mature, widely available solution for treating FGD wastewater, and it is not likely to be in the near future" and "VSEP is not yet proven as a commercially available technology and has not been operated at a commercial scale for treatment of FGD wastewater." (Ex. 18, pages 4 - 5). Despite The Southern Company's conclusions that VSEP systems are not presently viable for treating FGD wastewater, the Westech Proposed System still included them.
- 3 RO systems
- 3 AVARA thermal evaporator systems (AVARA is a vapor recompression treatment system), see https://www.prnewswire.com/news-releases/purestream-services-avara-advanced-vapor-recompression-system-deployed-to-treat-wastewater-to-epa-discharge-standards-at-commercial-facility-in-pennsylvania-300181216.html
- Brine solidification batch plant

The cost estimate for the Westech Proposed System is inflated in three main ways.

First, the inclusion of VSEP pretreatment filtration systems is an unnecessarily more complex approach than the pretreatment systems EPA considered as part of its membrane technology zero-discharge treatment system, such as ultrafiltration (a portion of which could be repurposed from CP systems that the plant has already installed and is currently using). Additionally, The Southern Company itself has opined that VSEP filtration is not a viable FGD wastewater treatment system, making its inclusion relative to established, less complex pretreatment filtration systems questionable from an engineering design basis. (Ex. 18, pages 4 – 5).

Second, thermal evaporation is not required to achieve zero-discharge for a membrane technology treatment system. Thermal evaporation is an unnecessary additional treatment unit with an associated unnecessary capital cost that EPA did not include as part of its membrane technology zero-discharge treatment system and compliance cost estimate.

The total cost estimate for the Westech Proposed System included an engineering cost estimate alone of nearly $16 million, which is an indication in and of itself of the complexity and overdesign of the Westech Proposed System relative to EPA's membrane technology treatment system. (Ex. 6, page 87 and App A).

Third, due to the inflated equipment and construction costs resulting from the Westech Proposed System's unnecessarily complex VSEP pretreatment system and unnecessary thermal evaporation system, the total cost estimate for the Westech Proposed System included sizeable markups that dramatically increased the total cost estimate, including a contingency and escalation cost totaling over $40 million, an allowance for funds used during construction ("AFDUC") cost totaling over $37 million, and startup and commissioning costs over $7 million. (Ex. 6, App. A, page 87). Markups such as these are commonly estimated based on a percentage of total construction costs. Thus, the unnecessary inflation of constructions costs results in corresponding inflated markup costs and further inflation of the total cost estimate. In the case of the Westech Proposed System, the costs for engineering, contingency and escalation, AFDUC, and startup and commissioning totaled approximately $100 million, more than 35% of the total cost estimate of $279 million. A zero-discharge treatment system consistent with the more reasonably designed EPA membrane technology treatment system to comply with the 2024 Rule would result in lower total construction costs and proportionally lower markup costs and total compliance costs.

Ultimately, the Westech Proposed System and its unnecessarily complex and over-engineered design results in an inflated associated cost estimate that is not comparable to EPA's compliance cost estimate and the membrane technology treatment system it is based on.

Georgia Power Company's Plant Bowen Compliance Cost Estimate

The Motion compares EPA's 2020 Rule compliance capital cost estimate of $28.6 million for installation of a low residence time reduction ("LRTR") biological treatment system to a purported actual cost of "nearly $110 million." (Motion, page 11). The exhibit cited for that statement suggests that the $110 million figure includes a much broader set of compliance costs than EPA's estimate, which focused only on LRTR installation costs, stating: the "design, engineering and construction effort" undertaken for Plant Bowen has already cost "$50 million to date" and will continue to cost "an additional $30-40 million, which will represent nearly all installation and capital costs of the system." (Motion, page 11 and Ex. 6, page 26). The ultimate comparison the Motion makes is to the "nearly $110 million in investment" Georgia Power

Company "will have made toward 2020 Rule compliance" instead of the specific estimate EPA provided for LRTR installation alone. Plant Bowen has an existing CP system, so presumably, no capital costs for CP were required. (Ex. 6, page 37).

Motion Exhibit 12 - EPRI Comments on Proposed Effluent Limitations Guidelines Rule (May 26, 2023)

Table 1 below compares three different cost estimates for converting from LRTR treatment systems to membrane filtration treatment systems: (1) the industry-wide compliance cost estimates prepared by the Electric Power Research Institute ("EPRI") in May 2023 and contained in Exhibit 12 to the Motion; (2); EPA's final industry-wide compliance cost estimates from the April 2024 Technical Development Document ("TDD") for the 2024 Rule and (3) EPA's industry-wide compliance cost estimates prepared in 2023 as presented by EPRI in Exhibit 12.

Table 1: Industry-Wide Compliance Cost Estimate Comparisons between EPRI and EPA

Compliance Cost (Million $)	EPRI	EPA 2024	EPA 2023 As Presented By EPRI
Capital	$ 5,410	$ 1,310	$ 613
Annual O&M	$ 2,783	$ 94	$ 65

Sources:

EPRI - Exhibit 12, Table 2-1

EPA 2024 - TDD, Table 11

EPA 2023 as Presented by EPRI - Exhibit 12, Table 2-1

Flow Rate Differences

EPRI estimated capital costs based on peak FGD flows (Ex. 12, page 39, Ex 7. Pages 2-2 and 2-3) and considered installation of a redundant membrane technology treatment system to accommodate unit downtimes. EPA estimated capital costs based on purge flow rates that represented the typical amount of FGD wastewater sent for treatment. (2024 TDD, page 39). EPA does not discuss inclusion of a redundant membrane technology treatment system (and specifically stated it did not consider a redundant membrane technology treatment system for bottom ash wastewater). (2024 TDD, page 50).

- EPA's approach to using a typical flow rate is reasonable, considering that the pretreatment CP system includes equalization tanks that can store peak flows and release them as needed to allow for a relatively consistent treatment flow rate. Using peak flows results in oversized treatment systems with considerable excess capacity and higher associated costs. In other words, using peak flows is unnecessary and leads to less cost-effective treatment systems, especially considering that equalization tanks are assumed to exist as part of CP systems and would account for no additional capital costs.

- CEAPC does concur that a degree of redundancy for treatment system downtime, such as for maintenance and repairs, is prudent engineering.

EPRI estimated annual O&M costs based on average annual FGD purge flow rates. (Ex. 12, page 40). EPA estimated annual O&M costs based on an optimized FGD purge flow, which reduces flows sent for treatment where equipment can handle recirculated purge water with higher chlorides. In using optimized flows, EPA considered plant-specific constraints such as maximum design chloride concentrations and operating chloride concentrations. (2024 TDD, page 39).

- EPA's assumption that plants will optimize purge flow rates to reduce the amount of wastewater requiring treatment is reasonable, especially considering that plant owners and operators have a financial incentive to reduce ongoing O&M costs that would be incurred, such as for chemicals, membrane replacement, electricity, labor, and waste brine management and disposal. Additionally, EPA received information from industry during its data and information gathering efforts for development of the 2020 Rule that implementation of the flow optimization approach EPA used in its O&M cost estimate methodology was anticipated upon FGD wastewater treatment system upgrades. (Ex. 14, page 1182).

EPRI Assumption on EPA's Membrane Recovery Rate

EPRI provides no basis for its opinion that EPA appears to have used a much higher membrane recovery rate than 70% in performing its compliance cost estimates. (Ex. 12, page 42). Contrary to EPRI's comment, EPA calculated brine flow rates based on an average recovery rate of 70% (2024 TDD, pages 41 and 53).

Brine Management Costs

EPRI asserts that a "significant reason" for the difference in estimated O&M compliance costs between EPA and EPRI "appears" to be EPA's underestimation of brine management requirements and costs. (Ex 12, page 35).

EPRI commented that EPA underestimated brine management costs by a factor of 35 based on analysis of a single plant, the Kyger Creek Power Plant and EPA's estimated total membrane filtration annual O&M cost for Kyger Creek of $2 million. (Ex. 12, pages 46 and 48). EPRI developed its own cost estimate for brine management alone for Kyger Creek that totaled $70 million. EPRI stated that it did not know EPA's methodology and assumptions for estimating brine management costs. (Ex. 12, page 48).

The 2024 TDD details EPA's methodology for membrane brine management, including:

- Estimating brine flows
- Determining the quantity of lime or other fillers needed

- Determining total solid disposal requirements
- Estimating on-site transportation capital and O&M costs
- Estimating on-site disposal costs
- Estimating on-site and offsite transportation and disposal costs

Associated with brine management costs, EPRI commented that fly ash shortages will require plants to acquire or harvest fly ash and EPA expected such shortages to be minimal. EPRI further commented that EPA ignored technical challenges and additional costs related to excavating, processing, and drying landfilled fly ash. (Ex. 12 page 52). EPA specifically increased its brine management/membrane technology treatment system O&M cost estimates by including costs in its final 2024 Rule compliance cost estimates based on supplemental fly ash purchases for fly-ash-deficient power plants and associated increased solids transportation and disposal costs. (2024 TDD, page 42).

EPRI Compliance Cost Estimates and Bases (May 2023) and Comparison to EPA Compliance Cost Estimates and Bases

EPRI's 2024 Rule compliance cost estimates appear to include costs related to compliance with the 2020 Rule that EPA did not include in its compliance cost estimates. EPRI's estimates also differ from EPA's in that they consider achieving zero-discharge only through membrane treatment technology, not other zero-discharge treatment systems like spray dryer evaporation ("SDE") systems. This suggests EPRI's compliance cost estimates do not provide a direct and accurate comparison to EPA's compliance cost estimates.

For the 2020 Rule, EPA estimated capital costs for installation of an LRTR treatment system. EPA detailed that LRTR included CP pretreatment and explained that its cost estimates for an LRTR biological treatment system include the following equipment (Ex. 2, page 5-27):

- Treatment equipment (anoxic/anaerobic bioreactor, flow control, backwash supply, storage tanks)
- Chemical feed system for nutrients
- Pretreatment system (for plants with nitrate/nitrite concentrations greater than 50 parts per million)
- Heat exchanger
- Ultrafilter
- Pollutant monitoring and analysis

- Transportation and disposal of solids in a landfill

EPA provided a detailed breakdown of the cost curves it utilized and inputs to develop its cost curves. (Ex. 2, pages 5-27 – 5-33). EPA identified the current level of treatment for FGD wastewater at plants and what specific treatment system would still be needed to comply with the 2020 Rule. (Ex. 2, page 5-20). Cost estimates were based on specific equipment upgrades to achieve compliance for FGD wastewater with the 2020 Rule.

EPRI states in its comments (Ex. 12, pages 32 – 33):

- "…EPA estimated costs for membrane filtration only. EPA did not estimate additional costs for CP pretreatment for the membrane filtration technology option, as plants are assumed to have come into compliance with the 2020 rule and already have this treatment in place." EPRI took a "similar" approach to EPA in developing its compliance cost estimates in order to "generally align" with EPA's compliance cost estimate bases. "… EPRI has adapted EPA's basis assuming that all 22 plants have already installed CP and biological treatment as a baseline for estimating capital costs. Therefore, the costs developed by EPRI consider the capital costs to convert each plant from CP and biological treatment to CP, membrane filtration, and brine encapsulation."

EPRI is ambiguous in its description of taking a "similar approach to generally align with EPA's cost basis [*sic*]" and, unlike EPA, does not explicitly state that the capital costs related to CP are not included in its compliance cost estimates. Thus, it is unclear whether EPRI included CP capital costs in its compliance cost estimate. Doing so would inflate EPRI's compliance cost estimate for the 2024 Rule as compared to EPA's compliance cost estimate, which expressly excluded CP capital costs.

Including capital costs related to pre-existing CP systems for estimating compliance costs for the 2024 Rule would be a flawed approach. Capital costs for installation of CP to comply with the 2020 Rule would have been incurred regardless of the need to comply with the 2024 Rule. Thus, they were not incurred specifically in response to the need to comply with the 2024 Rule and are not a cost related to compliance with the 2024 Rule.

EPRI also does not credit plants for avoided LRTR O&M costs after switching to a membrane technology treatment system, which EPA did by presenting annual compliance O&M costs as the incremental cost between operating an LRTR treatment system versus a membrane technology treatment system rather than a membrane technology treatment system alone. (Compare 2024 TDD, page 39 and Ex. 12, pages 32 – 33).

EPA's approach for estimating annual O&M costs for complying with the 2024 Rule is correct. The annual O&M cost resulting from complying specifically with the 2024 Rule is not the total annual O&M cost for wastewater treatment that a plant will incur after converting its treatment system to meet the zero-discharge ELGs. Rather, it is the difference in annual O&M costs between (1) the baseline annual O&M costs presently incurred from utilization of a plant's existing wastewater treatment system, which would be incurred regardless of implementation of the 2024 Rule, and (2) the costs that will be incurred after installation of a wastewater treatment system capable of complying with the 2024 Rule. This difference is the true annual O&M cost incurred specifically for complying with the 2024 Rule.

Additionally, in preparation of its compliance cost estimates for the 2024 Rule, EPA optimized plant-specific costs by using the least expensive zero-discharge treatment option between membrane technology and SDE systems, while EPRI estimated compliance costs only based on membrane technology. (2024 TDD, page 38).

EPRI Compliance Cost Estimate Summary

In sum, EPRI's methodology inflated its total industry-wide compliance cost estimates, as well as individual aspects of its compliance cost estimates, relative to EPA's compliance cost estimates due to the following factors:

- EPRI relied on peak FGD flow rates for membrane technology treatment system design that results in a larger membrane treatment system than necessary with associated higher capital costs rather than relying on typical FGD flow rates and use of existing equalization facilities.

- EPRI relied upon annual average FGD flow rates to estimate annual O&M costs rather than determining optimized FGD flow rates based on the ability to recirculate purge water through the FGD system, a practice that reduces the quantity of FGD wastewater requiring treatment that plant owners have a financial incentive to institute.

- EPRI incorrectly assumed EPA relied on a higher membrane treatment recovery rate than 70%.

- EPRI did not estimate compliance costs related to brine management consistent with EPA's detailed methodology and assumed a cost for EPA's brine management compliance cost estimate that considerably inflated the apparent difference in compliance costs.

- It is unclear whether EPRI included capital costs related to CP pretreatment equipment installed to comply with the 2020 Rule, which would inflate EPRI's compliance cost estimate as compared to EPA's compliance cost estimate. Additionally, EPRI did not credit plants for currently incurred LRTR O&M costs required to comply with the 2020 Rule by identifying the incremental increase in annual O&M costs related to a membrane technology treatment system relative to current annual O&M costs associated with the LRTR treatment system.

- EPRI estimated compliance costs based only on membrane treatment technology, while EPA optimized plant-specific costs by using the least expensive zero-discharge treatment option between membrane technology and SDE.

Motion Compares Cost Estimates Based on Dollar Amounts from Different Years and with Different Values

It is an inaccurate and flawed approach to compare cost estimates based on dollar amounts from different years that thus have corresponding different values. Over time, the value of the dollar generally depreciates and correspondingly the costs for capital projects increase.

EPA's compliance cost estimates for the 2020 Rule were based on 2018 dollars and the cost estimates in the Motion and its exhibits were prepared several years later and used nominal dollars instead of holding the dollar value constant to EPA's cost estimates. Nor did the Motion adjust EPA's compliance cost estimates to be based on dollar amounts with the same value as its cited compliance cost estimates, resulting in inaccurate comparisons that deflate EPA's cost compliance estimates and create the appearance of a larger difference. The impact that the 2020 Covid pandemic and resulting supply chain disruptions and across the board increases in construction, labor, material, and equipment costs that have occurred for capital projects and engineering have driven the differences in dollar values and corresponding cost estimates from different years considerably (if not dramatically) higher, further artificially inflating the difference between EPA's compliance cost estimates and the industry compliance cost estimates cited in the Motion.

As an example, Exhibit 6 does not provide a detailed breakdown of Georgia Power Company's efforts to comply with the 2020 Rule at the Bowen Plant and the associated costs that comprise its $110 million investment, and the Motion does not address the fact that EPA's capital cost estimate of $28.6 million is in 2018 dollars, prior to the impact on costs resulting from the 2020 Covid pandemic. When adjusting for the difference in values of the dollar amounts for EPA's and Georgia Power Company's capital costs estimates, the $30-$40 million installation and capital costs reported in Exhibit 6 by Georgia Power Company are in fact consistent with EPA's capital cost estimate.

Conclusion

Based on CEAPC's evaluation, it is my opinion that the Motion's cited utility compliance cost estimates are inflated and/or not direct or accurate comparisons to EPA's compliance cost estimates. EPA's cost estimating methodology was based on reasonable and prudent engineering practices and cost estimating practices, contrary to the criticisms in the Motion.

Attachment B

Kevin Draganchuk, P.E., BCEE

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Professional Profile:

Kevin Draganchuk, P.E., BCEE is an Environmental Engineer with over 15 years of experience in stormwater management design and permitting, wastewater collection and treatment, pollution prevention, water quality protection, site remediation, and litigation support.

He is a regular expert witness in Clean Water Act, environmental negligence, and flooding cases for settlement negotiations, deposition, and trial in local, State, and Federal courts.

He is President and Principal Engineer of CEA Engineers, P.C., a New York Professional Corporation.

Areas of Expertise:

Construction and industrial stormwater management evaluation, design, and permitting

Wastewater collection and treatment evaluation, design, and operations and maintenance

Sanitary Sewer Overflow (SSO) cause analysis and remediation

Pollutant discharge quantification and environmental impacts

Litigation support

Environmental advocacy support

Site remediation, including testing, monitoring, maintenance, and oversight

Watershed protection and flooding

Qualifications:

Education:

Rensselaer Polytechnic Institute Bachelor of Science, Magna Cum Laude, 2004, Chemical Engineering

Professional Licenses, Certifications and Organizations

Registered Professional Engineer

- New York
- New Jersey
- Florida

American Academy of Environmental Engineers & Scientists

- Board Certified Environmental Engineer (BCEE) – Water Supply and Wastewater Specialty

Water Environment Federation – Collection Systems Committee Member – Technical Practice Group

New York Water Environment Association - Member

National Association of Sewer Service Companies (NASSCO) Pipeline/Manhole/Lateral Assessment Certification Program (PACP/MACP/LACP)

24-Hour HAZWOPER Certified

CEA ENGINEERS

RELEVANT EXPERIENCE & REPRESENTATIVE PROJECTS

Wastewater Treatment and Collection Systems:

Litigation Support, Chesapeake Bay Foundation, et al, v. County of Henrico

Provided technical engineering litigation support for Clean Water Act (CWA) violations due to unpermitted sanitary sewer overflow (SSO) discharges from Henrico's sanitary sewer system, unpermitted wastewater treatment system bypasses (Bypasses), discharge of partially treated wastewater from Henrico's Water Reclamation Facility (WRF), and WRF NPDES permit effluent limitation exceedances for total suspended solids (TSS) and biological oxygen demand (BOD). Analyzed the impact of inflow and infiltration (I&I) on Henrico's sanitary sewer system, WRF, SSOs, Bypasses, and NPDES permit effluent limitation exceedances. Evaluated the sanitary sewer system's Operation and Maintenance (O&M) plan, Sewer System Evaluation Survey (SSES) Reports, SSO history, infrastructure attributes, work orders, capital improvement plans, and associated documents. Evaluated WRF Process Operation Reports, O&M manuals, design reports, and Bypass event reports. Analyzed Henrico's long-term Facilities Plan and associated capacity analysis of the sanitary sewer system and WRF. Prepared an Expert Report and Rebuttal Report within the constraints of a condensed, approximately 3-months long court schedule evaluating the causes of SSOs, Bypasses, and NPDES permit effluent limitation exceedances and recommended remedies to reduce and eliminate them. Developed rebuttal responses to Defendant's Expert Report. Provided testimony at deposition. Provided technical settlement support in addition to litigation support that resulted in a settlement agreement.

Litigation Support, Suncoast Waterkeeper, et al., v. City of Gulfport

Provided technical engineering litigation support for CWA violations due to unpermitted SSO discharges from Gulfport's collection system. Analyzed the collection system's O&M plan, SSES Report, pipe condition assessment reports, capital improvement plans, and associated documents. Prepared an Expert Report and Rebuttal Report evaluating the causes of SSOs, recommended remedies to reduce and eliminate SSOs, a cost estimate for the recommended remedy, and rebuttal responses to Defendant's Expert Reports. Prepared affidavits in support of motions for summary judgment and in opposition to Gulfport's motion to dismiss, the latter of which included analyses regarding the impact of rainfall patterns, magnitudes, and intensities on I&I, the effect of completed rehabilitation work on reducing I&I, and the potential for sewage exfiltration into Gulfport's storm drain system. Provided testimony at deposition. Evaluated reports, designs, and conducted additional analyses as required under the Stipulated Order achieved in settlement.

Litigation Support, Save the Sound v. Westchester County, et al.

Analyzed spill reports, WRF discharge monitoring reports, daily operational data, inspection reports, and non-compliance reports to determine the influence of I&I on SSOs and NPDES permit violations at several county owned WRFs. Determined which wet weather SSOs impacted surface waters and which impacted Municipal Separate Storm Sewers (MS4s). Prepared a technical report in support of a citizen's suit under the CWA, which resulted in a Stipulated Order (SO) requiring SSESs, development of Capacity, Management, Operation, and Maintenance (CMOM) plans, and sewer system rehabilitation within the County-owned collection system and several municipally owned and operated tributary sanitary sewer systems. Continues to provide settlement negotiation assistance, technical support, SO compliance oversight, and review of the SSES reports, CMOM Plans, and rehabilitation plans produced under the SO and resulting CDs with individual tributary municipalities. Frequently participates in settlement negotiations providing technical support and collaborates with municipal engineers on CMOM plan and rehabilitation plan development and implementation.

Litigation Support, San Francisco Baykeeper v. City of Sunnyvale, California and City of Mountain View, California

Provided technical engineering in support of a citizen's suit under the CWA to evaluate the potential that sanitary sewage was exfiltrating from the Sunnyvale and Mountain View (Cities) sanitary sewer systems, entering the Cities' storm sewer systems, and discharging to surface waters resulting in bacteria levels exceeding the California Environmental Protection Agency's water quality standards for inland surface waters, enclosed bays, and estuaries in California. Analyzed surface water sampling results for fecal indicator bacteria and human-specific molecular markers collected over multiple years, the infrastructure attributes of the Cities' sanitary sewer and storm sewer systems, the Cities' sanitary sewer pipe investigations and structural condition assessment results, the Cities' sanitary sewer management plans, and the Cities' programs to prevent exceedances of bacteria water quality standards required under the California MS4 permit. Determined the magnitude of bacteria water quality standard exceedances in sampled surface waters and estimated the quantity of sanitary sewer pipes in each city at a high risk of exfiltrating sewage into the Cities' storm sewer systems (Exfiltration) for subsequent surface water discharge based on the relative horizontal and vertical distances between adjacent sanitary and storm pipes, age, construction material, and sanitary sewer pipe structural condition. Prepared an Expert Report and a Rebuttal Report evaluating the likelihood of Exfiltration from the Cities' sanitary sewer systems. Recommended remedies to reduce and eliminate Exfiltration and provided a cost estimate for the recommended remedy. Prepared rebuttal responses to Defendant's Expert Reports. Provided testimony at deposition.

Sarasota County, Florida, Water Reclamation Facility Wastewater Treatment Upgrades and Sanitary Sewer Overflows

Suncoast Waterkeeper

Provided technical engineering settlement negotiation assistance evaluating options for wastewater treatment upgrades at one of Sarasota County's (County) three WRFs to meet advanced wastewater treatment (AWT) standards for nitrogen removal and for reclaimed water storage and disposal options to eliminate unpermitted overflows from the WRF's effluent storage pond. Developed technical portions of a Stipulated Order to prevent SSOs and reduce I&I into the sanitary sewer systems, including requirements for a SSES investigation and development of CMOM Plans for the County's three sanitary sewer collection systems. Participated in numerous settlement negotiation meetings with the County in-person and via conference call. Collaborated with County engineers to identify solutions to technical settlement obstacles for achieving AWT at the WRF, eliminating unpermitted discharges from the reclaimed water storage pond, and developing the SSES and CMOM program elements and implementation schedules to prevent SSOs. Continues to evaluate collection system and WRF reports, designs, and plans, conduct additional analyses, and collaborate with County engineers as required under the Stipulated Order achieved in settlement.

RELEVANT EXPERIENCE & REPRESENTATIVE PROJECTS

City of Largo, Florida, Water Reclamation Facility NPDES Permit Violations
Suncoast Waterkeeper/Our Children's Earth Foundation

Provided technical engineering settlement negotiation assistance evaluating options for Largo to upgrade its sanitary sewer system and WRF to end violations of the WRF's NPDES permit effluent limit exceedances for total nitrogen, total phosphorus, fecal coliform, and Dichlorobromomethane, a harmful disinfection byproduct, and reduce I&I into the sanitary sewer system. Developed technical portions of an SO aimed at achieving NPDES permit compliance and reducing pollutant discharge to Old Tampa Bay, the WRF's effluent receiving water, including treatment process improvements at the WRF and investigation and rehabilitation of the sanitary sewer system to reduce I&I. Participated in numerous settlement negotiation meetings and court mediation sessions with Largo and collaborated with Largo's engineers in identifying solutions to technical settlement obstacles for reducing I&I and eliminating NPDES permit violations. Continues to evaluate reports, designs, and plans, conduct additional analyses, and collaborate with Largo's engineers as required under the SO achieved during settlement.

Litigation Support, Vacation Village Homeowners Association v. Town of Fallsburg, New York
German Rubenstein LLP

Provided technical engineering support, including testimony at trial, in support of litigation related to the permitted discharge of treated wastewater effluent from the Town of Fallsburg Loch Sheldrake WRF into a privately owned lake that suffered from harmful algae blooms caused by elevated nutrient levels, namely phosphorus. Evaluated the adequacy of the design and operation of the WRF's treatment systems to remove phosphorus from wastewater and options for alternative effluent discharge locations. Reviewed and evaluated deposition testimony, SPDES permits, WRF design reports, effluent diversion studies, discharge monitoring reports, historical effluent flows and phosphorus loads data to the lake, and O&M manuals in preparation of an affidavit and trial testimony.

Advocacy Technical Support - Harrisburg, Pennsylvania Combined Sewer Overflows
Lower Susquehanna Riverkeeper/Environmental Integrity Project

Analyzed the adequacy of Harrisburg's combined sewer overflow (CSO) Long Term Control Plan (LTCP) and its recommended alternative for reducing CSO volumes, CSO events, and achieving compliance for its combined sewer system with the United States Environmental Protection Agency's (USEPA) CSO Control Policy. Evaluated CSO control alternatives and implementation timelines not recommended in the LTCP. Analyzed the cost effectiveness of the LTCP's recommended alternatives and the adequacy of the proposed Water Quality Monitoring Plan. The LTCP was originally developed under a 2015 Partial CD between the United States and the Pennsylvania Department of Environmental Protection (PADEP). Provided technical engineering settlement negotiation support on development of a modified Partial CD and revised LTCP in numerous settlement meetings between PADEP, USEPA, and the Department of Justice (DOJ); Harrisburg; and Lower Susquehanna Riverkeeper and Environmental Integrity Project.

RELEVANT EXPERIENCE & REPRESENTATIVE PROJECTS

Advocacy Technical Support – Food Production Facility Industrial Wastewater Treatment

Lower Susquehanna Riverkeeper/Environmental Integrity Project **Pennsylvania**

Provided technical engineering support to interveners in a litigation between the United States and PADEP and a food production facility (Facility) resulting from years of NPDES permit effluent limitation exceedances for ammonia, BOD, TSS, temperature, and fecal coliform and failed USEPA and PADEP inspections at the Facility's industrial wastewater treatment facility (IWTF). Evaluated the treatment system design and O&M practices of the IWTF and recommended remedies for treatment and O&M shortcomings contributing to the NPDES permit effluent limitation exceedances and failed USEPA and PADEP inspections. Analyzed the Engineering Evaluation performed by the Facility's engineering consultant, and its subsequent revisions, intended to identify the root causes of IWTF treatment failures and NPDES permit effluent limitation exceedances. Participated in numerous meetings between USEPA, DOJ, PADEP, and the Facility regarding the adequacy of the Engineering Evaluation's root cause analysis and recommended remedies to prevent future NPDES permit effluent limitation exceedances and correct IWTF deficiencies identified during USEPA and PADEP inspections. Collaborated with engineers from USEPA, DOJ, and PADEP in development of recommend revisions to the Engineering Evaluation and of a Compliance Plan to bring the IWTF into compliance with its NPDES permit under a proposed CD.

Sacramento County, California – Sanitary Sewer Overflows

California Coastkeeper Alliance

Provided technical engineering support during settlement negotiations evaluating options for Sacramento County to improve its ongoing O&M, inspection, and rehabilitation of approximately 4,700 mile sanitary sewer system. Developed technical portions of a CD aimed reducing blockage-related SSOs with special attention on reducing SSOs from the lateral pipe portion of the sanitary sewer system. Participated in numerous settlement negotiation meetings to identify solutions to technical settlement obstacles for reducing SSOs.

Litigation Support, San Francisco Baykeeper and West County Toxics Coalition v. City of Richmond

Provided technical engineering support in evaluating compliance with Richmond's Consent Decree. Analyzed hydraulic capacity, operation and maintenance, and rehabilitation improvements to Richmond's collection system toward preventing SSOs. Prepared a declaration in support of a Contempt Motion against Richmond for failing to meet the obligations of the Consent Decree and provided technical settlement negotiation assistance resulting in a new Settlement Agreement. Continues to evaluate reports, designs, and conduct additional analyses as required under the Settlement Agreement.

RELEVANT EXPERIENCE & REPRESENTATIVE PROJECTS

City of Bradenton, Florida, Water Reclamation Facility NPDES Permit Violations
Suncoast Waterkeeper/Our Children's Earth Foundation/Tampa Bay Waterkeeper

Provided technical engineering settlement negotiation assistance evaluating options for wastewater treatment upgrades at Bradenton's WRF, improvements in Bradenton's sanitary sewer system infrastructure and O&M practices, and reductions in I&I to eliminate WRF Bypasses and NPDES permit effluent limitation exceedances for total nitrogen and toxic disinfection byproducts. Developed technical sections of a CD aimed at achieving NPDES permit compliance, reducing I&I, improving sanitary sewer system O&M, and reducing pollutant discharges to the Manatee River, the WRF's effluent receiving water, including improvements to the WRF's secondary clarification, tertiary filtration, and disinfection treatment processes and investigation and rehabilitation of the sanitary sewer system to reduce I&I. Participated in numerous settlement negotiation meetings with Bradenton and collaborated with Bradenton's engineers in identifying solutions to technical settlement obstacles for reducing I&I and eliminating Bypasses and NPDES permit violations. Continues to evaluate reports, designs, plans, and O&M standard operating procedures, conduct additional analyses, and collaborate with Bradenton's engineers as required under the CD achieved during settlement.

Advocacy Technical Support – Petroleum Refining and Plastics Production Wastewater Treatment
Center for Biological Diversity **United States**

Evaluated the current Best Available Technology Economically Achievable (BAT) and effluent limitation guidelines (ELGs) based on existing Federal regulations for industrial wastewater generated by petroleum refineries (PR), with a specific focus on pollutants resulting from petroleum refining, hydrocarbon feedstock cracking processes, and plastic production facilities (PPF) for use in a public petition to EPA. Evaluated the effectiveness of current BAT and adequacy of ELGs based on EPA and independent studies to adequately remove identified pollutants of concern in wastewater discharges from PR and PPF and to treat wastewater generated from Light Tight Oil (LTO) refining. Drafted a technical report with recommended improvements to current BAT incorporating wastewater treatment technologies aimed specifically at removing pollutants of concern without existing ELGs and potential emerging pollutants resulting from increases in refining of LTO, which is produced by hydraulic fracturing.

Stormwater Management, Treatment, Permitting and Flooding Impacts:

Construction Stormwater Management System Design, Permitting, Inspections, Oversight, and Notice of Violation/Cease and Desist Order Remediation
Hotel Construction Project **Ulster County, New York**

Designed permanent stormwater treatment systems, a construction erosion and sediment control plan, obtained SPDES permit, and developed a Stormwater Pollution Prevention Plans (SWPPP) in compliance with New York State Department of Environmental Conservation (NYSDEC) and New York City Department of Environmental Protection (NYCDEP) standards under challenging circumstances. The hotel construction project was underway and near completion when it was issued a Notice of Violation (NOV) and Cease and Desist Order (CDO) from NYSDEC related to stormwater management and permitting violations. The project was located within the NYCDEP reservoir system watershed and was subject to NYCDEP oversight, review, and approval of the SWPPP and the design of stormwater treatment systems and erosion sediment controls contained in the SWPPP. The stormwater management and treatment system and SWPPP were developed within the difficult constraints created by the fact that

RELEVANT EXPERIENCE & REPRESENTATIVE PROJECTS

project planning was completed several years earlier and construction, including of numerous buildings and parking areas, was complete. Performed oversight of infiltration testing used for stormwater treatment system feasibility identification and design. Performed oversight of the installation of the stormwater treatment systems, including infiltration trenches, drywells, rain gardens, stormwater planter systems, and a riparian buffer. The stormwater treatment system design met NYSDEC water quality volume requirements, achieved groundwater recharge through infiltration of greater than 100% of the required water quality volume, and resulted in NYSDEC lifting of the NOV/CDO. Continues providing stormwater management oversight through completion of SPDES permit-required erosion and sediment control inspections and certification of stormwater treatment system installation.

Industrial Stormwater Permitting and Management, Staten Island Yacht Sales, Inc., Great Kills Yacht Club, Princess Bay Boatmen's Association, SOS Extreme Comfort Fuels, Rockland Transit Mix

Multiple clients **New York State**

Remedied NOVs, obtained required SPDES permits, and developed Industrial SWPPPs for marinas in Staten Island, including design of boat power-washing water collection and recycle systems. Remedied an NOV, obtained required SPDES permit, and developed an Industrial SWPPP for Rockland Transit Mix of Rockland County, a ready-mix concrete batch plant. Obtained an individual surface water SPDES permit for industrial discharge for SOS Extreme Comfort Fuels in Orange County, NY. Continues to provide technical assistance meeting SPDES permit monitoring and reporting requirements for marinas and Rockland Transit Mix, including SWPPP modifications, annual compliance inspections and reporting, and discharge monitoring.

Construction Stormwater Management System Design – Waterfront Commons, Bay Street Landing, Veterans Road West Shoprite Plaza, and Tyrellan Avenue

Multiple clients **Staten Island, New York**

Designed permanent stormwater treatment systems, obtained SPDES permits, and developed SWPPPs for the Waterfront Commons, Tyrellan Avenue, and Shoprite Plaza developments and the Bay Street Landing redevelopment. Incorporated a green roof, porous pavement, infiltration practices, underground detention, and a sand filtration system to meet water quality standards while accommodating small footprints. Designed infiltration stormwater treatment systems to increase groundwater recharge, and reduce runoff volumes.

RELEVANT EXPERIENCE & REPRESENTATIVE PROJECTS

Litigation Support, Raritan Baykeeper v. Faztec Industries, Inc., et al.

Super Law Group **Staten Island, New York**

Provided technical litigation and settlement negotiation support for CWA violations resulting from industrial stormwater discharges containing elevated levels of suspended sediment and metals from a construction and demolition processing facility located adjacent to state regulated wetlands and the Arthur Kill. Analyzed the facility's SWPPP, implementation of erosion and sediment controls, adequacy of stormwater collection and diversion, and treatment systems, including a sedimentation tank, truck washing system, and street sweeping protocols and performed dry-weather and wet-weather site inspections. Prepared an Expert Report evaluating the causes of polluted stormwater discharges from the facility and recommending remedies to reduce or eliminate polluted stormwater discharges and achieve compliance with the NYSDEC Multi-Sector General Permit. The recommended remedy include design of a subsurface sand filter treatment system, improved stormwater diversions, additional erosion and sediment control best management practices (BMPs), and new truck washing and street sweeping systems equipment and protocols. Estimated the costs for implementation of the recommended remedy. Developed a technical rebuttal memorandum to the Defendant's Expert Report used during successful settlement negotiations to reach agreement on a CD.

Litigation Support – Our Children's Earth Foundation v. Cargill, Inc.

Our Children's Earth Foundation (OCE) **Cayuga Lake, Lansing, NY**

Provided technical engineering settlement negotiation assistance for CWA and Resource Conservation and Recovery Act (RCRA) violations resulting from stormwater discharges and airborne deposition resulting from salt mining, processing, storage, and transport activities at Cargill Inc.'s (Cargill) facility along the banks of Cayuga Lake. Performed a site inspection to analyze facility operations, stormwater BMPs, and dust collection systems. Evaluated the adequacy of Cargill's Stormwater BMP Plan and recommended enhancements to facility BMPs and operational practices to reduce salt pollution in stormwater runoff and salt dust from becoming airborne. Participated in two in-person settlement negotiation meetings that resulted in a CD. Continues to evaluate reports, designs, and conduct additional analyses and site inspections as required under the CD.

Litigation Support, Center for Community Action and Environmental Justice v. Friends of Riverside Airport, LLC

Lozeau Drury LLP **Riverside, California**

Provided technical litigation and settlement negotiation support for Clean Water Act (CWA) violations resulting from stormwater discharges containing elevated levels of polychlorinated biphenyls (PCBs) and sediment from construction activities related to residential development and site remediation activities at a construction site containing PCB contaminated soils. Analyzed the site's implementation of erosion and sediment controls, including the design of sediment basins and management of off-site stormwater flows. Prepared an Expert Report evaluating the causes of polluted stormwater discharges and recommending remedies to reduce or eliminate polluted stormwater discharges, including design of conveyance systems to divert off-site stormwater run-on, a properly sized sediment basin, and a treatment system to remove PCB-contaminated sediments, and achieve compliance with the California Construction Stormwater General Permit. Estimated the costs for implementation of the recommended remedies.

RELEVANT EXPERIENCE & REPRESENTATIVE PROJECTS

Litigation Support, Sandra Wells v. Alpha Natural Resources, et al.
Calwell, Luce, diTrapano, PLLC **Mingo County, West Virginia**

Reviewed site plans, performed a site inspection, and developed a hydrologic model to analyze the impacts of stormwater runoff and downstream flooding from access roads to oil and gas extraction sites located on steep slopes. Analyzed Erosion & Sediment Control (ES&C) plans, practices, and maintenance, as well as pertinent West Virginia erosion and sediment control regulations. Developed expert opinions on the causes of downstream flooding and provided testimony at deposition.

Litigation Support, Plaintiffs, et al., v. Rabel Development, LLC, et al.
Calwell, Luce, diTrapano, PLLC **Charleston, West Virginia**

Prepared a Preliminary Report for Settlement on the impacts of runoff from construction of a residential development and its contribution to flooding of the Plaintiffs' properties. Analyzed site plans, E&SC plans, inspection reports, and performed site inspections to evaluate the adequacy of stormwater controls, retention structures, and conveyance systems. Performed a cost estimate for improvements to downstream conveyance systems, included streambed dredging, removal of existing undersized culverts, and the installation of new culverts with adequate capacity.

Litigation Support, Plaintiffs, et al., v. Arch Mineral Corporation, et al.
The Masters Law Firm **Mingo County, West Virginia**

Developed a hydrologic model and prepared a Preliminary Report for Settlement on the impacts of runoff from historical mountaintop mining and timbering operations resulting in catastrophic flooding in Pigeon Creek that impacted scores of private properties and dwellings. Analyzed site plans, mining operation inspection reports, and performed site inspections of numerous former mining and timbering locations and existing valley fills in Mingo County, West Virginia to evaluate conditions within the watershed tributary to Pigeon Creek.

Litigation Support, Tali Plaza of Nyack, LLC v. Village of Nyack and Town of Orangetown
Tali Plaza of Nyack **Nyack, New York**

Analyzed the Village's stormwater collection system, runoff management practices, and the design flaws in a channel and underground culvert system that diverts the Nyack Creek and caused flooding in support of litigation. Determined the location of hydraulic bottlenecks in the culvert system and resulting flooding rates. Assisted in preparation of an affidavit and trial testimony.

Water Quality Protection and Pollutant Discharge Impact Analysis

Advocacy Technical Support – New York State Environmental Quality Review (SEQR) and Planning Board Reviews
Multiple Clients **New York State**

Provided technical support to environmental advocacy groups and private citizens as part of the SEQR process in Putnam, Rockland, Greene, Dutchess, Sullivan, Orange, Ulster, and Suffolk counties regarding potential for flooding and adverse environmental impacts to downstream properties from improper stormwater collection, management, and treatment at proposed developments, land clearing activities, and

RELEVANT EXPERIENCE & REPRESENTATIVE PROJECTS

sanitary sewage collection and treatment, including for proposed projects consisting of a water bottling facility, condominium/apartment complexes, resort hotel, skiing resort, construction material processing facility, warehouse complexes, and residential subdivisions, Prepared technical reports and Planning Board presentations highlighting the potential adverse environmental impacts, including pollutant releases and adverse water quality impacts, resulting from development and the technical and conceptual shortcomings of proposed E&SC plans, post-construction stormwater treatment and controls, flood-impact prevention approach, and wastewater treatment.

Advocacy Technical Support – Mount Rushmore Firework Display Environmental Assessment Water Quality Impact Technical Review

National Parks Conservation Association **Mount Rushmore National Memorial, South Dakota**

Evaluated the National Parks Service Environmental Assessment (EA) on the proposed resumption of the Independence Day Fireworks Event at Mount Rushmore National Memorial for the potential for adverse environmental impacts from firework related pollutant release, especially the persistent pollutant perchlorate, with a focus on potential surface water, groundwater, and drinking water impacts and their associated risks to human health and aquatic species. Prepared a technical report to assist NPCA in submission of public comments on the EA.

Advocacy Technical Support – Potomac River/Tributaries Bacteria Total Maximum Daily Load

Potomac Riverkeeper Network **Washington, D.C.**

Analyzed the adequacy of the current bacteria (i.e., *E. coli*) total maximum daily load (TMDL) development and implementation for the Potomac River and its tributaries, including the Anacostia River. Evaluated the modeling contained within the Washington, D.C., combined sewer system's LTCP, its subsequent use in TMDL development by USEPA, and the waste load allocations for bacteria identified under the TMDL from the various sources of bacteria-containing water discharges (e.g., CSOs, treated wastewater, stormwater) to the Potomac River and its tributaries. Provided technical support for Potomac Riverkeeper Network in negotiations and meetings with USEPA and the Washington D.C. Department of Energy and Environment regarding development of a new bacteria TMDL for the Potomac River and its tributaries.

Litigation Support, Robert Carter, et al., v. Monsanto Company and Apogee Coal Company

Calwell, Luce, diTrapano, PLLC **Nitro, West Virginia**

Analyzed and reviewed historical documentation to quantify airborne dioxin deposition from an herbicide manufacturing process. Calculated mass balances of dioxin generated by the overall production process and individual unit processes and determined the quantities of dioxin that discharged to the environment via air emissions, solid waste streams, and sewer discharges over a 25-year production time frame. Calculated the mass of dioxin remaining in soils adjacent to the plant based on air deposition modeling and the half-life of dioxin. Assisted in preparation of an Expert Report.

RELEVANT EXPERIENCE & REPRESENTATIVE PROJECTS

Site Remediation:

Engineer of Record, Peter Jay Sharp Center for Opportunity
The DOE Fund, Inc. **Brooklyn, New York**
Professional Engineer of Record for a brownfield site regulated under NYSDEC's Voluntary Cleanup Program. Performs operation, maintenance, and monitoring of a soil vapor extraction (SVE) system to remediate chlorinated solvent contaminated soils and groundwater beneath a former knit goods mill. Monitoring activities include monthly groundwater and SVE system monitoring, semi-annual groundwater sampling, and annual treated groundwater discharge sampling. Analyzes monitoring results to evaluate remediation system performance and meet NYSDEC reporting requirements. Coordinates modifications to the remediation system, including installation of permanent vacuum monitoring locations, analysis of the SVE system's sub-surface vacuum, and conversion of the SVE to a sub-slab depressurization system. Responsible for monthly Progress Report, annual Periodic Review Report, and work plan submittals to the NYSDEC.

Advocacy Technical Support – NIPSCO Bailly Power Generation Remediation
National Parks Conservation Association **Indiana Dunes National Lakeshore, Indiana**
Evaluated the cleanup approach proposed by the Northern Indiana Public Service Company (NIPSCO) to remediate historical groundwater, soil, surface water, and sediment contamination (Proposed Remedy) that resulted from coal ash disposal from power generation at the Bailly Generating Station located in Chesterton, Indiana adjacent to the Indiana Dunes National Lakeshore (Indiana Dunes) and Lake Michigan. The evaluation considered the adequacy of NIPSCO's Proposed Remedy to be protective of human health and the sensitive ecological resources found at Indiana Dunes, inclusive of the technical aspects of contamination cleanup and long-term stewardship plan. Prepared a technical report to assist National Parks Conservation Association in submission of public comments on the Proposed Remedy.

Litigation Support, Valley Truck Services, Inc., et al., v. Textron, Inc., et al.
Transportation Injury Law Group, PLLC **Asheville, North Carolina**
Designed two different groundwater treatment systems to remediate a former industrial site contaminated with volatile organic compounds (VOCs) and potentially with 1,4-Dioxane. The first system consisted of an air stripper with air effluent treatment to remove VOCs. The second system consisted of advanced oxidation using hydrogen peroxide and ultra-violet light to treat VOCs and 1,4-Dioxane. Estimated the construction costs and performed a present worth analysis for each system, including 30 years of operation and maintenance, equipment replacement, and demolition costs.

Litigation Support, Penn Environment v. PPG Industries, Inc.
Terris, Pravlik & Millian, LLP **Ford City, Pennsylvania**
Assisted in design of the remedy for the discharge of heavy metals, silica, and high pH contaminated groundwater to the Allegheny River from a former industrial waste lagoon. Remedy included a collection system, treatment plant, horizontal groundwater well, and capping system. Performed cost estimate of the remedy capital and operation and maintenance costs.

RELEVANT EXPERIENCE & REPRESENTATIVE PROJECTS

Monitoring and Construction Oversight, 236 Richmond Valley Road
Charleston Equites/Tottenville Equities **Staten Island, New York**

Conducted monitoring and construction oversight for the redevelopment of a NYSDEC Brownfields Program site. Ensured all work was conducted in accordance with the site's Remedial Action Work Plan, Site Management Plan, and Health and Safety Plan. Conducted air quality monitoring and oversaw the proper handling and disposal of excavated contaminated materials. Responsible for daily reporting to the NYSDEC.

Pro Bono Assistance:

Sanitary Sewer Overflows (SSOs) - California State Water Board SSO Technical Working Group
California Coastkeeper Alliance (CCKA) **California**

Served as CCKA's technical engineering advisor in formulation of regulatory requirements contained within a new proposed state permit for operation and performance of sanitary sewer systems as part of CCKA's participation in the California State Water Board's SSO Technical Working Group (SSO Technical Working Group). Participated in SSO Technical Working Group meetings and CCKA team discussions. Continues to provide technical expertise to CCKA as part of the SSO Technical Working Group as needed.

Water Quality Protection – Land Development Impacts
Land Preservation Collective **Orange County, New York**

Advised a local, community-based advocacy group, Land Preservation Collective (LPC), related to the potential adverse impacts to a local stream and downstream receiving pond from a proposed nearby housing development. Assisted LPC in identifying potential adverse water quality impacts during and after construction, understanding local, State, and Army Corps of Engineers guidance and regulations, and preparing LPC's presentation to the local planning board.

Community Environmental and Health Protection – Auto Dealership Fire Community Impacts
Private Citizens **Ulster County, New York**

Advised a group of local citizens whose property was located adjacent to the site of an automobile dealership (Dealership) that burned down, destroying the entire structure, car maintenance areas, stored materials, and numerous automobiles. The Dealership was ruled condemned and contaminated by New York State Department of Environmental Conservation (NYSDEC) due to elevated levels of numerous dangerous chemicals, including asbestos, lead, cadmium, and potentially PFAS from firefighting activities. Condemned debris remained at the Dealership exposed to wind, precipitation and stormwater for months. Assisted with preparation and collection of soil and stormwater runoff samples and comparison of analytical results to NYSDEC regulatory standards. Continues to assist the local citizens as needed.

Kevin Draganchuk, P.E., BCEE

President, CEA Engineers P.C.

RELEVANT EXPERIENCE & REPRESENTATIVE PROJECTS

Publications:

Water Environment Federation, Reviewer, Existing Sewer Evaluation and Rehabilitation, Manual of Practice No. FD-6, 4th Edition, 2024.

Water Environment Federation, Author, Asset Management Fact Sheet, 2022.

Water Environment Federation, Contributing Preparer, Technologies for CMOM Activities in Wastewater Collection Systems, WEF Special Publication, 2022.

Draganchuk, Kevin, Sanitary Sewage Exfiltration to MS4s and Receiving Waters – Source Identification and Elimination, American Public Works Association, New York Chapter, 2022 Annual Conference and Exhibition, March 25, 2022.

Water Environment Federation, Reviewer, Wastewater Collection Systems Management, Manual of Practice No. 7, 7th Edition, 2021.

Draganchuk, Kevin, Preventing Sanitary Sewer Overflows – Lessons Learned for Watershed Protection, American Public Works Association, New York Chapter, 2021 Virtual Conference and Exhibition, March 26, 2021.

Draganchuk, Kevin, Road Salt Pollution Prevention at its Source – A Case Study in Best Practices, New York Water Environment Association, Virtual NYC Watershed Science and Technical Conference, September 15, 2020.

Draganchuk, Kevin, I&I Removal – Lessons Learned for Avoiding Pitfalls and Increasing Effectiveness, New York Water Environment Association, Virtual Spring Technical Conference and Exhibition, June 9, 2020.

Draganchuk, Kevin, Preventing SSOs – Lessons Learned for Watershed Protection, New York Water Environment Association, Spring Technical Conference and Exhibition, June 13, 2018.

Testimony History:

Chesapeake Bay Foundation, Inc. and James River Association v. County of Henrico, Deposition September 9, 2022.

Scott Pere, et al. individually, and on behalf of those similarly situated, Plaintiffs, v. Town of Fallsburg, et al., Defendants and Vacation Village Homeowners Association, Inc., Plaintiff, v. Town of Fallsburg, et al., Defendants, Trial, August 3, 2022.

San Francisco Baykeeper vs City of Sunnyvale and *San Francisco Baykeeper vs City of Mountain View,* Deposition, September 1, 2021.

Kevin Draganchuk, P.E., BCEE

President, CEA Engineers P.C.

RELEVANT EXPERIENCE & REPRESENTATIVE PROJECTS

Kenneth Horrocks, et al. v. Kanawha Energy Company, LLC, et al., Deposition, March 31, 2021.

Suncoast Waterkeeper, Our Children's Earth Foundation, and Ecological Rights Foundation v. City of Gulfport, Deposition, May 8, 2019.

Sandra Wells v. Alpha Resources, et al., Deposition, March 29, 2018.

Exhibit 7

ERG

MEMORANDUM

TO: Steam Electric Rulemaking Record

FROM: Elizabeth Gentile, ERG

DATE: October 17, 2019

SUBJECT: **FGD and Bottom Ash Implementation Timing – DCN SE08480**

On November 3, 2015, EPA issued a final rule revising the effluent limitations guidelines and standards (ELGs) for the steam electric power generating point source category. The revisions addressed and contained limitations and standards on various wastestreams at steam electric power plants including fly ash transport water, bottom ash transport water, flue gas mercury control wastewater, flue-gas desulfurization (FGD) wastewater, gasification wastewater, and combustion residual leachate.

Since promulgation of the 2015 rule, EPA received petitions from industry to reconsider the bottom ash transport water and FGD wastewater ELGs. During this reconsideration, ERG provided technical support to EPA to collect information from vendors on the estimated amount of time required to implement wastewater treatment technologies and handling systems. In order to review implementation timing information from different vendors, EPA requested the following data for full-scale and pilot-scale installations (if applicable):

- Time from receipt of initial request for proposal to when an award is granted.
- Time from when the award is granted to when the system is delivered.
- Time from when the system is delivered to when the system is installed.
- Time from when the system is installed to when it is fully operational.

EPA recognizes that there is also time required in order to establish the initial design basis. EPA did not ask vendors for information regarding the timeframe to evaluate current water balance or wastewater chemistry. Based on information from the industry, EPA determined that three months was the approximate about of time plants need to consider the initial design basis.

The following sections of this memorandum detail the information collected for the treatment technologies reviewed as part of the reconsideration.

1.0 FGD WASTEWATER

ERG reviewed implementation timing information from vendors for the low residence time reduction (LRTR) and membrane filtration installations. The information presented below is based on full- and pilot-scale installations for the steam electric and mining industries.

1.1 Implementation Timing Estimate for LRTR

Timing estimates for installing LRTR systems were collected from two vendors. The information from the vendors included six full-scale installations (for both FGD wastewater and mining wastewater) and three pilot-scale installations (for FGD wastewater), see Table 1 for a summary of the data received.

Table 1. Summary of LRTR Installation Timelines from Vendors

System ID	Type	Time (months)			
		Initial RFQ to Award	Award to Delivery	Delivery to Installed	Installed to Operational
1	Pilot-scale	6	2	0.5	N/A
2	Full-scale	9	15	3	1
3	Pilot-scale	6	0.5	0.5	N/A
4	Full-scale	3	12	6	4
5	Full-scale	2	10	6	6
6	Full-scale	10	13	0.5	1
7	Full-scale	4	14	5	5
8*	Full-scale	5	13	7	6
9	Pilot-scale	7	1	0.5	N/A
Range		2 - 10	1 - 15	1 - 7	1 - 6
Average		6	9	3	4

* Timing based on estimates.
N/A – Not applicable. Pilot systems are fully operational after installation. Values not included in average calculations.

Figure 1 presents a flow diagram showing the average timing estimates detailed in Table 1 above.

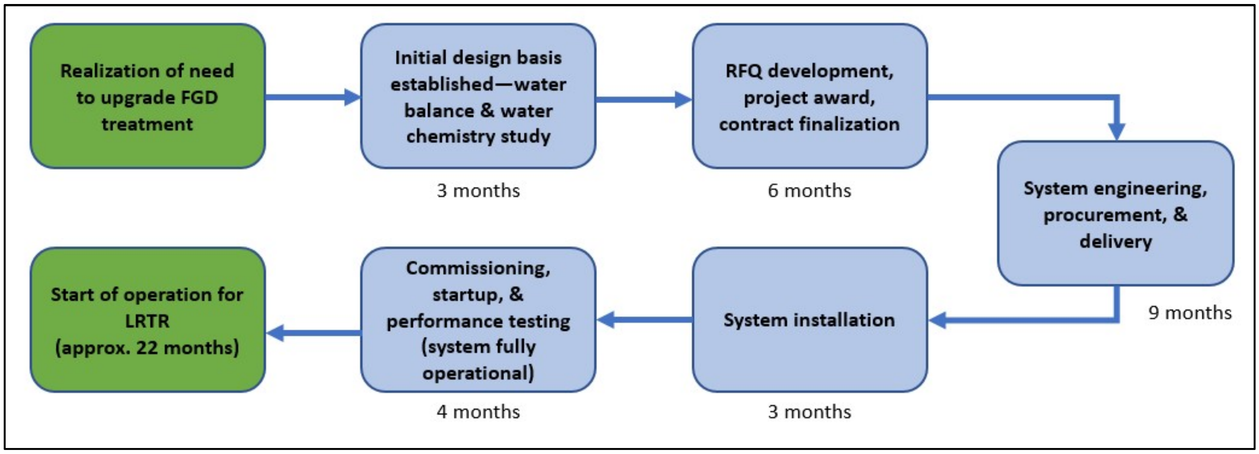

Figure 1. Typical Timeline for Installing LRTR

1.2 Implementation Timing Estimate for Membrane Filtration + Brine Encapsulation

Timing estimates for installing membrane filtration were collected from one vendor. These estimates indicate a total implementation timeframe of approximately 28 months. Figure 2 presents a flow diagram showing the time estimates for full implementation.

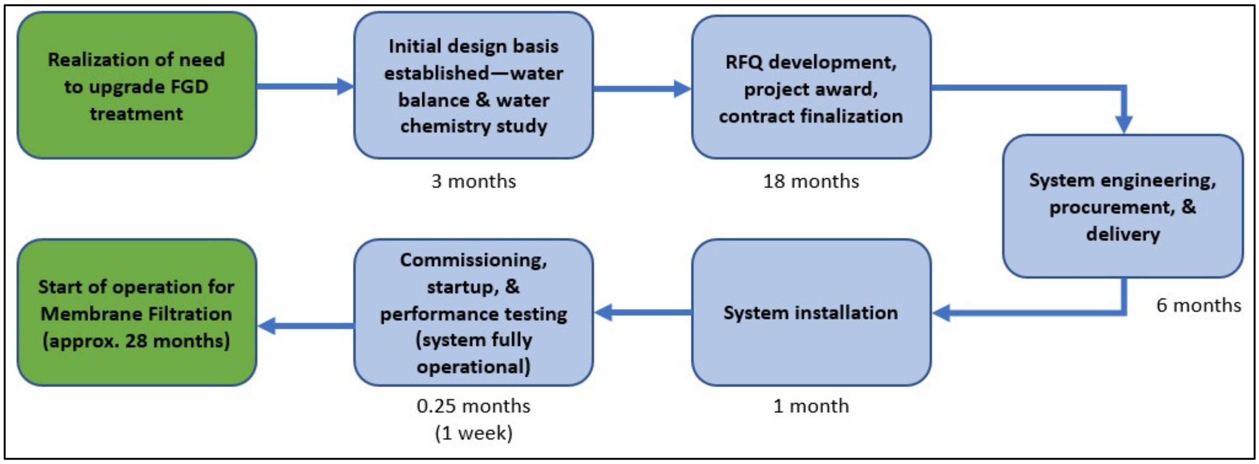

Figure 2. Typical Timeline for Installing Membrane Filtration

2.0 Bottom Ash Transport Water

ERG reviewed implementation timing information from two vendors on approximately 35 mechanical drag system (MDS) and remote mechanical drag system (rMDS) installations. Table 2 presents a summary of the average timing estimated for these bottom ash handling installations.

Table 2. Summary of Bottom Ash Handling Installation Timelines from Vendors

Type of Bottom Ash Handling System	Time (months)			
	Initial RFQ to Award	Award to Delivery	Delivery to Installed	Installed to Operational
MDS	4	19	4	2
rMDS	3	19	8	2

Figure 3 presents a flow diagram showing the average timing estimates detailed in Table 2 above.

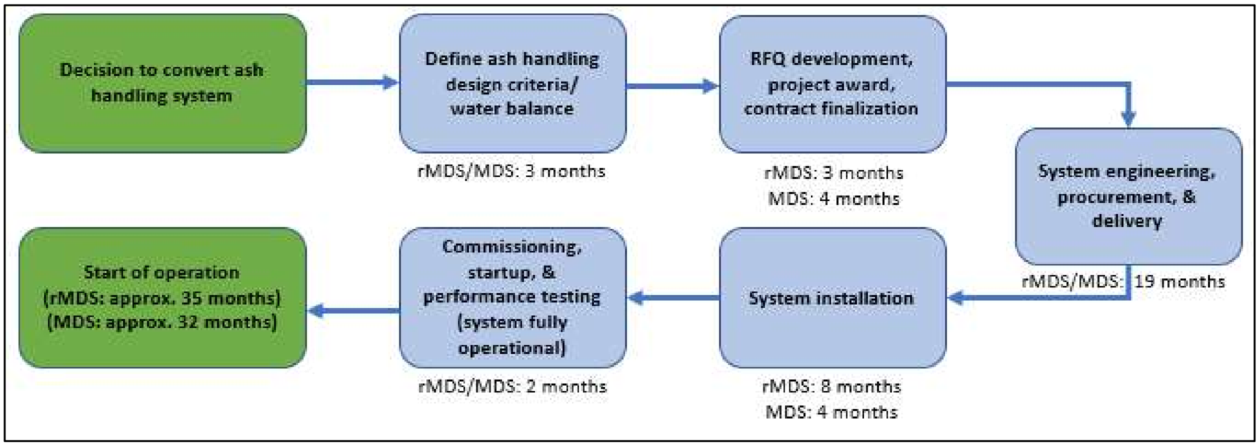

Figure 3. Typical Timeline for rMDS/MDS Installations

3.0 References

1. Johnson, Greg. 2019. New Logic Implementation Timing Information. (June 22). DCN SE08083.

2. McDonough, Kevin. 2019. UCC Implementation Timing Information. (October 7). DCNs SE08085 and SE08085A1.

3. Moskal, Tom. 2019. Bottom Ash Implementation Timeline. (August 28). DCNs SE08084 and SE08084A1.

4. Peterson, James. 2019. Frontier Water Systems Implementation Timing Information. (June 26). DCNs SE08081 and SE08081A1.

5. Tonga, Paul. 2019. Envirogen Implementation Timing Information. (June 28). DCNs SE08082 and SE08082A1.

Elizabeth Gentile

From: Greg Johnson <gjohnson@vsep.com>
Sent: Saturday, June 22, 2019 4:10 PM
To: Flanders, Phillip
Cc: Jordan, Ronald; Elizabeth Gentile
Subject: Re: Implementation Timelines for Membranes

Ron,

Regarding our system that was installed at the research center in Atlanta, I can confirm that it is begin moved to the new location and that it will be a permanent installation to treat about 50 gm of FGD effluent. This is the total flow that they have and this is not intended to be a pilot, it is a final treatment plant that will be permanent

Phillip,

We have done one full-scale installation in Atlanta and many pilots. The time lines for pilots vary a lot, but the time line for the full-scale that we did is pretty typical, so here are the numbers for that:

- Time (in months) from when you received the initial request for proposal to when an award was granted.
- Roughly 18 months. This includes bench testing, pilot testing, and preliminary engineering prior to getting the full-scale system order
- Time (in months) from when the award was granted to when the system was delivered.
- 6 Months
- Time (in months) from when the system was delivered to when the system was installed.
- 1 Month
- Time (in months) from when the system was installed to when it was fully operational.
- One week - training and commissioning

Greg Johnson

New Logic Research
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Minden, NV 89423
775-783-7600
510-655-7305 ext. 207
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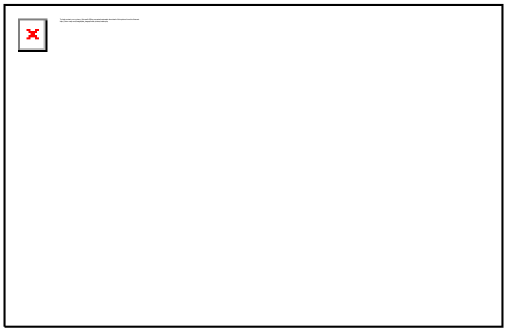
www.vsep.com



VSEP - New Logic Research, Inc.

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Welcome to New Logic Research, Inc. VSEP delivers results that conventional separations technology systems can't. Using Vibratory Shear Enhanced Processing (VSEP ...

On Jun 20, 2019, at 11:11 AM, Flanders, Phillip <Flanders.Phillip@epa.gov> wrote:

Good afternoon, Greg:

As you know, the U.S. Environmental Protection Agency (EPA) published revisions to the effluent limitations guidelines and standards ("ELGs") for the steam electric power generating point source category in November 2015. Currently, EPA is working to finalize documentation supporting a forthcoming proposed reconsideration of the 2015 ELGs.

We are trying to collect additional information on the timing required to implement membrane technologies to treat flue gas desulfurization wastewater. Specifically, could you provide implementation timelines for actual installations that you have completed? In order to protect confidential business information, we are only requesting the following information:

- Time (in months) from when you received the initial request for proposal to when an award was granted.
- Time (in months) from when the award was granted to when the system was delivered.
- Time (in months) from when the system was delivered to when the system was installed.
- Time (in months) from when the system was installed to when it was fully operational.

Timeframes should be provided without naming the specific project (e.g., Project A, Project B). EPA does not need to know the specific plant, location, or year of installation. While timelines for full-scale installations are more useful, if you are providing information for pilot-scale and full-scale installation please indicate which scale each timeline represents.

EPA requests that you provide any available information you have by Friday, June 28. Do not hesitate to contact me if you have any questions about this request or If you'd like to have a meeting or conference call (flanders.phillip@epa.gov or 202-566-8323). We appreciate your help with EPA's efforts and thank you in advance for your participation.

Thank you,

Phillip Flanders, Ph.D., P.E.

Environmental Engineer
Engineering and Analysis Division
Office of Science and Technology
Office of Water

<image001.png>

Mail Code 4303T
(202) 566-8323
www.epa.gov/eg

Burns & McDonnell

Centennial, Colorado

[redacted]

Proposal Description:	Budgetary Proposal - Wastewater Treatment & Water Reuse Systems
Proposal Number:	KW 17-0045
Submittal Date:	11/16/2017

Submitted By:

David Martin
KleeNwater, LLC
dmartin@prochemwater.com

Mark Pastore
KleeNwater, LLC
mpastore@eescorp.com

Portal # 20533

Section 1 – Summary

The following proposal outlines the process and projected costs (capital and operating) for a wastewater treatment and water reuse system that utilizes microfiltration (I-Micro™), industrial high-pressure reverse osmosis (I-PRO™), and brackish water reverse osmosis (B-PRO™) technologies. The proposed system is designed to treat up to 225 gallons per minute (gpm) of flue gas desulfurization (PFD) wastewater and achieve a minimum recovery rate of 90% (*recovery* is defined as the percentage of permeate water reclaimed from the treatment process).

The proposed system consists of the following subsystems described in this proposal:

- **Treatment system:** The tanks, pumps, membrane systems, instrumentation, piping, and other components used to treat the wastewater.
- **Control system:** The hardware and software used to operate and monitor the treatment system.

The combination of the treatment system and the control system is referred to as the *KLeeNwater system* in this proposal.

The proposed KLeeNwater system is designed based on the following water quality data:

Parameter	Average	Low	High
Total hardness, ppm	2,540	2,400	2,730
Calcium as CaCO3, ppm	1,500	1,400	1,600
Magnesium as CaC03, ppm	1,040	1,000	1,130
Alkalinity	0	0	0
Conductivity, umhos	3,100	2,900	3,300
TSS, ppm	120	40	750
TDS, ppm	3,500	3,000	4,300
pH	7.9	7.8	8.0
Temperature, °F	80	60	100

The pricing in this proposal is intended for budgetary purposes; an actual cost proposal can be prepared upon request.

Section 2 – System Description

Treatment System

Physical/Chemical Treatment

A physical/chemical treatment process will be used to remove sulfate ions, heavy metals, and suspended solids from the wastewater. Treated wastewater will be directed to the I-Micro™ system.

I-Micro™ System

Water will be pumped through an I-Micro™ system to remove residual suspended solids. Permeate will be directed to the I-PRO™ system, while concentrate will be recirculated through the I-Micro™ system until a predetermined solids concentration (typically 2%) is achieved. At this point, concentrate will be directed to a Sludge Holding Tank.

A clean in place (CIP) system will facilitate the removal of scale and contaminants that may form on the I-Micro™ membrane surfaces. Regular CIP will ensure that the membranes operate at peak capacity over their lifespan and will reduce overall operational costs by reducing membrane replacement costs. Wastewater from the CIP process will be redirected to the physical/chemical treatment process for retreatment.

I-PRO™ System

I-Micro™ permeate will be filtered through cartridge filters and injected with anti-scalant and microbiocide to prevent silica and sulfate fouling and microbiological growth on the I-PRO™ membrane surfaces, respectively. Concentrate from the I-PRO™ system will be recirculated through the I-PRO™ system until a until a predetermined TDS set point (typically 55,000 – 75,000 mg/l) is achieved. High TDS water will be able to be directed to the Concentrate Holding Tank. Permeate will be directed to the B-PRO™ Feed Tank.

A clean in place (CIP) system will facilitate the removal of scale and contaminants that may form on the I-PRO™ membrane surfaces. Regular CIP will ensure that the membranes operate at peak capacity over their lifespan and will reduce overall operational costs by reducing membrane replacement costs. Wastewater from the CIP process will be redirected to the physical/chemical treatment process for retreatment.

B-PRO™ System

An B-PRO™ system is proposed to polish the I-PRO™ system permeate prior to discharge or reuse. Permeate from the B-PRO™ system will be stored the Treated Water Storage Tank and directed to points of reuse, while concentrate will be recirculated through the B-PRO™ system until a high TDS is achieved (approximately 2,000 mg/L). High TDS water will be directed to the I-PRO™ system for retreatment.

A clean in place (CIP) system will facilitate the removal of scale and contaminants that may form on the B-PRO™ membrane surfaces. Regular CIP will ensure that the membranes operate at peak capacity over their lifespan and will reduce overall operational costs by reducing membrane replacement costs. Wastewater from the CIP process will be redirected to the physical/chemical treatment process for retreatment.

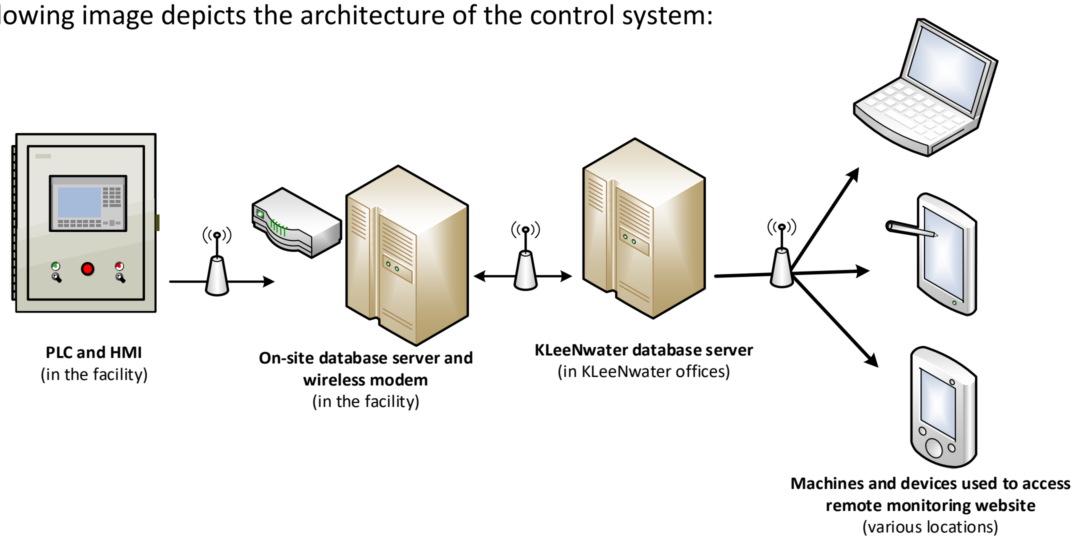
Concentrate Management Options

Concentrates from the proposed KLeeNwater system can be treated using solidification, crystallization, forward osmosis, or may be used to wet fly ash or for dust control. A concentrate management system is not included in this proposal, but KLeeNwater will work with Burns & McDonnell to determine the best concentrate management system for the facility.

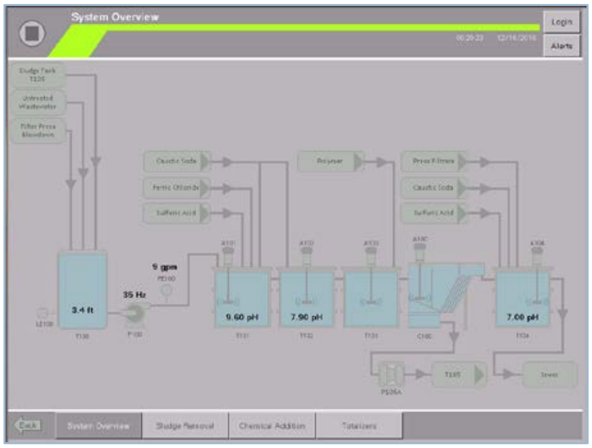
Control System

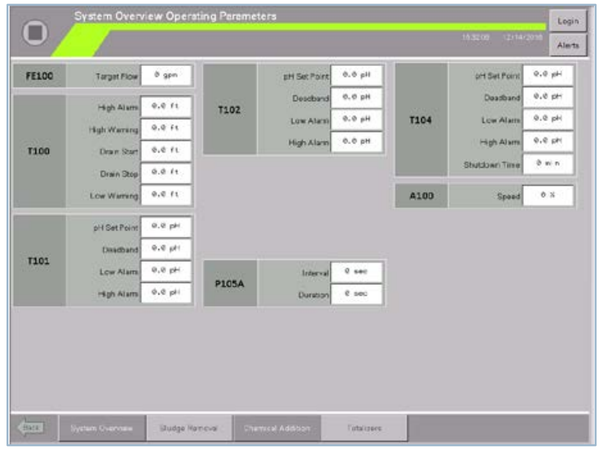
The control system consists of the hardware and software that allows the treatment system to be operated and monitored by its operators, Burns & McDonnell, and KLeeNwater. The KLeeNwater control system can be designed to integrate with existing networks or can be operate as a standalone system. The pricing in this proposal reflects operation as a standalone system; integration with existing networks will be priced separately upon request.

The following image depicts the architecture of the control system:

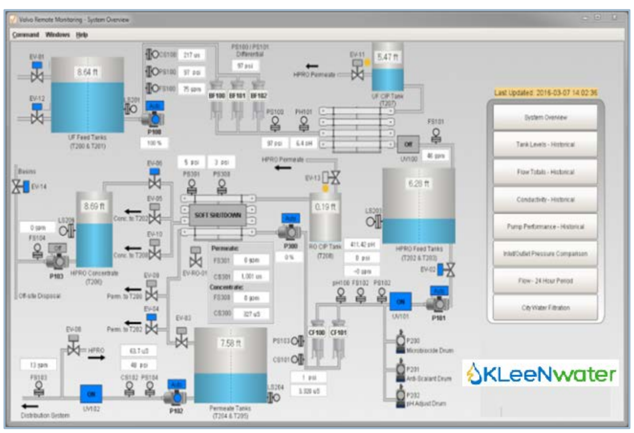


The human machine interface (HMI) used in the control system is designed to limit the amount of operator interaction required for basic operation of the treatment system, while still allowing for manual control of components as necessary (e.g., for maintenance activities). The HMI can accommodate multiple levels of security to achieve user-specific privileges related to modifying operating parameters and component settings. The following images show examples of HMI screens for similar treatment systems:





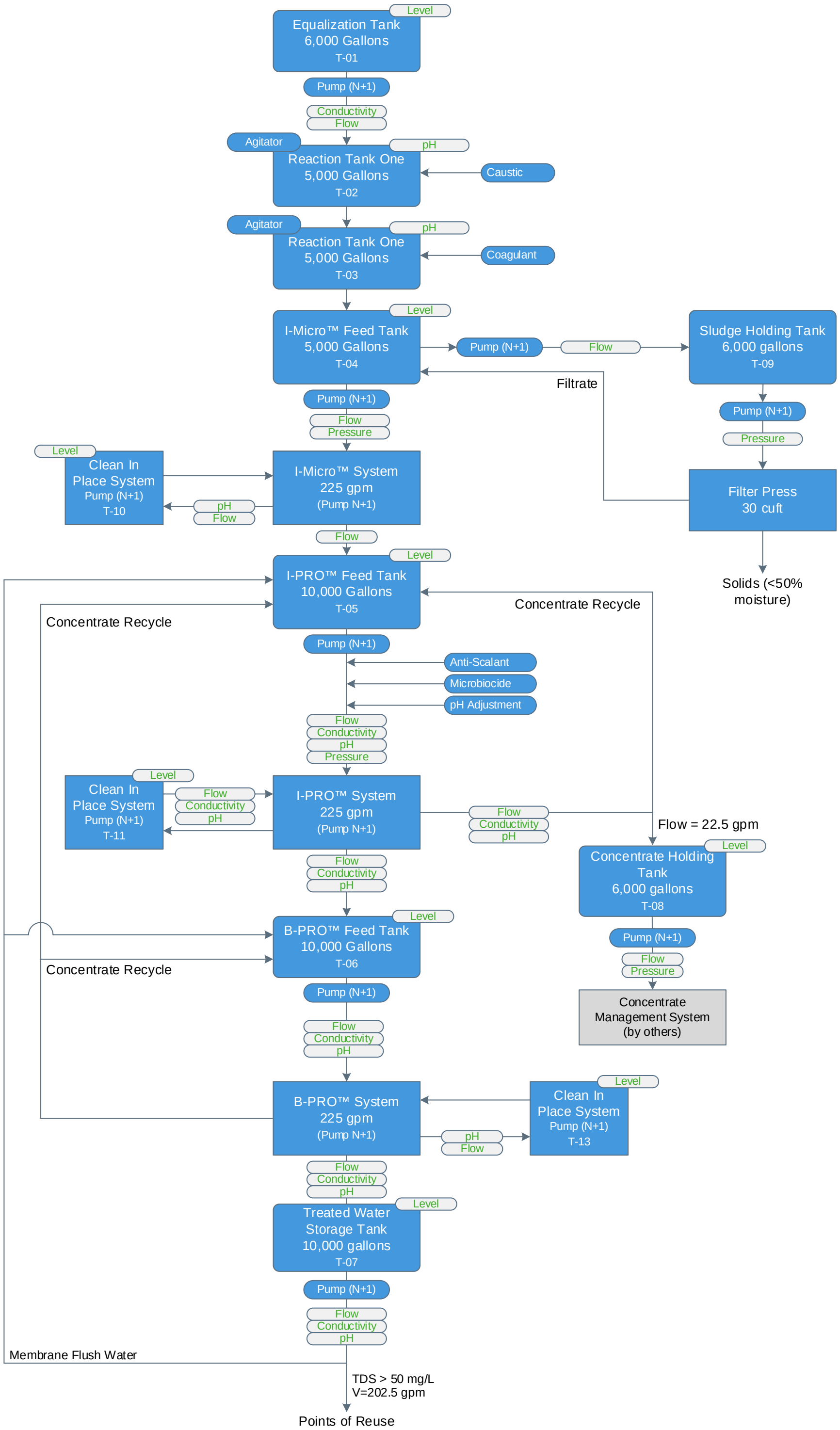
Additionally, a custom website provides operators and others a view of real-time and trend system data, in addition to email or SMS alerts. The following images show examples of remote monitoring websites for similar treatment systems:



Section 3 – System Diagrams

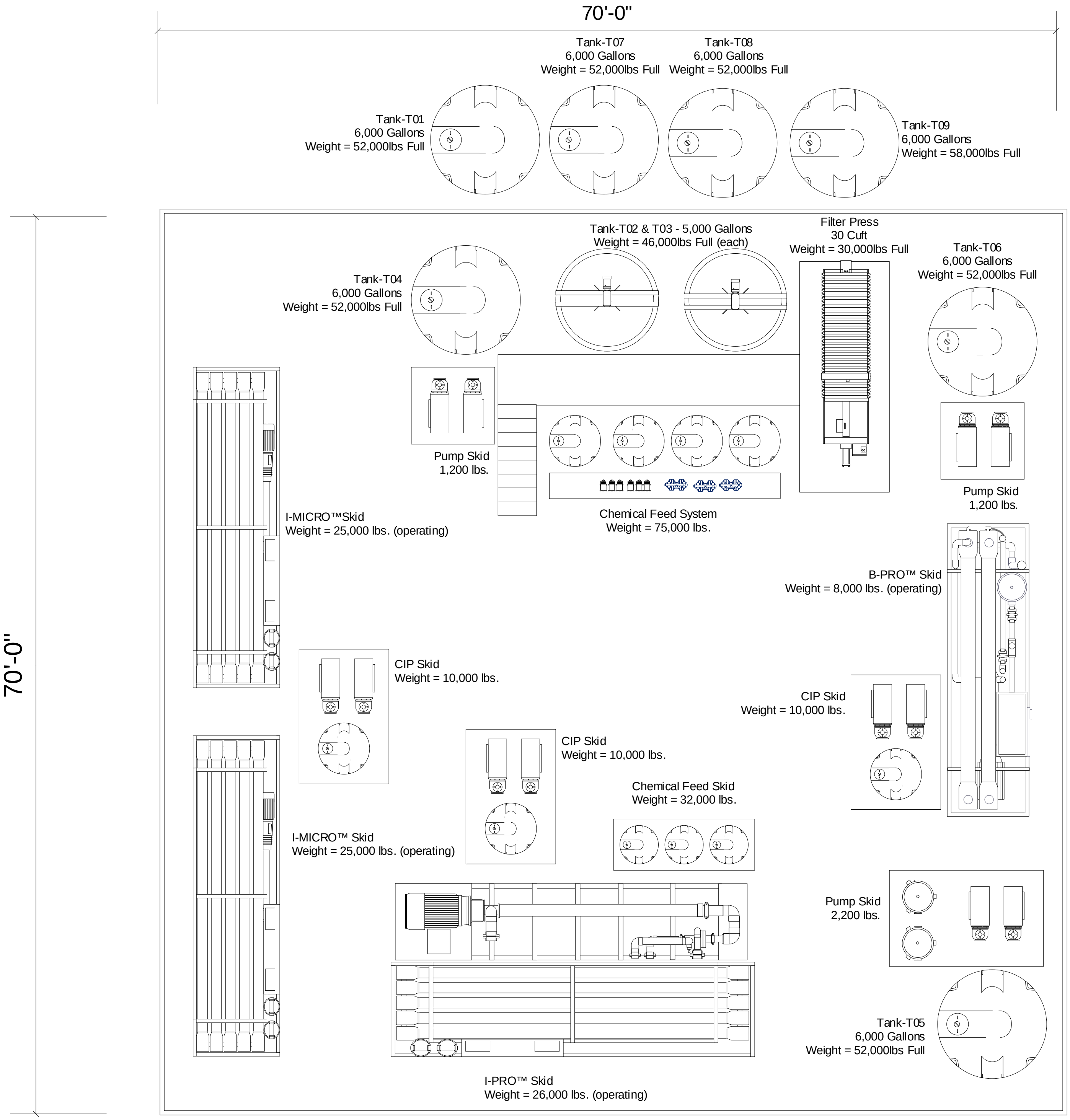
Process Flow Diagram (PFD)

The following PFD illustrates the treatment system described in **Section 2**:



System Footprint and Piping & Instrumentation Diagram (P&ID)

The following image illustrates a sample layout of the proposed system. KLeeNwater will provide a detailed footprint and P&ID will be provided upon receipt of purchase order.



Example System Images

The following images show examples of similar treatment systems:

Section 4 – System Documentation

KLeeNwater will provide the documentation listed in the following table over the course of the project. A schedule for these submittals and information about the file format of each submittal will be provided after receipt of purchase order.

Drawings
Process Flow Diagram
Piping & Instrumentation Drawings
General Arrangement Drawings
As-Built Drawings
Control System
Electrical Requirements
Utility Requirements
Single-Line Electrical Drawings
Electrical Schematics
PLC Program Files - changes made to PLC program files not authorized in writing will void warranty
Shipping, Installation, Operations, and Maintenance
Packing List
Installation Instructions - provided only for systems not installed by KLeeNwater
Spare Parts List and Pricing
Consumable Items List and Pricing
Commissioning Sign off and Performance Guarantee
Written Warranty
Operations Documentation

Section 5 – Installation, Start-Up, & Training

Installation

Burns & McDonnell and/or customer is responsible for facilitating installation of the KLeeNwater system (placing of all equipment and connection of all components and piping). KLeeNwater will provide installation oversight labor. Burns & McDonnell and/or customer is responsible for providing all rigging equipment required for installation and setting of equipment. Access to the customer site prior to the system installation and start-up may be required to place large equipment (e.g., large tanks). Delays in site access caused by the customer may result in additional charges (e.g., storage fees).

All waste materials will be disposed of in a container provided by the customer. KLeeNwater is not responsible for disposal of any hazardous materials generated during the installation process, including wastes that are created by the installation process. Prior to system shipment, customer representation must sign off on the following pre-installation requirements. Any delay in sign off may result in delay of shipment, installation, and/or start-up of the system.

- Customer-required safety training is made available to KLeeNwater installation oversight employees (if applicable).
- Customer-provided plumbing to and/or from the system is complete (if applicable).
- Power and air supplies are made available within ten feet of the control panel (unless otherwise specified).
- City water is made available at the start of installation (if applicable).
- Process water is made available at the start of installation.
- A staging area near the installation site is made available (if applicable) to temporarily store necessary equipment prior to installation.
- The installation site is free of debris and/or large material or equipment.
- Start-up treatment chemicals are ordered and available on-site (if applicable).

Start-Up and Training

KLeeNwater will provide start-up testing of equipment, calibrate all instruments, and perform water quality testing to ensure the system meets customer requirements. KLeeNwater will provide on-site training for system operators, including review of the system operations and maintenance documentation, and safety training.

Section 6 – Utility & I/O Estimates

Utilities

Electricity

The following electrical loads and consumption are estimated for the proposed KLeeNwater system:

- **Total Connected Electrical Load:** 800 kW
- **Total Operating Electrical Load:** 375 kW
- **Electrical Consumption:** 0.0278 kWh per gallon (or 27.8 Wh per gallon)

City Water

An estimated 15 gpm @ 40 psi (minimum) is required for the proposed KLeeNwater system.

Air

An estimated 70 SCFM is required for the proposed KLeeNwater system.

I/O Estimates

The following quantities are estimated for the proposed KLeeNwater system:

- **Discrete inputs:** 80
- **Discrete outputs:** 80
- **Analog inputs:** 80
- **Analog outputs:** 10

Section 7 – Projected Costs

The following table lists the projected capital costs and select operational costs for the proposed KLeeNwater system:

KLeeNwater System Projected Capital Costs	Price
Estimated Capital Costs	
KLeeNwater System – Material & Labor • Treatment system equipment and material • Control system equipment and material • Design and fabrication labor	**$3,380,000.00**
Installation Start-Up • Installation oversight labor (3 people for 30 days) • Start-up and training labor (3 people 5 days)	**$100,225.00**
Freight to Huntington, UT	**$54,750.00**
Spare Parts (2-year supply)	**$226,500.00**
Estimated Operational Costs	
Chemicals • Wastewater treatment chemicals (275-gallon totes) • Membrane cleaning chemicals (275-gallon totes)	**$0.001622 per gallon**
Replacement Membranes & Cartridge Filters	**$0.00218 per gallon**
On-Going Remote Monitoring Website Hosting First year of hosting included in system capital costs	**$250.00 per month**

Labor Estimates

Operations Labor

The hours per day that the proposed KLeeNwater system can be operated depends on the facility requirements. The following table summarizes the shift length, number of shifts per day, and number of operators per shift, depending on the facility operation requirements.

Hours Per Day Operation	Number of Shifts Per Day	Shift Length	Number of Operators Per Shift
24	2	12	1
16	2	8	1
8	1	8	1

Maintenance Labor

An estimated 415 hours of routine maintenance labor will be required on the proposed KLeeNwater system per year.

Section 8 – Estimated Schedule

The following table summarizes an estimated project schedule. A more detailed schedule will be provided if an actual cost proposal is requested.

Estimated Schedule	
Task Name	**Task Length - Days**
Receipt of Purchase Order	1
Process Flow Diagrams	5
Piping and Instrumentation Drawings	12
General Arrangement Drawings	20
Control Narrative & Panel Design Drawings	10
Component Approval	15
Equipment Fabrication	120
Factory Acceptance Testing	10
Delivery	10
Installation	30
Startup Testing & Operations Training	5
System Acceptance	1
Total Time	**239 (12 months)**

Section 9 – Condition of Sale

Confidentiality

KLeeNwater reserves its right of ownership with respect to materials generated by it, whether for Customer, and whether otherwise protected by any statutory and/or common laws relating to intellectual property rights, including, but not limited to, quotations, drawings, equipment and any other data tangible and/or capable of being perceived. Such materials are confidential and may not be used, copied, duplicated, or made available for reuse without KLeeNwater's written consent. KLeeNwater hereby excludes any liability to Customer for incidental or consequential damages, including, but not limited to, loss of time, loss of profits, waste disposal expenses, excess or unexpected treatment costs, regulatory fines and/or penalties.

Cancellation

After acceptance of the proposal by Customer, the contract between Customer and KLeeNwater may be canceled only with KLeeNwater's written consent and upon terms satisfactory to it. The contract shall include all change orders. The contract between the Customer and KLeeNwater shall be deemed to incorporate, without exception, all the terms and conditions hereof. No modification of these terms and conditions shall be of any force or effect unless reduced to writing and either signed by an officer of KLeeNwater Inc. or not the subject of any timely objection thereto by KLeeNwater.

Payments

Any price quoted by KLeeNwater shall be payable in U.S. Currency. KLeeNwater's price does not include any taxes or fees, all of which must be paid by Customer. Any clerical errors in any KLeeNwater proposal, including the price, are subject to correction in the sole discretion of KLeeNwater. If shipment of material is delayed through no fault of KLeeNwater regardless of whether such delay is due to any act or omission of Customer, payment of any invoices to KLeeNwater shall become due within thirty days after the equipment is ready for shipment. Customer agrees to pay interest of 1.5% per month on all past due invoices.

Title Risk of Loss

Title to any equipment sold by KLeeNwater to Customer shall pass to Customer upon its receipt thereof, unless Customer assumes the responsibility for shipment of the equipment, in which event title passes at the time of shipment; and until Customer has received such equipment or assumed responsibility for the shipment thereof, title thereto shall remain with KLeeNwater except as otherwise provided by law, in which event KLeeNwater retains a security interest in the equipment. The risk of loss or damage to any equipment shall belong to Customer once it has title thereto, as defined herein, except as otherwise provided by law.

Remedies

Upon the failure by Customer to comply in full with any of the terms provided in the condition of sale, including failure to make any payment due hereunder on a timely basis, the Customer shall be in default; and KLeeNwater Inc. shall have all rights and remedies available at law, including, but not limited to, those remedies available under the Uniform Commercial Code, if applicable, the right to retain any and all partial payments which may have been made, and the right to take immediate possession of any confidential information, any equipment and any materials delivered to the Customer hereunder. If requested by KLeeNwater, the Customer shall execute UCC Financing Statements and any other documents that may be reasonably necessary to evidence KLeeNwater's security interest and rights as a secured creditor to any equipment delivered to customer. In the event KLeeNwater takes legal action to enforce any of its rights hereunder, including the collection of any sums due, the Customer shall be liable to KLeeNwater for all costs or expenses incurred.

Section 10– Actual Cost Proposal Request

Requests for an actual cost proposal should be directed to **Mark Pastore (mpastore@eescorp.com)** and reference proposal number **KW 17-0045**.

ERG

MEMORANDUM

TO: Steam Electric Rulemaking Record

FROM: Eastern Research Group, Inc.

DATE: October 22, 2019

SUBJECT: **Technologies for the Treatment of Flue Gas Desulfurization Wastewater – DCN SE07367**

ERG is providing technical support to the U.S. Environmental Protection Agency's (EPA's) Office of Water, Engineering and Analysis Division for the reconsideration of the effluent limitations guidelines and standards (ELGs) for the Steam Electric Power Generating Industry promulgated in September 2015. EPA, with the support of ERG, collected information on technologies available for the treatment of power plant wastewater, specifically flue gas desulfurization (FGD) wastewater. This memorandum is a compilation of treatment technology information gathered since the 2015 rule.

- Appendix A: Aquatech Thermal Technology
- Appendix B: BKT FMX Membrane Technology
- Appendix C: Envirogen Technology
- Appendix D: Evoqua Technology
- Appendix E: Frontier Technology
- Appendix F: GE Alstom Spray Dryer Technology
- Appendix G: Heartland Technology
- Appendix H: HPD Thermal Technology
- Appendix I: KLeenWater Technology
- Appendix J: Mitsubishi Spray Dryer Technology
- Appendix K: New Logic Membrane Technology
- Appendix L: Oasys Forward Osmosis Technology
- Appendix M: Purestream Membrane Technology
- Appendix N: Saltworks Technology
- Appendix O: SUEZ ABMet Biological Treatment Technology
- Appendix P: SUEZ Thermal Technology
- Appendix Q: Sylvan Source Technology
- Appendix R: Vacom Technology

Appendix M – Purestream Membrane Technology

1.0 TECHNOLOGY DESCRIPTION

Purestream is a water services company formed in 2010 with a specialty in developing brine concentration and desalination technology for water reuse in power plants. Purestream's AVARA uses advanced mechanical vapor recompression to remove pollutants from wastewater and generates a reusable distillate stream and concentrated brine stream from wastewater. It can be used in municipal, commercial, and industrial wastewater treatment systems but is intended for power plant waste streams. It is designed as a modular system that could be used in the field to minimize wastewater, reducing or even eliminating the need to transport, treat, or dispose of wastewater elsewhere.

Each commercial AVARA module has a capacity of 35 gallons per minute (GPM), is skid-mounted (50 feet by 12 feet) and can easily be installed. The modular system, after being purchased or leased from Purestream, can be built in 180 days and is deployable within two days of on-site delivery; assembly only requires electrical and plumbing connections be established. Multiple 35 GPM units can operate together to create a larger capacity system. Each self-contained unit can be placed on-site on individual skids (one unit and ancillary equipment per skid) or equipment can be reconfigured (e.g., all compressors on one skid, all heat exchangers on one skid, etc.) for flexible installation. Purestream asserts that if pH, scaling potential, and solids are monitored and kept within an acceptable range, there are not any additional factors that would preclude installation of the system in any plant design. Influent concentrations are typically monitored and controlled at the feed tank prior to the heat exchanger. Figure 1 shows a process flow diagram for a typical AVARA system.

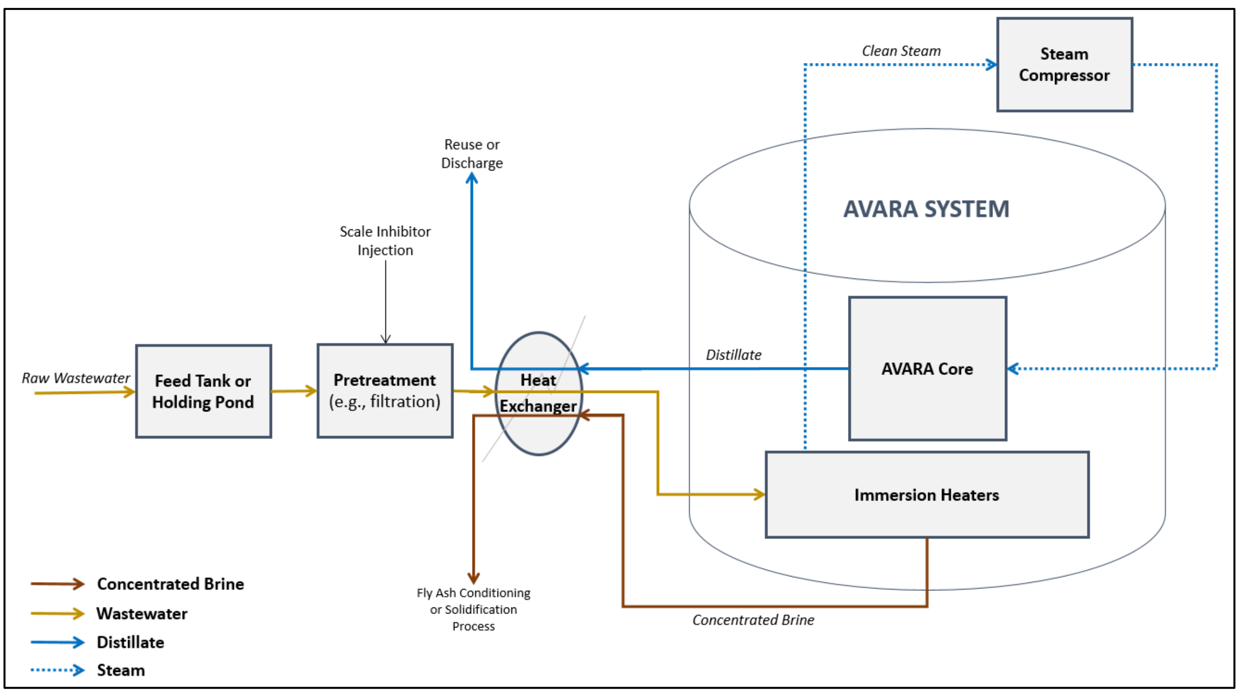


Figure 1. Process Flow Diagram for AVARA Mechanical Vapor Recompression System

FGD wastewater is pumped from a holding pond or tank through an influent filtration system to remove suspended solids; a scale inhibitor is added at the filtration system. To facilitate evaporation, wastewater is initially heated by immersion heaters to the desired temperature. As the wastewater inside the tank boils, steam vents from the top of the tank and passes through a steam compressor, which pushes the steam inside the AVARA cores; the cores are a proprietary design in vertical plate orientation. Heat transfers from steam inside the cores to the brine in the tank, while the steam condenses inside the cores and becomes the "clean" distillate stream. This distillate stream can be discharged or returned to the plant for beneficial reuse; it has a total dissolved solids (TDS) concentration below 300 parts per million (ppm). As wastewater evaporates and steam is generated, the TDS in the brine remaining in the tank becomes concentrated. Once the brine reaches a predetermined TDS set point concentration, not to exceed 200,000 ppm,[2] brine is discharged from the tank in a continuous stream through hydrocyclones. Heat exchangers recover and transfer energy from the hot brine and distillate streams to preheat influent entering the AVARA tank, reducing reliance on the immersion heaters. The concentrated brine may be combined with fly ash for disposal in a landfill or may be used as an ingredient for a solidification process.

In most FGD wastewater applications, raw FGD wastewater with a total suspended solids (TSS) concentration below 30 ppm can be pumped directly into the AVARA system. Wastewater with higher TSS concentrations may require clarification to lower this influent TSS concentration. However, a settling tank often provides sufficient pretreatment. Chemical addition may also be required to maintain the necessary pH between 5.5 and 6.5. Crystal inhibitors and antiscalants are also added to maintain optimal conditions and to mitigate scaling. The bubbles generated by the boiling liquid create turbulence, which also helps mitigate scaling on the immersed cores. Transducers create ultrasonic bubbles and turbulence in the tank that also prevent scale from building up on the cores. Water circulation within the tank also reduces scaling. The submerged core design leaves little potential for oxidation, so equipment corrosion is typically not an issue.

The AVARA's modular design allows for simple and quick core replacements and repairs. The cores can be considered akin to cartridges that can be removed and replaced with minimal system downtime. When removed, the cores can be serviced offline (i.e., mechanical or chemical cleaning) without affecting running operation of the system. AVARA can be kept in standby mode during shut-down periods of less than a week. In standby mode, burners are lowered to keep wastewater warm and prevent solids from precipitating. For extended shut-down periods, the system is purged, flushed, and residual steam is blown out. The small volumes of steam released from the vents are not typically scrubbed because this is an infrequent process. The AVARA system is marketed as a turn-key technology that includes operation and service (i.e., Purestream is contracted to operate the system for the facility). The longest system operating in the field has been running intermittently for three years.

[2] Above this concentration, the solution becomes saturated and solids have been observed precipitating out of solution. The system can treat influent with TDS concentrations as high as 120,000 ppm but will see lower recovery rates as the influent TDS concentration approaches the TDS set point.

The AVARA system typically requires on-site operators, but the system can be managed remotely with proper process controls. One operator can run up to five AVARA modules. When scale builds up and cleaning is required in a multi-unit fleet, one unit can be shut down for cleaning while the others continue operating. Based on a pilot-scale study treating FGD wastewater, Purestream estimates the system can operate a year or more before cleaning to remove scale is required. In testing and full-scale implementation to date, cores have been pressure washed to remove scale and have not required chemical cleaning.

2.0 Technology Status And Performance

In 2015, Purestream, in conjunction with the Electric Power Research Institute (EPRI), began exploring the potential for AVARA to manage wastewater from coal-fired power plants. Since that time, Purestream has been piloting AVARA with EPRI and three coal-fired power plants to treat FGD wastewater and other waste streams. In 2017, Purestream conducted another AVARA pilot-scale study to treat FGD wastewater at a coal-fired power plant in Northern Indiana. Each of these pilot-scale studies is summarized in Table 1.

Table 1. Pilot Scale AVARA Treatment Systems

Pilot Number/Plant Name	Test Duration and/or Test Date	Treatment Train	Treated Water	Recovery Rate
Pilot #1 – Springerville Plant (Arizona)	February – September 2016	Storage pond, settling pits, Induced Gas Flotation (IGF), 35 GPM AVARA	Cooling tower blowdown	86%
Pilot #2 – Plant Bowen (Georgia)	May – October 2016	3-GPM AVARA	FGD wastewater and brine concentrate	-
Pilot #3 – Merom Generating Station (Indiana)	October – December 2016	35-GPM AVARA	FGD wastewater	82.5%
Pilot #4 – Plant in Northern Indiana	July – September 2017	Chemical precipitation (first three quarters of study), 35-GPM AVARA	Pond effluent containing leachate and FGD wastewater	91%

3.0 References

1. ERG. 2018. Eastern Research Group, Inc. Final Purestream Meeting #1 Notes. (March 3). DCN SE07805.

2. ERG. 2019. Eastern Research Group, Inc. Final Notes from Meeting with Purestream Services. (August 12). DCN SE07042.

3. Purestream. 2017. Final Purestream Meeting #1 Notes - Appendix A - Presentation to EPA. (October 12). SE07805A1.

4. Purestream. 2019. Purestream Notes Appendix A: Overview of Purestream Technologies. (April 10). DCN SE07042A1.

ERG

MEMORANDUM

TO: Steam Electric Rulemaking Record

FROM: Sara Bossenbroek, ERG
Tara Stout, ERG

DATE: June 24, 2020

SUBJECT: **Notes from Meeting with DuPont**

On April 8, 2020, EPA held a meeting with DuPont to discuss zero liquid discharge (ZLD) and minimal liquid discharge (MLD) membrane systems. DuPont's ZLD and MLD technology is installed at power plants in China to treat flue gas desulfurization (FGD) wastewater. EPA was interested in gathering insights on system costs, installation challenges in operations and maintenance (O&M), lessons learned, and other experiences with the systems. In attendance was Yang Cheng, who has direct experience with piloting nanofiltration and reverse osmosis elements in FGD wastewater ZLD treatment processes in China. See Table 1 for a complete list of attendees. See Appendix A for the presentation from DuPont.

Table 1. List of Attendees for January 13 Meeting

Name	Affiliation	Contact Information
Tina Arrowood	DuPont	Email: tina.arrowood@dupont.com Phone: 952-838-3978
Kimberly Kupiecki	DuPont	Email: kimberly.kupiecki@dupont.com
Sundeep Ramachandran	DuPont	Email: sundeep.ramachandran@dupont.com
Yang Cheng	DuPont	Email: cheng.yang@dupont.com
Phillip Flanders	EPA	Email: flanders.phillip@epa.gov Phone: 202-566-8323
Richard Benware	EPA	Email: benware.richard@epa.gov Phone: 202-566-1369
Sara Bossenbroek	ERG	Email: sara.bossenbroek@erg.com Phone: 703-633-1674
Tara Stout	ERG	Email: tara.stout@erg.com Phone: 740-972-2053

The following is a summary of EPA's discussions with DuPont.

FGD Wastewater Treatment Technology Overview

- EPA received comments on the 2019 proposed rulemaking stating that membranes are available and economically achievable for FGD wastewater treatment and that regulations should be set based on this technology. EPA is aware of membrane installations in China and pilot studies in the U.S., so they are interested in gathering more information from technology vendors.

- ZLD systems are used when facilities need to meet stringent discharge regulations. They can make it easier to get permitted and maximize water recovery. ZLD also helps to recover sodium chloride. However, ZLD systems rely heavily on thermal methods of dewatering, which can be expensive, and produce a dry waste that must be landfilled.

- MLD systems can be more affordable and reduce landfill waste. A water reuse process begins with pretreatment such as ultrafiltration (UF) to remove suspended solids and softening to remove scaling potential followed by a primary reverse osmosis (RO) system. DuPont's MLD systems then add a secondary RO, an ultra high-pressure RO, and selective nanofiltration (NF) that generate permeate and a purified sodium chloride brine.

- Pretreatment requirements vary based on the wastewater influent quality. DuPont stated that in general, system operation increases in efficiency with greater softening.

- In DuPont's review of literature, 20 to 80 percent of the hardness is removed through softening pretreatment. However, with RO systems it is ideal to remove close to 100 percent of hardness as you recover and concentrate the ions in the water.

- Most plants can achieve 70 percent water recovery with typical RO installations. Thermal treatment of the remaining 30 percent is expensive. To be more cost effective, DuPont recommends membrane treatment be used first for up to 95 percent recovery, followed by thermal treatment for the last 5 percent. This combined treatment train greatly reduces cost from $12 to $13 per 1,000 gallons for thermal only, to $4 to $6 per 1,000 gallons with membrane treatment first.

Case Studies at Textile Mills in India

- The textile industry in India has used membrane treatment for about 10 years. India is a water-scarce region, so facilities must pay for freshwater withdrawal for their manufacturing processes. DuPont presented information from four ZLD textile mills applications to demonstrate that membrane treatment prior to thermal treatment reduces overall O&M costs.

- Typical textile mill wastewater is high in total dissolved solids (TDS) and chemical oxygen demand (COD) with moderate hardness. Pretreatment consists of UF and softening using weak acid cation (WAC) exchange or lime softening when hardness is higher, followed by three or more RO stages recovering 85-90% of the water before sending the concentrate to an evaporator and crystallizer.

- This treatment train results in an average cost of $1.76 per cubic meter ($m^3$) of wastewater treated. In addition, the textile mills recover sodium chloride salts for reuse in dye baths, thereby reducing the amount of salt the facility needs to purchase from the open market and minimizing salts sent to landfill.

- DuPont explained that an NF membrane allows sodium chloride to pass through but rejects sodium sulfate (i.e., divalent ions are rejected). If a textile mill introduces NF after the three-stage RO to improve recovery of sodium chloride from the RO concentrates, water recovery increases by 50 percent. This in turn reduces the amount of water being sent to the evaporator/crystallizer by 50 percent, and the overall average treatment cost is also reduced, to $1.49/m^3.

Design Alternatives and Considerations of Membrane Treatment in Power Plants

- DuPont outlined the following alternatives for power plants to treat FGD wastewater:
  - Thermal only ZLD: Chemical precipitation, brine concentrator, and crystallizer.
  - MLD-ZLD: Chemical precipitation, UF, ion exchange softening, RO, brine concentrator, and crystallizer.
  - MLD-ZLD with forward osmosis (FO): Chemical precipitation, UF, ion exchange softening, RO, FO, brine concentrator, and crystallizer.
  - MLD-ZLD with NF: Chemical precipitation, UF, NF, RO, brine concentrator, and crystallizer.
- Instead of a secondary or more robust precipitation softening step, DuPont recommends using WAC exchange to ensure a facility can achieve the desired recovery level. Precipitation softening produces waste solids that need to be landfilled. The ion exchange regeneration waste can be sent back to the lime and soda softening process.
- RO treatment is limited by osmotic pressure of the water and the designed pressure limits of the RO system and membrane module. Standard RO systems can be operated up to 1,200 pounds per square inch (psi). When applying 1,200 psi pressure to an RO membrane, water will stop permeating through the membrane when the water osmotic strength approaches 1,200 psi. Depending on the compositions of salts, the maximum concentration of salt achieved by a system operating at 1,200 psi will be approximately eight to 10 percent salt. For example, sodium chloride has a higher osmotic strength than sodium sulfate and will reach the maximum osmotic strength at a lower concentration than sodium sulfate. Ultra high-pressure RO systems are designed to operate up to 1,740 psi which enables salts to reach concentrations up to 10 to 20 percent depending on the salt composition. DuPont noted that a four-stage single-pass RO system, with the final stage being an ultra high-pressure RO, can achieve up to 95 percent water recovery. Booster pumps are used between stages to increase pressure.

- If possible, DuPont recommends operating membranes below 35 degrees Celsius to provide an improved permeate quality that can be suitable for reuse without the need for a second pass of RO treatment.

Case Studies at Power Plants in China

- At the Changxing Power Plant, the wastewater treatment system consists of lime soda softening, WAC exchange, two-pass RO, FO, and a brine concentrator/crystallizer. This plant uses two seawater RO systems with a concentrate TDS of 60,000 mg/L and has achieved between 70 to 75 percent recovery since it began operating in 2015. DuPont stated that according to Guohua and Dai's 2016 publication in *Industrial Water Treatment, 36*(8), 109-112 the plant's wastewater treatment O&M costs are as follows:
  - Steam at 55 percent,
  - Soda at 29 percent,
  - Lime at 3 percent,
  - Power at 12 percent, and
  - Caustic/acid/etc. at 1 percent.

  Steam comprises the greatest cost share because the FO and evaporator systems both require it; however, DuPont clarified that power plants have internal sources of steam that can be partially utilized for these needs and thus purchasing steam externally is minimized or not needed. See Appendix B for a summary of the key considerations and outcomes of this full-scale installation.

- At the Hanchuan Power Plant, the FGD wastewater treatment system consists of tubular microfiltration (MF) softening, NF, two-pass RO (seawater and brackish water systems), high-pressure RO, and ZLD technologies that generate industrial grade salt. Laboratory studies have demonstrated that NF concentrate contains sodium sulfate with some sodium chloride, and the permeate mostly consists of sodium chloride (98.5 percent). This treatment train was originally a pilot study that experienced stable operation for over two months and led to full scale implementation. In addition, the treatment train has resulted in more than six other commercial installations in China. See Appendix C for additional information on these case studies presented at IWC 2017.

- From design through commissioning, the Hanchuan project installation timeline was approximately one year including 1 to 2 months for a pilot study. DuPont noted that in their experience, there is not generally a fixed timeline; however, most projects in China take between 1 to 1.5 years if the end user has enough funds. Several power plants have used a system design similar to the Hanchuan treatment train. These plants did not need to conduct a pilot study, reducing the overall timeline. One factor that could delay installation is treatment component availability, e.g., if a pump is in limited supply from several suppliers and there are several FGD wastewater projects in progress, this would lengthen the installation timeline. Another factor specific to China, where the solid salt product is sold, is identifying an external customer to purchase the sodium chloride byproduct generated by the crystallizer.

- The DuPont installations at power plants in China are the first using RO and other membrane products to treat FGD wastewater. The biggest challenge in piloting the technology was controlling the pretreatment operations due variations in the FGD wastewater compositions. Lime and soda need to be carefully added to control feedwater composition. In general, membrane systems treating FGD wastewater must be more closely monitored and cleaned than membrane systems used in demineralization applications. This is also true for the ion exchange resin. An RO cleaning frequency of once per month is typical for RO systems treating wastewater for reuse; whereas, a frequency of every three to six months is more typical of RO systems treating surface waters.

- At a new power plant in Xi'an, the influent FGD wastewater quality is variable due to cycling at the plant and being in the early phases of a multiple phase process. Wastewater treatment equipment is sized for full capacity, but in the early stages of phasing in the plant, the wastewater treatment capacity may not be properly sized for ideal process control. For example, the evaporator was oversized with the anticipation that it may not operate continuously. Cost was not a factor in choosing the evaporator capacity because the smaller size can cost as much as the medium size. Because the evaporator was oversized, plant operators have not been able to achieve steady state operation to date in feeding the evaporator system. DuPont continues to follow this project as the power plant continues to phase in more and more capacity.

Exhibit 8

2020 ECR Plan Status Update Report
Quarterly Report – Update #15
July 30, 2024

Executive Summary:

General

This report covers LG&E and KU's ("Companies") progress on the 2020 Environmental Cost Recovery ("ECR") Plan through the second quarter of 2024. The Companies filed applications requesting approval of their 2020 ECR Plan on March 31, 2020[1] and received approval on September 29, 2020.

The 2020 ECR Plan safety performance through the second quarter of 2024 remains excellent with a Year-to-Date OSHA Recordable Incident Rate of 0.0 and an Inception-to-Date OSHA Recordable Incident Rate of 0.0, compared to the industry average of 2.4.

Work to date continues to focus on construction and startup activities at two of the three stations: Ghent ("GH") and Mill Creek ("MC'). Trimble County ("TC") achieved Commercial Operations on April 25, 2024. At GH and MC, work has included installation of above ground piping and electrical conduit/cable; ongoing loop checks for the control wiring which will continue into next quarter; start-up activities for Bottom Ash at GH; as well as performance testing of the TC Effluent Limitation Guidelines ("ELG") system.

Compared to the total 2020 ECR Plan projected cost of $405.2 million (net)[2], as provided in Case Nos. 2020-00060 (KU) and 2020-00061 (LG&E), the projected spend, as of the second quarter of 2024, remains at the $272.6 million (net)[2] reported last quarter. This projected spend continues to represent a $132.6 million (net) reduction from the original filing. The total spend to date increased to $247.4 million (net)[2] through June 30, 2024.

Background

The Environmental Protection Agency's ("EPA") 2015 ELG Rule and amendments precipitated the need to construct ELG water treatment systems at TC, MC and GH, as well as a Bottom Ash Transport Water ("BATW") recirculation system at GH. The EPA's proposed amendments to the 2015 ELG Rule were finalized in the Fall of 2020. The current ELG Rule includes daily maximum and monthly average limits for the concentration of mercury, nitrates/nitrites, selenium and arsenic allowed in Flue-Gas Desulfurization ("FGD") wastewater effluent.

To meet the revised limits for these constituents, the Companies are required to install ELG water treatment systems to treat the effluent from the physical/chemical FGD process water treatment systems recently placed into service as described in the 2016 ECR Plan quarterly reports. Without the proposed 2020 ECR Plan projects at TC, MC, and GH stations, the Companies would not be able to continue steam generating

[1] Case No. 2020-00060 and Case No. 2020-00061
[2] Co-Owners of the Trimble County plant: Illinois Municipal Electric Agency (IMEA) and Indiana Municipal Power Agency (IMPA) are responsible for 25%. IMEA owns 12.12% and IMPA owns 12.88%. Co-owner shares are not included in the costs provided in this report.

operations at these generating stations and simultaneously comply with the ELG Rule, as enforced by Kentucky Pollutant Discharge Elimination System ("KPDES") permits at each generating station. This would significantly impair the Companies' ability to fulfill their mandate to provide adequate, efficient, and reasonable service to their ratepayers, as these generating stations are the three largest generating stations within the Companies' generating fleet. The ELG Rule requires compliance for the FGD wastewater as soon as possible on or after November 1, 2020, but no later than December 31, 2025[3].

The final ELG Rule also includes up to 10 percent volumetric discharge limit (on a 30-day rolling average) for BATW, which also must be complied with "as soon as possible" but in no event later than December 31, 2025. This proposed discharge limit requires KU to construct a BATW recirculation system on the existing bottom ash transport system at GH. The recirculation system will collect the transport water currently discharged from the remote bottom ash dewatering facility and reroute it through tanks and piping systems back to the four generating units for reuse. TC and MC do not require a BATW recirculation system due to their bottom ash transport systems being previously converted to a dry transport instead of a wet sluicing system like GH's.

On May 9, 2024, the EPA promulgated the final ELG Rule ("ELG") requiring membrane filtration followed by solidification or thermal evaporation for zero discharge of FGD Wastewater; zero discharge of Bottom Ash Transport Water; and zero discharge of combustion residual leachate waters and did not establish specific limitations for Legacy Waste Water as the permitting authority will be responsible to establish site-specific technology-based limits. The ELG stipulates compliance as soon as possible, but no later than December 31, 2029. The ELG also creates a 2034 Permanent Cessation of Coal Combustion ("PCCC") subcategory. To qualify for the 2034 PCCC, facilities must file a Notice of Planned Participation ("NOPP") by December 31, 2025 committing to retire all coal-fired units by December 31, 2034. The EPA has set interim limits based on the 2020 ELG, and all facilities must fully comply starting on their respective 2020 ELG applicability date, until their 2024 ELG applicability date, or their 2034 PCCC retirement date. The Companies are currently reviewing the final ELG rule and are formulating a compliance strategy.

Because of the uncertainties created by ELG, the Companies expect legal challenges to the ELG. Respective outcomes may influence future compliance direction.

[3] 84 Fed. Reg. 64664.

Schedules

FGD Process Water Treatment Facilities and Diffusers

Project	Project #	Awarded Contractor	Status[4]	Planned / Actual In-Service Date[5]
Trimble County Effluent Limitations Guidelines Water Treatment System[6]	KU Project 44 LG&E Project 32	OKEP	Awarded March 15, 2021	Placed in service May 2024
Mill Creek Effluent Limitations Guidelines Water Treatment System[6]	LG&E Project 31	OKEP	Awarded March 15, 2021	November 2024
Mill Creek Outfall 025 Diffuser	LG&E Project 31	Tetra Tech	Awarded May 12, 2021	Placed in service December 2021
Ghent Effluent Limitations Guidelines Water Treatment System[6]	KU Project 43	OKEP	Awarded March 15, 2021	December 2024
Ghent Bottom Ash Transport Water Recirculation System[7]	KU Project 43	OKEP	Awarded March 15, 2021	April 2024
Ghent Outfall 001 Diffuser	KU Project 43	MAC Construction & Excavating	Awarded March 22, 2021	Placed in service December 2021

[4] Project Engineering Department or Engineering, Procurement, and Construction ("EPC") Contract work status.
[5] The Planned In-Service Dates are per the 2020 ECR Plan filing (Straight Testimony, page 4-5) or the current, active construction schedule. Actual in-service dates are signified with red font.
[6] ELG Equipment OEM: Frontier
[7] BATW Equipment OEM: United Conveyor Corporation

Quarterly Status Update:

General

The engineering, procurement, and construction ("EPC") contracts for TC, MC, and GH were awarded on March 15, 2021 to Old Kentucky Energy Partners ("OKEP"), which is a joint venture between Bowen Engineering (a local company) and United E&C. At GH and MC, work has included continued installation of above ground piping and electrical conduit/cable; installation of process equipment and electrical gear; installation of fiberglass tanks; heat tracing; initiation of commissioning activities at MC; and completion of performance testing on TC's ELG and GH's BATW systems. Both TC's ELG and GH's BATW systems were placed in service.

Burns & McDonnell ("B&McD") is the ELG Owner's Engineer and is assisting the Companies with reviewing engineering, design and construction support related to submittals and fieldwork from the EPC (OKEP) and ELG technology providers (Frontier – ELG) or United Conveyor Corporation (Ghent BATW).

KU Project 44 and LG&E Project 32 – Trimble County (TC) Station Effluent Limitations Guidelines (ELG) Water Treatment System

General

Project 44 (KU) and Project 32 (LG&E) are for construction of an ELG water treatment system at the TC generating station. The current forecasted capital cost to implement these facilities remains $51.6 million (net)[8], allocated between KU and LG&E. With Commercial Operations achieved in April 2024, the planned in-service date has been updated which previously noted impacts resulting from late delivery of critical electrical components and failure of the initial performance test due to biomass shed.

[8] KU's 48 percent ownership allocation equals $24.8 million (Project 44) and LG&E's 52 percent ownership allocation equals $26.8 million (Project 32) – both costs are net.

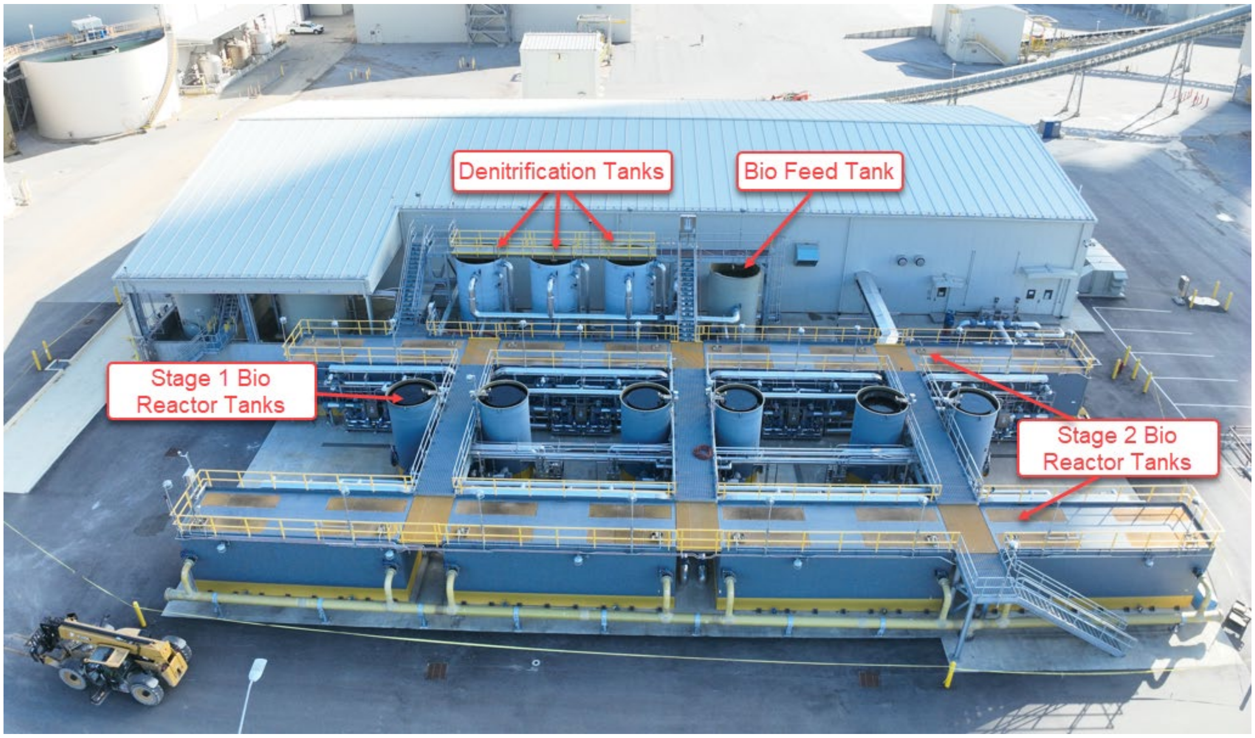
ELG

The ELG system is being constructed in close proximity to the recently completed process water treatment system ("PWS"). All facilities are being installed on land currently owned by KU and LG&E at the generating station. The system is designed to handle water flow capacity up to 750 gallons per minute. Engineering was completed in the first-quarter of 2024. The remaining home-office focus is the completion of as-built drawings. Field work continued with piping and electrical installation associated with the Maintenance Tank and pump house, and continuation of the ELG system Performance Testing.

As previously reported, the first Performance Test in late 2023 did not pass due to the noted biomass shed from the bioreactors. In line with how system testing often identifies process issues requiring tuning and optimization, OKEP and the OEM, Frontier, evaluated the conditions of the failed test and requested plant modifications upstream of the ELG system prior to the second Performance Test. Chemical modifications were made to the TC1 flue gas de-sulfurization unit (FGD) within the first quarter of 2024, resulting in a successful performance test. Achievement of Commercial Operation was completed during the second quarter of 2024 and Final Completion is anticipated within the third quarter of 2024.

Although the second Performance Test was successful, long-term system reliability and economic considerations led to the execution of a contract with B&McD to review possible FGD system chemical, mechanical, or operational (or a combination thereof) modifications to TC1. Until this engineering is vetted and a solution determined, the generating station will utilize the same chemicals which facilitated the successful Performance Test; this chemical change results in increased costs. B&McD's first draft of possible modifications is anticipated in the third quarter 2024.

Reliable operations and maintenance of the new ELG facility, requires on site spare parts and materials. A new warehouse is necessary for this purpose and will be constructed adjacent to the ELG facility. This construction contract was awarded to East & Westbrook Construction, Inc ("E&W"). The warehouse is planned to be a 22,500 square foot pre-engineered metal building with internal shelves and racking. During this quarter, E&W began performing preliminary civil/site design work, purchased the pre-engineered metal building ("PEMB"), and received delivery of the PEMB materials. E&W also applied for the site and foundation permit required for the building.



Trimble County – ELG Water Treatment Location – December 2023


Trimble County – ELG Water Treatment Location – March 2024 – July 2024 No Changes

LG&E Project 31 – Mill Creek (MC) Station Effluent Limitations Guidelines (ELG) Water Treatment System and Diffuser

General

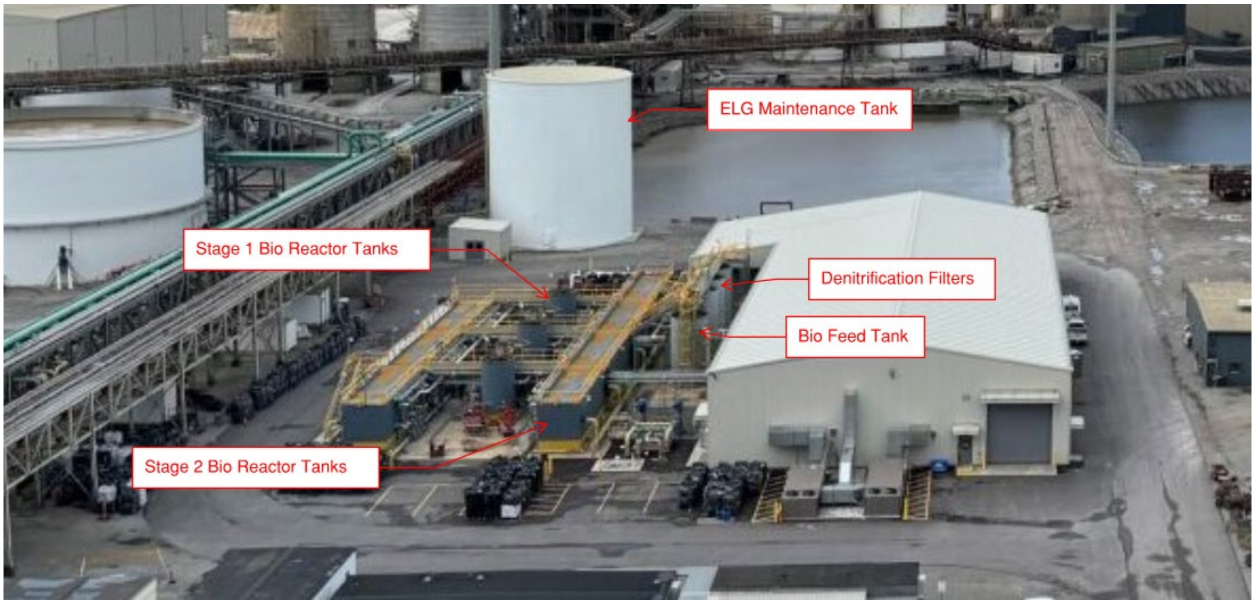
Project 31 is for construction of an ELG water treatment system and wastewater diffuser at the MC generating station. The current forecasted capital costs to implement this project is $71.2 million. The MC project team has engaged the TC and GH project teams during all major reviews to apply lessons learned from the other projects. This collaborative effort was implemented to ensure lessons learned are applied across all the projects to promote a common fleet approach to the ELG program.

ELG

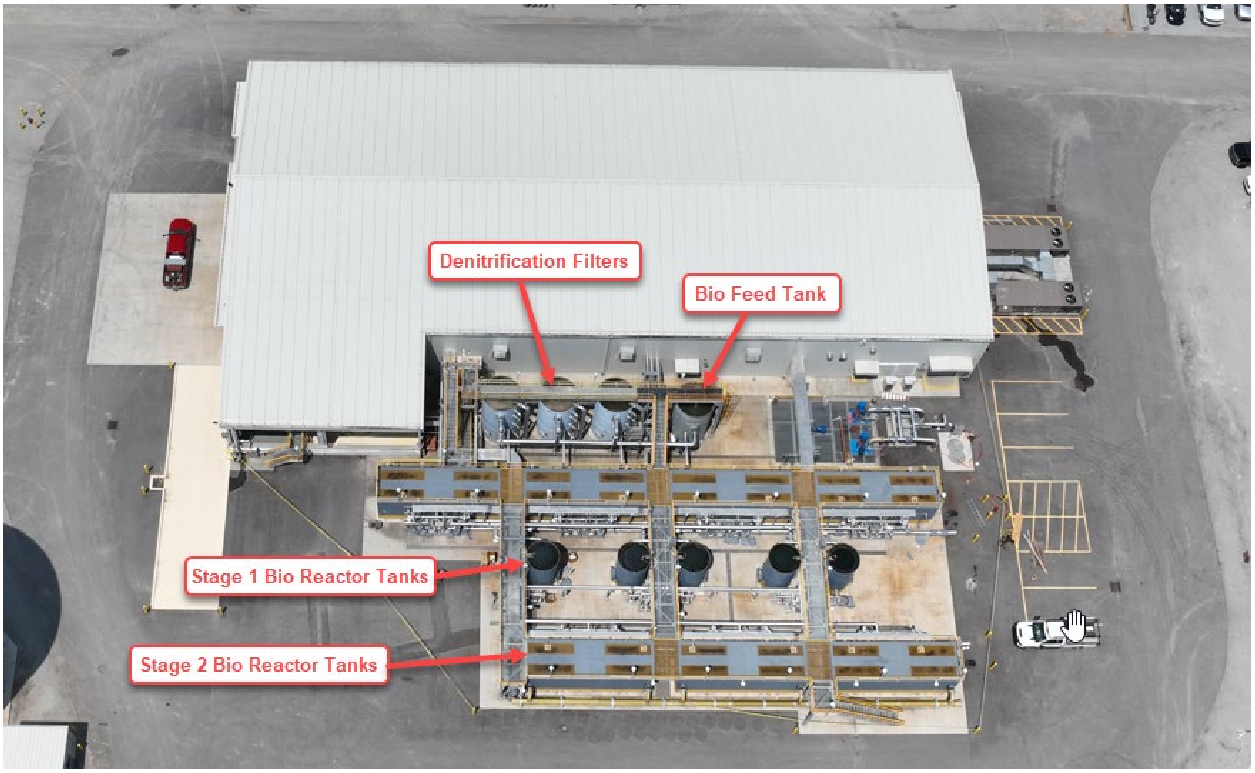
In the second quarter of 2024, OKEP completed installation of conduit, pipe and skid heat tracing, and the vast majority of insulation. HVAC and fire protections systems were completed and put in service. The 4kV "A" side feed was completed and tied-in. Construction turnover books were submitted to MC project team for review and comment. Treatment chemicals were delivered to the jobsite. Media was installed in the first and second stage bioreactors, followed by seeding of the bioreactor beds. Hot commissioning of the ELG system commenced with day shift operation and testing. OKEP trained Mill Creek Station operators during hot commissioning. Punchlist work continued to be addressed.

Diffuser

The diffuser was installed and placed into service in 2021.



Mill Creek – ELG Water Treatment – April 2024



Mill Creek – ELG Water Treatment – July 2024

KU Project 43 – Ghent (GH) Station Effluent Limitations Guidelines (ELG) Water Treatment System, Bottom Ash Transport Water (BATW) Recirculation System, and Diffuser

General

Project 43 is for construction of an ELG water treatment system, a BATW recirculation system, and a wastewater outfall diffuser at the GH generating station. These facilities are designed to process and lawfully discharge wastewater from GH in accordance with the EPA's existing and proposed amendments to the ELG Rule and the existing Kentucky Pollutant Discharge Elimination System ("KPDES") Permit for GH. The current forecasted capital costs to implement these facilities remains $149.8 million, with construction recently completed in April 2024 for the BATW recirculation system and anticipated for December 2024 for the ELG water treatment system.

The GH project team continues to engage the TC and MC project teams during all major reviews, to apply lessons learned from the other projects. This collaborative effort was implemented to ensure lessons learned are applied across all the projects to promote a common fleet approach to the ELG program.

ELG

Throughout the second quarter of 2024, electrical installation efforts continued including pulling and testing cable, the initial installation of heat trace and lightning protection systems, and OKEP energizing the ELG Building. The project team started system walkdowns of ELG turnover packages, unloaded initial system chemicals, and continues making preparations for upcoming performance testing. HVAC ductwork modifications were completed to enhance maintenance access while mechanical and electrical punch list items continue to progress. Consistent with TC and MC approach to system reliability, a change order was executed to incorporate a maintenance tank at GH that continues through final design. Soil borings and preliminary construction activities have begun in preparation for the maintenance tank's expected installation in October.

Bottom Ash Transport Water ("BATW")

During the second quarter, the BATW project achieved Mechanical and Commercial Operation for all subprojects by May 16th, with focused efforts on the Unit 3 Ash Subproject's high-pressure pump and piping installations. This period included successful resolution of variable frequency drive (VFD)-related complications during a 7-day operational test, and permanent drain line installations for improved maintenance and freeze protection. Extensive system walkdowns and environmental compliance activities initiated BATW water reduction tests to mitigate operational impacts. Final project phases involved addressing mechanical and electrical punch list items and developing final As-Built design document packages, targeting completion by the end of August.

Diffuser

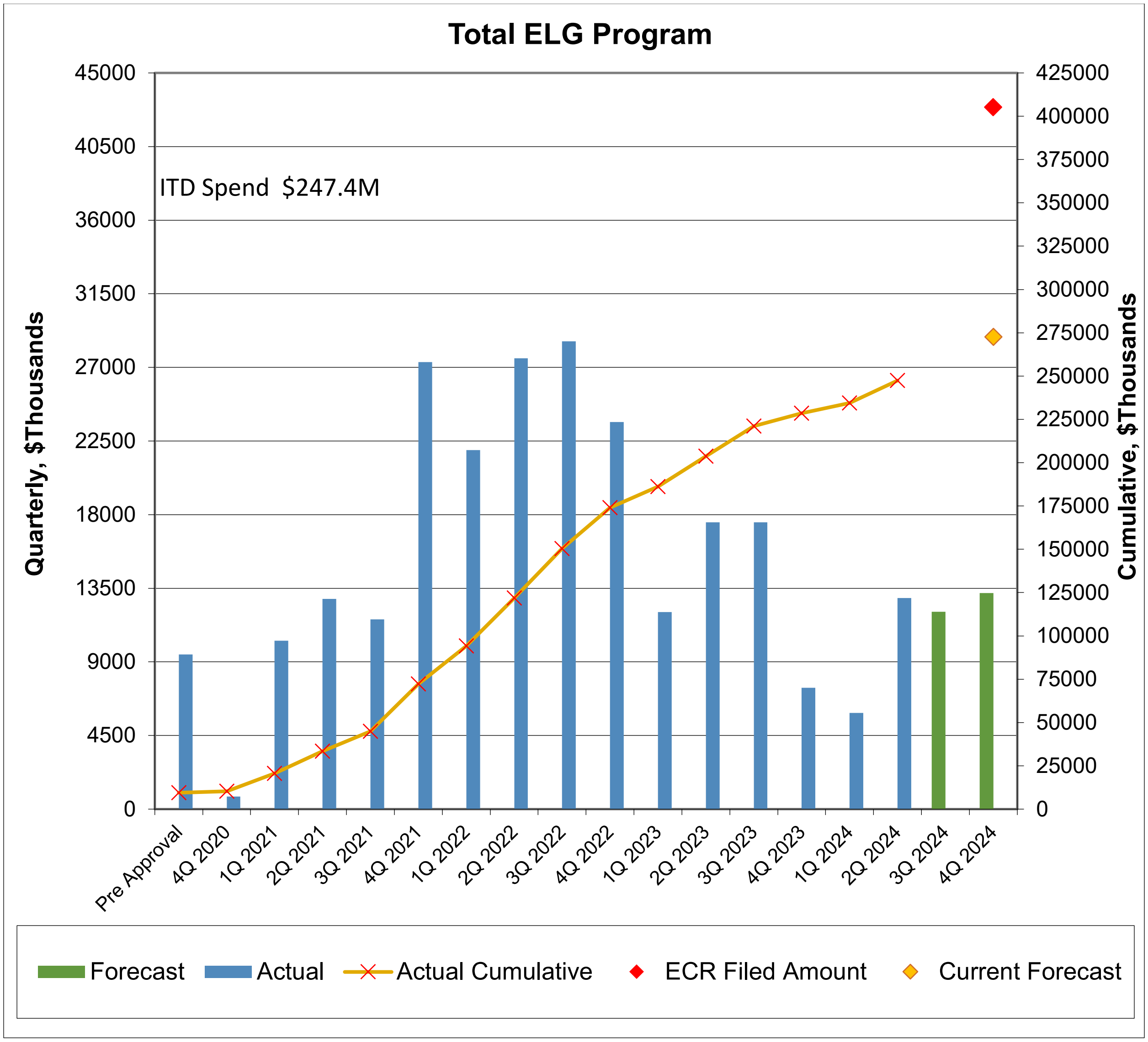
The diffuser was installed and placed into service in 2021.

Ghent – ELG Water Treatment – March 2024

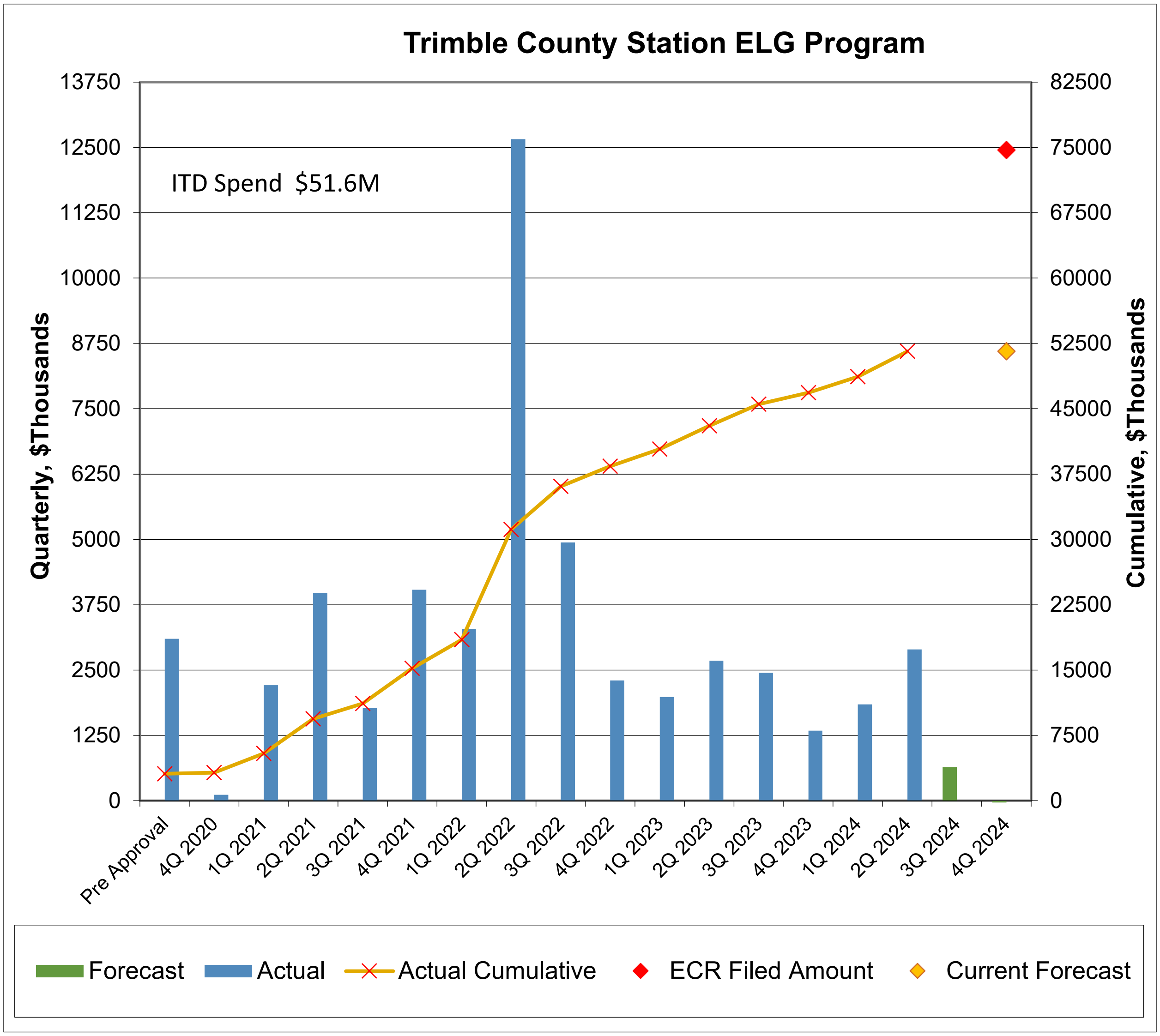
Ghent – ELG Water Treatment – July 2024

Financials:

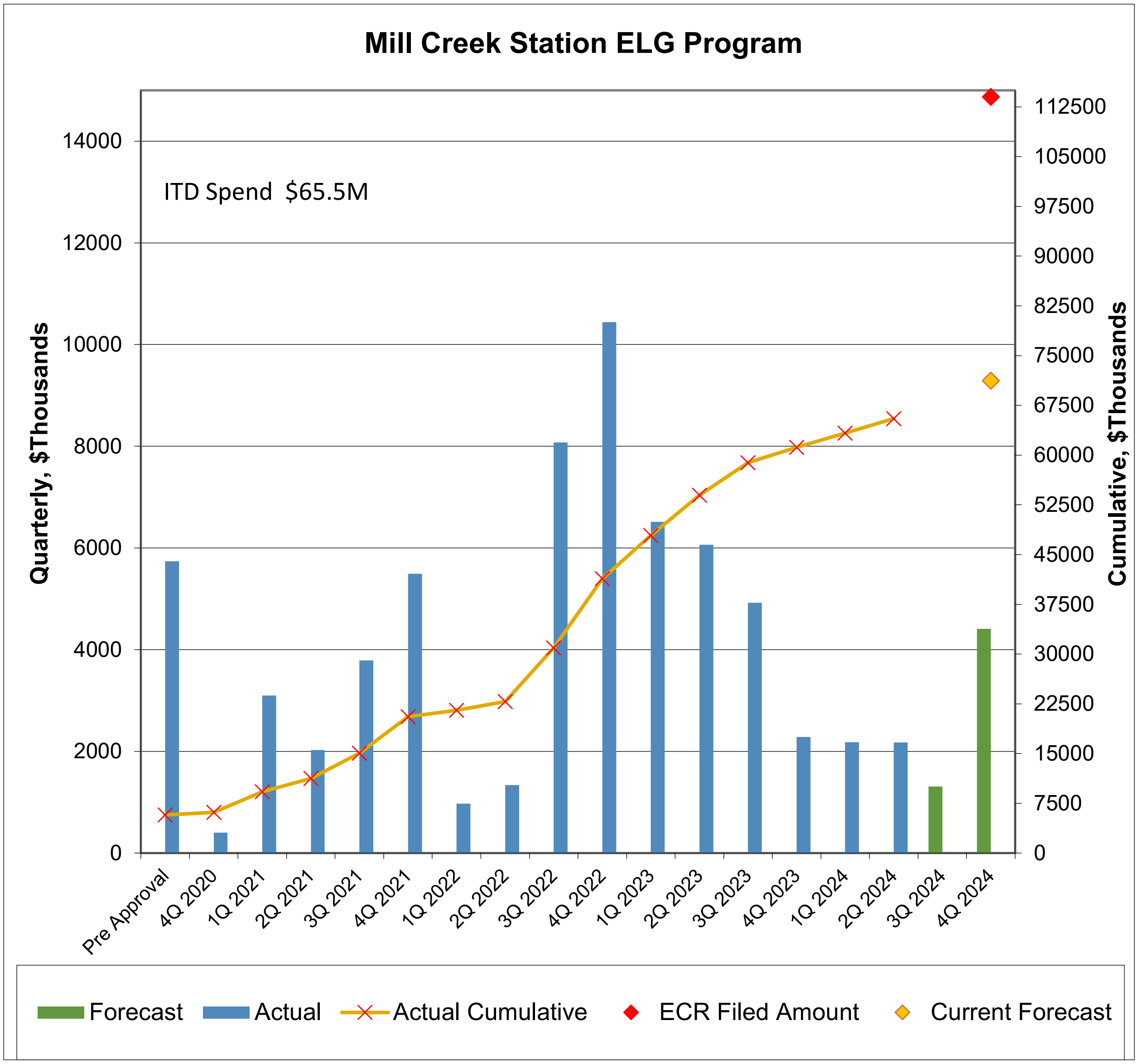
As previously reported, the total 2020 ELG Program forecasted cost was reduced from $405.2 million (net), as filed, to $272.6 million (net). The projected spend, as of the second quarter of 2024, remains $272.6 million (net). Total spend increased to $247.4 million (net)[2] through June 30, 2024. The graph below includes: 1) a symbol (◆) to show the current forecast to completion and 2) inception-to-date ("ITD") Spend in the upper left of the chart.



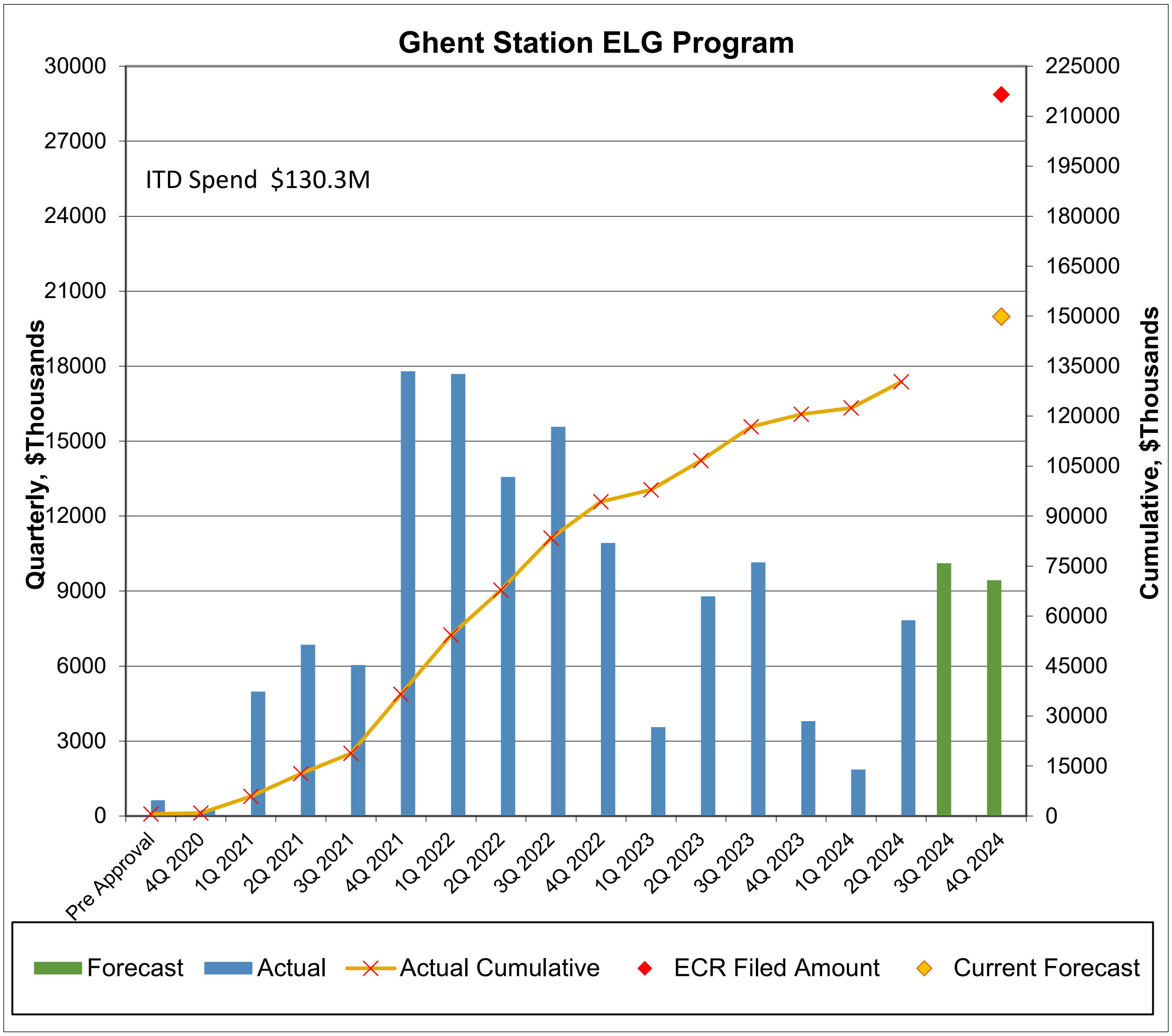
The total Trimble County Station ELG Program forecasted cost remains $51.6 million (net)[2]. Total spend increased to $51.6 (net)[2] through June 30, 2024. The graph below includes: 1) a symbol (◆) to show the current forecast to completion and 2) inception-to-date ("ITD") Spend in the upper left of the chart.



The total Mill Creek Station ELG Program and Diffuser forecasted cost is $71.2 million. Total spend was $65.5 million through June 30, 2024. The graph below includes: 1) a symbol (◆) to show the current forecast to completion and 2) inception-to-date ("ITD") Spend in the upper left of the chart.



The total Ghent Station ELG Program, BATW, and Diffuser forecasted remains $149.8 million. Total spend increased to $130.3 million through June 30, 2024. The graph below includes: 1) a symbol (◆) to show the current forecast to completion and 2) inception-to-date ("ITD") Spend in the upper left of the chart.



LG&E KU PPL companies

<u>Planned Activities for Next Quarter:</u>

KU Project 44 and LG&E Project 32 – Trimble County (TC) Station Effluent Limitations Guidelines (ELG) Water Treatment System

<u>ELG</u> – OKEP plans to complete commissioning of the maintenance tank and complete the update of remaining as-built drawings for record. B&McD will continue evaluating potential mechanical, chemical, and process modifications to the TC1 FGD. E&W will complete detailed engineering of the new warehouse, mobilize to the site, and begin construction on the new warehouse.

LG&E Project 31 – Mill Creek (MC) Station Effluent Limitations Guidelines (ELG) Water Treatment System and Diffuser

<u>ELG</u> – OKEP plans to achieve Mechanical Completion in July and begin the four (4) week performance test beginning in late July. Punchlist items will continue to be completed. Edits to Construction Turnover Books (CTO) books will be incorporated and resubmitted to the MC Project Engineering ("PE") team. OKEP will complete record drawings and submit for review. Final Completion expected during the fourth quarter of 2024.

<u>Diffuser</u> – No further work expected.

KU Project 43 – Ghent (GH) Station Effluent Limitations Guidelines (ELG) Water Treatment System, Bottom Ash Transport Water (BATW) Recirculation System, and Diffuser

<u>ELG</u> – OKEP plans to achieve Mechanical Completion in August and expects to begin the four (4) week performance test beginning in September 2024. Completion of punch list items will continue along with system walkdowns and system turnover book reviews. OKEP will complete record drawings and submit for review. Final Completion targeted for the late fourth quarter of 2024.

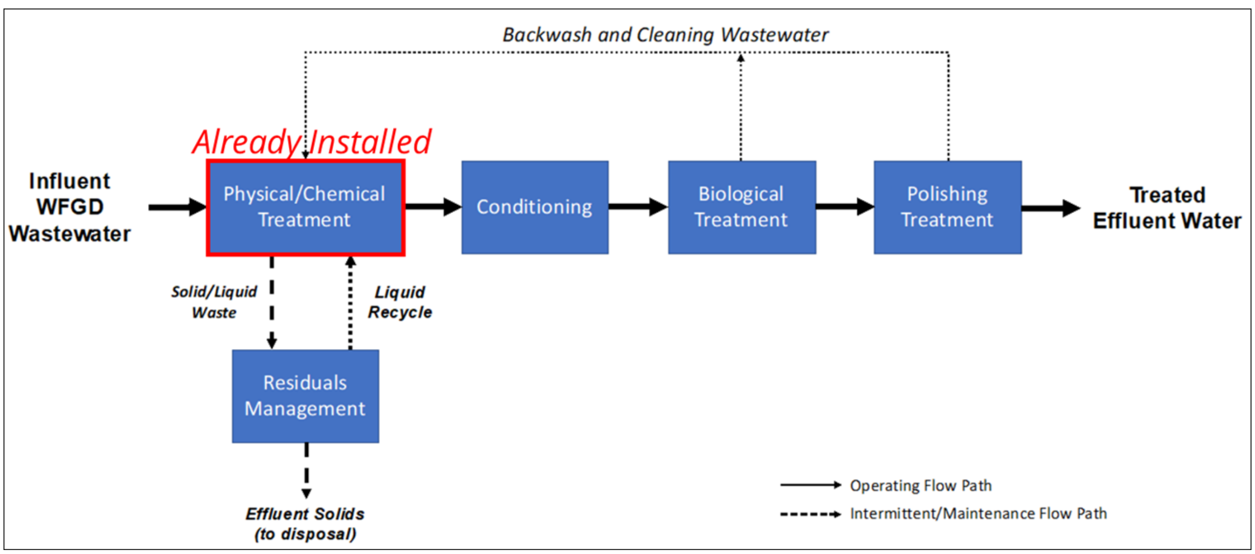
<u>BATW</u> – PE continues to work with OKEP to close punch list items and complete open remaining scope items that help reduce BATW water usage. These items include several smaller projects to minimize water intake into the reclaim tank in order to provide additional capacity for Bottom Ash water.

APPENDIX

ELG Water Treatment System Description – TC, MC, and GH

The ELG Rule requires the Companies to use the Best Available Technology Economically Achievable ("BAT")[9] to control particulate, metals, arsenic, mercury, selenium, and nitrates/nitrites. Current BAT technology is physical/chemical treatment plus biological treatment. The process water systems are physical/chemical systems designed to capture particulate and most metals; however, they are not designed to capture nitrates/nitrites and selenium. The levels of nitrate/nitrite and selenium capture required by the ELG Rule requires biological treatment of the process water treatment system's effluent.

The first step in the biological treatment process is denitrification, which is the reduction in concentration of nitrates/nitrites through a biological process utilizing denitrification equipment. Effluent from the denitrification equipment is discharged to the first stage reactor, which is comprised of fiberglass vessels and internal reactor surfaces. The reactor contains living microorganisms, which are fed nutrients and convert the nitrates/nitrites and selenium molecules in an aerobic atmosphere, to an elemental form. Effluent from the first stage reactor flows into a second stage reactor, where additional biological processes reduce remaining selenium. The elemental form of selenium is transferred, via a backwash phase of the process, to the equalization tanks at the beginning of the process water treatment system for particulate removal. The second stage reactor feeds to an ultrafiltration ("UF") system where remaining particulate metals are filtered out. The UF tank is then discharged to a series of clean water tanks, which can be used to backwash the biological and UF systems or be discharged. A "typical" flow diagram is shown below.



The majority of the mechanical and electrical systems will be constructed in a building for weather protection, whereas most of the biological process tanks will be located outside. The building houses the denitrification equipment, UF systems, effluent tanks, various pumps and support subsystems. The system also requires cleaning and chemical feed equipment, pumps, piping, valves, and electrical equipment.

[9] 84 Fed. Reg. 64624.

Separate rooms must be constructed inside the treatment building to house battery systems and electrical equipment. A control room is also required, along with restrooms. The reactor area, including the vessels housing the microorganisms, will be constructed outside the building under a weather canopy. All of the tanks and reactors in the system must be large enough to handle the immense volume of water flowing through the effluent treatment process. In other words, the system must be sized commensurate with the process water treatment systems recently commissioned to enable treatment of the effluent of flow from the process water treatment systems.

Diffusers Description – GH and MC

The diffusers planned to be installed at GH and MC are large multi-port pipes that connect to the stations' wastewater outfall pipe and are placed into the bottom of the Ohio River with the discharge ports above the riverbed and facing downstream. The pictures shown below provide a general concept of the GH diffuser, which will be similar to the proposed MC diffuser. As this graphic representatively shows, the diffuser is a single large discharge pipe that is installed in the riverbed. The diffuser ports face downstream to disperse the water out of multiple discharge ports instead of a single, larger point of discharge.

Ghent Outfall 001 Diffuser Concept

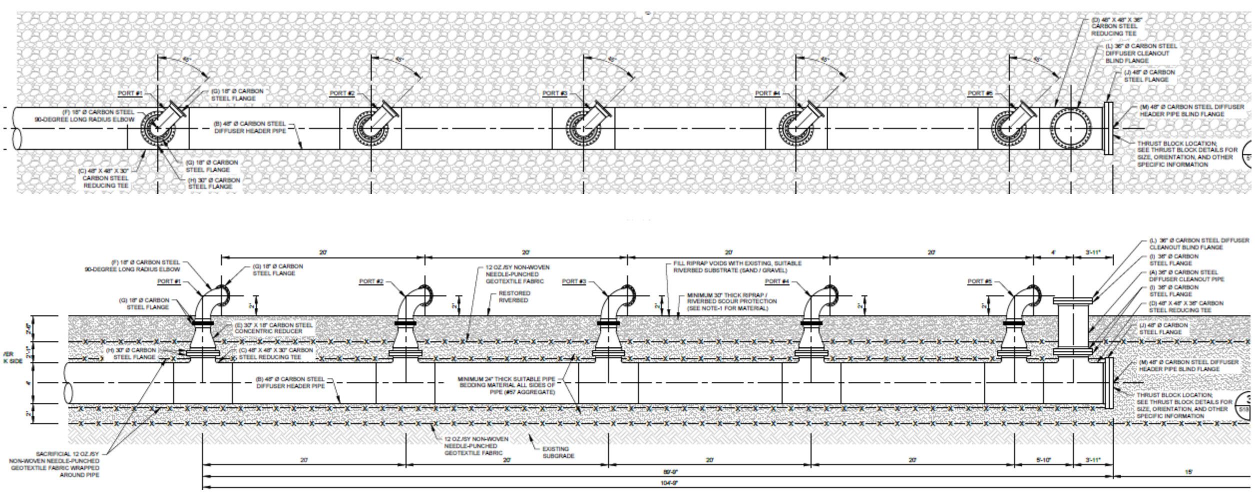


Exhibit 9

Part 2

Virginia State Corporation Commission
eFiling CASE Document Cover Sheet

220320302

Case Number (if already assigned)	PUR-2022-00001
Case Name (if known)	Petition of Appalachian Power Company for approval of a rate adjustment clause, the E-RAC, for costs to comply with state and federal environmental regulations pursuant to § 56-585.1 A 5 e of the Code of Virginia
Document Type	EXPE
Document Description Summary	Part 2 of 5 Petition of Appalachian Power Company
Total Number of Pages	99
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5.2 REC Price Sensitivities

The Company performed a lower cost sensitivity on the REC price using Plexos®. The sensitivity analysis reflected a 50% lower price than the base REC forecast. That sensitivity price curve was presented in Figure 8. The VCEA Plan (Portfolio 2) assumptions were used with the exception of a lower REC price forecast. The 30-year Net Present Value of Revenue Requirements for the lower REC sensitivity build plan was projected to be lower by 0.44% than Portfolio 2. Lowering the cost of RECs by 50% resulted in only two changes to the VCEA Plan. The changes were that the model selected RECs in 2036 which allowed 300 MW of solar to be delayed from 2035 to 2037, and that 95 MW of solar hybrid facilities previously added in 2038 were delayed until 2041 and reduced to 69 MW. By the end of the forecast horizon, the total amount of renewables (solar and wind) selected to be built under the lower REC price sensitivity case was unchanged from the VCEA Plan.

In addition to a lower priced REC sensitivity case, the Company evaluated higher REC prices. Based on the fact that RECs were not economically selected by the model in any of the six portfolios results displayed in the REC purchase table in Appendix B until 2036 or later, the Company did not use Plexos® to perform a higher priced REC sensitivity. That result would indicate that if RECs were not selected based on economics compared to physical resources at the base REC price, they would also not be selected at any higher REC price.

5.3 Portfolio Analysis and Economic Analysis Summary

Table 18 summarizes the net present value of the expected revenue requirement (NPVRR) for each compliant portfolio computed over 30 years. Total costs of each portfolio reflect a combination of fixed and variable costs and energy revenues from the Plexos® model, and certain other fixed costs and revenues, including capacity revenues and REC sales revenues calculated outside of Plexos®. The top half of the table displays each scenario's NPVRR broken down over four time periods which help to display the impacts of the assumed timing of the coal plant retirements. The 2028-2039 period is the period which will be most impacted by retirement of the coal plants in 2028 rather than their currently planned 2040 retirement dates.

The bottom half of the table under Column 3 displays the incremental cost of Portfolio 3 in which the coal plants retire in 2028 over Portfolio 1 in which the coal plants retire in 2040 assuming gas-fired resources are available to replace the plants. Column 4 in the bottom half of the table displays the incremental cost of Portfolio 4 in which the coal plants retire in 2028 over

Portfolio 2 in which the coal plants retire in 2040 assuming gas-fired resources are not available to replace the plants.

TABLE 18: NPV OF PORTFOLIO REVENUE REQUIREMENTS

Column	1	2	3	4	5	6
	Portfolio 1	Portfolio 2	Portfolio 3	Portfolio 4	Portfolio 5	Portfolio 6
Customer Revenue Requirements	2040 AM+MNTR Ret. RGGI CO2 Gas Option	2040 AM+MNTR Ret. RGGI-$15 CO2 No Gas Option	2028 AM+MNTR Ret. RGGI CO2 Gas Option	2028 AM+MNTR Ret. RGGI-$15 CO2 No Gas Option	2040 AM+MNTR Ret. RGGI-$15 CO2 No Gas Option High Wind Limits	2040 AM+MNTR Ret. RGGI-$15 CO2 No Gas Option Historical Wind CF
Net Present Value $M						
Utility NPV 2021-2027	$4,837	$4,839	$4,823	$5,018	$4,894	$4,850
Utility NPV 2028-2039	$7,047	$8,132	$8,615	$10,643	$8,041	$8,218
Utility NPV 2040-2051	$5,242	$6,078	$4,869	$5,878	$5,980	$6,435
NPV of End Effects beyond 2051	$4,494	$5,662	$4,556	$5,706	$5,276	$5,762
TOTAL Utility Cost, Net Present Value	$21,620	$24,710	$22,863	$27,245	$24,191	$25,266

Incremental Cost/ (Savings) of Early Coal Retirement

	Portfolio 3-Portfolio 1	Portfolio 4-Portfolio 2
Customer Revenue Requirements	2028-2040 RGGI CO2 Gas Option	2028-2040 RGGI-$15 CO2 No Gas Option
Net Present Value $M	Incremental Cost/ (Savings)	
Utility NPV 2021-2027	($14)	$179
Utility NPV 2028-2039	$1,568	$2,511
Utility NPV 2040-2051	($373)	($199)
NPV of End Effects beyond 2051	$62	$45
TOTAL Utility Cost, Net Present Value	$1,242	$2,535

5.4 Economic Analysis Conclusions

High-level conclusions from Table 18 include:

- The Scenarios that retired Amos and Mountaineer in 2040 would be less costly for customers than the scenarios (Portfolio 3 and 4) that retired them in 2028;
- Allowing gas-fired resources to replace a portion of the capacity of Amos and Mountaineer when they retire, whenever that is, is likely to be less costly than replacing them with 100% renewable resources. This does not reflect that additional technologies, particularly non-emitting technologies such as small modular nuclear reactors, hydrogen, carbon capture, advanced battery concepts, and renewables, will be available in the future, particularly when considering a 2040 retirement date for these units; and
- Portfolio 5 with 1,000 MW more near term wind has a lower NPVRR than the minimally compliant Portfolio 2 VCEA Plan, which indicates that the Company should seek to acquire more wind while PTCs are available than the minimum required for VCEA compliance. In addition, Portfolio 6, which was a lower wind capacity factor sensitivity case, indicates that the results are not very sensitive to

wind capacity factor. The capacity factor in that scenario was assumed to be 30.4% instead of the base case assumed 35%. Comparing the NPVRR to Portfolio 2, which is the other comparable "2040 retirement, no gas" case, reveals that the results are only 2.2% more expensive when viewed over 30 years.

5.5 Capital Investment Requirements

The six portfolios resulted in a wide range of potential capital investment in resources necessary to maintain both the required amount of capacity and meet the VCEA renewable energy targets. Total expected capital investment for all resources is summarized in Table 19.

TABLE 19: PORTFOLIO NEW RESOURCE CAPITAL INVESTMENT REQUIREMENTS

	Total 2025-2028 Capital Investment ($ Millions)		
	Total All Resources	Total Owned Resources	Total PPA Resources
Portfolio 1 2040 Ret With Gas	$628	$317	$311
Portfolio 2 2040 Ret No Gas	$628	$317	$311
Portfolio 3 2028 Ret With Gas	$4,230	$3,918	$311
Portfolio 4 2028 Ret No Gas	$5,746	$4,619	$1,127
Portfolio 5 2040 Ret No Gas High Wind	$2,039	$171	$1,868
Portfolio 6 2040 Ret No Gas Hist Wind CF	$700	$389	$311

	Total 30 year Capital Investment ($ Million)		
	Total All Resources	Total Owned Resources	Total PPA Resources
Portfolio 1 2040 Ret With Gas	$10,137	$8,057	$2,080
Portfolio 2 2040 Ret No Gas	$12,841	$10,771	$2,071
Portfolio 3 2028 Ret With Gas	$9,946	$7,652	$2,294
Portfolio 4 2028 Ret No Gas	$16,712	$13,945	$2,767
Portfolio 5 2040 Ret No Gas High Wind	$16,157	$10,367	$5,790
Portfolio 6 2040 Ret No Gas Hist Wind CF	$13,178	$10,654	$2,524

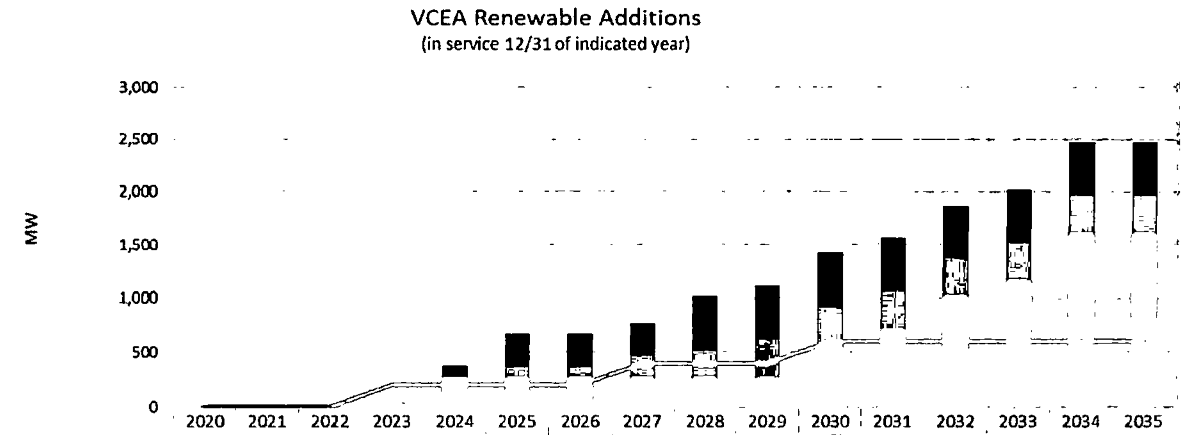
The analysis summarized in Table 19 shows that retiring Amos and Mountaineer in 2028 would result in $4-6 billion of investment between the Company and PPA providers between 2025 and 2028 to replace those plants. This level of investment is unprecedented, and is quite large relative to the overall size of APCo in a relatively short time frame, leading to large rate increases in a short period of time. The VCEA Plan (Portfolio 2) would delay the required capital investment in replacing Amos and Mountaineer, with very modest capital expense requirements in the 2025-2028 period for the resources required by the VCEA. Over the full 30-year period, the VCEA Plan would require the third highest amount of capital investment of the six portfolios. This is largely due to the high cost of storage which would be required in the event gas options are not available to replace the retiring coal plants in 2040.

The underlying construction costs of each resource type over the period on a real dollar cost per KW basis are presented in Appendix E. Based on projections by NREL that were adopted by the Company in this analysis and reflected in Appendix E, costs are expected to decline in real dollars terms over the near term on most resource types for several years before beginning to increase again towards the end of the 30-year period.

5.6 VCEA Plan Resource Additions

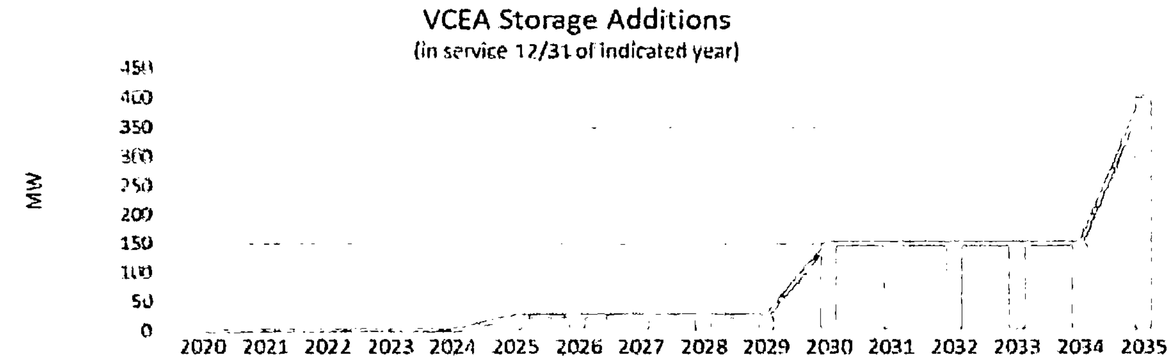
Figure 10 and Figure 11 illustrate the timing of new renewable and storage resources included in the VCEA Plan to meet the requirements. Additions of new renewable and intermittent resources to the fleet begin in 2021 and continue periodically through the planning period. Storage resources, are added beginning in 2025 and include gradual increases until meeting the 400 MW VCEA RPS minimum. Further details of the resource additions by resource type for all portfolios are presented in Appendix B.

FIGURE 10: VCEA COMPLIANT WIND AND SOLAR ADDITIONS



	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Wind Owned	0	0	0	0	102	302	302	302	502	502	502	502	502	502	502	502
Wind PPA						100	100	200	250	350	350	350	350	350	350	350
Solar-Utility	0	0	5	30	180	180	180	180	180	180	330	330	480	480	780	780
Solar-PPA	0	0	0	0	89	89	89	89	89	89	239	389	539	689	839	839
VCEA RPS Rqmt	0	0	0	200	200	200	200	400	400	400	600	600	600	600	600	600

FIGURE 11 VCEA COMPLIANT STORAGE ADDITIONS



	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Storage	0	0	0	0	0	25	25	25	25	25	150	150	150	150	150	400
VCEA Strg Rqmt	0	0	0	0	0	25	25	25	25	25	150	150	150	150	150	400

Table 20 lists the cumulative Energy Efficiency additions in the VCEA plan through 2025 to meet the VCEA requirements.

TABLE 20: VCEA PLAN ENERGY EFFICIENCY ADDITIONS

	Portfolios		Portfolio 2		
	Descriptions		2040 AM+MNTR Ret. RGGI-$15 CO2 No Gas Option		
	Tgt %	VCEA EE Trgt Svgs GWh	RES GWh	COM GWh	Surplus/ (Deficit) GWh
2022	0.5%	72	48	24	(0)
2023	1.0%	145	99	47	1
2024	1.5%	217	144	73	(0)
2025	2.0%	289	197	93	1

5.7 VCEA Plan Compliance Plan Summary

The composition of APCo's generation fleet, including existing and new resources modeled in the VCEA Plan (Portfolio 2) to meet the RPS requirements is illustrated in terms of nameplate capacity MW in Figure 12. APCo's capacity position versus its PJM UCAP capacity obligation is shown in tabular format in Table 21. In response to requirement (5) in the Order on the 2020 Filing, the Company, a multi-jurisdictional utility, is meeting its PJM capacity obligations through the use of all resource types, including fossil resources, where appropriate.

FIGURE 12: APCO VCEA PLAN 2021-2050 CAPACITY

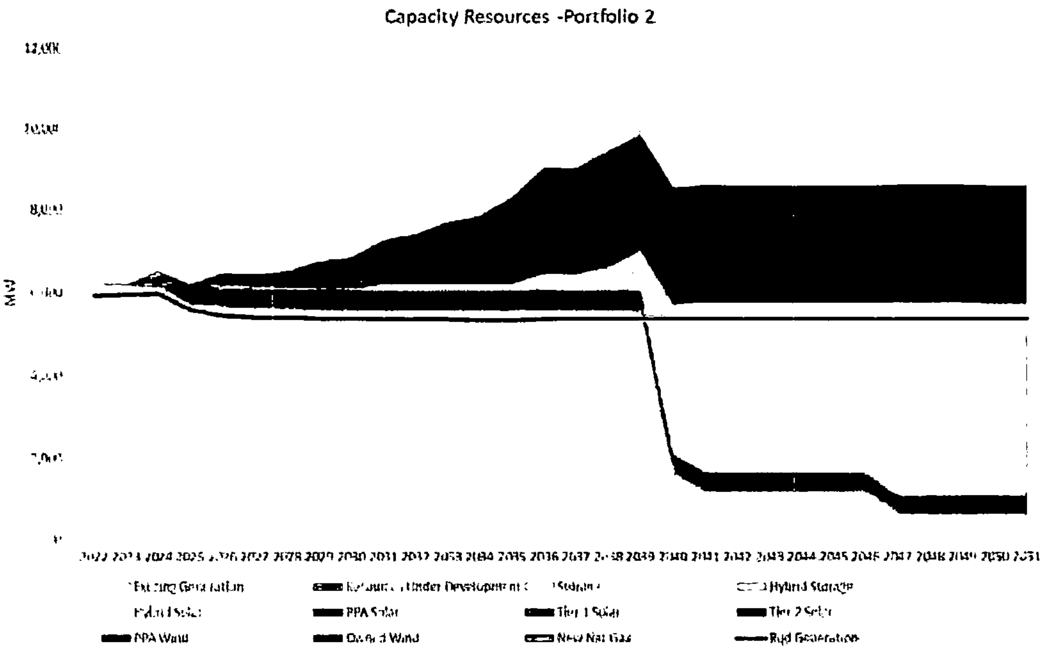
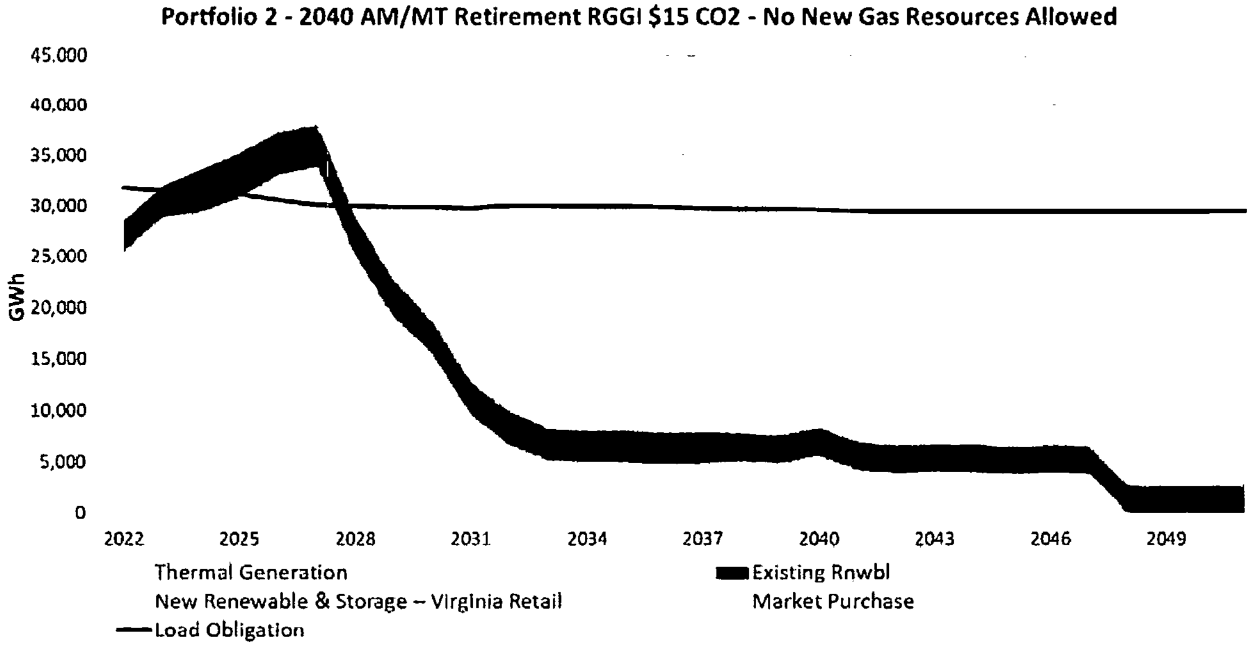


TABLE 21: VCEA PLAN (PORTFOLIO 2) RESOURCE ADDITIONS AND CAPACITY POSITION

Portfolio 2		2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
VCEA Compliant w/RGGI $15 CO2	Resources under Development (NmPlt)	15	65	418	507	507	507	507	507	507	507	507	507	507	507	507	507	507	507	507
	Resources under Development (Firm)	8	35	135	163	148	132	117	117	117	117	117	117	117	117	117	117	117	117	117
	New Nat. Gas-CC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	New Nat. Gas-CT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	New Utility Solar (NmPlt)	0	0	0	0	0	0	0	0	0	150	150	300	300	600	900	900	1,200	1,200	1,200
	New Utility Solar (Firm)	0	0	0	0	0	0	0	0	0	39	39	78	78	156	234	234	312	312	312
	New PPA Solar (NmPlt)	0	0	0	0	0	0	0	0	0	150	300	450	600	750	900	900	900	900	900
	New PPA Solar (Firm)	0	0	0	0	0	0	0	0	0	39	78	117	156	195	234	234	234	234	234
	New Paired Solar (NmPlt)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	111	411	636
	New Paired Solar (Firm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	107	165
	New Wind (Nameplate)	0	0	0	0	200	200	200	400	400	400	400	400	400	400	400	400	400	400	400
	New Wind (Firm)	0	0	0	0	26	24	22	44	40	40	40	40	40	40	40	40	40	40	40
	New Wind PPA (NmPlt)	0	0	0	0	100	100	200	250	350	350	350	350	350	350	350	350	350	350	350
	New Wind PPA (Firm)	0	0	0	0	13	12	22	28	35	35	35	35	35	35	35	35	35	35	35
	Storage Capacity (NmPlt)	0	0	0	0	25	25	25	25	25	150	150	150	150	150	400	400	400	400	2,725
	Storage Capacity (Firm)	0	0	0	0	18	18	18	17	19	137	137	137	137	137	364	364	364	364	2,480
	Storage Paired (NmPlt)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	137	212
	Storage Paired (Firm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	130	201
	New EE	14	29	44	57	75	71	68	16	13	10	8	6	5	4	6	7	8	9	10
	New VVO	0	0	0	0	0	0	0	0	0	0	0	0	0	6	16	29	38	47	56
	New DG	0	0	0	35	40	46	52	59	67	72	74	76	77	79	83	88	92	96	101
Total Additions (Firm & Degraded)		22	64	179	255	319	303	298	281	291	488	527	605	644	769	1,129	1,146	1,303	1,491	3,751
Capacity Reserves (MW) without new additions		290	198	133	121	204	194	195	205	204	208	212	214	216	216	207	186	186	185	(3,731)
Capacity Reserves (MW) with new additions		312	262	312	376	523	498	493	486	495	696	739	819	860	985	1,337	1,332	1,489	1,675	20

The transition to more intermittent and renewable resources will impact the Company's anticipated energy output from its fleet. The Company will maintain appropriate capacity reserves, however, energy delivered to APCo's non-Virginia customers is expected to be purchased from the market and from fossil resources as shown in Figure 13.

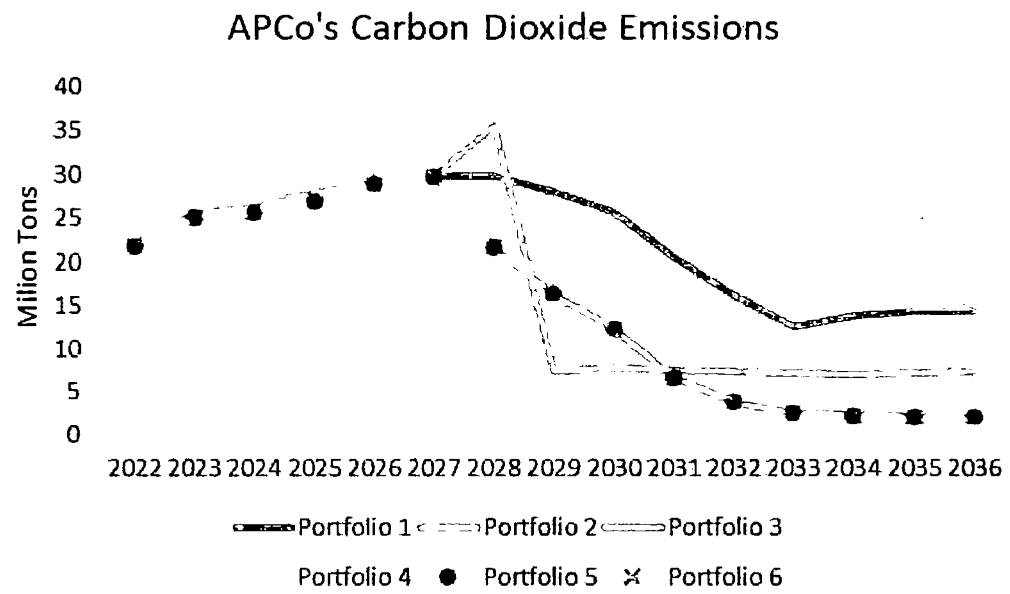
FIGURE 13: VCEA PLAN SOURCES OF ENERGY – TOTAL COMPANY



5.8 Carbon Dioxide Reduction Requirements

The Company's six modeled portfolios reflect a forecasted reduction of CO_2 emissions. Figure 14 illustrates the 2022-2036 reduction of CO_2 from associated with the modeled portfolios. Portfolios 1 and 3 reflect a RGGI-only carbon view, and Portfolios 2, 4, 5 and 6 reflect a RGGI plus $15/ton national carbon burden and show a quicker reduction of CO_2.

FIGURE 14: CARBON DIOXIDE EMISSIONS – TOTAL COMPANY



6.0 Rate Impacts

The Company prepared estimated rate impacts associated with the implementation of the VCEA under Portfolio 2. In order to estimate rate impacts, the Company assumed a consistent class allocation for the period 2022-2035, based on a 2020 test year. The class allocation methodology splits costs 85-15% between a 6-cp and an energy allocation methodology. The actual cost allocation methodology could vary from the Company's assumption in this proceeding.

6.1 VCEA Lifetime Revenue Requirement - Gross

The lifetime revenue requirement includes the costs of the renewables and storage, including financing costs. It is undiscounted, meaning that $100 in 2050 is not distinguished from $100 spent in 2021. This number is not particularly meaningful and can be misleading as it does not include the value of the energy or capacity generated by these renewable, efficiency and storage resources. Table 22 shows the gross revenue requirement by year and by component.

TABLE 22 JURISDICTIONAL GROSS REVENUE REQUIREMENT

Virginia Jurisdctional Gross Revenue Requirement By Year - No Offsets ($000)

	Specific Resources Under Development			Generic Resources					
	Wind	Solar	QF PPA's	Wind	Solar	Storage	EE / DR/ VVO	REC Purchases	Total $000
2021	-	-	278	-	-	-	-	140	418
2022	-	-	1,910	-	-	-	8,323	664	10,897
2023	472	-	1,935	-	-	-	8,589	5,673	16,668
2024	9,938	3,775	1,961	-	-	-	6,613	-	22,288
2025	8,661	21,817	1,989	-	-	-	5,061	-	37,528
2026	9,458	21,094	2,018	36,913	-	4,546	4,989	-	79,018
2027	9,822	21,260	2,048	36,913	-	4,541	120	-	74,704
2028	9,492	20,121	2,080	52,661	-	4,537	226	-	89,118
2029	9,860	18,742	2,114	95,325	-	4,530	211	-	130,783
2030	10,260	18,641	2,149	111,476	-	4,524	194	-	147,245
2031	10,148	18,261	2,186	111,476	31,345	26,015	262	-	199,693
2032	10,038	17,574	2,225	111,476	46,597	26,038	802	-	214,752
2033	9,963	17,146	2,266	111,476	78,906	26,049	1,013	-	246,819
2034	9,830	16,532	2,309	111,476	94,612	26,065	945	-	261,768
2035	9,716	25,297	2,354	111,476	145,194	26,081	2,133	-	322,251
2036	9,603	24,864	2,342	111,476	196,517	70,880	8,327	-	424,009
2037	9,536	24,370	-	111,476	196,517	70,905	9,771	-	422,575
2038	9,485	23,930	-	111,476	251,301	70,949	13,254	-	480,395
2039	9,358	23,527	-	111,476	302,215	70,993	16,750	-	534,320
2040	9,272	22,987	-	111,476	340,916	235,730	20,465	-	740,846
2041	9,186	22,512	-	111,476	347,725	276,075	25,729	-	792,703
2042	9,103	22,109	-	111,476	347,725	276,252	24,701	34,151	825,517
2043	9,062	21,648	-	111,476	347,725	276,417	24,860	35,089	826,277
2044	8,936	21,287	-	111,476	347,725	276,671	25,041	72,346	863,482
2045	8,854	20,736	-	111,476	347,725	276,782	25,189	93,737	884,498
2046	8,777	20,261	-	111,476	347,725	283,795	25,359	136,329	933,722
2047	8,683	19,839	-	111,476	347,725	347,551	27,135	161,822	1,024,230
2048	8,615	19,476	-	111,476	347,725	347,879	25,738	212,632	1,073,542
2049	8,459	19,030	-	111,476	347,725	348,020	25,901	265,167	1,125,779
2050	8,349	18,505	-	111,476	347,725	405,056	26,424	295,608	1,213,144
Lifetime (000)	$ 252,938	$ 545,341	$ 32,162	$ 2,562,814	$ 5,161,368	$ 3,786,882	$ 364,125	$ 1,313,360	$ 14,018,990

6.2 Rate Impacts

The Company has prepared the rate impacts of the VCEA relative to current rates. The increases are the result of multiple factors including the addition of resources required to meet the VCEA, assumptions about the start of a national carbon tax in 2028, the need to replace the Company's retiring coal and gas plants, and an assumption of general commodity price inflation. For illustrative purposes, the Company shows the estimated impact on a residential customer using 1,000 kWh, and SGS customer using 5,000 kWh, and a 1 MW customer with an 80% load factor in Table 23. Please note that the rate impacts show in table 23 are not solely the cost of VCEA RPS compliance. To show that impact the Company would need to model a non-RPS compliant plan and compare it to RPS compliant plans. The Company was instructed in the Commission's 2021 VCEA Order to no longer model non-RPS compliant plans.

TABLE 23 MONTHLY RATE IMPACTS

Estimated Monthly Rate Impacts - Selected Rate Schedules

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Residential Customer Gross [1000 kWh]	$ 117.09	$ 117.09	$ 117.09	$ 123.38	$ 126.83	$ 138.20	$ 149.96	$ 155.72	$ 185.51	$ 174.80	$ 165.31	$ 150.41	$ 143.78	$ 144.85	$ 148.43	$ 155.40
Offsets		0.04	0.25	(5.64)	(7.57)	(13.96)	(22.79)	(26.23)	(38.73)	(23.48)	(11.71)	5.76	15.69	18.68	18.87	16.39
Net Impact	$ 117.09	117.13	117.34	117.75	119.26	124.24	127.17	129.49	146.78	151.32	153.60	156.17	159.47	163.53	167.30	171.79
% increase (cumulative)		0%	0%	1%	2%	6%	9%	11%	25%	29%	31%	33%	36%	40%	43%	47%
SGS Customer Gross [5,000 kWh]	$ 495.99	$ 495.99	$ 495.99	$ 522.65	$ 537.27	$ 585.40	$ 635.23	$ 659.63	$ 785.82	$ 740.44	$ 700.26	$ 637.13	$ 609.05	$ 613.57	$ 628.76	$ 658.27
Offsets		$ 0.14	$ 1.02	$ (24.01)	$ (32.53)	$ (60.63)	$ (98.68)	$ (113.73)	$ (170.34)	$ (106.70)	$ (57.34)	$ 16.12	$ 57.50	$ 69.29	$ 69.29	$ 57.86
Net Impact	$ 495.99	$ 496.13	$ 497.01	$ 498.64	$ 504.73	$ 524.77	$ 536.56	$ 545.90	$ 615.48	$ 633.74	$ 642.92	$ 653.25	$ 666.54	$ 682.86	$ 698.06	$ 716.13
% increase (cumulative)		0%	0%	1%	2%	6%	8%	10%	24%	28%	30%	32%	34%	38%	41%	44%
LPS, 1 MW, 80% load factor Gross	$ 37,788.21	$ 37,788.21	$ 37,788.21	$ 39,819.19	$ 40,933.04	$ 44,599.80	$ 48,396.67	$ 50,255.53	$ 59,869.42	$ 56,412.28	$ 53,351.09	$ 48,541.16	$ 46,401.60	$ 46,746.16	$ 47,903.83	$ 50,151.81
Offsets		$ 17.88	$ 127.97	$ (1,699.04)	$ (2,048.28)	$ (3,202.86)	$ (5,521.31)	$ (6,208.72)	$ (7,097.16)	$ (1,348.97)	$ 2,862.50	$ 8,968.31	$ 12,775.09	$ 14,475.96	$ 15,224.71	$ 15,242.81
Net Impact	$ 37,788.21	$ 37,806.09	$ 37,916.18	$ 38,120.15	$ 38,884.76	$ 41,396.94	$ 42,875.36	$ 44,046.81	$ 52,772.26	$ 55,063.30	$ 56,213.60	$ 57,509.47	$ 59,176.68	$ 61,222.12	$ 63,128.53	$ 65,394.63
% increase (cumulative)		0%	0%	1%	3%	10%	13%	17%	40%	46%	49%	52%	57%	62%	67%	73%
Total Net Annual Increases		0.0%	0.2%	0.4%	1.5%	4.9%	2.7%	2.1%	15.4%	3.5%	1.7%	1.9%	2.4%	2.9%	2.6%	3.0%

7.0 RFP Process

The Company, by itself and through its support from AEPSC, has extensive RFP experience for the procurement of the resources required under the VCEA. AEPSC has previously performed RFPs in Virginia on behalf of APCo, and has also performed RFPs for AEP's other vertically-integrated utilities including KPCo, I&M, SWEPCO, PSO that have resulted in the procurement, or currently planned procurement, of thousands of megawatts of renewable resources. The Company has extensive experience analyzing purchase and sale agreements for both utility-owned and contracted renewables.

As reflected in Section 56.585.5, the Company is required to issue annual RFPs in order to meet the resource acquisition and RPS standards. The Company expects to procure materially all resources through this process, whether through acquisition or contracts for energy, capacity, and environmental attributes. The RFP process will be open to interested and qualified parties including, potentially, its own affiliates. The Company may also submit a "self-build" proposal.

In order to meet the 35% non-utility resource requirement, annual RFPs will allow for the procurement of both utility and non-utility owned resources. The Company does not expect to be able to meet the 35% PPA requirement included in Sections 56.585.5. D and 56.585.5. E with precision each year, as the most economic project sizes may not fit this metric in any given year. Nevertheless, it is the Company's intention to continue to adjust the RFP to target resources that will meet this requirement over time.

If the Company's competitive affiliates have the opportunity to participate in the RFP process, the Company will ensure that proper controls are in place to guarantee all bids are considered on an even basis. The Company and AEPSC have experience with monitoring bids from affiliates, and can ensure that all necessary protections to maintain an equitable and reasonable review process occur considering all bids on an equal basis.

Finally, the Company expects to issue its annual RFPs in the first quarter of each year.

8.0 Summary

The Company's 2021 VCEA plan includes a geographically varied portfolio of storage, solar and wind resources, both Company and third-party owned, as well as market REC purchases. In the petition accompanying this filing associated with this Plan, the Company is proposing a variety of resources to meet the mandates of the VCEA.

The Company has produced six portfolios for stakeholders' consideration that give an indication of the costs of compliance with the VCEA under various future resource assumptions.

Portfolio 2 is the Company's base plan, while Portfolio 5 is a modified Portfolio 2 that represents a lower cost option for customers, should the resources prove to be available. The Company's short-term Action Plan is as follows:

- Issue RFPs early in 2022 in support of Portfolio 5.
- Seek competitive offers for energy storage in support of non-wires alternatives and the storage requirements in Subsection E.
- Utilize 100% of the Company's hydro resources for VCEA compliance beginning in 2025 through intra-Company transactions at market value.
- Monitor federal and state regulatory developments related to continued operation of the Amos and Mountaineer plants
- Monitor developments in REC markets to evaluate RECs as a compliance option

APCo Exhibit No. ___
Witness: JFM
Schedule 1

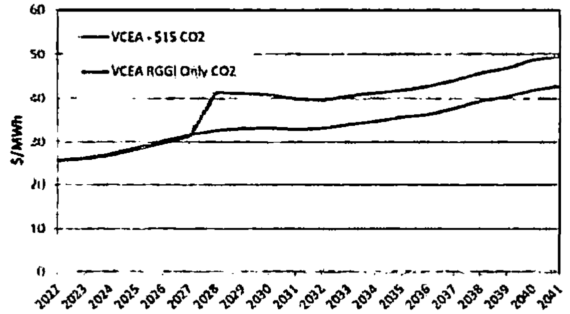
APPENDIX

220320302

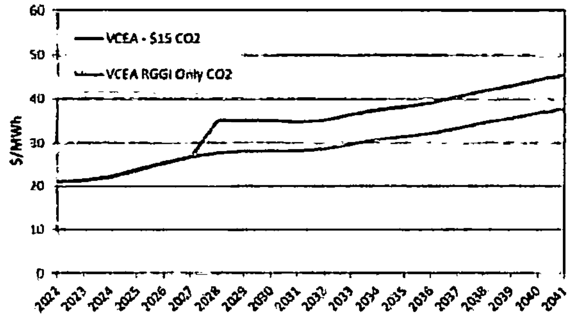
Appendix A: Fundamentals

FUNDAMENTALS

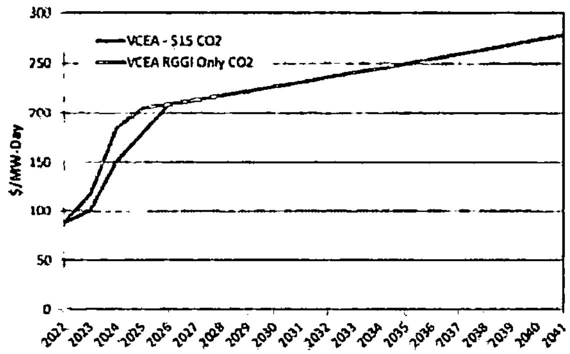
PJM AEP On-Peak Energy Prices - (Nominal $/MWh)



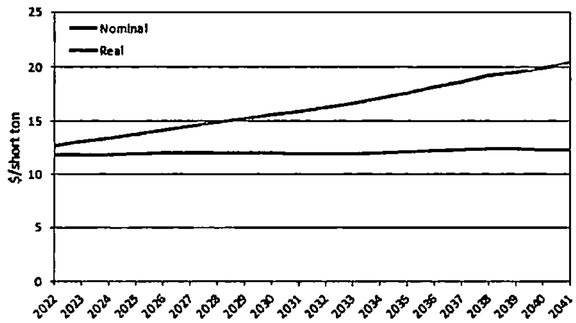
PJM AEP Off-Peak Energy Prices - (Nominal $/MWh)



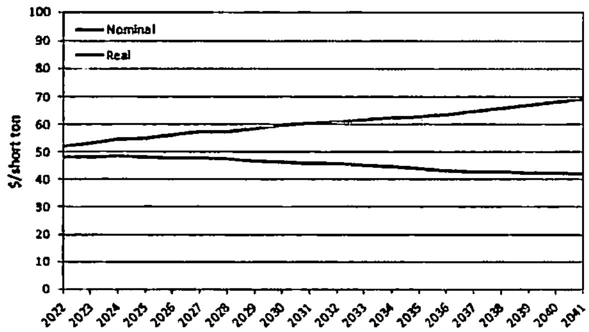
PJM AEP Capacity Prices (Nominal $/MW-day)



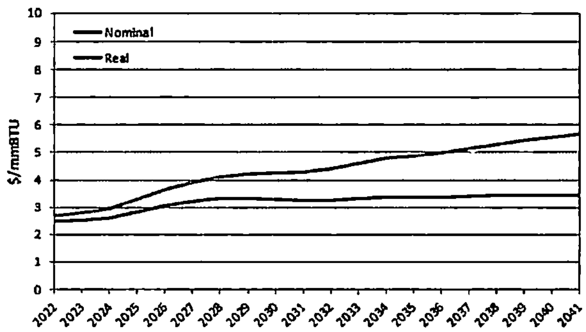
PRB 8800 Coal Prices - ($/ton, FOB Origin)



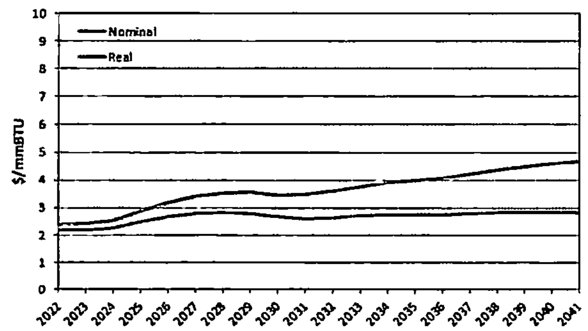
NAPP Coal Prices - ($/ton, FOB Origin)



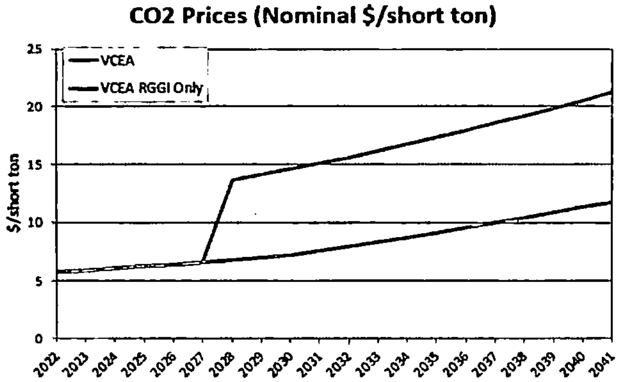
Henry Hub Gas Prices



Dominion South Delivered Gas Prices



APCo Exhibit No. ___
Witness: JFM
Schedule 1



Appendix B: Scenario Resource Plan Details

TABLE 24 PORTFOLIO 1 NAMEPLATE AND FIRM (UCAP) RESOURCE ADDITIONS AND CAPACITY

Portfolio 1		2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
VCEA Compliant w/RGGI $15 CO2	Resources under Development NmPlt)	15	65	418	506.9	506.9	506.9	506.9	506.9	506.9	506.9	506.9	506.9	506.9	506.9	506.9	506.9	506.9	506.9	506.9
	New Nat. Gas-CC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,390
	New Nat. Gas-CT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	714
	New Utility Solar (NmPlt)	0	0	0	0	0	0	0	0	0	150	150	300	300	300	600	900	1,200	1,200	1,200
	New Utility Solar (Firm)	0	0	0	0	0	0	0	0	0	39	39	78	78	78	156	234	312	312	312
	New PPA Solar (NmPlt)	0	0	0	0	0	0	0	0	0	150	300	450	600	750	900	900	900	900	900
	New PPA Solar (Firm)	0	0	0	0	0	0	0	0	0	39	78	117	156	195	234	234	234	234	234
	New Paired Solar (NmPlt)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	219	669
	New Paired Solar (Firm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57	174
	New Wind (Nameplate)	0	0	0	0	200	200	200	400	400	400	400	400	400	400	400	400	400	400	400
	New Wind (Firm)	0	0	0	0	26	24	22	44	40	40	40	40	40	40	40	40	40	40	40
	New Wind PPA (NmPlt)	0	0	0	0	100	100	200	250	350	350	350	350	350	350	350	350	350	350	350
	New Wind PPA (Firm)	0	0	0	0	13	12	22	28	35	35	35	35	35	35	35	35	35	35	35
	Storage Capacity (NmPlt)	0	0	0	0	25	25	25	25	25	150	150	150	150	150	400	400	400	400	400
	Storage Capacity (Firm)	0	0	0	0	18	18	18	17	19	137	137	137	137	137	364	364	364	364	364
	Storage Paired (NmPlt)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	73	223
	Storage Paired (Firm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	69	212
	New EE	14	29	44	57	71	68	65	13	11	8	6	4	2	1	0	1	1	2	2
	New VVO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	20	29	41
	New DG	0	0	0	35	40	46	52	59	67	72	74	76	77	79	83	88	92	96	101
Total Additions (Firm & Degraded)		29	94	462	599	675	675	685	669	679	876	916	993	1,032	1,072	1,420	1,513	1,605	1,745	4,126
Capacity Reserves (MW) without new additions		290	198	133	121	204	194	195	205	204	208	212	214	216	216	207	186	186	185	(3,731)
Capacity Reserves (MW) with new additions		312	262	312	376	519	494	490	483	493	694	737	817	858	898	1,237	1,308	1,400	1,539	5

Table 25 Portfolio 2 Nameplate and Firm (UCAP) Resource Additions And Capacity Position

Portfolio 2		2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
VCEA Compliant w/RGGI $15 CO2	Resources under Development (NmPlt)	15	65	418	507	507	507	507	507	507	507	507	507	507	507	507	507	507	507	507
	Resources under Development (Firm)	8	35	135	163	148	132	117	117	117	117	117	117	117	117	117	117	117	117	117
	New Nat. Gas-CC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	New Nat. Gas-CT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	New Utility Solar (NmPlt)	0	0	0	0	0	0	0	0	0	150	150	300	300	600	900	900	1,200	1,200	1,200
	New Utility Solar (Firm)	0	0	0	0	0	0	0	0	0	39	39	78	78	156	234	234	312	312	312
	New PPA Solar (NmPlt)	0	0	0	0	0	0	0	0	0	150	300	450	600	750	900	900	900	900	900
	New PPA Solar (Firm)	0	0	0	0	0	0	0	0	0	39	78	117	156	195	234	234	234	234	234
	New Paired Solar (NmPlt)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	111	411	636
	New Paired Solar (Firm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	107	165
	New Wind (Nameplate)	0	0	0	0	200	200	200	400	400	400	400	400	400	400	400	400	400	400	400
	New Wind (Firm)	0	0	0	0	26	24	22	44	40	40	40	40	40	40	40	40	40	40	40
	New Wind PPA (NmPlt)	0	0	0	0	100	100	200	250	350	350	350	350	350	350	350	350	350	350	350
	New Wind PPA (Firm)	0	0	0	0	13	12	22	28	35	35	35	35	35	35	35	35	35	35	35
	Storage Capacity (NmPlt)	0	0	0	0	25	25	25	25	25	150	150	150	150	150	400	400	400	400	2,725
	Storage Capacity (Firm)	0	0	0	0	18	18	18	17	19	137	137	137	137	137	364	364	364	364	2,480
	Storage Paired (NmPlt)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	137	212
	Storage Paired (Firm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	130	201
	New EE	14	29	44	57	75	71	68	16	13	10	8	6	5	4	6	7	8	9	10
	New VVO	0	0	0	0	0	0	0	0	0	0	0	0	0	6	16	29	38	47	56
	New DG	0	0	0	35	40	46	52	59	67	72	74	76	77	79	83	88	92	96	101
Total Additions (Firm & Degraded)		22	64	179	255	319	303	298	281	291	488	527	605	644	769	1,129	1,146	1,303	1,491	3,751
Capacity Reserves (MW) without new additions		290	198	133	121	204	194	195	205	204	208	212	214	216	216	207	186	186	185	(3,731)
Capacity Reserves (MW) with new additions		312	262	312	376	523	498	493	486	495	696	739	819	860	985	1,337	1,332	1,489	1,675	20

TABLE 26 PORTFOLIO 3 NAMEPLATE AND FIRM (UCAP) RESOURCE ADDITIONS AND CAPACITY POSITION

Portfolio 3		2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
VCEA Compliant w/RGGI Federal CO2	Resources under Development (NmPlt)	15	65	418	507	507	507	507	507	507	507	507	507	507	507	507	507	507	507	507
	Resources under Development (Firm)	8	35	135	163	148	132	117	117	117	117	117	117	117	117	117	117	117	117	117
	New Nat. Gas-CC	0	0	0	0	0	0	2,780	2,780	2,780	2,780	2,780	2,780	2,780	2,780	2,780	2,780	2,780	2,780	2,780
	New Nat. Gas-CT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	New Utility Solar (NmPlt)	0	0	0	0	0	0	0	0	0	150	150	150	300	450	750	1,050	1,050	1,050	1,050
	New Utility Solar (Firm)	0	0	0	0	0	0	0	0	0	39	39	39	78	117	195	273	273	273	273
	New PPA Solar (NmPlt)	0	0	0	0	150	150	300	450	600	750	750	900	900	900	900	900	900	900	900
	New PPA Solar (Firm)	0	0	0	0	66	63	117	162	186	195	195	234	234	234	234	234	234	234	234
	New Paired Solar (NmPlt)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	New Paired Solar (Firm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	New Wind (Nameplate)	0	0	0	0	200	200	200	200	200	200	400	400	400	400	400	400	600	600	600
	New Wind (Firm)	0	0	0	0	26	24	22	22	20	20	40	40	40	40	40	40	60	60	60
	New Wind PPA (NmPlt)	0	0	0	0	100	100	150	150	150	150	150	200	250	250	250	300	300	300	300
	New Wind PPA (Firm)	0	0	0	0	13	12	17	17	15	15	15	20	25	25	25	30	30	30	30
	Storage Capacity (NmPlt)	0	0	0	0	25	25	300	300	300	425	425	425	425	425	675	675	400	400	400
	Storage Capacity (Firm)	0	0	0	0	18	18	210	207	228	387	387	387	387	387	614	614	364	364	364
	Storage Paired (NmPlt)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Storage Paired (Firm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	New EE	18	31	49	75	106	102	99	44	38	30	23	16	11	7	4	2	2	1	0
	New VVO	0	0	0	0	0	12	23	23	23	23	23	23	23	23	23	23	23	23	23
	New DG	0	0	0	35	40	46	52	59	67	72	74	76	77	79	83	88	92	96	101
Total Additions (Firm & Degraded)		23	66	184	273	417	409	3,436	3,431	3,474	3,677	3,692	3,731	3,771	3,808	4,115	4,200	3,974	3,977	3,982
Capacity Reserves (MW) without new additions		290	198	133	121	204	194	(3,417)	(3,400)	(3,402)	(3,396)	(3,389)	(3,385)	(3,382)	(3,381)	(3,396)	(3,422)	(3,423)	(3,424)	(3,731)
Capacity Reserves (MW) with new additions		313	264	317	395	621	603	19	30	72	281	303	345	389	427	718	778	550	553	250

TABLE 27 PORTFOLIO 4 NAMEPLATE AND FIRM (UCAP) RESOURCE ADDITIONS AND CAPACITY POSITION

Portfolio 4		2022	2023	2024	2025	2026	2027	2028	2029	2030
VCEA Compliant w/RGGI $15 CO2	Resources under Development (NmPlt)	15	65	418	507	507	507	507	507	507
	Resources under Development (Firm)	8	35	135	163	148	132	117	117	117
	New Nat. Gas-CC	0	0	0	0	0	0	0	0	0
	New Nat. Gas-CT	0	0	0	0	0	0	0	0	0
	New Utility Solar (NmPlt)	0	0	0	300	600	600	600	600	600
	New Utility Solar (Firm)	0	0	0	144	264	252	234	216	186
	New PPA Solar (NmPlt)	0	0	0	150	300	300	300	300	300
	New PPA Solar (Firm)	0	0	0	72	132	126	117	108	93
	New Paired Solar (NmPlt)	0	0	0	0	148	148	148	148	148
	New Paired Solar (Firm)	0	0	0	0	65	62	58	53	46
	New Wind (Nameplate)	0	0	0	0	200	200	200	200	200
	New Wind (Firm)	0	0	0	0	26	24	22	22	20
	New Wind PPA (NmPlt)	0	0	0	0	100	100	100	100	100
	New Wind PPA (Firm)	0	0	0	0	13	12	11	11	10
	Storage Capacity (NmPlt)	0	0	0	0	25	1,075	3,575	3,725	3,725
	Storage Capacity (Firm)	0	0	0	0	18	774	2,503	2,570	2,831
	Storage Paired (NmPlt)	0	0	0	0	49	49	49	49	49
	Storage Paired (Firm)	0	0	0	0	31	34	35	36	42
	New EE	28	58	107	163	224	206	188	121	98
	New VVO	0	10	20	29	38	50	57	65	65
	New DG	0	0	0	35	40	46	52	59	67
Total Additions (Firm & Degraded)		36	104	262	606	998	1,718	3,394	3,378	3,575
Capacity Reserves (MW) without new additions		290	198	133	121	204	194	(3,417)	(3,400)	(3,402)
Capacity Reserves (MW) with new additions		326	302	395	728	1,202	1,913	5	6	201

Portfolio 4		2031	2032	2033	2034	2035	2036	2037	2038	2039	204(
VCEA Compliant w/RGGI $15 CO2	Resources under Development (NmPlt)	507	507	507	507	507	507	507	507	507	507
	Resources under Development (Firm)	117	117	117	117	117	117	117	117	117	117
	New Nat. Gas-CC	0	0	0	0	0	0	0	0	0	0
	New Nat. Gas-CT	0	0	0	0	0	0	0	0	0	0
	New Utility Solar (NmPlt)	600	600	900	900	1,050	1,350	1,350	1,650	1,950	1,95(
	New Utility Solar (Firm)	156	158	234	234	273	351	351	429	507	507
	New PPA Solar (NmPlt)	300	300	450	450	600	900	900	900	900	900
	New PPA Solar (Firm)	78	78	117	117	156	234	234	234	234	234
	New Paired Solar (NmPlt)	148	148	148	148	148	148	148	148	148	148
	New Paired Solar (Firm)	39	39	39	39	39	39	39	39	39	39
	New Wind (Nameplate)	200	200	200	200	200	200	200	200	200	200
	New Wind (Firm)	20	20	20	20	20	20	20	20	20	20
	New Wind PPA (NmPlt)	100	100	100	100	100	100	100	100	100	100
	New Wind PPA (Firm)	10	10	10	10	10	10	10	10	10	10
	Storage Capacity (NmPlt)	3,850	3,850	3,850	3,850	3,850	4,100	3,050	2,600	2,500	2,82
	Storage Capacity (Firm)	3,504	3,504	3,504	3,504	3,504	3,731	2,776	2,366	2,275	2,57
	Storage Paired (NmPlt)	49	49	49	49	49	49	49	49	49	49
	Storage Paired (Firm)	46	46	46	46	46	46	46	46	46	46
	New EE	75	55	39	25	16	10	9	9	9	10
	New VVO	65	65	65	65	65	71	79	79	79	79
	New DG	72	74	76	77	79	83	88	92	96	101
Total Additions (Firm & Degraded)		4,181	4,164	4,265	4,233	4,324	4,712	3,767	3,440	3,432	3,73
Capacity Reserves (MW) without new additions		(3,396)	(3,389)	(3,385)	(3,382)	(3,381)	(3,396)	(3,422)	(3,423)	(3,424)	(3,73
Capacity Reserves (MW) with new additions		814	803	908	900	943	1,316	345	17	7	2

TABLE 28 PORTFOLIO 5 NAMEPLATE AND FIRM (UCAP) RESOURCE ADDITIONS AND CAPACITY POSITION

Portfolio 5		2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
VCEA Compliant w/RGGI $15 CO2	Resources under Development (NmPlt)	15	65	418	507	507	507	507	507	507	507	507	507	507	507	507	507	507	507	507
	Resources under Development (Firm)	8	35	135	163	148	132	117	117	117	117	117	117	117	117	117	117	117	117	117
	New Nat. Gas-CC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	New Nat. Gas-CT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	New Utility Solar (NmPlt)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300	600	900	1,200
	New Utility Solar (Firm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	78	156	234	312
	New PPA Solar (NmPlt)	0	0	0	0	0	0	0	0	0	150	300	450	600	750	900	900	900	900	900
	New PPA Solar (Firm)	0	0	0	0	0	0	0	0	0	39	78	117	156	195	234	234	234	234	234
	New Paired Solar (NmPlt)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	450	900
	New Paired Solar (Firm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	117	234
	New Wind (Nameplate)	0	0	0	0	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	2,400
	New Wind (Firm)	0	0	0	0	156	144	132	132	120	120	120	120	120	120	120	120	120	120	240
	New Wind PPA (NmPlt)	0	0	0	0	100	100	100	100	100	100	100	100	100	100	150	250	350	350	350
	New Wind PPA (Firm)	0	0	0	0	13	12	11	11	10	10	10	10	10	10	15	25	35	35	35
	Storage Capacity (NmPlt)	0	0	0	0	25	25	25	25	25	150	150	150	150	150	400	400	400	400	2,325
	Storage Capacity (Firm)	0	0	0	0	18	18	18	17	19	137	137	137	137	137	364	364	364	364	2,116
	Storage Paired (NmPlt)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	148	297
	Storage Paired (Firm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	141	282
	New EE	14	29	44	57	75	71	68	16	13	10	7	5	3	1	1	2	4	6	8
	New VVO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	16	26	35	43
	New DG	0	0	0	35	40	46	52	59	67	72	74	76	77	79	83	88	92	96	101
Total Additions (Firm & Degraded)		22	64	179	255	449	423	397	352	346	504	543	581	619	659	939	1,044	1,147	1,498	3,722
Capacity Reserves (MW) without new additions		290	198	133	121	204	194	195	205	204	208	212	214	216	216	207	186	186	185	(3,731)
Capacity Reserves (MW) with new additions		312	262	312	376	653	618	592	557	550	712	754	794	835	875	1,147	1,230	1,333	1,683	2

TABLE 29 PORTFOLIO 6 NAMEPLATE AND FIRM (UCAP) RESOURCE ADDITIONS AND CAPACITY POSITION

Portfolio 6		2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
VCEA Compliant w/RGGI $15 CO2	Resources under Development (NmPlt)	15	65	418	507	507	507	507	507	507	507	507	507	507	507	507	507	507	507	507
	Resources under Development (Firm)	8	35	135	163	148	132	117	117	117	117	117	117	117	117	117	117	117	117	117
	New Nat. Gas-CC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	New Nat. Gas-CT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	New Utility Solar (NmPlt)	0	0	0	0	0	0	0	0	150	300	300	300	600	900	1,200	1,200	1,200	1,200	1,200
	New Utility Solar (Firm)	0	0	0	0	0	0	0	0	47	78	78	78	156	234	312	312	312	312	312
	New PPA Solar (NmPlt)	0	0	0	0	0	0	0	150	300	450	600	750	900	900	900	900	900	900	900
	New PPA Solar (Firm)	0	0	0	0	0	0	0	54	93	117	156	195	234	234	234	234	234	234	234
	New Paired Solar (NmPlt)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	141	291	441
	New Paired Solar (Firm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	76	115
	New Wind (Nameplate)	0	0	0	0	200	200	200	200	200	200	200	200	200	200	200	200	200	400	600
	New Wind (Firm)	0	0	0	0	26	24	22	22	20	20	20	20	20	20	20	20	20	40	60
	New Wind PPA (NmPlt)	0	0	0	0	100	150	250	350	350	350	350	350	350	350	350	350	350	350	350
	New Wind PPA (Firm)	0	0	0	0	13	18	28	39	35	35	35	35	35	35	35	35	35	35	35
	Storage Capacity (NmPlt)	0	0	0	0	25	25	25	25	25	150	150	150	150	150	400	400	400	400	2,800
	Storage Capacity (Firm)	0	0	0	0	18	18	18	17	19	137	137	137	137	137	364	364	364	364	2,548
	Storage Paired (NmPlt)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	47	97	147
	Storage Paired (Firm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45	92	140
	New EE	14	29	44	57	75	71	68	16	13	10	9	7	6	5	9	9	10	11	11
	New VVO	0	0	0	0	0	0	0	0	0	0	0	0	0	6	18	29	38	47	56
	New DG	0	0	0	35	40	46	52	59	67	72	74	76	77	79	83	88	92	96	101
Total Additions (Firm & Degraded)		22	64	179	255	319	309	303	324	410	585	625	664	781	866	1,192	1,207	1,303	1,423	3,728
Capacity Reserves (MW) without new additions		290	198	133	121	204	194	195	205	204	208	212	214	216	216	207	186	186	185	(3,731)
Capacity Reserves (MW) with new additions		312	262	312	376	523	504	499	529	614	793	837	878	997	1,083	1,399	1,393	1,488	1,608	1

TABLE 30 CAPACITY RESERVE MARGIN

Capacity Reserve Margin
with new additions %

	Portfolio 1	Portfolio 2	Portfolio 3	Portfolio 4	Portfolio 5	Portfolio 6
	2040 AM+MNTR Ret. RGGI CO2 Gas Option	2040 AM+MNTR Ret. RGGI-$15 CO2 No Gas Option	2028 AM+MNTR Ret. RGGI CO2 Gas Option	2028 AM+MNTR Ret. RGGI-$15 CO2 No Gas Option	2040 AM+MNTR Ret. RGGI-$15 CO2 No Gas Option High Wind Limits	2040 AM+MNTR Ret. RGGI-$15 CO2 No Gas Option Historical Wind CF
2022	14.3	14.3	14.4	14.6	14.3	14.3
2023	13.4	13.4	13.4	14.1	13.4	13.4
2024	14.3	14.3	14.4	15.8	14.3	14.3
2025	15.9	15.9	16.3	22.8	15.9	15.9
2026	19.0	19.1	21.0	32.6	21.7	19.1
2027	18.5	18.6	20.7	47.1	21.0	18.7
2028	18.5	18.5	9.0	8.7	20.5	18.6
2029	18.4	18.4	9.2	8.7	19.9	19.3
2030	18.6	18.6	10.1	12.7	19.8	21.1
2031	22.7	22.7	14.3	25.1	23.1	24.7
2032	23.6	23.6	14.8	24.9	23.9	25.6
2033	25.2	25.3	15.6	27.1	24.8	26.5
2034	26.1	26.1	16.5	26.9	25.6	28.9
2035	26.9	28.7	17.3	27.8	26.4	30.7
2036	33.7	35.8	23.2	35.3	31.9	37.0
2037	35.1	35.6	24.4	15.6	33.5	36.8
2038	37.0	38.8	19.8	8.9	35.6	38.8
2039	39.8	42.5	19.8	8.7	42.7	41.2
2040	8.7	9.0	13.7	8.6	8.7	8.6
2041	8.7	9.0	8.7	8.7	8.7	8.6
2042	8.7	9.1	8.7	8.9	8.7	8.6
2043	8.9	9.2	8.7	8.8	8.8	8.7
2044	9.0	9.3	8.8	8.8	8.8	8.8
2045	9.1	9.4	9.0	8.9	9.0	8.9
2046	9.2	9.5	9.9	9.0	9.1	9.0
2047	8.7	9.0	8.7	8.8	8.7	8.8
2048	8.8	9.1	8.9	8.7	8.7	8.9
2049	8.9	9.2	9.0	8.8	8.9	9.0
2050	9.0	8.8	9.1	8.9	9.0	8.7
2051	8.8	9.0	8.9	9.1	8.7	8.6

TABLE 31 VCEA ENERGY TARGET POSITION

	VCEA	VCEA	VCEA Annual Energy Target Over/(Under) (GWh)					
	TGT	GWh	Portfolio 1	Portfolio 2	Portfolio 3	Portfolio 4	Portfolio 5	Portfolio 6
			2040 AM+MNTR Ret. RGGI CO2 Gas Option	2040 AM+MNTR Ret. RGGI-$15 CO2 No Gas Option	2028 AM+MNTR Ret. RGGI CO2 Gas Option	2028 AM+MNTR Ret. RGGI-$15 CO2 No Gas Option	2040 AM+MNTR Ret. RGGI-$15 CO2 No Gas Option High Wind Limits	2040 AM+MNTR Ret. RGGI-$15 CO2 No Gas Option Historical Wind CF
2022	7%	1,051	210	210	210	210	210	210
2023	8%	1,200	112	112	112	112	112	112
2024	10%	1,499	557	557	557	557	557	557
2025	14%	2,100	181	181	181	1,115	181	181
2026	17%	2,546	1,017	1,017	1,328	3,194	4,083	1,017
2027	20%	2,999	489	489	800	2,666	3,555	642
2028	24%	3,601	135	135	604	2,006	2,895	289
2029	27%	4,055	336	336	350	1,440	2,329	341
2030	30%	4,505	61	61	78	858	1,747	380
2031	33%	4,956	174	174	192	349	1,549	494
2032	36%	5,406	61	61	381	(74)	1,437	381
2033	39%	5,861	254	254	417	429	1,319	263
2034	42%	6,314	139	139	455	3	1,203	770
2035	45%	6,772	18	640	334	193	1,083	960
2036	53%	7,985	(20)	251	334	115	225	260
2037	53%	7,994	170	170	328	34	1,072	529
2038	57%	8,608	215	448	364	79	1,424	599
2039	61%	9,219	101	504	490	127	2,414	252
2040	65%	9,829	472	403	267	(96)	7,086	607
2041	68%	10,301	667	42	105	162	6,957	179
2042	71%	10,761	203	279	32	48	6,494	69
2043	74%	11,227	116	(159)	(40)	(38)	6,056	(18)
2044	77%	11,694	29	104	(128)	(126)	5,618	(106)
2045	80%	12,171	282	8	126	128	5,171	148
2046	84%	12,798	44	120	23	(111)	4,583	(90)
2047	88%	13,427	312	(120)	26	0	3,993	21
2048	92%	14,053	76	(6)	141	114	3,406	135
2049	96%	14,695	174	92	(112)	(138)	2,803	(117)
2050	100%	15,325	283	(148)	(2)	(28)	2,212	(8)
2051	100%	15,349	280	199	(5)	(32)	2,209	(11)

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TABLE 32 ANNUAL REC PURCHASES

		Annual REC Purchases (GWh)					
		Portfolio 1	Portfolio 2	Portfolio 3	Portfolio 4	Portfolio 5	Portfolio 6
	VCEA Energy Requirement GWh	2040 AM+MNTR Ret. RGGI CO2 Gas Option	2040 AM+MNTR Ret. RGGI-$15 CO2 No Gas Option	2028 AM+MNTR Ret. RGGI CO2 Gas Option	2028 AM+MNTR Ret. RGGI-$15 CO2 No Gas Option	2040 AM+MNTR Ret. RGGI-$15 CO2 No Gas Option High Wind Limits	2040 AM+MNTR Ret. RGGI-$15 CO2 No Gas Option Historical Wind CF
2022	1,051	0	0	0	0	0	0
2023	1,200	0	0	0	0	0	0
2024	1,499	0	0	0	0	0	0
2025	2,100	0	0	0	0	0	0
2026	2,546	0	0	0	0	0	0
2027	2,999	0	0	0	0	0	0
2028	3,601	0	0	0	0	0	0
2029	4,055	0	0	0	0	0	0
2030	4,505	0	0	0	0	0	0
2031	4,956	0	0	0	0	0	0
2032	5,406	0	0	0	0	0	0
2033	5,861	0	0	0	0	0	0
2034	6,314	0	0	0	0	0	0
2035	6,772	0	0	0	0	0	0
2036	7,985	351	0	703	0	0	0
2037	7,994	0	0	0	0	0	350
2038	8,608	0	0	0	0	0	701
2039	9,219	0	0	701	0	0	0
2040	9,829	0	0	1,054	351	0	0
2041	10,301	0	0	701	1,051	0	0
2042	10,761	0	701	1,051	1,402	0	350
2043	11,227	350	701	1,402	1,752	0	701
2044	11,694	703	1,405	1,757	2,108	0	1,054
2045	12,171	1,402	1,752	2,453	2,803	0	1,752
2046	12,798	1,752	2,453	2,803	3,154	0	2,102
2047	13,427	2,453	2,803	2,453	3,854	0	2,803
2048	14,053	2,811	3,514	3,162	4,568	0	3,514
2049	14,695	3,504	4,205	3,504	4,906	0	3,854
2050	15,325	4,205	4,555	4,205	5,606	0	4,555
2051	15,349	4,555	5,256	4,555	5,957	350	4,906

TABLE 33 ENERGY EFFICIENCY RESOURCE ADDITIONS

Annual Energy Efficiency added for VCEA Compliance

	Portfolios		Portfolio 1			Portfolio 2			Portfolio 3			Portfolio 4			Portfolio 5			Portfolio 6		
	Descriptions		2040 AM+MNTR Ret. RGGI CO2 Gas Option			2040 AM+MNTR Ret. RGGI-$15 CO2 No Gas Option			2028 AM+MNTR Ret. RGGI CO2 Gas Option			2028 AM+MNTR Ret. RGGI-$15 CO2 No Gas Option			2040 AM+MNTR Ret. RGGI-$15 CO2 No Gas Option High Wind Limits			2040 AM+MNTR Ret. RGGI-$15 CO2 No Gas Option Historical Wind CF		
	Tgt %	VCEA EE Trgt Svgs GWh	RES GWh	COM GWh	Surplus/ (Deficit) GWh	RES GWh	COM GWh	Surplus/ (Deficit) GWh	RES GWh	COM GWh	Surplus/ (Deficit) GWh	RES GWh	COM GWh	Surplus/ (Deficit) GWh	RES GWh	COM GWh	Surplus/ (Deficit) GWh	RES GWh	COM GWh	Surplus/ (Deficit) GWh
2022	0.5%	72	48	24	(0)	48	24	(0)	48	26	2	107	26	61	48	24	(0)	48	24	(0)
2023	1.0%	145	99	47	1	99	47	1	99	51	5	223	51	130	99	47	1	99	47	1
2024	1.5%	217	144	73	(0)	144	73	(0)	160	76	19	424	76	284	144	73	(0)	144	73	(0)
2025	2.0%	289	197	93	1	197	93	1	256	102	69	659	102	472	197	93	1	197	93	1

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TABLE 34 RENEWABLE PORTFOLIO 2021 VCEA ORDER COMPLIANCE

Virginia Clean Economy Act Analysis

Renewable Portfolio Compliance

All Values in MWhs

	Order Rqmt 1	Order Rqmt 1.a.i	Order Rqmt 1.a.ii	Order Rqmt 1.a.iii	Order Rqmt 1.b.i	Order Rqmt 1.b.ii	Order Rqmt 1.b.iii	Order Rqmt 1.b.iv	Order Rqmt 1.b.v	Order Rqmt 1.b.vi	Order Rqmt 1.b.vii	Order Rqmt 1.c		
Year	Virginia Clean Energy Act Renewable Energy Requirement	Virginia	Coast	PJM (A)(B)(C)	Solar	On-shore Wind	Off-Shore Wind	falling water	waste to energy	biomass	REC Purchases	VA Domiciled Solar & Wind Nonutility Sources	VA Domiciled Solar & Wind Utility Sources	VCEA Domiciled Solar & Wind Nonutility Sources percent
2022	993,734	83,607	-	807,050	70,094	408,816	-	398,234	-	-	103,077	83,607	-	100%
2023	1,133,611	91,954	-	807,050	74,027	408,816	-	398,234	-	-	234,607	87,675	4,279	95%
2024	1,415,226	130,915	-	807,050	113,076	408,816	-	398,234	-	-	477,261	87,237	4,258	95%
2025	1,982,091	786,160	-	807,050	387,989	408,816	-	398,234	-	-	388,881	182,388	170,790	52%
2026	2,402,988	1,705,069	-	807,050	386,049	1,329,754	-	734,399	-	-	-	488,455	783,895	38%
2027	2,829,432	1,703,051	-	807,050	384,119	1,329,754	-	734,399	-	-	-	487,548	783,045	38%
2028	3,397,617	2,012,997	-	807,050	382,198	1,641,709	-	734,399	-	-	241,405	796,112	784,687	50%
2029	3,824,956	2,773,472	-	703,343	380,287	2,300,475	-	734,399	-	-	11,977	946,216	1,395,317	40%
2030	4,248,749	3,078,463	-	586,109	378,386	2,490,220	-	734,399	-	-	248,013	1,252,301	1,394,480	47%
2031	4,673,752	3,707,376	-	586,109	1,007,385	2,490,220	-	734,399	-	-	44,102	1,566,858	1,709,093	48%
2032	5,096,612	4,033,215	-	586,109	1,323,982	2,499,549	-	734,399	-	-	141,123	1,887,794	1,714,251	52%
2033	5,525,244	4,647,279	-	586,109	1,947,460	2,490,220	-	734,399	-	-	-	2,194,480	2,021,883	52%
2034	5,950,934	4,958,406	-	586,109	2,258,673	2,490,220	-	734,399	-	-	70,254	2,507,303	2,020,440	55%
2035	6,382,261	5,902,008	-	586,109	3,202,359	2,490,220	-	734,399	-	-	-	2,821,976	2,649,619	52%
2036	7,524,059	6,866,143	-	586,109	4,157,250	2,499,549	-	734,399	-	-	-	3,146,422	3,289,558	49%

Notes:

A VA Allocation of Existing Renewables = 50.10%

B VA Allocated 100% of Existing Hydro in 2026

C Assumes Summersville Hydro contract is extended for 15 years in 2027

Appendix C: Intentionally Left Blank

Appendix D: Overnight Installed Cost of Technologies in 2019 Real Dollars ($/kW)

TABLE 35 OVERNIGHT COSTS

Year	COMBUSTION TURBINE H CLASS, 1100-MW COMBINED CYCLE	COMBUSTION TURBINE H CLASS, COMBINED-CYCLE SINGLE SHAFT, 430 MW	COMBUSTION TURBINE F CLASS, 240-MW SIMPLE CYCLE	COMBUSTION TURBINES AERODERIVATIVE, 100-MW SIMPLE CYCLE	INTERNAL COMBUSTION ENGINES, 20 MW	ONSHORE WIND, LARGE PLANT FOOTPRINT, 200 MW	SOLAR PHOTOVOLTAIC, 150 MWAC, Tier 1	SOLAR PHOTOVOLTAIC, 150 MWAC, Tier 2	BATTERY ENERGY STORAGE SYSTEM, 50 MW / 200 MWH
2019	$1,063	$1,131	$763	$1,262	$1,958	$1,484	$1,550	$1,969	$1,450
2020	$1,059	$1,126	$756	$1,250	$1,939	$1,449	$1,534	$1,948	$1,379
2021	$1,053	$1,120	$749	$1,238	$1,921	$1,414	$1,467	$1,863	$1,296
2022	$1,051	$1,118	$745	$1,232	$1,912	$1,379	$1,400	$1,778	$1,214
2023	$1,039	$1,105	$730	$1,207	$1,873	$1,366	$1,333	$1,693	$1,131
2024	$1,034	$1,100	$722	$1,194	$1,852	$1,352	$1,266	$1,608	$1,049
2025	$1,034	$1,100	$719	$1,189	$1,845	$1,338	$1,199	$1,523	$967
2026	$1,030	$1,096	$714	$1,180	$1,832	$1,319	$1,132	$1,438	$932
2027	$1,021	$1,086	$703	$1,163	$1,804	$1,299	$1,066	$1,353	$897
2028	$1,017	$1,082	$698	$1,154	$1,790	$1,283	$999	$1,268	$862
2029	$1,012	$1,077	$693	$1,146	$1,779	$1,267	$932	$1,183	$828
2030	$1,008	$1,072	$690	$1,140	$1,770	$1,252	$865	$1,098	$793
2031	$1,005	$1,069	$687	$1,136	$1,763	$1,252	$857	$1,088	$783
2032	$1,000	$1,064	$683	$1,129	$1,751	$1,252	$849	$1,078	$773
2033	$994	$1,057	$678	$1,121	$1,740	$1,252	$842	$1,069	$763
2034	$990	$1,053	$674	$1,115	$1,731	$1,252	$834	$1,059	$753
2035	$986	$1,049	$671	$1,109	$1,722	$1,252	$826	$1,049	$743
2036	$980	$1,043	$666	$1,102	$1,710	$1,252	$818	$1,039	$733
2037	$976	$1,038	$663	$1,096	$1,701	$1,252	$811	$1,030	$724
2038	$973	$1,035	$659	$1,090	$1,692	$1,252	$803	$1,020	$714
2039	$968	$1,030	$657	$1,086	$1,685	$1,252	$795	$1,010	$704
2040	$964	$1,025	$652	$1,078	$1,673	$1,252	$788	$1,000	$694
2041	$959	$1,020	$649	$1,072	$1,664	$1,252	$780	$990	$684
2042	$955	$1,016	$645	$1,067	$1,655	$1,252	$772	$981	$674
2043	$952	$1,012	$641	$1,061	$1,646	$1,252	$765	$971	$664
2044	$947	$1,007	$638	$1,055	$1,637	$1,252	$757	$961	$654
2045	$944	$1,004	$635	$1,050	$1,630	$1,252	$749	$951	$644
2046	$940	$1,000	$632	$1,044	$1,621	$1,252	$741	$941	$634
2047	$936	$996	$628	$1,039	$1,612	$1,252	$734	$932	$624
2048	$930	$990	$624	$1,033	$1,602	$1,252	$726	$922	$614
2049	$926	$985	$620	$1,025	$1,591	$1,252	$718	$912	$605
2050	$915	$973	$613	$1,013	$1,573	$1,252	$711	$902	$595
2051	$904	$962	$606	$1,002	$1,554	$1,252	$703	$893	$585

Appendix E: Filing Requirements

Requirement	Citation	Development Plan/Testimony Location	Company Witness Sponsor
Submit an annual plan that (i) reflects, in the aggregate and over the duration, the Subsection D requirements for allocation between utility-owned facilities and PPAs, and (ii) includes a plan to meet energy storage development targets under Subsection E, including the goal of installing at least 10% behind the meter.	Va. Code§ 56-585.5 D 4	2021 RPS Development Plan	Witness Martinez
Consider the promotion of new renewable generation and energy storage resources within the Commonwealth, and associated economic development.	Va. Code§ 56-585.5 D 4	2021 RPS Development Plan	Witness Martinez
Consider the fuel savings projected to be achieved by the plan.	Va. Code§ 56-585.5 D 4	2021 RPS Development - Table 23 and Appendix C	Witness Castle
Report on the plan to meet and progress toward the interim targets set forth in the storage regulations.	20 VAC 5-335-30	2021 RPS Development Plan-Table 3	Witness Martinez
Report annually on any competitive solicitations for energy storage	20 VAC 5-335-40		Witness Casablanca
Address behind-the meter incentives related to energy storage projects	20 VAC 5-335-50		Witness Casablanca
Address non-wires alternative programs related to energy storage.	20 VAC 5-335-60		Witness Casablanca
Address peak demand reduction programs related to energy storage.	20 VAC 5-335-70		Witness Casablanca

Requirement	Citation	Development Plan/Testimony Location	Company Witness Sponsor
Analyze how the Company's plan and petition requests address and implement the RPS and carbon dioxide reduction requirements in Code§ 56-585.5, including but not necessarily limited to Code 56-585.5c.	PUR-2020-00135 Final Order at 4	Sec 5.8 Carbon Dioxide Reduction Requirements	Witness Martinez
Include a least cost plan consistent with the requirements of the 2020 IRP Final Order that meets (i) applicable carbon regulations and (ii) the mandatory RPS Program.	PUR-2020-00135 Final Order at 5	2021 RPS Development Plan-Table 19	Witness Martinez
Include an evaluation of RECs from all sources (with both high and low-price sensitivities), including utility-owned, third-party PPAs and unbundled REC purchases.	PUR-2020-00135 Final Order at 5	2021 RPS Development Plan-Figure 8, Section 5.3	Witness Martinez
Provide modeling of the Company's actual wind capacity factor and Virginia-specific or PJM-specific solar capacity factor.	PUR-2020-00135 Final Order at 5	See Portfolio 6 of the 2021 RPS Development Plan	Witness Martinez
Provide distributed generation sensitivities for unbundled REC purchases through Requests for Proposals ("RFPs"), fixed price offers and over-the-counter purchases.	PUR-2020-00135 Final Order at 5	2021 RPS-Development Plan-Figure 8 and Section 5.3	Witness Castle
Modeling of reliability impacts	PUR-2020-00135 Final Order at 5	Section 1.5	Witness Martinez
Provide updated fundamentals forecasts and commodity pricing that reflects the VCEA requirements.	PUR-2020-00135 Final Order at 5	Sec 3.4 Fundamentals Forecast	Witness Martinez
Provide a detailed chart showing how APCo has complied to date with the VCEA's RPS requirements.	PUR-2020-00135 Final Order at 5	2021 RPS Development Plan- Section 1.3	Witness Castle
The Company's bill analysis should include the effects of retirements, the effects of tax credits, offsets related to outside model additions, and any changes to customer class allocation factors.[1]	PUR-2020-00135 Final Order at 6	2021 RPS Development Plan Table 18	Witness Castle
Ensure modeling inputs and assumptions are consistent between IRP and RPS Development Plan proceedings and explain the reason behind any deviation in the assumptions and modeling used.	PUR-2020-00135 Final Order at 9	2021 RPS Development Plan Section 2.6	Witness Martinez

[1] This requirement initially included a requirement to file a bill analysis. The Company has filed a consolidated bill analysis consistent with the Order on the 2020 Filing which modified the bill analysis-related requirements.

Requirement	Citation	Development Plan/Testimony Location	Company Witness Sponsor
Provide the complete results of RPS-related RFPs must be included in each of the Company's RPS filings. In addition to the specific requirements set forth in Code § 56-585.5 D 3, the Company's RFPs shall address environmental justice considerations by assessing the impacts of proposed projects on underserved communities. The Company's RPS filing should identify how the RFP assessed environmental justice considerations, including any non-price considerations that were included in the Company's RFP analysis.	PUR-2020-00135 Final Order at 8	Testimony	Witness Jeffries/Witness Castle
The Company will propose reporting metrics, and any needed protocols, associated with RPS Program certification in its 2021 RPS filing.	PUR-2020-00135 Final Order at 6	Testimony	Witness Castle
Provide information related to accelerated renewable energy buyers ("ARBs")	PUR-2020-00135 Final Order at 7	Testimony Exhibit	Witness Sebastian
Present the Company proposed cost allocation methodology, along with the results of alternative cost allocation methodologies.	PUR-2020-00135 Final Order at 9	Testimony	Witness Spaeth/Witness Sebastian
Report each RPS-associated cost or benefit by type, month, general ledger account, rate mechanism and whether such cost or revenue is bypassable or non-bypassable.	PUR-2020-00135 Final Order at 10		Witness Spaeth/Witness Thomas/Witness Sebastian
(1) For each year, 2021 through 2035, provide an estimate of the yearly RPS Program requirement expressed in MWh in accordance with the schedule provided in § 56-585.5 C.	PUR-2020-00135 Order Establishing Proceeding Attachment	2021 RPS Development Plan Appendix B	Witness Martinez
(1) (a) For each year, 2021 through 2035, provide an estimate (MWhs or RECs) of the RPS Program requirement that is expected to be met from generation located: (i) in Virginia;(ii) off the coast of the Commonwealth; or (iii) otherwise located in PJM.	PUR-2020-00135 Order Establishing Proceeding Attachment	2021 RPS Development Plan Appendix B	Witness Martinez
(1) (b) For each year, 2021 through 2035, provide an estimate (MWhs or RECs) of the RPS Program requirement that is expected to be met from the following sources: (i) solar; (ii) on- shore wind; (iii) off-shore wind; (iv) falling water; (v) waste-to- energy or landfill gas; (vi) biomass; or (vii) any other qualifying resource.	PUR-2020-00135 Order Establishing Proceeding Attachment	2021 RPS Development Plan Appendix B	Witness Martinez

Requirement	Citation	Development Plan/Testimony Location	Company Witness Sponsor
(1) (c) For each year, 2021 through 2035, provide an estimate, expressed in MWhs, of the RPS Program requirement that must be provided by non-utility sources.	PUR-2020-00135 Order Establishing Proceeding Attachment	2021 RPS Development Plan Appendix B	Witness Martinez
(2) Provide the lifetime revenue requirement for the proposed RPS Program by component, including supporting calculations on an annual basis.1	PUR-2020-00135 Order Establishing Proceeding Attachment	2021 RPS Development Plan Appendix B	Witness Martinez
(3) State whether the utility in its RPS Filing will treat the term "capacity" referenced in§ 56-585.5 as nameplate capacity, or in some other way to be identified and described by the utility.	PUR-2020-00135 Order Establishing Proceeding Attachment	2021 RPS Development Plan Section 2.1	Witness Martinez
(4) Estimate the nameplate capacity of all renewable resources the utility will be required to procure to meet its capacity obligations in PJM, following the utility's full transition to renewable resources by 2045 (Phase II Utility), and 2050 (Phase I Utility), as required by § 56-585.5.	PUR-2020-00135 Order Establishing Proceeding Attachment	2021 RPS Development Plan Table 21	Witness Martinez
(5) Regarding the tranches described in § 56-585.5 D 1 a, b, and c for a Phase I utility, (i) describe how the utility will obtain the requisite 35% of energy, capacity and environmental attributes from non-utility sources as required by the statute, and (ii) state, in detail, whether affiliates of the utility may potentially provide any of that energy, capacity or environmental attributes.	PUR-2020-00135 Order Establishing Proceeding Attachment		Witness Castle

BRIAN D. SHERRICK
Direct Testimony

220320302

APCo Exhibit No. ____
Witness: BDS

DIRECT TESTIMONY OF
BRIAN D. SHERRICK
FOR APPALACHIAN POWER COMPANY
IN VIRGINIA S.C.C. CASE NO. PUR-2022-00001

APCo Exhibit No. ____
Witness: BDS

SUMMARY OF DIRECT TESTIMONY OF BRIAN D. SHERRICK

In this testimony, I

- Describe the Amos and Mountaineer Plants and the CCR/ELG project at both facilities;
- Describe AEP Generation's project stages and planning processes for projects and the status of the current APCo projects;
- Describe the costs of the projects at the Amos and Mountaineer Plants including the reasonableness and prudence of the Prerequisite ELG Project Costs; and
- Describe the Amos Units 1 & 2 DSI project and the cost of the project.

APCo Exhibit No. ____
Witness: BDS

DIRECT TESTIMONY OF
BRIAN D. SHERRICK
FOR APPALACHIAN POWER COMPANY
IN VIRGINIA S.C.C. CASE NO. PUR-2022-00001

Q. PLEASE STATE YOUR NAME, BUSINESS ADDRESS, AND POSITION.

A. My name is Brian D. Sherrick. My business address is 1 Riverside Plaza, Columbus, Ohio 43215. I am employed by AEPSC as the Managing Director of Projects for the AEP Generation Projects Controls and Construction organization. AEPSC is a wholly-owned subsidiary of AEP, the parent of APCo.

Q. PLEASE SUMMARIZE YOUR EDUCATIONAL BACKGROUND AND BUSINESS EXPERIENCE.

A. I received a Bachelor of Science Degree in Civil Engineering from the United States Military Academy in 1997 and a Master's of Civil Engineering Degree from University of Missouri Rolla in 2002. I hold a Project Management Professional certification from the Project Management Institute. My professional experiences includes over seven years as an Engineer in the U.S. Army and over 17 years working for AEP on new build and retrofit projects for coal, natural gas, solar, and wind power plants and their associated environmental controls. I have held various positions of increasing responsibility including Project Manager, Project Controls Manager, Startup and Commissioning Manager, Project Director, Director of Construction, and in 2020, I assumed my current position of Managing Director of Projects.

Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY?

A. The purpose of my direct testimony is to describe the CCR/ELG Projects at the Plants. Specifically, I will describe the current state of the Plants, the scope, cost, schedule, and project management methodology used for the projects, and the reasonableness and prudency of the previously incurred ELG project costs.

I also support the project undertaken at Amos to optimize the Units 1 & 2 Dry Sorbent Injection (DSI) system that is used to mitigate the emission of acid gases. Specifically, I will describe the current state of the project as well as the scope, estimated cost, and schedule.

Q. HAVE YOU PREVIOUSLY FILED TESTIMONY IN ANY REGULATORY PROCEEDINGS?

A. Yes. I testified before this Commission in Case No. PUR-2020-00258. I also testified before the WVPSC in Case No. 20-1040-E-PC, and before the KPSC in Case No. 2021-00004, which were other filings related to the CCR and ELG rules.

Q. ARE YOU SPONSORING ANY SCHEDULES IN THIS PROCEEDING?

A. I am sponsoring the following portions of Schedule 46 for the CCR/ELG Projects:

- APCo Schedule 46, Section 1 Statement 1 – Amos Project Cost Estimate
- APCo Schedule 46, Section 1 Statement 1 – Mountaineer Project Cost Estimate
- APCo Schedule 46, Section 2 Statement 2 – Amos Project Schedule
- APCo Schedule 46, Section 2 Statement 2 – Mountaineer Project Schedule

I am sponsoring the following portion of Schedule 46 for the Amos Units 1 & 2 DSI Project:

- APCo Schedule 46, Section 1 Statement 1 – Amos Units 1 & 2 DSI Estimate

I also sponsor other portions of Section 2 Statement 2 as part of this filing.

I. <u>CCR/ELG PROJECT OVERVIEW</u>

Q. PLEASE DESCRIBE THE PLANTS.

A. Amos is located approximately 15 miles northwest of Charleston, West Virginia on the Kanawha River. APCo owns 100% interest in Amos, which is comprised of three supercritical pulverized coal-fired base-load generating units. The nameplate capacities are 800MW each for Amos Units 1 & 2 and 1,330 MW for Amos Unit 3 for a total nameplate capacity of 2,930 MW. The units were placed in service in 1971, 1972, and 1973 respectively. Each unit is equipped with an electrostatic precipitator for control of particulate matter, a FGD system for sulfur dioxide control, both SCR technology and low-NO_x burners for control of NO_x emissions, and utilize a dry fly ash handling system. All three units currently transport bottom ash and miscellaneous wastewater streams to a shared pond system where the bottom ash is later dredged and trucked to a permitted landfill. The BATW and miscellaneous wastewater streams are then discharged to the Kanawha River through a NPDES permitted outfall.

Mountaineer is located approximately 12 miles northeast of Point Pleasant, West Virginia on the Ohio River. APCo owns 100% interest in Mountaineer, which has one super-critical pulverized coal-fired base-load generating unit with a 1,320 MW nameplate capacity placed in service in 1980. The plant is equipped with an electrostatic precipitator for control of particulate matter, a FGD system for sulfur dioxide control, both selective catalytic reduction technology and low-NO_x burners for control of NO_x emissions, a dry fly ash handling system, and a water Biological Treatment System for FGD wastewaters. The plant currently transports bottom ash and miscellaneous wastewater streams to a pond system where the bottom ash is later dredged and trucked to a permitted landfill. The BATW and miscellaneous wastewater streams are then discharged to the Ohio River through a NPDES permitted outfall.

The Commission approved cost recovery from APCo's Virginia ratepayers for the CCR projects for both Plants in the 2021 E-RAC Order.

Q. HOW WERE THE SCOPES OF THE CCR/ELG PROJECTS AT THE PLANTS DETERMINED?

A. The scopes of the CCR/ ELG compliance projects were determined through collaboration among AEPSC's Environmental Services, Engineering Services, Fossil & Hydro Generation, and Projects departments. As described in the testimony of Company witness Spitznogle, the Environmental Services department analyzed the rules, then the project teams determined the operational changes at the plants that would be required to comply with the CCR and ELG rules under the various compliance scenarios laid out under the rules. Considering the timing requirements of various compliance scenarios established under the regulations, the Projects department then worked with a third party vendor to develop cost estimates for the various compliance projects at the Plants.

Q. PLEASE BRIEFLY DESCRIBE THE SCOPE OF THE CCR/ ELG PROJECTS AT THE PLANTS.

A. A project that would allow Amos to continue to operate under the CCR/ELG requirements would require (i) removing ash from the Bottom Ash 1A and 1B, Reclaim, and Clear Water ponds; (ii) closing pond 1A and grading and seeding to establish natural drainage; (iii) lining the existing Reclaim and Clearwater ponds; (iv) constructing a new Lined Wastewater pond in place of Bottom Ash Pond 1B; (v) installing a chemical treatment system for non-CCR wastewater streams; (vi) modifications to the bottom ash handling systems to no longer allow the discharge of BATW, including the installation of submerged grind conveyor systems; (vii) installation of two new ash bunkers; (viii) retrofitting economizer ash handling systems on Units 1 & 2; and (ix) installation of a new FGD Biological Treatment System with Ultrafiltration.

A project that would allow Mountaineer to continue to operate under the CCR/ELG requirements would require (i) removing ash from the east and west Bottom Ash ponds; (ii) lining the cleaned east and west ponds to create east and west Wastewater Settling ponds; (iii) installing a chemical treatment system for non-CCR wastewater streams; (iv) potentially installing ground water remediation equipment; (v) modifications to the bottom ash handling system to no longer allow discharge of BATW including installation of a submerged grind conveyor system; (vi) installation of a new ash bunker; and (vii) retrofit of a new Ultrafiltration system onto the existing FGD Biological Treatment System.

Q. DID AEPSC EVALUATE ALTERNATE OPTIONS OR TECHNOLOGIES TO COMPLY WITH THE ELG RULE?

A. Yes. The ELG compliance options involved evaluating different vendor options to convert the wet bottom ash handling systems to dry systems and to treat the FGD wastewater streams. AEPSC also evaluated closed loop recycle systems for the Amos plant. Given the rule and operations requirements for all the plants, the project teams selected the technically feasible, least life cycle cost option for our customers.

II. <u>CCR/ELG PROJECT SCHEDULE AND PLANNING</u>

Q. DOES AEP GENERATION HAVE A STANDARD PROCESS THAT IT FOLLOWS TO PLAN AND CONSTRUCT ENVIRONMENTAL PROJECTS FOR ALL OF THE PROJECTS YOU DISCUSS IN YOUR TESTIMONY?

A. Yes. All project execution is governed by AEP's commitment to safety and utilizes a phased planning and construction process. The process includes management of procurement, cost, schedule, quality, and risk in accordance with quality assurance documents that follow industry standard project management practices.

Q. PLEASE DESCRIBE THE PHASED APPROACH TO PROJECT PLANNING AND EXECUTION.

A. The projects are executed from planning through completion using the same phased (stage) approach that has been successfully employed by AEP on many past projects:

- Stages 0 (Initiation) and 1 (Business Planning & Screening) are conducted during long range planning activities and typically before the first Capital Improvement Requisition (CI) funding gate. Stage 1 may include feasibility studies as required to meet project schedules.
- Stage 2 (Scope Selection) includes conducting and/or closing out feasibility studies and evaluation of risk balanced technical options.
- Stages 3 (Preliminary Engineering) and 4 (Detailed Engineering) consist of completing conceptual engineering, detailed engineering and design, permitting, and procurement of long lead-time equipment and supplies. It may include initial site construction activities.
- Stages 5 (Construction), 6 (Commissioning and Startup), and 7 (Close Out) consist of full-scale construction, startup, commissioning, and close out activities.

A detailed evaluation and review of the scope, schedule, and estimate are conducted between each funding request (Capital Improvement Requisition) to confirm the project is meeting project objectives. It also allows the project team to report progress to APCo management with respect to project success criteria, and any critical risks or opportunities that may have been identified, before obtaining financial authorization to proceed.

Q. PLEASE DESCRIBE THE ACTIVITIES THAT OCCUR DURING STAGE 2.

A. Stage 2 begins with the preparation and approval of a Capital Improvement Requisition approving funding for Stage 2 activities. An architect/engineer is then contracted to perform the engineering, design, and feasibility studies for Stage 2 and the ensuing stages of the project. The intent of the Stage 2 feasibility studies is to investigate the technical options and factors driving the project cost and schedule. During Stage 2, the architect/engineer, with input from a team of AEPSC engineers and managers, defines the scope of the project, prepares work plans, and develops a budgetary cost estimate and schedule for implementation. In addition, preliminary environmental permitting activities begin, any necessary regulatory approvals are identified, and AEPSC begins conceptual engineering.

The results of the Stage 2 conceptual engineering and feasibility studies are then presented to senior management, and authorization is sought to proceed to Stages 3 and 4. Approval to proceed is accomplished by a Capital Improvement Requisition revision request which typically includes a formal management meeting.

Q. WHAT ARE THE ACTIVITIES THAT TAKE PLACE IN STAGES 3 AND 4?

A. Stages 3 and 4 consist of preliminary engineering, detailed engineering and design, regulatory approval and permitting, and procurement work. During these stages, we refine the cost estimate and schedule, award the Original Equipment Manufacturer contract, procure long lead-time equipment, and develop engineering drawings to the point that detailed design work can begin.

Applicable modifications to existing air, water, and waste environmental permits are submitted to the state regulatory body to begin the evaluation and approval process. In addition, construction and site management teams begin design evaluations to ensure that the proposed scope of work is optimized for constructability. The team also defines site preparation plans, determine which, if any, facilities will need to be relocated, select site preparation contractor(s), and complete studies to support the various permitting activities that will be required.

The project team then proceeds to detailed engineering, design, contracting, and initial site construction work that can be performed prior to the final approval of applicable permits. During this stage, as detailed design progresses, construction bid packages are prepared and major equipment is specified, bid, and purchased. The construction and site management teams are mobilized and begin site construction work, and the team proceeds through the process of selecting and awarding the major construction contracts. Upon completion of Stages 3 and 4, the project is evaluated once again and a Capital Improvement Requisition revision is prepared for management approval to proceed with Stages 5 through 7.

Q. PLEASE DESCRIBE AEPSC'S PROJECT SCHEDULE MANAGEMENT PROCESS.

A. Schedule management ensures that the overall project is executed in support of the initial operation date. This is accomplished using scheduling tools, the monitoring of critical milestones, and through the establishment and monitoring of specific performance and production metrics.

An integrated project schedule is developed using activities and criteria for planning, execution, monitoring, and control. The project schedule development involves activity sequencing and activity duration estimating to develop detailed project schedules so that monitoring and controls are in place to complete the project on or ahead of schedule. The scope of work for the project is subdivided into manageable work packages using a project Work Breakdown Structure, which facilitates project cost estimating, scheduling, and controlling activities.

AEPSC, acting on behalf of APCo, assumes the primary responsibility for schedule management as the Schedule Integrator for the project. In that role, AEPSC accounts for the activities of ourselves, the architect/engineering contractor, equipment suppliers, and the construction contractors for the development of a fully integrated schedule. The contractors and vendors provide us with weekly comprehensive schedule activity updates along with monthly reports on project progress, a 30-day look ahead schedule, status of major activities, cost status updates, and other pertinent data. Schedules for the Amos and Mountaineer compliance plans are shown in APCo Schedule 46, Section 2 Statement 2 – Amos Project Schedule and APCo Schedule 46, Section 2 Statement 2 – Mountaineer Project Schedule.

Q. PLEASE DESCRIBE AEP'S PROJECT SAFETY MANAGEMENT.

A. All projects are conducted with AEP's 'Zero Harm' safety culture. Zero Harm distills safety into a simple idea – "No one gets hurt and everyone goes home in the same or better condition than they came to work." On a project, it means every employee, contractor and visitor, regardless of work location, is held accountable for the safety of themselves and each other. With this practice, a project can avoid unsafe activities and conditions that lead to accidents.

III. <u>CCR/ELG PROJECT COSTS</u>

Q. PLEASE BRIEFLY DESCRIBE THE COSTS OF THE CCR/ELG PROJECTS.

A. The total estimated cost of compliance under the CCR/ELG requirements for Amos is $215.8 million, including $197.3 million in capital, $6.2 million in other charges, and $12.3 million in ARO costs. A detailed breakdown of the Amos projects can be found in APCo Schedule 46, Section 1 Statement 1 – Amos Project Cost Estimate. ELG costs quantified for the purposes of this filing are the dry ash handling and wastewater treatment (WWT) capital costs. All the associated pond work is allocated to the CCR Rule. The components of the project estimated costs associated with just the ELG compliance are approximately $148.5 million at Amos.

The total estimated cost of compliance with the CCR/ELG Rules for Mountaineer is $82.8 million, including $78.9 million in capital, $3.2 million in other charges, and $701,000 in ARO costs. A detailed breakdown of the Mountaineer projects can be found in APCo Schedule 46, Section 1 Statement 1 – Mountaineer Project Cost Estimate. The components of the project estimated costs associated with just the ELG compliance are approximately $48.4 million at Mountaineer.

The cost estimates were developed by an independent engineering firm with inputs and oversight from AEPSC. AEPSC reviewed the independent consultant's estimate for completeness and included AEPSC's costs and contingency to arrive at the total project cost estimates. AEPSC has successfully used this cost estimation procedure for other construction projects throughout the AEP system.

I provided these cost estimates to Company witness Martin for the purposes of the economic analysis he supports in his testimony in this proceeding.

Q. **HOW DO THE CCR/ELG ESTIMATED COSTS COMPARE TO THE ESTIMATES PROVIDED IN THE 2021 E-RAC PROCEEDING?**

A. The current cost estimates are updated cost estimates based on increased detailed engineering and design, actual material and equipment pricing, and actual contract values for most of the labor work. The scope of the systems being installed did not materially change. The Amos and Mountaineer CCR component estimates increased by $22.3M and $5.6M respectively. The increases were due to quantity increases from preliminary to detailed engineering and design, material pricing changes due to the Coronavirus pandemic, and contractor unit prices coming in higher than estimated. The Amos and Mountaineer ELG component estimates increased by $16.4M and $4.4M respectively. The increases were due to material, equipment, and labor changes as part of design evolution and pricing changes due to the Coronavirus pandemic.

IV. CCR/ELG PROJECT STATUS

Q. IN WHAT STAGE ARE THE CCR/ELG PROJECTS CURRENTLY?

A. The Project Teams are currently performing Stages 4 and 5 activities, which include completing detailed engineering and design, procurement, and permitting from Stage 4 along with construction (Stage 5) of the ELG system. Construction activities as of the date of this filing include receiving equipment and material, relocations, clearing, site layout, equipment assembly, excavation, foundations installation, and equipment installation. Construction of the Amos CCR system is ongoing with removal of bottom ash and closure by removal of existing Pond 1B. Construction of the Mountaineer CCR system started in March 2022.

Q. WHAT COSTS HAVE BEEN INCURRED ON THE ELG PROJECTS AT THE PLANTS?

A. Through August 2021, the Amos and Mountaineer ELG Projects incurred approximately $19.5 million and $12.6 million respectively in ELG costs (the Prerequisite ELG Project Costs). The ELG costs incurred were for Stages 1 through 3 activities as discussed earlier in my testimony. Those activities include project initiation, technology feasibility studies, evaluation of risk balanced technical options, conceptual engineering, permitting, and site investigations (surveying, verifying as-built conditions, and geotechnical investigations). These costs were unavoidable prior to regulatory approval as they were necessary to establish the projects' scope, schedule, and cost estimate (project definition) to inform the regulatory process. Per the Association for the Advancement of Cost Engineering International (AACEI), this level of project definition is required to achieve a budgetary estimate in Process Industries, including Utilities. The activities were also required to meet environmental compliance deadlines. No physical construction related to ELG project activities had begun at the Amos or Mountaineer Plants as of August 2021.

Q. PLEASE DESCRIBE THE COSTS AND SCOPE OF THE ELG PROJECTS FORECASTED TO BE INCURRED THROUGH SEPTEMBER 2022.

A. From September 2021 through September 2022, the Amos ELG Project is projected to incur approximately $90.4 million in additional ELG costs and the Mountaineer ELG Project is projected to incur approximately $33.8 million in additional ELG costs to finish the permitting process, install dry bottom ash and wastewater treatment equipment, and startup and commission installed systems as described in APCO Schedule 46, Section 2 Statement 2. These activities are required to meet environmental compliance deadlines.

V. <u>AMOS UNITS 1 & 2 DSI PROJECT AND COSTS</u>

Q. PLEASE DESCRIBE THE AMOS UNITS 1 & 2 DSI PROJECT.

A. Amos currently uses trona for SO_3 mitigation and injects at the air heater (AH) outlet. As further supported by Company witness Spitznogle, this project will reconfigure the existing Amos Units 1 & 2 DSI system to more efficiently handle hydrated lime and reduce issues related to corrosion as well as gain benefits such as heat rate improvement, improved Equivalent Unplanned Outage Rate (EUOR), and lower minimum load. It also helps with the long term protection of the SCR catalyst, air heaters, and precipitators.

Q. PLEASE BRIEFLY DESCRIBE THE COSTS OF THE AMOS UNITS 1 & 2 DSI PROJECT.

A. The total estimated cost of the Amos Units 1 & 2 DSI project is $9.4 million. A detailed breakdown of the project can be found in APCo Schedule 46, Section 1 Statement 1 – Amos Units 1 & 2 DSI Estimate.

Q. WHAT ACTIVITIES ARE ONGOING AND WHAT IS THE SCHEDULE FOR THE AMOS 1 & 2 DSI PROJECT?

A. As of March 2022, the project team is conducting detailed engineering and design to support equipment fabrication and labor contract procurement activities. The system is scheduled to be retrofitted during fall 2022 unit outages.

Q. DOES THIS CONCLUDE YOUR DIRECT TESTIMONY?

A. Yes.

ROBERT A. GALLIMORE
Direct Testimony

2203203 02

APCo Exhibit No. ___
Witness: RAG

DIRECT TESTIMONY OF
ROBERT A. GALLIMORE
FOR APPALACHIAN POWER COMPANY
IN VIRGINIA S.C.C. CASE NO. PUR-2022-00001

220320302

APCo Exhibit No. ___
Witness: RAG

SUMMARY OF DIRECT TESTIMONY OF ROBERT A. GALLIMORE

In my testimony, I

- Describe Claytor and the dissolved oxygen project at the facility;
- Support the costs of the project; and
- Describe the alternatives that were considered for the project and its current status.

APCo Exhibit No. ___
Witness: RAG

DIRECT TESTIMONY OF
ROBERT A. GALLIMORE
FOR APPALACHIAN POWER COMPANY
IN VIRGINIA S.C.C. CASE NO. PUR-2022-00001

Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. My name is Robert A. Gallimore, and my business address is 40 Franklin Road SW, Roanoke, Virginia.

Q. BY WHOM ARE YOU EMPLOYED AND IN WHAT CAPACITY?

A. I am employed by AEPSC as the Hydroelectric (Hydro) Asset Manager. AEPSC is a wholly-owned subsidiary of AEP, the parent of APCo.

Q. PLEASE SUMMARIZE YOUR EDUCATIONAL AND PROFESSIONAL BACKGROUND.

A. I began my career with AEP in 1985 as an Engineering Technician. In that role I was responsible for assisting engineers with running fault studies, performing relay calculations, and updating drawings for new or upgraded stations. In 1990, I took a brief leave of absence to attend Ohio University where I earned a bachelor's degree in Electrical Engineering. In 1993, I was rehired by AEP as an Electrical Engineer in Hydro Generation where I was responsible for providing electrical/controls support for the hydro fleet, including equipment upgrades and troubleshooting problems. Since that time I have worked in various positions, including serving as maintenance superintendent for the electrical and controls team for the AEP Hydro fleet and Plant Manager for Hydro. In 2021, I was promoted to my current role, Hydro Asset Manager.

I am a licensed Professional Engineer in the Commonwealth of Virginia and have completed the AEP/Ohio State University Strategic Leadership Program and the AEP Power Systems Concepts course.

Q. WHAT ARE YOUR PRINCIPAL AREAS OF RESPONSIBILITY?

A. I am responsible for ensuring that all hydro assets are being managed and are performing at or above the forecasted production levels by identifying and implementing processes to improve and maintain the health of the assets, improve financial and operational metrics, and maximize the value of the assets.

Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY IN THIS PROCEEDING?

A. The purpose of my direct testimony is to describe the DO project at Claytor. Specifically, I will describe the current state of Claytor as well as the scope, cost, schedule, and discussed alternatives for the project.

Q. ARE YOU SPONSORING ANY EXHIBITS IN THIS PROCEEDING?

A. Yes. I am sponsoring the following portion of Schedule 46 for the Claytor DO Project:

- APCo Schedule 46, Section 1 Statement 1 – Claytor Project Cost Estimate
- APCo Schedule 46, Section 2 Statement 2 – Claytor DO Project

I. <u>THE CLAYTOR DO PROJECT</u>

Q. PLEASE DESCRIBE CLAYTOR.

A. Claytor is a hydroelectric facility made up of four generating units located on the New River in Radford, Virginia. The nameplate Claytor Unit capacities for each of the four Units is 18.75 MW, for a total nameplate capacity of 75 MW. The units were placed in service in 1939.

Q. PLEASE BRIEFLY DESCRIBE THE DISSOLVED OXYGEN PROJECT AT CLAYTOR.

A. FERC and the Virginia DEQ require hydro facility tailwaters to meet water quality standards for DO during normal operations. In a letter dated July 11, 2019, FERC required APCo to submit a redefined dissolved oxygen enhancement plan (for Claytor to improve low DO conditions). The specific DO requirements are discussed in greater detail in the testimony of Company witness Spitznogle.

The plan, as approved by FERC and the Virginia DEQ, proposed replacing the current turbines with auto-venting turbines (AVT) in two of the four generating units at Claytor. These two units, Units 3 and 4, were proposed because they are identical in manufacturer, are situated closest to the centerline of the tailrace, which is the water channel below the dam, and each unit will independently meet the DO requirements, which gives redundancy. Redundancy is a key factor in support of AVTs over alternative DO enhancement measures, which do not offer redundancy and require higher ongoing O&M costs. The AVT is a proven technology that has shown good results in reliability; provides the greatest percentage increased DO concentration; and because of the design of the turbine, is expected to produce an increase in megawatt output of at least 10% per unit. AVTs are the preferred method in the hydro industry for downstream DO enhancement, and given the current water passage design and civil structure at Claytor, it is the best, and most reliable, solution available. Additional project details can be found in APCo Schedule 46, Section 2, Statement 2 – Claytor DO Project.

Q. HOW WAS THE DISSOLVED OXYGEN PROJECT AT CLAYTOR DETERMINED?

A. The plan was developed through extensive research on DO enhancement engineering measures applicable to Claytor by the Company's Fossil & Hydro Generation and Projects departments. APCo also worked with an independent engineering firm, HDR, Inc., to evaluate DO enhancement options for Claytor. HDR, Inc. assisted in developing the specification that was used during the Request for Information (RFI) process. An RFI was then sent to vendors for possible solutions, and representatives of APCo attended presentations by the vendors that bid in response to the RFI.

Q. DID APCO EVALUATE ALTERNATE OPTIONS OR TECHNOLOGIES TO COMPLY WITH THE DISSOLVED OXYGEN RULE?

A. Yes. An alternative DO enhancement option was to install a line diffuser in the forebay (upstream) pond of Claytor, which would inject oxygen directly into the water. As the line diffuser would only inject into the water without disbursement into the water passage, a more concentrated form of oxygen injection would be required. This option would require oxygen storage and additional oxygen generation equipment to be installed on site, with on-site storage needed to act as a backup when oxygen generating equipment is not operational. Such on-site storage would also require regular deliveries of oxygen gas to the site to replenish the supply. The oxygen delivery, storage, generation, and injection equipment would require annual maintenance, which would increase the annual cost to operate and maintain the line diffuser. In addition, the diffuser would be subject to damage and blockage from lake debris because it would be installed in the forebay. As this option does not provide redundancy, any damage or blockage would cause the project to lose the ability to enhance the downstream DO levels while the system was out of service.

II. <u>PROJECT SCHEDULE AND COSTS</u>

Q. PLEASE BRIEFLY DESCRIBE THE TIMING OF THE DO PROJECT.

A. The contract with the selected vendor was signed and a purchase order to begin work was released in December 2021. Construction on the first unit is scheduled to begin in 2022 with a planned in-service date of November 2023, followed by the next unit, which will begin construction in 2023 with a planned in service date of November 2024.

Q. PLEASE BRIEFLY DESCRIBE THE COSTS OF THE DO PROJECT.

A. The total estimated cost of the DO project at Claytor is $12.414 million. A detailed breakdown of the project can be found in APCo Schedule 46, Section 1 Statement 1 – Claytor Project Cost Estimate.

Q. DOES THIS CONCLUDE YOUR DIRECT TESTIMONY?

A. Yes, it does.

GARY O. SPITZNOGLE
Direct Testimony

APCo Exhibit No. ___
Witness: GOS

220320302

DIRECT TESTIMONY OF
GARY O. SPITZNOGLE
FOR APPALACHIAN POWER COMPANY
IN VIRGINIA S.C.C. CASE NO. PUR-2022-00001

2203203032

APCo Exhibit No. ___
Witness: GOS

SUMMARY OF DIRECT TESTIMONY OF GARY O. SPITZNOGLE

In my testimony, I

- Describe the applicable environmental regulations that drive the need and timing for the environmental improvement projects at the Amos and Mountaineer Plants;
- Describe the requirements for compliance that result from the WVPSC's Orders related to those projects;
- Outline the permitting required to install the environmental controls that are the subject of this Petition;
- Support the identification of activities undertaken that are required to comply with state and federal environmental laws or regulations applicable to generation facilities used to serve the utility's native load obligations. These activities include O&M expenses associated with the handling and disposal of the byproducts of coal combustion, as well as new capital investments related to dissolved oxygen levels at APCo's hydroelectric generating units at Claytor, and the dry sorbent injection system at the Company's Amos Plant.
- Generally describe RGGI, and how Virginia's participation in RGGI caused the Company to incur costs.

APCo Exhibit No. ___
Witness: GOS

DIRECT TESTIMONY OF
GARY O. SPITZNOGLE
FOR APPALACHIAN POWER COMPANY
IN VIRGINIA S.C.C. CASE NO. PUR-2022-00001

Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. My name is Gary O. Spitznogle, and my business address is 1 Riverside Plaza, Columbus, Ohio 43215.

Q. BY WHOM ARE YOU EMPLOYED AND IN WHAT CAPACITY?

A. I am employed by AEPSC as the Vice President – Environmental Services. AEPSC is a wholly-owned subsidiary of AEP, the parent of APCo.

Q. PLEASE SUMMARIZE YOUR EDUCATIONAL AND PROFESSIONAL BACKGROUND.

A. I earned a bachelor's degree in chemical engineering from The Ohio State University College of Engineering in 1998. I joined AEPSC in 1997 and worked in various positions, including several related to research and development activities to improve the environmental performance of AEP's power generation. I served as Vice President of Regulatory and Finance for Ohio Power Company, an affiliate of APCo, from 2013 to December 2015. I then served as Managing Director of Coal Combustion Residuals Management for AEPSC until March 2019. I assumed my current position as Vice President - Environmental Services in July 2019.

Q. WHAT ARE YOUR PRINCIPAL AREAS OF RESPONSIBILITY?

A. I am responsible for oversight of the Environmental Services organization, which provides environmental support for all generation and energy delivery facilities owned by AEP operating companies. Specifically, the Environmental Services organization provides permitting and compliance support, guidance, procedures, recommendations, and training to AEP's operating companies to maintain and improve their environmental programs and enhance compliance with environmental laws, regulations, and policies. As part of this effort, Environmental Services is also involved in developing environmental regulations and coordinating with operating company staffs to support AEP's corporate strategies and values concerning the environment.

Q. HAVE YOU PREVIOUSLY FILED TESTIMONY IN ANY REGULATORY PROCEEDINGS?

A. Yes. I testified before this Commission in Case No. PUR-2020-00258. I also testified before the WVPSC in Case No. 20-1040-E-PC, and before the KPSC in Case No. 2021-00004, which were other filings related to the CCR and ELG rules.

I have also testified several times before the Public Utilities Commission of Ohio, and presented written and oral testimony before the United States House of Representatives Select Committee on Energy Independence and Global Warming, which was established to investigate new energy technologies with the goal of achieving energy independence while reducing or eliminating the emission of greenhouse gases.

Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY IN THIS PROCEEDING?

A. The purpose of my testimony is to describe the environmental regulations that drive the need and timing for the environmental improvement projects at the Company's generation units. The Projects are described in general in the Company's Petition and in greater detail in the testimony of Company witnesses. I will also outline the permitting required to install the environmental controls that are the subject of this application.

I support the identification of activities related to the handling and disposal of the byproducts of coal combustion necessary to comply with state or federal environmental laws or regulations applicable to generation facilities used to serve the APCo's native load obligations.

I support the activities undertaken at Claytor to comply with dissolved oxygen requirements issued by FERC, and I also support the activities undertaken at the Amos Plant to optimize the DSI system that is used to mitigate the emission of acid gases. The Company proposes to recover these capital investments through the E-RAC.

I will also describe RGGI, which imposes a cost on carbon emissions within the Commonwealth of Virginia. The Company proposes to recover these emission costs through the E-RAC as well.

I provided the above list of compliance activities to Company witness Ross, who used that information to identify environmental compliance costs incurred associated with those activities. The Company proposes to recover those expenses and investments in this E-RAC proceeding.

Q. **ARE YOU SPONSORING ANY EXHIBITS IN THIS PROCEEDING?**

A. I am sponsoring the following exhibit:

- APCo Exhibit No. __ (GOS) Schedule 1 – Environmental Activity Identification

I. THE AMOS AND MOUNTAINEER CCR/ELG PROJECTS

Q. PLEASE DESCRIBE THE REGULATORY REQUIREMENTS THAT DRIVE THE NEED FOR THE CCR/ELG PROJECTS AT THE PLANTS.

A. The federal regulations that drive the need for the CCR/ELG Projects at the Plants are the CCR Rule and the ELG Rule. The CCR Rule regulates the handling and storage of CCR material in an environmentally responsible manner. The ELG Rule regulates wastewater discharges for the protection of surface water.

Q. PLEASE DESCRIBE THE CCR RULE IN GREATER DETAIL.

A. On April 17, 2015, the EPA published the CCR Rule to regulate the disposal and beneficial use of CCR, which includes fly ash (ash that is collected in electrostatic precipitators or in the economizer), bottom ash (ash that is collected from the bottom of a coal-fired boiler), and gypsum (a by-product of the flue gas desulfurization, or FGD, process) that are generated at coal-fired electric generating units through normal unit operation. The rule applies to new and existing CCR landfills and CCR surface impoundments (ponds) at operating coal-fired electric generating facilities. The rule defines construction and operation obligations for CCR handling and storage, including location restrictions (such as seismic stability requirements and a 5-foot minimum separation between the bottom of the pond and the uppermost aquifer); design criteria for storage areas (such as specifications for liners and caps to isolate stored CCR from the environment); structural integrity requirements for impoundments; and groundwater monitoring and protection requirements that include frequent sampling and analysis of groundwater to determine if it is impacted by the

CCR storage site. If any of the above conditions are found to be lacking or outside of EPA-established acceptable ranges, remediation steps must be undertaken that could include any or all of the following: closure of the site, removal of the CCR material from the site, and/or groundwater treatment sufficient to attain applicable standards.

Some requirements of the CCR Rule, including applicable compliance dates, have been revised by EPA since the initial 2015 regulation. The most recent compliance date revisions were finalized in August 2020. The compliance timelines and options in this latest version of the CCR Rule are addressed in the remainder of my testimony.

Q. PLEASE DESCRIBE THE ELG RULE IN GREATER DETAIL.

A. On November 3, 2015, EPA published a final rule revising effluent limitation guidelines for steam-electric generating facilities. The rule established discharge limits on FGD wastewater, transport water used for fly ash and bottom ash handling, and other wastewaters. The requirements of the ELG Rule, including applicable compliance dates, have been revised by EPA since the initial 2015 regulation. The most recent revisions were finalized in October 2020. The revised rule eliminated the discharge of most ash transport waters and requires enhanced treatment of FGD wastewaters. These requirements are implemented through modifications to the existing state wastewater discharge permit (the NPDES permit) at each facility. The compliance timelines and options in the latest version of the ELG Rule are addressed in the remainder of my testimony.

Q. PLEASE DESCRIBE THE CCR/ELG PROJECTS CURRENTLY BEING

PERFORMED AT THE PLANTS.

A. Consistent with the Company's CCR extension requests filed with the EPA[1,2] on November 30, 2020, and the WVPSC Orders, the Company is pursuing projects to comply with both the CCR and ELG Rules so the Plants can comply with all known environmental regulations and continue to operate past 2028. The WVPSC Orders, and the previous Order from this Commission approving a "CCR-Only" option, are discussed in greater detail by Company witness Beam.

The projects being performed by the Company include closing the bottom ash ponds at the Plants (which are unlined), converting all steam generating units at the Plants to dry bottom ash handling systems, and installing (Amos) or upgrading (Mountaineer) bioreactors for the treatment of FGD wastewater. The projects being performed by the Company are discussed in greater detail in the testimony of Company witness Sherrick

The schedules for bottom ash pond closure and developing alternative management options for bottom ash and other wastewaters are site-specific and are subject to approval by the EPA.

The ELG Rule requires that discharge limits must be achieved as soon as possible before December 31, 2025, pursuant to a schedule that will be included in the NPDES permit for each facility. To expedite compliance, the Company has

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[1] Amos filing (127 MB): https://www.aep.com/Assets/docs/requiredpostings/ccr/2020/12-2-2020/AM-BAP-SIAlternateCapacityInfeasibleNotice-11302020.pdf.

[2] Mountaineer filing (128 MB): https://www.aep.com/Assets/docs/requiredpostings/ccr/2020/12-2-2020/MT-BAP-SIAlternateCapacityInfeasibleNotice-11302020.pdf.

developed coordinated compliance activities that would be necessary to address the requirements of the ELG Rule and the CCR Rule. The new bioreactors would bring Amos to full ELG compliance by the end of 2023 and the upgraded bioreactor would bring Mountaineer into ELG compliance by the end of 2023 as well.

Q. IS THE EPA'S APPROVAL OF THE DATES THE COMPANY REQUESTED IN ITS CCR EXTENSION REQUEST FILINGS GUARANTEED?

A. No. The compliance dates requested by the Company are based on the Company's estimate for as soon as possible compliance and the time required to perform those projects. It is possible that the EPA may disagree with the Company; modified CCR project schedules and changes to those dates could be included in its approval of the Company's extension request.

Q. WHEN WILL EPA ACT ON THE COMPANY'S REQUEST FOR AN EXTENSION?

A. The EPA was expected to act on extension requests within four months from the filing date. Based on the Company's understanding of the CCR Rule, EPA's response was due by no later than April 11, 2021. However, the EPA has tolled the April 11, 2021 date to begin closing the bottom ash ponds pending its decision on the extension requests. Although the Company has not received a ruling as of the date of this filing, the EPA began making decisions regarding extension requests on January 11, 2022, with more determinations planned in the coming months.[3] In the meantime, the Company must continue to make progress consistent with the project plan

[3] https://www.epa.gov/newsreleases/epa-takes-key-steps-protect-groundwater-coal-ash-contamination.

included in the extension requests that were filed with EPA on November 30, 2020.

II. <u>ENVIRONMENTAL PERMITTING</u>

Q. WHAT PERMITTING ACTIVITIES NEED TO BE COMPLETED PRIOR TO COMMISSIONING THE AMOS AND MOUNTAINEER PLANTS ENVIRONMENTAL PROJECTS?

A. EPA must approve the request to extend the date to cease ash pond operations under the CCR Rule. Prior to commissioning each ELG Project, the existing NPDES permit must be revised to incorporate the applicable requirements of the ELG Rule and the compliance schedule. Other permits to support the installation of any environmental control project include construction general storm water permit.

III. <u>IDENTIFICATION OF ENVIRONMENTAL COMPLIANCE ACTIVITIES</u>

Q. WHAT ENVIRONMENTAL COMPLIANCE ACTIVITIES DO YOU SUPPORT IN THIS PROCEEDING?

A. Based on the advice of counsel, the E-RAC Statute allows for cost recovery "…to comply with state or federal environmental laws or regulations applicable to generation facilities used to serve the utility's native load obligations…," provided the Commission finds that such costs are "…necessary to comply with such environmental laws or regulations."

The activities identified in APCo Exhibit No. __ (GOS) Schedule 1 – Environmental Activity Identification are directly associated with compliance with West Virginia State Solid Waste regulation, the NPDES permit, other provisions of the Clean Water Act, the ELG Rule, the CCR Rule, as well as costs incurred to comply with RGGI.

Q. HOW WERE THESE ACTIVITIES IDENTIFIED?

A. I was provided with detailed accounting reports that included actual 2021 activities associated with environmental compliance for January through November 2021. These reports include information such as the systems and equipment on which the work was performed. I reviewed those reports, and identified line items that qualify for recovery under Virginia law.

Q. PLEASE SUMMARIZE THE TYPES OF ACTIVITIES YOU IDENTIFIED.

A. By reviewing the detailed accounting reports I previously mentioned, I looked for activities associated with specific pieces of equipment and systems. Activities associated with CCR handling and disposal include, but are not limited to, items such as bottom ash pumps and transportation equipment, economizer ash handling equipment, fly ash handling equipment and disposal activities, gypsum handling and disposal equipment and systems, ponds, and landfills.

I also identified two capital projects that were required for environmental compliance, and also emission allowance costs associated with RGGI that were necessary to incur to comply with that rule.

Please see APCo Exhibit No. __ (GOS) Schedule 1 – Environmental Activity Identification, which contains the complete list of compliance activities I identified as being required to comply with the various environmental regulations.

I then provided Company witness Ross with the list of activities I identified as related to environmental compliance, and Company witness Ross could use the same accounting reports to identify the compliance expenses and investments incurred for each activity.

Q. IS IT REASONABLE TO ASSUME THE LEVEL OF ENVIRONMENTAL ACTIVITY FROM DECEMBER 2020 THROUGH NOVEMBER 2021 IS REPRESENTATIVE OF ONGOING LEVELS DURING THE PROJECTED PERIOD?

A. Yes. The Company is confident that the level of environmental activity related to ash and byproduct handling and disposal that is described in my testimony is reasonably representative of the level that is anticipated to occur prior to 2023. The level of environmental activity related to ash handling and disposal will change when the existing ponds are closed. There will also be costs associated with the new bioreactor system at Amos. These costs will include the cost for chemicals, maintenance, materials, and operating labor.

IV. <u>THE AMOS DSI PROJECT</u>

Q. DOES THE COMPANY PROPOSE TO INCLUDE ADDITIONAL PROJECTS IN THE E-RAC THAT ARE DRIVEN BY COMPLIANCE WITH ENVIRONMENTAL REGULATIONS?

A. Yes. The reconfiguration of the DSI at Amos is one such project that is required by environmental regulations and therefore are reasonable to include in the E-RAC.

Q. PLEASE DESCRIBE THE ENVIRONMENTAL CONTROLS AT THE AMOS PLANT.

A. Amos is equipped with SCR and FGD systems for the reduction of NO_X and SO_2, respectively. The SCR and FGD systems were installed to comply with NO_X and SO_2 emission limits established under various regulations including the Title IV Acid Rain provision of the Clean Air Act, and the Clean Air Interstate Rule (CAIR) that has now been replaced with the Cross-State Air Pollution Rule (CSAPR). The requirement for SCR and FGD installations and operations was further required under a Consent Decree entered into with the US EPA and other parties, and its subsequent modifications.

The FGD system installations at the Amos Plant included the addition of a DSI system to mitigate emissions of SO_3, an acid gas that can cause visible emissions from the stack that is a direct result of operating the SCR and FGD systems together. With the addition of the FGD system, the plant began to consume a fuel with higher sulfur content, and a small portion of the resulting SO_2 is converted to SO_3 in the SCR. Therefore, the operation of the SCR and FGD systems in tandem necessitates the installation and operation of the DSI system to mitigate the resulting SO_3 emissions.

Q. WHY IS THE COMPANY MODIFYING THE DSI SYSTEM AT AMOS?

A. When the DSI system was installed at Amos, it was designed to use trona, a sodium-based mineral, to react with and capture SO_3. The system is now being modified to use hydrated lime, a calcium-based sorbent. The switch from trona to hydrated lime will result in reduced O&M costs, while allowing the plant to continue mitigating the emission of acid gases.

V. THE CLAYTOR DISSOLVED OXYGEN PROJECT

Q. WHAT REGULATION(S) NECESSITATE THE COMPANY'S PROJECTS AT CLAYTOR?

A. As part of the licensing process for hydroelectric power projects, companies have to submit a water quality monitoring plan. On February 3, 2020, and supplemented on June 15, 2020, the Company filed a request to amend its water quality monitoring plan (the Claytor Plan) under license articles 401 and 406 of the FERC's Order Issuing New License[4] and condition E.4 of the Virginia Department of Environmental Quality (DEQ) Water Quality Certificate (WQC) for the Claytor Hydroelectric Project.

The Claytor Plan was previously modified by an Order issued June 12, 2012.[5] The Claytor Plan developed and incorporated methods for monitoring DO and water temperatures upstream and downstream of Claytor. More specifically, the Claytor Plan required water quality monitoring from early July through late September to reduce potential impacts to upstream and downstream aquatic organisms and angling opportunities.

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[4] 137 FERC ¶ 62,258 (issued December 27, 2011).

[5] *See* Order Modifying and Approving Revised Water Quality Monitoring Plan, 139 FERC ¶ 62,207 (issued June 12, 2012).

Q. WHY DID THE COMPANY FILE TO AMEND THE CLAYTOR PLAN IN JUNE 2020?

A. The Company is required to prepare annual water quality monitoring reports in consultation with the Water Quality/Water Management Technical Review Committee prior to filing with FERC by May 15 of each year. FERC reserves the right to require changes to the Claytor Plan based on the results of the annual reports. If the results of the studies conclude that the actions taken were not effective in enhancing water quality, the Company would be required to develop and provide alternative mitigation measures. After review of the Company's 2019 monitoring report, FERC, by letter dated July 11, 2019, requested that the Company prepare and file a redefined plan for providing measures to improve low DO conditions given the lack of progress in enhancing water quality conditions at the project over the past seven years. The Virginia DEQ recommended the Company explore alternative measures that may assist in improving DO concentrations during the June through September periods. In accordance with this recommendation, the Company developed and submitted for FERC approval a redefined plan for providing measures to improve low DO conditions downstream of Claytor. On May 5, 2020, the Virginia DEQ approved the amended plan and on June 25, 2020, FERC issued an Order[6] also approving the redefined plan.

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[6] *See* Order Modifying and Approving Revised Water Quality Monitoring Plan Under Article 406, 171 FERC ¶ 62,146 (issued June 25, 2020).

Q. WHAT IS THE REQUIRED DO CONCENTRATION AND HOW DOES THE REVISED PLAN ADDRESS THIS LIMIT?

A. Virginia Water Quality Standards for DO are a minimum concentration of 4.0 milligrams per liter instantaneous, with a daily average concentration of 5.0 milligrams per liter. The Company's revised plan includes the installation of two Auto Venting Turbines to aerate the water flow by injection of air into the unit discharge. Accordingly, this should improve and help achieve water quality standards in the New River.

VI. THE REGIONAL GREENHOUSE GAS INITIATIVE (RGGI)

Q. WHAT IS RGGI?

A. RGGI is a market based regional cap-and-invest program that was designed to reduce carbon dioxide (CO_2) emissions from fossil fuel power plants. A cap-and-invest system creates an overall limit (i.e., a cap) on emissions from the emission sources covered by the program. Cap-and-invest programs can vary by the emissions and sources covered. The covered sources, also referred to as regulated entities, often include major emitting sectors (e.g., power plants and carbon-intensive industries), fuel producers/processors (e.g., coal mines or petroleum refineries), or some combination of both.

For RGGI, the participating states worked together to develop a RGGI Model Rule that established a regional cap on CO_2 emissions, which set a limit on the emissions from covered entities within the RGGI states. This RGGI Model Rule acts as the template for each participating RGGI state to shape its own CO_2 budget trading program in which covered fossil fuel power plants with capacity greater than 25 megawatts are required to hold one CO_2 allowance in the RGGI CO_2 Allowance Tracking System (COATS) for each ton of CO_2 emitted during the preceding three-year control period. Allowances are collected in each year of the control period. Plants must hold allowances equal to 50 percent of their annual emissions in year one and also 50 percent of their annual emissions in year two with the remaining balance due by the end of year three. For example, the 2021 interim control period began on January 1, 2021 so regulated plants must hold allowances in COATS equal to 50 percent of their annual emissions by March 1, 2022. The second interim control period will begin on January 1, 2022 so regulated plants must hold allowances in COATS equal to 50 percent of that year's annual emissions by March 1, 2023. At the end of the three-year period they must hold allowances equal to 100 percent of their remaining emissions from year one and year two in addition to any additional annual emissions from year three. A CO_2 allowance represents a limited authorization to emit one ton of CO_2 as issued by a respective State. These CO_2 allowances are distributed at quarterly auctions where they can be purchased by power plants and other entities. Power plants may also purchase CO_2 allowances through secondary markets.

Q. WHAT STATES CURRENTLY PARTICIPATE IN RGGI?

A. Eleven states currently participate in RGGI: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont, and Virginia.

Q. CAN YOU EXPLAIN VIRGINIA'S CARBON RULE AS IT RELATES TO RGGI?

A. In 2020, the Virginia General Assembly enacted the VCEA and amended the Clean Energy and Community Flood and Preparedness Act, the latter of which directed the Virginia DEQ to adopt regulations to establish a cap-and-trade program for carbon dioxide emissions to comply with the RGGI Model Rule. Virginia's DEQ Carbon Rule caps CO_2 emissions for Virginia at 27.1 million short tons for the calendar year 2021, and decreases the emissions cap annually by approximately 3% to achieve a 30% reduction from 2020 levels to a level of 19.6 million short tons in 2030. The Virginia Energy Plan establishes a goal for the Commonwealth to reach net-zero emissions by 2045 and APCo to be 100 percent carbon-free by 2050.

Q. WHICH OF APCO'S POWER PLANTS FALL UNDER RGGI?

A. Clinch River is a two unit, 484 MW gas-fired plant. The units were previously coal-fired, but were converted to natural gas in 2016. These units are APCo's only carbon-emitting generators located in Virginia.

Accordingly, the Company will be required to purchase one CO_2 allowance for each ton of CO2 emitted from these units. The costs for purchasing CO_2 allowances are discussed by Company witness Ross and the forecasts for these purchases are reflected in the financial modeling performed by Company witness Martin.

Q. DOES THIS CONCLUDE YOUR DIRECT TESTIMONY?

A. Yes, it does.

220320302

Appalachian Power Company
Environmental Projects included in 2022 Environmental Rate Adjustment Clause

Plant and Unit		Applicable Environmental Regulation	Citation
1006 Gen - All Cos except Nuclear	CCR	Coal Cumbustion Residuals Rule	40 CFR 257.50(b)
	Landfill	State Solid Waste Regulation	33 CSR 1; WV Code 22-15-1
1469 Generation - All Companies	Landfill	State Solid Waste Regulation	33 CSR 1; WV Code 22-15-1 9 VAC 20-81; VA Code Title 10.1 40 CFR 257.50(b)
215 APCO Generation	Ash	Steam Electric Effluent Limitation Guidelines Rule, State Water Pollution Control Laws, NPDES Rule *	40 CFR 423; 47 CSR 10; WV Code 22-11
	Landfill	State Solid Waste Regulation	33 CSR 1; WV Code 22-15-1
	Gypsum	State Solid Waste Regulation	33 CSR 1; WV Code 22-15-1
	CCR	Coal Cumbustion Residuals Rule	40 CFR 257.50(b)
Amos Plant	Ash	Steam Electric Effluent Limitation Guidelines Rule, State Water Pollution Control Laws, NPDES Rule *	40 CFR 423; 47 CSR 10; WV Code 22-11
	CCR	Coal Cumbustion Residuals Rule	40 CFR 257.50(b)
	Landfill	State Solid Waste Regulation	33 CSR 1; WV Code 22-15-1
	Gypsum	State Solid Waste Regulation	33 CSR 1; WV Code 22-15-1
	Pond	Steam Electric Effluent Limitation Guidelines Rule, State Water Pollution Control Laws, NPDES Rule *	40 CFR 423; 47 CSR 10; WV Code 22-11
	Air	Clean Air Act; Cross-State Air Pollution Rule	CAA § 101-618; 42 USC 85; 85 FR 23054
Clinch River Plant	Ash	Steam Electric Effluent Limitation Guidelines Rule, State Water Pollution Control Laws, NPDES Rule *	40 CFR 423; 9 VAC 25-31; VA Code Title 62.1
	Pond	Steam Electric Effluent Limitation Guidelines Rule, State Water Pollution Control Laws, NPDES Rule *	40 CFR 423; 9 VAC 25-31; VA Code Title 62.1
	Air	Regulation for Emmissions Trading Programs Clean Energy and Community Flood and Preparedness Act	9 VAC5-140 VA Code Title 10.1-1330
Mountaineer Plant	Ash	Steam Electric Effluent Limitation Guidelines Rule, State Water Pollution Control Laws, NPDES Rule *	40 CFR 423; 47 CSR 10; WV Code 22-11
	CCR	Coal Cumbustion Residuals Rule	40 CFR 257.50(b)
	Landfill	State Solid Waste Regulation	33 CSR 1; WV Code 22-15-1
	Gypsum	State Solid Waste Regulation	33 CSR 1; WV Code 22-15-1
	Pond	Steam Electric Effluent Limitation Guidelines Rule, State Water Pollution Control Laws, NPDES Rule *	40 CFR 423; 47 CSR 10; WV Code 22-11
Claytor Plant	Water	Hydroelectric Licensing under the Federal Power Act Virginia Water Quality Certification	18 CFR 4; VA DEQ § 401

* National Pollutant Discharge Elimination System (NPDES)

TYLER H. ROSS

Direct Testimony

APCo Exhibit No. ____
Witness: THR

220320302

DIRECT TESTIMONY OF
TYLER H. ROSS
FOR APPALACHIAN POWER COMPANY
IN VIRGINIA S.C.C. CASE NO. PUR-2022-00001

220320302

APCo Exhibit No. ____
Witness: THR

SUMMARY OF DIRECT TESTIMONY OF TYLER H. ROSS

In my testimony, I:

- Review the E-RAC over-/under-recovery accounting recorded on APCo's books through December 31, 2021 based on the 2021 E-RAC Order.
- Provide details of accounting performed to date and proposed recovery and accounting regarding Virginia RGGI costs incurred at the Clinch River Plant.
- Provide an overview of costs incurred and forecasted costs related to construction projects at the Amos and Mountaineer Plants in order to comply with the ELG Rule.
- Provide an overview of costs incurred and forecasted costs associated with the DSI project at Amos and the DO project at Claytor..
- Describe the required accounting for costs incurred related to the CCR, ELG, DSI and DO projects.

APCo Exhibit No. ____
Witness: THR

DIRECT TESTIMONY OF
TYLER H. ROSS
FOR APPALACHIAN POWER COMPANY
IN VIRGINIA S.C.C. CASE NO. PUR-2022-00001

Q. PLEASE STATE YOUR NAME, BUSINESS ADDRESS, AND POSITION.

A. My name is Tyler H. Ross. My business address is 1 Riverside Plaza, Columbus, Ohio 43215. I am a Director of Regulatory Accounting Services for AEPSC, a wholly-owned subsidiary of AEP. AEP is the parent company of APCo.

Q. PLEASE SUMMARIZE YOUR EDUCATIONAL BACKGROUND AND BUSINESS EXPERIENCE.

A. I earned a Bachelor of Science Degree in Business Administration from The Ohio State University in 1996 with a major in accounting. I earned my Certified Public Accountant certification in 2003 and am a member of the Ohio Society of Certified Public Accountants. Starting with my hiring by AEPSC in 2001, I held staff and leadership positions within AEP's External Financial Reporting department. I was a Staff Accountant in External Financial Reporting from August 2001 through February 2005. In March 2005, I was promoted to Manager of External Financial Reporting and in August 2008, I was promoted to Director of External Financial Reporting. For AEP and its reporting subsidiaries, I led External Financial Reporting in the preparation and filing of quarterly and annual financial data in accordance with Generally Accepted Accounting Principles (GAAP) and the reporting requirements of both the Securities and Exchange Commission (SEC) and the Federal Energy Regulatory Commission (FERC). In January 2014, I started my present position as Director of Regulatory Accounting Services.

Q. WHAT ARE YOUR RESPONSIBILITIES AS DIRECTOR OF REGULATORY ACCOUNTING SERVICES?

A. As Director of Regulatory Accounting Services, my responsibilities include providing the AEP electric operating subsidiaries, such as APCo, with accounting support for regulatory filings including the preparation of cost of service adjustments, rate base adjustments, accounting schedules, and accounting testimony. In addition, I monitor regulatory proceedings and legislation impacting AEP subsidiaries in determining necessary regulatory accounting and financial reporting disclosures.

Q. HAVE YOU PREVIOUSLY TESTIFIED AS A WITNESS BEFORE ANY REGULATORY COMMISSIONS?

A. Yes. I have filed testimony and testified before:

- The Commission in the 2021 E-RAC Proceeding;
- The Indiana Utility Regulatory Commission on behalf of Indiana Michigan Power Company (I&M);
- The Kentucky Public Service Commission on behalf of Kentucky Power Company;
- The Michigan Public Service Commission on behalf of I&M (filed testimony only);
- The Public Utilities Commission of Ohio on behalf of Ohio Power Company; and
- The WVPSC on behalf of APCo and Wheeling Power Company.

Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY?

A. The purpose of my testimony is to support the Company's filing with the Commission of an E-RAC update pursuant to the E-RAC Statute. More specifically, I provide support for the accounting for costs that the Company has incurred and is projected to incur with respect to the ash pond updates at the Plants, the DSI project at Amos, and the DO project at Claytor Lake, as described in this filing and throughout my testimony. My testimony describes the accounting for the O&M Compliance Expenses related to coal combustion by-product management projects necessary to comply with state or federal environmental laws or regulations applicable to APCo's generation facilities. Finally, my testimony describes the Company's accounting for Virginia RGGI costs incurred at Clinch River.

Q. ARE YOU SPONSORING ANY SCHEDULES IN THIS PROCEEDING?

A. I am sponsoring portions of the following schedules:

- Schedule 46 Section 3 – Detail to Support Actual E-RAC Costs and True-up
- Schedule 46 Section 4 – Rate Base
- Schedule 46 Section 4 – Allowance for Funds Used during Construction (AFUDC)
- Schedule 46 Section 4 – Amortization Schedules
- Schedule 46 Section 4 – O&M Expenses
- Schedule 46 Section 4 – RGGI Costs

Q. WHAT UPDATED TEST PERIOD HAS THE COMPANY USED IN DETERMINING ITS PROPOSED UPDATE TO E-RAC RIDER RATES?

A. As described by Company witness Castle, the Company's proposes a December 2022 through November 2023 forecasted test year to update E-RAC rider rates. My testimony reflects actual E-RAC over-/under-recovery activity for the period ending December 31, 2021.

I. <u>OVERVIEW OF CURRENT E-RAC OVER-/UNDER-RECOVERY ACCOUNTING</u>

Q. PLEASE DESCRIBE THE COSTS CURRENTLY BEING RECOVERED AND THE ACCOUNTING BEING PERFORMED BY APCO WITH REGARDS TO ITS E-RAC RIDER.

A. As described in my testimony in the 2021 E-RAC Proceeding and in the 2021 E-RAC Order, APCo currently calculates and records monthly E-RAC over-/under-recovery entries by comparing current month E-RAC rider revenues against the following approved E-RAC costs:

- Monthly amortization (October 2021 through September 2022) of deferred AFUDC on CCR construction expenditures that were previously incurred up to the beginning of the Company's initial E-RAC rate year starting October 2021,
- Monthly amortization (October 2021 through September 2022) of deferred O&M Compliance Expenses and related carrying charges that were previously incurred over the period January 2020 through September 2021,
- Monthly O&M Compliance Expenses incurred, and
- Return on CWIP on CCR construction expenditures from the October 2021 beginning of the Company's initial E-RAC rate year through placement of assets in service.

Q. WHAT IS THE COMPANY'S E-RAC OVER-/UNDER-RECOVERY BALANCE AS OF DECEMBER 31, 2021?

A. Shown below is a summary of APCo's total net E-RAC under-recovery balance, including unamortized deferrals of previously incurred O&M Compliance Expense and AFUDC on CCR construction expenditures:

APCo E-RAC Under-Recovery – December 31, 2021	
Account 1823618 – VA Unamortized CCR O&M Compliance Expense Deferral	$12,647,325
Account 1823645 – VA Unamortized AFUDC on CCR Construction Expenditures	194,772
Account 1823647 – VA E-RAC Under-Recovery	233,682
Net APCo Virginia E-RAC Under-Recovery – December 31, 2021	**$13,075,779**

Q. WHEN WILL THE UNAMORTIZED BALANCES FOR O&M COMPLIANCE EXPENSE (ACCOUNT 1823618) AND AFUDC ON CCR CONSTRUCTION EXPENDITURES (ACCOUNT 1823645) BE FULLY AMORTIZED?

A. As approved in the 2021 E-RAC Order, the Company will fully amortize the deferral balances in Accounts 1823618 and 1823645 over the one-year period October 2021 through September 2022. During this period, amortization of these balances will be included as eligible costs for recovery in APCo's monthly E-RAC over-/under-recovery calculation and entry.

Q. HAS THE COMPANY INCLUDED UNAMORTIZED DEFERRALS RELATED TO CCR O&M EXPENSE (ACCOUNT 1823618) AND AFUDC (ACCOUNT 1823645) IN ITS PROPOSED E-RAC REVENUE REQUIREMENT IN THIS CASE?

A. No, the Company has properly excluded unamortized balances of Accounts 1823618 and 1823645 from its updated E-RAC revenue requirement in this filing as these costs will be fully recovered at the time APCo updates E-RAC rates in December 2022.

Q. WHAT IS THE COMPANY'S LATEST ESTIMATE AS TO WHEN CCR ASSETS AT THE PLANTS WILL BE PLACED IN SERVICE?

A. As confirmed with Company witness Sherrick, it is still estimated that CCR investments for wastewater pond upgrades at the Plants will be placed in service in October 2023 and December 2023, respectively.

Q. ARE THERE OTHER COSTS RELAED TO CCR INVESTMENTS THAT THE COMPANY WILL INCUR AND RECOVER THROUGH THE E-RAC ONCE CCR ASSETS ARE PLACED IN SERVICE AT THE PLANTS?

A. As also expressed in my direct testimony and based on the the 2021 E-RAC Order, the Company will incur the following costs on CCR investments when assets are placed in service at the Plants that will be included in APCo's future monthly E-RAC over-/under-recovery calculation and entry:

- Depreciation and return on net assets placed in service (net of accumulated depreciation and accumulated deferred federal income taxes),
- ARO asset depreciation expense, and
- ARO liability accretion expense.

Q. WILL THE COMPANY INCUR INCREMENTAL O&M EXPENSES RELATED TO THE CONSTRUCTION OF CCR ASSETS AT THE PLANTS?

A. The Company does not currently expect to incur incremental O&M expenses related to these CCR construction projects. For any incremental O&M expenses incurred related to the CCR projects at the Plants, the Company will include these O&M expenses as eligible costs for recovery in APCo's monthly E-RAC over-/under-recovery calculation and entry. The Company will describe any incurred O&M expenses in future E-RAC filings.

Q. DOES THE COMPANY PROPOSE ANY OTHER COSTS FOR RECOVERY RELATED TO CCR INVESTMENTS?

A. Yes, APCo also proposes to prospectively recover property tax expense incurred related to the Company's Virginia retail jurisdictional CCR CWIP and electric plant in service

(EPIS) balances. The Company mistakenly omitted requesting recovery of property tax expense on CCR investments in the 2021 E-RAC Proceeding.

II. ACCOUNTING AND PROPOSED RECOVERY OF RGGI COSTS

Q. PLEASE DESCRIBE RGGI COSTS

A. In April 2020, Sections 10.1-1330 and 10.1-1331 were added to the Code of Virginia regarding the Commonwealth of Virginia's participation in the RGGI and the corresponding model rule that established a regional carbon dioxide electric power sector cap-and-trade program. Section 10.1-1330 establishes the implementation of a market-based RGGI auction program to sell allowances for the operation of coal- or gas-fired generation facilities in Virginia.

Q. HAS THE COMPANY INCURRED RGGI COSTS RELATED TO THE OPERATION OF ITS GENERATING FACILITIES?

A. Yes. APCo began incurring RGGI costs in 2021 related to the continued operation of Clinch River, a gas-fired facility. Clinch River is the only APCo coal-fired or gas-fired plant that operates in Virginia.

Q. HAS THE COMPANY DEFERRED RGGI COSTS INCURRED?

A. Yes. Through December 31, 2021, APCo has deferred $340,981 of APCo Virginia retail jurisdictional RGGI costs incurred in accordance with Section 10.1-1331 which allows for recovery of RGGI costs incurred from Virginia retail customers as described below:

> That the costs of allowances purchased through a market-based trading program consistent with the provisions of Article 4 (§ 10.1-1329 et seq.) of Chapter 13 of Title 10.1 of the Code of Virginia as added by this act are deemed to constitute environmental compliance project costs that may be recovered by a Phase I Utility or Phase II Utility, as defined in subdivision A 1 of § 56-585.1 of the Code of Virginia, pursuant to subdivision A 5 e of § 56-585.1 of the Code of Virginia.

Q. HOW DOES THE COMPANY PROPOSE TO RECOVER ITS VIRGINIA RETAIL JURISDICTIONAL RGGI COSTS INCURRED?

A. APCo proposes to recover Virginia retail jurisdictional RGGI costs incurred through the E-RAC. Listed below are the periods of actual and forecasted APCo Virginia retail jurisdictional RGGI compliance expenses that the Company proposes for recovery in its update to the E-RAC revenue requirement effective December 2022 through November 2023:

- $340,981 incurred during the period January 2021 through December 2021;
- $158,159 forecasted for the period January 2022 through November 2022;
- $300,390 forecasted for the period December 2022 through November 2023.

Total RGGI costs incurred and deferred over the period January 2021 through November 2022 will be amortized over the period December 2022 through November 2023. This amortization was used in the development of proposed updated E-RAC rates in this case and would be included as an eligible E-RAC cost for recovery. Any difference between the monthly calculation of RGGI costs incurred and the forecasted level of RGGI costs in this E-RAC filing will be included as a part of the Company's monthly E-RAC over-/under-recovery calculation which will be trued-up in future APCo E-RAC proceedings.

III. <u>PROPOSED ACCOUNTING AND RECOVERY OF ELG COSTS</u>

Q. PLEASE PROVIDE AN OVERVIEW OF THE ELG WORK FOR WHICH THE COMPANY REQUESTS COST RECOVERY IN THIS PETITION.

A. As described further by Company witness Sherrick, the Company is currently incurring engineering, design, permitting, procurement, and construct costs related to the installation of systems to comply with ELG Rule requirements at the Plants. The proposed ELG construction projects at both plants include installation of:

- Dry ash handling systems, and
- Upgraded (Mountaineer) and new (Amos) water biological treatment systems with ultrafiltration

Q. PLEASE DESCRIBE THE COMPONENTS OF ELG INVESTMENTS THAT THE COMPANY IS PROPOSING FOR RECOVERY IN THIS CASE.

A. Through the E-RAC, the Company is proposing recovery of the following costs associated with the ELG investments at both Plants:

- AFUDC on ELG CWIP incurred up to the beginning of the Company's updated E-RAC rate year (December 2022),
- Return on ELG CWIP from the beginning of the Company's updated E-RAC rate year (December 2022) through placement of assets in service,
- Depreciation and return on net ELG assets placed in service (net of accumulated depreciation and accumulated deferred federal income taxes) and
- Property taxes on ELG CWIP and EPIS balances.

Q. WILL THE COMPANY INCUR O&M EXPENSES RELATED TO THE CONSTRUCTION OF ELG ASSETS AT THE PLANTS?

A. The Company does not currently expect to incur incremental O&M expenses related to these ELG construction projects. For any incremental O&M expenses incurred related to the ELG projects at the Plants, the Company will include these expenses as eligible costs for recovery when determining APCo's monthly E-RAC over-/under-recovery calculation and entry. The Company will describe any incurred ELG O&M expenses in future E-RAC filings.

Q. WHAT IS THE FORECASTED CONSTRUCTION PERIOD USED BY THE COMPANY IN DETERMINING THE REVENUE REQUIREMENT FOR THESE ELG INVESTMENTS?

A. As described by Company witness Sherrick, the Company currently forecasts the following in-service dates related to ELG projects at the Plants:

- Amos – Dry Ash Handling System – December 2022 in-service date
- Amos – Water Biological Treatment System with Ultrafiltration – September 2023 in-service date
- Mountaineer – Dry Ash Handling System – May 2022 in-service date
- Mountaineer – Upgraded water Biological Treatment System with Ultrafiltration – June 2023 in-service date

Q. IF THE COMMISSION WERE TO REJECT RECOVERY OF ELG INVESTMENTS AT AMOS AND MOUNTAINEER IN THIS CASE, WILL THE COMPANY PROPOSE CHANGES TO EXISTING DEPRECIATION AND RECOVERY OF THE REMAINING BASE GENERATING UNITS AT THESE FACILITIES?

A. Yes. In a future filing, the Company would propose a change to APCo Virginia retail jurisdictional depreciation rates for the Amos and Mountaineer base generating units. The Company is currently depreciating and recovering remaining Amos and Mountaineer base generating unit book values using the 2019 APCo Virginia depreciation study that was filed by the Company, modified by Staff and approved by the Commission in Case No. PUR-2020-00015. This study established depreciation rates using Amos Plant estimated retirement dates of 2032 for Units 1 and 2 and 2033 for Unit 3 and a Mountaineer Plant estimated retirement date of 2040.

Q. WHAT ARE THE PROJECTED DECEMBER 31, 2028 BOOK VALUES OF THE PLANTS (EXCLUDING ELG INVESTMENTS)?

A. As of December 31, 2021, the Company currently projects December 31, 2028 APCo total company Amos and Mountaineer book values of approximately $582 million and $474 million, respectively. These forecasted balances: a) were determined using APCo Virginia retail ratemaking adjustments consistent with prior APCo Virginia base case filings, b) include CCR investments, c) exclude ELG investments and d) exclude other Amos and Mountaineer base generating unit capital expenditures for the period 2022 through 2028.

Q. IF THE COMMISSION WERE TO REJECT RECOVERY OF ELG INVESTMENTS AT THE PLANTS IN THIS CASE, WILL THE COMPANY REQUEST RECOVERY OF ANY COSTS INCURRED RELATED TO THE CONSTRUCTION OF ELG ASSETS AT AMOS AND MOUNTAINEER?

A. Yes. If the Commission rejects recovery of ELG at the Plants, the Company requests recovery of invested capital (CWIP) and calculated debt and equity AFUDC on ELG CWIP balances through August 2021 when the Commission issued the 2021 E-RAC Order. As represented by Company witness Sherrick, due to environmental legislation, the Company was required to begin engineering, design, permitting, and procurement of the ELG projects at the Plants in advance of receiving Commission approval for recovery of costs incurred. If ELG were to be rejected by the Commission, the Company requests recovery of approximately $15.3 million of APCo Virginia retail jurisdictional ELG CWIP incurred through August 2021 and $526 thousand of APCo Virginia retail jurisdictional AFUDC (revenue requirement level that has been appropriately grossed-up for income taxes) incurred through August 2021 on Amos and Mountaineer ELG CWIP balances.

IV. PROPOSED RECOVERY OF OTHER ENVIRONMENTAL INVESTMENT COSTS

Q. ARE THERE ANY OTHER NEW ENVIRONMENTAL COSTS THAT THE COMPANY IS PROPOSING FOR RECOVERY IN THIS CASE?

A. Yes, the Company is currently incurring construction costs for a DSI project at units 1 and 2 of Amos and DO projects at units 3 and 4 of Claytor Lake. The Amos DSI project is described further by Company witnesses Sherrick, and the Claytor Lake DO project is further described by Company witness Gallimore. The Company requests recovery of costs related to these required environmental projects through the E-RAC.

Q. WHEN WILL THESE COSTS BE PLACED IN SERVICE?

A. As described by Company witnesses Sherrick (Amos Unit 1 and Unit 2 DSI) and Gallimore (Claytor Lake Unit 3 and Unit 4 DO), the Company forecasts the following in-service dates:

- Amos Plant Unit 1 and Unit 2 DSI – December 2022 in-service date
- Claytor Lake Plant Unit 3 DO – November 2024 in-service date
- Claytor Lake Plant Unit 4 DO – November 2023 in-service date

Q. PLEASE DESCRIBE THE COMPONENTS OF THE DSI AND DO INVESTMENTS THAT THE COMPANY IS PROPOSING FOR RECOVERY IN THIS CASE.

A. Through the E-RAC, the Company is proposing recovery of the following costs associated with the DSI investments at Amos and DO investments at Claytor Lake:

- AFUDC on DSI CWIP from January 2022 through November 2022,

- Return on CWIP on DSI and DO construction expenditures from December 2022 through the date of placement of assets in service,
- Depreciation and return on net DSI and DO assets placed in service (net of accumulated depreciation and net of accumulated deferred federal income taxes), and
- Property taxes on DSI and DO assets.

Q. WILL THE COMPANY INCUR INCREMENTAL O&M EXPENSES RELATED TO THE CONSTRUCTION OF AMOS DSI AND CLAYTOR LAKE DO ASSETS?

A. The Company does not currently expect to incur incremental O&M expenses related to these Amos DSI and Claytor Lake DO construction projects. For any incremental O&M expenses incurred related to these projects, the Company will include these O&M expenses as eligible costs for recovery in APCo's monthly E-RAC over-/under-recovery calculation and entry. The Company will describe any incurred O&M expenses in future E-RAC filings.

V. <u>REGULATORY ACCOUNTING</u>

Q. PLEASE DESCRIBE THE COMPANY'S PROPOSED REGULATORY ACCOUNTING AND COST RECOVERY FOR AFUDC RELATED TO THE ELG AND DSI CONSTRUCTION PROJECTS.

A. AFUDC related to the construction of fixed assets represents the estimated cost of borrowed and equity funds used by the Company to finance construction of capitalized assets, including APCo's proposed ELG and DSI construction projects. Similar to the accounting performed for APCo's CCR investments at the Plants, the Company proposes to record cumulative AFUDC through November 2022 by debiting a regulatory asset (FERC Account 182.3) and crediting FERC Accounts 432 and 419 for the income statement impacts of debt and equity AFUDC, respectively. As further detailed in the testimony and support of Company witness Castle, the Company then proposes to amortize the forecasted level of AFUDC incurred on the ELG and DSI projects through November 2022 over a 12-month period starting December 2022. Any difference between the actual amortization of AFUDC and the forecasted level of AFUDC recovered in E-RAC rates will be deferred as a part of the Company's ongoing E-RAC over-/under-recovery calculation and entry.

Q. PLEASE DESCRIBE THE COMPANY'S PROPOSED RECOVERY OF RETURN ON CWIP AND RELATED REGULATORY ACCOUNTING.

A. Similar to the existing accounting performed for CCR investments at the Plants, the Company proposes that for ongoing construction expenditures incurred from December 2022 through the time the ELG, DSI and DO assets are placed in service, APCo will calculate a monthly return on CWIP and will reflect this amount in the Company's monthly E-RAC over-/under-recovery calculation and entry. Company witness Castle has included a forecasted level of return on CWIP for the period December 2022 through November 2023 in the development of the Company's proposed updated E-RAC rider rates effective December 2022. Any difference between the monthly calculation of actual return on CWIP related to ELG, DSI and DO projects and the forecasted level of return on CWIP included in the development of monthly E-RAC rates will be included as a part of the Company's monthly E-RAC over-/under-recovery calculation and entry which will be trued-up in future APCo E-RAC proceedings.

Q. WHAT CARRYING CHARGE RATE WILL THE COMPANY USE TO CALCULATE THE RETURN ON ACTUAL CCR, ELG, DSI AND DO CWIP AND PLANT IN SERVICE INVESTMENTS?

A. In accordance with § 56-585.1 A 10, the Company will use its actual year-end capital structure and cost of capital to calculate a pre-tax weighted average cost of capital (WACC) rate reflecting the authorized ROE of 9.20% effective November 24, 2020 per the Commission order in the 2020 Triennial Review. The WACC rate used to calculate the actual return on CWIP and plant in-service investments for each month will be updated to reflect the actual year-end pre-tax WACC rate for that respective year consistent with past Commission treatment.

Q. PLEASE DESCRIBE THE COMPANY'S ACCOUNTING FOR CCR, ELG, DSI AND DO ASSETS PLACED IN SERVICE AND THE COMPANY'S PROPOSED RATEMAKING TREATMENT.

A. The Company will initially record these construction costs to FERC Account 107 before transferring the completed construction cost to FERC Account 101 (excluding AFUDC and carrying charges during construction) when the asset is placed in service. The Company will then record related depreciation expense to FERC Account 403 and corresponding accumulated depreciation to FERC Account 108. Consistent with ratemaking treatment in base rates, the Company proposes to reflect the investments described in this case as a component of rate base (electric plant in service less accumulated depreciation and less related accumulated deferred income taxes) in order to calculate a return on rate base and include such return along with the related depreciation expense as recoverable costs of service. Any difference between the monthly calculation of actual depreciation expense and return on rate base related to the CCR, ELG, DSI and DO projects and the forecasted levels included in monthly E-RAC rates will be included as a part of the Company's monthly E-RAC over-/under-recovery calculation and entry which will be trued-up in future APCo E-RAC proceedings.

Q. WHAT ARE THE CCR AND ELG DEPRECIATION RATES THAT THE COMPANY USED FOR DEVELOPING THE REVENUE REQUIREMENT IN THIS FILING?

A. The 2019 depreciation study that was filed by the Company, modified by Staff and approved by the Commission in the 2020 Triennial Review established depreciation rates using Amos estimated retirement dates of 2032 for Units 1 and 2 and 2033 for Unit 3 and a Mountaineer estimated retirement date of 2040. As proposed by the Company and approved by the Commission in the 2021 E-RAC Order, the Company will use initial depreciation rates of 9.52% for Amos and 5.71% for Mountaineer for CCR assets that are placed in service. These depreciation rates are based on average in-service dates of the CCR/ELG projects at Amos and Mountaineer. The Company proposes using these same depreciation rates for ELG assets when placed in service. The proposed depreciation rates do not consider a component for net salvage at this time. In future depreciation studies filed by the Company, APCo will request and upon approval, apply a net salvage factor to these assets.

Q. WILL THE COMPANY USE EXISTING DEPRECIATION RATES TO DEPRECIATE DSI AND DO INVESTMENTS DESCRIBED IN THIS FILING?

A. Yes, the Company will use existing generation depreciation rates based on the depreciation study filed by the Company, modified by Staff and approved by the

Commission in the 2020 Triennial Review. The Company will include any proposed updates to the depreciation rates used for DSI and DO investments and similar assets in future depreciation studies submitted to the Commission. For the development of the revenue requirement in this filing, the Company used the previous Commission-approved 4.63% depreciation rate for Amos Unit 1&2 DSI projects (FERC subaccount 312) and 3.64% depreciation rate for Claytor Lake Unit 3&4 DO projects (FERC subaccount 333).

Q. WILL THE COMPANY TRUE-UP THE RECOVERY OF COSTS THROUGH THE E-RAC?

A. Yes. The Company will continue to practice traditional over-/under-recovery deferral accounting by comparing the actual incurred costs described throughout my testimony with actual E-RAC revenues. Any net E-RAC under-recovery recorded as a regulatory asset or any net E-RAC over-recovery recorded as a regulatory liability will be included for future recovery or refund, respectively, through the proposed true-up to actual costs in subsequent E-RAC applications.

Q. WILL THE COMPANY USE UNIQUE ACCOUNTS TO TRACK MONTHLY E-RAC OVER-/UNDER-RECOVERY ACCOUNTING?

A. Yes. The Company will continue to use unique regulatory asset and liability subaccounts within FERC Accounts 182.3 and 254 for monthly E-RAC over-/under-recovery accounting. Corresponding income statement adjusting accounts will also be established for proper E-RAC over-/under-recovery accounting.

Q. HOW WILL THE COMPANY ENSURE THAT THE EXPENSES REQUESTED FOR RECOVERY IN THIS E-RAC FILING ARE EXCLUDED FROM THE COMPANY'S VIRGINIA BASE RATE CASE AND OTHER RIDER FILINGS?

A. As included for recovery in this E-RAC filing and described throughout my testimony, CCR, ELG, DSI and DO capital investments and E-RAC revenues and expenses will be excluded from any other rider recovery and future APCo Triennial earnings reviews through the use of unique projects and work orders to identify and track these costs.

Q. DOES THIS CONCLUDE YOUR DIRECT TESTIMONY?

A. Yes.

Exhibit 10

DECLARATION of METIN CELEBI, PH.D.

I, Dr. Metin Celebi, declare:

1. I am a Principal at The Brattle Group, a global economic consultancy. I hold a Ph.D. in Economics from Boston College and have over 20 years of experience in the U.S. electric sector. A copy of my resume is provided in Attachment A.

2. Based on my review of the U.S. Environmental Protection Agency's ("EPA") final rulemaking titled "Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category" and published at 89 Fed. Reg. 40198 (May 9, 2024) (the "Final Rule," "ELG Rule," or "Rule") and various supporting materials and public comments in the docket for that rulemaking, Docket ID No. EPA-HQ-OW-2009-0819, I offer the following expert opinions on the economics of coal-fired electric generating units ("EGUs") in the U.S. and the Rule's potential impacts on the U.S. coal fleet.

3. My opinions as expressed in this Declaration are informed by my training and extensive experience as an energy economist. I have routinely conducted economic analyses of coal plant operations, environmental regulations, and long-range planning for electric utilities—issues that are central to this Rule. I have testified in cases before the Federal Energy Regulatory Commission ("FERC"), the U.S. District Court for the Eastern District of Missouri, the Public Service Commission of Wisconsin, Iowa Utilities Board, the Pennsylvania Public Utility Commission, the Kentucky Public Service Commission, the Public Utility Commission of Texas, and the Superior Court of the State of Arizona on topics including the economics of coal plant retirements and their impact on wholesale energy prices, economic damages in energy contract disputes, locational marginal price spikes in the Pennsylvania-New Jersey-Maryland (known as "PJM") Regional Transmission Organization, allocation of certain ancillary services costs among

market participants in the Electric Reliability Council of Texas (known as "ERCOT"), and wholesale power prices in Arizona. More recently, I filed a declaration before the United States Court of Appeals for the DC Circuit regarding EPA's rule on GHG emissions from power plants, and before the Supreme Court of the United States concerning compliance requirements and options under the EPA's Good Neighbor Plan for the 2015 Ozone National Ambient Air Quality Standard.

4. The ELG Rule is a Clean Water Act regulation that supplements and updates EPA's 2015 and 2020 technology-based effluent limitations guidelines and standards for wastewater discharges from steam electric, coal-fired power plants larger than 50 MW. I understand that the Rule establishes a zero-discharge limitation for all pollutants in flue gas desulfurization ("FGD") wastewater, bottom ash ("BA") transport water, and managed combustion residual leachate (i.e., leachate collected and discharged through power plant's discharge system). The Rule also requires numeric (non-zero) discharge limitations for mercury and arsenic in unmanaged combustion residual leachate wastewater (i.e., leachate that is not collected, but discharges through discernable conveyances) and for legacy wastewater discharged from surface impoundments during the closure process. The requirements do not apply until the date they are incorporated into the facility's wastewater permit, as determined by the relevant permitting authority that is as soon as possible on or after July 8, 2024, but no later than December 31, 2029. Moreover, the Rule's discharge limits do not apply to power plants that commit to permanently cease burning coal by 2034.[1] For those power plants that intend to cease burning coal by 2034, the Rule also includes

[1] Federal Register Vol. 89, No. 91, Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category, May 2024 ("89 Fed. Reg."), at p. 40199, 40200.

reliability mechanisms allowing state or federal regulators to call on coal units to continue operating for reliability purposes without violating the Clean Water Act.[2]

5. EPA estimates that only 35 power plants out of 688 will incur compliance costs.[3] EPA's regulatory impact analysis indicates that under the Final Rule, by 2035, only five power plants are expected to retire somewhat earlier than planned under the current regulatory baseline.[4]

6. Coal-fired power plants in the U.S. have been facing a challenging set of economic and policy drivers, including low gas prices and decreasing costs of renewable energy, rising operation and maintenance ("O&M") costs, and states' climate and clean energy policies as well as federal environmental regulations (apart from the Rule in question). These drivers have persisted over the past decade, if not longer, and they will likely continue in their trajectory in the foreseeable future. Together, these drivers have eroded the economic viability of coal plants across the country. While the EPA's Final Rule may accelerate the timing of retirement for some coal-fired EGUs —the agency's analysis indicates that under the rule, by 2035, five facilities will retire early— the majority of future coal retirements over the next 10–15 years will likely happen regardless of this Rule. My opinions are based on several observations below.

Continuing Decline in Coal Plants' Capacity and Utilization

7. As of March 2023, 86.8 GW of the 218 GW coal fleet was announced to retire by 2040.[5] In other words, approximately 40% of U.S. coal capacity was already slated to retire before this Rule was proposed.

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[2] 89 Fed. Reg. at 40302.
[3] 89 Fed. Reg. at 40265, 40266.
[4] 89 Fed. Reg. at 40265, 40266.; EPA, Regulatory Impact Analysis for Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category, April 2024, at ES-6.
[5] Hitachi Powergrid, Velocity Suite, as-of March 6, 2023. Based on nameplate capacity, as tracked by Hitachi Powergrid. There may be discrepancies between the estimated coal fleet sizes reported here and what is used by EPA for its regulatory impact analysis that are a result of using different definitions to determine the active fleet. Fleet estimates used herein are based on the retirement date (or lack thereof) of units as tracked by Hitachi.

8. More coal plants will almost certainly retire than just those that have already announced their intent to retire. In fact, announced retirements have historically understated the actual retirements by more than 50%.[6] For instance, as of March 2018, only about 14 GW of coal capacity was announced to retire between 2019 and 2022. In reality, more than 44.5 GW of coal capacity was retired over that period, more than three times the expectation.

9. The large number of recent announced coal plant retirements is a continuation of a long-running and accelerating trend of declining coal usage in the U.S. After a small, albeit steady, increase in the early aughts, the total U.S. operating coal capacity began to decrease at a rapid pace in the early 2010s. By the end of 2023, there was 209 GW of coal capacity in the U.S., a decline of 35% over the past 18 years. Concurrently, the amount of electricity generated from coal plants also declined substantially: annual generation fell from 2,013 TWh in 2005 to 675 TWh in 2023, a greater than 65% decline. The fleet-wide capacity factor, a measurement of how fully power plants are operated, decreased from 67% to 38% over the same time period.[7] Not only has the U.S. coal fleet been reduced in size, it has also generated significantly less electricity both on a fleet-wide basis and a per-plant basis.

10. Recent analysis and reports anticipate that the decline in coal usage will continue well into the foreseeable future, with most U.S. coal plants expected to retire by 2040. For example, in the EPA's regulatory impact analysis of the Rule, only about 23% of current coal-fired plant capacity (or 42 GW out of 181 GW) is forecast to be online by 2040 under the business-as-usual scenario (i.e., baseline case without the ELG Rule).[8]

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[6] Celebi et al., A Review of Coal-Fired Electricity Generation in the U.S., The Brattle Group, April 27, 2023.

[7] Capacity factors were calculated using the net annual generation divided by the nameplate capacity multiplied by 8760 hours. Annual generation totals are based on data aggregated by Hitachi Powergrid, Velocity Suite,

[8] EPA, Regulatory Impact Analysis for the New Source Performance Standards for Greenhouse Gas Emissions from New, Modified, and Reconstructed Fossil Fuel-Fired Electric Generating Units; Emission Guidelines for Greenhouse Gas Emissions from Existing Fossil Fuel-Fired Electric Generating Units; and Repeal of the Affordable

Increasing Competitive Pressure and Rising Costs for Coal Plants

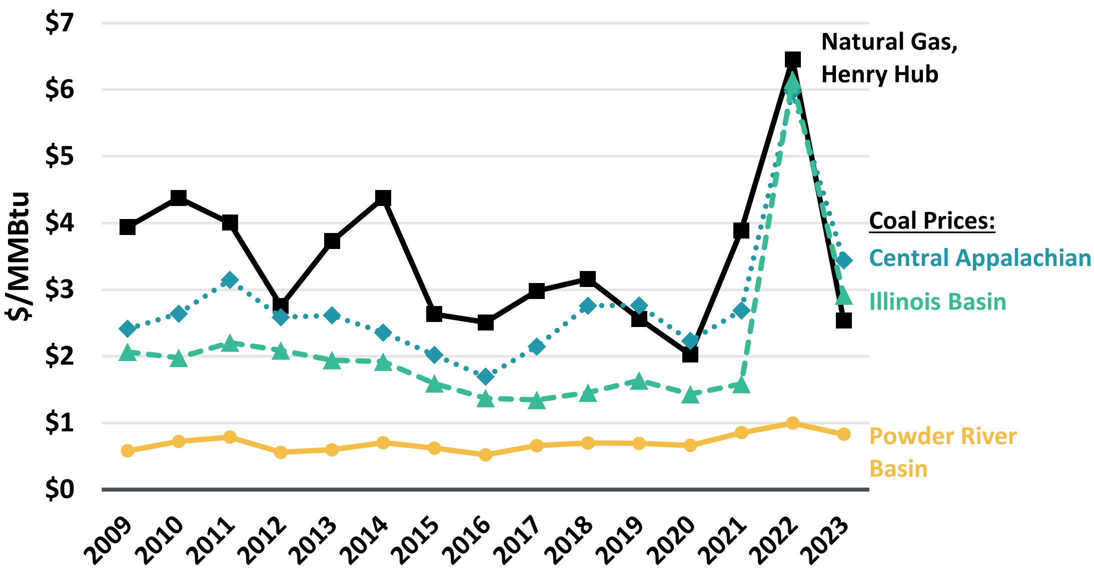
11. Low natural gas prices are a primary factor behind the U.S. coal plants' decline in economic competitiveness. In addition to making it cheaper to replace generation output of retiring coal-fired units, low gas prices also reduce wholesale power prices, undermining the profitability of coal plants. Indeed, the successful deployment of shale gas technology is the largest single factor responsible for lower wholesale power prices in the U.S.[9] As seen in Figure 1 below, gas prices over the 2009 to 2023 period experienced a sustained and substantial decline. Annual average spot prices at Henry Hub, a major gas trading hub in the U.S., over this period decreased from about $3.94/MMBtu to $2.54/MMBtu (in nominal dollars). Gas prices increased sharply during the occasional cold snaps, when demand for gas spiked, but mostly trended downward. Gas price forecasts remained elevated for some time as industry analysts were unsure about the permanent nature of low gas prices, but as the impacts of shale gas on the market became clearer, forecasts were revised downward.[10] In 2021 and 2022, increased LNG exports, Russia's invasion of Ukraine, and recovery from the pandemic drove gas prices higher, but the market has since adjusted to these shocks and appeared to stabilize. In contrast, annual average coal prices have increased over the last 14 years, from 2009 to 2023 (see Figure 1 below).

Clean Energy Rule ("RIA"), April 2024, at P. 3-20 and Table 3-14. Different data sources report different capacities for the total fleet size in the U.S. For consistency, the fleet-wide metrics are based on data collected by Hitachi Powergrid, Velocity Suite, unless otherwise specified.

[9] A. D. Mills, D. Millstein, R. Wiser, J. Seel, J. p. Carvallo, S. Jeong, W. Gorman, Impact of Wind, Solar, and Other Factors on Wholesale Power Prices: An Historical Analysis—2008 through 2017, Lawrence Berkeley National Laboratory, November 2019.

[10] Celebi et al., A Review of Coal-Fired Electricity Generation in the U.S., The Brattle Group, April 27, 2023.

Figure 1: Historical Coal Spot Prices versus Henry Hub Natural Gas Prices



Source: S&P Global Market Intelligence[11]

12. As gas prices have decreased, so too have the costs of new renewables and battery storage, making it more economic to deploy these technologies (see Figure 2A and Figure 2B). The greater level of renewable energy and battery storage deployment in many parts of the country in recent years further diminished the economic attractiveness of coal plants. Renewable energy resources with zero short-run marginal costs have similar effects on coal plants as cheap natural gas, pushing additional lower cost generation resources below the dispatch costs of coal units, hence reducing the wholesale power prices, coal-fired EGU profit margins, and the dispatch (operation) of coal-fired units in the energy markets. The combined effects of renewables and low-

[11] S&P Global Market Intelligence requires the following disclaimer to accompany presentations reflecting its services: "Reproduction of any information, data or material, including ratings ("Content") in any form is prohibited except with the prior written permission of the relevant party. Such party, its affiliates and suppliers ("Content Providers") do not guarantee the accuracy, adequacy, completeness, timeliness or availability of any Content and are not responsible for any errors or omissions (negligent or otherwise), regardless of the cause, or for the results obtained from the use of such Content. In no event shall Content Providers be liable for any damages, costs, expenses, legal fees, or losses (including lost income or lost profit and opportunity costs) in connection with any use of the Content. A reference to a particular investment or security, a rating or any observation concerning an investment that is part of the Content is not a recommendation to buy, sell or hold such investments or security, does not address the suitability of an investment or security and should be relied on as investment advice. Credit ratings are statements of opinions and are not statements of fact."

cost natural gas can lead to coal plants not being selected to serve load (and earn revenue) in many hours.

Figure 2A: Historical Solar and Wind Levelized Costs and Contract Prices

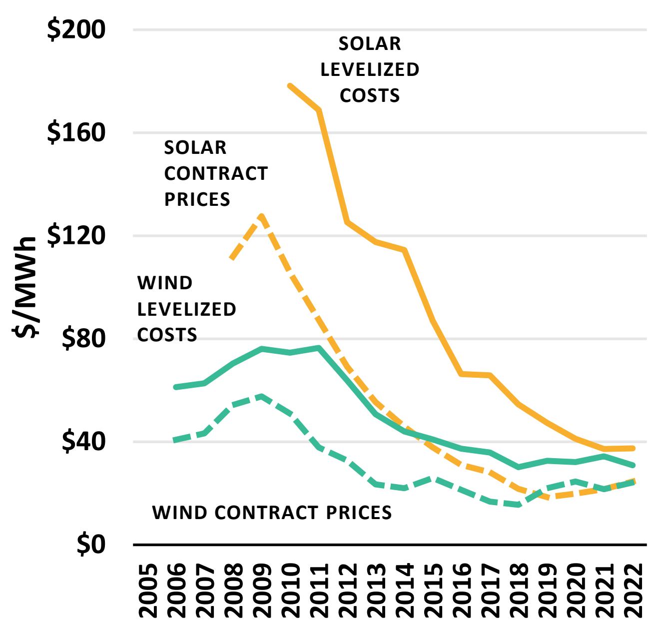
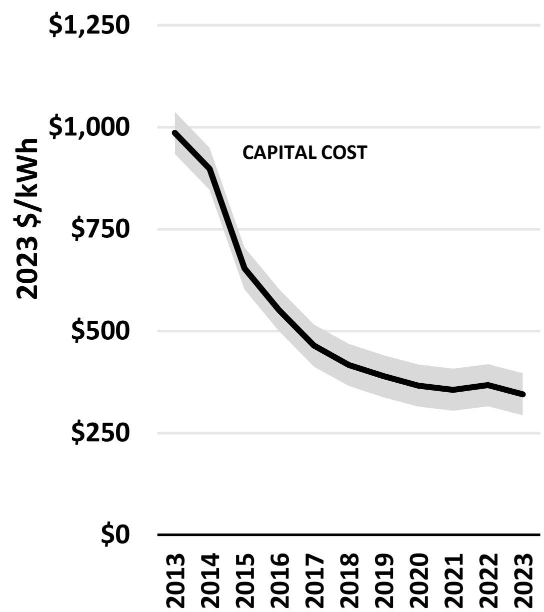


Figure 2B: Historical Cost Decline of Utility-Scale Battery Storage Facilities



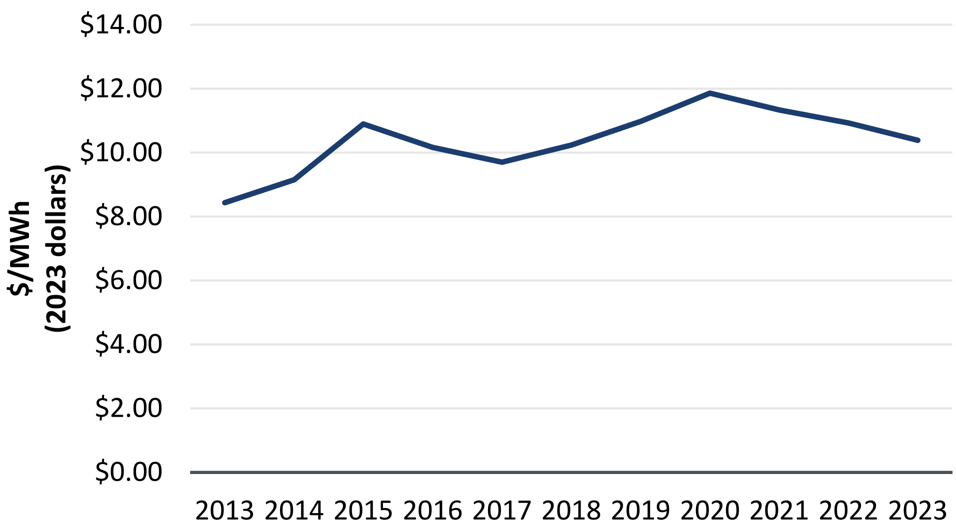
Notes and Sources:

- Wind and Solar: Brattle, Bulk System Reliability for Tomorrow's Grid, 2023, Figure 2. Costs expressed in nominal dollars.
- Storage: Brattle, Bulk System Reliability for Tomorrow's Grid, 2023, Figure 3. Shaded portion corresponds to a 25% low and high range on the non-pack costs of battery storage systems.

13. As U.S. coal plant owners struggle with the competitive pressure from cheap natural gas price and low-cost renewable energy and battery storage resources, they also have to grapple with rising costs to operate an aging coal fleet. On average, non-fuel O&M of the coal fleet operating in 2023 and owned by regulated utilities (investor-owned, municipal, and cooperative utilities) have increased in real 2023 dollars from $8.45/MWh in 2013 to $10.53/MWh in 2023 (see Figure 3 below). As coal units become older, they are more prone to outage and require more maintenance. Older plants tend to experience more frequent cycling, higher equipment failure rates, and therefore greater maintenance costs relative to the amount of power

generated and sold. Indeed, each additional year of an average coal unit's life corresponds to an additional $0.13/MWh of O&M costs.[12] Aging plants also require more capital investments: each additional year of a coal plant's life corresponds to an additional $0.04/MWh of annual capital expenses.[13] Non-fuel O&M costs will likely increase as the U.S. coal fleet becomes older. And the average age of the U.S. coal fleet is already higher than at any given point in the history of the coal fleet: the average age of the current operating fleet is 46 years, nearly 25% older than the fleet in 2005. Historically, average life of coal-fired units has been approximately 52 years.[14]

Figure 3: Historical Non-Fuel O&M Costs of U.S. Regulated Coal Plants



14. The EPA's estimate of the unit-specific incremental compliance costs associated with the ELG are quite modest for most of the affected coal-fired units relative to the typical capital and operating and maintenance (O&M) costs of coal-fired plants. Specifically, EPA estimated that the incremental capital costs to comply with the ELG rule would be lower than $59.37/kW of

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[12] These cost estimates are reported in 2017 dollars and reflect incremental costs for each year of a plant's age beyond a base total O&M cost of $5.44 per MWh. U.S. Energy Information Administration, Generating Unit Annual Capital and Life Extension Costs Analysis, 2019, p. 9.

[13] *Id.*

[14] Represents the average age of coal plants with retirement date between January 1, 2003 and January 1, 2023. Hitachi Powergrid, Velocity Suite, as-of March 6, 2023.

capacity for 75% (or 85 units) of the affected units in 2023 dollars. In comparison, the estimated capital cost to build a new coal-fired power plant is in the range of $4,693-$7,471/kW depending on the extent of carbon capture equipment.[15] Similarly, EPA's estimate for the incremental annual O&M costs to comply with the ELG rule is less than $4.49/kW-yr for 75% (or 85 units) of the affected units in 2023 dollars, compared to the estimated annual fixed O&M costs of $48-$70/kW-yr for new coal-fired units and the total O&M cost of $57/kW-yr for the existing coal-fired fleet on average.[16,17]

15. Competitive pressure from natural gas, renewable energy, and energy storage coupled with high O&M costs for operating the coal-fired plants means that many coal power plants are earning less from energy, capacity, and ancillary services revenue than their avoidable costs. For instance, in PJM, only 2% of coal-fired units fully recovered their avoidable costs in 2023 from all markets, compared to 83% of coal-fired units in 2014.[18] Unlike the remainder of the generating fleet (including natural gas plants, solar, wind, etc.), coal units are often unable to recover enough of their avoidable costs through the capacity market. The dark spread, a measurement of difference between market price and the cost of coal used to generate power, decreased across PJM hubs by 90% between 2014 and 2023, indicative of the current low profit margins that coal plants are facing.[19]

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[15] Energy Information Administration, "Assumptions to Annual Energy Outlook 2023: Electricity Market Module", March 2023, posted at https://www.eia.gov/outlooks/aeo/assumptions/pdf/EMM_Assumptions.pdf.

[16] For new coal-fired units, see Energy Information Administration, "Assumptions to Annual Energy Outlook 2023: Electricity Market Module", March 2023, posted at https://www.eia.gov/outlooks/aeo/assumptions/pdf/EMM_Assumptions.pdf. For existing coal-fired units, see Energy Information Administration, "Generating Unit Annual Capital and Life Extension Costs Analysis", December 2019 posted at https://www.eia.gov/analysis/studies/powerplants/generationcost/pdf/full_report.pdf

[17] Values for estimated capital and O&M costs of new and existing coal plants have been adjusted for inflation to reflect 2023 dollars.

[18] 2023 State of the Market Report for PJM, Monitoring Analytics, 2024, p. 415.

[19] 2023 State of the Market Report for PJM, Monitoring Analytics 2023; PJM, 2020 State of the Market Report for PJM, Monitoring Analytics, 2021.

16. Competitive pressure from renewable energy generation is likely to continue as a result of the implementation of the Inflation Reduction Act, which includes tax credits and other federal funds intended to incentive the transition to clean energy generation. The federal statute is expected to result in a significant increase in new renewable energy generation, which will further decrease the dispatch of coal plants in the energy market.

Many Coal Plants Have to Comply with States' Climate and Clean Energy Policies

17. Many states have stringent targets to reduce GHG emissions and increase reliance on clean energy. As of March 2023, 24.9 GW of the currently operating coal units that have not yet announced to retire by 2040 were in states that have aggressive decarbonization goals or mandates.[20] To comply with these clean energy and decarbonization requirements, coal plant owners will likely need to retire their coal assets or install CCS equipment before 2050. (They can also reduce GHG emissions from other power plants in their portfolio, but doing so would not be economic if the variable costs to operate coal EGUs are higher.) Compliance with other federal regulations will further add costs to operating coal plants.[21]

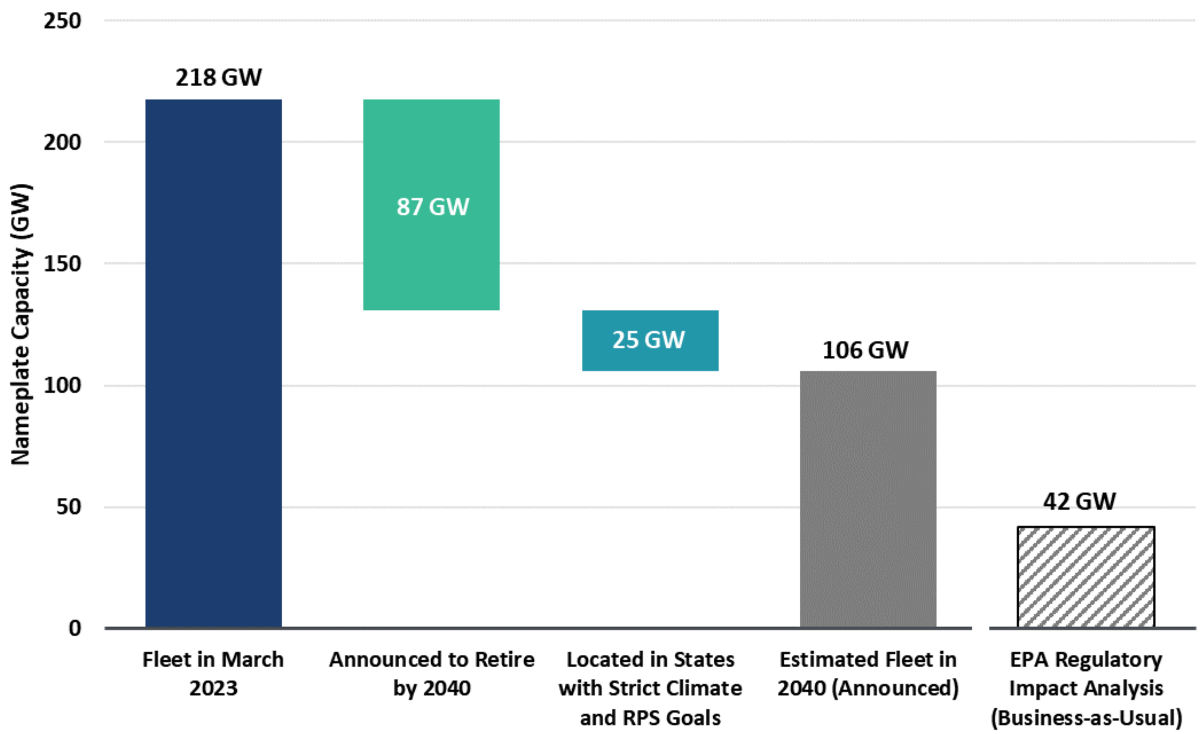
18. In summary, even without the EPA's new ELG rule requiring zero discharge of toxic pollutants in the three largest wastewater streams from existing coal-fired units, more than half of the coal fleet capacity as of March 2023 was either already slated for retirement by 2040 or located in states with strict decarbonization and RPS goals (see Figure 4). As explained above, the

[20] States with aggressive decarbonization goals or mandates (i.e., states with 100% clean energy targets; 100% greenhouse gas emissions reduction targets relative to an established baseline; or net zero greenhouse gas emissions targets) with greater than 100 MW of active coal capacity include Colorado, Delaware, Illinois, Louisiana, Maryland, Michigan, Minnesota, Nevada, New Mexico, New York, North Carolina, Virginia, Washington, and Wisconsin.

[21] These federal regulations include the Effluent Limitations Guidelines and Standards, Mercury and Air Toxics Standards, Good Neighbor Plan, Regional Haze Rule, and Coal Combustion Residual Rule, among others.

announced retirements are likely an understatement of the actual retirements by 2040, even without the ELG rule.

Figure 4: U.S. Coal-fired Generation Fleet Outlook without the EPA ELG Rule



ONGOING EFFORTS TO PLAN FOR LOAD GROWTH AND AN ORDERLY TRANSITION

19. The recently emerging load growth is unlikely to improve the long-term economic viability of coal plants. After decades of persistently low load growth, the U.S. power sector is entering a period of expansion. Data centers supporting web-based services, artificial intelligence, and cryptocurrency mining, along with manufacturing facilities (including those used to produce hydrogen) and the electrification of the transportation and building sectors will increase demand for electricity in the coming years. However, the exact magnitude of these load drivers is unclear at this time, as is where they will take place. But even if significant load growth will materialize, the industry can serve new load with renewables energy resources, storage, and existing and new natural gas units. In fact, of the 1,570 GW of generation capacity waiting in the interconnection

queues to be connected, clean energy projects such as wind and solar make up an overwhelming majority (~1,480 GW).[22] In addition, over 1,000 GW of storage capacity is in the queues. While only a fraction of the resources in the queues eventually will be built and connected to the grid, this snapshot indicates that a large portion of anticipated new load growth can be met with clean energy resources. Ongoing efforts by RTOs and FERC to shorten the time projects spend in the interconnection queues, to build new transmission assets proactively, and to introduce options for transferring capacity interconnection rights will help bring these renewable and other new resources online more speedily.[23] As a recent example, PJM is reviewing proposals for expediting the transfer of capacity interconnection rights to new resources.[24] Further, the push to leverage demand-side resources such as energy efficiency and load flexibility will further reduce the need for more supply resources.[25]

20. An orderly transition away from coal can preserve grid reliability and do so at lower costs to customers. The transition introduces challenges but also offers abundant opportunities and solutions to address those challenges, shifting the focus of grid reliability management

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[22] Joseph Rang et al., "Queued Up: 2024 Edition." Lawrence Berkeley National Laboratory, p. 3. https://emp.lbl.gov/sites/default/files/2024-04/Queued%20Up%202024%20Edition_R2.pdf.

[23] See *Improvements to Generator Interconnection Procedures and Agreements,* Order No. 2023, 184 FERC 61,054 (2023), and *Building for the Future Through Electric Regional Transmission Planning and Cost Allocation,* Order No. 1920, 187 FERC ¶ 61,068 (2024). In addition, U.S. Senators Joe Manchin and John Barrasso recently introduced a bill (Energy Permitting Reform Act of 2024) in July 2024 to accelerate permitting processes for various infrastructure projects including new transmission projects. See https://www.energy.senate.gov/2024/7/manchin-barrasso-release-bipartisan-energy-permitting-reform-legislation#:~:text=The%20Energy%20Permitting%20Reform%20Act%20will%20advance%20American%20energy%20once,now%2C%E2%80%9D%20said%20Chairman%20Manchin.

[24] See Monitoring Analytics, "CIR Transfer Efficiency -- IMM Package", July 16, 2024, available at https://www.monitoringanalytics.com/reports/Presentations/2024/IMM_PC_CIR_Transfer_Efficiency_IMM_Package_20240716.pdf

[25] According to a Brattle study, there is as much as 200 GW (20% of peak load) of cost-effective load flexibility potential in the U.S. by 2030. *See* Ryan Hledik, et al., "The National Potential for Load Flexibility: Value and Market Potential Through 2030." The Brattle Group. https://www.brattle.com/insights-events/publications/brattle-study-cost-effective-loadflexibility-can-reduce-costs-by-more-than-15-billion-annually/. A U.S. DOE report finds that demand-side resources can contribute to between 10-20% of peak demand. *See* Jennifer Downing et al., "Pathways to Commercial Liftoff: Virtual Power Plants," US Department of Energy. https://liftoff.energy.gov/wp-content/uploads/2023/10/LIFTOFF_DOE_VVP_10062023_v4.pdf.

practices.[26] Irrespective of the EPA's ELG rule, a comprehensive suite of reliability reforms is needed to address the transition challenges. Elements of such reliability reforms are already in place or underway at various grid operators, including resource and transmission adequacy planning that is already occurring at the state, federal, and regional transmission operator levels. Acceleration of these reforms should be a priority to ensure reliability during the transition. For specific cases in which EPA's ELG regulations result in transition-related challenges and reliability reforms do not keep pace, the Rule allows for regulatory flexibility in addressing bona fide reliability needs. For example, for units that qualified as "low utilization electric generating units" or those units that have opted to cease burning coal in 2028 or 2034 instead of complying with the 2020 or 2024 standards, the Rule, 40 C.F.R. § 423.18(a), includes options allowing those units to continue operating beyond 2028 or 2034, respectively, if called upon by the Department of Energy under § 202(c) of the Federal Power Act or by state regulators or independent system operators in response to a "reliability-related order, energy emergency alert, or agreement which results in operation "not contemplated when the certification was made."[27] In other words, grid operators already have, and are developing, tools that will help ensure system reliability over the next decade and beyond.

21. Coal plants across the country have been under great economic pressure due to high operating costs, low natural gas and renewable energy costs, and state and federal regulations—economic and policy drivers that are independent of the Rule. These drivers are likely to persist in the foreseeable future, and the majority of anticipated coal plant retirements over the next decade are likely to occur irrespective of this Rule.

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[26] Metin Celebi et al., "Bulk System Reliability for Tomorrow's Grid", The Brattle Group, December 20, 2023. https://www.brattle.com/wp-content/uploads/2023/12/Bulk-System-Reliability-for-Tomorrows-Grid_December-2023_Final.pdf.
[27] 89 Fed. Reg. at 40302.

I declare that the above is true and accurate under the penalty of perjury.

Executed in Boston, Massachusetts on August 16, 2024.

____

Metin Celebi

Attachment A

Metin Celebi

PRINCIPAL

Practice Leader: Electricity Litigation & Regulatory Disputes

Boston | +1.617.864.7900 | Metin.Celebi@brattle.com

Dr. Celebi is an expert in electricity markets, resource planning, and the analysis of environmental and climate policy.

He has assisted clients in the areas of electricity litigation and regulatory disputes, including on the economic viability of coal-fired and nuclear power plants, wholesale power pricing, and market design. Dr. Celebi has also analyzed federal and state climate policies, environmental regulations, the role of hydrogen in reducing economy-wide greenhouse gas (GHG) emissions, generation plant valuation, and transmission cost allocation.

Dr. Celebi has provided expert testimony in a number of cases before the Supreme Court of the United States, district courts, and federal and state energy regulatory agencies. His testimonies have covered topics including the compliance burden of federal environmental regulations; economic damages in energy contract disputes; transmission cost allocation; excessive charges in long-term power contracts; causes of LMP spikes in PJM; and the allocation of ancillary services costs among market participants in ERCOT. He has also consulted and testified on matters related to coal plants, the recovery of undepreciated past investments, and the impact of coal plant retirements on wholesale energy prices.

AREAS OF EXPERTISE

- Electricity Litigation & Regulatory Disputes
- Electricity Wholesale Markets & Planning

PROFESSIONAL EXPERIENCE

- **The Brattle Group (2000–Present)**
  Principal (2011–Present)
  Senior Associate (2006–2011)
  Associate (2000–2006)

- **London Economics, Inc. (1999–2000)**
  Associate
- **Boston College (1998–1999)**
  Teaching Fellow, Microeconomics and Macroeconomics

EDUCATION

- **Boston College**
  PhD in Economics
- **Bilkent University (Ankara, Turkey)**
  MA in Economics
- **Middle East Technical University (Ankara, Turkey)**
  BS in Industrial Engineering
- **Hebrew University**
  Summer School in Economic Theory on Auctions and Market Design

EXPERT TESTIMONY

- Before the United States Court of Appeals for the District of Columbia Circuit, declaration on behalf of Environmental and Public Health Respondent-Intervenors re: economics of coal-fired electric generating units in the U.S. and the potential impacts of EPA's GHG Rule on the U.S. coal fleet (June 7, 2024).
- Before the Supreme Court of the United States, declaration on behalf of Public Interest Respondents re: compliance requirements and flexibility to choose among compliance options under the EPA's Good Neighbor Plan for the 2015 Ozone National Ambient Air Quality Standard (October 26, 2023).
- Before the Iowa Utilities Board, direct and rebuttal testimony on behalf of Interstate Power and Light Company re: reasonableness of IPL continuing to fully recover the remaining net book value of Lansing Generating Station Unit 4, a coal-fired generating unit, after the unit's retirement (October 12, 2023 and May 13, 2024).
- Before the United States Court of Appeals for the Sixth Circuit, declaration on behalf of Conservation Groups re: compliance requirements and flexibility to choose among compliance options under the EPA's Good Neighbor Plan for the 2015 Ozone National Ambient Air Quality Standard (September 5, 2023).

- Before the United States Court of Appeals for the District of Columbia Circuit, declaration on behalf of Environmental and Public Health Intervenors re: compliance requirements and flexibility to choose among compliance options under the EPA's Good Neighbor Plan for the 2015 Ozone National Ambient Air Quality Standard (August 18, 2023).
- Before the District Court 165th Judicial District, Harris County, Texas, prepared expert report on behalf of Peaker Power, LLC re: economic damages from the counterparty's violation of heat rate call option contracts by exceeding the annual cap on exercise hours during Storm Uri in February 2021 (July 25, 2022).
- Before the Federal Energy Regulatory Commission (FERC), prepared answering testimony on behalf of Tri-State Generation and Transmission Association, Inc. re: the appropriate approach to determine the contract termination payment from a departing member (February 4, 2022, March 25, 2022).
- Before the United States District Court for the Western District of North Carolina Charlotte Division, direct and rebuttal expert reports on behalf of NTE Energy re: discounts provided by Duke Energy Progress (DEP) to City of Fayetteville in its wholesale power supply contract and the impacts on competition as well as on rates being charged to DEP's other wholesale and retail customers (January 14, 2022, February 18, 2022).
- Before the Public Service Commission of Wisconsin, prepared direct testimony on behalf of Wisconsin Power and Light Company re: appropriateness of WPL continuing to recover as a regulatory asset the undepreciated past investments at the Edgewater 5 coal unit after its proposed retirement in 2022 (May 27, 2021).
- Before Québec Régie de l'énergie, prepared direct testimony and oral testimony in hearing on behalf of Hydro-Québec Trans-Énergie (HQT) re: the adequacy of the categories used by HQT to classify its transmission investments and HQT's treatment of transmission losses in transmission planning (March 7, 2019).
- Before the Public Service Commission of Kentucky, prepared direct testimony on behalf of Big Rivers Electric Corporation re: economic viability of Station Two coal plant (May 1, 2018).
- Before the United States District Court Eastern District of Missouri Eastern Division, expert report on behalf of Ameren Missouri re: impacts of proposed mandates to install emission control equipment at Rush Island coal plant on revenue requirements and economic viability of the plant, Case No. 4:11 CV77 RWS (April 23, 2018 and April 27, 2018).

- Before the Superior Court of the State of Arizona, expert report on behalf of Vieste SPE, LLC and Vieste Energy LLC re: projected long-term wholesale power prices in Arizona (January 30, 2017 and February 21, 2017).
- Before the Federal Energy Regulatory Commission (FERC), prepared direct testimony on behalf of the California parties re: economic burden imposed by the prices in two long-term contracts that the California Department of Water Resources (CDWR) signed with Shell and Iberdrola during the California energy crisis (May 19, 2015 and October 6, 2015).
- Before the Public Service Commission of Wisconsin, pre-filed rebuttal and surrebuttal testimony on behalf of Wisconsin Public Service Corporation re: the impacts of pending coal plant retirements and environmental retrofits on energy and capacity prices in the MISO market region (December 14, 2012 and January 11, 2013).
- Before the District of Columbia Office of Tax and Revenue, affidavit on behalf of Pepco Energy Services re: categorization of electricity as a tangible property versus a service for determining the eligibility of electricity sales for exemption from sales tax (July 15, 2011).
- Before the Pennsylvania Public Utilities Commission, Docket No. P 2008 2020257, rebuttal and surrebuttal testimony on behalf of Pennsylvania Electric Company re: causes and pricing of transmission congestion in Wellsboro area in PJM (January 16, 2009 and March 10, 2009) (with P. Hanser).
- Before the Public Utilities Commission of Texas, Docket 33416, affidavit supporting Constellation New Energy's request for expedited hearing re: allocation of replacement reserve costs in ERCOT (November 8, 2006).

SELECTED CONSULTING EXPERIENCE

ENERGY LITIGATION AND REGULATION

- For PacifiCorp, provided analyses and presented in stakeholder meetings regarding the utilities' financial exposure to 3rd party damages claims from catastrophic wildfire events and potential alternatives in mitigating customers' cost exposure to such events. Evaluated customer benefits over time from using various insurance options to cover against different layers of the risk tranches, including available commercial insurance, self insurance, and a catastrophic wildfire fund.
- For an electric utility, supported testimony and managed the Brattle team to evaluate the prudence of the utility's decision in the past to uprate an existing nuclear power plant instead of building a new gas-fired power plant for meeting the projected supply needs to serve its customers.
- For a coal producer, provided litigation support to estimate potential economic damages from an alleged breach in a long-term coal supply agreement.
- For the owner of two gas-fired peaking generation plants in Texas, provided expert testimony before the District Court 165th Judicial District, Harris County, Texas regarding a dispute in a heat rate call option (HRCO) contract with Shell Energy North America. Estimated economic damages from the counterparty's violation of the HRCO contracts by exceeding the annual cap on exercise hours during Storm Uri in February 2021, and assessed the economic value of the cancelation clause in the HRCOs.
- For Calpine, managed a team of consultants to support expert testimony in a bankruptcy court regarding ERCOT wholesale power prices during a February 2021 storm when extreme weather conditions caused nearly half of Texas to lose power for several days. The testimony from a Brattle expert explained why the high power prices were consistent with the scarcity pricing mechanism and market design in ERCOT, and such prices reflected, or even understated, the value of loss load during the scarcity conditions.
- For NTE Energy, provided expert testimony on discounts provided by Duke Energy Progress (DEP) to City of Fayetteville in North Carolina in its long-term wholesale power supply contract, and the resulting impacts on wholesale competition as well as on rates being charged to DEP's other wholesale and retail customers.
- For Tri-State Generation and Transmission Association, Inc., provided expert testimony before the FERC regarding the appropriate economic principles to determine the contract termination payment from a departing member.

- For a generation owner in ERCOT region, managed a team of consultants to prepare expert testimony and provide economic litigation support in a bankruptcy proceeding regarding the real-time energy prices during the winter Storm Uri in February 2021.
- For the owner of a paper mill in Minnesota, provided economic litigation support in an arbitration dispute regarding the pricing terms of a steam supply contract with an electric utility that operated a cogeneration facility.
- For a co-owner of a nuclear power plant project in the Southeast United States, evaluated the prudency of past decisions to start and continue construction until the project was eventually terminated. These investment decisions by the co-owners of the project were subject to multiple lawsuits regarding the appropriateness of recovering past investment costs from the utility's customers. Evaluated the ranges of long-term outlooks on major market fundamentals and project costs as of past decision points to assess the projected economics of continuing the project against options involving termination and replacement by other new resources.
- For the owner of a coal plant in the eastern United States, developed an expert testimony in an arbitration proceeding regarding a *force majeure* claim for non-performance in supplying a pre-determined volume of coal combustion byproducts under a long-term contract. Evaluated the drivers of the historical reductions in generation output and the accompanying byproducts, and the impacts of the drivers outside the control of the plant owner on the supply of byproducts under the contract.
- For Hydro-Québec Trans-Énergie (HQT), provided expert testimony before Québec Régie De l'énergie on the adequacy of the categories used by HQT to classify its transmission investments and HQT's treatment of transmission losses in transmission planning. Provided expert opinions before the regulator on the adequacy of HQT's investment categories in allocating the investment costs across different categories for multi-objective projects. Compared the HQT practices against those adopted by other system operators in the United States and Canada.
- For investors in refined coal production facilities in the United States, managed several consulting teams in supporting expert testimonies submitted before a United States Tax Court on the economic rationale and requirements behind the refined coal production tax credit, and on the operational and environmental permitting risks for the investors of refined coal production facilities.

- In an international arbitration dispute involving a coal mine in South America, co-managed a team to support expert report on the economic damages associated with a change in royalty structure. The analysis included the impact of royalty terms on the incentives for increasing mine production and on royalty payments to the government, under base outlook and sensitivities for projected international coal prices, mine cost structure, and discount rates.
- In a coal bankruptcy case regarding the qualification of a coal supply contract under the safe harbor provisions in the United States Bankruptcy Code, assisted an electric utility to evaluate the effectiveness of a long-term coal supply agreement as a hedge against regional fuel and power prices, including alternative coal prices and the more volatile prices of natural gas and wholesale power.
- In a large litigation case before the FERC, provided testimony on the economic burden imposed by the prices in two long-term contracts that the California Department of Water Resources (CDWR) signed with Shell and Iberdrola during the California energy crisis. Estimated the "down the line" economic burden by comparing the payments under the contracts to prices in comparable contracts and market prices after the end of the dysfunction. Assessed whether the contract prices could be explained by the expected future market fundamentals in the California power markets by using DAYZER market simulation software for the near-term and expected cost of installing and operating a new generation unit for the long-term.
- For estimating breach-of-contract damages, managed a team to support expert testimony in a high-profile international arbitration case. Brattle team built and ran simulation models to forecast power prices and GHG allowance prices in California and the rest of the western states through 2050, accounting for very short-term operational effects as well as long-term capacity expansion needs. The simulation models covered all of the states in the full Western Electricity Coordination Council (WECC) region to capture California's dependency on imports from other areas and changes in price and availability of these imports over time. The modeling team evaluated the impact of GHG policies, RPS policies, changes in load forecasts, changes in hydro conditions, and changes in natural gas prices over time on the power and GHG allowance prices. The simulation models were benchmarked against historical unit dispatch and near term power price forwards to replicate actual market operations and expectations. The Brattle team used the resulting range of power price forecasts under expected range of future market conditions to estimate damages, including an options framework to simulate plant operations and show the threshold conditions for economic shutdown.

- In a New Source Review (NSR) litigation case, analyzed whether the repairs conducted in several coal-fired generation plants should have been expected to result in significant increases in emissions of certain pollutants. The major disagreements were on the choice of baseline emissions and the level of expected impact from the repairs.
- For a group of municipal electric utilities in Massachusetts buying energy from a generating facility under a long-term contract, assisted in evaluating their net benefits from requesting must-run operation of the facility relative to the operations chosen by the seller. The engagement also included a comparison of municipal utilities and investor-owned utilities with respect to their incentives under the Massachusetts Electric Restructuring Act to buy out their power purchase contracts.
- Helped a client in the western United States in a litigation case involving allegations of market power and market dysfunction affecting the prices and other terms of various long-term electricity purchase and sale contracts.
- Managed multiple cases related to estimation of damages resulting from early termination of power contracts.

COAL PLANT ECONOMICS – VIABILITY, RETIREMENTS, AND MARKET IMPACTS

- For the Center for Applied Environmental Law and Policy, co-authored a report to explain the key challenges and opportunities in maintaining a reliable bulk transmission system in the United States electric industry experiencing fundamental change. The report identified: (1) the key trends that have been changing the electricity system and their major drivers; (2) how each trend can support and/or stress various aspects of system reliability; (3) the reforms designed to respond to these reliability effects, and the extent to which the foregoing trends would or would not accelerate the need for such reforms; and (4) in the scenario where reliability reforms are not prioritized to keep pace with industry trends, how compliance flexibilities built into federal environmental regulations (which partly contributes to some industry trends) could help in maintaining reliable system operations nonetheless.
- For environmental and clean energy groups, submitted declarations before the United States Court of Appeals for the District of Columbia Circuit and the Sixth Circuit regarding compliance requirements and flexibility to choose among compliance options under the EPA's Good Neighbor Plan (GNP Rule) for the 2015 Ozone National Ambient Air Quality Standard.
- For the Center for Applied Environmental Law and Policy, co-authored a report on the recent history of changes in the United States coal generation fleet and explained factors

contributing to the decrease in coal-fired generation capacity over the past 20 years. The report also summarized the state of market fundamentals and regulations as of 2023 affecting the economics of coal plants in the United States as well as their near- and medium-term outlook. The report explained that provisions in the Inflation Reduction Act (IRA) that increased the economic attractiveness of clean energy resources prompted some coal plant owners to re-examine the options for their coal fleet.

- For Interstate Power and Light Company (IPL), provided expert testimony before the Iowa Utilities Board regarding the reasonableness of IPL continuing to fully recover the remaining net book value of Lansing Generating Station Unit 4, a coal-fired generating unit, after the unit's retirement at the end of May 2023. Specifically, the testimony reviewed (i) the prudency of IPL's decisions to make major capital investments at Lansing 4 since 2010, based on the then-projected cost-effectiveness of those investments as approved through the Emissions Plan and Budget (EPB) process by the Board; and (ii) the reasonableness of the modeling approach and results in IPL's Clean Energy Blueprint resource plan analysis in 2020 that evaluated the expected cost savings of the retirement of Lansing 4 and the addition of 400 MW of solar generation.
- For Alliant Energy, co-authored a report to describe rail service issues observed in the United States in 2022 and the impacts on coal use in the electric sector. During this period, acute logistical and capacity challenges in rail transportation limited many coal shippers' ability to deliver critical inputs to electric utilities. Rail service delivery issues were widespread throughout the country across many industries with shippers experiencing slower train speed, increased delays, poor on-time performance, and inability to satisfy demand for rail shipments.
- For Wisconsin Power and Light Company (WPL), provided expert testimony before the Public Service Commission of Wisconsin on the appropriateness of WPL continuing to recover as a regulatory asset the undepreciated past investments at the Edgewater 5 coal unit after its proposed retirement in 2022. Reviewed and analyzed the prudency of WPL's past decisions to make those investments and its proposal to retire the unit and replace it with new renewable resources. Explained that longstanding and economically well-justified principles and standards in the utility industry strongly indicated that prudent investments should be fully recoverable from customers, even if they eventually proved less economic than initially projected.
- For an electric utility operating in multiple states, reviewed the utility's draft internal planning studies for evaluating the future cost savings for its customers from early retirements of some coal units. Provided feedback on the reasonableness of the modeling

approach and key assumptions of the utility's internal modeling team, suggested potential improvements, and estimated the impacts of the suggested changes on the future cost savings from early retirements of the coal units.

- For the Public Service Company of New Mexico (PNM), managed a team to evaluate the prudency of retiring the San Juan Generation Station (SJGS) and replacing it with renewables and gas peakers, with securitization of remaining undepreciated and adjustment costs. Helped PNM to demonstrate the prudency of its proposed plan based on the findings that i) the expected cost savings and risk reductions of PNM's plan outweighed the option retrofitting the plant with carbon capture, utilization, and storage (CCUS); and ii) securitization was a beneficial approach for providing full cost recovery at low cost to customers, as the state moved to fully clean electricity. The New Mexico Public Regulation Commission ruled in favor of PNM, allowing the utility to abandon SJGS and to securitize up to $360.1 million of unrecovered investments and adjustment costs.
- For Big Rivers Electric Corporation, a municipal electric utility in the Midcontinent Independent System Operator (MISO) market region, provided expert testimony before the Kentucky state regulatory commission to evaluate the economic viability of an existing coal plant against the projected wholesale power prices in MISO. By using an in-house plant dispatch and commitment modeling tool, estimated the future annual capacity factor and variable costs of operating the plant, and compared the plant's avoidable future costs against the projected market prices of energy and capacity for the plant. Developed scenarios for future market prices by considering key uncertainties such as natural gas prices and potential pricing of CO_2 emissions. Estimated the savings from a potential early retirement of the coal plant.
- For an investor-owned electric utility in the MISO market region, provided expert testimony before a United States District Court to assess the potential for economic early retirement of a coal-fired plant under several scenarios including potential future requirements for retrofitting the plant with SO_2 emissions control equipment and future wholesale power market conditions. Estimated the likely impact of retrofits and early retirement on the utility's revenue requirements and retail rates.
- For an electric utility considering an early retirement for one of its coal plants, provided regulatory support to describe the changing economic viability of the existing coal plants in the United States wholesale power markets over the last decade. Conducted research on regulatory decisions in various state jurisdictions on recovery of past investments at retiring generation plants, and explained the perverse incentives on retirement decisions that would be created by disallowing prudently incurred past investments.

- For a merchant generation company in PJM, assessed the potential impacts of coal plant retirements on the future likely range of energy prices under key uncertainties for market fundamentals. The project team evaluated whether the recent price spikes under extreme weather and system conditions could be repeated in the future with increasing reliance on gas-fired generation plants.
- For an electric utility in Wisconsin, provided expert testimony on the likely changes in energy and capacity prices as a result of projected coal plant retirements and environmental retrofits in the MISO region. The analysis included a transparent model to estimate the impacts of retirements and retrofits on the regional supply curve and the impacts of nationwide coal retirements on natural gas prices. Reviewed the projected reserve margins in the MISO region with and without the coal retirements to evaluate the likely changes in capacity prices in the MISO region after 2016.
- Conducted a screening analysis of coal-fired units in the United States for a producer of biomass fuel that could be an alternative to burning coal in generating units in order to avoid or mitigate future compliance requirements with environmental regulations. The analysis compared the projected costs for each unit under the coal-fired operations (including the retrofit cost of environmental control equipment) against the costs under operations with the alternative fuel and the costs of replacement with a new gas-fired unit.
- For the American Coal Ash Association, conducted annual surveys for the production and use of coal combustion residuals in the United States. The Brattle team designed and implemented the survey circulated to coal generation plant operators and supplemented that information with Brattle's assessment of key market trends in the power industry. The results of the survey were published each year for consumption by energy and environmental agencies and industry analysts.
- For an investor, assessed the economic viability of selected merchant and regulated coal plants in the Midwest. The analysis focused on estimates of projected net revenues for merchant plants and cost of continued operations of the regulated coal plants against replacement power costs. In addition, estimated the projected capacity factor and coal use by each plant under selected future gas and CO_2 price sensitivities.
- Managed a case regarding the estimation of cost and performance benchmarks for two coal-fired generation plants in the eastern United States. Assessed their performance and cost by comparing them with similar coal plants in the country with respect to various performance metrics (heat rate, availability, forced outage rate, etc.) and cost metrics (fuel cost, maintenance costs, capital expenditure). Identified strong and weak points by using

various definitions of total costs and key performance metrics and analyzed the tradeoff between good performance and high costs among peer group plants.

RESOURCE PLANNING FOR ELECTRIC UTILITIES

- For an industry association, prepared a report on the potential role of clean hydrogen and other clean dispatchable resources in the future in a decarbonized electric system with a high penetration of variable renewable energy resources. The report summarized the findings and gaps in recent industry studies regarding the key attributes needed from clean dispatchable resources in such a system, including fast and sustained flexibility and ability to store energy across seasons. The report compared the effectiveness, availability and cost of clean hydrogen technologies against other clean dispatchable resources such as gas with carbon capture, small modular reactors, and long-duration storage.
- For the Clean Power Suppliers Association, performed a detailed review of the Carbon Plan, which is Duke Energy's recent integrated resource plan study on alternative resource portfolios to achieve 70% reduction in Duke Energy's North Carolina CO_2 emissions by 2030 relative to its 2005 emissions. Identified a number of modeling assumptions that made the comparison of costs across the portfolios flawed. Replicated the Carbon Plan modeling results through its GridSIM capacity expansion and production cost modeling software and simulated additional alternative portfolios that would result in lower future costs for Duke's customers.
- For Cypress Creek Renewables, prepared an economic study to analyze the generation costs and emissions impacts of a future resource mix for Duke Energy that achieved the requirements outlined in North Carolina's House Bill 951 (H951) and minimized the additional development of natural gas capacity. The study concluded that by shifting its resource mix from coal and gas resources to renewable energy and battery storage, Duke Energy could achieve over 70% GHG emissions reductions by 2030 (relative to 2005 emissions) while lowering generation costs. The study also found that use of securitization to finance the recovery of undepreciated past investment costs at some of the retiring coal plants was a major driver of the customer cost savings in addition to the avoided fixed operating and ongoing capital expenditures from early retirements.
- For a large Midwest utility serving electric and gas, assessed current and likely future industry developments with potential to create opportunities and risks for the regulated and nonregulated operations of the company. The key developments included emerging EPA air quality, water and ash regulations for power plants, potential climate policies, macroeconomic recovery, and smart grid technologies. In addition, conducted a comparison

of the risks and cost of capital associated with regulated and unregulated businesses, including behind-the-meter renewable generation. Presented the findings of these assessments to the board of directors.

- Assisted a municipal electric utility in developing a least-cost strategy to comply with environmental regulations. Developed a screening tool to compare the economics of environmental retrofits against alternatives such as replacement with a new gas-fired combined cycle or relying on market purchases of energy and capacity to meet the retail load obligations. Presented the results of the economic analysis and potential hedging strategies to the executive management.
- Co-authored a chapter of an EPRI report on decision-making complexities and factors in utility resource planning and environmental compliance investment decisions. The chapter described how various metrics of cost and performance could be used by power industry planners and executive decision makers, the limitations of those metrics and modeling techniques, and how this problem and modeling complexity may alter the type and timing of technology preferences. Some of the complexities were illustrated with examples on retire/retrofit choices for coal plants to comply with the environmental regulations and on decision-making for Carbon Capture and Sequestration (CCS) investment under CO_2 price volatility.
- Assisted an electric utility in the Midwest in their resource planning. Developed environmental regulation scenarios with the executives and experts at the utility, and assisted in modeling and reviewing the implications of regulatory and market scenarios on the least-cost strategy subject to meeting load, renewable energy standards, and capital constraints. The strategy options included retrofitting the coal-fired generation plants with necessary control equipment, retirement of coal-fired units and replacement with gas-fired units. Presented results to the utility executives.
- Assisted an electric utility in developing an Integrated Resource Plan under potential climate policy scenarios. The plan was developed by reviewing and choosing the best mix of supply side alternatives and demand side programs that would achieve the joint objectives of minimizing cost and mitigating CO_2 footprint subject to meeting the utility's obligation to serve its customers. The supply side options included combinations of conventional generation technologies, renewables and low CO_2 fossil fired generation, and new transmission investment.
- For a large independent generation company, led a team to assess the reasonableness of the evaluation procedures and criteria used by an electric utility in the southern United States in its RFP to acquire new generation assets and power purchase agreements.

Reviewed the RFP requirements and the papers supporting the RFP results in a brief period of time to identify the questionable assumptions and criteria used by the electric utility, and quantified the impacts of these on the relative costs of bids.

- For EPRI, analyzed and reviewed the major drivers of generation technology choice in various countries and regions around the world. Although the availability and degree of access to fuels was a common driver, other factors such as capital cost, attitude towards nuclear technology and renewables, constraints on carbon-intensive technologies, and degree of economic development played a varying degrees of roles in the choice of generation fuels and technologies in each country.

ENVIRONMENTAL AND CLIMATE POLICIES – DESIGN AND IMPLICATIONS

- For a merchant generation owner in New England, managed a team to conduct an economic study on the potential cost and emission impacts of making the existing clean energy generators eligible under an expanded Clean Energy Standard (CES) program in Massachusetts. Under the existing CES program, commercial operating date requirements limited eligibility to clean energy generators commencing operation after 2010. The study concluded that retaining existing clean generation that came online prior to 2010 under the CES program would reduce GHG emissions in Massachusetts and New England, and would reduce system production and customer costs.
- For a power industry association, co-authored a study to assess the carbon emission impacts of premature nuclear retirements. The study concluded that the vulnerability of some nuclear power plants to premature retirement could create a major threat to the attainment of desired CO_2 reduction. The analysis found that the retirement of a 1,000 megawatt nuclear plant could increase CO_2 emissions in the range of 4.1 to 6.7 million tons per year, or 0.52-0.84 tons per MWh of nuclear generation lost, depending on the region in which the nuclear retirement occurs. In addition, the increased level of CO_2 emissions arising from a premature nuclear retirement would not be confined to the state in which the unit resides. In fact, in most cases the majority of this increase would occur outside the state, and a significant amount of the emissions increase would occur in states beyond those adjacent to the state experiencing the retirement.
- For an industry association, co-authored a study to analyze the potential implications for competitive wholesale electricity markets if new gas-fired combined cycle (CC) plants were not covered under the Clean Power Plan’s (CPP) mass-based state implementation plans (SIPs). The authors found that if state implementation plans excluded new gas CC plants,

the electric sector could fall short of the carbon dioxide (CO_2) reduction goals set by the CPP, while incurring higher system costs per ton of CO_2 avoided. In addition, Brattle simulations illustrated that excluding new gas CCs from the emissions cap would introduce a discrepancy in the economics facing new and existing gas CCs that were identical in all respects other than their in-service dates. New CCs would earn greater profits in the energy market because they would be compensated as if they were entirely non-emitting plants.

- For a power industry association, conducted analysis of the EPA's proposed rule for regulating CO_2 from existing sources under Section 111(d) of the Clean Air Act, focusing on potential economic impact to hydropower. Summarized key aspects of the rule, and assessed how the compliance options for states could differ from the BSER options in setting target rates and how states could utilize hydropower (existing or new) as a compliance option under the rule.
- For a western electric utility, evaluated the EPA's development of CO_2 rate targets in Arizona and assessed the reasonableness of projected pace and level of emission reductions. Conducted a detailed assessment of the assumptions and modeling approach in EPA's IPM simulations and identified areas of improvements. Prepared a whitepaper to summarize the findings to be filed as part of the utility's comments to the EPA.
- For an electric utility in the western US, conducted a study to assess reliability and supply-chain implications of compliance with the EPA's Regional Haze Rule. The Regional Haze Rule aimed to reduce haze-forming pollution (primarily due to emissions of particulate matter and its precursors SO_2 and NOx) that reduced visibility in parks and wilderness areas, especially in the western United States. Assessed the impact of outages at coal units to tie-in the environmental retrofit equipment on available resources to meet the utility's load obligations in the future. In addition, compared the historical retrofits on coal units in the region against projected retrofits to comply with Regional Haze Rule.
- Co-authored a study commissioned by the MISO to evaluate the feasibility of the large number of simultaneous environmental retrofits and new generation that might be needed for coal plants to comply with the Environmental Protection Agency's Mercury and Air Toxics Standards (MATS) rule. The study found that compliance with the MATS rule posed significant challenges. The study took into account the historical level of actual retrofits and new generation construction, typical timelines to complete various types of projects, potential bottlenecks in specialized types of labor, and the required planned outages in coal plants to install and test the environment control equipment.
- Co-authored studies that analyzed the economics of retirement decisions for each coal plant operating in the United States under proposed and emerging EPA air quality and

water regulations, taking into account the predicted profitability and cost of replacement power for both regulated and unregulated plants. The regulations were expected to force coal plants to decide between retiring versus installing expensive control equipment to reduce emissions of SO_2, NOx, particulates, and hazardous air pollutants such as mercury, as well as cooling towers to reduce the use of cooling water.

- For a natural gas producer, analyzed the potential for change in natural gas demand as a result of the Waxman-Markey climate policy proposal. Using scenarios for new renewable capacity and price of natural gas relative to coal, analyzed effects of CO_2 prices on dispatch switching from coal-fired to gas-fired generation plants in various ISO regions, as well as on demand for gas in non-electric sectors.
- Assisted an electric utility in understanding the implications of the Waxman-Markey climate policy proposal on its renewable generation portfolio and its electricity sales to other regions. Identified opportunities and risks for specific renewable technologies due to provisions in the bill imposing renewable portfolio standards for electric utilities.
- For electric utility companies in the eastern United States, analyzed the potential effects of existing and developing environmental legislation and regulation on the existing generation fleet. The assignment included reviewing and summarizing the regulations by pollutant, identifying the specific generation plants that these regulations could affect, and estimating economics of retirement for each plant under a regulatory scenario.
- Conducted screening analyses for electric utilities to assess their exposure to allowance costs in the near- and long-term due to recent cap and trade climate policy proposals. Under alternative assumptions to comply with the regulations (from complete reliance on allowance purchases to reducing emissions to meet the economy-wide targets), estimated the potential cost of the policy net of free allowances under the proposal using various CO_2 price scenarios.
- For an electric utility, assisted in evaluating expected natural gas prices under potential CO_2 prices due to proposed federal climate policies in the United States. The analysis included modeling of changes in demand for natural gas in electric and non-electric sectors as a result of potential CO_2 prices, as well as feedback effects due to dispatch switching from coal-fired generation plants to gas-fired generation plants in electric sector.
- Helped a large energy company evaluate the implications of several climate policy options on United States CO_2 emissions from electric and transportation sectors, and consumption and prices of electricity, natural gas, and coal. The analysis focused primarily on long-term

implications for future generation capacity mix and provided insights about the feedback effects between fuel prices, electricity prices, and electricity consumption.

WHOLESALE MARKET ANALYSIS AND ASSET VALUATION

- For MISO, evaluated design options for the resource adequacy market to provide efficient signals to resource owners for making their resources available during hours when the system was at or near scarcity conditions. As a result of the increasing penetration of renewables in the MISO region, as well as the increasing prevalence of common mode failures at fossil-fuel generation plants, MISO evaluated design options with the understanding that critical resource adequacy periods would increasingly include periods outside the summer peak load hours. Evaluated alternative mechanisms for accreditation of resources under a sub-annual resource adequacy construct and for MISO's modeling of planned and forced outages in determining planning reserve requirements, and compared these mechanisms against practices of other system operators.
- For an asset management firm considering investing in a virtual trading company with operations in Regional Transmission Organizations (RTOs), performed due diligence analysis on the trading algorithm, profitability, achievable market size, and compliance with market monitoring rules.
- For a large electric utility in Canada, researched industry practices on the wind integration service rates charged by balancing authorities in the United States outside the organized wholesale power markets.
- For a group of market participants in Texas, managed a team to estimate the impacts of implementing marginal losses in the ERCOT market on system production costs, transmission losses, LMPs, load payments, and generator revenues. Simulated the ERCOT power system using PSO software, and calibrated the model to recent generation and load patterns. The study results were made public in a proceeding before the Texas Public Utility Commission.
- For a large group of generation owners and trade groups, conducted a study to estimate the above-market payments to certain merchant generation plants with 90-day fuel supply under the United States Department of Energy's (DOE) proposed payments. While the DOE's rationale for the proposed payments was to improve the resilient operations of the power system, the study concluded that 1) there was no evidence supporting the premise that 90 days of on-site fuel at individual power generating plants would improve the resilience of the grid in the regions where the rule would apply, and that 2) implementing

the proposed rule would undermine core market principles and diminish some of the most important advantages of competitive wholesale power markets.

- For a developer of a biogas power plant, submitted expert testimony on the outlook of projected long-term wholesale power prices in Arizona. Reviewed forward market prices for near term deliveries as of the execution date of a contract with the supplier of waste feedstock, and summarized the industry expectations for the timing of the need and cost to build new generation in the region.
- For a developer of solar PV generation plants, conducted research and analyses to identify potential opportunities for renewables to be offered to electric utilities as qualifying facilities (QFs) under the Public Utilities Regulatory Policies Act (PURPA). Summarized the states with the largest penetration of renewable QFs and most favorable contract/pricing terms, and presented the likely outlook on avoided cost rates by region.
- For an investment firm, evaluated the projected net margins from energy and capacity markets in the Northeast for a new gas-fired generation plant. Assessed the key market drivers and risk factors associated with the plant's future performance and conducted analyses to assess the implications for the asset's market value.
- For an independent power producer, analyzed the market trends in California power markets and explored potential value drivers of the client's existing gas-fired combined-cycle plant in California. Simulated the long-term wholesale energy prices in the Southern California region and developed a modeling tool to analyze the projected capacity payments for existing resources under the California's local resource adequacy construct.
- Assisted an electric utility in performing a valuation of a coal-fired unit. Managed the analysis to model the projected revenues from energy and capacity markets, as well as to project variable and fixed operating costs and environmental compliance costs in the future. Various market and regulatory scenarios were considered and presented to the client.
- For an investor, performed a valuation analysis of a potential new gas combustion turbine (CT) in Texas. Developed scenarios for future energy-only and capacity markets, estimated regional reserve margins under a few load-growth scenarios. In addition to estimating annual energy margins using a virtual commitment and dispatch model, estimated the projected run-hours for the new CT.
- For an investor, co-authored a valuation analysis of a large gas-fired cogeneration facility in the Midwest. In addition to projecting energy and capacity prices in the region under the key uncertainties on gas prices, coal plant retirements, and renewable generation additions,

the study analyzed the projected revenues under the existing long-term sale contracts to provide energy and steam.

- Co-lead team to assist a municipal electric utility in the Midwest United States to sell a portion of its share of energy and capacity from a new coal plant. Acted as sale advisor to design the sale process, solicit bids, prepare informational documents, and evaluate the bids.
- For an RTO in the Midwest United States, estimated the future costs and benefits from an electric utility joining that RTO as a member, compared to stand-alone and an alternative RTO membership. The analysis included impact on production cost savings, existing transmission constraints and interconnection capacities, wholesale trading activity, load diversity benefits, generation investment savings, and allocation of transmission costs and revenues.
- For a power plant developer, estimated the market potential for new wind, solar and gas peaking plants in the Eastern Interconnection. Developed and refined assumptions and scenarios on future fuel prices, capital costs of new plants, federal tax credits as well as federal climate policy. Economic potential for new generation alternatives were estimated by using Brattle's in-house simulation model Xpand, which optimized plant dispatch as well as generation entry and retirements in order to meet future electric demand and reserve margin requirements.
- For an electric cooperative in the Midwest, conducted studies to evaluate the impact of planned new wind and gas combined-cycle units at alternative locations on nodal energy prices and net revenues for generation fleet owned by the cooperative. Provided analytical support to assess likely allocations of auction revenue rights for hedging congestion.
- For a large merchant generation company in PJM, assessed the likely causes of high energy prices during polar vortex events. Analyzed the impact of each driver on market prices, and conducted simulations to evaluate the likely market prices in the future under similar weather conditions and sensitivities for coal plant retirements, increased penetration of demand-resources, and expected gas prices.
- For a large coal company, assisted in designing and evaluating innovative coal supply contracts with power plants. Developed a customized tool to simulate the regional energy and capacity prices in the eastern power markets and evaluated the profitability of various types of supply contracts from the perspective of the coal company and the power plant. In addition, identified coal-fired power plants that could be potential candidates to benefit from signing innovative coal supply contracts.

- For a group of electric utilities in the Midwest, led a team to assess the energy-related costs and benefits of joining an RTO. Using a nodal pricing simulation software, estimated the net costs to customers of the utilities with respect to energy, congestion, marginal losses, and allocation of financial transmission rights and loss refunds under each configuration (stand-alone and RTO membership).
- For clients in PJM, examined the variability of historical congestion patterns to help assess the reasonableness of the utilities' strategies to acquire financial transmission rights (FTRs) and Auction Revenue Rights (ARRs).
- Provided consulting services on the impact of moving into a locational marginal price (LMP) market design for a client in the Western Electricity Coordinating Council. In addition to quantifying the expected congestion cost exposure under LMP market design, examined the impacts of potential mitigating solutions on the cost exposure and on the client's ability to hedge these costs through acquisition of financial instruments.
- Estimated the economic benefits of a proposed power plant in California. The project included an analysis of benefits from reduced market-clearing prices, avoided/deferred transmission upgrades, and reliability improvements.
- For an independent power producer, assessed the competitive offer price for its planned gas-fired generation unit in the PJM capacity market. Under key scenarios reflecting uncertainty in market fundamentals and in reasonable modeling assumptions, estimated the net cost of new entry (Net CONE) for the generation plant using plant-specific cost and performance information supplemented by publicly available estimates for generic plants. The key modeling assumptions driving the range of results were the appropriate methodology to levelize overnight capital costs and the appropriate time period over which the costs of the generation plant would be recovered in the PJM markets.
- Assisted an energy company to understand the fundamentals of the PJM capacity markets to inform the company's bidding strategy in the capacity auctions. Conducted a training session to review the auction clearing mechanism, simulation of the market-clearing prices and quantities and alternative methodologies to project future market supply curves.
- For an energy trading company in the western United States, assessed the California Independent System Operator's (CAISO's) historical calculations of nodal energy prices at specific locations. The focus of the assessment was to understand the impact of modeling differences between day-ahead energy markets and annual Congestion Revenue Rights (CRRs) auctions on the nodal energy prices at those locations. The findings of this assessment were used to support a complaint at the FERC.

- For a transmission owner in Canada, assessed whether the proposed procedures to coordinate the Available Transmission Capacity (ATC) on its interfaces with neighboring systems were consistent with the FERC requirements and the practices of various United States counterparts. ATC coordination was required under FERC Order 890 in order to ensure that ATCs were calculated in a consistent manner by transmission providers and that transmission service was provided in a non-discriminatory manner.
- For an RTO in the eastern United States, assisted in the preparation two expert reports regarding an alleged manipulation of market credit rules through its trading activity in the FTR markets. The analysis involved a review of trading activity and an assessment of risks assumed by the trader through a review of historical congestion prices.
- Submitted rebuttal and surrebuttal testimony jointly before the Pennsylvania Public Utilities Commission on the causes of an episode of high locational marginal prices (LMPs) experienced by a small electric utility in PJM wholesale energy markets. Using data on potential causes of high congestion and detailed market simulation modeling, identified several causes including increased virtual bidding activity, reduced transmission capability, and changes to physical characteristics of certain transmission assets.
- For an electric utility considering joining an RTO, managed transmission flow analyses of generation and load deliverability, as well as LMP market simulations to assess the effects of the company's move on prices in its service territory.
- Co-authored a report reviewing the results and the performance of the ISO-NE Forward Capacity Market (FCM) auctions conducted for the 2010/2011 and 2011/2012 commitment periods.
- Submitted an affidavit at the Public Utilities Commission of Texas (PUCT) regarding a proposed rule to allocate costs of procuring replacement reserves to market participants in ERCOT.
- Analyzed the economic and network impacts of a utility signing renewable energy contracts with several potential renewable generation projects. Using market simulation tools such as MarketSymTM and PowerworldTM, simulated an entire reliability council to assess whether each of the potential renewable generation projects would cause additional transmission constraints, and estimated the impacts of these projects on LMPs across the region.
- Assisted an electric utility before the energy regulator in Quebec, Regie De l'Energie, involving third-party access to an electric transmission system owned and operated by another company.

- Assisted numerous clients in examining the potential for the exercise of horizontal and vertical market power under the FERC's market power tests as a result of asset acquisitions, mergers, and as part of periodical market-based rate (MBR) filings.
- Helped a client assess the potential liability and market impacts associated with offering the output of an out-of-service generation unit to the ISO-NE markets.
- Led efforts to prepare a report assessing the implications of the Open Access Transmission Tariff (OATT) filed by MISO on market efficiency and gaming opportunities.
- Contributed to Brattle's investigation of the California power crisis on issues involving physical or economic withholding and manipulative gaming strategies such as double-selling, circular scheduling, wheel-out, simulation of real-time energy, and ancillary services markets.
- Estimated the potential for the exercise of market power in a load pocket in the Northeast United States power markets. The study simulated strategic behavior in order to assess the price risk for a distribution company due to congested transmission facilities.

RETAIL ELECTRIC RATES – COST ESTIMATION AND RECOVERY

- For an electric utility in the western United States, managed a team to support expert testimony before Oregon and Wyoming regulators with respect to the appropriate recovery mechanisms for fuel and purchased power costs. Demonstrated the historical persistency of under-recovery of such costs due to the inherent asymmetric nature of the difference between actual net purchased power costs and year-ahead deterministic forecasts. Compared the existing true-up methodology for that utility against common industry practices across the United States with respect to the use of variance deadbands, earnings tests and sharing arrangements between ratepayers and shareholders.
- For multiple clients including a university, several hospitals and a hotel and shopping complex in Pennsylvania, conducted economic due diligence studies on the potential cost savings from installing an on-site combined heat and power (CHP) facility that would offset power and heating needs. Reviewed key drivers of potential cost savings, including net metering revenues from excess generation output from the CHP plant, reduction in cost of purchasing grid power, and future market prices for power and fuels. Presented findings to the executive teams and provided analytical support in contract negotiations.
- For an investor in distributed gas-fired generation assets in Texas, conducted a study on future savings in transmission and distribution service costs and potential market

penetration of distributed energy resources. Reviewed key aspects of the wholesale market structure that directly impact the long-term stability of the transmission tariff rate, and identified potential risks and mitigating factors associated with possible changes to the design of the market.

- In a merger involving two electric companies in the eastern United States, analyzed the impacts of the merger on competition in retail electricity markets. Both companies owned electric distribution companies, transmission assets, generation resources, and retail electricity providers in several states. The analysis involved assessment of whether the increased market share in wholesale energy markets would affect retail competition, number of suppliers in retail electricity markets, ease of entry and exit to provide electricity to retail customers directly or through Default Service (DS) procurements, and potential for abusing affiliate relationships with the electric distribution company to favor the retail electricity provider affiliate.
- For an association of suite meter providers in Canada, analyzed whether the incumbent electric utility had been cross-subsidizing the provision of suite meters to its residential customers at the expense of its other customers. The analysis involved a comparison of the estimated fully-allocated costs of providing suite meters to the net revenues from these customers under the regulated retail rates under alternative assumptions on the costs of meters and types of suite meter installations.
- Prepared a marginal cost study for an integrated electric utility in the PJM region. The study estimated the incremental costs to the utility of serving additional demand and customers by time period, sub-region, and customer class.
- For a large electric customer of a utility in the western United States, assisted in evaluating the utility's proposed rate design. Specifically, provided an assessment of alternative methods to classify generation costs (as demand, energy, or customer related) and to allocate the fixed costs among customer classes. The analysis included an assessment of the treatment of the costs and revenues associated with off system sales in determining the revenues to be recovered from various customer classes.
- For an electric customer in United States, analyzed whether a proposed change in rates by the electric utility would result in just and reasonable rates for transmission level and station service customers. The resulting testimony assessed whether the proposed rates were consistent with fundamental principles of ratemaking such as cost causation and rate stability, and compared the proposed rate design to the rate options provided by utilities in other jurisdictions for transmission level and station service customers. The parties settled

the case with reduced rates for the client based on the lower cost of serving transmission level customers relative to distribution level customers.

- For an electric utility planning to install smart meters and in-home displays in the eastern United States, assisted in estimating the likely benefits to retail customers and to the utility. The quantified benefits to the utility company mostly came from reduced costs of meter reading and outage managements, whereas the customer benefits came from reduced costs of energy, capacity, and carbon emissions as a result of reduced peak load and annual energy consumption.
- Co-managed a case regarding a Texas electric utility company auctioning off its generation assets in order to determine its stranded costs. Assessed whether the market value of the utility's jointly-owned generation assets was depressed due to the rights of first refusal (ROFR) provisions attached to these assets, and whether the utility company failed to take commercially reasonable steps to mitigate its stranded costs.
- Helped a client analyze the cost of providing ancillary services (reserves, regulation, voltage support, etc.) from its hydroelectric generation facilities. The analysis dealt with the implications of separating cost of energy and ancillary services on the electricity rates of different customer types.

ARTICLES & PUBLICATIONS

- "Bulk System Reliability for Tomorrow's Grid," with Andrew Levitt, Andrew Thompson, Ragini Sreenath, Xander Bartone, Sam Willett, and Hazel Ethier, prepared for the Center for Applied Environmental Law and Policy, December 20, 2023.
- "Role of Hydrogen in a Decarbonized Future," with Josh Figueroa and Andrew Thompson, presented at the Bank of America 2023 Hydrogen Conference, December 19, 2023.
- "A Review of Coal-Fired Electricity Generation in the US," with Long Lam, Jadon Grove and Natalie Northrup, prepared for The Center for Applied Environmental Law and Policy, April 27, 2023.
- "Rail Delivery Disruptions in the US in 2022: An Overview of Scale and Extent," with Nicholas Powers, prepared for Alliant Energy, March 30, 2023.
- "A Pathway to Decarbonization: Generation Cost & Emissions Impact of Proposed NC Energy Legislation," with Michael Hagerty, Matt Witkin, Julia Olszewski, and Frederick Corpuz, prepared for Cypress Creek Renewables, August 31, 2021.

- “Western Energy Imbalance Service and SPP Western RTO Participation Benefits,” with John Tsoukalis, Johannes P. Pfeifenberger, Sophie Leamon, Carson Peacock, and Sharan Ganjam, prepared for Southwest Power Pool, December 2, 2020.
- “The Role of Economics in Evaluating Contractual Performance Defenses: Emerging Disputes on COVID-Related Force Majeure Claims,” with Shaun D. Ledgerwood, Peter S. Fox-Penner, and Jake Zahniser-Word, September 2020.
- “The Brattle Group’s Notes on the Affordable Clean Energy Rule,” with David Luke Oates, Michael Hagerty, Yingxia Yang, and Marc Chupka, August 23, 2018.
- “The Cost of Preventing Baseload Retirements: A Preliminary Examination of the DOE Memorandum,” with Richard Sweet, Kelly Oh, and Marc Chupka, prepared for the Advanced Energy Economy (AEE), American Petroleum Institute (API), American Wind Energy Association (AWEA), Electricity Consumers Resource Council (ELCON), Electric Power Supply Association (EPSA), and Natural Gas Supply Association (NGSA), July 19, 2018.
- “New Technologies and Old Issues under PURPA,” with Robert S. Mudge, Marc Chupka, and Peter Cahill, Norton Rose Fulbright’s *Project Finance NewsWire*, February 26, 2018.
- “The Future of Cap-and-Trade Program in California: Will Low GHG Prices Last Forever?” with Yingxia Yang, Michael Hagerty, Ashley Palmarozzo, Hannah Sheffield, Marc Chupka, and Frank C. Graves, December 5, 2017.
- “Comments on Expanding CES Eligibility to Existing Nuclear Units,” with Onur Aydin, David Luke Oates, Tony Lee, and Kelly Oh, prepared for NextEra Energy Resources and presented to the Massachusetts Department of Environmental Protection in response to the proposed Clean Energy Standard-Existing (CES-E), November 30, 2017.
- “The Future of the U.S. Coal Generation Fleet,” with Marc Chupka, Dean M. Murphy, Samuel A. Newell, and Ira H. Shavel, ABA Antitrust Section Transportation and Energy Industries Committee Fall 2017 newsletter, November 30, 2017.
- “Evaluation of the DOE’s Proposed Grid Resiliency Pricing Rule,” with Judy Chang, Marc Chupka, Samuel A. Newell, and Ira H. Shavel, prepared for NextEra Energy, Inc., October 26, 2017.
- “Impacts of Marginal Loss Implementation in ERCOT,” with Toshiki Bruce Tsuchida, Rebecca Carroll, Colin McIntyre, and Ariel Kaluzhny, prepared for Ad Hoc Group, including Vistra Energy, The Wind Coalition, and First Solar, October 11, 2017.
- “Nuclear Retirement Effects on CO_2 Emissions: Preserving a Critical Clean Resource,” with Marc Chupka, Frank C. Graves, Dean Murphy, and Ioanna Karkatsouli, December 2016.

- “Covering New Gas-Fired Combined Cycle Plants under the Clean Power Plan: Implications for Economic Efficiency and Wholesale Electricity Markets,” with Judy Chang, Kathleen Spees, and Tony Lee, November 2016.
- “The Clean Power Plan: Focus on Implementation and Compliance,” with Marc Chupka, Judy Chang, Ira H. Shavel, Kathleen Spees, Jürgen Weiss, Pearl Donohoo-Vallett, Michael Hagerty, Michael A. Kline, prepared as a Brattle Policy Brief, January 2016.
- “EPA’s Proposed Clean Power Plan: Implications for States and the Electricity Industry,” with Kathleen Spees, Michael Hagerty, Samuel A. Newell, Dean Murphy, Marc Chupka, Jürgen Weiss, Judy Chang, and Ira Shavel, prepared as a Brattle Policy Brief, June 2014.
- “Coal Plant Retirements: Feedback Effects on Wholesale Electricity Prices,” with Onur Aydin and Frank C. Graves, November 2013.
- “Potential Coal Plant Retirements: 2012 Update,” with Frank C. Graves and Charles Russell, published by The Brattle Group, Inc., October 2012.
- “Supply Chain and Outage Analysis of MISO Coal Retrofits for MATS,” with Kathleen Spees, Quincy Liao, and Steve Eisenhart, May 2012.
- “State Regulatory Hurdles to Utility Environmental Compliance,” with Philip Q. Hanser and Bin Zhou, *Electricity Journal*, April 2012.
- “Decision Complexities in Utility Resource Planning and Environmental Compliance Investment,” with Frank C. Graves, chapter in EPRI report “The Market Backdrop to US Power Generation Coal Technology Goal-Setting and Learning, September 2011.
- “Marginal Cost Analysis in Evolving Power Markets: The Foundation of Innovative Pricing, Energy Efficiency Programs, and Net Metering Rates,” with Philip Q. Hanser, The Brattle Group Energy Newsletter Issue 2, 2010.
- “Virtual Bidding: The Good, the Bad, and the Ugly – Experience of RTOs with Virtual Bidding and Implications for Market Participants' Hedging Congestion Costs,” with Attila Hajos and Philip Q. Hanser, *Electricity Journal*, June 2010.
- “Can the US Congressional Ethanol Mandate be Met?” with Evan Cohen, Michael I. Cragg, David Hutchings, and Minal Shankar, The Brattle Group Discussion Paper, May 2010.
- “Prospects for Natural Gas Under Climate Policy Legislation: Will There be a Boom in Gas Demand?” with Steven H. Levine and Frank C. Graves, The Brattle Group Discussion Paper, March 2010.

- "Internal Market Monitoring Unit Review of the Forward capacity Market Auction Results and Design Elements," with Dave Laplante, Hung-po Chao, Samuel A. Newell, and Attila Hajos, filed at FERC by ISO-NE, June 5, 2009.
- "CO_2 Price Volatility: Consequences and Cures," with Frank C. Graves, The Brattle Group Discussion Paper, January 2009.
- A Lexicon Entry for "A Theory of Incentives in Procurement and Regulation – Laffont&Tirole," with Richard Arnott, Lexikon der Okonomischen Werke, 2006.
- Contributing author for the Energy Bar Association Antitrust Committee's report on 2005 Antitrust Development.
- "The CAISO's Physical Validation Settlement Service: A Useful Tool for All LMP Based Markets," with Philip Q. Hanser, Jared S. des Rosiers, and Joseph B. Wharton, *Electricity Journal*, October 2005.
- "The Design of Tests for Horizontal Market Power in Market-Based Rate Proceedings," with James Bohn and Philip Q. Hanser, *Electricity Journal*, May 2002.
- "Financial Transmission Rights: Implementation Issues," with Philip Q. Hanser, Working Paper, February 2002.
- "An Analysis of Incentives and Regulation in Providing Capacity and Reliability in Power Transmission Networks," unpublished PhD thesis for Boston College, September 2000.

PRESENTATIONS & SPEAKING ENGAGEMENTS

- "Cashing In On CHP: Increasing Energy Reliability and Savings with Combined Heat and Power (CHP)," with Frank C. Graves, Alan Seltzer, and John Povilaitis, June 3, 2021.
- "FERC's Recent Ruling on PURPA: Variable Energy Rate Option," EUCI Online Conference, December 15, 2020.
- "PURPA Notice of Proposed Rulemaking 2019," NRRI PURPA Perspectives Webinar, January 29, 2020.
- "PURPA Resurgence and Avoided Costs," EUCI Symposium, September 9, 2019.
- "Future of Coal: Clean Power Plan, Market Drivers, and Other Regulations," American Coal Ash Association's (ACAA) 2017 Winter Membership Meeting, January 25, 2017.
- "CO_2 Regulations and Coal," Energy Bar Association's (EBA) Energizer: Ongoing Climate Imperative, November 10, 2016.

- “Update on Clean Imperative and Sectoral Responses in the US Power Industry,” with Robert S. Mudge, Susan Nickey, Allyson Umberger Browne, and Elias B. Hinckley, American Bar Association (ABA) Business Law Section’s Annual Meeting, September 8, 2016.
- “The Clean Power Plan: Retirements and Reliability,” Wisconsin Energy Institute 2015 Energy Summit, October 2015.
- “The Clean Power Plan: Retirements and Reliability,” with Michael Hagerty, Yingxia Yang, and Nicole Irwin, EUCI Conference, April 1, 2015.
- “Hydropower and the EPA Section 111(d) Proposal,” with Marc Chupka and Kathleen Spees, National Hydropower Association, August 12, 2014.
- “Coal Plant Retirements and Market Impacts,” Wärtsilä Flexible Power Symposium, February 5, 2014.
- “U.S. Coal Plant Retirements: Outlook and Implications,” Coaltrans West Coast Conference, June 14, 2013.
- “U.S. Coal Plant Retirements: Outlook and Implications,” West LegalEd Center CLE Webcast, January 24, 2013.
- “Environmental Retrofits: Costs and Supply Chain Constraints,” MISO Annual Stakeholders’ Meeting, June 2012.
- “Potential Coal Plant Retirements in U.S. and Impact on Gas Demand,” CERI Conference, February 27, 2012.
- “Potential Coal Plant Retirements and Retrofits Under Emerging Environmental Regulations,” Minnesota Rural Electric Association (MREA) Annual Meeting, August 10, 2011.
- “Potential Coal Plant Retirements in ERCOT Under Emerging Environmental Regulations,” with Frank C. Graves, Public Utility Commission of Texas workshop on Potential Environmental Regulations and Resource Adequacy, June 22, 2011.
- “The Regulatory Landscape for Coal-Fired Power: EPA Rules and Implications,” with Frank C. Graves and Marc Chupka, EUCI Conference, January 24, 2011.
- “Potential Coal Plant Retirements under Emerging Environmental Regulations,” with Frank C. Graves, Gunjan Bathla, and Lucas Bressan, EUCI Webinar, December 8, 2010.
- “Financial Instruments in Power Markets: Virtual Bids and FTRs,” with Attila Hajos and Philip Q. Hanser, EUCI Conference, July 19, 2010.

- "Marginal Cost Studies in Ratemaking and Implications of Federal Climate Policy," Southeastern Electric Exchange Rates and Regulation Section Meeting, October 28, 2009.
- "CO_2 Price Volatility Delays Clean Generation Investment," Law Seminars International's Renewable Energy in New England Conference, June 25, 2009.
- "What to Expect from Electric Power and Transport Sectors in Response to U.S. Climate Policy," Rutgers University Center for Research in Regulated Industries, January 18, 2008.
- "Financial Transmission Rights: Necessary or Burdensome?" with Philip Q. Hanser, IAEE Conference, June 7, 2006.
- "Regulation of Transmission Investment and Reliability in Power Networks," METU International Conference in Economics V, September 2001.

SELECTED HONORS & AWARDS

1999	Summer Dissertation Award, Boston College Graduate School of Arts and Sciences
1998	Summer Dissertation Award, Boston College H. Michael Mann Fund
1991–1993	Scholarship, Yasar Holding Company
1988–1993	Tuition Scholarship and Stipend towards the completion of BSc in Industrial Engineering, Turkish Ministry of Education

PROFESSIONAL ASSOCIATIONS & MEMBERSHIPS

2021–Present **American Bar Association (ABA)**
Sections: Litigation; Environment, Energy, and Resources; Infrastructure and Related Industries

2022–Present **Energy Bar Association (EBA)**

LANGUAGES

- Turkish (native)

Exhibit 11

DECLARATION OF DEVI GLICK

I, Devi Glick, declare as follows:

1. I am a Senior Principal at Synapse Energy Economics, a research and consulting firm specializing in energy and environmental issues, including electric generation, transmission, and distribution system reliability, ratemaking and rate design, electric industry restructuring and market power, electricity market prices, stranded costs, efficiency, renewable energy, environmental quality, and nuclear power. At Synapse, I conduct economic analysis and write testimony and publications that focus on a variety of issues related to electric utilities. These issues include power plant economics, electric system dispatch, integrated resource planning, environmental compliance technologies and strategies, and valuation of distributed energy resources. I have submitted expert testimony in more than 60 regulatory dockets before state utility regulators in 20 states. In the course of my work, I develop in-house models and perform analysis using industry-standard electricity power system models. I am proficient in the use of spreadsheet analysis tools, as well as optimization and electric dispatch models. I have directly run EnCompass and PLEXOS and reviewed inputs and outputs for several other models including Aurora and Strategist. My qualifications are provided in my curriculum vitae, attached hereto as Attachment A.

2. I have reviewed the U.S. Environmental Protection Agency's ("EPA's") rule titled "Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category," 89 Fed. Reg, 40198 (May 9, 2024) (the "2024 ELG Rule"), and I am familiar with its requirements.

3. I have reviewed the Utility and State Petitioners' Motion for a Stay Pending Review and associated declarations and exhibits filed in the United States Court of Appeals for the Eighth Circuit on July 26, 2024, in *Southwestern Electric Power Company v. U.S. EPA*, No. 24-2123(L) (8th Cir.), and I am familiar with the Petitioners' arguments and requested relief.

4. My declaration focuses on three facts:

a. First, in my experience, prudent utilities—whether regulated or not—engage in continuous resource planning, modeling, and other analysis to evaluate the least-cost, least-risk generation portfolio for reliably serving forecasted energy demand, in light of forecasted energy and commodity prices, as well as regulatory risk. Utilities conduct resource planning analyses in an ongoing manner to reflect the dynamic nature of the electricity grid, market prices, and the regulatory landscape. Utilities can, and should, incorporate proposed or finalized regulations into their modeling as part of the normal course of business, just as they would incorporate regular updates to inputs such as commodity prices, resource costs, capacity accreditation frameworks, and others. The modeling of new regulations should not require substantial incremental effort in particular beyond the effort required to program the specific regulation into the model.

b. Second, the timeline for compliance with the 2024 ELG Rule provides ample time for utilities to install compliance technologies by the 2029 compliance deadline; the 2024 ELG Rule's alternative compliance pathway provides coal-burning power plants with more than sufficient time to convert to burn gas or secure reliable replacement generation resources by 2034.

c. Third, in general, the cost of compliance that utilities will incur during the pendency of the litigation is small relative to the value of the utilities seeking to stay the 2024 ELG Rule.

Section 1: Prudent utility resource planning is conducted in an ongoing manner to capture the dynamic nature of the electricity sector.

5. In my opinion, the following claim from American Electric Power ("AEP") declarant Gary Spitznogle overstates the incremental cost and effort required to study the impacts of the 2024 ELG Rule. Spitznogle claims that "prior

to building or acquiring replacement generation resources, AEP must begin spending money now for portfolio modeling and other studies so that the appropriate balance between replacement generation, market purchase, financial and fuel hedging, and other arrangements can be developed. This type of portfolio modeling would be a precursor to any definitive steps to obtain replacement generation resources."[1]

6. Resource planning is commonly conducted by utilities as part of the normal course of business across a range of dockets before state public utility commissions. Resource planning relies on modeling. Because changes in key inputs to the modeling can significantly impact modeling results and render outdated results obsolete, inputs are regularly updated to reflect changes in the market and regulatory environment.

7. More specifically, Integrated Resource Planning ("IRP") is required as part of the normal course of business for investor-owned utilities in thirty-two states. As part of the IRP process, utilities generally utilize capacity expansion and production cost models (for example, PLEXOS, Aurora, and EnCompass) to determine the least cost resource mix for their systems given current market factors, regulatory requirements, and reliability constraints.

[1] Motion Exhibit 1, at 8. Declaration of Gary O. Spitznogle.

8. In the eighteen states without a requirement for a formal IRP, nine require a less formal long-term plan, many of which are produced using the same capacity expansion and production cost software (for Example, Duke Energy Florida uses the EnCompass model to produce its Ten-Year Site Plan[2]). In the remaining nine states, many utilities still utilize capacity expansion and production cost software to make operational and procurement decisions, especially related to bringing new resources online (for example MidAmerican Energy Company used Aurora in the Wind PRIME docket,[3] Interstate Power and Light in Iowa used the Aurora model to create its Clean Energy Blue Print,[4] and Wisconsin Public Service Company in Wisconsin uses the PLEXOS model[5]).

9. These resource planning tools and models are readily available and regularly used to support other litigated dockets before state public utility

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[2] Duke Energy Florida, LLC Ten-Year Site Plan. April 2003. Available at https://www.duke-energy.com/-/media/pdfs/our-company/def-tysp/def-10-year-site-plan.pdf?rev=daa9c9c52b854508b63681cddda9c509.

[3] *See, for example,* Docket No. RPU-2022-0001. Environmental Intervenors Comments on Proposed Settlement. December 16, 2022. Available at https://www.iaenvironment.org/webres/File/2022-12-16%20EI%20Settlement%20Comments%20PUBLIC%20RPU-2022-0001.pdf.

[4] Docket No. RPI-2019-0001. Iowa Clean Energy Blueprint: 2020 Resource Planning. November 20, 2020. Available at https://wcc.efs.iowa.gov/cs/idcplg?IdcService=GET_FILE&allowInterrupt=1&RevisionSelectionMethod=latest&dDocName=2045593&noSaveAs=1

[5] *See, for example,* Docket No. 5-UR-110. Direct Testimony of Brandon Gerlikowski. Available at https://apps.psc.wi.gov/ERF/ERFview/viewdoc.aspx?docid=468299.

commissions, including rate cases, alternative ratemaking dockets, certificate of public convenience and necessity ("CPCN") dockets, rider dockets for environmental upgrades, and to evaluate request for proposal ("RFP") bids. In these dockets, the modeling is used for a variety of purposes, including to evaluate whether continued operation of existing resources is economic, to evaluate whether a major upgrade or investment in an existing resource is economic, to evaluate which new resource can most economically meet need, or to show that a resource bid is lowest cost relative to all other bids.

10. In my experience, even for unregulated utilities or in states where there is no formal resource planning requirement, prudent utility practice includes a continual/ongoing evaluation of the least-cost resources to serve demand, taking into account costs of maintenance or replacement, market and commodity prices, and regulatory compliance and other capital cost risks.

11. In many states, the formal IRP process (and some long-term plans) follows a set, predictable cycle every 1-3 years, with some states (for example Virginia[6]) requiring interim updates in intervening years between formal IRP filings, and other states allowing updates when there has been a major change in

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[6] Code of Virginia, § 56-599.

the utility's plan (for example in Georgia[7]). Although the formal IRP process—which generally involves modeling, publishing a draft IRP document, engaging stakeholders, accepting and responding to comments, issuing a final IRP, and then implementing procurement—can take one to two years, utilities are constantly evaluating resource options. In my experience, if a utility already has a set of relevant commodity and market forecasts, replacement cost estimates, and retrofit cost estimates, the Company can conduct a reasonable resource modeling analysis (i.e., an evaluation of the costs and benefits of retrofit versus replacement) quickly, in less than six months, and likely even within 1-2 months.

12. Thus, even though the formal IRP planning process generally takes place within a set timeframe, with results reported in a final report and portfolio, utilities conduct resource planning as part of various utility commission dockets in an ongoing process. Prudent resource planning is not about producing a static plan but rather creating an ongoing process where utilities can reevaluate whether their current resource mixes remain in the best interest of ratepayers as market and regulatory conditions change.

[7] Georgia Power, *Georgia PSC finalizes and approves Georgia Power's 2023 IRP Update.* April 14, 2024. Available at https://www.georgiapower.com/company/news-hub/company-news/georgia-psc-finalizes-and-approves-georgia-powers-2023-irp-update.html.

13. The inputs to an IRP process are constantly changing and require regular tracking and updating to maintain the accuracy of the resource planning results. These include commodity prices for fuel, market prices for energy in the organized markets, new resource costs for both conventional and clean energy resources, capacity accreditation frameworks for utilities that participate in organized markets, tax credits and incentives, federal and state regulations and programs. An updated regulation such as the 2024 ELG Rule, is just one of many changing conditions that utilities need to incorporate into their resource planning process and its one that utilities should have been prepared for.

14. The 2024 ELG Rule builds on, and supplements, EPA's 2015 and 2020 rules limiting the discharge of coal ash and flue gas desulfurization ("FGD") wastewater from coal-burning power plants. Specifically, I understand that the 2024 ELG Rule requires coal plants larger than 50 MWs to eliminate discharges of bottom ash ("BA"), FGD, and managed coal combustion residual leachate ("CRL") wastewater by 2029. (i.e., leachate collected and discharged through power plant's discharge system). The 2024 ELG Rule also requires numeric effluent limitations for mercury and arsenic discharged through unmanaged leachate, and for legacy wastewater discharged from surface impoundments during the process of closing a power plant. I understand that these requirements do not apply to specific sources until the relevant permitting agency incorporates the

requirements into the facility's wastewater discharge permit, no later than December 31, 2029. I also understand that for power plants that commit to conversion or retirement by 2034, the new wastewater limits do not apply. The 2024 ELG Rule also includes reliability mechanisms allowing state or federal regulators to call on coal units to continue operating for reliability purposes without violating the Clean Water Act.

15. As I understand it, the Clean Water Act's overarching goal is to eliminate pollution in the waters of the United States. To achieve that goal, I understand that EPA periodically implements increasingly stringent water pollution standards for industrial sources, like coal-burning power plants. Thus, utilities should not have been planning only to comply with existing 2015 and 2020 regulations, but they should be prepared for increased regulation of coal ash waste and wastewater, should be regularly evaluating whether continued operation is economic in light of the increased regulation of waste, and should be selecting no regrets options that minimize risk to ratepayers and are economic regardless of increased future regulation.

16. I have been engaged in more than 30 IRP proceedings across 17 states. While the full IRP process can take one to two years, the modeling and analysis itself can be done relatively quickly. I have been engaged in numerous dockets where my team at Synapse has replicated utility modeling to update inputs

and assumptions that are outdated or incorrect. When the base model is provided, this process can be done fairly quickly.

17. I have been engaged in dozens of other regulated proceedings where utilities relied on resource planning modeling to justify their asks. The process of updating resource planning modeling for use in a docket, or to evaluate the impact of an updated input, does not require the creation of an entire new IRP. Rather it requires the utility to update specific assumptions and inputs in the core model that it maintains and uses throughout its IRP and other dockets. The process of re-running the model to update assumptions is feasible, routine, and saves ratepayers costs far in excess of the time required to update the modeling.

18. AEP's regulated utilities—Appalachian Power Company, Indiana Michigan Power Company, Kentucky Power Company, Public Service Company of Oklahoma, and Southwestern Electric Power Company—regularly conduct resource planning for various dockets including IRPs, CPCNs, and rate cases.

19. In general, prudently incurred costs associated with the resource planning and procurement process can be recovered from ratepayers. The costs of an IRP exercise are minimal compared to the higher costs a utility would incur through maintaining a poorly planned system.

20. Prudent utility planning to identify the least-cost compliance measures can produce savings far in excess of the cost of updating the model. Prudent utility

planning requires evaluation of retirement of existing resources. However, utilities regularly lock in the retirement dates for existing resources based on a unit's depreciation schedule rather than letting the model select the economically optimal retirement date. This failure to evaluate the economics of an existing resource does not make that resource economic. It does, however, lock ratepayers into the cost of maintaining the resource. Regulatory updates such as this 2024 ELG Rule can drive the utility to model retirement scenarios that it would not otherwise have modeled. This allows them to identify whether retirement options are lower cost than continued reliance on the existing resources—something that may have been true even in the absence of the 2024 ELG Rule.

21. I do not agree with Spitznogle's claim that the 2024 ELG Rule requires AEP to abandon the existing bioreactor equipment that it installed for compliance with the 2020, and that because this equipment will not be fully depreciated by its decommissioning date it may be disallowed for cost recovery on the basis that it is not useful.[8] Provided that the costs were prudently incurred, and the Company conducted resource planning modeling to evaluate all compliance options, including retirement relative to retrofits at the time it made the decision to install the bioreactors, then there should be no risk of disallowance of these costs.

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[8] Motion Exhibit 1, at 8. Declaration of Gary O. Spitznogle.

22. If AEP did not evaluate reasonable alternatives to investing in retrofits to comply with the 2020 ELG Rule, a Commission could disallow some of those costs. Such an outcome would not be the direct result of EPA's 2024 ELG Rule. And in any event, such a disallowance would not likely take place until the relevant Commission's rate review—certainly not anytime within the immediate future.

Section 2: The timeline for compliance or retirement is sufficient to plan, procure, build, and interconnect replacement resources.

23. The 2024 ELG Rule includes three potential decision points for utilities. First, if a utility chooses to convert to burn gas or retire by 2034 instead of complying with the new standards, it will file a notice of its plan to the relevant permitting authority by December 31, 2025. Second, for power plants that wish to continue operating, they have until December 31, 2029, to comply with the "zero discharge" requirements of the 2024 ELG Rule. Third, sources that elect to convert to operate on gas or retire may continue operating without any additional costs until 2034. Each of these decision points provides utilities with sufficient time to evaluate their options.

24. I disagree with Spitznogle's claims that for replacement generation to be available before 2034, AEP must begin spending money now for planning,

design, siting, permitting, financing, equipment and fuel procurement, and construction.[9]

25. First, utilities now have more than sixteen months (until December 31, 2025) to evaluate the 2024 ELG Rule's alternative compliance pathway and notify the relevant permitting authority that they intend to cease burning coal by 2034. In my experience that is more than sufficient time to conduct any resource planning analysis.

26. Second, utilities that wish to continue operating have until December 31, 2029, to install any required pollution controls. The record for the 2024 ELG Rule makes clear that is sufficient time for planning and installation. Specifically, the record indicates that most facilities should be able to complete all steps to implement changes needed to comply with the BA transport water requirements within 32 to 35 months, the FGD wastewater requirements within 28 months, and the CRL requirements within 22 months.[10] These timelines all fall well within the five-year timeline for compliance.

27. Appalachian Power Company was able to install the bioreactor technology at three of its plants in four years.[11]

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[9] Motion Exhibit 1, at 8. Declaration of Gary O. Spitznogle.

[10] 89 Federal Register at 40282, footnote 223; Docket ID No. EPA-HQ-OW-2009-0819-8191; Docket ID No. EPA-HQ-OW-2009-0819-0659.

[11] Motion Exhibit 1, at 5. Declaration of Gary O. Spitznogle.

28. Finally, for those facilities that opt to cease burning coal, ten years is more than sufficient time to convert to burning gas or procure replacement resources. The construction timeline for solar is about two years, with interconnection and permitting taking another four years;[12] for wind it can range from three to four years;[13] for 4-hour battery energy storage ("BESS") it is two to two and half years after the interconnection agreement is signed; and for combustion turbines ("CT"), according to recent industry estimates, it is two to three years.[14] And the timeline to convert an existing plant to operate on gas is far less than ten years. For example, Xcel Energy announced plans in November 2020 to convert Harrington Station to operate on gas by 2025.[15] SWEPCO itself also agreed in November 2020 to convert the Welsh Power Plant to operate on gas by

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[12] Solar Energy Industry Associate, *Development Timeline for Utility-Scale Solar Power Plant. Available at https://www.seia.org/research-resources/development-timeline-utility-scale-solar-power-plant.*

[13] Energy.Gov. *Land-Based Wind Energy Economic Development Guide* At 10. Available at https://windexchange.energy.gov/economic-development-guide.pdf.

[14] See, for example, Paullin, Charlie. *Dominion reviving plans to build a natural gas peaker plant in Chesterfield* . Virginia Mercury. June 14. 2023. Available at https://virginiamercury.com/2023/06/14/dominion-reviving-plans-to-build-a-natural-gas-peaker-plant-in-chesterfield/; Lockwood, Denise. *We Energies advances plans for new $1.2 billion Oak Creek Natural Gas Plant.* February 8. 2024. Available at https://racinecountyeye.com/2024/02/08/new-oak-creek-natural-gas-plant/.

[15] Xcel Energy. *Xcel Energy's Harrington Station goes off coal by 2025.* November 10, 2020. Available at https://nm.my.xcelenergy.com/s/about/newsroom/press-release/xcel-energy-s-harrington-station-goes-off-coal-by-2025-MC6VIZLFV4S5F4VKXKQCNHNJNVB4.

2028.[16] These are both well within the ten-year timeline for conversion and compliance.

29. I disagree with Spitznogle's claims that "Low-capacity factor gas peaking generators combined with market purchases and / or renewables are in no way an adequate or equivalent replacement generation resources for high-capacity factor, dispatchable, load-following, baseload generation resources."[17]

30. Utilities around the country are retiring coal plants and replacing them with a combination of solar, wind, BESS and CT. For example, Arizona Public Service's Preferred Portfolio from its most recent IRP shows the Company retiring the Four Corners Power Plant in 2031 and replace it with a portfolio of wind firmed by gas (CTs).[18] Other utilities, including AES Indiana[19] and CenterPoint Indiana[20] are converting existing coal plants to gas and relying on wind and solar

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[16] Little Rock Public Radio, S*WEPCO plans for coal plant retirements, renewable energy capacity additions.* December 19, 2021. Available at https://www.ualrpublicradio.org/local-regional-news/2021-12-19/swepco-plans-for-coal-plant-retirements-renewable-energy-capacity-additions.
[17] Motion Exhibit 1, at 7-8. Declaration of Gary O. Spitznogle.
[18] Arizona Public Service, 2023 Integrated Resource Plan.
[19] AES Indiana: 2022 Integrated Resource Plan: Non-Technical Summary. Available at https://aesindiana.com/sites/default/files/2023-01/AES-Indiana_2022-IRP_Non-Technical-Summary_f0111.pdf.
[20] Center Point Energy 2022/2023 Integrated Resource Plan – Executive Summary (Non-Technical Summary). May 2023. Available at https://midwest.centerpointenergy.com/assets/downloads/planning/irp/2022-2023%20IRP%20Non-Technical%20Summary.pdf.

(and BESS, in the case of AES Indiana) to provide replacement energy and capacity.

Section 3: The cost of compliance that utilities will incur during the pendency of the litigation is de minimis when compared to the total value of each utility.

31. Finally, I believe the utility petitioners are overstating the potential costs at issue during the pendency of litigation. For example, utility petitioners assert that they must "immediately spend money on portfolio modeling," as well as consulting and engineering and that these costs "cannot be recouped or refunded."[21] This appears to refer to consulting and engineering feasibility studies. Even if utilities do incur costs during this time, these costs are not likely to be substantial and, as long as they are prudently incurred, should be recoverable.

32. In my experience, resource planning analysis can be conducted (starting from scratch), and model runs completed, for $100 - $150K. While the full utility IRP process, inclusive of stakeholder engagement and procurement, will be much more involved, just the modeling component required to evaluate an updated rule should cost only a small fraction of the cost of a full resource planning exercise. Even assuming the cost is ten times what it costs a consultant like Synapse (which is an unlikely assumption given that Synapse has to build utility footprints from scratch and utilities do not), that is still only $1 Million.

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[21] Motion at 26.

33. In 2023, for example, Southern Company, the ultimate parent of Plant Miller, had total operating revenues of $25.3 billion, its operating income was $5.8 billion, and its total assets summed to $139.3 billion.[22]

34. Using Southern Company's $16 million engineering costs at Plant Miller as representative of a potential (albeit inflated) engineering compliance cost,[23] the maximum risk during the pendency of this litigation[24] for a similarly sized plant (around 2,600 MW) would be $17 million (resource plan plus engineering), or 0.07 percent of Southern Company's $25.3 billion total operating revenue.[25] These costs would likely be able recoverable, assuming reasonable and prudent.

I declare under penalty of perjury under the laws of the United States, pursuant to 28 U.S.C. § 1746, that the foregoing is true and correct to the best of my knowledge.

Executed on this 20th day of August 2024, in __Freeport, Maine_______________.

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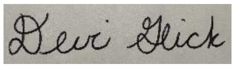
[22] Southern Company, 2023 10-k. Pages II-74-78. Available at https://d18rn0p25nwr6d.cloudfront.net/CIK-0000004904/f1c06f18-84d4-40c7-8073-e1ef64c3fc26.pdf.
[23] *See* Motion Exhibit 6 at 87.
[24] *See id.* at 151 for timeline.
[25] Additional Southern Company plants may incur compliance costs under the 2024 ELG Rule. *See, e.g.*, Motion at 11 (discussing Plant Bowen, which is owned by Southern Company subsidiary Georgia Power).



Devi Glick
Senior Principal
Synapse Energy Economics
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Attachment A

Devi Glick, Senior Principal

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dglick@synapse-energy.com

PROFESSIONAL EXPERIENCE

Synapse Energy Economics Inc., Cambridge, MA. *Senior Principal*, May 2022 – Present; *Principal Associate*, June 2021 – May 2022; *Senior Associate*, April 2019 – June 2021; *Associate*, January 2018 – March 2019.

Conducts research and provides expert witness and consulting services on energy sector issues. Examples include:

- Modeling for resource planning using PLEXOS and Encompass utility planning software to evaluate the reasonableness of utility IRP modeling.
- Modeling for resource planning to explore alternative, lower-cost and lower-emission resource portfolio options.
- Providing expert testimony in rate cases on the prudence of continued investment in, and operation of, coal plants based on the economics of plant operations relative to market prices and alternative resource costs.
- Providing expert testimony and analysis on the reasonableness of utility coal plant commitment and dispatch practice in fuel and power cost adjustment dockets.
- Serving as an expert witness on avoided cost of distributed solar PV and submitting direct and surrebuttal testimony regarding the appropriate calculation of benefit categories associated with the value of solar calculations.
- Reviewing and assessing the reasonableness of methodologies and assumptions relied on in utility IRPs and other long-term planning documents for expert report, public comments, and expert testimony.
- Evaluating utility long-term resource plans and developing alternative clean energy portfolios for expert reports.
- Co-authoring public comments on the adequacy of utility coal ash disposal plans, and federal coal ash disposal rules and amendments.
- Analyzing system-level cost impacts of energy efficiency at the state and national level.

Rocky Mountain Institute, Basalt, CO. August 2012 – September 2017
Senior Associate

- Led technical analysis, modeling, training and capacity building work for utilities and governments in Sub-Saharan Africa around integrated resource planning for the central electricity grid energy. Identified over one billion dollars in savings based on improved resource-planning processes.

- Represented RMI as a content expert and presented materials on electricity pricing and rate design at conferences and events.
- Led a project to research and evaluate utility resource planning and spending processes, focusing specifically on integrated resource planning, to highlight systematic overspending on conventional resources and underinvestment and underutilization of distributed energy resources as a least-cost alternative.

Associate

- Led modeling analysis in collaboration with NextGen Climate America which identified a CO2 loophole in the Clean Power Plan of 250 million tons, or 41 percent of EPA projected abatement. Analysis was submitted as an official federal comment which led to a modification to address the loophole in the final rule.
- Led financial and economic modeling in collaboration with a major U.S. utility to quantify the impact that solar PV would have on their sales and helped identify alternative business models which would allow them to recapture a significant portion of this at-risk value.
- Supported the planning, content development, facilitation, and execution of numerous events and workshops with participants from across the electricity sector for RMI's Electricity Innovation Lab (eLab) initiative.
- Co-authored two studies reviewing valuation methodologies for solar PV and laying out new principles and recommendations around pricing and rate design for a distributed energy future in the United States. These studies have been highly cited by the industry and submitted as evidence in numerous Public Utility Commission rate cases.

The University of Michigan, Ann Arbor, MI. *Graduate Student Instructor*, September 2011 – July 2012

The Virginia Sea Grant at the Virginia Institute of Marine Science, Gloucester Point, VA. *Policy Intern*, Summer 2011

Managed a communication network analysis study of coastal resource management stakeholders on the Eastern Shore of the Delmarva Peninsula.

The Commission for Environmental Cooperation (NAFTA), Montreal, QC. *Short Term Educational Program/Intern*, Summer 2010

Researched energy and climate issues relevant to the NAFTA parties to assist the executive director in conducting a GAP analysis of emission monitoring, reporting, and verification systems in North America.

Congressman Tom Allen, Portland, ME. *Technology Systems and Outreach Coordinator*, August 2007 – December 2008

Directed Congressman Allen's technology operation, responded to constituent requests, and represented the Congressman at events throughout southern Maine.

EDUCATION

The University of Michigan, Ann Arbor, MI
Master of Public Policy, Gerald R. Ford School of Public Policy, 2012
Master of Science, School of Natural Resources and the Environment, 2012
Masters Project: *Climate Change Adaptation Planning in U.S. Cities*

Middlebury College, Middlebury, VT
Bachelor of Arts, 2007
Environmental Studies, Policy Focus; Minor in Spanish
Thesis: *Environmental Security in a Changing National Security Environment: Reconciling Divergent Policy Interests, Cold War to Present*

PUBLICATIONS

Kwok, S., D. Glick, R. Anderson, T. Gyalmo. 2023. *Review of Southwestern Public Service Company 2023 Integrated Resource Plan*. Synapse Energy Economics for Sierra Club.

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Glick, D., P. Eash-Gates, J. Hall, A. Takasugi. 2021. *A Clean Energy Future for MidAmerican and Iowa.* Synapse Energy Economics for Sierra Club, Iowa Environmental Council, and the Environmental Law and Policy Center.

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Biewald, B., D. Glick, J. Hall, C. Odom, C. Roberto, R. Wilson. 2020. *Investing in Failure: How Large Power Companies are Undermining their Decarbonization Targets.* Synapse Energy Economics for Climate Majority Project.

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Glick, D., J. Frost, B. Biewald. 2020. *The Benefits of an All-Source RFP in Duke Energy Indiana's 2021 IRP Process.* Synapse Energy Economics for Energy Matters Community Coalition.

Camp, E., B. Fagan, J. Frost, N. Garner, D. Glick, A. Hopkins, A. Napoleon, K. Takahashi, D. White, M. Whited, R. Wilson. 2019. *Phase 2 Report on Muskrat Falls Project Rate Mitigation, Revision 1 – September 25, 2019.* Synapse Energy Economics for the Board of Commissioners of Public Utilities, Province of Newfoundland and Labrador.

Camp, E., A. Hopkins, D. Bhandari, N. Garner, A. Allison, N. Peluso, B. Havumaki, D. Glick. 2019. *The Future of Energy Storage in Colorado: Opportunities, Barriers, Analysis, and Policy Recommendations.* Synapse Energy Office for the Colorado Energy Office.

Glick, D., B. Fagan, J. Frost, D. White. 2019. *Big Bend Analysis: Cleaner, Lower-Cost Alternatives to TECO's Billion-Dollar Gas Project*. Synapse Energy Economics for Sierra Club.

Glick, D., F. Ackerman, J. Frost. 2019. *Assessment of Duke Energy's Coal Ash Basin Closure Options Analysis in North Carolina.* Synapse Energy Economics for the Southern Environmental Law Center.

Glick, D., N. Peluso, R. Fagan. 2019. *San Juan Replacement Study: An alternative clean energy resource portfolio to meet Public Service Company of New Mexico's energy, capacity, and flexibility needs after the retirement of the San Juan Generating Station*. Synapse Energy Economics for Sierra Club.

Suphachalasai, S., M. Touati, F. Ackerman, P. Knight, D. Glick, A. Horowitz, J.A. Rogers, T. Amegroud. 2018. *Morocco – Energy Policy MRV: Emission Reductions from Energy Subsidies Reform and Renewable Energy Policy.* Prepared for the World Bank Group.

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Allison, A., R. Wilson, D. Glick, J. Frost. 2018. *Comments on South Africa 2018 Integrated Resource Plan.* Synapse Energy Economics for Centre for Environmental Rights.

Hopkins, A. S., K. Takahashi, D. Glick, M. Whited. 2018. *Decarbonization of Heating Energy Use in California Buildings: Technology, Markets, Impacts, and Policy Solutions*. Synapse Energy Economics for the Natural Resources Defense Council.

Knight, P., E. Camp, D. Glick, M. Chang. 2018. *Analysis of the Avoided Costs of Compliance of the Massachusetts Global Warming Solutions Act*. Supplement to 2018 AESC Study. Synapse Energy

Economics for Massachusetts Department of Energy Resources and Massachusetts Department of Environmental Protection.

Fagan, B., R. Wilson, S. Fields, D. Glick, D. White. 2018. *Nova Scotia Power Inc. Thermal Generation Utilization and Optimization: Economic Analysis of Retention of Fossil-Fueled Thermal Fleet to and Beyond 2030 – M08059*. Prepared for Board Counsel to the Nova Scotia Utility Review Board.

Ackerman, F., D. Glick, T. Vitolo. 2018. *Report on CCR proposed rule*. Prepared for Earthjustice.

Lashof, D. A., D. Weiskopf, D. Glick. 2014. *Potential Emission Leakage Under the Clean Power Plan and a Proposed Solution: A Comment to the US EP*A. NextGen Climate America.

Smith, O., M. Lehrman, D. Glick. 2014. *Rate Design for the Distribution Edge*. Rocky Mountain Institute.

Hansen, L., V. Lacy, D. Glick. 2013. *A Review of Solar PV Benefit & Cost Studies*. Rocky Mountain Institute.

TESTIMONY

Public Service Commission of South Carolina (Docket No. 2024-203-E): Direct Testimony of Devi Glick in Application of Kingstree East 230 for a certificate of environmental compatibility and public convenience and necessity for the construction and operation of a 249 MW AC solar and battery facility in Williamsburg County, South Carolina Pursuant to S.C.Code Ann. § 58-33-10 et. Seq., and request to proceed with initial construction work, S.C. Code Ann. § 58-33-110(7). On behalf of Kingstree East 230 LLC. August 9, 2024.

Indiana Utility Regulatory Commission (Cause No. 46038): Direct Testimony of Devi Glick in Petition of Duke Energy Indiana, LLC Pursuant to Indiana code §§ 8-1-2-42.7 and 8-1-2-61, for authority to modify its rate and changes. On behalf of Citizens Action Coalition of Indiana, Inc. July 11, 2024.

State of Vermont Public Utility Commission (Case No. 23-1447-PET): Rebuttal testimony of Devi Glick in the Petition of VT Real Estate Holdings 1 LLC for a Certificate of Public Good, pursuant to 30 V.S.A. § 248, for a 20 MW ground-mounted solar array in Shaftsbury, Vermont. On behalf of VT Real Estate Holdings 1 LLC ("Shaftsbury Solar"). Revised June 27, 2024.

State of Vermont Public Utility Commission (Case No. 23-1447-PET): Direct testimony of Devi Glick in the Petition of VT Real Estate Holdings 1 LLC ("Shaftsbury Solar") for a Certificate of Public Good, pursuant to 30 V.S.A. § 248, authorizing the installation and operation of a 20 MW solar electric generation facility off Holy Smoke Road in Shaftsbury, Vermont to be known as the "Shaftsbury Solar Project". On behalf of VT Real Estate Holdings 1 LLC ("Shaftsbury Solar"). Revised June 27, 2024.

Iowa Utilities Board (RPU-2023-002): Supplemental Testimony of Devi Glick in re: Interstate Power and Light Company, Proposed Rate Increase. On behalf of Environmental Intervenors. June 21, 2024.

Florida Public Service Commission (Docket No. 20240026-EI): Direct testimony of Devi Glick in petition for rate increase by Tampa Electric Company. On behalf of Sierra Club. June 6, 2024.

Iowa Utilities Board (RPU-2023-0002): Surrebuttal Testimony of Devi Glick in re: Interstate Power and Light Company, Proposed Rate Increase. On behalf of Environmental Intervenors. June 3, 2024.

Iowa Utilities Board (RPU-2023-0002): Direct Testimony of Devi Glick in re: Interstate Power and Light Company, Proposed Rate Increase. On behalf of Environmental Intervenors. April 16, 2024.

Michigan Public Service Commission (Case No. U-21051): Direct Testimony of Devi Glick in the Matter of the application of DTE Electric Company for reconciliation of its power supply cost recovery plan (Case No. U-21050) for the 12 months ended December 31, 2022. On behalf of Michigan Environmental Council. March 8, 2024.

Michigan Public Service Commission (Case No. U-21427): Direct Testimony of Devi Glick in the matter of the Application of Indiana Michigan Power Company for approval of a Power Supply Cost Recovery plan and factors (2024). On behalf of Sierra Club and Citizens Utility Board of Michigan. March 4, 2024.

Georgia Public Service Commission (Docket No. 55378): Direct Testimony of Devi Glick and Lucy Metz in Re: Georgia Power Company's 2023 Integrated Resource Plan Update. On behalf of Sierra Club. February 15, 2024.

Louisiana Public Service Commission (Docket No. U-36923): Direct Testimony of Devi Glick in the Application of Cleco Power LLC for: (1) Implementation of changes in rates to be effective July 1, 2024; and (2) extension of existing formula rate plan. On behalf of Sierra Club. February 5, 2024.

Public Service Commission of South Carolina (Docket No. 2023-154-E): Supplemental Testimony of Devi Glick in re: 2023 Integrated Resource Plan for the South Carolina Public Service Authority. On behalf of Sierra Club. January 29, 2024.

Public Service Commission of South Carolina (Docket No. 2023-154-E): Surrebuttal Testimony of Devi Glick in re: 2023 Integrated Resource Plan for the South Carolina Public Service Authority. On behalf of Sierra Club. November 17, 2023.

Public Utilities Commission of Ohio (Case No. 21-477-EL-RDR): Direct Testimony of Devi Glick in the Matter of the OVEC Generation Purchase Rider Audits Required by 4928.148 for Duke Energy Ohio, Inc. the Dayton Power and Light Company, and AEP Ohio. On behalf of Union of Concerned Scientists and the Citizens Utility Board. October 10, 2023.

Public Service Commission of South Carolina (Docket No. 2023-154-E): Direct Testimony of Devi Glick in re: 2023 Integrated Resource Plan for the South Carolina Public Service Authority. On behalf of Sierra Club. September 22, 2023.

Public Utilities Commission of Ohio (Case No. 20-165-EL-RDR): Direct Testimony of Devi Glick in the matter of the review of the Reconciliation Rider of the Dayton Power and Light Company. On behalf of Office of the Ohio Consumers' Counsel. September 12, 2023.

Virginia State Corporation Commission (Case No. PUR-2023-00066): Direct Testimony of Devi Glick in re: Virginia Electric and Power Company's 2023 Integrated Resource Plan filing pursuant to Virginia Code to §56-597 *et seq.* On behalf of Sierra Club. August 8, 2023.

Public Utility Commission of Texas (PUC Docket No. 54634): Direct Testimony of Devi Glick in the application of Southwestern Public Service Company for authority to change rates. On behalf of Sierra Club. August 4, 2023

Arizona Corporation Commission (Docket No. E-1345A-22-0144): Surrebuttal Testimony of Devi Glick in the matter of the application of Arizona Public Service Company for a hearing to determine the fair value of the utility property of the company for ratemaking purposes, to fix a just and reasonable rate of return thereon, and to approve rate schedules designed to develop such return. On Behalf of Sierra Club. July 26, 2023.

Arizona Corporation Commission (Docket No. E-01345A-22-0144): Direct Testimony of Devi Glick in the matter of the application of Arizona Public Service Company for a hearing to determine the fair value of the utility property of the company for ratemaking purposes, to fix a just and reasonable rate of return thereon, and to approve rate schedules designed to develop such return. On Behalf of Sierra Club. June 5, 2023.

Virginia State Corporation Commission (Case No. PUR-2023-00005): Direct Testimony of Devi Glick in the Petition of Virginia Electric & Power Company for revision of rate adjustment clause, Rider E, for the recovery of costs incurred to comply with state and federal environmental regulations pursuant to §56-585.1 A 5 e of the Code of Virginia. On behalf of Sierra Club. May 23, 2023.

New Mexico Public Regulation Commission (Case No, 22-00286-UT): Direct Testimony of Devi Glick in the matter of Southwestern Public Service Company's application for: (1) Revisions of its retail rates under advance no. 312; (2) Authority to abandon the Plant X Unit 1, Plant X Unit 2, and Cunningham Unit 1 Generating Stations and amend the abandonment date of the Tolk Generating Station; and (3) other associated relief. On behalf of Sierra Club. April 21, 2023.

Michigan Public Service Commission (Case No. U-20805): Direct Testimony of Devi Glick in the matter of the Application of Indiana Michigan Power Company for a Power Supply Cost Recovery Reconciliation proceeding for the 12-month period ended December 31, 2021. On behalf of Michigan Attorney General. April 17, 2023.

Michigan Public Service Commission (Case No. U-21261): Direct Testimony of Devi Glick in the matter of the application of Indiana Michigan Power Company for approval to implement a Power Supply Cost Recovery Plan for the twelve months ending December 31, 2023. On Behalf of Sierra Club. March 23, 2023.

New Mexico Public Regulation Commission (Case No. 19-00099-UT / 19-00348-UT): Direct Testimony of Devi Glick in the matter of El Paso Electric Company's Application for Approval of Long-Term

Purchased Power Agreements with Hecate Energy Santa Teresa, LLC, Buena Vista Energy, LLC, and Canutillo Energy Center LLC. On Behalf of New Mexico Office of the Attorney General, January 23, 2023.

Arizona Corporation Commission (Docket No. E-01933A-22-0107): Direct Testimony of Devi Glick in the matter of the application of Tucson Electric Power Company for the establishment of just and reasonable rates and charges designed to realize a reasonable rate of return on the fair value of the properties of Tucson Electric Power Company devoted to its operations throughout the state of Arizona for related approvals. On Behalf of Sierra Club. January 11, 2023.

New Mexico Public Regulation Commission (Case No. 22-00093-UT): Direct Testimony of Devi Glick in the amended application for approval of El Paso Electric Company's 2022 renewable energy act plan pursuant to the renewable energy act and 17.9.572 NMAC, and sixth revised rate no. 38-RPS cost rider. On Behalf of New Mexico Office of the Attorney General, January 9, 2023.

Iowa Utilities Board (Docket No. RPU-2022-0001): Supplemental Direct and Rebuttal Testimony of Devi Glick in MidAmerican Energy Company Application for a Determination of Ratemaking Principles. On behalf of Environmental Intervenors. November 21, 2022.

Public Utility Commission of Texas (PUC Docket No. 53719): Direct Testimony of Devi Glick in the application of Entergy Texas, Inc. for authority to change rates. On behalf of Sierra Club. October 26, 2022.

Virginia State Corporation Commission (Case No. PUR-2022-00051): Direct Testimony of Devi Glick in re: Appalachian Power Company's Integrated Resource Plan filing pursuant to Virginia Code §56-597 *et seq*. On behalf of Sierra Club. September 2, 2022.

Public Service Commission of the State of Missouri (Case No. ER-2022-0129, Case No. ER-2022-0130): Surrebuttal Testimony of Devi Glick in the matter of Every Missouri Metro and Evergy Missouri West request for authority to implement a general rate increase for electric service. On behalf of Sierra Club. August 16, 2022.

Iowa Utilities Board (Docket No. RPU-2022-0001): Direct Testimony of Devi Glick in MidAmerican Energy Company Application for a Determination of Ratemaking Principles. On behalf of Environmental Intervenors. July 29, 2022.

Public Service Commission of the State of Missouri (Case No. ER-2022-0129, Case No. ER-2022-0130): Direct Testimony of Devi Glick in the matter of Every Missouri Metro and Evergy Missouri West request for authority to implement a general rate increase for electric service. On behalf of Sierra Club. June 8, 2022.

Virginia State Corporation Commission (Case No. PUR-2022-00006): Direct Testimony of Devi Glick in the petition of Virginia Electric & Power Company for revision of rate adjustment clause: Rider E, for the recovery of costs incurred to comply with state and federal environmental regulations pursuant to §56-585.1 A 5 e of the Code of Virginia. On behalf of Sierra Club. May 24, 2022.

Oklahoma Corporation Commission (Case No. PUD 202100164): Direct Testimony of Devi Glick in the matter of the application of Oklahoma gas and electric company for an order of the Commission authorizing application to modify its rates, charges, and tariffs for retail electric service in Oklahoma. On behalf of Sierra Club. April 27, 2022.

Public Utility Commission of Texas (PUC Docket No. 52485): Direct Testimony of Devi Glick in the application of Southwestern Public Service Company to amend its certifications of public convenience and necessity to convert Harrington Generation Station from coal to natural gas. On behalf of Sierra Club. March 25, 2022.

Public Utility Commission of Texas (PUC Docket No. 52487): Direct Testimony of Devi Glick in the application of Entergy Texas Inc. to amend its certificate of convenience and necessity to construct Orange County Advanced Power Station. On behalf of Sierra Club. March 18, 2022.

Michigan Public Service Commission (Case No. U-21052): Direct Testimony of Devi Glick in the matter of the application of Indiana Michigan Power Company for approval of a Power Supply Cost Recovery Plan and Factors (2022). On Behalf of Sierra Club. March 9, 2022.

Arkansas Public Service Commission (Docket No. 21-070-U): Surrebuttal Testimony of Devi Glick in the Matter of the Application of Southwestern Electric Power Company for approval of a general change in rate and tariffs. On behalf of Sierra Club. February 17, 2022.

New Mexico Public Regulation Commission (Case No. 21-00200-UT): Direct Testimony of Devi Glick in the Matter of the Southwestern Public Service Company's application to amend its certifications of public convenience and necessity to convert Harrington Generation Station from coal to natural gas. On behalf of Sierra Club. January 14, 2022.

Public Utilities Commission of Ohio (Case No. 18-1004-EL-RDR): Direct Testimony of Devi Glick in the Matter of the Review of the Power Purchase Agreement Rider of Ohio Power Company for 2018 and 2019. On behalf of the Office of the Ohio Consumer's Counsel. December 29, 2021.

Arkansas Public Service Commission (Docket No. 21-070-U): Direct Testimony of Devi Glick in the Matter of the Application of Southwestern Electric Power Company for Approval of a General Change in Rates and Tariffs. On behalf of Sierra Club. December 7, 2021.

Michigan Public Service Commission (Case No. U-20528): Direct Testimony of Devi Glick in the matter of the Application of DTE Electric Company for reconciliation of its power supply cost recovery plan (Case No. U-20527) for the 12-month period ending December 31, 2020. On behalf of Michigan Environmental Council. November 23, 2021.

Public Utilities Commission of Ohio (Case No. 20-167-EL-RDR): Direct Testimony of Devi Glick in the Matter of the Review of the Reconciliation Rider of Duke Energy Ohio, Inc. On behalf of The Office of the Ohio Consumer's Counsel. October 26, 2021.

Public Utilities Commission of Nevada (Docket No. 21-06001): Phase III Direct Testimony of Devi Glick in the joint application of Nevada Power Company d/b/a NV Energy and Sierra Pacific Power Company d/b/a NV Energy for approval of their 2022-2041 Triennial Intergrade Resource Plan and 2022-2024 Energy Supply Plan. On behalf of Sierra Club and Natural Resource Defense Council. October 6, 2021.

Public Service Commission of South Carolina (Docket No, 2021-3-E): Direct Testimony of Devi Glick in the matter of the annual review of base rates for fuel costs for Duke Energy Carolinas, LLC (for potential increase or decrease in fuel adjustment and gas adjustment). On behalf of the South Carolina Coastal Conservation League and the Southern Alliance for Clean Energy. September 10, 2021.

North Carolina Utilities Commission (Docket No. E-2, Sub 1272): Direct Testimony of Devi Glick in the matter of the application of Duke Energy Progress, LLC pursuant to N.C.G.S § 62-133.2 and commission R8-5 relating to fuel and fuel-related change adjustments for electric utilities. On behalf of Sierra Club. August 31, 2021.

Michigan Public Service Commission (Docket No. U-20530): Direct Testimony of Devi Glick in the application of Indiana Michigan Power Company for a Power Supply Cost Recovery Reconciliation proceeding for the 12-month period ending December 31, 2020. On behalf of the Michigan Attorney General. August 24, 2021.

Public Utilities Commission of Nevada (Docket No. 21-06001): Phase I Direct Testimony of Devi Glick in the joint application of Nevada Power Company d/b/a NV Energy and Sierra Pacific Power Company d/b/a NV Energy for approval of their 2022-2041 Triennial Intergrade Resource Plan and 2022-2024 Energy Supply Plan. On behalf of Sierra Club and Natural Resource Defense Council. August 16, 2021.

North Carolina Utilities Commission (Docket No. E-7, Sub 1250): Direct Testimony of Devi Glick in the Mater of Application Duke Energy Carolinas, LLC Pursuant to §N.C.G.S 62-133.2 and Commission Rule R8-5 Relating to Fuel and Fuel-Related Charge Adjustments for Electric Utilities. On behalf of Sierra Club. May 17, 2021.

Public Utility Commission of Texas (PUC Docket No. 51415): Direct Testimony of Devi Glick in the application of Southwestern Electric Power Company for authority to change rates. On behalf of Sierra Club. March 31, 2021.

Michigan Public Service Commission (Docket No. U-20804): Direct Testimony of Devi Glick in the application of Indiana Michigan Power Company for approval of a Power Supply Cost Recovery Plan and factors (2021). On behalf of Sierra Club. March 12, 2021.

Public Utility Commission of Texas (PUC Docket No. 50997): Direct Testimony of Devi Glick in the application of Southwestern Electric Power Company for authority to reconcile fuel costs for the period May 1, 2017- December 31, 2019. On behalf of Sierra Club. January 7, 2021.

Michigan Public Service Commission (Docket No. U-20224): Direct Testimony of Devi Glick in the application of Indiana Michigan Power Company for Reconciliation of its Power Supply Cost Recovery Plan. On behalf of the Sierra Club. October 23, 2020.

Public Service Commission of Wisconsin (Docket No. 3270-UR-123): Surrebuttal Testimony of Devi Glick in the application of Madison Gas and Electric Company for authority to change electric and natural gas rates. On behalf of Sierra Club. September 29, 2020.

Public Service Commission of Wisconsin (Docket No. 6680-UR-122): Surrebuttal Testimony of Devi Glick in the application of Wisconsin Power and Light Company for approval to extend electric and natural gas rates into 2021 and for approval of its 2021 fuel cost plan. On behalf of Sierra Club. September 21, 2020.

Public Service Commission of Wisconsin (Docket No. 3270-UR-123): Direct Testimony and Exhibits of Devi Glick in the application of Madison Gas and Electric Company for authority to change electric and natural gas rates. On behalf of Sierra Club. September 18, 2020.

Public Service Commission of Wisconsin (Docket No. 6680-UR-122): Direct Testimony and Exhibits of Devi Glick in the application of Wisconsin Power and Light Company for approval to extend electric and natural gas rates into 2021 and for approval of its 2021 fuel cost plan. On behalf of Sierra Club. September 8, 2020.

Indiana Utility Regulatory Commission (Cause No. 38707-FAC125): Direct Testimony and Exhibits of Devi Glick in the application of Duke Energy Indiana, LLC for approval of a change in its fuel cost adjustment for electric service. On behalf of Sierra Club. September 4, 2020.

Indiana Utility Regulatory Commission (Cause No. 38707-FAC123 S1): Direct Testimony and Exhibits of Devi Glick in the Subdocket for review of Duke Energy Indian, LLC's Generation Unit Commitment Decisions. On behalf of Sierra Club. July 31, 2020.

Indiana Utility Regulatory Commission (Cause No. 38707-FAC124): Direct Testimony and Exhibits of Devi Glick in the application of Duke Energy Indiana, LLC for approval of a change in its fuel cost adjustment for electric service. On behalf of Sierra Club. June 4, 2020.

Arizona Corporation Commission (Docket No. E-01933A-19-0028): Reply to Late-filed ACC Staff Testimony of Devi Glick in the application of Tucson Electric Power Company for the establishment of just and reasonable rates. On behalf of Sierra Club. May 8, 2020.

Indiana Utility Regulatory Commission (Cause No. 38707-FAC123): Direct Testimony and Exhibits of Devi Glick in the application of Duke Energy Indiana, LLC for approval of a change in its fuel cost adjustment for electric service. On behalf of Sierra Club. March 6, 2020.

Public Utility Commission of Texas (PUC Docket No. 49831): Direct Testimony of Devi Glick in the application of Southwestern Public Service Company for authority to change rates. On behalf of Sierra Club. February 10, 2020.

New Mexico Public Regulation Commission (Case No. 19-00170-UT): Testimony of Devi Glick in Support of Uncontested Comprehensive Stipulation. On behalf of Sierra Club. January 21, 2020.

Nova Scotia Utility and Review Board (Matter M09420): Expert Evidence of Fagan, B, D. Glick reviewing Nova Scotia Power's Application for Extra Large Industrial Active Demand Control Tariff for Port Hawkesbury Paper. Prepared for Nova Scotia Utility and Review Board Counsel. December 3, 2019.

New Mexico Public Regulation Commission (Case No. 19-00170-UT): Direct Testimony of Devi Glick regarding Southwestern Public Service Company's application for revision of its retail rates and authorization and approval to shorten the service life and abandon its Tolk generation station units. On behalf of Sierra Club. November 22, 2019.

North Carolina Utilities Commission (Docket No. E-100, Sub 158): Responsive testimony of Devi Glick regarding battery storage and PURPA avoided cost rates. On behalf of Southern Alliance for Clean Energy. July 3, 2019.

State Corporation Commission of Virginia (Case No. PUR-2018-00195): Direct testimony of Devi Glick regarding the economic performance of four of Virginia Electric and Power Company's coal-fired units and the Company's petition to recover costs incurred to company with state and federal environmental regulations. On behalf of Sierra Club. April 23, 2019.

Connecticut Siting Council (Docket No. 470B): Joint testimony of Robert Fagan and Devi Glick regarding NTE Connecticut's application for a Certificate of Environmental Compatibility and Public Need for the Killingly generating facility. On behalf of Not Another Power Plant and Sierra Club. April 11, 2019.

Public Service Commission of South Carolina (Docket No. 2018-3-E): Surrebuttal testimony of Devi Glick regarding annual review of base rates of fuel costs for Duke Energy Carolinas. On behalf of South Carolina Coastal Conservation League and Southern Alliance for Clean Energy. August 31, 2018.

Public Service Commission of South Carolina (Docket No. 2018-3-E): Direct testimony of Devi Glick regarding the annual review of base rates of fuel costs for Duke Energy Carolinas. On behalf of South Carolina Coastal Conservation League and Southern Alliance for Clean Energy. August 17, 2018.

Public Service Commission of South Carolina (Docket No. 2018-1-E): Surrebuttal testimony of Devi Glick regarding Duke Energy Progress' net energy metering methodology for valuing distributed energy resources system within South Carolina. On behalf of South Carolina Coastal Conservation League and Southern Alliance for Clean Energy. June 4, 2018.

Public Service Commission of South Carolina (Docket No. 2018-1-E): Direct testimony of Devi Glick regarding Duke Energy Progress' net energy metering methodology for valuing distributed energy resources system within South Carolina. On behalf of South Carolina Coastal Conservation League and Southern Alliance for Clean Energy. May 22, 2018.

Public Service Commission of South Carolina (Docket No. 2018-2-E): Surrebuttal testimony of Devi Glick on avoided cost calculations and the costs and benefits of solar net energy metering for South Carolina Electric and Gas Company. On behalf of South Carolina Coastal Conservation League and Southern Alliance for Clean Energy. April 4, 2018.

Public Service Commission of South Carolina (Docket No. 2018-2-E): Direct testimony of Devi Glick on avoided cost calculations and the costs and benefits of solar net energy metering for South Carolina Electric and Gas Company. On behalf of South Carolina Coastal Conservation League and Southern Alliance for Clean Energy. March 23, 2018.

Resume updated August 2024

Exhibit 12

United States
Environmental Protection
Agency

Technical Development Document for Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category

April 2024

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U.S. Environmental Protection Agency
Office of Water (4303T)
1200 Pennsylvania Avenue, NW
Washington, DC 20460

EPA-821-R-24-004

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Contents

List of Figures

List of Tables

List of Abbreviations

ACE	Affordable Clean Energy
BA	bottom ash
BAT	best available technology economically achievable
BCA	Benefit and Cost Analysis
BMP	best management practice
BOD	biochemical oxygen demand
CA	combined ash
CAA	Clean Air Act
CBI	confidential business information
CCR	coal combustion residuals
CFR	Code of Federal Regulations
CH_4	methane
CO_2	carbon dioxide
CP	chemical precipitation
CPP	Clean Power Plan
CRL	combustion residual leachate
CSAPR	Cross-State Air Pollution Rule
CSC	compact submerged conveyor
CUR	capacity utilization rates
CWA	Clean Water Act
CWT	centralized waste treatment
DOE	Department of Energy
EA	Environmental Assessment

EDR	electrodialysis reversal
EGU	electric generating unit
EIA	Energy Information Administration
EJA	Environmental Justice Analysis
ELGs	effluent limitations guidelines and standards
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
FA	fly ash
FBR	fluidized bed reactor
FGD	flue gas desulfurization
FGMC	flue gas mercury control
FO	forward osmosis
gal	gallon
GHG	greenhouse gas
GPD	gallons per day
GPM	gallons per minute
HAP	hazardous air pollutant
HRR	high recycle rate
HRT	hydraulic residence time
HRTR	high residence time reduction
HVAC	heating, ventilation, and air conditioning
ICR	information collection request
IPM	Integrated Planning Model
kWh	kilowatt-hour
L	liter
lb	pound
LRTR	low residence time reduction
LUEGU	low utilization electric generating unit
MATS	Mercury and Air Toxics Standards

MDS	mechanical drag system
mg	milligrams
MGD	million gallons per day
MGY	million gallons per year
mi	mile
µg	micrograms
MW	megawatts
MWh	megawatt-hours
N_2O	nitrous oxide
NA	not applicable
NAAQS	National Ambient Air Quality Standards
NERC	North American Electric Reliability Corporation
NOPP	notice of planned participation
NO_X	oxides of nitrogen
NPDES	National Pollutant Discharge Elimination System
NSPS	new source performance standards
NWQEI	non-water quality environmental impacts
O&M	operation and maintenance
OLEM	Office of Land and Emergency Management
ORCR	Office of Resource Conservation and Recovery
PM	particulate matter
POTW	publicly owned treatment works
PSES	pretreatment standards for existing sources
PSNS	pretreatment standards for new sources
QA	quality assurance
QC	quality control
RCRA	Resource Conservation and Recovery Act
RIA	Regulatory Impact Analysis
RO	reverse osmosis

SDE	spray dryer evaporator
SO_2	sulfur dioxide
TCLP	toxicity characteristic leaching procedure
TDD	Technical Development Document
TDS	total dissolved solids
TMT	trimercapto-s-triazine
TPY	tons per year
TSS	total suspended solids
VIP	Voluntary Incentives Program
WOTUS	Waters of the United States
ZVI	zero valent iron

1. Background

This Technical Development Document describes background information for the U.S. Environmental Protection Agency's (EPA's) 2024 final supplemental rulemaking (2024 final rule) for the steam electric power generating point source category. This final rulemaking is based on a review of the effluent limitations guidelines and standards (ELGs) promulgated in 2020 (referred to as the 2020 rule) under Executive Order 13990.

The EPA is finalizing revisions to the 2020 rule based on a review of publicly available data, additional data collected from the steam electric power generating industry, and comments on the 2023 proposed rulemaking. The revisions cover best available technology economically achievable (BAT) and pretreatment standards for existing sources (PSES) requirements for flue gas desulfurization (FGD) wastewater, bottom ash (BA) transport water, combustion residual leachate (CRL), and legacy wastewater from steam electric power plants; and new source performance standards (NSPS) and pretreatment standards for new sources (PSNS) for CRL from steam electric power plants. This document presents information for the revisions including details on EPA's data collection, industry profile updates (*e.g.,* retirements and treatment technology updates), methodologies for estimating costs, pollutant removals, and non-water quality environmental impacts.

In addition to this report, other supporting reports include:

- *Environmental Assessment for Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (EA), Document No. EPA-821-R-24-005. This report summarizes the potential environmental and human health impacts that are estimated to result from implementation of the revisions to the 2015 and 2020 rules.
- *Benefit and Cost Analysis for Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (BCA), Document No. EPA-821-R-24-006. This report summarizes estimated societal benefits and costs that are estimated to result from implementation of the revisions to the 2015 and 2020 rules.
- *Regulatory Impact Analysis for Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (RIA), Document No. EPA-821-R-24-007. This report presents a profile of the steam electric power generating industry, a summary of estimated costs and impacts associated with the proposed revisions to the 2015 and 2020 rules, and an assessment of the potential impacts on employment and small businesses.
- *Environmental Justice Analysis for Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (EJA), Document No. EPA-821-R-24-008. This report presents a profile of the communities and populations potentially impacted by the 2024 final rule, analysis of the distribution of impacts in the baseline and changes, and summary of input from potentially impacted communities that the EPA met with prior to the final rule.

The ELGs for the steam electric power generating category are based on data generated or obtained in accordance with the EPA's Quality Policy and Information Quality Guidelines. The EPA's quality assurance (QA) and quality control (QC) activities for this rulemaking include developing, approving, and implementing quality assurance project plans for the use of environmental data generated or collected from sampling and analyses, existing databases, and literature searches, and for developing any models that use environmental data.

1.1 Legal Authority

The EPA is revising the ELGs for the steam electric power generating point source category (40 CFR 423) under the authority of sections 301, 304, 306, 307, 308, 402, and 501 of the Clean Water Act, 33 U.S.C. 1311, 1314, 1316, 1317, 1318, 1342, and 1361.

Congress passed the Federal Water Pollution Control Act Amendments of 1972, also known as the Clean Water Act (CWA), to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters," per 33 U.S.C. 1251(a). The CWA establishes a comprehensive program for protecting the nation's waters. Among its core provisions, the CWA prohibits the discharge of pollutants from a point source to waters of the United States except as authorized under the CWA. Under section 402 of the CWA, discharges may be authorized through a National Pollutant Discharge Elimination System (NPDES) permit. The CWA also authorizes the EPA to establish national ELGs for discharges from categories of point sources. Refer to the CWA for more information on these limitations, which could affect direct dischargers and indirect dischargers. These final revisions relate primarily to the standards for BAT and to PSES.

1.2 Regulatory History

The EPA first issued a steam electric ELG in 1974, with subsequent revisions in 1977 and 1982. These limitations and standards included requirements on once-through cooling water, cooling tower blowdown, fly ash (FA) transport water, BA transport water, metal cleaning waste, coal pile runoff, and low-volume waste sources. Requirements do not apply to discharges from generating units that primarily use nonfossil or nonnuclear fuel sources (*e.g.,* wood waste, municipal solid waste).

In 2015, the EPA finalized new requirements for multiple wastestreams generated by new and existing steam electric power plants: BA transport water, CRL, FGD wastewater, flue gas mercury control wastewater, FA transport water, and gasification wastewater. Seven petitions for review of the 2015 rule were filed in various circuit courts by industry members, environmental groups, and drinking water utilities. In April 2017, in response to petitions from Utility Water Act Group and the Small Business Administration, the EPA postponed compliance dates for the 2015 rule through administrative action. The EPA later issued a rule, following public notice and an opportunity to comment, postponing the earliest dates for compliance with BAT limitations and PSES on FGD wastewater and BA transport water in the 2015 rule.

On August 11, 2017, the EPA Administrator announced a decision to review and revise BAT requirements for FGD wastewater and BA transport water. The Fifth Circuit Court of Appeals granted the EPA's request to sever and hold in abeyance aspects of litigation related to those two wastestreams. The Fifth Circuit Court of Appeals continued to hear litigation related to legacy wastewater and CRL. In a decision on April 12, 2019, the court vacated limitations on both legacy wastewater and CRL as arbitrary and capricious under the Administrative Procedure Act and unlawful under the CWA. *Southwestern Electric Power Co., et al.* v. *EPA*, 920 F.3d 999 (5th Cir. 2019).

On August 31, 2020, the EPA finalized a rule for the steam electric power generating category that established revised effluent limitations and standards for FGD wastewater and BA transport water. This 2020 rule revised the BAT technology basis for FGD wastewater and BA transport water, established new compliance dates, revised the FGD Voluntary Incentives Program (VIP), and established additional subcategories. See the *Supplemental Technical Development Document for Revisions to the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (EPA-821-R-20-001) for details related to the 2020 rule.

On March 29, 2023, the EPA finalized a direct final action to extend the date for existing steam electric power plants to submit a notice of planned participation (NOPP) for the permanent cessation of coal combustion by December 31, 2028 subcategory in the 2020 Steam Electric Reconsideration Rule. The EPA extended the NOPP date in 40 CFR 423.19(f) to June 27, 2023.

1.3 Other Key Regulatory Actions Affecting Steam Electric Power Generating

Multiple EPA offices are taking actions to reduce emissions, discharges, and other environmental impacts associated with steam electric power plants. The EPA made every effort to appropriately account for other rules affecting the industry in its analysis for the 2024 rule. This section provides a brief overview of recent changes to the regulatory requirements for steam electric power plants.

- Coal Combustion Residuals Disposal Rule. On April 17, 2015, the EPA promulgated the Disposal of Coal Combustion Residuals from Electric Utilities final rule (2015 CCR rule). This rule finalized national regulations to provide a comprehensive set of requirements for the safe disposal of CCR, commonly referred to as coal ash, from steam electric power plants. The final 2015 CCR rule was the culmination of extensive study on the effects of coal ash on the environment and public health. The rule established technical requirements for CCR landfills and surface impoundments under subtitle D of the Resource Conservation and Recovery Act (RCRA), the nation's primary law for regulating solid waste.

  These regulations established requirements for the management and disposal of coal ash, including requirements designed to prevent leaking of contaminants into groundwater, blowing of contaminants into the air as dust, and the catastrophic failure of coal ash surface impoundments. The 2015 CCR rule also set recordkeeping and reporting requirements, as well as requirements for each plant to establish and post specific information to a publicly accessible website. The rule also established requirements to distinguish the beneficial use of CCR from disposal.

  As a result of the D.C. Circuit Court decisions in *Utility Solid Waste Activities Group v. EPA*, 901 F.3d 414 (D.C. Cir. 2018) ("*USWAG* decision" or "*USWAG*"), and *Waterkeeper Alliance Inc. et al. v. EPA*, No. 18-1289 (D.C. Cir. filed March 13, 2019), the Administrator signed two rules: *A Holistic Approach to Closure Part A: Deadline to Initiate Closure and Enhancing Public Access to Information* (CCR Part A rule) on July 29, 2020, and *A Holistic Approach to Closure Part B: Alternate Liner Demonstration* (CCR Part B rule) on October 15, 2020. The EPA finalized five amendments to the 2015 CCR rule which are relevant to the management of the wastewaters covered by this ELG because these wastewaters have historically been co-managed with CCR in the same surface impoundments. First, the CCR Part A rule established a new deadline of April 11, 2021, for all unlined surface impoundments in which CCR are managed ("CCR surface impoundments"), as well as CCR surface impoundments that failed the location restriction for placement above the uppermost aquifer, to stop receiving waste and begin closure or retrofitting. The EPA established this date after evaluating the steps that owners and operators need to take for CCR surface impoundments to stop receiving waste and begin closure, and the timeframes needed for implementation. (This did not affect the ability of plants to install new, composite-lined CCR surface impoundments.) Second, the Part A rule established procedures for plants to obtain approval from the EPA for additional time to develop alternative disposal capacity to manage their wastestreams (both CCR and non-CCR) before they must stop receiving waste and begin closing their CCR surface impoundments. Third, the Part A rule changed the classification of compacted-soil-lined and clay-lined surface impoundments from lined to unlined. Fourth, the Part B rule finalized procedures potentially allowing a limited number of facilities to demonstrate to the EPA that, based on groundwater data and the design of a particular surface impoundment, the unit ensures there is no reasonable probability of adverse effects to human health and the environment. Should the EPA approve such a submission, these CCR surface impoundments would be allowed to continue to operate.

  As explained in the 2015 and 2020 ELG rules, the ELGs and CCR rules may affect the same EGU or activity at a plant. Therefore, when the EPA finalized the ELG and CCR rules in 2015, and revisions to both rules in 2020, the Agency coordinated the ELG and CCR rules to minimize the complexity of implementing engineering, financial, and permitting activities. Likewise, the EPA considered the interaction of the two rules during the development of this final rule. The EPA's analytic baseline includes the final requirements of these rules using the most recent data provided under the CCR rule reporting and recordkeeping requirements. This is further described in Supplemental TDD, Section 3. For more information on the CCR Part A and Part B rules, including information about their ongoing implementation, visit *www.epa.gov/coalash/coal-ash-rule*.

  Concurrently with the final ELG, in a separate rulemaking, the EPA is also finalizing regulatory requirements for inactive CCR surface impoundments at inactive utilities ("legacy CCR surface impoundment" or "legacy impoundment"). This action is being taken in response to the August 21, 2018, opinion by the U.S. Court of Appeals for the District of Columbia Circuit in the *USWAG* decision that vacated and remanded the provision exempting legacy impoundments from the CCR regulations. This action includes adding a definition for legacy CCR surface impoundments and other terms relevant to this rulemaking. It also requires that legacy CCR surface impoundments comply with certain existing CCR regulations with tailored compliance deadlines.

The EPA is also establishing requirements to address the risks from currently exempt solid waste management that involves the direct placement of CCR on the land. The EPA is extending a subset of the existing requirements in 40 CFR part 257, subpart D to CCR surface impoundments and landfills that closed prior to the effective date of the 2015 CCR rule, inactive CCR landfills, and other areas where CCR is managed directly on the land. In this action, the EPA refers to these as CCR management units, or CCRMU. This rule will apply to all existing CCR facilities and all inactive facilities with legacy CCR surface impoundments subject to this final rule.

Finally, the EPA is making a number of technical corrections to the existing regulations, such as correcting certain citations and harmonizing definitions. For further information on the CCR regulations, including information about the CCR Part A and Part B rules' ongoing implementation, visit *www.epa.gov/coalash/coal-ash-rule*.

- Air Pollution Rules and Implementation. The EPA is taking several actions to regulate a variety of conventional, hazardous, and greenhouse gas (GHG) air pollutants, including actions to regulate the same steam electric power plants subject to part 423. In light of these ongoing actions, the EPA has worked to consider appropriate flexibilities in this ELG rule to provide certainty to the regulated community while ensuring the statutory objectives of each program are achieved. Furthermore, to the extent that these actions have been published before this rule's signature and are already impacting steam electric power plant operations, the EPA has accounted for these changed operations in its Integrated Planning Model (IPM) modeling discussed in the preamble Section VIII.
- The Revised Cross State Air Pollution Rule Update and the Good Neighbor Plan for the 2015 Ozone National Ambient Air Quality Standards. On June 5, 2023, the EPA promulgated its final Good Neighbor Plan, which secures significant reductions in ozone-forming emissions of nitrogen oxides (NO_X) from power plants and industrial facilities. 88 FR 36654. The Good Neighbor Plan ensures that 23 states meet the Clean Air Act's (CAA's) "Good Neighbor" requirements by reducing pollution that significantly contributes to problems attaining and maintaining EPA's health-based air quality standard for ground-level ozone (or "smog"), known as the 2015 Ozone National Ambient Air Quality Standards (NAAQS), in downwind states. Further information on this action is available on the EPA's website.[1]

  As of September 21, 2023, the Good Neighbor Plan's "Group 3" ozone-season NO_X control program for power plants is being implemented in: Illinois, Indiana, Maryland, Michigan, New Jersey, New York, Ohio, Pennsylvania, Virginia, and Wisconsin. Pursuant to court orders staying the Agency's State Implementation Plan disapproval action in the following states, the EPA is not currently implementing the Good Neighbor Plan "Group 3" ozone-season NO_X control program for power plants in: Alabama, Arkansas, Kentucky, Louisiana, Minnesota, Mississippi, Missouri, Nevada, Oklahoma, Texas, Utah, and West Virginia.[2]

  On January 16, 2024, the EPA signed a proposal to partially approve and partially disapprove State Implementation Plan submittals addressing interstate transport for the 2015 ozone NAAQS from Arizona, Iowa, Kansas, New Mexico, and Tennessee and proposed to include these states in the Good Neighbor Plan beginning in 2025.

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[1] *See https://www.epa.gov/csapr/good-neighbor-plan-2015-ozone-naaqs*.

[2] Further information on EPA's response to the stay orders can be found online at: *https://www.epa.gov/Cross-State-Air-Pollution/epa-response-judicial-stay-orders.*

On April 30, 2021, the EPA published the final Revised Cross-State Air Pollution Rule (CSAPR) Update, 86 FR 23054, which resolved 21 states' good neighbor obligations for the 2008 ozone NAAQS, following the remand of the 2016 CSAPR Update (81 FR 74504) in *Wisconsin v. EPA*, 938 F.3d 308 (D.C. Cir. 2019). Together, these two rules establish the Group 2 and Group 3 market-based emissions trading programs for 22 states in the eastern United States for emissions of NO_X from fossil fuel-fired EGUs during the summer ozone season.

- Clean Air Act Section 111 Rule. Concurrently with the final ELG, the EPA is finalizing the repeal of the Affordable Clean Energy Rule, establishing Best System of Emissions Reduction (BSER) determinations and emission guidelines for existing fossil fuel-fired EGUs, and establishing BSER determinations and accompanying standards of performance for GHG emissions from new and reconstructed fossil fuel-fired stationary combustion turbines and modified fossil fuel-fired EGUs. Specifically, for coal-fired EGUs, the EPA is establishing final standards based on carbon capture and storage/sequestration with 90 percent capture with a compliance date of January 1, 2032. For coal-fired EGUs retiring by January 1, 2039, the EPA is establishing final standards based on 40 percent natural gas co-firing with a compliance date of January 1, 2030.

  While four subcategories for coal-fired EGUs were proposed, the EPA is finalizing just the two subcategories for coal-fired EGUs as described in the preceding paragraph. Consistent with 40 CFR 60.24a(e) and the Agency's explanation in the proposal, states have the ability to consider, *inter alia*, a particular source's remaining useful life when applying a standard of performance to that source.[3]

  In addition, the EPA is creating an option for states to provide for a compliance date extension for existing sources of up to one year under certain circumstances for sources that are installing control technologies to comply with their standards of performance. States may also provide, by inclusion in their state plans, a reliability assurance mechanism of up to one year that under limited circumstances would allow existing EGUs that had planned to cease operating by a certain date to temporarily remain available to support reliability. Any extensions exceeding 1-year must be addressed through a state plan revision. Further information about the CAA section 111 rule is available online at *https://www.epa.gov/stationary-sources-air-pollution/greenhouse-gas-standards-and-guidelines-fossil-fuel-fired-power*.

- Mercury and Air Toxics Standards Rule. On March 6, 2023, the EPA published a final rule which reaffirmed that it remains appropriate and necessary to regulate hazardous air pollutants (HAP), including mercury, from power plants after considering cost. This action revoked a 2020 finding that it was not appropriate and necessary to regulate coal- and oil-fired power plants under CAA section 112, which covers toxic air pollutants. The EPA reviewed the 2020 finding and considered updated information on both the public health burden associated with HAP emissions from coal- and oil-fired power plants, as well as the costs associated with reducing those emissions under the Mercury and Air Toxics Standards (MATS). After weighing the public risks these emissions pose to all Americans (and particularly exposed and sensitive populations) against the costs of reducing this harmful pollution, the EPA concluded that it remains appropriate and necessary to regulate these emissions. This action ensures that coal- and oil-fired power plants continue to control emissions of hazardous air pollution and that the Agency properly interprets the CAA to protect the public from hazardous air emissions.

  Concurrently with the final ELG, the EPA is finalizing an update to the National Emission Standards for Hazardous Air Pollutants for Coal- and Oil-Fired Electric Utility Steam Generating Units (EGUs), commonly known as the Mercury and Air Toxics Standards (MATS) for power plants, to reflect recent developments in control technologies and the performance of these plants. This final rule includes an important set of improvements and updates to MATS and also fulfills the EPA's responsibility under the Clean Air Act to periodically re-evaluate its standards in light of advancements in pollution control technologies to determine whether revisions are necessary. The improvements consist of:

[3] See 88 FR 33383 (invoking RULOF based on a particular coal-fired EGU's remaining useful life "is not prohibited under these emission guidelines").

  - Further limiting the emission of non-mercury HAP metals from existing coal-fired power plants by significantly reducing the emission standard for filterable particulate matter (fPM), which is designed to control non-mercury HAP metals. The EPA is finalizing a two-thirds reduction in the fPM standard;[4]
  - Tightening the emission limit for mercury for existing lignite-fired power plants by 70 percent;[5]
  - Strengthening emissions monitoring and compliance by requiring coal-and oil-fired EGUs to comply with the fPM standard using PM continuous emission monitoring systems (CEMS);[6]
  - Revising the startup requirements in MATS to assure better emissions performance during startup.
  - Additional information on the final MATS is available on the EPA's website.[7]
- National Ambient Air Quality Standards Rules for Particulate Matter. On February 7, 2024, the EPA Administrator signed a final rule strengthening the National Ambient Air Quality Standards for Particulate Matter (PM NAAQS) to protect millions of Americans from harmful and costly health impacts, such as heart attacks and premature death. Particle or soot pollution is one of the most dangerous forms of air pollution, and an extensive body of science links it to a range of serious and in some cases deadly illnesses. The EPA set the level of the primary (health-based) annual particulate matter ($PM_{2.5}$) standard at 9.0 micrograms per cubic meter to provide increased public health protection, consistent with the available health science. The EPA did not change the current primary and secondary (welfare-based) 24-hour $PM_{2.5}$ standards, the secondary annual $PM_{2.5}$ standard, and the primary and secondary PM10 standards. The EPA also revised the Air Quality Index to improve public communications about the risks from $PM_{2.5}$ exposures and made changes to the monitoring network to enhance protection of air quality in communities overburdened by air pollution. More information about this action is available on the EPA's website.[8]

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[4] Also, the EPA is finalizing the removal of the low-emitting EGU provisions for fPM and non-mercury HAP metals.

[5] This level aligns with the mercury standard that other coal-fired power plants have been achieving under the current MATS.

[6] PM CEMS provide regulators, the public, and facility owners or operators with cost-effective, accurate, and continuous emission measurements. This real-time, quality-assured feedback can lead to improved control device and power plant operation, which will reduce air pollutant emissions and exposure for local communities.

[7] *See https://www.epa.gov/stationary-sources-air-pollution/mercury-and-air-toxics-standards.*

[8] *See https://www.epa.gov/pm-pollution/national-ambient-air-quality-standards-naaqs-pm*.

2. Data Collection Activities

The U.S. Environmental Protection Agency (EPA) collected and evaluated information from various sources while developing the 2015 and 2020 rules, as described in Section 3 of the 2015 rule Technical Development Document (2015 TDD) and Section 2 of the 2020 rule Supplemental Technical Development Document (2020 Supplemental TDD), respectively. The EPA collected additional supplemental data for the 2024 final rule to update the industry profile; identify the steam electric power plants affected by the rule; reevaluate industry subcategorization; update plant-specific operations and wastewater characteristics; determine the technology options; and estimate the compliance costs, pollutant loadings and removals, and non-water quality environmental impacts of the technology options. This section briefly summarizes past data collection activities for the 2015 and 2020 rules (Section 2.1) and describes new data collection activities for flue gas desulfurization (FGD) wastewater, bottom ash (BA) transport water, legacy wastewater, and combustion residual leachate (CRL) for the 2024 final rule (Sections 2.2 through 2.4).

2.1 Summary of Data Collection for the 2015 and 2020 Rulemakings

For the 2015 and 2020 rules, the EPA collected and obtained information on the steam electric power generating industry from multiple sources including a detailed study of the industry, an information collection request (ICR), site visits, field sampling, Clean Water Act (CWA) section 308 industry requests, and voluntary requests as detailed below.

- *Detailed study.* The EPA studied the steam electric power generating industry between 2005 and 2009. Data collection included multiple site visits and six wastewater sampling episodes at steam electric power plants, a screener questionnaire sent to nine companies (operating 30 steam electric power plants), publicly available data sources, and outreach with EPA program offices, other governmental groups and industry stakeholders. The detailed study focused on wastewater from coal ash handling operations and from FGD air pollution control systems.
- *2009 Steam Electric Survey.* The EPA administered a survey to approximately 700 steam electric power plants to collect technical information related to wastewater generation and treatment, as well as economic information such as costs of wastewater treatment technologies and financial characteristics of potentially affected companies. The Agency used the responses to evaluate pollution control options for revising the effluent limitations guidelines and standards (ELGs) for the steam electric category, in addition to costs, loadings, and other rulemaking analyses.
- *Site visits.* The EPA conducted 73 site visits at steam electric power plants in 18 states between December 2006 and November 2014 to gather information about each plant's operation, pollution prevention and wastewater treatment options, and whether the plant was appropriate to include in the field sampling program. After promulgating the 2015 rule, between October and December 2017, the EPA conducted another seven site visits to steam electric power plants in five states to update information on methods for managing FGD wastewater and BA transport water. The EPA used data from site visits to update industry profile data; learn more about pollution control and wastewater treatment options evaluated as part of the rulemakings; and inform costs, loadings, and other rulemaking analyses.
- *Field sampling program.* For the 2015 rule, the EPA conducted 4-day sampling episodes at seven U.S. plants to obtain wastewater characterization data and wastewater treatment technology performance data. The EPA used these data in combination with other industry-supplied data to evaluate wastewater discharges from steam electric power plants and to evaluate technology options for managing these wastewaters. The sampling program primarily focused on wastewaters from wet FGD systems. The EPA also conducted a 3-day sampling episode at Enel's Federico II Power Plant (Brindisi), located in Brindisi, Italy, to characterize an FGD wastewater treatment system consisting of chemical precipitation followed by evaporation.

- *CWA 308 monitoring program.* For the 2015 rule, the EPA required four plants to collect four consecutive days of samples at two to four sampling locations chosen to characterize coal-gasification wastewaters, carbon capture wastewaters, and the treatment of FGD wastewater and coal-gasification wastewater by vapor-compression evaporation. These data were used to supplement the sampling data collected during the field sampling program.
- *Voluntary requests.* Following the 2015 rule, the EPA invited seven steam electric power plants to participate in a voluntary BA transport water sampling program. The EPA requested information from steam electric power plants operating surface impoundments that predominantly contain BA transport water. Plants were asked to provide sampling data for ash surface impoundment effluent and untreated BA transport water (*i.e.,* ash surface impoundment influent). Two plants chose to participate in the voluntary BA sampling program.
- *Other data sources.* The EPA used Electric Power Research Institute (EPRI) reports, data from the U.S. Department of Energy's (DOE's) Energy Information Administration (EIA), information from literature and internet searches, and information from environmental groups to supplement the industry profile; learn more about pollution control and wastewater treatment options evaluated as part of the rulemakings; and inform costs, loadings, and other rulemaking analyses.

2.2 Site Visits and Industry-Submitted Data

In support of the 2024 final rule, the EPA participated in a virtual site visit with representatives from Duke Energy in 2021. The visit focused on Duke Energy's coal-fired generating units and the treatment and management of BA transport water, FGD wastewater, legacy wastewater, and CRL since the 2020 rule. The EPA also gathered information on steam electric power generating processes, wastewater treatment technologies, and wastewater characteristics directly from the industry through a CWA 308 request, two voluntary requests, and other industry data provided during the 2023 proposed rule. The EPA used this information to learn more about the performance of FGD, CRL, and legacy wastewater treatment systems and obtain information useful for estimating the cost of installing candidate treatment technologies. The EPA also used this information to learn more about BA system performance, characterization and quantification of the overflow and purge from remote mechanical drag system (MDS) installations, and treatment technologies and pilot testing associated with CRL and legacy wastewater. The EPA used this information to supplement the data collected in support of the 2015 and 2020 rules.

2.2.1 CWA 308 Request

In January 2022, the EPA requested the following information for coal-fired power plants from three steam electric power companies:

- FGD wastewater pilot testing and installation data, including configuration, pretreatment and post-treatment, byproduct handling, and sampling data for thermal technology, membrane filtration technology, paste, solidification, or encapsulation of FGD wastewater brine; electrodialysis, and electrocoagulation.
- Overflow from an MDS, compact submerged conveyor (CSC), or remote MDS installation including purge rate and management from remote MDS, as well as any pollutant concentration data to characterize the overflow or purge.
- CRL treatment from on-site or off-site testing (full-, pilot-, or laboratory-scale).
- On-site or off-site testing (full-, pilot-, or laboratory-scale) and/or implementation of treatment technologies associated with surface impoundment dewatering treatment.
- Costs associated with these technologies.

After meeting with these three companies, the EPA sent four other power companies a request inviting them to provide the same data described above.

In July 2023, the EPA requested full-, pilot-, or laboratory-scale data associated with on-site or off-site testing or implementation of a recently commissioned spray dryer evaporator for FGD wastewater and legacy wastewater at a coal-fired power plant from one steam electric power company. The EPA also requested information on pretreatment or disposal systems necessary for spray dryer evaporator operations and any corresponding documentation (*e.g.,* wastestreams, process flow diagram).

2.2.2 Voluntary Industry Sampling Requests

In December 2021, the EPA invited eight steam electric power companies to participate in a voluntary request program. The specific voluntary requests are outlined below.

- Existing CRL data consistent with the EPA's request.
- Untreated and treated samples of CRL on the sampling schedule laid out in the EPA's request.
- Grab samples of landfill solids and leachate samples analyzed using EPA Methods 1313 and 1316 (leaching evaluations).

2.3 Technology Vendor Data

The EPA gathered data from technology vendors through presentations, conferences, site visits, meetings, and email and phone contacts regarding the FGD wastewater, BA handling, CRL, and legacy wastewater technologies used in the industry. The EPA used the data to inform the development of the technology costs and pollutant removal estimates for FGD wastewater, BA transport water, CRL, and legacy wastewater. During the development of the 2015 and 2020 rules, the EPA participated in multiple technical conferences and reviewed the papers presented for information relevant to the steam electric rulemakings. The EPA referenced this information to inform the 2024 final rule.

2.3.1 FGD Wastewater, CRL, and Legacy Wastewater Treatment

The EPA contacted companies that manufacture, distribute, or install various components of biological wastewater treatment, membrane filtration, or thermal evaporation treatment systems for FGD wastewater, CRL, and legacy wastewater treatment. The EPA also contacted consulting firms that design and implement treatment technologies associated with these wastestreams. The vendors and consulting firms provided the following types of information for the EPA's analyses:

- Operating details.
- Performance data where available.
- Equipment used in the system.
- Estimated capital and operation and maintenance (O&M) costs.
- System energy requirements.
- Timeline to bid, procure, and install.
- Changes in the industry since 2020 including retirements or fuel conversions, new FGD installations, and planned future installations.

2.3.2 BA Handling

The EPA contacted vendors as well as consulting firms that design and implement BA handling systems. The vendors and consulting firms provided the following types of information for the EPA's analyses:

- Systems available for reducing or eliminating ash transport water.
- Equipment, modifications, and demolition required to convert wet-sluicing systems to dry ash handling or high recycle rate (HRR) systems.
- Equipment that can be reused as part of the conversion from wet to dry handling or in a HRR system.

- Outage time estimated for installing the different types of ash handling systems.
- Maintenance estimated for each type of system.
- Estimated capital and O&M costs.
- Changes in the industry since 2020 including retirements or fuel conversions, new BA installations, and planned future installations.
- Purge from complete recycle systems, purge from under-boiler mechanical drag systems, and purge wastewater characteristics.

2.4 Public Comments and Public Hearing

During the 60-day public comment period for the 2023 proposed rule (March 29 to May 30, 2023), the EPA received more than 22,000 public comment submissions from private citizens, industry members, technology vendors, environmental groups, and trade associations. The EPA also hosted two online public hearings on April 20 and 25, 2023, where the public could voice comments on the proposed rule. The online hearings had 196 registered attendees, and 46 elected to provide comment. Available documents from the public hearing include the presentation given by the EPA and a transcript of the webinar (U.S. EPA, 2023 and 2023a).

2.5 Other Data Sources

The EPA gathered information on steam electric power generating processes, wastewater treatment, wastewater characteristics, and regulations from sources including EPRI, DOE, literature and internet searches, notices of planned participation (NOPPs), environmental groups, residents of affected communities, state and local governments, Tribes, and reporting by utilities via the "CCR Compliance Data and Information" websites required by the Coal Combustion Residuals (CCR) rule. Sections 2.5.1 through 2.5.6 summarize the data collected from these additional sources.

2.5.1 EPRI

EPRI conducts studies funded by the steam electric power generating industry to evaluate and demonstrate technologies that can potentially remove pollutants of concern from wastestreams or eliminate wastestreams using zero-discharge technologies. The EPA reviewed reports—listed in Table 1—that EPRI voluntarily provided, or that were provided in CWA 308 responses. These reports contained information relevant to characteristics of FGD wastewater, CRL and legacy treatment pilot studies, BA transport water characterization and BA handling practices.

Table 1. EPRI Reports and Studies Reviewed by the EPA for the 2024 Rule

Title of Report/Study	Date Published	Document Control Number
Effects of Alkaline Sorbents and Mercury Controls on Fly Ash and FGD Gypsum Characteristics and Implications for Disposal and Use	2014	SE10395
Review of Solidification/Stabilization Additives for Coal Combustion Fly Ash	2014	SE11719
Coal Combustion Residuals Leachate Management: Characterization of Leachate Quantity and Evolution of Leachate Minimization and Management Methods	2015	SE10386
Coal Combustion Residuals Leachate Management: Characterization of Leachate Quality	2016	SE10387
Evaporation Treatment of Flue Gas Desulfurization Wastewater	2017	SE06970
Landfill Leachate Characterization, Management and Treatment Options	2017	SE06959
Brine Encapsulation Laboratory Study	2018	SE10296

Table 1. EPRI Reports and Studies Reviewed by the EPA for the 2024 Rule

Title of Report/Study	Date Published	Document Control Number
Wastewater Encapsulation Testing References: Encapsulating Co-Management of Liquid Waste with Combustion Byproducts at Bench and Field Scale	2018	SE10295
Mercury, Methylmercury, and Selenium Interactions in Freshwater Fish	2018	SE10388
Performance Evaluation of the Vacom Thermal Vapor Recompression Technology for FGD Wastewater Treatment	2019	SE10389
Membrane Treatment Guidelines	2019	SE10297
Considerations for Treating Flue Gas Desulfurization Wastewater Using Membrane and Paste Encapsulation Technologies	2019	SE10396
Studies on the Encapsulation of Brine Generated from a Process Using Selective Electrodialysis Reversal	2020	SE10397
Landfill Leachate Treatment Study: Evaluations of Membrane, Evaporation, and Encapsulation Technologies	2020	SE10385
The Impacts of High Salinity Wastewater Chemistry and Fly Ash Reactivity on Encapsulation	2020	SE10298
Thermal Water/Wastewater Treatment System Chemistry Guidelines	2020	SE10390
Real-Time Online Membrane Monitor Demonstration	2020	SE10300
Understanding Chemical Reactions and Mineral Additives for Wastewater Encapsulation	2020	SE10299
Conference Proceedings of the 2020 Virtual Selenium Summit	2020	SE10391
FGD Wastewater Treatment Testing Using a Saltworks Flex EDR Selective Electrodialysis Reversal System Technology	2020	SE10398
Quantifying Leachate Volumes at Four Coal Combustion Product Landfills in the Southeastern United States	2021	SE10392
Review of Coal Combustion Product Leaching	2021	SE10393
Review of Established and Emerging Boron Treatment Technologies for Water at Coal Combustion Product Sites	2021	SE10399
Water Flow in Coal Combustion Products and Drainage of Free Water	2021	SE10394
Coal Combustion Product Landfill Terminology and Water Management Fundamentals	2021	SE10400
Leaching, Geotechnical, and Hydrologic Characterization of Coal Combustion Products from an Active Coal Ash Management Unit	2021	SE11718

2.5.2 Department of Energy

The EPA compiled information on steam electric power plants from EIA's Form EIA-860, *Annual Electric Generator Report,* and Form EIA-923, *Power Plant Operations Report.* The data collected in Form EIA-860 concern the design and operation of generators at plants, while data collected in Form EIA-923 concern the design and operation of the entire plant. The EPA used relevant data from EIA-923 and EIA-860 from 2009 to 2022 (U.S. DOE, 2021, 2021a). The EPA used these data to update the industry profile from the 2020 rule, including commissioning dates, energy sources, capacity, net generation, operating statuses, planned retirement dates, ownership, and pollution controls of the generating units. Consistent with the 2020 rule analyses, the EPA also used data reported to DOE to estimate bromide loadings from FGD discharges, including fuel consumption by coal type and coal purchases by county and coal type.

2.5.3 Office of Land and Emergency Management

The 2015 CCR rule established requirements for the safe disposal of CCRs from coal-fired steam electric power plants. The CCR regulations require owners or operators of CCR surface impoundments and landfills to record compliance with the rule's requirements and maintain a publicly available website of compliance information.

The EPA used plant-specific information on CCR landfills and surface impoundments from the EPA's Office of Land and Emergency Management (OLEM) as part of its CRL and legacy analyses. In September 2023, the EPA's OLEM provided the Office of Water with publicly available CCR compliance information for 779 CCR waste management units, corresponding to 302 facilities, subject to the CCR Part A rule requirements (U.S. EPA, 2023b).

2.5.4 Power Company CCR Websites

As described in Section 2.5.3, the 2015 CCR rule established requirements for the safe disposal of CCRs from coal-fired steam electric power plants and requires owners or operators of CCR surface impoundments and landfills to record compliance with the rule's requirements and maintain a publicly available website of compliance information. The EPA searched these websites for CCR unit-specific documents including:

- Closure plans/reports
- Liner certifications
- Run-on/run-off control plans
- Annual inspection reports
- Annual groundwater monitoring plans and corrective action reports
- Groundwater monitoring system design reports

See the EPA's memoranda *Evaluation of Unmanaged CRL* and *Legacy Wastewater at CCR Surface Impoundments* for more details on how this information was used as part of the EPA's unmanaged CRL and legacy analyses (U.S. EPA, 2024, 2024a).

2.5.5 Literature and Internet Searches

The EPA conducted literature and internet searches to gather information on FGD wastewater, CRL, and legacy wastewater treatment technologies, including information on pilot studies, applications in the steam electric power generating industry, and implementation costs and timeline. The EPA also used Internet searches to identify or confirm reports of planned plant/unit retirements or reports of planned unit conversions to dry or HRR ash handling systems. The EPA used industry journals and company press releases obtained from Internet searches to inform the industry profile and process modifications occurring in the industry.

2.5.6 Intergovernmental and Tribal Listening Sessions

As part of the 2024 supplemental rulemaking process, the EPA held consultation and coordination proceedings with intergovernmental agencies and Tribal governments, refer to *Summary of Input from State, Local Government, and Tribal Consultations* memorandum for additional information (U.S. EPA, 2023c). Consultations pursuant to Executive Order 13132, entitled "Federalism," and the Unfunded Mandates Reform Act (UMRA) were held January 27, 2022. The EPA received five sets of unique written comments after the meeting, including two comments from trade associations representing public water systems. These comments generally recommended more advanced treatment to reduce the pollutants making their way downstream to intakes for government-owned public water systems or, alternatively, to empower states to more effectively address these discharges. The remaining three comments came from the American Public Power Association and two of its member utilities. These comments recommended the retention of existing limitations and subcategories, a careful consideration of the CRL definition and BAT, and a compliance pathway for utilities that installed or are in the process of installing technologies to comply with the 2015 and 2020 rules compliant technologies. The EPA also held listening sessions via webinars with Tribal representatives on February 1 and 9, 2022. Following these consultations, the EPA received written comments from three Tribes: the Sault Ste. Marie Tribe of Chippewa Indians, the Mille Lacs Band of Ojibwe, and the Little Traverse Bay Bands of Odawa Indians. These comments conveyed the importance of historical Tribal waters and rights (*e.g.,* fishing, trapping) and recommended more stringent technological controls or encouraged retirement or fuel conversion of old coal-fired units to protect those rights.

2.5.7 Communities

In support of its environmental justice analysis, the EPA conducted a screening-level analysis of pollution exposures to potentially affected communities and identified nine communities with EJ concerns. The EPA planned outreach to community members to discuss ideas and strategies for limiting pollution from steam electric power plants, concerns related to these plants or other sources of pollution including impacts to nearby rivers, lakes, and streams or drinking water; and community health, social, and economic concerns. The EPA conducted initial outreach to local environmental and community development organizations, local government agencies, and individual community members. Between May and September 2022, the EPA held listening sessions with community members in five of the identified communities. Each meeting began with a presentation providing background information about the 2023 proposed supplemental rulemaking before opening the meeting for questions and comments from community members.

- The EPA received a broad range of input from individuals in these communities on regulatory preferences, environmental concerns, human health and safety concerns, economic impacts, cultural/spiritual impacts, ongoing communication/public outreach, and interest in other EPA actions. Three broad themes conveyed consistently across communities included:
- Community members perceive harmful impacts from steam electric power plants and desire more stringent regulations to reduce these harmful impacts.
- Community members desire more transparency to overcome their decreasing trust in the regulated plants and state regulatory agencies.
- Community members would prefer increased communication to understand the compliance of steam electric power plants.

Commenters also raised concerns unique to each community. For example, members of the Navajo Nation discussed with the EPA the spiritual and cultural impacts to the community from pollution related to steam electric power plants. In Jacksonville, Florida, community members raised concerns regarding tidal flows of pollution upstream and storm surges during extreme weather events that cause additional challenges in their community. See the *Environmental Justice Analysis for Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* for more details on these meetings (U.S. EPA, 2024b).

2.5.8 Notices of Planned Participation (NOPPs)

The 2020 rule required facilities to file a NOPP with their permitting authority no later than October 13, 2021, where the facility wished to participate in the low utilization electric generating unit (LUEGU) subcategory, the permanent cessation of coal combustion subcategory, or in the VIP. The direct final rule promulgated in March 2023 extended this NOPP date to June 27, 2023. While the EPA did not require that NOPPs be submitted to the Agency, the EPA obtained a number of these filings through various means including its standard permit review process, a plant providing the EPA a courtesy copy, the EPA states for their NOPPs, and environmental groups tracking NOPPs and sharing the information they had collected with the EPA. The EPA is currently aware of NOPPs covering 90 EGUs at 38 plants. At the time of the 2023 proposed rule, four EGUs (at two plants) requested participation in the LUEGU subcategory, an additional 12 EGUs (at four plants) requested participation in the 2020 rule VIP, and the remaining 74 EGUs (at 33 plants) requested participation in the permanent cessation of coal combustion subcategory (U.S. EPA, 2024c). Note that at least one plant (Plant Scherer) filed a permanent cessation of coal combustion NOPP for two EGUs and a 2020 rule VIP NOPP for the remaining two EGUs; thus, these groups are not additive. Following the 2023 direct final rule, the EPA obtained one additional NOPP stating that two EGUs (at one plant) requested participation in the permanent cessation of coal combustion subcategory instead of the 2020 rule VIP. The EPA notes that these counts are not a comprehensive picture of plants' plans for two reasons. First, the EPA was unable to obtain information for all plants and states; second, plants retain flexibility to transfer between subcategories through 40 CFR 423.13(o)(1)(ii). See Preamble Section VI.B for more information about NOPPs.

2.6 Protection of Confidential Business Information

Certain data in the rulemaking record have been claimed as confidential business information (CBI). As required by federal regulations at 40 CFR 2, the EPA took precautions to prevent the inadvertent disclosure of this CBI. The Agency withheld CBI from the public docket in the Federal Docket Management System. In addition, the EPA found it necessary to withhold from disclosure some data not directly claimed as CBI because the release of these data could indirectly reveal CBI. Where necessary, the EPA aggregated certain data in the public docket, masked plant identities, or used other strategies to prevent the disclosure of CBI. The Agency's approach to protecting CBI ensures that the data in the public docket explain the basis for the rule and provide the opportunity for public comment without compromising data confidentiality.

3. Current State of the Steam Electric Power Generating Industry

For the 2015 rule, the U.S. Environmental Protection Agency (EPA) generated a comprehensive industry profile using 2009 Department of Energy (DOE) Energy Information Administration (EIA) data, data from the EPA's 2009 *Questionnaire for the Steam Electric Power Generating Effluent Guidelines* (Steam Electric Survey), and U.S. Census Bureau data from 2007. See Section 4 of the 2015 rule's Technical Development Document (TDD). For the 2020 rule, the EPA updated the industry profile to account for current plant operations and plans for future modifications. See Section 3 of the 2020 Supplemental TDD.

For the 2024 final rule, the EPA updated the industry profile, evaluated changes in wastewater management practices, and assessed how other regulations have affected steam electric power plants since the 2020 rule analyses. This section describes the current state of the steam electric power generating industry as it relates to the technical aspects of the 2024 final rule, including the following:

- Changes in the steam electric power plant population (Section 3.1).
- Current information on evaluated wastestreams (Section 0).
- Other regulations affecting the steam electric power generating industry (Section 3.3).

3.1 Changes in the Steam Electric Power Generating Industry Since the 2020 Rule

The steam electric power generating industry is dynamic; the Agency recognizes that industry demographics and plant operations have changed since the 2020 rule analyses were completed.[9] Therefore, the EPA collected information on current plant operations and plans for future modifications to augment industry profile data collected for the 2015 and 2020 rules. This section discusses changes in the number and operating status of coal-fired electric generating units (EGUs) and updates to wet flue gas desulfurization (FGD) systems, FGD wastewater treatment, bottom ash (BA) handling systems, coal combustion residual (CCR) landfills and surface impoundments, and legacy wastewater.

The EPA gathered information from public sources, including company announcements and EIA data, to account for the following types of operation changes that have occurred or been announced since the 2020 rule analyses:

- Commissioning of new coal-fired EGUs.
- Retirement of coal-fired EGUs.[10]
- Fuel conversions of coal-fired EGUs from coal to another fuel source, such as natural gas or hydrogen fuel cells.
- Installation of wet FGD systems.
- Installation of, or conversion to, zero-discharge FGD wastewater treatment systems.

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[9] The EPA's 2020 rule analyses accounted for all industry profile changes announced and verified as of February 2020 that are in effect until 2028.

[10] For the purposes of this analysis, the EPA accounted for EGUs that will be indefinitely removed from service (*i.e.,* idled or mothballed) as retirements. See the preamble for discussion of the EPA's evaluation of coal-fired EGUs nearing end of life.

- Installation of, or conversion to, zero-discharge BA handling systems, such as dry BA handling and closed-loop recycle wet BA systems.[11]
- Addition of CCR landfills.
- Addition of CCR surface impoundments.

The EPA identified 235 coal-fired EGUs at 125 plants from the 2020 rule profile with at least one significant change in operation taking place by December 31, 2028 (the date on which the 2020 rule's subcategory for EGUs permanently ceasing coal combustion by December 31, 2028 is based). Table 2 presents the count of steam EGUs and plants, broken out by type of operation change for the 2024 rule.

Table 2. Industry Profile Updates Incorporated Since the 2020 Rule by Type of Change in Operation

Change in Operation	Count	
	EGUs	Plants
Commissioning of a new coal-fired EGU	0	0
Retirement of coal-fired EGU [a]	187	104
Fuel conversion to non-coal fuel type [b]	43	24
Installation of wet FGD system	1	1
Installation of zero-discharge FGD wastewater treatment system	5	2
Addition of CCR landfill	NA	39
Addition of CCR surface impoundment	NA	6

a—The EPA estimates an additional 52 coal-fired EGUs at 25 plants will retire between January 1, 2029, and December 31, 2034, and an additional 20 coal-fired EGUs at 13 plants will retire after January 1, 2035.

b—The EPA estimates an additional six coal-fired EGUs at four plants will convert to a non-coal fuel type between January 1, 2029 and December 31, 2034, and an additional 41 coal-fired EGUs at 18 plants will convert to a non-coal fuel type after January 1, 2035.

Figure 1 illustrates the change in the number of operating coal-fired EGUs and plants for the Steam Electric Survey, 2015 rule, 2020 rule, and 2024 rule. The population of coal-fired EGUs and plants decreased to 277 EGUs at 148 plants for the 2024 final rule, 35 percent fewer EGUs than the 2020 rule population.

Section 5 and Section 6 describe how the EPA accounted for the changes in operation identified in Table 2 in estimating compliance costs, pollutant loadings, and pollutant removals for the 2024 rule. More information on the specific coal-fired EGUs and plants identified as implementing each type of operation change is discussed in the memorandum titled *Changes to the Industry Profile for Coal-Fired Electric Generating Units for the 2024 Final Steam Electric ELGs* (U.S. EPA, 2024c).

[11] For this discussion, dry BA handling systems include all systems that do not generate BA transport water.

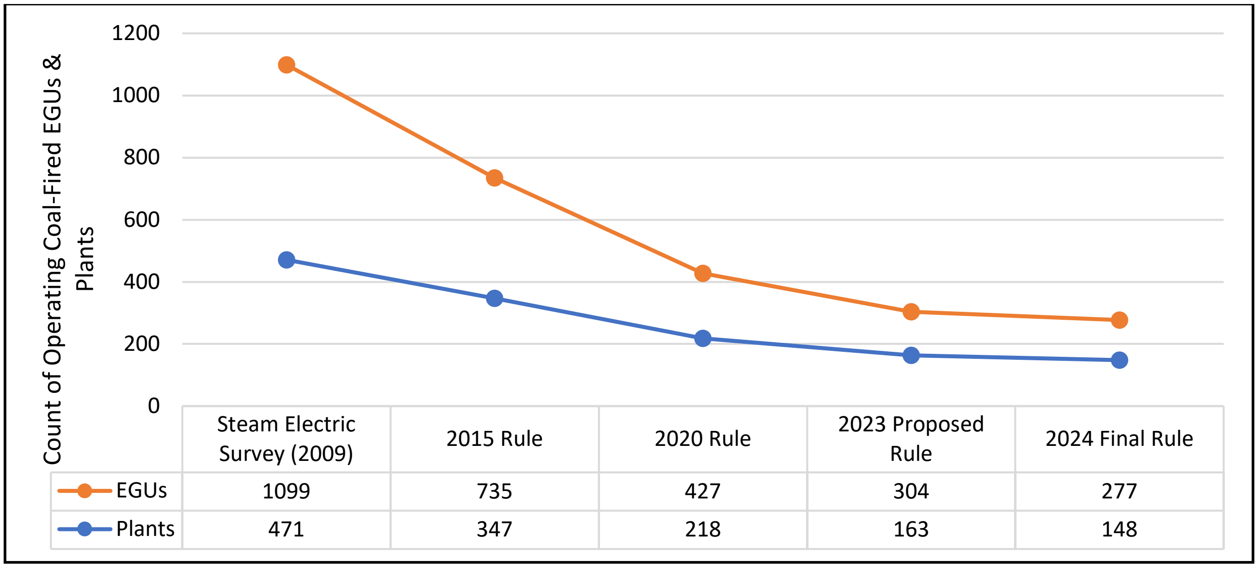

Figure 1. Change in Population of Coal-Fired EGUs and Plants[12]

3.2 Current Information on Evaluated Wastestreams

This section summarizes current information on the generation and discharge of FGD wastewater, BA transport water, CRL, and legacy wastewater that the EPA collected for the 2024 final rule.

3.2.1 FGD Wastewater

As discussed in Section 3, the EPA updated the industry profile to reflect coal-fired EGUs that will retire, convert fuels, or upgrade FGD wastewater treatment prior to December 31, 2028. Of the 277 coal-fired EGUs at 148 steam electric power plants in the updated profile, 127 EGUs at 57 plants are serviced by a wet FGD system. The EPA estimates EGUs with wet FGD systems have a total generating capacity of 77,854 megawatts (MW), representing approximately 63 percent of the industry's total coal-fired capacity.

Figure 2 shows the locations of plants operating wet FGD systems servicing at least one coal-fired EGU. In addition to wet FGD scrubbers, the EPA estimates that there are 38 plants operating dry FGD scrubbers servicing at least one coal-fired EGU in the industry. Although dry FGD scrubbers use water in their operation, the water in most systems evaporates, and they generally do not discharge wastewater. The EPA did not evaluate the wastewater generated from these dry FGD systems as part of the 2024 rule, and they are not subject to the FGD wastewater requirements in the ELGs.

[12] The 2015 rule analyses accounted for profile changes expected to occur before December 31, 2023 (the latest date that power plants were expected to comply with the established BAT effluent limitations), whereas the 2020 rule and the 2024 rule account for changes expected to occur before December 31, 2028.

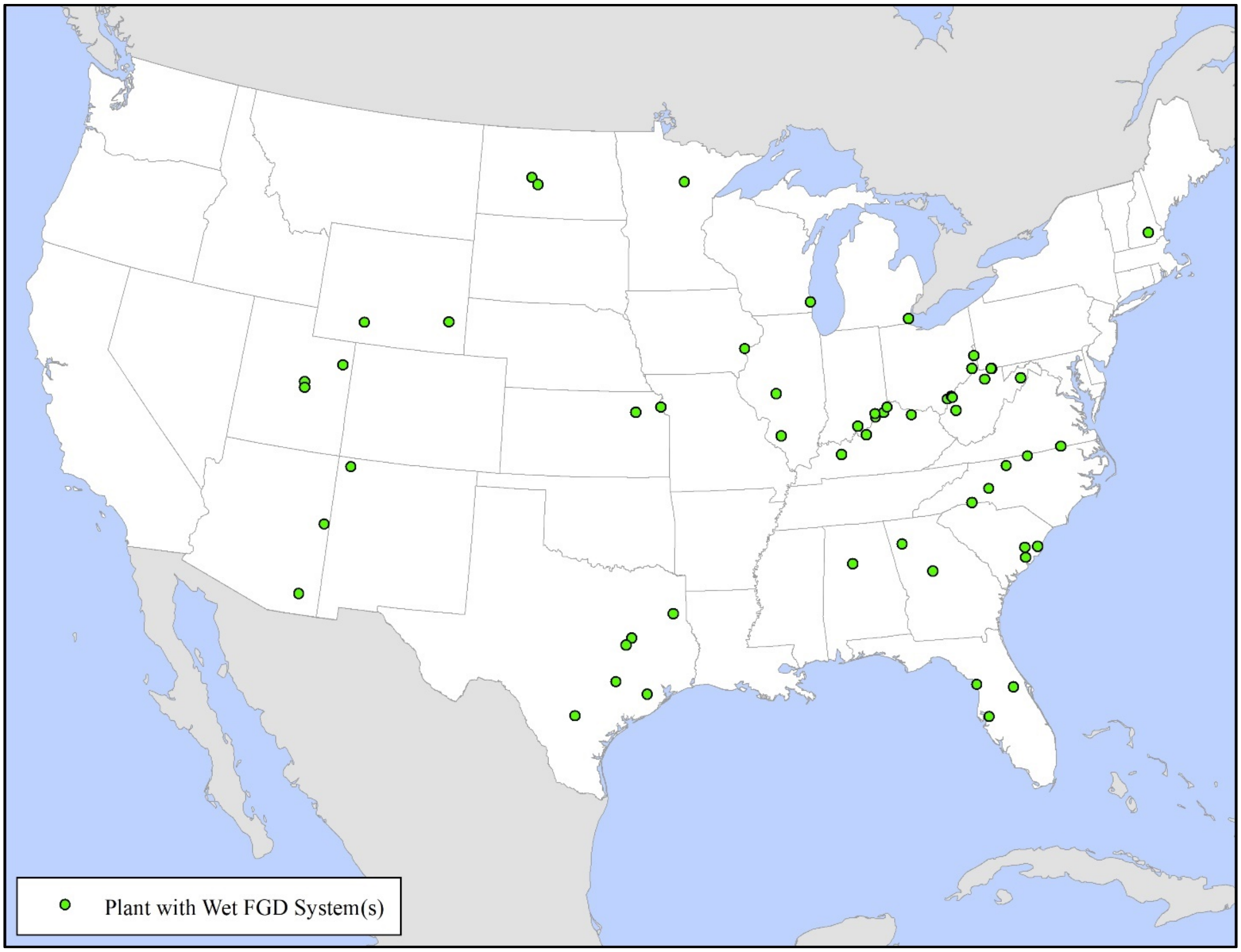

Figure 2. Wet FGD Systems at Steam Electric Power Plants

Although the number of wet FGD systems operated at steam electric power plants has decreased since promulgation of the 2020 rule, current FGD scrubber technologies are the same as those used at the time of the 2015 rule. These wet FGD systems typically use a limestone slurry with forced oxidation to remove sulfur dioxide (SO_2) from flue gas from EGUs burning bituminous coal. Often, plants also operate selective catalytic reduction systems on these EGUs to reduce NO_X emissions.

Following promulgation of the 2015 rule, the EPA collected new information on air pollution control practices at steam electric power plants that may affect the characteristics of FGD wastewater. Specifically, the EPA found that steam electric power plants may add halogens (*e.g.,* bromine, chlorine, iodine) to reduce mercury air emissions. While all coal contains some naturally occurring halogens, steam electric power plant operators can augment coal halogen concentrations at various points in the plant operations to enhance mercury oxidation for mercury capture (*e.g.,* directly injecting halogen during combustion, mixing bromide with coal to produce refined coal, using brominated activated carbon to control air emissions). Halogens in flue gas at steam electric power plants are captured by wet FGD systems and discharged in FGD wastewater.

Steam electric power plants have conducted on-site testing and/or installed a variety of technologies to treat FGD wastewater, including chemical precipitation, constructed wetlands, zero valent iron cementation, adsorption, ion exchange, low residence time reduction (LRTR) biological treatment, high residence time reduction (HRTR) biological treatment, advanced membrane filtration, spray dryer evaporators, and thermal evaporation treatment systems. The EPA identified that approximately 54 percent of steam electric power plants with wet FGD scrubbers have technologies in place or plan to install technologies that will meet the best available technology economically achievable (BAT) effluent limitations for FGD wastewater, including membrane filtration systems or other FGD wastewater management approaches that eliminate the discharge of FGD wastewater altogether. The EPA identified three domestic installations of spray evaporation technologies treating FGD wastewater and six installations of spray evaporation systems treating FGD wastewater in Asia. See Section 4 for more details on the treatment technologies some steam electric power plants employ to treat or reduce FGD wastewater discharges. Table 3 summarizes the FGD wastewater discharges from the steam electric power plants included in the EPA's costs and loadings analyses.

Table 3. FGD Wastewater Discharges from Steam Electric Power Plants

Number of Plants	Number of EGUs	FGD Wastewater Discharge Flow Rate			
		Total Daily Discharge Purge Flow Rate (MGD)	EGU Average Daily Discharge Purge Flow Rate (MGD per EGU)	Total Annual Discharge Purge Flow Rate (MGY)	EGU Annual Discharge Purge Flow Rate (MGY per EGU)
28	69	16.2	0.234	5,910	85.6

Abbreviations: MGD (million gallons per day), MGY (million gallons per year).

Note: Counts and flow rates do not include EGUs that will retire or convert fuels by December 31, 2028. In addition, this table does not include wet FGD systems at plants that are already achieving zero discharge.

3.2.2 BA Transport Water

Based on the Steam Electric Survey, approximately two-thirds of coal-fired power plants operated wet BA handling systems in 2009. Some plants operating wet BA handling systems recycled BA transport water from surface impoundments, dewatering bins, or other handling systems back to the wet-sluicing system; however, most BA transport water was discharged to surface water. At the time of the Steam Electric Survey, less than 40 percent of EGUs operated zero-discharge BA handling systems—dry, closed-loop recycle, or high recycle rate (HRR) systems. Because of changes in the industry in the years following the Steam Electric Survey, by 2015 more than half of EGUs operated or planned to convert to zero-discharge BA handling systems.

As discussed in Section 3, the EPA updated the industry profile and corresponding analyses to account for coal-fired EGUs that will retire, convert fuels, or install zero-discharge BA handling systems before December 31, 2028. Since the 2015 and 2020 rules, more plants have converted or are converting to dry BA handling systems or closed-loop BA handling systems, thereby eliminating discharge of BA transport water. In addition, based on data from the Steam Electric Survey, EGUs commissioned after 2009 likely operate dry or closed-loop recycle BA handling systems.[13] Further, the number of coal-fired EGUs operating wet-sluicing systems has decreased due to plant retirements and fuel conversions. Table 4 presents the count and total generating capacity of the EGUs operating wet-sluicing, closed-loop recycle and/or HRR, or dry BA handling systems. For the 2020 rule, the EPA estimated that more than 75 percent of EGUs operate either dry, closed-loop recycle, or HRR BA handling systems.[14] Based on conversations

[13] Data from the Steam Electric Survey show that more than 80 percent of EGUs built in the 20 years preceding the survey (1989–2009) installed dry BA handling systems at the time of construction. Because dry BA technologies are less expensive to operate than wet-sluicing systems and facilitate beneficial use of the BA, it is unlikely that power companies would find it advantageous to install wet-sluicing BA handling systems.

[14] Counts presented in this paragraph and Table 4 do not reflect BA handling conversions expected as a result of the CCR Part A rule.

with people in the steam electric industry, the EPA is aware that plants are still working to comply with the 2020 rule. Figure 3 illustrates the geographic distribution of plants operating the systems noted in Table 4. Plants that operate more than one type of system are shown as wet sluicing (with limited/no recycle or closed-loop/HRR, whichever is applicable).

Table 4. BA Handling Systems for Coal-Fired EGUs

Type of System	Number of Plants	Number of EGUs	Nameplate Capacity (MW)
Wet-sluicing system with limited or no recycle	24	58	27,700
Wet-sluicing closed-loop/HRR system	22	57	29,100
Dry BA handling system[a]	87	136	55,800
Total	**145**	**271**	**120,600**

Note: Counts and flow rates do not include EGUs that will retire or convert fuels by December 31, 2028.

a—The dry BA handling system counts presented in this table reflect conversions the EPA identified in the Steam Electric Survey and publicly available information from 2009 or later. Where data were available, the EPA tracked the specific types of BA handling conversions, such as mechanical drag systems (MDS) and remote MDS. However, the EPA identified 20 EGUs (corresponding to 8,000 MW at 12 plants) for which the data confirmed that the plant was not discharging BA transport water but did not confirm the specific type of non-discharging system.

b—Plant counts are not additive because plants may operate multiple types of BA handling systems.

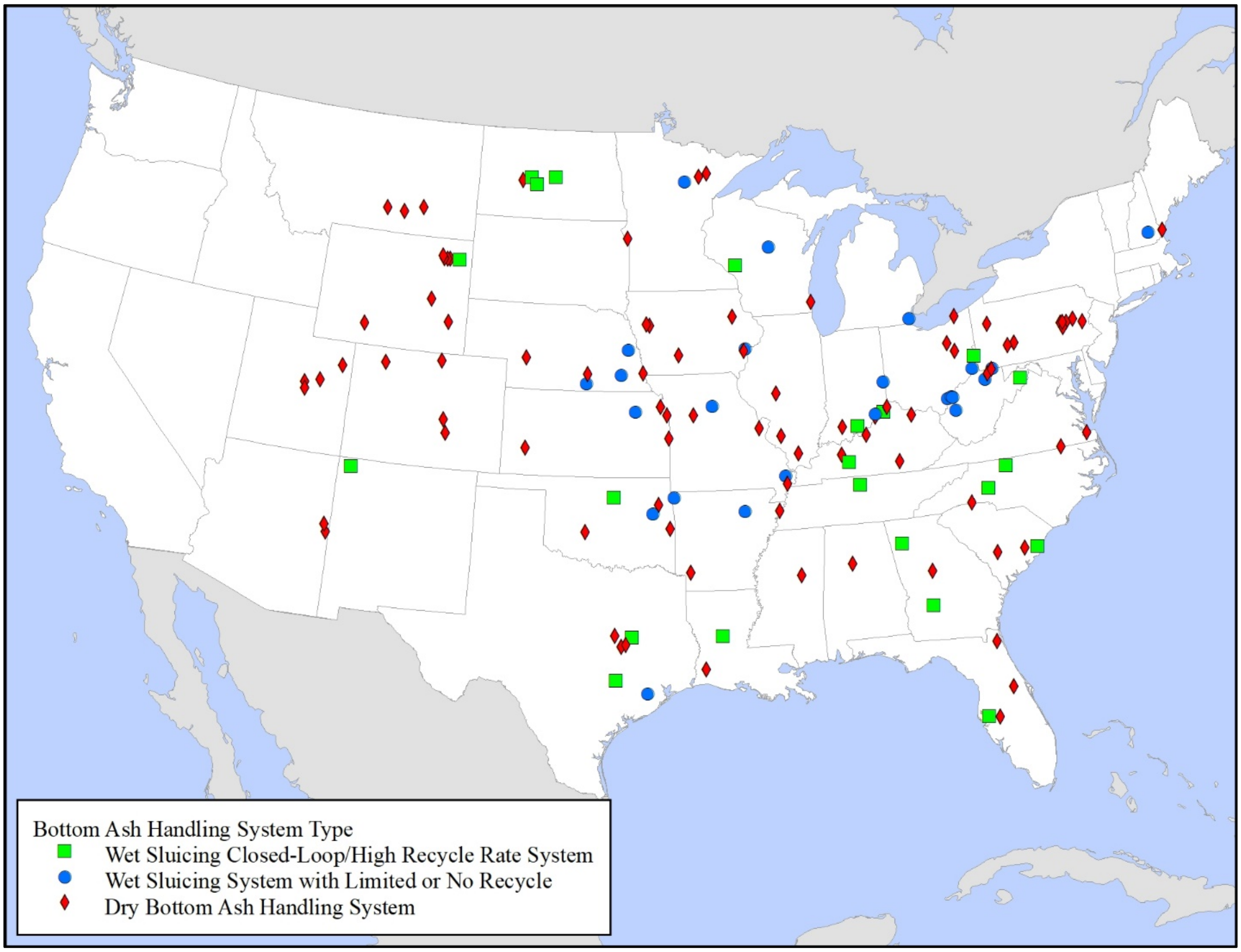

Figure 3. Plant-Level BA Handling Systems in the Steam Electric Power Generating Industry

Table 5 summarizes BA transport water discharges by the steam electric power plants included in the EPA's costs and loadings analyses. The estimated flow rates are based on compliance with the 2020 rule, which may represent full sluicing operations or a 10 percent allowable purge.

Table 5. BA Transport Water Discharges for the Steam Electric Power Plants

BA Wastewater Discharge Flow Rate					
Number of Plants	Number of EGUs	Total Daily Discharge Flow Rate (MGD)	EGU Average Daily Discharge Flow Rate (MGD per EGU)	Total Annual Discharge Flow Rate (MGY)	EGU Annual Discharge Flow Rate (MGY per EGU)
34	90	6.53	0.073	2,380	26.5

3.2.3 CRL

The EPA used data from the 2009 Steam Electric Survey (U.S. EPA, 2015) and the Office of Resource Conservation and Recovery's (ORCR's) Comprehensive Compliance Report (U.S. EPA, 2023b) to identify the population of landfills and surface impoundments containing combustion residuals that collect and discharge CRL to surface waters or publicly owned treatment works (POTWs). For the 2024 final rule, the EPA updated this data set to remove plants that intend to retire all coal-fired EGUs as of December 31, 2023, and add plants that either have constructed new landfills or surface impoundments since 2015 or have landfills or surface impoundments that were identified as having a composite liner as described in *Identification of Combustion Residual Leachate (CRL) Discharges from Leachate Collection Systems and Overview of Compliance Costs and Pollutant Loadings Analyses* (U.S. EPA, 2024d).[15] Table 6 summarizes CRL discharges by the steam electric power plants included in the EPA's costs and loadings analyses.

Table 6. CRL Wastewater Discharges for the Steam Electric Power Plants

CRL Wastewater Discharge Flow Rate					
Number of Plants	Number of EGUs	Total Daily Discharge Flow Rate (MGD)	EGU Average Daily Discharge Flow Rate (MGD per EGU)	Total Annual Discharge Flow Rate (MGY)	EGU Annual Discharge Flow Rate (MGY per EGU)
90	211	7.52	0.036	2,740	13.0

The EPA also notes that unlined landfills and surface impoundments potentially discharge unmanaged CRL that consists of: (1) discharges of CRL that the permitting authority determines are the functional equivalent of a direct discharge to Waters of the United States (WOTUS) through groundwater or (2) discharges of CRL that has leached from a waste management unit into the subsurface and mixed with groundwater prior to being captured and pumped to the surface for discharge directly to a WOTUS. As stated in the preamble, the EPA is not determining that all discharges through groundwater from landfills and surface impoundments are the functional equivalent of a direct discharges from a point source to a WOTUS. Rather, the EPA is establishing limitations that apply to any discharge of this kind that a permitting authority or facility owner or operator determines to be the functional equivalent of a direct discharge from a point source to a WOTUS, and thus requires an NPDES permit. The threshold standard for the "functional equivalence" determination is outside the scope of the final rule. The EPA analyzed the

[15] If a plant in the CRL population converted to a different fossil fuel source (*e.g.,* gas-fired source), the 2024 final rule still applies, and the plant remains in the CRL population.

potential costs and loadings associated with these discharges in both upper and lower bound scenarios documented in its memorandum *Evaluation of Unmanaged CRL* (U.S. EPA, 2024).

3.2.4 Legacy Wastewater

Legacy wastewater can be comprised of FGD wastewater, BA transport water, FA transport water, CRL, gasification wastewater, and/or flue gas mercury control (FGMC) wastewater generated before the "as soon as possible" date that more stringent effluent limitations from the 2015 or 2020 rules would apply. Discharges of legacy wastewater may occur through an intermediary source (*e.g.,* a tank or surface impoundment) or directly into a surface waterbody, with the vast majority of legacy wastewater currently contained in surface impoundments treating the wastestreams listed above. The EPA identified CCR units from the 2009 Steam Electric Survey (U.S. EPA, 2015) and ORCR's Comprehensive Compliance Report (U.S. EPA, 2023b). The EPA then used this list to identify the population of steam electric power plants that are expected to discharge legacy wastewater either directly into a surface waterbody or through an intermediate structure after the 2024 final rule takes effect. This population includes steam electric power plants with impoundments that are not required to have initiated closure under the CCR regulations prior to the effective date of the 2024 final rule (classified as "remaining open") and steam electric power plants with CCR surface impoundments that are expected to have initiated, but not yet completed closure prior to the effective date of the 2024 final rule (classified as "in closure process"). Plants that have completed the closure process for all impoundments are not expected to have legacy flows that would be subject to 2024 final rule. Table 7 summarizes discharges of these types of legacy wastewater. See Section 5.4.1 and the *Legacy Wastewater at CCR Surface Impoundments* memorandum (U.S. EPA, 2023b, 2024a) for details on the estimated volume and cost calculations.

Table 7. Estimate of Total Volume of Wastewater in CCR Surface Impoundments

Category	Total Number of Surface Impoundments	Total Estimated Volume of Wastewater (million gallons)
CCR surface impoundments that are remaining open	24	2,150
CCR surface impoundments in closure process	109	60,000

Source: U.S. EPA, 2024a.

Note: The EPA identified 398 additional surface impoundments that are expected to complete closure prior to the effective date of the 2024 final rule and therefore were not considered in 2024 final rule analyses.

3.3 Other Regulations on the Steam Electric Power Generating Industry

The Agency recognizes that effluent guidelines on steam electric power plants do not exist in isolation—other EPA regulations set requirements to control pollution emissions, discharges, and other releases from steam electric power plants. For the 2020 rule, the EPA assessed and incorporated impacts from the CCR regulations into the supporting analyses.

The EPA continues to account for industry profile changes associated with the CCR regulations. The EPA coordinated the requirements of the CCR regulations and the 2015 rule to mitigate potential impacts from the overlapping regulatory requirements and facilitate the implementation of engineering, financial, and permitting activities. Based on the CCR regulation requirements established in 2015, the EPA expected plants might alter how they operate their CCR surface impoundments in some of the following ways:

- Close the CCR-noncompliant disposal surface impoundment and open a new CCR-compliant disposal surface impoundment in its place.
- Convert the CCR-noncompliant disposal surface impoundment to a new storage impoundment.
- Close the CCR-noncompliant disposal surface impoundment and convert to dry handling operations.

- Make no changes to the operation of the CCR-compliant disposal surface impoundment.

As discussed in Section 1.3, the EPA finalized the CCR Part A rule on July 29, 2020, setting a deadline of April 11, 2021, for all unlined surface impoundments and surface impoundments that failed the location restriction for placement above the uppermost aquifer to stop receiving waste and begin closure. For the 2020 rule, the EPA developed a methodology for using CCR surface impoundment liner data to estimate operational changes at each coal-fired power plant under the CCR Part A rule. As described in Section 3.3 of the 2020 Supplemental TDD, plants with unlined or clay-lined CCR surface impoundments are required to change operation (*e.g.,* convert to dry handling) or install a new CCR-compliant surface impoundment. The EPA incorporated the CCR outputs into the 2020 rule (*i.e.,* baseline) engineering costs and loadings analyses in the following ways:

- Where all active CCR surface impoundments are unlined or clay-lined, the EPA predicted that a plant would install tank-based FGD wastewater treatment or tank-based BA handling under the CCR Part A rule.[16]
- For plants with at least one CCR surface impoundment not affected by the CCR Part A rule (*i.e.,* not identified as unlined or clay-lined,[17] or where no data were available in the ORCR data set), the EPA conservatively assumed the CCR Part A rule would have little to no impact on a plant's existing FGD wastewater treatment or BA handling systems. Thus, for these plants, the estimated compliance cost and pollutant loadings remain unchanged for the 2024 final rule.

For the 2024 final rule, the EPA determined that 50 plants within the BA engineering costs and loadings baseline analyses likely made changes to BA handling operations under the CCR Part A rule.[18] These changes were captured as part of the EPA's 2020 final rule (and reflected in the 2024 final rule baseline). Sections 5 and 6 of the 2020 Supplemental TDD describe how the EPA accounted for CCR Part A rule impacts in estimating BA compliance costs, pollutant loadings, and pollutant removals.

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[16] For plants with at least one surface impoundment in the ORCR data set, the EPA assumed the listed CCR surface impoundment(s) represent all surface impoundments receiving FGD wastewater and/or BA transport water at the plant.

[17] The ORCR data set includes 34 active CCR surface impoundments without liner designations. For these CCR surface impoundments, the EPA did not assume they were unlined or clay-lined; therefore, the EPA may be underestimating the number of plants that will install tank-based FGD wastewater treatment or BA handling in response to the CCR Part A rule.

[18] Any plant that installs a remote MDS to comply with the CCR Part A rule may incur costs to install a reverse osmosis system that will treat a slipstream of the recirculating BA transport water to remove dissolved solids and facilitate long-term operation of the system as a closed loop to comply with the BA zero-discharge requirements of the 2015 rule. There are approaches other than reverse osmosis to remove dissolved solids from the BA system, such as using the transport water as makeup water for the FGD system. Dissolved solids will also be removed from the system along with the dredged BA.

4. Treatment Technologies and Wastewater Management Practices

This section provides an overview of treatment technologies and wastewater management practices at steam electric power plants for flue gas desulfurization (FGD) wastewater; bottom ash (BA) transport water; combustion residual leachate (CRL) collected from landfills and surface impoundments containing combustion residuals; and legacy wastewater. This section focuses on only those technologies and practices considered as potential technology options for this 2024 rule: it is not a comprehensive listing of all technologies available for treatment and management of FGD wastewater, BA transport water, CRL, or legacy wastewater. For the U.S. Environmental Protection Agency's (EPA's) comprehensive evaluation of available technologies and practices for the 2015 rule and 2020 reconsideration, see the 2015 Technical Development Documents (TDD) and the 2020 Supplemental TDD. Also see the *Technologies for the Treatment of Flue Gas Desulfurization Wastewater, Coal Combustion Residual Leachate, and Pond Dewatering—2024 Final Rule* memorandum (U.S. EPA, 2024e) for details on other types of treatment technologies available.

This section discusses the following:

- FGD wastewater treatment technologies (Section 4.1).
- BA handling systems and transport water management and treatment technologies (Section 4.2).
- CRL treatment technologies and management practices (Section 4.3).
- Legacy wastewater treatment technologies (Section 4.4).

4.1 FGD Wastewater Treatment Technologies

For the 2024 rule, the EPA considered treatment technologies identified as part of the 2015 and 2020 rules for those plants that are still operating and discharging FGD wastewater. These technologies include low residence time reduction (LRTR) biological treatment and membrane filtration. The EPA also evaluated other treatment technologies capable of achieving zero discharge of FGD wastewater including spray evaporation, other types of thermal treatment, and encapsulation.

4.1.1 LRTR Biological Treatment

Several types of biological treatment systems are used to treat FGD wastewater, including:

- Anoxic/anaerobic biological treatment systems, designed to remove selenium and other pollutants.
- Sequencing batch reactors, designed to remove nitrates and ammonia.
- Aerobic bioreactors for reducing biochemical oxygen demand (BOD).

These biological treatment processes are typically operated downstream of a chemical precipitation system or a solids removal system (*e.g.,* clarifier or surface impoundment).

The anoxic/anaerobic biological technology is designed to remove selenium, nitrate/nitrite, mercury, and other pollutants. This process uses an anoxic/anaerobic fixed-film bioreactor that consists of an activated carbon bed or other permanent porous substrate that is inoculated with naturally occurring, beneficial microorganisms. The microorganisms grow within the substrate, creating a fixed film that retains the microorganisms and precipitated solids within the bioreactor. The system uses microorganisms chosen specifically for use in FGD systems because of their hardiness in the extreme water chemistry. The microorganisms reduce the selenate and selenite to elemental selenium, which forms nanospheres that adhere to the cell walls of the microorganisms. The technology can also remove other metals, including arsenic, cadmium, nickel, and mercury, by forming metal sulfides (Pickett, 2006).

As defined in the 2020 reconsideration, an LRTR biological treatment system consists of chemical precipitation[19] followed by an anoxic/anaerobic fixed-film bioreactor. In the years since it first identified anoxic/anaerobic biological technology in the 2015 rule, the EPA identified different systems with varying hydraulic residence times (HRT) in the bioreactor. During the development of the 2020 reconsideration, the EPA differentiated between high residence time reduction (HRTR) systems (which typically operate with HRT in the bioreactor between 10 and 16 hours) and LRTR systems (with HRT between one and four hours). Power companies and technology vendors have worked to develop processes that target removals of the same pollutants in a smaller system with a lower HRT in the bioreactor. These LRTR technologies use similar treatment mechanisms as HRTR to remove selenium, nitrate, nitrite, and other pollutants in less time.

One LRTR technology includes a chemical precipitation system followed by an anoxic, upflow bioreactor followed by a second stage downflow biofilter. The shorter HRT of this system allows for use of smaller bioreactors and other equipment, resulting in a treatment system that is physically much smaller than the HRTR system. Data provided by the power industry and an independent research organization show that LRTR's performance is comparable to HRTR's. Much of the LRTR bioreactor and related equipment is fabricated off site as modular components. Modular, prefabricated, skid-mounted components, coupled with smaller physical size, result in lower installation costs and shorter installation times than for HRTR systems, which are usually constructed on site. At least three plants have installed full-scale LRTR systems and are using them to treat FGD wastewater, and this technology has been pilot tested using FGD wastewater at more than a dozen steam electric power plants since 2012.

Another LRTR technology, fluidized bed reactors (FBRs), has been used to treat selenium in mining wastewaters; it is now being tested on FGD wastewater. The FBR system is also an anoxic/anaerobic fixed-film bioreactor design. It relies on an attached growth process, in which microbes grow on a granular activated carbon medium that is fluidized by the upflow of FGD wastewater through the suspended carbon medium. The EPA identified 12 pilot studies of the FBR technology for selenium removal in mining, refining/petrochemical, and steam electric power generating industries. For the steam electric power generating industry, the EPA identified three pilots involving FGD wastewater.

4.1.2 Membrane Filtration

Membrane filtration systems are specifically designed to treat wastestreams high in total dissolved solids (TDS) and total suspended solids (TSS) using thin semi-permeable filters or film membranes. Membrane filtration is used for the removal of dissolved materials from industrial wastewater and consists of one or more of the following: microfiltration, ultrafiltration, nanofiltration, reverse osmosis (RO), forward osmosis (FO), and electrodialysis reversal (EDR) membrane systems. As part of the 2020 reconsideration, the EPA identified several membrane filtration technologies being studied for use with FGD wastewater, including nanofiltration membranes, RO, and FO. The membrane pore size determines the particle size that can pass through the membrane, with RO membranes being the most restrictive and microfiltration being the least restrictive. Most membrane filtration systems use pumps to apply pressure to the solution from one side of the semi-permeable membrane to force wastewater through the membrane, leaving behind dissolved solids retained ("rejected") by the membrane and a portion of the water. The rate at which water passes through the membrane depends on a number of variables including the operating pressure, concentration of dissolved materials, and temperature, as well as the permeability of the membrane.

Membrane systems separate feed wastewater into two product streams: a permeate stream, which is the "clean" water that has passed through the membrane, and the concentrate stream, which is the water (or brine) rejected by the membrane. The percentage of membrane system feed that emerges from the system as permeate is known as the water recovery. Depending on wastewater characteristics,

[19] Consistent with both the 2015 and 2020 reconsideration rules, chemical precipitation includes hydroxide precipitation, organosulfide precipitation, and iron coprecipitation to treat FGD wastewater.

membrane systems may require pretreatment to prevent scaling and fouling by removing excess TSS, calcium, magnesium, sulfate, or organics. Fouling occurs when either dissolved or suspended solids deposit onto a membrane surface or a microbial biofilm grows on the membrane surface and degrades its overall performance. To reduce fouling, membrane filtration systems have been designed with vortex generating blades or vibratory movement. Other systems may use a microfiltration (or ultrafiltration/nanofiltration) or chemical precipitation pretreatment step that targets scale-forming ions where FGD wastewater characteristics indicate potential fouling.

FO uses a semi-permeable membrane and differences in osmotic pressures to achieve separation. FO systems use a draw solution at a higher concentration than the feed (*e.g.,* FGD wastewater) to induce a net flow of water through the membrane. This results in diluting the draw solution and concentrating the feed stream. This technology is different from RO, which uses hydraulic pressure to drive separation. FO technology is typically better suited for high-fouling streams than traditional RO because external pumps are not needed to drive treatment across the membrane.

EDR uses a semi-permeable membrane and differences in electrical charges to achieve separation of specific anions and cations. The first-of-its-kind domestic pilot of EDR for FGD wastewater indicates that treatment with electrodialysis reversal has continued to advance and become more available. This pilot is detailed in the 2020 Electric Power Research Institute report *FGD Wastewater Treatment Testing Using a Saltworks Flex EDR Selective (Electrodialysis Reversal System) Technology*, which found that "[t]he Flex EDR Selective pilot plant reliably operated for 61 days, 24/7, including weekends and unattended overnights." Other key findings included an average 93 percent water recovery, 98 percent uptime of continuous operations (over 1,440 hours), selective removal of chlorides, the elimination of the need for soda ash softening, "demonstrated versatility to treat wastewater of different concentrations and water chemistries with the same treatment plant," and the potential for cost savings when compared to comparable treatment systems (EPRI, 2020).

While microfiltration, ultrafiltration, and/or nanofiltration may provide sufficient pretreatment for membrane filtration systems, incorporating chemical precipitation pretreatment can improve the efficiency of the membrane system and may help lower the capital and operation and maintenance costs. Many of the systems piloted for FGD wastewater have included some type of pretreatment (*e.g.,* surface impoundment, chemical precipitation, microfiltration) to reduce TSS and/or soften the wastewater before it enters the membrane system. Membrane systems can be configured with polishing RO systems (*e.g.,* multi-stage RO systems) to further remove pollutants from the permeate. As well, membrane systems can be used in combination with other technologies (*e.g.,* thermal evaporation) to treat FGD wastewater or achieve zero discharge.

Permeate streams from these systems can be reused within the plant or discharged, while concentrate streams (*i.e.,* concentrated brine) would be disposed of in a landfill using encapsulation (see Section 4.1.5); in a commercial injection well; or through another process, such as thermal system treatment (see Sections 4.1.3 and 4.1.4).

The EPA identified two full-scale domestic installations of RO and one installation in South Africa for treating wastewater in the mining industry; and four domestic membrane filtration pilot studies in the petroleum refining and agriculture industries. The EPA further identified four full-scale installations of membrane filtration in the coal-to-chemical industry in China and the textile industry in India.[20] In the steam electric power generating industry, the EPA identified 30 pilot-scale studies of membrane filtration used for FGD wastewater treatment world-wide (U.S. EPA, 2024e, 2024f) as well as 12 full-scale foreign installations for FGD wastewater (refer to Section VII.B.1 of the preamble). Some of the full-scale systems employ pretreatment before a combination of RO and FO. Others operate pretreatment followed by

[20] The EPA has limited data on the performance and configuration of the full-scale and pilot-scale membrane systems (Wolkersdorfer, 2015; U.S. EPA, 2014; CH2M Hill, 2010; ERG, 2019, 2020). These systems may include nanofiltration, microfiltration, and RO systems.

nanofiltration and RO. At least one plant uses thermal treatment to produce a crystallized salt from the concentrate stream, which is sold for industrial use. Of the 30 pilot-scale studies, the EPA is aware of one U.S. facility that is conducting a long-term pilot project of membrane filtration for treating FGD wastewater, including testing to date of a 1-GPM treatment system and a 50-GPM treatment system (U.S. EPA, 2023d).

See the *Technologies for the Treatment of Flue Gas Desulfurization Wastewater, Coal Combustion Residual Leachate, and Pond Dewatering—2024 Final Rule* memorandum for more information on pilot testing of membrane filtration technologies (U.S. EPA, 2024e).

4.1.3 Spray Evaporation

Spray evaporation technologies, which include spray dryers and other similar proprietary variations, are an example of a thermal technology that is being applied to FGD wastewater treatment. Spray dryer systems evaporate wastewater by spraying fine misted wastewater into hot gasses. The hot gases allow the wastewater to evaporate before contacting the walls of the evaporation vessel, which allows spray evaporation systems to remove TDS, TSS, or scale-forming pollutants.

For FGD application, a slipstream of hot flue gas from upstream of the air heater can be used to evaporate FGD wastewater in a vessel. The FGD solids are carried along with the flue gas slipstream, which is recombined with the main flue gas stream. All solids are then removed with the fly ash (FA) by the main particulate control equipment (*e.g.,* electrostatic precipitator or fabric filter) and disposed of in a landfill. In cases where FA is marketable, and contamination is a concern, a separate particulate control system can be operated on the flue gas slipstream to capture FGD solids alone.

Spray evaporation systems can be used in combination with other volume reduction technologies, such as membranes, to maximize the efficiency of each process. For instance, RO systems can be installed upstream of spray evaporation technologies to reduce influent flows. Concentrate from the RO system can be processed through the spray evaporation system to achieve zero discharge. To achieve zero discharge, permeate from the RO system needs to be recirculated back into plant operation as process wastewater. Another method for reducing the volume of FGD wastewater influent to a spray evaporation system may involve reconfiguring process flow to exclude non-FGD wastewater from the treatment system (if wastewater is diluted by utility water streams prior to treatment).

The EPA identified a vendor that has developed a proprietary technology that combines concepts of a brine concentrator and spray dryer to achieve zero discharge. The system, referred to as an adiabatic evaporator, injects wastewater into a hot feed gas stream to form water vapor and concentrated wastewater. The air-water mixture is separated in an entrainment separator. Water vapor is exhausted, and the concentrated wastewater is sent to a solid-liquid separator. The separated wastewater is recycled and sent back through the system, while the solids can be landfilled. An alternative configuration would be to encapsulate the separated wastewater, by mixing it with FA, and then landfilling. Pretreatment of FGD wastewater is not required, but for situations where TSS exceeds 5 percent, it may be cost-effective to operate a clarifier upstream of the evaporator to decrease solids. The vendor operated a full-scale system at a coal-fired steam electric power plant for three years. FGD wastewater was pretreated using a clarifier, then sent to the adiabatic evaporator, where 100 percent of the FGD wastewater was evaporated and solids deposited in a landfill. Because propane was used as the heat source, operation and maintenance costs proved to be too high, and the system was replaced. Nevertheless, an adiabatic evaporator is capable of evaporating FGD wastewater using multiple thermal energy sources, including engine/turbine exhaust, a slipstream from coal-fired power plant flue gas, natural gas, or alternative fuel enclosed flare exhaust. Additionally, adiabatic evaporators can be used downstream of other volume reduction technologies, including RO, to reduce the amount of FA required for brine encapsulation.

The EPA identified three domestic installations of spray evaporation technologies treating FGD wastewater, including one installation at the Boswell Energy Center in Minnesota (U.S. EPA, 2024e; John

Wood Group PLC, 2022). The EPA also identified six installations of spray evaporation systems treating FGD wastewater outside of the U.S. (U.S. EPA, 2024e).

See the *Technologies for the Treatment of Flue Gas Desulfurization Wastewater, Coal Combustion Residual Leachate, and Pond Dewatering—2024 Final Rule* memorandum (U.S. EPA, 2024e) for more information on pilot testing of membrane filtration technologies.

4.1.4 Other Thermal Treatment Options

Thermal technologies use heat to evaporate water and concentrate solids and other contaminants. Some of these systems can be operated to achieve full evaporation of all liquid, resulting in only a solid product, or achieve partial evaporation of liquid. These thermal technologies can also be used in combination with other technologies to treat FGD wastewater or achieve zero discharge.

One type of thermal treatment uses brine concentrators followed by crystallizers; this generates a distillate stream and solid byproduct that can be disposed of in a landfill. EPA identified coal-fired steam electric power plants in China that have installed membrane treatment, followed by brine concentrators and crystallizers to treat FGD wastewater. Brine concentration followed by crystallization was evaluated as part of the 2015 rule as a possible treatment technology for the industry; see Section 7.1.4 of the 2015 TDD for a detailed description of this treatment configuration (U.S. EPA, 2015a).

Two U.S. plants have installed brine concentrator systems for FGD treatment and at least five steam electric power plants in Italy also operate this type of system for FGD wastewater (U.S. EPA, 2024e; EKPC, 2018).[21] In addition, there are two plants in China that use a combined evaporator and crystallizer for FGD wastewater treatment (U.S. EPA, 2024e).

The EPA identified one vendor that has developed a modular brine concentration technology to heat FGD wastewater and facilitate evaporation. As the wastewater boils, steam is collected, compressed, and directed into a proprietary technology that allows the thermal energy to transfer from the steam to the concentrated wastewater stream, causing it to become superheated. As water evaporates from the superheated wastewater, the steam is collected and condensed. This distillate stream can be reused in the plant as cooling tower make-up water or within the FGD scrubber. The concentrated wastewater, referred to as brine, is discharged from the system once it reaches a set TDS concentration (not to exceed 200,000 parts per million (ppm)). This brine stream is treated through hydrocyclones to remove suspended solids. The resulting liquid can be encapsulated and landfilled. Pretreatment of FGD wastewater is only required when TSS concentrations exceed 30 ppm. Chemicals are added to maintain pH and inhibit crystal and scale formation. This technology has been pilot tested at four steam electric power plants between 2015 and 2017.

4.1.5 Encapsulation

Encapsulation is a technology that can be used to eliminate FGD wastewater discharge. It uses chemical reactions and/or absorption processes to bond materials together so that wastewater is incorporated into the solid material. This process is also referred to as solidification. This technology has been used by plants operating inhibited oxidation scrubber systems, where byproducts from the scrubber are mixed with FA and lime to produce a non-hazardous landfillable material. This same approach has been tested with pretreated FGD wastewater by mixing concentrated FGD wastewater with combinations of FA, hydrated lime, sand, and/or Portland cement to encapsulate contaminants. Tests of these materials have

[21] Two additional plants in the U.S. previously installed thermal treatment for FGD wastewater but are retiring or refueling by 2028; one plant previously installed thermal treatment and later installed a different treatment system (U.S. EPA, 2024e; ERG, 2020a). One additional plant in Italy previously installed thermal treatment for FGD wastewater but no longer operates the system (U.S. EPA, 2024e).

confirmed that the solids generated meet solid waste leaching requirements, toxicity characteristic leaching procedure (TCLP), and other local landfill regulations (Pastore and Martin, 2017; Martin, 2019).

Encapsulation can be used alone or in combination with other treatment technologies. For instance, it can be incorporated on reduced volumes of the concentrated stream downstream of a membrane and/or thermal system. As described in Section 4.1.3, it can also be implemented downstream of spray or adiabatic evaporation technologies that achieve only partial evaporation and produce concentrated wastewater streams.

4.2 BA Handling Systems and Transport Water Management and Treatment Technologies

The EPA reviewed BA handling systems—operated at coal-fired steam electric power plants or marketed by BA handling vendors—that are designed to minimize or eliminate the discharge of BA transport water. Many plants have installed or are installing BA handling systems that minimize or eliminate the discharge of BA transport water. The BA handling technologies evaluated by the EPA and described in this section include mechanical drag systems, remote mechanical drag systems, compact submerged conveyors (CSCs), and mobile mechanical drag systems.

As part of previous rulemaking efforts in 2015 and 2020, the EPA also evaluated types of dry ash handling systems: dry mechanical conveyors and pneumatic systems (*i.e.,* dry vacuum or pressure systems). See the 2015 TDD and 2020 Supplemental TDD (U.S. EPA, 2015a; U.S. EPA, 2020).

4.2.1 Mechanical Drag System

A mechanical drag system collects BA from the bottom of the EGU through a transition chute and sends it into a water-filled trough. The water bath in the trough quenches the hot BA as it falls from the EGU and seals the EGU gases. The drag system uses a parallel pair of chains attached by crossbars at regular intervals. In a continuous loop, the chains move along the bottom of the water bath, dragging the BA toward the far end of the bath. The chains then move up an incline, dewatering the BA by gravity and draining the water back to the trough. Because the BA falls directly into the water bath from the bottom of the EGU and the drag chain moves constantly on a loop, BA removal is continuous. The dewatered BA is often conveyed to a nearby collection area, such as a small bunker outside the EGU building, from which it is loaded onto trucks and either sold or transported to a landfill. See Section 7.3.3 of the 2015 TDD for more specific system details (U.S. EPA, 2015a).

The mechanical drag system does generate some wastewater (*i.e.,* residual water that collects in the storage area as the BA continues to dewater). This wastewater is either recycled back to the quench water bath or directed to the low-volume waste system. This wastewater is not BA transport water because the transport mechanism is the drag chain, not the water (see 40 CFR 423.11(p)).[22]

This system may not be suitable for all EGU configurations and may be difficult to install if there is limited space below the EGU.[23] These systems cannot combine and collect BA from multiple EGUs, and most installations require a straight exit from the EGU to the outside of the building. In addition, these systems may be susceptible to maintenance outages due to BA fragments falling directly onto the drag chain.

[22] The mechanical drag system does not need to operate as a closed-loop system because it does not use water as the transport mechanism to remove the BA from the boiler; the conveyor is the transport mechanism. Therefore, any water leaving with the BA does not fall under the definition of "bottom ash transport water," but rather is a low-volume waste.

[23] In comments on the 2013 proposed ELG, three plants reported space constraints below the boiler such that a mechanical drag system could not be installed.

4.2.2 Remote Mechanical Drag System

Remote mechanical drag systems collect BA using the same operations and equipment as wet-sluicing systems at the bottom of the EGU. However, instead of sluicing the BA directly to a surface impoundment, the plant pumps the BA transport water to a remote mechanical drag system. This type of system has the same configuration as a mechanical drag system, but with additional dewatering equipment in the trough to enable recycling BA transport water back to the system. Also, it does not operate under the EGU, but rather in an open space on the plant property. See Section 7.3.4 in the 2015 TDD for more specific system design details (U.S. EPA, 2015a).

Plants converting their current BA handling systems can use this system if space or other restrictions limit the changes that can be made to the bottom of the EGU. Currently, over 50 coal-fired power plants have installed, or are planning to install, remote mechanical drag systems to handle BA.

Because of the chemical properties of BA transport water, some plants may need to add flocculant or polymer to aid in the settling of fines to prevent potential plugging of the sluice pipes. Other plants may have to treat the overflow (or a slipstream of the overflow) before recycling to prevent scaling and fouling in the system. Plants that require treatment to achieve complete recycling of BA transport water could install a pH adjustment system, chemical addition, or an RO membrane (as described in the EPA's cost methodology in Section 5) depending on the BA transport water characteristics and materials of construction.

Similar to the mechanical drag system, the drag chain conveys the ash to a collection area and the plant then sells or disposes of it in a landfill. There is also an opportunity for multiple unit synergies and redundancy with remote mechanical drag systems because they are not operating directly underneath the EGU. This system needs less maintenance than the mechanical drag system because the BA particles entering it have already been through the grinder prior to sluicing.

4.2.3 CSC

A CSC, also referred to as submerged grind conveyor, collects BA from the bottom of the EGU. A CSC uses existing equipment—BA hoppers or slag tanks, the BA gate, clinker grinders, and a transfer enclosure—to remove BA from the hopper continuously. From the bottom of the EGU, BA falls into the water impounded hopper or slag tank. It is then directed to the existing grinders to be ground into smaller pieces and is then transferred to a fully enclosed bottom carry chain and flight conveyor system. Similar to a mechanical drag system (except for the fully enclosed bottom carry design), a drag chain continuously carries and dewaters BA up an incline, away from the EGU. Because the transport mechanism is the conveyor instead of water, CSCs do not generate BA transport water.[24] The dewatered BA is transferred to one or more additional conveyors, which transports it to a BA silo or bunker where the BA is collected in a truck and transported to its final destination. CSCs use additional conveyors to avoid existing structures such as pillars and coal pulverizers while conveying BA out of the EGU house. This makes it possible to install CSCs in some plants where physical constraints prevent installation of mechanical drag systems; however, physical constraints could prevent CSC installation at other plants. CSCs can also use smaller chains and are narrower and shorter than mechanical drag systems, features that potentially allow them to fit in places with insufficient space for the larger mechanical drag system conveyors.

A CSC can be isolated from the hopper using the existing transfer enclosures to perform maintenance while the EGU remains online (made possible by the BA storage capacity of the hopper). It is also possible for some plants to install parallel conveyors for redundancy (ERG, 2020b, 2020c, 2020d, 2020e).

[24] Like mechanical drag systems, CSCs are considered a dry handling technology, because they do not use water as the transport mechanism.

For plants that can repurpose their wet-sluicing equipment (hoppers, slag tanks, and/or clinker grinders, etc.), the capital costs of converting to CSC systems are typically lower, and installation and outage times are shorter, than for other under-the-EGU BA handling systems. However, because a CSC serves just one EGU, the more EGUs a plant has, the less economical this technology becomes.

The EPA is aware of at least five plants that have installed and are operating CSC systems in the United States. The EPA understands that these facilities do not have vertical space constraints under the EGUs.

4.2.4 Mobile Mechanical Drag System

A mobile mechanical drag system is a BA transport water dewatering unit—similar to a remote mechanical drag system—with an additional clarification system (U.S. EPA, 2022). This technology is not intended to be set on a permanent location, which reduces capital costs associated with permanent infrastructure. Depending on the facility, a mobile mechanical drag system can either remain on a truck or be installed on facility grounds. From the mechanical drag system, BA transport water is taken to a mobile clarifier and polished to a level suitable for recirculation. This mixture is sent up an incline, dewatered, and discharged.

The mobile clarifiers are typically equipped with lamella separators, polymer addition, and mobile chemical injection systems, including coagulant (typically ferric chloride) and flocculant for solids removal and caustic and acid injection for pH control. Typically, thickened sludge from the mobile clarifier is pumped back to the mechanical drag unit, with the coarse particulates acting as ballast to assist the sludge up the ramp to the mechanical drag system. The fines from the underflow of the clarifier can be pumped to a mobile belt filter press to make filter cake.

In addition to reducing capital costs, benefits of mobile systems include reduced construction costs, a smaller footprint compared to other BA treatment options, increased flexibility, minimal invasion to the facility's existing systems, manual controls to reduce complexity of control system tie-in, and the ability to serve as a recirculation system.

Mobile mechanical drag systems may have relatively higher operation and maintenance costs: the system is often a single remote mechanical drag system and an upset condition may require the unit to be shut down, and nonpermanent infrastructure (such as flexible HDPE piping and hose connections) lacks the robust nature of carbon steel or ballast line materials.

The EPA is aware of one installation of a mobile system at a plant serving two coal-fired units and a full-scale pilot demo at a facility using a mobile system combined with a hydrocyclone vibrating screen to treat dewatering surface impoundment water.

4.3 CRL Treatment Technologies and Management Practices

In promulgating the 2015 rule, the EPA determined that CRL from landfills and surface impoundments includes similar types of constituents as FGD wastewater, albeit at potentially lower concentrations and smaller volumes. Based on this characterization of the wastewater and knowledge of treatment technologies, the EPA determined that certain treatment technologies identified for FGD wastewater could also be used to treat CRL from landfills and surface impoundments containing combustion residuals.

In support of the 2015 rule, the EPA identified facilities using surface impoundments, biological treatment, and constructed wetlands to treat CRL, sometimes commingled with FGD wastewater. The EPA also identified facilities using other management practices to manage CRL, including recycling the wastewater in other plant operations or for moisture conditioning of FA. This section describes treatment technologies the EPA considered for the treatment of CRL as part of this 2024 final rule, including technologies already being used by the industry.

4.3.1 Chemical Precipitation

In a chemical precipitation wastewater treatment system, chemicals are added to the wastewater to alter the physical/chemical state of dissolved and suspended solids to help precipitate, settle, and remove them. The specific chemical(s) used depends on the type of pollutant requiring removal. Steam electric power plants using chemical precipitation systems to treat FGD wastewater may include stages of hydroxide (lime), iron, and organosulfide addition, as well as clarification stages. Plants may either add all three chemicals to a single reaction tank or add the chemicals to separate tanks. Plants operating separate tanks typically target different pH set points within each tank for optimal precipitation of certain metals. Similar strategies may be applied to treat CRL, since this wastestream includes similar constituents as FGD wastewater.

In a hydroxide precipitation system, plants add lime (calcium hydroxide) to elevate the pH of the wastewater to a designated set point, helping precipitate metals into insoluble metal hydroxides that can be removed by settling or filtration. Sodium hydroxide can also be used in this type of system, but it is more expensive than lime and, therefore, not as common in the industry.

Plants use iron coprecipitation to increase the removal of certain metals in a hydroxide precipitation system. Steam electric power plants typically use ferric chloride to coprecipitate additional metals and organic matter. The ferric chloride also acts as a coagulant, forming a dense floc that enhances settling of the precipitated metals in downstream clarification stages.

Organosulfide precipitation systems use organosulfide chemicals (*e.g.,* trimercapto-s-triazine [TMT], Nalmet® 1689, MetClear™, sodium sulfide) to precipitate and remove heavy metals. Plants may test several organosulfide chemicals to determine which one is most appropriate for their treatment systems. Organosulfide precipitation can also optimize removal of metals with lower solubilities, such as mercury, more effectively than hydroxide precipitation or hydroxide precipitation with iron coprecipitation. EPA sampling data show that adding organosulfide to the FGD wastewater can reduce dissolved mercury concentrations to less than 10 parts per trillion (ERG, 2012). Organosulfide precipitation is more effective than hydroxide precipitation in removing metals with low solubilities because metal sulfides have lower solubilities than metal hydroxides. Due to the relatively low costs of hydroxide precipitation, plants usually use hydroxide precipitation first to remove most of the metals, and then organosulfide precipitation to remove the remaining low solubility metals. This configuration overall requires less organosulfide, therefore reducing costs.

The EPA's data demonstrate that well-operated systems maintain their chemical precipitation effluent concentrations because they actively monitor target metals, allowing them to adjust the operation of the chemical precipitation system as necessary. Some plants actively monitor the influent to the treatment system and adjust chemical addition in an equalization tank with a 24-hour holding time as the first step in the treatment system.

The EPA identified two facilities using chemical precipitation treatment systems for CRL. See Section 7.1.2 in the 2015 TDD for more specific chemical precipitation system design details (U.S. EPA, 2015a).

4.3.2 Biological Treatment

Some plants use the same biological wastewater treatment systems to treat both FGD wastewater and CRL, in some cases as a combined stream. Microorganisms consume biodegradable soluble organic contaminants and bind much of the less soluble fractions into floc. Pollutant concentrations may be reduced aerobically, anaerobically, and/or by using anoxic zones to remove metals and nutrients. The EPA identified two facilities using fixed-film bioreactors that reduce selenium and nitrate/nitrite to treat CRL. See Section 4.1.1 for more details on the LRTR system specific to FGD wastewater treatment, which can also be used to treat CRL.

4.3.3 Membrane Filtration

See Section 4.1.2 for a description of membrane treatment technologies, which can also be used to treat CRL from landfills and surface impoundments containing combustion residuals. There are three treatment technology vendors with full-scale domestic and foreign installations treating non-CCR landfill leachate using membrane filtration that discharge the permeate (U.S. EPA, 2022a, 2024e). One membrane filtration vendor has conducted a domestic pilot study on FA leachate (U.S. EPA, 2024e).

4.3.4 Spray Evaporation

See Section 4.1.3 for a description of spray evaporation treatment technologies that can also be used to treat CRL. There are two domestic installations by one technology vendor operating membrane filtration followed by spray evaporation at municipal landfills; this vendor also conducted a domestic pilot study treating CCR leachate with membrane filtration followed by spray evaporation. See the EPA's *Technologies for the Treatment of Flue Gas Desulfurization Wastewater, Coal Combustion Residual Leachate, and Pond Dewatering—2024 Final Rule* memorandum for more information (U.S. EPA, 2024e).

4.3.5 Other Thermal Treatment Options

See Section 4.1.4 for a description of other thermal treatment technologies that can also be used to treat CRL from landfills and surface impoundments containing combustion residuals. One technology vendor operates these systems at municipal landfills, and a second vendor has conducted a foreign pilot study on municipal landfill leachate that included membrane filtration followed by a combined brine concentrator and crystallizer (U.S. EPA, 2024e).

4.3.6 Management Strategies and Reuse

In promulgating the 2015 rule, the EPA also identified steam electric power plants using other types of management strategies for CRL from landfills and surface impoundments (U.S. EPA, 2015a):

- As of 2009, 24 plants collect combustion residual landfill or surface impoundment CRL and use it as water for moisture conditioning dry FA prior to disposal or dust control around dry unloading areas and landfills.
- As of 2009, the EPA identified five plants that use collected CRL from landfills or surface impoundments as truck wash and route it back to surface impoundments.
- As of 2009, approximately 40 percent of plants collect CRL from surface impoundments and recycle it directly back to the surface impoundments from which it was collected.

4.4 Legacy Wastewater Treatment Technologies and Management Practices

Legacy wastewater can be comprised of FGD wastewater, BA transport water, FA transport water, CRL, gasification wastewater and/or FGMC wastewater generated before the "as soon as possible" date that more stringent effluent limitations from the 2015 or 2020 rules would apply. Discharges of legacy wastewater may occur through an intermediary source (*e.g.,* a tank or surface impoundment) or directly into a surface waterbody, with the vast majority of legacy wastewater currently contained in surface impoundments. The EPA determined that the technologies described in the following subsections, which can also treat FGD wastewater, can be applied to treat this type of legacy wastewater.

The EPA recognizes that the characterization of legacy wastewater may differ within the layers of a CCR surface impoundment as it is dewatered and prepared for closure. Therefore, treatment requirements may change as closure continues. Wastewater characteristics may also differ across CCR surface impoundments due to different types of fuels burned at the plant, duration of impoundment operation, and ash type. The list of treatment technologies identified for legacy wastewater above are all applicable to all legacy wastewaters; however, treatment may require a combination of those technologies (*e.g.,* chemical precipitation and membrane filtration).

In addition, solids dewatering is necessary to dredge CCR materials from the surface impoundment. Mobile dewatering systems are typically self-contained units on a trailer, allowing for the entire system to be easily moved on site and off site. Legacy wastewater from a holding area (*e.g.,* pit, pond, collection tank) is pumped through a filter press to generate a filter cake and wastewater stream. A shaker screen can be added to the treatment train to remove larger particles prior to the filter press. Furthermore, the filter press can be equipped with automated plate shifters to allow solids to drop from the end of the trailer directly into a loader or truck. The resulting wastestream may be further treated to meet any discharge requirements.

4.4.1 Chemical Precipitation

See Section 4.3.1 for a description of chemical precipitation technologies that can also be used to treat this type of legacy wastewater.

4.4.2 Biological Treatment

See Sections 4.1.1 and 4.3.2 for descriptions of biological treatment technologies that can also be used to treat this type of legacy wastewater. Furthermore, Section 7.1.3 of the 2015 TDD and Section 4.1.1 of the 2020 Supplemental TDD include additional biological treatment system design details (U.S. EPA, 2015a; U.S. EPA, 2020).

4.4.3 Zero Valent Iron

Zero valent iron (ZVI), in combination with other systems such as chemical and physical treatment, can be used to target specific inorganics, including selenium, arsenic, nitrate, and mercury, in this type of legacy wastewater.

The technology entails mixing influent wastewater with ZVI (iron in its elemental form), which reacts with oxyanions, metal cations, and some organic molecules in wastewater. ZVI causes a reduction reaction of these pollutants, after which the pollutants are immobilized through surface adsorption onto iron oxide coated on the ZVI or generated from oxidation of elemental iron. The coated, or spent, ZVI, is separated from the wastewater with a clarifier. The quantity of ZVI required and the number of reaction vessels can be varied based on the composition and amount of wastewater being treated.

Treatment configurations may include chemical precipitation followed by ZVI treatment and may also include pretreatment to partially reduce influent nitrate concentrations. The purpose of the nitrate pretreatment is to reduce the consumption rate of the ZVI media, which reacts with both the nitrates and selenium in the wastewater.

The EPA identified two full-scale installations of the ZVI technology for selenium removal in mining wastewater and seven completed pilot-scale studies of ZVI used for FGD wastewater treatment.[25] In addition to the seven FGD pilots of ZVI, the EPA observed ZVI technology used to treat ash transport water during surface impoundment dewatering at a plant. In this application, the surface impoundment water was first treated by RO membrane filtration, and the membrane reject stream was sent to ZVI reactors for treatment. The membrane permeate and ZVI effluent streams were both discharged by the plant to surface waters. Although this application was not treating FGD wastewater, many of the pollutants present in FGD wastewater are also present in ash surface impoundments, and these pollutants were effectively removed by the ZVI process (ERG, 2019a). A similar treatment train has been suggested for FGD wastewater: chemical precipitation followed by RO membrane filtration, with the membrane reject stream sent to a ZVI stage consisting of three reactors in series. As with the treatment

[25] The EPA has limited data on the performance and configuration of the two full-scale ZVI systems treating mining wastewater (Butler, 2010). At least one of the systems includes ZVI in combination with an RO membrane system to target selenium removal.

system for the surface impoundment, the RO permeate and ZVI effluent would be discharged (unless the RO permeate was reused within the plant).

At least four additional pilot-scale studies for FGD wastewater treatment were in the planning stage at plants in the eastern United States, as of 2016. The data from a subset of these pilot tests indicate that the combination of chemical precipitation and ZVI technology, along with nitrate pretreatment where warranted, can produce effluent quality comparable to chemical precipitation followed by low residence time reduction (CP+LRTR), and chemical precipitation followed by high residence time reduction (CP+HRTR) technologies.

4.4.4 Membrane Filtration

See Section 4.1.2 for a description of membrane treatment technologies that can also be used to treat this type of legacy wastewater.

4.4.5 Thermal Treatment

See Sections 4.1.3 and 4.1.4 for a description of thermal treatment technologies, including spray evaporation, that can also be used to treat this type of legacy wastewater.

4.4.6 Encapsulation

See Section 4.1.5 for a description of encapsulation technologies that can also be used to treat this type of legacy wastewater.

4.4.7 Other Emerging Technologies

See Section 4.1.6 of the 2020 Supplemental TDD for descriptions of emerging technologies for FGD wastewater treatment that can also be applied to treat this type of legacy wastewater (U.S. EPA, 2020). These emerging technologies include electrodialysis reversal and RO technology, closed-loop mechanical vapor recompression, and distillation-based thermal transfer systems.

5. Engineering Costs

For the 2024 final rule, the U.S. Environmental Protection Agency (EPA) estimated compliance costs for flue gas desulfurization (FGD) wastewater; bottom ash (BA) transport water; combustion residual leachate (CRL) from landfills and surface impoundments; and legacy wastewater. These estimates further develop the estimated costs from the 2015 and 2020 rules. Section 9 of the 2015 TDD presents the EPA's methodology for estimating compliance costs for FGD wastewater, BA transport water, and CRL. Section 5 of the 2020 Supplemental TDD describes the EPA's cost estimates for FGD wastewater and BA transport water. Here, the EPA is presenting cost estimates for baseline compliance, post-compliance, and incremental costs, defined as follows:

- *Baseline compliance costs.* The EPA based its analysis on a modeled baseline that reflects the full implementation of the 2020 rule, the expected effects of announced retirements and fuel conversions, and the impacts of relevant final rules affecting the power sector. As such, the baseline appropriately includes the costs of achieving the 2020 rule limitations and standards, and the policy cases show the impacts resulting from changes to the existing 2020 limitations and standards. For more information, see the *Regulatory Impact Analysis for Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (RIA) (U.S. EPA, 2024g). For FGD wastewater and BA transport water, the baseline compliance costs anticipate that plants will have met the requirements of the 2020 rule; for CRL and legacy wastewater, baseline compliance costs consider current treatment in place.
- *Post-compliance costs*. Post-compliance costs are costs for plants to comply with effluent limitations based on the technologies considered in the 2024 rule technology options. The EPA estimated post-compliance costs with the expectation that all steam electric power plants subject to the requirements of the 2024 rule will install and operate wastewater treatment and pollution prevention technologies equivalent to the technology bases for the regulatory options.
- *Incremental costs*. Incremental costs reflect the difference between the baseline compliance costs and 2024 rule post-compliance costs for each regulatory option.

The EPA's compliance cost estimates include the following components:

- *Capital costs (one-time costs).* Capital costs comprise the direct and indirect costs associated with purchasing, delivering, and installing pollution control technologies. Capital cost elements include purchased equipment and freight, equipment installation, buildings, site preparation, engineering costs, construction expenses, contractor's fees, and contingencies.
- *Annual operation and maintenance (O&M) costs (incurred every year).* Annual O&M costs comprise all costs related to operating and maintaining the pollution control technologies for a period of one year. O&M cost elements include costs associated with operating labor, maintenance labor, maintenance materials (routine replacement of equipment due to wear and tear), chemical purchases, energy requirements, residuals disposal, and compliance monitoring.
- *Other one-time or recurring costs.* In some cases, the technology options may also result in costs that recur less often than annually (*e.g.,* three-year recurring costs for equipment replacement) or one-time costs other than capital investment (*e.g.,* one-time cost to consult with an engineer).

The EPA updated its industry profile as follows:

- The EPA began by updating its profile to reflect retirements of electric generating units (EGUs) that will occur by December 31, 2028, for the FGD wastewater and BA transport water populations.
- The EPA also removed any EGUs that will have converted to a non-coal fuel source by December 31, 2028, for FGD wastewater and BA transport water populations.

- Through August 2023, the EPA incorporated notices of planned participation (NOPPs) for any plants that opted into the Voluntary Incentives Program (VIP) for FGD wastewater.
- For CRL, the EPA removed plants that retired all coal-fired EGUs by December 31, 2023. The EPA did not remove EGUs that converted to different fossil fuel sources (*e.g.,* gas-fired) from the CRL population. These EGUs, which previously burned coal and generated coal combustion residuals (CCRs) that were disposed of in landfills and surface impoundments, remained in the population because the corresponding plant is still operating. The EPA updated its industry profile to include plants operating coal-fired EGUs or refueled EGUs that have an open or closed (retired) waste management unit (*i.e.,* landfill or surface impoundment) that discharges CRL.[26] Based on the applicability of 40 CFR 423, these plants and CRL are still subject to the guidelines. See Section 5.3.1 for details on how the EPA developed the CRL population.
- The EPA incorporated retired and operating plants with surface impoundments that are open (*i.e.,* have not initiated the closure process under the CCR regulations) using information from the Office of Land and Emergency Management (OLEM) and power company CCR websites, as described in Section 2.5.

The remainder of this section describes the EPA's methodology for estimating baseline compliance costs, post-compliance costs, and incremental costs by wastestream, as well as industry-level compliance costs for the 2024 rule.

5.1 FGD Wastewater

For the 2024 final rule, the EPA estimated costs for plants to install and operate four technologies: chemical precipitation followed by low residence time reduction (CP+LRTR), membrane filtration, spray dryer evaporator (SDE), and thermal evaporation.

For CP+LRTR, the EPA included the following treatment components for FGD wastewater, consistent with the 2020 rule methodology:

- CP treatment equipment (equalization and storage tanks, pumps, reaction tanks, solids-contact clarifier, and gravity sand filter).
- CP chemical feed systems (lime, organosulfide, ferric chloride, and polymers).
- LRTR treatment equipment (anoxic/anaerobic bioreactor, flow control, backwash supply, and storage tanks).
- LRTR chemical feed system for nutrients.
- Pretreatment system for nitrate/nitrite (for plants with nitrate/nitrite concentrations above 50 milligrams per liter [mg/L]).
- Heat exchanger.
- Ultrafilter.
- Compliance monitoring (including sample collection and analysis).
- Solids handling (sludge holding tank and filter press).
- Transportation and disposal of solids in a landfill.

[26] For a new subcategory of CRL, the EPA identified potential discharges of unmanaged CRL, which the EPA is defining in this rule to mean the following: (1) discharges of CRL that the permitting authority determines are the functional equivalent of a direct discharge to Waters of the United States (WOTUS) through groundwater, or (2) discharges of CRL that has leached from a waste management unit into the subsurface and mixed with groundwater prior to being captured and pumped to the surface for discharge directly to a WOTUS.

For membrane filtration, the EPA included the following FGD wastewater treatment components, consistent with the 2020 rule methodology:

- CP treatment equipment (equalization and storage tanks, pumps, reaction tanks, solids-contact clarifier, and gravity sand filter).
- CP chemical feed systems (lime, organosulfide, ferric chloride, and polymers).
- Membrane filtration treatment equipment (membrane filtration, reverse osmosis [RO], and storage tanks).
- Additional fly ash (FA) purchase (if plant was identified as having an FA deficit).[27]
- Brine encapsulation.
- Transportation and disposal of solids in a landfill.

For SDE, the EPA included the following FGD wastewater treatment components:

- Pretreatment using membrane filtration (for flows greater than 150 gallons per minute [GPM] only) (includes membrane filtration, RO, and storage tanks).
- SDE equipment.
- Transportation and disposal of solids in a landfill.

For thermal evaporation treatment of FGD wastewater, the EPA included the following treatment components:

- Membrane filtration treatment equipment (for preconcentration, as needed).
- Brine concentration and encapsulation or crystallization equipment.
- Transportation and disposal of solids in a landfill.

Section 5.1.1 describes the cost inputs and the methodology for updating the FGD wastewater flow rates from the 2020 rule. Sections 5.1.2, 5.1.3, 5.1.4, and 5.1.5 present the EPA's methodology for estimating costs for LRTR, membrane filtration, SDE, and thermal evaporation, respectively. Section 5.1.6 presents the EPA's methodology for determining the least cost zero-discharge technology option for FGD wastewater.

5.1.1 FGD Cost Calculation Inputs

To estimate plant-level baseline and post-compliance costs of implementing FGD wastewater treatment technologies, the EPA developed cost calculation databases. These databases combine plant-specific input values, including wastewater flow rates and baseline treatment technology, with the relationships between costs and FGD flow rates described in Sections 5.1.2, 5.1.3, and 5.1.4 to estimate baseline and post-compliance costs for each plant (ERG, 2024, 2024a). For the 2024 final rule, the EPA used input data compiled from the 2015 and 2020 rules—including Steam Electric Survey data, site visits, sampling episodes, and other industry-provided data—and updated these data using new information gathered from industry (see Section 2). This section describes the updates to cost inputs from the 2020 rule.

Population

The EPA identified coal-fired power plants that discharge FGD wastewater to surface water or a publicly owned treatment works (POTW) and that are not expected to retire or convert fuel sources by December 31, 2028. The EPA started with the population of plants from the 2020 rule and updated the population based on industry-provided data and new publicly available data on operational changes. The EPA also

[27] Refer to the *2024 Steam Electric Supplemental Final Rule: Fly Ash Analysis* memorandum for more information (U.S. EPA, 2024h).

compiled a list of the EGUs at these plants that discharge FGD wastewater, keeping in mind that some plants retire or convert individual EGUs and not the entire plant.

Flow Rate

For each plant, the EPA estimated two FGD wastewater flow rates: the FGD purge flow rate (the typical amount of wastewater from the FGD scrubber that is sent to FGD wastewater treatment) and the FGD optimized flow rate (a rate that considers a reduction in FGD wastewater purged from the system, where equipment metallurgy is able to accommodate increased chloride concentration in the FGD system). As in the 2020 rule, the EPA used the FGD purge flow rate to calculate capital costs to ensure that the installed treatment technologies would be able to accommodate the maximum possible FGD flow. The EPA also concluded that plants would optimize the FGD purge flow rate to reduce the flow that must be treated, and thereby reduce overall O&M compliance costs. As flows are recycled through the FGD system, chloride concentrations increase; therefore, when calculating an optimized flow rate, the EPA considered plant-specific constraints such as maximum design chloride concentrations and operating chloride concentrations for the FGD systems.

For the 2024 rule, the EPA largely used plant-specific FGD wastewater flows consistent with the 2020 rule (U.S. EPA, 2020). The EPA identified some facilities where changes to plant operations warranted updates to FGD wastewater flow rates. At plants where some, but not all, EGUs were designated for retirement or fuel conversion before December 31, 2028, the EPA adjusted FGD wastewater flow rates (purge and optimized) to remove flow for these EGUs. The EPA also incorporated any flow rate updates received in the 2023 proposed rule public comments. Refer to the *Flue Gas Desulfurization Flow Methodology for Compliance Costs and Pollutant Loadings – 2024 Final Rule* memorandum for a summary of these updates (U.S. EPA, 2024i).

Baseline Treatment Technology

For this cost analysis, the EPA assumed that plants subject to the FGD wastewater discharge requirements in the 2020 rule would install the treatment technology basis defined for the 2020 rule. If a plant opted into the 2020 rule VIP, then the EPA assumed membrane filtration as the baseline treatment technology. For all other FGD wastewater discharges, the EPA assumed CP+LRTR baseline treatment technology. Table 8 outlines the baseline scenarios for the plants included in the EPA's 2024 analyses and the corresponding estimated compliance costs.

Table 8. 2024 Rule FGD Wastewater Technology Bases

2024 Technology Option Evaluated	2020 Rule Subcategory [a]	2024 Baseline Treatment Technology	Estimated Incremental Capital Compliance Cost	Estimated Incremental O&M Compliance Cost
Zero discharge	VIP	Membrane filtration	Costs are equal to zero	Costs are equal to zero
	All other FGD wastewater discharges	CP+LRTR	Costs for membrane filtration (no CP costs) or SDE	Costs for membrane filtration (no CP costs) or SDE, minus LRTR [b]

a—The EPA did not evaluate costs associated with the 2020 rule FGD high-flow subcategory because the one applicable plant is scheduled to retire its coal-fired EGUs by December 31, 2028.

b—The EPA estimated O&M costs as the incremental costs between operating and maintaining an LRTR system (see Section 5.1.2) and operating and maintaining a membrane filtration system (see Section 5.1.3) or SDE system (see Section 5.1.4). For the zero-discharge technology option, the EPA assumed plants will stop operating the LRTR portion of the system. The EPA also assumed that plants installing membrane filtration specifically will continue operating the CP portion as pretreatment.

Landfill Data

The EPA used data from the Steam Electric Survey and public permit data to determine if each plant in the FGD wastewater population has a lined CCR landfill (active or inactive) for disposal of treatment residuals. For the 2024 final rule, the EPA updated this information to match the population used for CRL costs (see Section 0 for more information). Plants identified as having a landfill incurred compliance costs for on-site transportation and disposal of treatment residuals; all other plants incurred compliance costs for off-site transportation and disposal.

5.1.2 Cost Methodology for LRTR

As described in the RIA, the EPA's baseline appropriately includes the costs of achieving the 2020 rule limitations and standards, and the policy cases show the impacts resulting from changes to the existing 2020 limitations and standards. Therefore, the EPA assumed that plants have come into compliance with the 2020 rule, and all plants in the 2024 final rule analysis are assumed to have installed CP+LRTR, membrane filtration, or equivalent treatment. Since both technology bases include CP, the EPA did not estimate additional compliance costs for CP treatment. Further, since the EPA assumes that all plants that did not opt into the 2020 rule VIP have installed LRTR, no plants will incur incremental capital costs to install this technology. The EPA incorporated LRTR O&M as a cost savings for the zero-discharge technology option for non-VIP plants.

The EPA updated the LRTR O&M cost curves by adjusting the cost indexing values to 2023 dollars using data from the RSMeans Historical Cost Index (RSMeans, 2023). The 2021 cost index value was 238.3, and the 2023 cost index value was 318.8. The EPA multiplied the cost curve components by the ratio of these indexes (the 2023 index divided by the 2021 index equals 1.338), resulting in the equations presented below. To determine plant-specific nitrate/nitrite concentrations and consequently which LRTR cost curve to use, the EPA used sampling data from the 2015 rule analytical database (ERG, 2015, 2015a) and the Steam Electric Survey (U.S. EPA, 2015). Plants with nitrate/nitrite concentrations above 50 mg/L in untreated FGD wastewater require nitrate/nitrite pretreatment and are considered "high nitrates."

The resulting adjusted cost curves are as follows:

$$\text{LRTR O\&M cost – low nitrates (2023\$/year)} = 1.08 \times \text{FGD flow (gallons per day [GPD])} + 479{,}404$$

$$\text{LRTR O\&M cost – high nitrates (2023\$/year)} = 1.61 \times \text{FGD flow (GPD)} + 506{,}970$$

Similar to the 2020 and 2015 rules, the EPA estimated compliance monitoring costs to account for sampling labor and materials as well as the costs associated with sample preservation, shipping, and analysis for the pollutants selected for regulation (arsenic, mercury, nitrate/nitrite, and selenium for CP+LRTR). The EPA also updated the compliance monitoring cost to 2023 dollars, resulting in an amount of $110,968 for each plant.

The EPA estimated LRTR plant-level O&M cost savings as follows:

- For plants opting in to the 2020 rule VIP, the EPA estimated zero cost savings.
- For one plant that installed a CP system capable of meeting the 2020 rule's best available technology economically achievable (BAT) limitations, the EPA estimated LRTR O&M cost savings as compliance monitoring only ($110,968).
- For all other plants, the EPA estimated LRTR O&M cost savings using the LRTR O&M cost equations described above with the plant-specific FGD optimized flow rate.

5.1.3 Cost Methodology for Membrane Filtration

As with the LRTR cost methodology, the EPA did not estimate additional costs for CP pretreatment for the membrane filtration cost methodology, as plants are assumed to have come into compliance with the

2020 rule and already have this treatment in place. The EPA updated the membrane filtration cost curves by escalating them to 2023 dollars using the method described in Section 5.1.2.

The resulting curves are as follows:

membrane filtration capital cost with on-site transport/disposal (2023$) =
57.2 × FGD flow (GPD) + 2,388,069

membrane filtration O&M cost with on-site transport/disposal (2023$/year) =
8.41 × FGD flow (GPD) + 681,426

membrane filtration capital cost with off-site transport/disposal (2023$) =
52.8 × FGD flow (GPD) + 2,438,706

membrane filtration O&M cost with off-site transport/disposal (2023$/year) =
16.9 × FGD flow (GPD) + 681,825

In addition, plants that indirectly discharge receive an O&M cost savings for no longer paying annual fees for a POTW to accept and treat their FGD wastewater. The EPA identified one plant in the FGD wastewater population as an indirect discharger and assigned this plant $1.5M in O&M cost savings, the cited discharge fees in the utility's comment letter (EPA-HQ-2009-0819-10083-A1).

The EPA used the following equations to estimate the amount of brine and lime or other fillers to be disposed of, based on the EPA's *2024 Steam Electric Supplemental Final Rule: Fly Ash Analysis* (U.S. EPA, 2024h):

brine (tons) = brine flow (GPD) × density of brine (lb/gal) × 365 (days/year) × 0.0005 (ton/lb)

Where:

brine flow	=	FGD optimized flow (GPD) times brine production rate, 30%.
density of brine	=	8.84 pounds per gallon (lb/gal).

lime or other fillers (tons) = brine (tons) × ratio of lime or other fillers to brine

Where:

ratio of lime or other fillers to brine	=	Ratio by mass percentage of lime or other fillers to brine in encapsulation recipe, 0.28.

The EPA then summed the total solids for disposal as the following:

solids for disposal (tons) = brine (tons) + lime or other fillers (tons)

To estimate compliance costs for transporting and disposing of these solids, the EPA used equations from the 2015 rule and escalated them to 2023 dollars. For the on-site transportation capital cost and on-site disposal O&M cost equations, the EPA used RSMeans indexes to escalate from 2009 dollars with a ratio of 1.747; for all other transportation and disposal cost equations, the EPA used RSMeans indexes to escalate from 2011 dollars with a ratio of 1.717 (RSMeans, 2023). Because the membrane filtration capital and O&M cost curves already include transportation and disposal costs, the EPA subtracted out a percentage of transportation and disposal costs to avoid double counting. To protect confidential business information (CBI), the EPA estimated this amount as 25 percent.

The resulting equations are as follows:

transportation capital cost (on-site) (2023$) = $50.40 × solids for disposal (tons) × 0.75

transportation O&M cost (on-site) (2023$/year) = $5.59 × solids for disposal (tons) × 0.75

disposal O&M cost (on-site) (2023$/year) = $14.04 × solids for disposal (tons) × 0.75

transportation O&M cost (off-site) (2023$/year) = $15.85 × solids for disposal (tons) × 0.75

disposal O&M cost (off-site) (2023$/year) = $70.37 × solids for disposal (tons) × 0.75

For any plants with an FA deficit, as described in the *2024 Steam Electric Supplemental Final Rule: Fly Ash Analysis* (U.S. EPA, 2024h), the EPA supplemented the membrane filtration costs with the cost to purchase additional FA on an annual basis using the deficit of ash in tons: $35.49/ton. For plants with this FA deficit, the EPA also supplemented the transportation and disposal costs for brine and lime or other fillers with the cost to transport and dispose of this additional FA, using the equations described above with a factor of 1 (instead of 0.75).

In the 2024 final rule, the EPA is providing one year of flexibility to allow for membrane filtration permeate discharge as long as the plant reports monitoring data to a publicly available website. Refer to the *Membrane Monitoring Cost Methodology* and the *Membrane Recordkeeping and Reporting Cost Methodology* for additional information (U.S. EPA, 2024j, 2024k). The one-time plant-level cost would apply during the first year of membrane filtration operation, for a total of $152,374.

The EPA estimated plant-level membrane filtration costs as follows:

- For plants opting in to the 2020 rule VIP, the EPA estimated zero capital, zero O&M, and zero one-time costs.
- For all other plants with FGD wastewater discharges, the EPA estimated plant-specific capital, O&M, and one-time costs.
    - The EPA estimated capital costs for membrane filtration using the capital cost equations described above and the FGD purge flow rate. The EPA also estimated transportation capital costs (on-site only) using the FGD purge flow rate and summed this with the membrane filtration capital cost (where applicable).
    - The EPA estimated O&M costs as the difference between LRTR O&M costs and membrane filtration O&M costs, using the FGD optimized flow rate. All plants are assumed to be currently operating LRTR systems that they will replace with membrane systems for this technology option. To estimate this difference, the EPA estimated LRTR O&M costs using the equations in Section 5.1.2 and estimated membrane O&M costs using the equations discussed in this section (including transportation and disposal O&M costs and FA purchase O&M costs). O&M costs for the membrane filtration technology option were calculated as the difference between LRTR and membrane filtration values. The EPA also accounted for O&M cost savings for the one indirect discharger identified.
    - The EPA estimated the same one-time cost for all plants for monitoring and recordkeeping ($152,374).

5.1.4 Cost Methodology for SDE

The EPA identified several vendors using a similar type of technology to evaporate wastewater by spraying fine misted wastewater into hot gases. The EPA solicited information including costs, performance data, and treatment system configuration details from Heartland, General Electric, Mitsubishi, and Ljungström. Using data from each vendor, the EPA developed separate relationships for capital costs (*e.g.,* purchased equipment and freight, equipment installation, buildings, site preparation, engineering costs, construction expenses, contractor's fees, and contingency) and O&M costs (*e.g.,* operating labor, maintenance labor, maintenance materials, chemical purchases, energy requirements, and residuals disposal). The EPA developed comparable costs for the technologies for all vendors by evaluating the cost data provided by each vendor and augmenting those data with costs for missing components. See the *Spray Dryer Evaporator Cost Methodology* for a summary of the vendor-specific data (U.S. EPA, 2022b).

Based on feedback from SDE vendors, it is generally more cost effective to implement volume reduction (i.e., membrane filtration pretreatment) on wastewater streams above 200 GPM. As well, some vendors noted that some costs were only valid up to 150 GPM; therefore, the EPA estimated costs for spray evaporation only for small wastewater flows (≤ 150 GPM) and costs for volume reduction followed by spray evaporation for larger flows (>150 GPM). For each vendor, the EPA estimated both capital and O&M costs of an SDE treatment system over a range of FGD wastewater flows, from 0.69 GPM to 1,000 GPM. Consistent with feedback from vendors, the SDE treatment system for flows from 0.69 GPM to 150 GPM included only SDE and solids handling, while the SDE treatment system for flows from greater than 150 GPM to 1,000 GPM included preconcentration using membrane filtration followed by spray evaporation treatment of the brine.

Based on values from all four vendors at various flows within the range, the EPA calculated the average cost for capital and O&M costs. See Section 3 of the *Spray Dryer Evaporator Cost Methodology* for a summary of average costs by flow (U.S. EPA, 2022b). The EPA used the line of best fit derived from these average cost data points to develop capital and O&M cost equations based on wastewater flow (refer to Section 4 of the *Spray Dryer Evaporator Cost Methodology*). The EPA then escalated these cost equations from 2021 to 2023 dollars using a factor of 1.338.

The resulting equations are as follows:

Capital and O&M costs assuming on-site solids management for flows up to 150 GPM:

spray evaporation with on-site solids management – capital costs (2023$) = 128 × flow (GPD) + 14,717,560

spray evaporation with on-site solids management – O&M costs (2023$/year) = 12.1 × flow (GPD) + 144,207

Capital and O&M costs assuming off-site solids management for flows up to 150 GPM:

spray evaporation with off-site solids management – capital costs (2023$) = 124 × flow (GPD) + 14,717,560

spray evaporation with off-site solids management – O&M costs (2023$/year) = 18.1 × flow (GPD) + 144,207

Capital and O&M costs assuming on-site solids management for flows between 150 and 1,000 GPM:

membrane filtration followed by spray evaporation with on-site solids management – capital costs (2023$) = 77.2 × flow (GPD) + 18,411,536

membrane filtration followed by spray evaporation with on-site solids management – O&M costs (2023$/year) = 10.2 × flow (GPD) + 843,692

Capital and O&M costs assuming off-site solids management for flows between 150 and 1,000 GPM:

membrane filtration followed by spray evaporation with off-site solids management – capital costs (2023$) = 69.4 × flow (GPD) + 18,462,172

membrane filtration followed by spray evaporation with off-site solids management – O&M costs (2023$/year) = 19.5 × flow (GPD) + 844,091

The EPA estimated plant-level SDE costs as follows:

- For plants opting in to the 2020 rule VIP, the EPA estimated zero capital and zero O&M costs.
- For all other plants with FGD wastewater discharges, the EPA estimated plant-specific capital and O&M costs.
  - The EPA estimated capital costs for SDE using the FGD purge flow rate. Where a plant-level purge flow was greater than 1,000 GPM, the EPA estimated costs for a separate SDE system at each EGU at the plant, using the unit-level purge flow rate along with the corresponding cost equation, and then summed the unit-level costs to the plant level.
  - The EPA estimated O&M costs as the difference between LRTR O&M costs and SDE O&M costs, using the FGD optimized flow rate. All plants are assumed to be currently operating LRTR systems that they will replace with SDE systems for this technology option. To estimate this difference, the EPA estimated LRTR O&M costs using the equations in Section 5.1.2 and estimated SDE O&M costs using the equations discussed in this section. O&M costs for the SDE technology option were calculated as the difference between LRTR and SDE values. Where the plant-level purge flow was greater than 1,000 GPM, the EPA also estimated costs for separate SDE systems at each EGU at the plant, using the unit-level optimized flow rate along with the corresponding cost equation, and then summed the unit-level costs to the plant level.

5.1.5 Cost Methodology for Thermal Evaporation

As described in the *Flue Gas Desulfurization and Combustion Residual Leachate Thermal Evaporation Cost Methodology* memorandum, the EPA estimated plant-level thermal evaporation costs using average costs from two technology vendors (U.S. EPA, 2024l).

The resulting cost equations are as follows:

thermal evaporation capital cost (2023$) = (Vendor 1 capital cost + Vendor 2 capital cost) ÷ 2

thermal evaporation O&M cost (2023$/year) = (Vendor 1 O&M cost + Vendor 2 O&M cost) ÷ 2

The EPA estimated plant-level thermal evaporation costs as follows:

- For plants opting in to the 2020 rule VIP, the EPA estimated zero capital and zero O&M costs.
- For all other plants with FGD wastewater discharges, the EPA estimated plant-specific capital and O&M costs.
  - The EPA estimated capital costs for thermal evaporation using the FGD purge flow rate.
  - The EPA estimated O&M costs as the difference between LRTR O&M costs and thermal evaporation O&M costs, using the FGD optimized flow rate. All plants are assumed to be currently operating LRTR systems that they will replace with thermal evaporation systems for this technology option. To estimate this difference, the EPA estimated LRTR O&M costs using the equations in Section 5.1.2 and estimated thermal evaporation O&M costs using the equations discussed in this section. O&M costs for the thermal evaporation technology option were calculated as the difference between LRTR and thermal evaporation values.

5.1.6 Cost Methodology for Zero Discharge

To estimate zero-discharge costs for FGD wastewater, the EPA compared the costs for membrane filtration (see Section 5.1.3) and SDE (see Section 5.1.4) for each plant and selected the least cost technology. Refer to the Least-Cost Technology by Plant (U.S. EPA, 2024m). The EPA did not consider thermal evaporation costs in its least cost option assessment because some of the costs are being treated as CBI, pursuant to claims made by technology vendors.

5.2 BA Transport Water

The EPA estimated BA transport water costs for wastewater treatment and pollutant prevention technologies that are equivalent to the technology bases defined by the final regulatory options. The BA transport water technology options considered as part of the rule include high recycle rate (HRR) and zero discharge. For the HRR option, the EPA estimated costs for mechanical drag system (MDS) installations and remote MDS installations with a purge. For the zero-discharge option, the EPA estimated costs for MDS installations and closed-loop remote MDS installations. (A closed-loop remote MDS installation includes an RO system to allow complete recycle, along with return pumps, pipes, and surge tank capacity.)

For MDS installations, the EPA included costs to replace the existing boiler hopper and associated equipment, and to install and operate a semi-dry silo for temporary storage of the BA.

For remote MDS installations, the EPA included costs to install and operate the following, consistent with the 2020 rule methodology:

- Remote MDS (away from the boiler).
- Sump.
- Recycle pumps.
- Chemical feed system.[28]
- Semi-dry silo.

For both technology options considered, the EPA also included the capital and O&M costs of transporting all BA and disposing of it in a landfill.

Section 5.2.1 describes the cost inputs for the 2024 final rule. Sections 5.2.2 and 5.2.3 present the EPA's methodology for estimating costs for HRR and zero discharge, respectively.

5.2.1 BA Transport Water Cost Calculation Inputs

To estimate plant-level baseline and post-compliance costs of implementing BA transport water technologies, the EPA developed a cost calculation database. This database combines plant-specific input values (including details on BA production, current BA handling systems, and the use of on-site and off-site landfills) with the relationships between costs and EGU capacity or BA generation described in Sections 5.2.2 and 5.2.3 to estimate baseline and post-compliance costs for each plant (ERG, 2024b). For the 2024 final rule, the EPA used input data compiled from the 2015 and 2020 rules—including Steam Electric Survey data, site visits, sampling episodes, and other industry-provided data—and updated these data based on new information gathered from industry and information available from the Department of Energy and National Pollutant Discharge Elimination System permits (see Section 2). This section describes the updates to cost inputs from the 2020 rule.

Population

The EPA identified coal-fired power plants that operate wet BA handling systems and discharge BA transport water to surface water or a POTW, and that are not expected to retire or convert fuel sources

[28] The EPA included costs for a chemical feed system to control pH of the recirculating system to prevent scaling within the system. Information in the record indicates that few, if any, plants are likely to need chemical feed systems. However, because the EPA could not conclusively determine that none would, or which plants would be more likely to need chemical feed systems, the EPA estimated this cost for all plants. This likely overestimates the compliance costs for most plants; however, the cost for chemical addition is relatively small in relation to other costs for the remote MDS.

by December 31, 2028. The EPA started with the population of EGUs from the 2020 rule and updated that population based on industry-provided data and new publicly available data on operational changes.

Production Data

For each applicable EGU, the EPA estimated the amount of wet BA produced in tons per year (TPY), the generating capacity in megawatts (MW), and the net generation in megawatt-hours (MWh). The EPA used BA production and capacity values reported in the Steam Electric Survey as input values for estimating compliance costs for the 2024 final rule.

Cost Type Flags

The EPA used data from the Steam Electric Survey, site visits, public comments, and other industry sources, discussed in Section 2, to identify the types of BA handling systems currently operating at each plant. For each type of BA handling system, the EPA determined the equipment or services needed to implement each technology option. The EPA categorized each EGU into the following cost categories:

- Steam electric EGUs equipped with only wet BA handling systems that discharge BA transport water.
- Steam electric EGUs equipped with only wet BA handling systems that discharge BA transport water and have space constraints preventing the installation of MDSs.
- Steam electric EGUs already operating remote MDSs.
- Steam electric EGUs equipped with only wet BA handling systems that recycle all their BA sluice but that can discharge BA transport water from emergency outfalls. The EPA defined these as BA management plants.
- Steam electric EGUs operating dry BA handling systems.

Flow Rate

The EPA used industry-submitted data, data from public comments, and data from the Steam Electric Survey (discussed in Section 2) to calculate BA transport water flow rates for baseline conditions and for each technology option evaluated for the 2024 final rule.

The EPA defined the baseline as plants complying with the 2020 rule. For baseline conditions, the EPA estimated BA transport water flow rates for the HRR technology option, which would allow plants to discharge a portion of their BA transport water. The EPA estimated BA transport water flow rates for three compliance approaches available to most plants:

- *Zero flow.* For a plant using a dry BA handling system to comply with baseline or a technology option (*e.g.,* under-boiler mechanical drag system), the discharge flow rate equals zero.
- *Purge flow*. For each plant using a recirculating BA handling system to comply with baseline or a technology option (*e.g.,* remote MDS operated with a purge instead of a completely closed loop), the EPA estimated a BA transport water purge flow rate. The EPA calculated BA transport water purge flow rates for remote MDS installations based on the relationship between the plant's generating capacity and the volume of the total wetted, active components of the remote MDS, consistent with the methodology described in Section 5.2.3. Where the EPA identified EGUs that were designated for retirement or fuel conversion, the EPA adjusted the plant generating capacity to account for changes.
- *Sluice flow*. For plants using a surface impoundment plus best management practice (BMP) plan to comply with baseline (per the 2020 rule), the EPA identified one plant in the low utilization subcategory for which the discharge flow rate equals the plant's BA sluice flow.

Baseline Treatment Technology

For this cost analysis, the EPA assumed that plants subject to the BA transport water discharge requirements in the 2020 rule would install the treatment technology basis defined for the 2020 rule and any applicable subcategories (*i.e.,* baseline). For baseline and regulatory options costs, the EPA accounted for updates to the industry profile, including retirements and NOPPs. Table 9 outlines the baseline scenarios for the plants included in the EPA's final rule analyses and the corresponding estimated compliance costs. Baseline assumptions for BA transport water account for the CCR Part A rule (40 CFR 257).

Table 9. 2024 Rule BA Transport Water Technology Bases

2024 Technology Option Evaluated	2020 Rule Subcategory	2024 Baseline Treatment Technology	Estimated Incremental Capital Compliance Cost	Estimated Incremental O&M Compliance Cost
HRR	All other BA discharges	Dry handling or HRR system	Costs are equal to zero	Costs are equal to zero
	Low utilization boilers: all EGUs have 24-month average utilization < 10%	Surface impoundment + BMP plan	Costs for MDS/remote MDS with purge	Costs for MDS/remote MDS with purge
Zero discharge	All other BA discharges	Dry handling or HRR system	Costs for RO	Costs for RO
	Low utilization boilers: all EGUs have 24-month average utilization < 10%	Surface impoundment + BMP plan	Costs for MDS/remote MDS with purge	Costs for MDS/remote MDS with purge

5.2.2 *Cost Methodology for HRR*

As described in the RIA, the EPA's baseline appropriately includes the costs of achieving the 2020 rule limitations and standards, and the policy cases show the impacts resulting from changes to the existing 2020 limitations and standards. Therefore, the EPA assumed that plants will have installed MDS or remote MDS in compliance with the 2020 rule and will incur zero costs to comply with HRR technology options, except for the one plant in the 2020 rule low utilization subcategory. For the remaining low utilization plant, the EPA compared the costs of installing an MDS and a remote MDS and chose the least cost option as the technology basis for HRR. The EPA calculated plant-specific MDS and remote MDS compliance costs for the 2024 rule EGU-level BA generation and/or EGU capacity using the on-site cost equations (based on the characteristics of the low utilization plant). The EPA updated the 2020 rule cost curves by escalating them to 2023 dollars as described in Section 5.1.2. The recurring expenses for MDS and remote MDS installations account for the cost of chain replacement, which may be needed every three years for MDS installations and every five years for remote MDS installations. To estimate plant-level costs, the EPA first calculated the capital and O&M costs at the EGU-level, using the following curves:

$$\text{EGU MDS capital cost (2023\$)} = (52{,}567 \times [\text{MW}]) + 7{,}291{,}365$$

$$\text{MDS annual O\&M cost (2023\$/year)} = (25.186 \times [\text{TPY}]) + 770{,}542$$

$$\text{MDS three-year recurring O\&M cost (2023\$)} = \$302{,}076$$

$$\text{EGU remote MDS capital cost (2023\$)} = [(38{,}518 \times [\text{MW}]) + 5{,}063{,}145] + \text{building cost}$$

$$\text{remote MDS annual O\&M cost (2023\$/year)} = (25.937 \times [\text{TPY}]) + 1{,}144{,}271$$

remote MDS five-year recurring O&M cost (2023$) = $302,076

The EPA added surface impoundment cost savings to the MDS and remote MDS capital and O&M EGU-level costs. Consistent with the 2020 rule methodology, the EPA used Steam Electric Survey data to identify plants with at least one impoundment that contains BA transport water and that has not been designated for retirement. Where the EPA had data indicating plants had installed dry or HRR BA handling systems since the 2020 rule, the EPA assumed these plants would opt to no longer operate impoundments for BA handling, resulting in surface impoundment cost savings. The EPA also assumed that plants whose impoundments are expected to close due to CCR Part A rule requirements would no longer use impoundments for BA handling, resulting in surface impoundment cost savings. The EPA estimated plant-level cost savings for no-longer-operating impoundments based on the total amount of BA solids currently handled wet at the plant. The EPA updated the 2020 rule BA impoundment O&M cost savings by escalating them to 2023 dollars as described in Section 5.1.2.

total BA impoundment O&M cost savings (2023$/year) =
BA impoundment operating cost savings + BA earthmoving cost savings

Where:

BA impoundment operating cost savings	=	Total impoundment operating cost savings.
BA earthmoving cost savings	=	O&M cost associated with the earthmoving equipment savings.

The EPA estimated the BA impoundment operating cost savings by first calculating the plant MW factor and the plant-specific unitized cost.

$$\text{plant MW factor} = 7.569 \times (\text{plant size})^{-0.32}$$

Where:

plant size	=	Plant size in MW (the plant nameplate capacity for only those EGUs in the BA costed population).

plant-specific unitized cost = impoundment operating unitized cost × plant MW factor

Where:

plant-specific unitized cost	=	Plant-specific cost to operate a front-end loader (in 2023$/ton).
impoundment operating unitized cost	=	2010 unitized annual cost to operate a combustion residual impoundment. The EPA used a unitized cost value of $10.78 per ton (in 2023$).
plant MW factor	=	Factor to adjust combustion residual handling costs based on plant capacity.

Next, the EPA calculated the BA impoundment operating cost savings by multiplying the plant-specific unitized cost by the amount of BA produced by the plant, in TPY.

BA impoundment operating cost savings (2023$/year) =
plant-specific unitized cost × plant BA tonnage

Where:

plant-specific unitized cost	=	Plant-specific cost to operate a front-end loader (in 2023$/ton).
plant BA tonnage	=	Total BA tonnage, dry basis, for each plant (in TPY). The EPA calculated this value by multiplying the wet BA generation rate (in TPD) by operating days (days per year) for each EGU, then summing the EGU-level values to the plant level.

To calculate BA earthmoving cost savings, the EPA first calculated the plant-specific front-end loader unitized cost by multiplying the plant MW factor by the front-end loader unitized cost.

plant-specific front-end loader unitized cost (2023$/ton) =
front-end loader 2010 unitized O&M cost × plant MW factor

Where:

front-end loader 2010 unitized O&M cost	=	2010 unitized cost value that represents the O&M of the front-end loader used to redistribute ash at an impoundment. The EPA calculated this value to be $3.65 per ton (in 2023$).
plant MW factor	=	Factor to adjust combustion residual handling costs based on plant capacity.

Next, the EPA calculated the BA earthmoving cost savings by multiplying the plant-specific unitized cost by the amount of BA produced by the plant in TPY.

BA impoundment earthmoving cost savings (2023$) =
plant-specific front-end loader unitized cost × plant BA tonnage

Where:

plant-specific front-end loader unitized cost	=	Plant-specific cost value that represents the O&M of the front-end loader used to redistribute ash at an impoundment.
plant BA tonnage	=	Total BA tonnage, dry basis, for each plant (in TPY). The EPA calculated this value by multiplying the wet BA generation rate (in TPD) by operating days (days per year) for each EGU, then summing the EGU-level values to the plant level.

The EPA calculated 10-year recurring costs associated with operating the earthmoving equipment (*i.e.,* front-end loader) using the estimated cost and average expected life of a front-end loader. The EPA determined the cost of the earthmoving equipment to be $695,760 (2023$) and assumed an expected life of 10 years.

The EPA then summed the MDS and remote MDS EGU-level costs to the plant level. The EPA also added a plant-level capital cost of $1,534,191 (2023$) to build a roof over the remote MDS to mitigate stormwater contributions to the system. This additional roof cost was applied at the plant level because a plant would likely use one roof to cover the entire fleet of remote MDS installations. O&M costs for the roof were assumed to be zero, as the structure is only intended to protect from stormwater and does not have heating, ventilation, or air conditioning (HVAC).

The EPA estimated HRR plant-level costs using the following assumptions:

- The EPA identified one plant, Merrimack Station (Plant ID 3095), that submitted a NOPP for the low utilization subcategory.[29] For this plant, estimated capital costs are equal to MDS or remote MDS with purge. The EPA estimated HRR O&M costs using equations in Section 5.2.2.
- For all other plants with BA discharges, the EPA estimated zero capital and zero O&M costs.

5.2.3 Cost Methodology for Zero Discharge

The EPA estimated costs to treat a BA transport water purge stream using a high-pressure RO system to remove dissolved solids and comply with a zero-discharge standard. The EPA assumed a daily purge rate equal to 2 percent of the total estimated BA transport system volume (*i.e.,* the plant-level volume associated with the BA hoppers, remote MDS, sluice pipes, and surge tanks), excluding redundant spare systems, maintenance tanks, and similar infrequently used equipment. Permeate from the RO system would be recycled back into the remote MDS while the RO reject, or brine, would be transported to a centralized waste treatment facility for disposal. The EPA also assumed that managing the remote MDS as a zero-discharge system may require additional surge tank capacity to hold BA hopper water during maintenance activities. These additional costs associated with zero-discharge operation were calculated at the plant level because one RO system can treat the remote MDS slipstream from all remote MDSs operating at a plant.

For plants identified as likely to install remote MDSs to comply with the 2020 rule or the CCR Part A rule requirements, the EPA added capital costs for RO, surge tank, piping, and pumps to the plant-level total remote MDS capital cost described in Section 5.2.2. To estimate the total cost for a zero-discharge remote MDS, the EPA added O&M costs for the additional equipment, as well as the costs of transporting and disposing of the RO brine, to the remote MDS O&M cost described in Section 5.2.2. For plants identified as having installed remote MDSs to comply with the 2020 rule, the EPA assumed that the additional capital and annual O&M costs associated with treating a remote MDS slipstream with RO would be the only incremental costs incurred to operate the system as zero discharge.

To estimate the RO capital and O&M costs, the EPA used cost curves from the 2020 rule and escalated them to 2023 dollars as described in Section 5.1.2.

The EPA first estimated the total remote MDS volume based on information provided by equipment vendors knowledgeable about boiler configurations (including ash hopper volumes) and remote MDS configurations and sizes. For plants with plant-level capacities less than or equal to 200 MW, the EPA assumed that the total remote MDS volume is 175,000 gallons, based on data provided by vendors and best professional judgement (ERG, 2019b). For plants with plant-level capacities greater than 200 MW, the EPA used the following equation, developed from industry-level data on remote MDS installations, to estimate the total system volume (ERG, 2019b).

$$\text{total remote MDS volume (gallons)} = (347.29 \times \text{plant-level capacity}) + 146{,}398$$

Where:

plant-level capacity	=	Sum of EGU capacities (MW) flagged for BA compliance costs.

Based on the estimated total remote MDS volume, the EPA calculated the slipstream flow rate in GPM as follows:

[29] After the EPA completed final rule analyses, Granite Shore Power announced that Merrimack Station would voluntarily retire (refer to preamble Section VII.C.2).

$$\text{slipstream flow (GPM)} = (\text{total remote MDS volume} \times 0.02/\text{day}) \div 1{,}440 \text{ minutes/day}$$

Where:

total remote MDS volume	=	Total volume (in gallons) of all remote MDSs expected to be operating at the plant.

The EPA developed a relationship between total RO capital cost and purge flow, based on data collected from wastewater treatment vendors and best professional judgement (ERG, 2019b). The RO capital cost curve (equation shown below) was used to estimate EGU-level capital costs for RO treatment of the remote MDS slipstream.

$$\text{RO capital cost (2023\$)} = (86{,}361 \times \text{slipstream flow}) + 3{,}373{,}926$$

The EPA also developed a relationship between annual O&M cost and purge flow, based on data collected from wastewater treatment vendors (ERG, 2019b). The RO O&M cost curve (equation shown below) was used to estimate plant-level annual O&M costs for RO treatment of a BA transport water slipstream from the remote MDS.

$$\text{RO O\&M cost (2023\$/year)} = \$0.01468 \times \text{slipstream flow} \times 60 \text{ minutes/hour} \times 24 \text{ hours/day} \times 365 \text{ days/year}$$

The EPA calculated capital costs for the surge tank. The EPA assumed that only one EGU will need to empty the BA hopper at any one time; therefore, the EPA developed a relationship between surge tank size and the capacity of the largest EGU at the plant (defined by capacity in MW), based on information provided by the industry and vendors (ERG, 2019b).

Once the EGU with the largest nameplate capacity (MW) was identified, the EPA calculated the size of the surge tank in gallons. The EPA accounted for an additional 50 percent capacity for the surge tank by multiplying the relationship by a tank sizing factor (1.5).

$$\text{tank size (gallons)} = 63 \times \text{EGU capacity} \times \text{tank sizing factor}$$

Where:

EGU capacity	=	Capacity of the EGU (MW).
tank sizing factor	=	1.5.

The EPA then estimated the cost as a function of tank size based on information provided by vendors during the development of the 2015 rule. For tanks smaller than 50,000 gallons:

$$\text{tank capital cost (2023\$)} = [(3.170 \times \text{tank size}) + 33.32 \times (\text{tank size} \times 1.65)^{0.548}]$$

Where:

tank size	=	Size of the surge tank (in gallons).

For tanks larger than 50,000 gallons:

$$\text{tank capital cost (2023\$)} = [(5.058 \times \text{tank size}) + 33.316 \times (\text{tank size} \times 1.65)^{0.548}]$$

Where:

tank size	=	Size of the surge tank (in gallons).

The EPA estimated the purchased equipment capital costs for the piping and pumps using the methodology for the FGD wastewater recycle piping and wastewater forwarding pumps (used to return wastewater back to the scrubber). The EPA then calculated the pump capital cost as a function of the flow rate from the surge tank using cost information provided by vendors during the development of the 2015 rule.

$$\text{pump capital cost (2023\$)} = [3{,}227 \times \ln(1.61 \times \text{flow}) - 3{,}389.8] \times 6.101$$

Where:

flow	=	Daily flow rate from the surge tank (in GPM, assuming discharge over five hours).

The EPA estimated the capital cost of 2,640 feet of piping using an assumed distance of 0.25 miles between the surge tank and the BA hopper, based on the EPA's best professional judgement, information from BA handling vendors about remote MDS placement at a plant, and costs data provided by pipe vendors for the 2015 rule. The EPA's estimate of the capital cost for 2,640 feet of piping is $54,858 (2023$).

The EPA estimated the direct capital costs by multiplying the sum of the purchased equipment costs for the tank, pumps, and piping (*i.e.,* the total purchased equipment cost) by 2. The EPA used this relationship to account for the costs of delivery of purchased equipment, installation of purchased equipment, instrumentation and controls, piping and electrical, service facilities, building services, and land (if purchase is required).

$$\text{direct capital costs} = 2 \times \text{total purchased equipment cost}$$

The EPA then estimated the indirect capital costs by multiplying the sum of the total purchased equipment and direct capital costs by 0.43. The EPA used this relationship to account for engineering and supervision, construction expenses, contractor's fees, and contingency.

$$\text{indirect capital costs} = 0.43 \times (\text{total purchased equipment cost} + \text{direct capital costs})$$

Finally, the EPA estimated total capital costs by summing the total purchased equipment, direct, and indirect capital costs.

$$\text{total capital costs} = \text{total purchased equipment cost} + \text{direct capital costs} + \text{indirect capital costs}$$

The EPA calculated plant-level O&M costs associated with operating the surge tank, pumps, and piping. Total O&M costs include the energy cost associated with operating the pumps and the maintenance cost associated with the surge tank, pumps, and pipes.

$$\text{total tank/pump/piping O\&M costs} = \text{energy cost} + \text{maintenance cost}$$

To calculate the energy cost, the EPA estimated the annual energy requirement in kilowatt-hours (kWh) to operate the pumps, based on the 2015 rule cost methodology.

$$\text{annual energy requirement (kWh/year)} = (0.02219 \times \text{flow} + 2.019) \times 17.89$$

Where:

flow	=	Daily flow rate from the surge tank (in GPM, assuming discharge over five hours).

The EPA estimated the cost of operating the pumps using the pump energy requirement and the national energy cost per kWh, based on data reported by the U.S. DOE Energy Information Administration (U.S. DOE, 2011), in 2023 dollars.

$$\text{energy cost (2023\$)} = \text{national energy cost} \times \text{annual energy requirement}$$

Where:

national energy cost	=	($0.0485/kWh × 1.468) (in 2023$).
annual energy requirement	=	Annual energy requirement to operate pumps (in kWh/year).

To estimate the total maintenance costs for the 2015 rule, the EPA developed a relationship between BA slipstream flow and the cost to maintain the surge tank, pumps, and piping.

$$\text{maintenance cost (2023\$)} = 611.466 \times \text{flow}$$

Where:

flow	=	Daily flow rate from the surge tank (in GPM, assuming discharge over five hours).

To estimate costs for transportation and disposal of the RO brine, the EPA calculated O&M costs associated with hauling the brine off site to a centralized waste treatment (CWT) facility and the costs incurred for using CWT.

The EPA calculated brine flow rate based on the average recovery from the membrane treatment vendors used for FGD wastewater.

$$\text{brine flow} = 0.30 \times \text{purge flow}$$

The EPA estimated the weight of the brine based on the weight of the solids in the brine and the weight of the water. The EPA estimated the solids in the brine based on the average total dissolved solids (TDS) concentration in BA transport water for the entire purge flow (this assumes that all solids from the BA purge will be retained in the brine, which is likely an overestimate).

$$\text{annual brine solids (TPY)} = \text{BA purge (GPD)} \times \text{average TDS concentration} \times 3.78\ \text{L/gal} \times 0.001\ \text{g/mg} \times (1.102 \times 10^{-6}\ \text{tons/g}) \times 365\ \text{days per year}$$

Where:

BA purge	=	2 percent of the total BA system volume in GPD.
average TDS concentration	=	Average TDS concentration in BA transport water (see Table 6-2 of the 2020 Supplemental TDD), 1,290 mg/L.
annual brine water weight (TPY)	=	brine flow (GPD) × 0.00417 tons/gal × 365 days per year.

The EPA calculated the total weight of brine to be disposed of annually as the sum of the brine solids and the water weight.

annual brine weight (TPY) = annual brine solids + annual brine water weight

The EPA estimated the annual cost of transporting brine solids to a CWT facility using the 2015 methodology for off-site transportation, which is based on transportation of solids to an off-site location 25 miles from the plant.

transportation cost (2023$) = annual brine weight × $13.514 per ton

The EPA estimated disposal costs using data compiled as part of the rulemaking that established pretreatment standards for 40 CFR Part 435 (Oil and Gas Extraction), Subpart C (*i.e.,* onshore unconventional oil and gas). Wastewater management using a CWT for TDS removal ranged from $3 to $11 per barrel (U.S. EPA, 2016). Using the average value of $7 per barrel, the EPA estimated that the disposal cost at a CWT would be $0.167/gallon (2005$), which escalated to $0.245/gallon in 2023$. Annual disposal costs were estimated using the following equation:

disposal cost (2023$) = brine flow (GPD) × $0.245/gallon

To estimate the annual cost for brine transportation and disposal, the EPA summed the transportation and disposal costs.

brine transport and disposal annual cost = transportation cost + disposal cost

The EPA estimated zero-discharge plant-level costs according to the following assumptions:

- For plants opting in to the low utilization subcategory, the EPA estimated costs equal to an MDS or a remote MDS with a purge. For a plant to achieve zero discharge, the steps outlined in this section must be added to the plant's overall cost calculation from Section 5.2.2.
- For all other plants with BA discharges, the EPA estimated costs equal to the addition of an RO system only.

5.3 Combustion Residual Leachate

For the 2024 final rule, the EPA estimated costs for plants to install and operate four technologies for CRL: CP, membrane filtration, SDE, and thermal evaporation.

For CP treatment of CRL, the EPA included the following treatment components:

- CP treatment equipment (equalization and storage tanks, pumps, reaction tanks, solids-contact clarifier, and gravity sand filter).
- CP chemical feed systems for lime, organosulfide, ferric chloride, and polymers.
- Mercury analyzer.
- Compliance monitoring (including sample collection and analysis).
- Solids handling (sludge holding tank and filter press).
- Transportation and disposal of solids in a landfill.

For membrane filtration treatment of CRL, the EPA included the following components, consistent with the methodology used for FGD wastewater:

- CP treatment equipment (equalization and storage tanks, pumps, reaction tanks, solids-contact clarifier, and gravity sand filter).

- CP chemical feed systems for lime, organosulfide, ferric chloride, and polymers.
- Membrane filtration treatment equipment (membrane filtration, RO, and storage tanks).
- Additional FA purchase (if plant was identified as having an FA deficit).[30]
- Brine encapsulation.
- Transportation and disposal of solids in a landfill.

For SDE treatment of CRL, the EPA included the following treatment components, consistent with the methodology used for FGD wastewater:

- Pretreatment using membrane filtration (for flows greater than 150 GPM only) (includes membrane filtration, RO, and storage tanks).
- SDE equipment.
- Transportation and disposal of solids in a landfill.

For thermal evaporation treatment of CRL, the EPA included the following treatment components:

- Brine concentration and encapsulation or crystallization equipment.
- Transportation and disposal of solids in a landfill.

Section 5.3.1 describes the process for developing the CRL cost calculation inputs. Sections 5.3.2, 5.3.3, 5.3.4, and 5.3.5 present the EPA's methodology for estimating costs for CP, membrane filtration, SDE, and thermal evaporation, respectively. Section 5.3.6 presents the EPA's methodology for determining the least cost zero-discharge technology option for CRL.

As described in Section 3.2.3, the EPA notes that unlined landfills and unlined surface impoundments not expected to clean close may potentially discharge unmanaged CRL. Such discharges may be covered under the ELGs when they are determined on a case-by-case basis to be the functional equivalent of a direct discharge. To evaluate the potential costs and loadings of such discharges, the EPA conducted a bounding analysis, which is documented in the memorandum *Evaluation of Unmanaged CRL* (U.S. EPA, 2024). The EPA summarizes the costs for unmanaged CRL in Section 5.5.

5.3.1 CRL Cost Calculation Inputs

To estimate plant-level baseline and post-compliance costs of implementing CRL treatment technologies, the EPA developed cost calculation databases. These databases combine plant-specific input values, including CRL flow and existing treatment, with the relationships between costs and CRL flow rates described in Section 5.3.2 to estimate baseline and post-compliance costs for each plant (ERG, 2023, 2023a, 2023b, 2024). For the 2024 final rule, the EPA started with input data from the 2015 rule, including Steam Electric Survey data, and then updated the data with other publicly available data described in Section 2. This section describes the cost inputs.

Population

The EPA used data from the Steam Electric Survey (U.S. EPA, 2015) and the Office of Resource Conservation and Recovery's (ORCR's) Comprehensive Compliance Report (U.S. EPA, 2023b) to identify the population of landfills and surface impoundments that contain combustion residuals and that collect CRL and discharge it to surface waters or POTWs. The EPA updated this population to reflect recent changes to the profile of steam electric power plants and removed plants where all EGUs were retired by December 31, 2023, as described in *Identification of Combustion Residual Leachate (CRL) Discharges from*

[30] Refer to the *2024 Steam Electric Supplemental Final Rule: Fly Ash Analysis* for more information (U.S. EPA, 2024h).

Leachate Collection Systems and Overview of Compliance Costs and Pollutant Loadings Analyses (U.S. EPA, 2024d).[31]

For each new landfill and surface impoundment, the EPA used data from the Steam Electric Survey and other publicly available information to identify the most appropriate discharge location and receiving water. Where a plant reported all discharges to a single receiving water (*i.e.,* all outfalls discharge to the same waterbody), the EPA used this receiving water. Where a plant reported discharges to multiple waterbodies, the EPA evaluated outfall data and water balance diagrams to identify the most appropriate receiving water(s) for CRL. See the *Receiving Waters Characteristics Analysis and Supporting Documentation for the Environmental Assessment of the Final Supplemental Steam Electric Rule* memorandum for further details (U.S. EPA, 2024n,).

Flow Rate

The EPA used the methodology described in Section 9.4.1 of the 2015 TDD to estimate CRL flow rates. Where information on CRL flow rate was available in the Steam Electric Survey, the EPA used this value.

For landfills, where landfill size (acreage) information was available in the Steam Electric Survey, the EPA estimated that plants collect CRL from 75 percent of the total acreage for active landfills, 5 percent of the total acreage for inactive landfills, and 17 percent of the total acreage for retired landfills. The EPA also used survey data to estimate the median CRL discharge rate in GPD per acre of landfill: 887 for active and inactive landfills, and 113 for retired landfills. The EPA subsequently estimated the unknown CRL flow rates using this information and the landfill size.

For active landfills:

$$\text{CRL flow (GPD)} = 887\ \text{GPD/acre} \times 0.75 \times \text{landfill acreage}$$

For inactive landfills:

$$\text{CRL flow (GPD)} = 887\ \text{GPD/acre} \times 0.05 \times \text{landfill acreage}$$

For retired landfills[32]:

$$\text{CRL flow (GPD)} = 113\ \text{GPD/acre} \times 0.17 \times \text{landfill acreage}$$

Where no CRL flow or landfill size information was available, the EPA used the median CRL flow rate from the Steam Electric Survey: 46,160 GPD for active landfills and 29,651 GPD for inactive landfills.

For surface impoundments where information on CRL flow rate was not available, the EPA used the median CRL flow rate from the Steam Electric Survey: 34,560 GPD.

The EPA also considered the flow rate for active and inactive landfills following closure. The EPA estimates that, post closure, landfills and surface impoundments will continue to generate CRL at 10 percent of their active or inactive flow rate.

The EPA used the following equation to calculate the CRL post-closure flow:

$$\text{post-closure CRL flow} = \text{CRL flow (GPD)} \times 0.10$$

[31] If a plant in the CRL population converted to a different fossil fuel source (*e.g.,* gas-fired), the 2024 final rule still applies, and the plant remains in the CRL population.

[32] The EPA included retired landfills in the analysis if they are located at active plants with open (active/inactive) landfills as plants often combine CRL from all onsite landfills for treatment and discharge.

The EPA estimated technology option costs using both the CRL flow and the post-closure CRL flow. The EPA summed all landfill and surface impoundment flow rates at a particular plant and used this total flow rate to estimate technology option costs at the plant level.

Treatment-in-Place Data

In 2015, the EPA identified one plant that was operating a biological treatment system to treat landfill CRL (combined with FGD wastewater) and one plant that was building a biological treatment system to treat landfill CRL. In 2020, the EPA identified one plant that was operating a thermal treatment system to treat landfill CRL (combined with FGD wastewater) (ERG, 2020a). Through public comments, the EPA further identified two plants with CP treatment in place for landfill CRL (ERG, 2023). The EPA did not identify any plants with treatment in place for surface impoundment CRL.

Landfill Data

The EPA determined whether each plant in the population of landfills described in Section 0 will incur on-site or off-site transportation and disposal costs. Plants identified as having an active or inactive landfill incurred compliance costs for on-site transportation and disposal of treatment residuals; all other plants incurred compliance costs for off-site transportation and disposal. For post-closure cost estimates (for active and inactive landfills following closure), the EPA assumed off-site transportation and disposal.

5.3.2 Cost Methodology for CP

To estimate CP costs for CRL, the EPA used cost data from the 2015 and 2020 rules for CP as stand-alone treatment for FGD wastewater. Starting with the capital and O&M cost curves presented in Section 5.2.2 of the 2020 Supplemental TDD, the EPA sized the treatment system for CRL flows (rather than FGD flows). The EPA updated the 2020 rule cost curves by escalating them to 2023 dollars as described in Section 5.1.2.

The EPA used the following cost curves to estimate CP capital and O&M costs:

$$\text{CP capital costs with on-site transport/disposal (2023\$)} = 51.31 \times \text{CRL flow} + 10{,}334{,}835$$

$$\text{CP O\&M costs with on-site transport/disposal (2023\$/year)} = 5.939 \times \text{CRL flow} + 337{,}016$$

$$\text{CP capital costs with off-site transport/disposal (2023\$)} = 50.40 \times \text{CRL flow} + 10{,}906{,}369$$

$$\text{CP O\&M costs with off-site transport/disposal (2023\$/year)} = 8.116 \times \text{CRL flow} + 321{,}529$$

The CP system includes an in-line mercury analyzer. This process control mechanism has an expected life of six years. To estimate the recurring cost of replacing the mercury analyzer every six years, the EPA used costs originally obtained for the 2015 rule and escalated them to 2023 dollars. The recurring cost was estimated as $147,211 (2023$).

For plants identified as having existing treatment in place for CRL, the EPA estimated no additional capital costs or recurring costs but estimated O&M costs equal to $108,029 (2023$/year) to account for compliance monitoring of the treated effluent. Compliance monitoring includes sampling labor and materials as well as the costs associated with sample preservation, shipping, and analysis for the pollutants selected for regulation (arsenic and mercury).

5.3.3 Cost Methodology for Membrane Filtration

To estimate membrane filtration technology option costs for CRL, the EPA first estimated CP pretreatment costs. The EPA used cost data from the 2015 and 2020 rules for CP pretreatment of FGD wastewater, specifically the cost equations from Section 5.2.3 of the 2020 rule TDD (U.S. EPA, 2020). The EPA updated the cost equations to 2023 dollars as described in Section 5.1.2 of this TDD.

The EPA used the following cost curves to estimate CP pretreatment capital and O&M costs:

CP pretreatment capital costs with on-site transport/disposal (2023$) = 53.08 × CRL flow + 10,140,518

CP pretreatment O&M costs with on-site transport/disposal (2023$/year) = 6.035 × CRL flow + 223,603

CP pretreatment capital costs with off-site transport/disposal (2023$) = 52.79 × CRL flow + 10,727,925

CP pretreatment O&M costs with off-site transport/disposal (2023$/year) = 8.200 × CRL flow + 213,413

The EPA used the methodology described for FGD wastewater in Section 5.1.3 for estimating the membrane filtration costs.

The EPA estimated plant-level CRL capital, O&M, and one-time costs using the CRL flow rate in GPD as described in Section 0. The EPA estimated the total membrane filtration technology option costs as the sum of the CP pretreatment and membrane filtration costs. For plants identified as having existing treatment in place for CRL, the EPA estimated no CP pretreatment capital or O&M costs, except compliance monitoring of the treated effluent. The EPA did not incorporate LRTR O&M cost savings, as these are unique to FGD wastewater.

5.3.4 Cost Methodology for SDE

To estimate SDE costs for CRL, the EPA used the methodology described for FGD wastewater in Section 5.1.4. In place of the wastewater flow rate (FGD flow), the EPA used the CRL flow rate in GPD as described in Section 0. The EPA did not account for LRTR O&M cost savings, which are only applicable for FGD wastewater.

5.3.5 Cost Methodology for Thermal Evaporation

To estimate thermal evaporation costs for CRL, the EPA followed the same methodology described for FGD wastewater in Section 5.1.5, substituting the CRL flow rate for the FGD wastewater flow rate. The EPA did not incorporate LRTR O&M cost savings, which are only applicable for FGD wastewater.

5.3.6 Cost Methodology for Zero Discharge

To estimate zero-discharge costs for CRL, the EPA compared the costs for membrane filtration (see Section 5.3.3) and SDE (see Section 5.3.4) for each plant and selected the least cost technology. Refer to the Least-Cost Technology by Plant (U.S. EPA, 2024m). The EPA did not consider thermal evaporation costs in its least cost option assessment because some of the costs are being treated as CBI, pursuant to claims made by technology vendors.

However, where the EPA has information on plants expecting to retire under the 2024 final rule, the EPA considered the least cost option after taking into account reductions in CRL flow rates expected following the closure of a landfill or surface impoundment, as described in Section 0. Specifically, the EPA considered two treatment options for zero discharge for plants retiring after 2034:

- Installing a membrane filtration treatment system (see Section 5.3.3), designed for the CRL flow rate; or
- Installing an SDE treatment system (see Section 5.3.4), designed for the CRL flow rate, then installing a membrane filtration system (see Section 5.3.3), designed for the post-closure flow rate.

For plants that are retiring by 2034, the EPA compared the cost of installing an SDE with the cost of installing membrane filtration, both designed for the CRL flow rate. The EPA estimated the total cost for each of these treatment options and chose the least cost option, as described in the Least-Cost Technology by Plant (U.S. EPA, 2024m).

5.4 Legacy Wastewater

For the 2024 final rule, the EPA estimated costs for plants to install and operate CP treatment for legacy wastewater. The EPA included the following treatment components:

- CP treatment equipment (equalization and storage tanks, pumps, reaction tanks, solids-contact clarifier, and gravity sand filter).
- CP chemical feed systems for lime, organosulfide, ferric chloride, and polymers.
- Mercury analyzer.
- Compliance monitoring (including sample collection and analysis).
- Solids handling (sludge holding tank and filter press).
- Transportation and disposal of solids in a landfill.

Section 5.4.1 describes the process for developing the legacy wastewater cost calculation inputs.

5.4.1 Legacy Cost Calculation Inputs

To estimate plant-level post-compliance costs of implementing treatment technologies for legacy wastewater, the EPA developed a cost calculation database. This database combines plant-specific input values, including wastewater flow rates and landfill disposal locations (on-site or off-site), with the relationships between costs and legacy flow rates described in Section 5.4.2 to estimate post-compliance costs for each plant (ERG, 2024c). For the 2024 final rule, the EPA used input data compiled from annual inspection reports, annual groundwater monitoring reports, and closure plans for surface impoundments containing legacy CCR. This section describes the EPA's methodology.

Population

The EPA categorized surface impoundments containing legacy CCR material into three groups:

- Remaining open—surface impoundments with composite liners.
- In closure process—surface impoundments greater than or equal to 40 acres in surface area without composite liners.
- Not considered—surface impoundments with surface area less than 40 acres, without composite liners, and expected to close prior to implementation of the 2024 final rule.

The EPA included any CCR surface impoundments in the "remaining open" group that had not yet started the closure process as of ORCR's September 2023 Comprehensive Compliance Report (U.S. EPA, 2023b). The EPA assumed that any surface impoundment that had started the closure process by that point will complete dewatering as of the compliance date in the 2024 final rule (December 31, 2029); therefore, costs and loadings were only estimated for plants that were classified as remaining open.

Legacy wastewater flows include both surficial (or free) water removed from surface impoundments and wastewater removed from saturated CCR material during the dewatering process. For all surface impoundments classified as remaining open, the EPA used data from annual inspection reports to identify the volume of water and volume of CCR material. To calculate the total volume of legacy wastewater from each impoundment, the EPA first estimated the volume of wastewater that would be produced from dewatering the volume of CCR material. The EPA then added that volume of wastewater to the volume of surficial water. See the memorandum *Legacy Wastewater at CCR Surface Impoundments* (U.S. EPA, 2024a) for details on these estimates.

Flow Rate

The EPA estimated legacy wastewater flow using plant-specific and surface impoundment-specific information on legacy wastewater volume and closure duration (*e.g.,* calendar time available for the dewatering process). For closure duration, the EPA used information from closure plans. The EPA adjusted these closure durations as follows:

- The EPA used a maximum closure period of seven years (*e.g.,* the duration of a CCR permit cycle plus a two-year extension). For any closure described in a closure plan as being longer than seven years, the EPA used seven years to estimate wastewater flow rate.
- Where no closure duration data were available, the EPA used seven years to estimate wastewater flow.

Based on legacy wastewater volume and closure duration, the EPA calculated a legacy wastewater flow in GPD. This legacy wastewater flow was used to estimate both compliance costs and pollutant loadings.

Treatment-in-Place Data

The EPA did not identify any existing treatment for legacy wastewater.

Landfill Data

The EPA used the same population of landfills as described in Section 5.3.1. Plants with an active or inactive landfill incurred on-site transportation and disposal costs; all other plants incurred costs for off-site transportation and disposal.

5.4.2 Cost Methodology for CP

To estimate CP costs for legacy wastewater, the EPA used the methodology described for CRL in Section 5.3.2. The EPA used the legacy wastewater flow rate in GPD, described in Section 0, in place of the CRL flow rate.

5.5 Summary of National Engineering Costs for Regulatory Options

To estimate total industry compliance costs for each regulatory option, the EPA first estimated plant-level compliance costs (described in the subsections above) for all technologies evaluated for FGD wastewater, BA transport water, CRL, and legacy wastewater. Next, the EPA estimated EGU-level costs (including capital costs, O&M costs, one-time costs, and 5-, 6-, and 10-year recurring costs) using the equations described in Table 10Table 10.

Table 10. EGU Cost Estimation by Wastestream

Wastestream	EGU Equation
FGD wastewater	Unit flow fraction: FGD system purge flow (GPD) ÷ plant-level purge flow (GPD) × EGU capacity (MW) ÷ FGD system capacity (MW) EGU cost: unit flow fraction × plant-level cost (2023$)
BA transport water	EGU cost: EGU capacity (MW) ÷ plant capacity (MW) × plant-level cost (2023$)
CRL	EGU cost: EGU capacity (MW) ÷ plant capacity (MW) × plant-level cost (2023$)
Legacy wastewater	EGU cost: EGU capacity (MW) ÷ plant capacity (MW) × plant-level cost (2023$)

For each EGU, the EPA chose the appropriate technology cost to coincide with the regulatory option being evaluated. See the preamble for details on the combinations of wastestreams and treatment technologies based on the regulatory option. The EPA then summed the EGU-level costs for only those EGUs included in each regulatory option to estimate total industry-level regulatory option costs. See the *Generating Unit-Level Costs and Loadings Estimates by Regulatory Option for the 2024 Final Rule* memorandum for the details, broken out by EGU, on technologies selected for each regulatory option and estimates of compliance costs (U.S. EPA, 2024o).[33]

Table 11, Table 12, Table 13, and Table 14 present the total industry compliance cost estimates for FGD wastewater, BA transport water, CRL, and legacy wastewater, respectively, by regulatory option. For each wastestream, the number of plants incurring costs under each evaluated option is also included. Table 15 presents the aggregated, industry-level compliance costs by regulatory option. All cost estimates are expressed in pre-tax 2023 dollars and represent costs that would be incurred once all plants and EGUs achieved compliance with the regulatory option presented. Values presented in this document do not account for the timing or exact date of implementation (*e.g.,* when costs are incurred by the industry).

For the final rule, the EPA also estimated an upper and lower bound to evaluate the potential costs associated with unmanaged CRL. The upper bound estimates use proxies for the factors that make unmanaged CRL more likely to be subject to incurring compliance costs under the final rule. The lower bound estimates account for additional scenarios that may result in less CCR units than the actual population impacted by the final rule. Table 16 presents the average cost estimates for the upper and lower bound analyses, further detailed in the preamble and the EPA's memorandum *Evaluation of Unmanaged CRL* (U.S. EPA, 2024).

Table 11. Estimated Cost of Implementation for FGD Wastewater by Regulatory Option (in Millions of Pre-tax 2023 Dollars)

Regulatory Option	Number of Plants	Capital Cost	Annual O&M Cost	One-Time Cost	5-Year Recurring Cost	6-Year Recurring Cost	10-Year Recurring Cost
Baseline	28	$0	$0	$0	NA	NA	NA
A	28[a]	$1,310	$94.2	$1.37	NA	NA	NA
B	28[a]	$1,310	$94.2	$1.37	NA	NA	NA
C	28[b]	$1,500	$107	$1.68	NA	NA	NA

Abbreviation: NA (not applicable).

Note: Costs and savings are rounded to three significant figures.

a—Seven of these plants incur zero cost, meaning that there are 21 plants with nonzero estimated costs for implementation of Regulatory Options A and B.

b—Three of these plants incur zero cost, meaning that there are 25 plants with nonzero estimated costs for implementation of Regulatory Option C.

[33] The EPA made adjustments to select EGUs following final regulatory option cost estimation. Refer to the *Updates to Estimated Compliance Costs and Pollutant Loadings* memorandum for more information (U.S. EPA, 2024p).

Table 12. Estimated Cost of Implementation for BA Transport Water by Regulatory Option (in Millions of Pre-tax 2023 Dollars)

Regulatory Option	Number of Plants	Capital Cost	Annual O&M Cost	One-Time Cost	5-Year Recurring Cost	6-Year Recurring Cost	10-Year Recurring Cost[a]
Baseline	34	$0	$0	NA	$0	NA	$0
A	34[b]	$173	$9.68	NA	$0.604	NA	($1.39)
B	34[b]	$173	$9.68	NA	$0.604	NA	($1.39)
C	34[c]	$235	$16.9	NA	$0.604	NA	($1.39)

Abbreviation: NA (not applicable).

Note: Costs and savings are rounded to three significant figures.

a—The values in this column are negative and are presented in parentheses because they represent cost savings.

b—Seven of these plants incur zero cost, meaning that there are 27 plants with nonzero estimated costs for implementation of Regulatory Options A and B.

c—One of these plants incurs zero cost, meaning that there are 33 plants with nonzero estimated costs for implementation of Regulatory Option C.

Table 13. Estimated Cost of Implementation for CRL by Regulatory Option (in Millions of Pre-tax 2023 Dollars)

Regulatory Option	Number of Plants	Capital Cost	Annual O&M Cost	One-Time Cost	5-Year Recurring Cost	6-Year Recurring Cost	10-Year Recurring Cost
Baseline	90	$0	$0	$0	NA	$0	NA
A	90	$1,130	$54.5	$0	NA	$12.7	NA
B	90	$1,770	$119	$7.01	NA	$6.18	NA
C	90	$2,160	$110	$0.762	NA	$0	NA

Abbreviation: NA: (not applicable).

Note: Costs and savings are rounded to three significant figures.

Table 14. Estimated Cost of Implementation for Legacy Wastewater by Regulatory Option (in Millions of Pre-tax 2023 Dollars)

Regulatory Option	Number of Plants	Capital Cost	Annual O&M Cost	One-Time Cost	5-Year Recurring Cost	6-Year Recurring Cost	10-Year Recurring Cost
Baseline	17	$0	$0	NA	NA	$0	NA
A	17	$0	$0	NA	NA	$0	NA
B	17	$376	$24.7	NA	NA	$3.24	NA
C	17	$376	$24.7	NA	NA	$3.24	NA

Abbreviation: NA: (not applicable).

Note: Costs and savings are rounded to three significant figures.

Table 15. Estimated Cost of Implementation by Regulatory Option (in Millions of Pre-tax 2023 Dollars)

Regulatory Option	Number of Plants	Capital Cost	Annual O&M Cost	One-Time Cost	5-Year Recurring Cost	6-Year Recurring Cost	10-Year Recurring Cost[a]
Baseline	112	$0	$0	$0	$0	$0	$0
A	112[b]	$2,610	$158	$1.37	$0.604	$12.7	($1.39)
B	112[c]	$3,630	$248	$8.38	$0.604	$9.42	($1.39)
C	112[c]	$4,260	$258	$2.44	$0.604	$3.24	($1.39)

Abbreviation: NA: (not applicable).

Note: Costs and savings are rounded to three significant figures.

a—The values in this column are negative and are presented in parentheses because they represent cost savings.

b—Seven of these plants incur zero cost, meaning that there are 105 plants with nonzero estimated costs for implementation of Regulatory Option A.

c—One of these plants incurs zero cost, meaning that there are 111 plants with nonzero estimated costs for implementation of Regulatory Options B and C.

Table 16. Estimated Average Cost of Implementation for Unmanaged CRL for all Regulatory Options (in Millions of Pre-tax 2023 Dollars)

Analysis	Capital Cost	Annual O&M Cost	One-Time Cost	5-Year Recurring Cost	6-Year Recurring Cost	10-Year Recurring Cost
Upper Bound	$4,230	$463	NA	NA	$13	NA
Lower Bound	$880	$99	NA	NA	$3	NA

Abbreviation: NA: (not applicable).

Note: Costs and savings are rounded to three significant figures.

6. Pollutant Loadings and Removals

This section describes the annual pollutant discharge loading estimates for the steam electric power generating industry, as well as estimated pollutant loading removals associated with the 2024 final rule. Estimates for the 2024 final rule build on the pollutant loadings and removals calculations for regulated wastestreams from the 2015 and 2020 rules. Section 10 of the 2015 Technical Development Document (2015 TDD) includes pollutant loadings and removals estimates for flue gas desulfurization (FGD) wastewater, bottom ash (BA) transport water, and combustion residual leachate (CRL) (U.S. EPA, 2015a). Section 6 of the 2020 Supplemental TDD estimates FGD wastewater and BA transport water pollutant removals as the change in loadings from the 2015 to the 2020 regulatory requirements. For this 2024 final rule, the U.S. Environmental Protection Agency (EPA) estimated pollutant loadings and removals for the four wastestreams for which this rule is establishing new requirements (FGD wastewater, BA transport water, CRL, and legacy wastewater). The EPA evaluated loadings and removals for the same industry population for which it estimated regulatory compliance costs (refer to Section 5 for the industry population evaluated for this rule). The EPA estimated baseline and post-compliance pollutant loadings and pollutant removals as follows:

- *Baseline loadings*. Pollutant loadings, in pounds per year, in wastewater discharged to surface water or through publicly owned treatment works (POTWs) to surface water under 2020 final rule conditions. For FGD wastewater and BA transport water, baseline loadings characterize wastewater discharged from plants assumed to be in full compliance with the requirements of the 2020 rule; for CRL and legacy wastewater, baseline loadings characterize current discharges.
- *Post-compliance loadings*. Pollutant loadings, in pounds per year, in wastewater discharged to surface water or through POTWs to surface water after full implementation of the 2024 final rule technology options. The EPA estimated post-compliance pollutant loadings with the expectation that all steam electric power plants subject to the requirements of the 2024 final rule will install and operate wastewater treatment and pollution prevention technologies equivalent to the technology bases for the regulatory options.
- *Pollutant removals*. The difference between the baseline loadings and post-compliance loadings for each regulatory option.

This section describes the EPA's methodology for estimating plant-specific pollutant loadings and removals as well as industry-level results for each of the evaluated regulatory options:

- General methodology for estimating pollutant removals (Section 6.1).
- FGD wastewater (Section 6.2).
- BA transport water (Section 6.3).
- CRL (Section 6.4).
- Legacy wastewater (Section 6.5)
- Summary of industry-level baseline and regulatory option loadings and removals (Section 6.6).

6.1 General Methodology

For each plant discharging FGD wastewater, BA transport water, CRL, and/or legacy wastewater, the EPA estimated plant-level baseline loadings and post-compliance loadings and removals for each of the technology options described in Section 5. The EPA used sampling data collected in support of the 2015 rule and 2020 rule to characterize baseline and post-compliance pollutant concentrations, including data from the EPA's sampling program (described in Section 3 of the 2015 TDD), the Steam Electric Survey, public comments, industry submissions, and publicly available data sources. For CRL, the EPA received additional industry submissions in response to the 2023 proposed rule voluntary request and aggregated these data with prior data to characterize baseline pollutant concentrations (refer to Section 6.4 for additional details). The EPA evaluated these data sources to identify analytical data that meet its acceptance criteria for inclusion in analyses for characterizing discharges of FGD wastewater, BA transport water, CRL, and legacy wastewater. The EPA's acceptance criteria include:

- Sample locations must be unambiguous and clearly described such that the sample can be categorized by wastestream and level of treatment (*e.g.,* untreated, partially treated).
- Analytical data must provide enough information to identify units of measure and determine usability in the EPA's analyses.
- Analytical data must represent individual sample results, rather than average results for multiple plants or long-term averages for single plants.[34]
- Analytical data must not be duplicative of other accepted data.
- Sample analyses must be done using accepted analytical methods.
- Nondetect results are not acceptable if no detection or quantitation limit is provided.
- Sample results must represent total results for a pollutant (*i.e.,* dissolved results are not acceptable except for total dissolved solids).
- For biphasic samples, sample results must include both phases.

To ensure analytical data were representative, the EPA excluded data that did not meet the acceptance criteria as they were not fit for use in estimating pollutant loadings. Sections 6.2.2, 6.3.2, 6.4.2, and 6.5.2 describe additional wastestream-specific data acceptance criteria, if applicable, and present the average discharge pollutant concentrations used to estimate baseline and post-compliance loadings for FGD wastewater, BA transport water, CRL, and legacy wastewater, respectively.

First, the EPA calculated baseline loadings and post-compliance loadings for each plant using the plant-specific wastewater flow for the wastestream (as described in Section 5) and average pollutant concentrations for the specific wastestream using the following equation:

$$Loading_{pollutant}\text{ (lb/year)} = \text{flow rate} \times \text{discharge days} \times Conc_{pollutant} \times (2.20462\text{ lb}/10^9\ \mu g) \times (1{,}000\text{ L}/264.17\text{ gallons})$$

Where:

flow rate	=	Reported flow rate of the wastestream being discharged, in gallons per day, from the plant.
discharge days	=	Number of days per year the wastestream is discharged from the plant.
$Conc_{pollutant}$	=	Concentration of a specific pollutant in the wastestream, in micrograms per liter (µg/L). Refer to Table 18 for FGD wastewater, Table 19 for BA transport water, Table 20 for CRL, and Table 21 for legacy wastewater.

The EPA identified several plants that reported transferring wastewater to POTWs rather than directly discharging to surface waters. For these plants, the EPA adjusted the baseline and post-compliance loadings to account for pollutant removals expected during treatment at a well-operated POTW for each

[34] Where individual sample results and plant-level average sample concentrations were both available for a data set, the EPA preferentially used the individual sample results.

pollutant, shown in Table 17. The EPA used the following equation to adjust baseline and post-compliance loading estimates for each pollutant to account for removals achieved by the POTW:

$$Loading_{pollutant\_indirect}\ (lb/year) = Loading_{pollutant} \times [1 - (Removal_{POTW} / 100)]$$

Where:

$Loading_{pollutant}$	=	Estimated pollutant loading from a specific pollutant if it was being discharged directly to surface water, in pounds per year.
$Removal_{POTW}$	=	Estimated percentage of the pollutant loading that would be removed by a POTW (see Table 17).

Finally, the EPA calculated pollutant removals (*i.e.,* the change in pollutant loadings) for each plant by subtracting the baseline loadings from the post-compliance loadings, as shown in the following equation:

$$Removal_{pollutant}\ (lb/year) = Loading_{post\text{-}compliance} - Loading_{baseline}$$

Where:

$Loading_{post\text{-}compliance}$	=	Estimated pollutant loading discharged for a specific pollutant for the post-compliance technology option, in pounds per year (accounting for removals achieved by POTWs, where appropriate).
$Loading_{baseline}$	=	Estimated pollutant loading discharged for a specific pollutant for the baseline technology option, in pounds per year (accounting for removals achieved by POTWs where appropriate).

Table 17. POTW Removals

Pollutant	Median POTW Removal Percentage
Aluminum	91.0%
Ammonia	39.0%
Antimony	66.8%
Arsenic	65.8%
Barium	55.2%
Beryllium	61.2%
Biochemical oxygen demand	Not available
Boron	Not available
Cadmium	90.1%
Calcium	Not available
Chemical oxygen demand	Not available
Chloride	Not available
Chromium	80.3%
Chromium, hexavalent	Not available
Cobalt	10.2%
Copper	84.2%
Cyanide, total	Not available
Iron	Not available
Lead	77.5%
Magnesium	Not available
Manganese	40.6%

Table 17. POTW Removals

Pollutant	Median POTW Removal Percentage
Mercury	90.2%
Molybdenum	Not available
Nickel	51.4%
Nitrate/nitrite as N	90.0%
Nitrogen, Kjeldahl	Not available
Phosphorus, total	Not available
Selenium	34.3%
Silver	88.3%
Sodium	Not available
Sulfate	Not available
Thallium	53.8%
Tin	Not available
Titanium	Not available
Total dissolved solids	Not available
Total suspended solids	Not available
Vanadium	8.3%
Zinc	79.1%

Source: ERG, 2005.

Note: The EPA received public comment on the 2023 proposed rule regarding updating the POTW removals used in its pollutant loadings analysis. Refer to Code 12 (FGD Wastewater—Data) in the comment response document for additional details (U.S. EPA, 2024q).

6.2 FGD Wastewater

For each plant discharging FGD wastewater, as described in Section 5, the EPA estimated pollutant loading values for two conditions:

- Baseline conditions, in which plants were assumed to comply with the 2020 rule—*i.e.*, chemical precipitation (CP) followed by low residence time reduction (CP+LRTR) or membrane filtration (Voluntary Incentives Program [VIP] plants only).
- Compliance with the zero-discharge technology option (*i.e.,* zero loadings for either membrane filtration or spray dryer evaporator technologies).

As noted in Section 6.1, the EPA calculated pollutant loadings using a flow rate multiplied by an average pollutant concentration. For the 2024 rule, the EPA used data from the 2020 rule to characterize pollutant concentrations in FGD wastewater. See the *Development Memo for FGD Wastewater Data in the Analytical Database* for details on the acceptance criteria used to generate the EPA's FGD analytical data set (ERG, 2015a). Table 18 presents the average effluent concentrations for CP+LRTR treatment. Regarding membrane treatment, the EPA expects that plants will choose to reuse permeate as FGD scrubber make-up; therefore, membrane filtration average effluent concentrations were assumed to be zero.

As noted in the 2020 Supplemental TDD, the EPA supplemented these analytical data with additional data for bromide and iodide. Because sampling data for these pollutants were insufficient, the EPA developed a methodology to estimate pollutant loadings from both the naturally occurring bromine and iodine in the coal burned and any bromide or iodide additives that were being used for mercury emission control at each plant. This methodology is described in the *FGD Halogen Loadings from Steam Electric Power Plants Memorandum* – 2024 Final Rule (U.S. EPA, 2024r).

Section 6.2.1 describes FGD wastewater flow rates used for pollutant loading calculations, and Section 6.2.2 discusses the EPA's methodology for estimating baseline and post-compliance loadings.

Table 18. Average CP+LRTR Effluent Concentrations

Pollutant	Average Concentration (µg/L)
Conventional Pollutants	
Total suspended solids	8,590
Priority Pollutants	
Antimony	4.25
Arsenic	5.83
Beryllium	1.34
Cadmium	4.21
Chromium	6.45
Copper	3.78
Cyanide, total	949
Lead	3.39
Mercury	0.0507
Nickel	6.30
Selenium	5.72
Thallium	9.81
Zinc	20.0
Nonconventional Pollutants	
Aluminum	120
Ammonia as N	6,850
Barium	140
Boron	225,000
Calcium	1,920,000
Chloride	7,120,000
Cobalt	9.30
Iron	110
Magnesium	3,370,000
Manganese	12,500
Molybdenum	125
Nitrate/nitrite as N	647
Phosphorus, total	319
Sodium	276,000
Titanium	9.30
Total dissolved solids	24,100,000
Vanadium	12.6

Sources: ERG, 2024d.

Note: Concentrations are rounded to three significant figures.

6.2.1 FGD Wastewater Flows

To estimate all pollutant loadings, the EPA used the same set of flow rates as described in Section 5.1.1 for compliance cost estimates. As in the 2020 rule, the EPA used optimized flow rates, consistent with the operation and maintenance compliance cost assumption that plants will choose to optimize FGD flow through their treatment systems.

6.2.2 Baseline and Post-compliance Loadings

The EPA multiplied the average effluent pollutant concentrations shown in Table 18 by the plant-specific FGD wastewater optimized flow rate described in Section 6.2.1 to calculate the pollutant loadings discharged to surface water for each plant. The EPA identified one plant transferring FGD wastewater to a POTW. The EPA expects that this plant will continue to transfer the wastewater under baseline conditions. The EPA therefore adjusted the baseline loadings to account for pollutant removals associated with POTW treatment, as described in Section 6.1.

Baseline Loadings

For all plants discharging FGD wastewater that did not opt into the VIP, the EPA used CP+LRTR concentrations from Table 18 to represent baseline. The EPA assumes that plants subject to the 2020 rule have installed the best available technology economically achievable (BAT), CP+LRTR, or equivalent technology.

For plants that opted into the VIP, the EPA estimated baseline loadings of zero, reflecting membrane filtration treatment and reuse. The EPA assumes that plants will choose to reuse membrane permeate within the plant rather than discharge permeate and monitor the effluent for compliance with NPDES (National Pollutant Discharge Elimination System) permit limitations, due to the cost associated with monitoring and potential for noncompliance.

CP+LRTR Post-compliance Loadings

For the CP+LRTR technology option, the EPA assumed that plants already comply with the 2020 rule and estimated post-compliance loadings identical to baseline loadings.

Zero-Discharge Post-compliance Loadings

For the zero-discharge technology option, the EPA estimated post-compliance loadings of zero for all plants discharging FGD wastewater.

6.3 BA Transport Water

For each plant discharging BA transport water, as described in Section 5, the EPA estimated three pollutant loading values:

- Baseline conditions based on a high recycle rate system with a purge.
- Compliance with the dry handling or high recycle rate BA system with a purge (high recycle rate, or HRR) technology option.
- Compliance with the zero-discharge technology option.

As noted in Section 6.1, pollutant loadings were calculated using a flow rate multiplied by average pollutant concentrations. For the 2024 rule, the EPA used data from the 2020 rule to characterize pollutant concentrations in BA transport water. See *Development of the Bottom Ash Transport Water Analytical Dataset and Calculation of Pollutant Loadings for the Steam Electric Effluent Guidelines Proposed Rule* for details on the EPA's data sources, acceptance criteria, and development of the analytical data set used to characterize BA transport water (ERG, 2019b).

Data for BA transport water were typically collected from surface impoundments that receive multiple wastestreams, and these different wastestreams have the potential to dilute or otherwise alter the characteristics of the surface impoundment effluent. Because of this, the EPA has additional acceptance criteria specific to BA transport water samples:

- A sample must be at least 75 percent BA transport water by volume and not include any contribution of fly ash (FA) transport water.

- The sample must be representative of actual BA surface impoundment effluent collected during full-scale, typical plant operations.

The EPA used the BA transport water analytical data to calculate an industry average concentration for each pollutant present.[35] Table 19 presents the average effluent concentrations for pollutants present in BA transport water.

Table 19. Average BA Transport Water Effluent Concentrations

Pollutant	Average Concentration (µg/L)
Conventional Pollutants	
Chemical oxygen demand	20,800
Total suspended solids	13,400
Priority Pollutants	
Antimony	17.3
Arsenic	9.32
Cadmium	0.721
Chromium	5.08
Copper	3.95
Lead	10.4
Mercury	0.102
Nickel	17.5
Selenium	12.3
Thallium	1.13
Zinc	33.8
Nonconventional Pollutants	
Aluminum	854
Barium	106
Boron	5,310
Bromide	5,100
Calcium	154,000
Chlorides	321,000
Cobalt	9.19
Iron	676
Magnesium	55,700
Manganese	153
Molybdenum	28.3
Nitrate/nitrite as N	1,670
Phosphorus	222
Potassium	19,600
Silica	8,160
Sodium	119,000
Strontium	1,430
Sulfate	504,000
Sulfite	3,920

[35] BA surface impoundments typically include other wastestreams (*e.g.,* low-volume wastewaters, cooling water); as a result, the effluent concentrations due to BA transport water are likely suppressed somewhat due to dilution. Because of this, baseline pollutant loadings and post-compliance pollutant loadings are underestimated to some degree. Nevertheless, the EPA considers that the pollutant removal estimates calculated for this rule represent a reasonable estimate of the degree of pollutant removal that would be achieved by the BAT/pretreatment standards for existing sources (PSES) limitations.

Table 19. Average BA Transport Water Effluent Concentrations

Pollutant	Average Concentration (µg/L)
Titanium	35.9
Total dissolved solids	1,290,000
Total Kjeldahl nitrogen	968
Vanadium	10.1

Sources: ERG, 2024e.

Notes: Concentrations are rounded to three significant figures. The EPA did not calculate average concentrations for pollutants for which all sample results are less than the quantitation limit.

The EPA identified ammonia (as N) as a pollutant present in BA transport water; however, the EPA excluded this parameter from the calculation of pollutant loadings to avoid double-counting of nitrogen compounds. The EPA has no data on iodine concentrations in BA transport water and therefore could not calculate an average pollutant concentration.

6.3.1 BA Transport Water Flows

To estimate pollutant loadings, the EPA used the same set of flow rates as described in Section 5.2.1 for compliance cost estimates. For baseline loadings, where it assumed compliance with the 2020 rule (*i.e.,* high recycle rate), the EPA estimated the purge flows as 10 percent of the volume of the total wetted, active components of the remote mechanical drag system (MDS). In evaluating regulatory options for which the technology basis is still high recycle rate (*e.g.,* electric generating units [EGUs] permanently ceasing coal combustion by 2034), the EPA estimated purge flows as 2 percent of the volume of the total wetted, active components of the remote MDS (which the EPA found to be more consistent with current industry operations). This resulted in pollutant loading reductions for seven plants that the EPA estimates will not incur additional compliance costs.

6.3.2 Baseline and Post-compliance Loadings

For baseline and post-compliance loadings, the EPA calculated EGU-level pollutant loadings by multiplying the average concentration of each pollutant in Table 19 by the EGU-level discharge flow rate. Using the EGU-level loadings, the EPA then calculated the baseline and post-compliance loadings for each plant as the sum of pollutant loadings for all EGUs. The EPA did not identify any plants transferring BA transport water to a POTW.

Baseline Loadings

For all plants discharging BA transport water, the EPA used BA transport water concentrations from Table 19 to represent baseline. The EPA assumed that plants subject to the 2020 rule have installed BAT (*i.e.*, HRR using an MDS or remote MDS, both with a purge option). If a plant is in the low utilization subcategory, the EPA assumed post-compliance loadings reflecting a surface impoundment plus best management practice (BMP) plan.[36]

HRR Post-compliance Loadings

Under the HRR technology option, which would allow plants to discharge a portion of their BA transport water, the EPA estimated loadings associated with MDS and remote MDS installations with a purge. The EPA assumed that plants that already have HRR technologies installed have post-compliance loadings identical to baseline loadings.

[36] The EPA assumed that any plant subject to the implementation of a BMP plan under the 2020 rule subcategories will continue to discharge BA transport water consistent with current operations (*i.e.*, the BA sluice flow rate). The EPA used information from the Steam Electric Survey to calculate a normalized BA transport water discharge flow rate consistent with the methodology described in Section 10.3.2 of the 2015 TDD (U.S. EPA, 2015a).

Zero-Discharge Post-compliance Loadings

Under the zero-discharge technology option, the EPA estimated pollutant loadings associated with MDS and closed-loop remote MDS installations. (Closed-loop remote MDS installations use reverse osmosis systems to allow for complete recycle.) The EPA estimated post-compliance loadings of zero for all plants.

6.4 CRL

The EPA estimated CRL pollutant loadings under baseline conditions as well as for the CP technology option and zero discharge.

As described in the 2015 TDD, the EPA combined data from 26 landfills and 15 surface impoundments reported in the Steam Electric Survey to estimate the average effluent concentration of CRL (U.S. EPA, 2015a). The EPA used all data provided by the plants in the Steam Electric Survey, except for the following:

- For any value reported as less than the quantitation limit, the EPA assumed the concentration was equal to half the quantitation limit provided.
- If the plant did not provide a quantitation limit, the EPA assumed the concentration was equal to the method detection limit.

The EPA also obtained untreated landfill CRL sampling data in response to the 2023 proposed rule voluntary request, as described in Section 2.2.2. The EPA followed the same data quality criteria as described in this section and Section 6.1, with the following additional considerations:

- The EPA accepted sampling data that used solid waste leachate analytical methods accepted the data as long as the methodology is approved in 40 CFR 136 for the corresponding analyte (e.g., EPA Method 7470A for mercury is a cold-vapor atomic absorption procedure).
- The EPA excluded nondetect mercury observations that were sampled using methods other than 1631E, because those methods are insufficiently sensitive.
- When an original sample could be identified, the EPA included any field duplicate results and averaged the duplicate with its original sample.
- The EPA excluded data from retired landfills.

The EPA first calculated average analyte concentrations for each landfill. Then, the EPA calculated plant-level average analyte concentrations using all landfill and surface impoundment average analyte concentrations at a particular plant. Of the landfills with 2023 voluntary request data that met the data quality criteria, none had data from both the 2023 voluntary request and the 2015 rule. However, there were three plants that had data from both the 2015 rule and the 2023 voluntary request, so the EPA took the individual averages for all landfills and surface impoundments at a plant from both data sources and calculated a new plant-level average. Finally, the EPA calculated industry-level average concentrations using all plant-level average concentrations (those from the 2015 rule, those from the 2023 proposed rule, and the combined 2015/2023 rule averages for three plants). The EPA then updated the untreated CRL average concentration data set for calculating baseline loadings for the 2024 rule, as shown in Table 20. Refer to the *CRL Analytical Data Evaluation—2024 Final Rule* memorandum for additional details on the data sources, data processing, and data quality criteria (U.S. EPA, 2024s).

In 2015, the EPA identified one plant operating a biological treatment system to treat landfill CRL (combined with FGD wastewater) and one plant building a biological treatment system to treat its landfill CRL. Through the 2023 proposed rule public comments, the EPA also identified two plants that use CP to treat CRL. As described in Section 5.3.1, the EPA accounted for this treatment-in-place information in the 2024 analyses.

The EPA does not have analytical data from steam electric power plants using CP or biological treatment to treat CRL; therefore, the Agency used the same methodology as that of the 2015 rule, transferring the average FGD effluent concentrations for CP and biological treatment. In cases where the average concentration of the untreated CRL was less than the FGD treated concentration for CP or biological treatment, the EPA assumed that the treated concentration was equal to the untreated CRL average concentration. The EPA did not calculate removals of these pollutants by the wastewater treatment system. These concentrations are also presented in Table 20.

Table 20. Average CRL Pollutant Concentrations

Pollutant	Untreated CRL Average Concentration (µg/L)	Chemical Precipitation Average Concentration (µg/L)	Biological Treatment Average Concentration (µg/L)
Conventional Pollutants			
Total suspended solids	33,900	8,590	8,590
Priority Pollutants			
Antimony	3.82	3.75	3.75
Arsenic	32.2	5.83	5.83
Cadmium	8.17	4.21	4.21
Chromium	1,700	6.45	6.45
Copper	9.44	3.78	3.78
Mercury	0.940	0.139	0.0507
Nickel	45.6	9.11	6.30
Selenium	93.8	93.8	5.72
Thallium	1.55	1.16	1.16
Zinc	133	20.0	20.0
Nonconventional Pollutants			
Aluminum	3,190	120	120
Barium	148	53.2	53.2
Boron	22,000	22,000	22,000
Calcium	490,000	408,000	408,000
Chlorides	566,000	413,000	413,000
Cobalt	63.4	9.30	9.30
Iron	23,000	110	110
Magnesium	99,800	99,800	99,800
Manganese	2,840	2,720	2,720
Molybdenum	1,480	125	125
Sodium	328,000	276,000	276,000
Sulfate	1,630,000	1,240,000	1,240,000
Total dissolved solids	3,570,000	3,500,000	3,500,000
Vanadium	1,570	12.6	12.6

Sources: U.S. EPA, 2015a; ERG 2023c, 2023d.

As described in Section 3.2.3, the EPA also notes that unlined landfills and surface impoundments potentially discharge unmanaged CRL that may be covered under the ELGs when it is determined on a case-by-case basis to be the functional equivalent of a direct discharge. To evaluate the potential costs and loads of such discharges, the EPA conducted a bounding analysis, documented in its memorandum *Evaluation of Unmanaged CRL* (U.S. EPA, 2024). The EPA presents the pollutant loadings for unmanaged CRL in Section 6.6.

6.4.1 CRL Flows

As described in Section 5.3.1, the EPA used the same methodology from the 2015 rule to estimate CRL flow rates for the 2024 rule, with estimates deriving from the Steam Electric Survey. For plants without flow rate data, the EPA used the median CRL flow per landfill (active or inactive) or surface impoundment (refer to Section 5.3.1).

6.4.2 Baseline and Post-compliance Loadings

To estimate baseline and post-compliance loadings for the 2024 final rule, the EPA multiplied the appropriate average effluent pollutant concentrations from Table 20 by the CRL flow rate to calculate the pollutant loadings for each plant. All calculations, including baseline and the technology options, use the same CRL flow rate. The EPA estimated loadings using both the CRL flow and the post-closure CRL flow. The EPA adjusted pollutant loadings for plants discharging to a POTW to account for additional removals achieved by the POTW.

Baseline Loadings

For all plants except those with treatment in place, the EPA estimated baseline loadings using the untreated concentrations shown in Table 20.

For the two plants with biological treatment in place for CRL, the EPA used a methodology consistent with the 2015 rule and transferred the effluent concentrations from the FGD biological treatment, shown in Table 20, to calculate baseline loadings. For the two plants with CP treatment in place for CRL (identified through public comments), the EPA similarly transferred the FGD CP treatment effluent concentrations from Table 20 to calculate baseline loadings.

CP Post-compliance Loadings

To estimate CP post-compliance loadings for those plants without CRL treatment in place, the EPA used CRL flow rates and the CP effluent concentrations shown in Table 20. For the four plants with treatment in place, the EPA estimated option loadings identical to baseline loadings.

Zero-Discharge Post-compliance Loadings

For the zero-discharge technology option, the EPA estimated post-compliance loadings of zero for all plants discharging CRL.[37]

6.5 Legacy Wastewater

The EPA estimated legacy wastewater pollutant loadings under baseline conditions as well as for the CP technology option. The EPA used data collected in support of the 2015 ELG to characterize effluent concentrations for surface impoundments including FA, BA, combined ash (CA), and FGD wastewater. See Sections 11 and 12 of the *Final Steam Electric Incremental Costs and Pollutant Loadings Report* (ERG, 2015b) for details on how FGD wastewater and ash transport water characterization data were collected and edited to characterize effluent from surface impoundments containing these coal combustion residuals (CCRs).

As with CRL, the EPA does not have analytical data from steam electric power plants using CP to treat legacy wastewater; therefore, the EPA used a similar approach to that described in Section 6.4,

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[37] Following closure of all coal-fired EGUs, plants may discharge membrane filtration permeate and/or thermal evaporation distillate. This allows plants to continue treating CRL that may not have an on-site use for the permeate/distillate. Although the EPA is allowing plants to discharge following closure, plants will still be required to meet the 2020 rule VIP limitations for permeate from a membrane filtration system or the 2015 rule new source performance standards (NSPS) limitations for distillate from a thermal treatment system (refer to preamble Section VII.B.3 for details).

transferring the average FGD effluent concentrations for CP. Since characterization data for FGD surface impoundment effluent, FA surface impoundment effluent, BA surface impoundment effluent, CA surface impoundment effluent, and CP treatment include different types of analytes, pollutant loadings were only generated for analytes that are consistent across all data sets (26 total). See Table 21 for the average pollutant concentrations used to characterize untreated legacy wastewater and CP treated legacy wastewater.

Table 21. Average Legacy Wastewater Pollutant Concentrations

Pollutant	FGD Surface Impoundment Effluent Concentration (µg/L)	FA Surface Impoundment Effluent Concentration (µg/L)	BA Surface Impoundment Effluent Concentration (µg/L)	CA Surface Impoundment Effluent Concentration (µg/L)	FGD CP Effluent Concentration (µg/L)
Conventional Pollutants					
Total suspended solids	27,900	10,400	19,700	15,300	8,590
Priority Pollutants					
Arsenic	7.59	36.4	17.4	50.3	5.83
Cadmium	113	7.63	2.19	1.42	4.21
Chromium	17.8	27.4	5.59	21.6	6.45
Copper	21.8	68.8	13.9	21.9	3.78
Lead	4.66	13.7	12.1	7.52	3.39
Mercury	7.78	0.828	0.634	1.18	0.139
Nickel	878	30.5	16.5	19.1	9.11
Selenium	1,170	15.4	11.8	28.0	928
Thallium	13.7	10.3	89.4	31.0	9.81
Zinc	1,390	226	31.0	72.3	20.0
Nonconventional Pollutants					
Aluminum	2,080	2,230	1,240	1,200	120
Barium	303	121	110	188	140
Boron	243,000	6,630	541	1,960	225,000
Calcium	2,050,000	99,300	68,800	74,600	1,920,000
Chloride	7,120,000	12,800	28,100	16,300	7,120,000
Cobalt	183	5.67	14.5	6.00	9.30
Iron	1,510	855	1,420	601	110
Magnesium	3,370,000	13,600	34,500	15,300	3,370,000
Manganese	93,400	144	1,440	67.5	12,500
Molybdenum	125	483	29.7	142	125
Nitrate/nitrite as N	96,000	2,360	6,070	2,550	96,000
Phosphorus	319	71.8	204	196	319
Sodium	276,000	34,000	53,000	12,400	276,000
Titanium	27.1	4.83	40.9	22.8	9.30
Total dissolved solids	32,500,000	469,000	754,000	266,000	24,100,000

Source: U.S. EPA 2015a.

6.5.1 Legacy Wastewater Flows

The EPA estimated legacy wastewater flows as described in Section 5.4.1.

The EPA reviewed materials in the rulemaking record (*e.g.,* steam electric power generating industry questionnaire database) and publicly available information, including geographic information system (GIS) mapping, to identify the receiving waters for legacy discharges. See the EPA memorandum *Receiving Waters Characteristics Analysis and Supporting Documentation for the Environmental Assessment of the Final Supplemental Steam Electric Rule* (U.S. EPA, 2024n) for details on the analysis. Based on available information, the EPA identified plants that are currently zero discharge and assumed that legacy wastewater would be managed as zero discharge. The EPA identified all other plants as direct dischargers and assumed that their legacy wastewater would also be directly discharged.

6.5.2 Baseline and Post-compliance Loadings

To estimate baseline and post-compliance loadings for the rule, the EPA multiplied the appropriate average effluent pollutant concentrations from Table 21 by the plant-specific legacy wastewater flow rate to calculate the pollutant loadings for each plant. Calculations for both baseline and the CP technology option use the same legacy wastewater flow rate.

Baseline Loadings

For all plants, the EPA estimated baseline loadings using the untreated concentrations shown in Table 21. Where possible, the EPA used the CCR impoundment effluent data set (FGD wastewater, FA, BA, or CA) that matched the surface impoundment description based on closure plans or other surface-impoundment-specific data (*e.g.,* the EPA used the FGD wastewater data set where CCR impoundments were titled "FGD pond"). Where the CCR material could not be determined, the EPA used data from the Steam Electric Survey to determine the type of CCR in each surface impoundment and assigned the most appropriate data set (U.S. EPA, 2015). Lacking other data, where it determined a steam electric power plant had never operated a wet FGD system, the EPA assigned these surface impoundments the CA data set.

CP Post-compliance Loadings

To estimate CP post-compliance loadings for all plants, the EPA used plant-specific legacy wastewater flow rates and the CP effluent concentrations shown in Table 21.

6.6 Summary of Baseline and Regulatory Option Loadings and Removals

The EPA evaluated three regulatory options to control FGD wastewater, BA transport water, CRL, and legacy wastewater discharges. For each regulatory option, the EPA combined the wastestream-level pollutant loadings for baseline and each technology option to obtain total regulatory option loadings; the EPA also calculated pollutant removals as the difference between baseline and each regulatory option (ERG, 2024f). This section discusses the specific loadings and removals calculations for each regulatory option evaluated by the EPA. This section also presents aggregated industry-level loadings and removals for each wastestream and regulatory option.

The EPA applied different effluent limitations to the following:

- Steam electric EGUs with less than 50 megawatts of generating capacity.
- EGUs permanently ceasing coal combustion by 2034 (FGD wastewater, BA transport water, and CRL).

In calculating the pollutant loading estimates for each regulatory option, the EPA considered the subcategorizations established by each option. The preamble describes the subcategories and requirements applicable for each of the regulatory options evaluated by the EPA.

Table 22, Table 23, Table 24, and Table 25 present the EPA's estimated total industry pollutant loadings and removals for FGD wastewater, BA transport water, CRL, and legacy wastewater, respectively, in pounds per year for baseline and each regulatory option. Table 26 presents the EPA's aggregated, industry-level pollutant loadings and removals at baseline and each regulatory option. Pollutant loadings and removals presented in these tables are calculated as the sum of TDS and TSS. The EPA estimated the pollutant removals by subtracting the post-compliance loadings from the baseline loadings. The *Generating Unit-Level Costs and Loadings Estimates by Regulatory Option for the 2024 Final Rule* memorandum presents the baseline and post-compliance loadings for each wastestream and each regulatory option at the unit level (U.S. EPA, 2024o). Post-compliance loadings represent loadings once all plants and EGUs comply with the regulatory option presented. Values presented in this document do not account for the timing or exact date of implementation (*e.g.,* when treatment systems are installed by the industry).

Although they were not part of the main regulatory option analysis, the EPA also estimated industry-level pollutant loadings for discharges of unmanaged CRL. The EPA estimates pollutant removals associated with discharges of unmanaged CRL could be between 3.62 and 16.4 million pounds annually.

Table 22. Estimated Industry-Level FGD Wastewater Pollutant Loadings and Removals by Regulatory Option

Regulatory Option	Estimated Total Industry Loadings (lb/Year)	Estimated Total Industry Removals (lb/Year)
Baseline	655,000,000	—
A	74,600,000	580,000,000
B	74,600,000	580,000,000
C	—	655,000,000

Note: Loadings and removals are rounded to three significant figures.

Table 23. Estimated Industry-Level BA Transport Water Pollutant Loadings and Removals by Regulatory Option

Regulatory Option	Estimated Total Industry Loadings (lb/Year)	Estimated Total Industry Removals (lb/Year)
Baseline	7,570,000	—
A	353,000	7,220,000
B	353,000	7,220,000
C	—	7,570,000

Note: Loadings and removals are rounded to three significant figures.

Table 24. Estimated Industry-Level CRL Pollutant Loadings and Removals by Regulatory Option

Regulatory Option	Estimated Total Industry Loadings (lb/Year)	Estimated Total Industry Removals (lb/Year)
Baseline	48,100,000	—
A	46,900,000	1,200,000
B	3,500,000	44,600,000
C	—	48,100,000

Note: Loadings and removals are rounded to three significant figures.

Table 25. Estimated Industry-Level Legacy Wastewater Pollutant Loadings and Removals by Regulatory Option

Regulatory Option	Estimated Total Industry Loadings (lb/Year)	Estimated Total Industry Removals (lb/Year)
Baseline	96,400,000	—
A	96,400,000	—
B	72,300,000	24,100,000
C	72,300,000	24,100,000

Note: Loadings and removals are rounded to three significant figures.

Table 26. Estimated Industry-Level Pollutant Loadings and Removals by Regulatory Option

Regulatory Option	Estimated Total Industry Loadings (lb/Year)	Estimated Total Industry Removals (lb/Year)
Baseline	807,000,000	—
A	218,000,000	589,000,000
B	151,000,000	656,000,000
C	72,300,000	735,000,000

Note: Loadings and removals are rounded to three significant figures.

7. Non-Water Quality Environmental Impacts

Eliminating or reducing one form of pollution can aggravate other environmental problems, an effect often referred to as a cross-media impact. Sections 304(b) and 306 of the Clean Water Act (CWA) require the EPA to consider non-water quality environmental impacts (NWQEIs), including energy impacts, associated with effluent limitations guidelines and standards (ELGs). Accordingly, the EPA considered the potential impacts of the regulatory options considered for flue gas desulfurization (FGD) wastewater, bottom ash (BA) transport water, combustion residual leachate (CRL), and legacy wastewater discharged from steam electric power plants on energy consumption (including fuel usage), air emissions, solid waste generation, and water use. Like the costs discussed in Section 5 and pollutant removals discussed in Section 6, the NWQEIs associated with the regulatory options evaluated for this rulemaking are measured as incremental changes from baseline (*i.e.,* the 2020 rule).

As described in Section 3.2.3, the EPA also notes that unlined landfills and surface impoundments potentially discharge unmanaged CRL that may be covered under the ELGs when they are determined on a case-by-case basis to be the functional equivalent of a direct discharge. To evaluate the potential NWQEIs of such discharges, the EPA conducted analyses documented in its memorandum *Evaluation of Unmanaged CRL* (U.S. EPA, 2024). The EPA presents the NWQEIs for unmanaged CRL throughout Section 7, following the main regulatory option analysis.

7.1 Energy Requirements

Steam electric power plants use energy (including fuel) when transporting ash and other solids on or off site, operating wastewater treatment systems, or operating ash handling systems. For those plants that are estimated to incur costs associated with the rule, the EPA considered whether there would be an associated incremental change in energy need compared to the baseline. That need varies depending on the regulatory option evaluated and the current operations of the plant. Therefore, as applicable, the EPA estimated the change in annual energy consumption in megawatt hours (MWh) for equipment added to the plant systems or in consumed fuel (gallons) for transportation or equipment operation. Specifically, the EPA estimated energy usage associated with operating equipment for the FGD wastewater treatment systems, BA handling systems, CRL, and legacy wastewater treatment systems considered for this rule.

- To estimate changes in energy consumption associated with operating FGD wastewater treatment equipment, the EPA developed relationships between FGD wastewater flow and energy usage for the following technologies: low residence time reduction (LRTR) biological treatment, membrane filtration, and spray dryer evaporator (SDE).
- To estimate energy usage for operating BA handling systems, the EPA developed relationships between electric generating unit (EGU) capacity and energy usage for the following technologies: mechanical drag system (MDS), remote MDS with a purge, and remote MDS with RO treatment of a slipstream to achieve complete recycle. The EPA estimated electrical energy use from horsepower ratings of system equipment (*e.g.,* pumps, mixers, silo unloading equipment) and energy usage data provided by wastewater treatment vendors. See the *Methodology for Estimating NWQEI for the 2024 Final Steam Electric ELGs* memorandum for additional details (U.S. EPA, 2024t).
- To estimate energy usage for operating CRL wastewater treatment systems, the EPA relied on the methodology developed for the chemical precipitation technology for FGD wastewater treatment as part of the 2015 and 2020 rules. For membrane filtration and SDE, the EPA also relied on the methodology used for FGD wastewater but estimated energy usage for the system sized to accommodate the CRL flow. The EPA summed plant-specific energy usage estimates to calculate the net change in annual energy consumption for the regulatory options considered for the rule; this information is presented in Table 27.

- To estimate energy usage for operating legacy wastewater treatment using CP, the EPA used the methodology from CRL, but estimated plant-level energy usage for CP treatment based on legacy wastewater flows. The EPA summed plant-specific energy usage estimates to calculate the net change in annual energy consumption for the regulatory options considered for the rule.

Energy usage also includes the fuel consumption associated with the changes in transportation. These changes include transportation needed to landfill solid waste and combustion residuals (*e.g.*, ash) at steam electric power plants to on-site or off-site landfills using open dump trucks and disposal of concentrated brine from the treatment of a remote MDS BA slipstream with an RO system to off-site disposal using a tanker truck. In general, the EPA calculated fuel usage based on the estimated amount of time spent loading and unloading solid waste, combustion residuals, or concentrated brine into trucks and the fuel consumption during idling plus the estimated total transportation distance, number of trips required per year to dispose of the solid waste, combustion residuals, or concentrated brine, and fuel consumption. The frequency and distance of transport to a landfill depends on a plant's operation and configuration. For example, the volume of waste generated per day determines the frequency with which trucks will be travelling to and from the storage sites. The availability of either an on-site or off-site landfill, and its estimated distance from the plant, determines the length of travel time. See the *Methodology for Estimating NWQEI for the 2024 Final Steam Electric ELGs* memorandum, for more information on the specific calculations used to estimate fuel consumption associated with the transport and disposal of solid waste, combustion residuals, and concentrated brine (U.S. EPA, 2024t). Table 27 shows the net change in national annual fuel consumption associated with the regulatory options compared to baseline (*i.e.,* the 2020 rule).

Table 27. Net Change in Annual Energy Use for the Regulatory Options Compared to Baseline

Non-Water Quality Impact	Net Change in Energy Use Associated with the ELG		
	Option A	Option B	Option C
Electrical energy usage (MWh)	182,000	309,000	436,000
Fuel (gallons per year)	97,600	116,000	151,000

Source: ERG, 2024g

Note: Values rounded to three significant figures.

The EPA estimates that energy use associated with discharges of unmanaged CRL could amount to as much as 280,000 MWh and 442 thousand gallons of fuel annually.

7.2 Air Emissions

The 2024 final rule is expected to affect air pollution through three main mechanisms:

- Changes in power requirements by steam electric power plants to operate wastewater treatment and BA handling systems in compliance with the regulatory options.
- Changes to transportation-related emissions due to the trucking of combustion residual waste to landfills.
- Changes in the profile of electricity generation due to the regulatory options.

This section provides more detail on air emission changes associated with the first two mechanisms and presents the estimated net change in air emissions associated with all three. See also the EPA's *Benefit and Cost Analysis for Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Categor*y for further discussion of the third mechanism (U.S. EPA, 2024u).

Air pollution is generated when fossil fuels burn. Steam electric power plants also generate air emissions from operating vehicles such as dump trucks, tanker trucks, vacuum trucks, dust suppression water trucks, and earthmoving equipment, which all release criteria air pollutants and greenhouse gases. Criteria air pollutants are those pollutants for which a national ambient air quality standard (NAAQS) has been set and include sulfur dioxide (SO_2) and nitrogen oxides (NO_x). Greenhouse gases are gases such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) that absorb radiation, thereby trapping heat in the atmosphere and contributing to a wide range of domestic effects.[38] Conversely, decreasing energy use or less vehicle operation will result in decreased air pollution.

The EPA calculated air emissions resulting from the change in power requirements[39] using year-explicit emission factors estimated by the Integrated Planning Model (IPM)[40] for CO_2, NO_x, and SO_2. The IPM output provides estimates of electricity generation and resulting emissions by plant and North American Electric Reliability Corporation (NERC) region. The EPA used detailed outputs for the 2035 IPM run year to estimated plant- and NERC-level emission factors (mass of pollutant emitted per kilowatt-hour of electricity generated) over the period of analysis. This run year represents steady-state conditions after rule implementation, when all plants are estimated to meet the revised BAT limitations and pretreatment standards associated with the 2024 final rule.

The EPA calculated NO_X, CO_2, and SO_2 emissions resulting from changes in power requirements based on the incremental auxiliary power electricity consumption, the pollutant- and year-specific emission factors, and the timing plants are assumed to install the compliance technology and start incurring additional electricity consumption.

The EPA assumed that plants with capacity utilization rates (CUR) of 90.4 percent or less would generate the additional auxiliary electricity on site and therefore estimated emissions using plant-specific and year-explicit emission factors obtained from IPM outputs.[41]

The EPA assumed that plants with CUR greater than 90.4 percent would draw additional electricity from the grid within the NERC region, instead of generating it on site. These plants will be using part of their existing generation to power equipment; however, other plants within the same NERC region would need to generate electricity to compensate for this reduction and meet electricity demands. Therefore, for these high-CUR plants, the EPA used NERC-average emission factors instead of plant-specific emissions factors.

Because the EPA ran IPM for the 2024 final rule only, the EPA used IPM emission factors calculated for the 2024 final rule to estimate changes in power requirements air emissions for all other regulatory options.

To estimate air emissions associated with operation of transport vehicles, the EPA used the MOVES4 model to generate air emission factors for NO_x, SO_2, CO_2, and CH_4. The EPA assumed the general input parameters such as the year of the vehicle and the annual mileage accumulation by vehicle class to develop these factors (U.S. EPA, 2024v). Table 28 lists the transportation emission factors for each air pollutant considered in the NWQEI analysis.

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[38] The EPA did not specifically evaluate N_2O emissions as part of the NWQEI analysis. To avoid double-counting air emission estimates, the EPA calculated only NO_x emissions, which would include N_2O emissions.

[39] Power requirements refers to the electricity needed to operate FGD wastewater treatment, BA handling, CRL, and/or legacy wastewater treatment technologies. Plants may generate this electricity on site or purchase the electricity from the grid.

[40] IPM is a comprehensive electricity market optimization model that can evaluate cost and economic impacts within the context of regional and national electricity markets. IPM is used by the EPA to analyze the estimated impact of environmental policies on the U.S. power sector.

[41] Emission factors are calculated as plant-level emissions divided by plant-level generation.

Table 28. MOVES4 Emission Rates for Model Year 2010 Diesel-Fueled, Long-Haul Trucks Operating in 2024

Roadway Type	NO_x (Tons/mi)	SO_2 (Tons/mi)	CO_2 (Tons/mi)	CH_4 (Tons/mi)
Highway	3.20E-06	5.72E-09	0.0017	1.47E-08
Local	4.04E-06	5.93E-09	0.00176	2.00E-08

Source: MOVES4.0 (database version "movesdb20240104").

Abbreviations: mi (mile).

Vehicle types: Single and combination unit long-haul trucks, together.

Road types: Restricted access roads are "Highway" and unrestricted access are "Local."

The EPA calculated the air emissions associated with the operation of transport vehicles estimated for the regulatory options using the transportation pollutant-specific emission rate per mile, the estimated round-trip distance to and from the on-site or off-site landfill, and the number of calculated trips for one year in the transportation methodology to truck all solid waste or combustion residuals to the on-site or off-site landfill and concentrated brine for off-site disposal.

The EPA estimated the annual number of miles that dump trucks moving ash or wastewater treatment solids to on- or off-site landfills or tanker trucks transporting concentrated brine to off-site disposal would travel to comply with limitations associated with the regulatory options. See the EPA's memorandum *Methodology for Estimating NWQEI for the 2024 Final Steam Electric ELGs* for more information on the specific calculations used to estimate transport distance and number of trips per year (U.S. EPA, 2024t). The changes in national annual air emissions associated with auxiliary electricity and transportation for each of the regulatory options are shown in Table 29.

Table 29. Net Change in Industry-Level Air Emissions Associated with Power Requirements and Transportation by Regulatory Option

Non-Water Quality Impact	Air Emissions Associated with the ELG		
	Option A	Option B	Option C
NO_X (thousand tons/year)	0.045	0.090	0.104
SO_2 (thousand tons/year)	0.049	0.116	0.123
CO_2 (million metric tonnes/year)	0.063	0.126	0.146
CH_4 (thousand metric tonnes/year)	0.007	0.008	0.011

Source: ERG, 2024g

The EPA estimates that air emissions associated with discharges of unmanaged CRL could amount to as much as 0.048 million metric tonnes of CO_2, 0.022 thousand tons of NO_X, and 0.014 thousand tons of SO_2 annually.

The modeled output from IPM predicts changes in electricity generation due to compliance costs attributable to the regulatory options compared to baseline. These changes in electricity generation are, in turn, predicted to affect the amount of NOx, SO_2, and CO_2 emissions from steam electric power plants. A summary of the net change in annual air emissions associated with Option B for all three mechanisms are shown in Table 30. Similar to costs, the IPM from these options reflect the range of NWQEI associated with all three regulatory options. To provide some perspective on the estimated changes in annual air emissions, the EPA compared the estimated change in air emissions to the net amount of air emissions generated in a year by all steam electric power plants throughout the U.S. For a detailed breakout of each of the three sources of air emission changes, see the EPA's BCA (U.S. EPA, 2024u).

Table 30. Estimated Net Change in Industry-Level Air Emissions associated with Changes in Power Requirements, Transportation, and Electricity Generation for Option B Compared to Baseline

Non-Water Quality Impact	Change in Emissions—Option B	2020 Emissions by Electric Power Generating Industry
CO_2 (million tons/year)	-13	1,650
NO_X (thousand tons/year)	-8.7	1,020
SO_2 (thousand tons/year)	-13	954

Sources: U.S. EPA, 2024u; ERG, 2024g.

7.3 Solid Waste Generation

Solid waste associated with the implementation of the rule is based on the generation of residual treatment solids from the change in solids from membrane filtration versus LRTR, RO systems, and CP. The EPA estimated the amount of solid waste generated from each technology for each applicable plant.

- The EPA determined the FGD solids generated from membrane filtration with brine encapsulation by multiplying an aggregate solids value by the plant-specific optimized FGD flow rate (expressed in GPD). The EPA then subtracted out the backwash dry solids generated from an LRTR system. The EPA estimated FGD solids generated from SDE by multiplying an aggregate solids value by the plant-specific optimized FGD flow rate (expressed in gallons per day [GPD]). The EPA then subtracted out the backwash dry solids generated from an LRTR system.
- The EPA determined the BA solids (expressed in tons of brine solids per year) generated from RO systems by multiplying the purge flow (10 percent of the total BA system volume) by the average TDS concentration in BA transport water.[42]
- The EPA determined the CRL solids generated from CP treatment by multiplying a flow-normalized dewatered sludge generation rate (expressed in tons per day of sludge per gallon per minute CRL flow) by the plant's CRL flow rate. The EPA estimated CRL solids generated from membrane filtration and from SDE by multiplying an aggregate solids value by the plant-specific CRL flow rate (expressed in GPD).
- The EPA determined the legacy wastewater solids generated from CP treatment by multiplying a flow-normalized dewatered sludge generation rate (expressed in tons per day of sludge per gallon per minute legacy wastewater flow) by the plant's legacy wastewater flow rate.

The net change in national solid waste production associated with the regulatory options is shown in Table 31. The EPA estimated that solid waste generation associated with the treatment of discharges of unmanaged CRL could amount to as much as 4.2 million tons per year.

Table 31. Net Change in Industry-Level Solid Waste by Regulatory Option

Non-Water Quality Impact	Solid Waste Generation with the ELG		
	Option A	Option B	Option C
Solids (million tons/year)	1.33	1.74	2.23

Source: U.S. EPA, 2024u

[42] Similar to the 2020 rule methodology, the EPA assumed plants would transfer RO brine off site at an average distance of 40 miles.

7.4 Change in Water Use

Steam electric power plants generally use water for handling solid waste, including BA, and for operating wet FGD scrubbers. The EPA estimated the plant-specific change in water intake, or process water use, associated with FGD wastewater treatment and BA handling for each evaluated technology options and baseline.

Plants expected to install a membrane filtration system for FGD wastewater treatment under the regulatory options are expected to experience a decrease in water use compared to baseline because the EPA anticipates they will reuse the membrane permeate in the FGD scrubber. The EPA estimated the reduction in water use resulting from membrane filtration treatment compared to baseline is 70 percent of the optimized FGD flow.

The EPA estimates that the regulatory options evaluated will decrease water intake associated with BA handling as the regulatory options require zero discharge of the BA purge. The EPA used the purge volume for each plant, equivalent to 10 percent of the total remote MDS volume as defined in Section 5.2.1, to estimate the decrease in water intake for each plant for BA. The EPA does not expect the treatment technologies evaluated for the 2024 final rule have an impact on water use related to CRL or legacy wastewater treatment.

Table 32 presents the estimated incremental change in process water use for each regulatory option evaluated for the ELGs compared to baseline. The change in water use for each regulatory option is equivalent to the change in wastewater discharge. The industry-level process water use for membrane filtration is the same for all brine management options considered.

Table 32. Net Change in Industry-Level Process Water Use by Regulatory Option

Non-Water-Quality Impact	Change in Water Use with the Option		
	Option A	Option B	Option C
Water reduction (MGD)	5.52	5.52	5.80

Source: U.S. EPA, 2024u

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Exhibit 13

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Environmental Assessment for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category

Environmental Assessment for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category

EPA-821-R-15-006

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U.S. Environmental Protection Agency
Office of Water (4303T)
Engineering and Analysis Division
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TABLE OF CONTENTS

Page

TABLE OF CONTENTS (Continued)

Page

TABLE OF CONTENTS (Continued)

Page

LIST OF TABLES

Page

List of Tables (*Continued*)

Page

List of Tables (*Continued*)

Page

List of Figures

Page

ACRONYMS

ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
BAF	Bioaccumulation factor
BASINS	Better Assessment Science Integrating Point and Nonpoint Sources
BAT	Best Available Technology Economically Achievable
BCF	Bioconcentration factor
BPT	Best Practicable Control Technology Currently Available
CBI	Confidential business information
CCR	Coal combustion residuals
CFR	Code of Federal Regulations
CSCL	Chemical stressor concentration limit
CSF	Cancer slope factor
CWA	Clean Water Act
DBP	Disinfection by-products
DCN	Document control number
DMR	Discharge monitoring report
DOE	Department of Energy
EA	Environmental assessment
EF	Enrichment factors
EFDC	Environmental Fluid Dynamics Code
ELGs	Effluent Limitations Guidelines and Standards
EP	Extraction procedure
EPA	U.S. Environmental Protection Agency
ER	Exposure-response
ESA	Endangered Species Act
FGD	Flue gas desulfurization
FGMC	Flue gas mercury control
FR	Federal Register
FWS	U.S. Fish and Wildlife Service
IRIS	Integrated Risk Information System
IRW	Immediate receiving water
Kd_{sw}	Suspended sediment-surface water partition coefficient
LADD	Lifetime average daily dose
lbs/yr	Pounds per year
LC_{50}	Median lethal concentration
LECR	Lifetime excess cancer risk

MCL	Maximum contaminant level
MRL	Minimal risk level
MGD	Million gallons per day
mg/day	Milligrams per day
mg/kg	Milligrams per kilogram
mg/L	Milligrams per liter
MW	Megawatt
MWh	Megawatt-hour
NEHC	No effect hazard concentration
NHDPlus	National Hydrography Dataset Plus
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No-observed-adverse-effect level
NPDES	National Pollutant Discharge Elimination System
NRWQC	National Recommended Water Quality Criteria
NSPS	New Source Performance Standards
NWIS	National Water Information System
ORCR	Office of Resource Conservation and Recovery
OSWER	Office of Solid Waste and Emergency Response
PCB	Polychlorinated biphenyls
POC	Pollutant of concern
POTW	Publicly owned treatment works
ppm	Parts per million
PSES	Pretreatment Standards for Existing Sources
PSNS	Pretreatment Standards for New Sources
RCRA	Resource Conservation and Recovery Act
RfD	Reference dose
RIA	Regulatory impact analysis
RSEI	Risk-Screening Environmental Indicators
SDWA	Safe Drinking Water Act
SQuiRT	Screening Quick Reference Table
STORET	EPA’s STOrage and RETrieval Data Warehouse
T3	Trophic level 3
T4	Trophic level 4
TC	Toxicity characteristic
TCLP	Toxicity characteristic leaching procedure
TDD	Technical Development Document
TDS	Total dissolved solids
TEL	Threshold effects level

TMDL	Total maximum daily load
TOC	Total organic carbon
TRI	Toxics Release Inventory
TSS	Total suspended solids
TTF	Trophic transfer factor
TTHM	Total trihalomethanes
TWF	Toxic weighting factor
TWPE	Toxic weighted pound equivalent
µg/g	Micrograms per gram
µg/L	Micrograms per liter
USGS	United States Geological Survey
WASP	Water Quality Analysis Simulation Program
WHO	World Health Organization
WMA	Wildlife Management Area
WQI	Water quality index

GLOSSARY

Acute – having a sudden onset or lasting a short time. An acute stimulus is severe enough to induce a response rapidly. The word acute can be used to define either the exposure or the response to an exposure (effect). The duration of an acute aquatic toxicity test is generally 4 days or less and mortality is the response usually measured.

Aquifer – an underground formation or group of formations in rocks and soils containing enough ground water to supply wells and springs.

Benthic – pertaining to the bottom (bed) of a waterbody.

Bioaccumulation – general term describing a process by which chemicals are taken up by an organism either directly from exposure to a contaminated medium or by consumption of food containing the chemical, resulting in a net accumulation of the chemical by an organism due to uptake from all routes of exposure.

Bioavailability – the ability of a particular contaminant to be assimilated into the tissues of exposed organisms.

Biomagnification – result of the process of bioaccumulation and biotransfer by which tissue concentrations of chemicals in organisms at one trophic level exceed tissue concentrations in organisms at the next lower trophic level in a food chain.

Bottom ash – the ash, including boiler slag, which settles in the furnace or is dislodged from furnace walls. Economizer ash is included when it is collected with bottom ash.

Chronic – involving a stimulus that is lingering or continues for a long time; often signifies periods from several weeks to years, depending on the reproductive life cycle of the species. This term can be used to define either the exposure or the response to an exposure (effect). Chronic exposures typically induce a biological response of relatively slow progress and long duration.

Combustion residuals – solid wastes associated with combustion-related power plant processes, including fly and bottom ash from coal-, petroleum coke-, or oil-fired units; flue gas desulfurization (FGD) solids; flue gas mercury control wastes; and other wastewater treatment solids associated with steam electric power plant wastewater. In addition to the residuals that are associated with coal combustion, this also includes residuals associated with the combustion of other fossil fuels.

Combustion residual leachate – leachate from landfills or surface impoundments containing combustion residuals. Leachate is composed of liquid, including any suspended or dissolved constituents in the liquid, that has percolated through waste or other materials emplaced in a landfill, or that passes through the surface impoundment's containment structure (*e.g.*, bottom, dikes, berms). Combustion residual leachate includes seepage and/or leakage from a combustion residual landfill or impoundment unit. Combustion residual leachate includes wastewater from landfills and surface impoundments located on non-adjoining property when under the operational control of the permitted facility.

Criterion continuous concentration – an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely (chronic exposure) without resulting in an unacceptable effect.

Criterion maximum concentration – an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly (acute exposure) without resulting in an unacceptable effect.

Direct discharge – (a) Any addition of any "pollutant" or combination of pollutants to "waters of the United States" from any "point source," or (b) any addition of any pollutant or combination of pollutant to waters of the "contiguous zone" or the ocean from any point source other than a vessel or other floating craft which is being used as a means of transportation. This definition includes additions of pollutants into waters of the United States from: surface runoff which is collected or channeled by man; discharges though pipes, sewers, or other conveyances owned by a State, municipality, or other person which do not lead to a treatment works; and discharges through pipes, sewers, or other conveyances, leading into privately owned treatment works. This term does not include an addition of pollutants by any "indirect discharger."

Edema – swelling caused by fluid in body tissues.

Effluent limitation – under Clean Water Act (CWA) section 502(11), any restriction, including schedules of compliance, established by a state or the Administrator on quantities, rates, and concentrations of chemical, physical, biological, and other constituents which are discharged from point sources into navigable waters, the waters of the contiguous zone, or the ocean, including schedules of compliance.

Evaluated wastestreams – subset of steam electric power plant wastewaters evaluated in the environmental assessment (EA) and Benefits and Cost Analysis that includes FGD wastewater, fly ash transport water, bottom ash transport water, and combustion residual leachate collected from landfills or surface impoundments.

Exposure – the contact or co-occurrence of a stressor with a receptor.

Flue gas desulfurization (FGD) wastewater – wastewater generated specifically from the wet FGD scrubber system that comes into contact with the flue gas or the FGD solids, including but not limited to, the blowdown or purge from the FGD scrubber system, overflow or underflow from the solids separation process, FGD solids wash water, and the filtrate from the solids dewatering process. Wastewater generated from cleaning the FGD scrubber, cleaning FGD solids separation equipment, cleaning the FGD solids dewatering equipment, or that is collected in floor drains in the FGD process area is not considered FGD wastewater.

Flue gas mercury control (FGMC) wastewater – wastewater generated from an air pollution control system installed or operated for the purpose of removing mercury from flue gas. This includes fly ash collection systems when the particulate control system follows sorbent injection or other controls to remove mercury from flue gas. FGD wastewater generated at plants using oxidizing agents to remove mercury in the FGD system and not in a separate FGMC system is not included in this definition.

Fly ash – the ash that is carried out of the furnace by a gas stream and collected by a capture device such as a mechanical precipitator, electrostatic precipitator, and/or fabric filter. Economizer ash is included in this definition when it is collected with fly ash. Ash is not included in this definition when it is collected in wet scrubber air pollution control systems whose primary purpose is particulate removal.

Gasification wastewater – any wastewater generated at an integrated gasification combined cycle operation from the gasifier or the syngas cleaning, combustion, and cooling processes. Gasification wastewater includes, but is not limited to the following: sour/grey water; CO2/steam stripper wastewater; sulfur recovery unit blowdown, and wastewater resulting from slag handling or fly ash handling, particulate removal, halogen removal, or trace organic removal. Air separation unit blowdown, noncontact cooling water, and runoff from fuel and/or byproduct piles are not considered gasification wastewater. Wastewater that is collected intermittently in floor drains in the gasification process areas from leaks, spills and cleaning occurring during normal operation of the gasification operation is not considered gasification wastewater.

Ground water – water that is found in the saturated part of the ground underneath the land surface.

Hematological – pertaining to or emanating from blood cells.

Histopathological – pertaining to tissue changes.

Immediate receiving water – the segment of a receiving water where discharges from a point source enter the surface water. The segment is defined by the hydrographic dataset supporting the analysis (*e.g.*, National Hydrography Dataset Plus, Version 1).

Impaired waters – a surface water is classified as a 303(d) impaired water when pollutant concentrations exceed water quality standards and the surface water can no longer meet its designated uses (*e.g.*, drinking, recreation, and aquatic habitat).

Indirect discharge – wastewater discharged or otherwise introduced to a publicly owned treatment works (POTW).

Invertebrates – animals without a backbone or spinal column; *macroinvertebrates* are invertebrates that can be seen without a microscope (macro), such as aquatic insects, worms, clams, snails, and crustaceans.

Landfill – a disposal facility or part of a facility where solid waste, sludges, or other process residuals are placed in or on any natural or manmade formation in the earth for disposal and which is not a storage pile, a land treatment facility, a surface impoundment, an underground injection well, a salt dome or salt bed formation, an underground mine, a cave, or a corrective action management unit.

Leachate – see *combustion residual leachate*.

Lentic – pertaining to still or slow-moving water, such as lakes or ponds.

Lethal – causing death by direct action.

Lotic – pertaining to flowing water, such as streams and rivers.

Median lethal concentration (LC_{50}) – a statistically or graphically estimated concentration that is expected to be lethal to 50 percent of a group of organisms under specified conditions.

Mortality – death rate or proportion of deaths in a population.

Partition coefficient – the ratio of a pollutant concentration in one medium compared to another (*e.g.*, dissolved in the water column, sorbed to suspended sediment, and sorbed to benthic sediment in a receiving water).

Piscivorous – habitually feeds on fish.

Plant-receiving water – the combination of a steam electric power plant and the immediate receiving water into which evaluated wastestreams are discharged from that plant.

Point source – any discernable, confined, and discrete conveyance, including but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft from which pollutants are or may be discharged. The term does not include agricultural stormwater discharges or return flows from irrigated agriculture. See CWA section 502(14), 33 U.S.C. 1362(14); 40 CFR §122.2.

Population – an aggregate of individuals of a species within a specified location in space and time.

Publicly owned treatment works (POTW) – any device or system, owned by a state or municipality, used in the treatment (including recycling and reclamation) of municipal sewage or industrial wastes of a liquid nature that is owned by a state or municipality. This includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment. See CWA section 212, 33 U.S.C. 1292; 40 CFR §§122.2, 403.3.

Receptor – the ecological or human entity exposed to a stressor.

Receiving water – surface waters into which treated waste or untreated waste are discharged, including those portions of the surface water downstream from the point source.

Sediment – particulate material lying below water.

Sensitivity – in relation to toxic substances, organisms that are more sensitive exhibit adverse (toxic) effects at lower exposure levels than organisms that are less sensitive.

Steam electric power plant wastewater – wastewaters associated with or resulting from the combustion process, including ash transport water from coal-, petroleum coke-, or oil-fired units; air pollution control wastewater (e.g., FGD wastewater, FGMC wastewater, carbon capture wastewater); and leachate from landfills or surface impoundments containing combustion residuals.

Stressor – any physical, chemical, or biological entity that can induce an adverse response.

Sublethal – below the concentration that directly causes death. Exposure to sublethal concentrations of a substance can produce effects on behavior, biochemical, and/or physiological functions, and the structure of cells and tissues in organisms.

Surface water – all waters of the United States, including rivers, streams, lakes, reservoirs, and seas.

Teratogenic – able to disturb the growth and development of an embryo or fetus.

Transport water – any wastewater that is used to convey fly ash, bottom ash, or economizer ash from the ash collection or storage equipment, or boiler, and has direct contact with the ash. Transport water does not include low volume, short duration discharges of wastewater from minor leaks (*e.g.*, leaks from valve packing, pipe flanges, or piping) or minor maintenance events (*e.g.*, replacement of valves or pipe sections).

Trophic level – position of an organism in the food chain.

Toxic pollutants – as identified under the CWA, 65 pollutants and classes of pollutants, of which 126 specific substances have been designated priority toxic pollutants. See Appendix A to 40 CFR §423.

SECTION 1 INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is promulgating revised effluent limitations guidelines and standards (ELGs) for the Steam Electric Power Generating Point Source Category (40 CFR 423). In support of the development of the final rule, EPA conducted an environmental assessment (EA) to evaluate the environmental impact of pollutant loadings released under current (*i.e.*, baseline) discharge practices and assess the potential environmental improvement from pollutant loading removals under the final rule.[1]

Based on evidence in the literature, documented damage cases, and modeled receiving water pollutant concentrations, it is clear that current steam electric power plant wastewater discharge practices impact the water quality in receiving waters, impact the wildlife in the surrounding environments, and pose a human health threat to nearby communities. Substantial evidence exists that metals (*e.g.*, arsenic, cadmium, mercury, selenium) from steam electric power plant wastewater discharges transfer from the aquatic environment to terrestrial food webs, indicating a potential for broader impacts to ecological systems by altering population diversity and community dynamics in the areas surrounding steam electric power plants. Ecosystem recovery from exposure to pollutants in power plant wastewater discharges can be extremely slow, and even short periods of exposure (*e.g.*, less than a year) can cause observable ecological impacts that last for years.

Steam electric power plants discharge wastewater, which contains numerous pollutants,[2] into waterbodies used for recreation and can present a threat to human health. Due to steam electric power plant wastewater discharges, fish advisories have been issued to protect the public from exposure to fish with elevated pollutant concentrations. Leaching of pollutants from surface impoundments and landfills containing combustion residuals is known to impact off-site ground water and drinking water wells at concentrations above maximum contaminant level (MCL) drinking water standards, posing a threat to human health.[3]

In this report, EPA uses the term "steam electric power plant wastewater" to represent all combustion-related wastewaters that contain pollutants covered by the revised steam electric ELGs. For the EA, EPA evaluated only a subset of the wastestreams: flue gas desulfurization (FGD) wastewater, fly ash transport water, bottom ash transport water, and combustion residual

[1] The Clean Water Act does not require that EPA assess the water-related environmental impacts, or the benefits, of its ELGs, and EPA did not make its decision on the final steam electric ELGs based on the expected benefits of the rule. EPA does, however, inform itself of the benefits of its rule, as required by Executive Order 12866. See the Benefits and Cost Analysis for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generation Point Source Category (EPA-821-R-15-005).

[2] The steam electric ELGs control the discharge of pollutants to surface waters and do not specifically regulate "wastewater." To allow for more concise discussion in this EA report, EPA occasionally refers to "wastewater" discharges and impacts without specifically referencing the pollutants in the wastewater discharges.

[3] In this EA, EPA evaluated the threats to human health and the environment associated with pollutants leaching into ground water from surface impoundments and landfills containing combustion residuals. If these leached pollutants do not constitute the discharge of a pollutant to surface waters, then they are not controlled under the steam electric ELGs. While the Coal Combustion Residuals (CCR) rulemaking is the major controlling action for these pollutant releases to ground water, the ELGs could indirectly reduce impacts to ground water. These secondary improvements are discussed in Section 7.8.

leachate collected from landfills or surface impoundments). The goal of the EA was to answer the following five questions regarding pollutant loadings from the evaluated wastestreams:

- What are the environmental concerns under current (*i.e.*, baseline) discharge practices?
- What are the environmental and exposure pathways for steam electric power plant wastewater discharges to impact water quality, wildlife, and human health?
- What are the baseline environmental impacts to water quality and wildlife?
- What are the impacts to human health from baseline discharges?
- What are the potential improvements to water quality, wildlife, and human health under the final rule?

The EA evaluated environmental concerns and potential exposures (wildlife and humans) to pollutants commonly found in wastewater discharges from steam electric power plants. EPA completed both qualitative and quantitative analyses. Qualitative analyses included reviewing documented site impacts in literature and damage cases; assessing the pollutant loadings to receiving waters and sensitive environments; and reviewing the effects of pollutant exposure on ecological and human receptors. To quantify baseline impacts and improvements under the final rule, EPA developed computer models to determine pollutant concentrations in the immediate and downstream receiving waters, pollutant concentrations in fish tissue, and exposure doses to ecological and human receptors from fish consumption. EPA compared the values calculated by the models to benchmarks to determine the extent of the environmental impacts nationwide. EPA also developed a model to determine the risk of reproductive impacts among fish and waterfowl that have been exposed, via their diet, to selenium from steam electric power plant wastewater discharges.

This report presents the methodology and results of the qualitative and quantitative analyses performed to evaluate baseline discharges from steam electric power plants and improvements under the final rule. The analyses presented in this report incorporate some adjustments to current conditions in the industry. For example, these analyses account for publicly announced plans from the steam electric power generating industry to retire or modify steam electric generating units at specific power plants. These analyses also account for changes to the industry that are expected to occur as a result of the recent CCR rulemaking by EPA's Office of Solid Waste and Emergency Response (OSWER). These analyses, however, do not reflect changes in the industry that may occur as a result of the Clean Power Plan [Clean Air Act Section 111(d)].[4]

In addition to the EA, the final steam electric ELGs are supported by a number of reports including:

Regulatory Impact Analysis for Effluent Limitations Guidelines and Standards for the Steam Electric Power Generation Point Source Category, Document No. EPA-821-R-15-004. This report presents a profile of the steam electric power generating industry, a summary of the

[4] EPA completed a parallel set of quantitative EA analyses that reflect changes in the industry that may occur as a result of the Clean Power Plan. Appendix I provides the results of those analyses.

costs and impacts associated with the regulatory options, and an assessment of the final rule's impact on employment and small businesses.

Benefits and Cost Analysis for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generation Point Source Category (Benefits and Cost Analysis), Document No. EPA-821-R-15-005. This report summarizes the monetary benefits and societal costs that result from implementation of the final rule.

Technical Development Document for Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category (TDD), Document No. EPA-821-R-15-007. This report includes background on the final rule; applicability and summary of the final rule; industry description; wastewater characterization and identification of pollutants of concern; treatment technologies and pollution prevention techniques; and documentation of EPA's engineering analyses to support the final rule including cost estimates, pollutant loadings, and non-water-quality impact assessment.

These reports are available in the public record for the final rule and on EPA's website at http://water.epa.gov/scitech/wastetech/guide/steam_index.cfm.

The ELGs for the Steam Electric Power Generating Point Source Category are based on data generated or obtained in accordance with EPA's Quality Policy and Information Quality Guidelines. EPA's quality assurance and quality control activities for this rulemaking include the development, approval, and implementation of Quality Assurance Project Plans for using environmental data generated or collected from all sampling and analyses, existing databases, and literature searches, and for developing any models that used environmental data. Unless otherwise stated within this document, EPA evaluated the data used and associated data analyses as described in these quality assurance documents to ensure they are of known and documented quality, meet EPA's requirements for objectivity, integrity, and utility, and are appropriate for the intended use.

SECTION 2
BACKGROUND AND SCOPE

The final steam electric effluent limitations guidelines and standards (ELGs) apply to establishments whose generation of electricity is the predominant source of revenue or principal reason for operation, and whose generation results primarily from a process utilizing fossil-type fuels (coal, oil, or gas), fuel derived from fossil fuel (*e.g.*, petroleum coke, synthesis gas), or nuclear fuel in conjunction with a thermal cycle using the steam water system as the thermodynamic medium. The final rule applies to discharges associated with both the combustion turbine and steam turbine portions of a combined cycle generating unit (see 40 CFR 423.10). EPA is revising or establishing best available technology economically achievable (BAT) limitations, new source performance standards (NSPS), pretreatment standards for existing sources (PSES), and pretreatment standards for new sources (PSNS) that apply to certain discharges of seven wastestreams: flue gas desulfurization (FGD) wastewater, fly ash transport water, bottom ash transport water, combustion residual leachate, flue gas mercury control (FGMC) wastewater, gasification wastewater, and nonchemical metal cleaning wastes. See the Technical Development Document (TDD) (EPA-821-R-15-007) for more information on the rule applicability and definitions, industry description, wastestreams and pollutants of concern, treatment technologies, baseline and regulatory option pollutant loadings, costs of implementing treatment technologies, and revised standards.

Many steam electric power plants use large surface impoundments to store and treat wastewaters. These impoundments are hydrologically connected to surface and ground water.

As discussed in Section 1, EPA uses the term "steam electric power plant wastewater" to represent all combustion-related wastewaters covered by the revised steam electric ELGs. For the environmental assessment (EA), EPA evaluated only a subset of the wastestreams (see Table 2-1 below).[5] "Combustion residuals" are the solid wastes associated with combustion-related power plant processes, including fly and bottom ash; FGD solids; FGMC wastes; and other wastewater treatment solids associated with steam electric power plant wastewater. Steam electric power plants generate solid residuals from fuel combustion and from emission control technologies. These solid residuals include fly ash, bottom ash, and FGD solids. Plants remove these solid materials through both wet and dry handling methods. Dry handling typically involves transferring the solids to a storage silo or outdoor storage pile, to be either disposed of in a landfill or, depending on the particular residual,

[5] EPA evaluated technology options associated with FGMC wastewater, gasification wastewater, and nonchemical metal cleaning wastes as part of the regulatory options. However, no plants currently discharge FGMC wastewater, all existing gasification plants are operating the technology used as the basis for the regulatory option, and EPA will continue to reserve BAT/NSPS/PSES/PSNS for nonchemical metal cleaning wastes, as previously established regulations do. Therefore, EPA estimated zero compliance costs and zero pollutant reductions associated with these wastestreams and did not include these three wastestreams in the EA.

used to create beneficial by-products such as wallboard or cement. However, many plants use wet handling systems, which transport the wastes to a surface impoundment (*e.g.*, ash pond) using large quantities of water. For example, in wet systems, bottom ash collects at the bottom of the boiler in a water bath, and the water containing the bottom ash is then typically transported to a surface impoundment for storage and/or disposal. Fly ash may be handled similarly after it is collected from the particulate collection system. The slurry stream exiting wet FGD systems, which contains 10 to 20 percent FGD solids, is typically treated either in a surface impoundment or in an advanced wastewater treatment system, then discharged to a receiving stream or reused in other plant processes. Section 6 of the TDD describes the industry wastestreams in detail. Table 2-1 lists the specific wastestreams evaluated in the EA.

Table 2-1. Steam Electric Power Plant Wastestreams Evaluated in the EA

Evaluated Wastestream	Description
Fly ash transport water	Water used to convey the fly ash particles removed from the flue gas via a collection system. Untreated ash transport waters contain significant concentrations of total suspended solids (TSS) and metals, including arsenic, calcium, and titanium (see Section 6 of the TDD for further details). The effluent from surface impoundments generally contains low concentrations of TSS; however, metals are still present in the wastewater, predominantly in dissolved form.
Bottom ash transport water	Water used to convey the bottom ash particles collected at the bottom of the boiler. As noted above, untreated ash transport waters contain significant concentrations of TSS and metals.
FGD wastewater	Wastewater generated from a wet FGD scrubber system. Wet FGD systems are used to control sulfur dioxide (SO_2) emissions from the flue gas generated in the plant's boiler. The pollutant concentrations in FGD wastewater vary from plant to plant depending on the coal type, the sorbent used, the materials of construction in the FGD system, the FGD system operation, the level of recycle within the absorber, and the air pollution control systems operated upstream of the FGD system. FGD wastewater contains significant concentrations of chlorides, total dissolved solids (TDS), nutrients, and metals, including bioaccumulative pollutants such as arsenic, mercury, and selenium (see Section 6 of the TDD for further details).
Combustion residual leachate	Collected liquid that has percolated through or drains from a landfill or a surface impoundment, where the steam electric power plant disposes of or stores a variety of wastes from the combustion process. Leachate contains high concentration of metals, such as boron, calcium, chloride, and sodium, similar to FGD wastewaters and ash transport water. The metal concentrations in the leachate are generally lower than those in FGD wastewater and ash transport water (see Section 6 of the TDD for further details).

Surface impoundments accumulate high concentrations of toxic pollutants from fly ash transport water, bottom ash transport water, and FGD wastewater.

Surface impoundments act as a physical treatment process to remove particulate material from wastewater through gravitational settling. The wastewater in surface impoundments can include one specific type of wastewater (*e.g.*, fly ash transport water) or a combination of wastewaters (*e.g.*, fly ash transport water and FGD wastewater). Additionally, plants may transfer wastewater streams from other operations into their on-site impoundments (*e.g.*, cooling tower blowdown or metal cleaning wastes). The wastestreams sent to surface impoundments can also include coal pile runoff. Although coal pile runoff is not the result of a combustion process, it can contain many of the pollutants present in steam electric power plant wastewater. Leachate or seepage may occur from surface impoundments or landfills containing combustion residuals.[6] Regardless of whether they use surface impoundments or an advanced treatment system, steam electric power plants typically discharge wastewater into the natural environment where numerous studies have raised concern regarding the toxicity of these wastestreams [ERG, 2013a; NRC, 2006; Rowe *et al*., 2002; U.S. EPA, 2014a through 2014e]. Previous regulations at 40 CFR 423 control pH and polychlorinated biphenyls (PCBs) discharge from all wastestreams and TSS and oil and grease from ash transport waters and other “low volume wastes” that include air pollution control wastewater (see Section 1 of the TDD). Section 6 of the TDD discusses wastewater characterization and selection of pollutants of concern.

Based on data EPA obtained from the 2010 *Questionnaire for the Steam Electric Power Generating Effluent Guidelines* (Steam Electric Survey), EPA estimates that 1,079 steam electric power plants are subject to the final rule (see Section 4 of the TDD). EPA limited the scope of the EA to those plants that both 1) discharge directly to surface waters and 2) will reduce their pollutant loadings as a result of the regulatory options evaluated, based on EPA projections. Therefore, the EA scope excludes steam electric power plants that meet any of the following criteria:

- Plants that do not discharge any of the wastestreams that are included in the final rule (even if the plant does generate and reuse the wastestream without discharging to surface waters).
- Plants that already comply with final rule or have plans to comply with the final rule prior to the date when the plants would have to meet the new limitations and standards.

[6] In this EA, EPA evaluated the threats to human health and the environment associated with pollutants leaching into ground water from surface impoundments and landfills containing combustion residuals. If these leached pollutants do not constitute the discharge of a pollutant to surface waters, then they are not controlled under the steam electric ELGs. While the CCR rulemaking is the major controlling action for these pollutant releases to ground water, the ELGs could indirectly reduce impacts to ground water. These secondary improvements are discussed in Section 7.8.

- Plants that that have announced plans to retire steam generating units (that would otherwise be subject to the final rule) prior to the date that the plants would have to meet the new limitations and standards.
- Plants that, based on EPA projections, will either convert to dry ash handling or install tank-based FGD wastewater treatment systems to comply with the CCR rulemaking.
- Plants that discharge only to publicly owned treatment works (POTWs).

In the EA, EPA evaluated the current impact and potential improvement to the environment and human health from 195 plants that discharge directly to surface waters and that EPA projects will reduce pollutant loadings as a result of the regulatory options evaluated. Table 2-2 presents the number of plants by discharge type (direct or indirect) included in the cost and loadings analysis presented in Sections 9 and 10 of the TDD.

Table 2-2. Number of Plants Evaluated in the EA

Plant Description	Number of Plants
Number of Plants in Scope of Final Rule	
Plants that fall under the applicability of the final rule (40 CFR 423)	1,079
Cost and Loadings Analysis	
Plants for which EPA calculated loadings in the cost and loadings analyses (see Sections 9 and 10 of the TDD)	202
Plants that discharge only to surface waters (direct discharger)	191
Plants that discharge only to a POTW (indirect discharger)	7
Plants that discharge to surface waters and to a POTW (direct and indirect discharger)	4
Environmental Assessment	
Plants evaluated in the EA (includes all direct dischargers)[a]	195

a – For the pollutant loadings and removals presented in this report, EPA included indirect dischargers to protect confidential business information.

These 195 steam electric power plants discharge to the 222 immediate receiving waters illustrated in Figure 2-1 (some plants discharge to multiple receiving waters). The EA includes qualitative analysis of the pollutant loadings in evaluated wastestreams discharged from these plants and the associated potential for environmental and human health impacts. As discussed in Section 5, EPA developed and executed a national-scale immediate receiving water (IRW) model to perform further quantitative modeling of the water quality, wildlife, and human health impacts associated with discharges from the majority of these plants. The IRW model, which excludes discharges to the Great Lakes and estuaries, encompasses 188 steam electric power plants that discharge to 209 immediate receiving waters. As discussed in Section 8, EPA also performed more detailed case study modeling of discharges from six steam electric power plants. Figure 2-1 indicates the immediate receiving waters included in the IRW modeling and case study modeling scopes.

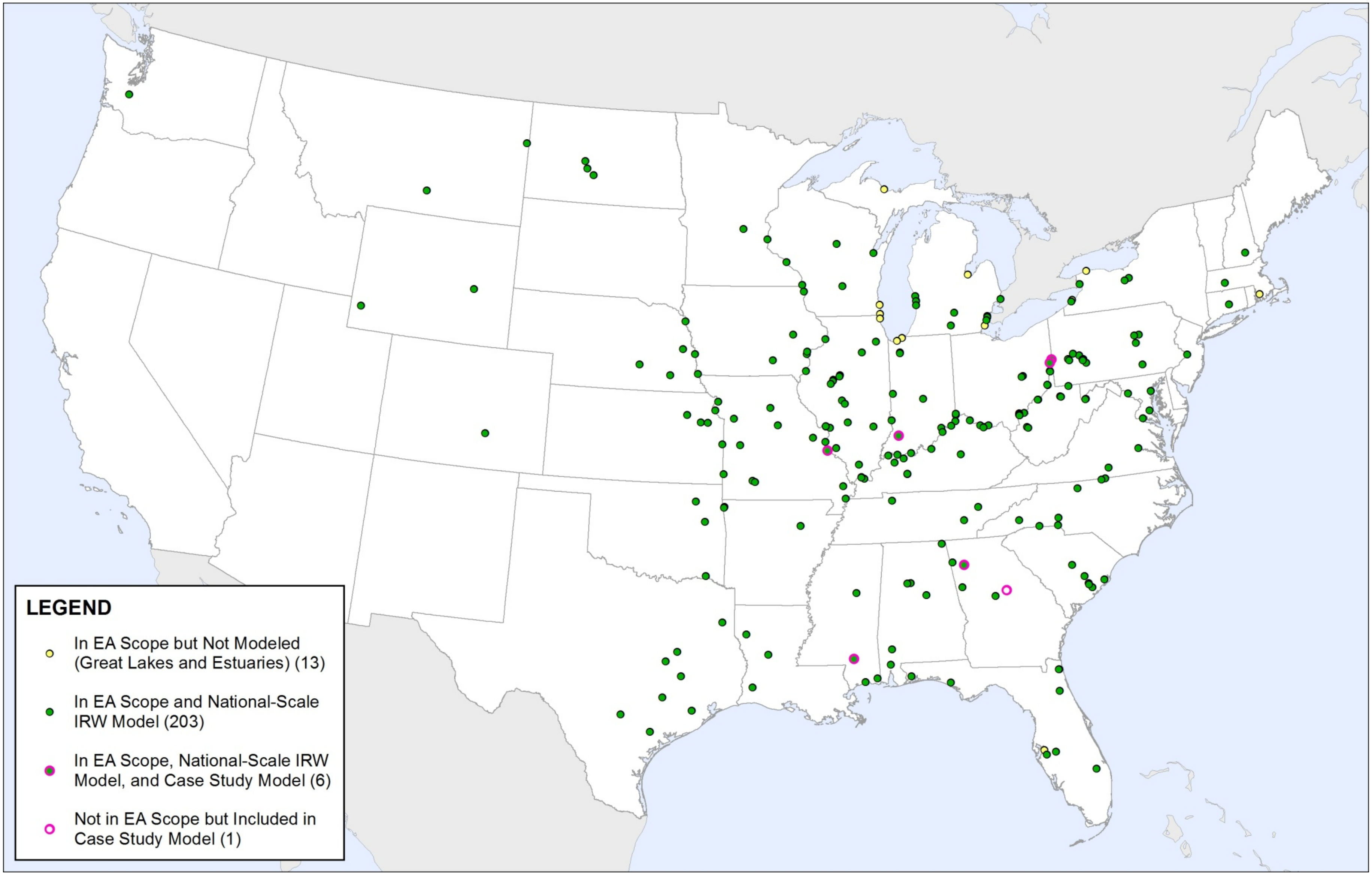


Figure 2-1. Locations and Counts of Immediate Receiving Waters in EA Scope and Modeling Analyses

EPA used the results from quantitative and qualitative assessments combined with the literature review to evaluate and describe the environmental impacts caused by the discharge of the evaluated wastestreams. EPA organized the remainder of this report into the following sections:

- Section 3 describes the environmental concerns associated with the evaluated wastestreams, including a discussion of the pollutants of concern and a review of damage cases and other documented site impacts showing negative impacts to surface water and ground water.
- Section 4 outlines how ecological and human receptors may be exposed to pollutants (i.e., environmental pathways), describes the factors that control environmental impacts for each pathway, and gives an overview of the methodology used to quantitatively evaluate the environmental and human health impacts.
- Section 5 presents the modeling performed to support the EA including an overview of the national-scale IRW model and the ecological risk model.
- Section 6 presents the environmental and human health impacts based on qualitative review and quantitative assessments (modeling of plant-specific discharges) of current (baseline) discharges.
- Section 7 presents the improvements to the environment and human health estimated from the implementation of the regulatory options.
- Section 8 describes EPA's case study modeling of discharges from six steam electric power plants, presents the environmental and human health impacts under baseline conditions, and discusses the modeled improvements under the final rule.
- Section 9 presents EPA's conclusions on the environmental and human health improvements estimated under the final rule.

SECTION 3
ENVIRONMENTAL AND HUMAN HEALTH CONCERNS

Current scientific literature indicates that steam electric power plant wastewater is not a benign waste [NRC, 2006; Rowe *et al*., 2002]. Many of the common pollutants (*e.g.*, selenium, mercury, and arsenic) found in the evaluated wastestreams (*i.e.*, fly ash and bottom ash transport water, flue gas desulfurization (FGD) wastewater, and combustion residual leachate) present an increased ecological threat due to their tendency to persist in the environment and bioaccumulate in organisms. This often results in slow ecological recovery times following exposure. The toxic impacts of steam electric power plant wastewater discharges on surface waters have been well documented in studies of over 30 aquatic ecosystems receiving discharges from steam electric power plants.[7]

Documented exceedances of drinking water maximum contaminant levels (MCLs) downstream of steam electric power plants and the issuance of fish advisories in receiving waters indicate an ongoing human health concern caused by steam electric power plant wastewater discharges. EPA identified more than 30 documented cases where ground water contamination from surface impoundments extended beyond the plant boundaries, illustrating the threat to ground water drinking water sources [ERG, 2015m].[8] In other damage cases, EPA documented locations where selenium in power plant wastewater discharges resulted in fish consumption advisories being issued for surface waters.

The pollutants commonly discharged in the evaluated wastestreams cause environmental harm by contaminating surface water and ground water (*e.g.*, selenium concentrations from steam electric power plants have resulted in fish kills). After being released into the environment, pollutants can reside for a long time in the receiving waters, bioaccumulating and binding with the sediment. There is documented evidence of slow ecological recovery as a result of these pollutant discharges. Steam electric power plants also discharge to sensitive environments (*e.g.*, impaired waters, waters under a fish consumption advisory, Great Lakes, valuable estuaries, and drinking water sources). Some impacts might not be realized for years due to the persistent and bioaccumulative nature of the pollutants released. Based on EPA's calculated baseline pollutant loadings, the total amount of toxic pollutants currently being released in wastewater discharges from steam electric power plants is significant and raises concerns regarding the long-term impacts to aquatic organisms, wildlife, and humans that are exposed to these pollutants. For details on the pollutant loadings analysis, see Section 10 of the Technical Development Document (TDD) (EPA-821-R-15-007).

This section details environmental concerns associated with wastewater discharges from steam electric power plants including changes in surface water quality and sediment contamination levels; changes in ground water quality and potential contamination of private

[7] Sources include ATSDR, 1998a, 1998b and 1998c; Charlotte Observer, 2010; DOE, 1992; EIP, 2010a and 2010b; Roe *et al.,* 2005; Sorensen *et al.,* 1983; Sorensen, 1988; Specht *et al.,* 1984; and Vengosh *et al.,* 2009.

[8] In this EA, EPA evaluated the threats to human health and the environment associated with pollutants leaching into ground water from surface impoundments and landfills containing combustion residuals. If these leached pollutants do not constitute the discharge of a pollutant to surface waters, then they are not controlled under the steam electric ELGs. While the Coal Combustion Residuals (CCR) rulemaking is the major controlling action for these pollutant releases to ground water, the ELGs could indirectly reduce impacts to ground water. These secondary improvements are discussed in Section 7.8.

drinking water wells; bioaccumulation of contaminants in fish and aquatic life, fish eaten by piscivorous wildlife (*i.e.*, fish-eating wildlife), and fish eaten by humans; and toxic effects on fish and aquatic life. The section is organized into the following subsections:

- Section 3.1: Types of pollutants discharged in steam electric power plant wastewater.
- Section 3.2: Pollutant loadings associated with steam electric power plant wastewater.
- Section 3.3: Environmental impacts from steam electric power plant wastewater, including ecological impacts, human health effects, damage cases and other documented site impacts, and potential for impacts to occur in other locations.
- Section 3.4: Sensitive environments, including pollutant loadings to the Great Lakes and Chesapeake Bay watersheds, impaired waters, waters issued fish advisories, threatened and endangered species habitats, and drinking water resources.
- Section 3.5: Long recovery times.

3.1 TYPES OF POLLUTANTS DISCHARGED IN STEAM ELECTRIC POWER PLANT WASTEWATER

This section provides an overview of the pollutants in steam electric power plant wastewater discharges that are frequently cited as affecting local wildlife or pose a threat to human health. A number of variables can affect the composition of steam electric power plant wastewater, including fuel composition, type of combustion process, air pollution control technologies implemented, and management techniques used to dispose of the wastewater [Carlson and Adriano, 1993]. In addition, commingling steam electric power plant wastewater with other wastestreams from the plant in surface impoundments can result in a chemically complex effluent that is released to the environment [Rowe *et al*., 2002]. To identify pollutants of concern for the final rule, EPA used the following sources of wastewater characterization data: EPA's field sampling program; data supplied by industry or members of the public (*e.g.,* in questionnaire responses and public comments on the proposed rule); and various literature sources (see Section 6 of the TDD and the preamble to the final rule for further details on pollutants of concern). Pollutants such as metals, nutrients, and total dissolved solids (TDS), including chloride and bromides, are the common pollutants found in steam electric power plant wastewater that have been associated with documented environmental impacts or could have the potential to cause environmental impacts based on the loadings and concentrations present in the evaluated wastestreams.

3.1.1 Metals and Toxic Bioaccumulative Pollutants

Studies commonly cite metals and toxic bioaccumulative pollutants (*e.g.,* mercury and selenium) as the primary cause of ecological damage following exposure to steam electric power plant wastewater [Rowe *et al*., 1996; Lemly, 1997a; Hopkins *et al*., 2000; Rowe *et al*., 2002] (see Section 3.3.1). An important consideration in evaluating these pollutants is their bioavailability–the ability of a particular contaminant to be assimilated into the tissues of exposed organisms. A pollutant's bioavailability is affected by the characteristics of both the pollutant and surrounding environment (*e.g.*, temperature, pH, salinity, oxidation-reduction (redox) potential, total organic content, suspended particulate content, and water velocity). Environmental conditions influence the tendency of a dissolved pollutant to remain in solution or precipitate out of solution, sorb to either organic or inorganic suspended matter in the water column, or sorb to the mixture of materials (*e.g.*, clays and humic matter) found in sediments [U.S. EPA, 2007a]. Pollutants that precipitate out of solution can become concentrated in the sediments of a waterbody. Regardless, organisms will bioaccumulate pollutants either by consuming pollutant-enriched sediments and suspended particles, and/or by filtering ambient water containing dissolved pollutants.

Table 3-1 lists some of the common metals and toxic bioaccumulative pollutants found in steam electric power plant wastewater that have been associated with documented health and environmental impacts or could potentially cause health and environmental impacts based on the loadings and concentrations present in the wastewater. Table 3-1 is intended to highlight the pollutants of concern in steam electric power plant wastewater that are associated with health and environmental impacts; it does not include all pollutants that may cause adverse impacts. Metals and toxic bioaccumulative pollutants in steam electric power plant wastewater are present in both soluble (*i.e.*, dissolved) and particulate (*i.e.*, suspended) form. For example, EPA sampling data collected for FGD wastewater in support of the steam electric ELGs shows that some pollutants such as arsenic are present mostly in particulate form while other pollutants such as selenium and boron are present mostly in soluble form. The remainder of the section provides additional details on several key metals included in the environmental assessment (EA).

Table 3-1. Key Metals and Toxic Bioaccumulative Pollutants Found In Steam Electric Power Plant Wastewater

Pollutant	Examples of Potential Health and Environmental Concerns
Aluminum	Aluminum contamination can lead to the inability of fish to maintain the balance of their fluids and is associated with damage to amphibian eggs and larvae, mostly in areas under acid stress. Human exposure to high concentrations has been linked to Alzheimer's disease.
Arsenic [a]	Arsenic contamination causes liver poisoning, developmental abnormalities, behavioral impairments, metabolic failure, reduced growth, and appetite loss in fish and is associated with an increased risk of the liver and bladder cancer in humans. Arsenic is also a potent endocrine disruptor at low, environmentally relevant levels. Non-cancer impacts to humans can include dermal, cardiovascular, and respiratory effects. Negative impacts can occur both after high-dose exposure and repeated lower-dose exposures. Chronic exposure via drinking water has been associated with excess incidence of miscarriages, stillbirths, preterm births, and low-birth weights.
Boron	Boron can be toxic to vegetation and to wildlife at certain water concentrations and dietary levels. Human exposure to high concentrations can cause nausea, vomiting, and diarrhea.
Cadmium	Cadmium contamination can lead to developmental impairments in wildlife and skeletal malformations in fish. Human exposure to high concentrations in drinking water and food can irritate the stomach, leading to vomiting and diarrhea, and sometimes death. Chronic oral exposure via diet or drinking water to lower concentrations can lead to kidney damage and weakened bones.
Chromium [b]	Chromium is not known to bioaccumulate in fish; however, high concentrations of chromium can damage gills, reduce growth, and alter metabolism in fish. Human exposure to high concentrations can cause gastrointestinal bleeding and lung problems.
Copper	Copper contamination can lead to reproductive failure, gill damage, and reduced sense of smell in fish. Human exposure to high concentrations can cause nausea, vomiting, diarrhea, and liver and kidney damage.
Iron	Iron contamination can reduce growth, increase susceptibility to injury and disease, and decrease egg hatchability in fish. Human exposure to high concentrations can cause metabolic changes and damage to the pancreas, liver, spleen, and heart.
Lead	Lead contamination can delay embryonic development, suppress reproduction, and inhibit growth in fish. Human exposure to high concentrations in drinking water can cause serious damage to the brain, kidneys, nervous system, and red blood cells.

Table 3-1. Key Metals and Toxic Bioaccumulative Pollutants Found In Steam Electric Power Plant Wastewater

Pollutant	Examples of Potential Health and Environmental Concerns
Manganese	Manganese primarily accumulates in organisms lower in the food chain such as phytoplankton, algae, mollusks, and some fish. Although high levels can be toxic to humans, manganese is not generally considered toxic when ingested. The most common impacts due to human exposure to high concentrations involve the nervous system.
Mercury [c]	Once in the environment, mercury can convert into methylmercury, increasing the potential for bioaccumulation. Methylmercury contamination can reduce growth and reproductive success in fish and invertebrates. Human exposure at levels above the MCL for relatively short periods can result in kidney and brain damage. Fetuses, infants, and children are particularly susceptible to impaired neurological development from methylmercury exposure.
Nickel	At low concentrations, nickel can inhibit the growth of microorganisms and algae. Nickel toxicity in fish and aquatic invertebrates varies among species and can damage the lungs, immune system, liver, and kidneys. Human exposure to high concentrations can cause gastrointestinal and kidney damage.
Selenium [d]	Selenium readily bioaccumulates. Elevated concentrations have caused fish kills and numerous sublethal effects (*e.g.*, organ damage, decreased growth rates, reproductive failure) to aquatic and terrestrial organisms. In humans, short-term exposure at levels above the MCL can cause hair and fingernail changes, damage to the peripheral nervous system, and fatigue and irritability. Long-term exposure can damage the kidney, liver, and nervous and circulatory systems.
Thallium	In humans, short-term exposure to thallium can lead to neurological symptoms, alopecia, gastrointestinal effects, and reproductive and developmental damage. Long-term exposures at levels above the MCL change blood chemistry and damage liver, kidney, intestinal and testicular tissues and cause hair loss.
Vanadium	Vanadium contamination can increase blood pressure and cause neurological effects in animals. There are very few reported cases of oral exposure to vanadium in humans; however, a few reported incidences documented diarrhea and stomach cramps. It also has been linked to the development of some neurological disorders and cardiovascular diseases.
Zinc	Zinc contamination changes behavior, reduces oxygen supply, and impairs reproduction in fish. In humans, short-term exposure can cause nausea, vomiting, and stomach cramps. Long-term exposure can cause anemia.

a – Arsenic exists in two primary forms: arsenic III (arsenite) and arsenic V (arsenate).

b – Chromium exists in two primary forms: chromium III oxide and chromium VI (hexavalent chromium).

c – The EA evaluated two forms of mercury: total mercury and methylmercury.

d – Selenium exists in two primary forms: selenium IV (selenite) and selenium VI (selenate).

Selenium

Selenium is the most frequently cited pollutant associated with documented environmental impacts to ecological receptors following exposure to steam electric power plant wastewater [NRC, 2006]. The toxic potential of selenium is related to its chemical form and solubility. The predominant chemical forms of selenium in aquatic systems that receive steam electric power plant wastewater discharges are selenite and selenate [Besser *et al*., 1996]. The uptake of selenium by aquatic organisms is controlled by dissolved oxygen levels, hardness, pH, salinity, temperature, and the other chemical constituents present [NPS, 1997]. In alkaline conditions, selenite [Se(IV)] will oxidize in the presence of oxygen to become selenate [Se(VI)]; selenate is both stable and soluble and is the commonly found form of the chemical in alkaline soils and waters. In acidic conditions, selenite is insoluble due to its tendency to bind to iron and aluminum oxides [WHO, 1987]. Organic forms of selenium are more bioavailable for uptake than selenate and selenite and may play an important role determining selenium toxicity in exposed aquatic organisms [Besser *et al*., 1993; Rosetta and Knight, 1995].

The extent to which selenium is found in ecological receptors is affected by bioaccumulation, biomagnification, and maternal transfer. Bioaccumulation occurs when an organism absorbs a toxic substance through food and exposure to the environment at a faster rate than the body can remove the substance. The bioaccumulation of selenium is of particular concern due to its potential to impact higher trophic levels through biomagnification [Coughlan and Velte, 1989] and offspring through maternal transfer [Hopkins *et al*., 2006; Nagle *et al*., 2001]. A laboratory study demonstrated that diet can be an important source of trace element exposure in aquatic snakes and potentially other amphibians [Hopkins *et al*., 2002]. Hopkins reported that the snakes accumulated significant concentrations of the trace elements, most notably selenium. This study also revealed that amphibian prey species are able to migrate considerable distances and can therefore be exposed to toxic levels of selenium even if they do not inhabit a contaminated site. Because of bioaccumulation and biomagnification, selenium-related environmental impacts can linger for years even after exposure to steam electric power plant wastewater has ceased [Rowe *et al*., 2002].

Toxic Pollutant Impacts to Ecological Receptors

- Selenium discharges have caused numerous cases of fish kills and population decline due to reproductive impacts. Bioaccumulation can cause selenium-related environmental impacts to linger for years even after exposure to steam electric power plant wastewater has ceased.
- Fish and invertebrates exposed to steam electric power plant wastewater have exhibited elevated mercury levels in their tissues and developed sublethal effects such as reduced growth and reproductive success.
- Elevated arsenic tissue concentrations are associated with several biological impacts such as liver tissue death, developmental abnormalities, and reduced growth.

Selenium-related impacts observed by scientists include lethal effects such as fish kills, sublethal effects such as histopathological changes and damage to reproductive and developmental success, and the impacts of these effects on aquatic populations and communities. In a 1991 study, Sorensen found that dissolved selenium levels as low as 3 to 8 micrograms per liter (µg/L) in aquatic environments can be life-threatening to fish [NPS, 1997]. Section 3.3.1 presents further details regarding the lethal and sublethal effects on aquatic organisms caused by selenium from steam electric power plant wastewater.

In addition to ecological impacts, EPA has documented numerous damage cases where selenium in steam electric power plant wastewater discharges resulted in fish consumption advisories being issued for surface waters and selenium MCLs being exceeded in ground water, suggesting that selenium concentrations in power plant wastewater have the potential to impact human health [NRC, 2006; U.S. EPA, 2014a through 2014e]. Short-term exposure at levels above the MCL, 0.05 mg/L [U.S. EPA, 2009e], can cause hair and fingernail changes, damage to the peripheral nervous system, and fatigue and irritability in humans. Long-term exposure can damage the kidney, liver, and nervous and circulatory systems.

Mercury

Mercury is a volatile metal and highly toxic compound that represents an environmental and human health threat even in small concentrations. One of the primary environmental concerns regarding mercury concentrations in steam electric power plant wastewater is the potential for methylmercury to form in combustion residual surface impoundments and constructed wetlands prior to discharge and in surface waters following discharge. Methylmercury is an organic form of mercury that readily bioaccumulates in fish and other organisms and is associated with high rates of reproductive failure [WHO, 1976]. Bacteria found in anaerobic conditions, such as those that may be present in sediments found on the bottom of combustion residual surface impoundments or in river sediments, convert mercury to methylmercury through a process called methylation [WHO, 1976]. Microbial methylation rates increase in acidic and anoxic environments with high concentrations of organic matter. Sublethal effects from mercury exposure include reduced growth and reproductive success, metabolic changes, and abnormalities of the liver and kidneys. Human exposure at levels above the MCL, 0.002 mg/L [U.S. EPA, 2009e], for relatively short periods of time can result in kidney and brain damage. Pregnant women who are exposed to mercury can pass the contaminant to their developing fetus, leading to possible mental retardation and damage to other parts of the nervous system [ATSDR, 1999]. Studies have documented fish and invertebrates exposed to mercury from steam electric power plant wastewater exhibiting elevated levels of mercury in their tissues and developing sublethal effects such as reduced growth and reproductive success [Rowe *et al*., 2002].

Toxic Pollutant Impacts to Human Receptors

- Pregnant women exposed to mercury can pass the contaminant to their developing fetus, leading to possible mental retardation and damage to other parts of the nervous system.
- Inorganic arsenic is a carcinogen (*i.e.*, causes cancer). Cadmium is a probable carcinogen.
- Human exposure to high concentrations of lead in drinking water can cause serious damage to the brain, kidneys, nervous system, and red blood cells, especially in children.

Arsenic

Arsenic, like selenium, is of concern because it is soluble in near-neutral pH and in alkaline conditions, which are commonly associated with steam electric power plant wastewater. As a soluble pollutant, arsenic leaches into ground water and is highly mobile. Arsenic is frequently observed at elevated concentrations at sites located downstream from combustion residual surface impoundments [NRC, 2006]. Inorganic arsenic, a carcinogen, is found in natural and drinking waters mainly as trivalent arsenite (As(III)) or pentavalent arsenate (As(V)) [WHO, 2001]. Both the arsenite and arsenate forms are highly soluble in water.

Arsenic is also of concern due to its tendency to bioaccumulate in aquatic communities and potentially impact higher-trophic-level organisms in the area. For example, studies have documented water snakes, which feed on fish and amphibians, with arsenic tissue concentrations higher than their prey [Rowe *et al*., 2002]. Elevated arsenic tissue concentrations are associated with several biological impacts such as liver tissue death, developmental abnormalities, behavioral impairments, metabolic failure, reduced growth, and appetite loss [NRC, 2006; Rowe *et al*., 2002; U.S. EPA 2011f].

Humans are exposed to arsenic primarily by ingesting contaminated drinking water [WHO, 2001]. Humans are also exposed to arsenic by consuming contaminated fish. Of greatest concern is inorganic arsenic, which can cause cancer in humans. Several studies have shown that most arsenic in fish is organic and not harmful to humans. Inorganic arsenic typically accounts for 4 percent or less of the total arsenic that accumulates in fish.[9] The highest potential exposure is for individuals whose diet is high in fish and particularly shellfish [U.S. EPA, 1997b].

As discussed in Section 3.3.4, EPA has documented several damage cases where arsenic levels exceeded drinking water standards in ground water near combustion residual surface impoundments [U.S. EPA, 2014b through 2014e]. Arsenic contamination of ground water at the levels documented represents a potential human health threat, if either the aquifer is used as a drinking water source or the ground water contaminates a downstream drinking water source.

Cadmium

The speciation and toxicity of cadmium in water depends on the water's salinity, hardness, temperature, and organic content [WHO, 1992]. Cadmium tends to bioaccumulate readily in mollusks, soil invertebrates, and microorganisms. Due to its chemical similarity to calcium, it can also interfere with calcium uptake in aquatic organisms, which can cause sublethal effects in fish such as skeletal malformation. Divalent cadmium (Cd(II)) is the species most commonly found in an aquatic environment, but depending on the quality of the water, cadmium can also occur as cadmium carbonate, hydroxide, sulfite, sulfate, or chlorides.

EPA determined that cadmium is a probable human carcinogen. Studies found lung cancer in humans and rats exposed to cadmium via inhalation. In humans, chronic low-level exposure to cadmium from contaminated air, drinking water, or food can cause kidney failure. Chronic low-level exposure from contaminated drinking water or food can also lead to fragile bones. Exposure via inhalation at high levels can damage lungs and exposure via food and drinking water can irritate the stomach, leading to vomiting and diarrhea [ATSDR, 2012].

Thallium

Thallium typically exists as the monovalent or trivalent thallium ion [WHO, 1996]. It is soluble in most waters and is readily available to aquatic life. Thallium can bioaccumulate in fish and vegetation in fresh and marine waters, as well as marine invertebrates, which suggests that thallium may be a potential threat to higher order organisms in vulnerable ecosystems [U.S. EPA, 2011a]. Studies in humans and animals indicate that thallium compounds are readily absorbed through ingestion of food and water and maternal transfer [WHO, 1996].

In humans, elevated thallium concentrations can lead to neurological symptoms (*e.g.*, weakness, sleep disorders, muscular problems), alopecia (*i.e.*, loss of hair from the head and body), and gastrointestinal effects (*e.g.*, diarrhea and vomiting). Long-term exposures at levels above the MCL, 0.002 mg/L [U.S. EPA, 2009e], lead to changes in blood chemistry, damage to liver, kidney, and intestinal and testicular tissues, and hair loss. Thallium exposure can also cause reproductive and developmental damage [U.S. EPA, 2009a].

[9] Based on a 1996 literature review of toxicity and exposure concerns related to arsenic in seafood prepared for U.S. EPA Region 10, inorganic arsenic comprised higher than four percent total arsenic for three species (shark, sturgeon, and sucker). Inorganic arsenic for all other species accounted for less than 4 percent of the total arsenic [U.S. EPA, 1997b].

Lead

Neither metallic lead nor many of its common mineral forms are soluble in water, although it can be soluble in some acids or water with low pH; thus, lead is commonly present in precipitate form in water. Therefore, steam electric power plant wastewater may initially have high concentrations of lead, but later sampling of the wastewater can show decreased concentrations because the lead settles out quickly. Lead will accumulate in aquatic organisms, but depends on the species. Studies have shown lead to delay embryonic development, suppress reproduction, and inhibit growth rate among fish, crab, and several other aquatic organisms [U.S. EPA, 1984]. Human exposure to high concentrations of lead in drinking water can seriously damage the brain, kidneys, nervous system, and red blood cells, especially in children.

Boron

Boron is primarily found in the environment combined with oxygen in compounds called borates [ATSDR, 2010b]. Boron concentrations in North American waters are typically below 0.1 mg/L [WHO, 1998], although areas with natural boron-rich deposits may have ground water levels as high as 300 mg/L [ATSDR, 2010b]. The World Health Organization (WHO) suggests that the potential of adverse effects of boron on the aquatic ecosystem is low because the no-effect concentration (1 mg/L) is much greater than levels found in the ambient environment. Boron does not magnify through the food chain, but does accumulate in aquatic and terrestrial plants. While it is an essential micronutrient for higher plants, there is a small range between deficiency and toxicity in some plants. Studies of acute exposure in fish yielded toxicity values ranging from approximately 10 to 300 mg/L with rainbow trout and zebra fish being the most sensitive. Mallard duckling growth was impacted at dietary levels of 30 and 300 milligrams per kilogram (mg/kg), while survival was reduced at 1,000 mg/kg [WHO, 1998].

EPA has not set a numerical criterion under the National Recommended Water Quality Criteria (NRWQC) for aquatic life, but it has issued a narrative criterion of 0.75 mg/L for sensitive crops that receive long-term irrigation.

EPA has not set a NRWQC for human health. Very few human studies have examined health effects resulting from boron exposure through oral ingestion. However, one study documents nausea, vomiting, and diarrhea in an adult male who ingested 85 mg/kg of boron (30 g as boric acid) [ATSDR, 2010b]. In addition, animal experiments indicate that boron in the form of boric acid and borate affects reproductive and developmental processes at levels that are approximately 100 to 1,000 times greater than normal exposure levels, approximately 1.2 milligrams per day (mg/day) [WHO, 1998].

Manganese

In water, manganese tends to attach to particles or settle into the sediment [ATSDR, 2008b]. It occurs in both dissolved and suspended forms, depending on the water chemistry (*e.g.*, pH) [WHO, 2011]. Manganese can bioaccumulate in lower organisms, such as phytoplankton, algae, mollusks, and some fish, but not in higher organisms. Studies suggest that biomagnification up the food chain is not significant [ATSDR, 2008b].

Due to a high bioaccumulation factor and concentrations in mollusks, EPA established a criterion to protect consumers of marine mollusks—100 micrograms per liter (µg/L) for marine waters [U.S. EPA, 1986]. Although high levels can be toxic to humans, manganese is an essential nutrient required to maintain health and is generally not considered to be toxic when ingested [WHO, 2011]. EPA did not set a primary MCL for manganese in drinking water; however, EPA did set secondary (nonenforceable) standards at 50 µg/L to minimize objectionable qualities in the drinking water that cause laundry stains and objectionable tastes in beverages [U.S. EPA, 2009e].

3.1.2 Nutrients

Nutrients (*e.g.*, phosphorus and nitrogen) are essential components for plants and animals to grow and develop; however, increased nutrient concentrations can upset the delicate balance of nutrient supply and demand required to maintain aquatic life in surface waters. For example, excess nutrients can cause low oxygen in surface waters (hypoxia) and harmful algal blooms. These are primarily problems for estuaries, such as the Chesapeake Bay, and coastal waters, such as the Gulf of Mexico. Nutrient concentrations present in steam electric power plant wastewater are primarily attributed to the fuel composition and air pollution controls in the combustion process.

Total nitrogen loadings from coal-fired power plants could potentially increase significantly in the future as air pollution limits become stricter and air pollution control use increases. While wastewater from an individual steam electric power plant can have a relatively low nitrogen concentration the total nitrogen loadings from a single plant can be significant due to high wastewater discharge flow rates. Total nutrient loadings from multiple power plants are especially a concern for waterbodies that are nutrient-impaired or in watersheds that contribute to downstream nutrient problems. High nutrient loadings to surface waters can affect the ecological stability of freshwater and saltwater aquatic systems. For example, excessive levels of nutrients can stimulate rapid growth of plants, algae, and cyanobacteria on or near the waterbody surface, which in turn can obstruct sunlight penetration, increase turbidity, and decrease dissolved oxygen levels [U.S. EPA, 2015a]. These aquatic changes can potentially kill bottom-dwelling aquatic plants. Cyanobacterial blooms can also produce toxic secondary metabolites, known as cyanotoxins, that can have negative impacts to humans and wildlife that consume water contaminated with cyanobacteria. The presence of high levels of cyanotoxins in recreational and drinking water may cause fever, headaches, abdominal pain, and other symptoms in humans. Severe human impacts include seizures, liver failure, respiratory arrest, and (rarely) death [U.S. EPA, 2012d].

3.1.3 TDS

TDS, a reflection of water's salinity level, is a measure of the amount of dissolved matter in water. TDS comprises primarily inorganic salts and dissolved metals, as well as a small amount of organic matter. Common inorganic salts found in TDS can include cations (positively charged ions), such as calcium, magnesium, potassium, and sodium, and anions (negatively charged ions) such as carbonates, nitrates, bicarbonates, chlorides, and sulfates. TDS concentrations in steam electric power plants wastestreams include contributions from dissolved metals, chlorides, and bromides. Dissolved metals and other TDS constituents are found in wastewater particularly at acidic pH levels when they exhibit high solubilities. The specific constituents in TDS in steam electric power plant wastewater cause the negative impacts.

<u>Bromides</u>

Bromide is the anion of bromine; it commonly exists as salts with potassium and other cations, which are usually very soluble in water. In water, bromide reacts to form hydrobromic acid (HBr) and hypobromous (HOBr), bromous ($HBrO_2$), and bromic ($HBrO_3$) oxyacids. Bromide is commonly found in nature, with levels ranging from trace amounts to 0.5 mg/L in fresh water and levels ranging from 65 to over 80 mg/L in seawater. The bromide ion has a low degree of toxicity, and animal testing suggests very low acute toxicity upon oral administration [WHO, 2009].

While bromide itself is not thought to be toxic at levels present in the environment, its reaction with other constituents in water may be cause for concern now and into the future. The bromide ion in water can form brominated disinfection by-products (DBPs) when drinking water plants use certain processes including chlorination and ozonation to disinfect the incoming source water. Bromide can react with the ozone, forming bromates, or with chlorine or chlorine-based disinfectants used at drinking water treatment plants, to form brominated and mixed chloro-bromo DBPs, such as trihalomethanes (THMs) or haloacetic acids (HAAs) [WHO, 2009]. EPA has set MCLs for the following DBPs in chlorinated water:

- 0.010 mg/L for bromate due to increased cancer risk from long-term exposure.
- 0.060 for HAAs due to increased cancer risk from long-term exposure HAAs include dichloroacetic acid, trichloroacetic acid, chloracetic acid, bromoacetic acid, and dibromoacetic acid.
- 0.080 mg/L for total trihalomethanes (TTHMs) due to increased cancer risk and liver, kidney, or central nervous system problems from long-term exposure [U.S. EPA, 2009e]. TTHMs include the brominated trihalomethanes (bromodichloromethane, bromoform, dibromochloromethane) and chloroform. MCL goals for the individual trihalomethanes include 0 (zero) for bromodichloromethane and bromoform.

Studies indicate that exposure to THMs and other DBPs from chlorinated water are associated with human bladder cancer [Villanueva *et al.*, 2004; Cantor *et al.*, 2010]. Bromine-substituted DBPs are generally thought to have higher risks of cancer and other adverse human health effects compared to DBPs containing chlorine instead of bromine [Cantor *et al.*, 2010]. EPA has determined that bromodichloromethane and bromoform are likely to be carcinogenic to humans by all exposure routes and there is suggestive evidence of dibromocloromethane carcinogencity. Excess cancer risk (based on increased risk to 1-in-a-million) occurs at concentrations above 0.001 mg/L for bromodichloromethane, 0.008 mg/L for bromoform, and 0.0008 mg/L for dibromochlormethane [U.S. EPA, 2005c].

DBP formation and the individual form of the DBP are influenced by factors such as bromide ion concentration, pH of the source water, the disinfectant dose (ozone or chlorine), reaction or contact time, and organic matter concentration and reactivity [Liang and Singer, 2003; U.S. EPA, 2005c]. Studies have shown that higher bromide levels in source waters shift the distribution of the TTHMs towards brominated species [Krasner *et al.*, 1989] and the types of HAAs from chlorinated to brominated and mixed chloro-bromo haloacetic acids [Heller-Grossman, 1993; Cowman and Singer, 1996].

Under the Safe Drinking Water Act (SDWA), drinking water treatment plants must reduce DBPs in their treated water and reduce exposure to customers. EPA conducted a nationwide survey that showed that bromide levels in source water above 400 µg/L corresponded with increased levels of DBPs in the treated water [Weinberg, 2002]. Due to increased bromide concentrations in surface water, drinking water treatment plants have found increased difficulty meeting regulatory limits on DBPs [U.S. EPA, 2012a; Handke, 2009; Fiske *et al.*, 2011; States *et al.*, 2013; Wilson *et al.*, 2013]. In general, drinking water produced using surface water had higher concentrations of the DBPs than drinking water produced using ground water [U.S. EPA, 2005c].

The city of Pittsburgh, in cooperation with the University of Pittsburgh, completed a multiyear study on the Allegheny River to determine the major sources of bromide discharges, including coal-fired power plants. Typically, bromide concentrations are very low in the river, but there are increased levels near industrial sites. The bromide concentration in the source water provided a linear correlation to bromination in the drinking water. At a concentration of 0.050 mg/L in the source water, 62 percent of the TTHMs were the three brominated trihalomethane species. At a concentration of 0.150 mg/L, 83 percent of the TTHMs were the three brominated trihalomethane species [States *et al.*, 2013].

The California Urban Water Agencies (CUWA) evaluated costs associated with increased bromide levels in the source water for baseline and potential future DBP controls. CUWA developed virtual water treatment plants (WTPs) to represent their different source water areas and treatment needs, with virtual WTP design capacities ranging from 40 to 800 million gallons per day. To achieve potential future standards on currently regulated pollutants, including DBPs, CUWA estimated costs for capital improvements and added annual operation and maintenance costs. On the low end, CUWA anticipated spending between $46 million to $923 million in capital improvements and $1 million to $59 million on annual operation and maintenance costs to each virtual WTP (costs vary based on the characteristics of the virtual WTP). On the high end, CUWA anticipated spending between $98 million and almost $2 billion in capital improvements and between $2 million and $127 million in annual operation and maintenance costs for each virtual WTP [CUWA, 2011].

Bromide is naturally present in coal at trace levels and becomes part of the flue gas air emissions following combustion at steam electric power plants. Combusting coal with higher levels of bromide is known to improve removal of mercury from air emissions at steam electric power plants that operate wet FGD scrubbers. Accordingly, steam electric power plant operators might add bromide-containing salts (*e.g.*, calcium bromide) during coal combustion to improve mercury removal efficiency. The bromide-containing salts convert the mercury Hg^0 form into the more water soluble Hg^{2+} form. Bromide is not typically removed from steam electric power plant wastewaters prior to discharge to surface waters. As discussed earlier, bromides in surface waters can react with organic matter in the surface water to form DBPs at drinking water treatment plants. A recent study identified four drinking water treatment plants that experienced increased levels of bromide in their source water, and corresponding increases in the formation of brominated DBPs, after upstream steam electric power plants installed wet FGD scrubbers [McTigue *et al.*, 2014]. Bromide loadings into surface waters from coal-fired steam electric power plants could potentially increase in the future as more plant operators add bromide to help control mercury emissions.

Chlorides

Studies have found that combustion residual leachate reaching ground water has caused chloride levels to exceed secondary MCLs [NRC, 2006]. Chlorides contribute to the high TDS levels typical of steam electric power plant wastewater, as do calcium and magnesium. Both chlorides and TDS levels affect the availability and toxicity of other steam electric power plant wastewater constituents, including metals. As TDS and chlorides levels fluctuate, so do the amounts of other metals that dissolve due to solubility characteristics.

EPA recommends the following for chlorides: criterion maximum concentration of 860 mg/L (acute effects) and criterion continuous concentration of 230 mg/L (chronic effects) [U.S. EPA, 2009d]. Exceeding these chlorides levels in wastewater discharges can be harmful to animals and plants in nonmarine surface waters and can disrupt ecosystem structure. It can also adversely affect biological wastewater treatment processes. Furthermore, excessively high chlorides concentrations in surface waters can impair their use as source waters for potable water supplies. If sodium is the predominant cation present, the water will have an unpleasant taste due to the corrosive action of chloride ions.

3.2 LOADINGS ASSOCIATED WITH STEAM ELECTRIC POWER PLANT WASTEWATER

As discussed above, the pollutants commonly found in steam electric power plant wastewater such as metals, nutrients, and TDS (including bromides and chlorides) can cause considerable harm to surface waters, aquatic life, wildlife, and human health. EPA estimated pollutant loadings for the steam electric power plant wastestreams evaluated and considered as part of the revision to the steam electric ELGs (*i.e.*, FGD wastewater, fly ash transport water, bottom ash transport water, and combustion residual leachate). The total pollutant loadings for the evaluated wastestreams are significant, with these discharges accounting for over one-third of the toxic pollutants reported to be discharged in industrial National Pollutant Discharge Elimination System (NPDES) permits [ERG, 2015a]. EPA estimated the amount of pollutants (*i.e.*, loadings) discharged by steam electric power plants throughout the United States for the evaluated wastestreams as almost 3 million toxic-weighted pound equivalents (TWPE) annually.[10] EPA uses TWFs as a way to better understand how treatment technologies and industry discharges compare to one another [U.S. EPA, 2012b]. Although EPA uses TWFs and the estimated TWPE as an indicator of a pollutant's relative potential to cause harm, EPA does not use TWPE to represent actual aquatic or human health impacts that may have occurred at specific locations due to these pollutant loadings. To assess

Pollutant Loadings: How Does the Steam Electric Power Generating Industry Compare?

EPA estimates that discharges from steam electric power plants alone contribute approximately one-third of the toxic weighted pound equivalent (TWPE) pollutant loadings to the environment among all industrial categories that report discharges under NPDES permits.

[10] To calculate the TWPE, EPA multiplies a mass loading of a pollutant in pounds per year (lb/yr) by a pollutant-specific weighting factor, called the toxic weighting factor (TWF), to derive a "toxic equivalent" loading (lb-equivalent/yr), or TWPE. TWFs account for differences in toxicity across pollutants and allow mass loadings of different pollutants to be compared on the basis of their toxic potential. EPA has developed TWFs for more than 1,000 pollutants based on aquatic life and human health toxicity data, as well as physical/chemical property data [U.S. EPA, 2012b].

impacts to aquatic life or human health, EPA uses the amount of pollutant loadings discharged to the surface water and the resulting concentrations in the surface waters.

When coupled with the types of impacts associated with the pollutants, the magnitude of the loadings raises concern about the risks that these discharges present to the aquatic environment and the surrounding ecosystem. This section presents the annual baseline[11] pollutant loadings associated with the evaluated wastestreams and compares steam electric discharges to those of other industries to provide perspective on the magnitude of the loadings and subsequent potential impact these wastestreams pose to the environment.

3.2.1 Annual Baseline Pollutant Loadings

In support of the final rule, EPA estimated the pollutant loadings discharged from steam electric power plants for the evaluated wastestreams, as described in Section 10 of the TDD.[12] Table 3-2 presents the baseline annual pollutant loadings discharged for select pollutants considered for analysis in the EA.[13] EPA presents these loadings in terms of pounds and TWPE and lists the TWF where applicable. The pollutants with the highest annual TWPE discharges are manganese, cadmium, boron, thallium, mercury, selenium, and arsenic. Although the total pounds discharged of arsenic, cadmium, mercury, and thallium are lower than other pollutants, their relative toxicity (as represented by the TWF) results in a large TWPE. Other pollutants, such as boron and manganese, are relatively low in toxicity but have a high TWPE due to the fairly high amount of these pollutants in steam electric power plant wastewater discharges. The high TWPE for selenium results from a combination of its quantity discharged in steam electric power plant wastewaters and its TWF.

Pollutant Loadings from Steam Electric Power Plants Evaluated Wastestreams

- 2,210,000,000 pounds of pollutants per year.
- 2,680,000 pounds of TWPE per year.

[11] The analyses presented in this report incorporate some adjustments to current conditions in the industry. See Section 1 for further details.

[12] Prior to finalizing the rulemaking, EPA revised the datasets used to calculate pollutant loadings for bottom ash transport water and fly ash transport water. The final industry loadings calculated using these revised datasets are presented in the TDD. The total industry loadings presented in Section 3.2 reflect the revised datasets. However, EPA did not rerun the EA models and other analyses to reflect the final loadings dataset. EA analyses used previously calculated version of the steam electric power plant pollutant loadings that were derived following the same methodology. The EA pollutant loadings are included in DCN SE05620. Pollutant-specific loadings and removals presented in this report are based on the previously calculated version. Appendix J presents the results of a sensitivity analysis that evaluated the potential for these loadings revisions to affect the EA analyses.

[13] EPA selected the pollutants listed in Table 3-2 (which represent a subset of all steam electric pollutants of concern) for analysis in the EA based on the following factors for each pollutant: presence of the pollutant in the evaluated wastestreams (see Table 2-1); documented elevated levels of the pollutant in surface waters or wildlife from exposure to steam electric power plant wastewater; and magnitude of the pollutant loadings to receiving waters.

Table 3-2. Annual Baseline Pollutant Discharges from Steam Electric Power Plants (Evaluated Wastestreams)

Pollutant [a]	TWF [b]	Annual Discharge, pounds (lbs) [c]	Annual TWPE, pound-equivalent (lb-eq) [c]
Metals and Toxic Bioaccumulative Pollutants			
Manganese	0.103	7,530,000	773,000
Cadmium	22.8	13,300	303,000
Boron	0.00834	31,300,000	261,000
Thallium	2.85	63,700	182,000
Mercury	110.0	1,490	164,000
Selenium	1.12	140,000	157,000
Arsenic	3.47	29,600	103,000
Aluminum	0.0647	1,410,000	91,500
Lead	2.24	19,700	44,100
Copper	0.623	31,200	19,500
Vanadium	0.280	66,000	18,500
Iron	0.00560	2,740,000	15,400
Nickel	0.109	120,000	13,100
Zinc	0.0469	174,000	8,160
Chromium VI	0.517	156	80.5
Nutrients			
Total Nitrogen [d]	Not applicable	16,900,000	Not applicable
Total Phosphorus	Not applicable	214,000	Not applicable
Other			
Chlorides	2.435×10^{-5}	930,000,000	22,600
Total dissolved solids			Not applicable
Total Pollutants [e]		2,210,000,000	2,680,000

Sources: Abt, 2008; ERG, 2015a; ERG, 2015b; ERG, 2015f; U.S. EPA, 2012c.

Note: Numbers are rounded to three significant figures.

a – The list of pollutants included in this table is only a subset of pollutants included in the loadings analysis (see Section 10 of the TDD).

b – TWFs for the following metals apply to all metal compounds: arsenic, chromium, copper, lead, manganese, mercury, nickel, selenium, thallium, vanadium, and zinc. EPA updated TWFs for arsenic, cadmium, copper, manganese, mercury, thallium, and vanadium for the steam electric ELGs pollutant loadings analysis.

c – These loadings reflect adjustments to current conditions in the industry. See Section 1 for further details. Data source for pollutant specific loadings is DCN SE05620.

d – Total nitrogen is the sum of total Kjeldahl nitrogen and nitrate/nitrite as N.

e – The totals represent the pollutant loadings in discharges of the evaluated wastestreams – specifically, FGD wastewater, fly ash transport wastewater, bottom ash transport wastewater, and combustion residual leachate (see Section 10 of the TDD). Loadings presented are based on the final loadings analysis presented in the TDD. The totals exclude loadings for pollutants not identified as POCs and for biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), total dissolved solids (TDS), and total suspended solids (TSS).

3.2.2 Comparison of Steam Electric Power Plant Loadings to Other Industries

The total TWPE discharges from the steam electric power generating industry are higher than the TWPEs estimated for many other industries. As part of the Preliminary 2010 Effluent Guidelines Program Plan published on October 30, 2009 (74 FR 68599), EPA identified 10 point source categories, out of 56, that represented the bulk of the estimated toxic wastewater discharges (as measured by TWPE) from existing industrial point source categories. EPA ranked each point source category by the amount of toxic pollutants in its discharges and identified the Steam Electric Power Generating Point Source Category (40 CFR 423) as the category with the highest TWPE. Table 3-3 presents the total TWPE estimated as part of the 2010 Effluent Guidelines Planning Process for the remaining nine point source categories with the highest TWPE [U.S. EPA, 2011d]. The TWPE estimated for the 2010 Effluent Guidelines Planning Process includes pollutant loadings estimated from discharge monitoring reports (DMRs) and Toxic Release Inventory (TRI) reporting. Therefore, the industry totals may include double-counting of certain chemical discharges (*i.e.*, a facility must report a chemical on both its DMR and its TRI reporting form).

Table 3-3. Pollutant Loadings for the Final 2010 Effluent Guidelines Planning Process: Top 10 Point Source Categories

40 CFR Part	Point Source Category	Total TWPE [a] (lb-eq/yr)
423	Steam Electric Power Generating	2,680000 [b]
430	Pulp, Paper, And Paperboard	1,030,000
419	Petroleum Refining	1,030,000
421	Nonferrous Metals Manufacturing	994,000
418	Fertilizer Manufacturing	826,000
414	Organic Chemicals, Plastics, And Synthetic Fibers	649,000
440	Ore Mining And Dressing	448,000
415	Inorganic Chemicals Manufacturing	299,000
444	Waste Combustors	254,000
410	Textile Mills	250,000

Source: U.S. EPA, 2011d.

a – Only TWPE totals for the steam electric power generating industry include updates to TWFs for arsenic, cadmium, copper, manganese, mercury, thallium, and vanadium. The TWPE for all other point source categories is estimated from DMRs and TRI reporting and may include double-counting of certain pollutant discharges (*i.e.*, a facility must report a pollutant on both its DMR and its TRI reporting form). Loadings are rounded to three significant figures.

b –EPA calculated the steam electric power generating industry (40 CFR 423) discharges for the final rule as total 2,680,000 TWPE annually (see Section 10 of the TDD). These loadings reflect adjustments to current conditions in the industry. See Section 1 for further details.

EPA estimated that the total baseline TWPE from steam electric power plant wastewater is almost three times the amount estimated for the pulp, paper, and paperboard industry, petroleum refining industry, and nonferrous metals manufacturing (second, third, and fourth highest ranking), and it is over five times the TWPE for four of the six other industries identified as the top TWPE dischargers in the Final 2010 Effluent Guidelines Program Plan [U.S. EPA, 2011d].[14] This suggests that the loadings from the subset of evaluated wastestreams represent a greater environmental concern within the context of all industrial dischargers across the United States.

3.2.3 Comparison of Steam Electric Power Plant Loadings to Publicly Owned Treatment Works

To provide additional perspective on the magnitude of the pollutant loadings from steam electric power plants, EPA compared loadings for the evaluated wastestreams to those of an average publicly owned treatment works (POTW). EPA selected POTWs for comparison because, for point sources, POTWs and steam electric power plants dwarf all other point source discharges in terms of total TWPE of metals discharged to waters in the United States [U.S. EPA, 2010c].[15] In addition, the more than 16,000 POTWs are located across the United States and provide a common metric to use for point source evaluations.

EPA calculated the average pollutant loadings discharged from a typical POTW using EPA's Effluent Guidelines Program Plan DMR database, DMRLoadsAnalysis2009_v02.mdb. EPA assumed that a typical POTW discharges wastewater at a rate of 3 to 5 million gallons per day (MGD)[16] based on the number of facilities by discharge flow rate reported in Metcalf and Eddy, 2003 [ERG, 2015a]. EPA developed queries in the DMRLoadsAnalysis2009_v02.mdb to do the following: 1) select POTWs that discharge between 3 and 5 MGD, and 2) calculate the average DMR loadings (in pounds and TWPE per year) for each pollutant [ERG, 2015a]. Table 3-4 compares the average steam electric pollutant loadings by wastestream[17] to the pollutant

[14] Data sources for the other industry discharges include DMRs and TRI reports. EPA recognizes that the DMR and TRI data have limitations (*e.g.*, only a subset of facilities and a subset of pollutants might be included in the estimated loadings); however, these are the most readily available data sets that represent discharges across the United States.

[15] Based on metal loadings (total TWPE) calculated by EPA's DMR Pollutant Loading Tool, 2010 data, by Standard Industrial Classification (SIC) code. The top two industries are SIC 4952 – Sewerage Systems (*i.e.*, POTWs) and SIC 4911 – Electrical Services. EPA's DMR Pollutant Loading Tool is an online tool (http://cfpub.epa.gov/dmr/) that calculates pollutant loadings from permit and DMR data from EPA's Permit Compliance System (PCS) and Integrated Compliance Information System for the National Pollutant Discharge Elimination System (ICIS-NPDES). The tool also ranks dischargers, industries, and watersheds based on pollutant mass and toxicity, and presents "top 10" lists to help users determine which facilities and industries are producing these discharges and which watersheds are impacted. Facilities report pollutant discharge monitoring data in their DMR as mass-based quantities (*e.g.*, pounds per day) and/or concentrations (*e.g.*, mg/L). The DMR Pollutant Loading Tool allows users to gather annual loadings data. For this EA, EPA reviewed the 2010 loadings reported in DMRs.

The use of the DMR data has its limitations. Only pollutants included in the facility's NPDES permit are included in the PCS and ICIS-NPDES databases; therefore, if a facility does not have mercury limitations, mercury discharges from that facility will not be included in the total for industrial discharges. States (or other permitting authority) have some discretion as to which data they make available (or enter) to PCS and ICIS-NPDES. For example, permitting authorities enter DMR and permit information for facilities that are considered major dischargers. However, they do not necessarily enter DMR or permit information into PCS for minor dischargers or facilities covered by a general permit.

[16] For comparison, the average discharge flow rates for the evaluated wastestreams are 0.45 MGD for FGD wastewater; 3.5 MGD for fly ash transport water; 2.1 MGD for bottom ash transport water; and 0.08-0.09 MGD for leachate [see Section 6 of the TDD].

[17] EPA calculated the average pollutant loadings for each wastestream by dividing the total pollutant loadings for the wastestream by the number of steam electric power plants discharging the wastestream [ERG, 2015a].

loadings from an average POTW assumed to discharge 3 to 5 MGD. The results of the analysis demonstrate the following:

- Average FGD wastewater discharges contain over 200 times more boron and manganese, over 75 times more selenium, and approximately 20 times more cadmium and nickel than average POTW discharges.
- Average fly ash transport water discharges contain over 10 times more boron, cadmium and thallium and over five times more arsenic, nickel, and selenium than average POTW discharges.
- Average bottom ash transport water discharges contain 30 times more thallium; approximately 10 times more manganese and nickel; and five times more cadmium than average POTW discharges.
- Average combustion residual leachate wastewater discharges contain more boron, iron, manganese, and selenium than average POTW discharges.

Loadings of the Evaluated Wastestreams Compared to POTWs

- FGD wastewater discharges contain:
  - 200 times more manganese
  - 200 times more boron
  - 75 times more selenium
  - 20 times more nickel
  - 20 times more cadmium
- Bottom ash transport water discharges contain 30 times more thallium and 10 times more manganese and nickel.
- Fly ash transport water discharges contain five times more arsenic, nickel, and selenium and 10 times more boron, cadmium, and thallium.
- Combustion residual leachate contains over four times more boron and iron.

Nutrient loadings (total nitrogen and total phosphorus) from the average steam electric wastestreams are generally lower than the nutrient loadings from an average POTW. Total nitrogen loadings from an average FGD wastestream are approximately equal to those of an average POTW. Nitrogen loadings from average fly ash and bottom ash transport waters are less than the total nitrogen discharges from an average POTW (approximately 20 percent). The amount of total phosphorus discharged by an average POTW is over 20 times higher than that in the average fly ash transport water, bottom ash transport water discharges, and FGD wastewater. EPA did not calculate nutrient loadings for combustion residual leachate.

For chlorides, EPA found that average FGD wastewater discharges contain approximately six times greater chlorides loadings than an average POTW discharge. The average discharges of fly ash transport water, bottom ash transport water, and combustion residual leachate from a steam electric power plant contain less chlorides than a typical POTW discharge (less than 10 percent). EPA's DMR data did not include pollutant loadings for TDS from POTWs; therefore, EPA could not compare these pollutant loadings between steam electric and POTW discharges.

Table 3-4. Comparison of Average Pollutant Loadings in the Evaluated Wastestreams to an Average POTW

Pollutant	Average Plant FGD Wastewater Discharge [a,b]		Average Plant Fly Ash Transport Water Discharge [a,c]		Average Plant Bottom Ash Transport Water Discharge [a,d]		Average Plant Combustion Residual Leachate Discharge [a,e]		Average POTW Discharge [a,f]	
	Loadings (lbs/yr)	**TWPE (lb-eq/yr)**	**Loadings (lbs/yr)**	**TWPE (lb-eq/yr)**	**Loadings (lbs/yr)**	**TWPE (lb-eq/yr)**	**Loadings (lbs/yr)**	**TWPE (lb-eq/yr)**	**Loadings (lbs/yr)**	**TWPE (lb-eq/yr)**
Aluminum	1,530	99.1	8,490	549	4,240	274	837	54.1	3,590	215
Arsenic	9.54	33.1	312	1,080	66.5	231	10.8	37.5	45.9	159
Boron	334,000	2,790	17,900	149	2,190	18.3	6,530	54.5	1,540	12.8
Cadmium	81.2	1,850	47.7	1,090	19.1	435	2.87	65.3	3.54	80.6
Chromium VI	(g)	(g)	2.62	1.35	0.136	0.070	(g)	(g)	17.7	9.02
Copper	17.9	11.1	263	164	89.0	55.5	2.16	1.34	154	95.3
Iron	1,150	6.42	5,140	28.8	7,610	42.6	10,400	58.4	2,530	14.2
Lead	5.71	12.8	152	340	63.4	142	(g)	(g)	48.5	109
Manganese	74,500	7,650	486	49.9	4,770	490	790	81.1	354	36.1
Mercury	5.50	605	7.85	864	3.19	351	0.298	32.8	3,180	350,000
Nickel	620	67.6	180	19.6	301	32.7	13.1	1.43	30.6	3.06
Selenium	1,410	1,580	134	150	32.4	36.3	31.2	35.0	18.5	20.7
Thallium	16.7	47.7	137	392	302	863	0.338	0.964	9.94	28.2
Vanadium	20.8	5.82	220	61.7	11.4	3.21	538	151	No data	No data
Zinc	983	46.1	734	34.4	247	11.6	59.1	2.77	453	18.1
Total Nitrogen	128,000	--	23,400	--	24,600	--	(g)	--	123,000	--
Total Phosphorus	457	--	864	--	715	--	(g)	--	17,800	--
Chlorides	10,200,000	248	83,500	2.03	96,700	2.35	120,000	2.93	1,610,000	39.3
TDS	40,400,000	--	1,760,000	--	2,560,000	--	1,020,000	--	No data	--

Note: Numbers are rounded to three significant figures.

a – TWPE presented in the table include updates to TWFs for arsenic, cadmium, copper, manganese, mercury, thallium, and vanadium.

b – Average loadings based on 88 plants assumed to discharge FGD wastewater under baseline conditions [ERG, 2015a].

c – Average loadings based on 50 plants assumed to discharge fly ash transport water under baseline conditions [ERG, 2015a].

d – Average loadings based on 183 plants assumed to discharge bottom ash transport water under baseline conditions [ERG, 2015a].

e – Average loadings based on 95 plants assumed to discharge combustion residual leachate under baseline conditions [ERG, 2015a].

f – Average loadings based on average loadings calculated for POTWs discharging 3 to 5 MGD of wastewater (see DCN SE01961).

g – EPA did not calculate loadings for this pollutant and wastestream. See the Costs and Loads Report (DCN SE05831).

To provide additional perspective on the magnitude of the loadings, EPA calculated the equivalent number of typical POTWs that would discharge loadings equal to the 202 steam electric power plants[18] included in the baseline loadings analysis. Table 3-5 presents total pollutant loadings for the evaluated wastestreams (for the 202 plants) and the number of typical POTWs that would discharge equivalent loadings. The results demonstrate that the magnitude of the total loadings from 202 steam electric power plants is equivalent to a significantly larger number of typical POTWs for many of the pollutants commonly known to cause environmental harm. For example, EPA estimated that the total loadings in discharges of the evaluated wastestreams from these 202 plants are equivalent to approximately 20,000 POTW discharges of boron and manganese; over 7,500 POTW discharges of selenium; over 6,000 POTW discharges of thallium; over 3,500 POTW discharges of cadmium and nickel; over 1,000 POTW discharges of iron; and over 500 POTW discharges of arsenic and chlorides. This suggests that, for the evaluated wastestreams, 202 steam electric power plants contribute substantial pollutant loadings to the environment.

Table 3-5. Estimated Number of POTW Equivalents for Total Pollutant Loadings from the Evaluated Wastestreams

Pollutant	Annual Discharge pounds (lbs)	Equivalent Number of Average POTWs [a]
Aluminum	1,410,000	394
Arsenic	29,600	646
Boron	31,300,000	20,300
Cadmium	13,300	3,760
Chromium VI	156	8.81
Copper	31,200	203
Iron	2,740,000	1,080
Lead	19,700	406
Manganese	7,530,000	21,300
Mercury	1,490	<1
Nickel	120,000	3,920
Selenium	140,000	7,560
Thallium	63,700	6,410
Vanadium	66,000	No values for comparison
Zinc	174,000	384
Total Nitrogen	16,900,000	138
Total Phosphorus	214,000	12.0
Chlorides	930,000,000	578
TDS	4,210,000,000	No values for comparison

Source: ERG, 2015a.

Note: Numbers are rounded to three significant figures.

a – Equivalent number of POTWs is estimated by dividing the total annual pollutant loadings from the 202 steam electric power plants by the average POTW loadings presented in Table 3-4 for a 4-MGD POTW.

[18] The count of 202 steam electric power plants includes seven indirect dischargers that discharge wastewater to a POTW and do not discharge any of the evaluated wastestreams directly to surface waters. EPA included these indirect dischargers to protect confidential business information.

3.3 ENVIRONMENTAL IMPACTS FROM STEAM ELECTRIC POWER PLANT WASTEWATER

EPA identified environmental impacts from EPA's assessment of damage cases and literature sources ("other documented site impacts") caused by steam electric power plant wastewater and combustion residuals. EPA found over 150 steam electric power plants causing environmental impacts to surface water and ground water environments following exposure to steam electric power plant wastewater. Impacts identified in the damage cases and other documented site impacts include lethal and sublethal impacts on fish, impacts on the diversity and size of populations in the ecosystem, and impacts on drinking water quality. While these impacted sites are often assumed to be anomalies, mounting evidence indicates that the characteristics contributing to the documented impact (*e.g.*, magnitude of the pollutant loadings, type of pollutant present, plant operations, and wastewater handling techniques) are common among steam electric power plant receiving water locations [Cherry *et al*., 2000; NRC, 2006; Rowe *et al*., 2002].

Section 3.3.1 presents a qualitative discussion of the lethal and sublethal ecological effects of pollutants in steam electric power plant wastewater. Section 3.3.2 summarizes documented instances where steam electric power plant wastewater discharges have caused fish advisories or exceeded MCLs presenting a potential human health concern. Section 3.3.3 and Section 3.3.4 summarize the damage cases and other documented site impacts to surface water and ground water, respectively. Section 3.3.5 discusses the potential for these environmental impacts to occur at other locations.

3.3.1 Ecological Impacts

Documented ecological impacts associated with exposure to steam electric power plant wastewater include acute effects (*e.g.*, fish kills) and chronic effects (*e.g.*, malformations, and metabolic, hormonal, and behavioral disorders) upon biota within the receiving water and surrounding environment. Effects have included reduced growth and reduced survival of aquatic organisms and changes to the local habitat [Carlson and Adriano, 1993; Rowe *et al*., 2002].

This section provides examples of the lethal and sublethal effects on organisms exposed to steam electric power plant wastewater pollutants (*e.g.*, arsenic, cadmium, chromium, copper, mercury, and selenium) in surface waters and sediment. Scientific studies reported in the literature included:

- Field studies in which organisms collected from known contaminated sites were compared to those collected from uncontaminated sites.
- Laboratory experiments in which organisms intentionally exposed to steam electric power plant wastewater were compared to those unexposed.

Many of the scientific studies documented in the literature focused on selenium as a key pollutant of environmental concern within steam electric power plant wastewater. However, due to the complex nature of the wastewater, many studies evaluated the environmental effects of metals in steam electric power plant wastewater in aggregate.

Lethal and Sublethal Effects of Selenium

Selenium can bioaccumulate to toxic levels in organisms inhabiting environments with low selenium concentrations. For example, Lemly conducted a field study that investigated the patterns of selenium biomagnification and toxicity in aquatic organisms inhabiting a cooling water reservoir that received effluent from a power plant's surface impoundment [Lemly, 1985a]. Throughout the study, selenium concentrations in the reservoir averaged 10 µg/L; however, Lemly reported that fish tissue concentrations reached levels ranging from 500 to 4,000 times the average reservoir water selenium concentration. The results of the study indicated that the extent of selenium bioaccumulation depended on the trophic level of the fish present in the reservoir. Lemly observed that the selenium accumulation increased as the trophic level increased, which potentially correlated with the observed elimination of multiple higher-tropic-level fish species. Therefore, these findings suggest that—even at low concentration within a surface water—selenium can accumulate and biomagnify to toxic levels in aquatic organisms and pose a lethal threat to fish at the top of the trophic structure [Lemly, 1985a]. Predicting the impacts of selenium in aquatic ecosystems can be particularly challenging, because impacts to the ecosystem cannot be determined solely on the selenium concentration in the receiving water as demonstrated in this study.

Selenium discharges also impact species diversity in receiving waters. In 1977, two years after the initial operation of the Belews Creek Steam Station in North Carolina, the fish community inhabiting the plant's cooling water reservoir (a lake) underwent rapid decline, and species diversity drastically altered [Lemly, 1985a]. Lemly observed that 17 of the 20 fish species originally present in the lake were eliminated after the power plant began operation, including all game species (temperate perch [*Percichthyidae*], true perch and pike perch [*Percidae*], and sunfish [*Centrarchidae*]). Lemly reported significant levels of selenium accumulation in the eliminated species and statistically unchanged levels of selenium accumulation in the surviving species, relative to levels before the power plant began operation. Only three species maintained reproducing populations in the reservoir: one native species (mosquitofish) and two introduced non-native species of minnows (fathead minnows and red shiners) [Lemly, 1985a].

A number of scientific studies express concern over selenium exposure within lakes and reservoirs where longer residence times allow for further bioaccumulation and a greater potential to reach lethal concentrations. This is demonstrated by a series of major fish kills that occurred in 1978 and 1979 at Martin Creek Lake (Texas) due to the elevated concentrations of selenium in the water and fish tissue [U.S. EPA, 2014b]. In particular, studies concluded that elevated selenium concentrations were likely the primary contributor to fish kills in lakes and reservoirs, decreasing population density and community diversity [Coughlan and Velte, 1989; Crutchfield, 2000b; Crutchfield and Ferguson, 2000a; Cumbie and Van Horn, 1978].

The sublethal effects of selenium vary widely and can impact growth, reproduction, and survival of susceptible organisms. Scientists have demonstrated that various fish and amphibian species are sensitive to elevated selenium concentrations such as those found in steam electric power plant wastewater. In addition to lethal effects described above, these fish and amphibian species have developed sublethal symptoms such as accumulation of selenium in tissue (histopathological effects) and in the blood (hematological effects), resulting in decreased growth, changes in weight, abnormal morphology, and reduced hatching success [Coughlan and Velte, 1989; Lemly, 1993; Sager and Colfield, 1984; Sorensen, 1988; Sorensen and Bauer, 1984a; Sorensen *et al*., 1982, 1983, 1984b].

The literature indicates that the extent of selenium accumulation in fish tissue varies by species, and selenium accumulates most significantly in the liver and reproductive tissues in most species [Baumann and Gillespie, 1986; Sager and Colfield, 1984; Sorensen, 1988]. Other studies have reported accumulation in the skeletal muscle, kidneys, gills, and hearts of fish, resulting in pathological lesions, morphological changes, increased organ weight, and decreased growth [Coughlan and Velte, 1989; Lemly, 2002; Sorensen and Bauer, 1984b]. Aquatic organisms exposed to steam electric power plant wastewater have exhibited elevated selenium concentrations in organs such as kidneys, liver, and gonads, resulting in abnormalities that hinder growth and survival [Rowe *et al*., 2002].

In addition, selenium is highly teratogenic (*i.e.*, able to disturb the growth and development of an embryo or fetus) and readily transferable from mother to egg [Chapman *et al.*, 2009; Janz *et al.*, 2010; Lemly, 1997b; Maier and Knight, 1994]. Selenium is known to bioaccumulate in the reproductive organs of fish and amphibian species. In one study, ovarian selenium concentrations in bluegill fish were observed at levels 1,000 times greater than the surrounding surface water [Baumann and Gillespie, 1986]. Multiple studies have documented reproductive failure or diminished reproductive success in both fish and amphibians inhabiting ponds, lakes, and reservoirs contaminated with selenium from steam electric power plant wastewater discharges [Baumann and Gillespie, 1986; Crutchfield, 2000b; Cumbie and Van Horn, 1978; Gillepsie *et al*., 1986; Hopkins *et al*., 2002; Nagle *et al*., 2001]. For example, Hopkins *et al*. [2006] observed reduced hatching success, abnormal swimming, and abnormalities in the face and skull in the offspring of selenium-contaminated female toads. Field and captive feeding studies also show reproductive impairment (reduced hatchability of eggs) among waterfowl exposed to elevated levels of selenium [Adams *et al.*, 2003; Ohlendorf, 2003 and 2007; Beckon *et al*., 2008; U.S. DOI, 1998; Smith *et al*., 1998].

Histopathological effects (*i.e.*, observable changes in tissue), increased metabolic rate, and decreased growth rates are effects typically caused by contamination from steam electric power plant wastewater. Water and fish samples collected before and after the discharge of power plant wastewater from the surface impoundment to the Texas Utilities Martin Creek Lake found that selenium concentrations were significantly elevated in the reservoir and in fish livers, kidneys, and gonads. In 1984, Garrett and Inman reported that elevated selenium concentrations persisted in the livers and kidneys of several species of fish for up to 3 years after the power plant wastewater discharges ceased. Additionally, a 1988 study by Sorensen found that red ear sunfish native to the reservoir exhibited ovary abnormalities related to elevated selenium concentrations up to 8 years following an 8-month exposure to power plant wastewater discharges. Although the surface impoundment discharge was short-lived, many of the histopathological effects persisted for years after the discharge had ceased [Rowe *et al*., 2002].

These sublethal effects of selenium, while not directly resulting in the mortality of exposed aquatic wildlife, can ultimately cause the types of population-level impacts described under lethal impacts above. The available scientific evidence indicates that reproductive success—specifically, offspring mortality and severe development abnormalities that affect the ability of fish to swim, feed, and successfully avoid predation—is the critical assessment endpoint when evaluating the potential for selenium exposure to result in population-level impacts to resident fish species.

For a summary of the impacts of selenium on surface water, refer to Table A-10 in Appendix A.

<u>*Lethal Effects of Other Pollutants*</u>

Scientific studies have confirmed that both acute and chronic exposure to pollutants in steam electric power plant wastewater can be lethal to a wide range of aquatic organisms. For example, Guthrie and Cherry [1976] found that shrimp darters and salamanders were highly sensitive to acute exposures of steam electric power plant wastewater and experienced nearly 100 percent mortality following a five-day exposure to power plant wastewater discharges. Invertebrates and fish also evaluated in the study were less sensitive to the acute exposure to power plant wastewater and reported lower rates of mortality [Guthrie and Cherry, 1976]. Chronic exposures to power plant wastewater are also of concern; however, studies show extreme differences in species sensitivity [Rowe *et al*., 2002]. For example, juvenile chubsuckers (a benthic fish) exposed for 45 days to sediments, water, and food contaminated with power plant wastewater experienced a 75 percent mortality rate [Hopkins *et al*., 2001]. In another study, bullfrogs exposed to sediment and water from a combustion residual surface impoundment for 34 days demonstrated an 87 percent mortality rate (which was 41 percent greater than the mortality rate of bullfrogs included in control group) [Rowe *et al*., 2002]. A third study reported no lethal effects for banded snakes exposed for 2 years to fish collected from combustion residual surface impoundments [Hopkins *et al*., 2002].

Other studies examined lethal effects of sediments contaminated with combustion residuals. For example, eggs and hatchlings of fish and reptiles raised in contaminated sediment reported higher mortality rates (16 to 94 percent) than eggs and hatchlings from control groups [Hopkins *et al*., 2000; Nagle *et al*., 2001; Roe *et al*., 2006; Rowe *et al*., 1998a, 1998b, 2001; Snodgrass *et al*., 2004]. Each of the studies observed elevated mortality rates in conjunction with higher concentrations of steam electric power plant wastewater pollutants (*e.g.*, arsenic, cadmium, chromium, copper, selenium) in the exposed sediment.

Three studies evaluated the lethal effects of specific pollutants in steam electric power plant wastewater on a variety of organisms (*i.e.*, insects, fish, and amphibians) and determined the median lethal concentration (LC_{50}) for each pollutant-organism combination. LC_{50} is the concentration expected to be lethal to 50 percent of a group of organisms exposed for a given time duration. Table 3-6 summarizes the results from the three experiments and Table 3-7 presents the LC_{50} concentrations reported in the studies. Overall, the LC_{50} studies report species-specific differences, particularly among species living downstream of fly ash surface impoundment discharges. The downstream species developed resistance to pollutants compared to those living in unpolluted ponds. Because the LC_{50} concentrations were much higher than actual aquatic concentrations, there was no evidence in these experiments of acute lethal effects, though long-term (1 to 3 months) lethal effects could not be ruled out [Benson and Birge, 1985; Birge, 1978; Specht *et al*., 1984].

Sublethal Effects of Other Pollutants

Although the majority of sublethal effects documented in the literature primarily focus on selenium concentrations in steam electric power plant wastewater, several studies discussed the sublethal effects of other pollutants, such as arsenic, cadmium, chromium, copper, and lead [Rowe *et al*., 2002]. Sublethal effects from exposure to pollutants other than selenium in power plant wastewater can include changes to morphology (*e.g.*, fin erosion, oral deformities), behavior (*e.g.*, swimming ability, ability to catch prey, ability to escape from predators), and metabolism that can negatively affect long-term survival. For example, a study of larval bullfrogs living in combustion residual surface impoundments found that more than 95 percent of individuals had abnormal oral structures, such as the absence of grazing teeth or entire rows of teeth, which altered feeding habits and subsequently reduced growth rates in the affected bullfrogs [Rowe *et al*., 1996]. In another study, tail malformations in larval bullfrogs attributed to power plant wastewater exposure caused abnormal swimming behavior, and the affected bullfrogs were preyed upon more frequently than bullfrogs from unpolluted sites [Raimondo *et al*., 1998].

Several studies have demonstrated increased metabolic rates and decreased growth rates in aquatic organisms exposed to steam electric power plant wastewater. Increased metabolism causes organisms to waste energy during normal metabolic processes, which can affect growth. In a 1998 study by Rowe, grass shrimp caged in a surface impoundment for eight months experienced a 51 percent increase in standard metabolic rate. Similarly, crayfish captured near the impoundment experienced increased metabolic rates and decreased growth rates—effects that were also observed in crayfish collected from unpolluted sites and exposed to contaminated sediments from the combustion residual surface impoundment [Rowe *et al*., 2002].

Table 3-6. Summary of Studies Evaluating Lethal Effects of Pollutants in Steam Electric Power Plant Wastewater

Citation	Studied Organism	Test Performed	Trace Elements Studied	Summary of Results
Birge, 1978	Eggs from goldfish, trout, and toads	7- to 28-day lethal effects	22 elements	Among the 22 elements tested, cadmium, chromium, mercury, nickel, lead, and silver were the most toxic to all three species, with most LC_{50} being 0.1 milligrams per liter (mg/L) or less.
Benson and Birge, 1985	Minnows (fish) living in fly ash-polluted ponds in Kentucky compared to those living in uncontaminated ponds	Acute (96-hour) toxicity	Cadmium Copper Zinc	The study found a higher tolerance to cadmium and copper in the exposed fish compared to the fish from unpolluted ponds. However, both exposed and unexposed populations exhibited similar tolerance to zinc. See Table 3-7 for LC_{50} values.
Specht *et al*., 1984	Insects (coleopterans, mayflies, and other insects) exposed to fly ash surface impoundment effluent from the Appalachian Power Plant in Giles County, Virginia, compared to those living in an uncontaminated pond	Acute (96-hour) toxicity	Cadmium Copper Zinc	The study observed a higher tolerance to pollutants in exposed insects compared to those living in unpolluted ponds. See Table 3-7 for LC_{50} values.

Table 3-7. Median Lethal Concentrations (LC_{50}) for Pollutants in Steam Electric Power Plant Wastewater

Pollutant	LC_{50}, mg/L						
	7- to 28-Day Exposure			96-Hour Exposure			
	Trout [Birge, 1978]	Goldfish [Birge, 1978]	Toad [Birge, 1978]	Exposed Minnows [Benson and Birge, 1985]	Control Minnows [Benson and Birge, 1985]	Mayflies [Specht *et al.*, 1984]	Other Insects [Specht *et al.*, 1984]
Aluminum	0.56	0.15	0.05				
Arsenic	0.54	0.49	0.04				
Cadmium	0.13	0.17	0.04	3.89 [a] 9.55 [b]	3.06 [a] 7.16 [b]	0.27	1.2-250
Chromium	0.18	0.66	0.03				
Cobalt	0.47	0.81	0.05				
Copper	0.09	5.2	0.04	0.36 [a] 0.41 [b]	0.21 [a] 0.39 [b]	0.18	0.03-8.3
Lead	0.18	1.66	0.04				
Mercury	0.005	0.12	0.001				
Nickel	0.05	2.14	0.05				
Selenium	4.18	8.78	0.09				
Silver	0.01	0.03	0.01				
Vanadium	0.16	4.6	0.25				
Zinc	1.06	2.54	0.01	6.14 [a] 5.96 [b]	6.09 [a] 7.45 [b]	18.44	18.2

Acronyms: mg/L – milligrams per liter.
Shaded cells indicate that the pollutant was not evaluated.
a – Nominal water hardness of 100 mg/L calcium carbonate ($CaCO_3$).
b – Nominal water hardness of 250 mg/L calcium carbonate ($CaCO_3$).

3.3.2 Human Health Effects

Exposure to pollutants can cause non-cancer effects in humans, including damage to the circulatory, respiratory, or digestive systems and neurological and developmental effects. Steam electric power plant wastewater includes toxic pollutants and known or suspected carcinogens (*e.g.*, arsenic and cadmium). In the literature review, EPA identified potential human impacts from consuming fish in contaminated waters and from ingesting drinking water contaminated by pollutants from combustion residuals.[19]

Numerous damage cases show exceedances of drinking water standards at ground water and drinking water wells due to leachate from nearby impoundments and landfills.

During the late 1970s, three power plant cooling water reservoirs in Texas received discharges from surface impoundments containing elevated selenium levels, resulting in a series of fish kills. The reservoirs included Brandy Branch Reservoir, located in Harrison County; Welsh Reservoir, located in Titus County; and Martin Creek Lake, located in Rusk County. Investigations at the reservoirs implicated elevated selenium levels in the fish tissue as the cause. In 1992, the Texas Department of Health issued a fish consumption advisory for the three reservoirs after determining that the level of selenium in fish could pose a potential health risk to humans, especially children 6 years or younger and pregnant women.

Ground water and drinking water supplies can be degraded by pollutants in steam electric power plant wastewater and combustion residual leachate [Cross, 1981]. Combustion residual leachate can migrate from the site in the ground water at concentrations that could contaminate public or private drinking water wells and surface waters, even years following disposal of combustion residuals [NRC, 2006], as exemplified in the following example. The Wisconsin Electric Power Company (WEPCO) plant in Port Washington, Wisconsin, had disposed of fly ash in a quarry for over 20 years (1943-1971) at a depth of 40 to 60 feet, with some of the disposed ash below the water table. The disposal site is located in an upland area where down-gradient ground water is used as a source of drinking water. The Wisconsin Department of Natural Resources was notified in January 1980 and November 1990 that elevated levels of sulfates, selenium, and boron were found in a private drinking water well located 250 feet down-gradient from the coal-fired power plant waste disposal site. The impacted private well was replaced with a deeper well to avoid further contamination [U.S. EPA, 2014c].

[19] In this EA, EPA evaluated the threats to human health and the environment associated with pollutants leaching into ground water from surface impoundments and landfills containing combustion residuals. If these leached pollutants do not constitute the discharge of a pollutant to surface waters, then they are not controlled under the steam electric ELGs. While the CCR rulemaking is the major controlling action for these pollutant releases to ground water, the ELGs could indirectly reduce impacts to ground water. These secondary improvements are discussed in Section 7.8.

As discussed in Section 3.3.4 and Appendix A, there have been documented exceedances of MCL drinking water standards at off-site ground water and drinking water wells. Exceedances of MCLs in the ground water indicate potential human health impacts if the pollutants enter private drinking water wells. Section 3.3.4 outlines three documented instances where combustion residual leachate contamination caused impacts to private drinking water wells.

Drinking water standards can also be exceeded in surface waters. For example, Duke Energy's Riverbend Plant discharges surface impoundment effluent into Mountain Island Lake, which supplies drinking water to 700,000 people. The county detected arsenic and zinc concentrations above state standards in an area near the surface impoundment discharge pipe [*Charlotte Observer*, 2010]. While most of the pollutants in the surface water would likely be reduced to safe levels during drinking water treatment, elevated levels of pollutants in source water can impact the effectiveness of drinking water treatment processes and the ability of drinking water treatment plants to meet MCLs. Section 3.4.6 presents further details on drinking water resources near steam electric power plants.

3.3.3 Damage Cases and Other Documented Surface Water Impacts

Changes in surface water chemistry due to contamination from steam electric power plant wastewater can negatively impact all levels of an ecosystem, including lower food chain organisms, which affect the ecosystem's food web; fish inhabiting the surface water; and wildlife and humans when they bathe in or drink the water. As described in earlier sections, pollutants in surface water can accumulate in aquatic organisms such as fish. When wildlife or humans ingest these aquatic organisms, they can be exposed to a higher dose of contamination than through direct exposure to the surface water. Documented surface water impacts associated with discharges of steam electric power plant wastewater include damage to fish populations (*i.e.*, physiological and morphological abnormalities and various behavioral, reproductive, and developmental effects), decreased diversity in insect populations, and decline of aquatic macroinvertebrate population. Impacts that affect humans include exceedances of NRWQC, fish consumption advisories, and designation of surface waters as impaired (limiting recreational activities).

Some wastewater surface impoundments are located in, or near, large river floodplains. Failure of the embankments of surface impoundments can release catastrophic amounts of pollutants into surrounding ecosystems.

EPA's damage case assessment found 26 proven damage case sites and 31 potential damage case sites with surface water impacts [U.S. EPA, 2014a through 2014e]. Including documented site impacts from the literature review, EPA identified impacts to surface waters at nearly 70 steam electric power plants following exposure to wastewater (more than 140 documented site impacts) [ERG, 2015m]. Some of the documented impact sites are the same locations identified by EPA as damage case sites. Table 3-8 highlights several damage case and other documented impact sites where negative surface water impacts from steam electric power plant wastewater discharges have been studied. In most cases, negative impacts have been studied and documented in multiple articles and reports. Tables A-6 and A-7 in Appendix A summarize the damage cases from combustion residual surface impoundments and landfills, respectively.

Table 3-8. Summary of Select Sites with Documented Surface Water Impacts from Steam Electric Power Plant Wastewater

Site Name and Location	Number of Documents that Discuss Surface Water Impacts at the Site	EPA Damage Case Assessment	Summary of Surface Water Impacts
Belews Lake, NC	13	Proven damage case [U.S. EPA, 2014b]	In 1970, Duke Power Company constructed Belews Lake as a cooling water reservoir to support the Belews Creek Steam Station. Almost immediately after surface impoundment effluent began discharging into the lake, fish populations experienced morphological changes, reproductive failure, and eventually death. In 1985, the Belews Creek Steam Station converted to a dry-ash transport system, ending the surface impoundment discharges to the lake. However, even 11 years after the discharges ceased, reproductive abnormalities persisted in the fish populations. Due to selenium concentrations, 16 of the 20 populations originally present in the reservoir were entirely eliminated, including all primary sport fish [Lemly, 1997a; U.S. EPA, 2014b].
Brandy Branch Reservoir, TX	1	Proven damage case [U.S. EPA, 2014b]	Brandy Branch Reservoir serves as a cooling water reservoir for Pirkey Power Plant. From 1986 to 1989, the Texas Parks and Wildlife Department's) reported increases in the selenium concentrations of the fish inhabiting the receiving water. As a result, the Texas Department of Health issued a fish consumption advisory for the reservoir, because of the potential health impact due to the levels of selenium in fish. Since the fish kills in the 1980s, Southwestern Electric Power Company has worked cooperatively to monitor fish tissue selenium concentrations, which have decreased since the late 1980s [ATSDR, 1998a].
Euharlee Creek, GA	1	Proven damage case [U.S. EPA, 2014b]	On July 28, 2002, a sinkhole developed in the surface impoundment at the Georgia Power Company in Cartersville, GA. The sinkhole expanded to 4 acres, and an estimated 2.25 million gallons of ash/water mixture was released to a tributary of the Euharlee Creek. Approximately 80 tons of ash entered Euharlee Creek through a stormwater drainage pipe. This discharge deposited an ash blanket in the creek up to 8 inches deep over 1,850 square feet of the stream bottom. Sampling at the ash discharge site found that concentrations of certain metals (arsenic, cadmium, chromium, copper, lead, mercury, and nickel) exceeded EPA Region IV ecological sediment screening values (ESV'S) indicating a potential for adverse impacts to aquatic life. Sediment concentrations of arsenic measured 14 ppm dry weight–over five times the toxic threshold. Biological sampling indicated that benthic organisms in the tributary and ash deposition zone of Euharlee Creek were either killed by contaminants or physically smothered. The resident fish community, which consisted of at least 25 species, was displaced due to the irritation of high turbidity in the ash plume as it moved through during the spill. One month after the spill, concentrations of selenium and cadmium were elevated in crayfish, clams, mollusks, and insects at a Euharlee Creek site downstream from the ash deposit.

Table 3-8. Summary of Select Sites with Documented Surface Water Impacts from Steam Electric Power Plant Wastewater

Site Name and Location	Number of Documents that Discuss Surface Water Impacts at the Site	EPA Damage Case Assessment	Summary of Surface Water Impacts
Gibson Lake, IN	4	Proven damage case [U.S. EPA, 2014b]	Gibson Lake is a man-made, shallow impoundment that receives surface impoundment effluent from Gibson Generating Station. Starting in 1986, least terns, an endangered species of migratory birds, began using the dike in Gibson Lake as a nesting ground for breeding. To protect the birds from potential toxic exposure, the plant began a cooperative program with the Indiana Department of Natural Resources to protect the nesting birds by creating a nearby alternative habitat, known as Cane Ridge Wildlife Management Area (WMA), which received water pumped from Gibson Lake. In April 2007, Duke Energy closed access to the lake for recreational fishing due to elevated selenium levels. A year later, the U.S. Fish and Wildlife Service (USFWS) became concerned about selenium levels in the water and fish in the Cane Ridge WMA. The USFWS stopped the flow of water from Gibson Lake into Cane Ridge, discouraged least terns from using the refuge, removed the contaminated fish, and plowed Cane Ridge to redistribute and bury the selenium in the soil. Subsequently, the USFWS stopped the flow of water from Gibson Lake into Cane Ridge and piped water from Wabash River instead. Cane Ridge was restocked with fish to lure back migratory birds. As of 2010, fish populations in Gibson Lake still had selenium levels above the toxic threshold [U.S. EPA, 2014b].
Glen Lyn, VA	5	Proven damage case [U.S. EPA, 2014b]	Glen Lyn Plant discharged fly ash transport water from a surface impoundment into Adair Run, a tributary of the New River. A 1984 study reported that the local insect diversity and density remained essentially the same upstream (reference site) and downstream of the surface impoundment when the impoundment was not close to capacity. However, as the settling impoundment reached its capacity, the insect density and diversity declined downstream. After closure of the surface impoundment, it took up to 10 months for the insect populations to recover [Specht *et al*., 1984].
Hyco Lake, NC	8	Proven damage case [U.S. EPA, 2014b]	Hyco Lake is a large cooling water reservoir that received effluent from a power plant, including combustion residual leachate and fly ash transport water discharges containing high levels of selenium. In 1981, a large-scale fish kill occurred in the reservoir, prompting numerous scientific studies to examine the extent and cause of the environmental damage. Multiple studies detected selenium concentrations in the water and tissue of fish inhabiting the reservoir, while other trace elements were within normal concentration ranges. The selenium accumulated in the fish in the lake, impacting reproduction and causing declines in fish populations in the late 1970s and the 1980s. A fish consumption advisory was issued in 1988 for this lake due to selenium contamination.

Table 3-8. Summary of Select Sites with Documented Surface Water Impacts from Steam Electric Power Plant Wastewater

Site Name and Location	Number of Documents that Discuss Surface Water Impacts at the Site	EPA Damage Case Assessment	Summary of Surface Water Impacts
Martin Creek Lake, TX	8	Proven damage case [U.S. EPA, 2014b]	Martin Creek Lake is a cooling water reservoir that also receives steam electric power plant wastewater discharges. In 1978 and 1979, a series of major fish kills occurred due to the elevated concentrations of selenium in the water and fish tissue. Numerous studies conducted throughout the 1980s documented histopathological and reproductive damage in the fish populations inhabiting the lake. In addition, the studies determined that, even 8 years after discharge ceased, the overall health of the aquatic populations near the discharge site remained adversely affected by the selenium pollution. In 1992, a fish consumption advisory was issued for the lake due to discharges from the steam electric power plant [U.S. EPA, 2014b].
McCoy Branch, TN	3	Proven damage case [U.S. EPA, 2014b]	In 1986, coal ash slurry discharges from the Department of Energy's (DOE's) Chestnut Ridge Y-12 power plant into McCoy Branch were found to contain elevated concentrations of trace elements, which violated the Tennessee Water Quality Act. A 1992 report written by DOE documented bioaccumulation of contaminants in fish tissues, decreased diversity in benthic macroinvertebrate communities, and increased fish mortality and abnormalities at the site [U.S. DOE, 1992].
Mountain Island Lake, NC	5	Location not assessed	Duke Energy's Riverbend Plant discharges surface impoundment effluent into Mountain Island Lake, which supplies drinking water to 700,000 people. The county staff has detected arsenic and zinc concentrations above state standards in an area near the surface impoundment discharge pipe [*Charlotte Observer*, 2010]. The plant continues to extensively monitor metal concentrations in Mountain Island Lake surrounding the point of discharge [NCDENR, 2011].
North Carolina (Multiple Locations)	Not applicable, multiple sites	Location not assessed	A study of receiving waters (including lakes and rivers) for 10 steam electric power plants in North Carolina evaluated the environmental and ecological impacts that wastewater discharges have on surface waters. The study found that the receiving waters at the 10 plants contain high levels of contaminants as a result of wastewater discharges. From the data collected between 2010 and 2012, contaminant levels at multiple surface waters exceeded drinking water standards and/or NRWQC. For example, arsenic concentrations at two outfalls were as high as 45 µg/L and 92 µg/L, respectively (the drinking water MCL for arsenic is 10 µg/L). When compared to the upstream pollutant concentrations at the 10 North Carolina locations, data showed elevated levels of contaminants such as boron, chromium, selenium, bromine, arsenic, and thallium. Elevated pollutant concentrations were also found in lake sediments (arsenic and selenium) and pore water near lake bottoms (including manganese, arsenic, nickel, and bromine). The study found elevated levels of arsenic and selenium in fish tissues for two of the lakes (Hyco Lake and Mayo Lake). A report on fish in Mayo Lake found deformities consistent with ingestion of high selenium levels [Ruhl *et al.*, 2012].

Table 3-8. Summary of Select Sites with Documented Surface Water Impacts from Steam Electric Power Plant Wastewater

Site Name and Location	Number of Documents that Discuss Surface Water Impacts at the Site	EPA Damage Case Assessment	Summary of Surface Water Impacts
Rocky Run Creek, WI	5	Proven damage case [U.S. EPA, 2014b]	Rocky Run Creek, a tributary of the Wisconsin River, receives effluent from Columbia Power Station's surface impoundments. After the power station began operation in 1975, the aquatic macroinvertebrate populations declined in the area. Two studies conducted at this site concluded that population density decreased, not because of death due to coal ash toxicity, but because the aquatic macroinvertebrate populations avoided the area due to sublethal alterations in the creek. Studies found increased TDS and total suspended solids (TSS), as well as a number of heavy metals, downstream from the discharge. Some species of macroinvertebrates were totally eliminated 4 months after discharges began.
Savannah River Site, SC	23	Proven damage case [U.S. EPA, 2014b]	The Savannah River Site, which is owned by DOE, is divided into several areas, based on production, land use, and other related characteristics. The D-area, a site utilized by numerous ecologists to study the impacts of coal-fired power plant waste, houses a coal-fired power plant that discharges ash into a series of surface impoundments and a swamp that ultimately drains into the Savannah River. Numerous studies observed organisms within these habitats accumulated high concentrations of trace elements in their tissues and exhibited various physiological, behavioral, and developmental effects. Sediments, water, and biota in the disposal system have elevated concentrations of trace elements and heavy metals derived from bottom ash and fly ash deposited in the basins. The studies documented several impacts to amphibians, reptiles, and fish, including five species of fish that have been eliminated.
TVA's Kingston Fossil Plant, TN	6	Proven damage case [U.S. EPA, 2014b]	On December 22, 2008, the retaining wall of a surface impoundment at TVA's Kingston Fossil Plant broke and released billions of gallons of coal ash slurry into the Emory, Clinch, and Tennessee Rivers. Tennessee Department of Environment and Conservation found exceedances of the more stringent criteria for chronic exposure of fish and aquatic life at least once in January 2009 for several metals (*e.g.*, aluminum, cadmium, iron, and lead). Seven months after the spill, all fish collected had concentrations of selenium above a toxic threshold, and most were still contaminated at that level 14 months after the spill. Twenty-one months after the spill, a high percentage of fish were found with lesions, deformities, and infections, all symptoms of extreme stress. In addition, studies have shown elevated levels of arsenic and mercury in sediments near the ash spill, as well as selenium levels exceeding the MCL in three wells underneath the Kingston's coal ash disposal area, ash processing area, and gypsum disposal facility [U.S. EPA, 2014b].

Table 3-8. Summary of Select Sites with Documented Surface Water Impacts from Steam Electric Power Plant Wastewater

Site Name and Location	Number of Documents that Discuss Surface Water Impacts at the Site	EPA Damage Case Assessment	Summary of Surface Water Impacts
Welsh Reservoir, TX	2	Proven damage case [U.S. EPA, 2014b]	Welsh Reservoir serves as a cooling water reservoir for Welsh Power Plant. From 1986 to 1989, the Texas Park and Wildlife Department reported increases in the selenium concentrations of the fish inhabiting the receiving water. As a result, the Texas Department of Health (TDH) issued a fish consumption advisory for the reservoir because of the potential health impact due to the levels of selenium in fish. In 1998, TDH collected 20 fish for reevaluation and observed an average selenium concentration in the fish above the reported national averages. Therefore, the Agency for Toxic Substances and Disease Registry (ATSDR) concluded in a report that there was no clear indication of an overall change in selenium fish tissue concentrations over the 12 years [ATSDR, 1998b].

Sources: ATSDR, 1998a; ATSDR, 1998b; *Charlotte Observer*, 2010; ERG, 2013b; Lemly, 1997a; NCDENR, 2011; Ruhl *et al.*, 2012; Specht *et al*., 1984; U.S. DOE, 1992; U.S. EPA, 2014b.

3.3.4 Damage Cases and Other Documented Ground Water Impacts

Pollutants in combustion residuals can leach into ground water from surface impoundments and landfills at the site. Older surface impoundments and landfills are of particular concern because they were often built without liners and leachate collection systems. Liners are typically made of synthetic material, asphalt, clay, or a composite of materials (*e.g.*, synthetic and clay) and are designed to collect leachate and prevent ground water contamination. Combustion residuals held in unlined surface impoundments can enter the subsurface and contaminate ground water. Pollutants in unlined landfills, used for the dry disposal of combustion residuals, can also leach as precipitation flows through the residuals pile and dissolves pollutants; the combustion residual leachate can eventually migrate into ground water. New plants are increasingly installing liners in surface impoundments and landfills, but pollutants can also enter the ground water when liners fail or when a disposal site is situated such that natural ground water fluctuations come into contact with the disposed waste. Furthermore, state regulation on leachate collection systems and impermeable liners is not uniform [EPRI, 1997; 65 FR 32214-32237, 2000].

Numerous damage cases and other documented site impacts demonstrate the toxic effects of steam electric power plant wastewater contamination to ground water and the potential to impact off-site sources due to combustion residual leachate migrating from landfills and surface impoundments (often unlined). EPA's damage case assessment found 24 proven damage case sites and 110 potential damage case sites with ground water impacts [U.S. EPA, 2014a through 2014e]. EPA identified impacts to ground water quality caused by combustion residual leachate from 140 steam electric power plants (more than 130 documented site impacts) [ERG, 2015m]. Some of these documented site impacts are caused by ash contributions from multiple plants (*e.g.*, a landfill that stores ash from multiple plants). EPA identified some of the documented impact sites as also being damage case sites. The majority of the damage cases and documented site impacts reported ground water pollutant levels in on-site wells above regulatory levels; however, only a portion of the cases indicated off-site contamination. Documented impacts to off-site ground water resources may be lower due to long migration times within the subsurface until the combustion residual leachate reaches a known monitoring point [NRC, 2006]. Further, the limited number of studies documenting off-site contamination might reflect less extensive monitoring of off-site ground water wells for evidence of impacts from combustion residual leachate, which suggests off-site impacts may be underrepresented in the documented ground water impacts [Cherry, 2000].

In surface impoundments, combustion residuals are in constant contact with water, allowing toxic pollutants to leach into and eventually contaminate ground water. From an environmental impact perspective, combustion residual surface impoundments are generally considered less desirable than landfills for disposal because they provide constant saturated or nearly saturated conditions and a relatively large hydraulic driving force to move combustion residual leachate into the subsurface [Theis and Gardner, 1990]. Table A-4 in Appendix A summarizes documented ground water damage cases from combustion residual surface impoundments [U.S. EPA, 2014a through 2014e].

Although more desirable than surface impoundments, landfills pose their own ground water contamination risks. If the landfills are not properly lined, the pollutants in combustion residuals can leach into the soil during precipitation. In areas with acid rain, the precipitation's low pH can accelerate the leaching of contaminants into ground water. In addition, heavy precipitation can not only accelerate leaching, but also carry pollutants in stormwater runoff, potentially contaminating ground water or surface water resources [Andersen and Madsen, 1983]. Table A-5 in Appendix A summarizes documented ground water damage cases from combustion residual landfills [MDNRE, 2010; U.S. EPA, 2014a through 2014e].

While many damage cases document elevated pollutant levels in ground water wells, it is unclear how many of these are private drinking water wells (as opposed to monitoring wells). However, the fact that many sites reported MCL exceedances in ground water testing suggests that potential impacts to drinking water resources are a realistic concern. The following three damage cases are documented instances where uncollected combustion residual leachate contaminated ground water and resulted in impacts to private drinking water wells.

Constellation Ash Disposal at Waugh Chapel and Turner Pits – Anne Arundel County, Maryland

For over a decade, Constellation Energy Group (Constellation) supplied fly ash for structural fill at the B.B.S.S. Inc. (BBSS) sand and gravel mines in Anne Arundel County, Maryland. Fly ash from Constellation's Brandon Shores and Wagner plants was used to reclaim portions of BBSS's Turner Pit starting in 1995 and the Waugh Chapel Pit starting in 2000. In the fall of 2006, Anne Arundel County Health Department officials documented concentrations of sulfate and metals (*i.e.*, antimony, beryllium, cadmium, manganese, and nickel) exceeding the state's screening criteria for potable aquifers in residential wells located downgradient from Waugh Chapel and Turner Pits [MDNR, 2007].

An independent study of the contamination confirmed that the elevated concentrations of sulfate and metals observed in the wells directly resulted from precipitation infiltrating the fly ash deposited in the BBSS sand and gravel mines [MDNR, 2007]. In October 2007, the Maryland Department of the Environment (MDE) fined Constellation and BBSS $1 million for the ground water contamination and required the companies to restore the local aquifer water quality [MDE, 2008]. In addition, Anne Arundel homeowners impacted by the contamination filed a class action lawsuit against Constellation and were awarded a $45 million settlement. The settlement required Constellation to pay the costs for converting 84 homes from well water to public water; cease future deliveries of new coal ash to the quarry; and to establish trust funds to compensate impacted property owners, enhance the neighborhood, and remediate and restore a former quarry site [Schultz, 2008].

Gibson Generating Station Plant – Gibson County, Indiana

The Gibson Generating Station Plant has six unlined surface impoundments (four surface impoundments and two settling/decant basins) and a landfill for combustion residuals. The landfill consists of a 94-acre older portion built in the late 1970s that is unlined and a 43-acre portion built in 2002 with a composite liner and leachate collection system. Additionally, the plant has a 400-acre landfill (South Landfill), permitted in 2005, which also has a composite liner and leachate collection system.

Samples from monitoring wells downgradient from the older landfill show high levels of arsenic, boron, iron, and manganese. Leaching from the landfill has contaminated 12 drinking water wells in the hamlet of East Mount Carmel, Indiana, with boron, manganese, iron, sulfate, sodium, and TDS. Sampling performed by Duke Energy in 2007 and by the Natural Resources Defense Council in 2008 show drinking water contamination from boron, iron, and manganese in at least nine off-site private residential wells [U.S. EPA, 2014b].

Ground Water Violations Near North Carolina Power Plants With Surface Impoundments – North Carolina

The North Carolina Department of Environment and Natural Resources reported ground water contamination near combustion residual surface impoundments at all 14 of the state's coal-fired power plants. Duke Energy and Progress Energy each own seven of the plants and perform ground water monitoring as required by the state. Manganese and lead concentrations exceeded state ground water standards at all 14 locations and TDS and chromium concentrations exceeded state standards at seven locations. Boron levels at six plants exceeded state ground water standards, and some plants had elevated levels of arsenic, selenium, thallium, antimony, chlorides, and nickel. The state and plants have not identified the source of the contamination but noted that the exceedances occurred at newly located wells. Drilling the wells may have affected the concentration of naturally occurring elements such as lead and manganese [Ballard, 2012].[20]

3.3.5 Potential for Impacts to Occur in Other Locations

Key environmental characteristics that contributed to the impacts documented in Sections 3.3.3 and 3.3.4, such as chronic exposure to large pollutant loadings, plants discharging to waters with long residence times, and unlined surface impoundments or landfills, are common at steam electric power plants. This suggests that the impacts documented above indicate the greater potential threat that steam electric power plant wastewater discharges pose to the environment. Although substantial events such as fish kills are well documented, the extent to which more subtle damages, such as histopathological changes, morphological deformities, and damage to reproductive success, occur elsewhere is not known due to the limited extent of monitoring programs.

Some of the documented environmental impacts discussed above occurred following discharges of steam electric power plant wastewater under normal operations. Although the actual amounts of pollutant loadings discharged may vary among steam electric power plants, documented site impacts under normal operations do not indicate that the pollutant loadings associated with the impacts are unusual for steam electric power plants. This suggests that chronic exposure to typical steam electric power plant wastewater pollutant loadings can impact the environment at other sites not documented in the literature.

The residence time of steam electric power plant wastewater pollutants in surface water is a major factor in determining the impact to the environment and the length of the recovery time. Many documented impact sites are lentic waterbodies such as lakes (*i.e.*, still waters) where pollutants can reside for long periods of time. These types of surface waters are at particular risk to impacts from steam electric power plant wastewater discharges. Steam electric power plants that discharge to a pond, lake, or reservoir may experience similar environmental effects as those observed in the documented impacts from analogous aquatic systems [ERG, 2015j].

[20] EPA notes that the impacts reported at North Carolina plants have not been documented in a peer-reviewed literature source; however, the information shows that elevated levels of metal contamination can occur near ash ponds.

3.4 DISCHARGE TO SENSITIVE ENVIRONMENTS

The pollutant loadings, ecological impacts, and human health concerns discussed in Section 3.2 and Section 3.3 are also of concern due to the proximity of many steam electric power plants to sensitive environments where the characteristics of steam electric power plant wastewater may impair water quality (*e.g.*, 303(d)-listed waters and waters with fish advisories) or pose a threat to threatened and endangered species.[21] EPA identified the number of surface waters that receive discharges of the evaluated wastestreams and are located in close proximity to the following sensitive environments:

- Great Lakes watershed (Section 3.4.1).
- Chesapeake Bay watershed (Section 3.4.2).
- Impaired waters (Section 3.4.3).
- Fish consumption advisory waters (Section 3.4.4).
- Threatened and endangered species habitats (Section 3.4.5).
- Drinking water resources (Section 3.4.6).

Table 3-9 summarizes the number and percentage of immediate receiving waters located in sensitive environments.

Table 3-9. Number and Percentage of Immediate Receiving Waters Identified as Sensitive Environments

Sensitive Environment	Number (Percentage) of Immediate Receiving Waters Identified [a]
Great Lakes watershed	25 (11%)
Chesapeake Bay watershed	13 (6%)
Impaired water	111 (50%)
Surface water impaired for a subset of pollutants associated with the evaluated wastestreams [b]	59 (27%)
Fish consumption advisory water	140 (63%)
Surface water with a fish consumption advisory for a subset of pollutants associated with the evaluated wastestreams [c]	93 (42%)
Drinking water resource within 5 miles	199 (90%)

a – For the sensitive environment proximity analysis, EPA evaluated 222 immediate receiving waters that receive discharges of the evaluated wastestreams [ERG, 2015c; ERG, 2015d].

b – Table B-1 in Appendix B contains a complete list of the impairment categories identified in EPA's 303(d)-listed waters and designates the subset of pollutants evaluated.

c – Table B-2 in Appendix B contains a complete list of the types of advisories identified under the sensitive environment proximity analysis, including pollutants that are not associated with the evaluated wastestreams.

3.4.1 Pollutant Loadings to the Great Lakes Watershed

The Great Lakes watershed includes hundreds of tributaries, thousands of smaller lakes, and extensive mineral deposits. The watershed provides a unique habitat that supports a wide range of flora and fauna, including over 200 globally rare plants and animals and more than 40 species found only in the Great Lakes watershed. Rare species include the white catspaw pearly mussel, the copper redhorse fish, and the Kirtland's warbler. The watershed provides a habitat

[21] See the ERG memorandum "Proximity Analysis Methodology" (DCN SE04448) for a description of the methodology used to evaluate the proximity of steam electric power plants to sensitive environments.

and food web for an estimated 180 species of native fish, including small- and large-mouth bass, muskellunge, northern pike, lake herring, whitefish, walleye, and lake trout [Great Lakes Restoration Initiative, 2010].

The Great Lakes provide humans with transportation, power, and recreational opportunities including fishing and boating. Between the United States and Canada, the Great Lakes have more than 10,000 miles of coastline and 30,000 islands. The watershed is home to more than 30 million people. Recreational spending directly supports 107,000 jobs and nearly 250,000 jobs when secondary impacts are taken into consideration [Great Lakes Restoration Initiative, 2010].

Environmental impacts documented in the Great Lakes are associated with a range of stressors, including toxic and nutrient pollutants, invasive species, and habitat degradation. EPA and Environment Canada have focused their Great Lakes Binational Toxics Strategy on persistent toxic substances such as mercury [U.S. EPA and Environment Canada, 1997; Great Lakes Restoration Initiative, 2010]. Mercury is a concern in all of the Great Lakes due to its bioaccumulation in fish and wildlife and potential impacts on humans. For example, in a study of 65 hair samples from fish-eating and non-fish-eating women, average mercury concentrations in hair were significantly greater (*i.e.*, 128 to 443 percent higher concentration) for women who ate several meals of sport-caught fish from the Great Lakes. EPA and Environment Canada have documented a range of wildlife impacts from mercury in the Great Lakes such as an increase of physiological abnormalities in herring gulls [U.S. EPA and Environment Canada, 2009].

Annual Discharges to the Great Lakes Watershed from the Evaluated Wastestreams

- 1.15 million pounds of total nitrogen
- 9,570 pounds of thallium
- 8,730 pounds of zinc
- 5,020 pounds of selenium
- 2,170 pounds of arsenic
- 1,900 pounds of lead

As part of the EA, EPA wanted to determine the extent of impacts to the Great Lakes watershed that might be caused by discharges of the evaluated wastestreams. The primary source of mercury in the Great Lakes watershed is atmospheric deposition from sources around the Great Lakes watershed (*e.g.*, fuel combustion, incineration, and manufacturing) emitting approximately 70,000 pounds of mercury annually [Evers *et al.*, 2011]. When compared to atmospheric deposition, mercury contributions from point source discharges are less of a concern. Due to the bioaccumulative nature of mercury, EPA has placed strict controls (*e.g.*, mixing zones are not allowed in permits) to limit the total amount of mercury entering the Great Lakes watershed. Monitoring within the Great Lakes watershed has indicated a decrease in mercury point source discharges, primarily because of implemented control strategies. EPA identified 23 steam electric power plants discharging to the Great Lakes watershed with the majority discharging to Lake Michigan (11 plants) and Lake Erie (6 plants) [ERG, 2015a]. In the Lake Erie Management Plan, EPA identified steam electric discharges as contributing 57 percent of the mercury to Lake Erie from wastewater sources [U.S. EPA, 2008b].

The potential for bioaccumulative pollutant retention in still or slow-moving water, such as the Great Lakes, is a particular concern. Many pollutants in steam electric power plant wastewater can bioaccumulate in fish and then affect higher trophic levels and terrestrial environments. Table 3-10 presents total pollutant loadings for the evaluated wastestreams discharging to the Great Lakes watershed.

Table 3-10. Pollutant Loadings to the Great Lakes Watershed from the Evaluated Wastestreams

Pollutant	Annual Discharge to the Great Lakes Watershed (lbs)	Annual TWPE Discharge to the Great Lakes Watershed (lb-eq)
Arsenic	2,170	7,510
Boron	997,000	8,310
Cadmium	648	14,700
Chromium VI	0.548	0.283
Copper	2,550	1,590
Lead	1,900	4,250
Manganese	242,000	24,900
Mercury	82.8	9,110
Nickel	9,840	1,070
Selenium	5,020	5,630
Thallium	9,570	27,300
Zinc	8,730	409
Total Nitrogen	1,150,000	--
Total Phosphorus	23,100	--
Chlorides	31,900,000	778
Total Dissolved Solids	186,000,000	--

Source: ERG, 2015a.

Note: Numbers are rounded to three significant figures.

3.4.2 Pollutant Loadings to the Chesapeake Bay Watershed

The Chesapeake Bay is the largest estuary in the United States and is a complex ecosystem that provides habitats and food webs for diverse groups of animals and plants. A variety of fish either live in the Chesapeake Bay and its tributaries year-round or visit its waters as they migrate along the East Coast. The Chesapeake Bay Watershed covers 64,000 square miles, with 11,684 miles of shoreline, and includes areas in six states: Delaware, Maryland, New York, Pennsylvania, Virginia, and West Virginia, plus Washington, DC. The watershed includes approximately 284,000 acres of tidal wetlands that provide critical habitats for fish, birds, crabs, and other species [Chesapeake Bay Program, 2015a and 2015b].

The Chesapeake Bay and its tributaries provide recreational and commercial opportunities, with more than 100,000 streams, creeks, and rivers in the watershed. Fishers commonly catch striped bass and white perch and seafood production from the Bay totals approximately 500 million pounds per year [Chesapeake Bay Program, 2015].

Annual Discharges to the Chesapeake Bay from the Evaluated Wastestreams

- 993,000 pounds of total nitrogen
- 6,560 pounds of selenium
- 5,830 pounds of zinc
- 5,280 pounds of thallium
  2,510 pounds of arsenic

The Chesapeake Bay was the first estuary in the nation to be selected for restoration as an integrated watershed and ecosystem. The watershed supports over 2,700 species of plants and animals, including 348 species of finfish and 173 species of shellfish. Other aquatic life includes algae, bay grasses, and other invertebrates. The watershed provides habitats for at least 29 species of waterfowl, with a population of nearly one million during the winter (representing approximately one-third of the Atlantic Coast's migratory population) [Chesapeake Bay Program, 2015].

Most of the Chesapeake Bay and its tidal waters are listed as impaired for excess nitrogen, phosphorus, and sediment. These pollutants cause oxygen-consuming algae blooms and create "dead zones" where fish and shellfish cannot survive, block sunlight that is needed for underwater grasses, and smother aquatic life on the bottom of the Bay. To restore water quality in the Bay, EPA established Total Maximum Daily Load (TMDL) limits for the Chesapeake Bay watershed in December 2010. These limits are 186 million pounds of nitrogen, 12.5 million pounds of phosphorus, and 6.45 billion pounds of sediment each year, reducing the discharges to the watershed by 25 percent for nitrogen, 24 percent for phosphorus, and 20 percent for sediment. Pollutant loadings to the Chesapeake Bay watershed come from both point sources and nonpoint sources. Point sources include municipal wastewater treatment facilities, industrial discharge facilities (*e.g.*, steam electric power plants and concentrated animal feeding operations), NPDES permitted stormwater (municipal separate storm sewer systems (MS4) and construction and industrial sites), and other sources. Nonpoint sources include agricultural land runoff, atmospheric deposition, forest land runoff, nonregulated stormwater runoff, stream banks and tidal shorelines, tidal resuspension, the ocean, wildlife, and natural background [U.S. EPA, 2010d].

EPA identified nine steam electric power plants discharging to the Chesapeake Bay watershed and estimated that these plants discharge almost one million pounds of nitrogen and over 16,000 pounds of phosphorus to the Bay annually [ERG, 2015a]. Table 3-11 presents the baseline pollutant loadings for the evaluated wastestreams.

Table 3-11. Pollutant Loadings to the Chesapeake Bay Watershed from the Evaluated Wastestreams

Pollutant	Annual Discharge to the Chesapeake Bay Watershed (lbs)	Annual TWPE Discharge to the Chesapeake Bay Watershed (lb-eq)
Arsenic	2,510	8,720
Boron	1,390,000	11,600
Cadmium	513	11,700
Chromium VI	16.7	8.62
Copper	2,210	1,380
Lead	1,560	3,490
Manganese	148,000	15,200
Mercury	88.8	9,770
Nickel	5,280	575
Selenium	6,560	7,360
Thallium	5,280	15,100
Zinc	5,830	273
Total Nitrogen	993,000	--
Total Phosphorus	16,800	--
Chlorides	43,000,000	1,050
Total Dissolved Solids	186,000,000	--

Source: ERG, 2015a.

Note: Numbers are rounded to three significant figures.

3.4.3 Proximity to Impaired Waters

A surface water is classified as a 303(d) impaired water when pollutant concentrations exceed water quality standards and the surface water can no longer meet its designated uses (*e.g.*, drinking, recreation, and aquatic habitat). Based on that definition, half of the immediate receiving waters included in the EA are impaired waters.[22] EPA reviewed the identified 303(d) impairment categories and determined that approximately 27 percent of the immediate receiving waters are impaired for a pollutant associated with the evaluated wastestreams, as shown in Table 3-12. Figure 3-1, Figure 3-2, and Figure 3-3 illustrate the geographical location of plants that directly discharge wastewater to a water classified as impaired by high concentrations of mercury, metals (other than mercury), and nutrients.

Table 3-12. Number and Percentage of Immediate Receiving Waters Classified as Impaired for a Pollutant Associated with the Evaluated Wastestreams

Pollutant Causing Impairment	Number (Percentage) of Immediate Receiving Waters Identified [a]
Mercury	30 (14%)
Metals, other than mercury [b]	28 (13%)
Nutrients	19 (9%)
TDS, including chlorides	4 (2%)
Total for Any Pollutant [c]	**70 (32%)**

a – For the impaired waters proximity analysis, EPA evaluated 222 immediate receiving waters that receive discharges of the evaluated wastestreams [ERG, 2015c; ERG, 2015d].

b – The EPA impaired water database listed 28 immediate receiving waters as impaired based on the "metal, other than mercury" impairment category. Of those 28 immediate receiving waters, 13 receiving waters are also listed as impaired for one or more specific metals in the EA analysis (arsenic, cadmium, chromium, copper, lead, manganese, selenium, and zinc). One additional immediate receiving water is impaired for boron (but not included in the "metals, other than mercury" impairment category).

c – Total does not equal the sum of the immediate receiving waters listed in the table. Some immediate receiving waters are impaired for multiple pollutants.

[22] Table B-1 in Appendix B lists the impairment categories identified under the sensitive environments proximity analysis, including pollutants that are not associated with the evaluated wastestreams.

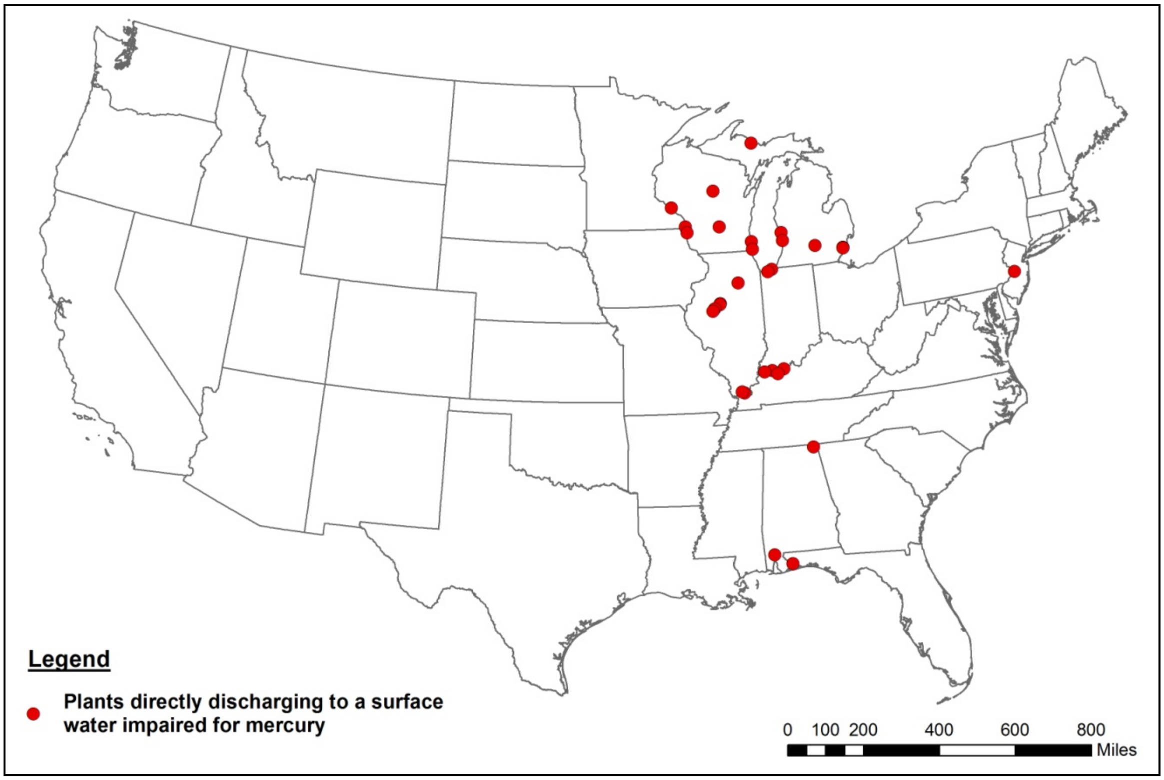


Figure 3-1. Location of Plants that Directly Discharge the Evaluated Wastestreams to a Surface Water Impaired due to Mercury

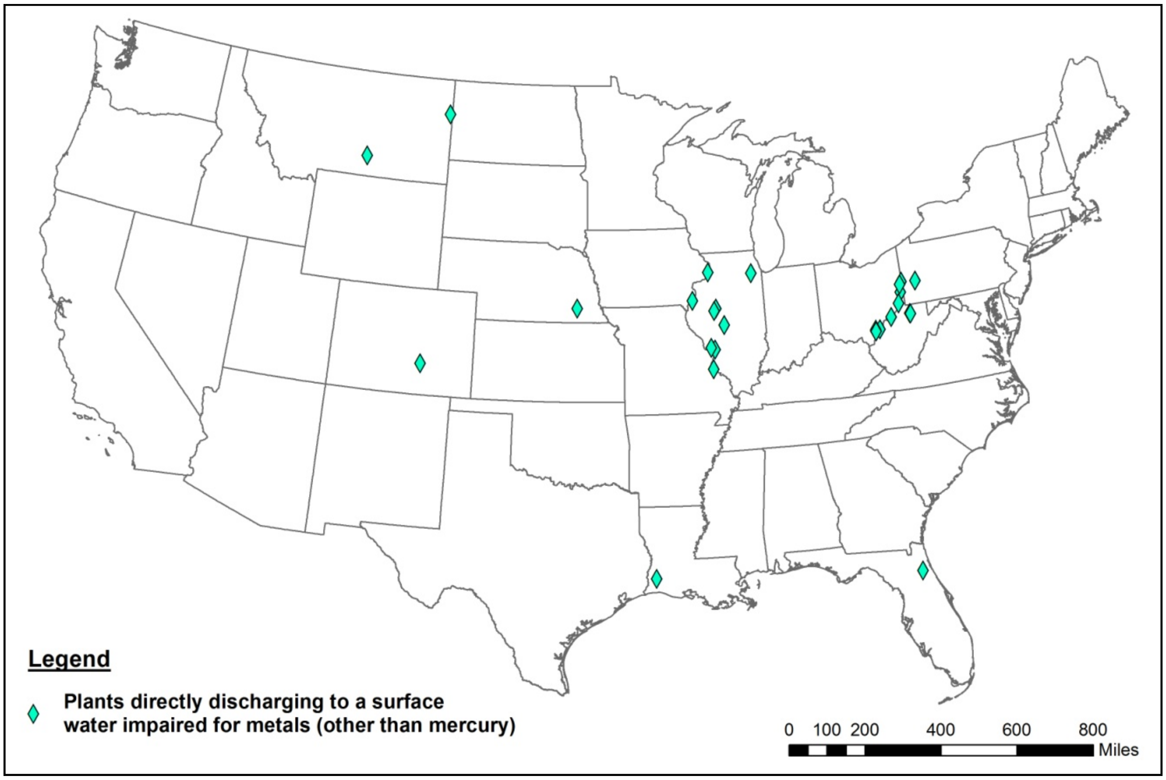


Figure 3-2. Location of Plants that Directly Discharge the Evaluated Wastestreams to a Surface Water Impaired due to Metals, Other than Mercury

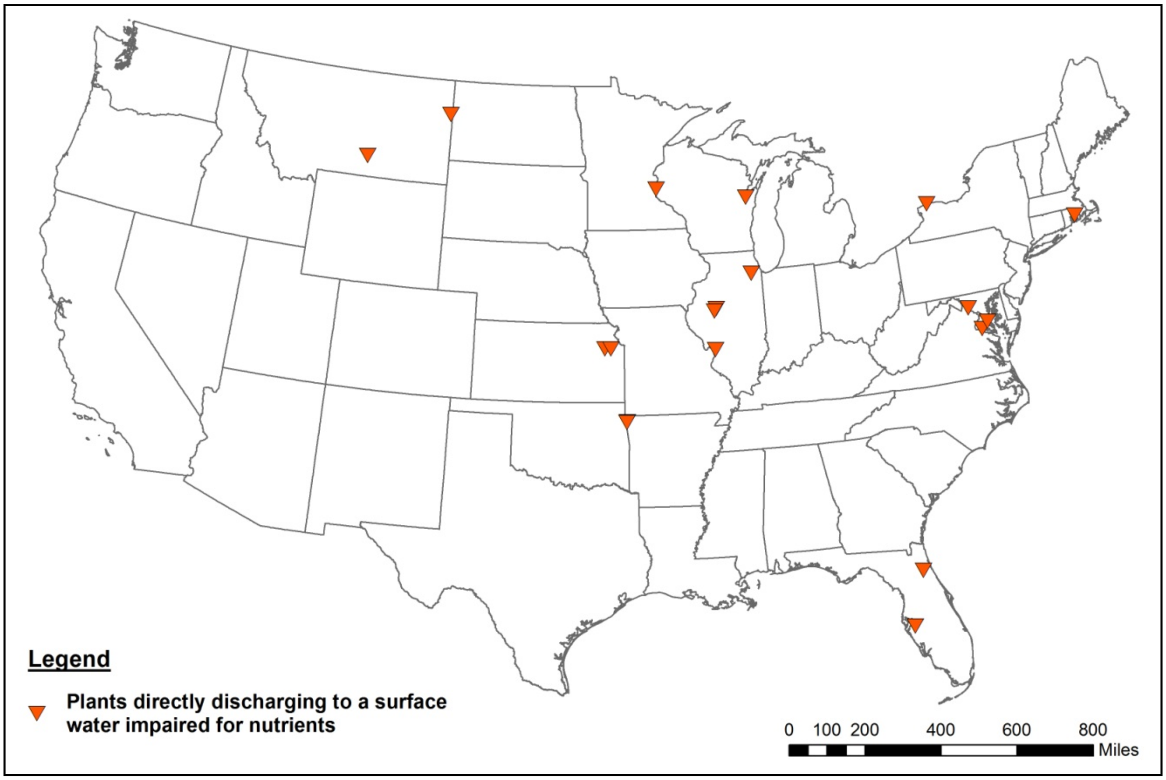


Figure 3-3. Location of Plants that Directly Discharge the Evaluated Wastestreams to a Surface Water Impaired due to Nutrients

3.4.4 Proximity to Fish Consumption Advisory Waters

States, territories, and authorized tribes issue fish consumption advisories when pollutant concentrations in fish tissue are considered unsafe for consumption [U.S. EPA, 2011e]. EPA determined that 140 of the immediate receiving waters included in the EA (63 percent) are under fish consumption advisories; 93 of the immediate receiving waters (42 percent) are under an advisory for a pollutant associated with the evaluated wastestreams.[23] All of these 93 immediate receiving waters are under a fish consumption advisory for mercury and one of the receiving waters is also under a fish consumption advisory for lead. EPA also reviewed fish consumption advisories for arsenic, cadmium, and selenium but did not identify any immediate receiving waters under advisories for these pollutants. Figure 3-4 illustrates the geographical location of plants that directly discharge steam electric power plant wastewater to surface waters with a fish consumption advisory for lead or mercury.

[23] Table B-2 in Appendix B lists the types of advisories identified under the sensitive environment proximity analysis, including pollutants that are not associated with the evaluated wastestreams.

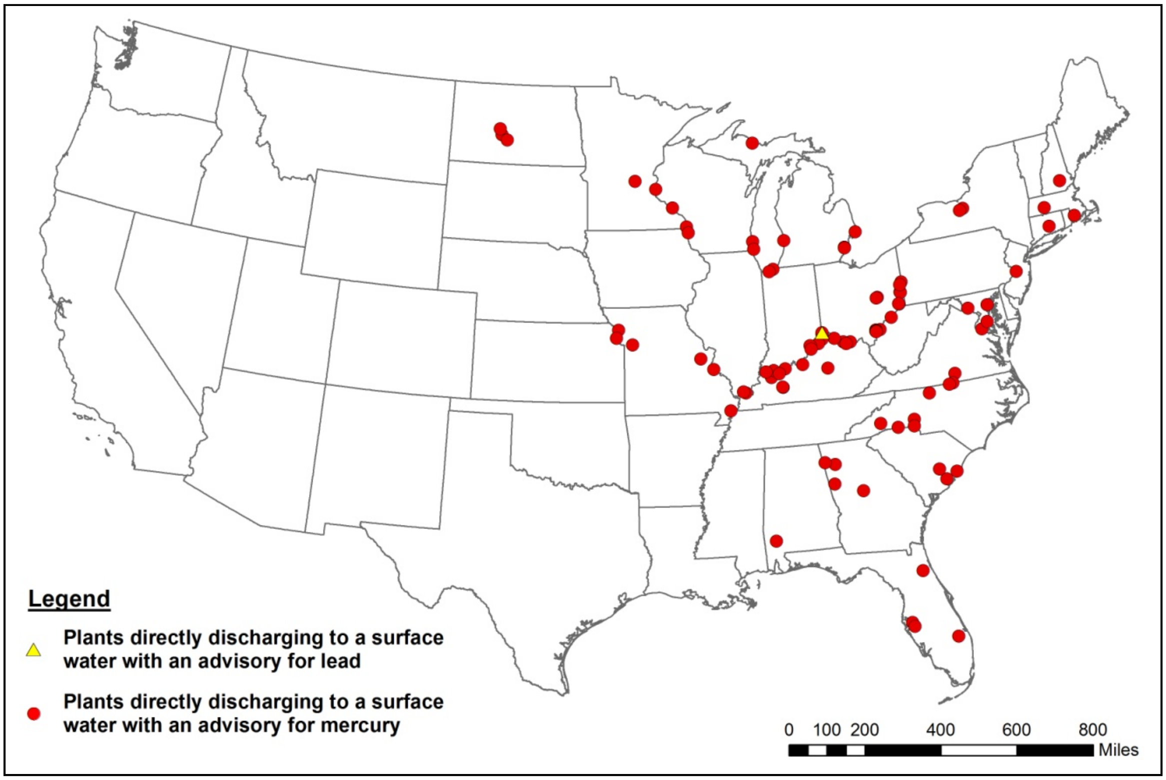


Figure 3-4. Location of Plants that Directly Discharge to a Surface Water with a Fish Consumption Advisory

3.4.5 <u>Proximity to Threatened and Endangered Species Habitats</u>

Under the Endangered Species Act (ESA), endangered species are those in danger of extinction throughout all or a significant portion of its range. Threatened species are those species that are likely to become endangered within the foreseeable future. A species may be listed solely on the basis of their biological status and threats to their existence. The USFWS considers five factors for listing: 1) damage to, or destruction of, a species' habitat; 2) overutilization of the species for commercial, recreational, scientific, or education purposes; 3) disease or predation; 4) inadequacy of existing protection; and 5) other natural or man-made factors that affect the continued existence of the species.

EPA evaluated the extent to which the estimated range and critical habitats of currently listed threatened and endangered species, or those in consideration for listing under the ESA (as of December 2014), overlap with surface waters that are potentially affected by the final rule. As described in the Benefits and Cost Analysis (EPA-821-R-15-005), these "affected areas" are receiving waters that do not meet water quality metrics recognized to cause harm in organisms under baseline conditions, but which do meet these metrics under the most stringent regulatory option EPA analyzed (Option E). EPA identified 138 threatened and endangered species whose habitats overlap with, or are located within, an "affected" surface water under baseline conditions.[24]

[24] The habitat locations evaluated for this analysis include waters downstream from steam electric power plant discharges and reflect changes in the industry as a result of the Clean Power Plan [Clean Air Act Section 111(d)].

In addition, EPA assessed the vulnerability of each species identified to changes in water quality and developed the following categories:

- High vulnerability: species living in aquatic habitats for several life history stages and/or species that obtain a majority of their food from aquatic sources.
- Moderate vulnerability: species living in aquatic habitats for one life history stage and/or species that obtain some of their food from aquatic sources.
- Low vulnerability: species whose habitats overlap bodies of water, but whose life history traits and food sources are terrestrial.

EPA classified 54 percent of the species (75 of 138 species) with habitats located within an "affected" surface water as highly vulnerable to changes in water quality. The habitats of these highly vulnerable species overlap a total of 145 affected stream reaches. For further details on the threatened and endangered species analysis and results, see the Benefits and Cost Analysis (EPA-821-R-15-005).

3.4.6 Proximity to Drinking Water Resources

EPA also evaluated the potential for steam electric power plants to pose a threat to public sources of drinking water. Although many of the pollutants (*e.g.*, selenium, mercury, arsenic, nitrates) in the evaluated wastestreams would likely be reduced to safe levels during drinking water treatment, these pollutants could potentially impact the effectiveness of the treatment processes, which could increase public drinking water treatment costs.[25] EPA evaluated the proximity of steam electric power plants to the following sensitive environments for drinking water resources:

- Drinking water intakes – drinking water sources that collect surface water through a public water system. Intakes are protected under the SDWA of 1974 and its 1986 and 1996 amendments, which require delegated states and tribes to perform routine testing to ensure that they meet state drinking water standards.
- Public wells – drinking water sources that collect ground water through a public water system. Public wells are protected under the SDWA, which requires delegated states and tribes to perform routine testing to ensure that they meet state drinking water standards.
- Sole-source aquifers – drinking water sources that supply at least 50 percent of the drinking water consumed in the area overlying the aquifer. These areas can have no reasonably available alternative drinking water source(s) if the aquifer were to become contaminated.

Table 3-13 summarizes the number and percentages of plants included in the national-scale proximity analysis that are located within five miles of the evaluated drinking water resources. The table also presents the number of drinking water resources that are located within this five-mile buffer zone. For example, 67 steam electric power plants are located within 5 miles

[25] For more information on drinking water treatment processes used to reduce or eliminate metals commonly detected in the evaluated wastestreams from steam electric power plants, see the ERG memorandum "Drinking Water Treatment Technologies that Can Reduce Metal and Selenium Concentrations Associated with Discharges from Steam Electric Power Plants" (DCN SE02154).

of a drinking water system intake or drinking water reservoir. Within 5 miles of these 67 plants are 113 drinking water system intakes or reservoirs.

Table 3-13. Comparison of Number and Percentage of Steam Electric Power Plants Located within 5 Miles of a Drinking Water Resource

Type of Drinking Water Resource	Number of Drinking Water Resources within 5 Miles of a Steam Electric Power Plant	Number (Percentage) of Steam Electric Power Plants Located within 5 Miles of a Drinking Water Resource [a]
Intakes and reservoirs	113	67 (33%)
Public wells [b]	2,057	157 (81%)
Sole-source aquifers	8	7 (4%)

Sources: ERG, 2015c; ERG, 2015d

a – For the drinking water resource proximity analysis, EPA evaluated 222 immediate receiving waters that receive discharges of the evaluated wastestreams from 195 steam electric power plants.

b – Counts include two springs and 29 wellheads.

3.5 Long Environmental Recovery Times Associated with Pollutants in Steam Electric Power Plant Wastewater

Recovery of the environment from exposure to steam electric power plant wastewater is affected by continued cycling of contaminants within the ecosystem, bioaccumulation, and the potential alterations to ecological processes, such as population and community dynamics in the surrounding ecosystems. The ability of aquatic and adjacent terrestrial environments to recover from even short periods of exposure to steam electric power plant wastewater depends on the distance from discharge, the pollutant concentrations, pollutant residence time, and the time elapsed since exposure. In particular, accumulation of metals and other bioacummulative pollutants in sediments can slow recovery of aquatic systems following exposure to power plant wastewater due to the potential for resuspension in the water column and for benthic organisms to provide a pathway for exposure long after power plant wastewater discharges have ended. For example, Lemly [1985a, 1997a, 1999] documented that benthic pathways can continue to provide toxic doses of selenium to wildlife even 10 years after water column selenium concentrations are below levels of concern. Ruhl *et al.* [2012] documented elevated levels of power plant wastewater pollutants (including arsenic and selenium) in pore water, even in cases where the water column concentrations are not elevated. This study found that arsenic is retained in lake sediments and pore water through a cycle of adsorption and desorption, likely in response to seasonal changes in the lake water chemistry [Ruhl *et al.*, 2012].

Short Exposures to Steam Electric Power Plant Wastewater Can Equate to Lasting Ecological Effects

In Martin Creek Lake, ecological effects persisted for at least 8 years following 8 months of fly ash discharges into the lake.

Ash pond discharges to Belews Lake in North Carolina resulted in elevated levels of arsenic, selenium, and zinc in the water and impacts to fish populations. Even 11 years after discharges ceased, selenium levels in the sediments still posed a risk to wildlife that feed on benthic organisms.

As discussed in Section 3.1, many of the pollutants in steam electric power plant wastewater (*e.g.*, arsenic, mercury, selenium) readily bioaccumulate in exposed biota. The bioaccumulation of these pollutants is of particular concern due to their impact on higher trophic levels, local terrestrial environments, and transient species, in addition to the aquatic organisms directly exposed to the wastewater. Aquatic systems with long residence times and potential contamination with bioaccumulative pollutants often experience persistent environmental effects following exposure to steam electric power plant wastewater.

Population decline attributed to exposure to steam electric power plant wastewater can alter the structure of aquatic communities and cause cascading effects within the food web that result in long-term impacts to ecosystem dynamics [Rowe *et al*., 2002]. Reductions in organism survival rates from abnormalities caused by exposure to power plant wastewater and alterations in interspecies relationships, such as declining abundance or quality of prey, can delay ecosystem recovery until key organisms within the food web return to levels prior to power plant wastewater exposure. In a 1980 study of a creek in Wisconsin, fungal decomposition of detritus was limited due to the effects of power plant wastewater. As a result, the benthic invertebrate population, which graze on detrital material, declined as did benthic fish that prey upon small invertebrates because of the reduced available resources [Magnuson *et al.*, 1980].

Studies have linked historical discharges of selenium from the Belews Creek Steam Station with persistent ecological impacts in the plant's cooling reservoir.

Belews Lake, a 1,500-hectare cooling reservoir constructed to support the Belews Creek Steam Station in Stokes County, North Carolina, is a well-documented site that highlights the effects that steam electric power plant wastewater can have on fish populations and the subsequent long recovery time. In 1970, Duke Energy began monitoring the fish populations in Belews Lake prior to any discharges of steam electric power plant wastewater. From 1974 to 1985, Duke Energy discharged surface impoundment effluent into Belews Lake. Almost immediately after these discharges began, rapid and dramatic changes in the fish populations were observed [Lemly, 1993]. By 1975, morphological abnormalities (*e.g.*, partial fin loss, head deformities, cataracts) were reported for all 19 fish species monitored in the lake. Within 2 years after surface impoundment effluent was released into the lake, several species stopped reproducing, leaving only four species by 1978 (*i.e.*, 4 years after discharges began). Water samples collected in the lake reported elevated levels of arsenic, selenium, and zinc. Large predatory fish were some of the first species to die out completely, due to the lethal and sublethal effects of exposure to surface impoundment effluent. Because a top predator was gone, some fish that exhibited developmental abnormalities were able to survive, despite their otherwise high susceptibility to predation [Lemly, 1993]. The study eventually correlated the observed fish abnormalities with high selenium whole-body concentrations, and identified the planktonic community as the key source of selenium to the impacted fish. In 1985, the Belews Creek Steam Station switched to disposing of the coal ash in a dry landfill and ended the surface impoundment discharges to the lake. In a 1997 study, Lemly determined that there was evidence that the lake was recovering; however, even 11 years after the discharges ceased, selenium levels in the sediments still posed a risk to wildlife that feed on benthic organisms. Lemly also observed that despite the reduction in the selenium concentration in fish ovaries, reproductive abnormalities remained persistent, highlighting the long ecological recovery time observed in Belews Lake.

In addition to population density effects, the diversity of species in the communities in both field and experimental studies exposed to steam electric power plant wastewater has altered, which can further prolong ecosystem recovery [Benson and Birge, 1985; Guthrie and Cherry, 1976; Rowe *et al*., 2001; Specht *et al*., 1984]. In a study of fish populations in Martin Creek Lake following a short 8-month period in which the lake received fly ash surface impoundment discharges, both planktivorous (*i.e.*, diet primarily consists of plankton) and carnivorous (*i.e.*, diet primarily consists of meat) fish populations were severely reduced [Garrett and Inman, 1984]. Three years after the effluent release was halted, planktivorous fish populations remained extremely low, while carnivorous fish populations had nearly recovered. Carnivorous fish have a more diverse diet than planktivorous fish and therefore benefited from an increase in food availability as the aquatic system recovered; however, the size of carnivorous fish in the lake suggested that surviving adults continued to have reproductive impairments [Garrett and Inman, 1984]. Sorensen (1988) documented that ecological impacts in the lake remained evident even up to 8 years after the 8-month exposure to fly ash transport water discharges, with sunfish populations continuing to exhibit tissue damage to the liver, kidneys, gills, and ovaries and impaired overall reproductive health. Fish samples taken in 1996 and 1997 showed that the selenium concentration (2.3 parts per million (ppm) average for all sample fish) remained well above the national average range of between 0.1 and 1.5 ppm [ATSDR, 1998a].

SECTION 4
ASSESSMENT OF EXPOSURE PATHWAYS

An exposure pathway is defined as the route a pollutant takes from its source (*e.g.*, combustion residual surface impoundments) to its endpoint (*e.g.*, a surface water), and how receptors (*e.g.*, fish, wildlife, or people) can come into contact with it. Exposure pathways are typically described in terms of five components:

- Source of contamination (*e.g.*, steam electric power plant wastewater).
- Environmental pathway—the environmental medium or transport mechanism that moves the pollutant away from the source through the environment (*e.g.*, discharges to surface waters).
- Point of exposure—the place (*e.g.*, private drinking water well) where receptors (*e.g.*, people) come into contact with a pollutant from the source of contamination.
- Route of exposure—the way (*e.g.*, ingestion, skin contact) receptors come into contact with the pollutant.
- Receptor population—the aquatic life, wildlife, or people exposed to the pollutant.

Pollutants from steam electric power plant wastewater stored in surface impoundments can reach receptor populations (such as wildlife or people) through various exposure pathways.

The exposure pathway plays an important role in determining the potential effects of steam electric power plant wastewater on the environment. For example, the physical and chemical characteristics of receiving waters can affect the fate and transport of pollutants from combustion residual surface impoundments to the environment and ultimately impact how the pollutants interact with the biological community.

EPA identified four primary exposure pathways of concern for steam electric power plant wastewater entering the environment: 1) discharges entering surface waters, 2) uncollected combustion residual leachate infiltrating through soil to nearby surface water, 3) uncollected combustion residual leachate entering ground water, and 4) direct contact with steam electric power plant wastewater stored in surface impoundments. This section describes the factors that control the magnitude of impacts to water quality, wildlife, and human health associated with exposure to steam electric power plant discharges and presents an overview of EPA's environmental assessment (EA) of the steam electric power generating industry, in which EPA evaluated the national-scale effects of power plant wastewater pollutants on the environment. Table 4-1 presents the environmental pathways, routes of exposure, and environmental concerns identified during the literature review and the types of analyses conducted to determine the impacts under baseline conditions and regulatory options.

Table 4-1. Steam Electric Power Plant Wastewater Environmental Pathways and Routes of Exposure Evaluated in the EA

Environmental Pathway	Route of Exposure	Environmental Concern	Analysis to Determine Environmental Impact
Steam electric power plant wastewater discharges to surface waters	Direct contact with surface water	Toxic effects on aquatic organisms [a]	Water quality impacts analysis (quantitative) – see Section 4.1.2
	Ingestion of surface water	Degradation of surface water quality used as intake to drinking water plants	
	Direct contact with sediment	Toxic effects on benthic organisms	Wildlife impacts analysis (quantitative) – see Section 4.1.2
	Consumption of aquatic organisms	Bioaccumulation of contaminants and resulting toxic effects on wildlife	
		Toxic effects on humans consuming contaminated fish	Human health impacts analysis (quantitative) – see Section 4.1.2
Uncollected combustion residual leachate infiltration to nearby surface waters from combustion residual surface impoundment or landfill	Direct contact with surface water or sediment	Toxic effects on humans and aquatic wildlife	Ground water quality impacts analysis (qualitative) – see Section 4.2.2
Uncollected combustion residual leachate entering ground water from combustion residual surface impoundment or landfill	Ingestion of ground water	Changes in ground water quality	
		Contaminated private drinking water wells	
Combustion residual surface impoundment	Direct contact with or ingestion of surface water	Toxic effects on wildlife	Attractive nuisances analysis (qualitative) – see Section 4.3
		Bioaccumulation of contaminants in wildlife	

a – The term "toxic effects" refers to impacts upon exposure, ingestion, inhalation, or assimilation into any organism, either directly from the environment or indirectly by ingestion through food chains. These effects can include death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), or physical deformations, in receptors (*e.g.*, aquatic organisms, wildlife, humans) or their offspring.

4.1 DISCHARGE AND LEACHING TO SURFACE WATERS

Steam electric power plants commonly discharge wastewater directly to surface waters following storage and treatment (*e.g.*, particulate settling) in surface impoundments. In addition to effluent discharges, uncollected combustion residual leachate can migrate through the soil and into the surface water. Section 4.2 further discusses the impacts of uncollected combustion residual leachate.

4.1.1 Factors Controlling Environmental Impacts in Surface Waters

One of the primary factors controlling the environmental impact of steam electric power plant wastewater on surface waters is the residence time of the pollutants once they enter an aquatic system. Residence times are often determined by the flow rate of the receiving water and type of ecosystem it supports. The potential for pollutant retention in lentic aquatic systems (*i.e.*, still or slow-moving water, such as lakes or ponds) and the creation of hot spots in lotic aquatic systems (*i.e.*, flowing water, such as streams and rivers) are of particular concern when bioaccumulative pollutants are present. Many of the pollutants in steam electric power plant wastewater discharges bioaccumulate, complicating estimates of potential impacts in surface waters because the pollutants can affect higher trophic levels, local terrestrial environments, and transient species, in addition to the aquatic organisms directly exposed to the wastewater.

Based on industry responses to EPA's 2010 *Questionnaire for the Steam Electric Power Generating Effluent Guideline* (Steam Electric Survey),[26] EPA determined that 18 percent of the 222 receiving waters included in the scope of the EA, all of which receive steam electric power plant wastewater discharges, are lentic systems such as lakes, ponds, reservoirs, and estuaries (Table 4-2). The majority of ecological studies on the impact of power plant wastewater in aquatic environments have focused on lentic systems [Rowe *et al*., 2002]. In lentic aquatic systems, the hydraulic residence time, or the amount of time it takes for the water in the aquatic system to be replaced by inflowing streams or precipitation is relatively long, allowing pollutants to build up over time and making these systems more vulnerable to impacts from power plant wastewater. In addition, aquatic organisms are limited in their ability to avoid areas of high pollutant concentrations and are restricted to the food supply available only within the waterbody.

Table 4-2. Receiving Water Types for Steam Electric Power Plants Evaluated in the EA

Receiving Water Type	Number (Percentage) of Immediate Receiving Waters [a]
River/Stream	183 (82%)
Lake/Pond/Reservoir	26 (12%)
Great Lakes	11 (5%)
Estuary and others (bay)	2 (1%)
Total Receiving Waters	**222 (100%)**

Source: ERG, 2015d.

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The immediate receiving water (IRW) model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters and loadings from 188 steam electric power plants.

Based on responses to EPA's Steam Electric Survey, EPA determined that 82 percent of aquatic environments that receive discharges of the evaluated wastestreams are lotic systems such as rivers and streams [ERG, 2015j]. Lotic systems dilute discharges more quickly than lentic systems. The moving water in lotic systems also provides a transport mechanism to disperse pollutants greater distances from the power plant, and enables aquatic organisms to move away from the areas contaminated by steam electric power plant discharges [Rowe *et al*.,

[26] Results presented in this report are based on plant responses to the Steam Electric Survey, which represent 2009 data. However, the analyses presented in this report incorporate some adjustments to current conditions in the industry. See Section 1 for further details.

2002]. Although power plant wastewater discharges into a lotic system can distribute pollutants across a greater spatial area, changes in flow velocity may result in the concentration of pollutants at a single location further downstream [Rowe *et al*., 2002]. For example, power plant wastewater discharged to a river may encounter areas of slower moving water downstream where pollutants would fall out of suspension and concentrate in a limited area. These pockets of higher pollutant concentrations, or hot spots, could be vulnerable to continued resuspension as stream velocities are affected by rainfall, resulting in the aquatic organisms being exposed to pollutants over much longer periods of time [Lemly, 1997a; Rowe *et al*., 2002].

4.1.2 Assessment of the Surface Water Exposure Pathway

EPA developed and executed models to quantify the water quality, wildlife, and human health impacts resulting from discharges of the evaluated wastestreams to surface waters. These models consist of the following: 1) a national-scale IRW model that evaluates the discharges from 186 steam electric power plants and focuses on impacts within the immediate surface water[27] where discharges occur, and 2) case study models that perform more sophisticated and extensive modeling of selected waterbodies that receive, or are downstream from, steam electric power plant wastewater discharges. Section 5 describes the IRW model and Section 8 describes the case study models. In addition, as part of the benefits and cost analysis, EPA also evaluated surface water concentrations downstream from steam electric discharges using EPA's Risk-Screening Environmental Indicators (RSEI) model; see the Benefits and Cost Analysis (EPA-821-R-15-005).

The remainder of this section discusses the scope of EPA's environmental assessment of the steam electric power generating industry in terms of evaluated pollutants, evaluated waterbody types, and evaluated environmental impacts.

Evaluated Pollutants

The EA quantitative analyses focused on the environmental impacts associated with discharges of toxic, bioaccumulative pollutants to surface waters. A key factor in determining the pollutants to include in the quantitative analyses was the potential for pollutant loadings to be diluted in the receiving waters following discharge. For example, EPA determined that the rivers and streams included in the IRW model had a median average annual flow of 2,808 cubic feet per second (cfs) and that 57 percent had an average annual flow greater than 1,000 cfs. Due to the potential for dilution, EPA focused the quantitative analyses on pollutants where the total mass loadings and not the concentration are critical factors in determining the potential for environmental impact. Section 5.1.2 lists the pollutants selected for quantitative analyses and how they were selected.

[27] The length of the immediate receiving water, as represented in the national-scale IRW model, ranges from between 1 to 5 miles from the steam electric power plant outfall. See the ERG memorandum "Water Quality Module: Plant and Receiving Water Characteristics" (DCN SE04513) for details on the immediate discharge zone and length of stream reach represented.

The EA quantitative analyses did not focus on water quality impacts associated with discharges of nutrients (total nitrogen and total phosphorus).[28] While discharges of large amounts of nutrients to surface waters can cause environmental problems (*e.g.*, eutrophication), EPA focused the EA quantitative analyses on 10 toxic pollutants that can bioaccumulate in fish and impact wildlife and human receptors via fish consumption. Additionally, nutrient-related impacts tend to be site-specific depending on environmental factors (*e.g.*, water-body temperature, the limiting nutrient in the system, algal species in the waterbody, and availability of oxygen in the water).

While the EA quantitative analyses did not address nutrient-related impacts, EPA did include nutrient loadings in the Benefits and Cost Analysis. EPA estimated total nitrogen and total phosphorus concentrations in receiving waters using dilution equations as input values to analyze benefits related to improvements in water quality. EPA used the SPARROW (SPAtially Referenced Regressions On Watershed attributes) model to provide baseline concentrations, as well as concentrations under each regulatory option. EPA used these concentrations to develop subindices for a water quality index (WQI), a value that translates water quality measurements, gathered for multiple parameters that represent various aspects of water quality, into a single numerical indicator. Total nitrogen and total phosphorous are only two of the subindices included in the WQI; the others are dissolved oxygen, biochemical oxygen demand, fecal coliform, total suspended solids (TSS), and heavy metals. EPA then used the WQI as a basis for calculating a willingness to pay for an increase in water quality as a result of the different regulatory options. See the Benefits and Cost Analysis for further details on the analysis and the results.

EPA identified total dissolved solids (TDS) and chlorides as the pollutants with the largest loadings under baseline conditions (see Table 3-2); however, EPA did not perform quantitative analyses of these pollutants for several reasons. TDS from the evaluated wastestreams consists largely of dissolved metals that are already captured in the analysis. Therefore, estimates of potential environmental impacts from TDS would double-count many of the environmental impacts and potential improvements assessed. Chlorides lack partition coefficient data (which are necessary for the water quality modeling performed in this EA) and have limited numeric threshold criteria data for comparison.

Evaluated Waterbody Types

In selecting the appropriate methodologies for the quantitative analyses, EPA considered the types of receiving waters commonly impacted by steam electric power plants and the pollutants typically found in the evaluated wastestreams. The IRW model and the selected case study models quantify the environmental risks within rivers/streams and lakes/ponds (including reservoirs), based on the determination that 94 percent of the final outfall receiving water designations fell within these two categories.

The EA quantitative analyses did not evaluate pollutant concentrations in the Great Lakes and estuarine systems, which represented 6 percent of all final outfall receiving waters. The

[28] EPA evaluated the nutrient impacts to the Great Lakes and Chesapeake Bay systems from a total mass loadings perspective, discussed in Section 3.4.

specific hydrodynamics and scale of the analysis required to appropriately model and quantify receiving water concentrations in the Great Lakes and estuarine systems are more complex than the IRW model.[29] In selecting the receiving waters to evaluate in the case study analyses, EPA focused primarily on rivers and streams based on the following: 1) the determination that 82 percent of the final outfall receiving water designations fell within this category, and 2) the relative simplicity of the hydrodynamics in river and stream case study models. This allowed EPA to develop and execute a larger set of case studies. EPA also developed one case study to represent the impacts of steam electric discharges to a lake. Refer to Section 8 for discussion of the receiving waters selected for case study analyses.

Evaluated Environmental Impacts

EPA focused the evaluation of environmental impacts on four key areas resulting from discharges of harmful pollutants to surface waters (rivers, streams, lakes, ponds, and reservoirs):

- Water Quality Impacts: Potential toxic effects to aquatic life based on changes in surface water quality—specifically, exceedances of the acute and chronic National Recommended Water Quality Criteria (NRWQC) for freshwater aquatic life.
- Wildlife Impacts: Potential toxic effects on benthic organisms based on changes in sediment quality within surface waters—specifically, exceedances of chemical stressor concentration limits (CSCL) for sediment biota.
- Wildlife Impacts: Bioaccumulaton of contaminants and potential toxic effects on wildlife from consuming contaminated aquatic organisms, specifically:
  - Risk of adverse reproductive impacts in fish and waterfowl that consume aquatic organisms with elevated levels of selenium (as determined by the ecological risk modeling methodology described in Section 5.2).
  - Potential risk of reduced reproduction rates in piscivorous wildlife, based on exceedances of no effect hazard concentration (NEHC) benchmarks.
- Human Health Impacts: Potential toxic effects to human health from consuming contaminated fish and water, specifically:
  - Exceedances of the human health NRWQC based on two standards: 1) standard for the consumption of water and organisms and 2) standard for the consumption of organisms.
  - Exceedances of drinking water maximum contaminant levels (MCLs). Although MCLs apply to drinking water produced by public water systems and not surface waters themselves, EPA identified immediate receiving waters that exceeded a MCL as an indication of the degradation of the overall water quality following exposure to the evaluated wastestreams.

[29] EPA evaluated the impacts to the Great Lakes and Chesapeake Bay systems from a total mass loadings perspective, discussed in Section 3.4. See the ERG memorandum "Site-Specific Estuary Dilution Analysis" (DCN SE02152) for details on EPA's initial screening analysis of the modeled receiving water concentrations in the Great Lakes and estuary systems compared to water quality benchmarks.

- Risk of cancer and non-cancer threats (*e.g.*, reproductive or neurological impacts) due to consuming fish caught from contaminated receiving waters.

4.2 LEACHING TO GROUND WATER

Combustion residual landfills and surface impoundments can impact local ground water through leaching.[30] Once in ground water, pollutants can migrate from the site and contaminate public or private drinking water wells and surface waters [NRC, 2006]. Contamination of drinking water wells is of particular concern because more than one-third of the U.S. population relies on ground water for drinking water. According to the U.S. Geological Survey (USGS), one in every five samples of ground water used as a source for drinking contains at least one contaminant at a level of concern for human health [USGS, 2015].

The fate of pollutants that leach from combustion residuals to ground water is controlled by many biological and geochemical (*e.g.*, adsorption, desorption, and precipitation reactions with aquifer materials) processes that can vary over large spatial and temporal scales [NRC, 2006]. This section describes the pollutant concentrations, chemical characteristics (*e.g.*, solubility, leachability, persistence, and mobility), and fate and transport processes that influence the potential environmental impact of uncollected combustion residual leachate.

4.2.1 Factors Controlling Environmental Impacts to Ground Water

Environmental impacts to ground water are determined by the pollutant concentrations in the combustion residual leachate and the rate of pollutant transport in the ground water. The pollutant concentrations in the combustion residual leachate depend on factors such as characteristics of the combustion residuals, site conditions (*e.g.*, rainfall amount and pH of the pore water in the surface impoundment or landfill), and combustion residual residence time in the surface impoundment or landfill.[31] The rate of pollutant transport in ground water depends on factors such as the biogeochemical characteristics of the subsurface (*e.g.*, soil pH and oxidation-reduction potentials), local rates of ground water recharge, and unsaturated and saturated ground water flow velocities.

Pollutant Concentrations in Combustion Residual Leachate

Combustion residual characteristics include the mineralogy of the waste (*e.g.*, lime, gypsum, iron, and aluminum oxide content) and pollutant solubility in the pore water. The mobility of pollutants may be altered due to changes in pH, carbon and chloride content, and interaction with other wastes from steam electric power plants [Thorneloe *et.al.*, 2010]. The waste mineralogy can vary based on the chemical composition in the fuel source (*e.g.*, the

[30] In this EA, EPA evaluated the threats to human health and the environment associated with pollutants leaching into ground water from surface impoundments and landfills containing combustion residuals. If these leached pollutants do not constitute the discharge of a pollutant to surface waters, then they are not controlled under the steam electric ELGs. While the Coal Combustion Residuals (CCR) rulemaking is the major controlling action for these pollutant releases to ground water, the ELGs could indirectly reduce impacts to ground water. These secondary improvements are discussed in Section 7.8.

[31] Leaching experiments indicate that the chemistry of leachates is based on both the chemical composition of the waste and other factors such as site conditions [Thorneloe *et al.*, 2010]. Thorneloe [2010] specifically looked at fly ash and bottom ash waste from coal-fired power plants.

specific coal seam and geographic location of the mine) and operational characteristics at the plant. Many laboratory investigations have examined the solubility characteristics of various pollutants associated with fly ash [Prasad *et al*., 1996; Thorneloe *et.al*., 2010]. The results of these investigations largely depend on multiple factors, and they tend to be more applicable qualitatively rather than quantitatively (*e.g.*, results from investigations can be used to determine the likelihood of a pollutant to dissolve in the combustion residual leachate, but not the amount). Concentrations of inorganic pollutants derived from calcium, sodium, magnesium, potassium, iron, sulfur, and carbon are relatively high in aqueous solution of fly ash because of their high total concentrations in the ash [Prasad *et al*., 1996].

The pH level of pore water in surface impoundments can strongly influence the concentration of pollutants in leachate from impoundments to ground water.

The pH of the pore water is a dominant factor in the leaching of pollutants from unlined surface impoundments and landfills. Because most pollutants in combustion residuals exhibit weak acidic or weak basic behavior in aqueous solution, the pore water pH strongly influences the concentrations of pollutants in the combustion residual leachate. Steam electric power plants generate combustion residuals in high-temperature processes, and many acids and acidic precursors (*e.g.*, carbon dioxide, hydrogen sulfide, hydrochloric acid) are volatilized prior to waste collection. Therefore, combustion residuals typically yield an alkaline reaction in water, but acidic reactions have also been observed [Theis and Gardner, 1990]. Acidic pore water allows pollutants from the combustion residuals to remain in solution, increasing their mobility and the potential for ground water contamination. The results of a study of three power plants in Turkey indicated that combustion residuals in the deeper layers of landfills and on the bottoms of the surface impoundments may continue to leach if the pH value drops in the surrounding environment [Baba and Kaya, 2004].[32]

Table 4-3 presents data collected by EPA's Steam Electric Survey regarding pollutant concentrations in the combustion residual leachate under acidic, neutral, and basic (or alkaline) conditions. Arsenic exceeded its MCL for more than 60 percent of the samples in both acidic and basic combustion residual leachate. Similarly, the majority of manganese samples exceeded its secondary MCL under all pH conditions, with 95 percent of the samples exceeding the MCL in

[32] This conclusion was based on a comparison of ash extraction procedures used. The study examined how the concentration of trace elements in the ash can vary based on the procedure used, comparing the EPA-developed EP (extraction procedure) and its replacement method, TCLP (toxicity characteristic leaching procedure), and the ASTM (American Society for Testing and Materials) Method D-3987. A comparison of the results revealed that the ASTM procedure indicated much lower dissolved metal concentrations than the EP and TCLP procedures. These results indicate that pH is an important parameter affecting the leaching rate of metals from ash deposits. The lower pH values in the EP and TCLP methods increase the leaching rate of inorganic constituents of fly ash and bottom ash [Fleming *et al*., 1996].

acidic conditions. Selenium had varying concentrations under all pH conditions, but exceeded its MCL more frequently under basic conditions. Overall, the results support the conclusion that pH levels influence the concentrations of pollutants in the combustion residual leachate.

Table 4-3. Exceedances of MCLs in Leachate Under Acidic, Neutral, and Basic Conditions

Pollutant	MCL (mg/L)	Total Number of Samples			Percentage of Total Samples Exceeding MCL		
		Acidic	Neutral	Basic	Acidic	Neutral	Basic
Arsenic	0.01	21	64	90	62%	30%	71%
Boron	7 [a]	21	64	91	14%	31%	31%
Cadmium	0.005	21	63	90	29%	3%	29%
Chromium	0.1	21	64	90	0%	0%	18%
Copper	1.3	21	64	91	0%	0%	0%
Lead	0.015	21	62	86	5%	0%	2%
Manganese	0.05 [b]	21	64	89	95%	81%	54%
Mercury	0.002	21	64	89	5%	16%	8%
Nickel	No MCL	21	64	87	NC	NC	NC
Selenium	0.05	21	64	90	14%	17%	31%
Thallium	0.002	21	62	86	52%	10%	14%
Zinc	5 [b]	21	63	86	0%	0%	0%

Source: ERG, 2015d.

Acronyms: mg/L (milligrams per liter); MCL (Maximum contaminant level); NC (not calculated; no MCL for comparison).

Note: Data are for untreated leachate collected in leachate collection systems at steam electric landfills and surface impoundments.

a – The drinking water equivalent level, used for noncarcinogenic endpoints, is listed rather than the MCL.

b – MCL is a secondary (nonenforceable) standard.

In addition to the pH of the pore water, amounts of precipitation can affect pollutant concentrations in the combustion residual leachate. Although landfills are dry disposal sites, rainfall and frozen precipitation infiltrate through the waste, dissolving pollutants that can then leach from the landfill. Landfills in drier climates generate less combustion residual leachate than landfills in wetter climates.

The last factor affecting pollutant concentrations in the combustion residual leachate is the combustion residual residence time in the surface impoundment or landfill. In a study of metals (calcium, copper, iron, lead, magnesium, manganese, potassium, sodium, and zinc) leaching from fly ash and bottom ash, all pollutants decreased in concentration with time of leaching, except for calcium, which released at a constant rate [Kopsick and Angino, 1981]. The most commonly noted leachate release curve is an initial flush curve, where the highest concentrations of pollutants are released as the leachate initially forms, with rapidly decreasing concentrations over time. Therefore, active surface impoundments receiving fresh combustion residuals will produce a leachate with elevated concentrations of pollutants that have a greater potential to contaminate drinking water sources and surface waters. Most inactive surface impoundments where pollutants have initially already leached from the combustion residuals should produce a leachate with decreasing concentrations of pollutants [Kopsick and Angino, 1981].

Thorneloe *et al*. [2010] studied the leaching behavior of coal combustion residuals in landfills, performing tests using a range of pH conditions and liquid-solid ratios expected during management via landfills or beneficial use. Combustion residual leachate concentrations for most pollutants were variable over a range of coal types, plant configurations, and combustion residual types (*i.e.*, fly ash or flue gas desulfurization (FGD) gypsum). The study showed significantly different leaching results (liquid-solid partitioning [equilibrium] as a function of pH) for similar combustion residual types and plants. The variability in pollutant leaching results was several orders of magnitude higher than the variability in the pollutant concentrations in the combustion residuals; this indicates that the pollutant concentrations alone cannot predict the leaching of metals, as noted above. Table 4-4 presents pollutant concentrations in combustion residual samples across a pH range of 5.4 to 12.4 and the range of pollutant concentrations in the combustion residual leachate. The table also includes indicator values for each pollutant: toxicity characteristic (TC) values for Resource Conservation and Recovery Act (RCRA) hazardous waste regulatory determination and drinking water MCLs for combustion residual leachate concentrations. As shown in the table, the maximum combustion residual leachate pollutant concentrations:

Most surface impoundments are unlined, allowing pollutants to infiltrate into ground water and eventually into surface waters.

- Exceed the TC values for RCRA hazardous waste determinations for arsenic, barium, chromium, and selenium (in fly ash).
- Exceed the TC values for RCRA hazardous waste determinations for selenium (in FGD gypsum).
- Exceed the MCLs for nine metals (in fly ash and FGD gypsum): antimony, arsenic, barium (fly ash only), boron, cadmium, chromium, molybdenum, selenium, and thallium.

The higher pollutant concentrations in the combustion residual leachate indicate greater mobility of the pollutant from the solid/slurry residual to the liquid phase. The concentration of the pollutants in the combustion residual leachate can be hundreds to thousands of times greater than the MCL.

Table 4-4. Range of Fly Ash and FGD Gypsum Total Content and Combustion Residual Leaching Test Results (Initial Screening Concentrations) for Trace Metals

	Range of Combustion Residual Content		Range of Leaching Test Results: Concentration in the Combustion Residual Leachate		Indicator Values	
Pollutant	**Fly Ash (mg/kg)**	**FGD Gypsum (mg/kg)**	**Fly Ash (µg/L)**	**FGD Gypsum (µg/L)**	**TC Value for Hazardous Waste Designation (µg/L)**	**Drinking Water MCL (µg/L)**
Antimony	3.0-14	0.14-8.2	<0.3-11,000	<0.3-330	--	6
Arsenic	17-510	0.95-10	0.32-18,000	0.32-1,200	5,000	10
Barium	50-7,000	2.4-67	50-670,000	30-560	100,000	2,000
Boron	NA	NA	210-270,000	12-270,000	--	7,000 [a]
Cadmium	0.3-1.8	0.11-0.61	<0.1-320	<0.2-240	1,000	5
Chromium	66-210	1.2-20	<0.3-7,300	<0.3-240	5,000	100
Mercury	0.1-1.5	0.01-3.1	<0.01-0.50	<0.01-0.66	200	2
Molybdenum	6.9-77	1.1-12	<0.5-130,000	0.36-1,900	--	200 [a]
Selenium	1.1-210	2.3-46	5.7-29,000	3.6-16,000	1,000	50
Thallium	0.72-13	0.24-2.3	<0.3-790	<0.3-1,100	--	2

Source: Thorneloe *et al*., 2010.

Acronyms: Acronyms: MCL (maximum contaminant level); mg/kg (milligrams per kilogram); TC (Toxicity Characteristics); µg/L (micrograms per liter); NA (Not Available).

a – The drinking water equivalent level, used for noncarcinogenic endpoints, is listed rather than the MCL.

Transporting Pollutants in the Ground Water

Predicting the movement of combustion residual pollutants in ground water can be challenging due to the wide range of biogeochemical characteristics between sites and within a given site. Pollutant transport times can vary, and combustion residual pollutants can take many years to reach local drinking water wells and surface waters [NRC, 2006]. For example, in the damage case at the Virginia Power Yorktown Power Station Chisman Creek Disposal Site in Yorktown, Virginia, fly ash had been disposed of in abandoned, unlined sand and gravel pits at the site for almost 20 years, from 1957 to 1974. However, ground water contamination was not discovered until 1980, when nearby shallow residential wells became contaminated with nickel and vanadium. Sampling also showed elevated levels of other heavy metals and toxic pollutants: arsenic, beryllium, chromium, copper, molybdenum, and selenium [U.S. EPA, 2014b].

Natural mechanisms, such as soil buffering capacity, attenuation of trace pollutants in certain soil types, amount of organic matter, and low soil permeability, can limit the transport of combustion residual pollutants in the subsurface environment. The mobility of pollutants in the subsurface strongly depends on soil-specific characteristics. Soil can have a buffering influence over the leachate by raising or lowering the pH. As noted previously, the solubility of most trace pollutants (the notable exceptions being arsenic and selenium) tends to decrease with increased pH (*i.e.*, alkaline conditions). In general, trace pollutants are less mobile in alkaline soils because the pollutants will precipitate and/or adsorb onto hydrous iron and aluminum oxides. Theis and Richter [1979] attempted to assess the factors influencing the attenuation of trace metals in soil/ground water. Results show that the major solubility control for cadmium, nickel, and zinc is adsorption by iron and manganese oxides while chromium, copper, and lead are controlled by precipitation. In some cases, particles in leachate may seal a surface impoundment or landfill, reducing the amount of leachate entering the ground water. Simsiman *et al*. [1987] and Kopsick and Angino [1981] both reported evidence of some sealing and reduced permeability of combustion residual surface impoundments, reducing seepage.

4.2.2 Assessment of the Ground Water Exposure Pathway

The EA focused on the discharges of toxic, bioaccumulative pollutants to surface waters from the evaluated wastestreams. While Section 3.3 provides qualitative discussion of ground water impacts based on a review of damage cases and other documented site impacts, the EA did not quantify the environmental and human health impacts resulting from pollutants leaching into the ground water from combustion residual surface impoundments and landfills. Additionally, the models used for this EA did not consider pollutant loadings to surface waters caused by combustion residual pollutants migrating through the soil and into surface waters, even though this may be occurring at many of the plants. As shown in Tables A-4 and A-5 in Appendix A, several damage cases have documented impacts to surface waters due to ground water contamination from combustion residual surface impoundments and landfills. The EA may therefore underestimate the number of cases where water quality standards are being exceeded in immediate receiving waters (see Section 6).

On April 17, 2015, EPA published a RCRA rule that regulates the disposal of CCRs from steam electric power plants (80 FR 21302). As part of the final CCR rulemaking, EPA's Office of Solid Waste and Emergency Response (OSWER) evaluated ground water contamination associated with combustion residuals in surface impoundments and landfills. The ground water impact analysis for the CCR rule identified and quantified human health risks to private drinking water wells due to potential ground water contamination from current CCR management practices. The analysis determined that human health risks were primarily from exposures to arsenic and molybdenum in ground water used as a source of drinking water. EPA identified additional human health risks from exposures to boron, cadmium, cobalt, fluoride, mercury, lithium, and thallium in ground water used as drinking water at certain sites based on the CCR disposal practices. Refer to the Regulatory Impact Analysis: EPA's 2015 RCRA Final Rule Regulating Coal Combustion Residual (CCR) Landfills and Surface Impoundments at Coal-Fired Electric Utility Power Plants (EPA-HQ-RCRA-2009-0640-12034) for the results of the national-scale analysis of ground water impacts.

4.3 Combustion Residual Surface Impoundments as Attractive Nuisance

An "attractive nuisance" is an area or habitat that attracts wildlife and is contaminated with pollutants at concentrations high enough to potentially harm exposed organisms. Two methods of handling steam electric power plant wastewater, surface impoundments and constructed wetlands, are classified as lentic systems supporting aquatic vegetation and organisms. These methods have been known to attract wildlife from other terrestrial habitats and therefore can be considered attractive nuisances. As an attractive nuisance, a surface impoundment can impact local wildlife as well as transient species that might rely on them during critical reproduction periods such as seasonal breeding events [Rowe *et al*., 2002].

Exposure to steam electric power plant wastewater during sensitive life cycle events is a concern given that it has been associated with complete reproductive failure in various vertebrate species [Cumbie and Van Horn, 1978; Gillespie and Baumann, 1986; Lemly, 1997a; Pruitt, 2000].

Organisms that frequent attractive nuisance sites at steam electric power plants, such as surface impoundments, risk exposure to elevated pollutant concentrations. Several studies have shown that terrestrial fauna nesting near combustion residual surface impoundments can have higher levels of arsenic, cadmium, chromium, lead, mercury, selenium, strontium, and vanadium than the same species at reference sites [Bryan *et al*., 2003; Burger *et al*., 2002; Hopkins *et al*., 1997, 1998, 2000, 2006; Nagle *et al*., 2001; Rattner *et al*., 2006]. Table A-8 in Appendix A summarizes documented examples of impacts to wildlife associated with attractive nuisances at steam electric power plants.

In several of these instances, histopathological effects (*i.e.*, changes in pollutant tissue concentrations) were observed. For example, birds nesting near a combustion residual surface impoundment produced eggs with higher selenium concentrations than eggs found at the reference site. Although egg selenium concentrations near combustion residual surface impoundments exceeded thresholds that signify adverse effects on reproduction, the study did not observe any reduction in reproductive success [Bryan *et al*., 2003]. In a study conducted by Hopkins *et al*. [1998], sediment from a contaminated combustion residual surface impoundment had arsenic levels more than 100 times higher than the levels found in reference site sediments. Adult toads captured in the contaminated surface impoundment reported a sevenfold difference in arsenic levels between those from reference sites [Hopkins *et al*., 1998]. Although the study did not measure any indicators of reduced survival or reproductive success in the toads, the results indicate that exposure to combustion residual surface impoundments are a potential threat [Hopkins *et al*., 1998].

Surface impoundments and constructed wetlands can act as attractive nuisances by attracting wildlife and exposing them to elevated pollutant levels.

Multiple studies have linked attractive nuisance areas at steam electric power plants to diminished reproductive success. Field studies have documented adverse effects on reproduction for turtles and toads living near selenium-laden combustion residual surface impoundments [Hopkins *et al*., 2006; Nagle *et al*., 2001]. In another study, an interior least tern *(Sternula antillarum),* an endangered migratory bird, began nesting at Gibson Lake, an artificial shallow pond that receives combustion residual surface impoundment effluent from the Gibson Generating Station in Indiana. Within several years, nearby combustion residual surface impoundments at the Gibson Generating Station were also attracting nesting least terns, placing these sensitive species in direct contact with steam electric power plant wastewater. To address the attractive nuisance problem presented by the surface impoundments, the Gibson Generating Station began a cooperative program with the Indiana Department of Natural Resources to protect the nesting birds by creating a nearby alternative habitat known as the Cane Ridge Wildlife Management Area (WMA) [Pruitt, 2000]. Cane Ridge WMA received water from Gibson Lake and, in 2008, the U.S. Fish and Wildlife Service became concerned about selenium levels in the water and fish present in the Cane Ridge WMA [USFWS, 2008]. Accordingly, the bottom of Cane Ridge was plowed to redistribute and bury the selenium in the soil and the water flowing from Gibson Lake into Cane Ridge was stopped and replaced with water piped from the Wabash River. Duke Energy paid to stock the Cane Ridge WMA ponds with fathead minnows to lure back migratory birds. As of June 2009, avocets, dunlins, black terns, Forster's terns, Caspian terns, and 50 endangered least terns have returned to Cane Ridge [USFWS, 2012].

Other well-documented cases of attractive nuisance settings with characteristics (*e.g.*, elevated concentrations of specific pollutants) similar to those associated with steam electric power plants provide further support that combustion residual surface impoundments have the potential to pose a threat to wildlife. For example, exposed organisms in attractive nuisance settings affected by urban and agricultural wastes have exhibited elevated tissue concentrations of pollutants, with some organisms experiencing a combination of reproductive or sublethal effects that adversely impact their survival [Clark, 1987; Hofer *et al*., 2010; King *et al*., 1994; Ohlendorf *et al*., 1986, 1988a, 1988b, 1989, 1990; Tsipoura *et al*., 2008]. Although these examples do not directly relate to steam electric power plants, they highlight the potential dangers of attractive nuisances and ability for pollutants to bioaccumulate in the surrounding wildlife [Ohlendorf *et al*., 1986, 1989, 1990]. Table A-9 in Appendix A summarizes documented examples of impacts to wildlife associated with attractive nuisances that are not specific to steam electric power plants.

SECTION 5
SURFACE WATER MODELING

Based on the documented environmental impacts discussed in the literature, EPA identified several key environmental and human health concerns and pathways of exposure to evaluate in the environmental assessment (EA). Environmental concerns include degradation of surface water, sediment, and ground water quality; toxic effects on aquatic and benthic organisms; bioaccumulation of contaminants and resultant toxic effects on wildlife; toxic effects on humans consuming contaminated fish; and contamination of drinking water resources.

EPA focused its quantitative analyses on discharges of the evaluated wastestreams to surface water – one of the primary exposure pathways of concern discussed in Section 4. To quantify baseline impacts and improvements under the final steam electric effluent limitations guidelines and standards (ELGs), EPA developed models to determine pollutant concentrations in the immediate receiving waters, pollutant concentrations in fish tissue, and exposure doses to ecological and human receptors from consuming aquatic organisms. This section describes the immediate receiving water (IRW) model and the ecological risk model used in developing this EA. Section 8 describes the development and execution of case study models using EPA's Water Quality Analysis Simulation Program (WASP) to supplement the results of the IRW model.

5.1 IMMEDIATE RECEIVING WATER (IRW) MODEL

EPA developed the IRW model[33] to quantify the environmental impacts to surface waters, wildlife, and human health from the wastestreams evaluated for the regulatory options. As part of this national assessment, EPA determined impacts in the immediate surface water where steam electric power generating industry discharges occur, between 1 and 5 miles from the outfall depending on the stream reach.[34] As part of the benefits and cost analysis, EPA also evaluated surface water concentrations downstream from steam electric discharges using EPA's Risk-Screening Environmental Indicators (RSEI) model; see the Benefits and Cost Analysis (EPA-821-R-15-005). The IRW model framework focused on four key areas of impacts:

- Impacts to aquatic life based on reduction in water quality from discharges of the evaluated wastestreams.
- Impacts to aquatic life based on reduction in sediment quality from discharges of the evaluated wastestreams.
- Impacts to wildlife from the bioaccumulation of contaminants in aquatic organisms and fish, including piscivorous (fish-eating) wildlife.
- Impacts to human health from consuming contaminated fish.

[33] The IRW model is the same model that EPA used for the national-scale analyses in support of the proposed ELGs. EPA assigned the "IRW model" label to help distinguish the national-scale model from the case study models developed in support of the final ELGs.
[34] See the ERG memorandum "Water Quality Module: Plant and Receiving Water Characteristics" (DCN SE04513) for details on the immediate discharge zone and length of stream reach represented.

As discussed in Section 4.1.2, EPA considered the type of receiving waters commonly impacted by steam electric power plants and the pollutants typically found in the evaluated wastestreams in selecting the appropriate methodologies for the quantitative analysis. The IRW model quantified the environmental risks within rivers/streams and lakes/ponds/reservoirs, and evaluated impacts from 10 toxic, bioaccumulative pollutants: arsenic, cadmium, copper, hexavalent chromium (chromium VI), lead, mercury, nickel, selenium, thallium, and zinc. EPA's IRW model includes three interrelated modules:

- Water quality module—calculates immediate-receiving-water-specific pollutant concentrations in the water column and sediment and evaluates the impacts that receiving water concentrations pose to aquatic life and human health.
- Wildlife module—evaluates the impact that sediment concentrations pose to aquatic life, calculates the pollutant concentrations in exposed fish populations, and evaluates the potential adverse effects to minks and eagles from consuming fish.
- Human health module—calculates non-cancer and cancer risks to human populations from consuming fish.

Additionally, EPA used the selenium outputs from the IRW water quality module to evaluate the risks to fish and waterfowl that consume aquatic organisms with elevated levels of selenium (see Section 5.2). This ecological risk analysis expands on the results of the IRW wildlife module described in this section.

The IRW water quality module uses plant-specific input data (plant-specific pollutant loadings and cooling water flow rate),[35] surface-water-specific characteristic data (*e.g.*, receiving water flow rate, lake volume), and representative environmental parameters (*e.g.*, partition coefficients) to quantify the environmental impacts of the evaluated wastestreams to surface waters. The module calculates pollutant concentrations in the surface water and sediment. These concentrations are inputs to the IRW wildlife module, which calculates the bioaccumulation of pollutants in fish tissue and determines impacts to wildlife. The fish tissue concentration calculated in the IRW wildlife module becomes an input to the IRW human health module. This section provides overviews of each module. Appendices C through E describe the IRW model equations, input data, and assumed environmental parameters in further detail. The appendices also describe the limitations and assumptions of the IRW model.

Figure 5-1 provides an overview of the IRW model inputs and the connections among the three modules to support EPA's national-scale modeling framework.

[35] EPA calculated annual pollutant loadings for the evaluated wastestreams and excluded any pollutants discharged with other wastewaters (*e.g.*, coal pile runoff). EPA incorporated cooling water flow rates into the IRW water quality module on a site-by-site basis. EPA assumed no pollutant loadings were associated with cooling water discharges to surface waters and used cooling water flow rates only to evaluate dilution effects.

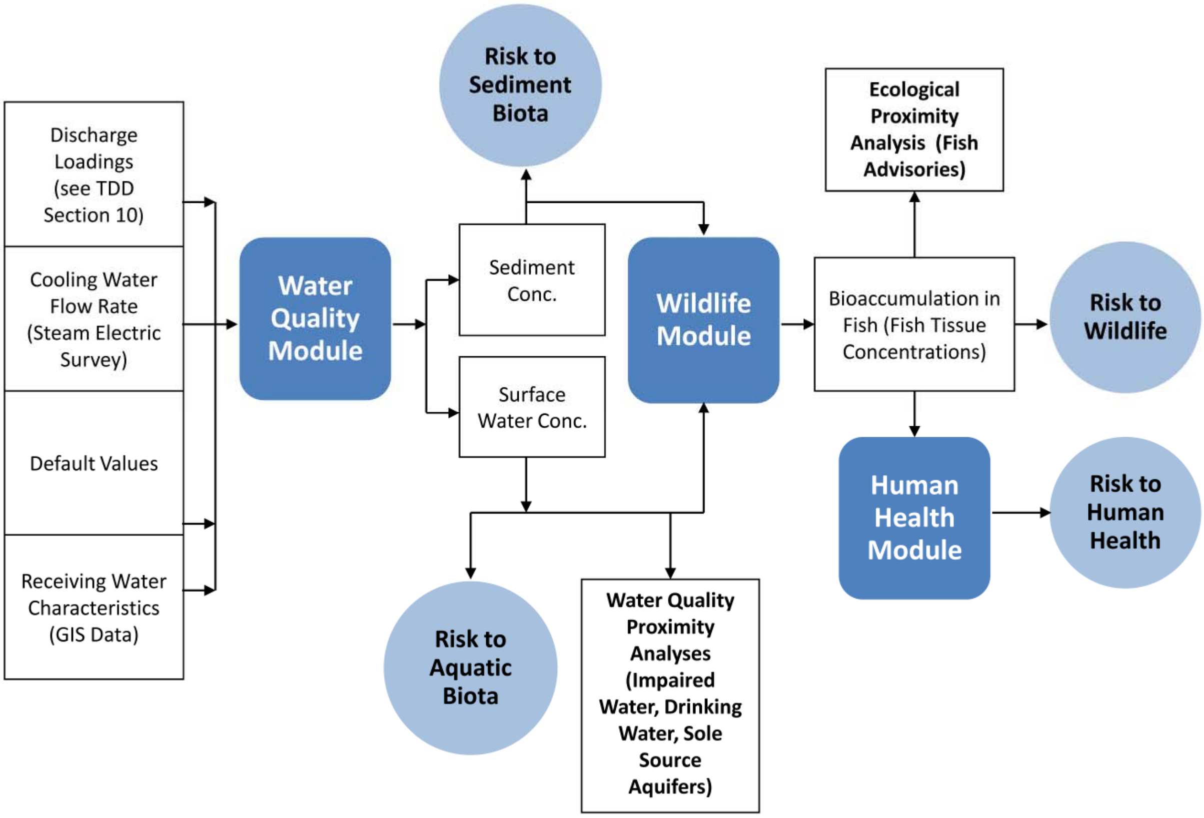


Figure 5-1. Overview of IRW Model

5.1.1 <u>Water Quality Module</u>

EPA selected the steady-state equilibrium-partitioning model described in EPA's *Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions* (EPA 600-R-98-137) for the IRW water quality module. This selection was based on three factors: 1) the model's ability to represent pollutants in the aquatic environment; 2) the model's complexity, which EPA judged to be appropriate for a national-scale evaluation;[36] and 3) the level of previous Agency and external peer reviews performed on the modeling methodology. An equilibrium-partitioning model assumes that dissolved and sorbed pollutants in a receiving water will quickly attain equilibrium in the immediate vicinity of the discharge point because they dissolve or sorb in the surface water faster than they can be transported or dispersed outside that area. The model also assumes that the equilibrium state for each pollutant can be represented by a partition coefficient that divides the total mass of a pollutant in the waterbody into four compartments:

- Constituents dissolved in the water column.
- Constituents sorbed onto suspended solids in the water column.

[36] For a national-scale environmental assessment of over 200 receiving waters, data limitations inhibit the feasibility of using more complex fate and transport receiving water models (dynamic or hydrodynamic) to estimate surface water concentrations.

- Constituents sorbed onto sediments at the bottom of the waterbody.
- Constituents dissolved in pore water in the sediments at the bottom of the waterbody.

Table 5-1 lists the pollutants commonly found in the evaluated wastestreams with known environmental impacts (see Section 3.1, Table 3-1). EPA selected a subset of these pollutants for the water quality model based on the following criteria:

- The pollutant is known to be present in the evaluated wastestreams (*i.e.*, identified as a pollutant of concern).
- Scientific literature documents elevated levels observed in surface waters or wildlife from exposure to steam electric power plant wastewater.
- Partition coefficient data are available for the water quality model.
- Benchmarks are available to evaluate potential threats to wildlife or human health.

For the immediate receiving water quality analysis, EPA modeled 10 of the pollutants shown in Table 5-1: arsenic, cadmium, chromium VI, copper, lead, mercury, nickel, selenium, thallium, and zinc.

Table 5-1. Pollutants Considered for Analysis in the Immediate Receiving Water Model

Pollutant	POC [a]	Literature Review [b]	Partition Coefficient [c]	NRWQC [d]	Maximum Contaminant Level (MCL)	Wildlife Benchmark [e]	Human Health Benchmark [f]	Included in Modeling Analysis [g]
Aluminum	✓			✓			✓	
Arsenic [h]	✓	✓	✓	✓	✓	✓	✓	✓
Boron	✓			✓			✓	
Cadmium	✓	✓	✓	✓	✓	✓	✓	✓
Chromium [i]	✓	✓	✓	✓	✓	✓	✓	✓
Copper	✓	✓	✓	✓	✓	✓	✓	✓
Iron	✓			✓			✓	
Lead	✓		✓	✓	✓	✓		✓
Manganese	✓			✓			✓	
Mercury [j]	✓	✓	✓	✓	✓	✓	✓	✓
Nickel	✓	✓	✓	✓		✓	✓	✓
Selenium [k]	✓	✓	✓	✓	✓	✓	✓	✓
Thallium	✓		✓	✓	✓		✓	✓
Vanadium	✓	✓	✓				✓	
Zinc	✓		✓	✓		✓	✓	✓

a – A check mark indicates that the pollutant is a pollutant of concern (POC) for one or more of the evaluated wastestreams (see Section 6 of the Technical Development Document (TDD) (EPA-821-R-15-007)).

b – Literature review identified documented cases of elevated pollutant levels in surface waters or wildlife near steam electric power plants [ERG, 2013b; ERG, 2015m].

c – Partition coefficients for modeling analysis identified in U.S. EPA, 1999, and U.S. EPA, 2005a.

d – National Recommended Water Quality Criteria (NRWQC) are available at http://water.epa.gov/scitech/swguidance/standards/current/index.cfm.

e – No effect hazard concentration (NEHC) identified in USGS, 2008, for minks and bald eagles.

f – Reference dose (RfD) identified in EPA's Integrated Risk Information System (IRIS) for all pollutants except copper and thallium (available at http://www.epa.gov/iris/); RfD for copper is the intermediate oral minimal risk level (MRL) [ATSDR, 2010a]; and RfD for thallium is the value for thallium chloride provided in U.S. EPA, 2010a. Cancer slope factor for arsenic identified in EPA's Integrated Risk Information System (IRIS) database [2011].

g – Pollutant is included in the quantitative modeling analysis discussed in this section.

h – Arsenic exists in two primary forms: arsenic III (arsenite) and arsenic V (arsenate). A check mark indicates that total arsenic, arsenite, and/or arsenate satisfied the criterion in the table header.

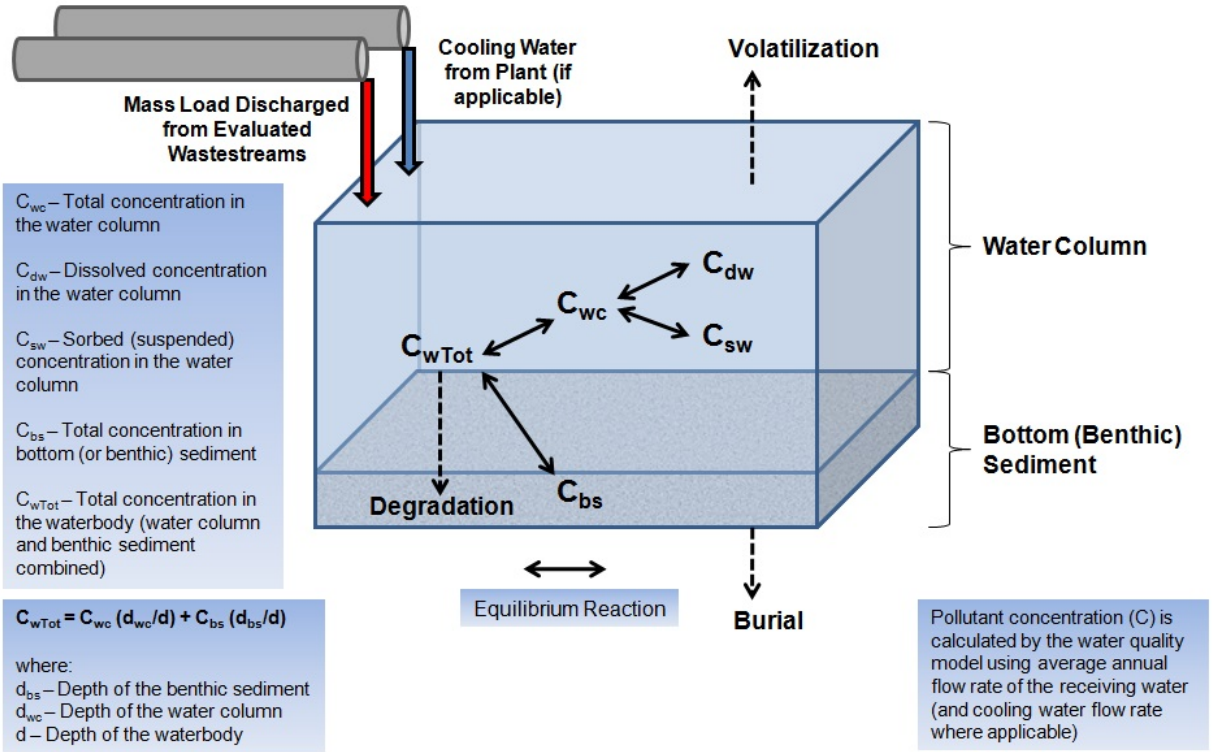
i – Chromium exists in two primary forms: chromium III and chromium VI. A check mark indicates that total chromium and/or chromium VI satisfied the criterion in the table header.

j – A check mark indicates that mercury and/or methylmercury satisfied the criterion in the table header.

k – Selenium exists in two primary forms: selenium IV (selenite) and selenium VI (selenate). A check mark indicates that total selenium, selenite, and/or selenate satisfied the criterion in the table header.

EPA developed the IRW water quality module in Microsoft Access™ using the equilibrium-partition equations presented in Appendix C. The IRW water quality module is a mathematical model used to represent the partitioning of pollutants through the surface water after the wastestream has been discharged. The module output provides site-specific pollutant concentrations in the water column (total, dissolved, and suspended) and sediment for 188 steam electric power plants located across the United States that discharge to a river or stream or to a lake, pond, or reservoir. Figure 5-2 depicts the pollutant concentrations calculated in the IRW water quality module. EPA implemented this modeling approach through the following steps:

1. Characterize the immediate receiving water characteristics (*e.g.*, depth of water column, depth of waterbody, receiving water width, and flow independent mixing value) using site-specific inputs. See the ERG memorandum "Water Quality Module: Plant and Receiving Water Characteristics" (DCN SE04513).
2. Using the immediate receiving water characteristics, determine the fraction of pollutant in the benthic sediment and in the water column and determine fraction of pollutant in the water column that is dissolved.
3. Using the immediate receiving water characteristics and assumed input values, calculate the water column volatilization rate constant, for volatile pollutants only (*i.e.*, mercury).
4. Calculate the water concentration dissipation rate (zero for nonvolatile pollutants).
5. Based on site-specific pollutant loadings (converting annual loadings to an average daily loading), cooling water flow rates (for a subset of plants), and immediate receiving water characteristics, calculate the total pollutant concentrations (*e.g.*, total arsenic) in the immediate receiving water, including the concentration in the water column and in the benthic sediment.
6. Calculate the concentration of dissolved pollutant in the water column. Section 10 of the TDD details the pollutant loadings methodology; the ERG memorandum "Water Quality Module: Plant and Receiving Water Characteristics" (DCN SE004513) describes the use of cooling water flow rates. Note that the pollutant loadings included in the module do not represent the total pollutant loadings from steam electric power plants; several wastestreams were not evaluated (*e.g.*, stormwater runoff, metal cleaning wastes, coal pile runoff). In addition, the module uses an annual average discharge rate, assuming no seasonal or daily variation.
7. Quantify the number of sites that exceed the NRWQC and drinking water maximum contaminant levels (MCLs) to evaluate the potential exposure of ecological receptors (*i.e.*, aquatic biota) and human receptors to toxic pollutants in the environment from the evaluated wastestreams.



Source: Adapted from U.S. EPA, 1998b.

Figure 5-2. Water Quality Module: Pollutant Fate in the Waterbody

As an indicator of potential impacts, EPA compared the immediate receiving water concentrations (under baseline and regulatory options) to the following NRWQCs:

- Freshwater acute and chronic aquatic life NRWQC.
- Human health NRWQC for the consumption of water and organisms.
- Human health NRWQC for the consumption of organisms.

EPA also compared immediate receiving water concentrations to drinking water MCLs. EPA identified immediate receiving waters that exceeded a NRWQC or MCL as an indication of the degradation of the overall water quality following exposure to the evaluated wastestreams. Section 6.3 summarizes the NRWQC and MCL exceedances under baseline pollutant loadings. Section 7.2 presents the percent reduction in number of immediate receiving waters that potentially impact water quality under the final rule.

As with any modeling, EPA recognizes that model limitations exist and certain assumptions need to be made. EPA used average annual pollutant loadings and normalized effluent flow rates, which do not take into account temporal variability (*e.g.*, variable plant operating schedules, storm flows, low-flow events, catastrophic events). The IRW water quality module does not account for ambient background pollutant concentrations or contributions from other point and nonpoint sources, and assumes a constant flow rate in the receiving water based on the annual average reported in National Hydrography Dataset Plus (NHDPlus). Appendix C discusses these and additional module-specific limitations and assumptions and Section 6 and

Section 7 present the results of the IRW water quality module under baseline and regulatory options.

5.1.2 Wildlife Module

As shown in Figure 5-1, the IRW wildlife module builds off the IRW water quality module by using the calculated immediate receiving water and sediment concentrations to calculate pollutant concentrations in fish populations exposed to the evaluated wastestreams and to assess the potential to impact wildlife for the following categories:

- Impact to aquatic organisms from contact with sediment contaminated by the evaluated wastestreams. To do this, the model quantifies the number of sites with potential exposure of ecological receptors (*i.e.*, sediment biota) to the pollutant in the environment.
- Impact to piscivorous wildlife (*i.e.*, wildlife that habitually feeds on fish) from consuming fish impacted by the evaluated wastestreams. To do this, the model quantifies the number of sites with potential exposure of ecological receptors (*i.e.*, piscivorous wildlife) to the pollutant in the environment.

EPA developed the wildlife model in Microsoft Access™ to calculate pollutant concentrations in fish populations exposed to the evaluated wastestreams and estimate daily contaminant dose for wildlife receptors (*i.e.*, minks and eagles) using equations presented in Appendix D. EPA determined potential impacts to wildlife by comparing the concentration in the contaminated media (*i.e.*, water, sediment, or fish) to concentrations known to be protective of negative impacts (*i.e.*, benchmark). Benchmarks, which are pollutant- and endpoint-specific and sometimes are species-specific, are an expression of the concentration level in contaminated media that is protective against a specific endpoint (*e.g.*, mortality). Endpoints frequently reflected in benchmark values include sublethal effects (*e.g.*, reduced reproduction, neurological effects) and lethal effects. EPA implemented the wildlife modeling approach through the following steps:

1. Compare the concentration of the contaminant in benthic sediment to the benchmark for sediment biota.
2. Calculate the pollutant concentration in fish for trophic level three (T3) or trophic level four (T4),[37] using the calculated pollutant concentration in the water column and the bioaccumulation factor (BAF) or bioconcentration factor (BCF).[38] For mercury, calculate the concentration of methylmercury in the fish. See Appendix D for details on the IRW wildlife module and calculation of methylmercury concentration in fish.
3. Compare the concentration of the contaminant in the fish to the wildlife benchmarks for ecological receptors (*i.e.*, mink and eagle).

[37] T3 fish (*e.g.*, carp, smelt, perch, catfish, sucker, bullhead, sauger) are those that primarily consume invertebrates and plankton, while T4 fish (*e.g.*, salmon, trout, walleye, bass) are those that primarily consume other fish.

[38] BCFs are more appropriate for use with pollutants where the primary pathway entering fish tissue is via the water, whereas BAFs are more appropriate for pollutants where the primary pathway entering fish tissue is through a food source (takes into account both water and diet). Where available, EPA used pollutant-specific BAFs.

4. Compare the baseline and regulatory option results (*i.e.*, number of sites with potential exposure of ecological receptors to concentrations above protective benchmarks).

Adverse Effects to Aquatic Organisms from Contact with Sediment

EPA compared the concentration in the benthic sediment to benchmarks protective of benthic organisms. EPA used threshold effects level (TEL) benchmarks provided in the National Oceanic and Atmospheric Administration (NOAA) 2008 Screening Quick Reference Tables (SQuiRTs), referred to as the chemical stressor concentration limit (CSCL), for the sediment biota adverse impacts analysis. The CSCL is a chemical-specific media concentration that is protective of ecological receptors of concern. The CSCL benchmark is species-specific, but can be used to represent a community of organisms, such as amphibians or fish. Usually the most sensitive (or lowest) CSCL for a species is used to represent the community. Table D-1 in Appendix D presents the benchmarks used for sediment exposure analysis. Section 6.2 discusses the results of this analysis for baseline pollutant loadings.

Assessment of Pollutant Bioconcentration in Fish

EPA calculated fish tissue concentrations based on the following: 1) total water column concentrations (*i.e.*, dissolved plus sorbed) calculated in the IRW water quality module, and 2) trophic-level-specific BAFs or BCFs. BAFs and BCFs are based on field and laboratory study results compiled to develop a single factor or ratio for estimating the amount of pollutant transferred into fish tissue at a given trophic level (*i.e.*, rank in the food chain) based on the pollutant concentration in the waterbody. EPA estimated fish tissue concentrations in milligrams per kilogram (mg/kg) for T3 and T4 fish to account for the variability in fish likely consumed by both wildlife and human receptors included in the IRW model.

Although using the total water column concentration in the bioaccumulation analysis may overestimate the level of pollutants in the fish, it provides for a more environmentally protective estimate of risk in the subsequent human health model because it assumes that all pollutants within the waterbody (both dissolved and sorbed) are bioavailable to the exposed fish. The exception to this methodology is mercury, where EPA based the fish tissue concentration calculation on the dissolved concentration of methylmercury in the waterbody [U.S. EPA, 2005b]. Appendix D presents the BCFs and model equations for the analysis of pollutant bioconcentration in fish tissue for T3 and T4 fish. EPA used the fish tissue concentrations to evaluate impacts to piscivorous wildlife (see next section) and impacts to human health receptors (see Section 5.1.3).

Impact to Piscivorous Wildlife

EPA based the piscivorous wildlife impact analysis on the methodology outlined in the 2008 U.S. Geological Survey (USGS) study *Environmental Contaminants in Freshwater Fish and Their Risk to Piscivorous Wildlife Based on a National Monitoring Program*. The study examined the impacts to minks and eagles from eating contaminated fish. Minks and eagles are commonly used in ecological risk assessments as indicator species for potential impacts to fish-eating mammals and birds in areas contaminated with bioaccumulative pollutants [USGS, 2008]. Minks and eagles are appropriate receptors for the steam electric power plant wildlife impact analysis because their habitats span most of the country and their diet largely consists of adult fish from the two trophic levels (*i.e.*, T3 and T4 fish) included in the IRW wildlife module. According to the literature [U.S. EPA, 1998a], minks consume mostly T3 fish, while eagles consume mostly T4 fish. EPA evaluated the potential adverse effects to minks and eagles for nine pollutants commonly found in the wastestreams of interest: arsenic, cadmium, chromium, copper, mercury, nickel, lead, selenium, and zinc.[39] The USGS method [USGS, 2008] is a wildlife impact analysis using NOAELs (no-observed-adverse-effect levels), which were derived from adult dietary exposure or tissue concentration studies based primarily on reproductive endpoints. The study calculated a NEHC benchmark, which is based on the NOAEL, the food consumption rate, and/or the biomagnification factor of each receptor. The report states that piscivorous wildlife may be at an elevated risk for reduced reproduction rates if the measured pollutant concentration in fish exceeds the NEHC. Therefore, EPA compared the mink-specific and eagle-specific NEHC values from the USGS study with the T3 and T4 fish tissue concentrations, respectively, to identify potential adverse impacts to the ecological receptors. In the piscivorous wildlife analysis, a benchmark exceedance indicates that piscivorous mammals or birds exposed to fish in the immediate receiving water of interest are at an elevated risk for reduced reproduction rates or other health effects.

Table D-3 in Appendix D presents the NEHC values used to evaluate potential adverse effects to wildlife. The text of Appendix D presents the equations used to compare model outputs to benchmarks (NEHCs), along with model-specific limitations and assumptions. The results of the IRW wildlife module under baseline conditions and the final rule are included in Section 6 and Section 7, respectively.

5.1.3 <u>Human Health Module</u>

As shown in Figure 5-1, the IRW human health module builds off the IRW wildlife module, using the calculated T3 and T4 fish tissue concentrations. Its purpose is to evaluate the cancer risk and potential to cause non-cancer health effects from consuming fish within the following age and consumption categories:

- Child recreational fishers (six cohorts covering different age ranges).[40]
- Child subsistence fishers (six cohorts covering different age ranges).
- Adult recreational fishers.
- Adult subsistence fishers.

In addition, EPA evaluated potential impacts to different race populations using these same cohorts as part of its environmental justice analysis. See the *Regulatory Impact Analysis for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (RIA) (EPA-821-R-15-004).

[39] Because there are no benchmarks for chromium VI or methylmercury, EPA used the total chromium and total mercury benchmarks, respectively, which may underestimate the risk to wildlife.

[40] The child cohort age ranges correspond to the ranges provided in the 2008 *Child-Specific Exposure Factors Handbook* (EPA-600-R-06-096F) for body weights.

EPA developed the IRW human health module in Microsoft Access™ to estimate the daily pollutant doses for human receptors as a result of eating T3 and T4 contaminated fish. EPA used a mathematical model to estimate the potential threats to human receptors from pollutant exposure. EPA estimated the average concentration of pollutants in a fish fillet consumed by humans based on a consumption diet of 36 percent T3 and 64 percent T4 fish (see Appendix E). The IRW human health module then calculates the daily dose of pollutants from fish consumption for each cohort included in the analysis. EPA varied the fish consumption rate based on the specific cohort using two factors: 1) type of fisher (recreational or subsistence) and 2) age (adult and six child cohorts). EPA first evaluated human health impacts based on type of fisher and age of cohort using national-level consumption rates. For the environmental justice analysis, EPA determined fish consumption rates using the race population in addition to the other two factors. See Appendix E for further details. Using the fish consumption rate, EPA determined an average daily pollutant dose for each human cohort evaluated. Table E-2 in Appendix E presents the cohorts included in the IRW human health module and the corresponding fish consumption rates used in the module. EPA implemented the human health modeling approach through the following steps:

1. Calculate the pollutant concentration in a fish fillet.
2. Calculate the average daily dose of pollutant from fish consumption by each receptor cohort (used for comparison to reference dose [RfD] values).
3. Calculate the lifetime average daily dose (LADD) for carcinogenic pollutants only, by each receptor cohort (used to determine cancer risk).
4. Calculate the lifetime excess cancer risk (LECR) for carcinogenic pollutants only, by each receptor cohort, using the LADD.
5. Compare the exposure doses of human receptor cohorts to appropriate benchmarks (RfD and selected cancer benchmark: 1-in-a-million).
6. Compare the baseline and regulatory option results: reduction in the number of immediate receiving waters with exposure doses from consuming fish that pose a potential threat to human receptors.

Non-Cancer Threat to Human Receptors

EPA evaluated the non-cancer threat (*e.g.*, reproductive or neurological impacts) to each cohort by comparing the pollutant-specific average daily dose values for fish consumption to the corresponding RfDs. EPA evaluated non-cancer risks for the following pollutants: inorganic arsenic,[41] cadmium, chromium VI, copper, methylmercury, nickel, selenium, thallium, and zinc. Table E-3 in Appendix E presents the RfD values used in the non-cancer threat analysis. RfD values are an expression of the consumption dose that is protective against a specific endpoint.

[41] For this analysis, EPA used only the concentration of inorganic arsenic for the human health impact assessment. Based on the literature review, arsenic in fish is mostly in the organic form and is not considered harmful. The wildlife model calculates a total arsenic fish tissue concentration. To convert this number to inorganic arsenic, EPA assumed that 4 percent of the total arsenic is inorganic based on EPA's 1997 document *Arsenic and Fish Consumption* (EPA-822-R-97-003). The 1997 document reported that the inorganic arsenic concentration in fish is between 0.4 and 4 percent of the total arsenic accumulating in fish [U.S. EPA, 1997b].

Endpoints frequently reflected in RfDs include various immunological, reproductive, neurological, and other non-cancer effects. In the IRW human health module, when the RfD is exceeded, it indicates a potential threat to humans for the endpoint associated with the RfD. For example, exceeding the RfD for selenium indicates that the exposure dose from fish consumption can cause non-cancer health effects, such as selenium-induced liver dysfunction or selenosis (hair or nail loss, morphological changes of the nails, etc.) [U.S. EPA, 2011c].

Cancer Risk to Human Receptors

Arsenic is the only pollutant included in the IRW model for which EPA has derived a cancer slope factor for ingestion exposures.[42] The IRW human health module calculates the LADD for each receptor cohort based on an exposure duration (*i.e.*, length of time a receptor is in contact with the carcinogen) averaged over a lifetime (*i.e.*, 70 years). For this analysis, EPA assumed the exposure duration to be equal to the number of years represented by each cohort. Using these exposure durations is appropriate for screening-level estimates of cancer risk and for comparing changes between baseline and regulatory options.[43] The model then multiplies the LADD by the cancer slope factor to calculate the LECR from arsenic. LECR is an estimate of the increase in cancer risk resulting from an exposure (*i.e.*, consumption of contaminated fish). EPA used the benchmark value for evaluating cancer risk of 1-in-a-million people. Therefore, a calculated LECR greater than 1×10^{-6} indicates an increased cancer risk for humans that consume fish exposed to discharges of evaluated wastestreams.

5.2 ECOLOGICAL RISK MODELING

Selenium bioaccumulation in aquatic organisms occurs primarily from ingesting food rather than through direct exposure to dissolved selenium in the water column [Fan *et al.*, 2002; Ohlendorf *et al.*, 1986; Saiki and Lowe, 1987; Presser and Ohlendorf, 1987; Luoma *et al.*, 1992; Presser *et al.*, 1994; Chapman *et al.*, 2009]. Unlike other bioaccumulative contaminants such as mercury, the single largest step in selenium accumulation in aquatic environments occurs in aquatic organisms at the base of the food web; algae, particulates, and microorganisms can accumulate selenium to levels far greater than the concentration in the water column. Bioaccumulation and transfer through aquatic food webs constitute the major selenium exposure pathway in aquatic ecosystems.

Macrophytes, algae, phytoplankton, zooplankton, and macroinvertebrates at the base of the food web easily bioaccumulate selenite and selenate and incorporate selenium in tissues as selenomethionine, an organo-selenide. This selenomethionine is then released back to the water

[42] Although EPA determined that lead and lead compounds can be "reasonably anticipated to be human carcinogens," no numeric value has been determined to quantify the cancer risk. As stated on the IRIS website, "quantifying lead's cancer risk involves many uncertainties, some of which may be unique to lead. Age, health, nutritional state, body burden, and exposure duration influence the absorption, release, and excretion of lead. In addition, current knowledge of lead pharmacokinetics indicates that an estimate derived by standard procedures would not truly describe the potential risk. Thus, the Carcinogen Assessment Group recommends that a numerical estimate not be used." (See http://www.epa.gov/iris/subst/0277.htm#reforal.)

[43] To completely assess risk to an individual, EPA recommends that risks should be calculated by integrating exposures throughout all life stages (*i.e.*, adding multiple cohort risks from screening analysis). For example, the exposure duration may be equal to the length of time a person lives in an area [U.S. EPA, 2011b].

column as these plants and organisms die or are consumed [U.S. EPA, 2014f]. In general, selenium concentrations in particulates (*e.g.*, sediment, detritus, and primary producers such as algae and biofilm) are 100 to 500 times higher than dissolved concentrations in selenate-dominated environments such as streams and rivers. Where selenite or organo-selenide is proportionately more abundant, such as in lakes, wetlands, some estuaries, and oceans, the ratio can be much higher (1,000 to 10,000 times higher than dissolved concentrations). This variability of particulate concentrations relative to dissolved concentrations across different aquatic environments makes it difficult to develop a simple relationship between the concentration of selenium in water and the concentration of selenium in organisms [Presser and Luoma, 2010].

The scientific community has devoted significant effort to understanding the mechanisms of selenium bioaccumulation. The preferred approach, as described in Presser and Luoma [2010], accounts for the variability in particulate concentrations described above by applying site-specific enrichment factors (EFs) that represent the ratio of the concentration of selenium at the base of the food web (*i.e.*, particulates) to the dissolved concentration in water. Subsequent bioaccumulation by aquatic organisms is described through a series of empirically derived, species-specific trophic transfer factors (TTFs) that link the selenium concentrations in particulates and invertebrates to higher trophic-level organisms such as fish and birds. TTFs can be derived from laboratory experiments or from field data. TTFs differ from traditional BCFs (described in Section 5.1.2) in that they are the ratio of the selenium concentration in each animal to the selenium concentration in its food, whereas BCFs represent the ratio of the selenium concentration in an animal to the selenium concentration in the water of its environment. Using TTFs therefore more accurately predicts selenium bioaccumulation in aquatic organisms because it accounts for the significant role of dietary exposure.

Selenium toxicity among exposed fish and birds primarily is transferred to the eggs and demonstrated via subsequent reproductive effects. Many studies and expert panels have shown that reproductive effects, linked to egg-ovary selenium concentrations, are of greatest concern and likely have led to observed reductions in sensitive fish species populations in waterbodies having excessive selenium concentrations [Chapman *et al*., 2009].

EPA developed and applied a probabilistic ecological risk model, based on the bioaccumulation concepts described above, to assess the risk of adverse reproductive impacts among fish and birds exposed to selenium in waterbodies that receive discharges of the evaluated wastestreams. Figure 5-3 provides a general schematic of the approach, which follows these general steps:

1. Apply a distribution of site-specific EFs (with separate distributions for lentic and lotic systems) to the predicted dissolved selenium concentration from the IRW water quality module, resulting in a distribution of predicted selenium concentrations in particulates and primary producers for each receiving water.
2. Apply a TTF distribution for invertebrates (TTF_{invert}) to the outputs from Step 1, resulting in a distribution of predicted selenium concentrations in invertebrates that inhabit each receiving water.
3. To predict the bioaccumulation and reproductive risk among fish:

a. Apply a TTF distribution for fish (TTF_{fish}) to the outputs from Step 2, resulting in a distribution of predicted selenium concentrations in the eggs and ovaries of fish that inhabit each receiving water (some of the TTFs incorporate tissue conversion factors to translate the outputs from whole body or muscle concentrations into fish egg-ovary concentrations).

b. Apply an exposure-response function for fish (ER_{fish}) to the outputs from Step 3a, resulting in a distribution showing the probability of a decline in reproductive success across exposed fish populations.

4. To predict the bioaccumulation and reproductive risk among birds (specifically, mallards):

a. Apply a TTF distribution for mallards ($TTF_{mallard}$) to the outputs from Step 2, resulting in a distribution of predicted selenium concentrations in the eggs of mallards that forage and/or breed in each receiving water.

b. Apply an exposure-response function for mallards ($ER_{mallard}$) to the outputs from Step 4a, resulting in a distribution showing the probability of a decline in reproductive success across exposed mallard populations.

This modeling approach is consistent with the approach taken in developing the External Peer Review Draft Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater [U.S. EPA, 2014f] (referred to as the external peer review draft selenium criterion) and is based on the same data sets and studies for EF, TTF_{invert}, TTF_{fish}, and ER_{fish}. For this EA, EPA expanded the model to include data sets for $TTF_{mallard}$ and $ER_{mallard}$ and to include several additional data sets and studies for EF, TTF_{invert}, TTF_{fish}, and ER_{fish} that were eventually incorporated into the Draft Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater [U.S. EPA, 2015b].

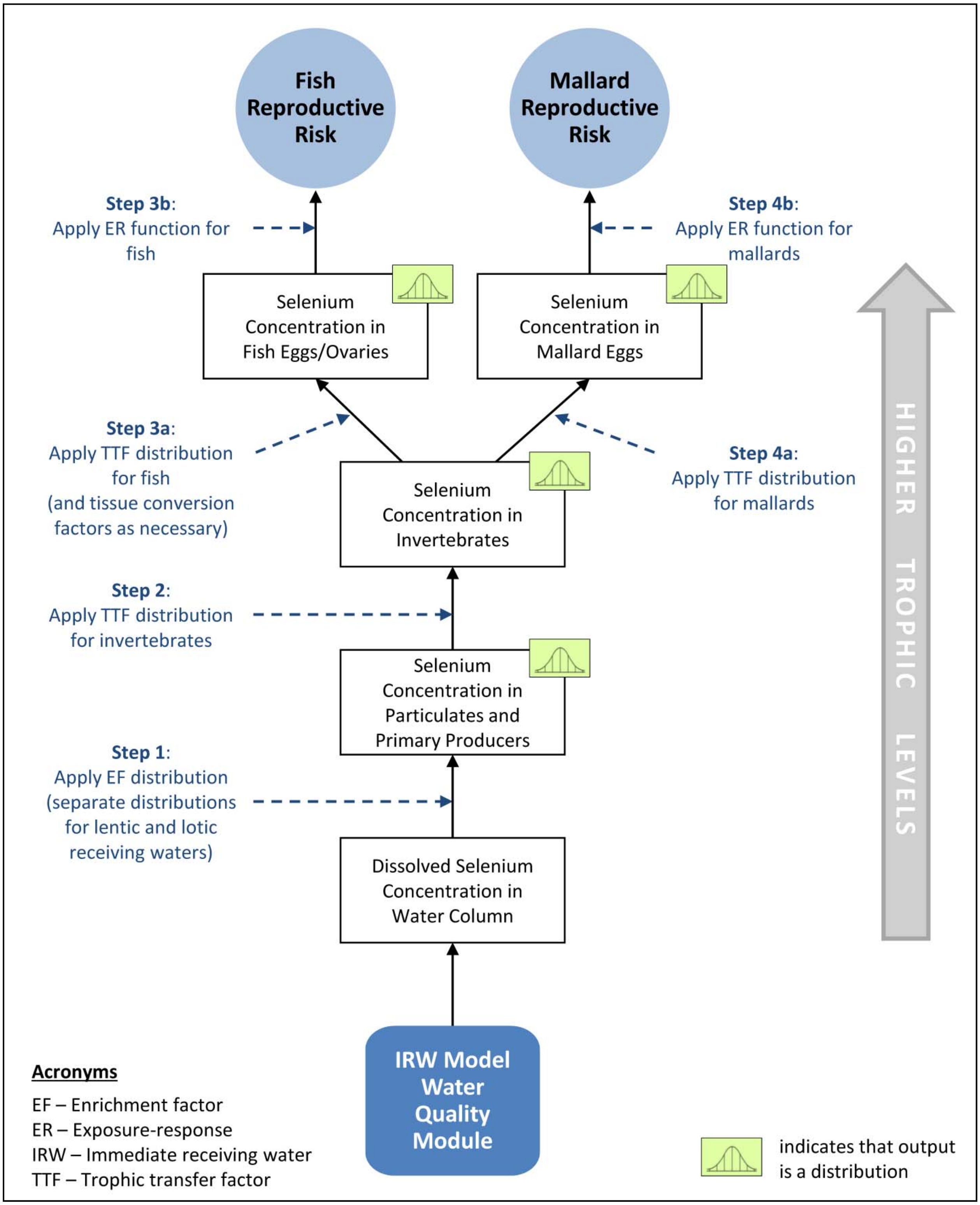


Figure 5-3. Flowchart of Selenium Ecological Risk Model

Detailed information for some of the factors that influence selenium bioaccumulation at a particular site, such as the form of selenium in the environment (*e.g.*, selenate, selenite, and organo-selenide) and the structure of the aquatic food web, is not available across the 209 immediate receiving waters modeled in this EA. The ecological risk model accounts for these unknowns by applying distributions of EFs and TTFs based on data representing a wide variety of lentic and lotic waterbodies and freshwater invertebrate and fish species, rather than relying on a single statistical measure (*e.g.*, mean or median) for those parameters. This approach accounts for the variability across aquatic systems and captures the full range of food web constructs that could occur in these receiving waters.

The remainder of this section further discusses EPA's development of the EFs, TTFs, and ER functions in the ecological risk model and use of those functions to calculate risk of adverse reproductive effects (performed using Oracle Crystal Ball software). Appendix F provides additional details regarding data sources, data acceptance criteria, statistical methods, and assumptions and limitations of the ecological risk model.

Enrichment Factors

EPA compiled a database of empirical measurements of selenium concentration (water, sediment, biofilm, algae, phytoplankton, and detritus) from relevant field studies across a range of aquatic systems. EPA then calculated EFs for a set of aquatic systems and applied statistical methods to distinguish categories with similar bioaccumulation characteristics, consistent with the approach followed in developing the external peer review draft selenium criterion [U.S. EPA, 2014f]. The key factor distinguishing EFs across systems is whether the data were collected from lentic systems (*e.g.*, lakes, reservoirs, and ponds) or lotic systems (*e.g.*, rivers, creeks, and streams). Therefore, the EPA developed EF distributions separately for lentic and lotic systems.

This effort produced EF distributions for both systems that are well described by lognormal distributions with means (standard deviations) of 1,738 (2,499)[44] for lentic systems and 692 (787) for lotic systems.

Trophic Transfer Factors for Invertebrates and Fish

EPA compiled a database of empirical measurements of selenium concentration in particulates, invertebrates, and fish from relevant field studies. EPA arranged the data by developing data pairs representing the concentration in the consumer organism (invertebrate or fish) and the concentration in the consumed material or lower-trophic-level organism (particulate or invertebrate). The ratio between these two values defines the TTF for the consumer organism. EPA limited these data pairs to measurements collected from the same aquatic site. EPA further limited the data pairs by excluding measurements of material or lower-trophic-level organisms deemed unlikely to be ingested by the higher-trophic-level organism. Many of the fish concentration measurements required a further conversion to the concentration of selenium in eggs, requiring a whole-body-to-egg/ovary conversion factor. This factor (egg/ovary concentration = whole body concentration × 1.9) is based on paired measurements from

[44] The EF incorporates a multiplier of 1,000. A mean EF of 1,738 for lentic systems indicates that, on average, the concentration of selenium at the base of the food web is 1.738 times greater than the dissolved concentration in water.

individual fish and is consistent with the value used to develop the external peer review draft selenium criterion [U.S. EPA, 2014f].

This effort resulted in a TTF_{invert} distribution with a mean (standard deviation) of 2.84 (2.49) and a TTF_{fish} distribution with a mean (standard deviation) of 1.6 (1.08).

Trophic Transfer Factors for Mallards

EPA selected the mallard (*Anas platyrhynchos*) as the representative bird species for the ecological risk analysis. The mallard has been extensively evaluated in both field and laboratory studies and has been shown to be relatively sensitive to selenium. Mallards are ubiquitous, occurring in every state at specific times during the year, and are the species with the highest probability of being found at any of the 209 modeled receiving waters. Dabbling ducks such as mallards contribute important ecosystem services, such as transferring eggs and seeds of aquatic organisms between isolated wetlands and maintaining the biodiversity of other organisms [Bengtsson *et al.*, 2014; Green and Elmberg, 2014].

Based on a review of Ohlendorf [2003], EPA developed a database of field measurements of mallards and their likely food sources, expressed as a ratio of measured egg concentrations to dietary concentrations. Many studies across a wide variety of species have shown that selenium concentrations in bird eggs range from roughly equal to or three or four times the concentrations in the diet of the female at the time of egg-laying [Ohlendorf and Heinz, 2011]. The resulting $TTF_{mallard}$ distribution is best described by a triangular distribution, with a likeliest value of 2.5, a minimum value of 0.4, and a maximum value of 4.1.

Exposure-Response Function for Fish

Larval mortality and reproductive teratogenesis (*i.e.*, deformities in offspring) from maternal transfer of selenium to eggs represent the most sensitive endpoints in fish. Deformities in fish that affect feeding or respiration can be lethal shortly after hatching. Deformities that are not directly lethal, but that distort the spine and fins, can affect larval survival by reducing swimming ability and overall fitness. EPA therefore selected larval mortality and deformities as the target endpoints for this analysis.

This approach is consistent with the approach taken to develop the external peer review draft selenium criterion, and used the same extensively peer-reviewed exposure-response function (*i.e.,* curve) as was used in that analysis [U.S. EPA, 2014f]. Appendix F provides the exposure-response function for fish, which translates the modeled egg-ovary concentration into the probability of adverse reproductive effects.

Exposure-Response Function for Mallards

To derive the exposure-response function for mallards, EPA used the same set of six progressive studies used to develop the $TTF_{mallard}$ distribution [Ohlendorf, 2003]. This approach ensures consistency in the predicted bioaccumulation and reproductive response across different selenium exposure levels.

The mallard exposure-response function in Ohlendorf [2003] is based on a regression meta-analysis of six different laboratory studies that evaluated the effect of selenium on mallard egg hatchability [Heinz *et al.,* 1987, 1989; Heinz and Hoffman, 1996, 1998; Stanley *et al.,* 1994, 1996]. This function formed the basis of the water quality criterion adopted by the Utah Water Quality Board for Lake Gilbert, and underwent peer review by EPA Region 8. For this analysis, EPA fit a logistic curve to the combined, control normalized data from the six mallard studies. Appendix F provides the resulting exposure-response function for mallards.

Calculation of Reproductive Risk

In this analysis, risk is defined as the probability of a percentage reduction in reproductive capacity based on larval mortality and deformity in fish and hatching success in mallards. For any given exposure concentration to selenium predicted from the EF-TTF model, the exposure-response function provides the probability of the effect occurring, termed a joint probability model.

The EF-TTF models provide the predicted exposure distributions in fish and mallard eggs. For each concentration, the probability of exposure occurring is compared to the probability of effect at that exposure level. The resulting functions provide the probability of larval mortality and deformities in fish and hatching failure in mallards.

SECTION 6
CURRENT IMPACTS FROM STEAM ELECTRIC POWER GENERATING INDUSTRY

EPA developed the immediate receiving water (IRW) model and ecological risk model described in Section 5 to quantify the current national-scale environmental impacts of direct surface water discharges of the evaluated wastestreams (*i.e.*, flue gas desulfurization (FGD) wastewater, fly ash transport water, bottom ash transport water, and combustion residual leachate) from steam electric power plants. This section presents the baseline results of the modeled pollutant concentrations in surface waters and fish tissue and their potential impacts to aquatic life, wildlife, and human health.

6.1 WATER QUALITY IMPACTS

The quality of a surface water is defined by its chemical, physical, and biological characteristics and is measured to evaluate a water's potential to harm aquatic life and human health. EPA assessed the quality of surface waters that receive discharges of the evaluated wastestreams by comparing estimated pollutant concentrations in the water column to the National Recommended Water Quality Criteria (NRWQC) and drinking water maximum contaminant levels (MCLs). Based on the modeling results for surface water quality impacts, approximately 62 percent of the lakes, ponds, and reservoirs (16 out of 26) and 43 percent of the rivers and streams (78 out of 183) that receive discharges of the evaluated wastestreams have estimated pollutant concentrations that exceed these water quality benchmarks and may have quantifiably impaired water quality due to those discharges. Based on the modeling results, human health criteria exceedances are more prevalent among the immediate receiving waters than aquatic life criteria exceedances. Approximately 17 to 45 percent of the immediate receiving waters had modeled pollutant concentrations that exceed a human health criterion, while approximately 4 to 17 percent of the immediate receiving waters had modeled pollutant concentrations that exceed an aquatic life criterion. The difference between exceedances for human health and aquatic life criteria is due to the human health criteria for arsenic and thallium, which are significantly lower than the aquatic life criteria for most of the modeled pollutants.

Due to data limitations at the national scale, EPA did not include other pollutant sources (*e.g.*, naturally -occurring pollutants, nonpoint source discharges, or other point source discharges) in the IRW model. Quantified exceedances estimated by the IRW model represent environmental impacts due entirely to the pollutant loadings in discharges of the evaluated wastestreams from steam electric power plants. Table 6-1 presents the number and percentage of immediate receiving waters with estimated pollutant concentrations that exceed each water quality criterion under baseline conditions.

EPA identified arsenic, thallium, cadmium, and selenium as the primary pollutants contributing to the water quality exceedances, as shown in Table 6-1. Humans are primarily at risk for exposure to arsenic and thallium. Out of the 209 modeled immediate receiving waters:

- 94 exceed the human health NRWQC for the consumption of arsenic-contaminated water and organisms (0.018 micrograms per liter (µg/L)).

- 65 exceed the arsenic NRWQC for consumption of organisms only (0.14 µg/L).
- 49 exceed the human health NRWQC for the consumption of thallium-contaminated water and organisms (0.24 µg/L).
- 45 exceed the thallium NRWQC for consumption of organisms only (0.47 µg/L).

Therefore, humans consuming water and/or organisms inhabiting these waters are more at risk of arsenic-related effects (skin damage, cardiovascular disease, and cancer in the skin, lungs, bladder, and kidney) and thallium-related effects (changes in blood chemistry; damage to liver, kidney, and intestinal and testicular tissues; hair loss; and reproductive and developmental damage).

Aquatic organisms are primarily at risk due to exposure to cadmium and selenium. Estimated pollutant concentrations in approximately 15 percent of the immediate receiving waters (29 and 33 out of 209, respectively) exceed the aquatic life criterion for chronic exposure to cadmium- and selenium-contaminated waters (0.25 and 5 µg/L, respectively). Therefore, aquatic organisms inhabiting these waters are under a greater threat for cadmium-related effects (tissue damage and organ abnormalities) and selenium-related effects (reproductive failure, deformities, reduced growth, increased metabolic rates, and death). Sublethal and lethal impacts from chronic selenium exposure are frequently cited in literature. For more information on these impacts, refer to Section 3.1.1.

Table 6-1. Number and Percentage of Immediate Receiving Waters with Estimated Water Concentrations that Exceed the Water Quality Criteria at Baseline

Evaluation Criterion		Number of Immediate Receiving Waters Exceeding a Criterion [a]			
		Number of Rivers and Streams	Number of Lakes, Ponds, and Reservoirs	Total Immediate Receiving Waters [b]	
				Number Exceeding	Percentage Exceeding
Aquatic Life Criteria	Freshwater Acute NRWQC	9	0	9	4%
	Freshwater Chronic NRWQC	30	5	35	17%
Human Health Criteria	Human Health Water and Organism NRWQC	78	16	94	45%
	Human Health Organism Only NRWQC	55	11	66	32%
	Drinking Water MCL	31	5	36	17%
Total Number of Unique Immediate Receiving Waters [c]		78	16	94	45%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: NRWQC (National Recommended Water Quality Criteria); MCL (maximum contaminant level).

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – These values are the sum and percentage of rivers, streams, lakes, ponds, and reservoirs impacted.

c – This represents the number of unique immediate receiving waters that exceeded at least one criterion.

Table H-1 in Appendix H presents additional details on the number and percentage of immediate receiving waters that are exceeding each water quality criterion by pollutant. For more detailed information on the modeled immediate receiving water concentrations under baseline conditions, see Figures H-1 to H-10 and Tables H-2 to H-11 in Appendix H.

6.2 WILDLIFE IMPACTS

As part of the national-scale wildlife impacts analysis, EPA assessed the impacts of the evaluated wastestreams on the following categories:

- Impacts to wildlife indicator species (*i.e.*, mink and eagle) due to consuming contaminated fish (using the wildlife component of the IRW model).
- Impacts to fish and waterfowl due to dietary exposure and trophic transfer of selenium (using the ecological risk model in combination with the water quality component of the IRW model).
- Impacts to benthic organisms due to contact with contaminated sediment (using the wildlife component of the IRW model).

The results of these analyses are described in the following sections.

6.2.1 <u>Impacts to Wildlife Indicator Species</u>

As described in Section 5.1.2, EPA assessed the potential impact to piscivorous wildlife from the evaluated wastestreams by modeling fish tissue pollutant concentrations and comparing these concentrations to no effect hazard concentrations (NEHC) for minks and eagles developed by the U.S. Geological Survey (USGS). Based on the estimated fish tissue concentrations, approximately 34 percent (71 out of 209) and 28 percent (58 out of 209) of the immediate receiving waters pose a potential threat to eagles and minks, respectively, through the consumption of contaminated fish. This result demonstrates that estimated pollutant concentrations in fish that inhabit receiving waters immediately downstream from steam electric power plant wastewater discharges pose a potential reproductive threat to surrounding minks and eagles and indicates the potential broader impacts that steam electric power plant wastewater discharges may pose to the greater environment as pollutants transfer from the aquatic environment and begin to accumulate in terrestrial food webs.

As expected, based on documented environmental impacts, modeling results indicate that pollutant concentrations in fish inhabiting lakes, ponds, and reservoirs are more likely to exceed the NEHC benchmarks than pollutant concentrations in fish inhabiting rivers and streams. The estimated fish tissue pollutant concentrations pose a potential reproductive threat to minks and eagles in approximately 46 percent of modeled lakes, ponds, and reservoirs (12 out of 26) and in 32 percent of rivers and streams (59 out of 183) that were evaluated. These results are expected, since fish populations inhabiting lake environments cannot travel to uncontaminated waters and therefore continue to bioaccumulate pollutants.

Table 6-2 presents the number and percentage of immediate receiving waters that exceed the USGS wildlife fish consumption NEHC for minks and eagles.

Table 6-2. Number and Percentage of Immediate Receiving Waters That Exceed Wildlife Fish Consumption NEHCs for Minks and Eagles (by Waterbody Type) at Baseline

Evaluation Criterion	Number of Rivers and Streams	Number of Lakes, Ponds, and Reservoirs	Total Receiving Waters [a,b]	
			Number Exceeding	Percentage Exceeding
Mink fish consumption NEHC	47	11	58	28%
Eagle fish consumption NEHC	59	12	71	34%
Total Number of Unique Immediate Receiving Waters [c]	59	12	71	34%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: NEHC (No Effect Hazard Concentration).

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – These values are the sum and percentage of rivers, streams, lakes, ponds, and reservoirs impacted.

c – This represents the number of unique immediate receiving waters that exceed a criterion.

The pollutants found to present the greatest threat to minks and eagles from fish consumption were mercury and selenium. The modeled concentrations of mercury in fish tissue exceeded the NEHC benchmarks for minks and eagles in 26 and 34 percent of the modeled immediate receiving waters, respectively. Approximately 20 percent of the immediate receiving waters contained fish with modeled selenium concentrations exceeding a fish consumption NEHC benchmark for minks and eagles.

Table 6-3 presents the number and percentage of immediate receiving waters that exceed a USGS wildlife fish consumption NEHC for minks and eagles by pollutant.

6.2.2 Impacts to Fish and Waterfowl due to Dietary Selenium Exposure

As discussed in Section 5.2, EPA expanded upon the piscivorous wildlife benchmark analysis to include ecological risk modeling of the reproductive risks among fish and waterfowl that consume aquatic organisms contaminated with elevated levels of selenium. Selenium is of particular concern in aquatic environments because it can accumulate in sediment and biomagnify to toxic levels in fish inhabiting selenium-contaminated waters (even at relatively low concentrations), potentially eliminating piscivorous (fish-eating) wildlife higher in the food chain [Ohlendorf *et al*., 1988a]. Impacts to fish populations are well documented in the literature [Garrett and Inman, 1984; Lemly, 1985a; Sorensen *et al*., 1982]. While exposed fish populations may not experience lethal impacts, the sublethal damage to their reproductive systems can eventually impact the survivability of fish populations near steam electric power plants. The documented impacts at Belews Lake illustrate this is especially an issue in lakes, ponds, and reservoirs, where healthy fish populations cannot migrate and seek out alternative food sources. Decreased fish populations may cause cascading effects within the food web that can adversely affect other organisms in the ecosystem.

Table 6-3. Number and Percentage of Immediate Receiving Waters That Exceed Wildlife Fish Consumption NEHCs for Minks and Eagles (by Pollutant) at Baseline

Pollutant	Mink			Eagle		
	Fish Consumption NEHC (µg/g) [a]	Immediate Receiving Waters		Fish Consumption NEHC (µg/g) [a]	Immediate Receiving Waters	
		Number Exceeding [b]	Percentage Exceeding		Number Exceeding [b]	Percentage Exceeding
Arsenic	7.65	0	0%	22.4	0	0%
Cadmium	5.66	6	3%	14.7	4	2%
Chromium VI	17.7 [c]	0	0%	26.6 [c]	0	0%
Copper	41.2	1	<1%	40.5	1	<1%
Lead	34.6	1	<1%	16.3	2	1%
Mercury	0.37	55	26%	0.5	71	34%
Nickel	12.5	0	0%	67.1	0	0%
Selenium	1.13	42	20%	4	42	20%
Thallium	ID	NC	NC	ID	NC	NC
Zinc	904	1	<1%	145	5	2%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: ID (Insufficient data; no benchmarks were identified in the wildlife analysis for thallium); NC (Not calculated); NEHC (No Effect Hazard Concentration); µg/g (micrograms/gram).

a – The wildlife fish consumption NEHC represents the maximum pollutant concentration in the fish that will result in no observable adverse effects in wildlife (*i.e.*, minks or eagles) [USGS, 2008].

b – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

c – An NEHC benchmark is not available for chromium VI; therefore, EPA used the total chromium benchmark.

The results of the ecological risk model indicate that, under baseline conditions, discharges of selenium from steam electric power plants elevate the risk of adverse reproductive impacts among fish and mallards that inhabit, forage, or breed in the immediate receiving waters. These reproductive impacts include larval mortality and deformities among fish and reduced egg hatchability among mallards.

The ecological risk modeling results indicate that 15 percent of the lakes, ponds, and reservoirs (four out of 26) and 11 percent of the rivers and streams (20 out of 183) that receive discharges of the evaluated wastestreams present an elevated risk of negative reproductive impacts to fish. For mallards, the counts are slightly higher, with 19 percent of the lakes, ponds, and reservoirs (five out of 26) and 14 percent of the rivers and streams (26 out of 183) presenting these risks. These results support the conclusion that lentic systems, which have higher potential for pollutant retention due to longer residence times, are more likely to experience ecological impacts due to discharges from steam electric power plants.

The results described above represent those immediate receiving waters whose median modeled egg/ovary concentration is predicted to impact reproduction among at least 10 percent of the exposed fish or mallard population. As described below, however, adjusting these criteria reveals additional perspective regarding the prevalence of immediate receiving waters that may be causing reproductive impacts due to selenium exposure.

Selecting the 90th percentile modeled egg/ovary concentration, meaning there is a 10 percent probability that the egg/ovary concentrations are greater than the selected concentration, reveals that 20 percent of the immediate receiving waters (42 out of 209) present reproductive risks to at least 10 percent of the exposed fish population. The results for mallards (21 percent) are very similar. These counts are considerably higher than the results obtained using the median modeled egg/ovary concentration, indicating the potential for more widespread ecological impacts among those waterbodies and food webs that tend to experience higher bioaccumulation of selenium.

The results of the ecological risk model indicate that sublethal effects from dietary exposure to selenium (from discharges of the evaluated wastestreams) can lead to hidden population-level effects among exposed fish and waterfowl by reducing reproductive success. The results for mallards illustrate the broader effects throughout the food web that can result from exposure to waterbodies contaminated with selenium. These results also indicate that impacts to aquatic-dependent wildlife are not limited to piscivorous wildlife such as mink and eagles.

The ecological risk model accounts only for those reproductive effects associated with exposure to selenium. There might be more immediate receiving waters whose pollutant levels result in elevated reproductive risk because they contain other pollutants at concentrations that are harmful to wildlife.

For more information on the potential environmental impacts from selenium exposure, refer to the selenium discussion in Section 3.1. For more detailed information on baseline modeled fish tissue concentrations in the immediate receiving water for selenium and other pollutants evaluated in the EA, see Figures H-11 to H-21 and Tables H-12 to H-22 in Appendix H.

6.2.3 Impacts to Benthic Organisms

EPA also assessed the potential impact to wildlife exposed to sediments in surface waters that receive discharges of the evaluated wastestreams by comparing estimated pollutant concentrations in the sediment to chemical stressor concentration limit (CSCL) benchmarks for sediment biota published by MacDonald, *et. al.* (2000) in *Archives of Environmental Contamination and Toxicology*. Table 6-4 presents the number and percentage of immediate receiving waters with sediment pollutant concentrations that exceed a CSCL. EPA calculated that 22 percent of rivers and streams (40 out of 183) and 35 percent of lakes, ponds, and reservoirs (9 out of 26) had estimated sediment pollutant concentrations that may be toxic to wildlife.

Benthic organisms are at risk primarily due to exposure to mercury, nickel, and cadmium. Estimated sediment pollutant concentrations in 13 to 23 percent of the immediate receiving waters (27 to 49 out of 209) exceed the sediment biota CSCL benchmarks for exposure to cadmium-contaminated, nickel-contaminated, and mercury-contaminated waters. Therefore, benthic organisms inhabiting these waters are under a greater threat for sublethal effects such as skeletal malformation and reduced growth and reproductive success. For more information on these impacts, refer to Section 3.1.1.

As expected, based on documented environmental impacts, modeling results indicate that pollutant concentrations in the benthic sediment in lakes, ponds and reservoirs are more likely to exceed the sediment biota CSCL benchmarks than pollutant concentrations in the benthic sediment of rivers and streams. Several publications in the literature confirm that sediment impacts are more likely to occur in lakes where pollutants can accumulate in sediments over time [Hopkins *et al*., 2000, 2003; Lemly, 1997a].

Table 6-4. Number and Percentage of Immediate Receiving Waters with Sediment Pollutant Concentrations Exceeding CSCLs for Sediment Biota at Baseline

Pollutant	Sediment Benchmark (mg/kg)	Number of Immediate Receiving Waters Exceeding CSCLs for Sediment Biota			
		Rivers and Streams	Lakes, Ponds, and Reservoirs	Total Immediate Receiving Waters	
				Number [a]	Percent
Arsenic	5.90	7	0	7	3%
Cadmium	0.596	22	5	27	13%
Chromium VI [b]	37.3	0	0	0	0%
Copper	35.7	6	1	7	3%
Lead	35	5	1	6	3%
Mercury	0.174	40	9	49	23%
Nickel	18.0	29	5	34	16%
Selenium	ID	NC	NC	NC	NC
Thallium	ID	NC	NC	NC	NC
Zinc	123	14	1	15	7%
Total Number of Unique Immediate Receiving Waters		**40**	**9**	**49**	**23%**

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: CSCL (Chemical stressor concentration limit); ID (Insufficient data; no benchmarks were identified); NC (Not calculated).a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – No benchmark for chromium VI. EPA used the total chromium benchmark, which may underestimate the impact to wildlife.

6.3 HUMAN HEALTH IMPACTS

In addition to assessing water quality impacts on human health as discussed in Section 3.3.2, EPA expanded the analysis to evaluate human health impacts from consuming fish in immediate receiving waters downstream from discharges of the evaluated wastestreams. The purpose of this analysis was to evaluate the broader bioaccumulative effects of pollutants in steam electric power plant discharges to see whether average daily doses of pollutants from fish consumption could potentially exceed human health thresholds where water concentrations may not indicate an issue. EPA evaluated multiple human cohorts (*i.e.*, recreational and subsistence fishers, children and adults) by calculating the average daily dose of pollutants from fish consumption using the estimated fish tissue concentrations calculated in the model. EPA varied the fish consumption rate of each cohort (based on age) to determine the average and long-term daily doses for each pollutant. EPA calculated the lifetime excess cancer risk (LECR) based on estimated fish tissue concentrations of inorganic arsenic and calculated non-cancer threats by comparing the average daily doses to threshold values for all pollutants with published reference doses. EPA first evaluated human health impacts based on type of fisher and age of cohort using national-level consumption rates. For the environmental justice analysis, EPA determined fish consumption rates using the race population in addition to the other two factors. For more information on how EPA identified potential impacts to human receptors, see Section 5.1.3 and Appendix E.

The human health module presents the risk results for each age group individually to allow for further manipulation in the benefits analysis. The true cancer risk to a child would depend on the amount of time the child consumed fish from locations downstream from steam electric power plant discharges. For example, the cancer risk for a 6-year-old child who was born and raised in the same place would be the sum of the LECRs from the 1 to <2 years, 2 to <3 years, and 3 to <6 years cohort groups.

A limitation of the national-scale IRW modeling that may underestimate the cancer risk is the use of an average annual pollutant loading rate as the basis for the risk estimation; as described earlier, the model does not consider the potential for pollutants to accumulate over time in the environment. The model estimates a minimal cancer risk from consuming fish in lakes, ponds, and reservoirs that receive discharges of the evaluated wastestreams. The cancer risk is likely greater in a lake, where fish are limited in their food sources and can bioaccumulate pollutants over a longer exposure period than is represented in the model.

6.3.1 <u>National-Scale Cohort Analysis</u>

Table 6-5 presents the number and percentage of immediate receiving waters where the estimated LECR for the national-scale human receptor exceeds the selected threshold, 1-in-a-million cancer risk for arsenic. Inorganic arsenic concentrations in fish result in an estimated cancer risk greater than 1-in-a-million to adult subsistence fishers in approximately 12 percent of the immediate receiving waters (25 out of 209) and to adult recreational fishers in approximately 6 percent of the immediate receiving waters (12 out of 209). Cancer risks for the child cohorts are lower, with LECRs exceeding the cancer risk threshold in 2 to 4 percent of the immediate receiving waters. Even given the limitations of the modeling framework discussed in Section 6.3, the inorganic arsenic concentrations in fish can pose a cancer risk to adult subsistence fishers in 12 percent of the lakes and to adult recreational fishers in 8 percent of the lakes.

Table 6-5. Number and Percentage of Immediate Receiving Waters That Exceed Human Health Evaluation Criteria (Lifetime Excess Cancer Risk) for Inorganic Arsenic at Baseline

Receptor	Cohort	Exposure Duration (Years)	Number of Immediate Receiving Waters Where Lifetime Excess Cancer Risk Exceeds 1-in-a-Million [a,b]			
			Number of Rivers and Streams	Number of Lakes, Ponds, and Reservoirs	Total Receiving Waters [c]	
					Number Exceeding	Percentage Exceeding
Child recreational fisher	1 to <2 years	1	4	0	4	2%
	2 to <3 years	1	4	0	4	2%
	3 to <6 years	3	6	0	6	3%
	6 to <11 years	5	6	0	6	3%
	11 to <16 years	5	6	0	6	3%
	16 to <21 years	5	6	0	6	3%
Adult recreational fisher		49	10	2	12	6%
Child subsistence fisher	1 to <2 years	1	6	0	6	3%
	2 to <3 years	1	6	0	6	3%
	3 to <6 years	3	7	0	7	3%
	6 to <11 years	5	8	1	9	4%
	11 to <16 years	5	6	0	6	3%
	16 to <21 years	5	6	0	6	3%
Adult subsistence fisher		49	22	3	25	12%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – Inorganic arsenic cancer slope factor of 1.5 per milligrams per kilogram (mg/kg) per day.

c – These values are the sum and percentage of rivers, streams, lakes, ponds, and reservoirs impacted.

Based on the estimated fish tissue concentrations and average daily pollutant doses by cohort, subsistence fishers (adults and children) have the greatest threat for non-cancer health effects. This is because the average daily doses (for one or more pollutant) exceed the oral reference dose values in 49 to 56 percent of the immediate receiving waters, depending on the age group evaluated. Recreational fishers (adult or child) have less of a threat, with average daily doses exceeding oral reference doses in 41 to 48 percent of the immediate receiving waters. These results suggest that fish downstream from discharges of the evaluated wastestreams pose a non-cancer health threat to surrounding fisher populations. Given the modeling limitations described above, these results may underestimate these non-cancer health impacts.

Table 6-6 presents the number and percentage of immediate receiving waters where the average daily dose of one or more pollutant exceeds an oral reference dose for non-carcinogens.

Table 6-6. Number and Percentage of Immediate Receiving Waters That Exceed Non-Cancer Oral Reference Dose Values at Baseline

Receptor	Cohort	Exposure Duration (Years)	Number of Immediate Receiving Waters where Estimated Exposure Doses Exceed Non-Cancer Reference Doses [a]			
			Number of Rivers and Streams	Number of Lakes, Ponds, and Reservoirs	Total Receiving Waters [b]	
					Number Exceeding	Percentage Exceeding
Child recreational fisher	1 to <2 years	1	82	18	100	48%
	2 to <3 years	1	82	18	100	48%
	3 to <6 years	3	80	18	98	47%
	6 to <11 years	5	76	16	92	44%
	11 to <16 years	5	72	14	86	41%
	16 to <21 years	5	72	14	86	41%
Adult recreational fisher		49	72	14	86	41%
Child subsistence fisher	1 to <2 years	1	98	20	118	56%
	2 to <3 years	1	98	20	118	56%
	3 to <6 years	3	92	19	111	53%
	6 to <11 years	5	87	19	106	51%
	11 to <16 years	5	84	18	102	49%
	16 to <21 years	5	84	18	102	49%
Adult subsistence fisher		49	85	18	103	49%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – These values are the sum and percentage of rivers, streams, lakes, ponds, and reservoirs impacted.

According to the exposure doses calculated from the estimated fish tissue concentrations, methylmercury poses the greatest threat to cause non-cancer health effects in humans from fish consumption. Mercury concentrations in fish pose a non-cancer threat to humans in approximately 52 percent of the immediate receiving waters. Therefore, humans who consume fish inhabiting these waters are at risk for developing mercury-related effects, which could include neurological symptoms (*e.g.*, affecting fine motor function, language skills, verbal memory) and cardiovascular disease if exposed at high enough doses. In addition, thallium concentrations in fish pose a non-cancer threat to humans in approximately 45 percent of immediate receiving waters.[45] Therefore, humans who consume thallium-contaminated fish inhabiting these waters are more likely to develop neurological symptoms (*e.g.*, weakness, sleep disorders, muscular problems), alopecia (*i.e.*, loss of hair from the head and body), and gastrointestinal effects (*e.g.*, diarrhea and vomiting).

Table 6-7 presents the number and percentage of immediate receiving waters where average daily doses exceed an oral reference dose for non-carcinogens by pollutant.

[45] EPA used the chronic oral exposure value cited in U.S. EPA, 2010a for thallium chloride as the reference dose.

Table 6-7. Number and Percentage of Immediate Receiving Waters That Exceed Non-Cancer Oral Reference Dose Values at Baseline by Pollutant

Pollutant	Oral Reference Dose (mg/kg/day)	Number of Immediate Receiving Waters where Estimated Exposure Doses Exceed Non-Cancer Reference Doses [a]	
		Number Exceeding	Percentage Exceeding
Inorganic arsenic	0.0003 [b]	3	1%
Cadmium	0.001 [b]	32	15%
Chromium VI	0.003 [b]	0	0%
Copper	0.01 [c]	6	3%
Lead	ID	NC	NC
Mercury (as methylmercury)	0.0001 [b]	109	52%
Nickel (soluble salts)	0.02 [b]	0	0%
Selenium	0.005 [b]	55	26%
Thallium (soluble salts)	0.00001 [d]	94	45%
Zinc	0.3 [b]	9	4%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: NC (Not calculated); ID (Insufficient data; there is no current reference dose for lead).

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – U.S. EPA, 2011c.

c – ATSDR, 2010a.

d – U.S. EPA, 2010a.

States, territories, and authorized tribes have the primary responsibility to protect residents from the health risks of consuming contaminated noncommercially caught fish. They inform the general population, including recreational and subsistence fishers, typically by issuing advisories that notify the public that chemical contamination found in local fish may present a public health hazard.

EPA modeled concentrations in T4 fish tissue and compared them to fish consumption advisory screening values to assess the potential for discharges of the evaluated wastestreams to cause or contribute to fish advisories and pose a human health hazard. Based on the modeling results, up to 48 percent of the immediate receiving waters evaluated may contain fish with contamination levels that could trigger advisories for recreational and subsistence fishers. Mercury and selenium are the pollutants most likely to exceed screening values. This result indicates that steam electric power plants are contributing to the already widespread concentrations of mercury and selenium in fish throughout the country.

Table 6-8 presents the number and percentage of immediate receiving waters where the modeled T4 fish tissue concentrations exceed screening values used for fish advisories.

Table 6-8. Comparison of T4 Fish Tissue Concentrations at Baseline to Fish Advisory Screening Values

Pollutant	Recreational Fishers			Subsistence Fishers		
	Screening Value (ppm)[a]	Number Exceeding [b]	Percentage Exceeding	Screening Value (ppm) [a]	Number Exceeding [b]	Percentage Exceeding
Inorganic arsenic (noncarcinogen)	1.2	0	0%	0.147	3	1%
Inorganic arsenic (carcinogen)	0.026	4	2%	0.00327	9	4%
Cadmium	4.0	8	4%	0.491	22	11%
Mercury (as methylmercury)	0.4	76	36%	0.049	101	48%
Selenium	20	22	11%	2.457	46	22%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: ppm (parts per million).

a – Screening values are defined as concentrations of target analytes in fish or shellfish tissue that are of potential public health concern and that are used as threshold values against which levels of contamination in similar tissue collected from the ambient environment can be compared. Exceedance of these screening values indicates that more intensive site-specific monitoring and/or evaluation of human health risk should be conducted [U.S. EPA, 2000a, Table 5-3].

b – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

6.3.2 Environmental Justice Analysis

As part of the EA, EPA evaluated whether the impacts from steam electric power plant wastewater discharges disproportionately impact minority groups. This environmental justice (EJ) analysis included looking at impacts based on race or Hispanic origin. Table 6-9 presents the number and percentage of immediate receiving waters where the estimated LECR for the human receptor exceeds the selected threshold, 1-in-a-million cancer risk for arsenic. Inorganic arsenic concentrations in fish result in an estimated cancer risk greater than 1-in-a-million to adult subsistence, minority fishers in approximately 12 to 15 percent of the immediate receiving waters (26 to 32 out of 209) and to adult recreational fishers in approximately 7 to 9 percent of the immediate receiving waters (14 to 19 out of 209). Cancer risks for the child cohorts are lower. The estimated cancer risk among adult minority fishers is higher than the risk among adult nonminority fishers (especially among the recreational fisher population).

Table 6-9. Number and Percentage of Immediate Receiving Waters That Exceed Human Health Evaluation Criteria (Lifetime Excess Cancer Risk) for Inorganic Arsenic at Baseline, by Race or Hispanic Origin

Receptor	Race or Hispanic Origin	Number of Immediate Receiving Waters Where Lifetime Excess Cancer Risk Exceeds 1-in-a-Million [a,b]						
		1 to <2 years	2 to <3 years	3 to <6 years	6 to <11 years	11 to <16 years	16 to <21 years	Adult
Recreational	Non-Hispanic White	3	3	4	6	6	6	12
	Non-Hispanic Black	3	3	5	6	6	6	14
	Mexican-American	4	4	6	6	6	6	18
	Other Hispanic	4	4	6	6	6	6	16
	Other, including Multiple Races	4	4	6	6	6	6	19
Subsistence	Non-Hispanic White	4	4	6	7	7	7	25
	Non-Hispanic Black	5	5	6	7	7	7	26
	Mexican-American	6	6	6	8	8	8	28
	Other Hispanic	6	6	6	7	7	7	28
	Other, including Multiple Races	6	6	7	10	10	10	32

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – Inorganic arsenic cancer slope factor of 1.5 per milligrams per kilogram (mg/kg) per day.

Based on the estimated fish tissue concentrations and average daily pollutant doses by cohort, subsistence fishers (adults and children) have the greatest threat for non-cancer health effects. This is because the average daily doses (for one or more pollutant) exceed the oral reference dose values in 49 to 56 percent of the immediate receiving waters, depending on the age group evaluated. Recreational fishers (adult or child) have less of a threat, with average daily doses exceeding oral reference doses in 41 to 48 percent of the immediate receiving waters. These results suggest that fish downstream from discharges of the evaluated wastestreams pose a non-cancer health threat to surrounding fisher populations. Given the modeling limitations described above, these results may underestimate these non-cancer health impacts.

Table 6-10 presents the number and percentage of immediate receiving waters where the average daily dose of one or more pollutant exceeds an oral reference dose for non-carcinogens.

Table 6-10. Number and Percentage of Immediate Receiving Waters That Exceed Non-Cancer Oral Reference Dose Values at Baseline, by Race or Hispanic Origin

Receptor	Race or Hispanic Origin	Number of Immediate Receiving Waters Where Pollutant Exceeds a Non-Cancer Reference Dose [a]						
		Inorganic Arsenic	Cadmium	Copper	Mercury [b]	Selenium	Thallium [c]	Zinc
Recreational, Child Fisher	Non-Hispanic White	0 (0%)	10 (5%)	3 (1%)	81 (39%)	32 (15%)	55 (26%)	4 (2%)
	Non-Hispanic Black	0 (0%)	12 (6%)	4 (2%)	84 (40%)	33 (16%)	58 (28%)	4 (2%)
	Mexican-American	0 (0%)	14 (7%)	4 (2%)	86 (41%)	33 (16%)	63 (30%)	4 (2%)
	Other Hispanic	0 (0%)	13 (6%)	4 (2%)	84 (40%)	33 (16%)	60 (29%)	4 (2%)
	Other, including Multiple Races	0 (0%)	14 (7%)	4 (2%)	88 (42%)	34 (16%)	63 (30%)	4 (2%)
Subsistence, Child Fisher	Non-Hispanic White	3 (1%)	21 (10%)	5 (2%)	98 (47%)	42 (20%)	76 (36%)	5 (2%)
	Non-Hispanic Black	3 (1%)	22 (11%)	5 (2%)	98 (47%)	43 (21%)	78 (37%)	5 (2%)
	Mexican-American	3 (1%)	25 (12%)	6 (3%)	100 (48%)	46 (22%)	79 (38%)	6 (3%)
	Other Hispanic	3 (1%)	25 (12%)	5 (2%)	100 (48%)	46 (22%)	79 (38%)	6 (3%)
	Other, including Multiple Races	3 (1%)	29 (14%)	6 (3%)	104 (50%)	48 (23%)	89 (43%)	6 (3%)
Recreational, Adult Fisher	Non-Hispanic White	0 (0%)	10 (5%)	3 (1%)	81 (39%)	32 (15%)	55 (26%)	4 (2%)
	Non-Hispanic Black	0 (0%)	12 (6%)	4 (2%)	84 (40%)	33 (16%)	58 (28%)	4 (2%)
	Mexican-American	0 (0%)	14 (7%)	4 (2%)	86 (41%)	33 (16%)	63 (30%)	4 (2%)
	Other Hispanic	0 (0%)	13 (6%)	4 (2%)	84 (40%)	33 (16%)	60 (29%)	4 (2%)
	Other, including Multiple Races	0 (0%)	14 (7%)	4 (2%)	88 (42%)	34 (16%)	63 (30%)	4 (2%)
Subsistence, Adult Fisher	Non-Hispanic White	3 (1%)	21 (10%)	5 (2%)	98 (47%)	42 (20%)	76 (36%)	5 (2%)
	Non-Hispanic Black	3 (1%)	22 (11%)	5 (2%)	98 (47%)	43 (21%)	78 (37%)	5 (2%)
	Mexican-American	3 (1%)	25 (12%)	6 (3%)	100 (48%)	46 (22%)	79 (38%)	6 (3%)
	Other Hispanic	3 (1%)	25 (12%)	5 (2%)	100 (48%)	46 (22%)	79 (38%)	6 (3%)
	Other, including Multiple Races	3 (1%)	29 (14%)	6 (3%)	104 (50%)	48 (23%)	89 (43%)	6 (3%)

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – Mercury, as methylmercury.

c – Reference dose based on thallium (soluble salts).

SECTION 7 ENVIRONMENTAL IMPROVEMENTS UNDER THE FINAL RULE

In Section 6, EPA presented the environmental impacts to surface water quality, wildlife, and human health estimated with EPA's immediate receiving water (IRW) model and ecological risk model resulting from baseline discharges of the evaluated wastestreams. Under the final steam electric effluent limitations guidelines and standards (ELGs), EPA evaluated six regulatory options (Options A, B, C, D, E, and F). As part of this quantitative environmental assessment (EA), EPA evaluated the environmental improvements associated with the reduction in pollutant loadings from the evaluated wastestreams (*i.e.*, flue gas desulfurization (FGD) wastewater, fly ash transport water, bottom ash transport water, and combustion residual leachate) under Options A, B, C, D, and E, described in Table 7-1.[46]

In the remainder of this document, EPA presents the results only for Options A through E for existing sources. During development of the final rule, EPA decided not to base the final rule on Option F for existing sources due primarily to the high cost of that Option, particularly in light of the costs associated with other rulemakings expected to impact the steam electric industry (see Section VIII.C.1 of the preamble). As a result, EPA chose not to conduct particular analyses for Option F to the same extent that it did for some of the other options considered. Section 8 of the Technical Development Document (TDD) (EPA-821-R-15-007) details the technology options for all wastestreams evaluated under each regulatory option for the final rule. As described in Section 8 of the TDD, EPA selected Option D as the technology basis for the best available technology economically achievable (BAT) and for pretreatment standards for existing sources (PSES). See Section 12 of the TDD for further information on the limitations and standards of the final rule. This section presents the improvements to surface water quality, wildlife, and human health under the final rule as quantified by EPA's IRW model and ecological risk model.

Based on the quantitative and qualitative analyses performed for the EA, EPA estimated that a variety of environmental improvements would result from the pollutant loading removals associated with the regulatory options. In particular, the EA evaluated the following: 1) improvements in water quality, 2) reduction in threats to wildlife, 3) reduction in human health cancer risks, 4) reduction in threats for non-cancer human health effects, and 5) other unquantified environmental improvements. Table 7-2 lists the quantified and unquantified environmental improvements estimated to result from the final rule's regulatory options and designates which quantified improvements were monetized in the benefits analysis described in the Benefits and Cost Analysis (EPA-821-R-15-005).

[46] In addition to the wastestreams listed in Table 7-1, EPA evaluated technology options associated with flue gas mercury control (FGMC) wastewater, gasification wastewater, and nonchemical metal cleaning wastes as part of the regulatory options. However, no plants currently discharge FGMC wastewater, all existing gasification plants are operating the technology used as the basis for the regulatory option, and EPA will continue to reserve BAT/NSPS/PSES/PSNS for nonchemical metal cleaning wastes, as previously established regulations do. Therefore, EPA estimated zero compliance costs and zero pollutant reductions associated with these wastestreams and did not include these three wastestreams in the EA.

Table 7-1. Regulatory Options for the Wastestreams Evaluated in the EA

Evaluated Wastestream [a]	Option A	Option B	Option C	Option D	Option E
FGD wastewater	Chemical precipitation	Chemical precipitation + biological treatment	Chemical precipitation + biological treatment	Chemical precipitation + biological treatment	Chemical precipitation + biological treatment
Fly ash transport water	Dry handling	Dry handling	Dry handling	Dry handling	Dry handling
Bottom ash transport water	Impoundment (equal to BPT)	Impoundment (equal to BPT)	Dry handling/ closed loop (for units >400 MW); impoundment (equal to BPT) for units ≤400 MW	Dry handling/ closed loop	Dry handling/ closed loop
Combustion residual leachate	Impoundment (equal to BPT)	Impoundment (equal to BPT)	Impoundment (equal to BPT)	Impoundment (equal to BPT)	Chemical precipitation

Acronyms: BPT (Best practicable control technology currently available); MW (Megawatt).

a – The evaluated wastestreams and regulatory options listed in the table are a subset of regulatory options for the steam electric ELGs. See Section 8 of the TDD for the full list of regulatory options.

Table 7-2. Description of Environmental Improvements Associated with the Final Rule

Assessment Category	Description of Environmental Improvement	Improvement Quantified	Improvement Monetized	More Information
Water Quality	Reduced number of immediate receiving waters exceeding an acute or chronic aquatic life NRWQC	✓		Section 7.2 Section 7.3
	Reduced number of immediate receiving waters exceeding a human health NRWQC	✓		Section 7.2 Section 7.3
	Reduced number of immediate receiving waters exceeding MCLs	✓		Section 7.2 Section 7.3
	Increased aesthetic benefits, such as enhancement of adjoining site amenities (*e.g.*, residing, working, traveling, and owning property near water)	✓	✓	Benefits and Cost Analysis [a]
	Improved water-based recreation, including swimming, fishing, boating, and near-water activities from improved water quality	✓	✓	Benefits and Cost Analysis [a]
	Improved quality of source water used for drinking, irrigation, and industrial use			Qualitative Discussion (Benefits and Cost Analysis)
	Increased property values from water quality improvements			Qualitative Discussion (Benefits and Cost Analysis)
	Increased tourism and participation in water-based recreation			Qualitative Discussion (Benefits and Cost Analysis)
	Pollutant removals to impaired waters	✓		Section 7.4
	Pollutant removals to the Great Lakes and Chesapeake Bay	✓		Section 7.5
	Pollutant removals of toxic contaminants, chlorides, and TDS to receiving waters	✓		Section 7.1
	Nutrient removals to receiving waters	✓	✓	Section 7.1 and Benefits and Cost Analysis [a]
	Reduced risk of surface impoundment failures	✓	✓	Benefits and Cost Analysis [a]
	Reduced sediment contamination			Qualitative Discussion (Benefits and Cost Analysis)
	Increased availability of ground water resources	✓	✓	Benefits and Cost Analysis [a]

Table 7-2. Description of Environmental Improvements Associated with the Final Rule

Assessment Category	Description of Environmental Improvement	Improvement Quantified	Improvement Monetized	More Information
Wildlife	Reduced exposure among minks to pollutants that bioaccumulate in fish	✓		Section 7.2 Section 7.3
	Reduced exposure among eagles to pollutants that bioaccumulate in fish	✓		Section 7.2 Section 7.3
	Reduced selenium concentrations in fish and waterfowl and associated reduced reproductive risk	✓		Section 7.2 Section 7.3
	Improved aquatic and wildlife habitat and improved protection of threatened and endangered species	✓	✓	Section 7.4 and Benefits and Cost Analysis [a]
	Improved commercial fisheries yield due to aquatic habitat improvement			Qualitative Discussion (Benefits and Cost Analysis)
	Enhanced existence, option, and bequest values from improved ecosystem health	✓	✓	Benefits and Cost Analysis [a]
	Reduced risks to aquatic life from exposure to steam electric pollutants		✓	Benefits and Cost Analysis [a]
	Reduced exposure to pollutants associated with the wastestreams of concern in surface impoundments that serve as attractive nuisances			Qualitative Discussion (Section 7.7)
Human Health	Reduced exposure to non-cancer pollutants for recreational and subsistence fishers	✓		Section 7.2 Section 7.3 Benefits and Cost Analysis [a]
	Reduced cancer risk in recreational and subsistence fishers	✓	✓	Section 7.2 Section 7.3 Benefits and Cost Analysis [a]
	Reduced incidences of cardiovascular disease from reduced arsenic and lead exposure	✓	✓	Benefits and Cost Analysis [a]
	Reduced adverse health effects from reduced in-utero mercury exposure from maternal fish consumption	✓	✓	Benefits and Cost Analysis [a]
	Reduced IQ loss and specialized education from reduced childhood exposure to lead from fish consumption	✓	✓	Benefits and Cost Analysis [a]
	Reduced adult mortality from air pollutant emissions	✓	✓	Benefits and Cost Analysis [a]
	Avoided climate change impacts from carbon dioxide emissions	✓	✓	Benefits and Cost Analysis [a]
	Reduced exposure to pollutants from recreational water uses			Qualitative Discussion (Benefits and Cost Analysis)

Table 7-2. Description of Environmental Improvements Associated with the Final Rule

Assessment Category	Description of Environmental Improvement	Improvement Quantified	Improvement Monetized	More Information
	Reduced injury associated with impoundment failures			Qualitative Discussion (Benefits and Cost Analysis)
	Reduced number of immediate receiving waters exceeding fish consumption advisory screening values	✓		Section 7.4

Acronyms: MCL (maximum contaminant level); NRWQC (National Recommended Water Quality Criteria); TDS (total dissolved solids).

a – The Benefits and Cost Analysis quantifies and monetizes individual environmental improvements for Options A, B, C, D, and E. See Benefits and Cost Analysis for more detail.

7.1 Pollutant Removals Under the Regulatory Options

EPA estimates that the regulatory options would significantly reduce pollutant loadings to receiving waters for the 10 pollutants modeled in the EA and for other pollutants that can adversely affect surface waters, such as boron, manganese, nutrients, chlorides, and TDS. Table 7-3 and Table 7-4 present the pollutant removals under the regulatory options for the evaluated wastestreams.

Under the final rule (Option D), EPA estimates that pollutant loadings from existing sources will decrease by over 95 percent for copper, lead, mercury, nickel, selenium, thallium, and zinc and over 90 percent for arsenic and cadmium. In turn, these pollutant removals will reduce the negative impacts on the environment as well as the potential exposure of these contaminants to ecological and human receptors. The selenium removals will significantly improve the water quality around the steam electric power plant discharge locations. Mercury removals will improve human health as mercury has been linked to decreased IQs in children whose pregnant mothers have been exposed to mercury by consuming fish.

Manganese and boron, while not generally considered toxic at levels seen in the aquatic environment, have the highest and third highest toxic-weighted pound equivalents (TWPEs), respectively, under baseline conditions for pollutants evaluated in the EA (see Section 3.2). As discussed in Section 3, boron can negatively impact fish and ducks and manganese can be toxic to humans at high levels. Under the final rule, the pollutant loadings for manganese and boron will decrease by 80 and 15 percent, respectively.

As discussed in Section 3, nutrients (*i.e.*, nitrogen and phosphorus) in excess quantities can adversely affect surface waters by causing oxygen-consuming harmful algae blooms and creating "dead zones" where fish and shellfish cannot survive. Under the final rule, EPA calculated that nitrogen loadings will decrease by 16.8 million pounds per year (99 percent) and phosphorus loadings will decrease by 174,000 pounds per year (81 percent). The nutrient removals will improve hypoxic areas (*i.e.*, low-oxygen surface waters) such as the Chesapeake Bay and the Gulf of Mexico (via reduced loadings to the Mississippi River Basin).

Excess chlorides levels in wastewater discharges can be harmful to animals and plants in nonmarine surface waters and can disrupt ecosystem structure. Under the final rule, annual chlorides loadings to surface waters will decrease by 21.8 million pounds (two percent).

The pollutant parameter, TDS, comprises dissolved solids such as chloride and metals. Under the final rule, EPA calculated that annual TDS loadings to surface waters will decrease by more than 1.32 billion pounds (31 percent). This decrease is at least partially due to the reduction in total and dissolved metals discharged to receiving waters.[47]

[47] EPA's estimated TDS removals do not account for additional removals that may be achieved as a result of steam electric power plants opting to participate in the voluntary incentives program, in which they would be subject to effluent limitations based on evaporation technology, including for TDS.

Table 7-3. Steam Electric Power Generating Industry Pollutant Removals for Metals, Bioaccumulative Pollutants, Nutrients, Chlorides, and TDS Under Regulatory Options

Pollutant	Pollutant Removals, lbs/yr (Percent Reduction) [a]				
	Option A	Option B	Option C	Option D	Option E
Arsenic	15,700 (53%)	15,700 (53%)	23,200 (78%)	27,900 (94%)	28,500 (96%)
Boron	4,230,000 (14%)	4,230,000 (14%)	4,480,000 (14%)	4,630,000 (15%)	4,630,000 (15%)
Cadmium	9,020 (68%)	9,020 (68%)	11,200 (84%)	12,500 (94%)	12,600 (95%)
Chromium VI	131 (84%)	131 (84%)	147 (95%)	156 (>99%)	156 (>99%)
Copper	14,300 (46%)	14,300 (46%)	24,300 (78%)	30,500 (98%)	30,600 (98%)
Lead	7,670 (39%)	7,670 (39%)	14,800 (75%)	19,200 (98%)	19,200 (98%)
Manganese	5,120,000 (68%)	5,120,000 (68%)	5,650,000 (75%)	5,990,000 (80%)	5,990,000 (80%)
Mercury	858 (58%)	868 (58%)	1,230 (83%)	1,450 (97%)	1,470 (99%)
Nickel	62,300 (52%)	62,600 (52%)	96,200 (80%)	117,000 (98%)	118,000 (99%)
Selenium	29,300 (21%)	130,000 (93%)	134,000 (96%)	136,000 (97%)	136,000 (97%)
Thallium	7,180 (11%)	7,180 (11%)	40,900 (64%)	62,300 (98%)	62,300 (98%)
Zinc	120,000 (69%)	120,000 (69%)	148,000 (85%)	166,000 (95%)	169,000 (97%)
Nitrogen, total [b]	1,980,000 (12%)	12,300,000 (73%)	15,100,000 (89%)	16,800,000 (99%)	16,800,000 (99%)
Phosphorus, total	43,100 (20%)	43,100 (20%)	123,000 (57%)	174,000 (81%)	174,000 (81%)
Chlorides	4,160,000 (<1%)	4,160,000 (<1%)	14,900,000 (2%)	21,800,000 (2%)	21,800,000 (2%)
TDS	849,000,000 (20%)	849,000,000 (20%)	1,130,000,000 (27%)	1,320,000,000 (31%)	1,320,000,000 (31%)

Source: ERG, 2015a.

Acronyms: TDS (Total Dissolved Solids); lbs/yr (pounds per year).

Note: Pollutant removals are rounded to three significant figures.

a – .>0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

b – Total nitrogen loadings are the sum of total Kjeldahl nitrogen and nitrate/nitrite as N loadings.

Table 7-4. Steam Electric Power Generating Industry TWPE Removals for Metals, Bioaccumulative Pollutants, Nutrients, Chlorides, and TDS Under Regulatory Options

Pollutant	Pollutant Removals, TWPE/year (Percent Reduction) [a]				
	Option A	**Option B**	**Option C**	**Option D**	**Option E**
Arsenic	54,600 (53%)	54,600 (53%)	80,400 (78%)	96,700 (94%)	98,900 (96%)
Boron	35,300 (13%)	35,300 (13%)	37,300 (14%)	38,600 (15%)	38,600 (15%)
Cadmium	205,000 (68%)	205,000 (68%)	254,000 (84%)	285,000 (94%)	287,000 (95%)
Chromium VI	6\7.5 (84%)	67.5 (84%)	76.1 (94%)	80.4 (>99%)	80.4 (>99%)
Copper	8,890 (46%)	8,890 (46%)	15,100 (78%)	19,000 (98%)	19,100 (98%)
Lead	17,200 (39%)	17,200 (39%)	33,100 (75%)	43,100 (98%)	43,100 (98%)
Manganese	526,000 (68%)	526,000 (68%)	580,000 (75%)	615,000 (80%)	615,000 (80%)
Mercury	94,400 (58%)	95,500 (58%)	136,000 (83%)	160,000 (97%)	162,000 (99%)
Nickel	6,790 (52%)	6,820 (52%)	10,500 (80%)	12,800 (98%)	12,900 (99%)
Selenium	32,900 (21%)	146,000 (93%)	150,000 (96%)	152,000 (97%)	152,000 (97%)
Thallium	20,500 (11%)	20,500 (11%)	117,000 (64%)	178,000 (98%)	178,000 (98%)
Zinc	5,650 (69%)	5,650 (69%)	6,950 (85%)	7,770 (95%)	7,940 (97%)
Nitrogen, total	N/A	N/A	N/A	N/A	N/A
Phosphorus, total	N/A	N/A	N/A	N/A	N/A
Chlorides	101 (<1%)	101 (<1%)	364 (2%)	531 (2%)	531 (2%)
TDS	N/A	N/A	N/A	N/A	N/A

Source: ERG, 2015a.

Acronyms: TDS (Total Dissolved Solids); TWPE (Toxic Weighted Pound Equivalents).

Note: Pollutant removals are rounded to three significant figures.

N/A – The TWPE/year is not provided for total nitrogen, total phosphorus, and TDS because EPA has not established a toxic weighting factor (TWF) for these pollutants.

a – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

7.2 Key Environmental Improvements

As part of this EA, EPA conducted modeling of the expected environmental improvements under Options A through E. EPA estimates the environmental improvements under Option F, which were not modeled, to be incrementally greater than those under Option E based on the pollutant reductions calculated.

Table 7-5 summarizes the key environmental improvements within the immediate receiving waters due to the pollutant removals under the final rule (Option D) and other evaluated regulatory options. The numbers of immediate receiving waters with water quality, wildlife, and human health exceedances would:

- Decrease under Options A and B by no more than 33 percent, with most exceedances being reduced by less than 15 percent.
- Decrease under Option C by 17 to 56 percent, with most exceedances being reduced by less than 40 percent.
- Decrease under Option D by 45 to 83 percent, with most exceedances being reduced by at least 56 percent.
- Decrease under Option E by 51 to 84 percent, with most exceedances being reduced by at least 61 percent.

The final rule (Option D) will substantially improve water quality, wildlife, and human health. Under the final rule, EPA estimates that:

- Receiving water exceedances of the NRWQC will decrease by 45 to 67 percent.
- Receiving water exceedances of the MCL benchmarks will decrease by 83 percent.
- The number of receiving waters with fish tissue concentrations exceeding the no effect hazard concentration (NEHC) for selenium for eagles and minks will decrease by 63 and 62 percent, respectively.
- Human exposures via fish consumption to pollutants with the potential to cause non-cancer health effects will decrease by up to 56 percent.
- Human exposures to pollutants that present a cancer risk will decrease by up to 75 percent.

Results for the final rule are discussed in further detail in the sections following Table 7-5.

7.2.1 Improvements in Water Quality Under the Final Rule

EPA estimates that pollutant removals to surface waters associated with the final rule will significantly improve water quality by reducing exceedances of the NRWQC and MCLs by up to 83 percent. The largest reductions in NRWQC exceedances are attributed to reduced loadings of cadmium, selenium, arsenic, and thallium. Due to the substantial pollutant removals, EPA projects that aquatic organisms will be less susceptible to chronic impacts such as:

- Skeletal malformations;
- Organ damage;
- Developmental abnormalities;
- Behavioral impairments;
- Reproductive failure;
- Metabolic failure;
- Neurological effects;
- Gastrointestinal effects; and
- Fish kills.[48]

EPA estimates that up to 45 percent of the 209 evaluated immediate receiving waters currently exceed NRWQC for the protection of human health, primarily due to arsenic and thallium. EPA estimates that these arsenic and thallium removals will lower the number of immediate receiving waters that exceed NRWQC designed to protect public health by 45 to 50 percent. By reducing MCL exceedances by 83 percent, the final rule will improve the quality of source water available to drinking water treatment plants downstream from steam electric power plants.

In addition to reducing NRWQC and MCL exceedances, the final rule will quantifiably improve overall water quality – in the immediate receiving waters and downstream from steam electric power plants. EPA calculates that, on average, receiving water concentrations of the 10 toxic, bioaccumulative pollutants evaluated in the EA will decrease by 57 percent.

[48] Impacts documented in ATSDR, 2008a; Coughlan and Velte, 1989; Lemly, 1985b; Nagle *et al*., 2001; NRC, 2006; Rowe *et al*., 2002; U.S. EPA, 2009a; and U.S. EPA, 2011f.

Table 7-5. Key Environmental Improvements Under the Regulatory Options

Evaluation Benchmark	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
	Number	Percentage	Option A	Option B	Option C	Option D	Option E
Water Quality Results							
Freshwater Acute NRWQC	9	4%	6 (33%)	6 (33%)	6 (33%)	3 (67%)	2 (78%)
Freshwater Chronic NRWQC	35	17%	34 (3%)	27 (23%)	21 (40%)	17 (51%)	17 (51%)
Human Health Water and Organism NRWQC	94	45%	90 (4%)	90 (4%)	69 (27%)	52 (45%)	43 (54%)
Human Health Organism Only NRWQC	66	32%	62 (6%)	62 (6%)	46 (30%)	33 (50%)	26 (61%)
Drinking Water MCL	36	17%	34 (6%)	33 (8%)	16 (56%)	6 (83%)	6 (83%)
Wildlife Results							
Fish Ingestion NEHC for Minks	58	28%	57 (2%)	51 (12%)	32 (45%)	22 (62%)	21 (64%)
Fish Ingestion NEHC for Eagles	71	34%	65 (8%)	61 (14%)	44 (38%)	26 (63%)	23 (68%)
Human Health Results—Non-Cancer							
Non-Cancer Reference Dose for Child (recreational)	100	48	92 (8%)	90 (10%)	68 (32%)	47 (53%)	38 (62%)
Non-Cancer Reference Dose for Adult (recreational)	86	41%	77 (10%)	74 (14%)	56 (35%)	38 (56%)	28 (67%)
Non-Cancer Reference Dose for Child (subsistence)	118	56%	107 (9%)	104 (12%)	79 (33%)	52 (56%)	46 (61%)
Non-Cancer Reference Dose for Adult (subsistence)	103	49%	94 (9%)	93 (10%)	71 (31%)	49 (52%)	39 (62%)

Table 7-5. Key Environmental Improvements Under the Regulatory Options

Evaluation Benchmark	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
	Number	Percentage	Option A	Option B	Option C	Option D	Option E
Human Health Results—Cancer							
Arsenic Cancer Risk for Child (recreational)	6	3%	5 (17%)	5 (17%)	5 (17%)	2 (67%)	2 (67%)
Arsenic Cancer Risk for Adult (recreational)	12	6%	9 (25%)	9 (25%)	6 (50%)	3 (75%)	2 (83%)
Arsenic Cancer Risk for Child (subsistence)	8	4%	7 (13%)	7 (13%)	6 (25%)	3 (63%)	2 (75%)
Arsenic Cancer Risk for Adult (subsistence)	25	12%	23 (8%)	23 (8%)	15 (40%)	11 (56%)	4 (84%)

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: MCL (maximum contaminant level); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

7.2.2 Reduced Threat to Wildlife Under the Final Rule

In the EA, EPA evaluated multiple threats to wildlife, including impacts to wildlife indicator species by consuming contaminated fish; impacts to fish and waterfowl due to dietary exposure to selenium; and exposure of benthic aquatic organisms to contaminated sediments. The combination of lethal and sublethal effects (*e.g.*, changes to morphology, behavior, and metabolism) of exposure to steam electric power plant wastewater can cause cascading effects through the food web.

As discussed in Section 7.2.1, the number of immediate receiving waters that can potentially pose an acute or chronic threat to wildlife will decrease under the final rule, improving wildlife populations and communities surrounding steam electric power plants (*e.g.*, reduced impacts to population density and species diversity as discussed in Section 3). EPA estimates that average fish tissue concentrations of the pollutants evaluated in the EA will decrease by an average of 57 percent. EPA projects that these lower pollutant concentrations will significantly improve the health of fish populations and the quality of fish available for consumption by both humans and wildlife near steam electric power plants.

Based on the threats to minks and eagles from consuming fish contaminated by steam electric power plant wastewater, pollutants can bioaccumulate and impact higher order species in the food chain. Under the final rule, EPA estimates that exceedances of the NEHC for eagles and minks will decrease by approximately 70 percent. See Section 7.3.3 for discussion of the reduced risk of adverse reproductive effects among aquatic wildlife (fish and mallards) resulting from dietary exposure to selenium.

EPA estimates that pollutant removals to surface waters associated with the final rule will decrease the exposure of aquatic organisms to pollutants in the sediment, as shown in Table 7-6. As discussed in Section 6.2.3, benthic organisms are at risk primarily due to exposure to mercury, nickel, and cadmium. Under the final rule, the number of immediate receiving waters with pollutant concentration in the sediment above chemical stressor concentration limits (CSCL) will decrease by over 60 percent.

Table 7-6. Number of Immediate Receiving Waters with Sediment Pollutant Concentrations Exceeding CSCLs for Sediment Biota Under the Regulatory Options

Pollutant	Modeled Immediate Receiving Waters Exceeding CSCLs Under Baseline Conditions [a]	Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
		Option A	Option B	Option C	Option D	Option E
Arsenic	7 (3%)	6 (14%)	6 (14%)	6 (14%)	3 (57%)	2 (71%)
Cadmium	27 (13%)	21 (22%)	21 (22%)	14 (48%)	10 (63%)	8 (70%)
Chromium VI [c]	0 (0%)	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)
Copper	7 (3%)	5 (29%)	5 (29%)	5 (29%)	2 (71%)	2 (71%)
Lead	6 (3%)	4 (33%)	4 (33%)	4 (33%)	1 (83%)	1 (83%)
Mercury	49 (23%)	45 (8%)	44 (10%)	26 (47%)	19 (61%)	7 (86%)
Nickel	34 (16%)	28 (18%)	28 (18%)	16 (53%)	11 (68%)	4 (88%)
Selenium	NC	NC	NC	NC	NC	NC
Thallium	NC	NC	NC	NC	NC	NC
Zinc	15 (7%)	9 (40%)	9 (40%)	9 (40%)	6 (60%)	2 (87%)
Total	**49 (23%)**	**45 (8%)**	**44 (10%)**	**27 (45%)**	**20 (59%)**	**8 (84%)**

Source: ERG, 2015d;ERG, 2015h; ERG, 2015i.

Acronyms: CSCL (Chemical stressor concentration limit); N/A (Not Applicable, no exceedances at baseline conditions to compare option results); NC (Not calculated; no benchmark for comparison).

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

c – EPA used the total chromium benchmark for this analysis.

7.2.3 Reduced Human Health Cancer Risk Under the Final Rule

Under baseline conditions, EPA estimates that 25 immediate receiving waters (12 percent) could contain fish contaminated with inorganic arsenic that present cancer risks above the 1-in-a-million threshold for the most sensitive, national-scale cohort. EPA calculates that the number of immediate receiving waters whose fish exceed this cancer risk threshold will decrease by at least 56 percent for all national-scale cohorts under the final rule.

7.2.4 Reduced Threat of Non-Cancer Human Health Effects Under the Final Rule

Chronic exposure to toxic, bioaccumulative pollutants in steam electric power plant wastewater can potentially compromise neurological and developmental functions and affect the circulatory, respiratory, and digestive systems of exposed populations. EPA estimates that the number of immediate receiving waters whose fish pose non-cancer health risks will decrease by at least 52 percent for all national-scale cohorts under the final rule. As discussed in Section 7.2.2, EPA found that the pollutant concentrations in fish tissue will decrease, improving the quality of fish available to recreational and subsistence fishers and subsequently lowering exposures to toxic, bioaccumulative pollutants and the potential for humans to develop non-cancer health effects (*e.g.*, nausea, abdominal pain, sleep disorders, muscular problems, and cardiovascular disease).

The pollutants that cause the potential for non-cancer health effects are selenium, cadmium, mercury (as methylmercury), and, to a lesser degree, thallium. EPA calculates that the final rule will decrease the number of immediate receiving waters with fish that, if consumed, would exceed the reference doses for these pollutants, by the following amounts:

- Selenium: decrease by at least 51 percent for all national-scale cohorts.
- Cadmium: decrease by at least 53 percent for all national-scale cohorts.
- Methylmercury: decrease by at least 52 percent for all national-scale cohorts.
- Thallium: decrease by at least 62 percent for all national-scale cohorts.

Although the EA did not directly assess the potential non-cancer health effects posed by lead,[49] the final rule will lower the total annual loadings of lead to the environment by 19,000 pounds (98 percent), thus reducing the potential threat of hypertension, coronary heart disease, and impaired cognitive function in exposed populations. For children in particular, lead exposure can cause additional negative impacts, such as hyperactivity, behavioral and attention difficulties, delayed mental development, and motor and perceptual skill deficits. The benefits to adults and children from the reduced lead discharges are discussed in the Benefits and Cost Analysis.

7.2.5 Reduced Human Health Risk for Environmental Justice Analysis

As discussed in Section 6.3.2, EPA evaluated the impacts that steam electric power plant discharges have on environmental justice (EJ) cohorts in addition to the national-scale cohorts. Under baseline conditions, EPA estimates that 32 immediate receiving waters (15 percent) could

[49] Currently, there is no reference dose for lead—there is no safe level for ingestion of lead (see EPA's Integrated Risk Information System (IRIS) website: http://www.epa.gov/IRIS/).

contain fish contaminated with inorganic arsenic that present cancer risks above the 1-in-a-million threshold for the most sensitive minority cohort. EPA estimates that the number of immediate receiving waters whose fish exceed this cancer risk threshold will decrease by at least 46 percent for the average recreational fisher minority cohort and at least 51 percent for the average subsistence fisher minority cohort under the final rule.[50] These improvements are similar to those for non-minority recreational and subsistence fisher cohorts (at least 33 and 50 percent, respectively) under the final rule.

EPA estimates that the number of immediate receiving waters whose fish pose non-cancer health risks will decrease by 56 percent for all recreational fisher minority cohorts and 53 percent for all subsistence fisher minority cohorts under the final rule. These improvements are similar to those for non-minority recreational and subsistence fisher cohorts (56 and 52 percent, respectively) under the final rule. The pollutants that cause the potential for non-cancer health effects are selenium, cadmium, mercury (as methylmercury), and, to a lesser degree, thallium.

7.3 POLLUTANT-SPECIFIC IMPROVEMENTS

EPA identified several key pollutants (*i.e.*, arsenic, mercury, selenium, cadmium, and thallium) whose pollutant removals would primarily be responsible for the improvements in water quality, wildlife, and human health attributed to the final rule. This section highlights the environmental improvements associated with these five pollutants.

7.3.1 Arsenic

Under the final rule, EPA estimates 27,900 pounds per year of arsenic removals from steam electric power plant discharges – a 94 percent reduction in annual loadings. The final rule will decrease the number of immediate receiving waters exceeding human health NRWQC for arsenic by up to 49 percent. The arsenic removals will reduce negative effects on aquatic organisms, such as liver tissue death, developmental abnormalities, behavioral impairments, metabolic failure, growth reduction, and appetite loss [NRC, 2006; Rowe *et al*., 2002; U.S. EPA, 2011f]. As a result, the final rule will decrease human exposure to arsenic through fish consumption and thus lower the potential for exposed populations to develop arsenic-related cancer and non-cancer health effects such as dermal, cardiovascular, and respiratory effects. The final rule will decrease the number of immediate receiving waters exceeding the human health cancer risk threshold for arsenic by up to 75 percent, depending on the evaluated cohort. Table 7-7 presents the key environmental improvements resulting from arsenic removals under the regulatory options evaluated in the EA.

EPA did not see a reduction in the number of immediate receiving waters exceeding the arsenic NEHCs for minks or eagles because there are no exceedances modeled at baseline. The final rule, however, will still reduce the bioaccumulation of arsenic in the food web.

[50] These values represent the average percentage improvements across the four race populations that comprise the minority cohorts.

Table 7-7. Key Environmental Improvements for Arsenic Under the Regulatory Options

Evaluation Benchmark	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
	Number	Percentage	Option A	Option B	Option C	Option D	Option E
Water Quality Results							
Freshwater Acute NRWQC	3	1%	2 (33%)	2 (33%)	2 (33%)	2 (33%)	1 (67%)
Freshwater Chronic NRWQC	4	2%	3 (25%)	3 (25%)	3 (25%)	2 (50%)	1 (75%)
Human Health Water and Organism NRWQC	94	45%	90 (4%)	90 (4%)	69 (27%)	52 (45%)	43 (54%)
Human Health Organism Only NRWQC	65	31%	61 (6%)	61 (6%)	45 (31%)	33 (49%)	26 (60%)
Drinking Water MCL	12	6%	9 (25%)	9 (25%)	6 (50%)	3 (75%)	2 (83%)
Wildlife Results							
Fish Ingestion NEHC for Minks	0	0%	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)
Fish Ingestion NEHC for Eagles	0	0%	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)
Human Health Results—Non-Cancer							
Non-Cancer Reference Dose for Child (recreational)	2	1%	1 (50%)	1 (50%)	1 (50%)	1 (50%)	0 (100%)
Non-Cancer Reference Dose for Adult (recreational)	0	0%	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)
Non-Cancer Reference Dose for Child (subsistence)	3	1%	2 (33%)	2 (33%)	2 (33%)	2 (33%)	1 (67%)
Non-Cancer Reference Dose for Adult (subsistence)	3	1%	2 (33%)	2 (33%)	2 (33%)	2 (33%)	1 (67%)

Table 7-7. Key Environmental Improvements for Arsenic Under the Regulatory Options

Evaluation Benchmark	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
	Number	Percentage	Option A	Option B	Option C	Option D	Option E
Human Health Results—Cancer							
Arsenic Cancer Risk for Child (recreational)	6	3%	5 (17%)	5 (17%)	5 (17%)	2 (67%)	2 (67%)
Arsenic Cancer Risk for Adult (recreational)	12	6%	9 (25%)	9 (25%)	6 (50%)	3 (75%)	2 (83%)
Arsenic Cancer Risk for Child (subsistence)	8	4%	7 (13%)	7 (13%)	6 (25%)	3 (63%)	2 (75%)
Arsenic Cancer Risk for Adult (subsistence)	25	12%	23 (8%)	23 (8%)	15 (40%)	11 (56%)	4 (84%)

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: MCL (Maximum contaminant level); N/A (Not Applicable, no exceedances at baseline conditions to compare option results); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

7.3.2 Mercury

Under the final rule, EPA estimates 1,450 pounds per year of mercury removals from steam electric power plant discharges – a 97 percent reduction in annual loadings. As discussed in Section 6.2, estimated fish tissue concentrations for mercury (and selenium) exceed levels that can affect reproduction in exposed mink and eagle populations. EPA estimates that the final rule will decrease the number of immediate receiving waters with fish tissue concentrations that exceed the mercury NEHC for eagles and minks by 62 and 64 percent, respectively. These reductions also represent the potential improvement in exposure to mercury above effects thresholds in other wildlife that consume fish from these receiving waters.

Under baseline pollutant loadings, EPA estimates that fish methylmercury concentrations pose a non-cancer threat to subsistence fishers and recreational fishers in up to 52 and 46 percent, respectively, of immediate receiving waters. EPA calculates that fish tissue concentrations of methylmercury will decrease under the final rule and, as a result, the number of immediate receiving waters with exposure doses from fish consumption that exceed the methylmercury reference dose will decrease by up to 57 percent. Because there are over 80 addressed by this final rule discharge to receiving waters that are under a fish advisory for mercury (see Section 3.4.4), the final rule will reduce mercury loadings to those receiving waters (see Section 7.4). Table 7-8 presents the key environmental improvements resulting from mercury removals under the regulatory options.

Table 7-8. Key Environmental Improvements for Mercury Under the Regulatory Options

Evaluation Benchmark	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
	Number	Percentage	Option A	Option B	Option C	Option D	Option E
Water Quality Results							
Freshwater Acute NRWQC	1	0%	0 (100%)	0 (100%)	0 (100%)	0 (100%)	0 (100%)
Freshwater Chronic NRWQC	1	0%	0 (100%)	0 (100%)	0 (100%)	0 (100%)	0 (100%)
Human Health Water and Organism NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Human Health Organism Only NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Drinking Water MCL	5	2%	4 (20%)	4 (20%)	4 (20%)	2 (60%)	1 (80%)
Wildlife Results							
Fish Ingestion NEHC for Minks	55	26%	50 (9%)	49 (11%)	30 (45%)	20 (64%)	8 (85%)
Fish Ingestion NEHC for Eagles	71	34%	61 (14%)	61 (14%)	44 (38%)	27 (62%)	18 (75%)
Human Health Results—Non-Cancer							
Non-Cancer Reference Dose for Child (recreational)	96	46%	87 (9%)	84 (13%)	63 (34%)	44 (54%)	35 (64%)
Non-Cancer Reference Dose for Adult (recreational)	82	39%	71 (13%)	69 (16%)	52 (37%)	35 (57%)	24 (71%)
Non-Cancer Reference Dose for Child (subsistence)	109	52%	97 (11%)	96 (12%)	75 (31%)	52 (52%)	46 (58%)
Non-Cancer Reference Dose for Adult (subsistence)	99	47%	89 (10%)	87 (12%)	66 (33%)	46 (54%)	36 (64%)

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: MCL (Maximum contaminant level); N/A (Not Applicable, no exceedances at baseline conditions to compare option results); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

7.3.3 Selenium

Under the final rule, EPA estimates 136,000 pounds per year of selenium removals from steam electric power plant discharges – a 97 percent reduction in annual loadings. Selenium is one of the primary pollutants identified in the literature and by EPA as causing documented environmental impacts to fish and wildlife from steam electric power plant discharges. EPA estimates that immediate receiving water concentrations of total selenium will decrease under the final rule by 71 percent on average, decreasing the amount of selenium that would bioaccumulate or persist in the aquatic environment. Under the final rule, the number of immediate receiving waters exceeding chronic aquatic life NRWQC will decrease by 55 percent and the number of immediate receiving waters exceeding a drinking water MCL for selenium will decrease by 75 percent.

Reducing selenium loadings and subsequent bioaccumulation will decrease by 52 percent the number of immediate receiving waters with fish tissue concentrations exceeding the NEHC for selenium for both eagles and minks. These reductions also represent the potential health improvements in other wildlife that consume fish from these receiving waters, as well as the potential decrease in bioaccumulation of toxic pollutants in the broader food web near steam electric power plants.

Selenium is known to cause fish deformities at high levels, such as these from Belews Lake, NC.

The results of the ecological risk model further support these predicted reductions in the bioaccumulative impact of selenium throughout the food web. Under the final rule, the ecological risk modeling results indicate that:

- The risk of negative reproductive impacts among fish and/or mallards will be reduced to less than one percent in each of the 26 modeled lentic immediate receiving waters.
- The number of immediate receiving waters that present a risk of reproductive impacts among at least 10 percent of the exposed population will be reduced by 67 percent (for fish) and 61 percent (for mallards).
- The number of immediate receiving waters that present a risk of reproductive impacts among at least 50 percent of the exposed population will be reduced by 70 percent (for fish) and 74 percent (for mallards).

These results are based on the median modeled egg/ovary selenium concentration in exposed fish and mallards. Use of the 90th percentile modeled egg/ovary concentration, which results in a higher predicted risk of reproductive impacts, shows similar improvements under the final rule:

- The risk of negative reproductive impacts among fish will be reduced to less than one percent in all but one of the 26 modeled lentic immediate receiving waters.
- The number of immediate receiving waters that present a risk of reproductive impacts among at least 10 percent of the exposed population will be reduced by 55 percent (for fish) and 52 percent (for mallards). Under the final rule, none of the lentic immediate receiving waters will pose this reproductive risk to fish or mallards.
- The number of immediate receiving waters that present a risk of reproductive impacts among at least 50 percent of the exposed population will be reduced by 53 percent (for fish) and 59 percent (for mallards).

Under the final rule, EPA estimates that fish selenium concentrations that pose a non-cancer threat to subsistence fishers and recreational fishers will decrease in up to 53 and 56 percent of immediate receiving waters, respectively. This reduces the risk of developing non-cancer health effects associated with selenium, such as pulmonary edema and lesions of the lung; cardiovascular effects such as tachycardia; gastrointestinal effects including nausea, vomiting, diarrhea, and abdominal pain; effects on the liver; and neurological effects such as aches, irritability, chills, and tremors [U.S. EPA, 2000b]. Table 7-9 presents the key environmental improvements resulting from selenium removals under the regulatory options.

Table 7-9. Key Environmental Improvements for Selenium Under the Regulatory Options

Evaluation Benchmark	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
	Number	**Percentage**	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
Water Quality Results							
Freshwater Acute NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Freshwater Chronic NRWQC [d]	33	16%	30 (9%)	20 (39%)	18 (45%)	15 (55%)	15 (55%)
Human Health Water and Organism NRWQC	8	4%	7 (13%)	3 (63%)	3 (63%)	2 (75%)	2 (75%)
Human Health Organism Only NRWQC	1	0%	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)
Drinking Water MCL	12	6%	10 (17%)	5 (58%)	5 (58%)	3 (75%)	3 (75%)
Wildlife Results							
Fish Ingestion NEHC for Minks	42	20%	40 (5%)	29 (31%)	23 (45%)	20 (52%)	20 (52%)
Fish Ingestion NEHC for Eagles	42	20%	40 (5%)	29 (31%)	23 (45%)	20 (52%)	20 (52%)
Negative Reproductive Effects in Fish [c]	24	11%	19 (21%)	10 (58%)	10 (58%)	8 (67%)	8 (67%)
Negative Reproductive Effects in Mallards [c]	31	15%	26 (16%)	16 (48%)	14 (55%)	12 (61%)	12 (61%)

Table 7-9. Key Environmental Improvements for Selenium Under the Regulatory Options

Evaluation Benchmark	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
	Number	Percentage	Option A	Option B	Option C	Option D	Option E
Human Health Results—Non-Cancer							
Non-Cancer Reference Dose for Child (recreational)	41	20%	39 (5%)	29 (29%)	23 (44%)	20 (51%)	20 (51%)
Non-Cancer Reference Dose for Adult (recreational)	32	15%	29 (9%)	18 (44%)	17 (47%)	14 (56%)	14 (56%)
Non-Cancer Reference Dose for Child (subsistence)	55	26%	51 (7%)	39 (29%)	33 (40%)	27 (51%)	27 (51%)
Non-Cancer Reference Dose for Adult (subsistence)	43	21%	40 (7%)	30 (30%)	23 (47%)	20 (53%)	20 (53%)

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: MCL (Maximum contaminant level); N/A (Not Applicable, no exceedances at baseline conditions to compare option results); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

c – These rows indicate the number of immediate receiving waters whose median modeled egg/ovary concentration is predicted to result in reproductive impacts among at least 10 percent of the exposed fish or mallard population, as determined using the ecological risk model.

d – The EA analyses use the EPA recommended water quality criteria for selenium in the water column of 5 µg/L -- in effect at the time of the modeling done, both for the proposed rule in 2012, and the final rule in 2015. EPA used this criterion in its modeling for the final rule to allow for consistent comparisons between the modeling done for the proposed rule and that done for the final rule. All modeling was done prior to EPA publishing new final draft criteria for selenium on July 27, 2015. The new final draft criteria, which EPA now recommends, of 3.1 µg/L in freshwater flowing systems (rivers, streams) and 1.2 µg/L in lakes and reservoirs, are lower than the criteria EPA used in these analyses. Had EPA conducted the modeling with these new recommended criteria, it would have resulted in slightly greater estimated impacts (more exceedances of the new selenium criteria) than that revealed using the old criteria. As a result, this would have led to slightly greater potential improvements due to control of selenium discharges under the final rule. Therefore, the estimates of the modeled selenium impacts, and potential improvements of the final ELG, are conservative and tend, if anything, to underestimate both the impacts and the benefits.

7.3.4 Cadmium

Under the final rule, EPA estimates 9,020 pounds per year of cadmium removals from steam electric power plant discharges – a 68 percent reduction in annual loadings. At baseline conditions, discharges of cadmium are the second largest toxic-weighted pollutant discharges from the steam electric power generating industry among those pollutants evaluated in the EA (see Section 3.2). The final rule will decrease the number of immediate receiving waters that exceed acute and chronic NRWQC by up to 67 and 59 percent, respectively. The number of immediate receiving waters with fish tissue concentrations that exceed NEHCs for minks and eagles will decrease by 67 and 50 percent, respectively. Under the final rule, the number of immediate receiving waters with fish containing cadmium concentrations that pose a risk of non-cancer health effects will decrease by 53 to 70 percent, depending on the cohort. Table 7-10 presents the key environmental improvements resulting from cadmium removals under the regulatory options.

7.3.5 Thallium

Under the final rule, EPA estimates 62,300 pounds per year of thallium removals from steam electric power plant discharges – a 98 percent reduction in annual loadings. EPA estimates that the final rule will decrease the number of immediate receiving waters exceeding human health NRWQC and MCLs for thallium by up to 85 percent. Under the final rule, the number of immediate receiving waters with fish containing thallium concentrations that can potentially cause non-cancer health effects in humans (*e.g.*, neurological symptoms, alopecia, gastrointestinal effects, and reproductive and developmental damage) will decrease by up to 69 percent, depending on the cohort. Table 7-11 presents the key environmental improvements resulting from thallium removals under the regulatory options.

Table 7-10. Key Environmental Improvements for Cadmium Under the Regulatory Options

Evaluation Benchmark	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
	Number	Percentage	Option A	Option B	Option C	Option D	Option E
Water Quality Results							
Freshwater Acute NRWQC	9	4%	6 (33%)	6 (33%)	6 (33%)	3 (67%)	2 (78%)
Freshwater Chronic NRWQC	29	14%	23 (21%)	23 (21%)	16 (45%)	12 (59%)	9 (69%)
Human Health Water and Organism NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Human Health Organism Only NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Drinking Water MCL	11	5%	7 (36%)	7 (36%)	6 (45%)	3 (73%)	2 (82%)
Wildlife Results							
Fish Ingestion NEHC for Minks	6	3%	5 (17%)	5 (17%)	5 (17%)	2 (67%)	2 (67%)
Fish Ingestion NEHC for Eagles	4	2%	3 (25%)	3 (25%)	3 (25%)	2 (50%)	2 (50%)
Human Health Results—Non-Cancer							
Non-Cancer Reference Dose for Child (recreational)	16	8%	12 (25%)	12 (25%)	9 (44%)	5 (69%)	3 (81%)
Non-Cancer Reference Dose for Adult (recreational)	10	5%	7 (30%)	7 (30%)	6 (40%)	3 (70%)	2 (80%)
Non-Cancer Reference Dose for Child (subsistence)	32	15%	26 (19%)	26 (19%)	19 (41%)	15 (53%)	10 (69%)
Non-Cancer Reference Dose for Adult (subsistence)	22	11%	17 (23%)	17 (23%)	11 (50%)	7 (68%)	4 (82%)

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: MCL (Maximum contaminant level); N/A (Not Applicable, no exceedances at baseline conditions to compare option results); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

Table 7-11. Key Environmental Improvements for Thallium Under the Regulatory Options

Evaluation Benchmark	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
	Number	Percentage	Option A	Option B	Option C	Option D	Option E
Water Quality Results							
Freshwater Acute NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Freshwater Chronic NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Human Health Water and Organism NRWQC	49	23%	46 (6%)	46 (6%)	27 (45%)	13 (73%)	13 (73%)
Human Health Organism Only NRWQC	45	22%	42 (7%)	42 (7%)	23 (49%)	8 (82%)	8 (82%)
Drinking Water MCL	34	16%	32 (6%)	32 (6%)	15 (56%)	5 (85%)	5 (85%)
Wildlife Results							
Fish Ingestion NEHC for Minks	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Fish Ingestion NEHC for Eagles	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Human Health Results—Non-Cancer							
Non-Cancer Reference Dose for Child (recreational)	74	35%	73 (1%)	73 (1%)	46 (38%)	27 (64%)	27 (64%)
Non-Cancer Reference Dose for Adult (recreational)	54	26%	51 (6%)	51 (6%)	31 (43%)	17 (69%)	17 (69%)
Non-Cancer Reference Dose for Child (subsistence)	94	45%	90 (4%)	90 (4%)	63 (33%)	35 (63%)	35 (63%)
Non-Cancer Reference Dose for Adult (subsistence)	77	37%	76 (1%)	76 (1%)	49 (36%)	29 (62%)	29 (62%)

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: MCL (Maximum contaminant level); N/A (Not Applicable, no exceedances at baseline conditions to compare option results); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The EA encompasses a total of 222 immediate receiving waters and loadings from 195 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

7.4 IMPROVEMENTS TO SENSITIVE ENVIRONMENTS

As discussed in Section 3.4, EPA evaluated pollutant discharges to sensitive environments (*i.e.*, impaired waters, threatened and endangered species, and fish consumption advisory waters) and sensitive watersheds (the Great Lakes and Chesapeake Bay). The purpose was to assess if steam electric power plants discharge to receiving waters with existing impairments or fish advisories and assess if discharges of the evaluated wastestreams increase stress on threatened and endangered species. This section presents EPA's estimated pollutant removals under five regulatory options to the evaluated sensitive environments.

The final rule will decrease pollutant loadings to sensitive environments, which will help impaired waters to recover; decrease the bioaccumulation of toxic pollutants in fish, thereby reducing the number of fish advisories; and reduce stress on threatened and endangered species and sensitive watersheds such as Chesapeake Bay and the Great Lakes (see Section 7.5).

7.4.1 <u>Impaired Waters</u>

EPA determined that 59 of the immediate receiving waters are 303(d)-listed waterbodies, designated as impaired for one or more pollutants found in the evaluated wastestreams.[51] Mercury (30 immediate receiving waters), nutrients (19 immediate receiving waters), and phosphorus (11 immediate receiving waters) are the most frequently identified impairment categories among the surface waters that directly receive the evaluated wastestreams. Table 7-12 presents the pollutant removals to impaired waters (by impairment category) as a result of the regulatory options.

Under the final rule, EPA estimates the following pollutant removals:

- Mercury removals of 168 pounds per year to mercury-impaired waters (decrease of 99 percent).
- Phosphorus removals of 4,100 pounds per year to nutrient-impaired waters (decrease of 78 percent).
- Nitrogen removals of 471,000 pounds per year to nutrient-impaired waters (decrease of 96 percent).
- Pollutant removals to receiving waters impaired for a metal (except mercury) include 4,100 pounds per year of arsenic (decrease of 95 percent); 1,770 pounds per year of cadmium (decrease of 93 percent); 2,630 pounds per year of lead (decrease of 97 percent); 21,500 pounds per year of selenium (decrease of 97 percent); and 7,130 pounds per year of thallium (decrease of 97 percent).[52]

[51] The count of impaired waters excludes the general impairment category "metals (not mercury)" and includes receiving waters impaired for arsenic, boron, cadmium, chromium, copper, lead, manganese, mercury, selenium, zinc, phosphorous, nutrients, TDS, or chlorides.

[52] EPA presents pollutant loadings and removals for metals, other than mercury, for immediate receiving waters designated as impaired for the general impairment category "metals (not mercury)" to protect confidential business information. See all results in Table 7-12.

Table 7-12. Pollutant Removals to Impaired Waters by Impairment Type

Impairment Type/Number of Receiving Waters [b]	Pollutant	Baseline Loadings (lbs/yr)	Pollutant Removals (lbs/yr) to Impaired Waters Under the Regulatory Options (Percent Reduction) [a]				
			Option A	Option B	Option C	Option D	Option E
Mercury-Impaired Receiving Waters							
30	Mercury	170	89.7 (53%)	90.2 (53%)	139 (81%)	168 (99%)	169 (99%)
Metals (Not Mercury)-Impaired Receiving Waters							
28	Arsenic	4,320	2,800 (65%)	2,800 (65%)	3,690 (85%)	4,110 (95%)	4,160 (96%)
	Boron	4,900,000	316,000 (6%)	316,000 (6%)	349,000 (7%)	361,000 (7%)	361,000 (7%)
	Cadmium	1,900	1,380 (73%)	1,380 (73%)	1,650 (87%)	1,770 (93%)	1,780 (94%)
	Chromium VI	27.2	23.4 (86%)	23.4 (86%)	26.9 (99%)	27.2 (>99%)	27.2 (>99%)
	Copper	4,420	2,490 (56%)	2,490 (56%)	3,790 (86%)	4,320 (98%)	4,320 (98%)
	Lead	2,700	1,360 (50%)	1,360 (50%)	2,240 (83%)	2,630 (97%)	2,630 (97%)
	Manganese	1,080,000	718,000 (66%)	718,000 (66%)	780,000 (72%)	810,000 (75%)	810,000 (75%)
	Nickel	15,600	9,270 (59%)	9,320 (60%)	13,300 (85%)	15,200 (97%)	15,300 (98%)
	Selenium	22,100	3,320 (15%)	20,900 (94%)	21,300 (96%)	21,500 (97%)	21,500 (97%)
	Thallium	7,330	1,260 (17%)	1,260 (17%)	5,220 (71%)	7,130 (97%)	7,130 (97%)
	Zinc	24,700	18,600 (75%)	18,600 (75%)	21,900 (89%)	23,500 (95%)	23,800 (96%)

Table 7-12. Pollutant Removals to Impaired Waters by Impairment Type

Impairment Type/Number of Receiving Waters [b]	Pollutant	Baseline Loadings (lbs/yr)	Pollutant Removals (lbs/yr) to Impaired Waters Under the Regulatory Options (Percent Reduction) [a]				
			Option A	Option B	Option C	Option D	Option E
Nutrient-Impaired Receiving Waters							
19	Total Nitrogen	492,000	7,250 (1%)	341,000 (69%)	395,000 (80%)	471,000 (96%)	471,000 (96%)
	Total Phosphorous	5,280	406 (8%)	406 (8%)	1,930 (37%)	4,090 (78%)	4,090 (78%)
TDS and Chlorides-Impaired Receiving Waters							
4	Chlorides	CBI	CBI	CBI	CBI	CBI	CBI
	TDS	CBI	CBI	CBI	CBI	CBI	CBI

Source: ERG, 2015c.

Acronyms: CBI (Confidential business information); lbs/yr (pounds per year).

Note: Loadings and pollutant reductions are rounded to three significant figures.

a – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

b – For the impaired waters proximity analysis, EPA evaluated 222 immediate receiving waters that receive discharges of the evaluated wastestreams.

c – The EPA impaired water database listed 28 immediate receiving waters as impaired based on the "metal, other than mercury" impairment category. Of those 28 immediate receiving waters, 13 receiving waters are also listed as impaired for one or more specific metals (arsenic, cadmium, chromium, copper, lead, manganese, selenium, and zinc). One additional immediate receiving water is impaired for boron (but not included in the "metals, other than mercury" impairment category).

d – Total phosphorous and total nitrogen loadings are presented with this impairment category. Total nitrogen loadings are the sum of total Kjeldahl nitrogen and nitrate/nitrite as N loadings.

7.4.2 Threatened and Endangered Species

As discussed in Section 3.4.5, EPA identified 138 threatened and endangered species whose habitats overlap with, or are located within, surface waters that exceeded NRWQC for the protection of aquatic life under baseline conditions.[53] To assess the potential improvements to threatened and endangered species under the final rule, EPA initially selected only those species identified as highly vulnerable to changes in water quality (75 of the 138 species) for evaluation. EPA further excluded species from the analysis based on the following criteria: the species is already presumed extinct, species habitat is unlikely to be affected by discharges of the evaluated wastestreams (*e.g.*, isolated headwaters), species listing status is due to habitat destruction unrelated to steam electric power plant discharges (*e.g.*, damming, stream channelization), and other criteria. Based on the analysis, EPA identified 15 species out of the 75 that are highly vulnerable to changes in water quality and whose recovery may be enhanced by the final rule. Four of these 15 species inhabit waters that will no longer exceed NRWQC for the protection of aquatic life following implementation of the final rule. The species may therefore experience increases in population growth rates as a result of the final rule. See the Benefits and Cost Analysis for further details on the methodology and results of EPA's threatened and endangered species analysis.

7.4.3 Fish Advisory Waters

States, territories, and authorized tribes issue fish advisories to notify the public (including recreational and subsistence fishers) of waterbodies containing fish with elevated and potentially unhealthy contamination levels. Mercury is the most common pollutant found in steam electric power plant wastewater for which fish advisories are issued to the surface waters that receive the evaluated wastestreams (see Section 3.4.4). EPA determined that 88 of the 222 immediate receiving waters included in the EA are under a fish advisory for mercury. Under the final rule, the number of immediate receiving waters with fish that exceed EPA's mercury screening value for recreational fishers (based on steam electric power plant discharges only) will decrease by 63 percent, thereby reducing the potential threat to human health from consuming contaminated fish.

7.5 Improvements to Watersheds

As discussed in Section 3.4, both the Great Lakes and Chesapeake Bay watersheds have a history of receiving pollutant discharges that negatively affect water quality, wildlife, and human health. Both are well-studied, sensitive environments that are affected by pollutants commonly found in steam electric power plant wastewater. Mercury is one of the primary pollutants of concern in the Great Lakes,[54] and nutrients are the primary pollutants of focus in the Chesapeake Bay.

EPA identified 23 steam electric power plants that discharge into the Great Lakes watershed. Table 7-13 presents the pollutant reductions to the Great Lakes watershed under the

[53] The habitat locations evaluated for this analysis include waters downstream from steam electric power plant discharges and reflect changes in the industry as a result of the Clean Power Plan [Clean Air Act Section 111(d)].
[54] One of the main environmental pathways for mercury in the Great Lakes is from atmospheric deposition, which is not in the scope of the final rule.

regulatory options considered by EPA. Under the final rule, EPA estimates the following pollutant removals to the Great Lakes watershed:

- 2,070 pounds of arsenic annually (96 percent reduction).
- 612 pounds of cadmium annually (95 percent reduction).
- 1,880 pounds of lead annually (99 percent reduction).
- 80.6 pounds of mercury annually (97 percent reduction).
- 4,800 pounds of selenium annually (96 percent reduction).
- 9,510 pounds of thallium annually (99 percent reduction).
- 1.15 million pounds of total nitrogen annually (>99 percent reduction).
- 21,800 pounds of total phosphorus annually (94 percent reduction).

EPA identified nine steam electric power plants that discharge to the Chesapeake Bay watershed. Under the final rule, EPA estimates the following pollutant removals to the Chesapeake Bay watershed:

- 2,430 pounds of arsenic annually (97 percent reduction).
- 476 pounds of cadmium annually (93 percent reduction).
- 1,540 pounds of lead annually (99 percent reduction).
- 87.1 pounds of mercury annually (98 percent reduction).
- 6,380 pounds of selenium annually (97 percent reduction).
- 5,220 pounds of thallium annually (99 percent reduction).
- 990,000 pounds of total nitrogen annually (>99 percent reduction).
- 14,900 pounds of total phosphorus annually (89 percent reduction).

Table 7-13. Pollutant Removals to the Great Lakes Watershed Under the Regulatory Options

Pollutant	Baseline Loadings to the Great Lakes Watershed (lbs/yr)	Pollutant Removals (lbs/yr) to Great Lakes Watershed Under the Regulatory Options (Percent Reduction) [a]				
		Option A	Option B	Option C	Option D	Option E
Arsenic	2,170	47.5 (2%)	47.5 (2%)	513 (24%)	2,070 (96%)	2,130 (98%)
Boron	997,000	9,190 (1%)	9,190 (1%)	22,600 (2%)	66,800 (7%)	66,800 (7%)
Cadmium	648	53.6 (8%)	53.6 (8%)	183 (28%)	612 (95%)	623 (96%)
Chromium VI	0.548	0.471 (86%)	0.471 (86%)	0.548 (>99%)	0.548 (>99%)	0.548 (>99%)
Copper	2,550	34.5 (1%)	34.5 (1%)	608 (24%)	2,510 (99%)	2,520 (99%)
Lead	1,900	19.4 (1%)	19.4 (1%)	449 (24%)	1,880 (99%)	1,880 (99%)
Manganese	242,000	35,500 (15%)	35,500 (15%)	70,500 (29%)	188,000 (77%)	188,000 (77%)
Mercury	82.8	4.56 (6%)	4.91 (6%)	22.6 (27%)	80.6 (97%)	82.2 (99%)
Nickel	9,840	402 (4%)	413 (4%)	2,550 (26%)	9,720 (99%)	9,790 (99%)
Selenium	5,020	126 (3%)	3,780 (75%)	4,010 (80%)	4,800 (96%)	4,800 (96%)
Thallium	9,570	23.5 (<1%)	23.5 (<1%)	2,200 (23%)	9,510 (95%)	9,510 (99%)
Zinc	8,730	658 (8%)	658 (8%)	2,410 (28%)	8,270 (95%)	8,600 (99%)
Nitrogen, total [b]	1,150,000	2,420 (<1%)	380,000 (33%)	556,000 (48%)	1,150,000 (>99%)	1,150,000 (>99%)
Phosphorus, total	23,100	135 (1%)	135 (1%)	5,110 (22%)	21,800 (94%)	21,800 (94%)
Chlorides	31,900,000	11,400 (<1%)	11,400 (<1%)	698,000 (2%)	3,000,000 (9%)	3,000,000 (9%)
TDS	186,000,000	3,890,000 (2%)	3,890,000 (2%)	22,300,000 (12%)	83,900,000 (45%)	83,900,000 (45%)

Source: ERG, 2015a; ERG, 2015c.

Acronyms: lbs/yr (pounds per year).

Note: Loadings and pollutant removals are rounded to three significant figures.

a – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

b – Total nitrogen loadings are the sum of total Kjeldahl nitrogen and nitrate/nitrite as N loadings.

7.6 ENVIRONMENTAL AND HUMAN HEALTH IMPROVEMENTS IN DOWNSTREAM SURFACE WATER

EPA estimates that the environmental and human health improvements in the immediate receiving waters expected from the final rule will translate into considerable improvements in water quality further downstream from steam electric power plant discharges. EPA calculated downstream receiving water pollutant concentrations using EPA's Risk-Screening Environmental Indicators (RSEI) model[55] and compared these concentrations to the same NRWQC and MCL water quality benchmarks used in the IRW model national-scale analysis. EPA also evaluated the wildlife (mink and eagle NEHC benchmarks) and human health (cancer and non-cancer) improvements in downstream surface waters using a simplified version of the IRW model national-scale analysis. This approach involved calculating the water pollutant concentrations that would result in exceedances if used as inputs to the wildlife and human health modules in the IRW model; EPA then compared the downstream receiving water pollutant concentrations in RSEI to these "threshold" concentrations to identify the downstream reaches that would have at least one exceedance of a particular wildlife or human health benchmark.[56] EPA used this approach to estimate the extent (in river miles) of environmental and human health impacts in downstream surface waters under baseline conditions and the improvements under the modeled regulatory options (Options A, B, C, D, and E). Table 7-14 presents the results of this downstream analysis.

Based on the results of the downstream modeling, thousands of downstream river miles are impacted by steam electric power plant discharges. Pollutant concentrations exceed NRWQC for human health (water and organism) in 4,400 river miles downstream from immediate receiving waters. However, under the final rule, this drops by 2,390 river miles (54 percent). The final rule reduces the number of downstream exceedances for each of the NRWQCs and MCLs evaluated. This reduction improves the water quality and aquatic habitats available to wildlife and human populations located outside of the immediate vicinity of steam electric power plants. In addition, pollutant removals under the final rule also reduce impacts to wildlife that rely on downstream aquatic habitats as a food source. Up to 1,040 miles of surface waters downstream from steam electric power plant discharges will no longer contain fish populations that exceed an NEHC benchmark for minks or eagles. The final rule also decreases potential exposure of humans to pollutants that can cause non-cancer health effects from consumption of contaminated fish in up to 5,470 river miles. These results demonstrate that steam electric power plant discharges are impacting surface waters beyond the immediate receiving waters. Pollutant removals associated with the final rule will substantially improve the environmental and human health for communities beyond the area immediately surrounding steam electric power plants.

[55] EPA used pollutant loadings discharged to each receiving reach by steam electric power plants to estimate concentrations in downstream reaches. The RSEI model uses a simple dilution and first-order decay equation to calculate receiving water concentrations (metals are treated as conservative substances). The RSEI model assumes that the plant's annual discharge is released at a constant rate throughout the year. In addition, EPA included pollutant loadings from EPA's Toxics Release Inventory (TRI) database for other industries to represent background pollutant concentrations in the downstream receiving waters. For further details on the RSEI model methodology and assumptions, see the Benefits and Cost Analysis.

[56] See the ERG memorandum "Downstream EA Modeling Methodology and Supporting Documentation" (DCN SE04455) regarding the calculation of these water pollutant concentration thresholds.

Table 7-14. Key Environmental Improvements for Downstream Waters Under the Regulatory Options

Evaluation Criteria	Number of River-Miles Exceeding Criteria Under Baseline Conditions	Number of River-Miles Exceeding Criteria (Percent Reduction from Baseline Conditions) Under the Regulatory Options [a]				
		Option A	Option B	Option C	Option D	Option E
Water Quality Results						
Freshwater Acute NRWQC	417	396 (5%)	396 (5%)	394 (5%)	390 (7%)	390 (7%)
Freshwater Chronic NRWQC	628	612 (3%)	569 (9%)	547 (13%)	518 (18%)	518 (18%)
Human Health Water and Organism NRWQC	4,400	3,670 (17%)	3,670 (17%)	2,620 (40%)	2,010 (54%)	1,760 (60%)
Human Health Organism-only NRWQC	1,560	1,300 (16%)	1,300 (16%)	1,070 (31%)	782 (50%)	713 (54%)
Drinking Water MCL	759	731 (4%)	726 (4%)	630 (17%)	487 (36%)	487 (36%)
Wildlife Results						
Fish Ingestion NEHC for Minks	1,180	917 (23%)	892 (25%)	723 (39%)	527 (56%)	504 (57%)
Fish Ingestion NEHC for Eagles	2,000	1,730 (13%)	1,720 (14%)	1,390 (30%)	959 (52%)	901 (55%)
Human Health Results—Non-Cancer						
Non-cancer reference dose for child (recreational)	6,350	4,900 (23%)	4,890 (23%)	3,130 (51%)	2,310 (64%)	2,150 (66%)
Non-cancer reference dose for adult (recreational)	3,760	2,960 (21%)	2,950 (21%)	2,050 (46%)	1,470 (61%)	1,380 (63%)
Non-cancer reference dose for child (subsistence)	10,100	8,380 (17%)	8,350 (17%)	6,150 (39%)	4,630 (54%)	4,240 (58%)
Non-cancer reference dose for adult (subsistence)	7,110	5,580 (22%)	5,570 (22%)	3,720 (48%)	2,770 (61%)	2,540 (64%)

Table 7-14. Key Environmental Improvements for Downstream Waters Under the Regulatory Options

Evaluation Criteria	Number of River-Miles Exceeding Criteria Under Baseline Conditions	Number of River-Miles Exceeding Criteria (Percent Reduction from Baseline Conditions) Under the Regulatory Options [a]				
		Option A	Option B	Option C	Option D	Option E
Human Health Results—Cancer						
Cancer risk for child (recreational)	231	216 (7%)	216 (7%)	211 (9%)	210 (9%)	207 (10%)
Cancer risk for adult (recreational)	286	263 (8%)	263 (8%)	251 (12%)	246 (14%)	245 (14%)
Cancer risk for child (subsistence)	262	241 (8%)	241 (8%)	239 (9%)	235 (10%)	231 (12%)
Cancer risk for adult (subsistence)	446	383 (14%)	383 (14%)	358 (20%)	328 (27%)	304 (32%)

Source: ERG, 2015i; ERG, 2015l.

Note: River miles are rounded to three significant figures.

a – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

b – EPA evaluated a total of 73,000 river-miles in the downstream receiving water analysis for toxic, bioaccumulative pollutants. Downstream receiving water concentrations are calculated until one of three conditions occurs: 1) the discharge travels 300 kilometers (km) downstream; 2) the discharge travels downstream for a week; or 3) the concentration reaches 1×10^{-9} milligrams per liter (mg/L).

7.7 Attractive Nuisances

EPA projects that the final rule will also decrease the environmental impact to wildlife exposed to pollutants through direct contact with surface impoundments and constructed wetlands at steam electric power plants. Multiple studies show that wildlife living near steam electric surface impoundments exhibit elevated levels of arsenic, cadmium, chromium, lead, mercury, selenium, strontium, and vanadium [Burger *et al*., 2002; Bryan *et al*., 2003; Hopkins *et al*., 1997, 1998, 2000, 2002, 2006; Nagle *et al*., 2001; Rattner *et al*., 2006]. Multiple studies have linked attractive nuisance areas at steam electric power plants to diminished reproduction [Hopkins *et al*., 2002, 2006; Nagle *et al*., 2001]. While the final rule does not control pollutants within surface impoundments or constructed wetlands prior to their discharge to surface waters, EPA estimates that the final rule will decrease pollutant loadings to these waterbodies (*e.g.*, through plants converting to dry handling their fly ash). These pollutant removals will decrease the exposure of wildlife populations to toxic pollutants and decrease the threat that combustion residual surface impoundments pose to surrounding wildlife.

7.8 Other Secondary Improvements

In addition to the improvements discussed above, other secondary, or ancillary, other resources will see improvements that are associated directly or indirectly with the final rule. Pollutant removals not only improve water quality in surface waters but enhances their aesthetic (*e.g.*, by improving clarity and decreasing odor and discoloration). Cleaner surface water improves the source of drinking water for both surface water treatment plants and wells that are influenced by surface water; water used for irrigation; and water used for industrial uses (less contaminants). Recreational benefits from water quality improvements include more enjoyment from swimming, fishing, and boating and potentially increased revenue from more people partaking of recreational activities. The final rule may also reduce economic impacts such as clean-up and treatment costs for contamination or impoundment failures, reduced injury associated with surface impoundment failures, reduced water usage, reduced potential for algal blooms, and decreased air emissions.

The Benefits and Cost Analysis monetizes benefits of implementing the final rule (increased aesthetics, recreational improvements, increased availability of ground water resources, reduced risk of surface impoundment failures, and air quality improvements). In addition, the document also qualitatively discusses improvements to the quality of source water for drinking, irrigation, and industrial use; quantity and quality of recreational opportunities; improved commercial fisheries yields; increased property values; and reduced sediment contamination within receiving waters.

While the final rule does not control pollutants leaching to ground water from surface impoundments and landfills containing combustion residuals, EPA estimates that the final rule will decrease pollutant loadings to surface impoundments (*e.g.*, through plants converting to dry handling their fly ash). These pollutant removals will decrease pollutants leaching from combustion residual surface impoundments to ground water and decrease the potential human health impacts associated with exposure to contaminated drinking water wells (see Section 3.3.4). EPA, however, did not quantify or monetize the benefits associated with this improvement to ground water quality.

7.9 Unresolved Drinking Water Impacts Due to Bromide Discharges

As discussed in Section 3.1.3, bromide in water can form brominated disinfection by-products (DBPs), some potentially carcinogenic, when drinking water plants use certain processes including chlorination and ozonation to disinfect the incoming source water. The national effluent limitations guidelines and standards under the final rule (regulatory Option D) do not directly control TDS levels (including bromides) in FGD wastewater discharges from all steam electric power plants.[57] Coal-fired steam electric power plants can discharge bromide due to its natural presence in coal (which is released when burned and/or captured in particulates by baghouses and FGD controls) or through bromide addition to flue gas control processes to reduce mercury emissions. Steam electric power plant discharges occur close to more than 100 public drinking water intakes on rivers and other waterbodies and there is evidence that bromide discharges are already having adverse effects on the quality of drinking water sources.

While bromide itself is not thought to be toxic at levels present in the environment, its reaction with other constituents in water may be of concern now and into the future. Drinking water utilities should be concerned about bromides affecting drinking water sources, as bromide loadings into surface waters could potentially increase in the future as more coal-fired steam electric power plant operators add bromide to help control mercury emissions. Although EPA decided not to finalize BAT requirements based on evaporation for treating FGD wastewater at all steam electric power plants in the final rule, evaporation technology is potentially available and may be appropriate for achieving water quality-based effluent limitations, depending on site-specific conditions, where drinking water supplies need to be protected.

[57] They do, however, directly control TDS in cases where steam electric power plants opt into the voluntary incentives program, in which they would be subject to effluent limitations based on evaporation technology.

SECTION 8 CASE STUDY MODELING

EPA developed dynamic water quality models of selected case study locations to supplement the water quality component of the national-scale immediate receiving water (IRW) model. EPA performed the case study modeling to provide additional resolution regarding the baseline impacts and the expected environmental and human health improvements under the final rule, while encompassing a broader temporal and spatial scope than what is included in the IRW model. The case study models also validate and provide additional perspective on the results of the IRW model for those waterbodies included in both models. The case study modeling improves upon the IRW model in the following ways:

- Accounts for long-term pollutant loadings from steam electric power plants (under both baseline conditions and the final rule) and estimates the resultant accumulation of pollutants within the water column and sediments of the receiving water. These models can more accurately assess baseline pollutant concentrations and the time frame and magnitude of environmental improvements associated with the final rule.
- Accounts for fluctuations in receiving water flow rates by using daily stream flow monitoring data instead of one annual average flow rate for the receiving water. This approach better reflects the varying influence of dilution (or lack thereof) within the receiving water during high-flow and low-flow conditions.
- Accounts for pollutant transport and accumulation within receiving water reaches that are downstream from the discharge location. This approach can more accurately estimate the river distance showing environmental impacts under baseline conditions and improvements under the final rule.[58]
- Accounts for pollutant contributions from other point, nonpoint, and background sources, to the extent practical, using available data sources. Incorporating non-steam-electric pollutant sources and available water quality data provides a more complete illustration of the compounding impacts of background pollutant concentrations, steam electric power plant pollutant loadings, and other point source dischargers.

This section describes EPA's methodology for developing and running the case study models (Section 8.1); presents the results of the case study models for the selected case study locations (Section 8.2); and compares the case study and IRW model results (Section 8.3).

[58] The case study downstream modeling described in this section is separate from the downstream modeling EPA performed using the Risk-Screening Environmental Indicators (RSEI) model and the SPARROW (SPAtially Referenced Regressions On Watershed attributes) model. EPA used the national-scale RSEI and SPARROW models to quantify changes in water quality in support of the benefits analysis for the final rule. See the *Benefits and Cost Analysis for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (EPA-821-R-15-005).

8.1 CASE STUDY MODELING METHODOLOGY

The case studies use EPA's Water Quality Analysis Simulation Program (WASP), a dynamic compartment-modeling program for aquatic systems that simulates pollutant fate and transport within both the water column and the benthic sediment. The WASP model helps users interpret and predict water quality responses to natural phenomena and man-made pollution for various pollutant management decisions. EPA's approach also relies on U.S. Geological Survey (USGS) daily stream flow data downloaded through EPA's Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) interface to provide input time series flow data for use in the WASP model.

This section is organized as follows:

- Section 8.1.1 discusses EPA's approach for selecting case study locations (*i.e.*, steam electric power plants and receiving waters) for case study modeling, including the differences in selection criteria for lotic, lentic, and estuarine water systems.
- Section 8.1.2 summarizes the scope and general technical approach for the case study modeling, including the selection of pollutants and wastestreams for modeling; the data sources evaluated for non-steam-electric pollutant contributions; and approaches for modeling pollutant levels before and after the assumed final rule compliance date.
- Section 8.1.3 explains the development and execution of the case study models using WASP. Appendix G provides additional information regarding the specific input parameters (*e.g.*, background pollutant concentrations, USGS time series flow data) and model settings (*e.g.*, solids transport parameters) for each of the WASP models. For additional documentation regarding the selection and calculation of the input parameters and settings, refer to the ERG memorandum, "Technical Approach for Case Study Water Quality Modeling of Aquatic Systems in Support of the Final Steam Electric Power Generating Industry Environmental Assessment" (DCN SE05570) (*Case Study Water Quality Modeling Memorandum*).
- Section 8.1.4 describes the use of the case study model outputs to determine impacts to aquatic life based on changes in water quality; impacts to aquatic life based on changes in sediment quality; impacts to wildlife from consuming contaminated aquatic organisms; and impacts to human health from consuming contaminated fish.
- Section 8.1.5 lists some of the limitations and assumptions involved with EPA's case study modeling.

8.1.1 <u>Selection of Case Study Locations for Modeling</u>

To select locations for detailed case study modeling, EPA developed site-selection criteria to identify a collection of steam electric power plants and receiving waters that, when evaluated as a group:

- Represent a reasonable cross-section of the range of receiving waters evaluated in the environmental assessment (EA).
- Illustrate pollutant removals across the regulatory options evaluated by EPA.

- Encompass discharges of all four wastestreams evaluated in the EA.
- Demonstrate pollutant loadings that are representative of those discharged by steam electric power plants evaluated in the EA (*i.e.*, discharges are typical of steam electric power plants and not outlier values).

EPA evaluated 195 steam electric power plants that discharge directly to aquatic systems with lotic characteristics (rivers and streams), lentic characteristics (lakes, ponds, and reservoirs), or that are estuarine systems. Through the site-selection process described below, EPA identified six representative case study locations (five lotic sites and one lentic site) that capture improvements across multiple regulatory options, represent all four evaluated wastestreams (flue gas desulfurization (FGD) wastewater, fly ash transport water, bottom ash transport water, and combustion residual leachate), and represent both lentic and lotic aquatic environments. Figure 8-1 and Table 8-1 present the six receiving waters that EPA selected for case study modeling.

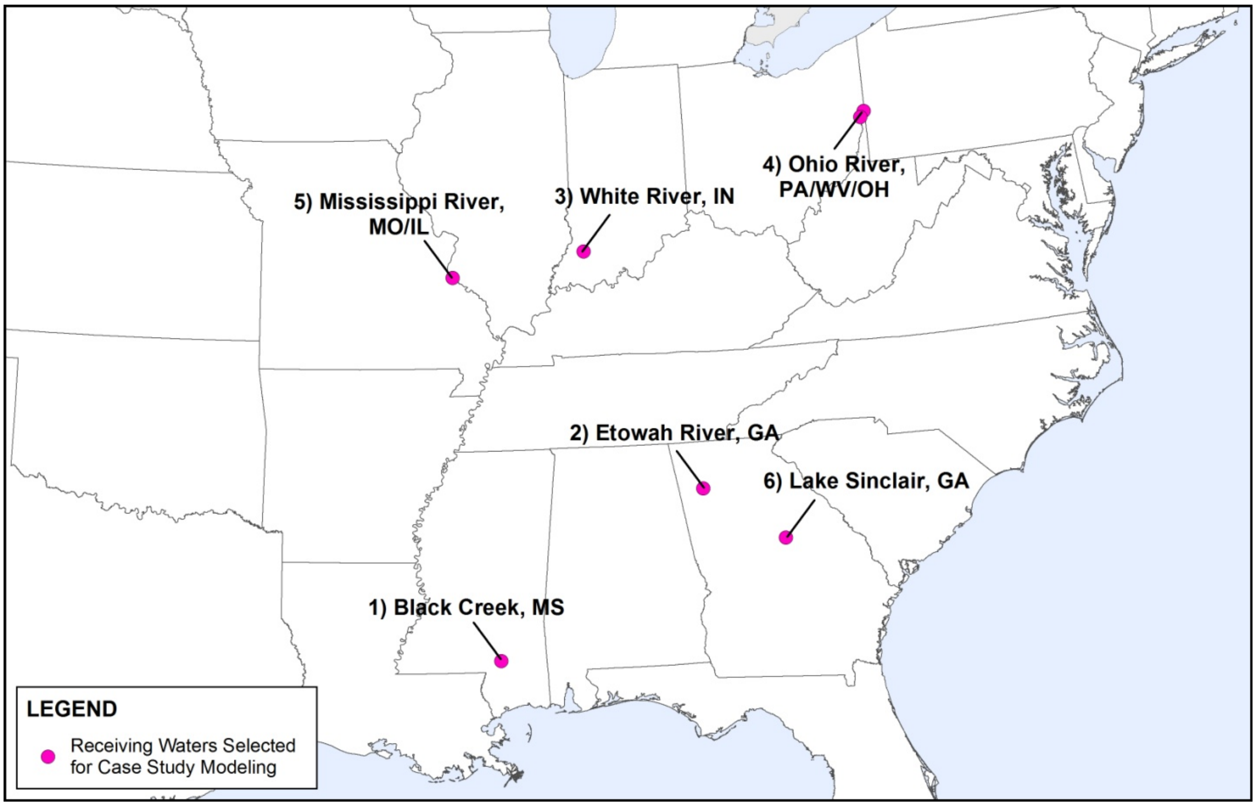


Figure 8-1. Overview of Case Study Modeling Locations

Table 8-1. Locations Selected for Case Study Modeling

Case Study Location	Water-body Type	Steam Electric Power Plant(s) Modeled	Evaluated Wastestreams Discharged				Regulatory Options Demonstrating Removals				Model Length (river-miles)	Modeling Period [a]
			FGD	Fly Ash	Bottom Ash	Leachate	A	B	C	D		
Black Creek, MS	Lotic	R.D. Morrow Sr. Generating Site	✓		✓	✓	✓	✓		✓	97	1982-2036 (55 years)
Etowah River, GA	Lotic	Plant Bowen	✓		✓		✓	✓	✓		35	1982-2032 (51 years)
Lick Creek & White River, IN	Lotic	Petersburg Generating Station	✓		✓			✓	✓	✓	53	1986-2034 (49 years)
Ohio River, PA/WV/OH	Lotic	Bruce Mansfield Plant & W.H. Sammis Plant	✓		✓	✓	✓	✓	✓	✓	44	1982-2036 (55 years)
Mississippi River, MO/IL	Lotic	Rush Island [b]		✓	✓		✓		✓		65	1982-2036 (55 years)
Lake Sinclair, GA	Lentic	Plant Harllee Branch [c]	✓	✓	✓		✓	✓	✓	✓	N/A	2012-2025 (14 years)

Acronym: FGD (flue gas desulfurization); N/A (Not applicable).

a – The modeling periods start at 1982 (the year of the last revision to the steam electric effluent limitations guidelines and standards (ELGs) or the date of installation of the most recent generating unit impacted by the final rule (if after 1982). The duration of the modeling period is influenced by the available time periods covered by USGS time series flow data and by the assumed date upon which the steam electric power plant would achieve the limitations under the final rule, as determined based on the plant's National Pollutant Discharge Elimination System (NPDES) permitting cycle.

b – EPA identified another steam electric power plant, Meramec, that discharges upstream of the Rush Island plant. EPA incorporated the pollutant loadings of the Meramec plant to account for the upstream pollutant contributions. EPA did not evaluate the water quality, wildlife, or human health impacts associated with discharges from the Meramec plant because this plant was not selected using the case study selection methodology described in this section.

c – This steam electric power plant has decertified and retired all of its steam electric generating units. EPA selected this plant to represent the potential impacts of discharges of the evaluated wastestreams to lentic waterbodies because it meets all of the case study selection criteria.

Selection of Lotic Case Study Locations

To select lotic receiving waters to model using WASP, EPA reviewed all combinations of steam electric power plants and their receiving waters evaluated in the EA for factors that would negatively influence the ability to use WASP for case study water quality modeling or the ability to discuss the case study modeling results in a public document. EPA completed an assessment using industry responses to the 2010 *Questionnaire for the Steam Electric Power Generating Effluent Guidelines* (the Steam Electric Survey), EPA's BASINS tool, National Hydrography Dataset Plus (NHDPlus Version 1) hydrography layers, and USGS National Water Information System (NWIS) data sources to identify and eliminate the lotic receiving waters that met one or more of the following criteria from consideration for case study modeling:

- Confidential Business Information (CBI). EPA identified and eliminated steam electric power plants with CBI claims on discharge flow rate data for any of the four evaluated wastestreams. EPA eliminated these plants as potential case study locations because CBI data, including modeled water concentrations based on CBI data, cannot be discussed in a public document such as this EA report.
- Stream gage flow data. EPA identified and eliminated receiving waters that lack sufficient stream gage flow data. Availability of a long-term, continuous stream flow record for both the receiving water being modeled and any significant downstream tributaries was a major factor in selecting case study locations because these data are needed to construct the hydrodynamics in WASP. The primary considerations when reviewing the sufficiency of stream gage flow data for use in WASP were the following:
    - Location of USGS stream gage stations (the ideal location is within the vicinity of the immediate receiving water being evaluated, plus additional locations within the model area).
    - A continuous stream flow record covering a time period that matches or exceeds the length of the desired modeling period.
    - Age of the stream gage flow data (data sets without data from within the previous 30 years were considered potentially unrepresentative of current flow conditions).
- Downstream waterbody characteristics. WASP's ability to accurately model water quality using USGS stream gage flow data can be affected by flow control structures such as dams that affect the linear flow and circulation of water, and thus influence the transport of pollutants. EPA identified and eliminated receiving waters whose downstream waterbodies exhibit these characteristics, unless the areas of concern were sufficiently downstream to allow for modeling of a reasonable distance (*i.e.*, at least 25 miles) before encountering the area of concern.
- Influence by other point source dischargers that could not be modeled. EPA identified receiving waters that could be significantly influenced by discharges from other point sources (including other steam electric power plants) and evaluated whether those point sources would meet the criteria listed above for case study modeling. If EPA determined that a receiving water would be significantly influenced by other point source discharges that could not be modeled (*e.g.*, an upstream steam electric power

plant exercising CBI claims) or represented in the model by STORET monitoring data (see Section 8.1.3), EPA eliminated the receiving water from consideration. If EPA deemed the pollutant loadings from the other point source discharges to be insignificant compared to the steam electric power plant pollutant loadings being evaluated, EPA included the receiving water in the analysis.[59]

Next, EPA assessed the representativeness of the steam electric power plants and receiving waters that were not eliminated based on the criteria above. EPA selected the receiving water flow rate, magnitude of pollutant loadings from the evaluated wastestreams, and water column concentrations output calculated based on these values as the primary factors in determining whether it considered a particular receiving water representative. EPA reviewed the average annual flow rates (as defined in NHDPlus Version 1), baseline loadings of the modeled pollutants, and water column concentrations output from the IRW model of each of the steam electric power plants and receiving waters that were not eliminated after application of the acceptance criteria. EPA assessed how each plant and receiving water compared to the general population in the EA and eliminated plant and receiving water combinations that did not reasonably represent typical conditions. From the population of lotic receiving waters that EPA determined would be suitable for WASP modeling and representative of typical pollutant loadings from discharges of the evaluated wastestreams, the Agency selected a collection that, when evaluated as a group, demonstrated pollutant removals across all modeled regulatory options and all four evaluated wastestreams. As a result, EPA identified five case study locations as the best candidates for modeling as part of a representative set of steam electric power plants that discharge to lotic systems. The selected case study locations are further described in Section 8.2.[60] Additional information about EPA's methodology for selecting plants and receiving waters that are representative and suitable for WASP modeling is further described in the *Case Study Water Quality Modeling Memorandum* (DCN SE05570).

Selection of Lentic and Estuarine Case Study Locations

Water quality modeling of lentic systems (lakes, ponds, and reservoirs) or estuarine systems involves more complex hydrodynamics that would not be adequately represented by stream gage flow data. Modeling steam electric power plants that discharge to lentic or estuarine systems requires using existing EPA-developed WASP models (or more specifically, the underlying hydrodynamic data) for the specific waterbodies of interest. Accordingly, EPA considered the availability of existing models a primary factor in selecting lentic and estuarine systems for case study water quality modeling.

[59] EPA considered receiving water flow rate, distance between outfalls, and relative magnitude of pollutant loadings when assessing whether the discharges from upstream or downstream plants or point sources could significantly affect the water quality modeling results for the selected case study location. EPA applied best professional judgment using these criteria, but did not apply numeric thresholds.

[60] Because of the level of effort required to design, execute, and evaluate the outputs for case study modeling, EPA did not complete case study modeling for all candidates that met all acceptance criteria and were determined to be representative. EPA used best professional judgment in determination of which five case study locations were the best candidates for modeling and represent a reasonable cross-section of the range of receiving waters evaluated in the EA.

EPA identified one preexisting WASP model for a lake (Lake Sinclair, GA) that receives steam electric power plant discharges from Georgia Power Company's Plant Harllee Branch. As of April 16, 2015, this plant has decertified and retired all four of its coal-fired generating units. Based on a review of the water concentration outputs generated by the IRW model in support of the proposed ELGs (which were developed prior to the announcement of plans to retire Plant Harllee Branch), EPA determined that Lake Sinclair remains a representative illustration of lentic waterbodies that receive discharges of the evaluated wastestreams. As discussed in Section 3, pollutant loadings to lentic systems often more strongly affect water quality and ecosystem health (compared to lotic systems) due to the longer residence times and associated long-term accumulation of pollutants in these systems. Accordingly, and despite the retirement of Plant Harllee Branch, EPA proceeded with case study modeling of Lake Sinclair to represent the potential impacts of steam electric power plant discharges on lentic waterbodies (including the 26 lake, pond, and reservoir receiving waters evaluated in this EA) and the potential environmental improvements under the final rule in other lentic waterbodies that receive discharges of the evaluated wastestreams.

EPA also identified one preexisting water WASP model for an estuary (Hillsborough Bay, FL) that receives steam electric power plant discharges. However, due to the hydrologic complexity of the model, and because estuarine systems represent less than 2 percent of the receiving waters evaluated in the EA, EPA elected to develop only freshwater river and lake WASP models for this case study analysis. Additionally, the ecological risk modeling approach described in Section 5.2 is based on selenium bioaccumulation within freshwater environments and would not be appropriate to apply to estuarine or marine aquatic systems, which would limit EPA's ability to analyze the ecological effects for the estuarine case study.

8.1.2 Scope and Technical Approach for Case Study Modeling

This section describes the scope and technical approach used for EPA's detailed case study modeling, including the selection of pollutants and wastestreams evaluated, the inclusion of other point and nonpoint sources, the development of a historical baseline for the case study location, and the prediction of decreased water and sediment pollutant concentrations under the regulatory options evaluated for the final rule.

Selection of Pollutants for Modeling

EPA approached the case study modeling with the goal of modeling the same 10 pollutants included in the IRW model, which are listed in Section 5.1. As described later in this section, however, EPA was unable to perform case study modeling for chromium VI and mercury. EPA performed case study water quality modeling for the following eight pollutants (or "toxicants" as defined in the WASP model), which were also included in the IRW model:

- Arsenic (As).
- Cadmium (Cd).
- Copper (Cu).
- Lead (Pb).
- Nickel (Ni).
- Selenium (Se).

- Thallium (Tl).
- Zinc (Zn).

These pollutants can be modeled using the Simple Toxicant module within WASP. Similar to the water quality module of the IRW model, the Simple Toxicant module applies pollutant-specific partition coefficients to estimate the degree to which pollutants in the water column will adsorb to benthic sediments and suspended solids. Unlike the IRW model, the Simple Toxicant module does not incorporate separate partition coefficients to define the benthic sediment/pore water equilibrium and the suspended sediment/water column equilibrium. Therefore, EPA selected only the suspended sediment-water (Kd_{sw}) partition coefficient for each pollutant (see Table C-4 in Appendix C).

EPA also considered using WASP to perform water quality modeling for chromium VI and mercury. These pollutants, however, require using more data-intensive modules within WASP. Accurately modeling chromium VI requires using the META4 module within WASP to accurately predict pollutant speciation and depends on the availability of extensive site-specific monitoring data. Modeling mercury (and methylmercury, a bioaccumulative organic form of mercury) requires using the MERC7 module within WASP to account for transformation processes such as methylation. Using the more data-intensive modules requires site-specific data that were not available for all locations.

Evaluated Wastestreams

The case study models quantified the water quality impacts resulting from discharges of the same four evaluated wastestreams included in the IRW model:

- Fly ash transport water.
- Bottom ash transport water.
- FGD wastewater.
- Combustion residual leachate.

As with the IRW model, EPA performed the WASP water quality modeling using average daily pollutant loadings derived from average annual pollutant loadings and normalized effluent flow rates. This assumption of a static loadings rate does not account for temporal variability in the loadings to receiving waters due to factors such as variable plant operating schedules, storm flows, low-flow events, and catastrophic events.

Inclusion of Other Point and Nonpoint Sources

Accounting for pollutant contributions from non-steam-electric point sources and nonpoint sources, to the extent practical using available data, can improve the accuracy of the case study water quality models. EPA identified the following data sources that provide pollutant loadings and/or concentration data for these other sources potentially affecting water quality in the case study location:

- Discharge Monitoring Reports (DMR). Point source dischargers are required to report certain wastewater monitoring data through the submittal of DMRs. However, they are required to report only for the pollutants that are listed in the facility's National

Pollutant Discharge Elimination System (NPDES) permit.[61] EPA evaluated 2011 pollutant loadings data for direct dischargers including publicly owned treatment works (POTWs) and industrial facilities.

- Toxics Release Inventory (TRI). TRI collects facility-reported estimates of wastewater loadings data for both direct and indirect dischargers. The TRI database does not include loadings from facilities with total annual chemical releases of less than 500 pounds and incorporates assumptions regarding plants with annual releases of less than 1,000 pounds. The point source loadings from smaller facilities, therefore, may not be well represented in the TRI database.[62] EPA evaluated 2011 pollutant loadings data for industrial facilities with indirect discharges of a modeled pollutant. EPA also evaluated TRI direct pollutant loadings data for these facilities and pollutants if the facilities are not also required to report this pollutant in their DMRs (to avoid double-counting direct discharges).
- STORET Monitoring Data. EPA's STORET database is a repository for water quality, biological, and physical data compiled from many data sources and locations throughout the country. The STORET database contains water quality and sediment quality monitoring data for all eight modeled pollutants and other input parameters for WASP including total organic carbon (TOC) and total suspended solids (TSS).

EPA reviewed these publicly available data sources to identify pollutant contributions from non-steam-electric point sources and nonpoint sources that may impact the case study water quality model. EPA also used available STORET monitoring data to help calibrate the modeled outputs. For additional documentation regarding EPA's collection and use of these data, refer to the *Case Study Water Quality Modeling Memorandum* (DCN SE05570).

Modeling of Pollutant Loadings Prior to the Final Rule

EPA developed and executed WASP models (as described in Section 8.1.3) for the selected case study locations to predict the baseline accumulation of pollutants in the receiving water and sediment leading up to implementation of the final rule.

The modeling periods start at 1982 (the year of the last revision to the steam electric ELGs) or the date of installation of the most recent generating unit impacted by this rulemaking (if after 1982), and extend to the assumed compliance date.[63] If the available stream gage flow

[61] In addition, states (or other permitting authorities) have some discretion as to which data they make available (or enter) to the national database (*i.e.*, Permit Compliance System (PCS) and Integrated Compliance Information System for the National Pollutant Discharge Elimination System (ICIS-NPDES)). For example, permitting authorities enter DMR and permit information for facilities that are considered major dischargers. However, they do not necessarily enter DMR or permit information into PCS for minor dischargers or facilities covered by a general permit.

[62] Other limitations of the data collected in TRI include the following: small establishments are not required to report, nor are facilities that do not meet reporting thresholds; releases reported are based on estimates, not measurements; certain chemicals are reported as a class, not as individual compounds; facilities are identified by North American Industrial Classification System (NAICS) code, not point source category; and TRI requires facilities to only report certain chemicals and therefore all pollutants discharged from a facility may not be captured.

[63] For each steam electric power plant in the case study modeling, EPA assumed a plant-specific date, derived from the plant's permitting cycle, that the plant would achieve the limitation under the final rule.

data did not cover the desired modeling period, EPA extrapolated the available data, incorporating another partial cycle of the flow data to reach the total desired modeling period.

Historical pollutant loadings data for the evaluated wastestreams and non-steam-electric point sources are very limited and difficult to obtain, so EPA used Steam Electric Survey data (representing plant operations in 2009), STORET monitoring data, and 2011 TRI and DMR loadings data as a representative set of discharge conditions. EPA acknowledges that these data may not reflect the actual pollutant loadings over the entire modeling period; however, they represent an appropriate estimation of annual pollutant loadings and how discharges may affect individual aquatic systems over time.

For each case study location, EPA assumed that the annual, historical pollutant loadings associated with fly ash transport water, bottom ash transport water, and combustion residual leachate discharges were equal to the baseline pollutant loadings calculated for these wastestreams (*i.e.*, the same annual pollutant loadings used to represent baseline conditions in the national-scale IRW model). The impoundment and discharge of these wastestreams has been a standard technique practiced since before 1982. EPA did not attempt to determine whether a modeled plant had historical discharges of an evaluated wastestream that are not represented in the baseline pollutant loadings. For example, for a plant that does not have fly ash transport water pollutant loadings under baseline conditions, EPA did not attempt to determine whether the plant had historical discharges of fly ash transport water.

In estimating the annual, historical pollutant loadings associated with FGD wastewater, EPA accounted for the fact that steam electric power plants may have installed FGD systems after the start of the modeling period. EPA used the FGD system installation dates, based on industry responses to the Steam Electric Survey, to determine how to incorporate FGD wastewater pollutant loadings into the case study model. If a plant installed multiple FGD systems during the modeling period, EPA assumed that the annual, historical FGD wastewater pollutant loadings associated with each individual system were proportional to that system's flow rate contribution compared to the total FGD wastewater flow rate under baseline conditions. The procedure for calculating and incorporating the proportional loadings for each FGD system is further described in the *Case Study Water Quality Modeling Memorandum* (DCN SE05570).

EPA accounted for pollutant loadings from non-steam-electric point sources within the modeling boundary by using 2011 TRI and DMR data. EPA assumed that the annual, historical pollutant loadings for these point sources throughout the modeling period were equal to the pollutant loadings reported in the 2011 TRI and DMR data sets. To account for contributions from nonpoint sources, EPA evaluated STORET water quality monitoring data collected upstream of the modeling boundary. The Agency used these monitoring data to represent the pollutant contributions from all point, nonpoint, and background sources upstream of the monitoring location, potentially avoiding the need to collect TRI and DMR pollutant loadings data and perform WASP modeling of those upstream or tributary reaches. The *Case Study Water Quality Modeling Memorandum* (DCN SE05570) further discusses how EPA incorporated DMR pollutant loadings data, TRI pollutant loadings data, and STORET monitoring data into the WASP water quality models.

The results of this baseline modeling provided initial receiving water and sediment concentrations for modeling discharges after the assumed compliance date, discussed in the following section.

Modeling of Pollutant Loadings Under the Final Rule

EPA developed and executed WASP water quality models (as described in Section 8.1.3) for the selected case study locations to predict the decreases of receiving water and sediment pollutant concentrations (relative to baseline conditions) following implementation of the final rule.

EPA executed separate models for continued baseline pollutant loadings and regulatory option pollutant loadings (Options A through D)[64]. These modeling periods started at the assumed compliance date, as determined by each steam electric power plant's permitting cycle, and continued for at least 10 years after the assumed compliance date. EPA used the pollutant loadings calculated under the regulatory options to represent the annual steam electric pollutant loadings for each year of the period following implementation of the final rule. EPA assumed that the pollutant contributions from non-steam-electric point sources (based on TRI and DMR data) and from nonpoint sources (based on STORET monitoring data) would remain constant and would be equal to those used to model the period leading up to implementation of the final rule.

8.1.3 Development and Execution of WASP Models

EPA built each case study model using the BASINS setup tool for WASP, known as the WASP Model Builder, which allows the user to open WASP directly from the BASINS interface. As described in Section 8.1.2, EPA's approach used the Simple Toxicant module within WASP for the eight modeled pollutants. The Simple Toxicant module puts stretches of the modeled receiving water into segments based on the hydrologic characteristics. The WASP model calculates the water column and benthic pollutant concentrations using user-defined parameters and default assumption values. The process described in this section is based on using WASP Version 7.52 and BASINS Version 4.1. Both represent the most current versions available for EPA's analysis.

EPA followed the general approach described below in developing the WASP models for each of the lotic case study locations:

- WASP calculates receiving water and sediment concentrations by dividing the waterbody into segments and performing calculations for each segment. EPA used NHDPlus Flowlines as the basis for defining waterbody segments. To maintain reasonable model runtimes and reduce system instability, EPA further refined these segments by combining short segments such that the flow time through each segment is at least a tenth of a day. In some cases, segment travel times were shorter than the

[64] Case study modeling omitted Option E because EPA determined that the additional pollutant removals for Option E are only marginally better than Option D. Under Option E, only R.D. Morrow Generating Station and W.H. Sammis plant would have additional removals.

desired minimum because the segment was located between an upstream and downstream tributary of some significance.

- EPA used USGS stream gage flow data to represent inflows at the upstream end of the case study location, as well as any significant tributary with a USGS stream gage station. In all cases, EPA scaled the stream gage flow data to account for the difference in drainage area between the actual gage location and the point where the contributing flow enters the model.
- For those tributaries without available USGS stream gage flow data for the simulation period, EPA set the flow rate equal to the average annual flow rate as per NHDPlus Version 1.
- To simplify the geographic extent of the modeling area, EPA did not model any tributaries with mean annual flow rates of less than 5 cubic feet per second (cfs) as per NHDPlus Version 1.
- EPA used stream gage flow data from the actual time period (*e.g.*, 1982 – 2014) to represent the baseline flow rate in the modeling area. EPA reused the historical flow data to the extent necessary to complete the modeling period through the assumed compliance date (*e.g.*, 2015 – 2020), preferentially selecting flow data from periods that excluded years of particularly high or low flow rates. Then EPA reused the historical flow data to represent the period through the end of the model run (*e.g.*, 2020 – 2036). This approach ensured that the modeling periods before and after the assumed compliance date were based on similar flow data.
- To represent non-steam-electric point sources within the modeling area, EPA assigned the TRI and DMR pollutant loadings to the stream reach (as represented in NHDPlus Version 1) that was closest to the location of the point source.
- EPA used STORET monitoring data, where available, to represent pollutant contributions flowing into the modeling area from upstream point sources, nonpoint sources, and background sources. Prior to incorporation into the WASP model, EPA converted the pollutant concentrations to mass loadings (for all pollutants except TOC and TSS) using the annual average flow rate for the stream segment where the sample was collected (as represented in NHDPlus Version 1). This approach ensured that the modeled pollutant concentrations flowing into the modeling area would vary with changes in the stream flow rate.
- To define initial concentrations for the organic solids, sands, and silts/fines parameters, EPA used TOC and TSS concentrations derived from STORET monitoring data collected within the modeling area.
- EPA calibrated the WASP water quality models by modifying the solids transport input parameters until the modeled pollutant concentrations in the benthic segments closely matched the sediment concentrations derived from STORET monitoring data.

The existing WASP model used for Lake Sinclair already divides the waterbody into segments and an existing Environmental Fluid Dynamics Code (EFDC) model provides hydrodynamics for the lentic system. Using an existing model of a lentic system was a reasonable approach to investigate the regulatory options without developing a detailed model from scratch. However, this approach does limit the modeling period to the period simulated in the existing EFDC model. Other than these differences, the approach for developing the WASP model for the lentic system was similar to the approach described above for lotic systems.

EPA developed the WASP water quality models (for both lotic and lentic systems) to provide output data for pollutant concentration (total, dissolved, and sorbed) in the water column and benthic segments on a daily output time step. The WASP models generate these outputs for both the immediate receiving water and every downstream segment. As described in Section 8.1.2, EPA then executed the models to represent conditions before and after implementation of the final rule.

Appendix G provides additional information regarding the specific input parameters (*e.g.*, background pollutant concentrations, USGS time series flow data) and model settings (*e.g.*, solids transport parameters) for each of the WASP water quality models. For additional documentation regarding the use or bypassing of specific WASP model features, incorporating stream gage flow and pollutant loadings data, and default settings and assumptions, refer to the *Case Study Water Quality Modeling Memorandum* (DCN SE05570).

8.1.4 Use of WASP Water Quality Model Outputs

For each modeled segment, EPA used the water column and benthic sediment pollutant concentration outputs (for baseline and Option D, both from the WASP model run representing the time period after the assumed compliance date) to perform the following environmental and human health analyses:

- EPA compared the modeled pollutant concentrations in the water column (daily outputs) to the water quality benchmarks listed in Table C-7 of Appendix C and calculated the frequency of exceedances over the entire modeling period (*i.e.*, the percentage of days that have a modeled exceedance).
- EPA compared the modeled pollutant concentrations in the benthic sediment (daily outputs) to the sediment biota chemical stressor concentration limit (CSCL) benchmarks listed in Table D-2 of Appendix D and calculated the frequency of exceedances over the entire modeling period (*i.e.*, the percentage of days with a modeled exceedance).
- EPA compared the modeled pollutant concentrations in the water column (averaged over the entire modeling period) to the water pollutant concentrations that would result in exceedances if used as inputs to the wildlife and human health modules in the IRW model (as described in Section 7.6).

For the Black Creek case study, which had relatively high concentrations of selenium compared to the other selected case studies, EPA also performed ecological risk modeling following the methodology described in Section 5.2.

Using the WASP water quality outputs in these analyses allowed EPA to evaluate, with greater focus and accuracy, the potential for additional environmental and human health impacts that were not reflected in the IRW model outputs. These included impacts associated with peak pollutant concentrations during low-flow periods; long-term accumulation of pollutants in benthic sediment; impacts in downstream receiving waters; and pollutant contributions from non-steam-electric sources.

8.1.5 Limitations of Case Study Modeling

The results of the case study models are intended to illustrate the types and magnitudes of environmental impacts that are likely to have occurred, and which may continue to occur, in surface waters that receive discharges of the evaluated wastestreams from steam electric power plants. Similarly, the case study modeling results provide valuable information regarding the relative magnitude of water quality improvements predicted for each of the regulatory options.

In developing the case study models, EPA found it necessary to incorporate several assumptions that simplified the modeling approach while introducing uncertainty into the model results. For example, due to a lack of data regarding temporal variability in point source loadings, EPA assumed that the pollutant loadings from steam electric power plants and other point sources are static loadings (*i.e.*, a constant daily average loading rate). This approach does not account for temporal variability in the loadings to receiving waters due to factors such as variable plant operating schedules, storm flows, low-flow events, and catastrophic events. In actuality, steam electric power plants and other point sources could adjust wastewater discharge rates based on stream flow conditions or other considerations. For instance, a plant could reduce discharges during periods of low flow in the receiving water and increase discharges during periods of high flow, resulting in surface water concentrations that differ from what is predicted by the case study model. These assumptions influence the relationship between modeled and actual surface water concentrations at specific locations and times.

Appendix G further discusses the limitations and assumptions made in developing the case study models and describes in more detail the development of each case study model, including input parameters (*e.g.*, pollutant loadings) and model settings. Refer to the *Case Study Water Quality Modeling Memorandum* (DCN SE05570) for discussion of EPA's technical approach and data acceptance criteria to incorporate DMR, TRI, and STORET monitoring data.

8.2 QUANTIFIED ENVIRONMENTAL IMPACTS AND IMPROVEMENTS FROM CASE STUDY MODELING

As described in Section 8.1.1, EPA identified six representative case study locations that would capture the types of impacts to surface waters associated with steam electric power plant discharges, capture the improvements expected across the regulatory options, represent the four wastestreams evaluated in the EA, and represent both lentic and lotic systems. Figure 8-1 and Table 8-1 present the six receiving waters that EPA selected for case study modeling.

Section 8.2 introduces each of the six selected case study locations and presents the scope, inputs, and modeling results. For each case study, EPA presents:

- Potential impacts to aquatic life, wildlife, and human health under baseline conditions;
- Improvements to aquatic life, wildlife, and human health following compliance with the final rule; and

- Comparison of the case study and IRW model results for the case study location.

Although EPA modeled the expected environmental improvements under Options A through D, this section primarily presents the water quality, wildlife, and human health improvements under the final rule (Option D). Appendix G of this report includes figures illustrating the water column concentrations output for the immediate receiving water both for baseline conditions and following compliance with the final rule, for those modeled pollutants that exceed one or more water quality benchmarks based on modeling results. These figures present the National Recommended Water Quality Criteria (NRWQC) and Maximum contaminant level (MCL) benchmarks for the modeled pollutant and the steady-state water column concentration results from the IRW model. Appendix G also includes the average total water column concentration for each of the modeled pollutants in WASP model segments downstream of the modeled case study plants.

8.2.1 Black Creek Case Study

Black Creek flows south-southeast through southern Mississippi from Hattiesburg through the De Soto National Forest until it converges with the Pascagoula River. Black Creek is Mississippi's only designated National Wild and Scenic River (for 21 miles) under the National Wild and Scenic Rivers System Act. South Mississippi Electric Power Association's R.D. Morrow, Sr. (Morrow) Generating Site (Plant ID 1185) is a 400-megawatt (MW) coal-fired power plant operating alongside Black Creek near Purvis, Mississippi. Morrow's two stand-alone steam turbine generating units reported producing more than 2,000,000 megawatt-hours (MWh) of electricity in 2009. Based on data obtained from the Steam Electric Survey, Morrow Generating Site discharges FGD wastewater, bottom ash transport water, and combustion residual leachate directly into Black Creek. Table 8-2 contains some general information on the two steam electric generating units at Morrow Generating Site.

Table 8-2. Summary of Morrow Generating Site Operations

SE Unit	Fuel	Capacity (MW)	Fly Ash	Bottom Ash	FGD (Year Installed)
1	Bituminous coal and No. 2 fuel oil	200	Dry conveyed	Wet handled to impoundment	Wet system (1978)
2	Bituminous coal and No. 2 fuel oil	200	Dry conveyed	Wet handled to impoundment	Wet system (1978)

Source: ERG, 2015j.

Acronyms: FGD (Flue gas desulfurization); MW (Megawatt); SE (steam electric).

Modeling Area

The Black Creek WASP model encompasses a 95-mile reach of Black Creek, extending from the Morrow Generating Site discharge outfall on Black Creek to the confluence of Black Creek and Red Creek. The immediate receiving water that Morrow Generating Site discharges to is approximately 1.6 miles long, as defined in the WASP model. This modeling area includes the 21-mile span of the waterway, from Moody's Landing to Fairley Bridge Landing, that is protected under the National Wild and Scenic River Systems Act. Figure 8-2 illustrates the location and extent of the Black Creek WASP model.

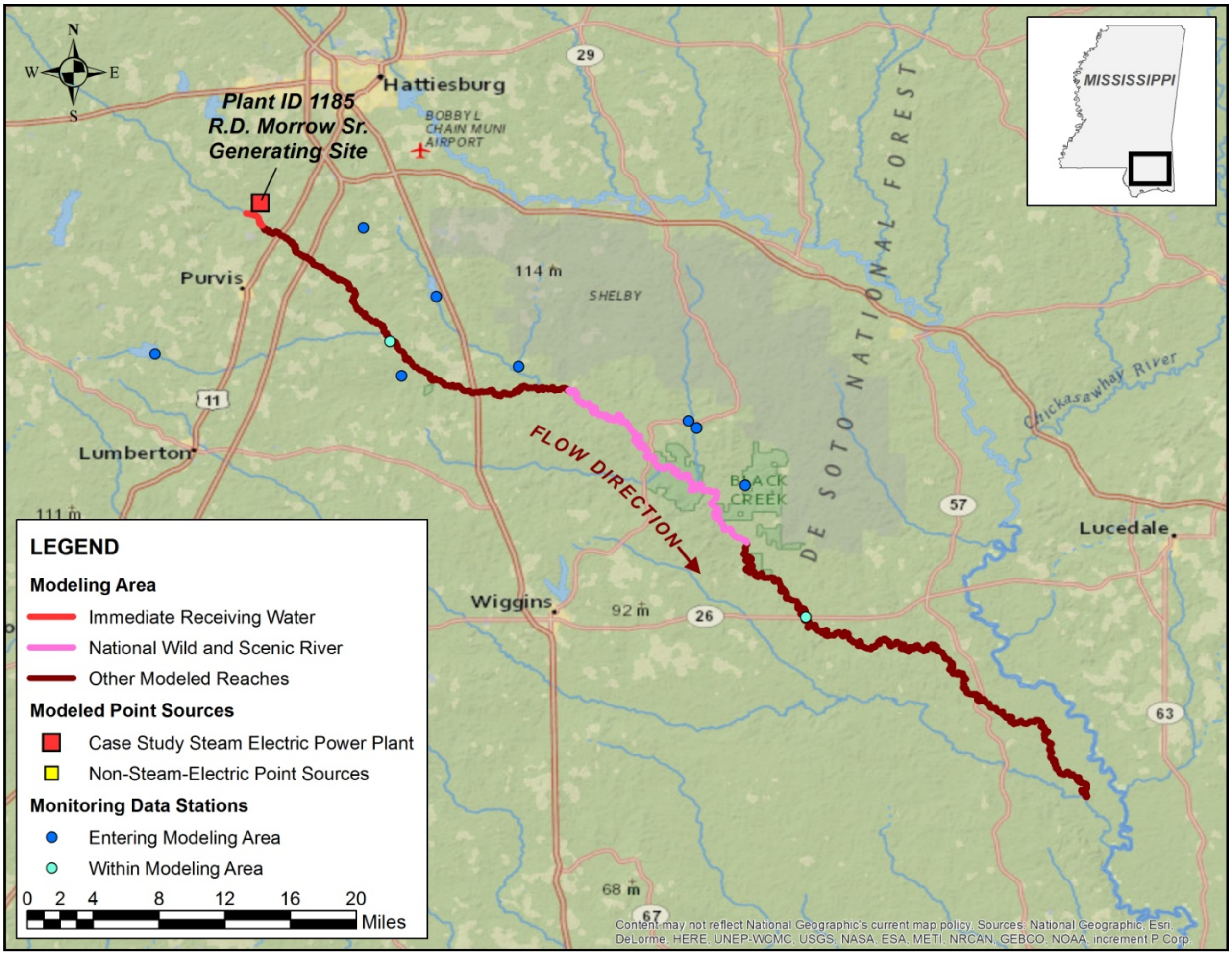


Figure 8-2. Black Creek WASP Modeling Area

Identified Point Sources and Background Concentrations

As discussed below, EPA reviewed available pollutant loadings (DMR and TRI) and monitoring data (STORET) for potential incorporation into the Black Creek WASP model to represent pollutant contributions from background and non-steam-electric point sources, and for use in calibrating the model results.

- **Upstream pollutant contributions**. EPA did not identify sufficient STORET monitoring data to represent pollutant contributions from upstream of the Morrow Generating Site immediate receiving water. EPA did not identify any upstream non-steam-electric point sources with loadings for the eight modeled pollutants. EPA therefore assumed pollutant concentrations of zero within the water column at the upstream boundary of the modeling area.
- **Downstream pollutant contributions**. EPA incorporated STORET data from eight monitoring stations to represent the pollutant contributions flowing into the modeling

area downstream of the Morrow Generating Site immediate receiving water (*i.e.*, tributaries flowing into Black Creek). EPA did not identify any non-steam-electric point sources whose pollutant loadings would significantly influence the model results in the downstream modeling area.

- **Monitoring data within the modeling area.** EPA compiled STORET data from two monitoring stations located within the modeling area and used these data to calibrate the WASP model.

Modeling Period

The modeling period starts in 1982 (the year of the last revision to the steam electric ELGs) and extends through 2036, covering a period of 55 years. Based on Morrow Generating Site's NPDES permitting cycle, EPA assumes that the plant will achieve the limitations under the final rule by 2019.

Modeling Results - Water Quality

Under baseline conditions, the modeled pollutant concentrations in the immediate receiving water and downstream reaches exceed the NRWQC water quality benchmarks for four modeled pollutants, indicating that pollutant loadings from the Morrow Generating Site may quantifiably reduce water quality in the modeled portions of Black Creek. The reduced water quality is primarily attributed to arsenic, cadmium, selenium, and thallium. Intervals of higher pollutant concentrations occur during periods of low flow in Black Creek for all eight modeled pollutants.

The baseline modeled pollutant concentrations exceed human health criteria primarily for arsenic, thallium, and selenium, as discussed below:

- Arsenic concentrations in the immediate receiving water exceed the water quality benchmark for consumption of water and organisms (0.018 micrograms per liter (µg/L)) for 99 percent of the modeling period. These exceedances continue downstream, generally at a reduced frequency, throughout the entire 95-mile-long modeling area downstream of the plant.
- Arsenic concentrations in the immediate receiving water also exceed the higher water quality benchmark for consumption of organisms only (0.14 µg/L) for 16 percent of the modeling period. These exceedances continue downstream, at a reduced frequency, throughout the entire 95-mile-long modeling area downstream of the plant.
- Thallium concentrations in the immediate receiving water exceed the water quality benchmark for consumption of water and organisms (0.24 µg/L) for 17 percent of the modeling period. These exceedances continue downstream, at a reduced frequency, throughout the entire 95-mile-long modeling area downstream of the plant.
- Thallium concentrations in the immediate receiving water also exceed the higher water quality benchmark for consumption of organisms only (0.47 µg/L) for 1 percent of the modeling period. These exceedances continue downstream throughout the entire 95-mile-long modeling area downstream of the plant. The frequency of

exceedances downstream ranges from less than 1 percent to 3 percent of the modeling period.

- On rare occasions (less than 1 percent of the modeling period), selenium concentrations in reaches downstream of the immediate receiving water exceed the water quality benchmark for consumption of water and organisms (170 µg/L). These exceedances occur in 5.3 miles of the modeling area downstream of the plant and up to 88 miles downstream of the plant.

These case study modeling results indicate that, under baseline conditions, humans consuming water and/or organisms inhabiting these modeled portions of Black Creek could be at an elevated risk of the negative effects associated with oral exposure to these pollutants (see Section 3.1.1).

Aquatic organisms may be at risk for exposure to cadmium and selenium under baseline conditions, as discussed below:

- Cadmium concentrations in the immediate receiving water exceed the freshwater aquatic life criteria for chronic exposure (0.25 µg/L) for 39 percent of the modeling period. These exceedances continue downstream, at a reduced frequency, throughout 28 miles of the modeling area downstream of the plant.
- Selenium concentrations in the immediate receiving water exceed the freshwater aquatic life criteria for chronic exposure (5.0 µg/L) for 43 percent of the modeling period. These exceedances continue downstream throughout the entire 95-mile-long modeling area downstream of the plant. The frequency of exceedances downstream ranges from 2 percent to 51 percent of the modeling period.

These case study modeling results indicate that, under baseline conditions, aquatic organisms inhabiting these modeled portions of Black Creek could be at an elevated risk of the negative effects associated with oral exposure to these pollutants (see Section 3.1.1).

Under baseline conditions, the modeled pollutant concentrations in the immediate receiving water and downstream reaches occasionally exceed the MCL drinking water benchmarks for three modeled pollutants. The baseline modeled pollutant concentrations exceed drinking water criteria for cadmium, selenium, and thallium, as discussed below:

- On rare occasions (less than 1 percent of the modeling period), cadmium concentrations in the immediate receiving water exceed the MCL benchmark (5 µg/L). These exceedances continue downstream throughout the entire 95- mile-long modeling area downstream of the plant. The frequency of exceedances downstream ranges from less than 1 percent to 5 percent of the modeling period.
- On rare occasions (less than 1 percent of the modeling period), selenium concentrations in the immediate receiving water exceed the MCL benchmark (50 µg/L). These exceedances continue downstream, generally at a reduced frequency, in 93 miles of the modeling area downstream of the plant.
- On rare occasions (less than 1 percent of the modeling period), thallium concentrations in downstream reaches of the modeling area exceed the MCL (2

µg/L). These exceedances occur in 8.9 miles of the modeling area downstream of the plant and up to 92 miles downstream of the plant.

Modeling results do not indicate any exceedances of NRWQC or MCL criteria for the other modeled pollutants (copper, nickel, lead, and zinc). Appendix G of this report includes figures that illustrate the water column pollutant concentration output for the immediate receiving water for arsenic, cadmium, selenium, and thallium. These figures also present the NRWQC and MCL benchmarks for the pollutant and the steady-state water column pollutant concentrations predicted by the IRW model.

The final rule modeling results show significantly decreased concentrations of all modeled pollutants in the immediate receiving water, which will greatly improve water quality. These pollutant removals result in fewer exceedances of NRWQC and MCL benchmarks compared to those estimated in the baseline modeling. Case study modeling results for Black Creek reveal the following water quality improvements under the final rule:

- For arsenic:
  - Exceedances of the human health water quality benchmark for consumption of water and organisms reduce in frequency from 99 percent to 94 percent of the modeling period in the immediate receiving water. Additionally, the exceedances of this benchmark reduce in frequency in all remaining sections of the downstream modeling area following compliance with the final rule. Despite the continued exceedances of this human health criteria, reducing the pollutant concentrations in the water column may decrease the risk to humans consuming contaminated water and organisms.
  - Exceedances of the human health water quality benchmark for consumption of organisms reduce in frequency from 16 percent to 6 percent of the modeling period in the immediate receiving water. Additionally, the exceedances of this benchmark reduce in frequency in all remaining sections of the downstream modeling area following compliance with the final rule. Despite the continued exceedances of this human health criteria, reducing the pollutant concentrations in the water column may decrease the risk to humans consuming contaminated organisms.
- For cadmium:
  - Exceedances of the aquatic life water quality criteria for chronic impacts are eliminated throughout the entire modeling area.
  - Exceedances of the MCL benchmark are eliminated throughout the entire modeling area.
- For selenium:
  - Exceedances of the human health water quality benchmark for consumption of water and organisms are eliminated throughout the entire modeling area.
  - Exceedances of the MCL benchmark are eliminated throughout the entire modeling area.

- Exceedances of the aquatic life water quality criteria for chronic impacts are eliminated in 13 miles of the modeling area, including the immediate receiving water. The exceedances of this benchmark reduce in frequency to less than 4 percent in all remaining sections of the downstream modeling area following compliance with the final rule. Most of these exceedances occur within the first year following compliance with the final rule (due to the gradual recovery of the system following the pollutant loading removals). Despite the continued exceedances of these human health criteria, reducing the pollutant concentrations in the water column may decrease risk to humans consuming contaminated water and/or organisms.

- For thallium:
  - Exceedances of the MCL benchmark are eliminated throughout the entire modeling area.
  - Exceedances of the human health water quality benchmark for consumption of water and organisms reduce in frequency from 17 percent to less than 1 percent of the modeling period in the immediate receiving water. Additionally, the exceedances of this benchmark reduce in frequency in all remaining sections of the downstream modeling area following compliance with the final rule. Despite the continued exceedances of this human health criteria, reducing the pollutant concentrations in the water column may decrease the risk to humans consuming contaminated water and organisms.
  - Exceedances of the human health water quality benchmark for consumption of organisms are eliminated in 6.2 miles of the modeling area, including the immediate receiving water. Additionally, the exceedances of these benchmarks reduce in frequency in all remaining sections of the downstream modeling area following compliance with the final rule. Despite the continued exceedances of this human health criteria, reducing the pollutant concentrations in the water column may decrease risk to humans consuming contaminated organisms.

Modeling Results – Wildlife

EPA assessed the potential threat to piscivorous wildlife from the evaluated wastestreams by modeling the average pollutant concentrations in the water column and comparing these to the concentrations that would trigger exceedances of no effect hazard concentrations (NEHC) for minks and eagles developed by the USGS. Under baseline conditions, Black Creek may pose a risk to minks and eagles that consume fish contaminated with selenium. The average modeled selenium concentrations in 90 miles of the Black Creek modeling area are greater than the concentration that would translate to NEHC exceedances for minks and eagles, demonstrating that the fish inhabiting these portions of Black Creek may pose a potential reproductive threat to terrestrial food webs.

EPA also assessed the potential impact to wildlife exposed to sediments in surface waters by comparing estimated pollutant concentrations in the sediment to sediment biota CSCL benchmarks. Modeling results demonstrate that cadmium concentrations in the upper benthic sediment of the immediate receiving water exceed the CSCL criteria (0.596 mg/kg) during 36 percent of the modeling period. These exceedances continue downstream for 36 miles of the total modeling area.

Ecological risk modeling results indicate that baseline selenium loadings also present an elevated risk of widespread negative reproductive impacts (larval mortality and deformities) among fish that inhabit the immediate receiving water of Black Creek. The results illustrate the significant increase in risk that can result from minor variations in selenium bioaccumulation patterns and toxicity responses within the organisms that inhabit a particular waterbody. Specifically:

- The median (50^{th} percentile) of the model outputs indicates that selenium concentrations in the fish eggs and ovaries would cause reproductive impacts in less than 1 percent of the exposed fish population.
- However, there is a 35 percent probability that these concentrations are high enough to cause reproductive impacts in more than 30 percent of the exposed fish population.
- There is a 25 percent probability that these concentrations are high enough to cause reproductive impacts in *more than 80 percent* of the exposed fish population.

Ecological risk modeling results also indicate an elevated risk of widespread negative reproductive impacts (hatching failure) among mallards that forage or breed in the immediate receiving water of Black Creek. Specifically:

- There is a 50 percent probability that selenium concentrations in the mallard eggs are high enough to cause reproductive impacts in at least 9 percent of the exposed mallard population.
- There is a 35 percent probability that these concentrations are high enough to cause reproductive impacts in more than 20 percent of the exposed mallard population.
- There is a 10 percent probability that these concentrations are high enough to cause reproductive impacts in *more than 70 percent* of the exposed mallard population.

Elevated risks of reproductive impacts to fish and mallards continue downstream from the immediate receiving water. Ecological risk modeling results indicate that the entire 95-mile modeled length of Black Creek has selenium concentrations that lead to a 10 percent or greater probability of negative reproductive impacts among at least 17 percent of the exposed fish or mallard populations. Additionally, several downstream segments of Black Creek (totaling 29 miles) have selenium concentrations that lead to a 25 percent or greater probability of negative reproductive impacts among at least 10 percent of the exposed mallard population.

The case study modeling results demonstrate that the final rule will significantly reduce pollutant concentrations and the associated impacts to wildlife that inhabit Black Creek. The final rule will eliminate selenium exceedances of the NEHC benchmarks for minks and eagles in all modeled reaches of Black Creek. The final rule will also eliminate CSCL benchmark exceedances for cadmium in 27 miles of the modeling area, including the immediate receiving water. The exceedances of this benchmark reduce in frequency to 3 percent or less in all remaining sections of the downstream modeling area following compliance with the final rule. Most of these remaining exceedances occur within the first year following compliance with the final rule. Ecological risk modeling results also indicate that the final rule will eliminate the risk of selenium-related adverse reproductive impacts among exposed fish and mallards in all modeled reaches of Black Creek (*i.e.*, the risk to fish and mallards is less than 0.1 percent at the 95th percentile egg/ovary concentration).

Modeling Results – Human Health

EPA evaluated the potential threat to human receptors due to consumption of contaminated fish from Black Creek. EPA modeled the average pollutant concentrations in the water column and compared these to the concentrations that would trigger exceedances of either the non-cancer reference dose or the 1-in-a-million lifetime excess cancer risk (LECR). Under baseline conditions, the average water column concentration of arsenic throughout the modeling area downstream of the plant does not result in an estimated cancer risk greater than 1-in-a-million for any of the national-scale cohorts. See Appendix E for details on the human health module of the IRW model and national-scale cohorts.

Based on the average pollutant concentrations in the water column under baseline conditions, cadmium, selenium, and thallium pose the greatest threat to cause non-cancer health effects in humans from fish consumption, as discussed below:

- Average thallium concentrations in the water column throughout the entire 95-mile-long modeling area are greater than the concentration that would translate to exceedance of the reference doses for at least one child subsistence fisher cohort (with all child subsistence cohorts impacted by 59 or more miles of the modeling area downstream of the plant), while the concentrations in 90 miles of the modeling area are high enough to trigger exceedance of the reference dose for adult subsistence fishers. Additionally, the average thallium concentrations in 59 miles of the modeling area are high enough to trigger exceedance of the reference dose for at least one child recreational fisher cohort.
- Average selenium concentrations in the water column throughout the entire 95-mile-long modeling area are greater than the concentration that would translate to exceedance of the reference dose for the adult subsistence fisher cohorts and at least one child subsistence fisher cohort (with all child subsistence cohorts impacted by 90 or more miles). Additionally, the average selenium concentrations are high enough to trigger exceedances of the reference doses for adult recreational fishers and at least one child recreational fisher cohort in 13 miles and 90 miles of the modeling area, respectively.
- Average cadmium concentrations in the water column in 38 miles of the modeling area are greater than the concentration that would translate to exceedance of the reference dose for at least one child subsistence fisher cohort.

Therefore, humans who consume cadmium-, selenium-, or thallium-contaminated fish inhabiting these waters may be at greater risk for developing the negative health effects associated with these pollutants, which are discussed in Section 3.1.1.

The modeling results demonstrate significant reductions in average water column concentrations of cadmium, selenium, and thallium under the final rule, which would reduce average cadmium and selenium concentrations enough to eliminate the risk for non-cancer health effects for all cohorts throughout the entire modeling area. These loadings reductions would also reduce the thallium concentrations enough to eliminate the risk for non-cancer health effects for adult subsistence and child recreational fishers. While the case study model continues to show average thallium concentrations that may pose non-cancer health effects for at least one child subsistence cohort, the total area of impact is reduced by up to 37 miles (with some child subsistence cohort non-cancer risks being eliminated throughout the entire modeling period downstream of the plant).

Interpretation of Black Creek Results

Case study modeling results for Black Creek indicate greater water quality, wildlife, and human health impacts to the immediate receiving water under baseline conditions than predicted by the IRW model. Case study modeling results for Black Creek also demonstrate water quality benchmark exceedances and risks to wildlife and humans sustaining beyond Morrow Generating Site's immediate receiving water. In some instances, the average water column concentrations can increase in some portions of the downstream modeling area, posing a greater threat to humans, aquatic organisms, and terrestrial ecosystems. This phenomenon is most pronounced for modeled pollutants with the largest partition coefficients (*i.e.*, lead, zinc, cadmium, and copper) suggesting that sediment transport has significant influence in this small receiving water. Under baseline conditions, significant water quality, wildlife, and human health impacts are identified in the modeled area corresponding with 21-mile span of the waterway that is protected under the National Wild and Scenic River Systems Act.

Ecological risk modeling results for the Black Creek case study indicate that the risk of negative reproductive effects among fish and mallards exposed to selenium may be significantly greater than predicted using water quality outputs from the IRW model. Use of the case study water quality outputs, which include extended periods of elevated selenium concentrations that are not reflected in the IRW model outputs, reveals the potential for widespread ecological impacts among wildlife that inhabit, forage, or breed in the immediate receiving water of Black Creek and its downstream waters.

The USGS stream gage flow data used in the case study model indicate that flow rates in Black Creek are typically lower than the annual average flow rate used in the IRW model, while greatly exceeding the annual average flow rate during occasional high-flow events. During the frequent periods of below-average flow, the pollutant concentrations in the modeling area quickly climb to levels associated with negative impacts to fish, wildlife, and humans.

The exceedances identified in the Black Creek WASP model are based solely on discharges of the evaluated wastestreams from the steam electric power plant because EPA did not identify any STORET monitoring data or point sources suggesting any other sources were contributing pollutant discharges to the modeling area. The Black Creek WASP model may be underestimating the pollutant concentrations actually present if there are other discharges that were not captured in the DMR and TRI data sets. Under the final rule, case study modeling of Black Creek indicates that the waterbody will exhibit fewer exceedances of water quality benchmarks; will no longer pose reproductive risks to higher trophic-level wildlife; will pose less risk to benthic organisms; and will pose less risk to humans consuming fish. The extent of improvements identified by the case study model is greater than what was projected by the IRW model. The decrease of the average pollutant concentrations within the immediate receiving water occurs very quickly after compliance with the final rule; however, some downstream reaches of the modeling area take up to a year to reach equilibrium.

8.2.2 Etowah River Case Study

The Etowah River is a 164-mile-long waterway north of Atlanta, Georgia. The river flows west-southwest from Amicalola Creek, the primary tributary, to Rome, Georgia, where it meets the Oostanaula River and forms the Coosa River at their confluence. Once estimated to have 91 native fish species, the Etowah watershed is biologically one of the richest river systems in North America. Eight imperiled fish species, three of which are federally listed as endangered or threatened, are known to inhabit the Etowah watershed, and five mollusk species are believed to have been decimated [Etowah Aquatic Habitat Conservation Plan, 2015].

Georgia Power Company's Plant Bowen

The Etowah River serves as a source of cooling water for, and receives steam electric wastewater discharges from, Southern Company's Plant Bowen (Plant ID 2244), located in Cartersville, Georgia. In commercial operation since 1975, Plant Bowen is bordered on two sides by the Etowah River and Euharlee Creek. Plant Bowen's four stand-alone steam turbine generating units have a total nameplate capacity of 3,499 MW. As the nation's ninth-largest power plant in net generation of electricity, Plant Bowen reported producing almost 23,000,000 MWh of electricity in 2009 [Georgia Power, 2014]. Based on data EPA obtained in responses to the Steam Electric Survey, Plant Bowen discharges two of the evaluated wastestreams, FGD wastewater and bottom ash transport water, directly to the Etowah River. Table 8-3 contains general information on the four steam electric generating units at Plant Bowen.

In estimating the historical pollutant loadings associated with Plant Bowen's four FGD systems, EPA incorporated the pollutant loadings from FGD wastewater as the systems were installed, between 2008 and 2011. EPA did not model any FGD wastewater pollutant loadings before the installation of Plant Bowen's first FGD system.

Table 8-3. Summary of Plant Bowen Operations

SE Unit	Fuel	Capacity (MW)	Fly Ash	Bottom Ash	FGD (Year Installed)
1	Bituminous coal and No. 2 fuel oil	806	Dry conveyed	Wet handled to impoundment	Wet system (2010)
2	Bituminous coal and No. 2 fuel oil	789	Dry conveyed	Wet handled to impoundment	Wet system (2009)
3	Bituminous coal and No. 2 fuel oil	952	Dry conveyed	Wet handled to impoundment	Wet system (2008)
4	Bituminous coal and No. 2 fuel oil	952	Dry conveyed	Wet handled to impoundment	Wet system (2008)

Source: ERG, 2015j.

Acronyms: FGD (Flue gas desulfurization); MW (Megawatt); SE (steam electric).

Modeling Area

The Etowah River WASP model encompasses a 35-mile segment of the Etowah River, extending from the immediate receiving water to the confluence of the Etowah River and Silver Creek. The immediate receiving water to which Plant Bowen discharges is approximately 3.6 miles long, as defined in the WASP model. Figure 8-3 illustrates the location and extent of the Etowah River WASP model.

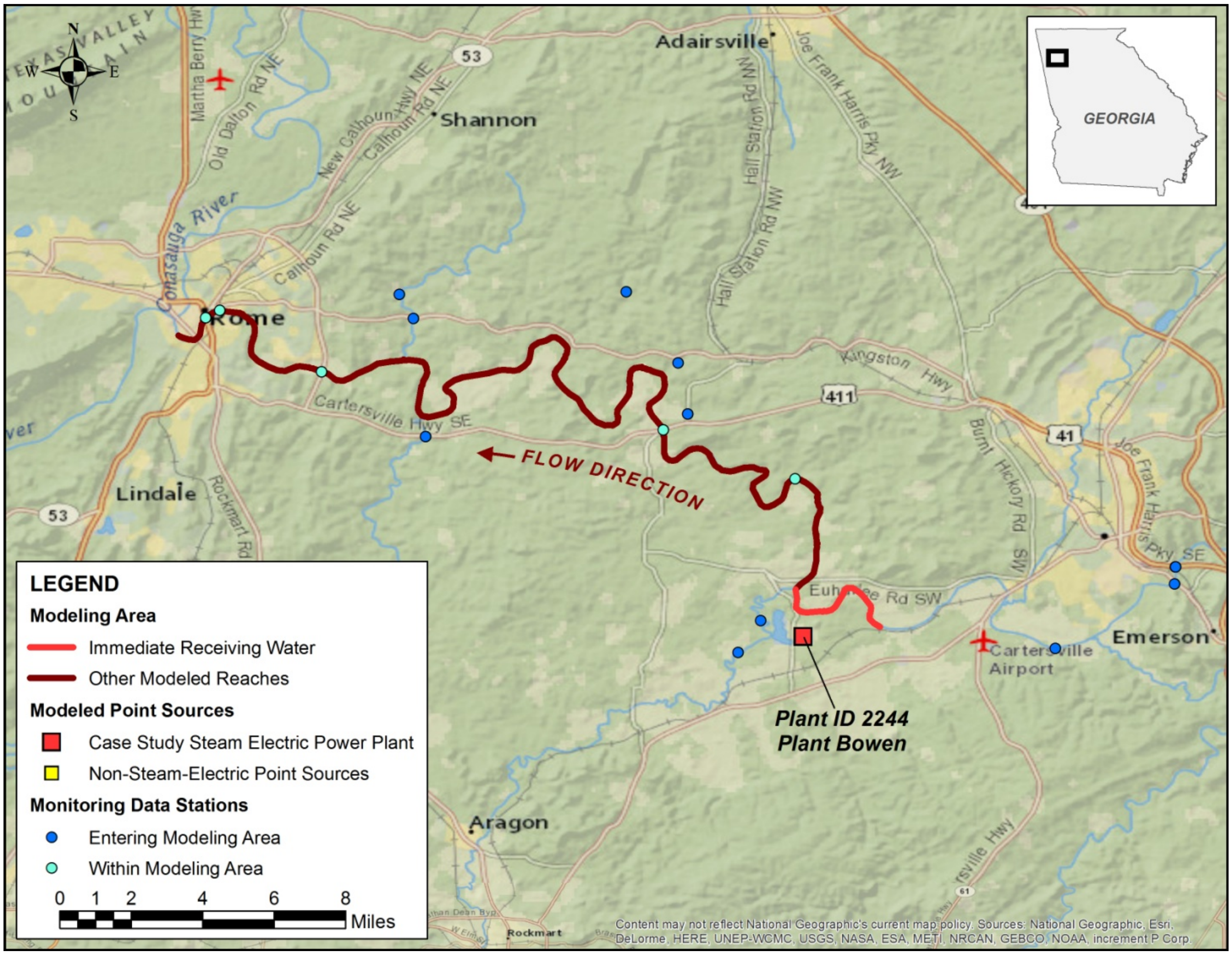


Figure 8-3. Etowah River WASP Modeling Area

Identified Point Sources and Background Concentrations

As discussed below, EPA reviewed available pollutant loadings (DMR and TRI) and monitoring data (STORET) for potential incorporation into the Etowah River WASP model to represent pollutant contributions from background and non-steam-electric point sources, and for use in calibrating the model results.

- **Upstream pollutant contributions**. EPA incorporated STORET data from four monitoring stations to represent the pollutant contributions from upstream of the Plant Bowen immediate receiving water. EPA also identified two upstream non-steam-electric point sources whose pollutant loadings (from DMR and TRI data sets) could influence the model results; however, EPA assumed that the STORET data from the four monitoring stations (which encompass all of the modeled pollutants except for selenium) adequately reflect the pollutant contributions from upstream point sources. Therefore, EPA did not incorporate pollutant loadings from the two identified upstream non-steam-electric point sources.

- **Downstream pollutant contributions**. EPA incorporated STORET data from 10 monitoring stations to represent the pollutant concentrations flowing into the modeling area downstream of the Plant Bowen immediate receiving water (*i.e.*, tributaries flowing into the Etowah River). EPA did not identify any non-steam-electric point sources whose pollutant loadings would significantly influence the model results in the downstream modeling area.
- **Monitoring data within the modeling area**. EPA compiled STORET data from six monitoring stations located within the modeling area and used these data to calibrate the WASP model.

The contributions of arsenic, cadmium, copper, lead, and thallium from upstream sources have a much greater influence on the modeled pollutant concentrations in the Etowah River than the pollutant loadings from Plant Bowen. The contributions of nickel and zinc from upstream sources also strongly influence the modeled pollutant concentrations in the Etowah River.

The Etowah River case study model did not account for the documented surface water impacts from Plant Bowen that are discussed in Section 3.3.3. In 2002, a sinkhole developed in the surface impoundment at Plant Bowen that released 2.25 million gallons of ash/water mixture, estimated to contain 80 tons of ash, to Euharlee Creek, which immediately flows into the Etowah River [U.S. EPA, 2014b]. Additionally, an extreme rainfall event in 2008 caused a dry ash stockpile to collapse, depositing approximately two tons of ash in Euharlee Creek. The surface water quality impacts resulting from these events are not reflected in this model; therefore, the case study modeling could under-represent the actual baseline impacts of Plant Bowen on the Etowah River.

Modeling Period

The modeling period starts in 1982 (the year of the last revision to the steam electric ELGs) and extends through 2032, covering a period of 51 years. Based on Plant Bowen's NPDES permitting cycle, EPA assumes that the plant will achieve the limitations under the final rule by 2021.

Modeling Results – Water Quality

Under baseline conditions, the modeled pollutant concentrations in the immediate receiving water and downstream reaches exceed the NRWQC water quality benchmarks for five modeled pollutants, indicating that pollutant loadings from Plant Bowen may contribute to a quantifiable reduction in water quality in the modeled portions of the Etowah River. The reduced water quality is primarily attributed to arsenic, cadmium, selenium, thallium, and lead.

The baseline modeled water concentrations exceed human health criteria primarily for arsenic and thallium, as discussed below:

- Arsenic concentrations in the immediate receiving water exceed the water quality benchmark for consumption of water and organisms (0.018 µg/L) for the entire modeling period. These exceedances continue downstream, at the same frequency, throughout the entire 35-mile-long modeling area downstream of the plant.

- Arsenic concentrations in the immediate receiving water also exceed the higher water quality benchmark for consumption of organisms only (0.14 µg/L) for the entire modeling period. These exceedances continue downstream, at the same frequency, throughout the entire 35-mile-long modeling area downstream of the plant.
- Thallium concentrations in the immediate receiving water exceed the water quality benchmarks for consumption of water and organisms (0.24 µg/L) for more than 99 percent of the modeling period. These exceedances continue downstream, at an increased frequency, throughout the entire 35-mile-long modeling area downstream of the plant.
- Thallium concentrations in the immediate receiving water also exceed the higher water quality benchmark for consumption of organisms only (0.47 µg/L) for 90 percent of the modeling period. These exceedances continue downstream, at an increased frequency, throughout the entire 35-mile-long modeling area downstream of the plant.

These case study modeling results indicate that, under baseline conditions, humans consuming water and/or organisms inhabiting these modeled portions of the Etowah River may be more at risk of the negative effects associated with oral exposure to arsenic and thallium (see Section 3.1.1).

Aquatic organisms may be at risk for exposure to cadmium and selenium under baseline conditions, specifically:

- Cadmium concentrations in the immediate receiving water exceed the freshwater aquatic life criteria for chronic exposure (0.25 µg/L) for 52 percent of the modeling period. These exceedances continue downstream throughout the 35-mile-long modeling area downstream of the plant. The frequency of exceedances downstream ranges from 33 percent to 55 percent of the modeling period.
- On rare occasions (less than 1 percent of the modeling period), selenium concentrations in downstream reaches of the modeling area exceed the freshwater aquatic life criteria for chronic exposure (5 µg/L). These exceedances occur in 4.7 miles of the downstream modeling area downstream of the plant and up to 35 miles downstream of the plant.

These modeling results indicate that, under baseline conditions, aquatic organisms residing in the portions of the Etowah River with modeled exceedances may be more at risk to negative impacts from chronic exposure to cadmium and selenium.

Under baseline conditions, the modeled pollutant concentrations in the immediate receiving water and downstream reaches exceed the MCL drinking water benchmarks for four modeled pollutants. The baseline modeled pollutant concentrations exceed drinking water criteria for thallium, arsenic, cadmium and lead as discussed below:

- Thallium concentrations in the immediate receiving water exceed the MCL benchmark (2 µg/L) for 29 percent of the modeling period. These exceedances continue downstream, at a reduced frequency, throughout the entire 35-mile-long modeling area downstream of the plant.

- On rare occasions (less than 1 percent of the modeling period), arsenic concentrations in the immediate receiving water exceed the MCL benchmark (10 µg/L). These exceedances do not occur beyond the 3.6-mile-long immediate receiving water.
- On rare occasions (less than 1 percent of the modeling period), cadmium concentrations in downstream reaches of the modeling area exceed the MCL benchmark (5 µg/L). These exceedances occur in 5.1 miles of the downstream modeling area downstream of the plant and up to 35 miles downstream of the plant.
- On rare occasions (less than 1 percent of the modeling period), lead concentrations in downstream reaches of the modeling area exceed the MCL benchmark (15 µg/L). These exceedances occur in 5.1 miles of the downstream modeling area downstream of the plant and up to 35 miles downstream of the plant.

Modeling results do not indicate any exceedances of NRWQC or MCL criteria for the other modeled pollutants (copper, nickel, and zinc). Appendix G of this report includes figures that illustrate the water column pollutant concentration output for the immediate receiving water for arsenic, cadmium, selenium, and thallium. These figures also present the NRWQC and MCL benchmarks for the pollutant and the steady-state water column pollutant concentrations predicted by the IRW model.

The final rule modeling results show a significant reduction in selenium concentrations and moderately decreased concentrations of cadmium, nickel, and zinc within the Etowah River, which will improve water quality. These pollutant removals result in fewer exceedances of NRWQC and MCL benchmarks compared to those estimated in the baseline modeling. Case study modeling results for the Etowah River reveal the following water quality improvements under the final rule:

- Exceedances of the cadmium aquatic life water quality criteria for chronic impacts reduce in frequency (by 13 percent) in the immediate receiving water. Additionally, the exceedances of these benchmarks reduce in frequency in all remaining sections of the downstream modeling area following compliance with the final rule. Despite continued exceedances of these aquatic life criteria, reducing the pollutant concentrations in the water column may decrease the risk to aquatic life in the Etowah River.
- Exceedances of the selenium aquatic life water quality criteria for chronic impacts are eliminated throughout the entire modeling area.

While case study modeling results continue to show exceedances for NRWQC benchmark exceedances of arsenic and thallium and MCL benchmark exceedances of arsenic, cadmium, lead, and thallium, the final rule will reduce loading contributions of these pollutants from Plant Bowen.

Modeling Results – Wildlife

Based on the average pollutant concentrations in the water column under baseline conditions, the modeled portion of the Etowah River does not exceed the concentrations that would translate to NEHC exceedances and does not pose a risk to minks and eagles that consume contaminated fish. Despite the modeling not being able to quantify any improvements to minks and eagles under the final rule, the pollutant loading removals will decrease bioaccumulation of toxic pollutants in the terrestrial food chains.

Modeling results do not indicate that there are any pollutant concentrations in the upper benthic sediment that exceed CSCL benchmarks of for any of the eight modeled pollutants; therefore, the Etowah River does not pose a threat to benthic organisms in contact with contaminated sediment. Despite the modeling not being able to quantify any improvements to benthic organisms under the final rule, the pollutant loading removals will decrease the concentrations of toxic pollutants in benthic sediment and decrease the exposure of organisms to these pollutants.

Modeling Results – Human Health

EPA modeled the average pollutant concentrations in the water column and compared these to the concentrations that would trigger exceedances of either the non-cancer reference dose or the 1-in-a-million lifetime excess cancer risk (LECR). Under baseline conditions, the average water column concentration of arsenic in the immediate receiving water over the modeling period results in an estimated cancer risk greater than 1-in-a-million for adult subsistence fishers. These exceedances do not occur beyond the 3.6-mile-long immediate receiving water. Therefore, adults who frequently consume arsenic-contaminated fish inhabiting the immediate receiving water may be at greater risks for development of cancer. Modeling results demonstrate no reduction in the cancer risk from inorganic arsenic under the final rule.

Based on the average pollutant concentrations in the water column under baseline conditions, selenium and thallium pose the greatest threat to cause non-cancer health effects in humans from fish consumption, as discussed below:

- Average selenium concentrations in the immediate receiving water are greater than the concentrations that would translate to exceedance of the reference doses for the child (younger than 11 years old) subsistence fisher cohorts. The average selenium concentrations throughout the entire 35-mile-long modeling area downstream of the plant are greater than the concentration that would translate to an exceedance of the reference dose for least one child subsistence cohort.
- Average thallium concentrations in the water column throughout the entire 35-mile-long modeling area downstream of the plant are greater than the concentrations that would translate to exceedance of the reference doses for adult and children recreational and subsistence fishers (all national-scale cohorts evaluated).

Therefore, humans who consume selenium- or thallium-contaminated fish inhabiting the modeled area of the Etowah River may be at greater risk for developing the negative health effects associated with these pollutants, which are discussed in Section 3.1.1.

The final rule modeling results demonstrate significant reductions in selenium concentrations in the Etowah River, which will eliminate selenium exceedances of the non-cancer health effects reference dose for all cohorts. While the modeling results continue to show thallium water concentrations that would translate to exceedances of the non-cancer health effects reference dose, the final rule will reduce thallium loading contributions from Plant Bowen.

Interpretation of Etowah River Results

Case study modeling results for the Etowah River indicate greater water quality and human health impacts than predicted by the IRW model (IRW modeling results did not indicate any quantifiable impacts in the immediate receiving water of Plant Bowen). By accounting for background pollutant contributions from upstream sources and other boundaries (for all modeled pollutants except selenium), case study modeling predicts higher pollutant concentrations under baseline conditions. For arsenic and thallium, and to a lesser extent cadmium, the projected exceedances are driven by the background concentrations flowing into the Etowah River modeling area. Plant Bowen's discharges of the evaluated wastestreams may be further impairing the degraded waterway.

Case study modeling results for the Etowah River also demonstrate water quality benchmark exceedances and risks to humans occur beyond Plant Bowen's immediate receiving water. In some instances, the average water column concentrations can increase in some portions of the downstream modeling area, posing a greater threat to humans and aquatic life. This phenomenon is most pronounced for modeled pollutants with the largest partition coefficients (*i.e.*, lead, zinc, cadmium, and copper), suggesting that sediment transport has moderate influence in the Etowah River.

Case study modeling of the Etowah River indicates that, under the final rule, the Etowah River will exhibit fewer exceedances of water quality benchmarks and pose less risk to humans consuming fish that inhabit these waters. The improvements identified by the case study model are more extensive than what was projected by the IRW model. This is due in part to the greater water quality and human health impacts under baseline conditions, which created additional opportunities for modeled improvements, and in part to the identified improvements in downstream reaches of the Etowah River that were not evaluated as part of the IRW model. The average pollutant concentrations throughout the entire modeling area reduce promptly after compliance with the final rule.

8.2.3 Lick Creek & White River Case Study

The White River is a two-forked river that primarily flows southwest through central and southern Indiana. The two forks, the West Fork and the East Fork, are nearly equal in size when they converge in Daviess Country, just north of Petersburg, Indiana. From this confluence, the White River flows west-southwest for 50 river-miles until it joins the Wabash River at the Illinois-Indiana state border. Located on the banks of the lower White River, Indianapolis Power & Light's (IPL) Petersburg Generating Station (Plant ID 3997) has four stand-alone steam turbine units with a nameplate capacity of 1,864 MW. The plant reported that these four coal-fired generating units produced more than 12,000,000 MWh of electricity in 2009 in the Steam

Electricity Survey. Petersburg Generating Station also operates three minor oil-burning internal combustion units, which are exempt from the requirements of the final rule. Based on data obtained in responses to the Steam Electric Survey, this power plant discharges FGD wastewater and bottom ash transport water. Table 8-4 contains general information on the four coal-fired generating units at Petersburg Generating Station.

In estimating the historical pollutant loadings associated with Petersburg Generating Station's four FGD systems, EPA incorporated the pollutant loadings from FGD wastewater as the systems were installed, between 1977 and 1996. EPA included the pollutant loadings from the FGD systems on units 3 and 4 at the start of the historical modeling period (1986).

IPL's Petersburg Generating Station

Table 8-4. Summary of Petersburg Generating Station Operations

SE Unit	Fuel	Capacity (MW)	Fly Ash [a]	Bottom Ash	FGD (Year Installed)
1	Subbituminous coal and No. 2 fuel oil	255	Dry conveyed	Wet handled to impoundment	Wet system (05/1996)
2	Subbituminous coal and No. 2 fuel oil	445	Dry conveyed	Wet handled to impoundment	Wet system (05/1996)
3	Subbituminous coal and No. 2 fuel oil	580	Dry conveyed	Wet handled to impoundment	Wet system (11/1977)
4	Subbituminous coal and No. 2 fuel oil	584	Dry conveyed	Wet handled to impoundment	Wet system (04/1986)

Source: ERG, 2015j.

Acronyms: FGD (Flue gas desulfurization); MW (Megawatt); SE (steam electric).

a – Based on EPA projections, Petersburg Generating Station will convert to dry ash handling to comply with the CCR rulemaking.

Modeling Area

Based on data obtained in responses to the Steam Electric Survey, Petersburg Generating Station discharges FGD wastewater and bottom ash transport water to Lick Creek, a 1.8-mile-long tributary emptying into the White River. The White River WASP model encompasses Lick Creek and a 52-mile reach of the White River, 49 miles of which is downstream of Lick Creek. The immediate receiving water, Lick Creek, is the first of three upstream modeling boundaries for this WASP model. The other upstream model boundaries are on the West Fork White River and East Fork White River approximately one mile upstream of their confluence. EPA extended the modeling area upstream of Lick Creek to capture and incorporate available STORET monitoring data as further described below. The Lick Creek and White River WASP model ends at the confluence of the White River with the Wabash River. Figure 8-4 illustrates the location and extent of the White River WASP model.

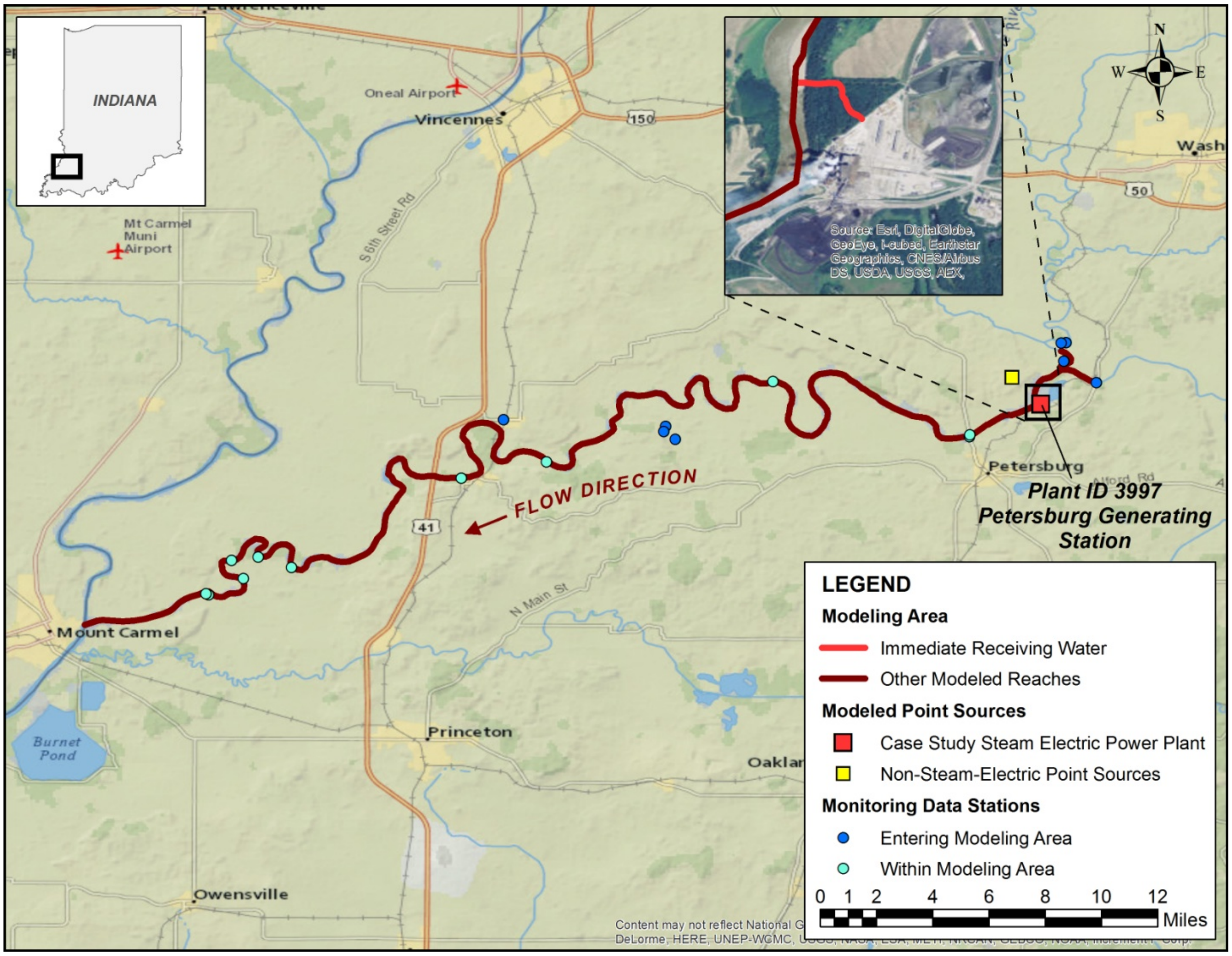


Figure 8-4. Lick Creek and White River WASP Modeling Area

Identified Point Sources and Background Concentrations

As discussed below, EPA reviewed available pollutant loadings (DMR and TRI) and monitoring data (STORET) for potential incorporation into the Lick Creek and White River WASP model to represent pollutant contributions from background and non-steam-electric point sources, and for use in calibrating the model results.

- **Upstream pollutant contributions (Lick Creek)**. EPA did not identify sufficient STORET monitoring data to represent pollutant contributions from upstream of the Petersburg Generating Station immediate receiving water (Lick Creek). EPA did not identify any upstream non-steam-electric point sources with loadings for the eight modeled pollutants on Lick Creek. EPA therefore assumed pollutant concentrations of zero within the water column at the upstream boundary of the modeling area.
- **Upstream pollutant contributions (West Fork White River)**. EPA incorporated STORET data from three monitoring stations to represent the pollutant contributions

from upstream on the west fork of the White River. EPA also identified three upstream non-steam-electric point sources whose pollutant loadings (from DMR and TRI data sets) could influence the model results; however, EPA assumed that the STORET monitoring data (which include all of the modeled pollutants except for thallium) adequately reflect the pollutant contributions from upstream point sources. Similarly, EPA identified that a steam electric power plant, Edwardsport Generating Station (Plant ID 8544), has historically discharged to the west fork of the White River 30 miles upstream of the start boundary. Edwardsport Generating Station discontinued operation of all steam electric generating units in 2011 to construct a new integrated gasification combined cycle power plant. EPA assumed that the STORET monitoring data adequately reflect the pollutant contributions from this point source. Therefore, EPA did not incorporate pollutant loadings from the three identified upstream non-steam-electric point sources or Edwardsport Generating Station into the WASP model.

- **Upstream pollutant contributions (East Fork White River)**. EPA incorporated STORET data from one monitoring station to represent the pollutant contributions from upstream on the east fork of the White River. EPA also identified one upstream non-steam-electric point source whose pollutant loadings (from DMR and TRI data sets) could influence the model results; however, EPA assumed that the STORET monitoring data (which include all of the modeled pollutants) adequately reflect the pollutant contributions from upstream point sources. Therefore, EPA did not incorporate pollutant loadings from this identified upstream non-steam-electric point source in the WASP model.
- **Downstream pollutant contributions**. EPA incorporated STORET data from four monitoring stations to represent the pollutant concentrations flowing into the modeling area downstream of the Petersburg Generating Station immediate receiving water, Lick Creek (*i.e.*, tributaries flowing into the White River). EPA did identify one non-steam-electric point source that discharges one or more of the modeled pollutants within the modeling area. EPA incorporated the pollutant loadings from the identified non-steam-electric point source into the model.
- **Monitoring data within the modeling area.** EPA compiled STORET data from 12 monitoring stations located within the modeling area and used these data to calibrate the WASP model.

The contributions of arsenic, cadmium, copper, nickel, lead, and zinc from upstream sources have a much greater influence on the modeled pollutant concentrations in White River than the pollutant loadings from Petersburg Generating Station.

Due to the lack of pollutant loadings data, the White River case study model did not account for the ground water impacts from Petersburg Generating Station associated with the damage case listed in Appendix A. In 1997, the catastrophic release of coal combustion residuals degraded the quality of ground water and surface water around the plant.

The White River case study model does not account for pollutant loadings from Hoosier Energy's Frank E. Ratts (Ratts) Generating Station (Plant ID 2314), a 232-MW steam electric power plant located less than a mile downstream of Petersburg Generating Station. Based on information obtained in responses to the Steam Electric Survey, Ratts Generating Station discharged one or more of the evaluated wastestreams directly to the White River. This plant, however, has publicly announced plans to retire all of its steam generating units prior to implementation of the final rule. EPA therefore excluded pollutant loadings from the Ratts Generating Station so that the changes in pollutant loadings during the modeling period, and the associated environmental improvements, reflect only those attributable to the final rule.

Modeling Period

The modeling period starts in 1986 (the year the last generating unit at Petersburg Generating Station began operating) and extends through 2034, covering a period of 49 years. Based on Petersburg Generating Station's NPDES permitting cycle, EPA assumes that the plant will achieve the limitations under the final rule by 2019.

Modeling Results – Water Quality

Under baseline conditions, the modeled pollutant concentrations in Lick Creek, the immediate receiving water exceed NRWQC water quality benchmarks for five modeled pollutants, indicating that pollutant loadings from the Petersburg Generating Station may quantifiably reduce water quality in the modeled portions of Lick Creek. Additionally, the modeled pollutant concentrations in portions of the White River downstream of Lick Creek exceed NRWQC water quality benchmarks for four of the modeled pollutants, indicating that the water quality downstream of Lick Creek may also be reduced by the pollutant loadings form Petersburg Generating Station.

The baseline modeled pollutant concentrations exceed human health criteria primarily for arsenic, thallium, and selenium, as discussed below:

- Arsenic concentrations in Lick Creek exceed the water quality benchmark for consumption of water and organisms (0.018 µg/L) for the entire modeling period. These exceedances continue downstream in the White River, at the same frequency, throughout the entire 50-mile-long modeling area downstream of the plant.
- Arsenic concentrations in Lick Creek also exceed the higher water quality benchmark for consumption of organisms only (0.14 µg/L) for the entire modeling period. These exceedances continue downstream in the White River, generally at the same frequency, throughout the entire 50-mile-long modeling area downstream of the plant.
- Thallium concentrations in Lick Creek exceed the water quality benchmarks for consumption of water and organisms (0.24 µg/L) for the entire modeling period. These exceedances continue downstream in the White River, at a much lower frequency (less than 2 percent of the modeling period), throughout the entire 50-mile-long modeling area downstream of the plant.
- Thallium concentrations in Lick Creek also exceed the higher water quality benchmark for consumption of organisms only (0.47 µg/L) for the entire modeling period. On rare occasions (less than 1 percent of the modeling period), thallium concentrations in reaches downstream in the White River also exceed this benchmark.

These downstream exceedances occur in 26 miles of the modeling area downstream of the plant and up to 31 miles downstream of the plant.

- On rare occasions (less than 1 percent of the modeling period), selenium concentrations in Lick Creek exceed the water quality benchmark for consumption of water and organisms (170 µg/L). These exceedances do not occur downstream after the confluence of the Lick Creek and White River.

These case study modeling results indicate that, under baseline conditions, humans consuming water and/or organisms inhabiting these modeled portions of Lick Creek and the White River may be more at risk of the negative effects associated with oral exposure to these pollutants (see Section 3.1.1).

Aquatic organisms may be at risk for exposure to copper, selenium, and cadmium under baseline conditions, as discussed below:

- Copper concentrations in Lick Creek exceed the freshwater aquatic life criteria for chronic exposure (9.0 µg/L) for 45 percent of the modeling period. These exceedances do not occur downstream after the confluence of the Lick Creek and White River.
- Copper concentrations in Lick Creek also exceed the higher freshwater aquatic life criteria for acute exposure (13 µg/L) for 25 percent of the modeling period. These exceedances do not occur downstream after the confluence of the Lick Creek and White River.
- Selenium concentrations in Lick Creek exceed the freshwater aquatic life criteria for chronic exposure (5.0 µg/L) for 99 percent of the modeling period. On rare occasions (less than 1 percent of the modeling period), selenium concentrations in reaches downstream in the White River also exceed this benchmark. These downstream exceedances occur in 21 miles of the modeling area downstream of the plant and up to 32 miles downstream of the plant.
- Cadmium concentrations in Lick Creek exceed the freshwater aquatic life criteria for chronic exposure (0.25 µg/L) for 86 percent of the modeling period. On rare occasions (less than 1 percent of the modeling period), cadmium concentrations in reaches downstream in the White River also exceed this benchmark. These downstream exceedances occur in 18 miles of the modeling area downstream of the plant.

These modeling results indicate that, under baseline conditions, aquatic organisms residing in the portions of Lick Creek and the White River with modeled exceedances may be more at risk to negative impacts from chronic exposure to cadmium and selenium. Additionally, the copper loadings from Petersburg Generating Station may pose a threat from chronic or acute exposure.

Under baseline conditions, the modeled pollutant concentrations in Lick Creek and downstream reaches in the White River exceed the MCL drinking water benchmarks for five modeled pollutants. The baseline modeled pollutant concentrations exceed drinking water criteria for thallium, selenium, arsenic, lead, and cadmium as discussed below:

- Thallium concentrations in Lick Creek exceed the MCL benchmark (2 µg/L) for 96 percent of the modeling period. These exceedances do not occur downstream after the confluence of the Lick Creek and White River.
- Selenium concentrations in Lick Creek exceed the MCL benchmark (50 µg/L) for 38 percent of the modeling period. These exceedances do not occur downstream after the confluence of the Lick Creek and White River.
- Arsenic concentrations in Lick Creek exceed the MCL benchmark (10 µg/L) for 34 percent of the modeling period. These exceedances occur in 8.0 miles of the modeling area downstream of the plant and up to 35 miles downstream of the plant.
- On rare occasions (less than 1 percent of the modeling period), lead concentrations in Lick Creek exceed the MCL benchmark (15 µg/L). These exceedances continue to occur downstream in 24 miles of the White River as far as the end of the model (50 miles downstream of the plant discharge).
- On rare occasions (less than 1 percent of the modeling period), cadmium concentrations in Lick Creek exceed the MCL benchmark (0.25 µg/L). These exceedances do not occur downstream after the confluence of the Lick Creek and White River.

Modeling results do not indicate any exceedances of NRWQC or MCL criteria for nickel or zinc. Appendix G of this report includes figures that illustrate the water column pollutant concentration output for the immediate receiving water for arsenic, cadmium, copper, lead, selenium, and thallium. These figures also present the NRWQC and MCL benchmarks for the pollutant and the steady-state water column pollutant concentrations predicted by the IRW model.

The final rule modeling results show significantly decreased concentrations of all modeled pollutants in the immediate receiving water (Lick Creek), which will greatly improve water quality. The final modeling results also demonstrate that the reduction of pollutant loadings from Petersburg Generating Station will significantly reduce the concentrations of selenium and thallium in the White River, downstream of Lick Creek. These pollutant removals result in fewer exceedances of NRWQC and MCL benchmarks compared to those estimated in the baseline modeling. Case study modeling results for Lick Creek and the White River reveal the following water quality improvements under the final rule:

- For arsenic:
    - Exceedances of the MCL benchmark are eliminated in Lick Creek. Despite the continued exceedances of this benchmark, at the same frequency, downstream in the White River, reducing the pollutant concentrations in the water column may decrease the human health risk.
    - Exceedances of the human health water quality benchmark for consumption of organisms reduce in frequency from 100 percent to 87 percent of the modeling

period in Lick Creek. Despite the continued exceedances of this human health criteria, at the same frequency, downstream in the White River, reducing the pollutant concentrations in the water column may decrease the risk to humans consuming contaminated organisms.

- For cadmium:
  - Exceedances of the aquatic life water quality criteria for chronic impacts are eliminated throughout the entire modeling area.
  - Exceedances of the MCL benchmark (observed only in Lick Creek under baseline conditions) are eliminated throughout the entire modeling area.
- For copper:
  - Exceedances of the aquatic life water quality criteria for chronic and acute impacts (observed only in Lick Creek under baseline conditions) are eliminated throughout the entire modeling area.
- For lead:
  - Exceedances of the MCL benchmark are eliminated in Lick Creek. Despite the continued exceedances of this benchmark, at the same frequency, downstream in the White River, reducing the pollutant concentrations in the water column may decrease the human health risk.
- For selenium:
  - Exceedances of the aquatic life water quality criteria for chronic impacts are eliminated throughout the entire modeling area.
  - Exceedances of the human health water quality benchmark for consumption of water and organisms (observed only in Lick Creek under baseline conditions) are eliminated throughout the entire modeling area.
  - Exceedances of the MCL benchmark (observed only in Lick Creek under baseline conditions) are eliminated throughout the entire modeling area.
- For thallium:
  - Exceedances of the MCL benchmark reduce in frequency from 96 percent to less than 1 percent of the modeling period in Lick Creek.
  - Exceedances of the human health water quality benchmark for consumption of water and organisms reduce in frequency from 100 percent to 84 percent of the modeling period in Lick Creek. Exceedances of this benchmark are eliminated through the modeling area downstream of the immediate receiving water (after the confluence of the Lick Creek and White River).
  - Exceedances of the human health water quality benchmark for consumption of organisms reduce in frequency from 100 percent to 61 percent of the modeling period in Lick Creek. Exceedances of this benchmark are eliminated through the modeling area downstream of the immediate receiving water (after the confluence of the Lick Creek and White River).

The final rule modeling results demonstrate that, due to background concentrations of arsenic from upstream sources, there will still be exceedances of the human health water quality benchmark for consumption of water and organisms throughout the entire modeling area downstream of the plant; however, the final rule will reduce the arsenic loadings that the Petersburg Generating Station contributes to the White River.

Modeling Results – Wildlife

Under baseline conditions, Lick Creek may pose a risk to minks and eagles that consume fish contaminated with selenium. The average modeled selenium concentration in Lick Creek is more than 18 times greater than the concentration that would translate to NEHC exceedances for minks and eagles, demonstrating that this portion of the immediate receiving water may pose a potential reproductive threat to terrestrial food webs. The water concentrations downstream after the confluence of the Lick Creek and White River do not pose a threat to these indicator species.

Modeling results indicate that on rare occasions (less than 1 percent of the modeling period), nickel concentrations in benthic sediment downstream reaches exceed the CSCL benchmark (18 mg/kg). These exceedances occur in 3.0 miles of the modeling area downstream of the plant and up to 35 miles downstream of the plant.

The case study modeling results demonstrate that the final rule will significantly reduce pollutant concentrations and the associated impacts to wildlife that inhabit Lick Creek. The final rule will eliminate selenium exceedances of the NEHC benchmarks for minks and eagles in all modeled reaches of Lick Creek. Despite the modeling not being able to quantify any improvements to benthic organisms under the final rule, the pollutant loading removals will decrease the concentrations of toxic pollutants in benthic sediment and decrease the exposure of organisms to these pollutants.

Modeling Results – Human Health

EPA modeled the average pollutant concentrations in the water column and compared these to the concentrations that would trigger exceedances of either the non-cancer reference dose or the 1-in-a-million LECR. Under baseline conditions, the average water column concentration of arsenic in the immediate receiving water over the modeling period results in an estimated cancer risk of approximately 3-in-a-million for adult subsistence fishers. Therefore, adults who frequently consume arsenic-contaminated fish inhabiting the immediate receiving water may be at greater risks for development of cancer.

Based on the average pollutant concentrations in the water column under baseline conditions, cadmium, selenium, and thallium pose the greatest threat to cause non-cancer health effects in humans from fish consumption, as discussed below:

- Average thallium concentrations in Lick Creek are significantly greater than the concentrations that would translate to exceedances of the reference doses for adult and children recreational and subsistence fishers (all national-scale cohorts evaluated), with some cohorts potentially being exposed to concentrations more than 200 times the reference dose. The water concentrations downstream after the confluence of the Lick Creek and White River do not pose a threat to any of the evaluated cohorts.

- Average selenium concentrations in Lick Creek are greater than the concentration that would translate to exceedances of the reference doses for adult and children recreational and subsistence fishers (all national-scale cohorts evaluated). The water concentrations downstream after the confluence of the Lick Creek and White River do not pose a threat to any of the evaluated cohorts.
- Average cadmium concentrations in Lick Creek are greater than the concentration that would translate to exceedances of the reference doses for the child (younger than 11 years old) subsistence fisher cohorts. The water concentrations downstream after the confluence of the Lick Creek and White River do not pose a threat to any of the evaluated cohorts.

Therefore, humans who consume thallium-, selenium-, or cadmium-contaminated fish inhabiting Lick Creek may be at greater risk for developing the negative health effects associated with these pollutants, which are discussed in Section 3.1.1.

The final rule modeling results demonstrate significant reductions in selenium and cadmium concentrations in Lick Creek, which will eliminate exceedances of the non-cancer health effects reference dose for all cohorts for these pollutants. While the modeling results continue to show thallium water concentrations that would translate to exceedances of the non-cancer health effects reference doses for all cohorts, the final rule will reduce the magnitude of the human health impacts and reduce thallium loading contributions from Petersburg Generating Station.

Interpretation of Lick Creek and White River Results

Case study modeling results for Lick Creek indicate that there are severe water quality, wildlife, and human health impacts in Lick Creek. Case study modeling of Lick Creek reveals more exceedances of water quality and human health benchmarks than the IRW model; however, the IRW model predicts more impacts to benthic organisms than the case study modeling results. The exceedances identified in Lick Creek are based solely on discharges of the evaluated wastestreams from Petersburg Generating Station because EPA did not identify any STORET monitoring data or point sources suggesting any other sources were contributing pollutant discharges on this small tributary.

The pollutant loadings discharged by Petersburg Generating Station contribute to the overall concentrations in the White River, along with other upstream sources. Case study modeling indicates that some of the water quality impacts identified in Lick Creek for arsenic, cadmium, selenium, thallium, and lead can occur in the White River, far downstream of where Lick Creek flows into it. For thallium, these downstream impacts are solely caused by the discharges of the evaluated wastestreams from the plant because EPA did not identify any other sources of thallium within the modeling period. For arsenic and lead, the projected exceedances are driven by the background concentrations flowing into the White River modeling area. Pollutant loadings from Petersburg Generating Station may be further impairing the degraded waterway for arsenic and lead. For lead and zinc, the average water column concentrations are highest downstream in the White River, indicating that pollutants with high partition coefficients may pose a greater threat to humans and aquatic life in the White River than in Lick Creek. The case study modeling results suggest that while high concentrations of toxic pollutants may dilute once Lick Creek empties into the White River, there are still impacts downstream that are not captured by the IRW model.

Under the final rule, case study modeling of Lick Creek and the White River indicate that both these waterbodies will exhibit fewer exceedances of water quality benchmarks. Additionally, Lick Creek will no longer pose reproductive risks to higher trophic-level wildlife and will pose less risk to humans consuming fish for cancer and non-cancer impacts. Case study modeling predicts more water quality improvements in the modeling area than the IRW model. This is due in part to the greater water quality impacts under baseline conditions, which created additional opportunities for modeled improvements, and in part to the identified improvements in downstream reaches of the White River that were not evaluated as part of the IRW model. Case study modeling predict fewer human health improvements than the IRW model. The average pollutant concentrations throughout the entire modeling area reduce promptly after compliance with the final rule.

8.2.4 Ohio River Case Study

The 948-mile Ohio River flows westward from Pittsburgh, Pennsylvania, to Cairo, Illinois, where it meets the Mississippi River. According to 2013 TRI reporting, 23 million pounds of chemicals were discharged into the Ohio River, more than any other surface water in the TRI database [U.S. EPA, 2013a]. EPA identified that 24 steam electric power plants evaluated in the EA discharge one or more of the evaluated wastestreams to the Ohio River or to tributaries that flow into the Ohio River in under five miles. FirstEnergy Corp. (FirstEnergy) owns and operates several of the coal-fired power plants that discharge to the Ohio River.

The Bruce Mansfield plant (Plant ID 2269) is FirstEnergy's largest coal-fired power plant by nameplate capacity. The plant is located in Shippingport, Pennsylvania, along the Ohio River, approximately 25 miles northwest of Pittsburgh. This plant operates three stand-alone steam turbines, each with a nameplate capacity of 914 MW. These three generating units have a total capacity of 2,741 MW and reported producing approximately 19,000,000 MWh of electricity in 2009 [ERG, 2015j]. The Bruce Mansfield plant discharges FGD wastewater and bottom ash transport water directly to the Ohio River from the Little Blue Run surface impoundment, which straddles the border of Pennsylvania and West Virginia. Table 8-5 contains general information about the three coal-fired generating units at the Bruce Mansfield plant.

Located along the Ohio River in Stratton, Ohio, FirstEnergy's W.H. Sammis plant (Plant ID 103) is the largest coal-fired power plant in Ohio. W.H. Sammis Plant's seven stand-alone steam turbine generating units have a total nameplate capacity of 2,460 MW. Based on data EPA obtained in responses to the Steam Electric Survey, the W.H. Sammis plant reported generating more than 9,500,000 MWh of energy with these seven coal-fired generating units in 2009. The W.H. Sammis plant discharges three of the evaluated wastestreams (FGD wastewater, bottom ash transport water, and combustion residual leachate) directly to the Ohio River. Table 8-6 contains general information about each of the seven steam electric generating units at the W.H. Sammis plant.

Table 8-5. Summary of Bruce Mansfield Operations

SE Unit	Fuel	Capacity (MW)	Fly Ash	Bottom Ash	FGD (Year Installed)
1	Bituminous coal and No. 2 fuel oil	914	Wet scrubber [a]	Wet handled to impoundment	Wet system (1975)
2	Bituminous coal and No. 2 fuel oil	914	Wet scrubber [a]	Wet handled to impoundment	Wet system (1977)
3	Bituminous coal and No. 2 fuel oil	914	Dry conveyed	Wet handled to impoundment	Wet system (1980)

Source: ERG, 2015j.

Acronyms: FGD (Flue gas desulfurization); MW (Megawatt); SE (steam electric).

a – EPA does not consider the ash collected by venturi-type wet scrubbers as fly ash, and therefore, the water generated by these systems is not considered fly ash transport water.

Table 8-6. Summary of W.H. Sammis Operations

SE Unit	Fuel	Capacity (MW)	Fly Ash	Bottom Ash	FGD (Year Installed)
1	Bituminous coal, subbituminous coal, and No. 2 fuel oil	190	Dry conveyed	Wet handled to impoundment	Wet system (2010)
2	Bituminous coal, subbituminous coal, and No. 2 fuel oil	190	Dry conveyed	Wet handled to impoundment	Wet system (2010)
3	Bituminous coal, subbituminous coal, and No. 2 fuel oil	190	Dry conveyed	Wet handled to impoundment	Wet system (2010)
4	Bituminous coal, subbituminous coal, and No. 2 fuel oil	190	Dry conveyed	Wet handled to impoundment	Wet system (2010)
5	Bituminous coal, subbituminous coal, and No. 2 fuel oil	334	Dry conveyed	Wet handled to impoundment	Wet system (2010)
6	Bituminous coal, subbituminous coal, and No. 2 fuel oil	680	Dry conveyed	Wet handled to impoundment	Wet system (2010)
7	Bituminous coal, subbituminous coal, and No. 2 fuel oil	680	Dry conveyed	Wet handled to impoundment	Wet system (2010)

Source: ERG, 2015j.

Acronyms: FGD (Flue gas desulfurization); MW (Megawatt); SE (steam electric).

In estimating the historical pollutant loadings associated with W.H. Sammis' three FGD systems, EPA incorporated the pollutant loadings for FGD wastewater as the systems were installed, between March and May 2010. EPA did not model any FGD wastewater pollutant loadings in the model prior to the installation of W.H. Sammis plant's first FGD system.

Modeling Area

The Ohio River WASP model encompasses a 49-mile-long reach of the Ohio River, 37 miles of which is downstream of one or both of the two modeled steam electric power plant immediate receiving waters. Located furthest upstream, the Bruce Mansfield plant discharges approximately 12 miles downstream of the start of the modeling area. The immediate receiving water that the Bruce Mansfield plant discharges to is approximately 3.3 miles long, as defined in the WASP model. W.H. Sammis plant discharges 13 miles downstream of the Bruce Mansfield plant's immediate receiving water. The immediate receiving water that W.H. Sammis plant discharges to is approximately 3.4 miles long, as defined in the WASP model. The modeling area ends just upstream of the discharges from another steam electric power plant, the Cardinal plant (Plant ID 3265). EPA did not model the pollutant loadings from the Cardinal plant because of CBI claims on one or more of the evaluated wastestream flow rates. Figure 8-5 illustrates the location and extent of the Ohio River WASP model.

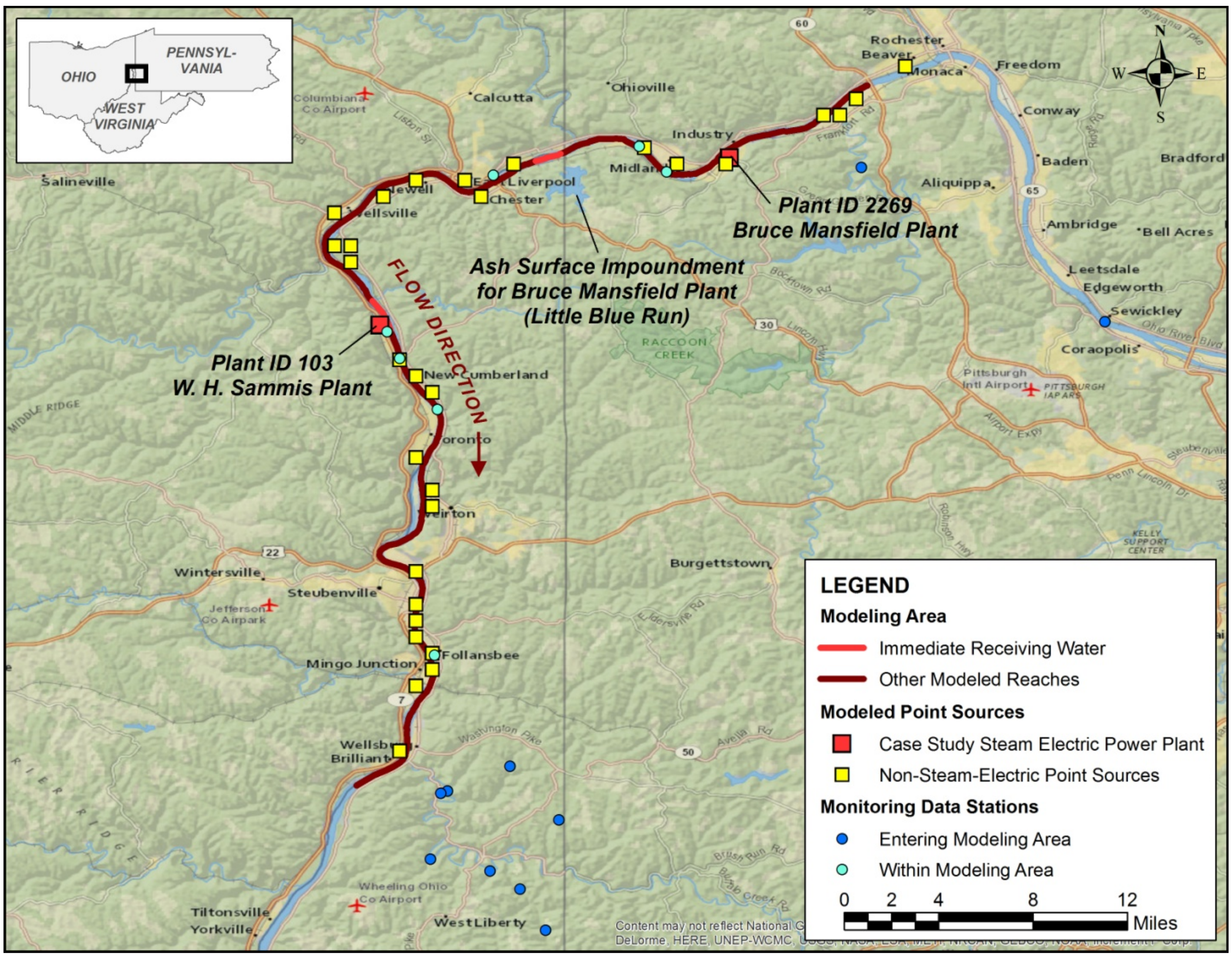


Figure 8-5. Ohio River WASP Modeling Area

Identified Point Sources and Background Concentrations

As discussed below, EPA reviewed available pollutant loadings (DMR and TRI) and monitoring data (STORET) for potential incorporation into the Ohio River WASP model to represent pollutant contributions from background and non-steam-electric point sources, and for use in calibrating the model results.

- **Upstream pollutant contributions**. EPA identified many upstream non-steam-electric point sources whose pollutant loadings could influence the model results. EPA identified STORET data from one monitoring station on the Ohio River (approximately 28 river-miles upstream of Bruce Mansfield plant's immediate receiving water). EPA incorporated the monitoring data (which encompass five of the modeled pollutants) to represent the pollutant contributions flowing into the modeling area. EPA identified additional STORET monitoring data from one station on a tributary to the Ohio River; EPA incorporated these data to represent pollutant contributions flowing in from that tributary. EPA also incorporated the pollutant loadings, based on DMR and TRI data, from seven non-steam-electric point sources upstream of the Bruce Mansfield plant's immediate receiving water to account for the pollutant contributions not captured by the STORET monitoring data.
- **Downstream pollutant contributions**. EPA incorporated STORET data from eight monitoring stations to represent TSS concentrations flowing into the modeling area downstream of both steam electric power plant immediate receiving waters (*i.e.*, tributaries flowing into the Ohio River). These monitoring stations all represent one tributary that flows into the Ohio River near the downstream end of the modeling area. EPA identified 29 non-steam-electric point sources whose pollutant loadings could influence the model results downstream of the Bruce Mansfield plant immediate receiving water and incorporated these pollutant loadings into the Ohio River WASP model.
- **Monitoring data within the modeling area.** EPA compiled STORET data from seven monitoring stations located within the modeling area and used these data to calibrate the WASP model.

The contributions of copper, lead, nickel, and zinc from upstream sources are significantly greater than the pollutant loadings from the Bruce Mansfield and W.H. Sammis plants.

The Ohio River case study model did not account for the documented surface water and ground water impacts from Bruce Mansfield or Little Blue Run that are listed in Appendix A. In 1993, a catastrophic release of steam electric power plant wastewater compromised the quality of ground water and surface water around the Bruce Mansfield plant and Little Blue Run impoundment. Due to the lack of pollutant loadings data, surface water quality impacts resulting from this event are not reflected in this model; therefore, the case study modeling could underrepresent the actual baseline impacts of the Bruce Mansfield plant on the Ohio River.

Modeling Period

The modeling period starts in 1982 (year of the last revision to the steam electric ELGs) and extends through 2036, covering a period of 55 years. Based on their NPDES permitting cycles, EPA assumes that the Bruce Mansfield and W.H. Sammis plants will achieve the limitations under the final rule by 2020 and 2021, respectively. EPA focused the assessment of the improvements under the final rule on the period after the 2021 assumed compliance date.

Modeling Results – Water Quality

Under baseline conditions, the modeled pollutant concentrations in the modeled portion of the Ohio River exceed a human health NRWQC water quality benchmark for one modeled pollutant (arsenic), indicating that arsenic loadings from the two steam electric power plants may contribute to a quantifiable reduction in water quality in the modeled portions of the Ohio River. Arsenic concentrations in 33 miles of the modeling area downstream of the Bruce Mansfield plant exceed the human health water quality benchmark for consumption of water and organisms (0.018 µg/L). These exceedances begin several miles downstream of the Bruce Mansfield plant due to the pollutant loadings from a non-steam-electric point source. This area of exceedances continues downstream of the W.H. Sammis plant for 24 miles (including the W.H. Sammis plant's immediate receiving water) and exceeds the arsenic benchmark during 30 percent of the modeling period. In some portions of the modeling area, the frequency of these exceedances increases due to arsenic contributions from other non-steam-electric point sources. These case study modeling results indicate that, under baseline conditions, humans consuming water and/or organisms inhabiting these modeled portions of the Ohio River may be more at risk of the negative effects associated with oral exposure to arsenic (see Section 3.1.1). On rare occasions (less than 1 percent of the modeling period), the modeled pollutant concentrations exceed the MCL drinking water benchmark for one pollutant (lead), indicating that lead loadings from the two steam electric power plants may contribute to a quantifiable reduction in water quality in the modeled portions of the Ohio River. These rare lead exceedances occur in 15 miles of the modeling area downstream of the Bruce Mansfield plant, of which 13 miles are also downstream of the W.H. Sammis plant (including the immediate receiving water).

Modeling results do not indicate any exceedances of human health NRWQC criteria for the other modeled pollutants (cadmium, copper, nickel, selenium, thallium, and zinc) and do not indicate any exceedances of aquatic life NRWQC or MCL criteria for any of the eight modeled pollutants. Appendix G of this report includes figures that illustrate the water column pollutant concentration output for the immediate receiving water for arsenic and lead. These figures also present the NRWQC and MCL benchmarks for the pollutant and the steady-state water column pollutant concentrations predicted by the IRW model.

The final rule modeling results show significantly decreased concentrations of four of the modeled pollutants (arsenic, cadmium, selenium, and thallium) in the modeled portion of the Ohio River, which will improve water quality. These pollutant removals result in less frequent exceedances of human health NRWQC benchmarks compared to those estimated in the baseline modeling. Arsenic exceedances of human health water quality benchmarks for consumption of water and organisms reduce in frequency from 30 percent to 6 percent of the modeling period in the W.H. Sammis plant's immediate receiving water. Additionally, the exceedances of these benchmarks reduce in frequency in all remaining sections of the downstream modeling area following compliance with the final rule. Despite the continued exceedances of the arsenic human health criteria and the lead MCL benchmark, reducing the pollutant concentrations in the water column may decrease the risk to humans.

Modeling Results – Wildlife

Based on the average pollutant concentrations in the water column under baseline conditions, the modeled portion of the Ohio River does not exceed the concentrations that would translate to NEHC exceedances and does not pose a risk to minks and eagles that consume contaminated fish. Despite the modeling not being able to quantify any improvements to minks and eagles under the final rule, the pollutant loading removals will decrease bioaccumulation of toxic pollutants in the terrestrial food chains.

Modeling results do not indicate that there are any pollutant concentrations in the upper benthic sediment that exceed CSCL benchmarks for any of the eight modeled pollutants; therefore, the modeled portion of the Ohio River does not pose a threat to benthic organisms in contact with contaminated sediment. Despite the modeling not being able to quantify any improvements to benthic organisms under the final rule, the pollutant loading removals will decrease the concentrations of toxic pollutants in benthic sediment and decrease the exposure of organisms to these pollutants.

Modeling Results – Human Health

Under baseline conditions, the average concentration of arsenic in fish over the modeling period does not result in an estimated cancer risk greater than 1-in-a-million for any of the national-scale cohorts.

Based on the average pollutant concentrations in the water column under baseline conditions, thallium poses the greatest threat to cause non-cancer health effects in humans from fish consumption. Average thallium concentrations in the W.H. Sammis plant's immediate receiving water are greater than the concentration that would translate to exceedances of the reference doses for the child (younger than 11 years old) subsistence fisher cohorts. Average thallium concentrations in 24 miles of the modeling area downstream of the W.H. Sammis plant are high enough to trigger exceedances of the reference dose for at least one subsistence cohort. Therefore, humans who consume fish inhabiting these waters may be at greater risk for developing the negative health effects associated with thallium, which are discussed in Section 3.1.1.

The final rule modeling results demonstrate significant reductions in thallium, eliminating thallium exceedances of the non-cancer health effects reference dose throughout the entire modeling area.

Interpretation of Ohio River Results

Case study modeling results for the Ohio River indicate greater water quality and human health impacts under baseline conditions than predicted by the IRW model. The impacts identified in the Ohio River by case study modeling are more extensive than the IRW model because EPA has accounted for pollutant contributions from upstream on the Ohio River, other waterways flowing into the Ohio River, and non-steam electric point sources. Modeled alone, the Bruce Mansfield plant and W.H. Sammis plant would not cause any quantifiable impacts over the modeling period; however the modeled potion of the Ohio River is heavily industrialized. EPA identified 34 non-steam electric point sources that discharge one or more of the modeled pollutants and report to DMR or TRI. The pollutant contributions from the Bruce Mansfield plant, W.H. Sammis plant, and these other non-steam electric point sources modeled accumulate in the waterbody, increasing the overall water column concentrations to a degree that adversely affects water quality and human health. EPA identified exceedances of human health benchmarks that indicate that consuming water and/or organisms from the modeled portion of the Ohio River, including the W.H. Sammis plant's immediate receiving water and areas downstream, can cause health problems related to arsenic, lead, or thallium. The Ohio River case study model results exemplify that, by not accounting for non-steam-electric point sources discharging to the same waterbodies as steam electric power plants, the IRW model may be under-representing the total number of receiving waters with impacts that are caused, in part, by pollutant contributions from the steam electric power generating industry. The case modeling results also suggest that the discharges of the evaluated wastestreams from Bruce Mansfield plant and W.H. Sammis plant may be further impairing the degraded waterway.

Case study modeling of the Ohio River indicates that, under the final rule, the Ohio River will exhibit less frequent exceedances of water quality benchmarks and will eliminate risk to humans consuming fish that inhabit these waters. The human health non-cancer impacts and improvements under the final rule are solely caused by the reduction in steam electric plant pollutant loadings (there are no other input sources of thallium in the Ohio River WASP model).The improvements identified by the case study model are more extensive than what was projected by the IRW model for either of Bruce Mansfield plant or W.H. Sammis plant. This is due in part to the greater water quality and human health impacts under baseline conditions, which created additional opportunities for modeled improvements, and in part to the identified improvements in downstream reaches of the Ohio River that were not evaluated as part of the IRW model. The average pollutant concentrations throughout the entire modeling area reduce within a year after compliance with the final rule.

8.2.5 Mississippi River Case Study

The Mississippi River watershed is the largest in North America, covering about 40 percent of the lower 48 states. The 190-mile stretch of the Mississippi River between the confluence with the Missouri River at St. Louis, Missouri, and the confluence with the Ohio River at Cairo, Illinois, is known as the Middle Mississippi River. South of St. Louis along this stretch of the river, Ameren Corporation operates the Rush Island steam electric power plant (Plant ID 5038) on the west bank of the Mississippi River. The Rush Island plant operates two stand-alone steam turbine units with a nameplate capacity of 670 MW each. Together, these two coal-fired generating units have a capacity of 1,340 MW and reported producing over 8,500,000 MWh of electricity in 2009 in the Steam Electric Survey. The Rush Island plant discharges fly ash and bottom ash transport water directly to the Mississippi River. Table 8-7 contains general information on the two coal-fired units at the Rush Island plant.

Table 8-7. Summary of Rush Island Operations

SE Unit	Fuel	Capacity (MW)	Fly Ash	Bottom Ash	FGD (Year Installed)
1	Subbituminous coal and No. 2 fuel oil	670	Dry conveyance & wet handled to impoundment	Wet handled to impoundment	No FGD system
2	Subbituminous coal and No. 2 fuel oil	670	Dry conveyance & wet handled to impoundment	Wet handled to impoundment	No FGD system

Source: ERG, 2015j.

Acronyms: FGD (Flue gas desulfurization); MW (Megawatt); SE (steam electric).

Modeling Area

The Mississippi River WASP model encompasses a 46-mile-long reach of the Mississippi River, 23 miles of which is downstream of the Rush Island plant immediate receiving water. The model has two start boundaries that are on the Meramec River and Mississippi River shortly upstream of their confluence. The immediate receiving water that the Rush Island plant discharges to is approximately 1.5 miles long, as defined in the WASP model. This model ends at the confluence of the Mississippi River and Kaskaskia River. Figure 8-6 illustrates the location and extent of the Mississippi River WASP model.

Identified Point Sources and Background Concentrations

As discussed below, EPA reviewed available pollutant loadings (DMR and TRI) and monitoring data (STORET) for potential incorporation into the Mississippi River WASP model to represent pollutant contributions from background and non-steam-electric point sources, and for use in calibrating the model results.

- **Upstream pollutant contributions from non-steam-electric point sources**. EPA identified several upstream non-steam-electric point sources whose loadings could influence the model results. EPA therefore extended the modeling area upstream to model these point sources and incorporate upstream monitoring data. EPA identified STORET data from four monitoring stations on the Mississippi River prior to the confluence with the Meramec River (approximately 24 river-miles upstream of Rush Island's immediate receiving water). EPA incorporated the monitoring data (which encompass all of the modeled pollutants except for thallium) to represent the pollutant contributions in the Mississippi River prior to where it converges with the Meramec River. EPA assumed that the monitoring data adequately reflect the pollutant contributions from upstream of this confluence. EPA incorporated the pollutant loadings from three non-steam-electric point sources downstream of the convergence to account for the pollutant contributions not captured by the STORET monitoring data.
- **Upstream pollutant contributions from steam electric sources**. EPA identified one steam electric power plant, Ameren's Meramec plant (Plant ID 1435), whose loadings could influence the model results at the Rush Island immediate receiving water and other downstream locations. EPA incorporated the loadings from the Meramec plant into the extended Mississippi River model, as discussed further below.

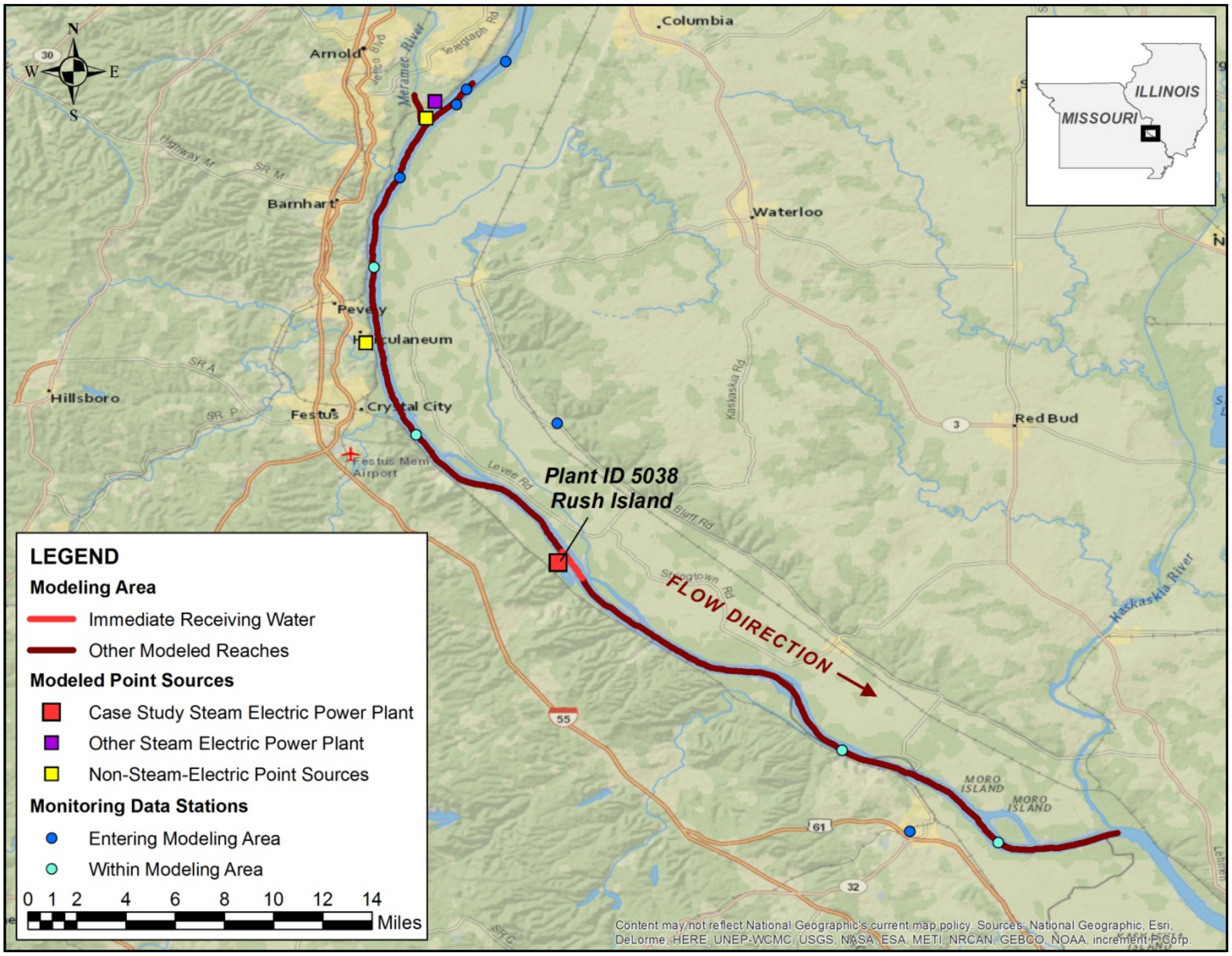


Figure 8-6. Mississippi River WASP Modeling Area

- **Downstream pollutant contributions**. EPA incorporated STORET data from two monitoring stations to represent pollutant concentrations flowing into the modeling area downstream of the Rush Island immediate receiving water (*i.e.*, tributaries flowing into the Mississippi River). EPA did not identify any non-steam-electric point sources whose pollutant loadings would significantly influence the model results in the downstream modeling area.
- **Monitoring data within the modeling area**. EPA compiled STORET data from four monitoring stations located within the modeling area and used these data to calibrate the WASP model.

The Meramec plant discharges approximately 24 river miles upstream of the Rush Island plant's immediate receiving water. EPA did not identify STORET monitoring data between the two plants to represent the pollutant concentrations from the Meramec plant; therefore, EPA incorporated the pollutant loadings from the Meramec plant (as calculated for this rulemaking) into the Mississippi River model. The Meramec plant operates four coal-fired generating units with a total nameplate capacity of 923 MW. All pollutant loadings from the evaluated wastestreams are from bottom ash transport water. EPA assumed that the Meramec plant will comply with the standards of the final rule by 2019. EPA did not evaluate the water quality, wildlife, or human health impacts associated with discharges from the Meramec plant because this plant did not meet the case study location selection criteria described in Section 8.1.1. EPA incorporated the loadings from Meramec plant solely to account for the upstream pollutant contributions flowing into the Rush Island plant's immediate receiving water from upstream, under baseline conditions and the final rule.

The contributions of arsenic, cadmium, copper, lead, nickel, and zinc from upstream sources are significantly greater than the pollutant loadings from the Rush Island plant.

Modeling Period

The modeling period starts in 1982 (year of the last revision to the steam electric ELGs) and extends through 2036, covering a period of 55 years. Based on their NPDES permitting cycles, EPA assumes that the Meramec and Rush Island plants will achieve the limitations under the final rule by 2019 and 2023, respectively. For the Rush Island plant's immediate receiving water and downstream reaches, EPA focused the assessment of the baseline impacts and improvements under the final rule on the period after the 2023 assumed compliance date.

Modeling Results – Water Quality

Under baseline conditions, the modeled pollutant concentrations in the Rush Island plant's immediate receiving water and downstream reaches exceed human health NRWQC water quality benchmarks for one modeled pollutant (arsenic), indicating that loadings from Rush Island may contribute to a quantifiable reduction in water quality in the modeled portions of the Mississippi River. Arsenic concentrations in the Rush Island plant's immediate receiving water exceed the human health water quality benchmark for consumption of water and organisms (0.018 µg/L) and the human health water quality benchmark for consumption organisms (0.14 µg/L) for the entire modeling period. These exceedances continue downstream, at the same frequency, throughout the entire 23-mile-long modeling area downstream of the plant. The case study modeling results indicate that, under baseline conditions, humans consuming water and/or organisms that inhabit these modeled portions of the Mississippi River may be more at risk of the negative effects associated with oral exposure to arsenic (see Section 3.1.1).

Modeling results do not indicate any exceedances of human health NRWQC benchmarks for the other modeled pollutants (cadmium, copper, nickel, lead, selenium, thallium, and zinc). In addition, modeling results do not indicate any exceedances of aquatic life NRWQC or MCL criteria for any of the eight modeled pollutants. Appendix G of this report includes figures that illustrate the water column pollutant concentration output for the immediate receiving water for arsenic. This figure also presents the NRWQC and MCL benchmarks for the pollutant and the steady-state water column pollutant concentrations predicted by the IRW model.

The final rule modeling continues to show human health NRWQC benchmark exceedances for arsenic within the Mississippi River due to additional arsenic contributions from other sources (*i.e.*, Mississippi River background concentrations and non-steam electric point sources). However, under the final rule, both the Meramec and Rush Island plants will no longer discharge any of the evaluated wastestreams and will therefore no longer contribute to the arsenic or lead impairment of the Mississippi River.

Modeling Results – Wildlife

Based on the average pollutant concentrations in the water column under baseline conditions, the modeled portion of the Mississippi River does not exceed the concentrations that would translate to NEHC exceedances and does not pose a risk to minks and eagles that consume contaminated fish. Despite the modeling not being able to quantify any improvements to minks and eagles under the final rule, the pollutant loading removals will decrease bioaccumulation of toxic pollutants in the terrestrial food chains.

Modeling results do not indicate that there are any pollutant concentrations in the upper benthic sediment that exceed CSCL benchmarks of for any of the eight modeled pollutants; therefore, the modeled portion of the Mississippi River does not pose a threat to benthic organisms in contact with contaminated sediment. Despite the modeling not being able to quantify any improvements to benthic organisms under the final rule, the pollutant loading removals will decrease the concentrations of toxic pollutants in benthic sediment and decrease the exposure of organisms to these pollutants.

Modeling Results – Human Health

EPA modeled the average pollutant concentrations in the water column and compared these to the concentrations that would trigger exceedances of either the non-cancer reference dose or the 1-in-a-million LECR. Under baseline conditions, the average water column concentration of arsenic throughout the modeling area downstream of the plant results in an estimated cancer risk greater than 1-in-a-million for adult subsistence fishers. Therefore, humans who consume arsenic-contaminated fish inhabiting the immediate receiving water may be at greater risks for development of cancer. Modeling results demonstrate no reduction in the cancer risk from inorganic arsenic under the final rule.

Under baseline conditions, the average pollutant concentrations over the modeling period does not pose the threat to cause non-cancer health effects for adult and children recreational and subsistence fishers (all national-scale cohorts evaluated).

Interpretation of Mississippi River Results

Case study modeling results for the Mississippi River indicate greater water quality and human health impacts under baseline conditions than predicted by the IRW model. By accounting for pollutant contributions from background and upstream sources, the case study model predicts higher pollutant concentrations under baseline conditions. For arsenic, the projected exceedances are driven by the pollutant contributions entering the Mississippi River upstream of the Rush Island plant. Alone, the steam electric discharges of the evaluated wastestreams would not cause any quantifiable impacts, which is consistent with the IRW model results; however, the pollutant loadings from the Rush Island plant may be further exacerbating the impairment of the degraded waterway.

The case study modeling of the Mississippi River indicates that, under the final rule, it will continue to exceed all of the water quality and human health benchmarks observed at baseline, with little to no reduction in frequency. Under the final rule, the Rush Island plant will no longer discharge any fly ash or bottom ash transport water. After compliance with the final rule, the modeled steam electric power plants will no longer contribute to the impairment of the Mississippi River and the overall magnitude of the pollutant concentrations in the aquatic system will decrease.

8.2.6 Lake Sinclair Case Study

Lake Sinclair is a reservoir located in central Georgia. The lake was created in 1953 when the waters of the Oconee River were dammed by Georgia Power, a subsidiary of Southern Company, to create a hydroelectric generating station. Georgia Power also owns and operates Plant Harllee Branch (Plant ID 5762), a steam electric power plant situated on the northern shore of Lake Sinclair. Based on 2009 data obtained in responses to the Steam Electric Survey, Plant Harllee Branch operated four coal-fired generating units with a total nameplate capacity of 1,750 MW and produced more than 6,800,000 MWh of electricity in 2009. As of April 16, 2015 (the date by which the plant would be required to comply with the U.S. EPA's Clean Power Plan [Clean Air Act Section 111(d)]), this plant has decertified and retired all four of its coal-fired generating units. Georgia Power cited several factors, including the cost to comply with existing and future environmental regulations, recent and future economic conditions, and lower natural gas prices, in the decision to close the plant. Plant Harllee Branch discharged FGD wastewater, fly ash transport water, and bottom ash transport water directly to Lake Sinclair. Table 8-8 contains general information on the four coal-fired units at Rush Island Plant.

Despite the retirement of all coal-fired generating units at this plant, EPA proceeded with case study modeling of Lake Sinclair to represent the potential impacts of steam electric discharges on lentic waterbodies (including the 26 lake, pond, and reservoir receiving waters evaluated in this EA) and the potential environmental improvements that could reasonably be expected under the final rule in other lentic waterbodies that receive discharges of the evaluated wastestreams. EPA did not include Plant Harllee Branch or Lake Sinclair in the other quantitative and qualitative analyses in this EA for the final rule (*e.g.*, the IRW model).

In estimating the historical pollutant loadings associated with Plant Harllee Branch, EPA incorporated the loadings only from generating unit IDs 3 and 4 because generating unit IDs 1 and 2 were flagged for retirement at the time of the proposed revised ELGs. EPA incorporated the loadings with the FGD wastewater as the systems were installed (starting in 2013). EPA did not model any FGD wastestream loadings in the historical model prior to the installation of Plant Harllee Branch's first FGD system.

Table 8-8. Summary of Plant Harllee Branch Operations

SE Unit	Fuel	Capacity (MW)	Fly Ash	Bottom Ash	FGD (Year Installed)
1 [a]	Bituminous coal and No. 2 fuel oil	299	Wet handled to impoundment	Wet handled to impoundment	Wet system (2014)
2 [a]	Bituminous coal and No. 2 fuel oil	359	Wet handled to impoundment	Wet handled to impoundment	Wet system (2014)
3	Bituminous coal and No. 2 fuel oil	544	Wet handled to impoundment	Wet handled to impoundment	Wet system (2013)
4	Bituminous coal and No. 2 fuel oil	544	Wet handled to impoundment	Wet handled to impoundment	Wet system (2013)

Source: ERG, 2015j.

Acronyms: FGD (Flue gas desulfurization); MW (Megawatt); SE (steam electric).

a – EPA did not model any pollutant loadings associated with these generating units.

Modeling Area

As discussed in Section 8.1.1, EPA relied upon the availability of existing models to perform case study modeling of lentic systems: an existing WASP model that divided the waterbody into segments and EFDC model that provided hydrodynamics and simulated the aquatic system in three dimensions. The EFDC model uses stretch or sigma vertical coordinates and Cartesian coordinates to represent the physical characteristics of Lake Sinclair.

The three-dimensional EFDC model, which provides the hydrodynamic foundation for the WASP model, divides the waterbody into 1,235 segments; each segment represents a unique location and stratum within Lake Sinclair. The model accounts for a total volume of approximately 340 million cubic meters. In contrast to the WASP models that EPA developed to model lotic systems, the Lake Sinclair model is not set up to quantify the pollutant concentrations in the benthic sediment; therefore, EPA was unable to assess whether pollutant accumulation in the sediment was occurring over prolonged discharge periods. Figure 8-7 illustrates the location and extent of the Lake Sinclair modeling area.

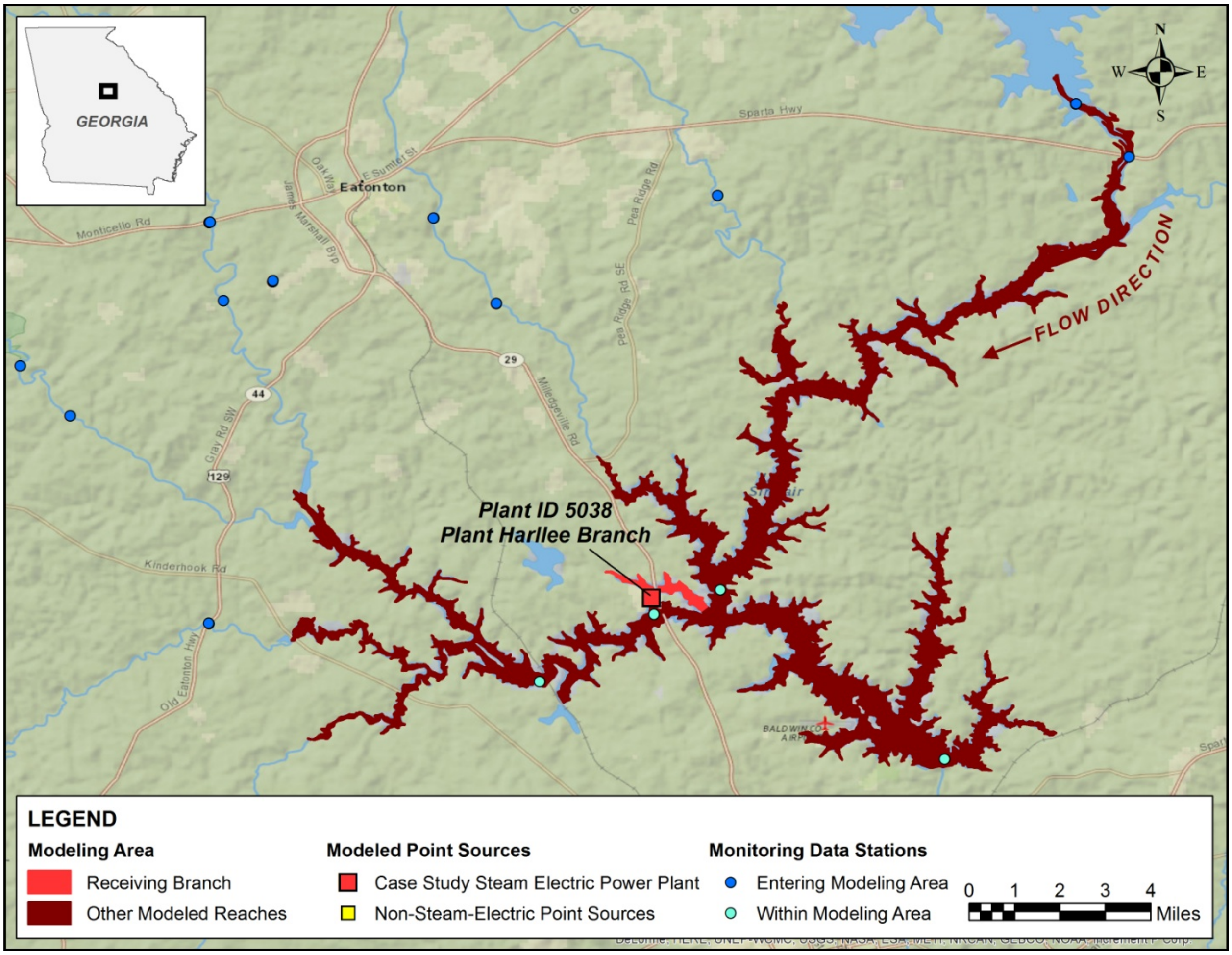


Figure 8-7. Lake Sinclair WASP and EDFC Modeling Area

Identified Point Sources and Background Concentrations

As discussed below, EPA reviewed available pollutant loadings (DMR and TRI) and monitoring data (STORET) for potential incorporation into the Lake Sinclair water quality model to represent pollutant contributions from background and non-steam-electric point sources, and for use in validating and calibrating the model results.

- **Upstream pollutant contributions.** EPA incorporated STORET data from three monitoring stations to represent TOC and TSS contributions from upstream of Lake Sinclair on the Oconee River. EPA did not identify sufficient STORET monitoring data to represent the pollutant contributions of the eight modeled pollutants or any upstream non-steam-electric point sources with loadings for the eight modeled pollutants. EPA therefore assumed pollutant concentrations of zero within the water column flowing into Lake Sinclair from the Oconee River.
- **Other pollutant contributions**. EPA incorporated STORET data from 15 monitoring stations to represent the modeled pollutants, TOC, and TSS concentrations flowing into Lake Sinclair from other streams. EPA did not identify any non-steam-electric

point sources whose pollutant loadings would significantly influence the model results.

- **Monitoring data within the modeling area.** EPA compiled STORET data from six monitoring stations located within the modeling area and used these data to calibrate the Lake Sinclair water quality model.

The pollutant concentrations entering the modeling area for arsenic, copper, lead, and thallium which EPA calculated using monitoring data, are much greater than the pollutant loadings from Lake Sinclair plant. The concentrations entering the modeling area for cadmium, nickel, and zinc also strongly influence the model outputs.

Modeling Period

As discussed earlier in this section, EPA adopted the preexisting Lake Sinclair EFDC model. The preexisting model was designed with seven years of hydrodynamic and flow input, limiting the length of the period EPA could model. Based on Plant Harllee Branch's NPDES permitting cycle, EPA assumed that the plant would have achieved the limitations under the final rule by 2019 if it continued to operate. The modeling period begins in February 2012 (approximately seven years before the assumed compliance date) and extends through November 2025 (approximately seven years after the assumed compliance date).

Modeling Results – Water Quality

EPA selected three portions of Lake Sinclair to evaluate the modeled pollutant concentrations: 1) the immediate receiving water (a 720,000-cubic-meter cell of the lake); 2) the average of all segments in the reach of the lake where Plant Harllee Branch discharges, including subsurface water segments (hereafter referred to as the "receiving branch"), and 3) the average of all segments included in the Lake Sinclair model, including subsurface water segments (hereafter referred to as the "entire modeling area").

Under baseline conditions, the modeled pollutant concentrations in Lake Sinclair, including the immediate receiving water and the receiving reach, exceed NRWQC water quality benchmarks for three modeled pollutants, indicating that pollutant loadings from Plant Harllee Branch may quantifiably reduce water quality in the modeled portions of Lake Sinclair. The reduced water quality is primarily attributed to arsenic, cadmium, and thallium.

The baseline modeled pollutant concentrations exceed human health criteria primarily for arsenic and thallium, as discussed below:

- Arsenic concentrations exceed the water quality benchmark for consumption of water and organisms (0.018 µg/L):
  - In the immediate receiving water for the entire modeling period.
  - In all modeled segments of the receiving branch for more than 99 percent of the modeling period.
  - In 97 percent of the entire modeling area for 10 percent or more of the modeling period.

- Arsenic concentrations also exceed the higher water quality benchmark for consumption of organisms (0.14 µg/L):
  - In five of the six modeled segments of the receiving branch for up to 19 percent of the modeling period.
  - In 54 percent of the entire modeling area for 10 percent or more of the modeling period.
- Thallium concentrations exceed the water quality benchmark for consumption of water and organisms (0.24 µg/L):
  - In three of the six modeled segments of the receiving branch for up to 6 percent of the modeling period.
  - In 14 percent of the entire modeling area for 10 percent or more of the modeling period.
- Thallium concentrations also exceed the higher water quality benchmark for consumption of organisms (0.47 µg/L):
  - In two of the six modeled segments of the receiving branch for less than 1 percent of the modeling period.
  - In 11 percent of the entire modeling area for 10 percent or more of the modeling period.

The case study modeling results indicate that, under baseline conditions, humans consuming water and/or organisms that inhabit these modeled portions of Lake Sinclair may be more at risk of the negative effects associated with oral exposure to arsenic and thallium (see Section 3.1.1).

Aquatic organisms may be at risk for exposure to cadmium under baseline conditions. Specifically, cadmium concentrations exceed the freshwater aquatic life criteria for chronic exposure (0.25 µg/L) in 4 percent of the entire modeling area for 10 percent or more of the modeling period. These case study modeling results indicate that, under baseline conditions, aquatic organisms inhabiting these modeled portions of Lake Sinclair could be at an elevated risk of the negative effects associated with oral exposure to cadmium (see Section 3.1.1).

Under baseline conditions, the modeled pollutant concentrations in Lake Sinclair occasionally exceed the MCL drinking water benchmarks for two of the modeled pollutants (arsenic and thallium), as discussed below:

- Arsenic concentrations exceed the MCL drinking water criteria (10 µg/L) in less than 1 percent of the segments for 10 percent or more of the modeling period.
- Thallium concentrations exceed the MCL drinking water criteria (2 µg/L) in 5 percent of the segments for 10 percent or more of the modeling period.

Modeling results do not indicate any exceedances of NRWQC or MCL criteria for the other modeled pollutants (copper, lead, nickel, selenium, and zinc). Appendix G of this report includes figures that illustrate the average water column pollutant concentration output for the entire lake for arsenic, cadmium, and thallium. These figures also present the NRWQC and MCL benchmarks for the pollutant and the steady-state water column pollutant concentrations predicted by the IRW model.

The final rule modeling results show significantly decreased average concentrations of two of the modeled pollutants (nickel and selenium) in the modeled portion of Lake Sinclair. Case study modeling results for Lake Sinclair reveal the water quality improvements for arsenic under the final rule. Specifically, arsenic exceedances of the human health NRWQC benchmark for consumption of water and organisms reduce in frequency from the entire modeling period to 23 percent of the modeling period in the immediate receiving water and reduce from above 99 percent of the modeling period to as low as 23 percent of the modeling period in the receiving branch. Additionally, slightly less (2 percent of the modeling area) of Lake Sinclair will exceed this benchmark under the final rule. Arsenic exceedances of the higher human health NRWQC benchmark for consumption of organisms also reduce throughout the entire lake as 12 percent less of the modeling area exceed this benchmark for more than 10 percent of the modeling period.

While the modeling results demonstrate continuing arsenic, cadmium, and thallium exceedances of NRWQC and MCL benchmarks in the receiving reach and the entire modeling area, the pollutant loading contributions to the lake would be reduced under the final rule (if Plant Harllee Branch did not retire all generating units).

Modeling Results – Wildlife

For the analysis of wildlife impacts and improvements, EPA assumed that aquatic life travel freely throughout Lake Sinclair and do not confine themselves within particular segments of the lake. EPA calculated the average fish tissue concentrations of all segments within the Lake Sinclair model (*i.e.*, entire modeling area) for purposes of the wildlife assessment.

Based on the average pollutant concentrations in the water column under baseline conditions, the modeled portion of Lake Sinclair does not exceed the concentrations that would translate to NEHC exceedances and does not pose a risk to minks and eagles that consume contaminated fish. Despite the modeling not being able to quantify any improvements to minks and eagles under the final rule, the pollutant loading removals will decrease bioaccumulation of toxic pollutants in the terrestrial food chains (if Plant Harllee Branch did not retire all generating units).

The Lake Sinclair EFDC model is not set up to quantify the pollutant concentrations in the benthic sediment; therefore, EPA was unable to assess whether pollutant concentrations in the sediment exceeded CSCL benchmarks and pose a threat to benthic organisms.

Modeling Results – Human Health

For the analysis of human health impacts and improvements, EPA also assumed that fish travel freely throughout Lake Sinclair and do not confine themselves within particular segments of the lake. EPA calculated the average fish tissue concentrations of all segments within the Lake Sinclair model (*i.e.*, entire modeling area) for purposes of the human health assessment.

Under baseline conditions, the average water column concentration of arsenic in Lake Sinclair over the modeling period does not result in an estimated cancer risk greater than 1-in-a-million for any of the national-scale cohorts.

Based on the average pollutant concentrations in the water column under baseline conditions, thallium poses the greatest threat to cause non-cancer health effects in humans from fish consumption. Average thallium concentrations in the water column of the entire Lake Sinclair modeling area are greater than the concentrations that would translate to exceedance of the reference doses for adult and children recreational and subsistence fishers (all national-scale cohorts evaluated). Therefore, humans who consume thallium-contaminated fish inhabiting the modeled area of Lake Sinclair may be at greater risk for developing the negative health effects associated with these pollutants, which are discussed in Section 3.1.1.

While the modeling results continue to show thallium water concentrations that would translate to exceedances of the non-cancer health effects reference dose, the final rule will reduce thallium loading contributions from Plant Harllee Branch (if Plant Harllee Branch did not retire all generating units).

Interpretation of Lake Sinclair Results

The case study modeling results indicate that the water quality impacts are greater in the receiving branch (closest portion of the lake to the Plant Harllee Branch discharge) of Lake Sinclair compared to the rest of the lake. EPA identified that the receiving branch of Lake Sinclair also exhibited more quantifiable improvements (*i.e.*, reduced NRWQC and MCL benchmark exceedances) under the final rule than the average of all Lake Sinclair model segments. Despite the model not indicating any wildlife or human health impacts in Lake Sinclair, the reduction of pollutant loadings under the final rule would lessen the contribution of steam electric power plant discharges on the entire aquatic and terrestrial ecosystems.

8.3 COMPARISON OF CASE STUDY AND IRW MODELING RESULTS

In general, the case study modeling results from the six case study models support the overall conclusions of the IRW model.

Case study modeling of smaller receiving waters, such as Black Creek and Lick Creek, indicate that more severe water quality, wildlife, and human health impacts are occurring at baseline conditions than the IRW model predicted. Since flow rates in small receiving waters fluctuate significantly, the case study modeling demonstrates impacts that can occur during periods when the flow is lower than the annual average used in the IRW model. During the frequent periods of low flow in smaller rivers and streams, the case study modeling shows that pollutant concentrations quickly climb to levels that will negatively affect fish, wildlife, and humans. The Black Creek and Lick Creek case study model also suggests the potential for additional improvements under the final rule than the IRW model predicts. Case study modeling therefore indicates that small receiving waters with highly variable flow rates may benefit from the final rule more than the IRW model results suggest.

The case study modeling also demonstrates that the impacts from steam electric power plant discharges can propagate much further downstream than the immediate receiving water used in the IRW modeling. In four of the six case study models, results illustrate that the pollutant loadings from steam electric power plant discharges of the evaluated wastestreams may contribute to water quality impacts up to 95 miles downstream of the plant discharge. These additional impacts, as well as additional improvements under the final rule, are not represented in the IRW modeling results.

Additionally, case study modeling of smaller water bodies revealed that downstream reaches may be heavily influenced by the sediment transport and exhibit much higher water column concentrations than the immediate receiving water. In the Black Creek, Etowah River, and White River results, "hot spots" with higher pollutant concentrations were observed and posed a greater risk to humans, aquatic life, and terrestrial food chains than reaches closer to the steam electric power plants.

EPA performed one case study model of a representative lentic receiving water to assess the potential impact on similar lakes or reservoirs that receive steam electric power plant discharges of the evaluated wastestreams. Case study modeling of Lake Sinclair showed that impacts are occurring in the lake, and these are more severe in the immediate area of the steam electric discharge as compared to the lake average. The water quality improvements demonstrated by the reduced exceedances of water quality benchmarks indicate that other lentic receiving waters may also exhibit similar improvements. Although the case study modeling of Lake Sinclair was unable to quantify the accumulation of pollutant concentrations in benthic sediment, lower concentrations of pollutants under the final rule should reduce pollutant long-term accumulation and consequential resuspension.

Each of the case study models demonstrated at least one exceedance of a water quality, wildlife, or human health benchmark for a modeled pollutant discharged from stream electric power plants. Under the final rule, the steam electric power plant(s) will contribute a reduced loading of the pollutant(s), thereby improving water quality in these receiving waters. As demonstrated by the Black Creek, Etowah River, Lick Creek and White River, Ohio River, and Lake Sinclair case study modeling results, pollutant removals will result in quantifiable improvements through reduced exceedances of environmental benchmarks.

SECTION 9
CONCLUSIONS

Based on evidence in the literature, damage cases, other documented impacts, and modeled receiving water pollutant concentrations, it is clear that current wastewater discharge practices at steam electric power plants are impacting the surrounding aquatic and terrestrial environments and pose a human health threat to nearby communities. EPA estimates that discharges from steam electric power plants contribute over one-third of the toxic-weighted pollutant loadings of the combined discharges of all industrial categories currently required to report discharges to U.S. waters. These discharges add large quantities of toxic bioaccumulative pollutants (*e.g.*, selenium, arsenic, and mercury) to the aquatic environment. Substantial evidence exists that pollutants from steam electric power plant wastewater discharges are transferring from the aquatic environment to terrestrial food webs; this indicates the potential for broader impacts to ecological systems by altering population diversity and community dynamics in the areas surrounding steam electric power plants. Ecosystem recovery from exposure to steam electric power plant wastewater discharges can be extremely slow and even short periods of exposure (*e.g.*, less than a year) can cause observable ecological impacts that last for years. The strong bioaccumulative properties and long residence times of pollutants in immediate receiving waters reinforce the threat of these wastes to the local environment, and many of the impacts may not be fully realized for years to come.

In addition, EPA's modeling demonstrates that pollutant loadings from discharges of the evaluated wastestreams are impacting areas beyond the immediate receiving waters and pose a threat to wildlife and human populations in thousands of river-miles downstream from steam electric power plants under current discharge practices. Furthermore, EPA predicts that the recently promulgated Clean Air Act requirements (*i.e.*, Clean Power Plan) and other state and local regulations may lead to additional air pollution controls (and resulting wastestreams) that will increase the pollutant loadings to surface waters in the future. These additional pollutant loadings above current baseline conditions will increase the number of immediate receiving waters exceeding water quality, wildlife, and human health benchmarks in the future.[65]

Steam electric power plants discharge wastewater into waterbodies used for recreation, and these discharges can present a potential threat to human health. Documented fish kills have resulted in states issuing fish advisories to protect the public from exposure to fish with elevated pollutant concentrations in recreational waters that receive these discharges. Combustion residual leachate from surface impoundments and landfills is known to impact off-site ground water and drinking water wells at concentrations above Maximum contaminant level (MCL) drinking water standards and pose a potential threat to human health.

[65] The analyses presented in this report incorporate some adjustments to current conditions in the industry. For example, these analyses account for publicly announced plans from the steam electric power generating industry to retire or modify steam electric generating units at specific power plants. These analyses also account for changes to the industry that are expected to occur as a result of the recent Coal Combustion Residuals (CCR) rulemaking by EPA's Office of Solid Waste and Emergency Response (OSWER). These analyses, however, do not reflect changes in the industry that may occur as a result of the proposed Clean Power Plan [Clean Air Act section 111(d)].

The final steam electric effluent limitations guidelines and standards (ELGs) will result in quantifiable improvements in ecological and human health by reducing immediate receiving water pollutant concentrations, on average, by 57 percent.[66] The final rule will result in the following environmental improvements as estimated by the national-scale immediate receiving water (IRW) model:

- A 51 to 67 percent reduction in the number of immediate receiving waters exceeding National Recommended Water Quality Criteria (NRWQC) for the protection of aquatic life.
- A 45 to 50 percent reduction in the number of immediate receiving waters exceeding an NRWQC for the protection of human health.
- A 63 to 64 percent reduction in the number of immediate receiving waters that support fish whose tissue pollutant concentrations exceed benchmarks for the protection of piscivorous wildlife (represented by minks and eagles).
- A 61 to 67 percent reduction in the number of immediate receiving waters where selenium contamination in the food web presents reproductive risks[67] to aquatic wildlife (represented by fish and mallards).
- A 56 to 75 percent reduction in the number of immediate receiving waters that support fish whose tissue pollutant concentrations pose a cancer risk to exposed populations.
- A 52 to 56 percent reduction in the number of immediate receiving waters that support fish whose tissue pollutant concentrations pose a risk of non-cancer health effects in exposed populations.

The results of the case study modeling for selected plants and receiving waters indicate that the environmental and human health impacts associated with steam electric power plant discharges, and the corresponding improvements under the final rule, could be even more extensive than those predicted by the IRW model. Case study modeling results demonstrate that the impacts from steam electric power plant discharges of the evaluated wastestreams can propagate much further downstream of the immediate receiving water. While the steam electric power plant discharges may not cause these impacts in isolation, case study modeling reveals that the discharges contribute to the further impairment of such waterways. Case study modeling results identified a larger increase in baseline impacts and improvements under the final rule in small receiving waters with variable flow than larger receiving waters. The analyses presented in the environmental assessment (EA) focus on quantifying the environmental improvements within rivers and lakes from post-compliance pollutant removals for metals, bioaccumulative pollutants, and nutrients.

[66] Reductions apply to the subset of pollutants evaluated in the environmental assessment (*i.e.*, arsenic, cadmium, chromium VI, copper, lead, mercury, nickel, selenium, thallium, and zinc).

[67] For this statistic, reproductive risk is indicated by a 50-percent (or higher) probability that adverse reproductive effects will occur in at least 10 percent of the exposed population of fish and mallards.

While extensive, the environmental improvements quantified above do not encompass the full range that will result from the final rule, such as the following improvements that are not quantified (or have only limited analysis) in this EA:

- Reducing the loadings of bioaccumulative pollutants to the broader ecosystem, decreasing long-term exposures and sublethal ecological effects.
- Reducing sublethal chronic effects of toxic pollutants on aquatic life not captured by the NRWQC.
- Reducing loadings of pollutants for which EPA did not perform water quality modeling in support of the EA (*e.g.*, boron, manganese, aluminum, vanadium, and iron).
- Mitigating impacts to aquatic and aquatic-dependent wildlife population diversity and community structures.[68]
- Reducing wildlife exposure to pollutants through direct contact with combustion residual impoundments and constructed wetlands built as treatment systems at steam electric power plants.
- Reducing water withdrawals from surface waters and aquifers, leading to greater availability of groundwater supplies for alternative uses and reducing fish impingement and entrainment mortality due to surface water intake structures.
- Reducing the potential of harmful algal blooms to form.

Data limitations prevented EPA from appropriately modeling the scale and complexity of the ecosystem processes potentially impacted by steam electric power plant wastewater and therefore did not fully quantify the improvements listed above. However, damage cases and other documented impacts in the literature reinforce that these impacts are common in the environments surrounding steam electric power plants and fully support the conclusion that pollutant removals will improve overall environmental and wildlife health.

As surface impoundments accumulate fly ash, bottom ash and flue gas desulfurization sludges, they can begin to fill up and lose their treatment capability.

Although the EA quantifies some impacts to wildlife that consume fish contaminated with pollutants from steam electric power plant wastewater, it does not capture the full range of exposure pathways through which bioaccumulative pollutants can enter the surrounding food web. Wildlife can encounter bioaccumulative pollutants from steam electric power plant wastewater discharges through direct exposure, drinking water, consuming

[68] EPA did evaluate impacts to aquatic and aquatic-dependent wildlife from selenium contamination as part of the ecological risk modeling. EPA did not quantify impacts that might occur due to other pollutant contamination.

contaminated vegetation, and consuming contaminated prey other than fish. Therefore, the quantified improvements underestimate the complete loadings of bioaccumulative pollutants that can impact wildlife in the ecosystem. EPA did quantify improvements to aquatic and aquatic-dependent wildlife due to reduced selenium exposure via the food web. The reduced selenium loadings under the final rule will significantly reduce the risk of negative reproductive effects to wildlife in waterbodies that receive discharges from steam electric power plants. In addition to the improvements resulting from reduced selenium loadings, EPA estimates that the post-compliance pollutant removals under the final rule will lower the total amount of bioaccumulative pollutants entering the food web in immediate receiving waters and downstream waters.

EPA estimates that pollutant removals will also decrease sublethal effects associated with many of the pollutants in steam electric power plant wastewater that may not be captured by comparisons with NRWQC for aquatic life. Well-documented studies suggest that organisms in aquatic environments near steam electric power plants exhibit chronic effects such as changes in metabolic rates, decreased growth rates, changes in morphology (*e.g.*, fin erosion, oral deformities), and changes in behavior (*e.g.*, decreased ability to swim, catch prey, or escape from predators) that can negatively affect long-term survival [Raimondo *et al*., 1998; Rowe *et al*., 1996, 2002]. However, these effects are not fully quantified in the EA due to data limitations, and therefore improvements to wildlife health and survival from the final rule may be underestimated. Reduced organism survival rates from chronic effects such as abnormalities can alter interspecies relationships (*e.g.*, declines in the abundance or quality of prey) and prolong ecosystem recovery. EPA was unable to quantify changes to aquatic and wildlife population diversity and community dynamics; however, population effects (*i.e.*, decline in number and type of organisms present) attributed to exposure to steam electric power plant wastewater are well documented in the literature [Lemly, 1985a; Garrett and Inman, 1984; Sorensen *et al*., 1982]. Changes in aquatic populations can alter the structure of aquatic communities and cause cascading effects within the food web that have long-term impacts to ecosystem dynamics. EPA estimates that post-compliance pollutant removals associated with the final rule will lower the stressors that can alter population and community dynamics and will improve the overall function of ecosystems surrounding steam electric power plants.

SECTION 10
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APPENDIX A
LITERATURE REVIEW METHODOLOGY AND RESULTS

This appendix presents the methodology, resources, and summary results for the literature review. The U.S. Environmental Protection Agency (EPA) used the keyword list in Table A-1 to identify peer-reviewed journal articles that document environmental and human health impacts caused by steam electric power plant discharges of the evaluated wastestreams. The literature search focused on information regarding impacts caused by pollutants of concern for the steam electric power generating industry (*e.g.*, toxic bioaccumulative pollutants such as mercury and selenium, metals such as arsenic and lead, and nutrients) in the discharges. EPA also searched for environmental assessments, impact studies, and related documents from state and federal governments.

In addition, the literature search involved collecting information from newspapers, environmental groups, industry organizations, and other non-peer-reviewed information sources. These sources are considered to be "gray literature" and are not acceptable forms of formal documentation of environmental impact events. However, these literature sources can provide useful information for identifying potential areas of concern. Often, an environmental event is reported in gray literature sources before it is well documented in peer-reviewed journals or government reports. EPA used gray literature to help highlight areas of interest and facilitate additional searches of peer-reviewed journals for more detailed information on the impacted area.

EPA used several different search engines to broaden the range of reference materials represented in the results. The Agency searched the following search engines in the order presented, using the keyword list in Table A-1:

- Scirus – A comprehensive science-specific search engine that provides access to a large database of scientific, technical, and medical journals.
- Science Direct – An online library that features full text journals from Elsevier, Academic Press, and other scholarly publishers.
- Ingenta – A scholarly research database that provides access to a large collection of academic and professional research articles.
- Google Scholar – A search engine used to find other articles that cited previously identified references as well as perform a general search of scholarly literature, including peer-reviewed papers, theses, books, abstracts, and articles from academic publishers, professional societies, preprint repositories, and universities and other scholarly organizations.
- Google – A search engine used to perform a general search of information readily available on the Internet.

Table A-1. Keyword Search Terms for Environmental Impacts from Steam Electric Power Plants

Category	Keyword
General Terms	Ash pond
	Discharge
	Lake
	Landfill
	Leachate
	Leaks
	Lotic system
	Plume
	Pond
	Power plant
	Receiving water
	River
	Sediment
	Steam electric
	Stream
	Surface waters
	Water
	Wastewater
	Water pollution
	Water quality
	Waste management
	Wastewater discharges
Environmental Terms	Algal blooms
	Attractive nuisance
	Background levels/concentrations
	Bioaccumulation
	Biomagnification
	Biomagnify
	Contamination
	Environmental impact
	Environmental assessment
	Eutrophication
	Fish
	Fish consumption advisory
	Fish kill
	Fish mortality
	Fish recovery
	Hot Spot
	Toxicity
	Wildlife
Pollutants of Concern	Arsenic
	Arsenate
	Arsenite
	Boron
	Boric Acid

Table A-1. Keyword Search Terms for Environmental Impacts from Steam Electric Power Plants

Category	Keyword
	Chloride(s)
	Chromium
	Magnesium
	Mercury
	Metals
	Methylmercury
	Nitrate
	Nitrogen
	Selenium
	Selenate
	Selenite
	Sulfate
Fuel Source Terms	Coal
	Coal combustion by-products
	Coal combustion residues
	Oil
Human Health Terms	Cancer
	Carcinogen
	Carcinogenic
	Drinking water
	Health effects
	Human health
	Toxicity
Other Terms	Case study
	Damage case assessment
	Environmental impacts
	Environmental aspects

To perform the literature search, EPA paired each fuel source term (see Table A-1) with at least one keyword to focus the search results. Although EPA used multiple fuel source terms, the environmental impacts from the steam electric power generating industry are documented most commonly for coal-fired power plants. EPA used best professional judgment to create multiple keyword combinations to further focus the literature search.

In addition to the key word combinations and search engines described above, EPA used the following supplemental methods to identify more articles for the targeted topic areas:

- Reviewed references cited in previously identified published literature for additional documented cases of environmental impact.
- Searched the Agency for Toxic Substances and Disease Registry's (ATSDR) website for public health assessments and health consultations with information on the case study sites referenced in Dr. Christopher Rowe's literature review paper published in 2002 [Rowe *et al.*, 2002].

- Searched for case studies of attractive nuisances unrelated to the steam electric power generating industry using the search engines described above.
- Reviewed EPA's December 2014 Coal Combustion Residuals (CCR) Damage Cases Database and supporting compendiums [U.S. EPA, 2014a; U.S. EPA, 2014b; U.S. EPA, 2014c; U.S. EPA, 2014d; U.S. EPA, 2014e][1] and Michigan's Department of Natural Resources and Environment (MDNRE's) Docket Comments (see Table A-3 for a full list of references).
- Searched magazines related to the steam electric industry and newspapers for articles documenting additional environmental impacts.

EPA created a database for the literature review that documents the identified literature and summarizes key information. EPA finalized the primary literature review on November 24, 2010; however, the database also includes literature identified after the primary search efforts were completed [ERG, 2013b]. EPA created a second database to summarize the damage cases and other documented site impacts [ERG, 2015m].

The following tables in Appendix A summarize information EPA gathered from the literature review:

- Table A-2. Summary of Literature Review Results by Information Source.
- Table A-3. Summary of Damage Cases and Other Documented Site Impacts to Surface Water and Ground Water from Steam Electric Power Plant Discharges.
- Table A-4. Summary of Documented Ground Water Damage Cases from Surface Impoundments.
- Table A-5. Summary of Documented Ground Water Damage Cases from Landfills.
- Table A-6. Summary of Documented Surface Water Damage Cases from Surface Impoundments.
- Table A-7. Summary of Documented Surface Water Damage Cases from Landfills.
- Table A-8. Summary of Attractive Nuisances Related to Steam Electric Power Plants.
- Table A-9. Summary of Attractive Nuisances Unrelated to Steam Electric Power Plants.
- Table A-10. Summary of Selenium Concentrations in the Environment and Organisms Experiencing Adverse Effects.

Table A-2 highlights the results of the literature search, including documents identified by keyword searches and relevant documents identified from supplemental methods. During the period following completion of the literature review and the associated database, EPA obtained additional documents (*e.g.*, through public comments and informal searches) that supported development of the final steam electric effluent limitations guidelines and standards (ELGs). EPA

[1] These 2014 references are updates to EPA's September 18, 2012 review of damage cases which were primarily identified in EPA's *Damage Case Assessment Report*; Environmental Integrity Project's (EIP's) *Out of Control: Mounting Damages From Coal Ash*; and EIP's *In Harm's Way: Lack of Federal Coal Ash Regulations Endangers Americans and Their Environment.*

incorporated relevant information from the additional literature in the EA report and in the other tables included in this Appendix.

Table A-3 summarizes the number of documented site impacts to surface water and ground water identified during the literature search and organized by steam electric power plant. Table A-4 and Table A-5 summarize the damage cases to ground water from combustion residuals surface impoundments and landfills, respectively. Table A-6 and Table A-7 summarize the damage cases to surface water from combustion residuals surface impoundments and landfills, respectively. Table A-8 and Table A-9 summarize attractive nuisances identified during the literature search, related and unrelated to steam electric power plants, respectively. Table A-10 presents selenium concentrations in the environment that are documented in the literature as causing sublethal and lethal effects to organisms.

Table A-2. Summary of Literature Review Results by Information Source

Source Type	Number of Documents Identified	Number of Documents Reviewed [f]	Number of Documents that Discussed Environmental and Human Health Impacts
Peer-Reviewed Literature [a]	151	128	117
Government Publication [b]	53	47	32
University Research [c]	13	12	9
Gray Literature [d]	18	16	14
Industry Publication [e]	4	3	3
Total	**239**	**206**	**175**

Source: ERG, 2013b.

a – Peer-reviewed literature consists of journal articles that undergo a formal review process prior to publishing.

b – Government publications are documents affiliated with state or federal government agencies.

c – University research includes finalized dissertations and theses, as well as papers published on behalf of a university or presented at a conference.

d – Gray literature includes documents that are subjected to a less stringent review process (*e.g.*, newspaper articles, environmental group publications).

e – Industry publications include documents prepared by or for industry-affiliated entities.

f – EPA did not review several documents as part of the formal literature review either because EPA was unable to acquire the full text of the document for review or because once the full text document was obtained a preliminary review determined the document was not appropriate for inclusion in the literature review.

Table A-3. Summary of Surface Water and Ground Water Impacts Reported in Damage Cases and Other Documented Sites from Steam Electric Power Plant Discharges

Plant Name	Number of Damage Cases and Other Literature that Document Surface Water Impacts [a]	Number of Damage Cases and Other Literature that Document Ground Water Impacts [a]
A.B. Brown Generating Station, Southern Indiana Gas and Electric Company (SIGECO) (IN)	0	1
Allen Fossil Plant Tennessee Valley Authority (TVA) (TN)	0	1
Allen Steam Generating Plant, Duke Power (NC)	1	1
Alma Station, Dairyland Power (WI)	0	2
Asheville Plant, Progress Energy (NC)	2	1
B.C. Cobb Power Plant, Consumers Energy (MI)	0	2
Bailly Generating Station, Northern Indiana Public Service Company (NIPSCO) (IN)	0	2
Belews Creek Steam Station, Duke Energy (NC)	14	1
Belle River Power Plant, Detroit Edison Company (MI)	1	1
Big Bend Station, Tampa Electric Company (FL)	1	1
Big Cajun 2 Power Plant, NRG Energy/Louisiana Generating, LLC (LA)	0	1
Brandon Shores, Constellation Energy (MD)	0	1
Brayton Point Station, Dominion (MA)	0	1
Bruce Mansfield Power Plant, First Energy (PA)	1	1
Buck Steam Station, Duke Energy (NC)	1	0
Bull Run Steam Plant, Tennessee Valley Authority (TVA) (TN)	1	1
C.D. McIntosh, Jr. Power Plant, City of Lakeland (FL)	0	1
C.R. Huntley Generating Station, NRG Energy (NY)	0	1
Canadys Plant, South Carolina Electric & Gas (SCE&E) (SC)	0	1
Cape Fear Steam Plant, Progress Energy (NC)	0	1
Cardinal Plant, American Electric Power (AEP) (OH)	1	1
Cargill Salt Power Plant, Cargill (MI)	1	1
Cayuga Generating Station, Duke Energy (NY)	1	1
Chalk Point Generating Station, Mirant (MD)	1	1
Chesapeake Energy Facility, Dominion Power (VA)	1	2

Table A-3. Summary of Surface Water and Ground Water Impacts Reported in Damage Cases and Other Documented Sites from Steam Electric Power Plant Discharges

Plant Name	Number of Damage Cases and Other Literature that Document Surface Water Impacts [a]	Number of Damage Cases and Other Literature that Document Ground Water Impacts [a]
Cholla Steam Electric Generating Station, Arizona Public Service Company (AZ)	0	1
Christ Power Plant, Gulf Power (Southern Company) (FL)	0	1
Clifty Creek Station, Indiana Kentucky Electric Company (IKEC) (IN)	0	1
Clinch River Plant, American Electric Power (AEP)/Appalachian Power (VA)	1	0
Coal Creek Station, Cooperative Power Association/United Power (ND)	0	1
Coffeen Power Station, Ameren (IL)	0	1
Colbert Fossil Plant, Tennessee Valley Authority (TVA) (AL)	0	1
Coleto Creek Power Station, International Power (TX)	0	1
Colstrip Power Plant, PPL Montana (MT)	0	1
Columbia Electric Generating Station (WI)	5	0
Columbia Energy Center, Alliant Energy (WI)	1	0
Conesville Power Plant, American Electric Power (AEP) (OH)	0	1
Cross Generating Station, Santee Cooper/South Carolina Public Service Authority (SCPSA) (SC)	0	1
Cumberland Steam Plant, Tennessee Valley Authority (TVA) (TN)	1	1
Curtis Stanton Energy Center, Orlando Utility Commission (FL)	1	1
Dallman Station, City Water, Light and Power (IL)	0	1
Dan River Steam Station, Duke Energy (NC)	2	1
Danskammer Generating Station, Dynegy (NY)	0	1
D-Area Coal-Fired Power Plant, Savannah River Site (SRS) (SC)	24	0
Dave Johnston Power Plant (WY)	1	1
Dickerson Generating Station, Mirant (MD)	1	1
Dolet Hills Power Station, Central Louisiana Electric Co-Op (CLECO) Power, LLC (LA)	0	1
Duck Creek Station, Central Illinois Light Company (IL)	0	1
Dunkirk Generating Station, NRG Energy (NY)	0	1
E.J. Stoneman Generating Station, Dairyland Power Cooperative (WI)	0	1

Table A-3. Summary of Surface Water and Ground Water Impacts Reported in Damage Cases and Other Documented Sites from Steam Electric Power Plant Discharges

Plant Name	Number of Damage Cases and Other Literature that Document Surface Water Impacts [a]	Number of Damage Cases and Other Literature that Document Ground Water Impacts [a]
East Bend Generating Station, Cinergy (KY)	0	1
Eckert Station, Lansing Board of Water & Light (MI)	0	1
Edgewater Generating Station, Alliant Energy (WI)	0	1
Elizabethtown Power Plant, North Carolina Power Holdings (NC)	0	1
Elrama Power Plant, Reliant Energy (PA)	1	1
Erickson Station, Lansing Board of Water & Light (MI)	0	1
Fair Station, Central Iowa Power Cooperative (IA)	0	2
Fayette Power Project, Lower Colorado River Authority (TX)	0	1
Flint Creek Power Plant, American Electric Power (AEP)/South West Electric Power Company (SWEPCO) (AR)	1	1
Gallatin Fossil Plant, Tennessee Valley Authority (TVA) (TN)	0	1
General James M. Gavin Power Plant, American Electric Power/Ohio Power Company (OH)	1	1
George Neal Station North, Berkshire Hathaway/MidAmerican Energy Company (IA)	0	1
George Neal Station South, Berkshire Hathaway/MidAmerican Energy Company (IA)	0	1
Gibson Generating Station, Duke Energy (IN)	5	1
Glen Lyn Plant, American Electric Power (AEP)/Appalachian Power (VA)	6	0
Grainger Generating Station, Santee Cooper/South Carolina Public Service Authority (SCPSA) (SC)	1	1
Greenidge Generation Plant, AES (NY)	0	1
Harbor Beach Power Plant, Detroit Edison Company (MI)	1	1
Hatfield's Ferry Power Station, Allegheny Energy (PA)	1	1
Havana Power Plant, Illinois Power Company (IL)	0	1
Hennepin Power Station, Illinois Power Company (IL)	0	1
Herbert A. Wagner, Constellation Energy (MD)	0	1
Hickling Generation Plant, AES (NY)	0	1
Hopewell Power Station, Dominion Power (VA)	0	1

Table A-3. Summary of Surface Water and Ground Water Impacts Reported in Damage Cases and Other Documented Sites from Steam Electric Power Plant Discharges

Plant Name	Number of Damage Cases and Other Literature that Document Surface Water Impacts [a]	Number of Damage Cases and Other Literature that Document Ground Water Impacts [a]
Hunlock Power Station, UGI Development Company (PA)	0	1
Hutsonville Power Station, Central Illinois Public Service Company (IL)	0	1
Independence Steam Station, Entergy/Arkansas Power and Light (AR)	0	1
Indian River Generating Station, NRG Energy (DE)	1	1
J.H. Campbell Power Plant, Consumers Energy (MI)	1	1
J.R. Whiting Generating Plant, CMS/Consumers Energy (MI)	1	0
Jennison Generation Plant, AES (NY)	0	1
John Amos Plant, American Electric Power (AEP)/Appalachian Power (WV)	1	0
John H. Warden Generating Station, Integrys (MI)	1	1
John Sevier Fossil Plant, Tennessee Valley Authority (TVA) (TN)	1	1
Johnsonville Fossil Plant, Tennessee Valley Authority (TVA) (TN)	2	2
Joliet Generating Station 9, Midwest Generation (IL)	0	2
Joppa Steam Plant, Ameren (Electric Energy) (IL)	0	1
Karn/Weadock Generating Facility, Consumer Energy (MI)	0	1
Kenansville Plant, Green Power Energy Holdings (NC)	0	1
Kingston Fossil Plant, Tennessee Valley Authority (TVA) (TN)	7	1
Lansing Smith Plant, Florida Power and Light (FL)	0	1
Lee Steam Plant, Progress Energy (NC)	0	1
Leland Olds Station, Basin Electric Power Cooperative (ND)	0	1
Lumberton Power Plant, North Carolina Power Holdings (NC)	0	1
Marion Plant, Southern Illinois Power Cooperative (IL)	1	1
Marshall Steam Station, Duke Energy (NC)	1	0
Martin Lake Steam Station, Texas Utilities Electric Service Company (TX)	9	0
Martin's Creek Power Plant, PPL (PA)	1	0
Marysville Power Plant, Detroit Edison Company (MI)	1	1

Table A-3. Summary of Surface Water and Ground Water Impacts Reported in Damage Cases and Other Documented Sites from Steam Electric Power Plant Discharges

Plant Name	Number of Damage Cases and Other Literature that Document Surface Water Impacts [a]	Number of Damage Cases and Other Literature that Document Ground Water Impacts [a]
Mayo Steam Station, Progress Energy (NC)	1	0
McMeekin Station, SCANA/South Carolina Electric & Gas Company (SCE&G) (SC)	0	1
Mendosa Power Station, Ameren Energy Generating Company, (IL)	0	1
Merom Generating Station, Hoosier Energy (IN)	1	1
Miamiview Landfill, Cincinnati Gas & Electric Company (OH) [b]	0	1
Michigan City Generating Station, Northern Indiana Public Service Company (NIPSCO) (IN)	0	1
Mill Creek Plant, E ON U.S./Louisville Gas & Electric (LG&E) (KY)	0	1
Mitchell Power Station, Allegheny Energy (PA)	0	1
Montville Generating Station, NRG Energy/Montville Power, LLC (CT)	1	1
Morgantown Generating Station, Mirant (MD)	2	2
Muskingum River Plant, American Electric Power (AEP)/ Ohio Power Company (OH)	0	1
Nelson Dewey Generating Station, Alliant Energy (WI)	0	1
Northeastern Station, American Electric Power/Public Service Company Oklahoma (OK)	0	1
Oak Creek Power Plant, Wisconsin Energy (WE Energies (WE))/Wisconsin Electric Power Company (WI)	1	0
Oak Ridge Y-12 Plant, Department of Energy (TN)	4	1
Paradise Fossil Plant, Tennessee Valley Authority (TVA) (KY)	0	1
Parish Generating Station, NRG Energy/Texas Genco II (TX)	0	1
Pearl Station, Prairie Power Inc./Soyland Power Coop (IL)	0	1
Petersburg Generating Station, Indianapolis Power & Light (IN)	0	1
Phillips Power Plant, Duquesne Light Company (PA)	1	1
Pirkey Power Plant, Southwestern Electric Power Company (SWEPCO) (TX)	2	0
Plant Bowen, Georgia Power (GA)	1	0
Port Washington Facility, Wisconsin Electric Power Company (WEPCO) (WI)	0	2
Portland Generating Station, RRI Energy (PA)	1	1

Table A-3. Summary of Surface Water and Ground Water Impacts Reported in Damage Cases and Other Documented Sites from Steam Electric Power Plant Discharges

Plant Name	Number of Damage Cases and Other Literature that Document Surface Water Impacts [a]	Number of Damage Cases and Other Literature that Document Ground Water Impacts [a]
Powerton Plant, Commonwealth Edison (IL)	1	1
Prairie Creek Station, Interstate Power and Light (Alliant) (IA)	0	1
Presque Isle Power Plant, WE Energies (WE) (MI)	0	1
Pulliam Power Plant, Wisconsin Public Service Corp. (WI)	0	1
R.M. Heskett Station, Montana-Dakota Utilities (ND)	0	1
R.M. Schahfer Generating Station (IN)	0	1
Reid Gardner Generating Facility, Nevada Energy (NV)	1	1
Riverbend Steam Station, Duke Energy (NC)	4	0
Rock River Generating Station, Alliant Energy (WI)	0	1
Rocky Mount Power Plant (NC)	0	1
Rodemacher Power Station, Central Louisiana Electric Co-Op (CLECO) Power, LLC (LA)	0	1
Roxboro Plant, Progress Energy (NC)	8	0
Salem Harbor Station, Dominion (MA)	0	1
SCANA Williams Station (SC)	1	0
Seminole Generating Station, Seminole Electric Cooperative (FL)	1	1
Seward Generating Station, RRI Energy (PA)	1	1
Shawnee Fossil Plant, Tennessee Valley Authority (TVA) (KY)	1	1
Sheldon Station, Nebraska Public Power District (NE)	0	1
Sherburne County (Sherco) Generating Plant, Xcel Energy/Southern Minnesota Municipal Power Agency (MN)	0	1
Shiras, Marquette Board of Light & Power (MI)	0	1
Spurlock Station, Eastern Kentucky Power Cooperative (KY)	0	1
Sutton Steam Plant, Progress Energy (NC)	1	1
Unnamed Plant 1[c]	1	0

Table A-3. Summary of Surface Water and Ground Water Impacts Reported in Damage Cases and Other Documented Sites from Steam Electric Power Plant Discharges

Plant Name	Number of Damage Cases and Other Literature that Document Surface Water Impacts [a]	Number of Damage Cases and Other Literature that Document Ground Water Impacts [a]
Unnamed Plant 2 [c]	1	0
Unnamed Plant 3 [c]	1	0
Unnamed Plant 4 [c]	1	0
Urquhart Station, South Carolina Electric & Gas Company (SGE&E) (SC)	0	1
Valley Power Plant, Wisconsin Energy (WI)	0	1
Venice Power Station, Union Electric Company/Ameren Energy/AmerenUE (IL)	0	1
Vermillion Power Station, Illinois Power (IL)	0	1
W.C. Beckjord Station, Duke Energy (formerly Cinergy) (OH)	0	1
W.J. Neal Station, Basin Electric Power Cooperative (ND)	1	1
Wateree Station, SCE&G (SC)	1	1
Waukegan Generating Station, Midwest Generation (Edison International) (IL)	0	1
Welsh Power Plant, Southwestern Electric Power Company (SWEPCO) (TX)	3	0
Westover Generation Plant, AES (NY)	0	1
Widows Creek Fossil Plant, Tennessee Valley Authority (TVA) (AL)	0	1
Winyah Generating Station, Santee Cooper/South Carolina Public Service Authority (SCPSA) (SC)	0	1
Wood River Power Station, Illinois Power Company (IL)	0	1
Yorktown Power Station, Virginia Electric Power and Power Company (VEPCO) (VA)	0	1
Total	**152**	**149**

Source: ERG, 2015m; U.S. EPA, 2014a through 2014e.

a – One case study or damage case may document impacts to both ground water and surface water.

b – The damage case source did not specifically identify the plant name; therefore, EPA used the name of the damage case.

c – EPA was unable to identify the steam electric power plant associated with this documented impact. For the purpose of counting the unique number of plants, these impacts were assumed to be associated with a plant not already identified elsewhere in this table.

Table A-4. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Allen Fossil Plant Tennessee Valley Authority (TVA) (TN)	Pond/Impoundment	Arsenic, Manganese, TDS	X			
Allen Steam Generating Plant, Duke Power (NC)	Pond/Impoundment	Manganese, Iron, pH, Nitrate, Nickel	X			
Alma Off-site Fly Ash Landfill, Dairyland Power (WI)	Pond/Impoundment	Sulfate, Manganese, Boron, Selenium, Cadmium				
Asheville Steam Electric Plant, Progress Energy (NC)	Pond/Impoundment	Boron, Chromium, Iron, Manganese, Thallium, Nitrate, Sulfate, pH, TDS, Cadmium, Arsenic, Antimony	X	X		X
Bailly Generating Station, Northern Indiana Public Service Company (NIPSCO) (IN)	Pond/Impoundment, Landfill	Arsenic, Cadmium	X			
Bangor Quarry Ash Disposal Site, Portland Generating Station, RRI Energy (PA)	Pond/Impoundment, Landfill	Selenium, Boron, Cadmium, Hexavalent Chromium, Iron, Manganese, Sulfate, TDS, Aluminum, Fluoride	X	X		
BC Cobb, Consumers Energy (MI)	Pond/Impoundment	Boron, Lithium, Manganese, Sulfate, Ammonia	X			
Belews Creek Steam Station, Duke Energy (NC)	Pond/Impoundment, Landfill	Selenium, Arsenic, Boron, Cadmium, Iron, Lead, Manganese, Nitrate, Sulfate, pH, Bromide	X	X	X	X
Big Bend Station, Tampa Electric Company (FL)	Pond/Impoundment, Landfill	Arsenic, Aluminum, Boron, Chloride, Fluoride, Iron, Manganese, Molybdenum, Sulfate, Sodium, Thallium, TDS	X		X	X
Big Cajun 2 Power Plant, NRG Energy/Louisiana Generating, LLC (LA)	Pond/Impoundment	Selenium, TDS, Barium, Arsenic	X			

Table A-4. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Brandywine Coal Ash Landfill, Mirant Mid-Atlantic LLC (MD)	Pond/Impoundment, Landfill	Selenium, Cadmium, Lead, Manganese, Iron, Aluminum, Sulfate, TDS, Chloride	X	X		X
Bull Run Steam Plant, Tennessee Valley Authority (TVA) (TN)	Pond/Impoundment	Aluminum, Cadmium, Iron, Sulfate, Arsenic, Cobalt, Calcium, Manganese, Molybdenum, Boron, Nickel	X			
C.D. McIntosh, Jr. Power Plant, City of Lakeland (FL)	Pond/Impoundment, Landfill	Selenium, Arsenic, Cadmium, Lead, Manganese, Vanadium, Nitrate, Iron, Sulfate, TDS, pH	X			
C.R. Huntley Flyash Landfill (NY)	Pond/Impoundment, Landfill	Arsenic, Iron, Manganese, Sulfate, TDS, Cadmium, Barium, Lead, TSS	X	X		
Canadys Plant, South Carolina Electric & Gas (SCE&E) (SC)	Pond/Impoundment	Arsenic, Nickel, Selenium	X			X
Cape Fear Steam Plant, Progress Energy (NC)	Pond/Impoundment	Lead, Chromium, Boron, Iron, Manganese, Sulfate, Selenium	X	X		
Cardinal Fly Ash Reservoir (FAR) 1 and 2, American Electric Power (AEP) (OH)	Pond/Impoundment, Landfill	Arsenic, Boron, Molybdenum	X	X		
Cayuga Coal Ash Disposal Landfill, AES (NY)	Pond/Impoundment, Landfill	Selenium, Arsenic, Boron, Cadmium, Lead, TDS, Aluminum, Manganese, Sulfate, Barium, Sodium, Iron, Chromium, Zinc	X	X	X	X
Cholla Steam Electric Generating Station, Arizona Public Service Company (AZ)	Pond/Impoundment	Sulfate, TDS, Chloride, Fluoride	X			

Table A-4. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Clifty Creek Station, Indiana Kentucky Electric Company (IKEC) (IN)	Pond/Impoundment, Landfill	Boron, Manganese, Iron, Sulfate, Magnesium	X			
Coal Creek Station Surface Impoundments, Cooperative Power Association/United Power (ND)	Pond/Impoundment	Selenium, Arsenic, Sulfate, Chloride, Boron, Chromium, Iron, Sodium, TDS	X			
Colbert Fossil Plant, Tennessee Valley Authority (TVA) (AL)	Pond/Impoundment, Landfill	Cadmium, Antimony, Arsenic, Lead, Nitrate, Aluminum, Iron, Manganese, Boron, Molybdenum, Cobalt, Lithium, Sulfate, Chromium	X			
Coleto Creek Power Station, International Power (TX)	Pond/Impoundment	Arsenic, Lead, Boron, Cobalt, Nickel, Vanadium	X			
Colstrip Power Plant, PPL Montana (MT)	Pond/Impoundment, Landfill	Selenium, Boron, Sulfate, TDS, Molybdenum, Arsenic, Chloride	X			X
Cross Generating Station, Santee Cooper/South Carolina Public Service Authority (SCPSA) (SC)	Pond/Impoundment, Landfill	Arsenic, Cadmium, Chromium, Sodium, Sulfate, Iron, Aluminum, Chloride, TDS	X			
Cumberland Steam Plant, Tennessee Valley Authority (TVA) (TN)	Pond/Impoundment, Landfill	Selenium, Arsenic, Aluminum, Boron, Chloride, Iron, Manganese, Sulfate, TDS, Vanadium	X	X		
Curtis Stanton Energy Center, Orlando Utility Commission (FL)	Pond/Impoundment, Landfill	Aluminum, Chloride, Iron, Manganese, Sodium, Sulfate, TDS, Vanadium, pH				
Dallman Station Ash and FGD Ponds, City Water, Light and Power (IL)	Pond/Impoundment, Landfill	Arsenic, Chromium, Sodium, Boron, Manganese, Iron, Sulfate, TDS	X X			

Table A-4. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Dan River Steam Station, Duke Energy (NC)	Pond/Impoundment, Landfill	Chromium, Iron, Lead, Manganese, Silver, Sulfate, Arsenic, Antimony, Boron, TDS, pH	X	X		
Dave Johnston Power Plant (WY)	Pond/Impoundment, Landfill	Cadmium, Manganese, Sulfate, Boron	X			
Dolet Hills Power Station, Central Louisiana Electric Co-Op (CLECO) Power, LLC (LA)	Pond/Impoundment, Landfill	Selenium, Arsenic, Lead, Chloride, TDS, Sulfate, Iron, pH	X			
Duck Creek Station, Central Illinois Light Company (IL)	Pond/Impoundment	Sulfate, TDS, Chloride, Manganese, Iron, Boron				
E.J. Stoneman Generating Station, Dairyland Power Cooperative (WI)	Pond/Impoundment	Cadmium, Chromium, Sulfate, Manganese, Iron, Zinc, Boron, Barium	X			X
Edgewater 1-4 Ash Disposal Site, Alliant (formerly Wisconsin Power & Light) (WI)	Pond/Impoundment, Landfill	Boron, Sulfate, Iron, Chloride, TDS, Arsenic, Selenium	X			X
Fayette Power Project (Sam Seymour), Lower Colorado River Authority (TX)	Pond/Impoundment, Landfill	Selenium, Aluminum, Chloride, Cobalt, Manganese, Molybdenum, Sulfate, TDS, Vanadium	X			
Flint Creek Power Plant, American Electric Power (AEP)/South West Electric Power Company (SWEPCO) (AR)	Pond/Impoundment, Landfill	Selenium, Barium, Cadmium, Chromium, Iron, Lead, Manganese, pH, Silver, Sulfate, TDS	X	X		
Fly Ash Landfill, Coffeen/White & Brewer Trucking (IL)	Pond/Impoundment, Landfill	Sulfate, TDS, Manganese, Cadmium, Chromium, Thallium, Beryllium, Boron, Nickel, Barium, Iron, Zinc, Aluminum, Sodium	X			

Table A-4. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Gallatin Fossil Plant, Tennessee Valley Authority (TVA) (TN)	Pond/Impoundment	Boron, Beryllium, Cadmium, Iron, Manganese, Nickel, Sulfate, TDS, Arsenic, Mercury, Vanadium, Cobalt	X			
General James M. Gavin Power Plant, American Electric Power/Ohio Power Company (OH)	Pond/Impoundment, Landfill	Arsenic, Barium, Cadmium, Lead, Molybdenum, Sulfate, TDS, Aluminum, Copper, Nickel, Zinc, Manganese, Chloride	X	X		X
George Neal Station North Landfill, Berkshire Hathaway/MidAmerican Energy Company (IA)	Landfill, Pond/Impoundment	Iron, Manganese, Sulfate, Arsenic	X			X
Gibson Generating Station, Duke Energy (IN)	Pond/Impoundment, Landfill, Cooling Reservoir	Selenium, Arsenic, Boron, Manganese, Iron, Sodium	X	X		X
Grainger Generating Station, Santee Cooper/South Carolina Public Service Authority (SCPSA) (SC)	Pond/Impoundment	Arsenic, pH	X			
Havana Power Plant, Illinois Power Company (IL)	Pond/Impoundment	Manganese, Sulfate, Boron				
Hennepin Power Station, Illinois Power Company (IL)	Pond/Impoundment, Landfill	Sulfate, TDS, Boron, Iron, Manganese	X			
Hunlock Power Station, UGI Development Company (PA)	Pond/Impoundment	Arsenic, Iron, Manganese	X		X	
Hutsonville Power Station, Central Illinois Public Service Company (IL)	Pond/Impoundment	Sulfate, TDS, Manganese, Boron				

Table A-4. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Independence Steam Station, Entergy/Arkansas Power and Light (AR)	Pond/Impoundment, Landfill	Cadmium, Iron, Lead, Manganese, pH, Sulfate, TDS, Arsenic, Chlorine	X			X
J.H. Campbell, Consumers Energy (MI)	Pond/Impoundment	pH, Antimony, Boron, Cadmium, Chromium, Iron, Lead, Selenium, Vanadium, Aluminum, Nickel, Thallium, Manganese, Zinc	X	X		
John Sevier Fossil Plant, Tennessee Valley Authority (TVA) (TN)	Pond/Impoundment	Arsenic, Aluminum, Cadmium, Manganese, Boron, Strontium, Sulfate, Selenium, Hexavalent Chromium	X	X	X	X
Johnsonville Fossil Plant, Tennessee Valley Authority (TVA) (TN)	Pond/Impoundment, Landfill	Arsenic, Aluminum, Boron, Cadmium, Chromium, TDS, Iron, Lead, Manganese, Molybdenum, Sulfate, Cobalt	X	X	X	X
Joppa Steam Plant Ash Ponds, Ameren (Electric Energy) (IL)	Pond/Impoundment	Lead, Chromium, Cobalt, Boron, Manganese, Sulfate, Iron, TDS	X			
Karn/Weadock Generating Facility, Consumer Energy (MI)	Pond/Impoundment, Landfill	Arsenic, Boron, Lithium,	X			X
Kingston Fossil Plant, Tennessee Valley Authority (TVA) (TN)	Pond/Impoundment	Arsenic, Selenium, Manganese, Cobalt, Aluminum, Ammonia, Thallium, Iron	X	X		X
Lansing Smith Plant, Florida Power and Light (FL)	Pond/Impoundment	Aluminum, Cadmium, Chloride, Chromium, Fluoride, Sulfate, Manganese, Iron, Radium-226, Radium-228, TDS, Sodium	X			
Lee Steam Plant, Progress Energy (NC)	Pond/Impoundment	Arsenic, Lead, Boron, Manganese, Iron, Chromium, pH	X			X
Leland Olds Station, Basin Electric Power Cooperative (ND)	Pond/Impoundment	Arsenic, Boron, Lead, Sulfate	X			

Table A-4. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Lincoln Stone Quarry Landfill, Joliet Generating Station 29, Midwest Generation (IL)	Pond/Impoundment	Antimony, Manganese, Sulfate, Chloride, TDS	X			
Lincoln Stone Quarry Landfill, Joliet Generating Station 9, Midwest Generation (IL)	Pond/Impoundment, Landfill	Arsenic, Ammonia, Boron, Molybdenum, pH, Sulfate, TDS, Barium, Copper, Selenium, Cadmium	X			X
Little Blue Run Surface Impoundment, Bruce Mansfield Power Plant, First Energy (PA)	Pond/Impoundment	Selenium, Arsenic, Aluminum, Antimony, Barium, Boron, Cadmium, Calcium, Chloride, Hexavalent Chromium, Fluoride, Iron, Lead, Manganese, pH, Sodium, Sulfate, TDS, TSS, Thallium, Turbidity	X	X		X
Mahoney Landfill, Powerton Plant, Commonwealth Edison (IL)	Pond/Impoundment, Landfill	Arsenic, Selenium, Chromium, TDS, Cadmium, Lead, Nitrate, Iron, Manganese, Sulfate, Boron,	X			
Marion Plant, Southern Illinois Power Cooperative (IL)	Pond/Impoundment, Landfill	Boron, Cadmium, Iron, Aluminum, TDS, Sulfate	X	X	X	X
McMeekin Station, SCANA/South Carolina Electric & Gas Company (SCE&G) (SC)	Pond/Impoundment, Landfill	Chromium, Lead, Sulfate, Iron, TDS	X			
Mendosa Power Station Ash Ponds, Ameren Energy Generating Company, (IL)	Pond/Impoundment	Arsenic, Boron, Manganese, Chromium (?), Sulfate, TDS	X	X		
Michigan City Site (IN)	Pond/Impoundment	Arsenic, Lead	X			
Mill Creek Plant, E ON U.S./Louisville Gas & Electric (LG&E) (KY)	Pond/Impoundment, Landfill	Arsenic, Chloride, Sulfate, TDS	X			

Table A-4. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Mitchell Power Station, Allegheny Energy (PA)	Pond/Impoundment, Landfill	Arsenic, Boron, Iron, Molybdenum, Manganese, Nickel	X			X
Montville Generating Station, NRG Energy/Montville Power, LLC (CT)	Pond/Impoundment	Arsenic, Beryllium, Cadmium, Copper, Iron, Lead, Manganese, Nickel, pH, Zinc	X	X		X
Morgantown Generating Station, Faulkner Off-site Disposal Facility (MD)	Pond/Impoundment, Landfill	Iron, pH, Cadmium, Aluminum, Chloride, Manganese, Sulfate, TDS, Copper, Lead, Selenium	X	X	X	X
Muskingum River Plant, American Electric Power (AEP)/ Ohio Power Company (OH)	Pond/Impoundment	Barium, Iron, Sulfate	X			X
Nelson Dewey Ash Disposal Facility, Alliant (formerly Wisconsin Power & Light) (WI)	Pond/Impoundment	Selenium, Arsenic, Sulfate, Boron, Fluoride, Cadmium (?), Iron				
Northeastern Station Ash Landfill, American Electric Power/Public Service Company Oklahoma (OK)	Landfill, Pond/Impoundment	Selenium, Arsenic, Barium, Chromium, Lead, Vanadium, Thallium, Sulfate, pH	X		X	X
Oak Ridge Y-12 Plant, Chestnut Ridge Operable Unit 2, Oak Ridge Reservation, Department of Energy (TN)	Pond/Impoundment	Selenium, Arsenic, Aluminum, Iron, Zinc, Manganese, Thallium (?)	X		X	
Paradise Fossil Plant, Tennessee Valley Authority (TVA) (KY)	Pond/Impoundment	Arsenic, Boron, Chromium, Copper, Manganese	X			
Parish Generating Station, NRG Energy/Texas Genco II (TX)	Pond/Impoundment, Landfill	Arsenic, Selenium, Barium, Boron, Chromium, Cobalt, Manganese, Molybdenum, Sulfate	X			
Pearl Station, Prairie Power Inc./Soyland Power Coop (IL)	Pond/Impoundment	Arsenic, Chromium, Boron, Manganese, Sulfate, Chlorine, Iron, TDS, Lead, Boron	X			

Table A-4. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Phillips Power Plant Landfill, Duquesne Light Company (PA)	Pond/Impoundment, Landfill	TDS, Chloride, Fluoride, Manganese, Aluminum, Arsenic	X	X	X	X
Prairie Creek Generating Station Ash Landfill, Interstate Power and Light (Alliant) (IA)	Pond/Impoundment, Landfill	Arsenic, Boron, Manganese, Sulfate, Iron	X	X		
R.M. Schahfer Generating Station (IN)	Landfill, Pond/Impoundment	Sulfate, Iron, Manganese, Molybdenum, Chlorine, Sodium, Boron				
Reid Gardner Generating Facility, Nevada Energy (NV)	Pond/Impoundment, Landfill	Selenium, Arsenic, Chloride, Sulfate, TDS, Nitrate, Boron, Chromium, Manganese, Magnesium, Molybdenum, Sodium, Vanadium, Titanium, Barium, Iron, Aluminum	X	X	X	X
Rock River Ash Disposal Facility, Alliant (formerly Wisconsin Power & Light) (WI)	Pond/Impoundment	Mercury, Arsenic, Sulfate, Iron, Selenium, Boron, TDS	X			
Rodemacher Power Station, Central Louisiana Electric Co-Op (CLECO) Power, LLC (LA)	Pond/Impoundment, Landfill	Arsenic, Lead, pH, TDS, Chloride, Sulfate	X			
Seminole Generating Station, Seminole Electric Cooperative (FL)	Pond/Impoundment, Landfill	Arsenic, Chloride, Chlorine, Sulfate, Iron, TDS, Boron, Aluminum, Lead, Sodium	X	X		X
Seward Generating Station, RRI Energy (PA)	Pond/Impoundment, Landfill	Selenium, Arsenic, Aluminum, Antimony, Cadmium, Chloride, Chromium, Iron, Lead, Manganese, Nickel, pH, Sulfate, TDS, Zinc,	X	X		X

Table A-4. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Shawnee Fossil Plant, Tennessee Valley Authority (TVA) (KY)	Pond/Impoundment, Landfill	Selenium, Arsenic, Boron, pH, Sulfate, TDS, Beryllium, Cobalt, Nickel, Molybdenum, Manganese, Vanadium	X		X	X
Sherburne County (Sherco) Generating Plant, Xcel Energy/Southern Minnesota Municipal Power Agency (MN)	Pond/Impoundment, Landfill	Arsenic, Cadmium, Lead, Sulfate, Selenium, Boron	X			
Spurlock Station, Eastern Kentucky Power Cooperative (KY)	Pond/Impoundment, Landfill	Arsenic, Sulfate, TDS	X			X
Sutton Steam Plant, Progress Energy (NC)	Pond/Impoundment	Arsenic, Boron, Manganese, Iron, Thallium, Selenium, Antimony, Lead, Sulfate, TDS	X	X		X
Urquhart Station, South Carolina Electric & Gas Company (SGE&E) (SC)	Pond/Impoundment, Landfill	Arsenic, Nickel	X			
Venice Power Station Ash Ponds, Union Electric Company/Ameren Energy/AmerenUE (IL)	Pond/Impoundment	Arsenic, Boron, Cadmium, Iron, Manganese, TDS	X	X		X
Vermillion Power Station, Illinois Power (IL)	Pond/Impoundment	Sulfate, TDS, Boron, Iron, Manganese, Chloride				
W.C. Beckjord Station, Duke Energy (formerly Cinergy) (OH)	Pond/Impoundment	Selenium, Sulfate	X			
W.J. Neal Station Surface Impoundment, Basin Electric Power Cooperative (ND)	Pond/Impoundment	Selenium, Arsenic, Chromium, Cadmium, Lead, Zinc, Aluminum	X		X	X
Wateree Station, SCE&G (SC)	Pond/Impoundment, Landfill	Arsenic, Chromium, Cadmium, Lead, Iron	X	X		X

Table A-4. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Waukegan Generating Station Ash Ponds, Midwest Generation (Edison International) (IL)	Pond/Impoundment, Landfill	Arsenic, Antimony, Boron, Manganese, Sulfate, TDS, Iron	X	X		
Weber Ash Disposal Site, AES Creative Resources (NY)	Pond/Impoundment, Landfill	Sulfate, TDS, Manganese, Iron, Aluminum, pH	X			
Westland Disposal Site, Dickerson Generating Station, Mirant (MD)	Pond/Impoundment, Landfill	Selenium, Arsenic, Barium, Chromium, Cobalt, Copper, Iron, Zinc, Sulfate, Chlorine, Hardness, TDS, Aluminum	X	X	X	
Widows Creek Fossil Plant, Tennessee Valley Authority (TVA) (AL)	Pond/Impoundment	Lead, Cobalt, Boron, Iron, Manganese, Aluminum, Sulfate	X			
Winyah Generating Station, Santee Cooper/South Carolina Public Service Authority (SCPSA) (SC)	Pond/Impoundment	Arsenic, Chromium, Sulfate, Iron, Chloride	X	X		
Wood River Power Station, Illinois Power Company (IL)	Pond/Impoundment	Sulfate, TDS, Chloride, Manganese, Iron, Boron				
Yorktown Power Station, Chisman Creek Disposal Site, Virginia Electric Power and Power Company (VEPCO) (VA)	Pond/Impoundment, Landfill	Sulfate, Nickel, Vanadium, Selenium	X			

Sources: ERG, 2015m; U.S. EPA, 2012e (DCN SE01966); U.S. EPA, 2013b; U.S. EPA, 2014a through 2014e.

Acronyms: FGD (Flue Gas Desulfurization); MCL (Maximum Contaminant Level); TDS (Total Dissolved Solids); WQC (Water Quality Criteria).

a – The term "ash" was used when the impact case study source did not identify the type of ash present at the waste management unit.

b – An "X" indicates that one or more of the pollutants listed exceeded MCLs or federal/state WQC/standards.

c – An "X" indicates that the ground water contaminated the surface water with one or more of the pollutants listed.

d – An "X" indicates that the ground water contaminated a source outside the plant property boundaries.

Table A-5. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
A.B. Brown Generating Station, Southern Indiana Gas and Electric Company (SIGECO) (IN)	FGD	Arsenic, Sodium, Boron, Sulfate, TDS, Chloride, pH	X			
Alma On-site Fly Ash Landfill, Dairyland Power (WI)	Fly Ash	Sulfate, Manganese				
Bailly Generating Station, Northern Indiana Public Service Company (NIPSCO) (IN)	Ash	Arsenic, Cadmium	X			
Bangor Quarry Ash Disposal Site, Portland Generating Station, RRI Energy (PA)	Bottom Ash, Fly Ash, Other	Selenium, Boron, Cadmium, Hexavalent Chromium, Iron, Manganese, Sulfate, TDS, Aluminum, Fluoride	X	X		
Battlefield Golf Club, Chesapeake Energy Facility, Dominion Power (VA)	Fly Ash	Arsenic, Cadmium, Chromium, Copper, Lead, Manganese, Thallium, Zinc, Vanadium, Iron, Boron, Aluminum	X			
BBSS Sand and Gravel Quarries, Constellation Energy (MD)	Fly Ash, Bottom Ash	Arsenic, Selenium, Aluminum, Cadmium, Thallium, Manganese, Sulfate, Beryllium, Lead, Nickel	X			X
Belews Creek Steam Station, Duke Energy (NC)	Fly Ash, FGD	Selenium, Arsenic, Boron, Cadmium, Iron, Lead, Manganese, Nitrate, Sulfate, pH, Bromide	X	X	X	X
Big Bend Station, Tampa Electric Company (FL)	Bottom Ash, Fly Ash, FGD, Other	Arsenic, Aluminum, Boron, Chloride, Fluoride, Iron, Manganese, Molybdenum, Sulfate, Sodium, Thallium, TDS	X		X	X
Brandywine Coal Ash Landfill, Mirant Mid-Atlantic LLC (MD)	Bottom Ash, Fly Ash	Selenium, Cadmium, Lead, Manganese, Iron, Aluminum, Sulfate, TDS, Chloride	X	X		X
C.D. McIntosh, Jr. Power Plant, City of Lakeland (FL)	Ash, FGD	Selenium, Arsenic, Cadmium, Lead, Manganese, Vanadium, Nitrate, Iron, Sulfate, TDS, pH	X			

Table A-5. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
C.R. Huntley Flyash Landfill (NY)	Bottom Ash, Fly Ash, Other	Arsenic, Iron, Manganese, Sulfate, TDS, Cadmium, Barium, Lead, TSS	X	X		
Cardinal Fly Ash Reservoir (FAR) 1 and 2, American Electric Power (AEP) (OH)	Bottom Ash, Fly Ash, FGD	Arsenic, Boron, Molybdenum	X	X		
Cayuga Coal Ash Disposal Landfill, AES (NY)	Bottom Ash, Fly Ash, Other	Selenium, Arsenic, Boron, Cadmium, Lead, TDS, Aluminum, Manganese, Sulfate, Barium, Sodium, Iron, Chromium, Zinc	X	X	X	X
CCW Landfill, Trans-Ash, Inc. (TN)	Bottom Ash, Fly Ash	Mercury, Iron, Boron, Sulfate, Arsenic, Chromium, Lead	X			X
Cedar-Sauk Landfill, Wisconsin Electric Power Company (WEPCO) (WI)	Fly Ash, Bottom Ash	Selenium, Sulfate, Boron	X			
Clifty Creek Station, Indiana Kentucky Electric Company (IKEC) (IN)	Fly Ash, Other	Boron, Manganese, Iron, Sulfate, Magnesium	X			
Coal Ash Pit #3, Sheldon Station, Nebraska Public Power District (NE)	Fly Ash	Selenium, Sulfate	X			X
Coal Combustion Waste Landfill, Merom Generating Station, Hoosier Energy (IN)	Fly Ash, Bottom Ash	Barium, Chromium, Cadmium, Lead, Sulfate, Chloride, Sodium	X			
Colbert Fossil Plant, Tennessee Valley Authority (TVA) (AL)	Bottom Ash, Fly Ash, Other	Cadmium, Antimony, Arsenic, Lead, Nitrate, Aluminum, Iron, Manganese, Boron, Molybdenum, Cobalt, Lithium, Sulfate, Chromium	X			
Colstrip Power Plant, PPL Montana (MT)	Bottom Ash, Fly Ash, FGD	Selenium, Boron, Sulfate, TDS, Molybdenum, Arsenic, Chloride	X			X

Table A-5. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Conesville Fixed FGD Sludge Landfill, American Electric Power (AEP) (OH)	Fly Ash, FGD	Arsenic, Cadmium, Chromium, Calcium, Magnesium, TDS, Sulfate, Iron, Selenium	X			
Crist Plant Ash Landfill, Gulf Power (Southern Company) (FL)	Fly ash, Bottom Ash, FGD	Arsenic, Cadmium, Manganese, Chromium, Sodium, Sulfate, Aluminum, Chlorine, Iron, pH, TDS	X			
Cross Generating Station, Santee Cooper/South Carolina Public Service Authority (SCPSA) (SC)	Bottom Ash, FGD	Arsenic, Cadmium, Chromium, Sodium, Sulfate, Iron, Aluminum, Chloride, TDS	X			
Cumberland Steam Plant, Tennessee Valley Authority (TVA) (TN)	Bottom Ash, Fly Ash, FGD	Selenium, Arsenic, Aluminum, Boron, Chloride, Iron, Manganese, Sulfate, TDS, Vanadium	X	X		
Curtis Stanton Energy Center, Orlando Utility Commission (FL)	Bottom Ash, Other	Aluminum, Chloride, Iron, Manganese, Sodium, Sulfate, TDS, Vanadium, pH		X		
Dallman Station Ash and FGD Ponds, City Water, Light and Power (IL)	Ash, FGD	Arsenic, Chromium, Sodium, Boron, Manganese, Iron, Sulfate, TDS	X			
Dan River Steam Station, Duke Energy (NC)	Bottom Ash, Fly Ash, Other	Chromium, Iron, Lead, Manganese, Silver, Sulfate, Arsenic, Antimony, Boron, TDS, pH	X	X		
Danskammer Waste Management Facility, Central Hudson Gas and Electric Corporation (NY)	Ash	Sulfate, Sulfide, TDS, Turbidity, Iron, Magnesium, Manganese, Sodium, Boron, pH				
Dave Johnston Power Plant (WY)	Fly Ash	Cadmium, Manganese, Sulfate, Boron	X			
Dolet Hills Power Station, Central Louisiana Electric Co-Op (CLECO) Power, LLC (LA)	Bottom Ash, Fly Ash, FGD, Other	Selenium, Arsenic, Lead, Chloride, TDS, Sulfate, Iron, pH	X			
East Bend Scrubber Sludge Landfill, Cinergy (KY)	FGD	TDS, Iron, Sulfate, Manganese, Chloride				

Table A-5. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Edgewater 1-4 Ash Disposal Site, Alliant (formerly Wisconsin Power & Light) (WI)	Ash	Boron, Sulfate, Iron, Chloride, TDS, Arsenic, Selenium	X			X
Fair Station Ash Landfill, Central Iowa Power Cooperative (IA)	Ash	Selenium, Manganese, Sulfate, Iron	X			
Fayette Power Project (Sam Seymour), Lower Colorado River Authority (TX)	Bottom Ash, Fly Ash, FGD, Other	Selenium, Aluminum, Chloride, Cobalt, Manganese, Molybdenum, Sulfate, TDS, Vanadium	X			
Fern Valley Landfill, Orion Power Holdings, Inc. (a subsidiary of RRI Energy) (PA)	Fly Ash	Selenium, Aluminum, Boron, Chloride, Sulfate, TDS	X	X	X	X
Flint Creek Power Plant, American Electric Power (AEP)/South West Electric Power Company (SWEPCO) (AR)	Bottom Ash, Fly Ash, Other	Selenium, Barium, Cadmium, Chromium, Iron, Lead, Manganese, pH, Silver, Sulfate, TDS	X	X		
Fly Ash Landfill, Coffeen/White & Brewer Trucking (IL)	Fly Ash, FGD, Bottom Ash	Sulfate, TDS, Manganese, Cadmium, Chromium, Thallium, Beryllium, Boron, Nickel, Barium, Iron, Zinc, Aluminum, Sodium	X			
Fly Ash Landfill, Don Frame Trucking, Inc. (NY)	Bottom Ash, Fly Ash, Other	Lead, Sulfate, TDS, Manganese, Iron	X			
General James M. Gavin Power Plant, American Electric Power/Ohio Power Company (OH)	Bottom Ash, Fly Ash, FGD, Other	Arsenic, Barium, Cadmium, Lead, Molybdenum, Sulfate, TDS, Aluminum, Copper, Nickel, Zinc, Manganese, Chloride	X	X		X
George Neal Station North Landfill, Berkshire Hathaway/MidAmerican Energy Company (IA)	Fly Ash	Iron, Manganese, Sulfate, Arsenic	X			X

Table A-5. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
George Neal Station South Ash Monofill, Berkshire Hathaway/MidAmerican Energy Company (IA)	Bottom Ash, Fly Ash	Selenium, Arsenic, Barium, Zinc, Iron, Manganese, Sulfate	X			
Gibson Generating Station, Duke Energy (IN)	Bottom Ash, Fly Ash	Selenium, Arsenic, Boron, Manganese, Iron, Sodium	X	X		X
Hatfield's Ferry Power Station, Allegheny Energy (PA)	Bottom Ash, Fly Ash, FGD	Arsenic, Aluminum, Boron, Chromium, Manganese, Molybdenum, Thallium, TDS, Sulfate, Selenium	X	X		X
Hennepin Power Station, Illinois Power Company (IL)	Fly Ash	Sulfate, TDS, Boron, Iron, Manganese	X			
Highway 59 Landfill, Wisconsin Electric Power Company (WEPCO) (WI)	Bottom Ash, Fly Ash	Selenium, Sulfate, Boron, Manganese, Chloride, Iron, Arsenic, Molybdenum, TDS		X		X
Independence Steam Station, Entergy/Arkansas Power and Light (AR)	Bottom Ash, Fly Ash, Other	Cadmium, Iron, Lead, Manganese, pH, Sulfate, TDS, Arsenic, Chlorine	X			X
Indian River Generating Station, NRG Energy (DE)	Ash	Selenium, Mercury, Arsenic, Aluminum, Barium, Cadmium, Chromium, Copper, Lead, Nickel, Thallium, Zinc, Iron, Manganese	X	X		X
John Warden Ash Site (MI)	Ash, Other	Boron, Lithium				
Johnsonville Fossil Plant, Tennessee Valley Authority (TVA) (TN)	Bottom Ash, Fly Ash	Arsenic, Aluminum, Boron, Cadmium, Chromium, TDS, Iron, Lead, Manganese, Molybdenum, Sulfate, Cobalt	X	X	X	X
K.R. Rezendes South Main Street Ash Landfill, Salem Harbor and Brayton Point Plants, Pacific Gas and Electric (PG&E) (MA)	Ash	Selenium, Arsenic (?)	X			

Table A-5. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Karn/Weadock Generating Facility, Consumer Energy (MI)	Ash, Fly Ash, Bottom Ash	Arsenic, Boron, Lithium,	X			X
Lincoln Stone Quarry Landfill, Joliet Generating Station 9, Midwest Generation (IL)	Ash	Arsenic, Ammonia, Boron, Molybdenum, pH, Sulfate, TDS, Barium, Copper, Selenium, Cadmium	X			X
Mahoney Landfill, Powerton Plant, Commonwealth Edison (IL)	Bottom Ash, Fly Ash, Other	Arsenic, Selenium, Chromium, TDS, Cadmium, Lead, Nitrate, Iron, Manganese, Sulfate, Boron,	X			
Marion Plant, Southern Illinois Power Cooperative (IL)	Bottom Ash, Fly Ash, FGD	Boron, Cadmium, Iron, Aluminum, TDS, Sulfate	X	X	X	X
McMeekin Station, SCANA/South Carolina Electric & Gas Company (SCE&G) (SC)	Ash	Chromium, Lead, Sulfate, Iron, TDS	X			
Miamiview Landfill, Cincinnati Gas & Electric Company (OH)	FGD	Sulfate, Manganese				
Mill Creek Plant, E ON U.S./Louisville Gas & Electric (LG&E) (KY)	Bottom Ash, Fly Ash, FGD, Other	Arsenic, Chloride, Sulfate, TDS	X			
Mitchell Power Station, Allegheny Energy (PA)	Bottom Ash, Fly Ash	Arsenic, Boron, Iron, Molybdenum, Manganese, Nickel	X			X
Morgantown Generating Station, Faulkner Off-site Disposal Facility (MD)	Bottom Ash, Fly Ash, Other	Iron, pH, Cadmium, Aluminum, Chloride, Manganese, Sulfate, TDS, Copper, Lead, Selenium	X	X	X	X
Muscatine County Landfill (IA)	Ash	Selenium, Sulfate	X			
Muskegon County Type III Landfill (MI)	Fly Ash	Boron, Manganese		X		
North Lansing Landfill, Lansing Board of Water & Light (MI)	Ash, Other	Selenium, Boron, Lithium, Manganese, Sulfate, Lead	X			

Table A-5. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Northeastern Station Ash Landfill, American Electric Power/Public Service Company Oklahoma (OK)	Bottom Ash, Fly Ash	Selenium, Arsenic, Barium, Chromium, Lead, Vanadium, Thallium, Sulfate, pH	X		X	X
Parish Generating Station, NRG Energy/Texas Genco II (TX)	Fly Ash, Bottom Ash, FGD (Emergency Only)	Arsenic, Selenium, Barium, Boron, Chromium, Cobalt, Manganese, Molybdenum, Sulfate	X			
Petersburg Generating Station, Indianapolis Power & Light (IN)	Not Specified	Sulfate, TDS	X			
Phillips Power Plant Landfill, Duquesne Light Company (PA)	Ash, FGD	TDS, Chloride, Fluoride, Manganese, Aluminum, Arsenic	X	X	X	X
Pine Hill Landfill, Marquette Board of Light & Power (MI)	Fly Ash	Boron, Lithium, Sodium		X		
Port Washington Facility, Wisconsin Electric Power Company (WEPCO) (WI)	Bottom Ash, Fly Ash	Selenium, Boron, Sulfate				X
Prairie Creek Generating Station Ash Landfill, Interstate Power and Light (Alliant) (IA)	Ash	Arsenic, Boron, Manganese, Sulfate, Iron	X	X		
Presque Isle Power Plant, WE Energies (WE) (MI)	Bottom Ash, Fly Ash	Boron, Molybdenum, Selenium, Sodium, Sulfate, Lithium				
Pulliam Ash Disposal Site, Wisconsin Power Supply Company (WPSC) (WI)	Bottom Ash, Fly Ash	Sulfate, Manganese, Iron, Boron, Zinc, Aluminum, Chlorine, TDS, pH				
R.M. Heskett Station, Montana-Dakota Utilities (ND)	Ash	Sulfate, Boron, Cadmium, Selenium, Nitrate	X			
R.M. Schahfer Generating Station (IN)	Ash, FGD	Sulfate, Iron, Manganese, Molybdenum, Chlorine, Sodium, Boron				

Table A-5. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Range Road Landfill, Detroit Edison (MI)	Ash	Boron, Lithium, Manganese		X		X
Reid Gardner Generating Facility, Nevada Energy (NV)	Fly Ash, FGD	Selenium, Arsenic, Chloride, Sulfate, TDS, Nitrate, Boron, Chromium, Manganese, Magnesium, Molybdenum, Sodium, Vanadium, Titanium, Barium, Iron, Aluminum	X	X	X	X
Rodemacher Power Station, Central Louisiana Electric Co-Op (CLECO) Power, LLC (LA)	Bottom Ash, Fly Ash, Other	Arsenic, Lead, pH, TDS, Chloride, Sulfate	X			
Seminole Generating Station, Seminole Electric Cooperative (FL)	Fly Ash, FGD, Other	Arsenic, Chloride, Chlorine, Sulfate, Iron, TDS, Boron, Aluminum, Lead, Sodium	X	X		X
Seward Generating Station, RRI Energy (PA)	Ash, Other	Selenium, Arsenic, Aluminum, Antimony, Cadmium, Chloride, Chromium, Iron, Lead, Manganese, Nickel, pH, Sulfate, TDS, Zinc,	X	X		X
Shawnee Fossil Plant, Tennessee Valley Authority (TVA) (KY)	Bottom Ash, Fly Ash	Selenium, Arsenic, Boron, pH, Sulfate, TDS, Beryllium, Cobalt, Nickel, Molybdenum, Manganese, Vanadium	X		X	X
Sherburne County (Sherco) Generating Plant, Xcel Energy/Southern Minnesota Municipal Power Agency (MN)	Bottom Ash, Fly Ash, FGD	Arsenic, Cadmium, Lead, Sulfate, Selenium, Boron	X			
Spurlock Station, Eastern Kentucky Power Cooperative (KY)	Bottom Ash, Fly Ash, FGD	Arsenic, Sulfate, TDS	X			X
Swift Creek Structural Fill, ReUse Technology, Inc./ Full Circle Solutions (NC)	Fly Ash	Arsenic, Lead, Sulfate	X	X		X

Table A-5. Summary of Ground Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded MCL [b]	Exceeded Federal/ State WQC/ Standards [b]	Ground Water Impacted Surface Waters [c]	Impacted Off-Site Source [d]
Urquhart Station, South Carolina Electric & Gas Company (SGE&E) (SC)	Fly Ash, Bottom Ash, Other	Arsenic, Nickel	X			
Wateree Station, SCE&G (SC)	Bottom Ash, Fly Ash, FGD	Arsenic, Chromium, Cadmium, Lead, Iron	X	X		X
Waukegan Generating Station Ash Ponds, Midwest Generation (Edison International) (IL)	Ash	Arsenic, Antimony, Boron, Manganese, Sulfate, TDS, Iron	X	X		
Weber Ash Disposal Site, AES Creative Resources (NY)	Ash	Sulfate, TDS, Manganese, Iron, Aluminum, pH	X			
Westland Disposal Site, Dickerson Generating Station, Mirant (MD)	Fly Ash	Selenium, Arsenic, Barium, Chromium, Cobalt, Copper, Iron, Zinc, Sulfate, Chlorine, Hardness, TDS, Aluminum	X	X	X	
Yard 520 Landfill Site (Brown's Landfill),Northern Indiana Public Service Company (NIPSCO) (IN)	Fly Ash, Other	Arsenic, Manganese, Boron, Molybdenum, Lead, Selenium, Iron, Sulfate, Ammonium	X			X
Yorktown Power Station, Chisman Creek Disposal Site, Virginia Electric Power and Power Company (VEPCO) (VA)	Fly Ash	Sulfate, Nickel, Vanadium, Selenium	X			

Sources: ERG, 2015m; U.S. EPA, 2012e (DCN SE01966); U.S. EPA, 2013b; U.S. EPA, 2014a through 2014e.

Acronyms: FGD (Flue Gas Desulfurization); MCL (Maximum Contaminant Level); TDS (Total Dissolved Solids); WQC (Water Quality Criteria).

a – The term “ash” was used when the impact case study source did not identify the type of ash present at the waste management unit.

b – An “X” indicates that one or more of the pollutants listed exceeded MCLs or federal/state WQC/standards.

c – An “X” indicates that the ground water contaminated the surface water with one or more of the pollutants listed.

d – An “X” indicates that the ground water contaminated a source outside the plant property boundaries.

Table A-6. Summary of Surface Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded Federal/State WQC/Standards [b]	Issued a Fish Consumption Advisory [c]	Impact Resulted from Ground Water Contamination [d]	Impacted Off-Site Source [e]
Asheville Steam Electric Plant, Progress Energy (NC)	Pond/Impoundment	Boron, Chromium, Iron, Manganese, Thallium, Nitrate, Sulfate, pH, TDS, Cadmium, Arsenic, Antimony	X			X
Bangor Quarry Ash Disposal Site, Portland Generating Station, RRI Energy (PA)	Pond/Impoundment, Landfill	Selenium, Boron, Cadmium, Hexavalent Chromium, Iron, Manganese, Sulfate, TDS, Aluminum, Fluoride	X			
Belews Creek Steam Station, Duke Energy (NC)	Pond/Impoundment, Landfill	Selenium, Arsenic, Boron, Cadmium, Iron, Lead, Manganese, Nitrate, Sulfate, pH, Bromide	X		X	X
Big Bend Station, Tampa Electric Company (FL)	Pond/Impoundment, Landfill	Arsenic, Aluminum, Boron, Chloride, Fluoride, Iron, Manganese, Molybdenum, Sulfate, Sodium, Thallium, TDS			X	X
Brandywine Coal Ash Landfill, Mirant Mid-Atlantic LLC (MD)	Pond/Impoundment, Landfill	Selenium, Cadmium, Lead, Manganese, Iron, Aluminum, Sulfate, TDS, Chloride	X			X
Bull Run Steam Plant, Tennessee Valley Authority (TVA) (TN)	Pond/Impoundment	Aluminum, Cadmium, Iron, Sulfate, Arsenic, Cobalt, Calcium, Manganese, Molybdenum, Boron, Nickel				
Cardinal Fly Ash Reservoir (FAR) 1 and 2, American Electric Power (AEP) (OH)	Pond/Impoundment, Landfill	Arsenic, Boron, Molybdenum	X			
Cayuga Coal Ash Disposal Landfill, AES (NY)	Pond/Impoundment, Landfill	Selenium, Arsenic, Boron, Cadmium, Lead, TDS, Aluminum, Manganese, Sulfate, Barium, Sodium, Iron, Chromium, Zinc	X		X	X

Table A-6. Summary of Surface Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded Federal/State WQC/Standards [b]	Issued a Fish Consumption Advisory [c]	Impact Resulted from Ground Water Contamination [d]	Impacted Off-Site Source [e]
Clinch River Plant, American Electric Power (AEP)/Appalachian Power (VA)	Pond/Impoundment	Aluminum, pH, Copper	X			X
Columbia Energy Center, Alliant Energy (WI)	Pond/Impoundment, Landfill	Cadmium, Copper, Barium, Aluminum, Iron, Zinc, Arsenic, Selenium, Lead, Manganese	X			X
Cumberland Steam Plant, Tennessee Valley Authority (TVA) (TN)	Pond/Impoundment, Landfill	Selenium, Arsenic, Aluminum, Boron, Chloride, Iron, Manganese, Sulfate, TDS, Vanadium	X			
Curtis Stanton Energy Center, Orlando Utility Commission (FL)	Pond/Impoundment, Landfill	Aluminum, Chloride, Iron, Manganese, Sodium, Sulfate, TDS, Vanadium, pH	X			
Dan River Steam Station, Duke Energy (NC)	Pond/Impoundment	Arsenic, Copper, Iron, Aluminum	X	X		
Dave Johnston Power Plant (WY)	Pond/Impoundment, Landfill	Cadmium, Manganese, Sulfate, Boron				
Flint Creek Power Plant, American Electric Power (AEP)/South West Electric Power Company (SWEPCO) (AR)	Pond/Impoundment, Landfill	Selenium, Barium, Cadmium, Chromium, Iron, Lead, Manganese, pH, Silver, Sulfate, TDS	X			
General James M. Gavin Power Plant, American Electric Power/Ohio Power Company (OH)	Pond/Impoundment, Landfill	Arsenic, Barium, Cadmium, Lead, Molybdenum, Sulfate, TDS, Aluminum, Copper, Nickel, Zinc, Manganese, Chloride	X			X
Gibson Generating Station, Duke Energy (IN)	Pond/Impoundment, Landfill, Cooling Reservoir	Selenium, Arsenic, Boron, Manganese, Iron, Sodium	X			X

Table A-6. Summary of Surface Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded Federal/State WQC/Standards [b]	Issued a Fish Consumption Advisory [c]	Impact Resulted from Ground Water Contamination [d]	Impacted Off-Site Source [e]
Glen Lyn Plant, American Electric Power (AEP)/Appalachian Power (VA)	Pond/Impoundment	Selenium, Cadmium, Copper, Chromium, Zinc, pH, Nickel	X			X
Grainger Generating Station, Santee Cooper/South Carolina Public Service Authority (SCPSA) (SC)	Pond/Impoundment	Arsenic, pH				
J.H. Campbell, Consumers Energy (MI)	Pond/Impoundment	pH, Antimony, Boron, Cadmium, Chromium, Iron, Lead, Selenium, Vanadium, Aluminum, Nickel, Thallium, Manganese, Zinc	X			
J.R. Whiting Generating Plant, CMS/Consumers Energy (MI)	Pond/Impoundment	Selenium, Arsenic, Cobalt, Nickel, Bromine, Chromium				
John Sevier Fossil Plant, Tennessee Valley Authority (TVA) (TN)	Pond/Impoundment	Arsenic, Aluminum, Cadmium, Manganese, Boron, Strontium, Sulfate, Selenium, Hexavalent Chromium	X		X	X
Johnsonville Fossil Plant, Tennessee Valley Authority (TVA) (TN)	Pond/Impoundment, Landfill	Arsenic, Aluminum, Boron, Cadmium, Chromium, TDS, Iron, Lead, Manganese, Molybdenum, Sulfate, Cobalt	X		X	X
Kingston Fossil Plant, Tennessee Valley Authority (TVA) (TN)	Pond/Impoundment	Arsenic, Selenium, Manganese, Cobalt, Aluminum, Ammonia, Thallium, Iron	X	X		X

Table A-6. Summary of Surface Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded Federal/State WQC/Standards [b]	Issued a Fish Consumption Advisory [c]	Impact Resulted from Ground Water Contamination [d]	Impacted Off-Site Source [e]
Little Blue Run Surface Impoundment, Bruce Mansfield Power Plant, First Energy (PA)	Pond/Impoundment	Selenium, Arsenic, Aluminum, Antimony, Barium, Boron, Cadmium, Calcium, Chloride, Hexavalent Chromium, Fluoride, Iron, Lead, Manganese, pH, Sodium, Sulfate, TDS, TSS, Thallium, Turbidity	X			X
Little Scary Creek Fly Ash Impoundment, John Amos Plant, American Electric Power (AEP)/Appalachian Power (WV)	Pond/Impoundment	Selenium, Mercury, Arsenic, Copper	X			
Mahoney Landfill, Powerton Plant, Commonwealth Edison (IL)	Pond/Impoundment, Landfill	Arsenic, Selenium, Chromium, TDS, Cadmium, Lead, Nitrate, Iron, Manganese, Sulfate, Boron,				
Marion Plant, Southern Illinois Power Cooperative (IL)	Pond/Impoundment, Landfill	Boron, Cadmium, Iron, Aluminum, TDS, Sulfate	X		X	X
Martin's Creek Power Plant, PPL (PA)	Pond/Impoundment	Arsenic, Selenium, Lead, Aluminum, Copper, Chromium, Iron	X			X
Montville Generating Station, NRG Energy/Montville Power, LLC (CT)	Pond/Impoundment	Arsenic, Beryllium, Cadmium, Copper, Iron, Lead, Manganese, Nickel, pH, Zinc	X			X
Morgantown Generating Station, Faulkner Off-site Disposal Facility (MD)	Pond/Impoundment, Landfill	Iron, pH, Cadmium, Aluminum, Chloride, Manganese, Sulfate, TDS, Copper, Lead, Selenium	X		X	X

Table A-6. Summary of Surface Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded Federal/State WQC/Standards [b]	Issued a Fish Consumption Advisory [c]	Impact Resulted from Ground Water Contamination [d]	Impacted Off-Site Source [e]
Oak Ridge Y-12 Plant, Chestnut Ridge Operable Unit 2, Oak Ridge Reservation, Department of Energy (TN)	Pond/Impoundment	Selenium, Arsenic, Aluminum, Iron, Zinc, Manganese, Thallium (?)			X	
Phillips Power Plant Landfill, Duquesne Light Company (PA)	Pond/Impoundment, Landfill	TDS, Chloride, Fluoride, Manganese, Aluminum, Arsenic	X		X	X
Plant Bowen, Georgia Power (GA)	Pond/Impoundment	Arsenic, Cadmium, Chromium, Lead, Mercury, Nickel, Copper	X			X
Reid Gardner Generating Facility, Nevada Energy (NV)	Pond/Impoundment, Landfill	Selenium, Arsenic, Chloride, Sulfate, TDS, Nitrate, Boron, Chromium, Manganese, Magnesium, Molybdenum, Sodium, Vanadium, Titanium, Barium, Iron, Aluminum	X		X	X
Savannah River Site, D-Area, Department of Energy (SC)	Pond/Impoundment	Cadmium, Chromium, Copper, Mercury, Selenium, Zinc, Iron, Aluminum	X			
Seminole Generating Station, Seminole Electric Cooperative (FL)	Pond/Impoundment, Landfill	Arsenic, Chloride, Chlorine, Sulfate, Iron, TDS, Boron, Aluminum, Lead, Sodium	X			X
Seward Generating Station, RRI Energy (PA)	Pond/Impoundment, Landfill	Selenium, Arsenic, Aluminum, Antimony, Cadmium, Chloride, Chromium, Iron, Lead, Manganese, Nickel, pH, Sulfate, TDS, Zinc,	X			X
Shawnee Fossil Plant, Tennessee Valley Authority (TVA) (KY)	Pond/Impoundment, Landfill	Selenium, Arsenic, Boron, pH, Sulfate, TDS, Beryllium, Cobalt, Nickel, Molybdenum, Manganese, Vanadium			X	X

Table A-6. Summary of Surface Water Impacts Reported in Damage Cases from Steam Electric Power Plant Surface Impoundments

Damage Case Site	Type of Waste in Impoundment [a]	Pollutants of Concern	Exceeded Federal/State WQC/Standards [b]	Issued a Fish Consumption Advisory [c]	Impact Resulted from Ground Water Contamination [d]	Impacted Off-Site Source [e]
Sutton Steam Plant, Progress Energy (NC)	Pond/Impoundment	Arsenic, Boron, Manganese, Iron, Thallium, Selenium, Antimony, Lead, Sulfate, TDS	X			X
W.J. Neal Station Surface Impoundment, Basin Electric Power Cooperative (ND)	Pond/Impoundment	Selenium, Arsenic, Chromium, Cadmium, Lead, Zinc, Aluminum			X	X
Wateree Station, SCE&G (SC)	Pond/Impoundment, Landfill	Arsenic, Chromium, Cadmium, Lead, Iron	X			X
Westland Disposal Site, Dickerson Generating Station, Mirant (MD)	Pond/Impoundment, Landfill	Selenium, Arsenic, Barium, Chromium, Cobalt, Copper, Iron, Zinc, Sulfate, Chlorine, Hardness, TDS, Aluminum	X		X	

Sources: ERG, 2015m; U.S. EPA, 2012e (DCN SE01966); U.S. EPA, 2013b; U.S. EPA, 2014a through 2014e.

Acronyms: FGD (Flue Gas Desulfurization); TDS (Total Dissolved Solids); TOC (Total Organic Carbon); TOH (Total Organic Hydrocarbons); TSS (Total Suspended Solids); WQC (Water Quality Criteria).

a – The term “ash” was used when the impact case study source did not identify the type of ash present at the waste management unit.

b – An “X” indicates that one or more of the pollutants listed exceeded federal/state WQC/standards.

c – An “X” indicates that the contaminated surface water was issued a fish consumption advisory.

d – An “X” indicates that the ground water contaminated the surface water with one or more of the pollutants listed.

e – An “X” indicates that the surface water contaminated a source outside the plant property boundaries.

Table A-7. Summary of Surface Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded Federal/ State WQC/ Standards [b]	Issued a Fish Consumption Advisory [c]	Impact Resulted from Ground Water Contamination [d]	Impacted Off-Site Source [e]
Bangor Quarry Ash Disposal Site, Portland Generating Station, RRI Energy (PA)	Bottom Ash, Fly Ash, Other	Selenium, Boron, Cadmium, Hexavalent Chromium, Iron, Manganese, Sulfate, TDS, Aluminum, Fluoride	X			
Battlefield Golf Club, Chesapeake Energy Facility, Dominion Power (VA)	Fly Ash	Arsenic, Cadmium, Chromium, Copper, Lead, Manganese, Thallium, Zinc, Vanadium, Iron, Boron, Aluminum				
Belews Creek Steam Station, Duke Energy (NC)	Fly Ash, FGD	Selenium, Arsenic, Boron, Cadmium, Iron, Lead, Manganese, Nitrate, Sulfate, pH, Bromide	X		X	X
Big Bend Station, Tampa Electric Company (FL)	Bottom Ash, Fly Ash, FGD, Other	Arsenic, Aluminum, Boron, Chloride, Fluoride, Iron, Manganese, Molybdenum, Sulfate, Sodium, Thallium, TDS			X	X
Brandywine Coal Ash Landfill, Mirant Mid-Atlantic LLC (MD)	Bottom Ash, Fly Ash	Selenium, Cadmium, Lead, Manganese, Iron, Aluminum, Sulfate, TDS, Chloride	X			X
Cardinal Fly Ash Reservoir (FAR) 1 and 2, American Electric Power (AEP) (OH)	Bottom Ash, Fly Ash, FGD	Arsenic, Boron, Molybdenum	X			
Cayuga Coal Ash Disposal Landfill, AES (NY)	Bottom Ash, Fly Ash, Other	Selenium, Arsenic, Boron, Cadmium, Lead, TDS, Aluminum, Manganese, Sulfate, Barium, Sodium, Iron, Chromium, Zinc	X		X	X
CCW Landfill, Trans-Ash, Inc. (TN)	Bottom Ash, Fly Ash	Mercury, Iron, Boron, Sulfate, Arsenic, Chromium, Lead				X
Coal Combustion Waste Landfill, Merom Generating Station, Hoosier Energy (IN)	Fly Ash, Bottom Ash	Barium, Chromium, Cadmium, Lead, Sulfate, Chloride, Sodium				
Columbia Energy Center, Alliant Energy (WI)	Bottom Ash, Fly Ash	Cadmium, Copper, Barium, Aluminum, Iron, Zinc, Arsenic, Selenium, Lead, Manganese	X			X

Table A-7. Summary of Surface Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded Federal/ State WQC/ Standards [b]	Issued a Fish Consumption Advisory [c]	Impact Resulted from Ground Water Contamination [d]	Impacted Off-Site Source [e]
Cumberland Steam Plant, Tennessee Valley Authority (TVA) (TN)	Bottom Ash, Fly Ash, FGD	Selenium, Arsenic, Aluminum, Boron, Chloride, Iron, Manganese, Sulfate, TDS, Vanadium	X			
Curtis Stanton Energy Center, Orlando Utility Commission (FL)	Bottom Ash, Other	Aluminum, Chloride, Iron, Manganese, Sodium, Sulfate, TDS, Vanadium, pH	X			
Dave Johnston Power Plant (WY)	Fly Ash	Cadmium, Manganese, Sulfate, Boron				
Fern Valley Landfill, Orion Power Holdings, Inc. (a subsidiary of RRI Energy) (PA)	Fly Ash	Selenium, Aluminum, Boron, Chloride, Sulfate, TDS	X		X	X
Flint Creek Power Plant, American Electric Power (AEP)/South West Electric Power Company (SWEPCO) (AR)	Bottom Ash, Fly Ash, Other	Selenium, Barium, Cadmium, Chromium, Iron, Lead, Manganese, pH, Silver, Sulfate, TDS	X			
General James M. Gavin Power Plant, American Electric Power/Ohio Power Company (OH)	Bottom Ash, Fly Ash, FGD, Other	Arsenic, Barium, Cadmium, Lead, Molybdenum, Sulfate, TDS, Aluminum, Copper, Nickel, Zinc, Manganese, Chloride	X			X
Gibson Generating Station, Duke Energy (IN)	Bottom Ash, Fly Ash	Selenium, Arsenic, Boron, Manganese, Iron, Sodium	X			X
Hatfield's Ferry Power Station, Allegheny Energy (PA)	Bottom Ash, Fly Ash, FGD	Arsenic, Aluminum, Boron, Chromium, Manganese, Molybdenum, Thallium, TDS, Sulfate, Selenium	X			X
Indian River Generating Station, NRG Energy (DE)	Ash	Selenium, Mercury, Arsenic, Aluminum, Barium, Cadmium, Chromium, Copper, Lead, Nickel, Thallium, Zinc, Iron, Manganese	X			X

Table A-7. Summary of Surface Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded Federal/ State WQC/ Standards [b]	Issued a Fish Consumption Advisory [c]	Impact Resulted from Ground Water Contamination [d]	Impacted Off-Site Source [e]
John Warden Ash Site (MI)	Ash, Other	Boron, Lithium				
Johnsonville Fossil Plant, Tennessee Valley Authority (TVA) (TN)	Bottom Ash, Fly Ash	Arsenic, Aluminum, Boron, Cadmium, Chromium, TDS, Iron, Lead, Manganese, Molybdenum, Sulfate, Cobalt	X		X	X
Mahoney Landfill, Powerton Plant, Commonwealth Edison (IL)	Bottom Ash, Fly Ash, Other	Arsenic, Selenium, Chromium, TDS, Cadmium, Lead, Nitrate, Iron, Manganese, Sulfate, Boron,				
Marion Plant, Southern Illinois Power Cooperative (IL)	Bottom Ash, Fly Ash, FGD	Boron, Cadmium, Iron, Aluminum, TDS, Sulfate	X		X	X
Morgantown Generating Station, Faulkner Off-site Disposal Facility (MD)	Bottom Ash, Fly Ash, Other	Iron, pH, Cadmium, Aluminum, Chloride, Manganese, Sulfate, TDS, Copper, Lead, Selenium	X		X	X
Oak Creek Power Plant, Wisconsin Energy (WE Energies (WE))/Wisconsin Electric Power Company (WI)	Bottom Ash, Fly Ash, FGD, Other	Arsenic, Chromium, TCE, Diesel Fuel	X			X
Phillips Power Plant Landfill, Duquesne Light Company (PA)	Ash, FGD	TDS, Chloride, Fluoride, Manganese, Aluminum, Arsenic	X		X	X
Range Road Landfill, Detroit Edison (MI)	Ash	Boron, Lithium, Manganese	X			X
Reid Gardner Generating Facility, Nevada Energy (NV)	Fly Ash, FGD	Selenium, Arsenic, Chloride, Sulfate, TDS, Nitrate, Boron, Chromium, Manganese, Magnesium, Molybdenum, Sodium, Vanadium, Titanium, Barium, Iron, Aluminum	X		X	X

Table A-7. Summary of Surface Water Impacts Reported in Damage Cases from Steam Electric Power Plant Landfills

Damage Case Site	Type of Waste in Landfill [a]	Pollutants of Concern	Exceeded Federal/ State WQC/ Standards [b]	Issued a Fish Consumption Advisory [c]	Impact Resulted from Ground Water Contamination [d]	Impacted Off-Site Source [e]
Seminole Generating Station, Seminole Electric Cooperative (FL)	Fly Ash, FGD, Other	Arsenic, Chloride, Chlorine, Sulfate, Iron, TDS, Boron, Aluminum, Lead, Sodium	X			X
Seward Generating Station, RRI Energy (PA)	Ash, Other	Selenium, Arsenic, Aluminum, Antimony, Cadmium, Chloride, Chromium, Iron, Lead, Manganese, Nickel, pH, Sulfate, TDS, Zinc,	X			X
Shawnee Fossil Plant, Tennessee Valley Authority (TVA) (KY)	Bottom Ash, Fly Ash	Selenium, Arsenic, Boron, pH, Sulfate, TDS, Beryllium, Cobalt, Nickel, Molybdenum, Manganese, Vanadium			X	X
Wateree Station, SCE&G (SC)	Bottom Ash, Fly Ash, FGD	Arsenic, Chromium, Cadmium, Lead, Iron	X			X
Westland Disposal Site, Dickerson Generating Station, Mirant (MD)	Fly Ash	Selenium, Arsenic, Barium, Chromium, Cobalt, Copper, Iron, Zinc, Sulfate, Chlorine, Hardness, TDS, Aluminum	X		X	

Sources: ERG, 2015m; U.S. EPA, 2012e (DCN SE01966); U.S. EPA, 2013b; U.S. EPA, 2014a through 2014e.

Acronyms: FGD (Flue Gas Desulfurization); TDS (Total Dissolved Solids); TOC (Total Organic Carbon); TOH (Total Organic Hydrocarbons); TSS (Total Suspended Solids); WQC (Water Quality Criteria).

a – The term “ash” was used when the impact case study source did not identify the type of ash present at the waste management unit.

b – An “X” indicates that one or more of the pollutants listed exceeded federal/state WQC/standards.

c – An “X” indicates that the contaminated surface water was issued a fish consumption advisory.

d – An “X” indicates that the ground water contaminated the surface water with one or more of the pollutants listed.

e – An “X” indicates that the surface water contaminated a source outside the plant property boundaries.

Table A-8. Summary of Attractive Nuisances Related to Steam Electric Power Plants

Species	Attractive Nuisance Site Description	Pollutant Concentrations in the Environment or Diet	Pollutant Concentrations in the Organism (µg/g)	Observed Effects	Study Type	Citation
Common Grackles (*Quiscalus quiscala*)	Nested in close proximity to a coal-fired power plant's fly ash pond.	Not measured in study	Eggs = 5.9 selenium	Histopathological	Field	Bryan *et al.*, 2003
Raccoons (*Procyon lotor*)	Lived in close proximity to a coal-fired power plant's ash pond.	Not measured in study	• Heart = 2.8 arsenic • Kidney = 3.2 cadmium, 0.43 strontium • Muscle = 0.95 chromium • Liver = 0.34 lead, 1.5 mercury	Histopathological	Field	Burger *et al.*, 2002
Interior Least Tern (*Sterna antillarum*)	Nested on a dike in a coal-fired power plant's ash pond.	Not measured in study	Not observed in study	Not observed in study	Field	Pruitt, 2000 and Duke Energy, 2007
Southern Toads (*Bufo terrestris*)	• Inhabited an ash basin and nearby swamp. • Reference (control) site organisms were transferred to contaminated locations.	Not measured in study	Not measured in study	Elevated corticosterone and testosterone levels	Outdoor mesocosm	Hopkins *et al.*, 1997
Southern Toads (*Bufo terrestris*)	• Inhabited an ash pond and nearby swamp. • Reference site organisms were transferred to contaminated locations.	Pond sediment = 39.64 µg/g arsenic, 4.38 µg/g selenium	Adult males = 1.58 arsenic, 17.40 selenium	Histopathological	Outdoor mesocosm	Hopkins *et al.*, 1998

Table A-8. Summary of Attractive Nuisances Related to Steam Electric Power Plants

Species	Attractive Nuisance Site Description	Pollutant Concentrations in the Environment or Diet	Pollutant Concentrations in the Organism (µg/g)	Observed Effects	Study Type	Citation
Larval Bullfrogs (*Rana catesbeiana*)	Inhabited bottom ash ponds near a coal-fired power plant.	Pond sediment = 49.39 µg/g arsenic, 0.72 µg/g cadmium, 23.85 µg/g chromium, 84.72 µg/g copper, 6.11 µg/g selenium, 106.39 µg/g strontium, 45.83 µg/g vanadium	Whole body concentration = 33.10 arsenic, 5.47 cadmium, 18.25 chromium, 116.72 copper, 20.25 selenium, 39.89 strontium, 17.32 vanadium	• Morphological • Decreased swimming speeds	Field	Hopkins *et al.*, 2000
Eastern Narrow-Mouth Toads (*Gastrophryne carolinensis)*	Inhabited a selenium-laden site located near a coal-fired power plant.	• Site water = 3.93 µg/L selenium • Soil = 38.25 µg/L selenium • Lab water = 0.28 µg/L selenium	• Females = 42.40 selenium • Eggs = 43.96 selenium	• Reproductive • Histopathological	Outdoor mescosm	Hopkins *et al.*, 2006
Barn Swallow (*Hirundo rustica*)	Nested near a selenium-laden pond associated with a coal-fired power plant.	Not provided in the literature	Eggs = 2.8 selenium	Histopathological	Field	King *et al.*, 1994
Slider Turtles (*Trachemys scripta*)	• Inhabited a selenium-laden basin that receives fly ash transport water near a coal-fired power plant. • Eggs were incubated in ash-contaminated soil.	Ash-contaminated soil = 2.56 µg/g selenium	Adult Females = 37.18 (mean concentration), selenium	Reproductive	Outdoor mescosm	Nagle *et al.*, 2001
Canada Geese (*Branta Canadensis*)	Inhabited pens near a vanadium-laden ash pond associated with an oil-fired power plant	Site water = 467,000 µg/L vanadium	• Liver = 57.3 vanadium • Kidney = 226 vanadium	• Lethal • Histopathological	Outdoor mesocosm	Rattner *et al.*, 2006

Acronyms: µg/g (Micrograms per Grams); µg/L (Micrograms per Liters).

Table A-9. Summary of Attractive Nuisances Unrelated to Steam Electric Power Plants

Site Name, Location, and Contamination Source	Organism Affected	Documented Effects	Trace Pollutant Concentrations (ppm)	Citation
Kesterson Reservoir, CA Agricultural Runoff	California Vole (*Microtus californicus*)	Mean selenium concentrations in livers were significantly elevated.	Liver = 119 selenium	Clark *et al.*, 1987
Kesterson Reservoir, CA Agricultural Runoff	American Coot (*Fulica americana*), Mallard (*Anas platyrhynchos*)	Mean selenium concentrations in bird eggs and livers were elevated; organisms exhibited severe reproductive failure and deformities.	• Eggs = 2.2 – 110 selenium • Liver = 19 – 130 selenium • Water = 300,000 selenium	Ohlendorf *et al.*, 1986
Kesterson Reservoir, CA Agricultural Runoff	Pied-Billed Grebes (*Podilymbus podiceps*), Common Moorhen (*Gallinula chloropus*), Black-Necked Stilts (*Himantopus mexicanus*)	Selenium concentrations in livers were 10 times those found in nearby control areas; organisms exhibited severe lesions and embryonic deformities.	• Liver = 94.4 selenium • Water = 300,000 selenium	Ohlendorf *et al.*, 1988a
Kesterson Reservoir, CA Agricultural Runoff	Gopher Snakes (*Pituophis melanoleucus*), Bullfrogs (*Rana catesbeiana*)	Selenium concentrations in snake and frog livers were significantly elevated.	• Snake liver = 11.1 selenium • Frog liver = 45.0 selenium	Ohlendorf *et al.*, 1988b
Kesterson Reservoir, CA Agricultural Runoff	Eared Grebe (*podiceps nigricollis*), Mallard (*Anas platyrhynchos*), Cinnamon Teal (*Anas cyanoptera*), Gadwall (*Anas strepera*), American Coot (*Fulica americana*), Killdeer (*Charadrius vociferous*), Black-Necked Stilt (*Himantopus mexicanus*), American Avocet (*Recurvirostra americana)*	Hatchlings exhibited mortality, deformity, and lack of embryonic development.	Water = 300 selenium	Ohlendorf *et al.*, 1989
Kesterson Reservoir, CA Agricultural Runoff	Mosquitofish (*Gambusia affinis*), American Coot (*Fulica americana)*, Ducks (*Anas spp*.)	Selenium concentrations in livers, kidneys, and muscles were elevated; organisms exhibited reduced body weight.	• Fish = 120 – 140 selenium • Coot liver = 76.7 selenium • Duck liver = 25.2 selenium	Ohlendorf *et al.*, 1990
Liberty State Park, NJ Industrial and Urban Activities	House Wren (*troglodytes aedon*), American Robin (*Turdus migratorus*)	Lead, arsenic, chromium, copper, and iron concentrations in bird feathers were elevated.	Feather = 4,200 lead; 1,000 chromium; 6,200 copper; 600 arsenic	Hofer *et al.*, 2010

Table A-9. Summary of Attractive Nuisances Unrelated to Steam Electric Power Plants

Site Name, Location, and Contamination Source	Organism Affected	Documented Effects	Trace Pollutant Concentrations (ppm)	Citation
Meadowlands, NJ Industrial and Urban Activities	Red-winged blackbird (*agelaius phoeniceus*), marsh wrens (*Cistothorus palustris*), tree swallow (*Tachycineta bicolor*)	Lead and chromium concentrations in blood were elevated; mercury and chromium concentrations in eggs were elevated.	• Swallow blood = 0.94 lead; 1.03 chromium • Wren eggs = 0.2 mercury • Blackbird eggs = 0.12 chromium	Tsipoura *et al.*, 2008

Acronym: ppm (parts per million).

Table A-10. Summary of Selenium Concentrations in the Environment and Organisms Experiencing Adverse Effects

Plant Name	Species	Route of Selenium Exposure	Selenium Concentrations in the Environment (µg/L) or Diet (µg/g)	Selenium Concentrations in the Organism (µg/g)	Observed Effects	Study Type (Surface Water Type)	Citation
Belews Creek Steam Station, Duke Energy (NC)	Striped bass (*Morone saxatilis*)	Consumed a selenium-laden diet by eating red shiners collected from a site receiving coal ash pond sluice water.	Red Shiners = 9.6 µg/g (average whole-body concentration), wet	Skeletal muscle = 3.8 (higher average concentration), wet	Modified behavior Decreased growth Histopathological Lethal	Laboratory (reservoir)	Coughlan and Velte, 1989
	Largemouth bass (*Micropterus salmoides*) [a] *Pomoxis spp.*	Inhabited a selenium-laden cooling water reservoir receiving both fly ash and bottom ash pond effluent from a coal-fired power plant.	Site water [d] = 10 µg/L	Biomass [e] = 0.1 – 1.0 (mean)	Lethal Reproductive	Field (reservoir)	Cumbie and Van Horn, 1978
	Lepomis spp. [b]			Body = 41.0 – 77.1 (54.6 mean concentration), wet			
	Lealurus spp. [c]			Body = 0.31 – 15.5 (6.32 mean concentration), wet			
	Largemouth bass (*Micropterus salmoides)*	Inhabited a selenium-laden cooling water reservoir receiving effluent from the coal ash pond.	Ash effluent = 100-200 µg/L Site water = 10 µg/L	Visceral tissue = 40+ (highest mean concentration), wet	Lethal	Field (reservoir)	Lemly, 1985a
	Green sunfish (*Lepomis cyanellus*)	Inhabited a selenium-laden lake receiving coal fly ash sluice water.	Site water = 13 µg/L Sediment = 5 – 14 µg/g, dry	Liver = 21.4, wet Skeletal muscle = 12.9, wet Hematocrit = 33, wet	Histopathological Hematological	Field (lake)	Sorensen *et al.*, 1984b
D-Area Coal-Fired Power Plant, Savannah River Site (SRS) (SC)	Banded water snakes (*Nerodia fasciata*)	Consumed a selenium-laden diet by eating prey collected from a contaminated site located near a coal-fired power plant.	Prey items [f] = 22.7 µg/g (geometric least squared mean), dry	Gonads = 17.64 (female), 19.06 (male) Kidney = 25.38 (female), 32.04 (male) Liver = 24.08 (female), 24.22 (male)	Reproductive Histopathological	Laboratory (not specified)	Hopkins *et al.*, 2002

Table A-10. Summary of Selenium Concentrations in the Environment and Organisms Experiencing Adverse Effects

Plant Name	Species	Route of Selenium Exposure	Selenium Concentrations in the Environment (µg/L) or Diet (µg/g)	Selenium Concentrations in the Organism (µg/g)	Observed Effects	Study Type (Surface Water Type)	Citation
	Eastern narrow-mouth toads (*Gastrophryne carolinensis)*	Inhabited a selenium-laden site located near a coal-fired power plant.	Site water = 3.93 µg/L Soil = 8.25 µg/L Lab water = 0.28 µg/L	Females = 42.40 Eggs = 43.96	Reproductive Histopathological	Outdoor mescosm (combustion residuals pond)	Hopkins *et al.*, 2006
	Slider turtles (*Trachemys scripta*)	Inhabited a selenium-laden pond receiving sluiced fly ash near a coal-fired power plant. Eggs were incubated in ash-contaminated soil.	Ash-contaminated soil = 2.56 µg/g, dry	Adult females = 37.18 (mean concentration), dry	Reproductive	Outdoor mescosm (combustion residuals pond)	Nagle *et al.*, 2001
Roxboro Plant, Progress Energy (NC)	Largemouth bass (*Micropterus salmoides*)	Inhabited a selenium-laden cooling water reservoir receiving ash pond effluent from a coal-fired power plant.	Not provided in the literature.	Carcass = 2.86 (mean, female), 2.63 (mean, male) Gonad = 4.40 (mean, female), 2.38 (mean, male)	Reproductive Histopathological	Field (reservoir)	Baumann and Gillespie, 1986
	Bluegill (*Lepomis macrochirus*)			Carcass = 2.74 (mean, female), 4.64 (mean, male) Gonad = 4.63 (mean, female), 3.35 (mean, male)			
	Bluegill (*Lepomis macrochirus*)	Inhabited a selenium-laden reservoir receiving coal ash pond effluent.	Not provided in the literature	Not provided in the literature	Lethal	Field (reservoir) [g]	Crutchfield and Ferguson, 2000a
	Green sunfish [h] (*Lepomis cyanellus)*	Inhabited a selenium-laden reservoir receiving coal ash pond effluent.	Site water [i] = 7 – 14 µg/L	Biomass [j] = 2,744 – 3,793 (mean)	Lethal Reproductive	Field (reservoir)	Crutchfield, 2000b

Table A-10. Summary of Selenium Concentrations in the Environment and Organisms Experiencing Adverse Effects

Plant Name	Species	Route of Selenium Exposure	Selenium Concentrations in the Environment (µg/L) or Diet (µg/g)	Selenium Concentrations in the Organism (µg/g)	Observed Effects	Study Type (Surface Water Type)	Citation
	Bluegill (*Lepomis macrochirus*)	Inhabited a selenium-laden cooling water reservoir of a coal-fired power plant.	Site water [k] = 9 – 12 µg/L	Testes = 4.37 (mean concentration) Ovaries = 6.96 (mean concentration)	Reproductive	Laboratory (reservoir)	Gillepsie *et al.*, 1986
	Bluegill [l] (*Lepomis macrochirus*)	Inhabited a selenium-laden cooling water reservoir of a coal-fired power plant.	Site water = <10–20 µg/L	Liver = 34 (mean concentration), wet Gonad = 12.1 (mean, female), 5.4 (mean, male), wet Muscle = 13 (mean concentration), wet	Histopathological	Field (reservoir)	Sager and Colfield, 1984
	Largemouth bass [m] (*Micropterus salmoides*)			Liver = 10.2 (mean concentration), wet Gonad = 10.3 (mean, female), wet Muscle = 6.7 (mean concentration), wet			
Martin Lake Steam Station, Texas Utilities Electric Service Company (TX)	Green sunfish (*Lepomis cyanellus*)	Inhabited a selenium-laden lake receiving coal fly ash, scrubber sludge, and coal bottom ash.	Not provided in the literature	Hepatopancreas = 1.31 – 9.30, wet	Histopathological	Field (lake)	Sorensen *et al.*, 1982
	Redear sunfish (*Lepomis microlophus*)			Hepatopancreas = 2.8 – 11.03, wet			
	Redear sunfish (*Lepomis microlophus*)	Inhabited a selenium-laden lake receiving coal fly ash, scrubber sludge, and coal bottom ash.	Not provided in the literature	Liver = 20	Histopathological	Field (lake)	Sorensen *et al.*, 1983

Table A-10. Summary of Selenium Concentrations in the Environment and Organisms Experiencing Adverse Effects

Plant Name	Species	Route of Selenium Exposure	Selenium Concentrations in the Environment (µg/L) or Diet (µg/g)	Selenium Concentrations in the Organism (µg/g)	Observed Effects	Study Type (Surface Water Type)	Citation
	Redear sunfish (*Lepomis microlophus*)	Inhabited a selenium-laden lake receiving coal ash pond wastewater.	Not provided in the literature	Hepatopancreas = 8.4 – 27.2 µg/L Kidney = 11.4 – 115.7 µg/L Ovaries = 0 – 5.9 µg/L Testes = 0 – 54.2 µg/L	Increased weight loss	Field (lake)	Sorensen and Bauer, 1984a
	Redear sunfish (*Lepomis microlophus*)	Inhabited a selenium-laden lake located near a coal-fired power plant.	Not provided in the literature	Liver = 7.63 (mean concentration)	Histopathological Reproductive	Field (lake)	Sorensen, 1988

Acronyms: kg/ha (kilogram per hectacre); µg/L (micrograms per liter); µg/g (micrograms per gram).

a – Multiple fish species were studied; however, as presented by the report, the largemouth bass and *pomoxis spp.* had the lowest documented selenium biomass concentrations.

b – Multiple fish species were studied; however, as presented by the report, the *Lepomis spp.* had the highest documented selenium skeletal muscle concentrations.

c – Multiple fish species were studied; however, as presented by the report, the *Letalurus spp.* had the lowest documented selenium body concentrations.

d – This selenium concentration is dissolved.

e – This concentration is measured in the units kg/ha. The range of selenium concentrations was reported annually from 1982 to 1989, before the steam electric power plant converted to dry ash handling. Both fish species had the same range of selenium concentrations.

f – The banded water snakes were fed weekly combinations of previously frozen prey items inhabiting the coal ash-contaminated site.

g – The data used in this study were census data collected from routine biological monitoring undertaken by the steam electric power plant.

h – Multiple fish species were studied; however, as presented by the report, the green sunfish had the highest documented selenium biomass concentrations.

i – These are the selenium water concentrations detected prior to the conversion to a dry fly ash handling system.

j – This concentration is measured in the units kg/ha. The range of selenium concentrations was reported annually from 1982 to 1989, before the steam electric power plant converted to dry ash handling.

k – This concentration was not measured for this study but was reported in a previous study conducted at the same site.

l – Multiple fish species were studied; however, as presented by the report, the bluegills had the highest documented selenium liver tissue concentration.

m – Multiple fish species were studied; however, as presented by the report, the largemouth bass had the lowest documented selenium liver tissue concentration.

APPENDIX B
PROXIMITY ANALYSES SUPPORTING TABLES

Table B-1. Immediate Receiving Waters 303(d) Impairments Listing

Cause Group Name	Cause Name	Found in Combustion Wastewater	Evaluated in the EA
Algal Growth	Algal Growth		
Algal Growth	Chlorophyll-A		
Cause Unknown	Cause Unknown		
Cause Unknown - Impaired Biota	Benthic Macroinvertebrates Bioassessments		
Cause Unknown - Impaired Biota	Fish Bioassessments		
Dioxins	2,3,7,8-Tetrachlorodibenzo-P-Dioxin (Only)		
Dioxins	Dioxin		
Dioxins	Dioxins		
Fish Consumption Advisory	Fish Consumption Advisory		
Flow Alteration(s)	Flow Alteration(s)		
Habitat Alterations	Habitat Alterations		
Mercury	Fish Consumption Advisory - Mercury	✓	✓
Mercury	Mercury	✓	✓
Mercury	Mercury In Fish Tissue	✓	✓
Metals (Other Than Mercury)	Aluminum	✓	✓
Metals (Other Than Mercury)	Arsenic	✓	✓
Metals (Other Than Mercury)	Cadmium	✓	✓
Metals (Other Than Mercury)	Chromium, Total	✓	✓
Metals (Other Than Mercury)	Copper	✓	✓
Metals (Other Than Mercury)	Iron	✓	✓
Metals (Other Than Mercury)	Lead	✓	✓
Metals (Other Than Mercury)	Manganese	✓	✓
Metals (Other Than Mercury)	Metals (Other Than Mercury)	✓	✓
Metals (Other Than Mercury)	Selenium	✓	✓
Metals (Other Than Mercury)	Silver	✓	✓
Metals (Other Than Mercury)	Zinc	✓	✓
Noxious Aquatic Plants	Macrophytes		
Nutrients	Eutrophication	✓	✓
Nutrients	Nitrogen, Total	✓	✓
Nutrients	Nutrient/Eutrophication Biological Indicators	✓	✓
Nutrients	Nutrients	✓	✓
Nutrients	Phosphorus	✓	✓
Nutrients	Phosphorus, Total	✓	✓

Table B-1. Immediate Receiving Waters 303(d) Impairments Listing

Cause Group Name	Cause Name	Found in Combustion Wastewater	Evaluated in the EA
Oil And Grease	Oil	✓	
Oil And Grease	Oil And Grease	✓	
Organic Enrichment/Oxygen Depletion	Dissolved Oxygen	✓	
Organic Enrichment/Oxygen Depletion	Dissolved Oxygen Saturation	✓	
Pathogens	Bacteria		
Pathogens	Coliforms		
Pathogens	Enterococcus Bacteria		
Pathogens	Escherichia Coli (*E. Coli*)		
Pathogens	Fecal Coliform		
Pathogens	Indicator Bacteria		
Pathogens	Pathogens		
Pesticides	Atrazine		
Pesticides	Chlordane		
Pesticides	Chlorpyrifos		
Pesticides	DDD		
Pesticides	DDE		
Pesticides	DDT		
Pesticides	Dieldrin		
Pesticides	Mirex		
Pesticides	Organochlorine Pesticides		
pH/Acidity/Caustic Conditions	pH	✓	
pH/Acidity/Caustic Conditions	pH, Low	✓	
Polychlorinated Biphenyls (PCBs)	Fish Consumption Advisory - PCBs		
Polychlorinated Biphenyls (PCBs)	PCBs In Fish Tissue		
Polychlorinated Biphenyls (PCBs)	Polychlorinated Biphenyls (PCBs)		
Salinity/Total Dissolved Solids/Chlorides/Sulfates	Salinity/Total Dissolved Solids/Chlorides	✓	✓
Salinity/Total Dissolved Solids/Chlorides/Sulfates	Total Dissolved Solids (TDS)	✓	✓
Sediment	Sedimentation/Siltation	✓	
Sediment	Siltation	✓	
Sediment	Solids (Suspended/Bedload)	✓	
Sediment	Suspended Sediment	✓	
Taste, Color, And Odor	Taste and Odor		
Temperature	Temperature		
Toxic Inorganics	Boron	✓	✓
Toxic Organics	Polycyclic Aromatic Hydrocarbons (PAHs) (Aquatic Ecosystems)		

Table B-1. Immediate Receiving Waters 303(d) Impairments Listing

Cause Group Name	Cause Name	Found in Combustion Wastewater	Evaluated in the EA
Turbidity	Total Suspended Solids (TSS)	✓	
Turbidity	Turbidity	✓	

Source: U.S. EPA, 2014i. National 303(d) Listed Impaired Waters National Hydrography Data (NHD) Indexed Dataset. Reach Address Database (RAD). Extracted on August 4. Available online at: http://www.epa.gov/waters/data/downloads.html. DCN SE04544.

Note: A surface water is classified as a 303(d) impaired water when pollutant concentrations exceed water quality standards and the surface water can no longer meet its designated uses (*e.g.*, drinking, recreation, and aquatic habitat). In even-numbered years, states submit their lists of impaired waters (known as the "303(d) list") to EPA. These state-submitted, Geographic Information System (GIS) datasets are collected by EPA and indexed to the National Hydrography Dataset (NHDPlus) at 1:100K resolution (*i.e.*, 303(d) impaired waters proximity database). For this EA, EPA reviewed the 303(d) impaired waters proximity database to identify steam electric power plant immediate receiving waters identified as impaired for a pollutant associated with the evaluated wastestreams (*i.e.*, FGD wastewater, fly ash transport water, bottom ash transport water, and combustion residual leachate).

Table B-2. Immediate Receiving Waters Fish Consumption Advisory Listing

Pollutant	Found in Combustion Wastewater	Evaluated in the EA
Chlordane		
Chlorinated pesticides		
DDT		
Dieldrin		
Dioxin		
Lead	✓	✓
Mercury	✓	✓
Mirex		
Not Specified		
PCBs (Total)		
Perfluorooctane sulfonate		
Toxaphene		

Source: U.S. EPA, 2014h. National Fish Consumption Advisories NHD Indexed Dataset. RAD. Extracted on July 7. Available online at: http://epamap32.epa.gov/radims/. DCN SE04545.

APPENDIX C
WATER QUALITY MODULE METHODOLOGY

This appendix presents the model equations, input variables, pollutant benchmarks, and methodology limitations/assumptions for the immediate receiving water (IRW) model water quality module.

The IRW water quality module equations are organized by the methodology for nonvolatile pollutants (*i.e.*, arsenic, cadmium, chromium (VI), copper, lead, nickel, selenium, thallium, and zinc) and volatile pollutants (*i.e.*, mercury). EPA used the equations to calculate total and dissolved pollutant concentrations in receiving waters and total pollutant concentrations in sediment within the immediate discharge zone. Model input requirements for the equations presented in Appendix C can be divided into four major categories: 1) input variable described by another equation; 2) site-specific input variable; 3) model assumption variable; and 4) site-specific assumption variable based on predetermined data. The following tables in Appendix C describe the input requirements and data sources used in the water quality module:

- Table C-1. Site-Specific Model Input Variables.
- Table C-2. Model Assumption Input Variables.
- Table C-3. Site-Specific Assumption Input Variables.
- Table C-4. Surface Water Partition Coefficients.
- Table C-5. Total Suspended Solids (TSS) Concentrations in Surface Waters.
- Table C-6. Regional Surface Water Temperatures.
- Table C-7. National Recommended Water Quality Criteria (NRWQC) and Drinking Water Maximum Contaminant Level (MCL) Benchmarks.

EPA calculated pollutant loadings from the evaluated wastestreams as part of its engineering analysis (see Section 10 of the Technical Development Document for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category (TDD) [EPA 821-R-15-007]). The IRW water quality module performs calculations on a per immediate-receiving-water basis. For steam electric power plants that discharge to multiple receiving waters, EPA divided the plant-specific pollutant loadings accordingly among the receiving waters based on water diagrams provided in the Questionnaire for the Steam Electric Power Generating Effluent Guidelines (Steam Electric Survey) responses. EPA used the IRW model to evaluate the environmental impacts from 188 steam electric power plants in the receiving water quantitative analysis (209 unique immediate receiving waters).

EPA modeled chromium (VI) in the water quality module, but did not take into consideration arsenic or mercury speciation. EPA included assumptions of pollutant speciation for arsenic and mercury as appropriate in the subsequent wildlife and human health modules (see Appendix D and Appendix E, respectively). EPA used total selenium loadings in the water quality module; however, due to the partition coefficients available, EPA assumed the dominant form of selenium in the receiving water was selenate (*i.e.*, selenium (VI)). Although selenium speciation likely occurs within combustion residual surface impoundments prior to discharge, EPA selected the selenate partition coefficient because it is expected to be the predominant form present in well-oxygenated alkaline surface waters and the rate of conversion between selenate and selenite (*i.e.*, selenium (IV)) is reported to be slow in most natural waters [U.S. EPA, 2004].

IRW Model: Water Quality Module Equations

EPA calculated the nonvolatile pollutant concentrations for the following compartments within the receiving water:

Total pollutant concentration in water column (C_{wc});
Dissolved pollutant concentration in water column (C_{dw}); and
Total pollutant concentration in sediment (C_{bs}).

EPA used the equations presented below to calculate receiving water concentrations for arsenic, cadmium, chromium (VI), copper, lead, mercury, nickel, selenium, thallium, and zinc.

EQUATION C-1

$$Cw_{Tot,\ Rivers} = \frac{L_{total}}{(Q_{cool} + Q_{river}) \times f_{water} + K_{wt} \times V_{river}}$$

Where:

$Cw_{Tot,Rivers}$	=	Total pollutant concentration in the waterbody (water and sediment) in rivers and streams from pollutant loading (grams per cubic meter [g/m^3] or milligrams per liter [mg/L])	Output from Equation C-1
L_{total}	=	Average pollutant loading from steam effluent (grams per day [g/day])	Site-specific value from engineering analysis, based on annual average (see Table C-1)
Q_{cool}	=	Total cooling water effluent flow (cubic meters per day [m^3/day])	Site-specific value from engineering analysis (see Table C-1)
Q_{river}	=	Receiving water average annual flow (m^3/day)	Site-specific value from NHD Plus (see Table C-1)
f_{water}	=	Fraction of total waterbody pollutant concentration in water column (unitless)	Output from Equation C-6
K_{wt}	=	Water concentration dissipation rate constant (1/day)	Output from Equation C-10
V_{river}	=	Flow independent mixing volume for rivers and streams (m^3)	Output from Equation C-11

EQUATION C-2

$$Cw_{Tot,\ Lake} = \frac{L_{total}}{(Q_{cool} + Q_{lake}) \times f_{water} + K_{wt} \times V_{lake}}$$

Where:

$Cw_{Tot,\ Lake}$	=	Total pollutant concentration in the waterbody (water and sediment) in lakes, ponds, and reservoirs from pollutant loading (g/m^3 or mg/L)	Output from Equation C-2
L_{total}	=	Average pollutant loading from steam effluent (g/day)	Site-specific value from engineering analysis, based on annual average (see Table C-1)
Q_{cool}	=	Total cooling water effluent flow (m^3/day)	Site-specific value from engineering analysis (see Table C-1)
Q_{lake}	=	Average annual flow exiting the lake, pond, or reservoir (m^3/day)	Site-specific value from NHD Plus (see Table C-1)
f_{water}	=	Fraction of total waterbody pollutant concentration in water column (unitless)	Output from Equation C-6
K_{wt}	=	Water concentration dissipation rate constant (1/day)	Output from Equation C-10
V_{lake}	=	Flow independent mixing volume for lakes, ponds, and reservoirs (m^3)	Output from Equation C-12

EQUATION C-3

$$C_{wc} = f_{water} \times Cw_{tot\ (Rivers\ or\ Lakes)} \times \frac{d_z}{d_w}$$

Where:

C_{wc}	=	Total pollutant concentration in water column (mg/L)	Output from Equation C-3
f_{water}	=	Fraction of total waterbody pollutant concentration in water column (unitless)	Output from Equation C-6
Cw_{Tot} (Rivers or Lakes)	=	Total pollutant concentration in the waterbody (water and sediment) from pollutant loading (g/m^3 or mg/L)	Output from Equation C-1 or Equation C-2

d_z (Rivers or Lakes)	=	Depth of the waterbody (meters [m])	River or stream: output from Equation C-9 Lake, pond, or reservoir: site-specific value (see Table C-1)
d_w (Rivers or Lakes)	=	Depth of water column (m)	River or stream: output from Equation C-7 Lake, pond, or reservoir: site-specific value (see Table C-1)

EQUATION C-4

$$C_{dw} = C_{wc}\left(\frac{1}{1 + Kd_{sw} \times TSS \times 0.000001}\right)$$

Where:

C_{dw}	=	Dissolved pollutant concentration in water (mg/L)	Output from Equation C-4
C_{wc}	=	Total pollutant concentration in water column (mg/L)	Output from Equation C-3
Kd_{sw}	=	Suspended sediment-surface water partition coefficient (milliliters per gram [mL/g])	Model assumption value (see Table C-2 and Table C-4)
TSS	=	Total suspended solids (mg/L)	Site-specific assumption value (see Table C-3 and Table C-5)
0.000001	=	Conversion factor (L/mL)(g/mg)	Conversion factor

EQUATION C-5

$$C_{bs} = f_{Benth} \times Cw_{tot\ (Rivers\ or\ Lakes)} \times \frac{d_z}{d_b}$$

Where:

C_{bs}	=	Total pollutant concentration in sediment (mg/L)	Output from Equation C-5
f_{Benth}	=	Fraction of total waterbody pollutant concentration in benthic sediment (unitless)	Output from Equation C-15
Cw_{Tot} (Rivers or Lakes)	=	Total pollutant concentration in the waterbody (water and sediment) from pollutant loading (g/m^3 or mg/L)	Output from Equation C-1 or Equation C-2

d_z (Rivers or Lakes)	=	Depth of the waterbody (m)	River or stream: output from Equation C-9 Lake, pond, or reservoir: site-specific value (see Table C-1)
d_b (Rivers or Lakes)	=	Depth of upper benthic sediment layer (m)	Model assumption value of 0.03 m (see Table C-2)

EQUATION C-6

$$f_{water} = \frac{[1 + (Kd_{sw} \times TSS \times 0.000001)] \times \frac{d_w}{d_z}}{\left[[1 + (Kd_{sw} \times TSS \times 0.000001)] \times \frac{d_w}{d_z}\right] + \left[(bsp + Kd_{bs} \times bsc) \times \frac{d_b}{d_z}\right]}$$

Where:

f_{water}	=	Fraction of total waterbody pollutant concentration in water column (unitless)	Output from Equation C-6
Kd_{sw}	=	Suspended sediment-surface water partition coefficient (mL/g)	Model assumption value (see Table C-2 and Table C-4)
TSS	=	Total suspended solids (mg/L)	Site-specific assumption value (see Table C-3 and Table C-5)
0.000001	=	Conversion factor (L/mL)(g/mg)	Conversion factor
d_w (Rivers or Lakes)	=	Depth of water column (m)	River or stream: output from Equation C-7 Lake, pond, or reservoir: site-specific value (see Table C-1)
d_z (Rivers or Lakes)	=	Depth of the waterbody (m)	River or stream: output from Equation C-9 Lake, pond, or reservoir: site-specific value (see Table C-1)
bsp	=	Bed sediment porosity (cubic centimeter per cubic centimeter [cm^3/cm^3])	Model assumption value of 0.6 cm^3/cm^3 (see Table C-2)
Kd_{bs}	=	Bottom sediment-pore water partition coefficient (mL/g)	Model assumption value (see Table C-2 and Table C-4)

bsc	=	Bed sediment particle concentration (gram per cubic centimeter [g/cm^3]) or (kilogram per liter [kg/L])	Model assumption value of 1 g/cm^3 (see Table C-2)
d_b	=	Depth of upper benthic layer (m)	Model assumption value of 0.03 m (see Table C-2)

EQUATION C-7

$$d_w = \frac{Q_{river}}{v \times Width}$$

Where:

$d_{w,\ river}$	=	Depth of water column (m)	Output from Equation C-7
Q_{river}	=	Receiving water average annual flow (m^3/s)	Site-specific value from NHD Plus (see Table C-1)
v	=	Receiving water velocity (m/s)	Site-specific value from NHD Plus (see Table C-1)
$Width_{river}$	=	Receiving water width (m)	Output from Equation C-8

EQUATION C-8

$$Width_{river} = 5.1867 \times Q_{river}^{0.4559}$$

Where:

$Width_{river}$	=	Receiving water width (m)	Output from Equation C-8
Q_{river}	=	Receiving water average annual flow (m^3/s)	Site-specific value from NHD Plus (see Table C-1)

EQUATION C-9

$$d_{z,\ river} = d_b + d_{w,\ river}$$

Where:

$d_{z,\ river}$	=	Depth of the waterbody (m)	Output from Equation C-9
d_b	=	Depth of upper benthic sediment layer (m)	Model assumption value 0.03 m (see Table C-2)

$d_{w,\ river}$	=	Depth of water column (m)	Output from Equation C-7

EQUATION C-10

$$K_{wt} = (f_{water} \times k_{sw}) + (f_{benth} \times k_{sed}) + (f_{water} \times k_{vol}) + (f_{benth} \times K_b)$$

Where:

K_{wt}	=	Water concentration dissipation rate constant (1/day) for nonvolatile pollutants (see Equation C-16 for volatile pollutants)	Output from Equation C-10
f_{water}	=	Fraction of total waterbody pollutant concentration in water column (unitless)	Output from Equation C-6
k_{sw}	=	Degradation rate for water column (1/day)	Model assumption value of 0/day (see Table C-2)
f_{benth}	=	Fraction of total waterbody pollutant concentration in benthic sediment (unitless)	Output from Equation C-15
k_{sed}	=	Degradation rate for sediment (1/day)	Model assumption value of 0/day (see Table C-2)
k_{vol}	=	Water column volatilization loss rate constant (1/day)	Model assumption value of 0/day (see Table C-2)
K_b	=	Benthic burial rate (1/day)	Output from Equation C-14

EQUATION C-11

$$V_{river} = Width_{river} \times Len \times d_{z,river}$$

Where:

V_{river}	=	Flow independent mixing volume for rivers and streams (m^3)	Output from Equation C-11
$Width_{river}$	=	Receiving water width (m)	Output from Equation C-8
Len	=	Length of stream reach (m)	Site-specific value from NHD Plus (see Table C-1)
$d_{z,\ river}$	=	Depth of the waterbody (m)	Output from Equation C-9

EQUATION C-12

$$V_{lake} = Area \times d_{z,lake}$$

Where:

V_{lake}	=	Flow independent mixing volume for lakes, ponds, and reservoirs (m^3)	Output from Equation C-12
Area	=	Surface area of the lake (m)	Site-specific value from NHD Plus (see Table C-1)
$d_{z,lake}$	=	Depth of the lake (m)	Site-specific value (see Table C-1)

EQUATION C-13

$$f_d = \frac{1}{1 + Kd_{sw} \times TSS \times 0.000001}$$

Where:

f_d	=	Dissolved fraction in water (unitless)	Output from Equation C-13
Kd_{sw}	=	Suspended sediment-surface water partition coefficient (mL/g)	Model assumption value (see Table C-2 and Table C-4)
TSS	=	Total suspended solids (mg/L)	Site-specific assumption value (see Table C-3 and Table C-5)
0.000001	=	Conversion factor (L/mL)(g/mg)	Conversion factor

EQUATION C-14

$$K_b = f_{benth} \times \frac{WB}{d_b}$$

Where:

K_b	=	Benthic burial rate (1/day)	Output from Equation C-14
f_{benth}	=	Fraction of total waterbody pollutant concentration in benthic sediment (unitless)	Output from Equation C-15
WB	=	Rate of burial (m/day)	Model assumption value of 0 m/day (see Table C-2)

d_b	=	Depth of upper benthic sediment layer (m)	Model assumption value of 0.03 m (see Table C-2)

EQUATION C-15

$$f_{Benth} = \frac{(bsp + Kd_{bs} \times bsc) \times \frac{d_b}{d_z}}{\left[[1 + (Kd_{sw} \times TSS \times 0.000001)] \times \frac{d_w}{d_z}\right] + \left[(bsp + Kd_{bs} \times bsc) \times \frac{d_b}{d_z}\right]}$$

Where:

f_{benth}	=	Fraction of total waterbody pollutant concentration in benthic sediment (unitless)	Output from Equation C-15
bsp	=	Bed sediment porosity (cm^3/cm^3)	Model assumption value of 0.6 cm^3/cm^3 (see Table C-2)
Kd_{bs}	=	Bottom sediment-pore water partition coefficient (mL/g)	Model assumption value (see Table C-2 and Table C-4)
bsc	=	Bed sediment particle concentration (g/cm^3) or (kg/L)	Model assumption value of 1 g/cm^3 (see Table C-2)
d_b	=	Depth of upper benthic sediment layer (m)	Model assumption value of 0.03 m (see Table C-2)
d_z	=	Depth of the waterbody (m)	Output from Equation C-9
Kd_{sw}	=	Suspended sediment-surface water partition coefficient (mL/g)	Model assumption value (see Table C-2 and Table C-4)
TSS	=	Total suspended solids (mg/L)	Site-specific assumption value (see Table C-3 and Table C-5)
0.000001	=	Conversion factor (L/mL)(g/mg)	Conversion factor
d_w (Rivers or Lakes)	=	Depth of water column (m)	River or stream: output from Equation C-7 Lake, pond, or reservoir: site-specific value (see Table C-1)

EPA calculated the volatile pollutant concentrations in each of the three compartments within the receiving water by building off the equations used to calculate nonvolatile pollutant concentrations. The water concentration dissipation rate constant, K_{wt}, in Equation C-10 was replaced with a $K_{wt,volatile}$ factor (see Equation C-16) that takes into account volatilization loss

(k_{vol}). EPA used the equations presented below in combination with the preceding equations to calculate receiving water concentrations for mercury only.

EQUATION C-16

$$K_{wt,\ volatile} = (f_{water} \times k_{sw}) + (f_{benth} \times k_{sed}) + (f_{water} \times f_d \times k_{vol}) + (f_{benth} \times K_b)$$

Where:

$K_{wt,\ volatile}$	=	Water concentration dissipation rate constant (1/day)	Output from Equation C-16
f_{water}	=	Fraction of total waterbody pollutant concentration in water column (unitless)	Output from Equation C-6
k_{sw}	=	Degradation rate for water column (1/day)	Model assumption value of 0/day (see Table C-2)
f_{benth}	=	Fraction of total waterbody pollutant concentration in benthic sediment (unitless)	Output from Equation C-15
k_{sed}	=	Degradation rate for sediment (1/day)	Model assumption value of 0/day (see Table C-2)
f_d	=	Dissolved fraction in water (unitless)	Output from Equation C-13
k_{vol}	=	Water column volatilization loss rate constant (1/day)	Output from Equation C-17
K_b	=	Benthic burial rate (1/day)	Output from Equation C-14

EQUATION C-17

$$k_{vol} = \frac{K_v \times f_d}{d_w}$$

Where:

k_{vol}	=	Water column volatilization loss rate constant (1/day)	Output from Equation C-17
K_v	=	Diffusion transfer rate (m/day)	Output from Equation C-18
f_d	=	Dissolved fraction in water (unitless)	Output from Equation C-13

d_w (Rivers or Lakes)	=	Depth of water column (m)	River or stream: output from Equation C-7 Lake, pond, or reservoir: site-specific value (see Table C-1)

EQUATION C-18

$$K_v = \frac{1}{\left(\frac{1}{K_L}\right) + \left(\frac{1}{K_g \times \left(\frac{HLC}{R \times T_w}\right)}\right)} \theta_{water}^{(T_w - T_{hic})}$$

Where:

K_v	=	Diffusion transfer rate (m/day)	Output from Equation C-18
Θ_{water}	=	Temperature correction (unitless)	Model assumption value of 1.026 (see Table C-2)
T_w	=	Temperature of the waterbody (degrees Kelvin [°K])	River or stream: site-specific assumption value (see Table C-3 and Table C-6) Lake, pond, or reservoir: model assumption value (see Table C-3 and Table C-6)
T_{hlc}	=	Temperature of HLC (°K)	Default model value of 298°K (see Table C-2)
K_L (Rivers or Lakes)	=	Liquid-phase transfer coefficient (m/day)	River or stream: output from Equation C-19 Lake, pond, or reservoir: output from Equation C-21
K_g (Rivers or Lakes)	=	Gas-phase transfer coefficient (m/day)	River or stream: model assumption value of 100 m/day (see Table C-2) Lake, pond, or reservoir: output from Equation C-23

HLC	=	Henry's Law Constant (atm-m^3/mole) [1]	Known value of 0.0113 atm-m^3/mol (see Table C-2)
R	=	Universal gas constant (atm-m^3/°K-mole)	Known value of 0.00008205 atm-m^3/°K-mole (see Table C-2)

EQUATION C-19

$$K_{L(Rivers)} = \sqrt{\frac{10^{-4} \times D_w \times v}{d_z}} \times 86{,}400$$

Where:

$K_{L(Rivers)}$	=	Liquid-phase transfer coefficient (m/day)	Output from Equation C-19
D_w	=	Diffusivity of the pollutant in water (square centimeter per second [cm^2/s])	Output from Equation C-20
v	=	Receiving water velocity (m/s)	Site-specific value from NHD Plus (see Table C-1)
$d_{z,river}$	=	Depth of waterbody (m)	Output from Equation C-9
86,400	=	Conversion factor (s/day)	Conversion factor

EQUATION C-20

$$D_w = \frac{22 \times 10^{-5}}{MW^{2/3}}$$

Where:

D_w	=	Diffusivity of the pollutant in water (cm^2/s)	Output from Equation C-20
MW	=	Molecular weight (grams per mole [g/mol])	Known value of 200.59 g/mol for mercury (see Table C-2)

[1] Units for Henry's Law Constant are atmospheres of absolute pressure (atm) per cubic meter (m^3) per mole (mol).

EQUATION C-21

$$K_{L(Lakes)} = \sqrt{C_d} \times w_{10} \times \sqrt{\frac{\rho_a}{\rho_w}} \times \left(\frac{k^{0.33}}{\lambda_2}\right) \times Sc_w^{-0.67} \times 86{,}400$$

Where:

$K_{L(Lakes)}$	=	Liquid-phase transfer coefficient (m/day)	Output from Equation C-21
C_d	=	Drag coefficient (unitless)	Model assumption value of 0.0011 (see Table C-2)
W_{10}	=	Wind velocity 10 meters above water surface (m/s)	Site-specific assumption value (see Table C-3)
ρ_a	=	Density of air corresponding to water temperature (g/cm^3)	Model assumption value of 0.0012 g/cm^3 (see Table C-2)
ρ_w	=	Density of water corresponding to water temperature (g/cm^3)	Model assumption value of 1 g/cm^3 (see Table C-2)
k	=	Von Karman's constant (unitless)	Known value of 0.4 (see Table C-2)
λ_2	=	Dimensionless viscous sublayer thickness (unitless)	Model assumption value of 4 (see Table C-2)
Sc_w	=	Water Schmidt number (dimensionless)	Output from Equation C-22
86,400	=	Conversion factor (s/day)	Conversion factor

EQUATION C-22

$$Sc_w = \frac{\mu_w}{\rho_w \times D_w}$$

Where:

Sc_w	=	Water Schmidt number (dimensionless)	Output from Equation C-22
μ_w	=	Viscosity of water corresponding to water temperature (g/cm-s)	Model assumption value of 0.0169 g/cm-s (see Table C-2)
ρ_w	=	Density of water corresponding to water temperature (g/cm^3)	Model assumption value of 1 g/cm^3 (see Table C-2)
D_w	=	Diffusivity of the pollutant in water (cm^2/s)	Output from Equation C-20

EQUATION C-23

$$K_{g(Lakes)} = \sqrt{C_d} \times W_{10} \times \left(\frac{k^{0.33}}{\lambda_2}\right) \times Sc_a^{-0.67} \times 86{,}400$$

Where:

$K_{g(lakes)}$	=	Gas-phase transfer coefficient (m/day)	Output from Equation C-23
C_d	=	Drag coefficient (unitless)	Model assumption value of 0.0011 (see Table C-2)
W_{10}	=	Wind velocity 10 meters above water surface (m/s)	Site-specific assumption value (see Table C-3)
k	=	Von Karman's constant (unitless)	Known value of 0.4 (see Table C-2)
λ_2	=	Dimensionless viscous sublayer thickness (unitless)	Model assumption value of 4 (see Table C-2)
Sc_a	=	Air Schmidt number (dimensionless)	Output from Equation C-24
86,400	=	Conversion factor (s/day)	Conversion factor

EQUATION C-24

$$Sc_a = \frac{(1.32 + 0.009T_a) \times 10^5}{\frac{1.9}{MW^{2/3}}}$$

Where:

Sc_a	=	Air Schmidt number (dimensionless)	Output from Equation C-24
T_a	=	Air temperature °K	Site-specific assumption value (see Table C-3)
MW	=	Molecular weight (g/mol)	Known value of 200.59 g/mol for mercury (see Table C-2)

EPA calculated the potential water quality impacts to aquatic life and humans by comparing the pollutant concentration in the water column (C_{wc} or C_{dw}, depending on the benchmark) to the water quality benchmarks presented in Table C-7.

IRW Model: Water Quality Module Inputs

Table C-1. Site-Specific Input Variables

Input Variable	Input Category and Description	Data Source
L_{total}	Plant-specific effluent characteristic Total waterbody loading	EPA estimated the pollutant discharge loadings using the methodology presented in Section 10 of the TDD.
Q_{cool}	Plant-specific effluent characteristic Total cooling water effluent flow by receiving water	EPA determined the estimated cooling water flow for each plant by outfall based an assessment of industry survey results using the methodology outlined in *Water Quality Module: Plant and Receiving Water Characteristics* [ERG, 2015e].
Q_{river}	Receiving water characteristic for rivers and streams Waterbody annual flow	EPA extracted average annual flow values from the NHD Plus dataset using the methodology outlined in *Water Quality Module: Plant and Receiving Water Characteristics* [ERG, 2015e]. The NHD Plus dataset includes estimated mean annual flow values for each stream reach within the network using the Vogel Method [Vogel *et al.*, 1999] and the Unit Runoff Method.
v	Receiving water characteristic for rivers and streams Receiving water velocity	EPA extracted average annual velocity values from the NHD Plus dataset using the methodology outlined in *Water Quality Module: Plant and Receiving Water Characteristics* [ERG, 2015e]. The NHD Plus dataset includes estimated mean annual velocity values for each stream reach within the network using the Jobson Method [Jobson, 1996] and the estimated mean annual flow values.
Len	Receiving water characteristic for rivers and streams Length of stream reach	EPA estimated the stream reach length based on outfall locations using the methodology described in *Water Quality Module: Plant and Receiving Water Characteristics* [ERG, 2015e].
Q_{lake}	Receiving water characteristic for lakes, ponds, and reservoirs Average discharge flow exiting the lake/pond system	EPA extracted average annual flow values from the NHD Plus dataset using the methodology outlined in *Water Quality Module: Plant and Receiving Water Characteristics* [ERG, 2015e]. The NHD Plus dataset includes estimated mean annual flow values for the stream reach exiting the lake using the Vogel Method [Vogel *et al.*, 1999] and the Unit Runoff Method.
Area	Receiving water characteristic for lakes, ponds, and reservoirs Surface area of the lake, pond, or reservoir	EPA estimated the lake surface area based on NHD Plus data or site-specific sources as described in *Water Quality Module: Plant and Receiving Water Characteristics* [ERG, 2015e].
$d_{z,lake}$	Receiving water characteristic for lakes, ponds, and reservoirs Depth of the lake, pond, or reservoir	EPA estimated the depth of the lake, pond, or reservoir based on site-specific data as described in *Water Quality Module: Plant and Receiving Water Characteristics* [ERG, 2015e].
$d_{w,lake}$	Receiving water characteristic for lakes, ponds, and reservoirs Depth of the water column	EPA estimated the depth of the lake, pond, or reservoir based on site-specific data as described in *Water Quality Module: Plant and Receiving Water Characteristics* [ERG, 2015e].

Table C-2. Model Assumption Input Variables and Known Variables

Input Variable	Description	Assumed/ Known Value	Assumption Rationale/Data Source
bsp	Bed sediment porosity	0.6 cm^3/cm^3	Bed sediment porosity is the volume of water per volume of benthic space with typical values ranging between 0.8 and 0.4 [U.S. EPA, 1998b]. EPA selected an average value to use for this input variable.
bsc	Bed sediment particle concentration	1 g/cm^3	Bed sediment particle concentrations typically range between 0.5 to 1.5 g/cm^3 [U.S. EPA, 1998d]. EPA selected an average value to use for this input variable.
d_b	Depth of upper benthic layer	0.03 m	The upper benthic layer variable represents the portion of the bed in equilibrium with the water column. Typical values can range from 0.01 to 0.05 m [U.S. EPA, 1998b]. EPA selected an average value to use for this input variable.
k_{sw}	Degradation rate for water column	0/day	EPA assumed no loss from pollutant degradation in the water column, as an environmentally conservative assumption.
k_{vol}	Water column volatilization loss rate constant	0/day	EPA selected a volatilization rate of 0 for nonvolatile pollutants (*i.e.*, all pollutants except mercury).
k_{sed}	Degradation rate for sediment	0/day	EPA assumed no loss from pollutant degradation in the sediment, as an environmentally conservative assumption.
WB	Rate of burial	0/day	EPA assumed no pollutant loss from burial within the waterbody sediments, as an environmentally conservative assumption.
Θ_{water}	Temperature correction	1.026 (unitless)	EPA selected the temperature correction factor based on the value provided in U.S. EPA, 1998b.
$K_{g(Rivers)}$	Gas phase transfer coefficient for rivers or streams	36,500 m/yr (100 m/day)	EPA selected the gas phase transfer coefficient for rivers and streams based on the value provided in U.S. EPA, 1998b.
R	Ideal gas constant	0.00008205 atm-m^3/ K-mole	The ideal gas constant is a known chemical constant.
C_d	Drag coefficient	0.0011 (unitless)	EPA selected the drag coefficient based on the value provided in U.S. EPA, 1998b.
ρ_a	Density of air corresponding to water temperature	0.0012 g/cm^3	EPA selected the density of air corresponding to water temperature based on the value provided in U.S. EPA, 2005b.
ρ_w	Density of water corresponding to water temperature	1 g/cm^3	EPA selected the density of water corresponding to water temperature based on the value provided in U.S. EPA, 2005b.
k	Von Karman's constant	0.4 (unitless)	The von Karman constant is a known dimensionless constant used to describe the velocity profile of a turbulent fluid flow near a boundary.

Table C-2. Model Assumption Input Variables and Known Variables

Input Variable	Description	Assumed/ Known Value	Assumption Rationale/Data Source
Kd_{sw}	Suspended sediment- surface water partition coefficient	Table C-4	The suspended sediment partition coefficient describes the partitioning of a pollutant between sorbing material, in this case suspended sediment and surface water. EPA identified U.S. EPA, 2005a as the primary source for the pollutant-specific suspended sediment partition coefficients.
Kd_{bs}	Bottom sediment-pore water partition coefficient	Table C-4	The bottom sediment partition coefficient describes the partitioning of a pollutant between sorbing material, in this case bottom sediment and pore water. EPA identified U.S. EPA, 2005a as the primary source for the pollutant-specific bed sediment partition coefficients.
λ_2	Dimensionless viscous sublayer thickness	4 (unitless)	EPA selected the viscous sublayer thickness value based on the value provided in U.S. EPA, 2005b.
μ_w	Viscosity of water corresponding to water temperature	0.0169 g/cm-s	EPA selected the viscosity of water value based on the value provided in U.S. EPA, 2005b.
HLC	Henry's Law Constant	0.0113 atm-m^3/mol	Henry's Law Constant is used in Equation C-18 to estimate the receiving water concentration for volatile pollutants. Mercury is the only volatile pollutant included in the IRW model. Therefore, the assumed model default value is set to Henry's Law Constant for mercury at 298 °K.
T_{hlc}	Temperature of Henry's Law Constant	298 °K	The value 298 °K is the standard temperature value provided for Henry's Law Constant.
MW	Molecular weight	200.59 g/mol	Molecular weight is used in Equation C-20 and Equation C-24 to estimate the receiving water concentration for volatile pollutants. Mercury is the only volatile pollutant included in the IRW model. Therefore, the assumed model default value is set to the molecular weight for mercury.

Table C-3. Site-Specific Assumption Input Variables

Input Variable	Description	Assumed Value	Data Source
TSS	Total suspended solids	Table C-5	EPA used the geometric mean of the regional and national TSS concentrations determined as part of the *Human and Ecological Risk Assessment of Coal Combustion Residuals* [U.S. EPA, 2014g].

Table C-3. Site-Specific Assumption Input Variables

Input Variable	Description	Assumed Value	Data Source
W_{10}	Wind velocity 10 m above the water surface	Table C-1	National Climatic Data Center national mean annual wind speed GIS coverage (downloaded 05/12/2011 from http://hurricane.ncdc.noaa.gov/cgi-bin/climaps/climaps.pl?directive=quick_search&subrnum). EPA selected, as an environmentally conservative estimate, the lower of the wind speed range values for the analysis.
T_a	Air temperature	Table C-2	National Climatic Data Center national mean annual temperature GIS coverage (downloaded 05/12/2011 from http://hurricane.ncdc.noaa.gov/cgi-bin/climaps/climaps.pl?directive=quick_search&subrnum). EPA selected, as an environmentally conservative estimate, the lower of the air temperature range values for the analysis.
T_w	Temperature of the surface water	Table C-6	EPA used the regional surface temperatures determined as part of the *Human and Ecological Risk Assessment of Coal Combustion Residuals* [U.S. EPA, 2014g].

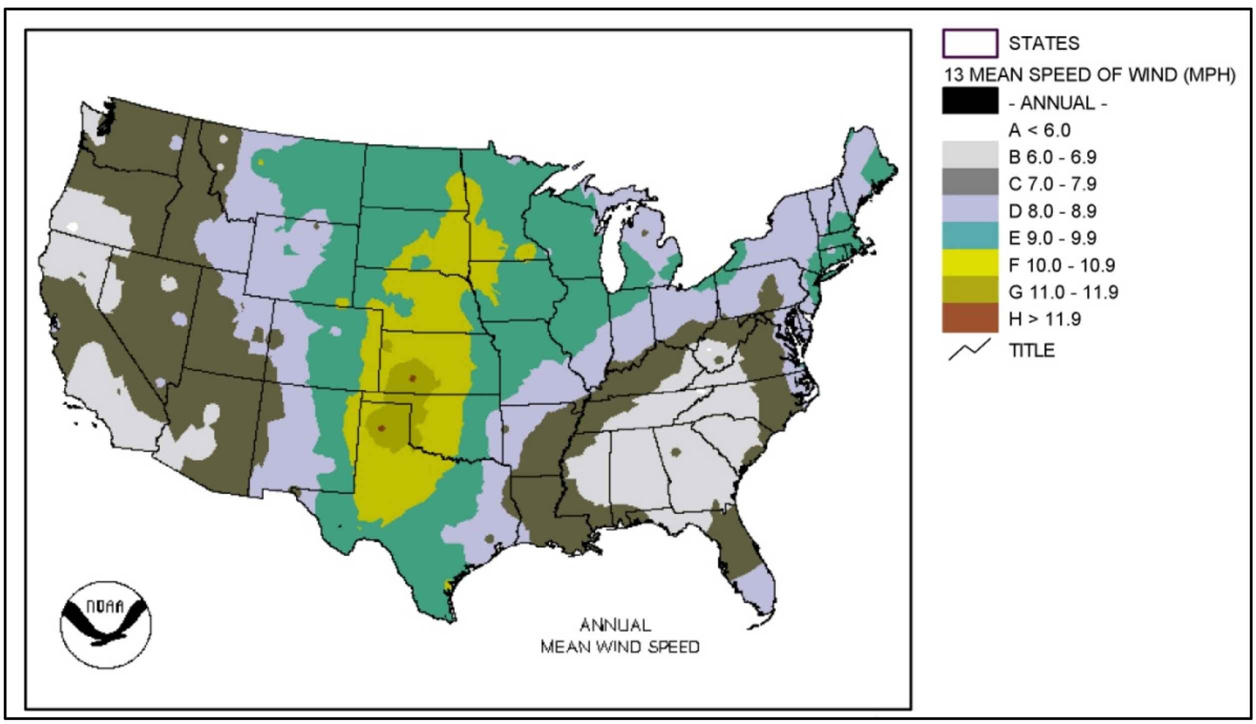


Figure C-1. National Climatic Data Center National Mean Annual Wind Speed

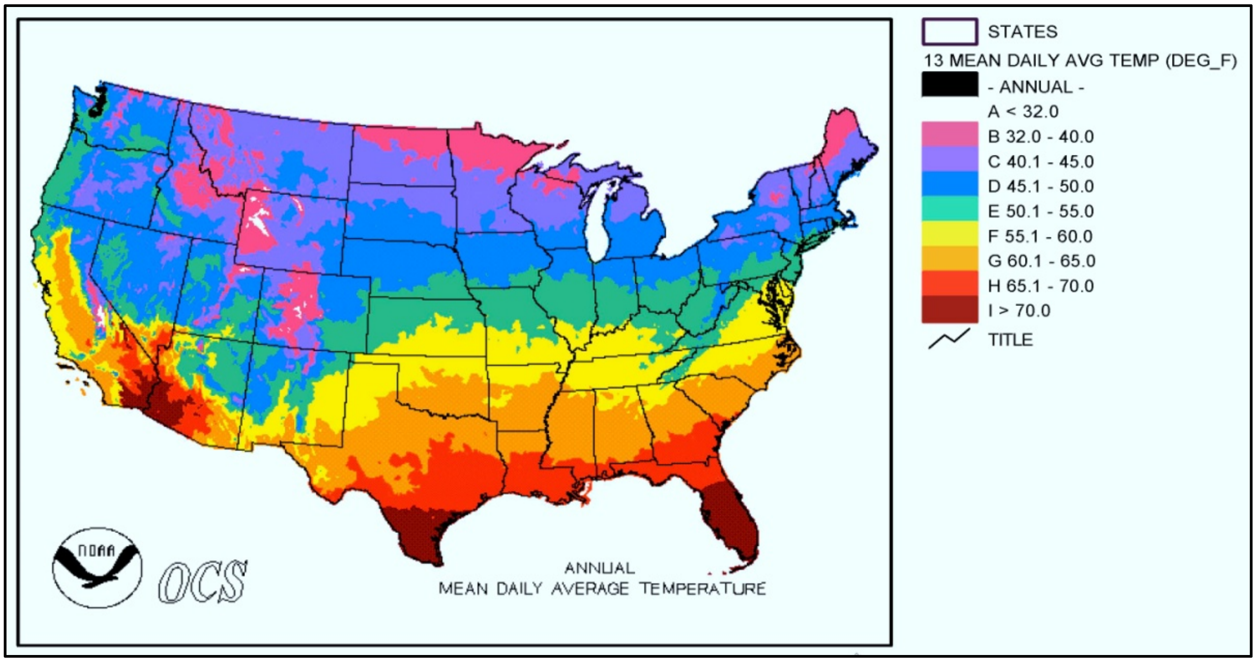


Figure C-2. National Climatic Data Center National Mean Annual Temperature

Table C-4. Partition Coefficients

Pollutant	Suspended Sediment-Water Partition Coefficient (Kd_{sw}) (mL/g)	Bottom Sediment-Pore Water Partition Coefficient (Kd_{bs}) (mL/g)
Arsenic	7,900	250
Cadmium	79,000	2,000
Chromium (VI)	16,000	50
Copper	50,000	3,200
Lead	500,000	40,000
Mercury (II)	200,000	79,000
Nickel	20,000	7,900
Selenium (IV)	25,000	4,000
Thallium	13,000	20
Zinc	100,000	13,000

Source: U.S. EPA, 2005a.

Table C-5. TSS Concentrations in Surface Waters

Hydrologic Region [a]	Number of Measurements	Number of Annual Medians	Annual Median TSS (mg/L) (log triangular distribution)			
			Min	Max	Geometric Mean	Weighted Geometric Mean
1	9,007	33	3.2	40	8	6
2	47,202	38	10	316	32	40
3	43,395	36	6.3	79	25	25
4	29,577	37	6.3	794	25	25
5	39,900	38	4	100	25	25
6	4,137	28	5	316	16	20
7	34,494	37	32	1,585	63	100
8	46,231	38	50	316	158	126
9	3,254	35	13	3,162	32	63
10	62,791	38	10	398	126	126
11	48,969	38	25	794	200	126
12	7,280	35	40	1,995	79	126
13	13,974	37	32	79,433	200	398
14	26,699	38	16	5,012	158	251
15	9,162	37	20	19,953	200	398
16	19,965	33	4	2,512	16	25
17	173,136	37	2	316	6	10
18	42,022	37	13	398	63	50
Lakes (national)	4,360	99	1	398	25	25

Source: U.S. EPA, 2010b; Legacy STORET database.

a – For rivers and streams, EPA used the geometric mean TSS concentration for the corresponding hydrogeologic region. For lakes, ponds, and reservoirs, EPA used a national geometric mean.

Table C-6. Regional Surface Water Temperatures

Hydrologic Region	Climate	Surface Water Temperature (°C)	Surface Water Temperature (°K)
1	North	14 (Northern Median)	287
2	North	16	289
3	South	21	294
4	North	14	287
5	North	17	290
6	South	18	291
7	North	15	288
8	South	20	293
9	North	10	283
10	North	13	286

Table C-6. Regional Surface Water Temperatures

Hydrologic Region	Climate	Surface Water Temperature (°C)	Surface Water Temperature (°K)
11	South	17	290
12	South	21	294
13	South	17 (Southern Median)	290
14	South	9	282
15	South	17	290
16	South	9	282
17	North	14 (Northern Median)	287
18	South	15	288

Source: U.S. EPA, 2010b; Legacy STORET database.

Table C-7. NRWQC and MCL Benchmarks

Pollutant	FW Acute NRWQC Benchmark [a,b] (mg/L)	FW Chronic NRWQC Benchmark [a,b] (mg/L)	HH WO NRWQC Benchmark [a,b] (mg/L)	HH O NRWQC Benchmark [a,b] (mg/L)	MCL Benchmark [a,c] (mg/L)
Arsenic	0.34 (d)	0.15 (d)	0.000018 (f)	0.00014 (f)	0.01
Cadmium	0.002 (d)	0.00025 (d)	--	--	0.005
Chromium (VI)	0.016 (d)	0.011 (d)	--	--	0.1 (g)
Copper	0.013 (d,e)	0.009 (d,e)	1.3	--	1.3 (Action Level); 1.0 (h)
Lead	0.065 (d)	0.0025 (d)	--	--	0.015 (Action Level)
Mercury	0.0014 (d)	0.00077 (d)	--	--	0.002 (f)
Nickel	0.47 (d)	0.052 (d)	0.61	4.6	-
Selenium	--	0.005	0.17	4.2	0.05
Thallium	--	--	0.00024	0.00047	0.002
Zinc	0.12 (d)	0.12 (d)	7.4	26	5 (h)

Acronyms: MCL (Maximum Contaminant Level); NRWQC (National Recommended Water Quality Criteria).

a – "--" designates instances where a benchmark does not exist for the pollutant or the benchmark is a secondary standard.

b – National Recommended Water Quality Criteria. Washington, D.C. [U.S. EPA, 2009d]. Pollutant concentrations were compared to the freshwater (FW) acute and chronic NRWQC and the human health (HH) water and organisms (WO) and organisms only (O) NRWQC.

c – National Primary Drinking Water Regulations. EPA 816-F-09-004. May. Washington, D.C. [U.S. EPA, 2009e].

d – Benchmark is expressed in terms of the dissolved pollutant in the water column.

e – The 2009 NRWQC for copper are calculated using the biotic ligand model; therefore, there is no national value. For this analysis, EPA used the 2002 NRWQC values [U.S. EPA, 2002].

f – Benchmark is for inorganic form of pollutant.

g – MCL is for total chromium.

h – Secondary (nonenforceable) drinking water standard.

IRW Model: Water Quality Module Methodology Limitations and Assumptions

The limitations and assumptions in the IRW water quality module are as follows:

- The module is based on annual-average pollutant loadings, normalized effluent flow rates from the steam electric power plants, and annual-average flow rates within the immediate receiving waters. The module does not consider temporal variability (*e.g.*, seasonal differences, storm flows, low-flow events, catastrophic events). The result of this limitation on the water quality module outputs is unknown.
- The module represents only the waterbody concentration within the immediate discharge zone (*i.e.*, approximately 1 to 10 kilometers [km] from the outfall) and does not calculate pollutant concentrations in downstream waters. This limitation results in a potential underestimation of the extent of surface waters with environmental and human health impacts under baseline conditions and improvements under the regulatory options.
- The module does not take into consideration pollutant speciation within the receiving stream. This limitation is particularly relevant to the wildlife impact analysis as many of the ecological impacts are tied to a specific pollutant species. For example, inorganic arsenic is typically more toxic to aquatic life than organic arsenic. This limitation results in a potential overestimation of the number of immediate receiving waters with exceedances of water quality benchmarks for inorganic forms of the pollutant (*e.g.*, the human health NRWQCs for arsenic).
- The module assumes that equilibrium is quickly attained within the waterbody following discharge and is consistently maintained between the water column and surficial bed sediments. This assumption is especially significant regarding pollutant equilibrium within lakes, ponds, and reservoirs. The module equations presented in Appendix C do not take into consideration the effects of currents, inversion, or temperature variations within the water column, but assume that the entire mass of the lake, pond, or reservoir is at equilibrium. As a result, the module outputs do not reflect the potential spatial and temporal variability of pollutant concentrations within the immediate receiving water, and potentially underestimate the existence of isolated "hot spots" of elevated pollutant concentrations. The module does not account for the accumulation of pollutant concentrations in bottom sediments and pore water that occur over prolonged discharge periods.
- The module assumes that pollutants dissolved or sorbed within the water column and bottom sediments can be described by a partition coefficient. EPA used a single partition coefficient to characterize the pollutant in the immediate receiving waters. The partition coefficient in a specific waterbody will be influenced by geochemical parameters (*e.g.*, pH and presence of particulate organic matter and other sorbing material). EPA used a mean or median value for the partition coefficients (central tendency of K_d values) based on data gathered from published sources, statistical analysis of retrieved data, geochemical modeling, and expert judgment [U.S. EPA, 2005a]. The result of this assumption on the water quality module outputs is unknown because of unknown site-specific factors.

- The module assumes that pollutants sorbed to bottom sediments are considered a net loss from the water column. This assumes that bottom sediments are not resuspended and deposited further downstream, but remain within the immediate discharge zone and do not further contribute to the dissolved or suspended sediment concentrations within the water column. This assumption results in a potential overestimation of pollutant concentrations within the benthic sediments and a potential underestimation of pollutant concentrations within the water column and downstream reaches.
- The module assumes a pollutant burial rate of zero within benthic sediment. This is an environmentally protective assumption that might overestimate impacts to sediment receptors to some degree. The burial rate constant is a function of the deposition of sediments from the water column to the upper bed and accounts for the soil eroding into a waterbody becoming bottom sediment rather than suspended sediment. The rate of burial used for each segment of a waterbody may be difficult to obtain [U.S. EPA, 1998b]. EPA had neither measured values nor the data to determine burial rates for each immediate receiving water. The pollutants with more than 10 percent immediate receiving waters showing impacts to sediment receptors include cadmium, mercury, and nickel (see Table 6-4). This assumption results in a potential overestimation of impacts in the benthic sediment.
- The module does not take into account ambient background pollutant concentrations or contributions from other point and nonpoint sources. Also, the pollutant loadings included in the module are not representative of the total pollutant loadings from steam electric power plants, as there are several waste streams that are not included in the analysis (*e.g.*, stormwater runoff, metal cleaning wastes, coal pile runoff). Because of this approach, the module potentially underestimates the number and magnitude of benchmark exceedances at baseline and under the regulatory options. The module also potentially underestimates the number of environmental and human health improvements under the regulatory options (*i.e.*, a higher number of exceedances under baseline conditions creates additional opportunities for improvement under the regulatory options). The results of EPA's case study modeling, which does take into account ambient background pollutant concentrations and contributions from other point and nonpoint sources, support this assessment of the water quality module's limitations (see Section 8).

APPENDIX D
WILDLIFE MODULE METHODOLOGY

This appendix presents the model equations, input variables, pollutant benchmarks, and methodology limitations/assumptions for the immediate receiving water (IRW) model wildlife module. Wildlife impacts include the following ecological receptors:

- Aquatic and sediment organisms (amphibians, fish, invertebrates) in direct contact with receiving water and/or sediment in the immediate discharge zone of steam electric power plants.
- Wildlife (minks and eagles)[1] that consume fish from receiving waters in the immediate discharge zone of steam electric power plants.

EPA estimated pollutant concentrations in the immediate receiving water and sediment using the IRW model water quality module (see Appendix C). The wildlife module uses these concentrations as inputs.

Model input requirements for the equations presented in Appendix D can be divided into four major categories: 1) input variable described by another equation; 2) site-specific input variable; 3) model assumption variable; and 4) pollutant-specific variable. The following tables in Appendix D describe the input requirements and data sources used in the wildlife module and impacts analysis:

- Table D-1. Chemical Stressor Concentration Limits (CSCLs) for Sediment Biota.
- Table D-2. Bioconcentration Factors (BCFs) and Bioaccumulation Factors (BAFs) for Trophic Level 3 (T3) and Trophic Level 4 (T4) Fish.
- Table D-3. No Effect Hazard Concentration (NEHC) Benchmarks for Minks and Bald Eagles.

IRW Model: Wildlife Module Equations, Input Variables, and Impact Analysis

Impact to Aquatic Life Receptors from Direct Contact with Sediment. EPA determined the potential negative impact to aquatic organisms from direct contact with the sediment in immediate receiving waters by comparing the pollutant concentration in the sediment (C_{bs} from the water quality module) to the CSCL benchmarks for sediment biota listed in Table D-1. The wildlife module expresses this comparison as a hazard quotient (HQ). An HQ of higher than one (*i.e.*, pollutant concentration exceeds benchmark) indicates a potential impact to the exposed organism. EPA used Equation D-1 to calculate the HQ for sediment biota.

[1] EPA selected minks and eagles to represent national-scale impacts from steam electric power plants because their habitats cover the entire United States (*i.e.*, can be used for a national assessment).

EQUATION D-1

$$HQ_{sed} = \frac{C_{bs}}{CSCL_{sed}}$$

Where:

HQ_{sed}	=	Hazard quotient for contact with sediment	Output from Equation D-1
C_{bs}	=	Total pollutant concentration in sediment (milligrams per liter [mg/L])	Water quality module output Equation C-5
$CSCL_{sed}$	=	Ecological benchmark for sediment (milligrams per kilograms [mg/kg])	Receptor-specific benchmark (see Table D-1)

<u>Adverse Effects to Piscivorous Wildlife</u>. EPA determined the potential negative impact to piscivorous wildlife (*i.e.*, wildlife that consume fish) from the ingestion of contaminated fish by calculating fish tissue concentrations and comparing these concentrations to ecological benchmarks. Equation D-2 calculates pollutant concentrations in fish for the evaluated pollutants, except for mercury. Because the more toxic form of mercury is methylmercury, EPA used Equation D-3 for this pollutant [U.S. EPA, 2005b]. Equation D-3 estimates the concentration of methylmercury in fish tissue, as opposed to total mercury.

EQUATION D-2

$$C_{fishT} = C_{wc} \times BCF_T$$

EQUATION D-3

$$C_{fishT} = (0.15 \times C_{dw}) \times BCF_T$$

Where:

C_{fishT}	=	Pollutant concentration in fish (wet weight), where T represents trophic level T3 or T4 (mg/kg)	Output from Equation D-2 or Equation D-3
C_{wc}	=	Total pollutant concentration in water (mg/L)	Water quality module output Equation C-3
C_{dw}	=	Dissolved pollutant concentration in water (mg/L)	Water quality module output Equation C-4
0.15	=	Fraction of dissolved total mercury as dissolved methylmercury (unitless)	Model assumption value [U.S. EPA, 2005b]
BCF_T	=	Bioconcentration factor or bioaccumulation factor for specified trophic level (liters per kilogram [L/kg])	Pollutant-specific value (see Table D-2)

EPA compared the calculated T3 fish tissue concentration to the ecological benchmark for minks and the calculated T4 fish tissue concentration to the ecological benchmark for eagles. EPA selected NEHC benchmarks for minks and eagles (Table D-3) as the ecological benchmarks for piscivorous wildlife. The wildlife module expresses this comparison as an HQ. EPA used Equation D-4 to calculate HQ values for arsenic, cadmium, chromium (VI), copper, lead, mercury (as methylmercury), nickel, selenium, thallium, and zinc.

EQUATION D-4

$$HQ_I = \frac{C_{fishT}}{NEHC}$$

Where:

HQ_I	=	Hazard quotient for ingestion of fish	Output from Equation D-4
C_{fishT}	=	Pollutant concentration in fish (wet weight), where T represents trophic level T3 or T4 (mg/kg)	Output from Equation D-2 or Equation D-3
NEHC	=	No effect hazard concentration (μg/g)	Receptor- and pollutant-specific (see Table D-3)

Table D-1. CSCL Benchmarks for Sediment Biota [a]

Pollutant in Wildlife Impact Assessment	CSCL Benchmark Value (mg/kg)	Notes
Arsenic	5.90	
Cadmium	0.596	
Chromium (VI)	37.3	No benchmark for chromium VI. EPA used the total chromium benchmark, which may underestimate the impact to wildlife.
Copper	35.7	
Lead	35	
Mercury	0.174	EPA compares the mercury, not methylmercury, concentration in the sediment to the benchmark.
Nickel	18.0	
Selenium	None identified	EPA could not complete the analysis for this pollutant – no benchmark for comparison.
Thallium	None identified	
Zinc	123	

Source: MacDonald, D.D.; C. G. Ingersoll; and T. A. Berger. Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. Archives of Environmental Contamination and Toxicology 2000, 39(1)20 (as cited in NOAA, 2008).

a – The benchmarks used for the analysis are threshold effect levels (TELs).

Table D-2. Bioconcentration Factors (BCFs) and Bioaccumulation Factors (BAFs) for Trophic Level 3 (T3) and Trophic Level 4 (T4) Fish

Pollutant	BCF or BAF	Factor for Trophic Level 3 (T3) Fish (L/kg)	Factor for Trophic Level 4 (T4) Fish (L/kg)	Source
Arsenic	BCF	4.00E+00	4.00E+00	Barrows *et al.*, 1980
Cadmium	BCF	2.70E+02	2.70E+02	Kumada *et al.*, 1972
Chromium (VI)	BCF	6.00E-01	6.00E-01	Stephan, 1993
Copper [a]	BCF	3.60E+01	3.60E+01	U.S. EPA, 1980
Lead	BAF	4.60E+01	4.60E+01	Stephan, 1993
Methylmercury	BAF	1.60E+06	6.80E+06	U.S. EPA, 1997a
Nickel [b]	BCF	0.8	0.8	Stephan, 1993
Selenium	BAF	4.90E+02	1.70E+03	Lemly, 1985a
Thallium	BCF	3.40E+01	1.30E+02	Barrows *et al.*, 1980 and Stephan, 1993
Zinc	BCF	3.50E+02	3.50E+02	Murphy *et al.*, 1978

a – BCF not specific to a particular trophic level; applies to fish consumed by humans.
b – Nickel (soluble salts).

Table D-3. NEHC Benchmarks for Mink and Bald Eagles

Pollutant in Wildlife Impact Assessment	NEHC Benchmark Value for Mink (T3 Fish) (μg/g)	NEHC Benchmark Value for Eagle (T4 Fish) (μg/g)	Notes
Arsenic	7.65	22.4	
Cadmium	5.66	14.7	
Chromium (VI)	17.7	26.6	No benchmark for chromium VI. EPA used the total chromium benchmark, which may underestimate the impact to wildlife.
Copper	41.2	40.5	
Lead	34.6	16.3	
Methylmercury	0.37	0.5	No benchmark for methylmercury. EPA used the total mercury benchmark, which may underestimate the impact to wildlife.
Nickel,	12.5	67.1	
Selenium	1.13	4	
Thallium	None identified	None identified	EPA could not complete the analysis for this pollutant – no benchmark for comparison.
Zinc	904	145	

Source: USGS, 2008.

IRW Model: Wildlife Module Methodology Limitations and Assumptions

EPA was required to make assumptions about various inputs, resulting in limitations with respect to the wildlife module output and interpretation. Variability occurs from heterogeneous characteristics, such as body weight differences within a population or the contaminant levels in the environment. Uncertainty represents a lack of knowledge about factors such as the adverse effects from exposure to pollutants. The assumptions and limitations of the wildlife module include the following:

- ***Additive Risks Across Pathways.*** The wildlife module does not consider additive risks across pathways. For example, the modeled impacts to wildlife from ingesting contaminated fish do not consider the risk from direct contact with surface water. The receptors chosen for the wildlife ingestion model, minks and eagles, do not spend large amounts of time in contact with the surface water; therefore, not including the impact of direct contact with surface water should only minimally underestimate the impacts. In addition, the wildlife module does not consider the impact from water ingestion. Because many of the pollutants considered in this analysis are bioaccumulative in nature, the model considers only ingestion of the food source since it is likely the dose from the food source dominates the dose from water ingestion.
- ***Use of BCFs and BAFs***. Where available, EPA used BAFs to represent the accumulation of pollutants in fish tissue *(e.g.,* for selenium and methylmercury). Otherwise, EPA used BCFs, which do not account for accumulation of pollutants via the food web. For certain pollutants, exposure via the aquatic food web can be more significant than exposure via ingestion of water.[2] The result of this limitation on the wildlife module output for those pollutants that use a BCF is an under-representation of pollutant bioaccumulation in fish tissue where exposure via the aquatic food web is significant. However, BCFs are useful in a screening-level assessment and appropriate for a national-level environmental assessment (EA) where site-specific data are not available and collection of site-specific data is not viable. The limitation of using a single, national-level BAF/BCF is unknown due to site-specific considerations.
- ***Receptor Populations Evaluated.*** EPA considered the limitations and made multiple assumptions in choosing receptor populations to evaluate. First, EPA assumed that, because this is a national model, the receptor species and receiving water occur together (*i.e.*, all receiving waters evaluated in the wildlife module are habitat for the receptor species even though that may not always be the case). In addition, due to the scope of the project, EPA considered a limited number of species for use as receptors. For the wildlife receptors, EPA chose minks and eagles due to their national distribution and data available to conduct the analysis [USGS, 2008]. By choosing a limited number of species, the wildlife module inherently excludes the impacts to critical assessment endpoints such as threatened and endangered species. EPA attempts to address this

[2] EPA Office of Water Health and Ecological Criteria Division agrees that all the routes (*e.g.,* food, sediment, and water) by which fish and shellfish are exposed to highly bioaccumulative pollutants may be important in determining the accumulation in fish tissue and the subsequent transfer to human receptors. In addition, EPA agrees that distributions of BAFs/BCFs may be better than single BAFs/BCFs because they account for changes in bioaccumulation/bioconcentration rates at different water concentrations. EPA is working to develop BAF/BCF distributions for several pollutants to better represent the bioaccumulation in aquatic organisms.

limitation in the impact assessment by presenting a proximity analysis of steam electric power plants to habitats of threatened and endangered species (see Section 3.4.5 of this report) and an evaluation of the ecological risk to aquatic organisms and avian receptors from selenium contamination (see Section 5.2 of this report).

- ***Wildlife Receptor Diet***. To provide an environmentally protective estimate of dietary pollutant exposure, the wildlife module assumes that the diet of adult minks and bald eagles consists entirely of fish inhabiting the immediate receiving waters. EPA believes this assumption is reasonable based on the following two factors: 1) It is possible that in some habitats the dietary composition for both minks and eagles consists largely of fish and EPA aims to be protective of wildlife across all habitats. For example, studies have shown dietary composition as high as 75 and 85 percent fish for bald eagles and minks, respectively [U.S. EPA, 1993]. In addition, it is likely that the other organisms consumed by minks and eagles are also contaminated with the pollutants of concern and are unaccounted for in the model; and 2) With respect to home ranges, the case study water quality modeling results (see Section 8) demonstrate that pollutants discharged from steam electric power plants can continue to occur at elevated levels downstream from the immediate receiving waters, contaminating fish outside of immediate receiving waters and resulting in additional potential for pollutant exposure among piscivorous wildlife. Overall, however, this assumption likely results in a potential overestimation of exposure to the modeled species.
- ***Bioavailability and Speciation of Pollutants.*** The IRW model assumes that all forms of a pollutant are equally bioavailable to ecological receptors. Therefore, data inputs for the wildlife module include total pollutant concentration in the water column (*i.e.*, dissolved plus particles sorbed to suspended sediment) or sediment concentration for all pollutants analyzed, except where noted. In addition, some pollutant forms are more toxic to organisms, such as various forms of arsenic. While different forms of arsenic exist in the water column, it is not possible to determine the percentages of each due to the complexities of the chemistry of a particular waterbody. Because of bioavailability and pollutant speciation assumptions made for the wildlife impact assessment, the impact to receptors may be over- or underestimated.
- ***Indirect Ecological Effects.*** The wildlife module does not consider indirect ecological effects, such as depletion of food sources. Such indirect effects are difficult to assess and are thought to have minimal impact on some wildlife species because the impacted receiving water is only a small portion of the species' habitat. In addition, many species will move into other areas in search of prey if food sources in their current habitat decline.
- ***Full Mixing Effects for Receiving Water.*** The water quality module assumes that the receiving waterbody is fully mixed. In reality, the water in lakes might stratify, especially if they are deep enough. Chemical speciation, mostly based on pH, varies by strata; for example, if the hypolimnion (*i.e.*, lowest stratum of a lake) has a much lower pH than the epilimnion (*i.e.*, upper stratum), the concentration or speciation of many pollutants may vary between the two layers. Therefore, bottom-dwelling organisms would be exposed to different species and concentrations of pollutants. Due to the complexity of these relationships and necessity for site-specific data, none of the impact analyses considered stratification of receiving waters. The result of this limitation on the wildlife module outputs is unknown.

- ***Multiple Pollutant Exposures.*** According to EPA's *Steam Electric Power Generating Point Source Category: Final Detailed Study Report* [U.S. EPA, 2009b], receptors will be exposed to multiple constituents simultaneously. However, the wildlife module examines the impact of individual pollutants to receptors and does not take into account how the interaction of multiple pollutants impacts the receptors. For example, EPA did not consider the impact of mercury on the uptake or toxicity of selenium. There is evidence in the literature that these two compounds interact with each other in the environment and may decrease the level of impact of each pollutant on a receptor; conversely, the interaction of other pollutants may increase the impact to a receptor. However, because benchmarks are based on the toxicity of individual chemicals, and the relationships between chemicals are complex, it is beyond the scope of this analysis to include the effects of multiple pollutant interactions on receptors.
- ***Ecological Benchmarks.*** EPA used ecological benchmarks as described above to determine impacts to aquatic organisms from direct contact with contaminated sediment. The benchmarks represent threshold effect levels TELs. If an organism ingests chemical concentration above the TEL, some effect (or response) will be produced. If the concentration ingested is below the TEL, no effect (or response) will occur. The TEL represents the concentration of a chemical that would result in "no effect," therefore the results presented in EA report are a more environmentally protective impact estimate [USGS, 2008].

APPENDIX E
HUMAN HEALTH MODULE METHODOLOGY

This appendix presents the model equations, input variables, benchmarks, and methodology limitations/assumptions for the immediate receiving water (IRW) model human health module. Human health impacts include the following receptor groups:

- Child cohorts (recreational) that consume fish exposed to pollutants as a result of discharges from steam electric power plants.
- Child cohorts (subsistence) that consume fish exposed to pollutants as a result of discharges from steam electric power plants.
- Adult cohorts (recreational) that consume fish exposed to pollutants as a result of discharges from steam electric power plants.
- Adult cohorts (subsistence) that consume fish exposed to pollutants as a result of discharges from steam electric power plants.

In addition to the national-scale cohorts evaluated as part of the environmental assessment (EA), EPA also estimated annual-average daily dose of pollutants for human receptors based on race and Hispanic origin as an environmental justice analysis.

EPA estimated pollutant concentrations in fish tissue using the IRW model wildlife module (see Appendix D). The human health module uses these concentrations as inputs.

Model input requirements for the equations presented in Appendix E can be divided into five major categories: 1) input variable described by another equation; 2) site-specific input variable; 3) model assumption variable; 4) receptor cohort-specific variable; and 5) pollutant-specific variable. The following tables in Appendix E describe the input requirements and data sources used in the human health module:

- Table E-1. Calculation of Consumption Ratio for Trophic Level 3 (F_{T3}) and Trophic Level 4 (F_{T4}) Fish.
- Table E-2. Model Assumption Input Variables for the Human Health Module.
- Table E-3. Receptor Cohort-Specific Input Variables for the Human Health Module.
- Table E-4. Environmental Justice Analysis: Receptor Cohort-Specific Consumption Rate by Race or Hispanic Origin for the Human Health Module.
- Table E-5. Pollutant-Specific Input Variables in the Human Health Module.

IRW Model: Human Health Module Equations

EPA estimated the pollutant concentrations in fish fillets consumed by humans (*i.e.*, dose) using an assumed consumption ratio of T3 and T4 fish and site-specific pollutant concentrations in fish. For each cohort, EPA calculated the average daily dose (ADD) of the pollutant from eating fish and compared this ADD to non-cancer human health benchmarks (*i.e.*, reference doses [RfDs]). The human health module expresses this comparison as a hazard quotient (HQ). An HQ of higher than one (*i.e.*, pollutant dosage exceeds benchmark) indicates a potential non-cancer threat to the human cohort. EPA also calculated a lifetime average daily dose (LADD) and a corresponding lifetime excess cancer risk (LECR) for each cohort. This study used the 1-in-a-million cancer risk benchmark as an acceptable risk threshold when evaluating exposures associated with fish consumption.

EPA used the equations presented below to calculate the pollutant concentration in the fish fillet; the ADD for arsenic, cadmium, chromium (VI), copper, lead, mercury, nickel, selenium, thallium, and zinc; the associated non-cancer threat HQ; and the LADD and LECR values for arsenic.

EQUATION E-1

$$C_{fish\_fillet} = F_{T3} \times C_{fishT3F} + F_{T4} \times C_{fishT4F}$$

Where:

C_{fish_fillet}	=	Average fish fillet concentration ingested by humans (milligrams per kilograms [mg/kg])	Output from Equation E-1
$C_{fishT3F}$	=	Concentration of contaminant in fish at trophic level 3 (mg/kg)	Site-specific wildlife module output Equation D-2 and Equation D-3
$C_{fishT4F}$	=	Concentration of contaminant in fish at trophic level 4 (mg/kg)	Site-specific wildlife module output Equation D-2 and Equation D-3
F_{T3}	=	Fraction of trophic level 3 fish intake (unitless)	Model assumption value of 0.36 (see calculation below)
F_{T4}	=	Fraction of trophic level 4 fish intake (unitless)	Model assumption value of 0.64 (see calculation below)

To determine the fraction of T3 and T4 fish intake for human cohorts, EPA started with the data presented in the 2011 Emissions Factor Handbook, Table 10-74 [U.S. EPA, 2011b]. EPA then completed the following analysis:

1. Assigned trophic levels to fish if not already listed in the table.
2. Totaled the quantities of fish consumed by trophic level.
3. Determined fraction of fish consumed at each trophic level.

Table E-1 documents the data and analysis performed. EPA chose to use the factors for fish intake that corresponded to rivers and streams; this is the most common receiving water source in the IRW model.

Table E-1. Calculation of Consumption Ratio for Trophic Level 3 (F_{T3}) and Trophic Level 4 (F_{T4}) Fish

Species	Trophic Level	Ice Fishing		Lakes and Ponds		Rivers and Streams	
		Count of Fish Consumed	Mass Consumed (kg)	Count of Fish Consumed	Mass Consumed (kg)	Count of Fish Consumed	Mass Consumed (kg)
Landlocked salmon	4	832	290	928	340	305	120
Atlantic salmon	4	3	1.1	33	9.9	17	11
Togue (Lake trout)	4	483	200	459	160	33	2.7
Brook trout	4	1,309	100	3,294	210	10,185	420
Brown trout	4	275	54	375	56	338	23
Yellow perch	3	235	9.1	1,649	52	188	7.4
White perch	3	2,544	160	6,540	380	3,013	180
Bass (Smallmouth and largemouth)	4	474	120	73	5.9	787	130
Pickerel	3	1,091	180	553	91	303	45
Lake whitefish	3	111	20	558	13	55	2.7
Hornpout (Catfish and bullheads)	3	47	8.2	1,291	100	180	7.8
Bottom fish (Suckers, carp and sturgeon)	3	50	81	62	22	100	6.7
Chub	3	0	0	252	35	219	130
Smelt	3	7,808	150	428	4.9	4,269	37
Other	4	201	210	90	110	54	45
TOTALS		**15,463**	**1,583**	**16,587**	**1,590**	**20,046**	**1,168**
Totals by Trophic Level							
	T3 Total	11,886	608	11,333	698	8,327	417
	T4 Total	3376	765.1	5162	781.8	11665	751.7
Calculation of Factors by Trophic Level							
	T3 Factor	0.77	0.38	0.68	0.44	0.42	**0.36**
	T4 Factor	0.22	0.48	0.31	0.49	0.58	**0.64**

Source: U.S. EPA, 2011b.

Bold indicates factors selected for the human health model.

Equation E-2 calculates the ADD, which is the daily intake of the contaminant from fish ingestion. Based on a literature review (including EPA and Agency for Toxic Substances and Disease Registry (ATSDR) references), arsenic in fish is mostly in the organic form and not harmful to humans. The inorganic form of arsenic is harmful to humans; EPA's 1997 document, *Arsenic and Fish Consumption*, reported the inorganic arsenic concentration in fish is between 0.4 – 4 percent of the total arsenic accumulating in fish. EPA estimated the inorganic arsenic concentration in fish by assuming 4 percent of the total arsenic is inorganic. EPA used the inorganic arsenic concentration in fish to determine human health impacts. The human health model multiplies the C_{fish_fillet} concentration by 4 percent for arsenic (converting concentration from total to inorganic).

Equation E-3 calculates the LADD, based on the ADD. Arsenic is the only carcinogenic pollutant included in the EA. The model calculates the LADD of arsenic for each child cohort (six recreational and six subsistence) and for each adult cohort (one recreational and one subsistence). EPA assumed the exposure durations (ED) for use in the LADD calculation are equal to the length of time in that cohort range. EPA selected an exposure frequency of 350 days per year, assuming residents take an average of two weeks of vacation away from their homes each year.

Equation E-4 calculates the non-cancer HQ, based on the ADD.

Equation E-5 calculates the LECR for inorganic arsenic, based on the LADD.

EQUATION E-2

$$ADD = \frac{C_{fish\_fillet} \times CR_{fish} \times F_{fish}}{1{,}000 \times BW}$$

Where:

ADD	=	Daily dose of pollutant from fish ingestion (mg/kg BW/day)	Output from Equation E-2
C_{fish_fillet}	=	Average fish fillet concentration ingested by humans (mg/kg)	Output from Equation E-1
CR_{fish}	=	Consumption rate of fish (g ww/day)	Receptor cohort-specific value (see Table E-3 and Table E-4)
F_{fish}	=	Fraction of fish intake from contaminated source	Model assumption value of 1
1,000	=	Conversion factor (grams per kilograms [g/kg])	Conversion factor
BW	=	Body weight (kg)	Receptor cohort-specific value (see Table E-3)

EQUATION E-3

$$LADD = \frac{ADD \times ED \times EF}{AT \times 365}$$

Where:

LADD	=	Lifetime average daily dose (mg/kg BW/day)	Output from Equation E-3
ADD	=	Daily dose of pollutant from fish ingestion (mg/kg BW/day)	Output from Equation E-2
ED	=	Exposure duration for oral ingestion (yr)	Receptor cohort-specific value (assumed value) (see Table E-3)
EF	=	Exposure frequency (days/yr)	Model assumption value of 350
AT	=	Averaging time (yr)	Model assumption value of 70 [U.S. EPA, 2011b]
365	=	Conversion factor (days/yr)	

EQUATION E-4

$$HQ = \frac{ADD}{RfD}$$

Where:

HQ	=	Hazard quotient	Output from Equation E-4
ADD	=	Daily dose of pollutant from fish ingestion (mg/kg BW/day)	Output from Equation E-2
RfD	=	Non-cancer reference dose (mg/kg BW/day)	Pollutant-specific value (see Table E-5)

EQUATION E-5

$$LECR = LADD \times CSF$$

Where:

LECR	=	Lifetime excess cancer risk	Output from Equation E-5
LADD	=	Lifetime average daily dose (mg/kg BW/d)	Output from Equation E-3
CSF	=	Cancer slope factor $(mg/kg\ BW/day)^{-1}$	Pollutant-specific value (see Table E-5)

IRW Model: Human Health Module Inputs and Benchmarks

Table E-2. Model Assumption Input Variables for the Human Health Module

Input Variable	Description	Assumed Value	Assumption Rationale/Data Source
F_{T3}	Fraction of trophic level 3 fish intake	0.36	U.S. EPA, 2011b
F_{T4}	Fraction of trophic level 4 fish intake	0.64	U.S. EPA, 2011b
F_{fish}	Fraction of fish intake from contaminated source	1	EPA assumed that all fish consumed by the receptor is from the contaminated surface water.
EF	Exposure frequency (days/yr)	350	EPA assumed that the fisher travels away from home for 15 days per year and does not eat fish from contaminated surface water during that period.
AT	Averaging time (yr)	70	U.S. EPA, 2011b

For the EA and benefits analyses,[1] EPA focused on human exposure to contaminated fish for recreational and subsistence fishers. Recreational fishers are non-commercial, non-subsistence fishers and are more vulnerable to pollutant exposure by intake of contaminated fish from a specific waterbody compared to the general population. Subsistence fishers are individuals who consume fresh caught fish as a major food source. Intake rates for subsistence fishers are generally higher than for the general population, and subsistence fishers are more vulnerable to pollutant exposure by intake of contaminated fish from a specific waterbody compared to both recreational fishers and the general population. Because of the focus of human exposure to a subset of the general population that more frequently consume local fish, EPA selected fish consumption rates from studies based on "consumer only" data. Consumer-only fish consumption rates are the average intake rates across only those individuals that consumed fish and shellfish during the survey time period. See the memorandum "Fish Consumption Rates Used in the Environmental Assessment Human Health Module" for further details [ERG, 2015g].

The human health module calculates annual-average daily doses of pollutants for recreational and subsistence fishers and does not calculate the annual-average daily doses of pollutants for the general population. In its benefits analysis (see the Benefits and Cost Analysis), EPA only evaluates impacts to a subset of the population living near the immediate and downstream receiving waters.

The EPA document, *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health* (Table 5-1) determined protective fish intake rates using the following percentiles by fisher type: 1) general population and recreational fisher: 90th percentile of per capita data and 2) subsistence fisher: 99th percentile of per capita data [U.S. EPA, 2000c]. The document does not provide guidance on which percentiles to use for consumer-only fish intake rates. Therefore, EPA used best professional judgment and using the following percentiles by fisher type: 1) recreational fisher: mean of consumer-only data and 2) subsistence fisher: 95th percentile of consumer-only data.

[1] See the *Benefits and Cost Analysis for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generation Point Source Category* (EPA-821-R-15-005) (Benefits and Cost Analysis).

Table E-3. Receptor Cohort-Specific Input Variables for the Human Health Module

Receptor	Cohort [a]	Body Weight (kg) [a]	Consumption Rate (g/kg-day) [b]	Consumption Rate (g/day) [b]	Exposure Duration (years)
Child Recreational Fisher	1 to <2 years	11.4	1.60	18.2	1
	2 to <3 years	13.8	1.60	22.1	1
	3 to <6 years	18.6	1.30	24.2	3
	6 to <11 years	31.8	1.10	35.0	5
	11 to <16 years	56.8	0.660	37.5	5
	16 to <21 years	71.6	0.660	47.3	5
Child Subsistence Fisher	1 to <2 years	11.4	4.90	55.9	1
	2 to <3 years	13.8	4.90	67.6	1
	3 to <6 years	18.6	3.60	67.0	3
	6 to <11 years	31.8	2.90	92.2	5
	11 to <16 years	56.8	1.70	96.6	5
	16 to <21 years	71.6	1.70	121.7	5
Adult Recreational Fisher [c]		80	0.665	53.2	49
Adult Subsistence Fisher [c]		80	2.05	164	49

Sources: U.S. EPA, 2008a; U.S. EPA, 2011b.

Acronyms: g/day (grams per day); g/kg-day (grams per kilogram body weight per day); kg (kilograms).

a – The child cohort age ranges correspond to the ranges provided in the 2008 *Child-Specific Exposure Factor Handbook (EFH)* for body weights [U.S. EPA, 2008a].

b – EPA determined consumption rates for child cohorts using data from Table 10-1 (Recommend Per Capita and Consumer-Only Values for Fish Intake) for finfish consumption [U.S. EPA, 2011b]. EPA used consumer-only fish consumption rates: mean values for recreational fishers and 95th percentile values for subsistence fishers. EPA converted the listed consumption rate (g/kg-day) to g/day by multiplying by mean body weight for each cohort as listed in U.S. EPA, 2008b [ERG, 2015g]. Fish intake rates provided in the reference [U.S. EPA, 2011b] are recommended for the consumer-only population; the selection of consumption rates for exposure assessment purposes may vary depending on the exposure scenarios being evaluated.

c – Table 10-1[U.S. EPA, 2011b] presented multiple adult groups. EPA used the average fish consumption rate for age groups “21 to <50 years” and “50+ years” to calculate a single adult cohort fish consumption rate.

Table E-4. Environmental Justice Analysis: Receptor Cohort-Specific Input Consumption Rate by Race or Hispanic Origin for the Human Health Module

Receptor	Race or Hispanic Origin	CR_{fish}, g/kg-day (All ages) [a]	Consumption Rate (CR_{fish}), g/day, by Cohort [b]						
			1 to <2 years	2 to <3 years	3 to <6 years	6 to <11 years	11 to <16 years	16 to <21 years	Adult
Recreational	Non-Hispanic White	0.67	7.64	9.25	12.5	21.3	38.1	48	53.6
	Non-Hispanic Black	0.77	8.78	10.6	14.3	24.5	43.7	55.1	61.6
	Mexican-American	0.93	10.6	12.8	17.3	29.6	52.8	66.6	74.4
	Other Hispanic	0.82	9.35	11.3	15.3	26.1	46.6	58.7	65.6
	Other, including Multiple Races	0.96	10.9	13.2	17.9	30.5	54.5	68.7	76.8
Subsistence	Non-Hispanic White	1.9	21.7	26.2	35.3	60.4	108	136	152
	Non-Hispanic Black	2.1	23.9	29.0	39.1	66.8	119	150	168
	Mexican-American	2.8	31.9	38.6	52.1	89.0	159	200	224
	Other Hispanic [c]	2.7	30.8	37.3	50.2	85.9	153	193	216
	Other, including Multiple Races [c]	3.6	41.0	49.7	67.0	114	204	258	288

Source: U.S. EPA, 2011b.

Acronyms: CR_{fish} (consumption rate); g/day (grams per day); g/kg-day (grams per kilogram body weight per day)

a – For recreational fishers, EPA used the mean, consumer-only fish consumption rate for finfish (excludes shellfish). For subsistence fishers, EPA used the 95th percentile, consumer-only fish consumption rate for finfish (excludes shellfish). See Table 10-8 of U.S. EPA, 2011b.

b – Consumption rates provided as single value by race and Hispanic origin (as g/kg-day). EPA multiplied these values by cohort-specific body weights, as listed in Table E-3, to calculate a cohort-specific consumption rate in g/day. Numbers presented as three significant digits.

c – Consumption rates for this race or Hispanic origin are less statistically reliable due to the comparatively smaller data set.

Table E-5. Pollutant-Specific Benchmarks for the Human Health Module

Pollutant in Human Health Impact Assessment	RfD (mg/kg-day)	CSF (mg/kg-day) $^{-1}$	Notes [a]
Arsenic, inorganic	3.00E-04	1.50E+00	RfD and CSF for drinking water ingestion
Cadmium, total	1.00E-03		RfD for food consumption
Chromium (VI)	3.00E-03		RfD for drinking water ingestion
Copper	1.00E-02		Used the intermediate oral minimal risk level (MRL) as the reference dose [ATSDR, 2010a]
Lead, total	None available		
Methylmercury	1.00E-04		RfD for fish consumption only
Nickel, total	2.00E-02		RfD for soluble salts; used for food consumption
Selenium, total	5.00E-03		RfD for food consumption
Thallium, total	1.00E-05		Used value cited in U.S. EPA, 2010a for thallium chloride as the reference dose; used for chronic oral exposure
Zinc, total	3.00E-01		RfD for food consumption

Acronyms: mg/kg-day (milligrams per kilogram body weight per day)

a – References include ATSDR, 2010a for copper; U.S. EPA, 2010a for thallium, and U.S. EPA, 2011c for all other pollutants.

IRW Model: Human Health Module Limitations and Assumptions

The human health module limitations and assumptions include the following:

- ***Additive Risks Across Pathways.*** The human health module does not consider additive risks across pathways. For example, the module assumes that the human population consuming the fish is not also ingesting contaminated drinking water. Exposures from fish consumption and drinking water are likely to occur over different time frames (because of ground water travel) and may involve different receptors (*e.g.*, a resident near a receiving water exposed to ground water contamination may not be a recreational fisher). Similarly, the module assumes that these populations are not coming in direct contact with contaminated surface water or sediment through recreation. Based on these assumptions, the model may underestimate total risk to human health from combustion wastewater.
- ***Bioavailability and Speciation of Pollutants.*** The assumptions listed for the wildlife module in Appendix D apply to pollutant concentrations modeled in fish and therefore affect the human health impact assessment.
- ***Full Mixing Effects for Receiving Water.*** The assumptions listed for the wildlife module in Appendix D apply to pollutant concentrations modeled in fish and therefore affect the human health impact assessment.
- ***Multiple Pollutant Exposures.*** According to previous analyses and literature reviewed [U.S. EPA, 2009b], people who ingest fish from impacted waters will be exposed to

multiple pollutants from the wastestreams evaluated. However, the module evaluates each pollutant individually. Such an approach does not account for interactive effects that might be associated with exposures to mixtures. For example, some pollutants may have a higher risk when consumed together because of their interaction, whereas other pollutants may have less impact on human health when consumed together. Due to the complexity of these interactions and because benchmarks are based on the toxicity of individual pollutants, it is not possible to examine these synergistic effects in this analysis. Based on this limitation, risks of pollutants may be over- or underestimated.

- ***Sources of Consumed Fish***. The human health module assumes that all of the fish consumed by recreational and subsistence fishers is caught from the immediate receiving water, except during a two-week time period once per year. This assumption potentially overestimates the annual-average daily dose of the pollutants for these receptors, particularly for recreational fishers. The proportion of fish eaten by an individual from local surface waters will vary (*e.g.*, consumption rate estimates in studies might include seafood purchased from a grocery store and not locally caught).[2]
- ***Human Exposure Factors.*** Individual exposure factors, such as ingestion rate, body weight, and exposure duration, are variable due to the physical characteristics, activities, and behavior of the individual. EPA used the most current data regarding exposure assumptions, and these values represent EPA's current guidance on exposure data [U.S. EPA, 2008a; U.S. EPA, 2011b].
- ***Human Health Benchmarks.*** Uncertainties generally associated with human health benchmarks are discussed in detail in EPA's *Guidelines for Carcinogen Risk Assessment* [U.S. EPA, 2005c] and Integrated Risk Information System (IRIS) [U.S. EPA, 2011c]. IRIS defines the RfD as "an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable threat of deleterious effects during a lifetime." RfDs are typically based on an assumption of lifetime exposure and may not be appropriate when applied to less-than-lifetime exposure situations [U.S. EPA, 2011c]. The cancer slope factor is an estimate of the human cancer risk per milligram of chemical per kilogram body weight per day. To calculate the LADD used for the cancer risk assessment, EPA used the time in the cohort group (*i.e.*, 1, 3, or 5 years depending on child cohort and 49 years for adult cohort) as the ED. The ED is the length of time exposure occurs at the concentration. This analysis may over- or under-estimate the cancer risk if exposure is shorter than or longer than the ED, respectively. LADDs are appropriate when developing screening-level estimates; however, EPA recommends calculating that risk by integrating exposures or risks through all life stages (*e.g.*, chronic exposure for a child may occur across cohorts) [U.S. EPA, 2011b].

[2] For the benefits analysis, EPA further defined the affected population (*i.e.*, individuals potentially exposed to steam electric power plant pollutants via consumption of contaminated fish) as recreational and subsistence fishers who fish reaches that are affected by steam electric power plant discharges (including immediate receiving waters and downstream reaches), as well as their household members. EPA estimated the number of people who are likely to fish affected reaches based on typical travel distances to a fishing site, presence of substitute fishing locations, data on the locations and status of fish consumption advisories for affected reaches, and information on anglers' awareness and adherence to those advisories. See the Benefits and Cost Analysis.

APPENDIX F
OVERVIEW OF ECOLOGICAL RISK MODELING SETUP AND OUTPUTS

This appendix summarizes the inputs, outputs, and methodology limitations/assumptions for the ecological risk modeling that EPA used to evaluate reproductive risks associated with dietary exposure to selenium. EPA performed ecological risk modeling for two sets of water quality outputs:

- Dissolved selenium concentrations in the immediate receiving waters of all modeled steam electric power plants, based on the outputs from the water quality module of the national-scale immediate receiving water (IRW) model (see Appendix C).
- Dissolved selenium concentrations in the immediate receiving water and downstream reaches of Black Creek, Mississippi, based on the outputs from the Black Creek case study water quality model (see Appendix G).

Model input requirements for the ecological risk model can be divided into four major categories: 1) dissolved selenium concentrations; 2) site-specific enrichment factors (EFs), which represent the ratio of the concentration of selenium at the base of the food web (*i.e.*, particulates) to the dissolved concentration in water; 3) species-specific trophic transfer factors (TTFs), which describe subsequent bioaccumulation by higher trophic-level aquatic organisms such as fish and birds; and 4) exposure-response (ER) functions, which translate the modeled selenium concentrations in fish and birds into the associated reduction in reproductive success.

The ecological risk modeling methodology is described in Section 5.2 of the EA report. This modeling approach is consistent with the approach taken in developing the Draft Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater [U.S. EPA, 2014f] (referred to as the draft selenium criterion) and is based on the same data sets and studies for EF, TTF_{invert}, TTF_{fish}, and ER_{fish}. For this EA, EPA expanded the model to include data sets for $TTF_{mallard}$ and $ER_{mallard}$.

The following sections describe these inputs and their sources; summarize the ecological risk modeling results; and discuss the limitations and assumptions associated with this modeling.

Dissolved Selenium Concentrations

As described above, the dissolved selenium concentrations for the national-scale and case study ecological risk models are derived from the IRW water quality module and the Black Creek case study water quality model, respectively. Dissolved selenium concentrations used in the national-scale ecological risk model are provided in DCN SE04612.[1] Dissolved selenium concentrations used in the case study ecological risk model are provided in DCN SE04615. Prior to use as inputs for the Black Creek case study ecological risk model, EPA calculated three-month rolling averages of the dissolved selenium concentration output from the Black Creek case study water quality model. This resulted in one average concentration for each calendar month

[1] EPA removed identifying information, such as the immediate receiving water name and the steam electric power plant name, from this reference to prevent disclosure of confidential business information (CBI).

throughout the entire modeling period after the assumed compliance date for the Morrow Generating Site (2019-2036). Use of a three-month rolling average avoided the calculation of significantly elevated reproductive risks in response to short-term (*e.g.*, daily or weekly) fluctuations in the dissolved selenium concentration.

Enrichment Factors

As discussed in Section 5.2 of the EA report, the EFs used in the ecological risk modeling effort are consistent with those used in developing the draft selenium criterion [U.S. EPA, 2014f]. This effort produced EF distributions for lentic systems (*e.g.*, lakes, reservoirs, and ponds) and lotic systems (*e.g.*, rivers, creeks, and streams). These distributions are well described by lognormal distributions with means (standard deviations) of 1,738 (2,499)[2] for lentic systems and 692 (787) for lotic systems. These EF distributions are illustrated in Figure F-1 and Figure F-2.

Trophic Transfer Factors

As discussed in Section 5.2 of the EA report, the TTFs used to represent selenium bioaccumulation in invertebrates and fish in the national-scale ecological risk model are also consistent with those used in developing the draft selenium criterion [U.S. EPA, 2014f]. This resulted in a TTF_{invert} distribution with a mean (standard deviation) of 2.84 (2.49)[3] and a TTF_{fish} distribution with a mean (standard deviation) of 1.6 (1.08). These TTF distributions are illustrated in Figure F-1.

Based on a review of Ohlendorf [2003], EPA developed a TTF distribution for mallards. The resulting $TTF_{mallard}$ distribution is best described by a triangular distribution, with a likeliest value of 2.5, a minimum value of 0.4, and a maximum value of 4.1. This TTF distribution is illustrated in Figure F-1.

For the Black Creek case study ecological risk model, EPA refined the TTF_{invert} and TTF_{fish} datasets to include only invertebrate and fish species that are representative of those collected during surveys of Black Creek and other nearby rivers and streams as part of EPA's National Aquatic Resource Survey (NARS). This resulted in smaller distributions that are more likely to reflect bioaccumulation patterns within the species that actually inhabit Black Creek. These TTF distributions are illustrated in Figure F-2.

Exposure Response Functions

To estimate the risk of negative reproductive effects among fish, EPA used the same extensively peer-reviewed ER function (*i.e.*, curve) as was used in the draft selenium criterion [U.S. EPA, 2014f]. This ER function is illustrated in Figure F-3.

[2] The EF for a given waterbody is the ratio of the concentration of selenium at the base of the food web (*i.e.*, particulates) to the dissolved concentration in water, multiplied by 1,000. A mean EF of 1,738 for lentic systems indicates that, on average, the concentration of selenium at the base of the food web is 1.738 times greater than the dissolved concentration in water.

[3] The TTF for a given trophic level is the ratio of the concentration in the organism to the concentration in the consumed material or lower-trophic-level organism. A mean TTF of 2.84 for invertebrates indicates that, on average, the concentration of selenium in the tissues of invertebrates is 2.84 times greater than the concentration in particulates consumed by invertebrates.

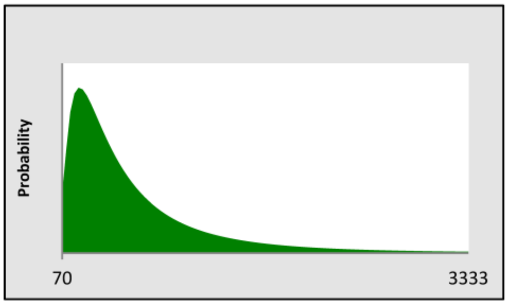
To develop the ER function for mallards, EPA fit a logistic curve to the combined, control normalized data from six different laboratory studies that evaluated the effect of selenium on mallard egg hatchability [Heinz *et al.*, 1987, 1989; Heinz and Hoffman, 1996, 1998; Stanley *et al.*, 1994, 1996]. This ER function is illustrated in Figure F-4.

Lotic EF Distribution

Lognormal distribution with parameters:

Location	33.00
Mean	692.00
Std. Dev.	787.00

Selected range is from 70.00 to 3,333.00

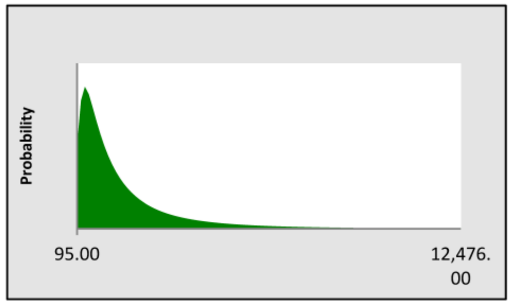


Lentic EF Distribution

Lognormal distribution with parameters:

Location	21.00
Mean	1,738.00
Std. Dev.	2,499.00

Selected range is from 95.00 to 12,476.00

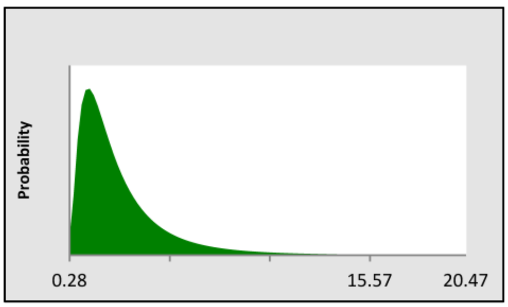


Invertebrate TTF (TTF_{invert}) Distribution

Lognormal distribution with parameters:

Location	0.12
Mean	2.84
Std. Dev.	2.49

Selected range is from 0.13 to 20.47

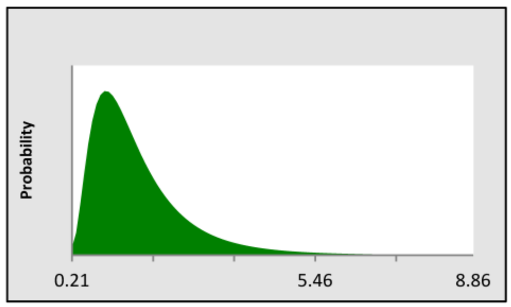


Fish TTF (TTF_{fish}) Distribution

Lognormal distribution with parameters:

Location	0.04
Mean	1.63
Std. Dev.	1.08

Selected range is from 0.08 to 58.00



Mallard TTF ($TTF_{mallard}$) Distribution

Triangular distribution with parameters:

Minimum	0.36
Likeliest	2.50
Maximum	4.10

Selected range is from 0.36 to 4.10

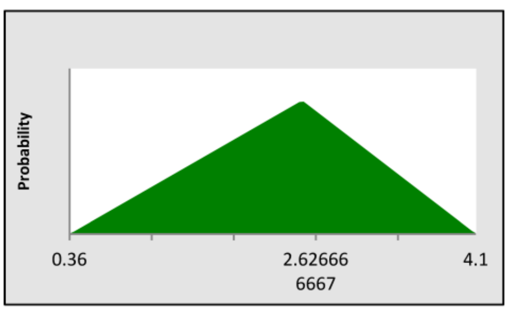


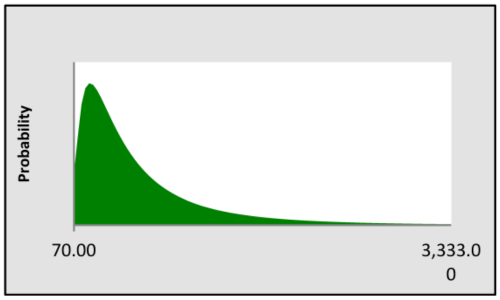
Figure F-1. Input EF and TTF Distributions for National-Scale Ecological Risk Model – Baseline and Final Rule (Option D)

Lotic EF Distribution

Lognormal distribution with parameters:

Location	33.00
Mean	692.00
Std. Dev.	787.00

Selected range is from 70.00 to 3,333.00

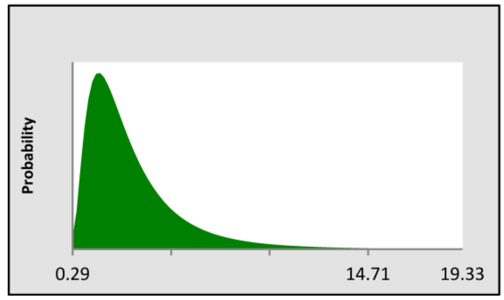


Invertebrate TTF (TTF_{invert}) Distribution

Lognormal distribution with parameters:

Location	0.05
Mean	3.21
Std. Dev.	2.52

Selected range is from 0.24 to 19.33

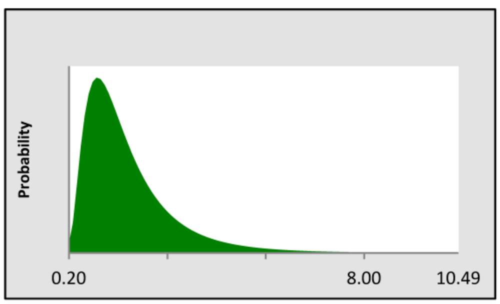


Fish TTF (TTF_{fish}) Distribution

Lognormal distribution with parameters:

Location	0.04
Mean	1.76
Std. Dev.	1.25

Selected range is from 0.13 to 58.00

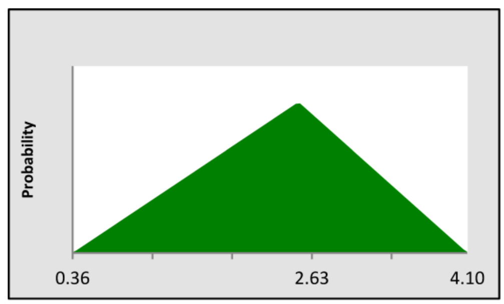


Mallard TTF ($TTF_{mallard}$) Distribution

Triangular distribution with parameters:

Minimum	0.36
Likeliest	2.50
Maximum	4.10

Selected range is from 0.36 to 4.10

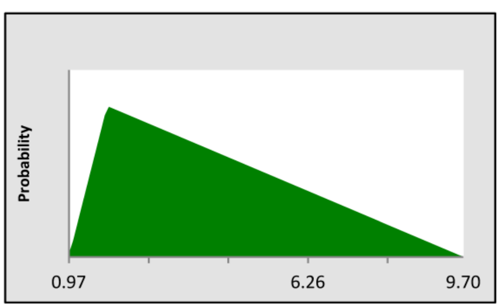


Dissolved Selenium (ug/L) Distribution - Baseline

Triangular distribution with parameters:

Minimum	0.97
Likeliest	1.82
Maximum	9.70

Selected range is from 0.97 to 9.70



Dissolved Selenium (ug/L) Distribution - Final Rule

Triangular distribution with parameters:

Minimum	0.01
Likeliest	0.05
Maximum	0.28

Selected range is from 0.01 to 0.28

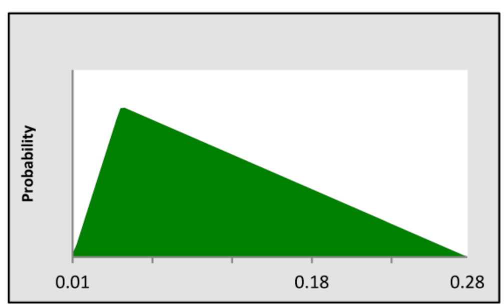


Figure F-2. Input EF, TTF, and Dissolved Selenium Distributions for Morrow Generating Site Immediate Receiving Water (Black Creek Case Study) Ecological Risk Model – Baseline and Final Rule (Option D)

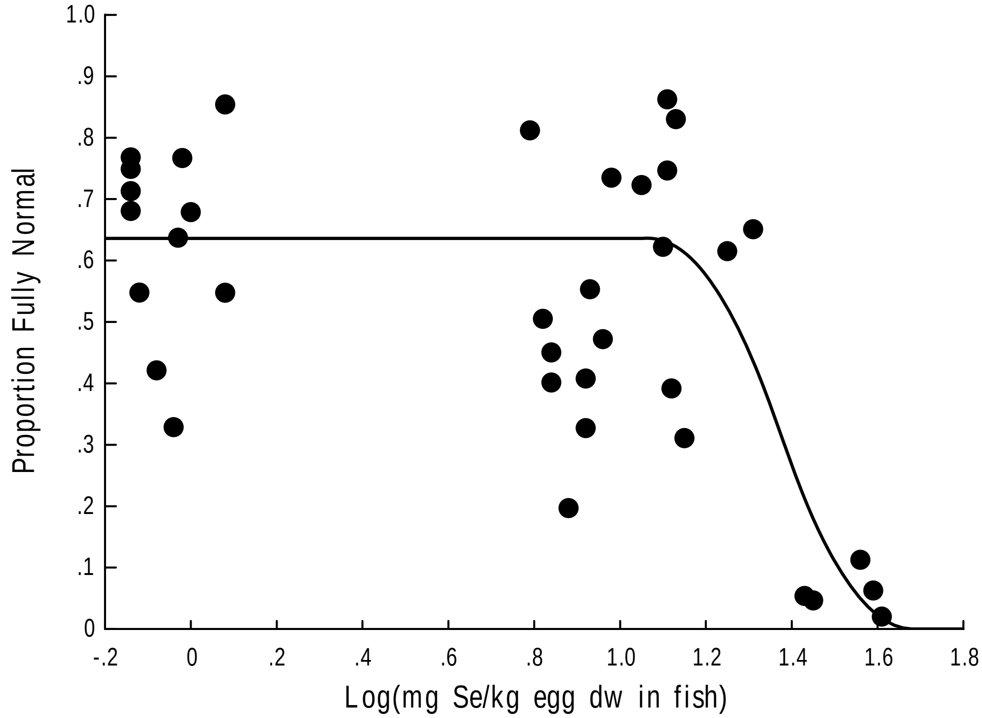


Figure F-3. Exposure-Response Function for Fish Reproductive Success

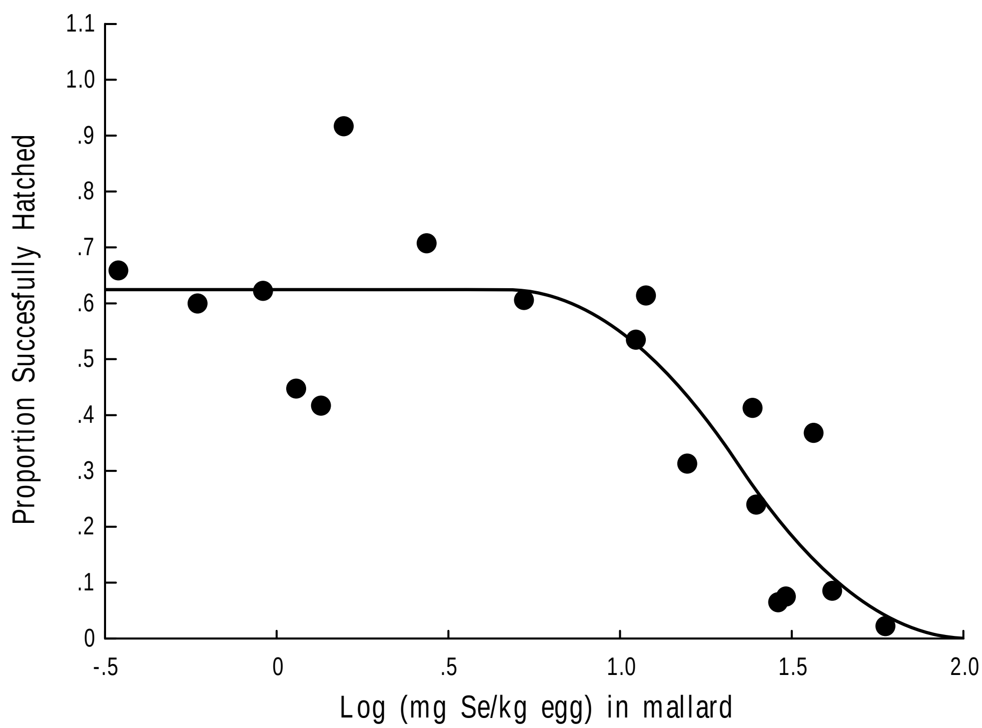


Figure F-4. Exposure-Response Function for Mallard Egg Hatchability

Ecological Risk Model Outputs

Table F-1 and Table F-2 summarize the results of the national-scale ecological risk model for fish under baseline conditions and the final rule, respectively.

Table F-3 and Table F-4 summarize the results of the national-scale ecological risk model for mallards under baseline conditions and the final rule, respectively.

Table F-5 and Table F-6 summarize the results of the case study ecological risk model for birds and mallards, respectively, under baseline conditions. Under the final rule, none of the modeled stream segments resulted in a modeled risk of greater than 0.1 percent for either fish or mallards.

Table F-1. Number (and Percentage) of Receiving Waters in National-Scale Ecological Risk Model with Selenium-Driven Reproductive Effects in Fish – Baseline

Percentile [a]	Lake [b]	River [b]	Total [b]
1 Percent of Fish Population Experiencing Negative Reproductive Effects			
10th:	0 (0%)	14 (7.7%)	14 (6.7%)
25th:	2 (7.7%)	17 (9.3%)	19 (9.1%)
Median:	4 (15%)	24 (13%)	28 (13%)
75th:	6 (23%)	32 (17%)	38 (18%)
90th:	8 (31%)	36 (20%)	44 (21%)
95th:	8 (31%)	42 (23%)	50 (24%)
10 Percent of Fish Population Experiencing Negative Reproductive Effects			
10th:	0 (0%)	12 (6.6%)	12 (5.7%)
25th:	1 (3.8%)	14 (7.7%)	15 (7.2%)
Median:	4 (15%)	20 (11%)	24 (11%)
75th:	6 (23%)	29 (16%)	35 (17%)
90th:	7 (27%)	35 (19%)	42 (20%)
95th:	8 (31%)	39 (21%)	47 (22%)
50 Percent of Fish Population Experiencing Negative Reproductive Effects			
10th:	0 (0%)	10 (5.5%)	10 (4.8%)
25th:	0 (0%)	14 (7.7%)	14 (6.7%)
Median:	3 (12%)	17 (9.3%)	20 (9.6%)
75th:	5 (19%)	27 (15%)	32 (15%)
90th:	6 (23%)	34 (19%)	40 (19%)
95th:	8 (31%)	35 (19%)	43 (21%)
75 Percent of Fish Population Experiencing Negative Reproductive Effects			
10th:	0 (0%)	10 (5.5%)	10 (4.8%)
25th:	0 (0%)	14 (7.7%)	14 (6.7%)
Median:	3 (12%)	17 (9.3%)	20 (9.6%)
75th:	5 (19%)	26 (14%)	31 (15%)
90th:	6 (23%)	31 (17%)	37 (18%)
95th:	7 (27%)	34 (19%)	41 (20%)
90 Percent of Fish Population Experiencing Negative Reproductive Effects			
10th:	0 (0%)	9 (4.9%)	9 (4.3%)
25th:	0 (0%)	13 (7.1%)	13 (6.2%)
Median:	2 (7.7%)	17 (9.3%)	19 (9.1%)
75th:	5 (19%)	22 (12%)	27 (13%)
90th:	6 (23%)	29 (16%)	35 (17%)
95th:	6 (23%)	34 (19%)	40 (19%)

Notes:

a – Percentile refers to the risk percentile. For example, values in the 90th percentile row indicate the numbers of receiving waters whose selenium concentrations are high enough to result in a 10 percent probability of the indicated reproductive effect.

b – The national-scale ecological risk model encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

Table F-2. Number (and Percentage) of Receiving Waters in National-Scale Ecological Risk Model with Selenium-Driven Reproductive Effects in Fish – Final Rule (Option D)

Percentile [a]	Lake [b]	River [b]	Total [b]
1 Percent of Fish Population Experiencing Negative Reproductive Effects			
10th:	0 (0%)	3 (1.6%)	3 (1.4%)
25th:	0 (0%)	5 (2.7%)	5 (2.4%)
Median:	0 (0%)	11 (6%)	11 (5.3%)
75th:	0 (0%)	16 (8.7%)	16 (7.7%)
90th:	1 (3.8%)	21 (11%)	22 (11%)
95th:	1 (3.8%)	25 (14%)	26 (12%)
10 Percent of Fish Population Experiencing Negative Reproductive Effects			
10th:	0 (0%)	3 (1.6%)	3 (1.4%)
25th:	0 (0%)	3 (1.6%)	3 (1.4%)
Median:	0 (0%)	8 (4.4%)	8 (3.8%)
75th:	0 (0%)	15 (8.2%)	15 (7.2%)
90th:	0 (0%)	19 (10%)	19 (9.1%)
95th:	1 (3.8%)	23 (13%)	24 (11%)
50 Percent of Fish Population Experiencing Negative Reproductive Effects			
10th:	0 (0%)	3 (1.6%)	3 (1.4%)
25th:	0 (0%)	3 (1.6%)	3 (1.4%)
Median:	0 (0%)	6 (3.3%)	6 (2.9%)
75th:	0 (0%)	12 (6.6%)	12 (5.7%)
90th:	0 (0%)	19 (10%)	19 (9.1%)
95th:	0 (0%)	20 (11%)	20 (9.6%)
75 Percent of Fish Population Experiencing Negative Reproductive Effects			
10th:	0 (0%)	2 (1.1%)	2 (0.96%)
25th:	0 (0%)	3 (1.6%)	3 (1.4%)
Median:	0 (0%)	5 (2.7%)	5 (2.4%)
75th:	0 (0%)	9 (4.9%)	9 (4.3%)
90th:	0 (0%)	15 (8.2%)	15 (7.2%)
95th:	0 (0%)	19 (10%)	19 (9.1%)
90 Percent of Fish Population Experiencing Negative Reproductive Effects			
10th:	0 (0%)	2 (1.1%)	2 (0.96%)
25th:	0 (0%)	3 (1.6%)	3 (1.4%)
Median:	0 (0%)	4 (2.2%)	4 (1.9%)
75th:	0 (0%)	9 (4.9%)	9 (4.3%)
90th:	0 (0%)	15 (8.2%)	15 (7.2%)
95th:	0 (0%)	19 (10%)	19 (9.1%)

Notes:

a – Percentile refers to the risk percentile. For example, values in the 90th percentile row indicate the numbers of receiving waters whose selenium concentrations are high enough to result in a 10 percent probability of the indicated reproductive effect.

b – The national-scale ecological risk model encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

Table F-3. Number (and Percentage) of Receiving Waters in National-Scale Ecological Risk Model with Selenium-Driven Reproductive Effects in Mallards – Baseline

Percentile [a]	Lake [b]	River [b]	Total [b]
1 Percent of Mallard Population Experiencing Hatching Failure			
10th:	3 (12%)	18 (9.8%)	21 (10%)
25th:	5 (19%)	26 (14%)	31 (15%)
Median:	6 (23%)	34 (19%)	40 (19%)
75th:	8 (31%)	38 (21%)	46 (22%)
90th:	9 (35%)	47 (26%)	56 (27%)
95th:	13 (50%)	52 (28%)	65 (31%)
10 Percent of Mallard Population Experiencing Hatching Failure			
10th:	0 (0%)	14 (7.7%)	14 (6.7%)
25th:	3 (12%)	17 (9.3%)	20 (9.6%)
Median:	5 (19%)	26 (14%)	31 (15%)
75th:	6 (23%)	32 (17%)	38 (18%)
90th:	8 (31%)	36 (20%)	44 (21%)
95th:	8 (31%)	42 (23%)	50 (24%)
50 Percent of Mallard Population Experiencing Hatching Failure			
10th:	0 (0%)	10 (5.5%)	10 (4.8%)
25th:	0 (0%)	13 (7.1%)	13 (6.2%)
Median:	2 (7.7%)	17 (9.3%)	19 (9.1%)
75th:	4 (15%)	22 (12%)	26 (12%)
90th:	6 (23%)	28 (15%)	34 (16%)
95th:	6 (23%)	34 (19%)	40 (19%)
75 Percent of Mallard Population Experiencing Hatching Failure			
10th:	0 (0%)	7 (3.8%)	7 (3.3%)
25th:	0 (0%)	10 (5.5%)	10 (4.8%)
Median:	0 (0%)	14 (7.7%)	14 (6.7%)
75th:	3 (12%)	17 (9.3%)	20 (9.6%)
90th:	5 (19%)	22 (12%)	27 (13%)
95th:	6 (23%)	27 (15%)	33 (16%)
90 Percent of Mallard Population Experiencing Hatching Failure			
10th:	0 (0%)	3 (1.6%)	3 (1.4%)
25th:	0 (0%)	8 (4.4%)	8 (3.8%)
Median:	0 (0%)	12 (6.6%)	12 (5.7%)
75th:	1 (3.8%)	14 (7.7%)	15 (7.2%)
90th:	4 (15%)	18 (9.8%)	22 (11%)
95th:	5 (19%)	22 (12%)	27 (13%)

Notes:

a – Percentile refers to the risk percentile. For example, values in the 90th percentile row indicate the numbers of receiving waters whose selenium concentrations are high enough to result in a 10 percent probability of the indicated reproductive effect.

b – The national-scale ecological risk model encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

Table F-4. Number (and Percentage) of Receiving Waters in National-Scale Ecological Risk Model with Selenium-Driven Reproductive Effects in Mallards – Final Rule (Option D)

Percentile [a]	Lake [b]	River [b]	Total [b]
1 Percent of Mallard Population Experiencing Hatching Failure			
10th:	0 (0%)	7 (3.8%)	7 (3.3%)
25th:	0 (0%)	12 (6.6%)	12 (5.7%)
Median:	0 (0%)	19 (10%)	19 (9.1%)
75th:	0 (0%)	23 (13%)	23 (11%)
90th:	0 (0%)	26 (14%)	26 (12%)
95th:	2 (7.7%)	26 (14%)	28 (13%)
10 Percent of Mallard Population Experiencing Hatching Failure			
10th:	0 (0%)	3 (1.6%)	3 (1.4%)
25th:	0 (0%)	6 (3.3%)	6 (2.9%)
Median:	0 (0%)	12 (6.6%)	12 (5.7%)
75th:	0 (0%)	17 (9.3%)	17 (8.1%)
90th:	0 (0%)	21 (11%)	21 (10%)
95th:	0 (0%)	25 (14%)	25 (12%)
50 Percent of Mallard Population Experiencing Hatching Failure			
10th:	0 (0%)	3 (1.6%)	3 (1.4%)
25th:	0 (0%)	3 (1.6%)	3 (1.4%)
Median:	0 (0%)	5 (2.7%)	5 (2.4%)
75th:	0 (0%)	9 (4.9%)	9 (4.3%)
90th:	0 (0%)	14 (7.7%)	14 (6.7%)
95th:	0 (0%)	18 (9.8%)	18 (8.6%)
75 Percent of Mallard Population Experiencing Hatching Failure			
10th:	0 (0%)	2 (1.1%)	2 (0.96%)
25th:	0 (0%)	3 (1.6%)	3 (1.4%)
Median:	0 (0%)	3 (1.6%)	3 (1.4%)
75th:	0 (0%)	6 (3.3%)	6 (2.9%)
90th:	0 (0%)	9 (4.9%)	9 (4.3%)
95th:	0 (0%)	13 (7.1%)	13 (6.2%)
90 Percent of Mallard Population Experiencing Hatching Failure			
10th:	0 (0%)	1 (0.55%)	1 (0.48%)
25th:	0 (0%)	2 (1.1%)	2 (0.96%)
Median:	0 (0%)	3 (1.6%)	3 (1.4%)
75th:	0 (0%)	3 (1.6%)	3 (1.4%)
90th:	0 (0%)	6 (3.3%)	6 (2.9%)
95th:	0 (0%)	9 (4.9%)	9 (4.3%)

Notes:

a – Percentile refers to the risk percentile. For example, values in the 90th percentile row indicate the numbers of receiving waters whose selenium concentrations are high enough to result in a 10 percent probability of the indicated reproductive effect.

b – The national-scale ecological risk model encompasses a total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) and loadings from 188 steam electric power plants.

Table F-5. Risk of Selenium-Driven Reproductive Effects in Fish Downstream from Morrow Generating Site Immediate Receiving Water (Black Creek Case Study) – Baseline

	Black Creek WASP Model Segment ID [b,c]												
Percentile [a]	**39**	**38**	**37**	**36**	**35**	**34**	**33**	**32**	**31**	**30**	**29**	**28**	**27**
10th:	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
25th:	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
Median:	0.381%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
75th:	83.0%	17.8%	18.9%	8.00%	6.25%	3.46%	5.70%	8.80%	<0.1%	<0.1%	<0.1%	1.62%	1.46%
90th:	>99.9%	98.7%	98.3%	94.6%	93.4%	87.7%	95.2%	94.4%	40.8%	36.3%	20.5%	82.6%	79.6%
95th:	>99.9%	>99.9%	>99.9%	>99.9%	>99.9%	99.8%	>99.9%	>99.9%	94.2%	92.8%	80.6%	99.7%	99.6%
	26	**25**	**24**	**23**	**22**	**21**	**20**	**19**	**18**	**17**	**16**	**15**	**14**
10th:	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
25th:	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
Median:	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
75th:	1.11%	0.226%	2.42%	2.39%	2.14%	1.82%	1.81%	2.41%	0.723%	0.330%	0.345%	0.331%	0.323%
90th:	80.9%	57.1%	86.5%	87.8%	83.9%	80.1%	81.0%	84.1%	73.4%	66.5%	64.6%	60.3%	58.4%
95th:	99.7%	97.8%	99.8%	99.7%	99.7%	99.5%	99.6%	99.7%	99.1%	98.9%	98.7%	97.9%	97.7%
	13	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
10th:	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
25th:	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
Median:	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
75th:	0.237%	0.273%	0.266%	0.993%	0.509%	0.303%	0.312%	0.273%	0.313%	0.375%	0.375%	0.292%	0.421%
90th:	57.9%	60.3%	59.2%	72.3%	66.7%	59.1%	59.7%	56.3%	58.4%	63.1%	63.1%	59.5%	59.5%
95th:	97.6%	98.5%	97.9%	98.9%	97.8%	97.5%	97.8%	97.8%	97.4%	98.4%	98.4%	97.9%	98.3%

Note: Percentages are rounded to three significant figures.

a – Percentile refers to the risk percentile. For example, based on the values in the 75th percentile row for Segment 39, there is a 25 percent probability that selenium concentrations in fish eggs/ovaries are high enough to cause negative reproductive effects in 83 percent of the exposed fish population inhabiting that segment of Black Creek.

b – Segment 39 is the immediate receiving water for Morrow Generating Site. Segment 1 is farthest downstream from the immediate receiving water. The 39 segments comprise a total of 95 miles of Black Creek.

c – >0 to 5 percent risk; 5 to 35 percent risk; 35 to 65 percent risk; 65 to 95 percent risk; >95 percent risk.

Table F-6. Risk of Selenium-Driven Reproductive Effects in Mallards Downstream from Morrow Generating Site Immediate Receiving Water (Black Creek Case Study) – Baseline

	Black Creek WASP Model Segment ID [b,c]												
Percentile [a]	**39**	**38**	**37**	**36**	**35**	**34**	**33**	**32**	**31**	**30**	**29**	**28**	**27**
10th:	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
25th:	0.872%	0.268%	0.253%	0.153%	0.155%	0.139%	0.117%	0.167%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
Median:	9.18%	3.46%	3.21%	2.33%	2.27%	1.90%	1.92%	2.33%	0.463%	0.451%	0.298%	1.17%	1.10%
75th:	37.3%	19.4%	18.6%	15.0%	14.8%	12.6%	13.7%	14.6%	5.33%	4.81%	3.57%	9.98%	9.13%
90th:	71.1%	49.5%	47.4%	41.4%	40.5%	38.3%	40.5%	41.6%	22.1%	21.2%	17.6%	33.6%	32.0%
95th:	86.1%	68.0%	66.7%	60.5%	58.6%	57.2%	59.7%	60.6%	38.4%	37.2%	33.2%	52.5%	51.7%
	26	**25**	**24**	**23**	**22**	**21**	**20**	**19**	**18**	**17**	**16**	**15**	**14**
10th:	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
25th:	<0.1%	0.11%	0.109%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
Median:	1.14%	1.66%	1.53%	1.51%	1.57%	1.12%	1.12%	1.55%	1.12%	0.911%	0.698%	0.698%	0.698%
75th:	9.46%	11.5%	11.2%	11.5%	10.9%	10.0%	10.7%	10.9%	9.28%	7.76%	7.53%	7.06%	7.32%
90th:	33.2%	35.3%	35.6%	36.0%	34.5%	32.9%	33.5%	33.9%	31.1%	27.2%	27.4%	26.6%	26.5%
95th:	53.1%	53.7%	54.7%	55.3%	53.5%	52.5%	51.2%	52.4%	50.2%	44.9%	44.9%	44.9%	44.4%
	13	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
10th:	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
25th:	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
Median:	0.698%	0.698%	0.698%	1.09%	0.986%	0.750%	0.750%	0.75%	0.789%	0.750%	0.898%	<0.1%	0.900%
75th:	7.20%	7.12%	6.63%	8.59%	7.89%	7.35%	7.42%	7.17%	7.21%	7.03%	7.65%	6.75%	7.20%
90th:	25.5%	26.1%	25.4%	31.0%	26.8%	26.5%	26.0%	25.9%	26.9%	26.1%	27.0%	27.2%	27.3%
95th:	44.3%	44.4%	44.2%	48.6%	45.7%	44.3%	43.4%	43.6%	44.9%	43.6%	44.8%	45.6%	45.5%

Note: Percentages are rounded to three significant figures.

a – Percentile refers to the risk percentile. For example, based on the values in the 75th percentile row for Segment 39, there is a 25 percent probability that selenium concentrations in mallard eggs are high enough to cause negative reproductive effects in 37.3 percent of the exposed mallard population inhabiting that segment of Black Creek.

b – Segment 39 is the immediate receiving water for Morrow Generating Site. Segment 1 is farthest downstream from the immediate receiving water. The 39 segments comprise a total of 95 miles of Black Creek.

c – >0 to 5 percent risk; 5 to 35 percent risk; 35 to 65 percent risk; 65 to 95 percent risk; >95 percent risk.

Ecological Risk Model Methodology Limitations and Assumptions

The limitations and assumptions of the ecological risk modeling methodology include the following:

- ***Water Quality Inputs.*** The assumptions listed for the IRW model water quality module in Appendix C apply to the dissolved selenium concentrations that support the national-scale ecological risk model. The assumptions listed for the case study water quality model in Appendix G apply to the Black Creek case study ecological risk model. As discussed in Section 8 of the EA report, the case study models do incorporate available data regarding background pollutant concentrations and pollutant loading contributions from non-steam-electric point sources. For the Black Creek case study, however, EPA did not identify sufficient STORET monitoring data to represent upstream pollutant contributions, and did not identify any upstream non-steam-electric point sources with loadings for the modeled pollutants. EPA therefore assumed pollutant concentrations of zero within the water column at the upstream boundary of the modeling area. This results in a potential underestimation of dissolved selenium concentrations (and the associated risk of negative reproductive effects among fish and mallards) within the Black Creek modeling area.
- ***Receptor Populations Evaluated.*** EPA assumed that the receptor species and receiving water occur together (*i.e.*, all receiving waters evaluated in the national-scale and case study ecological risk models are habitat for fish and mallards even though that may not always be the case). This results in a potential overestimation of the number of immediate receiving waters whose elevated selenium concentrations are causing negative reproductive impacts among exposed fish and mallards.
- ***Species Represented by Exposure-Response Functions.*** EPA used exposure-response functions that are based on vetted functions from the literature for brown trout (representative of fish) and mallard (representative of avian). Brown trout are amongst the most sensitive fish species to selenium [U.S. EPA, 2014f]. EPA selected the mallard as the representative avian species, which may not reflect potential impacts to other species that consume primarily fish rather than invertebrates, and that may show differential sensitivity. The literature suggests that mallards are among the most sensitive bird species to selenium [Chapman *et al*., 2009]. Therefore, use of these exposure-response functions results in an environmentally protective estimate of reproductive risk among the fish and avian species found at any given waterbody.
- ***Multiple Pollutant Exposures.*** According to EPA's *Steam Electric Power Generating Point Source Category: Final Detailed Study Report* [U.S. EPA, 2009b], receptors will be exposed to multiple constituents simultaneously. However, the ecological risk model examines the impact of only selenium to receptors and does not take into account how the interaction of multiple pollutants impacts the receptors. For example, EPA did not consider the impact of mercury on the uptake or toxicity of selenium. There is evidence in the literature that these two compounds interact with each other in the environment and may decrease the level of impact of selenium on a receptor;[4] conversely, the interaction of other pollutants may increase the impact to a receptor. It

[4] In a notable but unexplained exception to this general rule, Heinz and Hoffman (1998) found that selenium and mercury interact to create additive or synergistic toxic effects in mallard embryos.

is beyond the scope of this analysis to include the effects of multiple pollutant interactions on receptors; however, the consideration of only selenium-driven impacts in this analysis likely results in an underestimation of the overall negative reproductive impacts among fish and mallards resulting from exposure to the variety of pollutants in steam electric power plant wastewater discharges.

- ***Composition of Fish and Mallard Diet.*** In this analysis, EPA assumed that mallard diets consisted entirely of invertebrates, which potentially overestimates the dietary intake of selenium (because invertebrates tend to bioaccumulate selenium to a higher degree than submerged aquatic vegetation, another component of mallard diets). EPA also assumed that the diets of fish and mallards consisted entirely of aquatic organisms that inhabit the modeled waterbodies. These assumptions result in an environmentally protective estimation of dietary selenium uptake if fish and mallards also consume organisms from other waterbodies that are not contaminated with selenium.

APPENDIX G
OVERVIEW OF CASE STUDY MODELING SETUP AND OUTPUTS

This appendix presents additional information about the model development, input variables, pollutant benchmarks, and methodology limitations/assumptions applicable to case study modeling performed using EPA's Water Quality Analysis Simulation Program (WASP). This appendix also presents additional information regarding the site-specific design, site-specific input parameters (*e.g.*, background pollutant concentrations, U.S. Geological Survey (USGS) time series flow data, steam electric power plant pollutant loadings), and model settings (*e.g.*, solids constants and sediment transport parameters) for each of the WASP models. For additional documentation regarding the selection of case study locations, development of the case study models, and outputs produced by the WASP models, refer to the ERG memorandum, "Technical Approach for Case Study Water Quality Modeling of Aquatic Systems in Support of the Final Steam Electric Power Generating Industry Environmental Assessment" (DCN SE05570) (*Case Study Water Quality Modeling Memorandum*).

CASE STUDY MODEL SETUP – ALL MODELS

This section of the appendix focuses on the development of the case study models, including the limitations/assumptions, input parameters, and methodologies that are applicable to all of the case study models.

Model Development & Input Variables

WASP Model Default Parameters. The Simple Toxicant module within WASP groups reaches of the modeled receiving water (*i.e.*, the individual COMIDs as defined in NHDPlus Version 1) into segments based on the hydrologic characteristics. The WASP model calculates the water column and benthic pollutant concentrations of the eight modeled pollutants using user-defined parameters and default assumption values. Table G-1 presents the WASP default parameters and values that EPA used for all the case study models.

Benthic Sediment Depth. All of the case study models are designed with two layers of segments representing the upper and lower benthic sediment layer, except for the Lake Sinclair model where benthic layers are not simulated. For each model, the depth of the upper and lower benthic sediment layers are 0.03m and 0.25m, respectively.

Pollutant Partition Coefficients & Densities. The Simple Toxicant module within WASP applies pollutant-specific partition coefficients to estimate the degree to which pollutants in the water column will adsorb to benthic sediments and suspended solids. EPA selected the suspended sediment-water (Kd_{sw}) partition coefficient for each of the eight modeled pollutants. Refer to Table C-4 in Appendix C of the *Environmental Assessment for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (EPA-861-R-15-006), hereafter referred to as the "EA Report," for the suspended sediment water partition coefficients used for each modeled pollutant. Additionally, the Simple Toxicant module requires the user to input a density for each modeled pollutant. Table G-2 presents the density values EPA used for each pollutant, based on published values from literature.

Table G-1. Solids Constants and Sediment Transport Parameters – All Models

Input Parameter	Description	Value Used	Units
Silts and Fines Density	WASP default density for silts/fines	2.650	g/cm^3
Sand Density	WASP default density for sand	2.650	g/cm^3
Organic Solids Density	WASP default density for organic solids	1.350	g/cm^3
fcritcoh	Critical cohesive sediment fraction; above which sediment bed acts cohesively	0.200	(fraction)
vRCohMult	Shear stress multiplier for cohesive resuspension	2.500	$g/m^2/sec$
vRCohExp	Shear stress exponent for cohesive resuspension	2.500	(unitless)
vRNonCohEx	Shear stress exponent for noncohesive resuspension	1.500	(unitless)
D50_silt	Particle diameter for silt	0.025	mm
D50_sand	Particle diameter for sand	0.250	mm
D50_POM	Particle diameter for organic solids	0.012	mm
vDexp_silt	Shear stress exponent for silt deposition	1.000	(unitless)
vD_exp_san	Shear stress exponent for sand deposition	1.000	(unitless)
vD_exp_POM	Shear stress exponent for organic solids deposition	1.000	(unitless)
TAUcritcoh [a]	Critical shear stress for erosion of cohesive bed	3.500 or 5.000	N/m^2
TAU_cD1_si [b]	Lower critical shear stress for silt; below which deposition is maximum	3.500 or 5.000	N/m^2
TAU_cD2_si [b]	Upper critical shear stress for sand; above which deposition is zero	7.000 or 10.000	N/m^2
TAU_cD1_sa	Lower critical shear stress for sand; below which deposition is maximum	4.000	N/m^2
TAU_cD2_sa	Upper critical shear stress for sand; above which deposition is zero	5.000	N/m^2
TAU_cD1_PO [b]	Lower critical shear stress for organic solids; below which deposition is maximum	3.500 or 5.000	N/m^2
TAU_cD2_PO [b]	Upper critical shear stress for organic solids; above which deposition is zero	7.000 or 10.000	N/m^2

Acronyms: g/cm^3 (grams per cubic centimeter); $g/m^2/sec$ (grams per square meter per second); mm (millimeter); N/m^2 (newton per square meter)

a – The value of this input parameter varies the critical sheer stress values for sediment transport. The value specified for this parameter, which can be set between 0.5 and 8.0 N/m^2, was determined as a result of calibration performed for each case study model. EPA determined that for all WASP models except for the Mississippi River site, a value of 3.5 N/m^2 was reasonable and resulted in modeled solids output comparable to the actual monitoring data results. For the Mississippi River WASP model, a value of 5.0 N/m^2 was deemed more appropriate based on model calibration.

b – WASP uses default values for these input parameters based on the value specified for ‘TAUcritcoh.’

Table G-2. Pollutant Densities - All Models

Pollutant	Density (g/cm^3)
Arsenic	5.75
Cadmium	8.70
Copper	8.96
Lead	11.34
Nickel	8.91
Selenium	4.80
Thallium	11.85
Zinc	7.14

Organic Solids, Sands, and Silts/Fines. To define initial concentrations for the organic solids, sands, and silts/fines parameters, EPA used total organic carbon (TOC) and total suspended solids (TSS) concentrations derived from STORET monitoring data collected within the WASP modeling area. EPA calculated the concentrations of organic solids (OS), sands, and silts/fines using Equation G-1, **Error! Reference source not found.** Equation G-2, and Equation G-3 below.

Equation G-1

$$C_{os} = TOC \times f_{os}$$

Equation G-2

$$C_{sand} = (TSS - C_{os}) \times f_{sand}$$

Equation G-3

$$C_{sf} = (TSS - C_{os}) \times f_{sf}$$

Where:

C_{os}	=	Initial concentration of organic solids (mg/L)	Output from Equation G-1
C_{sand}	=	Initial concentration of sands (mg/L)	Output from Equation G-2
C_{sf}	=	Initial concentration of silts/fines (mg/L)	Output from Equation G-3
TOC	=	Total organic carbon (mg/L)	Site-specific value derived from STORET monitoring data
TSS	=	Total suspended solids (mg/L)	Site-specific value derived from STORET monitoring data
f_{os}	=	Fraction of total organic carbon that is organic solids (unitless)	Model assumption value of 0.5
f_{sand}	=	Fraction of total suspended solids composed of sands	Model assumption value of 0.05
f_{sf}	=	Fraction of total suspended solids composed of silts/fines	Model assumption value of 0.95

Calibration of Sediment Transport Parameters. The concentrations of the modeled pollutants are influenced by sediment transport; therefore, EPA calibrated specific sediment transport parameters where possible. EPA calibrated the model outputs by manipulating one sediment transport parameter, 'Critical Shear Stress for Erosion of Cohesive Bed' (defined as 'TAUcritcoh' in WASP), until the modeled TSS concentrations in the water column segments (represented by the sum of organic matter, sands, and silts/fines) closely matched the available TSS STORET monitoring data. The 'Critical Shear Stress for Erosion of Cohesive Bed' value used for each case study model is presented in the case study model-specific sections of this appendix.[1]

Calibration of Initial Concentration of Sediment in Benthic Segments. In some cases, the initial concentration of sediment in the benthic segments was adjusted during the calibration process, as very large spikes in total solids concentration were sometimes observed during high

[1] If EPA observed a significant difference between the modeled TSS concentrations and actual observed TSS concentrations, the sediment transport calibration values were given further review; however, those differences, when they occurred, were often attributable to the pollutant contributions flowing in from the model boundaries.

flow events near the beginning of the simulation period. These large spikes were an indication that too much sediment was present in the modeled benthic segments at the start of the simulation, indicating that calibration of the sediment concentration was necessary. Where monitored pollutant data were available, the total concentration of pollutant was plotted alongside the actual observed results from STORET monitoring data as another check in the calibration process. The initial concentrations of the organic solids, sands, and silts/fines in the benthic sediment used for each case study model are presented in the case study model-specific sections of this appendix.

Steam Electric Power Plant Pollutant Loadings. EPA calculated pollutant loadings from the evaluated wastestreams as part of its engineering analysis (see Section 10 of the *Technical Development Document for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (TDD) [EPA 821-R-15-007]). The baseline and regulatory option pollutant loadings used for each case study are presented in the case study model-specific sections of this appendix. The *Case Study Water Quality Modeling Memorandum* further describes the methodology for calculating and incorporating steam electric power plant loadings data into the WASP models.

Non-Steam Electric Loadings. EPA incorporated pollutant loadings and/or concentrations data from Discharge Monitoring Reports (DMR), the Toxics Release Inventory (TRI), and EPA's STORET monitoring database to represent pollutant contributions from non-steam-electric point sources and nonpoint sources that may impact the case study water quality model. EPA incorporated pollutant loadings data from DMR and TRI data for each of the eight pollutants to account for the pollutant contributions within the modeling area. STORET monitoring data were incorporated to account for contributions upstream of the modeling boundaries and for use in calibration. For the modeled pollutants (not including TOC and TSS), EPA converted the average concentration or annual load to a daily mass loading.[2] Each case study model-specific section of this appendix presents the non-steam electric pollutant loadings incorporated into the model. The *Case Study Water Quality Modeling Memorandum* further describes the methodology for collecting, assessing, and incorporating DMR and TRI pollutant loadings data into the WASP models.

WASP Output Analysis Methodology

The WASP models generate output data for pollutant concentration (total, dissolved, and sorbed) in each water column and benthic segment on a daily output time step. For the purposes of assessing the baseline impacts and the improvements under the final rule, EPA used the baseline and regulatory option WASP model outputs from the period after the steam electric power plant's assumed compliance date.[3] Using this period of water quality output ensures that the baseline and regulatory option analyses are both based on the same underlying flow data, meaning that the differences in modeled pollutant concentrations are solely attributable to the pollutant loading reductions under the final rule.

[2] EPA converted the average concentration calculated from the STORET monitoring data to a mass loading using the average annual flow rate for the stream reach represented by the monitoring station(s).

[3] For case studies with pollutant loadings from multiple steam electric power plants (Ohio River and Mississippi River), EPA used the later of the two assumed compliance dates.

Water Quality Assessment. The WASP models generate daily pollutant concentrations in the water column of all water column segments within the models. EPA quantified the water quality impacts as the percent of days where the water column concentration, total or dissolved, exceed the National Recommended Water Quality Criteria (NRWQC) or Maximum Contaminant Level (MCL) benchmarks listed in Table C-7 in Appendix C. EPA also quantified the total river miles exhibiting exceedances and the distance downstream of the steam electric power plant(s) that showed any exceedances of these benchmarks at any point during the modeling period.

Wildlife Assessment. The WASP models generate daily pollutant concentrations in the upper and lower benthic sediment segments within the models. EPA quantified the impact to benthic organisms as the percent of days where the total sediment concentration in the upper benthic segments exceed the Chemical Stressor Concentration Limit (CSCL) benchmarks for sediment biota listed in Table D-1 in Appendix D. EPA also quantified the total number of river miles exhibiting exceedances and the distance downstream of the steam electric power plant(s) that showed any exceedances of these CSCLs at any point during the modeling period.

EPA calculated the annual average pollutant concentrations in the water column (averaged over the entire modeling period) of all water column segments. To determine negative impacts to piscivorous wildlife (*i.e.*, wildlife that consume fish) from the ingestion of contaminated fish, EPA compared the calculated annual average water column concentrations to "threshold" water concentrations that would result in exceedances of no effect hazard concentrations (NEHCs) for minks and eagles developed by the USGS.[4] Since minks are estimated to have a four-year life expectancy, EPA completed this analysis using four-year rolling average water concentration values. EPA quantified the total river miles with NEHC exceedances and how far downstream of the plant these impacts are observed.

Refer to Appendix F regarding the methodology for performing ecological risk modeling using water quality outputs from the Black Creek WASP model.

Human Health Assessment. EPA calculated the annual average pollutant concentrations in the water column (averaged over the entire modeling period) of all water column segments. To determine negative impacts to human receptors from the ingestion of contaminated fish, EPA compared the calculated annual average concentrations to "threshold" water concentrations that would trigger exceedances of either the non-cancer reference dose or the 1-in-a-million lifetime excess cancer risk (LECR) benchmark for selected cohorts.[5] EPA quantified the total river miles with LECR benchmark exceedances and how far downstream of the plant these impacts are observed.

<u>Case Study Modeling Methodology Limitations and Assumptions</u>

The case study modeling methodology shares the following limitations and assumptions with the IRW model water quality module (see Appendix C for further discussion):

[4] Refer to the memorandum "Downstream EA Modeling Methodology and Supporting Documentation" (DCN SE04455) for the water column concentrations that result in exceedances of the NEHC benchmarks.

[5] Refer to the memorandum "Downstream EA Modeling Methodology and Supporting Documentation" (DCN SE04455) for the water column concentrations that result in exceedances of the non-cancer reference doses or LECR benchmark for selected cohorts.

- The models are based on annual-average pollutant loadings and normalized flow rates from the steam electric power plants. Unlike the water quality module, however, the case study models do account for temporal variability in the receiving water flow rates.
- The models do not take into consideration pollutant speciation within the receiving stream.
- The models assume that pollutants dissolved or sorbed within the water column and bottom sediments can be described by a single partition coefficient.
- The pollutant loadings included in the models are not representative of the total pollutant loadings from steam electric power plants, as there are several waste streams that are not included in the analysis (*e.g.*, stormwater runoff, metal cleaning wastes, coal pile runoff). Unlike the water quality module, however, the case study models do take into account ambient background pollutant concentrations and contributions from other point and nonpoint sources.

In addition to the above, the case study modeling methodology incorporates the following limitations and assumptions:

- The models assume that pollutant contributions from background sources and other point and nonpoint sources are constant over the entire modeling period. This assumption reduces the variability in modeled pollutant concentrations over time and results in a potential underestimation of periods with elevated pollutant concentrations above benchmark levels (under both baseline conditions and the regulatory options).
- The models incorporate DMR and TRI loadings data to represent other point source dischargers. In DMR, facilities are required to report loadings only for the pollutants that are listed in the facility's National Pollutant Discharge Elimination System (NPDES) permit. This limitation results in a potential underestimation of the pollutant loadings from point sources that discharge a modeled pollutant but are not required to report wastewater monitoring data as part of their NPDES permit. TRI collects facility-reported estimates of wastewater loadings data for both direct and indirect dischargers. The TRI releases database does not include loadings from facilities with total annual chemical releases of less than 500 lbs and incorporates assumptions regarding plants with annual releases of less than 1,000 lbs. This limitation results in a potential underestimation of pollutant loadings from smaller point sources. Other limitations of the data collected in TRI include the following: small establishments are not required to report, nor are facilities that do not meet reporting thresholds; releases reported are based on estimates, not measurements; certain chemicals are reported as a class, not as individual compounds; facilities are identified by NAICS code, not point source category; and TRI requires facilities to report only certain chemicals, therefore all pollutants discharged from a facility may not be captured. The effect of these limitations on the case study model outputs is unknown.
- In cases where STORET monitoring data results are reported as below the quantitation limit, EPA assumed the result was equal to one-half the low-level analytical method detection limit for purposes of averaging the monitoring data results. The effect of this assumption on the case study model outputs is unknown and

depends on whether actual background concentrations at the time and location of monitoring were higher or lower than the assumed concentration.

- The models assume that stream flow conditions throughout the modeling period can be represented by selected ranges of historical stream flow data. The effect of this assumption on the case study model outputs is unknown and depends on whether actual stream flow rates are higher or lower than those used in the models.
- For each steam electric power plant, EPA assumed a plant-specific date (derived from the plant's permitting cycle) upon which the plant would achieve compliance with the final rule. The selection of the assumed compliance date influences the timing of when the modeled baseline impacts and improvements under the final rule would occur, but does not affect the magnitude of these impacts and improvements.
- By incorporating wildlife, human health, and ecological risk analyses, the models incorporate all of the limitations and assumptions described for those analyses (see Appendices D, E, and F).

CASE STUDY MODEL SETUPS AND OUTPUTS – BLACK CREEK, MS

This section presents information regarding the site-specific design, site-specific input parameters (*e.g.*, background pollutant concentrations, USGS time series flow data), model settings (*e.g.*, sediment transport parameters), and case study modeling results for the Black Creek case study model.

Model Development & Input Variables

WASP Model Design. The Black Creek WASP model starts at the R.D. Morrow, Sr. (Morrow) Generating Site's immediate receiving water (COMID 18104316), as defined by the IRW model, and extends approximately 95 miles downstream to just upstream of where Big Black Creek converges with Red Creek (COMID 18106998).

The Black Creek WASP model consists of 174 modeled segments. Segment IDs 1-39 represent the surface water of Black Creek with Segment ID 1 being the most downstream segment and Segment ID 39 being the most upstream segment and immediate receiving water. The remaining model segments represent tributary surface waters (Segment IDs 40-58), the upper benthic layers (Segment IDs 59-116), and the lower benthic layers (Segment IDs 117-174). Figure G-1 illustrates the segmentation of the Black Creek WASP model.

The modeling period starts in 1982 (the year of the last revision to the steam electric ELGs) and extends through 2036, covering a period of 55 years. Based on Morrow Generating Site's NPDES permitting cycle, EPA assumes that the plant will achieve the limitations under the final rule by 2019.

Incorporation of Flow Data. EPA used USGS stream flow data from one USGS stream gage to represent inflow at the upstream end of the modeling area of the Black Creek WASP model. EPA scaled the Black Creek stream gage data from Gage ID 02479130 to account for the difference in drainage area between the actual gage location and the point where the contributing flows enter the modeling area.

EPA used USGS stream flow data from one USGS stream gage to represent inflow from Cypress Creek, a significant tributary to the Black Creek WASP modeling area. EPA scaled the Cypress Creek stream gage data from Gage ID 0247155 to account for the difference in drainage area between the actual gage location and the point where the contributing flows enter the modeling area.

Figure G-1 illustrates the two stream flow gages from which EPA incorporated USGS stream flow data. Table G-3 presents additional information about the two stream gages and the time period covered in the stream flow data record at each. Table G-4 presents how EPA incorporated the stream flow data from these stream gages into the model to complete a full record of flow data for the entire modeling period. For all other local inflows, EPA used the mean annual flow defined in NHDPlus Version 1.

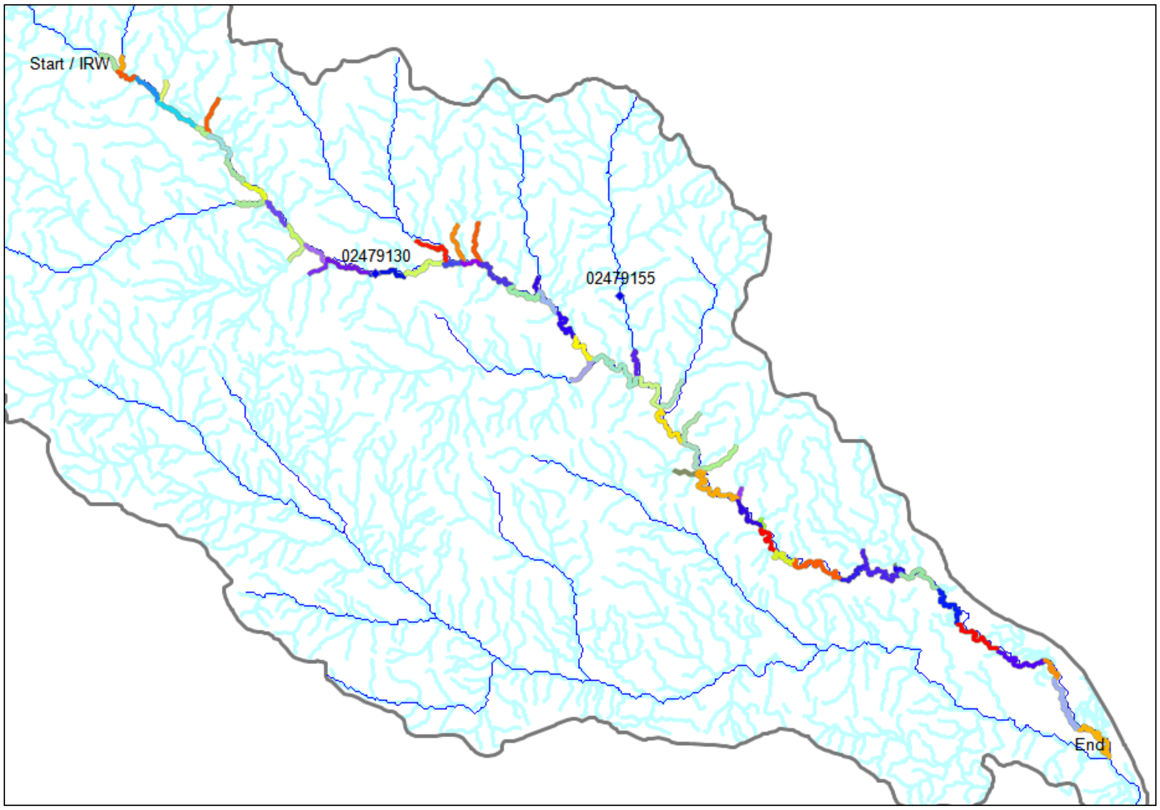


Figure G-1. Geographic Extent and Segmentation – Black Creek WASP Model

Model Input Variables. Table G-5 presents the pollutant loadings modeled from Morrow Generating Plant at the evaluated wastestream level, both at baseline and after the plant achieves the limitations under the final rule. EPA did not identify any point sources with 2011 DMR or TRI loadings which would impact the Black Creek case study model.

Table G-6 presents the pollutant contributions flowing into the Black Creek WASP model boundaries calculated using available STORET monitoring data.

Table G-7 presents the initial concentrations for the organic solids, sands, and silts/fines values derived from STORET monitoring data collected. For tributaries where STORET monitoring data were not available, EPA assumed the average boundary concentration from all tributaries entering the modeling area. Based on the average of STORET data available within the model, EPA calculated the initial concentrations of organic solids, sands, and silts/fines in the water column segments were 3.43 mg/L, 0.78 mg/L, and 14.74 mg/L, respectively.

EPA calibrated the model outputs by manipulating the sediment transport parameters until the modeled concentrations in the benthic segments closely matched the available sediment concentration monitoring data derived from STORET. Table G-8 presents the sediment transport parameters resulting from EPA's calibration effort. EPA assumed the initial concentrations of organic solids, sands, and silts/fines in the benthic segments were equal to 10,000 mg/L each.

Model Results

Case study modeling of Black Creek revealed water quality benchmark exceedances in the immediate receiving water and/or in downstream segments for arsenic, cadmium, selenium, and thallium. Figure G-2, Figure G-3, and Figure G-4 illustrate the water concentration outputs for these pollutants in the immediate receiving water before and after the assumed compliance date for the final rule.[6]

Case study modeling of Black Creek revealed that average water column concentrations of three pollutants (cadmium, selenium, and thallium) in the immediate receiving water and/or downstream segments would trigger exceedances of wildlife and/or human health benchmarks. Table G-9 and Table G-10 illustrate the average modeled pollutant concentration in each water column segment downstream of Morrow Generating Site (including the immediate receiving water) for baseline and following compliance with the final rule, respectively. Table G-11 and Table G-12 present the total miles with average water column concentrations translating to exceedances of these benchmarks for baseline and under the final rule, respectively.

Refer to Appendix F regarding the results of ecological risk modeling using water quality outputs from the Black Creek WASP model.

[6] To improve clarity, Figure G-2, Figure G-3, and Figure G-4 present the baseline water column concentrations leading up to the assumed compliance date of Morrow Generating Station. All analyses of the WASP model outputs were performed on the baseline output after the assumed compliance date.

Table G-3. USGS Stream Gages with Flow Data Used in Black Creek WASP Model

Gage ID	USGS Gage Location	Stream Flow Record Period	Cumulative Drainage Area Represented by Gage (sq km)	Model Boundary	Cumulative Drainage Area at Model Boundary (sq km)	Scale Factor
2479130	Black Creek near Brooklyn, MS	Full Record from 10/01/1970 - 04/14/2014	929	Black Creek	379	0.408
2479155	Cypress Creek near Janice, MS	Full Record from 10/01/1966 - 04/15/2014	138	Cypress Creek	158	1.143

Acronyms: USGS (U.S. Geological Survey).

Table G-4. Stream Flow Data Periods – Black Creek WASP Model

Modeling Period	Corresponding Stream Flow Data Period
Black Creek (Gage ID 2479130)	
01/01/1982 - 09/30/2013	01/01/1982 - 09/30/2013
10/01/2013 – 12/31/2020	10/01/2005 – 12/31/2012
01/01/1998 - 09/30/2029	01/01/1982 - 09/30/2013
10/01/2029 – 12/31/2036	10/01/2005 – 12/31/2012
Cypress Creek (Gage ID 2479155)	
01/01/1982 - 09/30/2013	01/01/1982 - 09/30/2013
10/01/2013 – 12/31/2020	10/01/2005 – 12/31/2012
01/01/1998 - 09/30/2029	01/01/1982 - 09/30/2013
10/01/2029 – 12/31/2036	10/01/2005 – 12/31/2012

Table G-5. Pollutant Loadings - Morrow Generating Site

Wastestream	Pollutant Loadings (g/day)							
	As	**Cd**	**Cu**	**Ni**	**Pb**	**Se**	**Tl**	**Zn**
Baseline [a]								
FGD Wastewater	6.87	101.88	19.68	794.50	4.22	1,057.22	12.43	1,259.97
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	3.68	1.02	4.50	16.93	3.39	1.87	17.26	13.83
Combustion Residual Leachate	6.29	1.66	1.24	7.61	--	18.19	0.19	34.52
Total	**16.84**	**104.56**	**25.42**	**819.03**	**7.61**	**1,077.27**	**29.88**	**1,308.32**
Final Rule [b]								
FGD Wastewater	5.28	3.81	3.42	5.70	3.07	5.18	8.87	18.07
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	--	--			--			--
Combustion Residual Leachate	6.29	1.66	1.24	7.61	--	18.19	0.19	34.52
Total	**11.57**	**5.47**	**4.66**	**13.32**	**3.07**	**23.37**	**9.06**	**52.59**

Acronyms: FGD (flue gas desulfurization).

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a – The baseline pollutant loadings are modeled throughout the entire modeling period (from 01/01/1982 through 12/31/2036).

b – The final rule pollutant loadings are modeled only after the assumed compliance date (from 01/01/2019 through 12/31/2036).

Table G-6. Pollutant Contributions from STORET Monitoring Data – Black Creek WASP Model

Model Boundary	Model Boundary COMID	Station ID(s) (lat, long)	Parameter	Average Concentration (µg/L)[a]	Mass Loading (g/day)[b]
Clear Creek	18104458	NLA06608-2010 (31.20,-89.30)	TOC	4,420.00	--
Little Black Creek	18104706	PA361 (31.09,-89.49)	TOC	7,400.00	--
			TSS	4,642.86	--
Big Creek [c]	18104940	PA043 (31.07,-89.27)	TOC	10,000.00	--
			TSS	7,000.00	--
Big Creek [c]	18104992	PA240 (31.07,-89.17) PA360 (31.14,-89.24)	TOC	10,333.33	--
			TSS	4,666.67	--
Cypress Creek	18108034	OWW04440-HBN8 (31.02,-89.01) PA056 (31.03,-89.02)	TSS	10,000.00	--
			TOC	18,000.00	--
Hickory Creek	18106316	112D33 (30.97,-88.97)	TOC	3,000.00	--

Acronyms: TOC (Total Organic Carbon); TSS (Total Suspended Solids).

a –Where more than one monitoring station located on the same tributary system reported acceptable results for the same pollutant, EPA calculated and incorporated the weighted average concentration across the monitoring stations (weighted by number of samples at each station).

b – For the modeled pollutants (not including TOC and TSS), EPA converted the average concentration to a mass loading using the average annual flow rate for the stream reach represented by the monitoring station(s).

c – There are two distinct tributary systems that are identified as “Big Creek” in the National Hydrography Dataset Plus (NHDPlus Version 1) database.

Table G-7. Organic Solids, Sands, and Silts/Fines Inputs – Black Creek WASP Model

Model Boundary	Model Boundary COMID	Organic Solids Concentration (mg/L)[a]	Sands Concentration (mg/L)[b]	Silts/Fines Concentration (mg/L)[c]
Black Creek [d]	18104316	3.43	0.78	14.74
Clear Creek	18104458	2.21	*	*
Little Black Creek	18104706	3.70	0.23	4.41
Big Creek [e]	18104940	5.00	0.35	6.65
Big Creek [e]	18104992	5.17	0.23	4.43
Cypress Creek	18108034	5.00	0.90	17.10
Hickory Creek	18106316	1.50	*	*
All Other Inflows [f]	N/A	3.76	0.43	8.14

Acronyms: N/A (Not Applicable).

* – No TSS results available. The ‘All Other Inflows’ concentration was used in this scenario.

a – The organic solids concentration was calculated using Equation G-1and the STORET monitoring data presented in Table G-6.

b – The sands concentration was calculated using Equation G-2 and the STORET monitoring data presented in Table G-6.

c – The silts/fines concentration was calculated using Equation G-3 and the STORET monitoring data presented in Table G-6.

d – The organic solids, sands, and silts/fines concentrations presented for this segment were used as the initial surface water conditions.

e – There are two distinct tributary systems that are identified as “Big Creek” in the National Hydrography Dataset Plus (NHDPlus Version 1) database.

f – For tributaries where boundary concentrations from STORET monitoring data were not available, EPA assumed the average boundary concentration from all tributaries entering the modeling area.

Table G-8. Sediment Transport Parameters – Black Creek WASP Model

Input Parameter	Value Used	Units
TAUcritcoh	3.5	N/m^2
TAU_cD1_si [a]	3.5	N/m^2
TAU_cD2_si [a]	7.0	N/m^2
TAU_cD1_PO [a]	3.5	N/m^2
TAU_cD2_PO [a]	7.0	N/m^2

Note: Table G-1 presents additional solids constants and sediment transport parameters that are used in each of the case study models.

a – This parameter is a WASP model default based on the value of the 'TAUcritcoh' parameter.

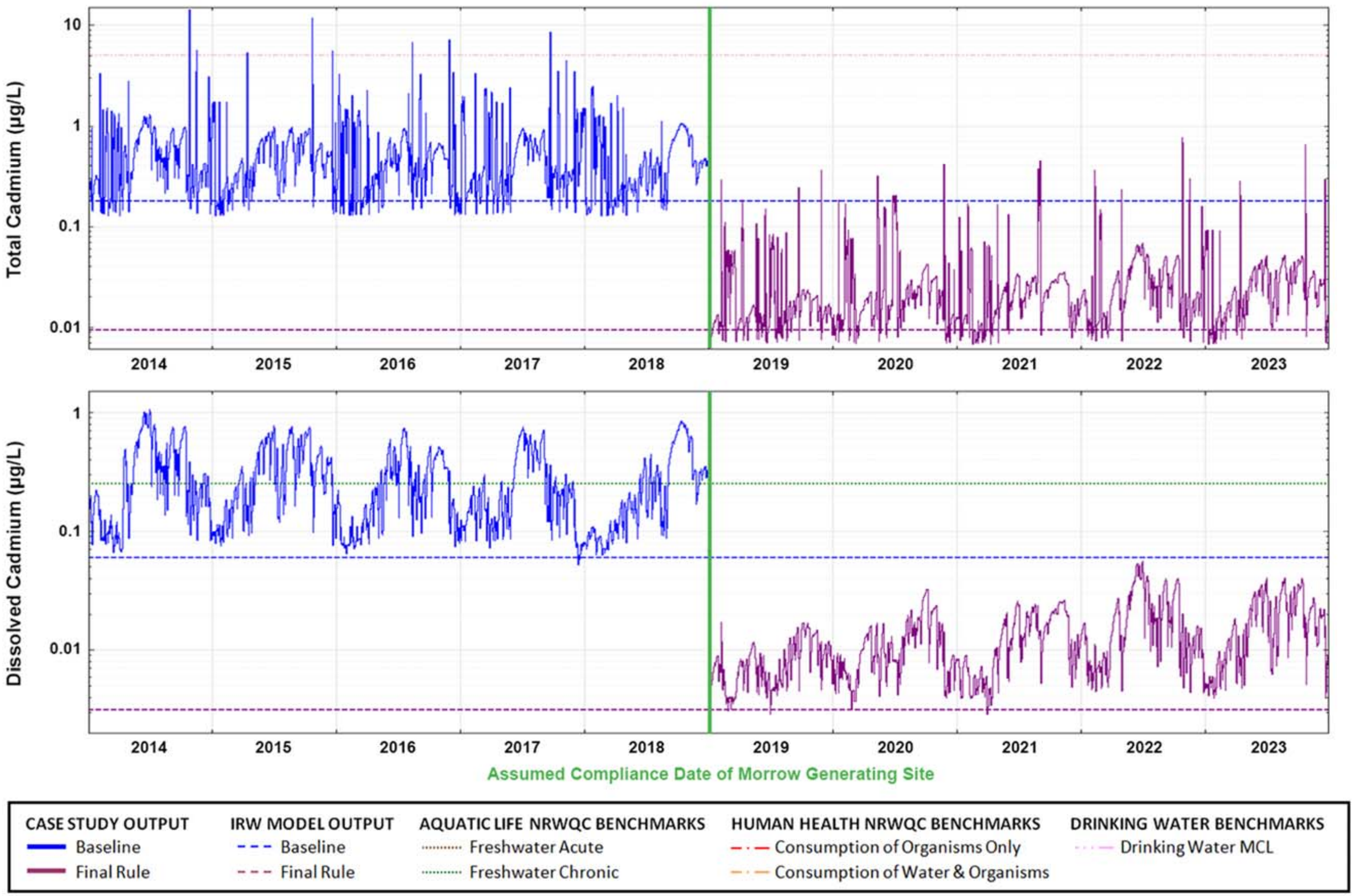

Figure G-2. Modeled Concentrations in Black Creek Water Column at Morrow Generating Site Immediate Receiving Water (Total Cadmium, Dissolved Cadmium)

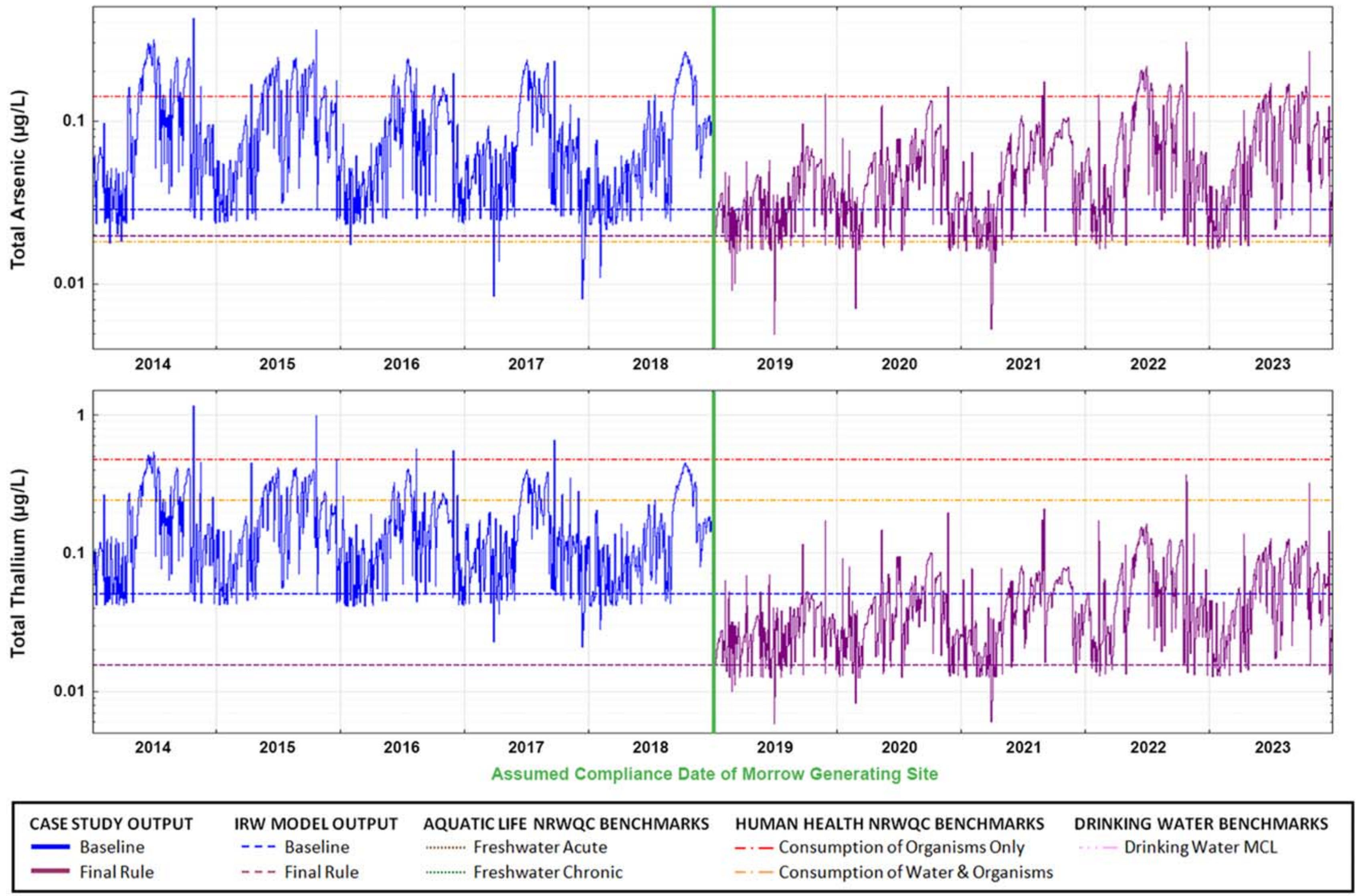

Figure G-3. Modeled Concentrations in Black Creek Water Column at Morrow Generating Site Immediate Receiving Water (Total Arsenic, Total Thallium)

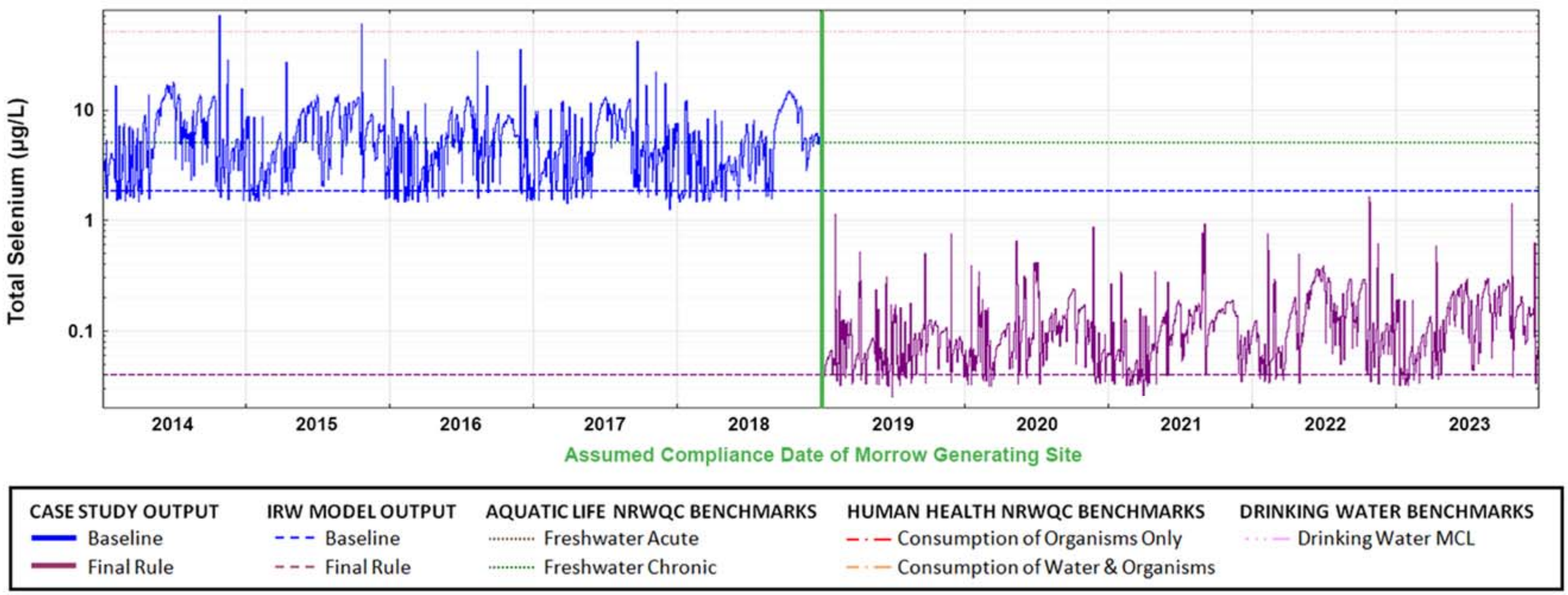

Figure G-4. Modeled Concentrations in Black Creek Water Column at Morrow Generating Site Immediate Receiving Water (Total Selenium)

Table G-9. Average Water Column Concentrations Downstream of Morrow Generating Site at Baseline

Segment Data				Average Total Water Column Concentration over Modeling Period (µg/L)[a]							
Segment ID	Segment Name	Segment Length (mi)	Distance Downstream (mi)	As	Cd	Cu	Pb	Ni	Se	Tl	Zn
39	Black Creek/ IRW	1.64	1.64	0.0833	0.6045	0.1407	0.0498	4.2330	5.6497	0.1510	7.7217
38	Black Creek	1.44	3.08	0.0543	0.4095	0.0942	0.0346	2.7890	3.7362	0.0989	5.2410
37	Black Creek	2.23	5.31	0.0521	0.3172	0.0774	0.0226	2.5298	3.3195	0.0926	3.9426
36	Black Creek	2.68	7.99	0.0445	0.2883	0.0693	0.0218	2.2009	2.9067	0.0798	3.6359
35	Black Creek	0.93	8.92	0.0450	0.3114	0.0735	0.0249	2.2628	3.0074	0.0812	3.9689
34	Black Creek	2.10	11.01	0.0420	0.2960	0.0696	0.0240	2.1255	2.8291	0.0760	3.7863
33	Black Creek	1.89	12.90	0.0483	0.6251	0.1220	0.0625	3.0284	4.2797	0.0988	6.3651
32	Black Creek	1.68	14.58	0.0476	0.6712	0.1307	0.0694	3.1224	4.4510	0.1000	7.4057
31	Black Creek	1.84	16.43	0.0313	0.5851	0.1074	0.0619	2.3412	3.4341	0.0695	6.2251
30	Black Creek	1.48	17.90	0.0282	0.3999	0.0783	0.0400	1.8857	2.6870	0.0597	4.5225
29	Black Creek	1.44	19.35	0.0241	0.3275	0.0650	0.0324	1.5902	2.2546	0.0509	3.7426
28	Black Creek	2.64	21.99	0.0396	0.9409	0.1816	0.1095	3.4735	5.2132	0.0969	12.6119
27	Black Creek	2.09	24.08	0.0364	0.7642	0.1489	0.0866	3.0067	4.4546	0.0868	9.9344
26	Black Creek	2.66	26.74	0.0348	0.6855	0.1344	0.0764	2.7946	4.1124	0.0821	8.7650
25	Black Creek	1.31	28.05	0.0398	1.1003	0.2131	0.1383	3.8927	5.9734	0.0951	14.4045
24	Black Creek	1.07	29.12	0.0413	1.2014	0.2311	0.1532	4.1371	6.3833	0.0999	15.7678
23	Black Creek	2.86	31.98	0.0425	1.3070	0.2498	0.1688	4.3820	6.7989	0.1045	17.2212
22	Black Creek	3.02	35.00	0.0425	1.3056	0.2499	0.1690	4.3861	6.8023	0.1048	17.2252
21	Black Creek	1.59	36.59	0.0382	1.1168	0.2147	0.1431	3.8483	5.9276	0.0931	14.6726
20	Black Creek	2.50	39.09	0.0396	1.2133	0.2319	0.1569	4.0771	6.3200	0.0977	15.9712
19	Black Creek	1.98	41.07	0.0399	1.2327	0.2352	0.1596	4.1222	6.3956	0.0986	16.2267
18	Black Creek	4.21	45.29	0.0349	1.1106	0.2114	0.1451	3.6660	5.7048	0.0873	14.5811
17	Black Creek	2.62	47.91	0.0315	0.9820	0.1872	0.1276	3.2730	5.0823	0.0783	12.8610
16	Black Creek	2.75	50.66	0.0299	0.9354	0.1780	0.1218	3.1087	4.8313	0.0743	12.2591
15	Black Creek	2.09	52.75	0.0309	1.0301	0.1945	0.1357	3.3126	5.1842	0.0782	13.5792

Table G-9. Average Water Column Concentrations Downstream of Morrow Generating Site at Baseline

Segment Data				Average Total Water Column Concentration over Modeling Period (µg/L)[a]							
Segment ID	Segment Name	Segment Length (mi)	Distance Downstream (mi)	As	Cd	Cu	Pb	Ni	Se	Tl	Zn
14	Black Creek	4.55	57.30	0.0305	1.0067	0.1903	0.1325	3.2498	5.0822	0.0769	13.2571
13	Black Creek	2.35	59.65	0.0300	0.9822	0.1860	0.1290	3.1903	4.9820	0.0756	12.9326
12	Black Creek	2.14	61.79	0.0194	0.2514	0.0569	0.0208	1.4524	2.0605	0.0409	3.0507
11	Black Creek	2.01	63.80	0.0192	0.2467	0.0558	0.0211	1.4283	2.0254	0.0402	2.9991
10	Black Creek	4.00	67.80	0.0269	0.5034	0.1033	0.0565	2.2124	3.2481	0.0604	6.4548
9	Black Creek	1.80	69.61	0.0282	0.6248	0.1242	0.0747	2.4762	3.6902	0.0655	8.1467
8	Black Creek	3.50	73.10	0.0265	0.5620	0.1125	0.0662	2.2782	3.3875	0.0610	7.3174
7	Black Creek	3.02	76.12	0.0261	0.5480	0.1099	0.0642	2.2346	3.3201	0.0600	7.1365
6	Black Creek	3.33	79.45	0.0261	0.5551	0.1109	0.0650	2.2472	3.3481	0.0603	7.2115
5	Black Creek	3.16	82.61	0.0260	0.5475	0.1096	0.0639	2.2301	3.3199	0.0599	7.1144
4	Black Creek	3.36	85.97	0.0263	0.5658	0.1129	0.0666	2.2768	3.3970	0.0609	7.3715
3	Black Creek	1.90	87.87	0.0248	0.4646	0.0947	0.0517	2.0354	2.9817	0.0557	5.9687
2	Black Creek	3.66	91.54	0.0241	0.4279	0.0877	0.0462	1.9406	2.8222	0.0536	5.4496
1	Black Creek/ End	3.85	95.38	0.0247	0.4799	0.0943	0.0492	2.0362	2.9758	0.0556	5.7478

Acronyms: IRW (Immediate receiving water).

a - Concentrations represent the average daily total pollutant concentration in the water column. The averaging period is the entire modeling period after the assumed compliance date.

Table G-10. Average Water Column Concentrations Downstream of Morrow Generating Site Under Final Rule

Segment Data				Average Total Water Column Concentration over Modeling Period (µg/L)[a]							
Segment ID	Segment Name	Segment Length (mi)	Distance Downstream (mi)	As	Cd	Cu	Pb	Ni	Se	Tl	Zn
39	Black Creek/ IRW	1.64	1.64	0.0575	0.0322	0.0261	0.0204	0.0702	0.1250	0.0460	0.3167
38	Black Creek	1.44	3.08	0.0375	0.0218	0.0175	0.0141	0.0464	0.0828	0.0301	0.2153
37	Black Creek	2.23	5.31	0.0360	0.0169	0.0144	0.0092	0.0419	0.0734	0.0282	0.1615
36	Black Creek	2.68	7.99	0.0308	0.0153	0.0129	0.0089	0.0366	0.0644	0.0243	0.1485
35	Black Creek	0.93	8.92	0.0311	0.0166	0.0136	0.0102	0.0378	0.0669	0.0247	0.1629
34	Black Creek	2.10	11.01	0.0290	0.0158	0.0129	0.0098	0.0355	0.0629	0.0232	0.1555
33	Black Creek	1.89	12.90	0.0335	0.0532	0.0273	0.0274	0.1016	0.1766	0.0309	0.6420
32	Black Creek	1.68	14.58	0.0330	0.0545	0.0286	0.0301	0.0972	0.1717	0.0312	0.6460
31	Black Creek	1.84	16.43	0.0217	0.0469	0.0233	0.0269	0.0778	0.1392	0.0217	0.5689
30	Black Creek	1.48	17.90	0.0196	0.0335	0.0171	0.0174	0.0635	0.1107	0.0187	0.3883
29	Black Creek	1.44	19.35	0.0167	0.0274	0.0142	0.0140	0.0534	0.0927	0.0159	0.3143
28	Black Creek	2.64	21.99	0.0272	0.0639	0.0358	0.0460	0.0916	0.1718	0.0301	0.7238
27	Black Creek	2.09	24.08	0.0249	0.0536	0.0300	0.0366	0.0823	0.1518	0.0270	0.6070
26	Black Creek	2.66	26.74	0.0239	0.0491	0.0274	0.0323	0.0784	0.1434	0.0255	0.5566
25	Black Creek	1.31	28.05	0.0279	0.1061	0.0442	0.0607	0.1996	0.3454	0.0313	1.3552
24	Black Creek	1.07	29.12	0.0289	0.1205	0.0486	0.0675	0.2233	0.3880	0.0330	1.5491
23	Black Creek	2.86	31.98	0.0298	0.1339	0.0530	0.0746	0.2437	0.4253	0.0347	1.7278
22	Black Creek	3.02	35.00	0.0298	0.1349	0.0534	0.0748	0.2467	0.4305	0.0348	1.7427
21	Black Creek	1.59	36.59	0.0268	0.1214	0.0469	0.0639	0.2291	0.3976	0.0311	1.5701
20	Black Creek	2.50	39.09	0.0278	0.1276	0.0500	0.0697	0.2351	0.4099	0.0325	1.6503
19	Black Creek	1.98	41.07	0.0280	0.1291	0.0507	0.0709	0.2370	0.4137	0.0329	1.6710
18	Black Creek	4.21	45.29	0.0245	0.1176	0.0458	0.0643	0.2143	0.3747	0.0291	1.5246
17	Black Creek	2.62	47.91	0.0221	0.1029	0.0404	0.0565	0.1881	0.3285	0.0261	1.3331

Table G-10. Average Water Column Concentrations Downstream of Morrow Generating Site Under Final Rule

Segment Data				Average Total Water Column Concentration over Modeling Period (µg/L)[a]							
Segment ID	**Segment Name**	**Segment Length (mi)**	**Distance Downstream (mi)**	**As**	**Cd**	**Cu**	**Pb**	**Ni**	**Se**	**Tl**	**Zn**
16	Black Creek	2.75	50.66	0.0209	0.0988	0.0386	0.0540	0.1821	0.3154	0.0248	1.2784
15	Black Creek	2.09	52.75	0.0217	0.1092	0.0422	0.0602	0.1951	0.3423	0.0261	1.4175
14	Black Creek	4.55	57.30	0.0214	0.1085	0.0416	0.0590	0.1937	0.3421	0.0257	1.4070
13	Black Creek	2.35	59.65	0.0210	0.1068	0.0408	0.0574	0.1921	0.3385	0.0253	1.3864
12	Black Creek	2.14	61.79	0.0136	0.0236	0.0118	0.0090	0.0729	0.1176	0.0134	0.2752
11	Black Creek	2.01	63.80	0.0134	0.0232	0.0116	0.0095	0.0716	0.1157	0.0132	0.2737
10	Black Creek	4.00	67.80	0.0187	0.0514	0.0223	0.0249	0.1231	0.2037	0.0200	0.6375
9	Black Creek	1.80	69.61	0.0197	0.0652	0.0271	0.0330	0.1485	0.2420	0.0218	0.8157
8	Black Creek	3.50	73.10	0.0185	0.0585	0.0245	0.0291	0.1352	0.2222	0.0203	0.7296
7	Black Creek	3.02	76.12	0.0182	0.0571	0.0240	0.0282	0.1322	0.2181	0.0200	0.7113
6	Black Creek	3.33	79.45	0.0183	0.0580	0.0242	0.0286	0.1333	0.2201	0.0201	0.7222
5	Black Creek	3.16	82.61	0.0182	0.0568	0.0239	0.0281	0.1314	0.2174	0.0200	0.7066
4	Black Creek	3.36	85.97	0.0184	0.0582	0.0245	0.0292	0.1329	0.2204	0.0203	0.7233
3	Black Creek	1.90	87.87	0.0173	0.0510	0.0211	0.0228	0.1250	0.2041	0.0186	0.6233
2	Black Creek	3.66	91.54	0.0169	0.0469	0.0195	0.0204	0.1196	0.1936	0.0186	0.5720
1	Black Creek/ End	3.85	95.38	0.0173	0.0497	0.0208	0.0217	0.1233	0.1998	0.0186	0.5997

Acronyms: IRW (Immediate receiving water).

a - Concentrations represent the average daily total pollutant concentration in the water column. The averaging period is the entire modeling period after the assumed compliance date.

Table G-11. Total Miles of Black Creek with Wildlife And Human Health Impacts at Baseline

Wildlife & Human Health Impact Thresholds	Total Miles with Average Water Column Concentration Translating to Wildlife or Human Health Benchmark Exceedances (mi)							
	As	Cd	Cu	Pb	Ni	Se	Tl	Zn
WL - NEHC, T3 (mink)	0.00	0.00	0.00	0.00	0.00	89.79	No NEHC	0.00
WL - NEHC, T4 (eagle)	0.00	0.00	0.00	0.00	0.00	89.79	No NEHC	0.00
HH - Non-Cancer Adult Subsistence	0.00	0.00	0.00	No RfD	0.00	95.38	89.79	0.00
HH - Non-Cancer Adult Recreational	0.00	0.00	0.00	No RfD	0.00	12.75	0.00	0.00
HH - Non-Cancer Child Subsistence (1 to <2 y.o.) [a]	0.00	37.64	0.00	No RfD	0.00	95.38	95.38	0.00
HH - Non-Cancer Child Subsistence (16 to <21 y.o) [b]	0.00	0.00	0.00	No RfD	0.00	89.79	58.53	0.00
HH - Non-Cancer Child Recreational (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	89.79	58.53	0.00
HH - Non-Cancer Child Recreational (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	11.43	0.00	0.00
HH - Cancer Adult Subsistence	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Adult Recreational	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (6 to <11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (6 to 11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR

Acronyms: WL (Wildlife); HH (Human health); NEHC (No effect hazard concentration); Rfd (Reference dose); LECR (Lifetime excess cancer risk); y.o. (year old).

a – This row represents the most sensitive child fisher cohort.

b – This row represents the least sensitive child fisher cohort.

Table G-12. Total Miles of Black Creek with Wildlife And Human Health Impacts Under Final Rule

Wildlife and Human Health Impact Thresholds	Total Miles with Average Water Column Concentration Translating to Wildlife or Human Health Benchmark Exceedances (mi)							
	As	Cd	Cu	Pb	Ni	Se	Tl	Zn
WL - NEHC, T3 (mink)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
WL - NEHC, T4 (eagle)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
HH - Non-Cancer Adult Subsistence	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Adult Recreational	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Subsistence (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	58.53	0.00
HH - Non-Cancer Child Subsistence (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Recreational (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Recreational (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Cancer Adult Subsistence	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Adult Recreational	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (6 to <11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (6 to 11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR

Acronyms: WL (Wildlife); HH (Human health); NEHC (No effect hazard concentration); Rfd (Reference dose); LECR (Lifetime excess cancer risk); y.o. (year old).

a – This row represents the most sensitive child fisher cohort.

b – This row represents the least sensitive child fisher cohort.

Case Study Model Setups and Outputs – Etowah River, GA

This section presents information regarding the site-specific design, site-specific input parameters (*e.g.*, background pollutant concentrations, USGS time series flow data), model settings (*e.g.*, sediment transport parameters), and case study modeling results for the Etowah River case study model.

Model Development & Input Variables

WASP Model Design. The Etowah River WASP model starts at Plant Bowen's immediate receiving water (COMID 6499098), as defined by the IRW model, and extends approximately 35 miles downstream to just upstream of where the Etowah River converges with Silver Creek (COMID 6500350).

The Etowah River WASP model consists of 96 modeled segments. Segment IDs 1-18 represent the surface water of the Etowah River with Segment ID 1 being the most downstream segment and Segment ID 18 being the most upstream segment and immediate receiving water. The remaining model segments represent tributary surface waters (Segment IDs 19-32), the upper benthic layers (Segment IDs 33-64), and the lower benthic layers (Segment IDs 65-96). Figure G-5 illustrates the segmentation of the Etowah River WASP model.

The modeling period starts in 1982 (the year of the last revision to the steam electric ELGs) and extends through 2032, covering a period of 51 years. Based on Plant Bowen's NPDES permitting cycle, EPA assumes that the plant will achieve the limitations under the final rule by 2021.

Incorporation of Flow Data. EPA used USGS stream flow data from one USGS stream gage to represent inflow at the upstream end of the modeling area of the Etowah River WASP model. EPA scaled the Etowah River stream gage data from Gage ID 02395000 to account for the difference in drainage area between the actual gage location and the point where the contributing flows enter the modeling area.

EPA used USGS stream flow data from one USGS stream gage to represent inflow from Two Run Creek, a significant tributary to the Etowah River WASP modeling area. EPA scaled the Two Run Creek stream gage data from Gage ID 02395120 to account for the difference in drainage area between the actual gage location and the point where the contributing flows enter the modeling area.

Figure G-5 illustrates the two stream flow gages from which EPA incorporated USGS stream flow data. Table G-13 presents additional information about the two stream gages and the time period covered in the stream flow data record at each. Table G-14 presents how EPA incorporated the stream flow data from these stream gages into the model to complete a full record of flow data for the entire modeling period. For all other local inflows, EPA used the mean annual flow defined in NHDPlus Version 1.

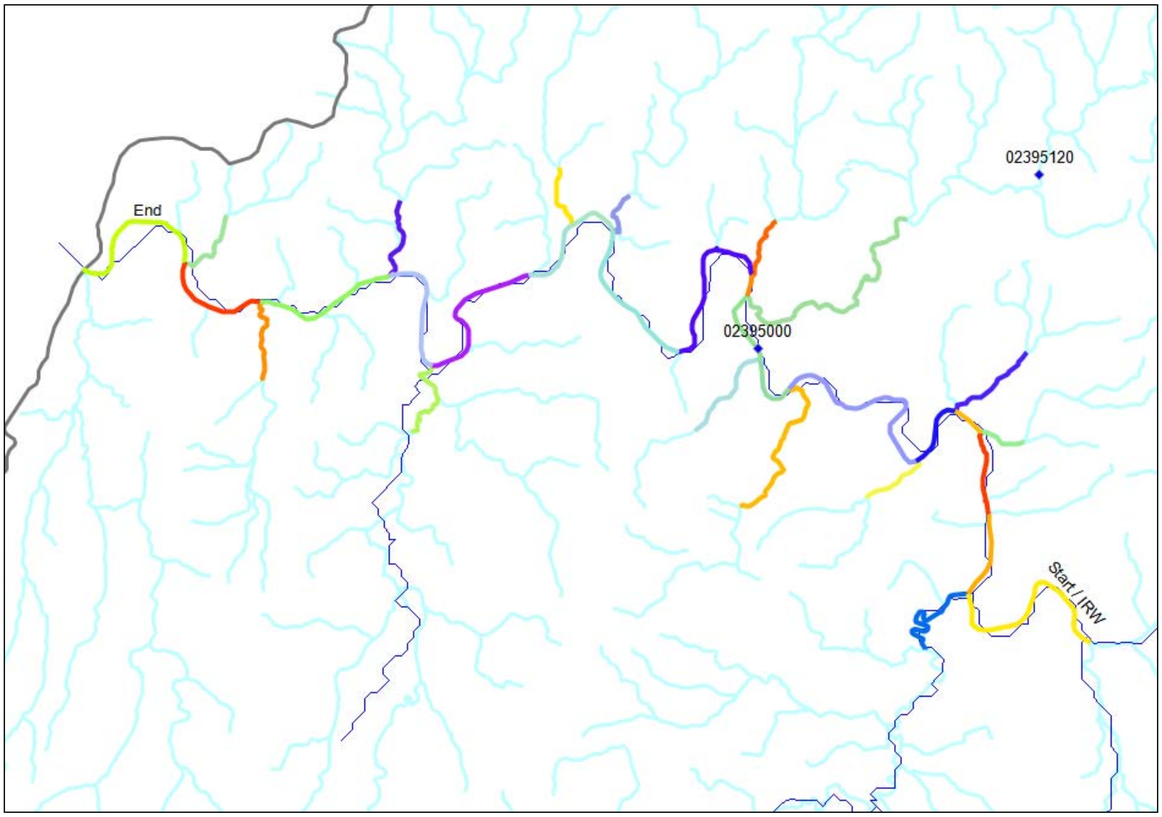

Figure G-5. Geographic Extent and Segmentation – Etowah River WASP Model

Model Input Variables. Table G-15 presents the pollutant loadings modeled from Plant Bowen at the evaluated wastestream level, both at baseline and after the plant achieves the limitations under the final rule. EPA did not identify any point sources with 2011 DMR or TRI loadings which would impact the Etowah River case study model and could not be accounted for using STORET monitoring data.

Table G-16 presents the pollutant contributions flowing into the Etowah River WASP model boundaries calculated using available STORET monitoring data.

Table G-17 presents the initial concentrations for the organic solids, sands, and silts/fines values derived from STORET monitoring data collected. For tributaries where STORET monitoring data were not available, EPA assumed the average boundary concentration from all tributaries entering the modeling area. Based on the average of STORET data available within the model, EPA calculated the initial concentrations of organic solids, sands, and silts/fines in the water column segments were 2.56 mg/L, 0.90 mg/L, and 17.19 mg/L, respectively.

EPA calibrated the model outputs by manipulating the sediment transport parameters until the modeled concentrations in the benthic segments closely matched the available sediment concentration monitoring data derived from STORET. Table G-18 presents the sediment transport parameters resulting from EPA's calibration effort. EPA assumed the initial concentrations of organic solids, sands, and silts/fines in the benthic segments were equal to 500 mg/L each.

Model Results

Case study modeling of the Etowah River revealed water quality benchmark exceedances in the immediate receiving water and/or in downstream segments for arsenic, cadmium, selenium, and thallium.[7] Figure G-6 and Figure G-7 illustrate the water concentration outputs for these pollutants in the immediate receiving water before and after the assumed compliance date for the final rule.[8]

Case study modeling of the Etowah River revealed that average water column concentrations of three pollutants (arsenic, selenium, and thallium) in the immediate receiving water and/or downstream segments would trigger exceedances of human health benchmarks. Table G-19 and Table G-20 illustrate the average modeled pollutant concentration in each water column segment downstream of Plant Bowen (including the immediate receiving water) for baseline and following compliance with the final rule, respectively. Table G-21 and Table G-22 present the total miles with average water column concentrations translating to exceedances of these benchmarks for baseline and under the final rule, respectively.

[7] Case study modeling also revealed isolated downstream exceedances of water quality benchmarks for lead.

[8] To improve clarity, Figure G-6 and Figure G-7 present the baseline water column concentrations leading up to the assumed compliance date of Plant Bowen. All analyses of the WASP model outputs were performed on the baseline output after the assumed compliance date.

Table G-13. USGS Stream Gages with Flow Data Used in Etowah River WASP Model

Gage ID	USGS Gage Location	Stream Flow Record Period	Cumulative Drainage Area Represented by Gage (sq km)	Model Boundary	Cumulative Drainage Area at Model Boundary (sq km)	Scale Factor
02395000	Etowah River near Kingston, GA	Partial Record from 07/18/2928 – 09/30/2013 (Missing Data between 10/24/1995 – 10/01/2008)	4,239	Etowah River	3,683	0.869
02395120	Two Run Creek near Kingston, GA	Full Record from 05/02/1980 – 09/30/2013	85	Two Run Creek	130	1.52

Acronyms: USGS (U.S. Geological Survey).

Table G-14. Stream Flow Data Periods – Etowah River WASP Model

Modeling Period	Corresponding Stream Flow Data Period
Etowah River (Gage ID 02395000)	
01/01/1982 - 10/23/1995	01/01/1982 - 10/23/1995
10/24/1995 - 09/30/2008	10/24/1967 - 09/30/1980
10/01/2008 - 9/30/2013	10/01/2008 - 9/30/2013
10/01/2013 – 12/31/2020	10/01/2005 – 12/31/2012
01/01/1994 - 10/23/2007	01/01/1982 - 10/23/1995
10/24/2007 - 09/30/2020	10/24/1967 - 09/30/1980
10/01/2020 - 9/30/2025	10/01/2008 - 9/30/2013
10/01/2025 – 12/31/2032	10/01/2005 – 12/31/2012
Two Run Creek (Gage ID 02395120)	
01/01/1982 - 09/30/2013	01/01/1982 - 09/30/2013
10/01/2013 – 12/31/2020	10/01/2005 – 12/31/2012
01/01/1994 - 09/30/2025	01/01/1982 - 09/30/2013
10/01/2025 – 12/31/2032	10/01/2005 – 12/31/2012

Table G-15. Pollutant Loadings – Plant Bowen

Wastestream	Pollutant Loadings (g/day)							
	As	Cd	Cu	Ni	Pb	Se	Tl	Zn
Baseline [a]								
FGD Wastewater [c]	27.56	408.74	78.96	3187.42	16.93	4241.43	49.87	5054.84
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	13.79	3.81	16.86	63.46	12.69	6.99	64.69	51.86
Combustion Residual Leachate	--	--	--	--	--	--	--	--
Total	**41.35**	**412.55**	**95.82**	**3,250.88**	**29.62**	**4,248.42**	**114.56**	**5,106.71**
Final Rule [b]								
FGD Wastewater	21.18	15.28	13.71	22.89	12.31	20.77	35.60	72.51
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	--	--			--			--
Combustion Residual Leachate	--	--	--	--	--	--	--	--
Total	**21.18**	**15.28**	**13.71**	**22.89**	**12.31**	**20.77**	**35.60**	**72.51**

Acronyms: FGD (flue gas desulfurization).

-- -- -- --

a – The baseline pollutant loadings are modeled throughout the entire modeling period (from 01/01/1982 through 12/31/2032).

b – The final rule pollutant loadings are modeled only after the assumed compliance date (from 01/01/2021 through 12/31/2032).

c - In estimating the historical pollutant loadings associated with Plant Bowen's four FGD systems, EPA incorporated the pollutant loadings from FGD wastewater as the systems were installed, between 2008 and 2011. EPA did not model any FGD wastewater pollutant loadings before the installation of Plant Bowen's first FGD system.

Table G-16. Pollutant Contributions from STORET Monitoring Data – Etowah River WASP Model

Model Boundary	Model Boundary COMID	Station ID(s) (lat, long)	Parameter	Average Concentration (µg/L)[a]	Mass Loading (g/day)[b]
Etowah River	6499098	14310011 (34.15,-84.77) 1404130102 (34.15,-84.77) 1404130103 (34.15,-84.77) 1404130105 (34.12,-84.82)	As	--	9,993.11
			Cd	--	1,279.89
			Cu	--	5,103.32
			Ni	--	2,909.40
			Pb	--	2,631.57
			Tl	--	5,004.55
			Zn	--	7,666.84
			TOC	3,531.41	--
			TSS	8,775.41	--
Euharlee Creek	6497752	1404140704 (34.13,-84.94) 1404140701 (34.12,-84.95)	Pb	--	1,480.69
			TOC	6,734.53	--
			TSS	16,323.08	--
Two Run Creek	6497374	14340201 (34.22,-84.97)	As	--	693.96
			Cd	--	86.75
			Cu	--	346.98
			Ni	--	173.49
			Pb	--	138.79
			Tl	--	346.98
			Zn	--	693.96
			TOC	7,996.03	--
			TSS	12,847.83	--
Connesena Creek	6497306	1404150501 (34.24,-84.97)	TOC	4,191.06	--
			TSS	4,640.00	--
Toms Creek	6499778	1404160201 (34.26,-84.99)	TOC	9,465.83	--

Table G-16. Pollutant Contributions from STORET Monitoring Data – Etowah River WASP Model

Model Boundary	Model Boundary COMID	Station ID(s) (lat, long)	Parameter	Average Concentration (µg/L)[a]	Mass Loading (g/day)[b]
Spring Creek	6499820	1404160301 (34.21,-85.07) 14340991 (34.21,-85.07)	As	--	541.04
			Cd	--	67.63
			Cu	--	270.52
			Ni	--	202.89
			Pb	--	54.10
			Tl	--	270.52
			Zn	--	270.52
			TOC	8,526.71	--
			TSS	14,434.78	--
Dykes Creek	6499782	1404160401 (34.25,-85.08) 1404160402 (34.26,-85.09)	TOC	2,350.53	--
			TSS	3,661.11	--

Acronyms: TOC (Total Organic Carbon); TSS (Total Suspended Solids).

a –Where more than one monitoring station located on the same tributary system reported acceptable results for the same pollutant, EPA calculated and incorporated the weighted average concentration across the monitoring stations (weighted by number of samples at each station).

b – For the modeled pollutants (not including TOC and TSS), EPA converted the average concentration to a mass loading using the average annual flow rate for the stream reach represented by the monitoring station(s).

Table G-17. Organic Solids, Sands, and Silts/Fines Inputs – Etowah River WASP Model

Model Boundary	Model Boundary COMID	Organic Solids Concentration (mg/L)[a]	Sands Concentration (mg/L)[b]	Silts/Fines Concentration (mg/L)[c]
Etowah River	6499098	1.77	0.44	8.33
Euharlee Creek	6497752	3.37	0.82	15.50
Two Run Creek	6497374	4.00	0.64	12.20
Connesena Creek	6497306	2.10	0.23	4.41
Toms Creek	6499778	4.73	*	*
Spring Creek	6499820	4.26	0.72	13.71
Dykes Creek	6499782	1.18	0.18	3.48
All Other Inflows [d]	N/A	3.06	0.51	9.61

Acronyms: N/A (Not Applicable).

* – No TSS results available. The ‘All Other Inflows’ concentration was used in this scenario.

a – The organic solids concentration was calculated using Equation G-1 and the STORET monitoring data presented in Table G-16.

b – The sands concentration was calculated using Equation G-2 and the STORET monitoring data presented in Table G-16.

c – The silts/fines concentration was calculated using Equation G-3 and the STORET monitoring data presented in Table G-16.

d – For tributaries where boundary concentrations from STORET monitoring data were not available, EPA assumed the average boundary concentration from all tributaries entering the modeling area.

Table G-18. Sediment Transport Parameters – Etowah River WASP Model

Input Parameter	Value Used	Units
TAUcritcoh	3.5	N/m^2
TAU_cD1_si[a]	3.5	N/m^2
TAU_cD2_si[a]	7.0	N/m^2
TAU_cD1_PO[a]	3.5	N/m^2
TAU_cD2_PO[a]	7.0	N/m^2

Note: Table G-1 presents additional solids constants and sediment transport parameters that are used in each of the case study models.

a – This parameter is a WASP model default based on the value of the ‘TAUcritcoh’ parameter.

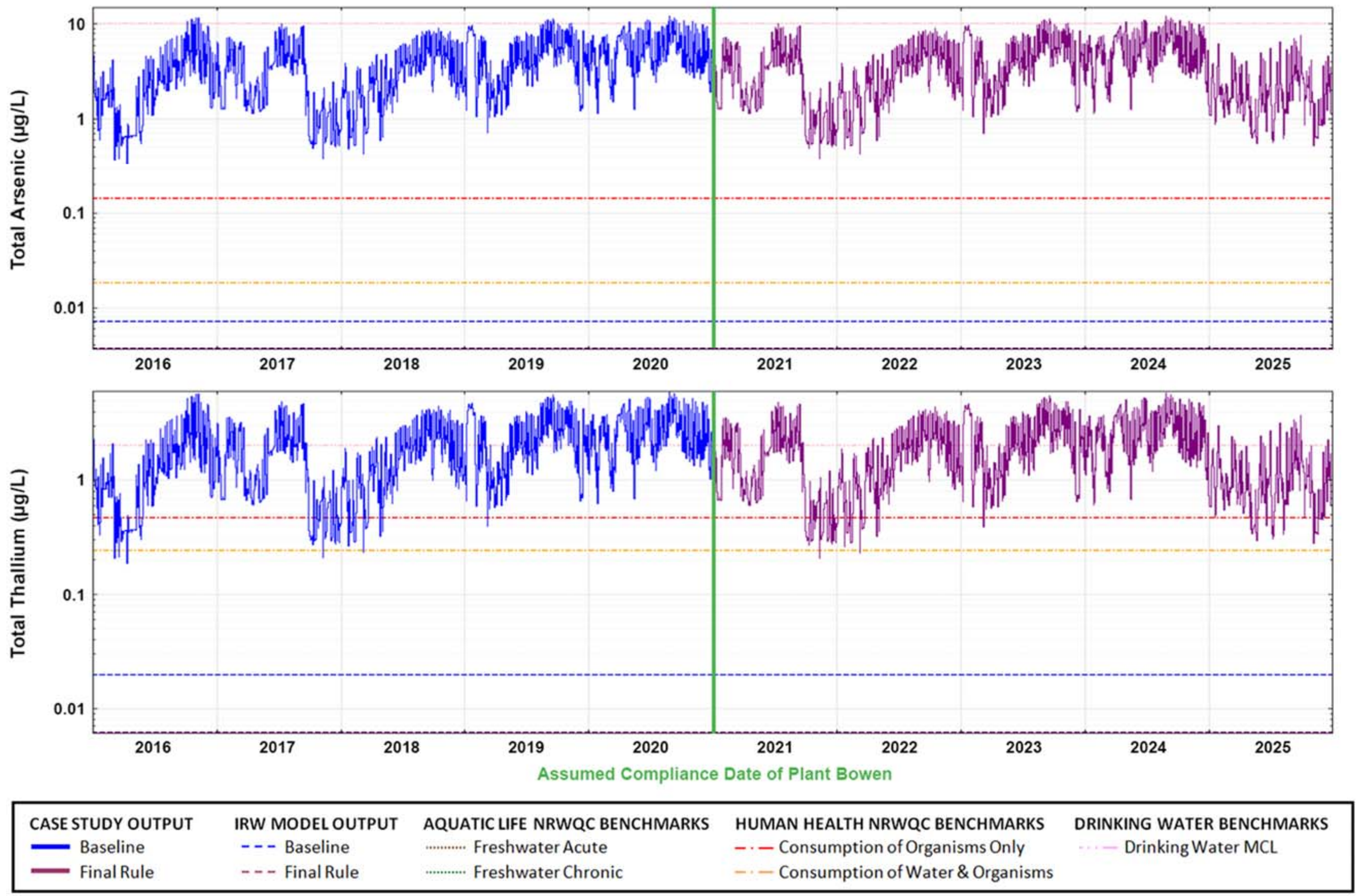

Figure G-6. Modeled Concentrations in Etowah River Water Column at Plant Bowen Immediate Receiving Water (Total Arsenic, Total Thallium)

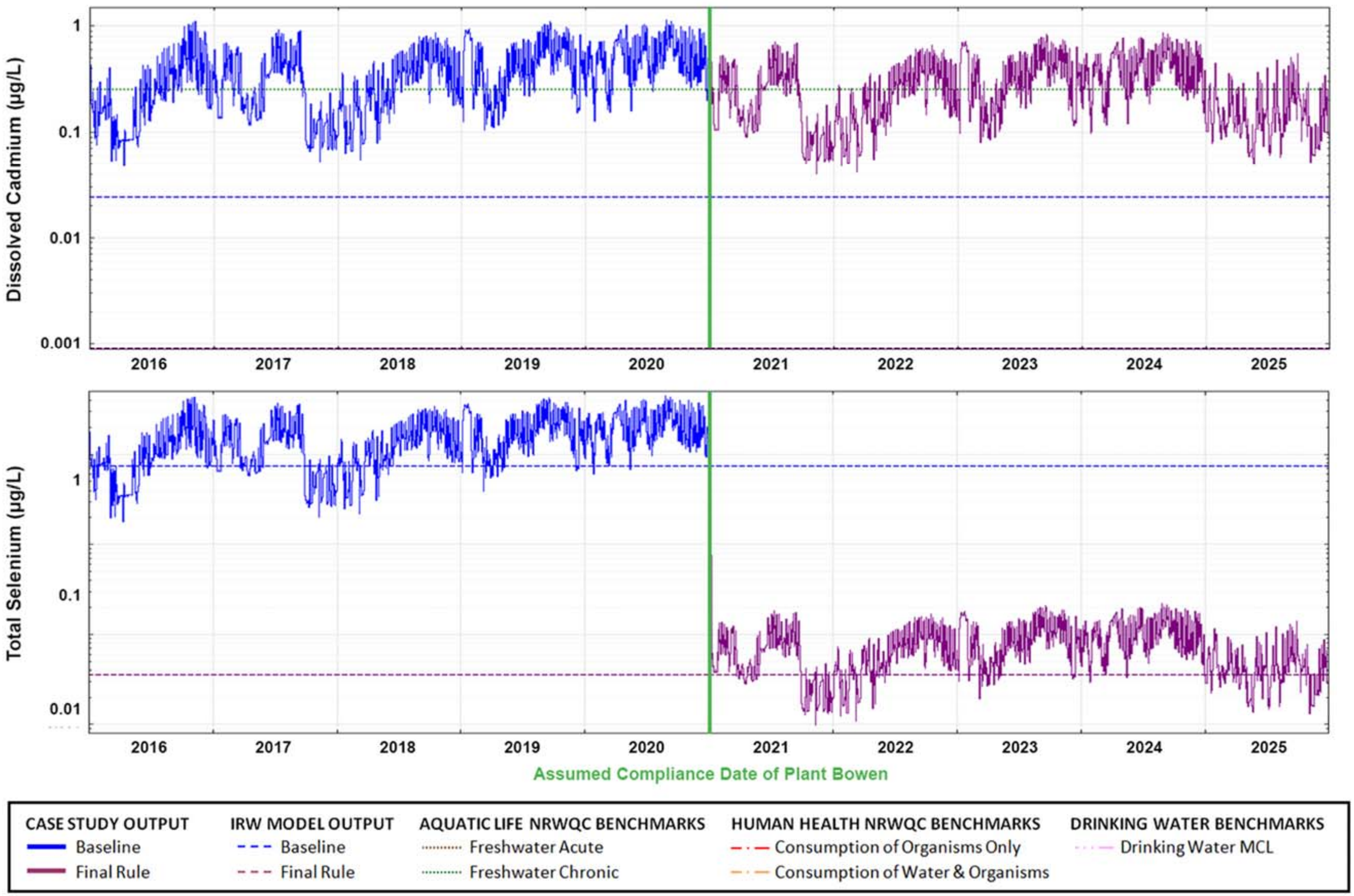

Figure G-7. Modeled Concentrations in Etowah River Water Column at Plant Bowen Immediate Receiving Water (Dissolved Cadmium, Total Selenium)

Table G-19. Average Water Column Concentrations Downstream of Plant Bowen at Baseline

Segment Data				Average Total Water Column Concentration over Modeling Period (µg/L)[a]							
Segment ID	Segment Name	Segment Length (mi)	Distance Downstream (mi)	As	Cd	Cu	Pb	Ni	Se	Tl	Zn
18	Etowah River / IRW	3.61	3.61	3.5521	0.5095	1.6421	0.6667	2.0928	1.4225	1.7789	3.7456
17	Etowah River	1.48	5.09	2.5373	0.3532	1.1484	0.5990	1.4836	1.0056	1.2664	2.5855
16	Etowah River	1.42	6.51	2.4625	0.3077	1.0395	0.4300	1.4091	0.9470	1.2178	2.2000
15	Etowah River	0.58	7.10	2.4351	0.2988	1.0163	0.4017	1.3887	0.9320	1.2025	2.1272
14	Etowah River	1.20	8.29	2.3959	0.2871	0.9850	0.3660	1.3601	0.9111	1.1809	2.0316
13	Etowah River	3.69	11.99	2.4026	0.3190	1.0550	0.4924	1.3918	0.9399	1.1944	2.3093
12	Etowah River	1.09	13.08	2.3771	0.3115	1.0354	0.4681	1.3739	0.9269	1.1805	2.2502
11	Etowah River	1.29	14.36	2.3582	0.2976	1.0034	0.4155	1.3538	0.9108	1.1678	2.1304
10	Etowah River	0.37	14.74	2.4742	0.3076	1.0550	0.4226	1.3632	0.8887	1.2246	2.2114
9	Etowah River	2.95	17.69	2.4181	0.3033	1.0363	0.4246	1.3339	0.8701	1.1972	2.1861
8	Etowah River	2.70	20.39	2.7308	0.5530	1.6659	1.3016	1.7191	1.1694	1.4387	4.2600
7	Etowah River	0.90	21.29	2.6890	0.5256	1.5999	1.1982	1.6785	1.1380	1.4116	4.0264
6	Etowah River	1.26	22.55	2.6458	0.4943	1.5239	1.0827	1.6334	1.1032	1.3821	3.7597
5	Etowah River	2.82	25.38	2.6189	0.4847	1.4972	1.0559	1.6113	1.0873	1.3658	3.6830
4	Etowah River	2.19	27.57	2.7324	0.6494	1.8852	1.7094	1.7807	1.2069	1.4685	5.0578
3	Etowah River	2.48	30.05	2.6886	0.6536	1.8873	1.7431	1.7639	1.1981	1.4495	5.1046
2	Etowah River	1.89	31.94	2.6892	0.6629	1.9009	1.7746	1.7696	1.2032	1.4526	5.1547
1	Etowah River / End	2.81	34.75	2.6554	0.6282	1.8203	1.6351	1.7279	1.1704	1.4270	4.8579

Acronyms: IRW (Immediate receiving water).

a - Concentrations represent the average daily total pollutant concentration in the water column. The averaging period is the entire modeling period after the assumed compliance date.

Table G-20. Average Water Column Concentrations Downstream of Plant Bowen Under Final Rule

Segment Data				Average Total Water Column Concentration over Modeling Period (µg/L)[a]							
Segment ID	Segment Name	Segment Length (mi)	Distance Downstream (mi)	As	Cd	Cu	Pb	Ni	Se	Tl	Zn
18	Etowah River/IRW	3.61	3.61	3.5450	0.3900	1.6162	0.6624	0.9963	0.0072	1.7515	2.2700
17	Etowah River	1.48	5.09	2.5322	0.2704	1.1302	0.5960	0.7063	0.0051	1.2469	1.5668
16	Etowah River	1.42	6.51	2.4576	0.2355	1.0231	0.4278	0.6709	0.0048	1.1990	1.3333
15	Etowah River	0.58	7.10	2.4302	0.2287	1.0003	0.3998	0.6611	0.0047	1.1840	1.2891
14	Etowah River	1.20	8.29	2.3911	0.2197	0.9695	0.3642	0.6475	0.0046	1.1626	1.2312
13	Etowah River	3.69	11.99	2.3978	0.2442	1.0384	0.4900	0.6627	0.0049	1.1760	1.4006
12	Etowah River	1.09	13.08	2.3723	0.2385	1.0191	0.4657	0.6542	0.0049	1.1624	1.3636
11	Etowah River	1.29	14.36	2.3534	0.2278	0.9876	0.4134	0.6446	0.0048	1.1499	1.2910
10	Etowah River	0.37	14.74	2.3036	0.2401	1.0396	0.4206	0.6706	0.0046	1.2071	1.4017
9	Etowah River	2.95	17.69	2.2517	0.2368	1.0212	0.4227	0.6560	0.0045	1.1801	1.3855
8	Etowah River	2.70	20.39	2.5377	0.4328	1.6418	1.2965	0.8479	0.0062	1.4182	2.7158
7	Etowah River	0.90	21.29	2.4979	0.4113	1.5768	1.1935	0.8280	0.0060	1.3915	2.5654
6	Etowah River	1.26	22.55	2.4579	0.3866	1.5019	1.0785	0.8056	0.0059	1.3624	2.3926
5	Etowah River	2.82	25.38	2.4331	0.3791	1.4753	1.0525	0.7947	0.0059	1.3462	2.3441
4	Etowah River	2.19	27.57	2.4324	0.5100	1.8580	1.7033	0.8992	0.0072	1.4481	3.2327
3	Etowah River	2.48	30.05	2.3930	0.5134	1.8602	1.7368	0.8908	0.0072	1.4295	3.2636
2	Etowah River	1.89	31.94	2.3926	0.5197	1.8754	1.7578	0.8939	0.0073	1.4325	3.2965
1	Etowah River/End	2.81	34.75	2.3624	0.4923	1.7955	1.6212	0.8728	0.0072	1.4072	3.1060

Acronyms: IRW (Immediate receiving water).

a - Concentrations represent the average daily total pollutant concentration in the water column. The averaging period is the entire modeling period after the assumed compliance date.

Table G-21. Total Miles of Etowah River with Wildlife And Human Health Impacts at Baseline

Wildlife and Human Health Impact Thresholds	Total Miles with Average Water Column Concentration Translating to Wildlife or Human Health Benchmark Exceedances (mi)							
	As	Cd	Cu	Pb	Ni	Se	Tl	Zn
WL - NEHC, T3 (mink)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
WL - NEHC, T4 (eagle)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
HH - Non-Cancer Adult Subsistence	0.00	0.00	0.00	No RfD	0.00	0.00	34.75	0.00
HH - Non-Cancer Adult Recreational	0.00	0.00	0.00	No RfD	0.00	0.00	34.75	0.00
HH - Non-Cancer Child Subsistence (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	34.75	34.75	0.00
HH - Non-Cancer Child Subsistence (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	34.75	0.00
HH - Non-Cancer Child Recreational (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	34.75	0.00
HH - Non-Cancer Child Recreational (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	34.75	0.00
HH - Cancer Adult Subsistence	3.61	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Adult Recreational	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (6 to <11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (6 to 11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR

Acronyms: WL (Wildlife); HH (Human health); NEHC (No effect hazard concentration); Rfd (Reference dose); LECR (Lifetime excess cancer risk); y.o. (year old).

a – This row represents the most sensitive child fisher cohort.

b – This row represents the least sensitive child fisher cohort.

Table G-22. Total Miles of Etowah River with Wildlife And Human Health Impacts Under Final Rule

Wildlife and Human Health Impact Thresholds	Total Miles with Average Water Column Concentration Translating to Wildlife or Human Health Benchmark Exceedances (mi)							
	As	Cd	Cu	Pb	Ni	Se	Tl	Zn
WL - NEHC, T3 (mink)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
WL - NEHC, T4 (eagle)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
HH - Non-Cancer Adult Subsistence	0.00	0.00	0.00	No RfD	0.00	0.00	34.75	0.00
HH - Non-Cancer Adult Recreational	0.00	0.00	0.00	No RfD	0.00	0.00	34.75	0.00
HH - Non-Cancer Child Subsistence (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	34.75	0.00
HH - Non-Cancer Child Subsistence (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	34.75	0.00
HH - Non-Cancer Child Recreational (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	34.75	0.00
HH - Non-Cancer Child Recreational (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	34.75	0.00
HH - Cancer Adult Subsistence	3.61	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Adult Recreational	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (6 to <11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (6 to 11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR

Acronyms: WL (Wildlife); HH (Human health); NEHC (No effect hazard concentration); Rfd (Reference dose); LECR (Lifetime excess cancer risk); y.o. (year old).

a – This row represents the most sensitive child fisher cohort.

b – This row represents the least sensitive child fisher cohort.

CASE STUDY MODEL SETUPS AND OUTPUTS – LICK CREEK & WHITE RIVER, IN

This section presents information regarding the site-specific design, site-specific input parameters (*e.g.*, background pollutant concentrations, USGS time series flow data), model settings (*e.g.*, sediment transport parameters), and case study modeling results for the Lick Creek and White River case study model.

Model Development & Input Variables

WASP Model Design. The Lick Creek and White River WASP model starts at the convergence of the West Fork White River (COMID 18471042) and the East Fork White River (COMID 18446060). The model extends approximately 52 miles downstream to just upstream of where the White River converges with the Wabash River (COMID 18471318). Petersburg Generating Station's immediate receiving water, Lick Creek (COMID 18471122) is approximately 3 miles downstream of the confluence of the East Fork and West Fork of the White River.

The Lick Creek and White River WASP model consists of 78 modeled segments. Segment IDs 1-19 represent the surface water of the White River with Segment ID 1 being the most downstream segment, Segment ID 19 being the West Fork White River, and Segment 18 being the East Fork White River. Lick Creek, the immediate receiving water, is represented as Segment 76 and intersects the White River between Segment 16 and Segment 17. The remaining model segments represent tributary surface waters (Segment IDs 20-25), the upper benthic layers (Segment IDs 26-50 & 77), and the lower benthic layers (Segment IDs 51-75 & 78). Figure G-8 illustrates the segmentation of the Etowah River WASP model.

The modeling period starts in 1986 (the year the last generating unit at Petersburg Generating Station began operating) and extends through 2034, covering a period of 49 years. Based on Petersburg Generating Station's NPDES permitting cycle, EPA assumes that the plant will achieve the limitations under the final rule by 2019.

Incorporation of Flow Data. EPA used USGS stream flow data from one USGS stream gage to represent inflow at the upstream end of the modeling area of the Lick Creek and White River WASP model. EPA scaled the White River stream gage data from Gage ID 033740000 to account for the difference in drainage area between the actual gage location and the point where the contributing flows enter the modeling area at the East Fork White River and West Fork White River modeling boundaries.

No USGS stream flow data were available on Lick Creek; therefore, EPA used stream flow data from one USGS stream gage on nearby Kessinger Ditch as a surrogate stream to represent inflow from Lick Creek. EPA scaled the Kessinger Ditch stream gage data from Gage ID 03360895 to produce a dataset with an average annual flow rate that closely approximates that of Lick Creek, as defined by NHDPlus Version 1.

Figure G-8 illustrates the two stream flow gages from which EPA incorporated USGS stream flow data. Table G-23 presents additional information about the two stream gages and the time period covered in the stream flow data record at each. Table G-24 presents how EPA incorporated the stream flow data from these stream gages into the model to complete a full record of flow data for the entire modeling period. For all other local inflows, EPA used the mean annual flow defined in NHDPlus Version 1.

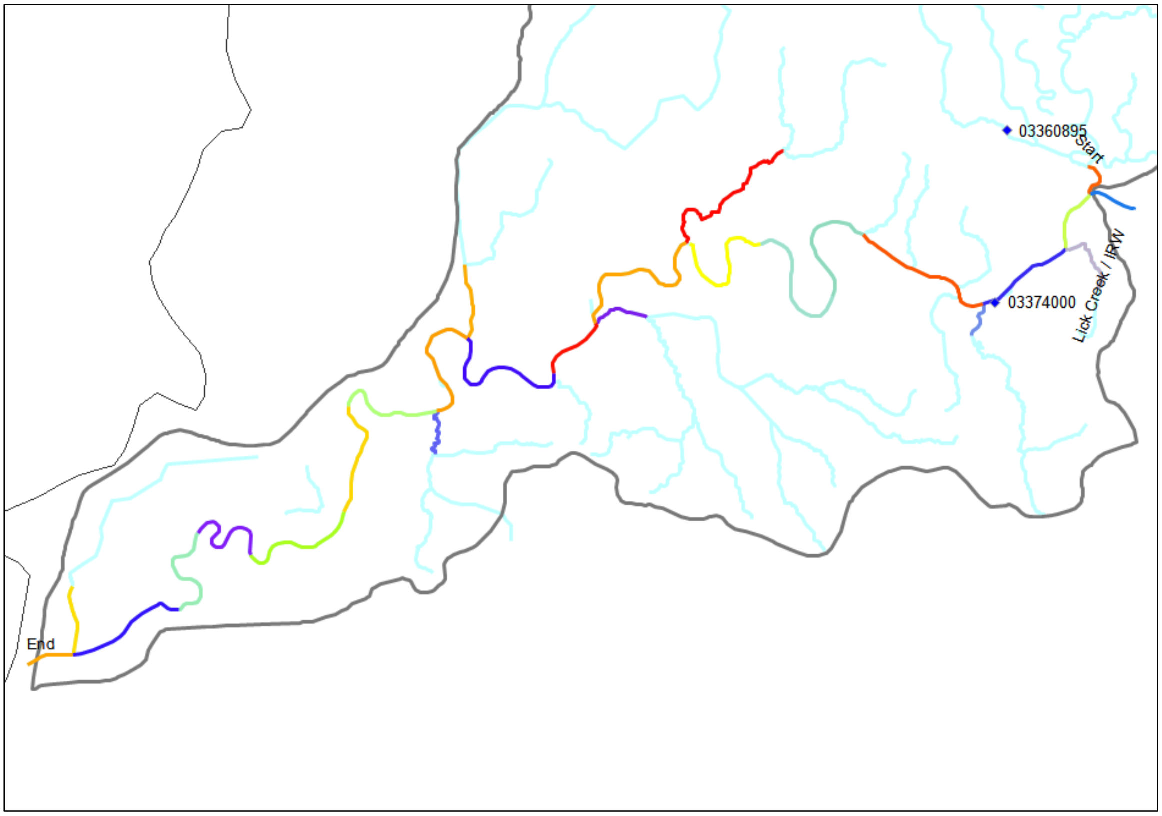

Figure G-8. Geographic Extent and Segmentation – Lick Creek & White River WASP Model

Model Input Variables. Table G-25 presents the pollutant loadings modeled from Petersburg Generating Station at the evaluated wastestream level, both at baseline and after the plant achieves the limitations under the final rule.

Table G-26 presents the pollutant loadings modeled from non-steam electric point sources with 2011 DMR or TRI loadings which would impact the Lick Creek and White River case study model.

Table G-27 presents the pollutant contributions flowing into the Lick Creek and White River WASP model boundaries calculated using available STORET monitoring data.

Table G-28 presents the initial concentrations for the organic solids, sands, and silts/fines values derived from STORET monitoring data collected. For tributaries where STORET monitoring data were not available, EPA assumed the average boundary concentration from all tributaries entering the modeling area. Based on the average of STORET data available within the model, EPA calculated the initial concentrations of organic solids, sands, and silts/fines in the water column segments were 1.99 mg/L, 4.70 mg/L, and 89.24 mg/L, respectively.

EPA calibrated the model outputs by manipulating the sediment transport parameters until the modeled concentrations in the benthic segments closely matched the available sediment concentration monitoring data derived from STORET. Table G-29 presents the sediment transport parameters resulting from EPA's calibration effort. EPA assumed the initial concentrations of organic solids, sands, and silts/fines in the benthic segments were equal to 500 mg/L each.

Model Results

Case study modeling of Lick Creek and the White River revealed water quality benchmark exceedances in the immediate receiving water and/or in downstream segments for arsenic, cadmium, copper, lead, selenium, and thallium. Figure G-9, Figure G-10, Figure G-11, and Figure G-12 illustrate the water concentration outputs for these pollutants in the immediate receiving water before and after the assumed compliance date for the final rule.[9]

Case study modeling of Lick Creek and the White River revealed that average water column concentrations of four pollutants (arsenic, cadmium, selenium, and thallium) in the immediate receiving water and/or downstream segments would trigger exceedances of wildlife and/or human health benchmarks. Table G-30 and Table G-31 illustrate the average modeled pollutant concentration in each water column segment downstream of Petersburg Generating Station (including the immediate receiving water) for baseline and following compliance with the final rule, respectively. Table G-32 and Table G-33 present the total miles with average water column concentrations translating to exceedances of these benchmarks for baseline and under the final rule, respectively.

[9] To improve clarity, Figure G-9, Figure G-10, Figure G-11, and Figure G-12 present the baseline water column concentrations leading up to the assumed compliance date of Petersburg Generating Station. All analyses of the WASP model outputs were performed on the baseline output after the assumed compliance date.

Table G-23. USGS Stream Gages with Flow Data Used in Lick Creek and White River WASP Model

Gage ID	USGS Gage Location	Stream Flow Record Period	Cumulative Drainage Area Represented by Gage (sq km)	Model Boundary	Cumulative Drainage Area at Model Boundary (sq km)	Scale Factor
3374000	White River near Petersburg, IN	Full Record from 04/01/1928 - 12/11/2013	28,825	West Fork White River	13,923	0.483
3374000	White River near Petersburg, IN	Full Record from 04/01/1928 - 12/11/2013	28,825	East Fork White River	14,880	0.516
3360895	Kessinger Ditch near Monroe City, IN	Full Record from 10/01/1992 - 9/30/1998	64.27 [a]	Lick Creek	4.46 [b]	0.069 [c]

Acronyms: USGS (U.S. Geological Survey).

a – This value represents the mean annual flow (in cfs), as defined by NHDPlus Version 1, at gage ID 3360895.

b – This value represents the mean annual flow (in cfs), as defined by NHDPlus Version 1, of the Lick Creek immediate receiving water.

c – This value represents the scale factor determined by the dividend of the mean annual flow of at gage ID 3360895 and the Lick Creek immediate receiving water.

Table G-24. Stream Flow Data Periods – Lick Creek and White River WASP Model

Modeling Period	Corresponding Stream Flow Data Period
White River (Gage ID 3374000)	
01/01/1986 - 12/11/2013	01/01/1986 - 12/11/2013
12/12/2013 – 12/31/2018	12/12/2005 – 12/31/2010
01/01/2002 - 12/11/2029	01/01/1986 - 12/11/2013
12/12/2029 – 12/31/2034	12/12/2005 – 12/31/2010
Kessinger Ditch (Gage ID 3360895)	
01/01/1986 - 9/30/1986	01/01/1998 - 09/30/1998
10/01/1986 - 9/30/1992	10/01/1992 - 09/30/1998
10/01/1992 - 9/30/1998	10/01/1992 - 09/30/1998
10/01/1998 - 9/30/2004	10/01/1992 - 09/30/1998
10/01/2004 - 9/30/2010	10/01/1992 - 09/30/1998
10/01/2010 - 9/30/2016	10/01/1992 - 09/30/1998
10/01/2016 - 12/31/2018	10/01/1992 - 12/31/1994
01/01/2002 - 9/30/2002	01/01/1998 - 09/30/1998
10/01/2002 - 9/30/2008	10/01/1992 - 09/30/1998
10/01/2008 - 9/30/2014	10/01/1992 - 09/30/1998
10/01/2014 - 9/30/2020	10/01/1992 - 09/30/1998
10/01/2020 - 9/30/2026	10/01/1992 - 09/30/1998
10/01/2026 - 9/30/2032	10/01/1992 - 09/30/1998
10/01/2032 - 12/31/2034	10/01/1992 - 12/31/1994

Table G-25. Pollutant Loadings – Petersburg Generating Station

Wastestream	Pollutant Loadings (g/day)							
	As	**Cd**	**Cu**	**Ni**	**Pb**	**Se**	**Tl**	**Zn**
Baseline [a]								
FGD Wastewater [c]	2.86	2.07	1.85	4.47	1.66	455.14	4.81	9.80
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	49.78	25.34	174.33	150.96	79.01	5.40	67.21	152.59
Combustion Residual Leachate	--	--	--	--	--	--	--	--
Total	**52.64**	**27.40**	**176.18**	**155.43**	**80.67**	**460.54**	**96.27**	**162.39**
Final Rule [b]								
FGD Wastewater	2.86	2.07	1.85	3.09	1.66	2.81	4.81	9.80
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	--	--			--			--
Combustion Residual Leachate	--	--	--	--	--	--	--	--
Total	**2.86**	**2.07**	**1.85**	**3.09**	**1.66**	**2.81**	**4.81**	**9.80**

Acronyms: FGD (flue gas desulfurization).

-- -- -- --

a – The baseline pollutant loadings are modeled throughout the entire modeling period (from 01/01/1986 through 12/31/2034).

b – The final rule pollutant loadings are modeled only after the assumed compliance date (from 01/01/2019 through 12/31/2034).

c – In estimating the historical pollutant loadings associated with Petersburg Generating Station's four FGD systems, EPA incorporated the pollutant loadings from FGD wastewater as the systems were installed, between 1977 and 1996. The pollutant loadings associated with FGD systems installed before the start of the modeling period (01/01/1986) are incorporated at the beginning or the model.

Table G-26. Pollutant Contributions from Non-Steam Electric Point Sources – Lick Creek and White River WASP Model

Facility Name	Model COMID	City	Location (lat, long)	Parameter	Average Daily Pollutant Loadings (g/day)
Pride Mine S-321 [a]	18471050 (White River)	Monroe City	(38.54,-87.27)	Cu	9.23
				Ni	9.23
				Zn	9.23

a – EPA identified that this industrial facility is a direct discharger with 2011 DMR loadings.

Table G-27. Pollutant Contributions from STORET Monitoring Data – Lick Creek and White River WASP Model

Model Boundary	Model Boundary COMID	Station ID(s) (lat, long)	Parameter	Average Concentration (µg/L)[a]	Mass Loading (g/day)[b]
West Fork White River	18471042	10947 (38.56,-87.24) 2719 (38.56,-87.24) WWL090-0028 (35.55,-87.24)	As	--	19,498.53
			Cu	--	74,468.84
			Ni	--	130,549.28
			Pb	--	37,390.75
			Zn	--	228,842.01
			TOC	5,104.00	--
			TSS	104,000.00	--
East Fork White River	18446060	2619 (38.54,-87.22)	As	--	17,881.15
			Cd	--	506.03
			Cu	--	35,794.47
			Ni	--	43,219.91
			Pb	--	20,429.79
			Zn	--	134,155.14
			TOC	3,475.43	--
			TSS	62,087.96	--

Table G-27. Pollutant Contributions from STORET Monitoring Data – Lick Creek and White River WASP Model

Model Boundary	Model Boundary COMID	Station ID(s) (lat, long)	Parameter	Average Concentration (µg/L)[a]	Mass Loading (g/day)[b]
Conger Creek	18471078	2511 (38.52,-87.45) 2513 (38.51,-87.45) WWL100-0002 (38.51,-87.44)	Cu	--	1,045.39
			Pb	--	269.15
			Zn	--	2,736.70
			TOC	5,700.00	--
			TSS	95,200.00	--
Upper River Deshee	18471082	2512 (38.52,-87.53)	Pb	--	362.50
			Zn	--	1,100.85
			TOC	3,120.00	--
			TSS	18,600.00	--

Acronyms: TOC (Total Organic Carbon); TSS (Total Suspended Solids).

a –Where more than one monitoring station located on the same tributary system reported acceptable results for the same pollutant, EPA calculated and incorporated the weighted average concentration across the monitoring stations (weighted by number of samples at each station).

b – For the modeled pollutants (not including TOC and TSS), EPA converted the average concentration to a mass loading using the average annual flow rate for the stream reach represented by the monitoring station(s).

Table G-28. Organic Solids, Sands, and Silts/Fines Inputs – Lick Creek and White River WASP Model

Model Boundary	Model Boundary COMID	Organic Solids Concentration (mg/L)[a]	Sands Concentration (mg/L)[b]	Silts/Fines Concentration (mg/L)[c]
West Fork White River	18471042	2.55	5.20	98.80
East Fork White River	18446060	1.74	3.10	58.98
Conger Creek	18471078	2.85	4.76	90.44
Upper River Deshee	18471082	1.56	0.93	17.67
All Other Inflows [d]	N/A	2.17	3.50	66.47

Acronyms: N/A (Not Applicable).

a – The organic solids concentration was calculated using Equation G-1 and the STORET monitoring data presented in Table G-27.

b – The sands concentration was calculated using Equation G-2 and the STORET monitoring data presented in Table G-27.

c – The silts/fines concentration was calculated using Equation G-3 and the STORET monitoring data presented in Table G-27.

d – For tributaries where boundary concentrations from STORET monitoring data were not available, EPA assumed the average boundary concentration from all tributaries entering the modeling area.

Table G-29. Sediment Transport Parameters – Lick Creek and White River WASP Model

Input Parameter	Value Used	Units
TAUcritcoh	3.5	N/m^2
TAU_cD1_si[a]	3.5	N/m^2
TAU_cD2_si[a]	7.0	N/m^2
TAU_cD1_PO[a]	3.5	N/m^2
TAU_cD2_PO[a]	7.0	N/m^2

Note: Table G-1 presents additional solids constants and sediment transport parameters that are used in each of the case study models.

a – This parameter is a WASP model default based on the value of the ‘TAUcritcoh’ parameter.

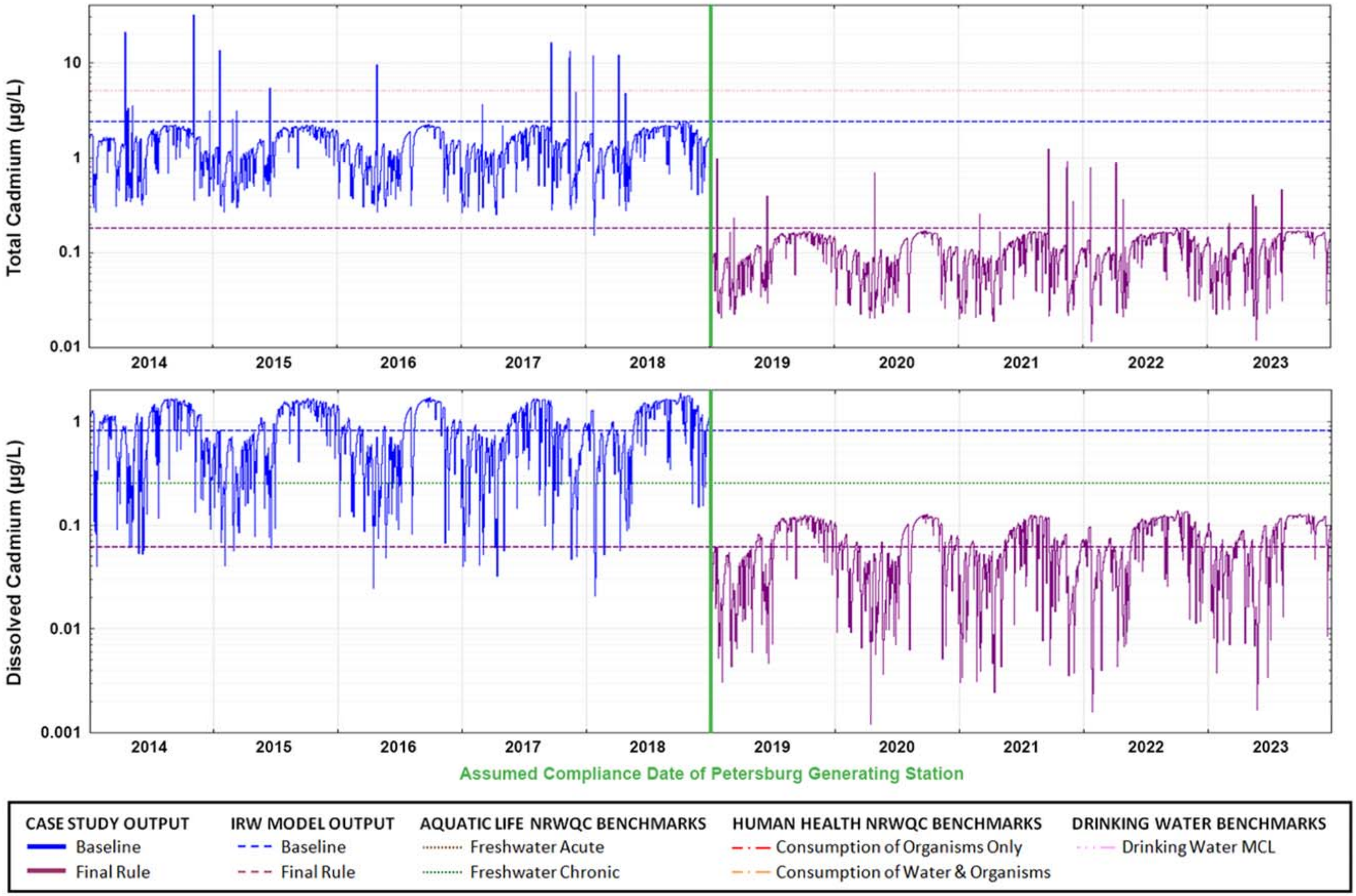

Figure G-9. Modeled Concentrations in Lick Creek Water Column at Petersburg Generating Station Immediate Receiving Water (Total Cadmium, Dissolved Cadmium)

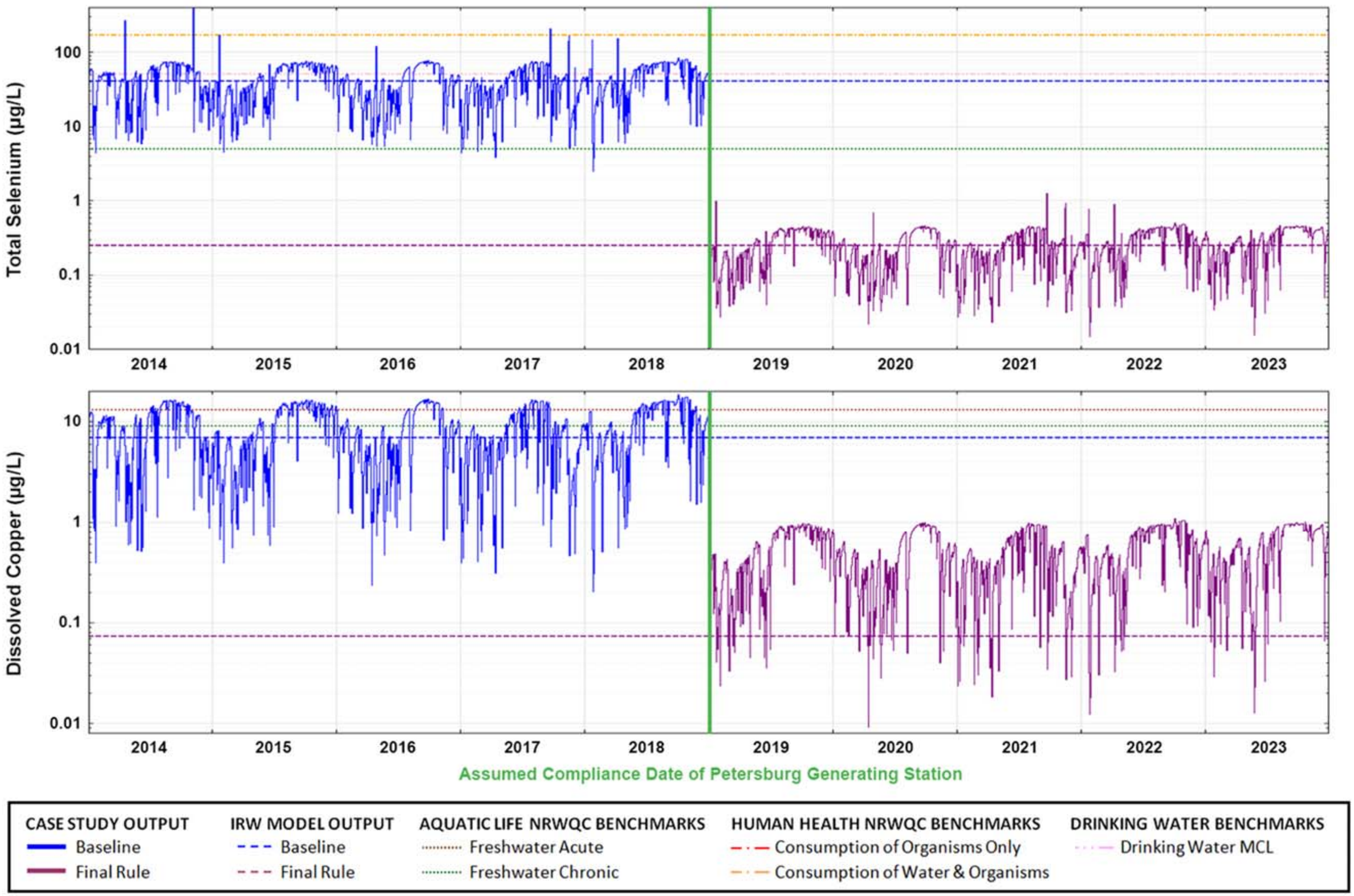

Figure G-10. Modeled Concentrations in Lick Creek Water Column at Petersburg Generating Station Immediate Receiving Water (Total Selenium, Dissolved Copper)

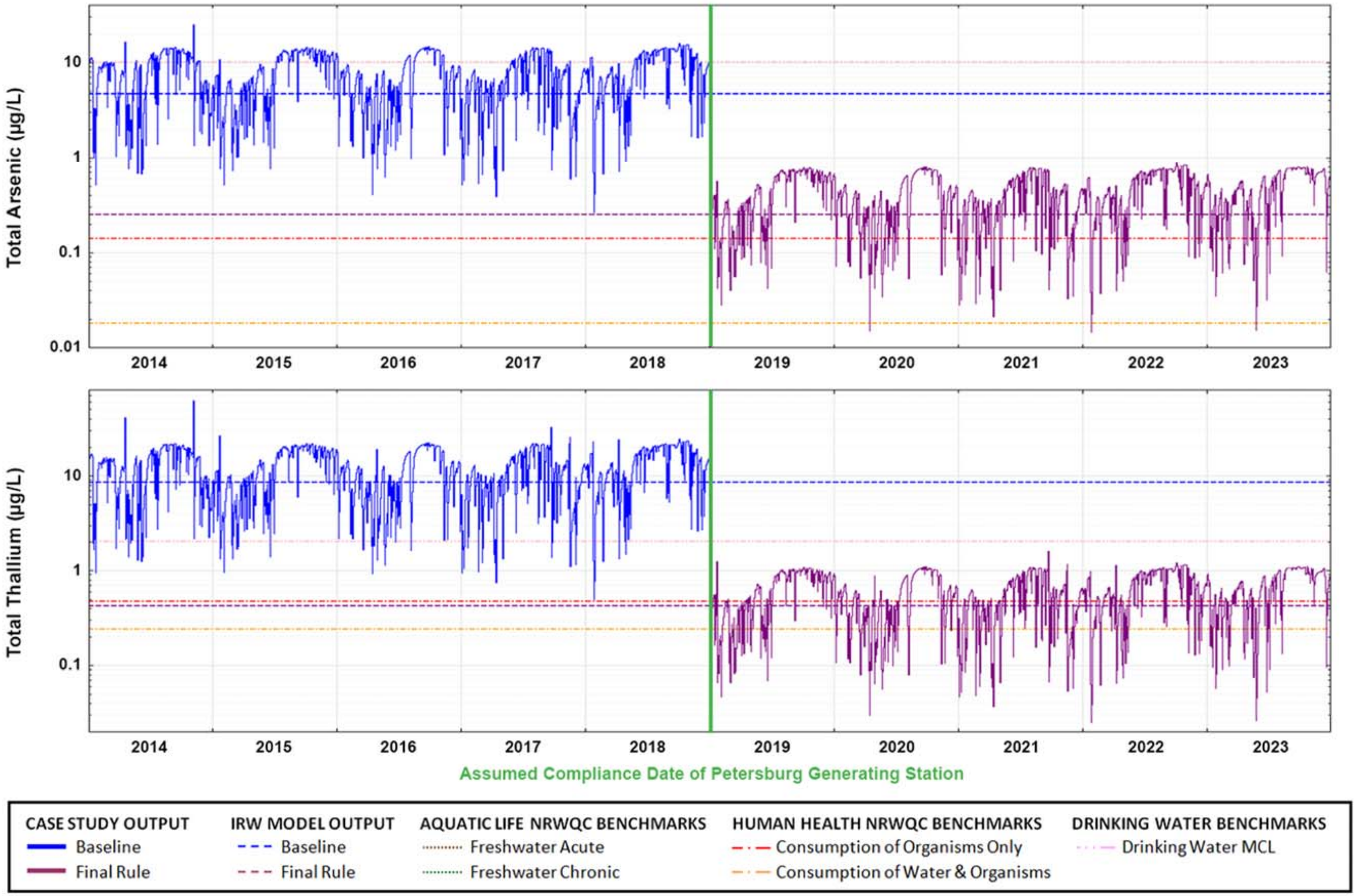

Figure G-11. Modeled Concentrations in Lick Creek Water Column at Petersburg Generating Station Immediate Receiving Water (Total Arsenic, Total Thallium)

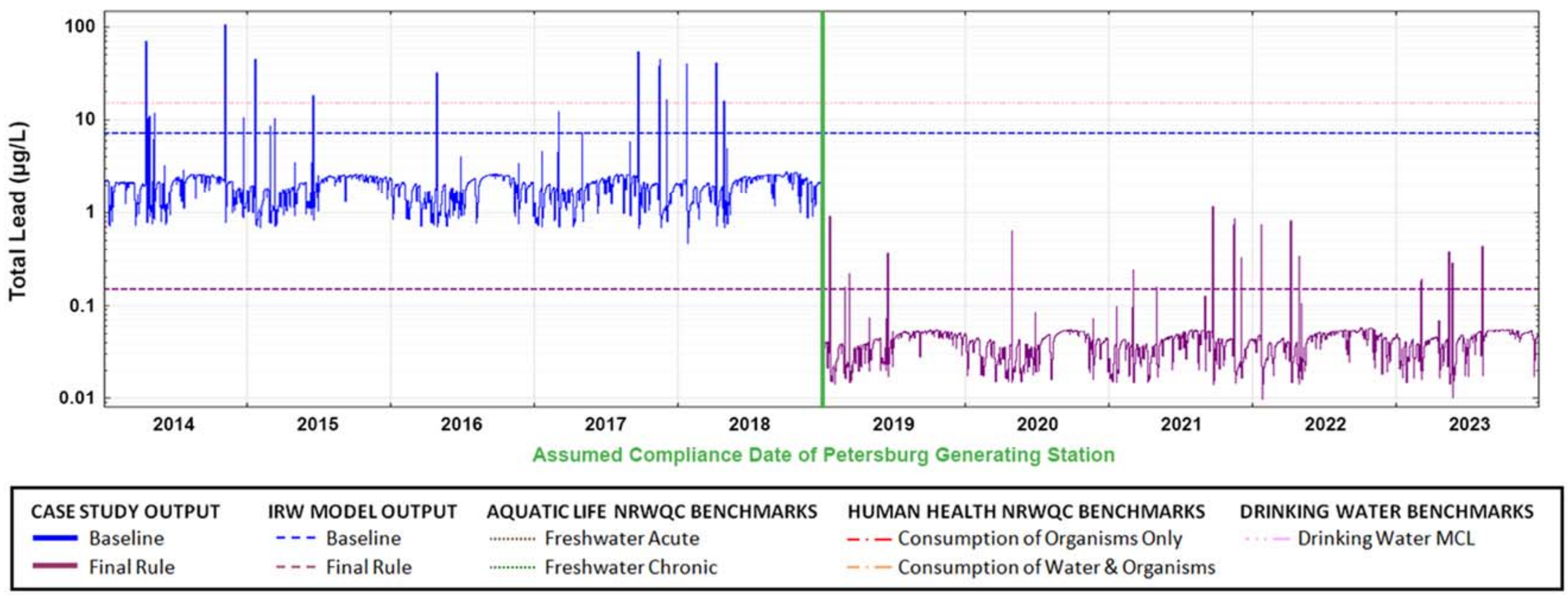

Figure G-12. Modeled Concentrations in Lick Creek Water Column at Petersburg Generating Station Immediate Receiving Water (Total Lead)

Table G-30. Average Water Column Concentrations Downstream of Petersburg Generating Station at Baseline

Segment Data				Average Total Water Column Concentration over Modeling Period (µg/L)[a]							
Segment ID	Segment Name	Segment Length (mi)	Distance Downstream (mi)	As	Cd	Cu	Pb	Ni	Se	Tl	Zn
76	Lick Creek / IRW	1.82	1.82	7.8099	1.4260	12.1623	2.2256	17.0962	43.0318	12.0267	7.9902
16	White River	2.53	4.35	2.1741	0.0169	3.9202	1.4878	7.9745	0.0217	0.0053	11.0843
15	White River	3.64	7.99	1.9842	0.0130	3.1428	1.0360	6.8940	0.0176	0.0046	8.3919
14	White River	3.39	11.38	1.8988	0.0108	2.7187	0.7764	6.3429	0.0156	0.0042	6.8805
13	White River	3.39	14.77	1.8498	0.0096	2.4878	0.6399	6.0350	0.0147	0.0041	6.0692
12	White River	3.39	18.17	1.8294	0.0090	2.3642	0.5643	5.8819	0.0143	0.0040	5.6257
11	White River	4.43	22.59	1.9038	0.0165	3.4944	1.4571	6.9169	0.0290	0.0056	10.2181
10	White River	1.78	24.37	1.8990	0.0197	4.0254	1.8743	7.2995	0.0333	0.0060	12.3741
9	White River	3.88	28.26	1.9106	0.0187	3.8692	1.7404	7.2015	0.0325	0.0059	11.7421
8	White River	3.22	31.48	2.8165	0.0657	11.7204	7.8841	15.3397	0.0872	0.0119	44.4205
7	White River	2.97	34.45	2.9378	0.0572	10.4477	6.5913	14.7231	0.0813	0.0119	38.2040
6	White River	2.97	37.42	2.6471	0.0521	9.4987	6.0681	13.2868	0.0724	0.0105	34.9036
5	White River	2.97	40.39	2.5550	0.0494	9.0307	5.7329	12.7097	0.0687	0.0101	33.1043
4	White River	2.97	43.36	2.4986	0.0474	8.6786	5.4787	12.3055	0.0661	0.0098	31.7293
3	White River	2.97	46.33	2.4569	0.0457	8.3900	5.2645	11.9847	0.0640	0.0095	30.5571
2	White River	2.97	49.30	2.4265	0.0443	8.1520	5.0746	11.7264	0.0623	0.0093	29.5784
1	White River / End	1.17	50.47	2.4061	0.0455	8.3071	5.2341	11.7954	0.0646	0.0095	30.2942

Acronyms: IRW (Immediate receiving water).

a - Concentrations represent the average daily total pollutant concentration in the water column. The averaging period is the entire modeling period after the assumed compliance date.

Table G-31. Average Water Column Concentrations Downstream of Petersburg Generating Station Under Final Rule

Segment Data				Average Total Water Column Concentration over Modeling Period (µg/L)[a]							
Segment ID	Segment Name	Segment Length (mi)	Distance Downstream (mi)	As	Cd	Cu	Pb	Ni	Se	Tl	Zn
76	Lick Creek / IRW	1.82	1.82	0.4306	0.1093	0.7301	0.0469	1.2803	0.2617	0.5995	0.8859
16	White River	2.53	4.35	2.1711	0.0159	3.9132	1.4855	7.9669	0.0001	0.0003	11.0790
15	White River	3.64	7.99	1.9815	0.0123	3.1377	1.0346	6.8877	0.0001	0.0002	8.3882
14	White River	3.39	11.38	1.8962	0.0103	2.7144	0.7754	6.3372	0.0001	0.0002	6.8771
13	White River	3.39	14.77	1.8473	0.0092	2.4838	0.6392	6.0295	0.0001	0.0002	6.0663
12	White River	3.39	18.17	1.8269	0.0086	2.3604	0.5636	5.8767	0.0001	0.0002	5.6229
11	White River	4.43	22.59	1.9010	0.0156	3.4867	1.4556	6.9088	0.0054	0.0006	10.2123
10	White River	1.78	24.37	1.8961	0.0185	4.0157	1.8722	7.2905	0.0064	0.0007	12.3665
9	White River	3.88	28.26	1.9077	0.0176	3.8599	1.7386	7.1928	0.0063	0.0007	11.7352
8	White River	3.22	31.48	2.8120	0.0608	11.6855	7.8735	15.3177	0.0137	0.0013	44.3905
7	White River	2.97	34.45	2.9331	0.0530	10.4162	6.5828	14.7021	0.0129	0.0013	38.1791
6	White River	2.97	37.42	2.6430	0.0484	9.4716	6.0604	13.2683	0.0117	0.0011	34.8812
5	White River	2.97	40.39	2.5510	0.0459	9.0055	5.7261	12.6922	0.0110	0.0011	33.0831
4	White River	2.97	43.36	2.4948	0.0440	8.6545	5.4724	12.2886	0.0106	0.0011	31.7090
3	White River	2.97	46.33	2.4531	0.0425	8.3679	5.2585	11.9682	0.0102	0.0010	30.5324
2	White River	2.97	49.30	2.4228	0.0411	8.1243	5.0689	11.7104	0.0099	0.0010	29.5539
1	White River / End	1.17	50.47	2.4024	0.0421	8.2818	5.2278	11.7788	0.0100	0.0010	30.2683

Acronyms: IRW (Immediate receiving water).

a - Concentrations represent the average daily total pollutant concentration in the water column. The averaging period is the entire modeling period after the assumed compliance date.

Table G-32. Total Miles of Lick Creek and White River with Wildlife And Human Health Impacts at Baseline

Wildlife and Human Health Impact Thresholds	Total Miles with Average Water Column Concentration Translating to Wildlife or Human Health Benchmark Exceedances (mi)							
	As	**Cd**	**Cu**	**Pb**	**Ni**	**Se**	**Tl**	**Zn**
WL - NEHC, T3 (mink)	0.00	0.00	0.00	0.00	0.00	1.82	No NEHC	0.00
WL - NEHC, T4 (eagle)	0.00	0.00	0.00	0.00	0.00	1.82	No NEHC	0.00
HH - Non-Cancer Adult Subsistence	0.00	0.00	0.00	No RfD	0.00	1.82	1.82	0.00
HH - Non-Cancer Adult Recreational	0.00	0.00	0.00	No RfD	0.00	1.82	1.82	0.00
HH - Non-Cancer Child Subsistence (1 to <2 y.o.) [a]	0.00	1.82	0.00	No RfD	0.00	1.82	1.82	0.00
HH - Non-Cancer Child Subsistence (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	1.82	1.82	0.00
HH - Non-Cancer Child Recreational (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	1.82	1.82	0.00
HH - Non-Cancer Child Recreational (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	1.82	1.82	0.00
HH - Cancer Adult Subsistence	1.82	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Adult Recreational	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (6 to <11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (6 to 11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR

Acronyms: WL (Wildlife); HH (Human health); NEHC (No effect hazard concentration); Rfd (Reference dose); LECR (Lifetime excess cancer risk); y.o. (year old).

a – This row represents the most sensitive child fisher cohort.

b – This row represents the least sensitive child fisher cohort.

Table G-33. Total Miles of Lick Creek and White River with Wildlife And Human Health Impacts Under Final Rule

Wildlife and Human Health Impact Thresholds	Total Miles with Average Water Column Concentration Translating to Wildlife or Human Health Benchmark Exceedances (mi)							
	As	Cd	Cu	Pb	Ni	Se	Tl	Zn
WL - NEHC, T3 (mink)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
WL - NEHC, T4 (eagle)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
HH - Non-Cancer Adult Subsistence	0.00	0.00	0.00	No RfD	0.00	0.00	1.82	0.00
HH - Non-Cancer Adult Recreational	0.00	0.00	0.00	No RfD	0.00	0.00	1.82	0.00
HH - Non-Cancer Child Subsistence (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	1.82	0.00
HH - Non-Cancer Child Subsistence (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	1.82	0.00
HH - Non-Cancer Child Recreational (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	1.82	0.00
HH - Non-Cancer Child Recreational (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	1.82	0.00
HH - Cancer Adult Subsistence	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Adult Recreational	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (6 to <11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (6 to 11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR

Acronyms: WL (Wildlife); HH (Human health); NEHC (No effect hazard concentration); Rfd (Reference dose); LECR (Lifetime excess cancer risk); y.o. (year old).

a – This row represents the most sensitive child fisher cohort.

b – This row represents the least sensitive child fisher cohort.

Case Study Model Setups and Outputs – Ohio River, PA/WV/OH

This section presents information regarding the site-specific design, site-specific input parameters (*e.g.*, background pollutant concentrations, USGS time series flow data), model settings (*e.g.*, sediment transport parameters), and case study modeling results for the Ohio River case study model.

Model Development & Input Variables

WASP Model Design. The Ohio River WASP model starts approximately 12 miles upstream of the first steam electric power plant immediate receiving water at COMID 3821033. There are two coal-fired plants modeled in the Ohio River WASP simulation. The upstream plant, Bruce Mansfield plant, discharges to the Ohio River (COMID 3821113) from a large surface impoundment named Little Blue Run. Approximately 13 miles downstream of this immediate receiving water is the W.H. Sammis plant immediate receiving water (COMID 3821343). Ending just upstream of the Cardinal Plant immediate receiving water, the entire Ohio River WASP model is 49 miles long.

The Ohio River WASP model consists of 84 modeled segments. Segment IDs 1-17 represent the surface water of the Ohio River with Segment ID 1 being the most downstream segment and Segment ID 17 being the most upstream segment. The immediate receiving waters of the Bruce Mansfield plant and the W.H. Sammis plant are located at Segment ID 13 and 9, respectively. The remaining model segments represent tributary surface waters (Segment IDs 18-28), the upper benthic layers (Segment IDs 29-56), and the lower benthic layers (Segment IDs 57-84). Figure G-13 illustrates the segmentation of the Ohio River WASP model.

The modeling period starts in 1982 (year of the last revision to the steam electric ELGs) and extends through 2036, covering a period of 55 years. Based on their NPDES permitting cycles, EPA assumes that Bruce Mansfield and W.H. Sammis plants will achieve the limitations under the final rule by 2020 and 2021, respectively. EPA focused the assessment of the improvements under the final rule on the period after the 2021 assumed compliance date for W.H. Sammis Plant.

Incorporation of Flow Data. EPA used USGS stream flow data from one USGS stream gage to represent inflow at the upstream end of the modeling area of the Ohio River WASP model. EPA scaled the Ohio River stream gage data from Gage ID 03086000 to account for the difference in drainage area between the actual gage location and the point where the contributing flows enter the modeling area.

EPA used USGS stream flow data from three USGS stream gages to represent inflow from three tributaries to the Ohio River WASP modeling area, as described below:

- EPA scaled the Little Beaver Creek stream gage data from Gage ID 03109500 to account for the difference in drainage area between the actual gage location and the point where the contributing flows enter the modeling area.
- EPA scaled the Yellow Creek stream gage data from Gage ID 03110000 to account for the difference in drainage area between the actual gage location and the point where the contributing flows enter the modeling area.

- EPA scaled the Raccoon Creek stream gage data from Gage ID 03108000 to account for the difference in drainage area between the actual gage location and the point where the contributing flows enter the modeling area.

Figure G-13 illustrates the two stream flow gages from which EPA incorporated USGS stream flow data. Table G-34 presents additional information about the four stream gages and the time period covered in the stream flow data record at each. Table G-35 presents how EPA incorporated the stream flow data from these stream gages into the model to complete a full record of flow data for the entire modeling period. For all other local inflows, EPA used the mean annual flow defined in NHDPlus Version 1.

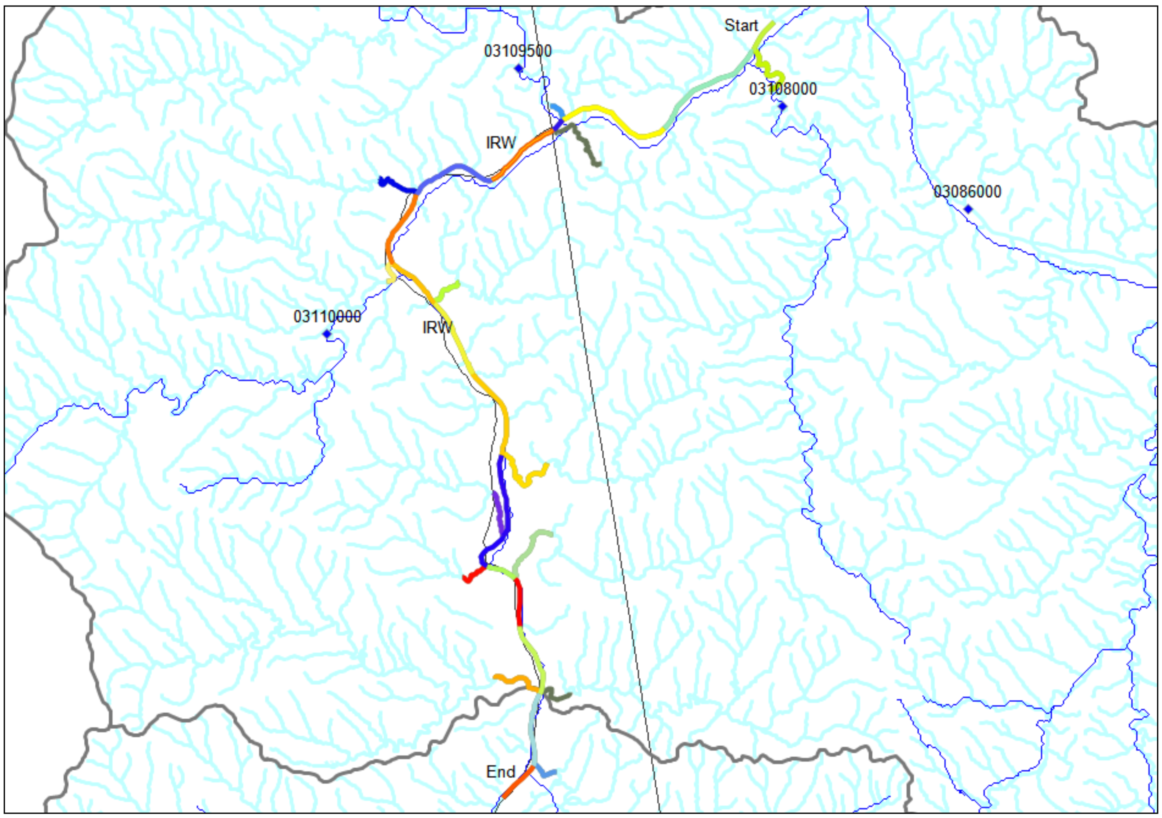

Figure G-13. Geographic Extent and Segmentation – Ohio River WASP Model

Model Input Variables. Table G-36 presents the pollutant loadings modeled from Bruce Mansfield plant at the evaluated wastestream level, both at baseline and after the plant achieves the limitations under the final rule. Table G-37 presents the pollutant loadings modeled from W.H. Sammis plant at the evaluated wastestream level, both at baseline and after the plant achieves the limitations under the final rule.

Table G-38 presents the pollutant loadings modeled from non-steam electric point sources with 2011 DMR or TRI loadings which would impact the Ohio River case study model.

Table G-39 presents the pollutant contributions flowing into the Ohio River WASP model boundaries calculated using available STORET monitoring data.

Table G-40 presents the initial concentrations for the organic solids, sands, and silts/fines values derived from STORET monitoring data collected. For tributaries where STORET monitoring data were not available, EPA assumed the average boundary concentration from all tributaries entering the modeling area. Based on the average of STORET data available within the model, EPA calculated the initial concentrations of organic solids, sands, and silts/fines in the water column segments were 1.36 mg/L, 0.57 mg/L, and 10.85 mg/L, respectively.

EPA calibrated the model outputs by manipulating the sediment transport parameters until the modeled concentrations in the benthic segments closely matched the available sediment concentration monitoring data derived from STORET. Table G-41 presents the sediment transport parameters resulting from EPA's calibration effort. EPA assumed the initial concentrations of organic solids, sands, and silts/fines in the benthic segments were equal to 100 mg/L each.

Model Results

Case study modeling of the Ohio River revealed water quality benchmark exceedances in the W.H. Sammis plant immediate receiving water and/or in downstream segments for arsenic and lead. Figure G-14 illustrates the water concentration outputs for these pollutants in the immediate receiving water before and after the assumed compliance date for the final rule.[10]

Case study modeling of the Ohio River revealed that average water column concentrations of thallium in the W.H. Sammis plant immediate receiving water and/or downstream segments would trigger exceedances of human health benchmarks. Figure G-15 illustrates the water concentration outputs for thallium in the W.H. Sammis plant immediate receiving water before and after the assumed compliance date for the final rule. Table G-42 and Table G-43 illustrate the average modeled pollutant concentration in each water column segment downstream of Bruce Mansfield plant (including the Bruce Mansfield plant immediate receiving water) for baseline and following compliance with the final rule, respectively. Table G-44 and Table G-45 present the total miles with average water column concentrations translating to exceedances of these benchmarks for baseline and under the final rule, respectively.

[10] To improve clarity, Figure G-14 and Figure G-15 present the baseline water column concentrations leading up to the assumed compliance date of Bruce Mansfield plant and W.H. Sammis plant. All analyses of the WASP model outputs were performed on the baseline output after the assumed compliance date.

Table G-34. USGS Stream Gages with Flow Data Used in Ohio River WASP Model

Gage ID	USGS Gage Location	Stream Flow Record Period	Cumulative Drainage Area Represented by Gage (sq km)	Model Boundary	Cumulative Drainage Area at Model Boundary (sq km)	Scale Factor
3086000	Ohio River near Sewickley, PA	Full Record from 01/01/1982 - 09/30/2013	50,475	Ohio River	58,947	1.170
3109500	Little Beaver Creek	Full Record from 01/01/1982 - 09/30/2013	1,286	Little Beaver Creek	1,345	1.046
3110000	Yellow Creek	Full Record from 01/01/1982 - 09/30/2013	382	Yellow Creek	612	1.600
3108000	Raccoon Creek	Full Record from 01/01/1982 - 09/30/2013	464	Raccoon Creek	477	1.028

Acronyms: USGS (U.S. Geological Survey).

Table G-35. Stream Flow Data Periods – Ohio River WASP Model

Modeling Period	Corresponding Stream Flow Data Period
Ohio River (Gage ID 3086000)	
01/01/1982 - 09/30/2013	01/01/1982 - 09/30/2013
10/01/2013 – 12/31/2020	10/01/2005 – 12/31/2012
01/01/1998 - 09/30/2029	01/01/1982 - 09/30/2013
10/01/2029 – 12/31/2036	10/01/2005 – 12/31/2012
Little Beaver Creek (Gage ID 3109500)	
01/01/1982 - 09/30/2013	01/01/1982 - 09/30/2013
10/01/2013 – 12/31/2020	10/01/2005 – 12/31/2012
01/01/1998 - 09/30/2029	01/01/1982 - 09/30/2013
10/01/2029 – 12/31/2036	10/01/2005 – 12/31/2012
Yellow Creek (Gage ID 3110000)	
01/01/1982 - 09/30/2013	01/01/1982 - 09/30/2013
10/01/2013 – 12/31/2020	10/01/2005 – 12/31/2012
01/01/1998 - 09/30/2029	01/01/1982 - 09/30/2013
10/01/2029 – 12/31/2036	10/01/2005 – 12/31/2012
Raccoon Creek (Gage ID 3108000)	
01/01/1982 - 09/30/2013	01/01/1982 - 09/30/2013
10/01/2013 – 12/31/2020	10/01/2005 – 12/31/2012
01/01/1998 - 09/30/2029	01/01/1982 - 09/30/2013
10/01/2029 – 12/31/2036	10/01/2005 – 12/31/2012

Table G-36. Pollutant Loadings – Bruce Mansfield Plant

Wastestream	Pollutant Loadings (g/day)							
	As	**Cd**	**Cu**	**Ni**	**Pb**	**Se**	**Tl**	**Zn**
Baseline [a]								
FGD Wastewater	29.09	431.42	83.34	3,364.27	17.87	4,476.75	52.63	5,335.30
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	50.21	13.86	61.38	231.01	46.21	25.46	235.52	188.79
Combustion Residual Leachate	--	--	--	--	--	--	--	--
Total	**79.30**	**445.28**	**144.72**	**3,595.28**	**64.08**	**4,502.21**	**288.15**	**5,524.09**
Final Rule [b]								
FGD Wastewater	22.35	16.13	14.48	24.16	12.99	21.93	37.58	76.53
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	--	--			--			--
Combustion Residual Leachate	--	--	--	--	--	--	--	--
Total	**22.35**	**16.13**	**14.48**	**24.16**	**12.99**	**21.93**	**37.58**	**76.53**

Acronyms: FGD (flue gas desulfurization).

-- -- -- --

a – The baseline pollutant loadings are modeled throughout the entire modeling period (from 01/01/1982 through 12/31/2036).

b – The final rule pollutant loadings are modeled only after the assumed compliance date (from 01/01/2021 through 12/31/2036).

Table G-37. Pollutant Loadings – W.H. Sammis Plant

Wastestream	Pollutant Loadings (g/day)							
	As	**Cd**	**Cu**	**Ni**	**Pb**	**Se**	**Tl**	**Zn**
Baseline [a]								
FGD Wastewater [c]	5.82	4.20	3.77	9.09	3.38	925.46	9.78	19.92
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	353.61	97.59	432.31	1,626.99	325.44	179.30	1,658.76	1,329.69
Combustion Residual Leachate	2.34	0.62	0.46	2.83	-	6.75	0.07	12.82
Total	**361.77**	**102.41**	**436.54**	**1,638.91**	**328.82**	**1,111.51**	**1,668.61**	**1,362.43**
Final Rule [b]								
FGD Wastewater	5.82	4.20	3.77	6.29	3.38	5.71	9.78	19.92
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	--	--			--			--
Combustion Residual Leachate	2.34	0.62	0.46	2.83	-	6.75	0.07	12.82
Total	**8.16**	**4.82**	**4.23**	**9.12**	**3.38**	**12.46**	**9.85**	**32.74**

Acronyms: FGD (flue gas desulfurization).

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a – The baseline pollutant loadings are modeled from 01/01/1982 through 12/31/2036.

b – The final rule pollutant loadings are modeled from 01/01/2021 through 12/31/2036.

c - In estimating the historical pollutant loadings associated with W.H. Sammis plant's three FGD systems, EPA incorporated the pollutant loadings from FGD wastewater as the systems were installed, between March and May 2010. EPA did not model any FGD wastewater pollutant loadings before the installation of W.H. Sammis plant's first FGD system.

Table G-38. Pollutant Contributions from Non-Steam Electric Point Sources –Ohio River WASP Model

Facility Name	Model COMID	City, State	Location (lat, long)	Parameter	Average Daily Pollutant Loadings (g/day)
City of Chester [a]	3821165 (Ohio River)	Chester, WV	(40.61,-80.57)	Cu	32.63
				Pb	24.40
				Zn	87.47
East Liverpool WWTP [a]	3821167 (Ohio River)	East Liverpool, OH	(40.62,-80.58)	Cu	13.96
				Zn	375.00
Town of Newell [a]	3821149 (Ohio River)	Newell, WV	(40.62,-80.61)	Cu	3.92
				Pb	1.49
				Zn	6.80
Wellsville STP [a]	3821273 (Ohio River)	Wellsville, OH	(40.60,-80.66)	Cu	48.94
				Pb	2.64
				Zn	134.64
Hancock County PSD [a]	3821301 (Ohio River)	New Cumberland, WV	(40.58,-80.66)	Cu	4.69
				Pb	1.57
Hancock County PSD WWTP [a]	3821355 (Ohio River)	New Cumberland, WV	(40.51,-80.62)	Cu	6.05
				Pb	0.87
				Zn	45.16
City of New Cumberland [a]	3824147 (Ohio River)	New Cumberland, WV	(40.49,-80.60)	Cu	6.85
				Pb	0.48
				Zn	18.25
Toronto WWTP [a]	3824175 (Ohio River)	Toronto, OH	(40.50,-80.61)	Zn	150.75

Table G-38. Pollutant Contributions from Non-Steam Electric Point Sources –Ohio River WASP Model

Facility Name	Model COMID	City, State	Location (lat, long)	Parameter	Average Daily Pollutant Loadings (g/day)
City of Weirton [a]	3824185 (Ohio River)	Weirton, WV	(40.38,-80.61)	As	12.03
				Cd	15.49
				Cu	149.90
				Ni	101.78
				Pb	60.88
				Zn	1,040.57
City of Steubenville, Wastewater Treatment Plant [a]	3824195 (Ohio River)	Steubenville, OH	(40.36,-80.61)	Cu	116.49
				Zn	560.18
City of Follansbee [a]	3824211 (Ohio River)	Follansbee, WV	(40.32,-80.60)	As	1.47
				Cd	14.91
				Cu	183.20
				Ni	24.38
				Pb	14.08
				Zn	392.83
Mingo Junction WTP [a]	19453097 (Cross Creek)	Mingo Junction, OH	(40.31,-80.61)	Cu	35.80
City of Wellsburg [a]	19453103 (Ohio River)	Wellsburg, WV	(40.27,80.62)	As	436.14
				Cd	31.90
				Cu	1,159.12
				Ni	2.26
				Pb	0.24
				Zn	20.64
CBS Beaver Groundwater Remediation [b]	3821033 (Two Mile Run)	Beaver, PA	(40.69,-80.31)	Zn	1,772.26

Table G-38. Pollutant Contributions from Non-Steam Electric Point Sources –Ohio River WASP Model

Facility Name	Model COMID	City, State	Location (lat, long)	Parameter	Average Daily Pollutant Loadings (g/day)
Horsehead Corp Monaca Smelter [b]	3821033 (Ohio River)	Monaca, PA	(40.67,-80.34)	As	16.34
				Cd	66.43
				Cu	190.61
				Pb	63.10
				Se	12.39
				Zn	1,259.91
BASF Monaca Plant [b]	3821039 (Ohio River)	Monaca, PA	(40.66,-80.35)	Zn	257.26
Lyondell Chem Beaver Valley [b]	3821057 (Ohio River)	Monaca, PA	(40.66,-80.36)	Cu	72.06
				Ni	64.22
				Pb	36.23
				Zn	83.68
Allegheny Technologies Midland Plant [b]	3821109 (Ohio River)	Midland, PA	(40.64,-80.47)	Ni	441.29
Heritage-WTI Inc. [b]	3821157 (Ohio River)	East Liverpool, OH	(40.63,-80.55)	As	0.84
				Cd	0.57
				Cu	5.42
				Ni	2.69
				Pb	5.00
				Zn	48.85
Homer Laughlin China Co [b]	3821149 (Ohio River)	Newell, WV	(40.62,-80.61)	Cd	1.13
				Ni	7.71
				Pb	0.99
				Se	1.45
				Zn	1,101.25

Table G-38. Pollutant Contributions from Non-Steam Electric Point Sources –Ohio River WASP Model

Facility Name	Model COMID	City, State	Location (lat, long)	Parameter	Average Daily Pollutant Loadings (g/day)
Ergon West Virginia Inc [b]	3821189 (Ohio River)	Newell, WV	(40.61,-80.63)	As	304.33
				Cu	7.99
				Zn	13.55
Marsh Bellofram Corporation [b]	3821301 (Ohio River)	Newell, WV	(40.58,-80.65)	Cu	2.24
				Ni	0.30
				Pb	0.15
				Zn	1.03
Mountaineer Park Incorporated [b]	3821301 (Ohio River)	Chester, WV	(40.57,-80.65)	Cu	2,669.15
				Pb	2,358.45
				Zn	36,768.62
Titanium Metals Corp [b]	3824175 (Ohio River)	Toronto, OH	(40.45,-80.61)	Cu	0.09
				Zn	1.63
Mittal Steel USA Weirton Inc [b]	3824175 (Ohio River)	Weirton, WV	(40.43,-80.60)	Cu	385.18
				Ni	63.48
				Pb	182.75
				Se	252.54
				Zn	1,935.80
Severstal Wheeling Inc - Steubenville Plant [b]	3824211 (Ohio River)	Steubenville, OH	(40.35,-80.61)	Zn	1,042.47
Severstal Wheeling Inc - Follansbee [b]	3824211 (Ohio River)	Follansbee, WV	(40.35,-80.61)	As	250.85
				Cd	0.01
				Cu	201.14
				Ni	0.06
				Pb	0.33
				Se	3,364.80
				Zn	460.56

Table G-38. Pollutant Contributions from Non-Steam Electric Point Sources –Ohio River WASP Model

Facility Name	Model COMID	City, State	Location (lat, long)	Parameter	Average Daily Pollutant Loadings (g/day)
RG Steel Wheeling LLC Beech Bottom Plant [b]	3824211 (Ohio River)	Beech Bottom, WV	(40.35,-80.61)	As	2.22
				Cu	3.57
				Ni	68.46
				Pb	2.86
				Se	5.92
				Zn	229.79
Koppers Follansbee Tar Plant [b]	3824211 (Ohio River)	Follansbee, WV	(40.34,-80.61)	As	11.94
				Se	2.33
				Zn	15.42
Wheeling-Nisshin [b]	3824211 (Ohio River)	Follansbee, WV	(40.33,-80.60)	Pb	5.06
				Zn	55.43
Wheeling Pittsburgh Steel Steubenville South Mingo [b]	3824211 (Ohio River)	Mingo Junction, OH	(40.32,-80.60)	Cu	0.73
				Zn	9.33
NGC Industries LLC A Subsidiary [c]	3821097 (Ohio River)	Shippingport, PA	(40.63,-80.42)	Pb	0.62
Whemco-Steel Castings Inc [c]	3821109 (Ohio River)	Midland, PA	(40.63,-80.45)	Ni	0.76
Mittal Steel USA Weirton Inc [c]	3824175 (Ohio River)	Weirton, WV	(40.42,-80.60)	Cu	518.22
				Ni	134.22
				Pb	334.29
				Zn	1,923.75

a – EPA identified that this publicly operated treatment works (POTW) facility is a direct discharger with 2011 DMR loadings.

b - EPA identified that this industrial facility is a direct discharger with 2011 DMR loadings.

c - EPA identified that this facility is a direct discharger with 2011 TRI loadings.

Table G-39. Pollutant Contributions from STORET Monitoring Data – Ohio River WASP Model

Model Boundary	Model Boundary COMID	Station ID(s) (lat, long)	Parameter	Average Concentration (µg/L)[a]	Mass Loading (g/day)[b]
Ohio River	3821033	WQN0902 (40.53,-80.19)	Cu	--	175,758.13
			Ni	--	126,664.12
			Pb	--	79,371.40
			Zn	--	1,247,520.00
			TOC	2,426.67	--
			TSS	21,434.78	--
Raccoon Creek	3821043	WQN0903 (40.63,-80.34)	Cu	--	376.43
			Ni	--	1,663.34
			Pb	--	525.00
			Zn	--	13,504.33
			TOC	2,232.63	--
			TSS	16,893.62	--
Buffalo Creek	19453099	O-092-0004 (40.26,-80.55) O-092-0003 (40.25,-80.59) O-092-0001 (40.24,-80.59) O-092-0012 (40.23,-80.52) O-092-0006 (40.20,-80.60) O-092-0002 (40.20,-80.56) O-092-0007 (40.19,-80.55) O-092-0008 (40.16,-80.53)	TSS	10,333.33	--

Acronyms: TOC (Total Organic Carbon); TSS (Total Suspended Solids).

a –Where more than one monitoring station located on the same tributary system reported acceptable results for the same pollutant, EPA calculated and incorporated the weighted average concentration across the monitoring stations (weighted by number of samples at each station).

b – For the modeled pollutants (not including TOC and TSS), EPA converted the average concentration to a mass loading using the average annual flow rate for the stream reach represented by the monitoring station(s).

Table G-40. Organic Solids, Sands, and Silts/Fines Inputs – Ohio River WASP Model

Model Boundary	Model Boundary COMID	Organic Solids Concentration (mg/L)[a]	Sands Concentration (mg/L)[b]	Silts/Fines Concentration (mg/L)[c]
Ohio River	3821033	1.21	1.07	20.36
Raccoon Creek	3821043	1.12	0.84	16.05
Buffalo Creek	3821043	*	0.52 [e]	9.82 [e]
All Other Inflows [d]	N/A	1.16	0.81	15.41

Acronyms: N/A (Not Applicable).

* – No TOC results available. The 'All Other Inflows' concentration was used in this scenario.

a – The organic solids concentration was calculated using Equation G-1 and the STORET monitoring data presented in Table G-39.

b – The sands concentration was calculated using Equation G-2 and the STORET monitoring data presented in Table G-39.

c – The silts/fines concentration was calculated using Equation G-3 and the STORET monitoring data presented in Table G-39.

d – For tributaries where boundary concentrations from STORET monitoring data were not available, EPA assumed the average boundary concentration from all tributaries entering the modeling area.

e – These concentrations were calculated using the 'All Other Inflows' concentration.

Table G-41. Sediment Transport Parameters – Ohio River WASP Model

Input Parameter	Value Used	Units
TAUcritcoh	3.5	N/m^2
TAU_cD1_si[a]	3.5	N/m^2
TAU_cD2_si[a]	7.0	N/m^2
TAU_cD1_PO[a]	3.5	N/m^2
TAU_cD2_PO[a]	7.0	N/m^2

Note: Table G-1 presents additional solids constants and sediment transport parameters that are used in each of the case study models.

a – This parameter is a WASP model default based on the value of the 'TAUcritcoh' parameter.

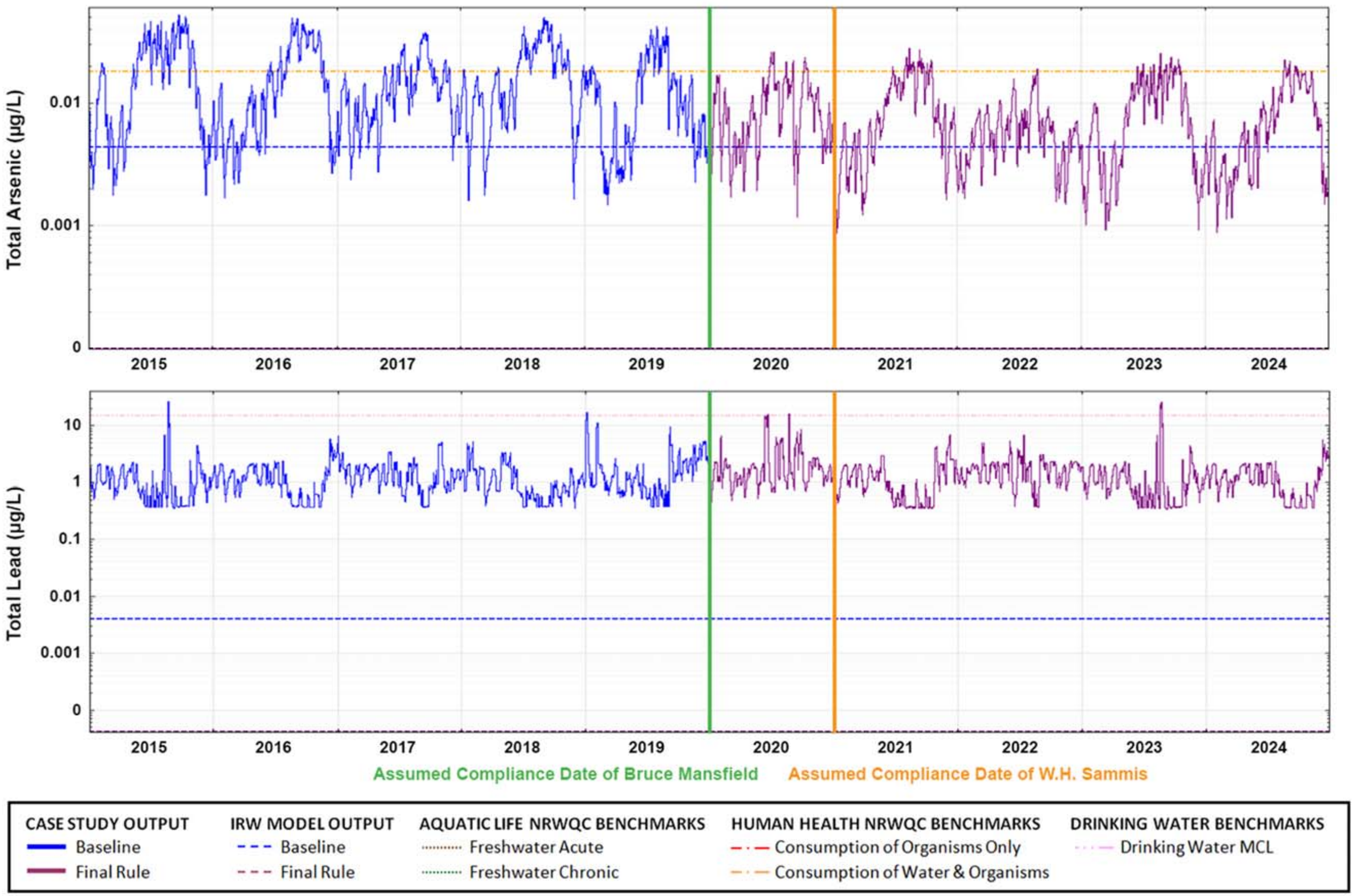

Figure G-14. Modeled Concentrations in Ohio River Water Column at W.H. Sammis Plant Immediate Receiving Water (Total Arsenic, Total Lead)

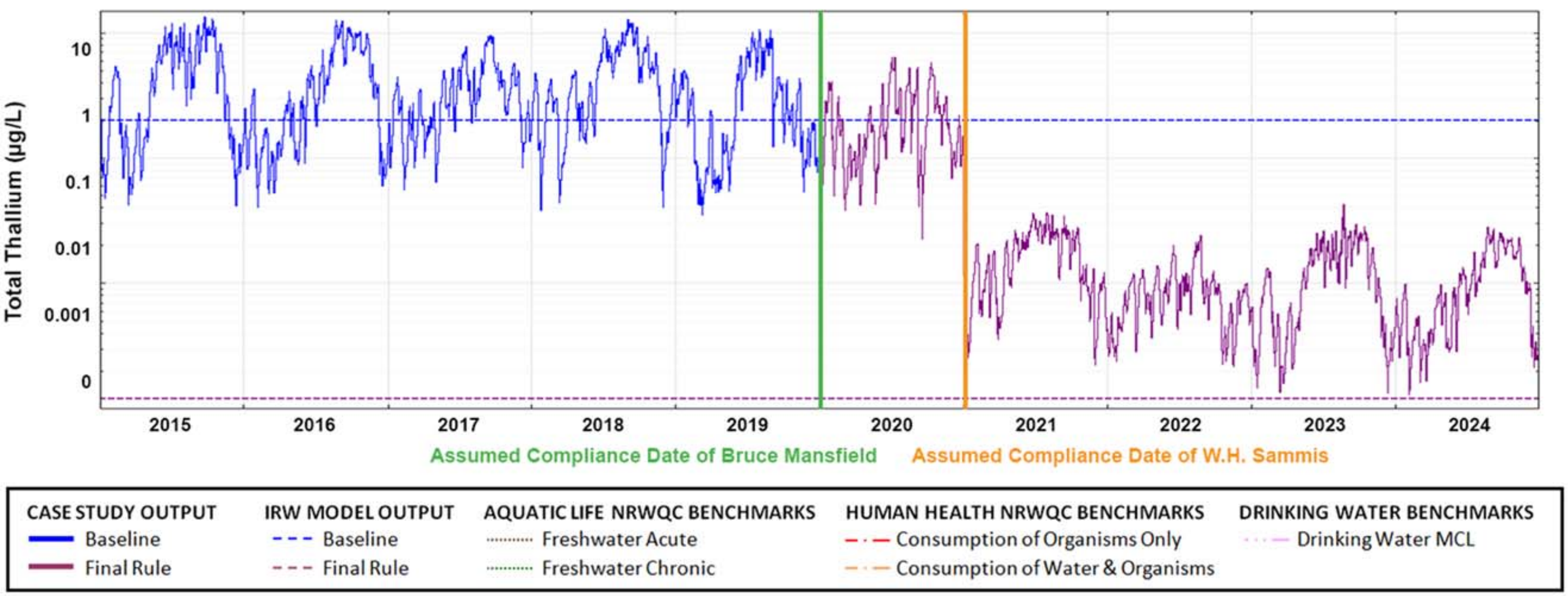

Figure G-15. Modeled Concentrations in Ohio River Water Column at W.H. Sammis Plant Immediate Receiving Water (Total Thallium)

Table G-42. Average Water Column Concentrations Downstream of Bruce Mansfield Plant at Baseline

Segment Data				Average Total Water Column Concentration over Modeling Period (µg/L)[a]							
Segment ID	Segment Name	Segment Length (mi)	Distance Downstream (mi)	As	Cd	Cu	Pb	Ni	Se	Tl	Zn
13	Ohio River / Mansfield IRW	3.31	3.31	0.0020	0.0082	2.6416	0.6965	2.4564	0.0867	0.0058	15.5174
12	Ohio River	3.71	7.02	0.0083	0.0094	2.8186	0.8586	2.4577	0.0883	0.0057	17.6384
11	Ohio River	3.26	10.29	0.0083	0.0111	3.1227	0.9913	2.5719	0.0939	0.0059	20.0130
10	Ohio River	2.40	12.69	0.0093	0.0145	3.9276	1.4032	3.0175	0.1118	0.0067	26.6303
9	Ohio River / Sammis IRW	3.43	16.12	0.0158	0.0165	3.8615	1.4652	2.8946	0.1285	0.0394	26.8808
8	Ohio River	3.88	20.00	0.0165	0.0147	3.6063	1.1281	2.9481	0.1275	0.0401	23.2738
7	Ohio River	3.45	23.45	0.0157	0.0127	3.2123	0.9050	2.7435	0.1225	0.0380	19.8669
6	Ohio River	1.76	25.21	0.0155	0.0121	3.0856	0.8119	2.6984	0.1200	0.0375	18.6383
5	Ohio River	1.33	26.54	0.0157	0.0120	3.0046	0.7527	2.6689	0.1183	0.0372	17.8563
4	Ohio River	2.02	28.56	0.0156	0.0117	2.9513	0.7228	2.6419	0.1171	0.0369	17.3905
3	Ohio River	3.08	31.64	0.0209	0.0182	3.1309	0.8725	2.7427	0.1877	0.0371	19.0188
2	Ohio River	3.06	34.70	0.0202	0.0183	3.0956	0.9017	2.6655	0.1836	0.0360	19.1172
1	Ohio River / End	1.85	36.55	0.0285	0.0195	3.1928	0.9529	2.6998	0.1859	0.0362	19.7848

Acronyms: IRW (Immediate receiving water).

a - Concentrations represent the average daily total pollutant concentration in the water column. The averaging period is the entire modeling period after the assumed compliance date.

Table G-43. Average Water Column Concentrations Downstream of Bruce Mansfield Plant Under Final Rule

Segment Data				Average Total Water Column Concentration over Modeling Period (µg/L)[a]							
Segment ID	Segment Name	Segment Length (mi)	Distance Downstream (mi)	As	Cd	Cu	Pb	Ni	Se	Tl	Zn
13	Ohio River / Mansfield IRW	3.31	3.31	0.0008	0.0011	2.6393	0.6959	2.3863	0.0006	0.0008	15.4307
12	Ohio River	3.71	7.02	0.0072	0.0013	2.8161	0.8577	2.3875	0.0007	0.0007	17.5355
11	Ohio River	3.26	10.29	0.0071	0.0016	3.1199	0.9900	2.4986	0.0012	0.0008	19.8906
10	Ohio River	2.40	12.69	0.0080	0.0020	3.9241	1.4013	2.9313	0.0014	0.0009	26.4824
9	Ohio River / Sammis IRW	3.43	16.12	0.0076	0.0021	3.8493	1.4561	2.7809	0.0016	0.0010	26.7054
8	Ohio River	3.88	20.00	0.0080	0.0019	3.5949	1.1213	2.8337	0.0016	0.0011	23.1208
7	Ohio River	3.45	23.45	0.0076	0.0016	3.2019	0.8995	2.6370	0.0063	0.0010	19.7342
6	Ohio River	1.76	25.21	0.0075	0.0016	3.0756	0.8069	2.5936	0.0062	0.0010	18.5127
5	Ohio River	1.33	26.54	0.0077	0.0018	2.9948	0.7481	2.5653	0.0061	0.0010	17.7351
4	Ohio River	2.02	28.56	0.0077	0.0018	2.9417	0.7183	2.5393	0.0061	0.0010	17.2733
3	Ohio River	3.08	31.64	0.0130	0.0075	3.1209	0.8674	2.6388	0.0746	0.0010	18.8868
2	Ohio River	3.06	34.70	0.0125	0.0076	3.0855	0.8961	2.5642	0.0731	0.0010	18.9822
1	Ohio River / End	1.85	36.55	0.0208	0.0084	3.1826	0.9468	2.5974	0.0738	0.0010	19.6433

Acronyms: IRW (Immediate receiving water).

a - Concentrations represent the average daily total pollutant concentration in the water column. The averaging period is the entire modeling period after the assumed compliance date.

Table G-44. Total Miles of Ohio River with Wildlife And Human Health Impacts at Baseline

Wildlife and Human Health Impact Thresholds	Total Miles with Average Water Column Concentration Translating to Wildlife or Human Health Benchmark Exceedances (mi)							
	As	Cd	Cu	Pb	Ni	Se	Tl	Zn
WL - NEHC, T3 (mink)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
WL - NEHC, T4 (eagle)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
HH - Non-Cancer Adult Subsistence	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Adult Recreational	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Subsistence (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	23.86	0.00
HH - Non-Cancer Child Subsistence (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Recreational (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Recreational (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Cancer Adult Subsistence	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Adult Recreational	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (6 to <11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (6 to 11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR

Acronyms: WL (Wildlife); HH (Human health); NEHC (No effect hazard concentration); Rfd (Reference dose); LECR (Lifetime excess cancer risk); y.o. (year old).

a – This row represents the most sensitive child fisher cohort.

b – This row represents the least sensitive child fisher cohort.

Table G-45. Total Miles of Ohio River with Wildlife And Human Health Impacts Under Final Rule

Wildlife and Human Health Impact Thresholds	Total Miles with Average Water Column Concentration Translating to Wildlife or Human Health Benchmark Exceedances (mi)							
	As	Cd	Cu	Pb	Ni	Se	Tl	Zn
WL - NEHC, T3 (mink)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
WL - NEHC, T4 (eagle)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
HH - Non-Cancer Adult Subsistence	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Adult Recreational	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Subsistence (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Subsistence (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Recreational (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Recreational (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Cancer Adult Subsistence	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Adult Recreational	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (6 to <11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (6 to 11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR

Acronyms: WL (Wildlife); HH (Human health); NEHC (No effect hazard concentration); Rfd (Reference dose); LECR (Lifetime excess cancer risk); y.o. (year old).

a – This row represents the most sensitive child fisher cohort.

b – This row represents the least sensitive child fisher cohort.

CASE STUDY MODEL SETUPS AND OUTPUTS – MISSISSIPPI RIVER, MO/IL

This section presents information regarding the site-specific design, site-specific input parameters (*e.g.*, background pollutant concentrations, USGS time series flow data), model settings (*e.g.*, sediment transport parameters), and case study modeling results for the Mississippi River case study model.

Model Development & Input Variables

WASP Model Design. The Mississippi River WASP model encompasses a 46-mile-long reach of the Mississippi River, 23 miles of which is downstream of the Rush Island plant immediate receiving water (COMID 3629181). The model has two start boundaries that are on the Meramec River (COMID 5052703) and Mississippi River (COMID 3629071) shortly upstream of their confluence. This model ends at the confluence of the Mississippi River and Kaskaskia River (COMID 5089872).

The Mississippi River WASP model consists of 90 modeled segments. Segment IDs 1-16 represent the surface water of the Ohio River with Segment ID 1 being the most downstream segment and Segment ID 16 being the most upstream segment. The Meramec River start boundary, which is also the Meramec plant's immediate receiving water (COMID 5052703), is represented by Segment ID 17. The immediate receiving water of the Rush Island is located at Segment ID 9. The remaining model segments represent tributary surface waters (Segment IDs 18-30), the upper benthic layers (Segment IDs 31-60), and the lower benthic layers (Segment IDs 61-90). Figure G-16 illustrates the segmentation of the Mississippi River WASP model.

The modeling period starts in 1982 (year of the last revision to the steam electric ELGs) and extends through 2036, covering a period of 55 years. Based on their NPDES permitting cycles, EPA assumes that the Meramec and Rush Island plants will achieve the limitations under the final rule by 2019 and 2023, respectively. For the Rush Island plant's immediate receiving water and downstream reaches, EPA focused the assessment of the baseline impacts and improvements under the final rule on the period after the 2023 assumed compliance date for the Rush Island plant.

Incorporation of Flow Data. EPA used USGS stream flow data from one USGS stream gage to represent inflow at the upstream end of the modeling area of the Mississippi River WASP model. EPA scaled the Mississippi River stream gage data from Gage ID 07010000 to account for the difference in drainage area between the actual gage location and the point where the contributing flows enter the modeling area.

EPA used USGS stream flow data from one other USGS stream gages to represent inflow from the Meramec River, a tributary to the Mississippi River WASP modeling area. EPA scaled the Meramec River stream gage data from Gage ID 07019000 to account for the difference in drainage area between the actual gage location and the point where the contributing flows enter the modeling area.

Figure G-16 illustrates the two stream flow gages from which EPA incorporated USGS stream flow data. Table G-46 presents additional information about the four stream gages and the time period covered in the stream flow data record at each. Table G-47 presents how EPA incorporated the stream flow data from these stream gages into the model to complete a full record of flow data for the entire modeling period. For all other local inflows, EPA used the mean annual flow defined in NHDPlus Version 1.

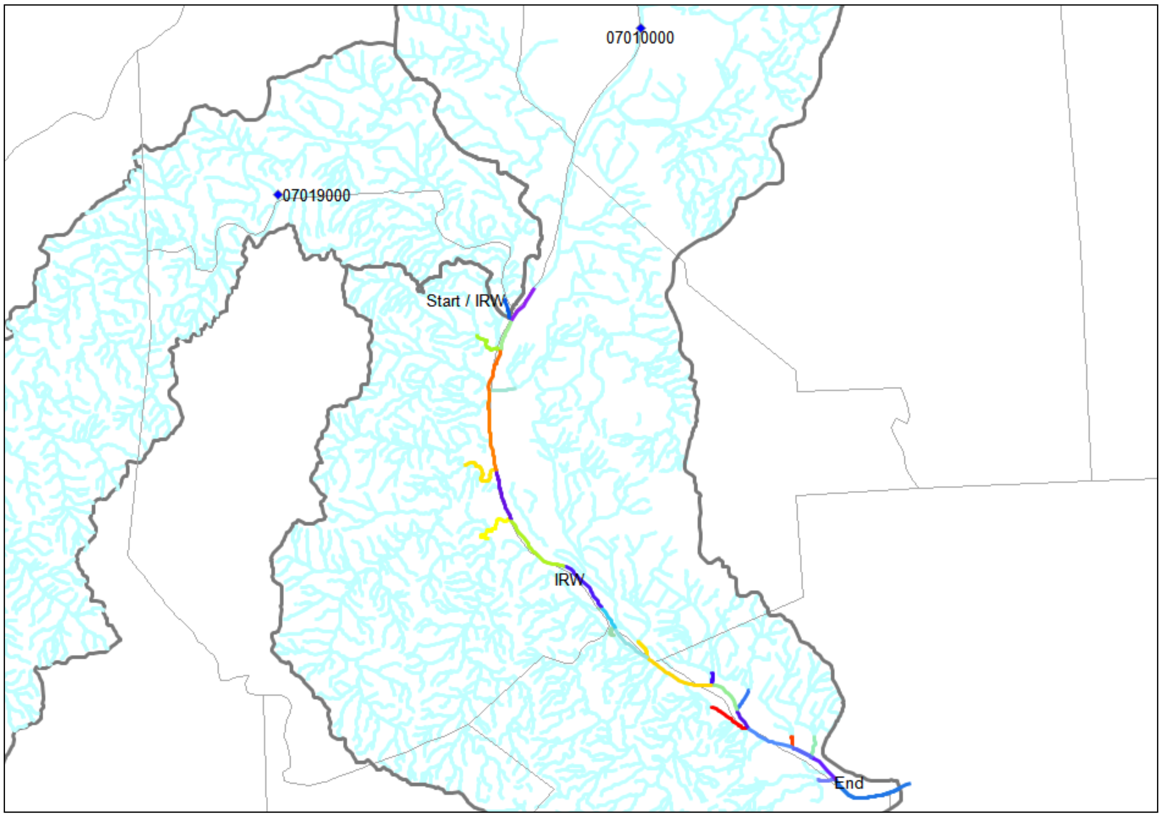

Figure G-16. Geographic Extent and Segmentation – Mississippi River WASP Model

Model Input Variables. Table G-48 presents the pollutant loadings modeled from Bruce Meramec plant at the evaluated wastestream level, both at baseline and after the plant achieves the limitations under the final rule. Table G-49 presents the pollutant loadings modeled from Rush Island plant at the evaluated wastestream level, both at baseline and after the plant achieves the limitations under the final rule.

Table G-50 presents the pollutant loadings modeled from non-steam electric point sources with 2011 DMR or TRI loadings which would impact the Mississippi River case study model.

Table G-51 presents the pollutant contributions flowing into the Mississippi River WASP model boundaries calculated using available STORET monitoring data.

Table G-52 presents the initial concentrations for the organic solids, sands, and silts/fines values derived from STORET monitoring data collected. For tributaries where STORET monitoring data were not available, EPA assumed the average boundary concentration from all tributaries entering the modeling area. Based on the average of STORET data available within the model, EPA calculated the initial concentrations of organic solids, sands, and silts/fines in the water column segments were 2.74 mg/L, 2.73 mg/L, and 51.94 mg/L, respectively.

EPA calibrated the model outputs by manipulating the sediment transport parameters until the modeled concentrations in the benthic segments closely matched the available sediment concentration monitoring data derived from STORET. Table G-53 presents the sediment transport parameters resulting from EPA's calibration effort. EPA assumed the initial concentrations of organic solids, sands, and silts/fines in the benthic segments were equal to 100 mg/L each.

Model Results

Case study modeling of the Mississippi River revealed water quality benchmark exceedances in the immediate receiving water and/or in downstream segments for arsenic. Figure G-17 illustrates the water concentration outputs for arsenic in the Rush Island plant immediate receiving water before and after the assumed compliance date for the final rule.[11]

Case study modeling of the Mississippi River revealed that average water column concentrations of arsenic in the Rush Island plant's immediate receiving water and/or downstream segments would trigger exceedances of human health benchmarks. Table G-54 and Table G-55 illustrate the average modeled pollutant concentration in each water column segment downstream of the Rush Island plant (including the immediate receiving water) for baseline and following compliance with the final rule, respectively. Table G-56 and Table G-57 present the total miles with average water column concentrations translating to exceedances of these benchmarks for baseline and under the final rule, respectively.

[11] To improve clarity, Figure G-17 presents the baseline water column concentrations leading up to the assumed compliance date of Rush Island plant. All analyses of the WASP model outputs were performed on the baseline output after the assumed compliance date.

Table G-46. USGS Stream Gages with Flow Data Used in Mississippi River WASP Model

Gage ID	USGS Gage Location	Stream Flow Record Period	Cumulative Drainage Area Represented by Gage (sq km)	Model Boundary	Cumulative Drainage Area at Model Boundary (sq km)	Scale Factor
7010000	Mississippi River near St. Louis, MO	Full Record from 01/01/1880 - 11/19/2014	1,668,452	Mississippi River	1,667,867	1.000
7019000	Meramec River near Eureka, MO	Full Record from 10/01/1903 - 02/04/2015	9,811	Meramec River	10,264	1.046

Acronyms: USGS (U.S. Geological Survey).

Table G-47. Stream Flow Data Periods – Mississippi River WASP Model

Modeling Period	Corresponding Stream Flow Data Period
Mississippi River (Gage ID 7010000)	
01/01/1982 - 09/30/2014	01/01/1982 - 09/30/2014
10/01/2014 – 12/31/2020	10/01/2002 – 12/31/2008
01/01/1998 - 09/30/2030	01/01/1982 - 09/30/2014
10/01/2030 – 12/31/2036	10/01/2002 – 12/31/2008
Meramec River (Gage ID 7019000)	
01/01/1982 - 09/30/2014	01/01/1982 - 09/30/2014
10/01/2014 – 12/31/2020	10/01/2002 – 12/31/2008
01/01/1998 - 09/30/2030	01/01/1982 - 09/30/2014
10/01/2030 – 12/31/2036	10/01/2002 – 12/31/2008

Table G-48. Pollutant Loadings – Meramec Plant

Wastestream	Pollutant Loadings (g/day)							
	As	**Cd**	**Cu**	**Ni**	**Pb**	**Se**	**Tl**	**Zn**
Baseline [a]								
FGD Wastewater	--	--			--			--
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	425.25	117.36	519.89	1,956.61	391.37	215.63	1,994.81	1,599.08
Combustion Residual Leachate	--	--	--	--	--	--	--	--
Total	**425.25**	**117.36**	**519.89**	**1,956.61**	**391.37**	**215.63**	**1,994.81**	**1,599.08**
Final Rule [b]								
FGD Wastewater	--	--			--			--
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	--	--			--			--
Combustion Residual Leachate	--	--	--	--	--	--	--	--
Total	--	--			--			--

Acronyms: FGD (flue gas desulfurization).

a – The baseline pollutant loadings are modeled throughout the entire modeling period (from 01/01/1982 through 12/31/2036).

b – The final rule pollutant loadings are modeled only after the assumed compliance date (from 01/01/2019 through 12/31/2036).

Table G-49. Pollutant Loadings – Rush Island Plant

Wastestream	Pollutant Loadings (g/day)							
	As	**Cd**	**Cu**	**Ni**	**Pb**	**Se**	**Tl**	**Zn**
Baseline [a]								
FGD Wastewater	--	--			--			--
Fly Ash Transport Water	2,617.69	338.24	1,490.40	1,152.47	1,054.61	1,171.40	1,220.86	3,112.40
Bottom Ash Transport Water	109.07	55.52	381.96	330.76	173.11	11.83	200.40	334.33
Combustion Residual Leachate	--	--	--	--	--	--	--	--
Total	**2,726.76**	**393.76**	**1,872.36**	**1,483.22**	**1,227.72**	**1,183.23**	**1,421.26**	**3,446.73**
Final Rule [b]								
FGD Wastewater	--	--			--			--
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	--	--			--			--
Combustion Residual Leachate	--	--	--	--	--	--	--	--
Total	--	--			--			--

Acronyms: FGD (flue gas desulfurization).

-- -- -- --

a – The baseline pollutant loadings are modeled from 01/01/1982 through 12/31/2022.

b – The final rule pollutant loadings are modeled from 01/01/2023 through 12/31/2036.

-- -- -- --

Table G-50. Pollutant Contributions from Non-Steam Electric Point Sources – Mississippi River WASP Model

Facility Name	Model COMID	City, State	Location (lat, long)	Parameter	Average Daily Pollutant Loadings (g/day)
MSD Meramec Treatment Plant [a]	3629071 (Mississippi River)	St. Louis, MO	(38.39,-90.34)	As	139.02
				Cd	3.50
				Cu	52.2
				Ni	52.5
				Pb	156.5
				Zn	999.6
Doe Run Co Herculaneum Smelter [b]	3629127 (Mississippi River)	Herculaneum, MO	(38.26,-90.38)	Cd	156.87
				Cu	11.56
				Pb	49.42
				Zn	66.51
Doe Run Co Herculaneum Smelter [c]	3634867 [d] (Joachim Creek)	Herculaneum, MO	(38.26,-90.38)	As	6.09
				Cd	6.09
				Cu	8.35
				Ni	0.61
				Pb	280.97
				Zn	36.80

a – EPA identified that this publicly operated treatment works (POTW) facility is a direct discharger with 2011 DMR loadings.

b - EPA identified that this industrial facility is a direct discharger with 2011 DMR loadings.

c - EPA identified that this facility is also an indirect discharger with 2011 TRI loadings.

d – These pollutant loadings for Doe Run Co Herculaneum are indirectly discharged to Joachim Creek via the Herculaneum Sewer District POTW.

Table G-51. Pollutant Contributions from STORET Monitoring Data – Mississippi River WASP Model

Model Boundary	Model Boundary COMID	Station ID(s) (lat, long)	Parameter	Average Concentration (µg/L)[a]	Mass Loading (g/day)[b]
Mississippi River	3629071	1707.02/3.7 (38.43,-90.29) GRW04449-331 (38.41,-90.32) J-36 (38.40,-90.32) 1707.03/41.0 (38.36,-90.36)	As	--	1,533,384.42
			Cd	--	63,000.95
			Cu	--	1,772,153.59
			Ni	--	4,216,002.40
			Pb	--	1,764,990.67
			Zn	--	6,485,964.73
			TSS	220,098.26	--
			TOC	5,298.95	--
Maeystown Creek	3629179	JD-02 (38.21,-90.26)	As	--	49.83
			Cd	--	1.21
			Cu	--	38.90
			Ni	--	11.55
			Pb	--	29.09
			Zn	--	152.55
			TOC	3,928.00	--
			TSS	43,000.00	--
South Gabouri Creek	3630453	1707.02/121/0.9/1.5 (37.97,-90.06)	TSS	5,000.00	--

Acronyms: TOC (Total Organic Carbon); TSS (Total Suspended Solids).

a –Where more than one monitoring station located on the same tributary system reported acceptable results for the same pollutant, EPA calculated and incorporated the weighted average concentration across the monitoring stations (weighted by number of samples at each station).

b – For the modeled pollutants (not including TOC and TSS), EPA converted the average concentration to a mass loading using the average annual flow rate for the stream reach represented by the monitoring station(s).

Table G-52. Organic Solids, Sands, and Silts/Fines Inputs – Mississippi River WASP Model

Model Boundary	Model Boundary COMID	Organic Solids Concentration (mg/L)[a]	Sands Concentration (mg/L)[b]	Silts/Fines Concentration (mg/L)[c]
Mississippi River	3629071	2.65	11.00	209.09
Maeystown Creek	3629179	1.96	2.15	40.85
South Gabouri Creek	3630453	*	0.25 [e]	4.75 [e]
All Other Inflows [d]	N/A	2.31	4.47	84.90

Acronyms: N/A (Not Applicable).

* – No TOC results available. The ‘All Other Inflows’ concentration was used in this scenario.

a – The organic solids concentration was calculated using Equation G-1 and the STORET monitoring data presented in Table G-51.

b – The sands concentration was calculated using Equation G-2 and the STORET monitoring data presented in Table G-51.

c – The silts/fines concentration was calculated using Equation G-3 and the STORET monitoring data presented in Table G-51.

d – For tributaries where boundary concentrations from STORET monitoring data were not available, EPA assumed the average boundary concentration from all tributaries entering the modeling area.

e – These concentrations were calculated using the ‘All Other Inflows’ concentration.

Table G-53. Sediment Transport Parameters – Mississippi River WASP Model

Input Parameter	Value Used	Units
TAUcritcoh	5.0	N/m^2
TAU_cD1_si[a]	5.0	N/m^2
TAU_cD2_si[a]	10.0	N/m^2
TAU_cD1_PO[a]	5.0	N/m^2
TAU_cD2_PO[a]	10.0	N/m^2

Note: Table G-1 presents additional solids constants and sediment transport parameters that are used in each of the case study models.

a – This parameter is a WASP model default based on the value of the ‘TAUcritcoh’ parameter.

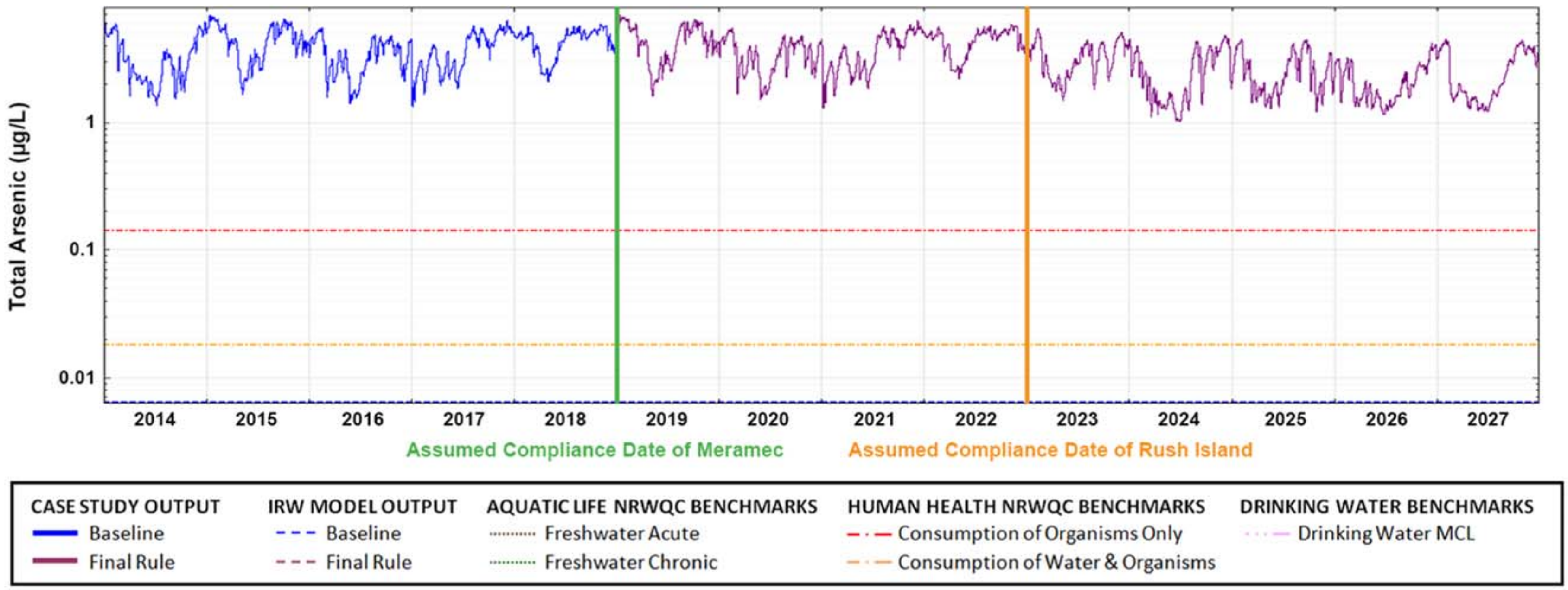

Figure G-17. Modeled Concentrations in Mississippi River Water Column at Rush Island Plant Immediate Receiving Water (Total Arsenic)

Table G-54. Average Water Column Concentrations Downstream of Rush Island Plant at Baseline

Segment Data				Average Total Water Column Concentration over Modeling Period (µg/L)[a]							
Segment ID	Segment Name	Segment Length (mi)	Distance Downstream (mi)	As	Cd	Cu	Pb	Ni	Se	Tl	Zn
9	Mississippi River / Rush Island IRW	1.48	1.48	3.2912	0.1287	3.5878	3.5149	8.7116	0.0044	0.0086	13.0108
8	Mississippi River	2.69	4.17	4.0944	0.1237	3.5546	3.2102	9.5052	0.0046	0.0099	12.3554
7	Mississippi River	4.33	8.49	3.0972	0.1171	3.2754	3.1789	8.0477	0.0040	0.0080	11.8195
6	Mississippi River	2.21	10.70	3.1050	0.1174	3.2833	3.1859	8.0684	0.0040	0.0080	11.8468
5	Mississippi River	1.25	11.95	3.1057	0.1174	3.2834	3.1858	8.0693	0.0040	0.0080	11.8467
4	Mississippi River	2.93	14.88	3.1055	0.1173	3.2816	3.1835	8.0667	0.0040	0.0080	11.8392
3	Mississippi River	1.40	16.27	3.1065	0.1173	3.2819	3.1834	8.0682	0.0040	0.0080	11.8395
2	Mississippi River	1.92	18.19	3.1078	0.1173	3.2820	3.1831	8.0699	0.0040	0.0080	11.8393
1	Mississippi River / End	5.06	23.25	3.1123	0.1173	3.2832	3.1830	8.0766	0.0040	0.0080	11.8412

Acronyms: IRW (Immediate receiving water).

a - Concentrations represent the average daily total pollutant concentration in the water column. The averaging period is the entire modeling period after the assumed compliance date.

Table G-55. Average Water Column Concentrations Downstream of Rush Island Plant Under Final Rule

Segment Data				Average Total Water Column Concentration over Modeling Period (µg/L)[a]							
Segment ID	Segment Name	Segment Length (mi)	Distance Downstream (mi)	As	Cd	Cu	Pb	Ni	Se	Tl	Zn
9	Mississippi River / Rush Island IRW	1.48	1.48	3.2833	0.1275	3.5819	3.5109	8.7034	0.0008	0.0006	12.9984
8	Mississippi River	2.69	4.17	4.0847	0.1225	3.5488	3.2066	9.4964	0.0009	0.0006	12.3438
7	Mississippi River	4.33	8.49	3.0898	0.1159	3.2700	3.1753	8.0402	0.0008	0.0005	11.8083
6	Mississippi River	2.21	10.70	3.0976	0.1162	3.2779	3.1823	8.0609	0.0008	0.0005	11.8357
5	Mississippi River	1.25	11.95	3.0984	0.1162	3.2780	3.1822	8.0618	0.0008	0.0005	11.8356
4	Mississippi River	2.93	14.88	3.0982	0.1161	3.2763	3.1799	8.0592	0.0008	0.0005	11.8281
3	Mississippi River	1.40	16.27	3.0992	0.1162	3.2765	3.1798	8.0607	0.0008	0.0005	11.8284
2	Mississippi River	1.92	18.19	3.1004	0.1162	3.2767	3.1795	8.0624	0.0008	0.0005	11.8282
1	Mississippi River / End	5.06	23.25	3.1049	0.1162	3.2779	3.1795	8.0691	0.0008	0.0005	11.8300

Acronyms: IRW (Immediate receiving water).

a - Concentrations represent the average daily total pollutant concentration in the water column. The averaging period is the entire modeling period after the assumed compliance date.

Table G-56. Total Miles of Mississippi River with Wildlife And Human Health Impacts at Baseline

Wildlife and Human Health Impact Thresholds	Total Miles with Average Water Column Concentration Translating to Wildlife or Human Health Benchmark Exceedances (mi)							
	As	Cd	Cu	Pb	Ni	Se	Tl	Zn
WL - NEHC, T3 (mink)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
WL - NEHC, T4 (eagle)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
HH - Non-Cancer Adult Subsistence	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Adult Recreational	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Subsistence (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Subsistence (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Recreational (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Recreational (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Cancer Adult Subsistence	23.25	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Adult Recreational	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (6 to <11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (6 to 11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR

Acronyms: WL (Wildlife); HH (Human health); NEHC (No effect hazard concentration); Rfd (Reference dose); LECR (Lifetime excess cancer risk); y.o. (year old).

a – This row represents the most sensitive child fisher cohort.

b – This row represents the least sensitive child fisher cohort.

Table G-57. Total Miles of Mississippi River with Wildlife And Human Health Impacts Under Final Rule

Wildlife and Human Health Impact Thresholds	Total Miles with Average Water Column Concentration Translating to Wildlife or Human Health Benchmark Exceedances (mi)							
	As	Cd	Cu	Pb	Ni	Se	Tl	Zn
WL - NEHC, T3 (mink)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
WL - NEHC, T4 (eagle)	0.00	0.00	0.00	0.00	0.00	0.00	No NEHC	0.00
HH - Non-Cancer Adult Subsistence	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Adult Recreational	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Subsistence (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Subsistence (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Recreational (1 to <2 y.o.) [a]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Non-Cancer Child Recreational (16 to <21 y.o.) [b]	0.00	0.00	0.00	No RfD	0.00	0.00	0.00	0.00
HH - Cancer Adult Subsistence	23.25	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Adult Recreational	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (6 to <11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Subsistence (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (6 to 11 y.o.) [a]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR
HH - Cancer Child Recreational (1 to <2 y.o.) [b]	0.00	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR	No LECR

Acronyms: WL (Wildlife); HH (Human health); NEHC (No effect hazard concentration); Rfd (Reference dose); LECR (Lifetime excess cancer risk); y.o. (year old).

a – This row represents the most sensitive child fisher cohort.

b – This row represents the least sensitive child fisher cohort.

CASE STUDY MODEL SETUPS AND OUTPUTS – LAKE SINCLAIR, GA

This section presents information regarding the site-specific design, site-specific input parameters (*e.g.*, background pollutant concentrations, EFDC model flow data), model settings (*e.g.*, sediment transport parameters), and case study modeling results for the Lake Sinclair case study model.

Model Development & Input Variables

WASP Model Design. As discussed in Section 8.1.1 of the EA Report, EPA relied on the availability of an existing water quality model to perform case study modeling of Lake Sinclair. In contrast to the lotic case study models, the Lake Sinclair WASP model relies on Environmental Fluid Dynamics Code (EFDC) hydrodynamics to simulate the aquatic system in three dimensions.[12] The scope of the Lake Sinclair WASP model is limited by the boundaries of the pre-existing EFDC hydrodynamics. The modeling area encompasses the main body of Lake Sinclair, from Wallace Dam to Sinclair Dam, and the major tributaries feeding into the Lake.

The three-dimensional EFDC model, which provides the hydrodynamic foundation for the WASP model, divides the waterbody into 1,235 segments. Each segment represents a unique location and stratum within Lake Sinclair. The EFDC model uses stretch or sigma vertical coordinates and Cartesian coordinates to represent the physical characteristics of Lake Sinclair. Plant Harllee Branch's immediate receiving water is identified by the coordinate code I=30 J=32 K=5, where each coordinate represents the position on x, y, and z axes, respectively. The Lake Sinclair model does not have any segments representing benthic sediment. The model accounts for a total volume of approximately 340 million cubic meters.

As discussed earlier in this section, EPA adopted the preexisting Lake Sinclair EFDC model. The pre-existing model was designed with seven years of hydrodynamic and flow input, limiting the length of the period EPA could model. Based on Plant Harllee Branch's NPDES permitting cycle, EPA assumed that the plant would have achieved the limitations under the final rule by 2019, if it continued to operate. The modeling period begins in February 2012 (approximately seven years before the assumed compliance date) and extends through November 2025 (approximately seven years after the assumed compliance date).

Incorporation of Flow Data. EPA did not incorporate any USGS flow data into the Lake Sinclair WASP model. Instead, EPA used the seven years of hydrodynamic and flow input integrated into the EFDC model. Table G-58 presents how the EFDC hydrodynamic data were incorporated into the model to complete a full record of flow data for the entire modeling period.

Model Input Variables. As discussed in Section 8.2.6 of the EA Report, Plant Harllee Branch retired all of coal-fired generating units in April 2015. Despite the retirement of this plant, EPA proceeded with case study modeling of Lake Sinclair to represent the potential impacts of steam electric discharges on lentic waterbodies. Table G-59 presents the pollutant loadings modeled from Plant Harllee Branch at the evaluated wastestream level, both at baseline and after

[12] The Black Creek, Etowah River, Lick Creek and White River, Ohio River, and Mississippi River case study models relied on NHDPlus Version 1 hydrodynamics for simulating lotic aquatic systems.

the plant achieves the limitations under the final rule.[13] EPA did not identify any point sources with 2011 DMR or TRI loadings which would impact the Lake Sinclair case study model.

Table G-60 presents the pollutant contributions flowing into the Lake Sinclair WASP model boundaries calculated using available STORET monitoring data.

Table G-61 presents the initial concentrations for the organic solids, sands, and silts/fines values derived from STORET monitoring data collected. For tributaries where STORET monitoring data were not available, EPA assumed the average boundary concentration from all tributaries entering the modeling area. Based on the average of STORET data available within the model, EPA calculated the initial concentrations of organic solids, sands, and silts/fines in the water column segments were 1.91 mg/L, 0.20 mg/L, and 3.85 mg/L, respectively.

Model Results

Case study modeling of Lake Sinclair revealed water quality benchmark exceedances in the immediate receiving water and neighboring segments for arsenic and thallium. Figure G-18 illustrates the water concentration outputs averaged for all model segments before and after the assumed compliance date for the final rule.[14] Case study modeling also revealed frequent (more than 50 percent of the modeling period) water quality benchmark exceedances of three pollutants (arsenic, cadmium, and thallium) in some segments of Lake Sinclair.

Case study modeling of the Lake Sinclair revealed that the average water column concentrations of thallium of all segments in the WASP model would trigger exceedances of human health benchmarks.

[13] EPA calculated pollutant loadings at the wastestream level for Plant Harllee Branch using the same loadings methodology that EPA used for other plants in the loadings analyses. EPA did not include Plant Harllee Branch or Lake Sinclair in the other quantitative and qualitative analyses in this EA for the final rule (*e.g.*, the IRW model).

[14] To improve clarity, Figure G-18 presents the baseline water column concentrations leading up to the assumed compliance date of Plant Harllee Branch. All analyses of the WASP model outputs were performed on the baseline output after the assumed compliance date.

Table G-58. Stream Flow Data Periods – Lake Sinclair WASP Model

Modeling Period	Corresponding Stream Flow Data Period
Lake Sinclair (EFDC Hydrodynamic Model)	
02/01/2012 – 12/31/2018	2/1/2001 – 12/31/2007
01/01/2019 – 11/30/2025	2/1/2001 – 12/31/2007

Table G-59. Pollutant Loadings – Plant Harllee Branch

Wastestream	Pollutant Loadings (g/day)							
	As	**Cd**	**Cu**	**Ni**	**Pb**	**Se**	**Tl**	**Zn**
Baseline [a]								
FGD Wastewater [c]	35.18	521.69	100.78	4,068.20	21.61	5,413.46	63.65	6,451.65
Fly Ash Transport Water	44.28	12.01	97.91	55.28	39.77	14.80	13.57	360.25
Bottom Ash Transport Water	22.29	6.15	27.25	102.56	20.52	11.30	104.56	83.82
Combustion Residual Leachate	--	--	--	--	--	--	--	--
Total	**101.75**	**539.85**	**225.94**	**4,226.04**	**81.90**	**5,439.56**	**181.78**	**6,895.72**
Final Rule [b]								
FGD Wastewater	27.03	19.50	17.50	29.21	15.71	26.51	45.44	92.54
Fly Ash Transport Water	--	--			--			--
Bottom Ash Transport Water	--	--			--			--
Combustion Residual Leachate	--	--	--	--	--	--	--	--
Total	**27.03**	**19.50**	**17.50**	**29.21**	**15.71**	**26.51**	**45.44**	**92.54**

Acronyms: FGD (flue gas desulfurization).

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Note: Plant Harllee Branch has retired all coal-fired generating units. EPA calculated pollutant loadings at the wastestream level for Plant Harllee Branch using the same loadings methodology that EPA used for other plants in the loadings analyses. EPA did not include Plant Harllee Branch in the other quantitative and qualitative analyses in this EA for the final rule (*e.g.*, the IRW model).

a – The baseline pollutant loadings are modeled throughout the entire modeling period (from 02/01/2012 through 11/30/2025).

b – The final rule pollutant loadings are modeled only after the assumed compliance date (from 01/01/2019 through 11/30/2025).

c - In estimating the historical pollutant loadings associated with Plant Harllee Branch's FGD systems, EPA incorporated the pollutant loadings from FGD wastewater when the system was installed in 2013. EPA did not model any FGD wastewater pollutant loadings before the installation of Plant Harllee Branch's FGD system.

Table G-60. Pollutant Contributions from STORET Monitoring Data – Lake Sinclair WASP Model

Model Boundary	Model Boundary COMID	Station ID(s) (lat, long)	Parameter	Average Concentration (µg/L)[a]	Mass Loading (g/day)[b]
Oconee River	1057503	0301100602 (33.35,-83.16) 3038901 (33.35,-83.16) 0301100603 (33.33,-83.14)	TOC	3,818.44	--
			TSS	6,941.46	--
Crooked Creek	1056407	0301180202 (33.32,-83.28)	TOC	7,124.62	--
			TSS	18,992.31	--
Rooty Creek	1057629	0301180301 (33.32,-83.27) 3040101 (33.32,-83.37) 0301180302 (33.29,-83.35) 3040501 (33.29,-83.25)	As	--	58.89
			Cd	--	14.99
			Cu	--	45.10
			Ni	--	33.07
			Pb	--	29.59
			Tl	--	58.95
			Zn	--	452.25
			TOC	5,347.26	--
			TSS	11,635.71	--
Little River	1057681	3042001 (33.30,-83.42) 0301150301 (33.29,-83.43) 0301150302 (33.29,-83.43) 3041701 (33.31,-83.44) 0301150102 (33.31,-83.44)	As	--	960.78
			Cd	--	243.11
			Cu	--	1,037.67
			Ni	--	644.08
			Pb	--	482.01
			Tl	--	961.37
			Zn	--	6,098.66
			TOC	4,960.21	--
			TSS	15,576.92	--

Table G-60. Pollutant Contributions from STORET Monitoring Data – Lake Sinclair WASP Model

Model Boundary	Model Boundary COMID	Station ID(s) (lat, long)	Parameter	Average Concentration (µg/L)[a]	Mass Loading (g/day)[b]
Murder Creek	1057679	0301160703 (33.27,-83.48) 3043401 (33.25,-83.48) 0301160701 (33.25,-83.48)	As	--	642.79
			Cd	--	162.65
			Cu	--	328.26
			Ni	--	347.78
			Pb	--	322.48
			Tl	--	643.18
			Zn	--	1,654.57
			TOC	2,773.47	--
			TSS	21,383.33	--
Big Cedar Creek	1056893	3043801 (33.19,-83.44) 0301170401 (33.19,-83.44)	As	--	450.16
			Cd	--	113.90
			Cu	--	229.89
			Ni	--	243.56
			Pb	--	225.84
			Tl	--	450.44
			Zn	--	345.37
			TOC	3,407.30	--
			TSS	20,223.08	--

Acronyms: TOC (Total Organic Carbon); TSS (Total Suspended Solids).

a –Where more than one monitoring station located on the same tributary system reported acceptable results for the same pollutant, EPA calculated and incorporated the weighted average concentration across the monitoring stations (weighted by number of samples at each station).

b – For the modeled pollutants (not including TOC and TSS), EPA converted the average concentration to a mass loading using the average annual flow rate for the stream reach represented by the monitoring station(s).

Table G-61. Organic Solids, Sands, and Silts/Fines Inputs – Lake Sinclair WASP Model

Model Boundary	Model Boundary COMID	Organic Solids Concentration (mg/L)[a]	Sands Concentration (mg/L)[b]	Silts/Fines Concentration (mg/L)[c]
Oconee River	1057503	1.91	0.35	6.59
Crooked Creek	1056407	3.56	0.95	18.04
Rooty Creek	1057629	2.67	0.58	11.05
Little River	1057681	2.48	0.78	14.80
Murder Creek	1057679	1.39	1.07	20.31
Big Cedar Creek	1056893	1.70	1.01	19.21
All Other Inflows [d]	N/A	2.29	0.79	15.00

Acronyms: N/A (Not Applicable).

a – The organic solids concentration was calculated using Equation G-1 and the STORET monitoring data presented in Table G-60.

b – The sands concentration was calculated using Equation G-2 and the STORET monitoring data presented in Table G-60.

c – The silts/fines concentration was calculated using Equation G-3 and the STORET monitoring data presented in Table G-60.

d – For tributaries where boundary concentrations from STORET monitoring data were not available, EPA assumed the average boundary concentration from all tributaries entering the modeling area.

Table G-62. Sediment Transport Parameters – Lake Sinclair WASP Model

Input Parameter	Value Used	Units
TAUcritcoh	3.5	N/m^2
TAU_cD1_si[a]	3.5	N/m^2
TAU_cD2_si[a]	7.0	N/m^2
TAU_cD1_PO[a]	3.5	N/m^2
TAU_cD2_PO[a]	7.0	N/m^2

Note: Table G-1 presents additional solids constants and sediment transport parameters that are used in each of the case study models.

a – This parameter is a WASP model default based on the value of the 'TAUcritcoh' parameter.

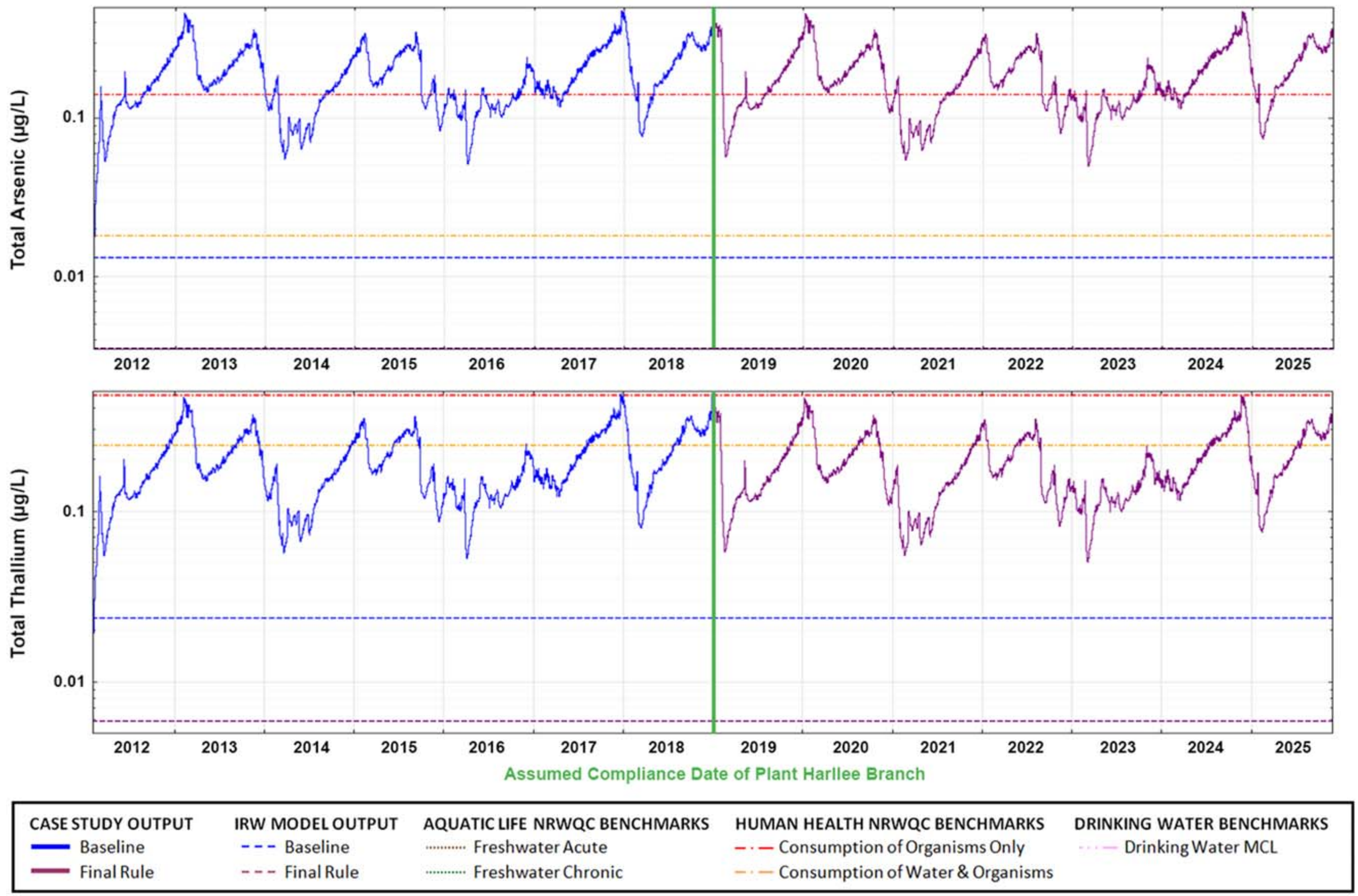


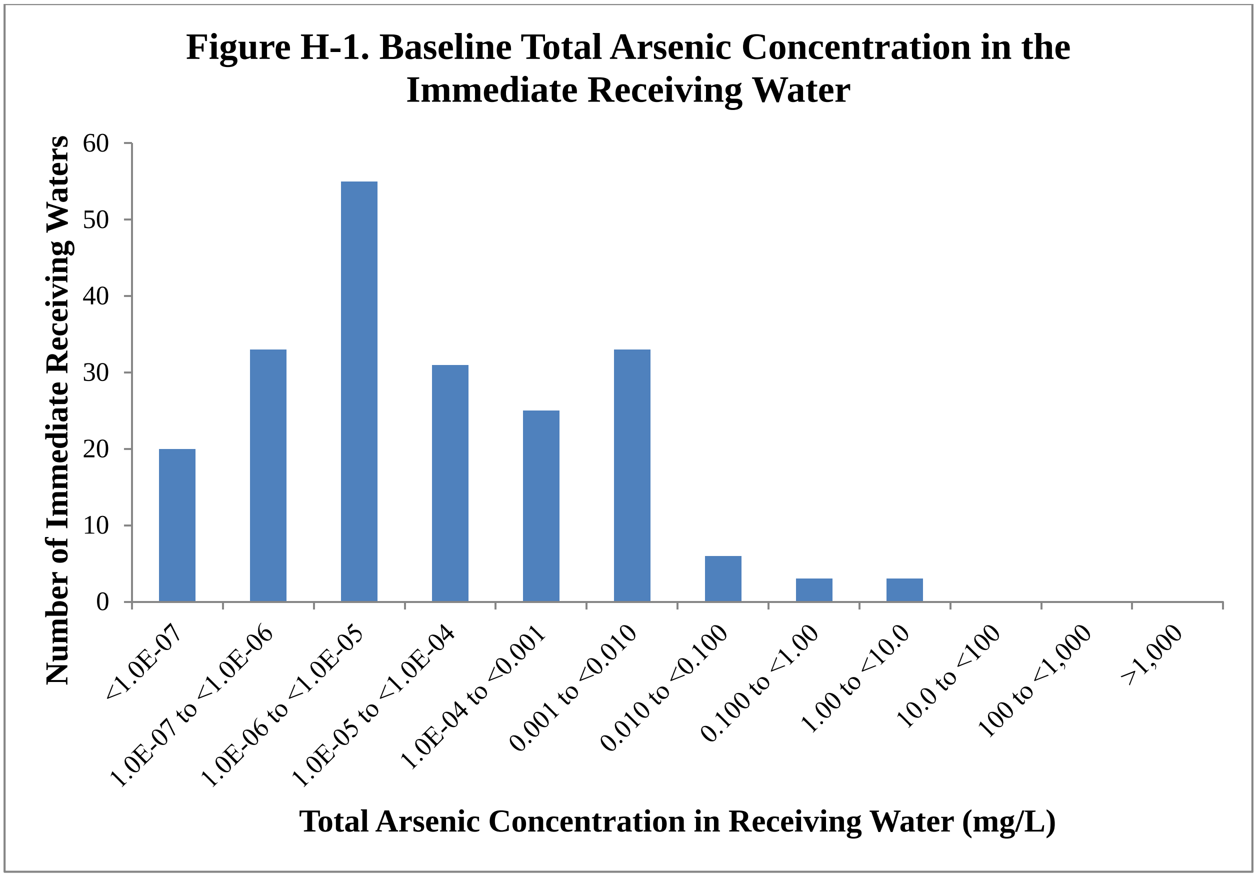
Figure G-18. Average Modeled Concentrations in All Segments in Lake Sinclair WASP Model (Total Arsenic, Total Thallium)

APPENDIX H
ADDITIONAL MODEL RESULTS

Table H-1. Number and Percentage of Immediate Receiving Waters that Exceeded a Criterion by Pollutant and Criteria Type at Baseline Pollutant Loadings

Pollutant	Number of Immediate Receiving Waters that Exceeded a Criterion [a]						
	Freshwater Acute NRWQC	Freshwater Chronic NRWQC	Human Health Water and Organism NRWQC	Human Health Organism Only NRWQC	Drinking Water MCL	Total Receiving Waters [b]	
						Number Exceeding	Percentage Exceeding
Arsenic	3 (c)	4 (c)	94 (d)	65 (d)	12	94	45%
Cadmium	9 (c)	29 (c)	No criterion	No criterion	11	29	14%
Chromium VI	0 (c)	0 (c)	No criterion	No criterion	0 (e)	0	0%
Copper	6 (c)	7 (c)	0	No criterion	0 (f); 1 (g)	7	3%
Lead	0 (c)	5 (c)	No criterion	No criterion	7 (f)	7	3%
Mercury	1 (c)	1 (c)	No criterion	No criterion	5 (d)	5	2%
Nickel	2 (c)	8 (c)	4	0	No criterion	8	4%
Selenium	No criterion	33	8	1	12	33	16%
Thallium	No criterion	No criterion	49	45	34	49	23%
Zinc	4 (c)	4 (c)	1	0	1 (g)	4	2%

Source: ERG, 2015d; ERG, 2015h.
Acronyms: MCL (Maximum Contaminant Level); NRWQC (National Recommended Water Quality Criteria).
a – A total of 209 immediate receiving waters (183 rivers and streams; 26 lakes, ponds, and reservoirs) were included in the water quality model. Table C-7 presents the criteria used for the analysis.
b – These values are the sum and percentage of rivers, streams, lakes, ponds, and reservoirs impacted.
c – NRWQC is expressed in terms of the dissolved pollutant in the water column.
d – NRWQC or MCL is for inorganic form of metal. For the benchmark comparison, EPA used the total pollutant concentration in the water column. This might overestimate the number of exceedances.
e – MCL is for total chromium.
f - MCL used for comparison is the drinking water action level.
g – MCL used for comparison is a secondary (nonenforceable) drinking water standard.

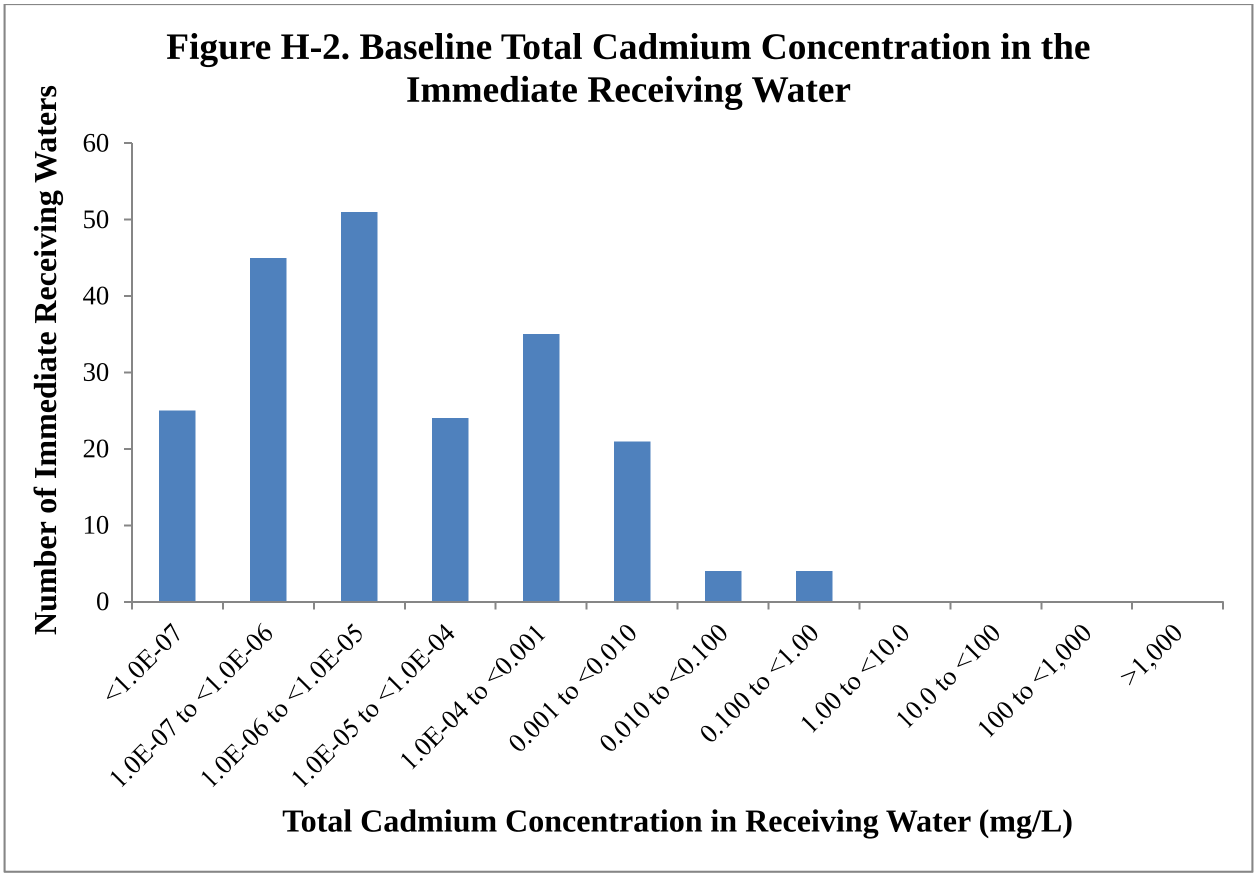


Source: ERG, 2015d; ERG, 2015h.

Table H-2. Total Arsenic Concentration (mg/L) in the Immediate Receiving Water by Percentile

Percentile	Scenario					
	Baseline	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
5th	3.45E-08	2.07E-08	2.07E-08	0	0	0
25th	9.61E-07	6.28E-07	6.28E-07	1.21E-07	0	0
50th	7.88E-06	5.49E-06	5.49E-06	2.82E-06	3.62E-07	1.93E-07
75th	0.001	4.40E-04	4.40E-04	9.23E-05	1.62E-05	9.68E-06
95th	0.016	0.008	0.008	0.006	0.003	9.76E-04
Max	1.86	1.86	1.86	1.86	1.86	1.13

Source: ERG, 2015d; ERG, 2015h.



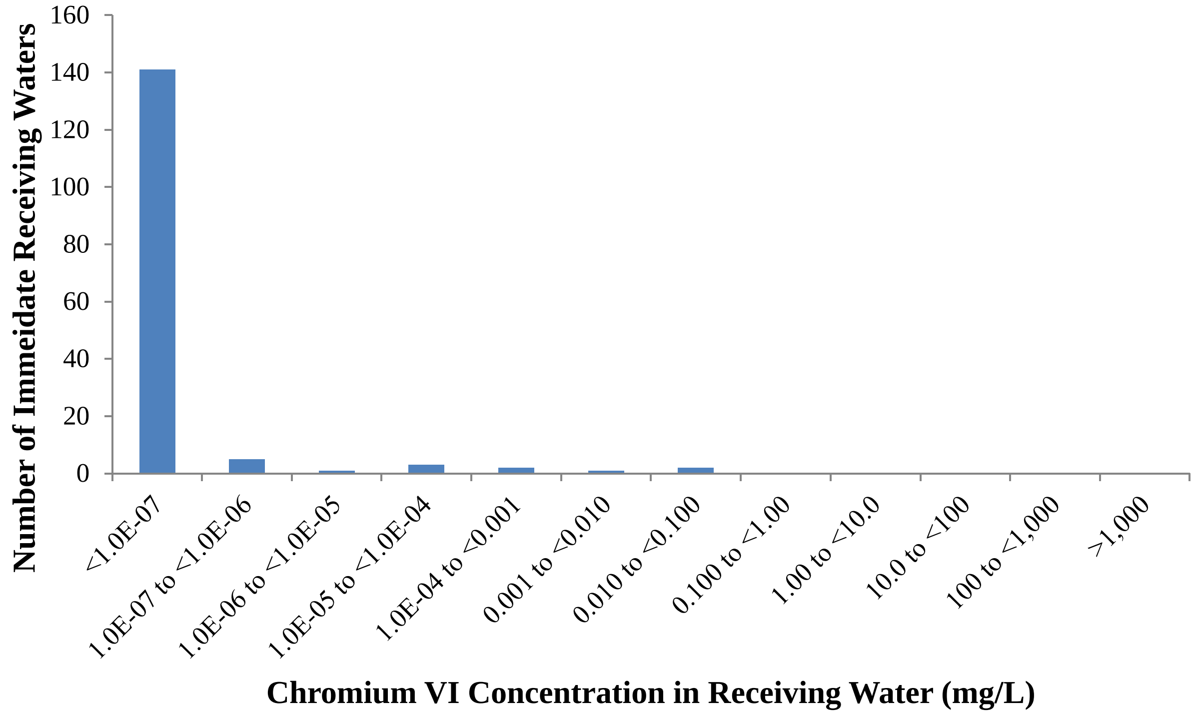
Source: ERG, 2015d; ERG, 2015h.

Table H-3. Total Cadmium Concentration (mg/L) in the Immediate Receiving Water by Percentile

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	1.43E-08	1.04E-08	1.04E-08	0	0	0
25th	5.10E-07	2.25E-07	2.25E-07	5.15E-08	0	0
50th	5.15E-06	2.10E-06	2.10E-06	9.87E-07	1.54E-07	1.36E-07
75th	1.75E-04	1.22E-04	1.22E-04	3.66E-05	8.42E-06	6.99E-06
95th	0.005	0.003	0.003	0.002	0.001	7.04E-04
Max	0.490	0.490	0.490	0.490	0.490	0.204

Source: ERG, 2015d; ERG, 2015h.

Figure H-3. Chromium VI Concentration in the Immediate Receiving Water

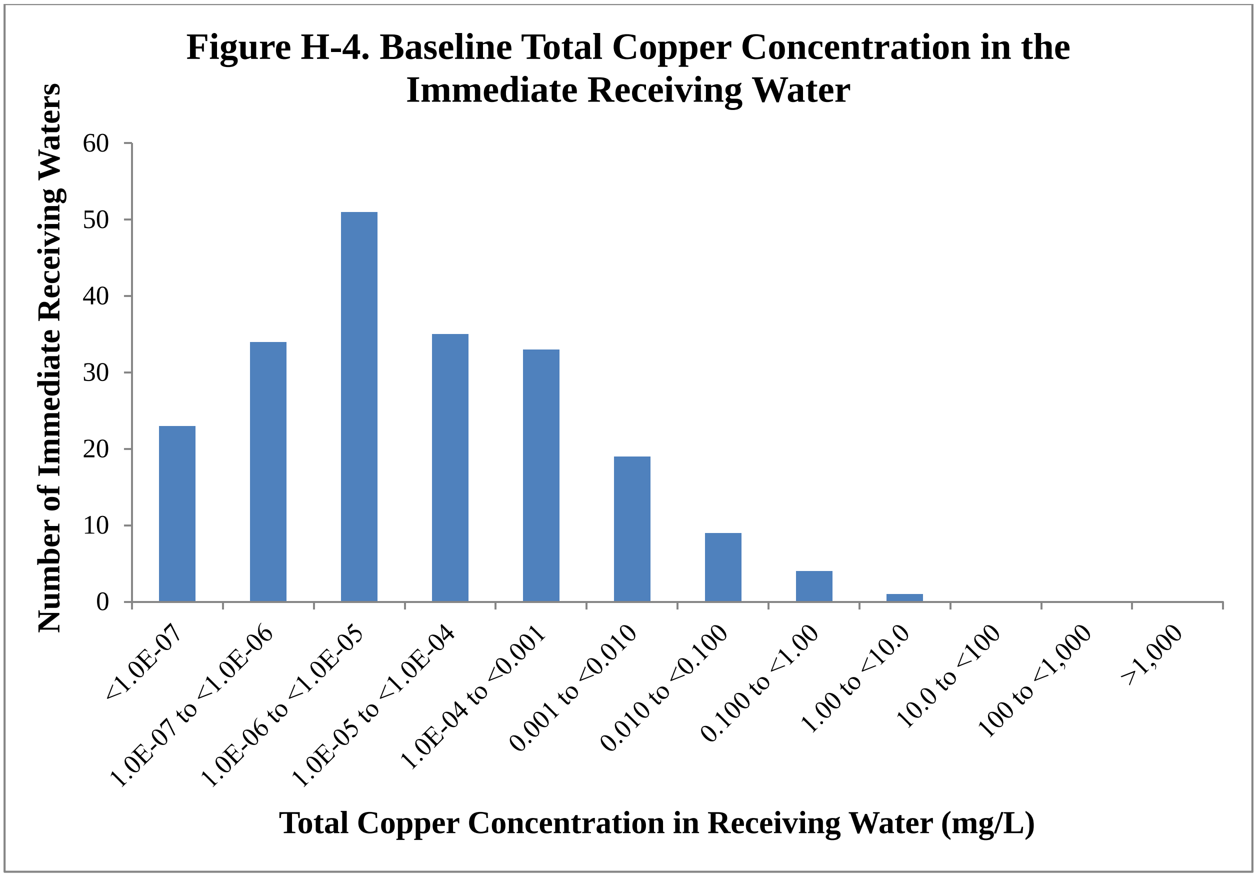


Source: ERG, 2015d; ERG, 2015h.

Table H-4. Chromium VI Concentration (mg/L) in the Immediate Receiving Water by Percentile

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	0	0	0	0	0	0
25th	0	0	0	0	0	0
50th	0	0	0	0	0	0
75th	0	0	0	0	0	0
95th	5.38E-06	1.33E-06	1.33E-06	7.87E-08	0	0
Max	0.019	0.013	0.013	0.013	0.013	0.013

Source: ERG, 2015d; ERG, 2015h.



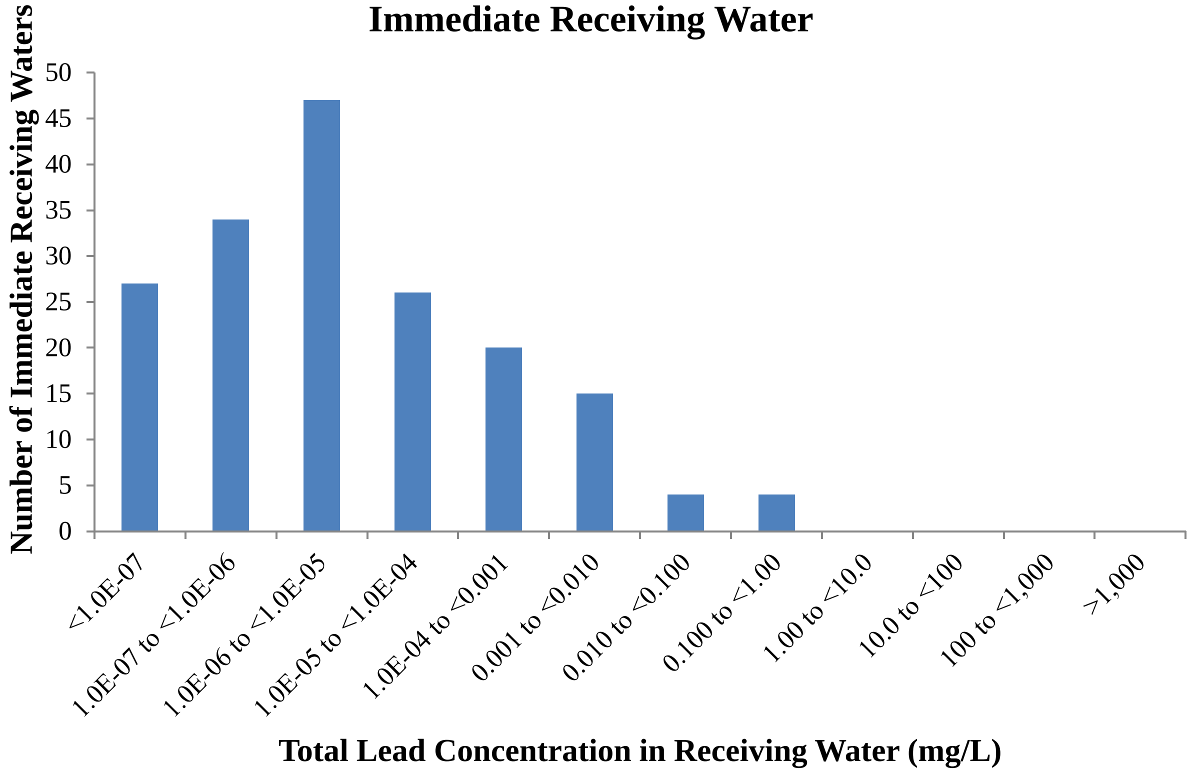
Source: ERG, 2015d; ERG, 2015h.

Table H-5. Total Copper Concentration (mg/L) in the Immediate Receiving Water by Percentile

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	1.64E-08	1.01E-08	1.01E-08	0	0	0
25th	8.86E-07	5.37E-07	5.37E-07	7.86E-08	0	0
50th	8.30E-06	6.27E-06	6.27E-06	1.57E-06	1.33E-07	1.21E-07
75th	2.81E-04	2.33E-04	2.33E-04	4.21E-05	7.10E-06	6.27E-06
95th	0.015	0.009	0.009	0.002	0.001	6.32E-04
Max	1.15	0.778	0.778	0.778	0.778	0.778

Source: ERG, 2015d; ERG, 2015h.

Figure H-5. Baseline Total Lead Concentration in the Immediate Receiving Water



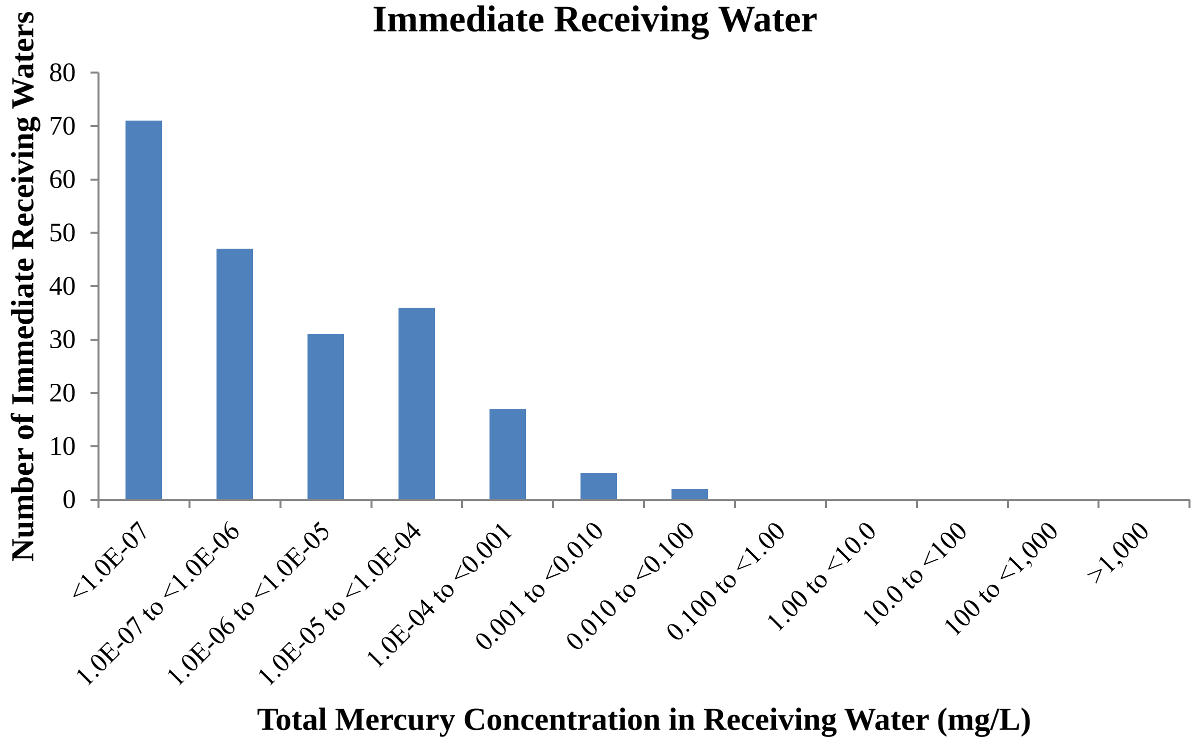
Source: ERG, 2015d; ERG, 2015h.

Table H-6. Total Lead Concentration (mg/L) in the Immediate Receiving Water by Percentile

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	1.41E-09	0	0	0	0	0
25th	4.47E-07	2.22E-07	2.22E-07	1.36E-09	0	0
50th	3.61E-06	2.91E-06	2.91E-06	3.65E-07	2.65E-09	2.65E-09
75th	7.65E-05	6.98E-05	6.98E-05	5.99E-06	4.47E-07	4.47E-07
95th	0.009	0.007	0.007	0.001	7.22E-05	7.22E-05
Max	0.757	0.510	0.510	0.510	0.510	0.510

Source: ERG, 2015d; ERG, 2015h.

Figure H-6. Baseline Total Mercury Concentration in the Immediate Receiving Water



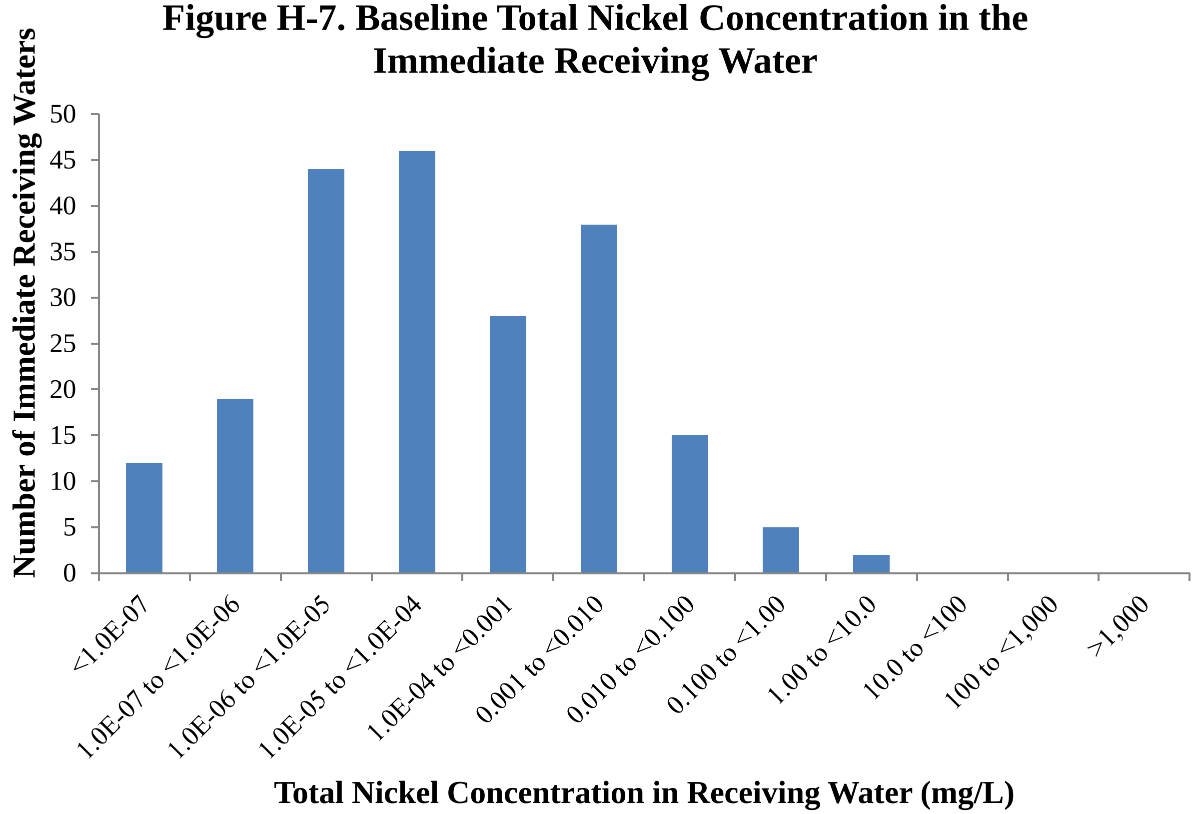
Source: ERG, 2015d; ERG, 2015h.

Table H-7. Total Mercury Concentration (mg/L) in the Immediate Receiving Water by Percentile

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	1.70E-09	5.32E-10	3.94E-10	0	0	0
25th	4.50E-08	2.29E-08	1.86E-08	1.86E-09	0	0
50th	3.56E-07	1.79E-07	1.77E-07	6.24E-08	4.20E-09	2.32E-09
75th	1.68E-05	1.34E-05	1.28E-05	2.31E-06	2.14E-07	1.05E-07
95th	0.001	2.62E-04	2.58E-04	1.15E-04	4.17E-05	8.96E-06
Max	0.056	0.020	0.020	0.020	0.020	0.020

Source: ERG, 2015d; ERG, 2015h.

Figure H-7. Baseline Total Nickel Concentration in the Immediate Receiving Water

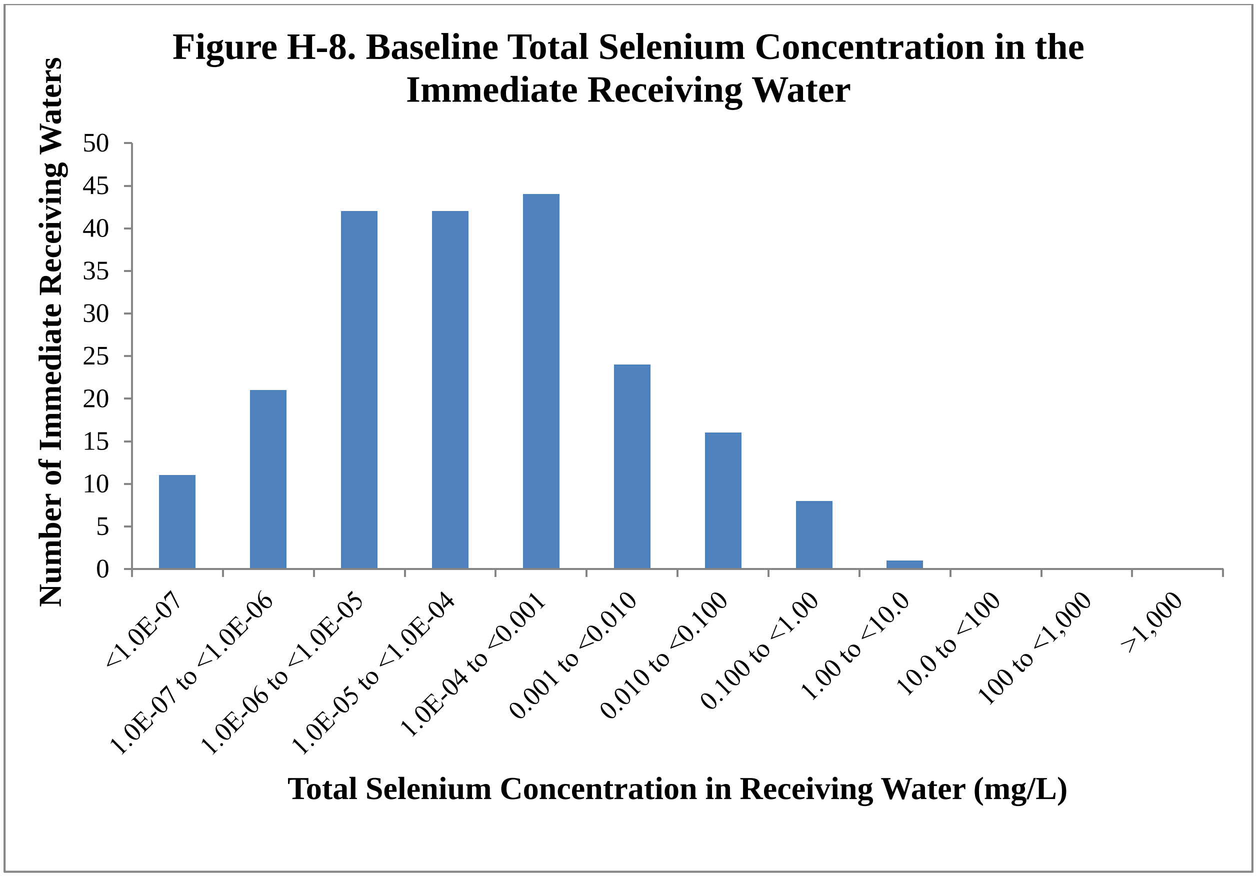


Source: ERG, 2015d; ERG, 2015h.

Table H-8. Total Nickel Concentration (mg/L) in the Immediate Receiving Water by Percentile

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	7.14E-08	4.16E-08	3.00E-08	0	0	0
25th	3.31E-06	1.31E-06	1.11E-06	1.86E-07	0	0
50th	3.34E-05	1.81E-05	1.81E-05	4.58E-06	4.17E-07	2.47E-07
75th	0.001	0.001	0.001	1.37E-04	1.62E-05	1.05E-05
95th	0.049	0.034	0.033	0.008	0.004	0.002
Max	2.25	2.25	2.25	2.25	2.25	0.616

Source: ERG, 2015d; ERG, 2015h.



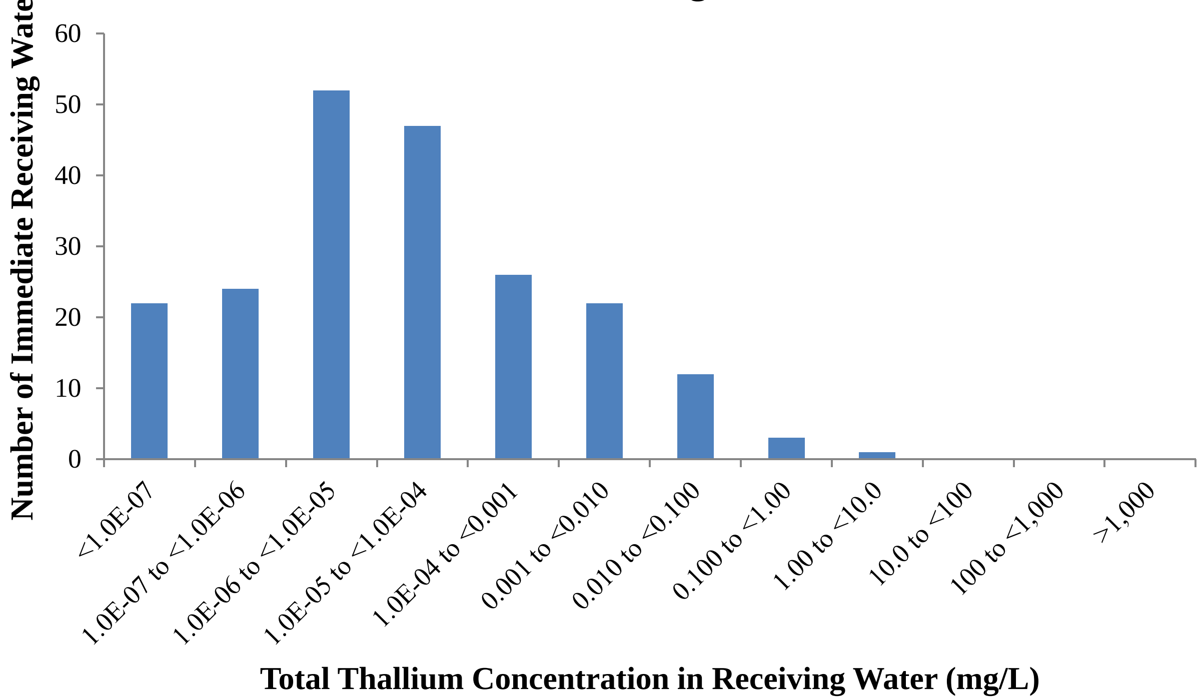
Source: ERG, 2015d; ERG, 2015h.

Table H-9. Total Selenium Concentration (mg/L) in the Immediate Receiving Water by Percentile

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	9.12E-08	3.84E-08	2.05E-08	0	0	0
25th	2.74E-06	2.46E-06	5.01E-07	1.19E-07	0	0
50th	5.46E-05	3.67E-05	5.30E-06	2.35E-06	3.82E-07	3.82E-07
75th	0.001	0.001	3.08E-04	9.68E-05	2.61E-05	2.61E-05
95th	0.064	0.040	0.017	0.013	0.010	0.010
Max	5.38	5.38	5.38	5.38	5.38	5.38

Source: ERG, 2015d; ERG, 2015h.

Figure H-9. Baseline Total Thallium Concentration in the Immediate Receiving Water



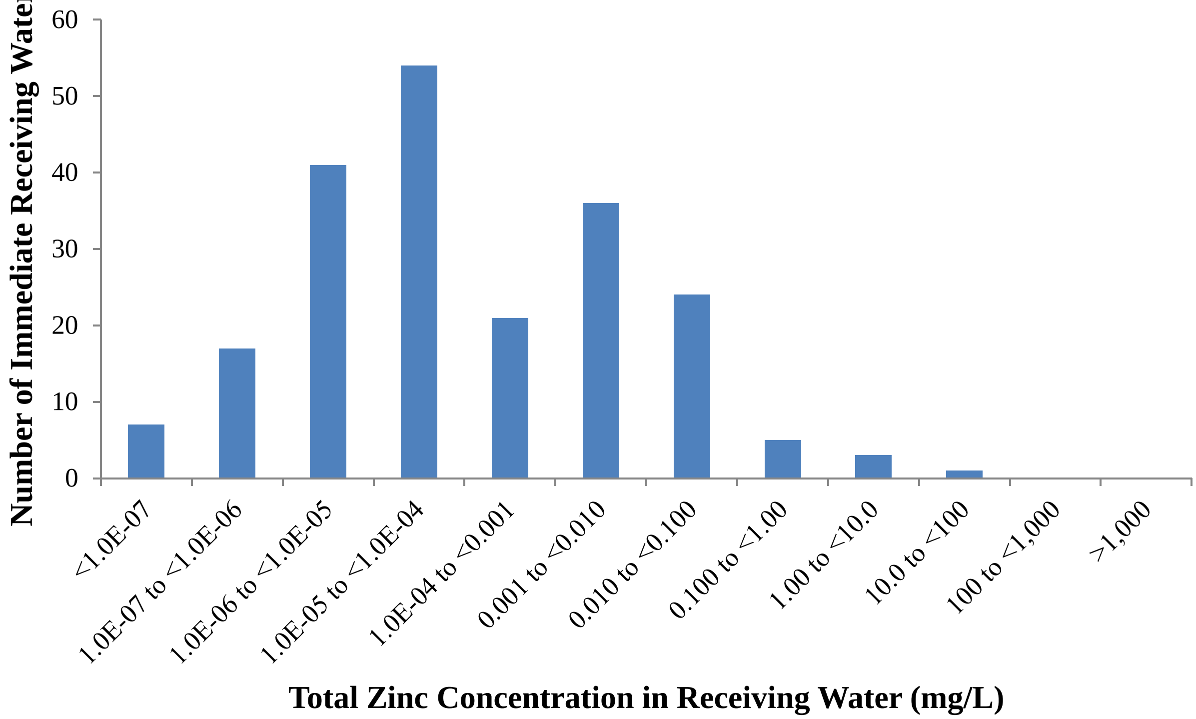
Source: ERG, 2015d; ERG, 2015h.

Table H-10. Total Thallium Concentration (mg/L) in the Immediate Receiving Water by Percentile

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	1.09E-08	5.95E-09	5.95E-09	0	0	0
25th	1.31E-06	7.82E-07	7.82E-07	6.08E-08	0	0
50th	1.49E-05	1.20E-05	1.20E-05	2.33E-06	1.89E-07	1.89E-07
75th	1.91E-04	1.54E-04	1.54E-04	3.71E-05	5.87E-06	5.87E-06
95th	0.035	0.033	0.033	0.004	3.42E-04	3.42E-04
Max	1.75	1.75	1.75	1.75	0.591	0.591

Source: ERG, 2015d; ERG, 2015h.

Figure H-10. Baseline Total Zinc Concentration in the Immediate Receiving Water



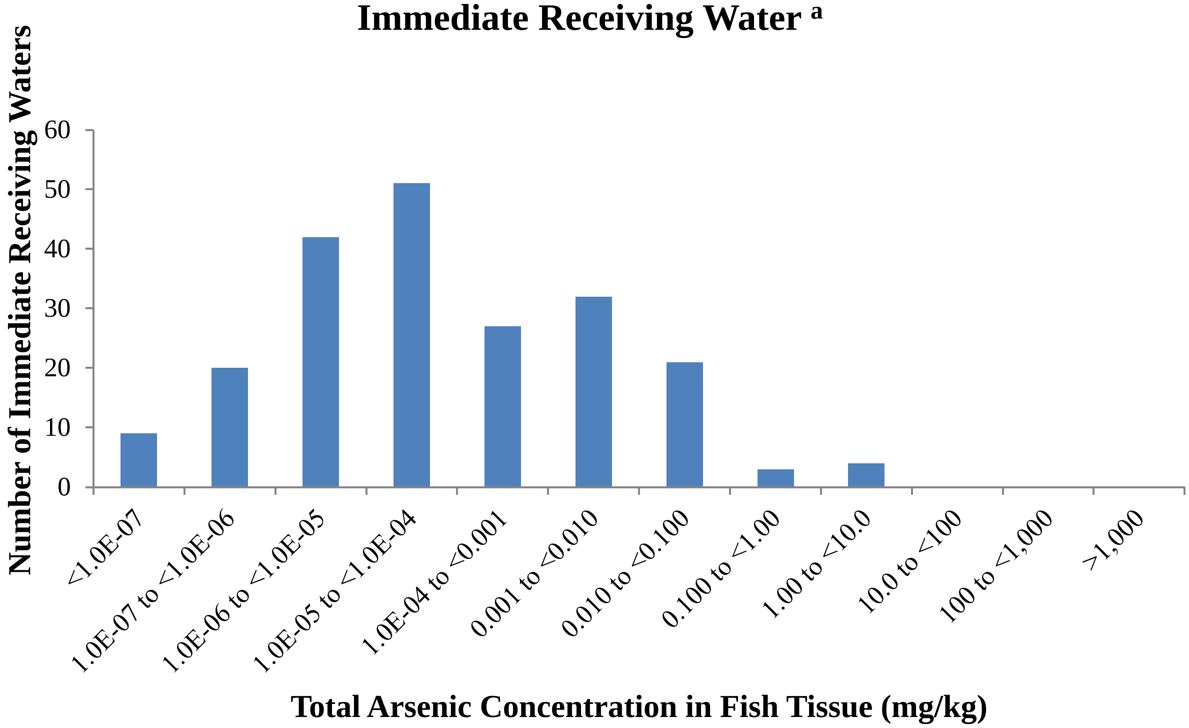
Source: ERG, 2015d; ERG, 2015h.

Table H-11. Total Zinc Concentration (mg/L) in the Immediate Receiving Water by Percentile

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	2.07E-07	9.14E-08	9.14E-08	0	0	0
25th	5.40E-06	2.43E-06	2.43E-06	4.67E-07	0	0
50th	6.37E-05	2.12E-05	2.12E-05	1.10E-05	1.44E-06	7.84E-07
75th	0.002	0.002	0.002	4.11E-04	7.72E-05	3.54E-05
95th	0.081	0.039	0.039	0.032	0.019	0.003
Max	10.2	10.2	10.2	10.2	10.2	1.43

Source: ERG, 2015d; ERG, 2015h.

Figure H-11. Baseline Total Arsenic Concentration in Trophic Level 3 and Trophic Level 4 Fish Tissue in the Immediate Receiving Water [a]



Source: ERG, 2015d; ERG, 2015i.

a – The wildlife module applies the same total arsenic bioconcentration factors (BCFs) for both trophic level 3 (T3) and trophic level 4 (T4) fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.

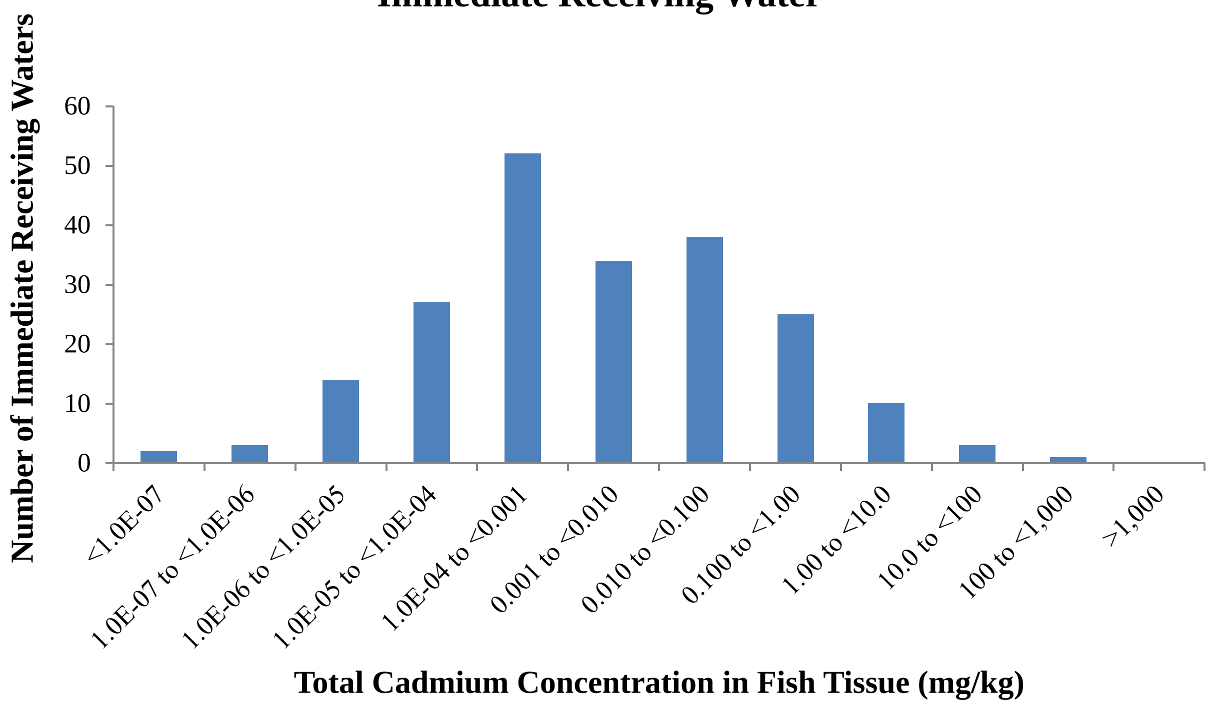
Table H-12. Total Arsenic Concentration (mg/kg) in Fish Tissue (Trophic Level 3 & Trophic Level 4) by Percentile [a]

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	1.38E-07	8.28E-08	8.28E-08	0	0	0
25th	3.85E-06	2.51E-06	2.51E-06	4.86E-07	0	0
50th	3.15E-05	2.20E-05	2.20E-05	1.13E-05	1.45E-06	7.71E-07
75th	0.002	0.002	0.002	3.69E-04	6.49E-05	3.87E-05
95th	0.062	0.032	0.032	0.024	0.014	0.004
Max	7.45	7.45	7.45	7.45	7.45	4.53

Source: ERG, 2015d; ERG, 2015i.

a – The wildlife module applies the same total BCFs for both trophic level 3 (T3) and trophic level 4 (T4) fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.

Figure H-12. Baseline Total Cadmium Concentration in Trophic Level 3 and Trophic Level 4 Fish Tissue in the Immediate Receiving Water [a]



Source: ERG, 2015d; ERG, 2015i.

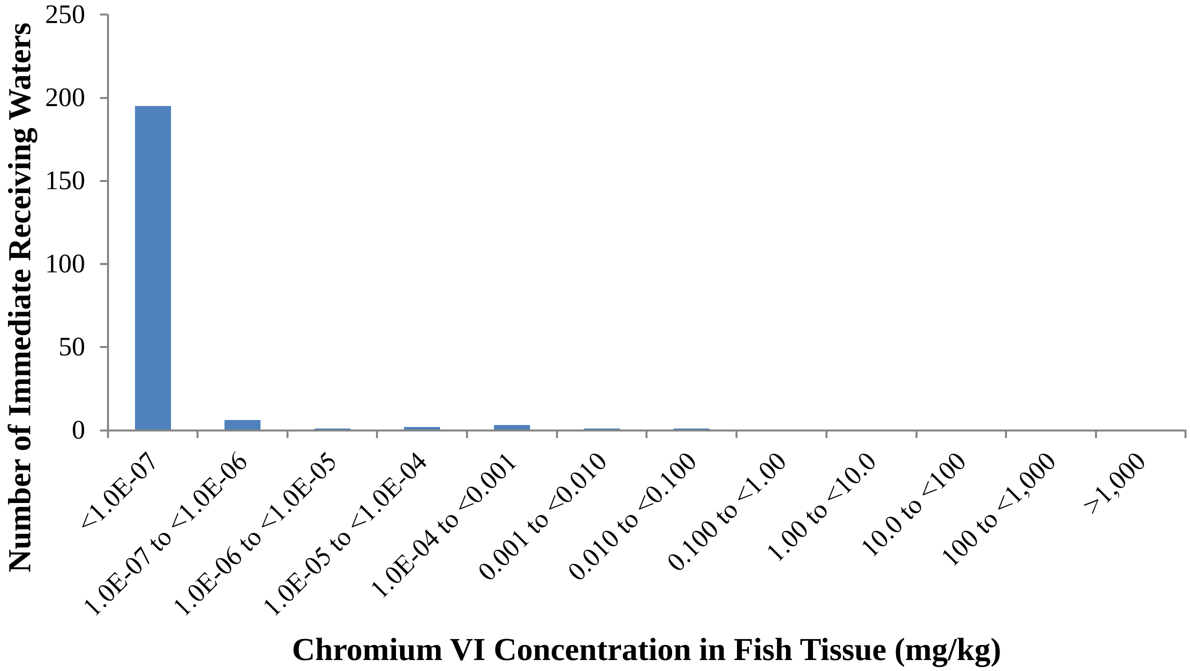
a – The wildlife module applies the same total cadmium BCFs for both T3 and T4 fish (see Appendix D**Error! Reference source not found.**). Therefore, the estimated concentrations presented here are identical for both trophic levels.

Table H-13. Total Cadmium Concentration (mg/kg) in Fish Tissue (Trophic Level 3 & Trophic Level 4) by Percentile [a]

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	3.85E-06	2.81E-06	2.81E-06	0	0	0
25th	1.38E-04	6.08E-05	6.08E-05	1.39E-05	0	0
50th	0.001	5.67E-04	5.67E-04	2.66E-04	4.17E-05	3.67E-05
75th	0.047	0.033	0.033	0.010	0.002	0.002
95th	1.40	0.738	0.738	0.505	0.332	0.190
Max	132	132	132	132	132	55.1

Source: ERG, 2015d; ERG, 2015i.
a – The wildlife module applies the same total cadmium BCFs for both trophic level 3 (T3) and trophic level 4 (T4) fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.

Figure H-13. Baseline Chromium VI Concentration in Trophic Level 3 and Trophic Level 4 Fish Tissue in the Immediate Receiving Water [a]



Source: ERG, 2015d; ERG, 2015i.

a – BCFs for chromium VI are not available; EPA used the total chromium BCF values. The wildlife module applies the same total chromium BCFs for both T3 and T4 fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.

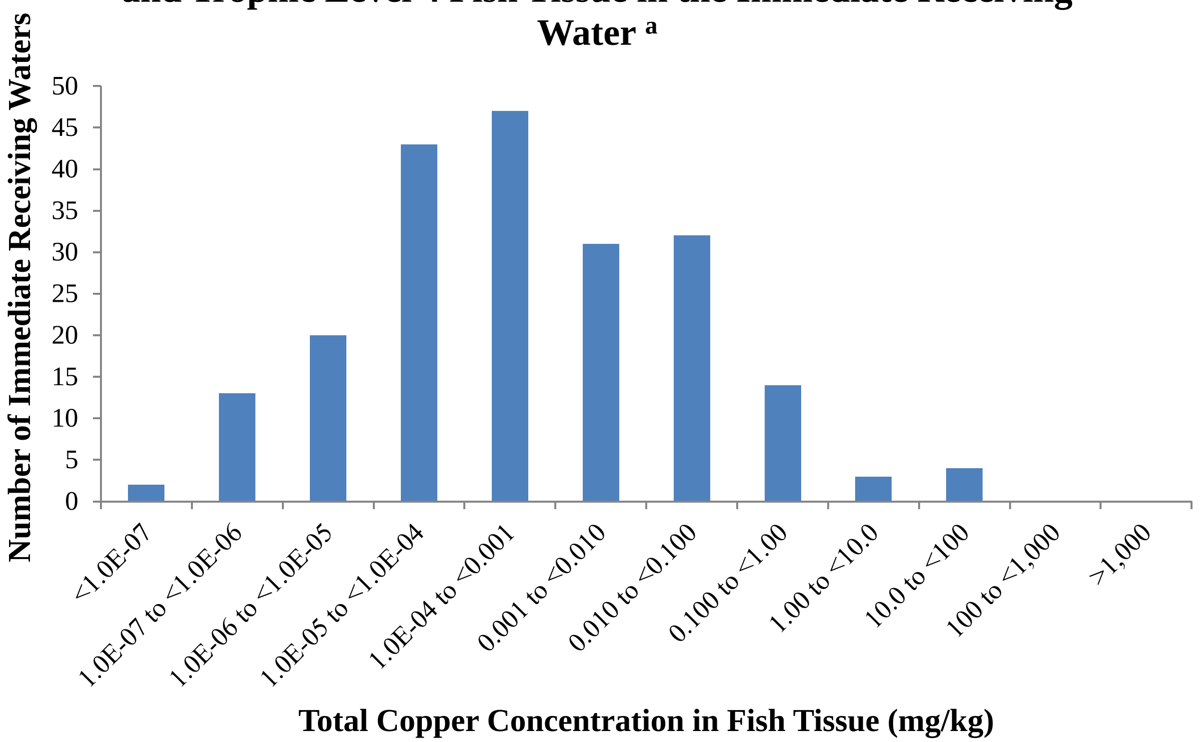
Table H-14. Chromium VI Concentration (mg/kg) in Fish Tissue (Trophic Level 3 & Trophic Level 4) by Percentile [a]

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	0	0	0	0	0	0
25th	0	0	0	0	0	0
50th	0	0	0	0	0	0
75th	0	0	0	0	0	0
95th	3.67E-07	5.18E-08	5.18E-08	3.91E-09	0	0
Max	0.011	0.008	0.008	0.008	0.008	0.008

Source: ERG, 2015d; ERG, 2015i.

a – The wildlife module applies the same total chromium BCFs for both trophic level 3 (T3) and trophic level 4 (T4) fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.

Figure H-14. Total Copper Concentration in Trophic Level 3 and Trophic Level 4 Fish Tissue in the Immediate Receiving Water [a]



Source: ERG, 2015d; ERG, 2015i.

a – The wildlife module applies the same total copper BCFs for both T3 and T4 fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.

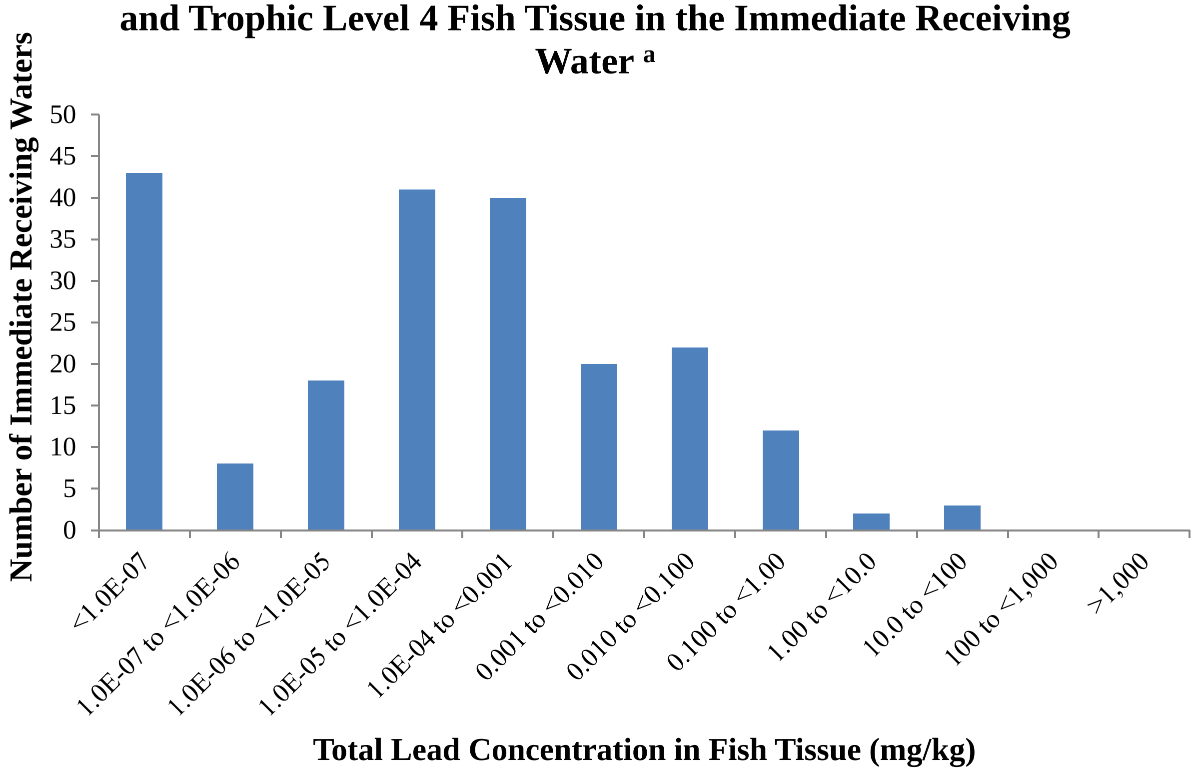
Table H-15. Total Copper Concentration (mg/kg) in Fish Tissue (Trophic Level 3 & Trophic Level 4) by Percentile [a]

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	5.89E-07	3.65E-07	3.65E-07	0	0	0
25th	3.19E-05	1.93E-05	1.93E-05	2.83E-06	0	0
50th	2.99E-04	2.26E-04	2.26E-04	5.66E-05	4.78E-06	4.36E-06
75th	0.010	0.008	0.008	0.002	2.56E-04	2.26E-04
95th	0.540	0.340	0.340	0.072	0.036	0.023
Max	41.5	28.0	28.0	28.0	28.0	28.0

Source: ERG, 2015d; ERG, 2015i.

a – The wildlife module applies the same total copper BCFs for both trophic level 3 (T3) and trophic level 4 (T4) fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.

Figure H-15. Total Lead Concentration in Trophic Level 3 and Trophic Level 4 Fish Tissue in the Immediate Receiving Water [a]

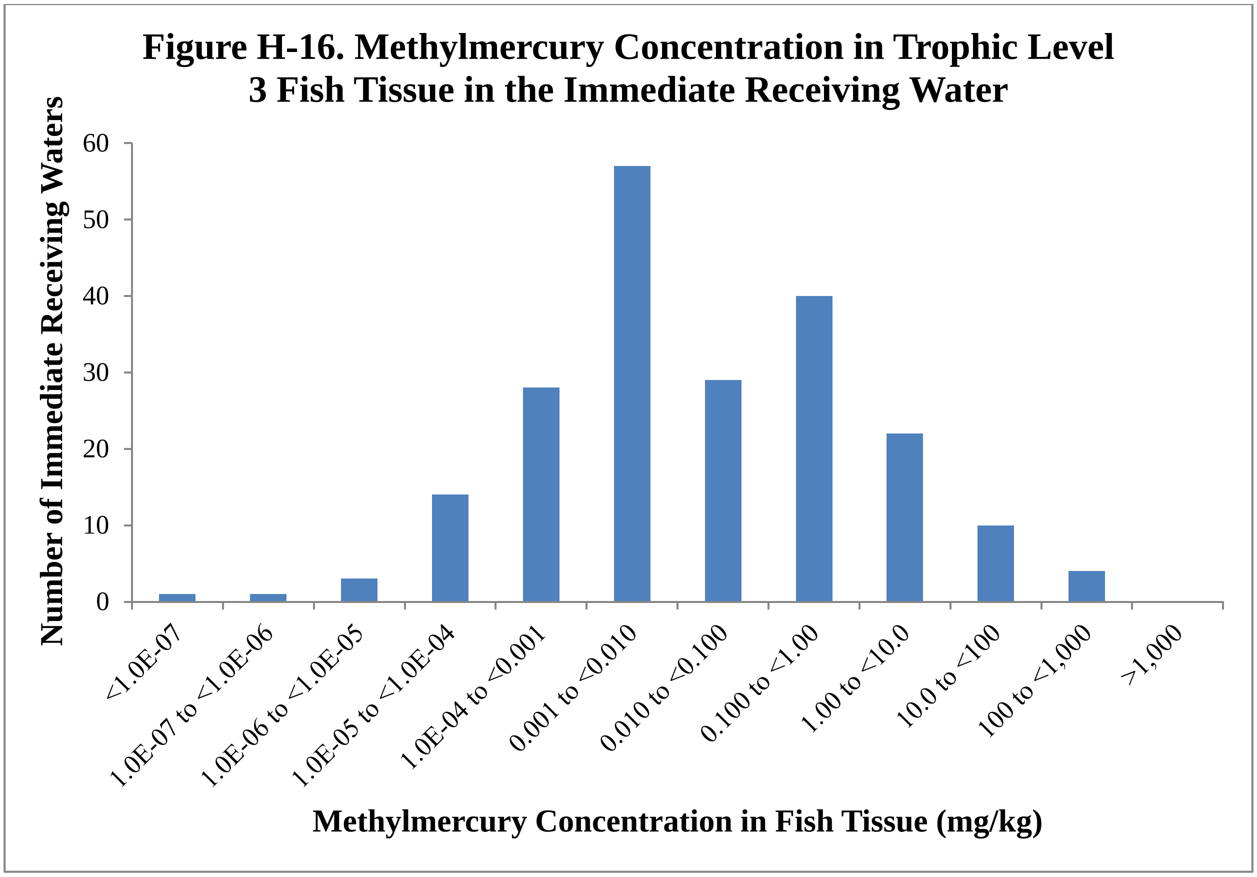


Source: ERG, 2015d; ERG, 2015i.
a – The wildlife module applies the same total lead BCFs for both T3 and T4 fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.

Table H-16. Total Lead Concentration (mg/kg) in Fish Tissue (Trophic Level 3 & Trophic Level 4) by Percentile [a]

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	0	0	0	0	0	0
25th	2.12E-06	7.94E-07	7.94E-07	0	0	0
50th	7.01E-05	4.95E-05	4.95E-05	5.57E-06	0	0
75th	0.001	0.001	0.001	1.83E-04	1.03E-05	1.03E-05
95th	0.343	0.319	0.319	0.047	0.002	0.002
Max	34.8	23.5	23.5	23.5	23.5	23.5

Source: ERG, 2015d; ERG, 2015i.
a – The wildlife module applies the same total lead BCFs for both trophic level 3 (T3) and trophic level 4 (T4) fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.



Source: ERG, 2015d; ERG, 2015i.

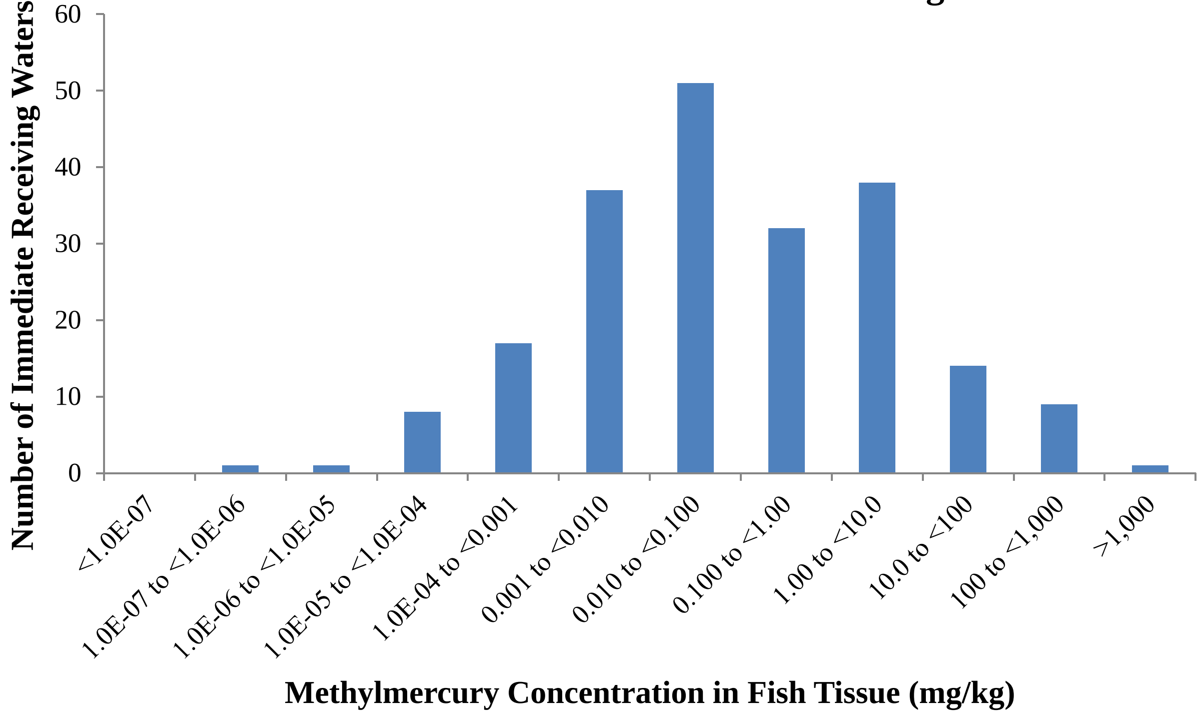
Table H-17. Methylmercury Concentration (mg/kg) in Fish Tissue (Trophic Level 3) by Percentile [a]

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	2.86E-05	1.63E-05	9.58E-06	0	0	0
25th	0.001	8.10E-04	4.69E-04	5.71E-05	0	0
50th	0.010	0.005	0.005	0.001	1.76E-04	9.28E-05
75th	0.455	0.314	0.279	0.045	0.006	0.004
95th	16.826	9.42	9.42	2.66	1.43	0.230
Max	414.6	183	183	183	183	183

Source: ERG, 2015d; ERG, 2015i.

a – EPA calculated methylmercury fish tissue concentrations using bioaccumulation factors which do not fully account for the complexity of biogeochemical reactions that can occur within an aquatic environment and result in lower bioaccumulation rates of mercury in fish. For example, fish are known to bioaccumulate mercury at lower rates when exposed to surface waters with high selenium concentrations. In addition, bioaccumulation factors do not account for a maximum limit a fish could accumulate before a lethal concentration is reached. To address the outliers in mercury fish tissue concentrations, EPA compared fish tissue concentrations to site-specific data available in the national fish advisory database and established calibration factors to lower the outlier values. Fish tissue concentrations presented in the figure and table above represent the uncalibrated values calculated by the wildlife model. For further details on the methodology for selecting calibration factors see ERG memorandum "EA Model Validation and Calibration" (DCN SE04454).

Figure H-17. Methylmercury Concentration in Trophic Level 4 Fish Tissue in the Immediate Receiving Water



Source: ERG, 2015d; ERG, 2015i.

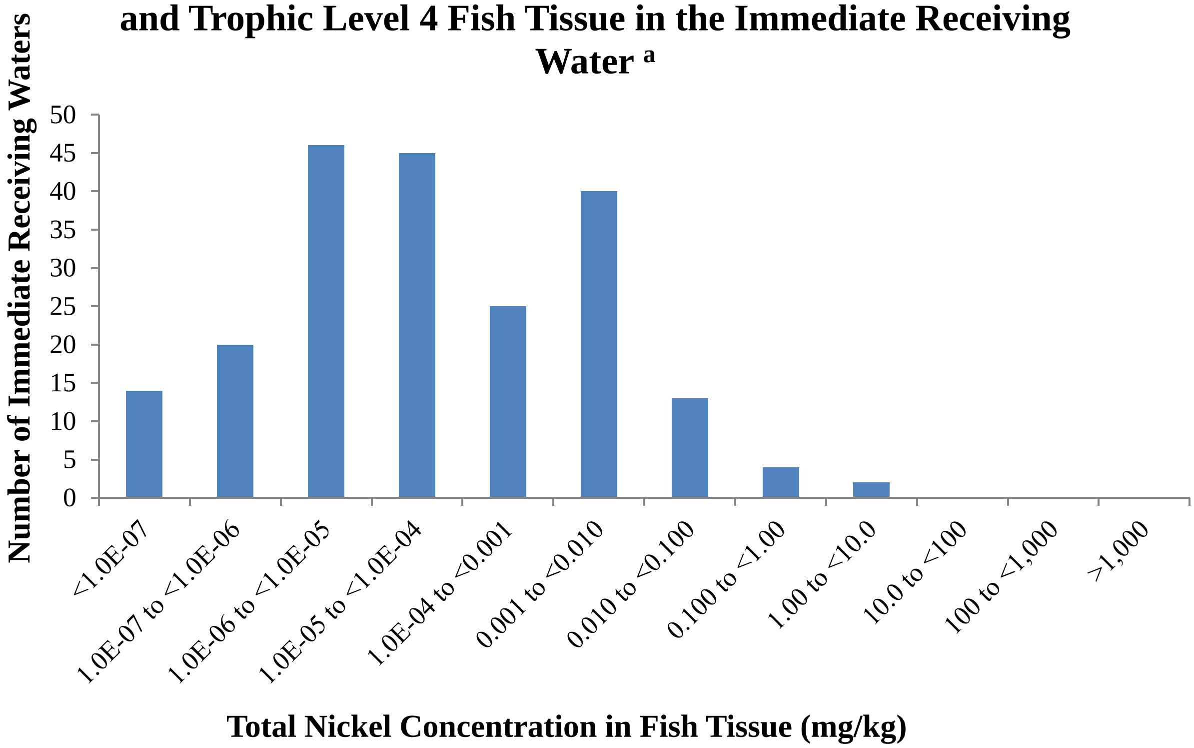
Table H-18. Methylmercury Concentration (mg/kg) in Fish Tissue (Trophic Level 4) by Percentile [a]

Percentile	Scenario					
	Baseline	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
5th	1.21E-04	6.91E-05	4.07E-05	0	0	0
25th	0.005	0.003	0.002	2.43E-04	0	0
50th	0.044	0.021	0.020	0.006	7.48E-04	3.94E-04
75th	1.93	1.33	1.19	0.190	0.027	0.017
95th	71.5	40.1	40.1	11.3	6.07	0.976
Max	1,762	779	779	779	779	779

Source: ERG, 2015d; ERG, 2015i.

a – EPA calculated methylmercury fish tissue concentrations using bioaccumulation factors which do not fully account for the complexity of biogeochemical reactions that can occur within an aquatic environment and result in lower bioaccumulation rates of mercury in fish. For example, fish are known to bioaccumulate mercury at lower rates when exposed to surface waters with high selenium concentrations. In addition, bioaccumulation factors do not account for a maximum limit a fish could accumulate before a lethal concentration is reached. To address the outliers in mercury fish tissue concentrations, EPA compared fish tissue concentrations to site-specific data available in the national fish advisory database and established calibration factors to lower the outlier values. Fish tissue concentrations presented in the figure and table above represent the uncalibrated values calculated by the wildlife model. For further details on the methodology for selecting calibration factors see ERG memorandum “EA Model Validation and Calibration” (DCN SE04454).

Figure H-18. Total Nickel Concentration in Trophic Level 3 and Trophic Level 4 Fish Tissue in the Immediate Receiving Water [a]



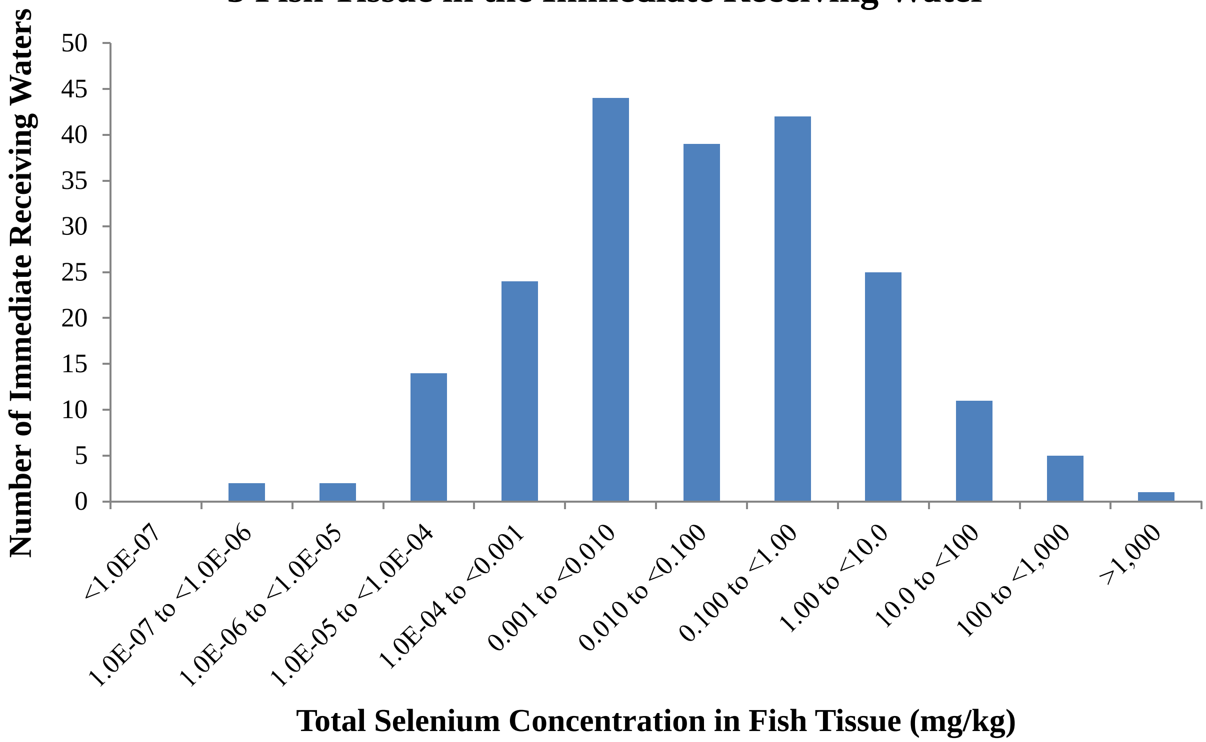
Source: ERG, 2015d; ERG, 2015i.
a – The wildlife module applies the same total nickel BCFs for both T3 and T4 fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.

Table H-19. Total Nickel Concentration (mg/kg) in Fish Tissue (Trophic Level 3 & Trophic Level 4) by Percentile [a]

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	5.71E-08	3.33E-08	2.40E-08	0	0	0
25th	2.65E-06	1.05E-06	8.88E-07	1.49E-07	0	0
50th	2.67E-05	1.44E-05	1.44E-05	3.66E-06	3.34E-07	1.98E-07
75th	0.001	0.001	0.001	1.09E-04	1.30E-05	8.37E-06
95th	0.040	0.027	0.027	0.007	0.003	0.001
Max	1.80	1.80	1.80	1.80	1.80	0.493

Source: ERG, 2015d; ERG, 2015i.
a – The wildlife module applies the same total nickel BCFs for both trophic level 3 (T3) and trophic level 4 (T4) fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.

Figure H-19. Total Selenium Concentration in Trophic Level 3 Fish Tissue in the Immediate Receiving Water



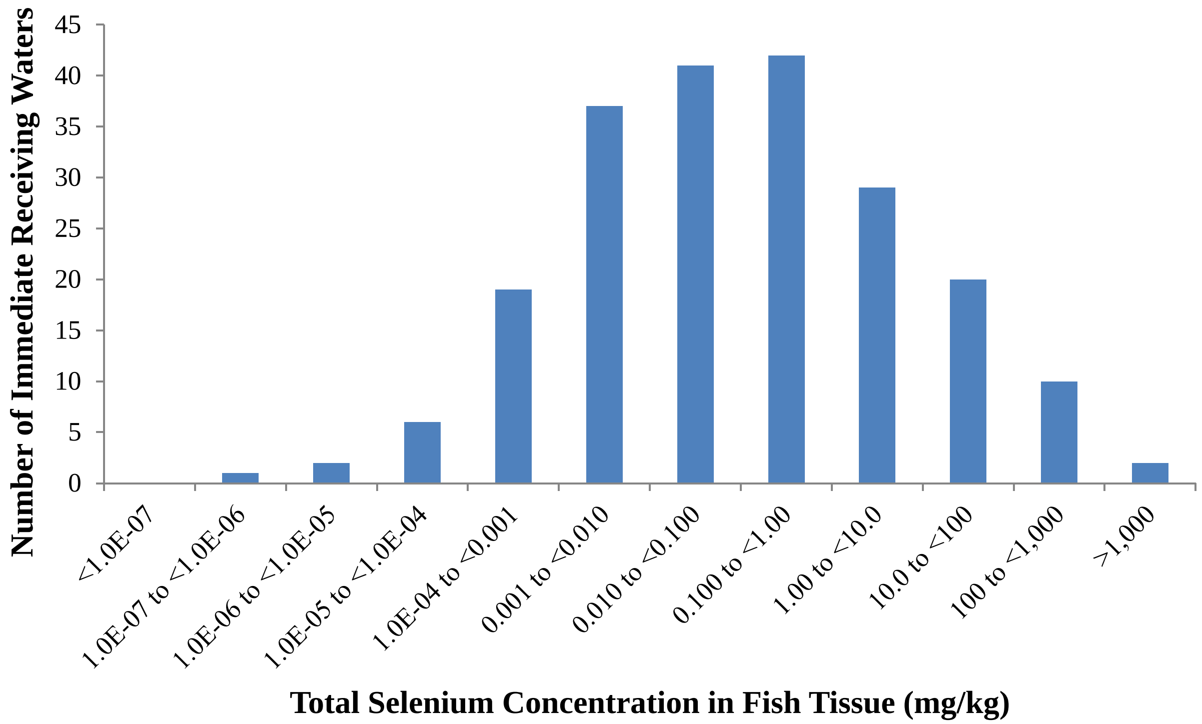
Source: ERG, 2015d; ERG, 2015i.

Table H-20. Total Selenium Concentration (mg/kg) in Fish Tissue (Trophic Level 3) by Percentile

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	4.47E-05	1.88E-05	1.01E-05	0	0	0
25th	0.001	0.001	2.45E-04	5.83E-05	0	0
50th	0.027	0.018	0.003	0.001	1.87E-04	1.87E-04
75th	0.428	0.374	0.151	0.047	0.013	0.013
95th	31.6	19.5	8.12	6.55	4.86	4.86
Max	2,638	2,638	2,638	2,638	2,638	2,638

Source: ERG, 2015d; ERG, 2015i.

Figure H-20. Total Selenium Concentration in Trophic Level 4 Fish Tissue in the Immediate Receiving Water



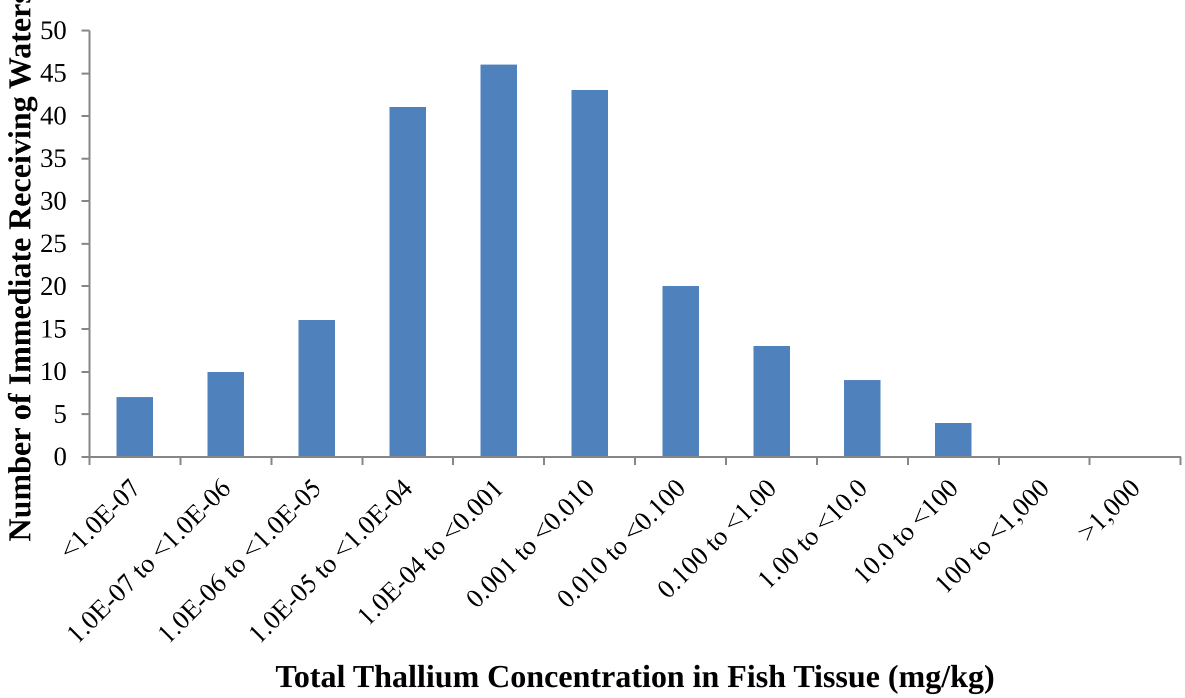
Source: ERG, 2015d; ERG, 2015i.

Table H-21. Total Selenium Concentration (mg/kg) in Fish Tissue (Trophic Level 4) by Percentile

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	1.55E-04	6.54E-05	3.49E-05	0	0	0
25th	0.005	0.004	8.51E-04	2.02E-04	0	0
50th	0.093	0.062	0.009	0.004	6.50E-04	6.50E-04
75th	1.48	1.30	0.523	0.165	0.044	0.044
95th	110	67.5	28.2	22.7	16.9	16.9
Max	9,151	9,151	9,151	9,151	9,151	9,151

Source: ERG, 2015d; ERG, 2015i.

Figure H-21. Total Thallium Concentration in Trophic Level 3 Fish Tissue in the Immediate Receiving Water



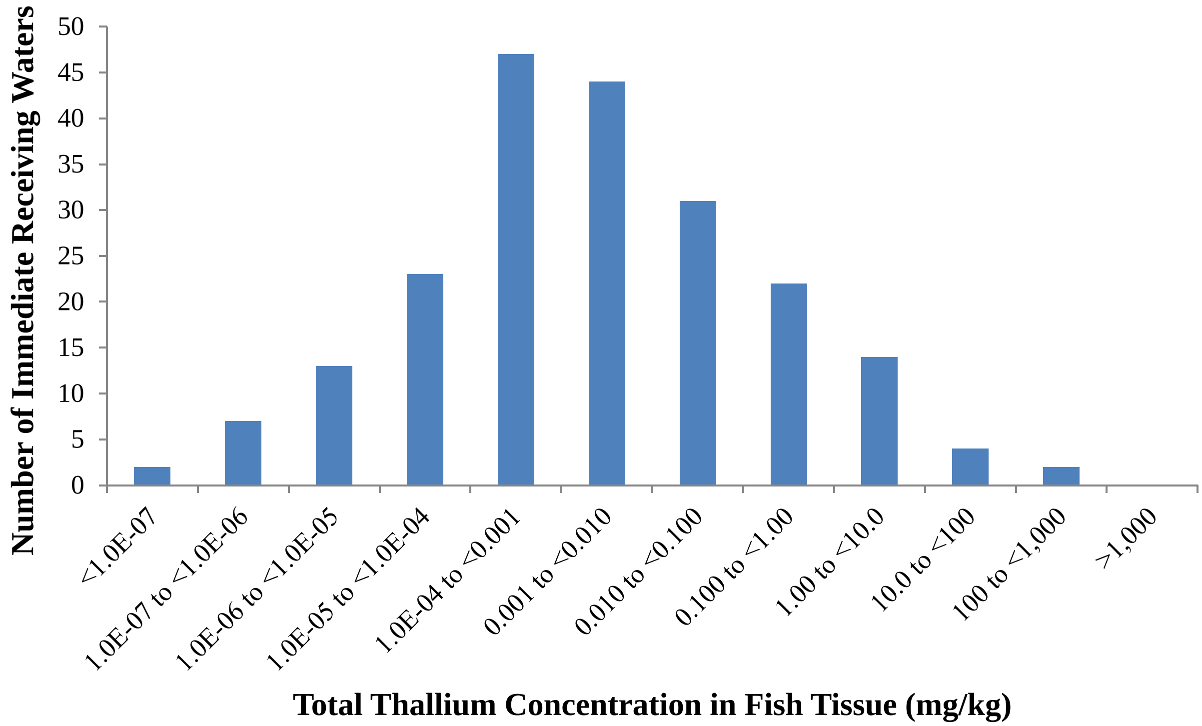
Source: ERG, 2015d; ERG, 2015i.

Table H-22. Total Thallium Concentration (mg/kg) in Fish Tissue (Trophic Level 3) by Percentile

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	3.70E-07	2.02E-07	2.02E-07	0	0	0
25th	4.46E-05	2.66E-05	2.66E-05	2.07E-06	0	0
50th	5.05E-04	4.07E-04	4.07E-04	7.91E-05	6.43E-06	6.43E-06
75th	0.006	0.005	0.005	0.001	2.00E-04	2.00E-04
95th	1.20	1.13	1.13	0.131	0.012	0.012
Max	59.6	59.6	59.6	59.6	20.1	20.1

Source: ERG, 2015d; ERG, 2015i.

Figure H-22. Total Thallium Concentration in Trophic Level 4 Fish Tissue in the Immediate Receiving Water



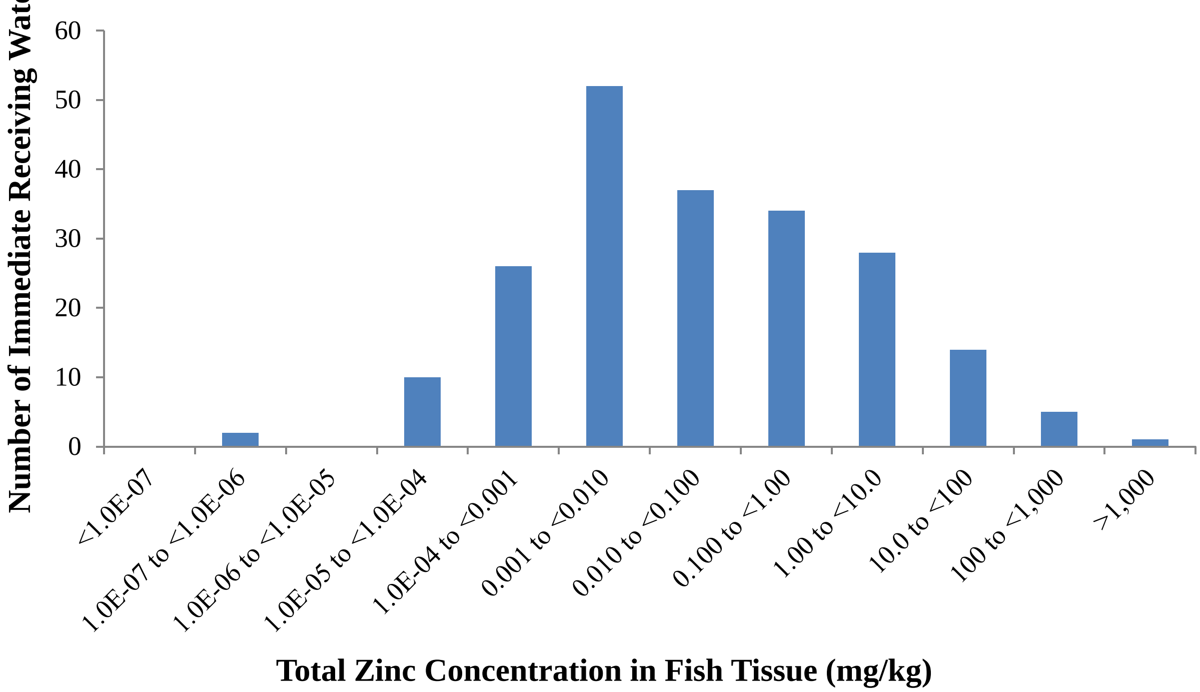
Source: ERG, 2015d; ERG, 2015i.

Table H-23. Total Thallium Concentration (mg/kg) in Fish Tissue (Trophic Level 4) by Percentile

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	1.41E-06	7.74E-07	7.74E-07	0	0	0
25th	1.70E-04	1.02E-04	1.02E-04	7.90E-06	0	0
50th	0.002	0.002	0.002	3.02E-04	2.46E-05	2.46E-05
75th	0.025	0.020	0.020	0.005	7.63E-04	7.63E-04
95th	4.58	4.31	4.31	0.500	0.044	0.044
Max	228	228	228	228	76.8	76.8

Source: ERG, 2015d; ERG, 2015i.

Figure H-23. Total Zinc Concentration in Trophic Level 3 and Trophic Level 4 Fish Tissue in the Immediate Receiving Water [a]



Source: ERG, 2015d; ERG, 2015i.
a – The wildlife module applies the same total zinc BCFs for both T3 and T4 fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.

Table H-24. Total Zinc Concentration (mg/kg) in Fish Tissue (Trophic Level 3 & Trophic Level 4) by Percentile [a]

Percentile	Scenario					
	Baseline	Option A	Option B	Option C	Option D	Option E
5th	7.25E-05	3.20E-05	3.20E-05	0	0	0
25th	0.002	8.50E-04	8.50E-04	1.63E-04	0	0
50th	0.022	0.007	0.007	0.004	5.04E-04	2.74E-04
75th	0.809	0.687	0.687	0.144	0.027	0.012
95th	28.4	13.6	13.6	11.0	6.59	1.17
Max	3,576	3,576	3,576	3,576	3,576	501

Source: ERG, 2015d; ERG, 2015i.
a – The wildlife module applies the same total zinc BCFs for both trophic level 3 (T3) and trophic level 4 (T4) fish (see Appendix D). Therefore, the estimated concentrations presented here are identical for both trophic levels.

APPENDIX I
ANALYSIS FOR ALTERNATE SCENARIO WITH CLEAN POWER PLAN

As discussed in Section 1, the environmental assessment (EA) report presents the methodology and results of the qualitative and quantitative analyses performed to evaluate baseline discharges from steam electric power plants and improvements under the final steam electric effluent limitations guidelines and standards (ELGs). The analyses presented in the report incorporate some adjustments to current conditions in the industry. The analyses in the report, however, do not reflect changes in the industry that may occur as a result of the Clean Power Plan [Clean Air Act Section 111(d)] (CPP). This appendix presents the results of EPA's quantitative EA analysis that does reflect changes in the industry that may occur as a result of the CPP. Table I-1 presents the number of plants included in this alternate scenario analysis compared to those in the EA report.

Table I-1. Number of Plants Evaluated in the EA Alternate Scenario Analysis Compared to the EA Report

Plant Description	Number of Plants in EA Report	Number of Plants in Alternate Scenario Analysis
Number of Plants in Scope of Final Rule		
Plants that fall under the applicability of the final rule (40 CFR 423)	1,079	1,079
Cost and Loadings Analysis		
Plants for which EPA calculated loadings in the cost and loadings analyses (see Sections 9 and 10 of the TDD)	202	151
Plants that discharge only to surface waters (direct discharger)	191	145
Plants that discharge only to a POTW (indirect discharger)	7	3
Plants that discharge to surface waters and to a POTW (direct and indirect discharger)	4	3
Environmental Assessment		
Plants evaluated in the EA (includes all direct dischargers)[a]	195	148

Acronyms: CFR (Code of Federal Regulations); POTW (publicly owned treatment works); TDD (*Technical Development Document for Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category (TDD),* Document No. EPA-821-R-15-007)

a – For the pollutant loadings and removals presented in this appendix, EPA included indirect dischargers to protect confidential business information.

The 148 steam electric power plants in the EA alternate scenario analysis discharge to the 172 immediate receiving waters illustrated in Figure I-1 (some plants discharge to multiple receiving waters). Table I-2 presents the count of receiving water types for the 172 immediate receiving waters.

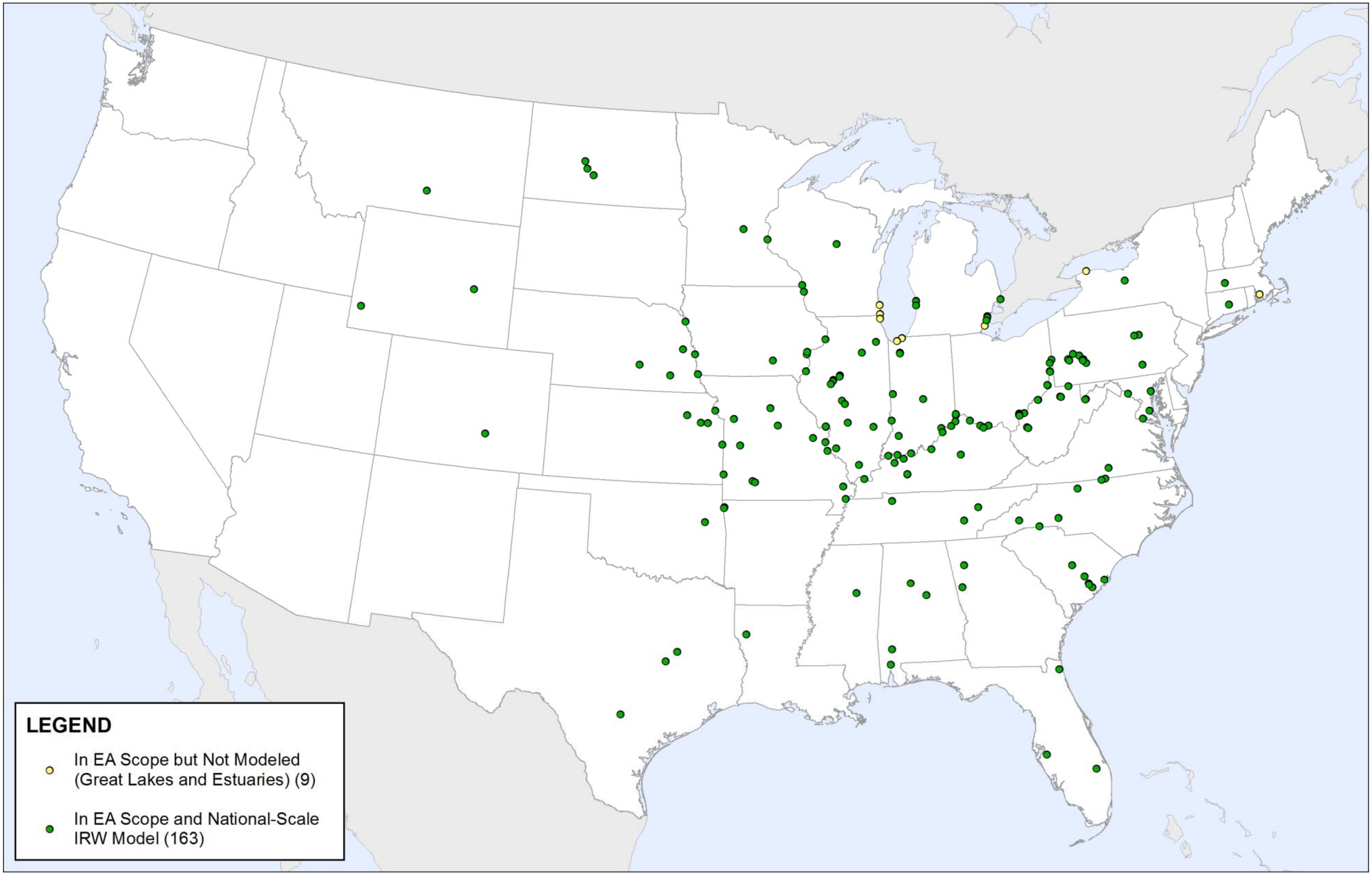


Figure I-1. Locations and Counts of Immediate Receiving Waters in EA Scope and Modeling Analyses

Table I-2. Receiving Water Types for Steam Electric Power Plants Evaluated in the EA

Receiving Water Type	Number (Percentage) of Immediate Receiving Waters in the Alternate Scenario Analysis [a]
River/Stream	144 (84%)
Lake/Pond/Reservoir	19 (11%)
Great Lakes	8 (5%)
Estuary	1 (<1%)
Total Receiving Waters	**172 (100%)**

Source: ERG, 2015d.

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The immediate receiving water (IRW) model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

EPA evaluated the annual baseline pollutant discharges of the evaluated wastestreams from steam electric power plants reflecting changes in the industry that may occur as a result of the CPP. Table I-3 presents the annual pollutant loadings in pounds and toxic-weighted pound equivalents (TWPE).[1,2] Table I-4 compares pollutant discharges, as TWPE, from the steam electric power generating industry to discharges from the other top ten discharging point source categories, as estimated by EPA for the 2010 Effluent Guidelines Planning Process [U.S. EPA, 2011d].

[1] To calculate the TWPE, EPA multiplies a mass loading of a pollutant in pounds per year (lb/yr) by a pollutant-specific weighting factor, called the toxic weighting factor (TWF), to derive a "toxic equivalent" loading (lb-equivalent/yr), or TWPE. TWFs account for differences in toxicity across pollutants and allow mass loadings of different pollutants to be compared on the basis of their toxic potential. EPA has developed TWFs for more than 1,000 pollutants based on aquatic life and human health toxicity data, as well as physical/chemical property data [U.S. EPA, 2012b].

[2] Prior to finalizing the rulemaking, EPA revised the datasets used to calculate pollutant loadings for bottom ash transport water and fly ash transport water. The final industry loadings calculated using these revised datasets are presented in the TDD. The total industry loadings presented in Appendix I reflect the revised datasets. However, EPA did not rerun the EA models and other analyses to reflect the final loadings dataset. EA analyses used previously calculated version of the steam electric power plant pollutant loadings that were derived following the same methodology. The EA pollutant loadings are included in DCN SE05622. Pollutant-specific loadings and removals presented in this report are based on the previously calculated version. Appendix J presents the results of a sensitivity analysis that evaluated the potential for these loadings revisions to affect the EA analyses.

Table I-3. Annual Baseline Pollutant Discharges from Steam Electric Power Plants (Evaluated Wastestreams)

Pollutant [a]	TWF [b]	Annual Discharge, pounds (lbs) [c]	Annual TWPE, pound-equivalent (lb-eq) [c]
Metals and Toxic Bioaccumulative Pollutants			
Manganese	0.103	6,320,000	649,000
Cadmium	22.8	10,900	249,000
Boron	0.00834	24,600,000	205,000
Mercury	110.0	1,180	129,000
Selenium	1.12	113,000	127,000
Thallium	2.85	43,900	125,000
Arsenic	3.47	22,200	77,100
Aluminum	0.0647	1,070,000	69,400
Lead	2.24	14,600	32,700
Vanadium	0.280	55,600	15,600
Copper	0.623	24,000	15,000
Iron	0.00560	2,110,000	11,800
Nickel	0.109	94,200	10,300
Zinc	0.0469	145,000	6,800
Chromium VI	0.517	119	61.4
Nutrients			
Total Nitrogen [d]	Not applicable	13,100,000	Not applicable
Total Phosphorus	Not applicable	154,000	Not applicable
Other			
Chlorides	2.435×10^{-5}	722,000,000	17,600
Total dissolved solids	Not applicable	3,290,000,000	Not applicable
Total Pollutants [e]		**1,700,000,000**	**2,140,000**

Sources: Abt, 2008; ERG, 2015a; ERG, 2015b; ERG, 2015f; U.S. EPA, 2012c.

Note: Numbers are rounded to three significant figures.

a – The list of pollutants included in this table is only a subset of pollutants included in the loadings analysis (see Section 10 of the Technical Development Document (TDD) (EPA-821-R-15-007).

b – TWFs for the following metals apply to all metal compounds: arsenic, chromium, copper, lead, manganese, mercury, nickel, selenium, thallium, vanadium, and zinc. EPA updated TWFs for arsenic, cadmium, copper, manganese, mercury, thallium, and vanadium for the steam electric ELGs pollutant loadings analysis.

c – These loadings reflect adjustments to current conditions in the industry to account for publicly announced plans from the steam electric power generating industry to retire or modify steam electric generating units at specific power plants; changes to the industry that are expected to occur as a result of the recent Coal Combustion Residuals (CCR) rulemaking by EPA's Office of Solid Waste and Emergency Response (OSWER); and changes to the industry that are expected to occur as a result of the CPP. Data source for pollutant specific loadings is DCN SE05622.

d – Total nitrogen is the sum of total Kjeldahl nitrogen and nitrate/nitrite as N.

e – The totals represent the pollutant loadings in discharges of the evaluated wastestreams – specifically, flue gas desulfurization (FGD) wastewater, fly ash transport wastewater, bottom ash transport wastewater, and combustion residual leachate (see Section 10 of the TDD). Loadings presented are based on the final loadings analysis presented in the TDD. The totals exclude loadings for pollutants not identified as pollutants of concern (POCs) and for biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), total dissolved solids (TDS), and total suspended solids (TSS).

Table I-4. Pollutant Loadings for the Final 2010 Effluent Guidelines Planning Process: Top 10 Point Source Categories

40 CFR Part	Point Source Category	Total TWPE [a] (lb-eq/yr)
423	Steam Electric Power Generating	2,140,000 [b]
430	Pulp, Paper, And Paperboard	1,030,000
419	Petroleum Refining	1,030,000
421	Nonferrous Metals Manufacturing	994,000
418	Fertilizer Manufacturing	826,000
414	Organic Chemicals, Plastics, And Synthetic Fibers	649,000
440	Ore Mining And Dressing	448,000
415	Inorganic Chemicals Manufacturing	299,000
444	Waste Combustors	254,000
410	Textile Mills	250,000

Source: U.S. EPA, 2011d.

Note: Numbers are rounded to three significant figures.

a – Only TWPE totals for the steam electric power generating industry include updates to TWFs for arsenic, cadmium, copper, manganese, mercury, thallium, and vanadium. The TWPE for all other point source categories is estimated from discharge monitoring reports (DMRs) and Toxic Release Inventory (TRI) reporting and may include double-counting of certain pollutant discharges (*i.e.*, a facility must report a pollutant on both its DMR and its TRI reporting form).

b –EPA calculated the steam electric power generating industry (40 CFR 423) discharges for the alternate scenario analysis as total of 2,140,000 TWPE annually (see Section 10 of the TDD).

EPA estimated that the total alternate scenario analysis TWPE from steam electric power plant wastewater (see Table I-4) is over two times the amount estimated for the pulp, paper, and paperboard industry; petroleum refining industry; and nonferrous metals manufacturing (second, third, and fourth highest ranking), and it is over five times the TWPE for four of the six other industries identified as the top TWPE dischargers in the Final 2010 Effluent Guidelines Program Plan [U.S. EPA, 2011d].[3]

To provide additional perspective on the magnitude of the pollutant loadings from steam electric power plants in the alternate scenario analysis, EPA compared loadings for the evaluated wastestreams to those of an average publicly owned treatment works (POTW). Table I-5 compares the average steam electric pollutant loadings by wastestream[4] to the pollutant loadings from an average POTW assumed to discharge 3 to 5 MGD. EPA also calculated the equivalent number of typical POTWs that would discharge loadings equal to the 151 steam electric power plants[5] included in the alternate scenario analysis. Table I-6 presents total pollutant loadings for

[3] Data sources for the other industry discharges include DMRs and TRI reports. EPA recognizes that the DMR and TRI data have limitations (*e.g.*, only a subset of facilities and a subset of pollutants might be included in the estimated loadings); however, these are the most readily available data sets that represent discharges across the United States.

[4] EPA calculated the average pollutant loadings for each wastestream by dividing the total pollutant loadings for the wastestream by the number of steam electric power plants discharging the wastestream [ERG, 2015a].

[5] The count of 151 steam electric power plants includes three indirect dischargers that discharge wastewater to a POTW and do not discharge any of the evaluated wastestreams directly to surface waters. EPA included these indirect dischargers to protect confidential business information.

the evaluated wastestreams (for the 151 plants) and the number of typical POTWs that would discharge equivalent loadings.

Table I-5. Comparison of Average Pollutant Loadings in the Evaluated Wastestreams to an Average POTW

Pollutant	Average Plant FGD Wastewater Discharge [a,b]		Average Plant Fly Ash Transport Water Discharge [a,c]		Average Plant Bottom Ash Transport Water Discharge [a,d]		Average Plant Combustion Residual Leachate Discharge [a,e]		Average POTW Discharge [a,f]	
	Loadings (lbs/yr)	TWPE (lb-eq/yr)	Loadings (lbs/yr)	TWPE (lb-eq/yr)	Loadings (lbs/yr)	TWPE (lb-eq/yr)	Loadings (lbs/yr)	TWPE (lb-eq/yr)	Loadings (lbs/yr)	TWPE (lb-eq/yr)
Aluminum	1,720	111	9,010	583	3,880	251	988	63.9	3,590	215
Arsenic	9.68	33.6	310	1,080	61.1	212	12.7	44.2	45.9	159
Boron	333,000	2,780	19,800	166	2,060	17.2	7,700	64.2	1,540	12.8
Cadmium	91.7	2,090	49.2	1,120	17.7	403	3.39	77.2	3.54	80.6
Chromium VI	(g)	(g)	2.48	1.28	0.145	0.0750	(g)	(g)	17.7	9.02
Copper	19.6	12.2	282	176	83.0	51.7	2.55	1.59	154	95.3
Iron	1,270	7.10	5,740	32.1	6,960	39.0	12,200	68.5	2,530	14.2
Lead	5.82	13.0	157	351	58.6	131	(g)	(g)	48.5	109
Manganese	81,800	8,400	522	53.6	4,340	446	933	95.8	354	36.1
Mercury	6.24	687	7.76	854	3.04	334	0.351	38.7	3,180	350,000
Nickel	701	76.4	188	20.5	275	30.0	15.4	1.68	30.6	3.06
Selenium	1,470	1,640	132	148	29.5	33.1	36.7	41.2	18.5	20.7
Thallium	17.0	48.6	134	384	276	789	0.399	1.14	9.94	28.2
Vanadium	21.0	5.87	209	58.5	12.2	3.42	631	177	No data	No data
Zinc	1,110	52.3	814	38.2	227	10.6	69.8	3.27	453	18.1
Total Nitrogen	132,000	--	25,000	--	22,500	--	(g)	--	123,000	--
Total Phosphorus	453	--	849	--	657	--	(g)	--	17,800	--
Chlorides	10,100,000	246	84,600	2.06	88,500	2.16	142,000	3.45	1,610,000	39.3
TDS	40,800,000	--	1,870,000	--	2,340,000	--	1,200,000	--	No data	--

Note: Numbers are rounded to three significant figures.
a – TWPE presented in the table include updates to TWFs for arsenic, cadmium, copper, manganese, mercury, thallium, and vanadium.
b – Average loadings based on 69 plants assumed to discharge FGD wastewater under baseline conditions [ERG, 2015a].
c – Average loadings based on 40 plants assumed to discharge fly ash transport water under baseline conditions [ERG, 2015a].
d – Average loadings based on 135 plants assumed to discharge bottom ash transport water under baseline conditions [ERG, 2015a].
e – Average loadings based on 70 plants assumed to discharge combustion residual leachate under baseline conditions [ERG, 2015a].
f – Average loadings based on average loadings calculated for POTWs discharging 3 to 5 MGD of wastewater (see DCN SE01961).
g – EPA did not calculate loadings for this pollutant and wastestream. See the Costs and Loads Report (DCN SE05831).

Table I-6. Estimated Number of POTW Equivalents for Total Pollutant Loadings from the Evaluated Wastestreams

Pollutant	Annual Discharge pounds (lbs) [a]	Equivalent Number of Average POTWs [b]
Aluminum	1,070,000	299
Arsenic	22,200	484
Boron	24,600,000	16,000
Cadmium	10,900	3,090
Chromium VI	119	6.72
Copper	24,000	156
Iron	2,110,000	835
Lead	14,600	301
Manganese	6,320,000	17,800
Mercury	1,180	0.370
Nickel	94,200	3,080
Selenium	113,000	6,110
Thallium	43,900	4,410
Vanadium	55,600	No values for comparison
Zinc	145,000	320
Total Nitrogen	13,100,000	107
Total Phosphorus	154,000	8.65
Chlorides	722,000,000	448
TDS	3,290,000,000	No values for comparison

Source: ERG, 2015a.

Note: Numbers are rounded to three significant figures.

a – Annual discharge based on pollutant discharges from 151 steam electric power plants, including three indirect dischargers.

b – Equivalent number of POTWs is estimated by dividing the total annual pollutant loadings from the 151 steam electric power plants by the average POTW loadings presented in Table I-5 for a 4-MGD POTW.

EPA identified the number of surface waters that receive discharges of the evaluated wastestreams and are located in close proximity to sensitive environments. Table I-7 summarizes the number and percentage of immediate receiving waters in the alternate scenario analysis that are located in sensitive environments.

Table I-7. Number and Percentage of Immediate Receiving Waters Identified as Sensitive Environments

Sensitive Environment	Number (Percentage) of Immediate Receiving Waters Identified [a]
Great Lakes watershed	15 (9%)
Chesapeake Bay watershed	11 (6%)
Impaired water	91 (53%)
Surface water impaired for a subset of pollutants associated with the evaluated wastestreams [b]	45 (26%)
Fish consumption advisory water	116 (67%)
Surface water with a fish consumption advisory for a subset of pollutants associated with the evaluated wastestreams [c]	79 (46%)
Drinking water resource within 5 miles	152 (88%)

a – For the sensitive environment proximity analysis, EPA evaluated 172 immediate receiving waters that receive discharges of the evaluated wastestreams [ERG, 2015c; ERG, 2015d].

b – Table B-1 in Appendix B contains a complete list of the impairment categories identified in EPA's 303(d)-listed waters and designates the subset of pollutants evaluated.

c – Table B-2 in Appendix B contains a complete list of the types of advisories identified under the sensitive environment proximity analysis, including pollutants that are not associated with the evaluated wastestreams.

d – The values presented in Section 3.4.5 of the report are based on an analysis of habitat locations that reflect changes in the industry as a result of the CPP.

Table I-8 and Table I-9 present the pollutant loadings to the Great Lakes watershed and the Chesapeake Bay watershed, respectively, accounting for changes in the industry baseline as a result of the CPP. Table I-10 presents the number of immediate receiving waters classified as impaired in the alternate scenario analysis.

Based on a review of immediate receiving waters that reflect changes in the industry as a result of the CPP, EPA determined that 116 immediate receiving waters (67 percent) are under fish consumption advisories; 79 of the immediate receiving waters (46 percent) are under an advisory for a pollutant associated with the evaluated wastestreams.[6] All of these 79 immediate receiving waters are under a fish consumption advisory for mercury and one of the receiving waters is also under a fish consumption advisory for lead.

The results of the threatened and endangered species analysis presented in Section 3.4.5 already account for changes in the industry as a result of the CPP. Table I-11 presents the number of steam electric power plants located within five miles of a drinking water resource and the number of drinking water resources located within five miles of a steam electric power plant.

[6] Table B-2 in Appendix B lists the types of advisories identified under the sensitive environment proximity analysis, including advisories for pollutants that are not associated with the evaluated wastestreams.

Table I-8. Pollutant Loadings to the Great Lakes Watershed from the Evaluated Wastestreams [a]

Pollutant	Annual Discharge to the Great Lakes Watershed (lbs)	Annual TWPE Discharge to the Great Lakes Watershed (lb-eq)
Arsenic	1,030	3,590
Boron	760,000	6,340
Cadmium	286	6,520
Chromium VI	0.548	0.283
Copper	1,170	728
Lead	869	1,950
Manganese	112,000	11,500
Mercury	37.5	4,130
Nickel	4,310	470
Selenium	3,540	3,960
Thallium	4,320	12,300
Zinc	3,860	181
Total Nitrogen	646,000	--
Total Phosphorus	10,900	--
Chlorides	24,100,000	587
Total Dissolved Solids	116,000,000	--

Source: ERG, 2015a.

Note: Numbers are rounded to three significant figures.

a – Pollutant loadings based on 14 steam electric power plants discharging to 15 immediate receiving waters in the Great Lakes watershed.

Table I-9. Pollutant Loadings to the Chesapeake Bay Watershed from the Evaluated Wastestreams [a]

Pollutant	Annual Discharge to the Chesapeake Bay Watershed (lbs)	Annual TWPE Discharge to the Chesapeake Bay Watershed (lb-eq)
Arsenic	680	2,360
Boron	1,080,000	9,000
Cadmium	199	4,530
Chromium VI	0	0
Copper	765	477
Lead	571	1,280
Manganese	106,000	10,900
Mercury	24.4	2,690
Nickel	2,880	313
Selenium	4,710	5,290
Thallium	2,880	8,210
Zinc	2,630	123
Total Nitrogen	670,000	--
Total Phosphorus	7,920	--
Chlorides	34,200,000	832
Total Dissolved Solids	139,000,000	--

Source: ERG, 2015a.

Note: Numbers are rounded to three significant figures.

a – Pollutant loadings based on seven steam electric power plants discharging to 11 immediate receiving waters in the Chesapeake Bay watershed.

Table I-10. Number and Percentage of Immediate Receiving Waters Classified as Impaired for a Pollutant Associated with the Evaluated Wastestreams

Pollutant Causing Impairment	Number (Percentage) of Immediate Receiving Waters Identified [a]
Mercury	21 (12%)
Metals, other than mercury [b]	24 (14%)
Nutrients	15 (9%)
TDS, including chlorides	2 (1%)
Total for Any Pollutant [c]	**56 (33%)**

a – For the impaired waters proximity analysis, EPA evaluated 172 immediate receiving waters that receive discharges of the evaluated wastestreams [ERG, 2015c; ERG, 2015d].

b – The EPA impaired water database listed 24 immediate receiving waters as impaired based on the "metal, other than mercury" impairment category. Of those 24 immediate receiving waters, 13 receiving waters are also listed as impaired for one or more specific metals in the EA analysis (arsenic, cadmium, manganese, selenium, and zinc). One additional immediate receiving water is impaired for boron (but not included in the "metals, other than mercury" impairment category).

c – Total does not equal the sum of the immediate receiving waters listed in the table. Some immediate receiving waters are impaired for multiple pollutants.

Table I-11. Comparison of Number and Percentage of Steam Electric Power Plants Located within 5 Miles of a Drinking Water Resource

Type of Drinking Water Resource	Number of Drinking Water Resources within 5 Miles of a Steam Electric Power Plant	Number (Percentage) of Steam Electric Power Plants Located within 5 Miles of a Drinking Water Resource [a]
Intakes and reservoirs	87	52 (35%)
Public wells [b]	1,530	116 (78%)
Sole-source aquifers	5	5 (3%)

Sources: ERG, 2015c; ERG, 2015d.

a – For the drinking water resource proximity analysis, EPA evaluated 172 immediate receiving waters that receive discharges of the evaluated wastestreams from 148 steam electric power plants.

b – Counts include two springs and 29 wellheads.

Current impacts from the steam electric power generating industry under the alternate scenario analysis include water quality impacts (Table I-12); wildlife impacts (Table I-13 and Table I-14); impacts to benthic organisms (Table I-15); human health impacts to national-scale cohorts representing recreational and subsistence fishers (Table I-16 through Table I-19); and human health impacts to cohorts representing recreational and subsistence fishers by race or Hispanic origin (Table I-20 and Table I-21, respectively).

The ecological risk modeling results under the alternate scenario analysis indicate that 16 percent of the lakes, ponds, and reservoirs (3 out of 19) and 13 percent of the rivers and streams (18 out of 144) that receive discharges of the evaluated wastestreams present an elevated risk of negative reproductive impacts to fish. For mallards, the counts are slightly higher, with the same number of lakes, ponds, and reservoirs and 15 percent of the rivers and streams (22 out of 144) presenting these risks.

Selecting the 90th percentile modeled egg/ovary concentration, meaning there is a 10 percent probability that the egg/ovary concentrations are greater than the selected concentration, reveals that 19 percent of the immediate receiving waters (31 out of 163) present reproductive risks to at least 10 percent of the exposed fish population. The results for mallards (20 percent) are very similar. These counts are considerably higher than the results obtained using the median modeled egg/ovary concentration, indicating the potential for more widespread ecological impacts among those waterbodies and food webs that tend to experience higher bioaccumulation of selenium.

Table I-12. Number and Percentage of Immediate Receiving Waters with Estimated Water Concentrations that Exceed the Water Quality Criteria

Evaluation Criterion		Number of Immediate Receiving Waters Exceeding a Criterion [a]			
		Number of Rivers and Streams	Number of Lakes, Ponds, and Reservoirs	Total Immediate Receiving Waters [b]	
				Number Exceeding	Percentage Exceeding
Aquatic Life Criteria	Freshwater Acute NRWQC	7	0	7	4%
	Freshwater Chronic NRWQC	25	3	28	17%
Human Health Criteria	Human Health Water and Organism NRWQC	61	12	73	45%
	Human Health Organism Only NRWQC	44	7	51	31%
	Drinking Water MCL	25	4	29	18%
Total Number of Unique Immediate Receiving Waters [c]		61	12	73	45%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: NRWQC (National Recommended Water Quality Criteria); MCL (maximum contaminant level).

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters (144 rivers and streams; 19 lakes, ponds, and reservoirs) and loadings from 143 steam electric power plants.

b – These values are the sum and percentage of rivers, streams, lakes, ponds, and reservoirs impacted.

c – This represents the number of unique immediate receiving waters that exceeded at least one criterion.

Table I-13. Number and Percentage of Immediate Receiving Waters That Exceed Wildlife Fish Consumption NEHCs for Minks and Eagles (by Waterbody Type)

Evaluation Criterion	Number of Rivers and Streams	Number of Lakes, Ponds, and Reservoirs	Total Receiving Waters [a,b]	
			Number Exceeding	Percentage Exceeding
Mink fish consumption NEHC	38	8	46	28%
Eagle fish consumption NEHC	48	8	56	34%
Total Number of Unique Immediate Receiving Waters [c]	48	8	56	34%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i

Acronyms: NEHC (No Effect Hazard Concentration).

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters (144 rivers and streams; 19 lakes, ponds, and reservoirs) and loadings from 143 steam electric power plants.

b – These values are the sum and percentage of rivers, streams, lakes, ponds, and reservoirs impacted.

c – This represents the number of unique immediate receiving waters that exceed a criterion.

Table I-14. Number and Percentage of Immediate Receiving Waters That Exceed Wildlife Fish Consumption NEHCs for Minks and Eagles (by Pollutant)

Pollutant	Mink			Eagle		
	Fish Consumption NEHC (ug/g) [a]	Immediate Receiving Waters		Fish Consumption NEHC (ug/g) [a]	Immediate Receiving Waters	
		Number Exceeding [b]	Percentage Exceeding		Number Exceeding [b]	Percentage Exceeding
Arsenic	7.65	0	0%	22.4	0	0%
Cadmium	5.66	5	3%	14.7	4	2%
Chromium VI	17.7 [c]	0	0%	26.6 [c]	0	0%
Copper	41.2	0	0%	40.5	0	0%
Lead	34.6	0	0%	16.3	2	1%
Mercury	0.37	43	26%	0.5	55	34%
Nickel	12.5	0	0%	67.1	0	0%
Selenium	1.13	33	20%	4	33	20%
Thallium	ID	NC	NC	ID	NC	NC
Zinc	904	1	1%	145	4	2%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: ID (Insufficient data; no benchmarks were identified in the wildlife analysis for thallium); NC (Not calculated); NEHC (No Effect Hazard Concentration); ug/g (micrograms/gram).

a – The wildlife fish consumption NEHC represents the maximum pollutant concentration in the fish that will result in no observable adverse effects in wildlife (*i.e.*, minks or eagles) [USGS, 2008].

b – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

c – An NEHC benchmark is not available for chromium VI; therefore, EPA used the total chromium benchmark.

Table I-15. Number and Percentage of Immediate Receiving Waters with Sediment Pollutant Concentrations Exceeding TELs for Sediment Biota

Pollutant	Sediment Benchmark (mg/kg)	Number of Immediate Receiving Waters Exceeding TELs for Sediment Biota			
		Rivers and Streams	Lakes, Ponds, and Reservoirs	Total Immediate Receiving Waters	
				Number [a]	Percent
Arsenic	5.90	5	0	5	3%
Cadmium	0.596	19	3	22	13%
Chromium VI [b]	37.3	0	0	0	0%
Copper	35.7	4	1	5	3%
Lead	35	3	1	4	2%
Mercury	0.174	33	7	40	25%
Nickel	18.0	24	3	27	17%
Selenium	ID	NC	NC	NC	NC
Thallium	ID	NC	NC	NC	NC
Zinc	123	12	1	13	8%
Total Number of Unique Immediate Receiving Waters		**33**	**7**	**40**	**25%**

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: ID (Insufficient data; no benchmarks were identified); NC (Not calculated).

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters (144 rivers and streams; 19 lakes, ponds, and reservoirs) and loadings from 143 steam electric power plants.

b – No benchmark for chromium VI. EPA used the total chromium benchmark, which may underestimate the impact to wildlife.

Table I-16. Number and Percentage of Immediate Receiving Waters That Exceed Human Health Evaluation Criteria (Lifetime Excess Cancer Risk) for Inorganic Arsenic

Receptor	Cohort	Exposure Duration (Years)	Number of Immediate Receiving Waters Where Lifetime Excess Cancer Risk Exceeds 1-in-a-Million [a,b]			
			Number of Rivers and Streams	Number of Lakes, Ponds, and Reservoirs	Total Receiving Waters [c]	
					Number Exceeding	Percentage Exceeding
Child recreational fisher	1 to <2 years	1	4	0	4	2%
	2 to <3 years	1	4	0	4	2%
	3 to <6 years	3	4	0	4	2%
	6 to <11 years	5	4	0	4	2%
	11 to <16 years	5	4	0	4	2%
	16 to <21 years	5	4	0	4	2%
Adult recreational fisher		49	7	2	9	6%
Child subsistence fisher	1 to <2 years	1	4	0	4	2%
	2 to <3 years	1	4	0	4	2%
	3 to <6 years	3	5	0	5	3%
	6 to <11 years	5	6	0	6	4%
	11 to <16 years	5	4	0	4	2%
	16 to <21 years	5	4	0	4	2%
Adult subsistence fisher		49	19	2	21	13%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters (144 rivers and streams; 19 lakes, ponds, and reservoirs) and loadings from 143 steam electric power plants.

b – Inorganic arsenic cancer slope factor of 1.5 per milligrams per kilogram (mg/kg) per day.

c – These values are the sum and percentage of rivers, streams, lakes, ponds, and reservoirs impacted.

Table I-17. Number and Percentage of Immediate Receiving Waters That Exceed Non-Cancer Oral Reference Dose Values

Receptor	Cohort	Exposure Duration (Years)	Number of Immediate Receiving Waters where Estimated Exposure Doses Exceed Non-Cancer Reference Doses [a]			
			Number of Rivers and Streams	Number of Lakes, Ponds, and Reservoirs	Total Receiving Waters [b]	
					Number Exceeding	Percentage Exceeding
Child recreational fisher	1 to <2 years	1	62	13	75	46%
	2 to <3 years	1	62	13	75	46%
	3 to <6 years	3	61	13	74	45%
	6 to <11 years	5	60	12	72	44%
	11 to <16 years	5	57	10	67	41%
	16 to <21 years	5	57	10	67	41%
Adult recreational fisher		49	57	10	67	41%
Child subsistence fisher	1 to <2 years	1	76	14	90	55%
	2 to <3 years	1	76	14	90	55%
	3 to <6 years	3	70	14	84	52%
	6 to <11 years	5	67	14	81	50%
	11 to <16 years	5	63	13	76	47%
	16 to <21 years	5	63	13	76	47%
Adult subsistence fisher		49	65	13	78	48%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters (144 rivers and streams; 19 lakes, ponds, and reservoirs) and loadings from 143 steam electric power plants.

b – These values are the sum and percentage of rivers, streams, lakes, ponds, and reservoirs impacted.

Table I-18. Number and Percentage of Immediate Receiving Waters That Exceed Non-Cancer Oral Reference Dose Values at Baseline by Pollutant

Pollutant	Oral Reference Dose (mg/kg/day)	Number of Immediate Receiving Waters where Estimated Exposure Doses Exceed Non-Cancer Reference Doses [a]	
		Number Exceeding	Percentage Exceeding
Inorganic arsenic	0.0003 [b]	3	2%
Cadmium	0.001 [b]	27	17%
Chromium VI	0.003 [b]	0	0%
Copper	0.01 [c]	4	2%
Lead	ID	NC	NC
Mercury (as methylmercury)	0.0001 [b]	84	52%
Nickel (soluble salts)	0.02 [b]	0	0%
Selenium	0.005 [b]	41	25%
Thallium (soluble salts)	0.00001 [d]	72	44%
Zinc	0.3 [b]	7	4%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: NC (Not calculated); ID (Insufficient data; there is no current reference dose for lead).

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

b – U.S. EPA, 2011c.

c – ATSDR, 2010a.

d – U.S. EPA, 2010a.

Table I-19. Comparison of T4 Fish Tissue Concentrations to Fish Advisory Screening Values

Pollutant	Recreational Fishers			Subsistence Fishers		
	Screening Value (ppm)[a]	Number Exceeding [b]	Percentage Exceeding	Screening Value (ppm) [a]	Number Exceeding [b]	Percentage Exceeding
Inorganic arsenic (noncarcinogen)	1.2	0	0%	0.147	3	2%
Inorganic arsenic (carcinogen)	0.026	4	2%	0.00327	7	4%
Cadmium	4.0	6	4%	0.491	18	11%
Mercury (as methylmercury)	0.4	58	36%	0.049	77	47%
Selenium	20	19	12%	2.457	36	22%

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: ppm (parts per million).

a – Screening values are defined as concentrations of target analytes in fish or shellfish tissue that are of potential public health concern and that are used as threshold values against which levels of contamination in similar tissue collected from the ambient environment can be compared. Exceedance of these screening values indicates that more intensive site-specific monitoring and/or evaluation of human health risk should be conducted [U.S. EPA, 2000a, Table 5-3].

b – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

Table I-20. Number and Percentage of Immediate Receiving Waters That Exceed Human Health Evaluation Criteria (Lifetime Excess Cancer Risk) for Inorganic Arsenic, by Race or Hispanic Origin

Receptor	Race or Hispanic Origin	Number of Immediate Receiving Waters Where Lifetime Excess Cancer Risk Exceeds 1-in-a-Million [a,b]						
		1 to <2 years	2 to <3 years	3 to <6 years	6 to <11 years	11 to <16 years	16 to <21 years	Adult
Recreational	Non-Hispanic White	3	3	4	4	4	4	9
	Non-Hispanic Black	3	3	4	4	4	4	11
	Mexican-American	4	4	4	4	4	4	14
	Other Hispanic	4	4	4	4	4	4	13
	Other, including Multiple Races	4	4	4	4	4	4	15
Subsistence	Non-Hispanic White	4	4	4	5	5	5	21
	Non-Hispanic Black	4	4	4	5	5	5	22
	Mexican-American	4	4	4	6	6	6	23
	Other Hispanic	4	4	4	5	5	5	23
	Other, including Multiple Races	4	4	5	7	7	7	26

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

b – Inorganic arsenic cancer slope factor of 1.5 per milligrams per kilogram (mg/kg) per day.

Table I-21. Number and Percentage of Immediate Receiving Waters That Exceed Non-Cancer Oral Reference Dose Values, by Race or Hispanic Origin

Receptor	Race or Hispanic Origin	Number of Immediate Receiving Waters Where Pollutant Exceeds a Non-Cancer Reference Dose [a]						
		Inorganic Arsenic	Cadmium	Copper	Mercury [b]	Selenium	Thallium [c]	Zinc
Recreational, Child Fisher	Non-Hispanic White	0 (0%)	8 (5%)	3 (2%)	63 (39%)	26 (16%)	44 (27%)	4 (2%)
	Non-Hispanic Black	0 (0%)	9 (6%)	4 (2%)	64 (39%)	27 (17%)	45 (28%)	4 (2%)
	Mexican-American	0 (0%)	11 (7%)	4 (2%)	66 (40%)	27 (17%)	48 (29%)	4 (2%)
	Other Hispanic	0 (0%)	10 (6%)	4 (2%)	64 (39%)	27 (17%)	47 (29%)	4 (2%)
	Other, including Multiple Races	0 (0%)	11 (7%)	4 (2%)	68 (42%)	28 (17%)	48 (29%)	4 (2%)
Subsistence, Child Fisher	Non-Hispanic White	0 (0%)	8 (5%)	3 (2%)	63 (39%)	26 (16%)	44 (27%)	4 (2%)
	Non-Hispanic Black	0 (0%)	9 (6%)	4 (2%)	64 (39%)	27 (17%)	45 (28%)	4 (2%)
	Mexican-American	0 (0%)	11 (7%)	4 (2%)	66 (40%)	27 (17%)	48 (29%)	4 (2%)
	Other Hispanic	0 (0%)	10 (6%)	4 (2%)	64 (39%)	27 (17%)	47 (29%)	4 (2%)
	Other, including Multiple Races	0 (0%)	11 (7%)	4 (2%)	68 (42%)	28 (17%)	48 (29%)	4 (2%)
Recreational, Adult Fisher	Non-Hispanic White	3 (2%)	17(10%)	4 (2%)	74 (45%)	33 (20%)	58 (36%)	4 (2%)
	Non-Hispanic Black	3 (2%)	18 (11%)	4 (2%)	74 (45%)	34 (21%)	58 (36%)	4 (2%)
	Mexican-American	3 (2%)	20 (12%)	4 (2%)	76 (47%)	36 (22%)	60 (37%)	5 (3%)
	Other Hispanic	3 (2%)	20 (12%)	4 (2%)	76 (47%)	36 (22%)	60 (37%)	5 (3%)
	Other, including Multiple Races	3 (2%)	24 (15%)	4 (2%)	79 (48%)	38 (23%)	67 (41%)	5 (3%)
Subsistence, Adult Fisher	Non-Hispanic White	3 (2%)	17(10%)	4 (2%)	74 (45%)	33 (20%)	58 (36%)	4 (2%)
	Non-Hispanic Black	3 (2%)	18 (11%)	4 (2%)	74 (45%)	34 (21%)	58 (36%)	4 (2%)
	Mexican-American	3 (2%)	20 (12%)	4 (2%)	76 (47%)	36 (22%)	60 (37%)	5 (3%)
	Other Hispanic	3 (2%)	20 (12%)	4 (2%)	76 (47%)	36 (22%)	60 (37%)	5 (3%)
	Other, including Multiple Races	3 (2%)	24 (15%)	4 (2%)	79 (48%)	38 (23%)	67 (41%)	5 (3%)

Sources: ERG, 2015d; ERG, 2015h; ERG, 2015i.

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

b – Mercury, as methylmercury.

c – Reference dose based on thallium (soluble salts).

EPA evaluated environmental improvements as a result of the regulatory options, reflecting changes in the industry as a result of the CPP. Table I-22 and Table I-23 present pollutant removals under the regulatory options.

Table I-22. Steam Electric Power Generating Industry Pollutant Removals for Metals, Bioaccumulative Pollutants, Nutrients, Chlorides, and TDS Under Regulatory Options

Pollutant	Pollutant Removals, lbs/yr (Percent Reduction) [a]				
	Option A	Option B	Option C	Option D	Option E
Arsenic	12,500 (56%)	12,500 (56%)	18,500 (83%)	20,700 (93%)	21,300 (96%)
Boron	3,150,000 (13%)	3,150,000 (13%)	3,350,000 (14%)	3,420,000 (14%)	3,420,000 (14%)
Cadmium	7,900 (72%)	7,900 (72%)	9,650 (88%)	10,300 (94%)	10,400 (95%)
Chromium VI	99.1 (83%)	99.1 (83%)	115 (96%)	119 (>99%)	119 (>99%)
Copper	12,200 (51%)	12,200 (51%)	20,500 (85%)	23,400 (98%)	23,500 (98%)
Lead	6,340 (43%)	6,340 (43%)	12,100 (83%)	14,200 (98%)	14,200 (98%)
Manganese	4,520,000 (72%)	4,520,000 (72%)	4,950,000 (78%)	5,110,000 (81%)	5,110,000 (81%)
Mercury	728 (62%)	736 (63%)	1,040 (89%)	1,140 (97%)	1,160 (99%)
Nickel	55,100 (58%)	55,300 (59%)	82,300 (87%)	92,400 (98%)	93,100 (99%)
Selenium	24,100 (21%)	106,000 (94%)	109,000 (96%)	110,000 (97%)	110,000 (97%)
Thallium	5,640 (13%)	5,640 (13%)	32,700 (74%)	42,800 (98%)	42,800 (98%)
Zinc	107,000 (74%)	107,000 (74%)	130,000 (89%)	138,000 (95%)	141,000 (97%)
Nitrogen, total [b]	1,590,000 (12%)	10,000,000 (76%)	12,200,000 (93%)	13,100,000 (99%)	13,100,000 (99%)
Phosphorus, total	33,900 (22%)	33,900 (22%)	98,300 (64%)	122,000 (79%)	122,000 (79%)
Chlorides	3,380,000 (<1%)	3,380,000 (<1%)	12,000,000 (2%)	15,300,000 (2%)	15,300,000 (2%)
TDS	684,000,000 (21%)	684,000,000 (21%)	913,000,000 (28%)	999,000,000 (30%)	999,000,000 (30%)

Source: ERG, 2015a.

Acronyms: TDS (Total Dissolved Solids); lbs/yr (pounds per year).

Note: Pollutant removals are rounded to three significant figures.

a – .>0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

b – Total nitrogen loadings are the sum of total Kjeldahl nitrogen and nitrate/nitrite as N loadings.

Table I-23. Steam Electric Power Generating Industry TWPE Removals for Metals, Bioaccumulative Pollutants, Nutrients, Chlorides, and TDS Under Regulatory Options

Pollutant	Pollutant Removals, TWPE/year (Percent Reduction) [a]				
	Option A	Option B	Option C	Option D	Option E
Arsenic	43,400 (56%)	43,400 (56%)	64,200 (83%)	71,900 (93%)	73,900 (96%)
Boron	26,200 (13%)	26,200 (13%)	28,000 (14%)	28,600 (14%)	28,600 (14%)
Cadmium	180,000 (72%)	180,000 (72%)	220,000 (88%)	234,000 (94%)	236,000 (95%)
Chromium VI	51.2 (83%)	51.2 (83%)	59.2 (96%)	61.3 (>99%)	61.3 (>99%)
Copper	7,630 (51%)	7,630 (51%)	12,800 (85%)	14,600 (98%)	14,600 (98%)
Lead	14,200 (43%)	14,200 (43%)	27,200 (83%)	31,900 (98%)	31,900 (98%)
Manganese	464,000 (72%)	464,000 (72%)	508,000 (78%)	524,000 (81%)	524,000 (81%)
Mercury	80,100 (62%)	80,900 (63%)	115,000 (89%)	126,000 (97%)	128,000 (99%)
Nickel	6,000 (58%)	6,020 (59%)	8,970 (87%)	10,100 (98%)	10,100 (99%)
Selenium	27,000 (21%)	119,000 (94%)	122,000 (96%)	123,000 (97%)	123,000 (97%)
Thallium	16,100 (13%)	16,100 (13%)	93,300 (74%)	122,000 (98%)	122,000 (98%)
Zinc	5,040 (74%)	5,040 (74%)	6,090 (89%)	6,470 (95%)	6,630 (97%)
Nitrogen, total	N/A	N/A	N/A	N/A	N/A
Phosphorus, total	N/A	N/A	N/A	N/A	N/A
Chlorides	82.2 (<1%)	82.2 (<1%)	293 (2%)	372 (2%)	372 (2%)
TDS	N/A	N/A	N/A	N/A	N/A

Source: ERG, 2015a.

Acronyms: TDS (Total Dissolved Solids); TWPE (Toxic Weighted Pound Equivalents).

Note: Pollutant removals are rounded to three significant figures.

N/A – The TWPE/year is not provided for total nitrogen, total phosphorus, and TDS because EPA has not established a toxic weighting factor (TWF) for these pollutants.

a – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

Table I-24 presents key environmental improvements as a result of the regulatory options and reflecting changes in the industry as a result of the CPP. Table I-25 shows environmental improvements for benthic organisms. Key environmental improvements based on reduced discharges of arsenic, mercury, selenium, cadmium, and thallium are included in Table I-26 through Table I-30.

Table I-24. Key Environmental Improvements Under the Regulatory Options

Evaluation Benchmark	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
	Number	Percentage	Option A	Option B	Option C	Option D	Option E
Water Quality Results							
Freshwater Acute NRWQC	7	4%	5 (29%)	5 (29%)	5 (29%)	3 (57%)	2 (71%)
Freshwater Chronic NRWQC	28	17%	27 (4%)	22 (21%)	18 (36%)	16 (43%)	16 (43%)
Human Health Water and Organism NRWQC	73	45%	70 (4%)	70 (4%)	55 (25%)	42 (42%)	35 (52%)
Human Health Organism Only NRWQC	51	31%	48 (6%)	48 (6%)	36 29%)	28 (45%)	22 (57%)
Drinking Water MCL	29	18%	27 (7%)	26 (10%)	12 (59%)	6 (79%)	6 (79%)
Wildlife Results							
Fish Ingestion NEHC for Minks	46	28%	46 (0%)	41 (11%)	25 (46%)	19 (59%)	18 (61%)
Fish Ingestion NEHC for Eagles	56	34%	52 (7%)	48 (14%)	34 (39%)	23 (59%)	20 (64%)
Human Health Results—Non-Cancer							
Non-Cancer Reference Dose for Child (recreational)	75	46%	69 (8%)	67 (11%)	51 (32%)	38 (49%)	30 (60%)
Non-Cancer Reference Dose for Adult (recreational)	67	41%	60 (10%)	58 (13%)	44 (34%)	32 (52%)	23 (66%)
Non-Cancer Reference Dose for Child (subsistence)	90	55%	81 (10%)	79 (12%)	59 (34%)	43 (52%)	39 (57%)
Non-Cancer Reference Dose for Adult (subsistence)	78	48%	72 (8%)	71 (9%)	54 (31%)	40 (49%)	32 (59%)

Table I-24. Key Environmental Improvements Under the Regulatory Options

Evaluation Benchmark	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
	Number	Percentage	Option A	Option B	Option C	Option D	Option E
Human Health Results—Cancer							
Arsenic Cancer Risk for Child (recreational)	4	2%	3 (25%)	3 (25%)	3 (25%)	2 (50%)	2 (50%)
Arsenic Cancer Risk for Adult (recreational)	9	6%	7 (22%)	7 (22%)	5 (44%)	3 (67%)	2 (78%)
Arsenic Cancer Risk for Child (subsistence)	6	4%	6 (0%)	6 (0%)	5 (17%)	3 (50%)	2 (67%)
Arsenic Cancer Risk for Adult (subsistence)	21	13%	19 (10%)	19 (10%)	13 (38%)	11 (48%)	4 (81%)

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: MCL (maximum contaminant level); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

Table I-25. Number of Immediate Receiving Waters with Sediment Pollutant Concentrations Exceeding TELs for Sediment Biota Under the Regulatory Options

Pollutant	Modeled Immediate Receiving Waters Exceeding CSCLs Under Baseline Conditions [a]	Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
		Option A	Option B	Option C	Option D	Option E
Arsenic	5 (3%)	4 (20%)	4 (20%)	4 (20%)	3 (40%)	2 (60%)
Cadmium	22 (13%)	17 (23%)	17 (23%)	12 (45%)	10 (55%)	8 (64%)
Chromium VI [c]	0 (0%)	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)
Copper	5 (3%)	4 (20%)	4 (20%)	4 (20%)	2 (60%)	2 (60%)
Lead	4 (2%)	3 (25%)	3 (25%)	3 (25%)	1 (75%)	1 (75%)
Mercury	40 (25%)	36 (10%)	35 (13%)	20 (50%)	16 (60%)	7 (83%)
Nickel	27 (17%)	22 (19%)	22 (19%)	12 (56%)	10 (63%)	4 (85%)
Selenium	NC	NC	NC	NC	NC	NC
Thallium	NC	NC	NC	NC	NC	NC
Zinc	13 (8%)	7 (46%)	7 (46%)	7 (46%)	6 (54%)	2 (85%)
Total	**40 (25%)**	**36 (10%)**	**35 (13%)**	**21 (48%)**	**17 (58%)**	**8 (80%)**

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: CSCL (Chemical stressor concentration limit); N/A (Not Applicable, no exceedances at baseline conditions to compare option results); NC (Not calculated; no benchmark for comparison).

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

c – EPA used the total chromium benchmark for this analysis.

Table I-26. Key Environmental Improvements for Arsenic Under the Regulatory Options

Evaluation Benchmark	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
	Number	Percentage	Option A	Option B	Option C	Option D	Option E
Water Quality Results							
Freshwater Acute NRWQC	3	2%	2 (33%)	2 (33%)	2 (33%)	2 (33%)	1 (67%)
Freshwater Chronic NRWQC	4	2%	3 (25%)	3 (25%)	3 (25%)	2 (50%)	1 (75%)
Human Health Water and Organism NRWQC	73	45%	70 (4%)	70 (4%)	55 (25%)	42 (42%)	35 (52%)
Human Health Organism Only NRWQC	51	31%	48 (6%)	48 (6%)	36 (29%)	28 (45%)	22 (57%)
Drinking Water MCL	9	6%	7 (22%)	7 (22%)	5 (44%)	3 (67%)	2 (78%)
Wildlife Results							
Fish Ingestion NEHC for Minks	0	0%	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)
Fish Ingestion NEHC for Eagles	0	0%	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)
Human Health Results—Non-Cancer							
Non-Cancer Reference Dose for Child (recreational)	2	1%	1 (50%)	1 (50%)	1 (50%)	1 (50%)	0 (100%)
Non-Cancer Reference Dose for Adult (recreational)	0	0%	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)
Non-Cancer Reference Dose for Child (subsistence)	3	2%	2 (33%)	2 (33%)	2 (33%)	2 (33%)	1 (67%)
Non-Cancer Reference Dose for Adult (subsistence)	3	2%	2 (33%)	2 (33%)	2 (33%)	2 (33%)	1 (67%)

Table I-26. Key Environmental Improvements for Arsenic Under the Regulatory Options

Evaluation Benchmark	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
	Number	Percentage	Option A	Option B	Option C	Option D	Option E
Human Health Results—Cancer							
Arsenic Cancer Risk for Child (recreational)	4	2%	3 (25%)	3 (25%)	3 (25%)	2 (50%)	2 (50%)
Arsenic Cancer Risk for Adult (recreational)	9	6%	7 (22%)	7 (22%)	5 (44%)	3 (67%)	2 (78%)
Arsenic Cancer Risk for Child (subsistence)	6	4%	6 (0%)	6 (0%)	5 (17%)	3 (50%)	2 (67%)
Arsenic Cancer Risk for Adult (subsistence)	21	13%	19 (10%)	19 (10%)	13 (38%)	11 (48%)	4 (81%)

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: MCL (Maximum contaminant level); N/A (Not Applicable, no exceedances at baseline conditions to compare option results); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

Table I-27. Key Environmental Improvements for Mercury Under the Regulatory Options

Evaluation Benchmark	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
	Number	Percentage	Option A	Option B	Option C	Option D	Option E
Water Quality Results							
Freshwater Acute NRWQC	0	0%	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)	0 (N/A)
Freshwater Chronic NRWQC	1	1%	0 (100%)	0 (100%)	0 (100%)	0 (100%)	0 (100%)
Human Health Water and Organism NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Human Health Organism Only NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Drinking Water MCL	4	2%	4 (0%)	4 (0%)	4 (0%)	2 (50%)	1 (75%)
Wildlife Results							
Fish Ingestion NEHC for Minks	43	26%	40 (7%)	39 (9%)	23 (47%)	17 (60%)	8 (81%)
Fish Ingestion NEHC for Eagles	55	34%	48 (13%)	48 (13%)	34 (38%)	23 (58%)	17 (69%)
Human Health Results—Non-Cancer							
Non-Cancer Reference Dose for Child (recreational)	72	44%	65 (10%)	62 (14%)	46 (36%)	35 (51%)	27 (63%)
Non-Cancer Reference Dose for Adult (recreational)	64	39%	55 (14%)	54 (16%)	41 (36%)	30 (53%)	20 (69%)
Non-Cancer Reference Dose for Child (subsistence)	84	52%	74 (12%)	73 (13%)	55 (35%)	41 (51%)	37 (56%)
Non-Cancer Reference Dose for Adult (subsistence)	75	46%	68 (9%)	66 (12%)	49 (35%)	37 (51%)	29 (61%)

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: MCL (Maximum contaminant level); N/A (Not Applicable, no exceedances at baseline conditions to compare option results); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

Table I-28. Key Environmental Improvements for Selenium Under the Regulatory Options

Evaluation Benchmark	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
	Number	Percentage	Option A	Option B	Option C	Option D	Option E
Water Quality Results							
Freshwater Acute NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Freshwater Chronic NRWQC	27	17%	25 (7%)	17 (37%)	16 (41%)	14 (48%)	14 (48%)
Human Health Water and Organism NRWQC	8	5%	7 (13%)	3 (63%)	3 (63%)	2 (75%)	2 (75%)
Human Health Organism Only NRWQC	1	1%	1 (0%)	1 (0%)	1 (0%)	1 (0%)	1 (0%)
Drinking Water MCL	10	6%	9 (10%)	4 (60%)	4 (60%)	3 (70%)	3 (70%)
Wildlife Results							
Fish Ingestion NEHC for Minks	33	20%	32 (3%)	23 (30%)	19 (42%)	17 (48%)	17 (48%)
Fish Ingestion NEHC for Eagles	33	20%	32 (3%)	23 (30%)	19 (42%)	17 (48%)	17 (48%)
Negative Reproductive Effects in Fish [c]	21	13%	17 (19%)	9 (57%)	9 (57%)	8 (62%)	8 (62%)
Negative Reproductive Effects in Mallards [c]	25	15%	21 (16%)	13 (48%)	12 (52%)	11 (56%)	11 (56%)

Table I-28. Key Environmental Improvements for Selenium Under the Regulatory Options

Evaluation Benchmark	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
	Number	Percentage	Option A	Option B	Option C	Option D	Option E
Human Health Results—Non-Cancer							
Non-Cancer Reference Dose for Child (recreational)	33	20%	32 (3%)	23 (30%)	19 (42%)	17 (48%)	17 (48%)
Non-Cancer Reference Dose for Adult (recreational)	26	16%	23 (12%)	14 (46%)	14 (46%)	13 (50%)	13 (50%)
Non-Cancer Reference Dose for Child (subsistence)	41	25%	39 (5%)	31 (24%)	28 (32%)	24 (41%)	24 (41%)
Non-Cancer Reference Dose for Adult (subsistence)	34	21%	32 (6%)	23 (32%)	19 (44%)	17 (50%)	17 (50%)

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: MCL (Maximum contaminant level); N/A (Not Applicable, no exceedances at baseline conditions to compare option results); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

c – These rows indicate the number of immediate receiving waters whose median modeled egg/ovary concentration is predicted to result in reproductive impacts among at least 10 percent of the exposed fish or mallard population, as determined using the ecological risk model.

Table I-29. Key Environmental Improvements for Cadmium Under the Regulatory Options

Evaluation Benchmark	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
	Number	Percentage	Option A	Option B	Option C	Option D	Option E
Water Quality Results							
Freshwater Acute NRWQC	7	4%	4 (43%)	4 (43%)	4 (43%)	3 (57%)	2 (71%)
Freshwater Chronic NRWQC	23	14%	18 (22%)	18 (22%)	13 (43%)	11 (52%)	9 (61%)
Human Health Water and Organism NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Human Health Organism Only NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Drinking Water MCL	8	5%	6 (25%)	6 (25%)	5 (38%)	3 (63%)	2 (75%)
Wildlife Results							
Fish Ingestion NEHC for Minks	5	3%	4 (20%)	4 (20%)	4 (20%)	2 (60%)	2 (60%)
Fish Ingestion NEHC for Eagles	4	2%	3 (25%)	3 (25%)	3 (25%)	2 (50%)	2 (50%)
Human Health Results—Non-Cancer							
Non-Cancer Reference Dose for Child (recreational)	13	8%	9 (31%)	9 (31%)	7 (46%)	5 (62%)	3 (77%)
Non-Cancer Reference Dose for Adult (recreational)	8	5%	6 (25%)	6 (25%)	5 (38%)	3 (63%)	2 (75%)
Non-Cancer Reference Dose for Child (subsistence)	27	17%	22 (19%)	22 (19%)	17 (37%)	15 (44%)	10 (63%)
Non-Cancer Reference Dose for Adult (subsistence)	18	11%	13 (28%)	13 (28%)	9 (50%)	7 (61%)	4 (78%)

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: MCL (Maximum contaminant level); N/A (Not Applicable, no exceedances at baseline conditions to compare option results); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

Table I-30. Key Environmental Improvements for Thallium Under the Regulatory Options

Evaluation Benchmark	Modeled Immediate Receiving Waters Exceeding Benchmark Under Baseline Conditions [a]		Number of Immediate Receiving Waters Exceeding Benchmark (Percent Reduction from Baseline Conditions) Under the Regulatory Options [b]				
	Number	Percentage	Option A	Option B	Option C	Option D	Option E
Water Quality Results							
Freshwater Acute NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Freshwater Chronic NRWQC	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Human Health Water and Organism NRWQC	39	24%	36 (8%)	36 (8%)	22 (44%)	12 (69%)	12 (69%)
Human Health Organism Only NRWQC	35	21%	32 (9%)	32 (9%)	18 (49%)	8 (77%)	8 (77%)
Drinking Water MCL	27	17%	25 (7%)	25 (7%)	11 (59%)	5 (81%)	5 (81%)
Wildlife Results							
Fish Ingestion NEHC for Minks	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Fish Ingestion NEHC for Eagles	No benchmark for comparison		N/A	N/A	N/A	N/A	N/A
Human Health Results—Non-Cancer							
Non-Cancer Reference Dose for Child (recreational)	55	34%	54 (2%)	54 (2%)	36 (35%)	23 (58%)	23 (58%)
Non-Cancer Reference Dose for Adult (recreational)	43	26%	41 (5%)	41 (5%)	26 (40%)	16 (63%)	16 (63%)
Non-Cancer Reference Dose for Child (subsistence)	72	44%	69 (4%)	69 (4%)	47 (35%)	30 (58%)	30 (58%)
Non-Cancer Reference Dose for Adult (subsistence)	58	36%	58 (0%)	58 (0%)	39 (33%)	25 (57%)	25 (57%)

Source: ERG, 2015d; ERG, 2015h; ERG, 2015i.

Acronyms: MCL (Maximum contaminant level); N/A (Not Applicable, no exceedances at baseline conditions to compare option results); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

b – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

Under the alternate scenario analysis, EPA evaluated environmental improvements to sensitive waters as a result of the regulatory options and reflecting changes in the industry as a result of the CPP. EPA determined that 91 of the immediate receiving waters are 303(d)-listed waterbodies, designated as impaired for one or more pollutants found in the evaluated wastestreams.[7] Table I-31 presents the pollutant removals to impaired waters under the regulatory options.

EPA determined that 79 of the 172 immediate receiving waters included in the alternate scenario analysis are under a fish advisory for mercury. Under the final rule, the number of immediate receiving waters with fish that exceed EPA's mercury screening value for recreational fishers (based on steam electric power plant discharges only) will decrease by 59 percent, thereby reducing the potential threat to human health from consuming contaminated fish.

Under the alternate scenario analysis, EPA identified 14 steam electric power plants that discharge into the Great Lakes watershed. Table I-32 presents the pollutant removals to the Great Lakes watershed under the regulatory options considered by EPA.

Under the alternate scenario analysis, EPA identified seven steam electric power plants that discharge to the Chesapeake Bay watershed. Under the final rule, EPA estimates the following pollutant removals to the Chesapeake Bay watershed:

- 603 pounds of arsenic annually (89 percent reduction).
- 167 pounds of cadmium annually (84 percent reduction).
- 555 pounds of lead annually (97 percent reduction).
- 22.8 pounds of mercury annually (93 percent reduction).
- 4,550 pounds of selenium annually (96 percent reduction).
- 2,830 pounds of thallium annually (98 percent reduction).
- 667,000 pounds of total nitrogen annually (>99 percent reduction).
- 6,450 pounds of total phosphorus annually (81 percent reduction).

Finally, EPA evaluated the improvements to downstream receiving waters. Table I-33 presents the number of river miles impacted by steam electric power plant discharges at baseline and under the regulatory options for the alternate scenario analysis. The table also presents the percent reduction in number of impacted river miles.

[7] The count of impaired waters excludes the general impairment category "metals (not mercury)" and includes receiving waters impaired for arsenic, boron, cadmium, chromium, copper, lead, manganese, mercury, selenium, zinc, phosphorous, nutrients, TDS, or chlorides.

Table I-31. Pollutant Removals to Impaired Waters by Impairment Type

Impairment Type/Number of Receiving Waters [b]	Pollutant	Baseline Loadings (lbs/yr)	Pollutant Removals (lbs/yr) to Impaired Waters Under the Regulatory Options (Percent Reduction) [a]				
			Option A	Option B	Option C	Option D	Option E
Mercury-Impaired Receiving Waters							
21	Mercury	123	52.3 (42%)	52.6 (43%)	100 (81%)	123 (99%)	123 (>99%)
Metals (Not Mercury)-Impaired Receiving Waters							
24	Arsenic	4,020	2,660 (66%)	2,660 (66%)	3,540 (88%)	3,830 (95%)	3,880 (96%)
	Boron	4,420,000	312,000 (7%)	312,000 (7%)	344,000 (8%)	353,000 (8%)	353,000 (8%)
	Cadmium	1,810	1,360 (75%)	1,360 (75%)	1,630 (90%)	1,710 (94%)	1,720 (95%)
	Chromium VI	25.6	22.0 (86%)	22.0 (86%)	25.5 (>99%)	25.6 (>99%)	25.6 (>99%)
	Copper	4,150	2,410 (58%)	2,410 (58%)	3,690 (89%)	4,060 (98%)	4,060 (98%)
	Lead	2,500	1,300 (52%)	1,300 (52%)	2,170 (87%)	2,440 (98%)	2,440 (98%)
	Manganese	1,030,000	718,000 (70%)	718,000 (70%)	778,000 (76%)	800,000 (78%)	800,000 (78%)
	Nickel	14,700	9,210 (62%)	9,250 (63%)	13,200 (89%)	14,500 (99%)	14,600 (99%)
	Selenium	20,000	3,250 (16%)	19,100 (95%)	19,500 (98%)	19,700 (98%)	19,700 (98%)
	Thallium	6,620	1,190 (18%)	1,190 (18%)	5,070 (77%)	6,450 (97%)	6,450 (97%)
	Zinc	23,600	18,400 (78%)	18,400 (78%)	21,700 (92%)	22,800 (96%)	23,100 (98%)

Table I-31. Pollutant Removals to Impaired Waters by Impairment Type

Impairment Type/Number of Receiving Waters [b]	Pollutant	Baseline Loadings (lbs/yr)	Pollutant Removals (lbs/yr) to Impaired Waters Under the Regulatory Options (Percent Reduction) [a]				
			Option A	Option B	Option C	Option D	Option E
Nutrient-Impaired Receiving Waters							
15	Total Nitrogen	242,000	0 (0%)	158,000 (65%)	212,000 (87%)	241,000 (99%)	241,000 (99%)
	Total Phosphorous	2,870	0 (0%)	0 (0%)	1,520 (53%)	2,330 (81%)	2,330 (81%)
TDS and Chlorides-Impaired Receiving Waters							
2	Chlorides	CBI	CBI	CBI	CBI	CBI	CBI
	TDS	CBI	CBI	CBI	CBI	CBI	CBI

Source: ERG, 2015c.

Acronyms: CBI (Confidential business information); lbs/yr (pounds per year).

Note: Loadings and pollutant removals are rounded to three significant figures.

a – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

b – For the impaired waters proximity analysis, EPA evaluated 172 immediate receiving waters that receive discharges of the evaluated wastestreams.

c – The EPA impaired water database listed 24 immediate receiving waters as impaired based on the “metal, other than mercury” impairment category. Of those 24 immediate receiving waters, 13 receiving waters are also listed as impaired for one or more specific metals (arsenic, cadmium, manganese, selenium, and zinc). One additional immediate receiving water is impaired for boron (but not included in the “metals, other than mercury” impairment category).

d – Total phosphorous and total nitrogen loadings are presented with this impairment category. Total nitrogen loadings are the sum of total Kjeldahl nitrogen and nitrate/nitrite as N loadings.

Table I-32. Pollutant Removals to the Great Lakes Watershed Under the Regulatory Options

Pollutant	Baseline Loadings to the Great Lakes Watershed (lbs/yr)	Pollutant Removals (lbs/yr) to Great Lakes Watershed Under the Regulatory Options (Percent Reduction) [a]				
		Option A	Option B	Option C	Option D	Option E
Arsenic	1,030	46.7 (5%)	46.7 (5%)	509 (49%)	955 (92%)	1,000 (97%)
Boron	760,000	1,380 (<1%)	1,380 (<1%)	14,700 (2%)	27,300 (4%)	27,300 (4%)
Cadmium	286	6.03 (2%)	6.03 (2%)	134 (47%)	257 (90%)	266 (93%)
Chromium VI	0.548	0.471 (86%)	0.471 (86%)	0.548 (>99%)	0.548 (>99%)	0.548 (>99%)
Copper	1,170	26.6 (2%)	26.6 (2%)	596 (51%)	1,140 (98%)	1,150 (98%)
Lead	869	18.8 (2%)	18.8 (2%)	446 (51%)	856 (99%)	856 (99%)
Manganese	112,000	47.3 (<1%)	47.3 (<1%)	34,700 (31%)	68,300 (61%)	68,300 (61%)
Mercury	37.5	1.20 (3%)	1.48 (4%)	19.1 (51%)	35.7 (95%)	37.1 (99%)
Nickel	4,310	20.6 (<1%)	29.3 (1%)	2,150 (50%)	4,210 (98%)	4,260 (99%)
Selenium	3,540	20.9 (1%)	2,890 (82%)	3,120 (88%)	3,350 (95%)	3,350 (95%)
Thallium	4,320	21.8 (1%)	21.8 (1%)	2,190 (51%)	4,280 (99%)	4,280 (99%)
Zinc	3,860	55.5 (1%)	55.5 (1%)	1,790 (46%)	3,470 (90%)	3,760 (97%)
Nitrogen, total [b]	646,000	2,420 (<1%)	299,000 (46%)	474,000 (73%)	643,000 (>99%)	643,000 (>99%)
Phosphorus, total	10,900	135 (1%)	135 (1%)	5,080 (47%)	9,850 (91%)	9,850 (91%)
Chlorides	24,100,000	11,400 (<1%)	11,400 (<1%)	693,000 (3%)	1,350,000 (6%)	1,350,000 (6%)
TDS	116,000,000	187,000 (<1%)	187,000 (<1%)	18,400,000 (16%)	36,100,000 (31%)	36,100,000 (31%)

Source: ERG, 2015a; ERG, 2015c.

Acronyms: lbs/yr (pounds per year); TDS (total dissolved solids).

Note: Loadings and pollutant removals are rounded to three significant figures.

a – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

b – Total nitrogen loadings are the sum of total Kjeldahl nitrogen and nitrate/nitrite as N loadings.

Table I-33. Key Environmental Improvements for Downstream Waters Under the Regulatory Options

Evaluation Criteria	Number of River-Miles Exceeding Criteria Under Baseline Conditions	Number of River-Miles Exceeding Criteria (Percent Reduction from Baseline Conditions) Under the Regulatory Options [a]				
		Option A	Option B	Option C	Option D	Option E
Water Quality Results						
Freshwater Acute NRWQC	412	395 (4%)	395 (4%)	393 (5%)	388 (6%)	388 (6%)
Freshwater Chronic NRWQC	605	592 (2%)	560 (8%)	542 (10%)	514 (15%)	514 (15%)
Human Health Water and Organism NRWQC	4,050	3,390 (16%)	3,390 (16%)	2,480 (39%)	1,930 (52%)	1,710 (58%)
Human Health Organism-only NRWQC	1,500	1,230 (18%)	1,230 (18%)	1,030 (31%)	781 (48%)	713 (52%)
Drinking Water MCL	751	725 (3%)	720 (4%)	629 (16%)	487 (35%)	487 (35%)
Wildlife Results						
Fish Ingestion NEHC for Minks	1,070	893 (17%)	862 (19%)	720 (33%)	524 (51%)	503 (53%)
Fish Ingestion NEHC for Eagles	1,870	1,580 (15%)	1,560 (16%)	1,260 (32%)	957 (49%)	899 (52%)
Human Health Results—Non-Cancer						
Non-cancer reference dose for child (recreational)	5,800	4,380 (24%)	4,380 (25%)	2,890 (50%)	2,250 (61%)	2,080 (64%)
Non-cancer reference dose for adult (recreational)	3,420	2,830 (17%)	2,820 (17%)	1,960 (43%)	1,430 (58%)	1,350 (61%)
Non-cancer reference dose for child (subsistence)	9,240	7,790 (16%)	7,760 (16%)	5,520 (40%)	4,490 (51%)	4,080 (56%)
Non-cancer reference dose for adult (subsistence)	6,540	5,050 (23%)	5,050 (23%)	3,330 (49%)	2,620 (60%)	2,410 (63%)

Table I-33. Key Environmental Improvements for Downstream Waters Under the Regulatory Options

Evaluation Criteria	Number of River-Miles Exceeding Criteria Under Baseline Conditions	Number of River-Miles Exceeding Criteria (Percent Reduction from Baseline Conditions) Under the Regulatory Options [a]				
		Option A	Option B	Option C	Option D	Option E
Human Health Results—Cancer						
Cancer risk for child (recreational)	227	216 (5%)	216 (5%)	211 (7%)	210 (8%)	207 (9%)
Cancer risk for adult (recreational)	286	263 (8%)	263 (8%)	251 (12%)	246 (14%)	245 (14%)
Cancer risk for child (subsistence)	262	241 (8%)	241 (8%)	239 (9%)	235 (10%)	231 (12%)
Cancer risk for adult (subsistence)	414	375 (9%)	375 (9%)	355 (14%)	328 (21%)	304 (26%)

Source: ERG, 2015i; ERG, 2015l.

Note: River miles are rounded to three significant figures.

a – >0 to 15 percent reduction; 16 to 30 percent reduction; 31 to 45 percent reduction; 46 to 60 percent reduction; >60 percent reduction.

b – EPA evaluated a total of 72,100 river-miles in the downstream receiving water analysis for toxic, bioaccumulative pollutants. Downstream receiving water concentrations are calculated until one of three conditions occurs: 1) the discharge travels 300 kilometers (km) downstream; 2) the discharge travels downstream for a week; or 3) the concentration reaches 1 x 10^{-9} milligrams per liter (mg/L).

APPENDIX J
EA LOADINGS AND TDD LOADINGS: SENSITIVITY ANALYSIS

As discussed in Section 3, the analyses presented in the environmental assessment (EA) report are based on loadings datasets that differ from those that are summarized in the *Technical Development Document for Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category (TDD)*, Document No. EPA-821-R-15-007. This appendix presents a sensitivity analysis that evaluates the difference between the two pollutant loadings datasets (the "EA loadings" and the "TDD loadings") and estimates the change in counts of environmental exceedances that would have resulted from use of the TDD loadings dataset. The analyses in this section reflect changes in the industry that may occur as a result of the Clean Power Plan [Clean Air Act Section 111(d)] (CPP).

Table J-1 quantifies the difference in baseline loadings between the EA loadings and TDD loadings for each of the ten pollutants that are modeled in the EA analyses.

<u>Impacts to Exceedances across All Pollutants</u>

To estimate the influence that using the TDD loadings would have on the overall counts of exceedances identified in the EA Report, EPA took the following steps:

1. EPA determined how many immediate receiving waters had exceedances that were due, in part or in whole, to selenium, thallium, or chromium VI. Because the EA loadings for these pollutants are equal to (or, in the case of selenium, slightly greater than) the corresponding TDD loadings, each immediate receiving water in this group would have had exceedances if EPA had used the TDD loadings.
2. Of the remaining receiving waters with exceedances, EPA determined how many had exceedances that were due, in part or in whole, to arsenic (whose loadings are 9.4 percent lower using the TDD loadings). By assuming that the difference in loadings would result in an equal change in the count of exceedances, EPA assumed that use of the TDD loadings would have resulted in 9.4 percent fewer exceedances among this group of immediate receiving waters.
3. Of the remaining receiving waters with exceedances, EPA determined how many had exceedances that were due, in part or in whole, to zinc (whose loadings are 14 percent lower in the TDD loadings). By assuming that the difference in loadings would result in an equal change in the count of exceedances, EPA assumed that use of the TDD loadings would have resulted in 14 percent fewer exceedances among this group of immediate receiving waters.
4. EPA repeated this process for the remaining modeled pollutants (in order of increasing change between the EA loadings and TDD loadings) until all immediate receiving waters with exceedances were taken into account.

Table J-2 presents the results of this analysis, which demonstrates that use of the TDD loadings in place of the EA loadings would have only minimal effect on the overall counts of exceedances identified by the immediate receiving water (IRW) model. The benchmark exceedances that would be most affected by use of the TDD loadings are exceedances of chemical stressor concentration limits (CSCLs) for sediment biota. Exceedances of this benchmark under baseline conditions would be approximately 4 percentage points lower (41 percent versus 45 percent) based on use of the TDD loadings instead of the EA loadings. All other benchmark exceedances change by 2 percentage points or less.

This analysis assumes a linear relationship between a loadings reduction and a change in exceedances for that pollutant. As discussed below, however, this assumption likely overestimates the effect of a loadings change on the count of exceedances.

Impacts to Individual Pollutant Exceedances

Table I-22 in Appendix I presents the industry-wide pollutant-specific removals under the regulatory options (reflecting changes in the industry as a result of the CPP). Table I-25 through Table I-30 present the pollutant-specific environmental improvements under the regulatory options. A comparison of the values in these tables indicates that an industry-wide pollutant loading reduction of *x* under the regulatory options usually results in a reduction in benchmark exceedances of *less than x*. For example, looking at Option A:

- *Cadmium*: Loadings reduced by 72 percent; exceedances reduced by approximately 19 to 43 percent.
- *Mercury*: Loadings reduced by 62 percent; exceedances reduced by approximately 7 to 14 percent.
- *Arsenic*: Loadings reduced by 56 percent; exceedances reduced by approximately 4 to 33 percent.
- *Selenium*: Loadings reduced by 21 percent; exceedances reduced by approximately 3 to 19 percent.
- *Thallium*: Loadings reduced by 13 percent; exceedances reduced by approximately 0 to 9 percent.

This suggests that the use of the TDD loadings instead of the EA loadings would have a less-than-linear effect on the number of exceedances in the EA for each pollutant. Based on this observation, EPA estimates that use of the TDD loadings would result in the following approximate effects in the baseline counts of pollutant-specific exceedances identified using the EA loadings:

- *Selenium, thallium, and chromium VI*: No decrease in exceedances.
- *Arsenic, zinc, mercury*: Approximately 10 percent fewer exceedances.
- *Cadmium, copper, and nickel*: Approximately 20 percent fewer exceedances.
- *Lead*: Approximately 25 percent fewer exceedances.

Table J-1. Comparison of Annual Baseline Pollutant Discharges from Steam Electric Power Plants (Evaluated Wastestreams), EA Loadings versus TDD Loadings

Pollutant	Baseline Loadings			Option D Removals			Option D Removals		
	EA Version (lbs/yr)	TDD Version (lbs/yr)	Percent Change	EA Version (lbs/yr)	TDD Version (lbs/yr)	Percent Change	EA Version (%)	TDD Version (%)	Percent Change
Arsenic	22,200	20,100	-9.4%	20,700	18,700	-10%	93%	93%	-0.73%
Cadmium	10,900	8,290	-24%	10,300	7,660	-26%	94%	92%	-1.9%
Chromium (VI)	119	119	0%	119	119	0%	100%	100%	0%
Copper	24,000	16,400	-32%	23,400	15,800	-33%	98%	97%	-1.1%
Lead	14,600	7,670	-47%	14,200	7,340	-48%	98%	96%	-2.0%
Mercury	1,180	992	-16%	1,150	961	-16%	97%	97%	-0.47%
Nickel	94,200	61,900	-34%	92,400	60,200	-35%	98%	97%	-0.87%
Selenium	113,000	115,000	1.4%	110,000	111,000	1.4%	97%	97%	0.032%
Thallium	43,900	43,900	0%	42,800	42,800	0.0%	98%	98%	-0.020%
Zinc	145,000	124,000	-14%	138,000	117,000	-15%	95%	95%	-0.79%

Source: ERG, 2015o.

Note: Loadings and pollutant removals are rounded to three significant figures. Percentages are rounded to two significant figures.

Table J-2. Comparison of Modeled Baseline Exceedances (Using EA Loadings) and Approximated Baseline Exceedances (Using TDD Loadings)

Evaluation Benchmark	Baseline Exceedances in Appendix I (EA Loadings Version)		Baseline Approximated Exceedances (TDD Loadings Version)	
	Number [a]	Percentage	Number [a]	Percentage
Freshwater Acute NRWQC	7	4%	5.85	4%
Freshwater Chronic NRWQC	28	17%	27.8	17%
Human Health Water and Organism NRWQC	73	45%	69.8	43%
Human Health Organism Only NRWQC	51	31%	49.5	30%
Drinking Water MCL	29	18%	29.0	18%
Fish Ingestion NEHC for Minks	46	28%	44.0	27%
Fish Ingestion NEHC for Eagles	56	34%	52.4	32%
CSCLs for Sediment Biota	40	25%	34.2	21%
Negative Reproductive Effects in Fish from Selenium [b]	21	13%	21.0	13%
Negative Reproductive Effects in Mallards from Selenium [b]	25	15%	25.0	15%
Non-Cancer Reference Dose for Child (recreational)	75	46%	72.7	45%
Non-Cancer Reference Dose for Adult (recreational)	67	41%	64.2	39%
Non-Cancer Reference Dose for Child (subsistence)	90	55%	87.8	54%
Non-Cancer Reference Dose for Adult (subsistence)	78	48%	75.7	46%

Source: ERG, 2015o.

Acronyms: CSCL (Chemical stressor concentration limit); MCL (Maximum contaminant level); NEHC (No Effect Hazard Concentration); NRWQC (National Recommended Water Quality Criteria).

a – The alternate scenario analysis encompasses a total of 172 immediate receiving waters and loadings from 148 steam electric power plants (some of which discharge to multiple receiving waters). The IRW model, which excludes the Great Lakes and estuaries, encompasses a total of 163 immediate receiving waters and loadings from 143 steam electric power plants.

b – These rows indicate the number of immediate receiving waters whose median modeled egg/ovary concentration is predicted to result in reproductive impacts among at least 10 percent of the exposed fish or mallard population, as determined using the ecological risk model.

Exhibit 14

United States
Environmental Protection
Agency

Environmental Assessment for Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category

April 2024

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U.S. Environmental Protection Agency
Office of Water (4303T)
1200 Pennsylvania Avenue, NW
Washington, DC 20460

EPA-821-R-24-005

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Contents

Attachments

List of Figures

List of Tables

List of Abbreviations

AETX	aetokthonotoxin
BA	bottom ash
BAT	best available technology economically achievable
BCA	benefit and cost analysis
Br-DBP	brominated disinfection byproduct
CCR	coal combustion residuals
CFR	Code of Federal Regulations
CRL	combustion residual leachate
CSF	cancer slope factor
CWA	Clean Water Act
DBP	disinfection byproduct
DCN	document control number
D-FATE	Downstream Fate and Transport Equations
DNA	deoxyribonucleic acid
DWTP	drinking water treatment plant
EA	environmental assessment
EGU	electric generating unit
EJ	environmental justice
ELGs	effluent limitations guidelines and standards
EPA	U.S. Environmental Protection Agency
FGD	flue gas desulfurization
FR	Federal Register
FW	freshwater
HAAs	haloacetic acids
HANs	haloacetonitriles
HH O	human health for the consumption of organism only
HH WO	human health for the consumption of water and organism
I-DBP	iodinated disinfection byproduct
IRIS	Integrated Risk Information System
IRW	immediate receiving water
lb/year	pounds per year
LC50	median lethal concentration
LECR	lifetime excess cancer risk
MCL	maximum contaminant level
MRL	minimal risk level
mg/kg	milligrams per kilogram

mg/kg-day	milligrams per kilogram body weight per day
mg/L	milligrams per liter
µg/g	micrograms per gram
N	nitrogen
NEHC	no effect hazard concentration
NHDPlus	National Hydrography Dataset Plus
NRWQC	National Recommended Water Quality Criteria
POTW	publicly owned treatment works
ppm	parts per million
PSES	pretreatment standards for existing sources
RfD	reference dose
RIA	regulatory impact analysis
SO2	sulfur dioxide
T3	trophic level 3
T4	trophic level 4
TDD	technical development document
TDS	total dissolved solids
TEC	threshold effect concentration
THMs	trihalomethanes
TKN	total Kjeldahl nitrogen
TSS	total suspended solids
UV	ultraviolet
VM	vacuolar myelinopathy
WHO	World Health Organization

1. Introduction

The U.S. Environmental Protection Agency (EPA) promulgated revised effluent limitations guidelines and standards (ELGs) for the Steam Electric Power Generating Point Source Category (40 CFR 423) on November 3, 2015 (80 FR 67838), referred to hereinafter as the “2015 rule.” Following promulgation, the EPA received seven petitions for review of the 2015 rule and the Administrator announced his decision to reconsider the 2015 rule. The EPA finalized a revision to the regulations for the Steam Electric Power Generating category (85 FR 64650, October 13, 2020), referred to as the “2020 rule,” which established revised ELGs for flue gas desulfurization (FGD) wastewater and bottom ash (BA) transport water discharged from steam electric power plants. See the *Technical Development Document for Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category,* or TDD (EPA-821-R-24-004) for more background and information on the rulemaking history.

This 2024 supplemental rulemaking is based on a review of the ELGs promulgated in 2020 under Executive Order 13990. The supplement rule covers best available technology economically achievable (BAT) and pretreatment standards for existing sources (PSES) requirements for FGD wastewater, BA transport water, combustion residual leachate (CRL), and legacy wastewater from steam electric power plants. It also establishes new source performance standards (NSPS) and pretreatment standards for new sources (PSNS) for CRL.

In support of the development of the 2015 rule and the 2020 rule, the EPA conducted an environmental assessment (EA) to evaluate the environmental impact of pollutant loadings discharged by steam electric power plants and assess the potential environmental improvement from pollutant loading changes under the rules. The EPA documented the EA in the September 2015 report *Environmental Assessment for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (EPA-821-R-15-006) (U.S. EPA, 2015a), referred to hereinafter as the “2015 EA,” and the *Supplemental Environmental Assessment for Revisions to the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (EPA-821-R-20-002) (U.S. EPA, 2020a), referred to hereinafter as the “2020 EA.” To support the 2024 final rule, the EPA updated its EA for the 2015 rule and 2020 rule to include the steam electric power plants discharging one or more of the four wastestreams. In addition, the EPA evaluated potential cumulative impacts from multiple pollutants (Joint Toxic Action analysis) in support of the proposed rulemaking.

The Clean Water Act does not require that the EPA assess the water-quality-related environmental impacts, or the benefits, of its ELGs, and the Agency did not make its decisions in the final rule based on the expected benefits of the rule. The EPA does, however, inform itself and the public of the benefits of its proposed and final rules, as required by Executive Order 12866. See the *Benefit and Cost Analysis for Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category*, or BCA Report (EPA-821-R-24-006). This EA report presents the EPA’s evaluation of the potential environmental impacts due to pollutant loadings under baseline discharge practices (*i.e.*, following full implementation of the requirements under the 2015 rule and 2020 rule and any known retirements, fuel conversions, and treatment technologies in place at in-scope steam electric power plants) and the improvements to those impacts under the evaluated regulatory options.

1.1 Background on Steam Electric Power Plant Wastewater Discharges

Based on demonstrated impacts documented in literature and modeled receiving water pollutant concentrations, discharges of steam electric power plant wastewater can affect the water quality in receiving waters, affect the wildlife in the surrounding environments, and pose a human health risk to nearby communities. There is substantial evidence that certain pollutants found in these wastewater discharges, such as mercury and selenium, propagate from the aquatic environment to terrestrial food webs, indicating a potential for broader impacts on surrounding ecological systems by diminishing population diversity and disrupting community dynamics. Ecosystem recovery from exposure to these pollutants can be extremely slow, and even short periods of exposure (*e.g.*, less than a year) can cause observable ecological impacts that last for years.

Steam electric power plants often discharge wastewater into waterbodies used for fishing, for recreation, and/or as sources of drinking water. Many studies have raised concerns about the toxicity of these wastestreams and their impacts on downstream drinking water treatment systems. For example, these discharges can elevate halogen levels in surface water, which may contribute to disinfection byproduct formation at downstream drinking water treatment plants. Leaching of pollutants from surface impoundments and landfills containing combustion residuals is known to affect off-site groundwater and drinking water wells at concentrations above maximum contaminant level drinking water standards, posing a threat to human health.

1.2 Scope of the EA

The Steam Electric Power Generating Point Source Category ELGs apply to establishments whose generation of electricity is the predominant source of revenue or principal reason for operation, and whose generation results primarily from a process using fossil-type fuels (coal, oil, or gas), fuel derived from fossil fuel (*e.g.*, petroleum coke, synthesis gas), or nuclear fuel in conjunction with a thermal cycle using the steam water system as the thermodynamic medium. The EPA evaluated four wastestreams from steam electric power plants whose limitations and standards would be revised under the new rulemaking: FGD wastewater, BA transport water, CRL, and legacy wastewater, as described in Table 1.

Table 1. Wastestreams Evaluated in the EA

Evaluated Wastestream	Description
FGD wastewater	Wastewater generated from a wet FGD scrubber system. Wet FGD systems are used to control sulfur dioxide (SO_2) and mercury emissions from the flue gas generated in the plant's electric generating unit (EGU). The pollutant concentrations in FGD wastewater vary from plant to plant depending on the coal type, the burning of refined coal, the sorbents and additives used, the materials used to construct the FGD system, the FGD system operation, the level of recycle within the absorber, and the air pollution control systems operated upstream of the FGD system. FGD wastewater contains total dissolved solids (TDS), total suspended solids (TSS), nutrients, halogens, metals, and other toxic and bioaccumulative pollutants, such as arsenic and selenium (see the TDD [U.S. EPA, 2024a] for further details).
BA transport water	Water used to convey the BA particles collected at the bottom of the EGU. BA transport waters contain halogens, TDS, TSS, metals, and other toxic and bioaccumulative pollutants, such as arsenic and selenium (see the TDD [U.S. EPA, 2024a] for details). The effluent from BA surface impoundments typically contains low concentrations of TSS; however, arsenic, bromide, selenium, and metals are still present in the wastewater, predominantly in dissolved form.
CRL	Leachate is composed of liquid, including any suspended or dissolved constituents in the liquid, that has percolated through waste or other materials emplaced in a landfill, or that passes through the surface impoundment's containment structure (*e.g.*, bottom, dikes, berms). CRL includes seepage and/or leakage from a combustion residual landfill or impoundment unit. CRL contains pollutants similar to those in FGD wastewater.

Table 1. Wastestreams Evaluated in the EA

Evaluated Wastestream	Description
Legacy wastewater	As described in the preamble to the final rule, legacy wastewater is comprised of FGD wastewater, BA transport water, fly ash transport water, CRL, gasification wastewater, and/or flue gas mercury control wastewater generated before the "as soon as possible" date that more stringent effluent limitations from the 2015 or 2020 rules would apply. Legacy wastewater contains pollutants similar to those in the other wastestreams described in this table.

The goal of the EA is to answer the following questions about pollutant loadings from the four evaluated wastestreams:

- What are the environmental concerns?
- What are baseline environmental impacts to water quality and wildlife and impacts to human health?
- What are the potential improvements to water quality, wildlife, and human health under the regulatory options?

This EA report presents the EPA's evaluation of environmental concerns and potential exposures (ecological and human) to pollutants commonly found in wastewater discharges from steam electric power plants. The EPA carried out both qualitative and quantitative analyses. Qualitative analyses included reviewing additional literature documenting site impacts and pollutant-specific research. Quantitative analyses included assessing the pollutant loadings to receiving waters—including those designated as impaired or with a fish consumption advisory—under baseline and the evaluated regulatory options and reviewing the effects of pollutant exposure on ecological and human receptors. To quantify impacts associated with these discharges, the EPA used a computer model to estimate pollutant concentrations in the immediate receiving waters, pollutant concentrations in fish tissue, and potential exposure doses to ecological and human receptors from fish consumption. The EPA compared the values calculated by the model to benchmark values to assess the extent of the environmental impacts nationwide. The EPA evaluated the impacts of FGD wastewater, BA transport water, CRL,[1] and legacy wastewater discharges.

The EPA evaluated three regulatory options, summarized in Table VII-1 of the preamble to the final rule. The EPA evaluated 112 plants that discharge FGD wastewater, BA transport water, CRL, and/or legacy wastewater directly or indirectly to surface waters under baseline and/or the regulatory options and performed the quantitative modeling of pollutants in the immediate receiving water on a subset of 100 of these plants. The analyses presented in this report account for notice of planned participation as described in Section VI of the preamble to the final rule. See Section 3.7 of this report for additional details on the scope of this EA.

The assessments described in this EA report focus on environmental impacts caused by exposure to pollutants in the evaluated wastestreams through the surface water exposure pathway. However, the final rule may have other environmental impacts unrelated to exposure to pollutants in wastewater discharges. Examples include changes in groundwater and surface water withdrawals by plants and

[1] The EPA is establishing a new subcategory for discharges of unmanaged CRL, which the EPA is defining in this rule to mean the following: (1) discharges of CRL that the permitting authority determines are the functional equivalent of a direct discharge to a waters of the United States (WOTUS) through groundwater or (2) discharges of CRL that has leached from a waste management unit into the subsurface and mixed with groundwater prior to being captured and pumped to the surface for discharge directly to a WOTUS (see Section VII.C.5 of the preamble to the final rule). This subcategory of CRL is not evaluated in the EA.

changes in air emissions due to changes in electricity use, transportation requirements, and the profile of electricity generation. These impacts are discussed in the EPA's BCA Report (U.S. EPA, 2024b).

This EA report does not discuss impacts caused by pollutants in unmanaged CRL. See Section VII.C.5 of the preamble to the final rule.

This report presents the methodology and results of the qualitative and quantitative analyses performed for the EA to support the supplemental rule. In addition to this EA, the final rule is supported by several reports:

- *Technical Development Document for Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (TDD), Document No. EPA-821-R-24-004 (U.S. EPA, 2024a). This report includes background on the final rule, the industry, and treatment technologies and pollution prevention techniques; it also documents the EPA's engineering analyses to support the supplemental rule, including cost estimates, wastewater characterization and pollutant loadings, and a non-water-quality environmental impact assessment.
- *Benefit and Cost Analysis for Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (BCA Report), Document No. EPA-821-R-24-006 (U.S. EPA, 2024b). This report summarizes the monetary benefits and societal costs of implementing the regulatory options.
- *Regulatory Impact Analysis for Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (RIA), Document No. EPA-821-R-24-007 (U.S. EPA, 2024c). This report presents a profile of the steam electric power generating industry, a summary of the costs and impacts associated with the regulatory options, and an assessment of the supplemental rule's impact on employment and small businesses.
- *Environmental Justice Analysis for Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (EJ Report). Document No. EPA-821-R-24-008 (U.S. EPA, 2024d). This report presents the environmental justice (EJ) analysis to support the supplemental rule, including screening analysis to identify communities with potential EJ concerns, community outreach, literature review, and risk analysis.

The ELGs for the Steam Electric Power Generating Category are based on data generated or obtained in accordance with the EPA's Quality System and Information Quality Guidelines. The EPA's quality assurance and quality control activities for this rulemaking include developing, approving, and implementing quality assurance project plans for the use of environmental data generated or collected from sampling and analyses, existing databases, and literature searches, and for developing any models that used environmental data.

2. Literature Review of the Environmental and Human Health Concerns Associated with the Evaluated Wastestreams

Discharges of the evaluated wastestreams from steam electric power plants—flue gas desulfurization (FGD) wastewater, bottom ash (BA) transport water, combustion residual leachate (CRL), and legacy wastewater—contain toxic and bioaccumulative pollutants (*e.g.*, selenium, mercury, arsenic, nickel), halogens (containing bromides, chlorides, or iodides), nutrients, and total dissolved solids (TDS), which can cause environmental harm through the contamination of surface waters. Certain pollutants in the discharges pose a danger to ecological communities due to their persistence in the environment and bioaccumulation in organisms. These factors can slow ecological recovery and can have long-term impacts on aquatic organisms, wildlife, and human health. Many studies document ecological impacts such as fish mortality, genotoxicity, and lower fish survival and reproduction rates resulting from exposure to pollutants in steam electric power plant discharges (Brandt et al., 2017 and 2019; Carlson and Adriano, 1993; Hopkins et al., 2000; Javed et al., 2016; Lemly, 1997b and 2018; Rowe et al., 1996 and 2002). Halogens associated with steam electric power plant discharges also raise ecological and human health concerns. Halogens in source water for drinking water treatment plants (DWTPs) can interact with disinfection processes to form halogenated disinfection byproducts (DBPs), which can pose a risk to human health (Cantor et al., 2010; Chisholm et al., 2008; Dong et al., 2019; Hanigan et al., 2017; National Toxicology Program, 2018; Regli et al., 2015; Richardson et al., 2007 and 2008; Richardson and Plewa, 2020; U.S. EPA, 2016a; Villanueva et al., 2004, 2007, and 2015; Wagner and Plewa, 2017; Wei et al., 2013; Yang et al., 2014).

The EPA documented environmental and human health concerns from steam electric power plant discharges in the 2015 final environmental assessment, or 2015 EA (U.S. EPA, 2015a) and the 2020 EA (U.S. EPA, 2020a). For this EA, the EPA conducted a supplemental literature review in 2022 that consisted of identifying and evaluating peer-reviewed journal articles and other materials published since its last full literature review (2010) that focus on current environmental, ecological, and human health impacts resulting from discharges of pollutants in the evaluated wastestreams. The EPA also incorporated relevant articles submitted with public comments and published since the 2022 review into its analysis for the final rule. This section summarizes relevant findings from the EPA's literature reviews, including an overview of the pollutants discharged in the evaluated wastestreams and their associated environmental concerns. Some of the articles documented impacts of steam electric power plant discharges but did not provide specific wastestream details. When such details were documented in reviewed articles, the EPA included details on applicable wastestreams. See the memorandum *Literature Review for the 2024 Steam Electric Supplemental Rule Environmental Assessment* (U.S. EPA, 2024e) for details.

2.1 Pollutants Discharged in the Evaluated Wastestreams

Several variables can affect the composition of steam electric power plant wastewater, including fuel composition (*e.g.*, parent coal composition varies by coal type and geographic region and inclusion of other fuels in the combustion process), air pollution control technologies (*e.g.*, use of dry versus wet systems), and management techniques used to dispose of the wastewater (*e.g.*, whether the plant commingles its wastestreams) (Carlson and Adriano, 1993; Rowe et al., 2002). Commingling steam electric power plant wastewaters in surface impoundments can result in a complex mixture of pollutants in the effluent that is released to the environment (Rowe et al., 2002).

2.1.1 Metals and Toxic Bioaccumulative Pollutants

Studies commonly cite metals and toxic bioaccumulative pollutants (*e.g.*, arsenic, mercury, and selenium) as the primary cause of ecological damage following exposure to steam electric power plant wastewater (U.S. EPA, 2015a). An important consideration in evaluating these pollutants is their bioavailability, defined as the ability of a particular contaminant to be assimilated into the tissues of exposed organisms.

A pollutant's bioavailability is affected by the characteristics of both the pollutant (*e.g.*, speciation, particle size) and the surrounding environment (*e.g.*, temperature, pH, salinity, oxidation-reduction potential, total organic content, suspended particulate content, and water velocity). Metals and toxic bioaccumulative pollutants in steam electric power plant wastewater are present in both soluble (*i.e.*, dissolved) and particulate (*i.e.*, suspended) form. For example, the EPA collected sampling data for FGD wastewater in support of the steam electric effluent limitations guidelines and standards. These data show that some pollutants, such as arsenic, are present mostly in particulate form while other pollutants, such as selenium and boron, are present mostly in soluble form (ERG, 2012). Environmental conditions influence the tendency of a dissolved pollutant to remain in solution or precipitate out of solution, sorb to either organic or inorganic suspended matter in the water column, or sorb to the mixture of materials (*e.g.*, clays and humic matter) found in sediments (U.S. EPA, 2007). Pollutants that precipitate out of solution can become concentrated in the sediments of a waterbody. Organisms will bioaccumulate pollutants by consuming pollutant-enriched sediments and suspended particles, filtering ambient water containing dissolved pollutants, or both.

Appendix A of the 2020 EA (U.S. EPA, 2020a) provides examples of potential adverse impacts to humans, wildlife, and aquatic organisms resulting from exposure to metals and toxic bioaccumulative pollutants in the evaluated wastestreams and provides the minimal risk level (MRL) for human oral exposure (or similar benchmark value) for reference. Adverse impacts from steam electric power plant discharges of these pollutants are discussed further in the 2015 EA (U.S. EPA, 2015a).

2.1.2 Nutrients

Nutrients (*e.g.*, phosphorus and nitrogen) are essential components for plants and animals to grow and develop; however, increased nutrient concentrations can upset the delicate balance of nutrient supply and demand required to maintain aquatic life in surface waters. For example, excess nutrients can cause harmful algal blooms and low oxygen (hypoxia) in surface waters. These are primarily problems for estuaries, such as the Chesapeake Bay, and coastal waters, such as the Gulf of Mexico. Nutrient loadings from multiple power plants are especially a concern for waterbodies that are nutrient-impaired or in watersheds that have nutrient problems downstream. Nutrient concentrations present in steam electric power plant wastewater are primarily attributed to the fuel composition and air pollution controls in the combustion process.

Nutrient loadings to surface waters can affect the ecological stability of freshwater and saltwater aquatic systems. For example, elevated levels of nutrients can stimulate rapid growth of plants, algae, and cyanobacteria on or near the waterbody surface, which in turn can obstruct sunlight penetration, increase turbidity, and decrease dissolved oxygen levels (U.S. EPA, 2015b). Adverse impacts from steam electric power plant discharges of nutrients are discussed further in the 2015 EA (U.S. EPA, 2015a).

2.1.3 TDS and Salinity

TDS represents the concentration of combined dissolved organic and inorganic matter, whereas salinity represents the total concentration of dissolved inorganic salts. Common inorganic salts found in TDS can include cations (positively charged ions), such as calcium, magnesium, potassium, and sodium, and anions (negatively charged ions), such as carbonates, nitrates, bicarbonates, chlorides, and sulfates. TDS concentrations in steam electric power plants wastestreams include contributions from dissolved metals and halogens (*e.g.*, chlorides, bromides, and iodides).

Salts can enter water naturally through erosion of soils and geologic formations and introduction of their dominant ions to local freshwater systems (Hem, 1985; Olson and Hawkins, 2012; Pond, 2004; U.S. EPA, 2011). In addition to steam electric power plants, other sources of TDS are widespread in the environment, making it more likely that receiving waters for the discharges of the evaluated wastestreams already carry excessive TDS loadings. These other sources include mining activities, use of road salt for de-icing, and discharge of sewage and industrial wastewater (Cañedo-Argüelles et al., 2013; Corsi et al., 2010). Once salinity has increased in freshwater systems, the effect can be persistent. In lentic waters such as lakes and ponds, even small increases in salt levels can result in long-term increases in salinity, lasting months or years (Evans and Frick, 2001). Kaushal et al. (2005) reported that, after application of deicing salts in winter, chloride concentrations in urban streams remain elevated into spring, summer, and fall and contribute to an accumulation of salts in groundwater and aquifers that may persist over several decades.

Harb et al. (2021) studied how changes in freshwater salinity can have environmental impacts on (1) spray aerosol generation from the breaking of waves and (2) diversity of aquatic bacteria. As waves break, aquatic bacteria can be aerosolized (*i.e.*, transferred from water to air). Changes in the bacteria being transferred from water to air could affect regional climate by altering aerosolized bacteria that act as cloud condensation nuclei (*i.e.*, particles in the air onto which water vapor will condense) and ice-nucleating particles (*i.e.*, particles for formation of cloud ice crystals). In addition, alterations in the aerosolized bacteria could affect public health by increasing inhalation exposure to airborne pathogens (Harb et al., 2021). Harb et al. (2021) sought to understand how increased freshwater salinity can impact the abundance and diversity of aerosolized aquatic bacteria. In freshwater salinity ranges, researchers found that aerosolization of bacteria increased as salinity increased. The study found that salinity altered the transfer of some bacterial families to an aerosol, with some families exhibiting enhanced, diminished, or no change in water to air transfer (Harb et al., 2021).

Exposure to dissolved bioaccumulative pollutants and halogens found in the evaluated wastestreams may cause human health and ecological effects. Researchers have documented the potential consequences of elevated salinity on aquatic ecosystems. Increased salinity has been linked to adverse effects including increases in invasive species, lower rates of organic matter processing, changes in biogeochemical cycles, decreased riparian vegetation, and altered composition of primary producers (*i.e.*, plants, bacteria, and algae) (Cañedo-Argüelles et al., 2013). Increases in aquatic salinity may cause shifts in biotic communities, limit biodiversity, exclude less-tolerant species, and result in acute or chronic effects at specific life stages (Weber-Scannell and Duffy, 2007). Salt additions can lead to loss of exchangeable cations in soil, and the mobility and toxicity of some pollutants, especially metals, can be enhanced at high salt concentrations (Stets et al., 2020). Because interactions between ions can affect the bioavailability and toxicity of individual TDS constituents, the net ecological effect of elevated TDS levels in the aquatic environment depends on its ionic composition (Moore et al., 2017; Mount et al., 1993 and 1997). The 2020 EA (U.S. EPA, 2020a) provides further details on adverse impacts from discharges of TDS and increased salinity in freshwater systems.

2.1.4 Bromine/Bromide

Bromine is naturally present in coal. Some coal-fired steam electric power plants also add bromine, in the form of bromide compounds, to their combustion processes to enhance mercury emissions control or burn refined coal amended with bromide compounds (U.S. EPA, 2020b). After combustion, bromine partitions in part to FGD wastewater and BA transport water in its anion form, known as bromide (EPRI, 2014; Peng et al., 2013). Documented bromide levels in FGD wastewater vary widely and can exceed 175 milligrams per liter (mg/L) (EPRI, 2009; Good, 2018; U.S. EPA, 2015c and 2020b). Average bromide levels of 5.1 mg/L have been documented in BA transport wastewaters (U.S. EPA, 2020b). These levels are higher than the average levels of 0.014 mg/L to 0.2 mg/L reported for freshwater surface waters (Flury and Papritz, 1993; Health Canada, 2015; McGuire et al., 2002). Field-based and modeling studies document elevated bromide levels in surface waters downstream of steam electric power plants and identify FGD wastewater discharges as a substantial source of bromide loadings from the plants (Cornwell et al., 2018; Good and VanBriesen, 2016, 2017, and 2019; Kolb et al., 2020; McTigue et al., 2014; Ruhl et al., 2012; States et al., 2013; U.S. DOJ, 2015; U.S. EPA, 2015c).

Bromide has a low toxicity in freshwater aquatic environments compared to substances such as copper or cadmium cations. Flury and Papritz (1993) present the results from two previous studies on the median lethal toxic concentration (LC_{50}) of bromide compared to other chemicals.

- For golden orfe (*Leuciscus idus melanotus*), the LC_{50} for bromide is greater than 7,765 mg/L, compared to 0.32 mg/L for copper and 4.5 to 35.4 mg/L for cadmium (Juhnke and Lüdemann, 1978).

- For fathead minnow (*Pimephales promelas*), the LC_{50} for bromide is greater than 67 mg/L, compared to 0.555 to 1.4 mg/L for copper (Ewell et al., 1986).

Reviews of freshwater aquatic organism toxicology studies cite effect concentrations of bromide that range from 110 to 4,600 mg/L for single-celled organisms, 2.2 to 11,000 mg/L for invertebrates, and 7.8 to 24,000 mg/L for fish (EPRI, 2014; Flury and Papritz, 1993).

The World Health Organization (WHO) estimates that consumption of drinking water supplies with bromide concentrations below 2.0 mg/L would meet acceptable daily intake levels for both children and adults (WHO, 2009). Bromide's toxicity associated with its contribution to DBP formation in drinking water treatment and distribution systems can be of a greater concern (Krasner et al., 2006; Krasner, 2009; Regli et al., 2015; Richardson and Postigo, 2011; U.S. EPA, 2016a; Yang et al., 2014). DBPs are a broad class of compounds that form as byproducts of drinking water disinfection, and some of them have toxic properties. Bromide in source water becomes highly reactive in the presence of commonly used drinking water disinfectants and can form brominated DBPs (Br-DBPs) at low source water concentrations (Bond et al., 2014; Chang et al., 2001; Heeb et al., 2014; Landis et al., 2016; Parker et al., 2014; Richardson et al., 2007; U.S. EPA, 2016a; Wang et al., 2017; Westerhoff et al., 2004). Although multiple factors affect DBP formation, increases and decreases in source water bromide levels are typically associated with concurrent increases and decreases in both total DBP and bromide speciation levels in treated water (AWWARF and U.S. EPA, 2007; Bond et al., 2014; Cornwell et al., 2018; Ged and Boyer, 2014; Hua et al., 2006; Huang et al., 2019; Landis et al., 2016; McTigue et al., 2014; Obolensky and Singer, 2008; Pan and Zhang, 2013; Regli et al., 2015; Sawade et al., 2016; States et al., 2013; Yang and Shang, 2004; Zha et al., 2014).

The 2020 EA (U.S. EPA, 2020a) provides further details on bromide in freshwater systems and adverse impacts in source water for DWTPs.

2.1.5 Iodine/Iodide

Iodine is naturally present in coal.[2] Some coal-fired steam electric power plants also add iodine, in the form of iodide compounds, to their combustion processes to enhance mercury emissions control or burn refined coal amended with iodide compounds (ADES, 2016; Gadgil, 2016; ICAC, 2019; Sahu, 2017; Senior et al., 2016; Sjostrom et al., 2016; Sjostrom and Senior, 2019; Tinuum, 2020).[3] Iodine volatilizes during combustion and partitions to FGD wastewaters and, to a lesser extent, to BA transport waters (ADES, 2016; ICAC, 2019; Meij, 1994; Peng et al., 2013; Sjostrom et al., 2016). In FGD wastewaters, iodine occurs as iodide/triiodide anions and elemental iodine (Sjostrom et al., 2016). Data on typical iodine concentrations in FGD wastewater and BA transport waters are limited. One study (Sjostrom et al., 2016) indicated that iodine concentrations in FGD wastewater should be below about 100 mg/L to ensure normal FGD system operation and to recover iodine for reuse.

Typical iodine levels in freshwater surface waters are less than 0.020 mg/L, though levels ranging from 0.00001 to 0.212 mg/L have been reported.[4] In freshwater, elemental iodine dissociates to its anionic form and/or reacts with organic material to form iodinated organic compounds. Iodide is highly soluble and exhibits conservative fate and transport in freshwater (Fuge and Johnson, 1986; Moran et al., 2002).

According to available data, iodide has lower ecotoxicity in freshwater aquatic environments than other substances such as copper or cadmium cations. For golden orfe (*Leuciscus idus melanotus*), the LC_{50} for

[2] Native iodine levels in coal range from 0.14 to 12.9 parts per million (ppm) (Bettinelli et al., 2002; Gluskoter et al., 1977; Good, 2018). One source states that many coals used by utility plants have iodine levels greater than 3 ppm (Sjostrom et al., 2016).

[3] Addition rates are reported to range from 1 to 30 ppm and are typically less than 10 ppm (Gadgil, 2016; ICAC, 2019; Sahu, 2017; Sjostrom et al., 2016).

[4] The highest measured levels reflect influence of irrigation water return flows in arid areas.

iodide is greater than 4,525 mg/L compared to 0.32 mg/L for copper and 4.5 to 35.4 mg/L for cadmium (Juhnke and Lüdemann, 1978). Estimates of LC_{50} for iodide range from 860 to 8,230 mg/L for freshwater fish and from 0.17 to 0.83 mg/L for *Daphnia magna*, an aquatic invertebrate (Flury and Papritz, 1993; Laverock et al., 1995). Toxicity to single-celled organisms is reported to be similar to that of bromide (Bringmann and Kühn, 1980; Flury and Papritz, 1993). In comparison, elemental iodine toxicity is higher for freshwater fish, with LC_{50} concentrations from 0.53 mg/L to greater than 10 mg/L, and is similar to iodide toxicity for *D. magna,* with LC_{50} concentrations from 0.16 to 1.75 mg/L (Laverock et al., 1995; LeValley, 1982).

For humans, iodine is an essential element for thyroid hormone production and metabolic regulation. Excessive consumption can lead to hypothyroidism (diminished production of thyroid hormones), hyperthyroidism (excessive production and/or secretion of thyroid hormones), or thyroiditis (inflammation of the thyroid gland) (ATSDR, 2004). The MRL for acute and chronic oral exposure to iodide is 0.01 milligrams per kilogram per day based on endocrine effects (ATSDR, 2023).

As with bromide, most toxicity concerns for iodine/iodide are associated with its contribution to DBP formation in drinking water treatment and distribution systems. Iodine in source water becomes reactive during chlorine-, chlorine dioxide-, chloramine-, or ultraviolet (UV)-based disinfection, when it can combine with organic material in source waters to form iodinated DBPs (I-DBPs) (Bichsel and Von Gunten, 2000; Criquet et al., 2012; Dong et al., 2019; Ersan et al., 2019; Hua et al., 2006; Hua and Reckhow, 2007; Krasner, 2009; Krasner et al., 2006; Postigo and Zonja, 2019; Richardson et al., 2008; Tugulea et al., 2018; U.S. EPA, 2016a; Weinberg et al., 2002). Both iodide and iodinated organic compounds in source waters can contribute to I-DBP formation during drinking water disinfection (Ackerson et al., 2018; Dong et al., 2019; Duirk et al., 2011; MacKeown et al., 2020; Pantelaki and Voutsa, 2018; Tugulea et al., 2018). Iodate, a non-toxic iodine compound that can form in the presence of oxidants (including certain DWTP disinfectants), can also contribute to I-DBP formation under certain conditions (Dong et al., 2019; Postigo and Zonja, 2019; Tian et al., 2017; Xia et al., 2017; Yan et al., 2016; Zhang et al., 2016). I-DBP levels are influenced by multiple factors and have been found to increase with iodide or total iodine levels in source water (Criquet et al., 2012; Dong et al., 2019; Gruchlik et al., 2015; Postigo and Zonja, 2019; Tugulea et al., 2018; Ye et al., 2013; Zha et al., 2014).[5]

The 2020 EA (U.S. EPA, 2020a) provides further details on iodine and adverse impacts in source water for DWTPs.

2.2 Potential Impacts from the Evaluated Wastestreams

Changes in surface water chemistry due to contamination from steam electric power plant wastewater can harm all levels of an ecosystem, including organisms at lower trophic levels; this in turn affects the ecosystem's food web and fish inhabiting the surface water. Pollutants in surface water can bioaccumulate in aquatic organisms such as fish. When wildlife or humans ingest these aquatic organisms, they can be exposed to a higher dose of contamination than through direct exposure to the surface water. Surface water impacts associated with discharges of steam electric power plant wastewater include damage to fish populations (*i.e.*, physiological and morphological abnormalities and various behavioral, reproductive, and developmental effects), decreased diversity in insect populations, and decline of aquatic macroinvertebrate population (see Section 2.2.1). Impacts that affect humans include exceedances of National Recommended Water Quality Criteria, fish consumption advisories, designation of surface waters as impaired (limiting recreational activities), and contamination of downstream drinking water sources (see Section 2.2.2 and Section 4).

[5] Other factors influencing I-DBP formation include pH, temperature, disinfection process type and dosage level, bromide levels, ammonium levels, organic material levels and type, and treatment and distribution system residence time.

This section provides an overview of the environmental impacts caused by exposure to pollutants in discharges of the evaluated wastestreams. It also summarizes additional studies identified as part of the literature review conducted to support this EA and the final supplemental rulemaking. Details of previous literature reviews are included in the 2015 EA (U.S. EPA, 2015a) and the 2020 EA (U.S. EPA, 2020a).

2.2.1 Ecological Impacts

Many of the pollutants in steam electric power plant wastewater (*e.g.*, arsenic, mercury, selenium) readily accumulate in exposed biota. This bioaccumulation is of particular concern due to their impact on higher trophic levels, local terrestrial environments, and transient species, in addition to the aquatic organisms directly exposed to the wastewater. Aquatic systems with long residence times and potential contamination with bioaccumulative pollutants often experience persistent environmental effects following exposure to steam electric power plant wastewater.

Population decline attributed to exposure to steam electric power plant wastewater can alter the structure of aquatic communities and cause cascading effects within the food web that result in long-term impacts to ecosystem dynamics (Rowe et al., 2002). Reductions in organism survival rates from abnormalities caused by exposure to power plant wastewater, and alterations in interspecies relationships, such as declining abundance or quality of prey, can delay ecosystem recovery until key organisms within the food web return to levels prior to power plant wastewater exposure. In a 1980 study of a creek in Wisconsin, fungal decomposition of detritus was limited due to the effects of power plant wastewater. Because of this reduction in available resources, the population of benthic invertebrates (which graze on detrital material) declined, as did benthic fish that prey upon small invertebrates (Magnuson et al., 1980).

Ecological impacts associated with exposure to steam electric power plant wastewater include lethal impacts, such as fish kills, and sublethal impacts, such as teratogenic deformities, oxidative stress, deoxyribonucleic acid (DNA) damage, reduced growth, and genotoxicity (Brandt et al., 2017 and 2019; Carlson and Adriano, 1993; Javed et al., 2016; Lemly, 2018; Rowe et al., 2002). Much of the scientific literature focuses on selenium as a key pollutant of environmental concern in steam electric power plant wastewater. Selenium can bioaccumulate to toxic levels in organisms inhabiting environments with low selenium concentrations. As studied by Lemly (1985), the extent of selenium bioaccumulation depends on the trophic level of the fish present in the water. Lemly observed that selenium accumulation increased as the trophic level increased, which potentially correlates with the observed elimination of multiple higher-tropic-level fish species. The study also found that selenium discharges also affect species diversity in receiving waters (Lemly, 1985). Selenium discharges can lead to long-term issues in ecosystems due to prolonged retention in the environment and cycling and propagation in the food chain (Brandt et al., 2019).

The sublethal effects of selenium vary widely and can affect growth, reproduction, and survival of susceptible organisms. Scientists have demonstrated that various fish and amphibian species are sensitive to elevated selenium concentrations similar to those found in steam electric power plant wastewater. In addition to lethal effects, these fish and amphibian species have developed sublethal symptoms such as accumulation of selenium in tissue (histopathological effects) and in the blood (hematological effects), resulting in decreased growth, changes in weight, abnormal morphology, and reduced hatching success (Coughlan and Velte, 1989; Lemly, 1993 and 2018; Sager and Colfield, 1984; Sorensen, 1988; Sorensen and Bauer, 1984; Sorensen et al., 1982, 1983, 1984). In addition, selenium is highly teratogenic (*i.e.*, able to disturb the growth and development of an embryo or fetus) and readily transferable from mother to egg (Chapman et al., 2009; Janz et al., 2010; Lemly, 1997a; Maier and Knight, 1994).

Although effects documented in the literature primarily focus on selenium, several studies discussed the sublethal effects of other pollutants, such as arsenic, cadmium, chromium, copper, and lead (Rowe et al., 2002), and decreased diversity in receiving water fish species (Javed et al., 2016). Sublethal effects from exposure to pollutants other than selenium in power plant wastewater can include changes to morphology (*e.g.*, fin erosion, oral deformities), behavior (*e.g.*, ability to swim, catch prey, and escape from predators), and metabolism that can negatively affect long-term survival (Rowe et al., 2002). Vengosh et al. (2019) found concentrations of coal combustion residuals (CCR) pollutants in Sutton Lake, North Carolina, indicating the potential for unmonitored spills of coal ash into nearby receiving waters. From samples taken in 2015 and 2018, researchers found that the lake sediment contained one to two orders of magnitude higher levels of antimony, arsenic, copper, molybdenum, selenium, and thallium compared to a reference lake. Vengosh et al. (2019) noted recent hurricanes across the area may have led to flooding of ash ponds (surface impoundments) and contamination of surface waters. Researchers noted that concentrations in the sediments exceeded freshwater ecological screening standards (Vengosh et al., 2019).

In the literature reviews for this supplemental rule, the EPA identified studies that discussed concerns with bromide and halogenated DBPs' impact on ecological receptors and potential impacts from pollutants in CRL. As noted in Section 2.1.4, bromide is one of the pollutants discharged by steam electric power plants, and the discharge of bromide and iodine can lead to increased DBP formation at downstream DWTPs (see Section 2.1.5).

Since 1994, scientists noted the spread of vacuolar myelinopathy (VM), a neurological disease, in bald eagles, other birds of prey, and waterfowl. At DeGray Lake in Arkansas, more than 70 eagle mortalities were found in two years, and investigators began noticing eagles and other waterbirds with neurological impairments across the southeastern United States (Breinlinger et al., 2021). VM has also been found in other wildlife including amphibians, reptiles, and fish. Field and laboratory studies have shown that VM can be transferred up the food chain from fish to wildlife and birds of prey. Documented cases in avian species have been found near artificial waterbodies with abundant aquatic vegetation located in the southeastern United States. Breinlinger et al. (2021) conducted field studies in southeastern U.S. waters and laboratory studies to identify the causative agent of VM. The scientist showed that a neurotoxin, which they termed aetokthonotoxin (AETX), was the causative agent of VM. AETX is produced by *Aetokthonos hydrillicola* (cyanobacterium) growing on aquatic vegetation (*Hydrilla verticillata*). The researchers noted that AETX's structure has characteristics not previously observed in nature and investigated the biosynthesis of the neurotoxin. Breinlinger et al. (2021) determined that the biosynthesis of AETX depends on the bioavailability of bromide, along with other factors (*e.g.*, temperature).

Cui et al. (2021) investigated the potential toxicity and ecological risk to freshwater organisms from exposure to halogenated DBPs. Research was prompted by the increased use of chlorine as a disinfecting agent due to the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) outbreak and increased DBP levels in wastewater treatment effluent. The organisms studied covered three trophic levels: phytoplankton (*Scenedesmus sp.*), zooplankton (*Daphnia magna*), and fish (*Danio rerio*). Cui et al. (2021) found that *Scenedesmus sp.* were most sensitive to haloacetic acids (HAAs) and *Daphnia magna* were most sensitive to haloacetonitriles (HANs) and trihalomethanes (THMs). Cui et al. (2021) cited other research on the toxicity of brominated DBPs to aquatic organisms and findings that DBPs can have reproductive impacts on *Daphnia magna* and adversely affect embryonic development of zebrafish. Observed impacts from the DBP exposure (for most of the DBPs tested) included the following:

- Inhibited growth for phytoplankton (*Scenedesmus sp.*).
- Decreased swimming ability (immobilization) for zooplankton (*Daphnia magna*).
- Induced mortality and abnormal development for fish (*Danio rerio*).

Frankel et al, (2022) conducted a study to determine the potential impact on freshwater snails (*Planorbella duryi*) exposed to CRL trace elements (*i.e,* aluminum, arsenic, calcium, cadmium, chromium, copper, iron, lead, magnesium, manganese, and selenium). The study found that "exposure to environmentally relevant concentrations" of coal ash leachate caused delays in embryonic development, reduced shell width growth in juveniles, and decrease in egg deposition. Bioaccumulation of arsenic, cadmium, chromium, and lead occurred in the snails studied, with arsenic and cadmium concentrations in the tissue reaching over 85,000 and 170,000 times higher than measured in the leachate solution, respectively.

2.2.2 Human Health Effects

Exposure to pollutants can increase risk for noncancer effects in humans, including damage to the circulatory, respiratory, or digestive systems and neurological and developmental effects. Steam electric power plant wastewater contains toxic pollutants and known or suspected carcinogens (*e.g.*, arsenic and cadmium). Documented exceedances of drinking water maximum contaminant levels (MCLs) downstream of steam electric power plants, and the issuance of fish advisories in receiving waters, indicate an ongoing human health concern caused by power plant wastewater discharges. The primary exposure route investigated in this EA is through fish consumption (see Sections 3 and 4). As noted in Section 2.1, pollutants in steam electric power plant discharges can bioaccumulate in fish that are then consumed by recreational and subsistence fishers. For example, Lemly (2014) studied selenium contamination in fish found in Lake Sutton—a popular fishing location that is also used as a cooling reservoir for discharges from the L.V. Sutton Steam Plant settling pond before the water moves downstream into the Cape Fear River. Based on data collected between 1987 and 2011, the selenium concentration in bluegill (*Lepomis macrochirus*) exceeded the toxic thresholds established by researchers, and physical examination showed elevated deformities in the fish (*e.g.*, skeletal and craniofacial defects) compared to a reference lake (29 percent in Lake Sutton to 0.5 percent in the reference lake). Researchers noted similar results in morphological abnormalities at other lakes that receive power plant discharges (*e.g.*, Belews Lake and Hyco Reservoir).

In addition, groundwater and drinking water supplies can be degraded by pollutants in steam electric power plant wastewater (Cross, 1981). Power plants may dispose of or store CCR, or coal ash, in landfills or surface impoundments. Leachate and legacy wastewater (see Section 1), which contain pollutants from the CCR, can migrate from the power plant landfills and surface impoundments via the groundwater at concentrations that could contaminate public or private drinking water wells and surface waters, even years following disposal of combustion residuals (National Research Council of the National Academies, 2006).

As discussed in Sections 2.1.4 and 2.1.5, the discharge of bromide and iodine into drinking water sources is a concern due to the formation of DBPs in DWTPs and their distribution systems.

- Toxicology and epidemiology studies have documented evidence of genotoxic (including mutagenic), cytotoxic, and carcinogenic properties of DBPs, including Br-DBPs (National Toxicology Program, 2018; Richardson et al., 2007; U.S. EPA, 2016a). Studies have documented evidence of a link between DBP exposure and bladder cancer and, to a lesser degree, colon and rectal cancer, other cancers, and reproductive and developmental effects (Cantor et al., 2010; Chisholm et al., 2008; Regli et al., 2015; Richardson et al., 2007; U.S. EPA, 2016a; Villanueva et al., 2004, 2007, and 2015). Br-DBPs typically have higher toxicity than their chlorinated analogues (Cortés and Marcos, 2018; Plewa et al., 2008; Richardson et al., 2007; Sawade et al., 2016; U.S. EPA, 2016a; Yang et al., 2014). Due to bromide's reactivity and DBP toxicity, elevated bromide levels in source waters have been associated with elevated health risks from disinfected water (Hong et al., 2007; Kolb et al., 2017; Regli et al., 2015; Sawade et al., 2016; Wang et al., 2017; Yang et al., 2014). In a 2022 study, Weisman et al. (2022) estimated that approximately 9,000 of the 79,000 annual bladder cancer cases could potentially be attributed to trihalomethanes in the drinking water, with 84 percent of the approximately 9,000 cases are from drinking water systems with surface water, as opposed to groundwater, as the system's intake source.
- *In vitro* toxicology studies with bacteria and mammalian cells have documented evidence of genotoxic (including mutagenic), cytotoxic, tumorigenic, and developmental toxicity properties of I-DBPs. Individual I-DBP species have higher toxicity than their chlorinated and brominated analogues and are among the most cytotoxic DBPs identified to date (Dong et al., 2019; Hanigan et al., 2017; National Toxicology Program, 2018; Richardson et al., 2007 and 2008; Richardson and Plewa, 2020; U.S. EPA, 2016a; Wagner and Plewa, 2017; Wei et al., 2013; Yang et al., 2014). While studies have documented evidence linking disinfected drinking water and DBP exposure to adverse human health effects (see the 2020 EA: U.S. EPA, 2020a), more research is needed to characterize the contribution of I-DBPs to

these effects (Cortés and Marcos, 2018; Dong et al., 2019; Postigo and Zonja, 2019; U.S. EPA, 2016a). In a 2021 study, Long et al. (2021) concluded that iodoacetic acid exposure results in reproductive and developmental toxicity effects. Because conventional drinking water treatment processes do not effectively remove iodide from source waters and vary in their reduction of organic material levels (U.S. EPA, 2016a; Watson et al., 2015), they have the potential to generate I-DBPs when their source waters contain iodine.

2.2.3 Groundwater Impacts

Pollutants in CCR can leach into groundwater from surface impoundments and landfills. Older surface impoundments and landfills are of particular concern because they were often built without liners and leachate collection systems. Liners are typically made of synthetic material, asphalt, clay, or a composite of materials (*e.g.*, synthetic and clay) and are designed to collect leachate and prevent groundwater contamination. CCR held in unlined surface impoundments can enter the subsurface and contaminate groundwater. Pollutants in unlined landfills, used for the dry disposal of CCRs, can also leach as precipitation flows through the residuals pile and dissolves pollutants; the CRL can eventually migrate into groundwater. The EPA has promulgated a series of rules to mitigate CCR disposal issues (*e.g.*, seeping of pollutants into groundwater, airborne pollutants as dust, and surface impoundment failures resulting in larger coal ash spills), starting with the Disposal of Coal Combustion Residuals from Electric Utilities final rule (80 FR 21301), which established requirements for the safe disposal of CCR nationwide. Even with additional requirements in place, pollutants can still enter the groundwater when liners fail or when a disposal site is situated such that natural groundwater fluctuations come into contact with the disposed waste.

Before the CCR regulations, the EPA identified more than 30 documented cases where groundwater contamination from surface impoundments extended beyond the plant boundaries, illustrating the threat to groundwater and drinking water sources (ERG, 2015a). Based on a review of exceedances of state or federal groundwater quality standards at surface impoundments, exceedances were most often due to boron, sulfate, or arsenic (Lewis et al., 2017). In a 2016 study, Harkness et al. (2016) evaluated pollutant migration from coal ash ponds (surface impoundments) to groundwater and surface waters at sites in the southeastern United States. The evaluation found pollutants above background concentrations at the tested sites, including levels above drinking water and ecological impact standards for some surface waters. The researchers note that the closing of the coal ash surface impoundments did not necessarily stop the migration of pollutants from the surface impoundments (Harkness et. al., 2016).

Landfills pose their own groundwater contamination risks. If the landfills are not properly lined, the pollutants in CCR can leach into the soil during precipitation. In areas with acid rain, the precipitation's low pH can accelerate the leaching of contaminants into groundwater. In addition, heavy precipitation can not only accelerate leaching, but also carry pollutants in stormwater runoff, potentially contaminating groundwater or surface water resources (Andersen and Madsen, 1983). Based on a review of CCR landfill damage cases compiled by the EPA, Lewis et al. (2017) noted that all the landfills were constructed before 1990 (before the Resource Conservation and Recovery Act requirements for liners went into effect), and only four of the 32 cited landfills were fully lined. As with groundwater exceedances from surface impoundments, the most common pollutants with exceedances included boron and sulfate. Iron and manganese had exceedances at more than half of the landfills (Lewis et al., 2017).

Frankel et al. (2023) evaluated potential impacts to Quantico Creek, a tributary to the Chesapeake Bay, from the leakage of a nearby CRL landfill and coal ash surface impoundments Samples taken from the creek near the CRL landfill and coal ash surface impoundments were compared to upstream and downstream locations. Researchers found elevated concentrations of the parameters in the sediment but not the surface water, with the highest concentrations of pollutants including arsenic, boron, cadmium, chromium, copper, selenium, and zinc in samples adjacent to the coal ash surface impoundments. Ecological impacts included reduced species diversity and increased concentrations of aluminum, cadmium, and zinc in the tissues of banded killfish (*Fundulus diaphanous*) near the coal ash landfill compared to upstream and downstream sites. Frankel et al. (2023) did not find arsenic, chromium, or selenium in the fish tissue samples.

2.2.4 CCR Surface Impoundments as Attractive Nuisances

An "attractive nuisance" is an area or habitat that attracts wildlife and is contaminated with pollutants at concentrations high enough to potentially harm exposed organisms. Two methods of handling steam electric power plant wastewater, surface impoundments and constructed wetlands, are classified as lentic systems supporting aquatic vegetation and organisms. These methods have been known to attract wildlife from other terrestrial habitats and therefore can be considered attractive nuisances. For example, a surface impoundment can affect local wildlife as well as transient species that might rely on them during critical reproduction periods such as seasonal breeding events (Rowe et al., 2002). Exposure to steam electric power plant wastewater during sensitive life cycle events is a concern, given that it has been associated with complete reproductive failure in various vertebrate species (Cumbie and Van Horn, 1978; Gillespie and Baumann, 1986; Lemly, 1997b; Pruitt, 2000).

Several studies have shown that terrestrial fauna nesting near CCR surface impoundments can have higher levels of arsenic, cadmium, chromium, lead, mercury, selenium, strontium, and vanadium than the same species at reference sites (Bryan et al., 2003; Burger et al., 2002; Hopkins et al., 1997, 1998, 2000, 2006; Nagle et al., 2001; Rattner et al., 2006). Field studies have also documented adverse effects on reproduction for turtles and toads living near selenium-laden CCR surface impoundments (Hopkins et al., 2006; Nagle et al., 2001).

In addition to being attractive nuisances, surface impoundments near surface waters can be a source of coal ash spills that damage the environment, ecosystems, and downstream waters. Concerns with these spills include the large economic loss and costs to remediate, along with ecological damage, potential effects on human health, recreational impacts, and losses of consumptive use and aesthetic value. Researchers and state agencies have monitored the receiving water ecosystems following coal ash spills, notably the 2008 coal ash spill that affected the Emory River and Clinch River and the 2014 coal ash spill to the Dan River.

- Following the 2008 coal ash spill at the Tennessee Valley Authority's Kingston Plant, the Tennessee Department of Environment and Conservation found exceedances of the more stringent criteria for chronic exposure of fish and aquatic life at least once in January 2009 for several metals (*e.g.*, aluminum, cadmium, iron, and lead). Seven months after the spill, all fish collected had concentrations of selenium above a toxic threshold, and most were still contaminated at that level 14 months after the spill. Twenty-one months after the spill, a high percentage of fish were found with lesions, deformities, and infections, all symptoms of extreme stress. In addition, studies have shown elevated levels of arsenic and mercury in sediments near the ash spill, as well as selenium levels exceeding the MCL in three wells underneath the Kingston Plant's coal ash disposal area, ash processing area, and gypsum disposal facility (U.S. EPA, 2014). In a study eight years after the coal ash spill, researchers determined downstream sediment concentrations of arsenic and selenium are likely from the coal ash; however, other metals in downstream sediment are likely from other anthropogenic sources (Ramsey et al., 2019).
- In 2011 and 2012, Van Dyke et al. (2017) measured trace contaminant concentrations in freshwater turtles in the Emory River, Clinch River, and a reference (unaffected) river. Turtles in the Emory River and Clinch River had higher concentrations of arsenic, copper, iron, mercury, manganese, selenium, and zinc than turtles in the reference river. However, the concentrations were low relative to values known to be toxic to other vertebrates. Researchers stated that they found little evidence that the residual coal ash in the affected rivers had an effect on contaminant bioaccumulation in turtles.
- Ku et al. (2020) evaluated mercury concentration in the Dan River 17 to 29 months following the coal ash spill, which was much smaller than the spill at the Emory and Clinch rivers. They found that mercury contamination in the Dan River surface sediments (0–16 centimeters) could be accounted for by organic matter, rather than the coal ash spill. The study also examined methylmercury

bioaccumulation in invertebrates and fish and did not find evidence of elevated methylmercury bioaccumulation. The researchers concluded that the mercury contamination from the coal ash spill was largely absent in the surface sediment and biota three years after the spill. Alternatively, they suggested that the mercury from the coal ash spill was not typically bioavailable.

- Silva et al. (2023) studied environmental and ecological contamination from ash surface impoundments at a retired coal-fired power plant and decommissioned nuclear reactor. Researchers sampled beetles associated with carrion in west central South Carolina and found substantial trace elements within the beetles' organs and tissues. Compared to the uncontaminated (control) site, the beetles had higher levels of arsenic, selenium, and thallium. Beetles at the uncontaminated site had higher levels of chromium, copper, and nickel.

3. Environmental Assessment Methodology

This section presents the EPA's evaluation of environmental concerns and potential exposures to pollutants commonly found in wastewater discharges from steam electric power plants. It describes the following:

- Pollutant loadings for the evaluated wastestreams.
- Pollutant exposure pathways.
- Methodologies used to quantify the environmental, ecological, and human health effects of pollutants discharged to surface waters from the evaluated wastestreams.
- Environmental assessment (EA) scope (*i.e.*, plants and immediate receiving waters).

3.1 Pollutant Loadings for the Evaluated Wastestreams

As discussed in Section 2, the pollutants commonly found in steam electric power plant wastewater—such as metals, total dissolved solids (TDS), and halogens—can result in impacts to water quality, aquatic life, wildlife, and human health. The EPA analyzed three regulatory options for the final supplemental rule, as shown in Table VII-1 of the rule's preamble. The EPA estimated pollutant loadings for the evaluated wastestreams considered as part of the supplemental rule as described in Section 6 of the technical development document (TDD) (U.S. EPA, 2024a). The EPA calculated plant-specific and receiving-water specific *baseline* and *regulatory option* pollutant loadings (in pounds per year) for flue gas desulfurization (FGD) wastewater, bottom ash (BA) transport water, combustion residual leachate (CRL), and legacy wastewater being discharged to surface water or through publicly owned treatment works (POTWs) to surface water.

Most steam electric power plants (over 95 percent) evaluated for the supplemental rule discharge directly to surface water. Six plants reported transferring BA transport water, FGD wastewater, or CRL to a POTW rather than discharging directly to surface water.[6] For these POTW transfers, the EPA adjusted the baseline and regulatory option loadings to account for pollutant removals expected during treatment at the POTW for each analyte. See Section 6 of the TDD for industry-wide annual baseline pollutant loadings for the evaluated wastestreams, as well as the reductions in pollutant loadings (relative to baseline) for each of the regulatory options.

The EPA used these pollutant loadings as inputs to support the quantitative evaluation of environmental impacts via the surface water exposure pathway (see Section 3.2). Table 2 presents baseline pollutant loadings and the estimated reduction in pollutant loadings under the evaluated regulatory options for select pollutants. The memorandum *Pollutant Loadings Analysis and Supporting Documentation for the Environmental Assessment of the Final Supplemental Steam Electric Rule* (U.S. EPA, 2024h) discusses the EPA's methodology for estimating pollutant loadings for each immediate receiving water.

[6] The EPA excluded CRL discharges at one plant from the EA that indirectly discharges to a POTW that does not discharge to any receiving waters, and one indirect discharging plant is only included in the proximity analysis (see U.S. EPA, 2024f).

Table 2. Estimated Annual Baseline Mass Pollutant Loadings and Estimated Reduction in Loadings Under Regulatory Options for the Evaluated Wastestreams[a]

Pollutant	Estimated Baseline Pollutant Loadings (lb/year)	Estimated Reduction in Pollutant Loadings Relative to Baseline (lb/year)		
		Option A	Option B	Option C
Aluminum	60,400	45,000	58,600	59,300
Arsenic	777	513	700	726
Boron	7,140,000	5,450,000	5,770,000	6,492,000
Bromide (min) [b]	1,310,000	1,150,000	1,150,000	1,310,000
Bromide (max) [b]	6,810,000	6,380,000	6,380,000	6,810,000
Cadmium	553	152	512	529
Chlorides	223,000,000	175,000,000	180,000,000	203,000,000
Chromium	21,100	20,800	21,000	21,000
Copper	398	181	348	365
Iodine (min) [b]	86,100	76,200	76,200	86,100
Iodine (max) [b]	269,000	250,000	250,000	269,000
Iron	300,000	287,000	299,000	299,000
Lead	230	138	187	200
Magnesium	103,000,000	81,700,000	82,900,000	93,500,000
Manganese	648,000	301,000	565,000	606,000
Mercury	40.0	11.5	38.5	38.8
Molybdenum	22,500	19,700	21,300	31,800
Nickel	3,430	693	3,320	3,350
Nitrogen, total[c]	522,000	194,000	194,000	218,000
Phosphorus, total	12,100	8,930	8,930	9,980
Selenium	4,810	205	1,970	2,080
Thallium	781	245	664	695
Total dissolved solids	806,000,000	588,000,000	656,000,000	734,000,000
Vanadium	19,600	19,400	19,500	19,600
Zinc	6,570	2,040	6,310	6,400

Sources: U.S. EPA, 2024a, 2024g, and 2024h.

Abbreviations: lb/year (pounds per year).

Note: Pollutant loadings and removals are rounded to three significant figures.

a—Includes a subset of all steam electric power-generating pollutants of concern. The EPA selected the pollutants listed in this table based on the following factors: presence of the pollutant in the evaluated wastestreams; documented elevated levels of the pollutant in surface waters or wildlife from exposure to steam electric power plant wastewater; and magnitude of the pollutant loadings to receiving waters.

b—The EPA did not identify data indicating the specific halogen additive (*i.e.*, bromine or iodine) used at each plant to reduce mercury emissions. Therefore, the EPA estimated potential ranges of bromide and iodine loadings.

c—Total nitrogen loadings are the sum of ammonia and nitrate-nitrite (as N) loadings from FGD wastewater, nitrate-nitrite (as N) and total Kjeldahl nitrogen (TKN) loadings from BA transport water, and nitrate-nitrite (as N) loadings from legacy wastewater.

The pollutants with the greatest estimated reductions in annual mass loadings under the final rule (Option B) are TDS (656 million pounds per year, or lb/year, decrease relative to baseline), chlorides (180 million lb/year decrease), magnesium (83 million lb/year decrease), bromide (between 1.15 and 6.38 million lb/year decrease),[7] and boron (5.77 million lb/year decrease).

Implementation timing under the final rule for each plant varies by wastestream, subcategorization, and the plant's permit renewal schedule. See the preamble for further discussion of the regulatory options and associated deadlines. Due to the differing timelines for individual wastestreams and plants, the net reduction in pollutant loadings and corresponding environmental changes will be staggered over time as the plants implement control technologies. The EA presents the EPA's estimates of environmental improvements associated with each regulatory option using steady-state annual average pollutant loadings reflecting full implementation of the effluent limitations guidelines and standards. Therefore, the results presented in the EA may underestimate short-term environmental impacts for the period before full implementation of the final rule during which plants transition from current discharges to discharges associated with full implementation. In addition, the EA did not evaluate the impacts of any discharges other than the four evaluated wastestreams; therefore, the pollutant loadings and subsequent quantitative analyses do not represent a complete assessment of environmental impacts from steam electric power plants.

3.2 Pollutant Exposure Pathways

An exposure pathway is defined as the route a pollutant takes from its source (*e.g.*, combustion residual surface impoundments) to its endpoint (*e.g.*, a surface water), and how receptors (*e.g.*, fish, wildlife, or people) can come into contact with it. Exposure pathways are typically described in terms of five components:

- Source of contamination (*e.g.*, steam electric power plant wastewater).
- Environmental pathway—the environmental medium or transport mechanism that moves the pollutant away from the source through the environment (*e.g.*, discharges to surface waters).
- Point of exposure—the place (*e.g.*, private drinking water well) where receptors (*e.g.*, people) come into contact with a pollutant from the source of contamination.
- Route of exposure—the way (*e.g.*, ingestion, skin contact) receptors come into contact with the pollutant.
- Receptor population—the aquatic life, wildlife, or people exposed to the pollutant.

[7] The EPA did not identify data indicating the specific halogen additive (*i.e.*, bromine or iodine) used at each plant to reduce mercury emissions. Therefore, the EPA estimated potential ranges of bromide and iodine loadings. The EPA defined the ranges' lower and upper bounds as follows (U.S. EPA, 2024a and 2024g):

- Bromide (min): Bromide loadings in BA transport water and FGD wastewater from native coal content and the addition of bromide in the flue gas (*i.e.*, as brominated activated carbon). The EPA analyzed additional CRL data that included bromide concentrations in CRL at five plants; however, more than half of the samples were nondetect values. Therefore, the EPA did not estimate bromide loadings in CRL. See the memorandum *2024 Final Rule - Combustion Residual Leachate Analytical Data Evaluation* (U.S. EPA, 2024m).
- Bromide (max): Same as "Bromide (min)" plus bromide loadings due to the use of refined coal or halogen addition at the EGU. Assumes all plants burning refined coal or adding halogens at the EGU use bromine additives.
- Iodine (min): Iodine loadings in FGD wastewater from native coal content only. The EPA had insufficient data to estimate iodine loadings in other receiving waters.
- Iodine (max): Same as "Iodine (min)" plus iodine loadings due to the use of refined coal or halogen addition at the EGU. Assumes all plants burning refined coal or adding halogens at the EGU use iodine additives.

The exposure pathway plays an important role in determining the potential effects of steam electric power plant wastewater on the environment. For example, the physical and chemical characteristics of receiving waters can affect the fate and transport of pollutants from combustion residual surface impoundments to the environment and ultimately impact how the pollutants interact with the biological community.

The EPA identified four primary exposure pathways of concern for steam electric power plant wastewater entering the environment. Table 3 presents the environmental pathways, routes of exposure, and environmental concerns identified from the literature review and the types of analyses conducted to determine the impacts under baseline and potential environmental improvements under the regulatory options. In its analyses to determine environmental impacts and improvements, the EPA evaluated each environmental concern via a given route of exposure and pathway individually (*i.e.*, the combined impact of multiple routes of exposure were not jointly evaluated).

Table 3. Steam Electric Power Plant Wastewater Environmental Pathways and Routes of Exposure Evaluated in the Environmental Assessment for the Final Supplemental Rule

Environmental Pathway	Route of Exposure	Environmental Concern	Analysis to Determine Environmental Impact
Steam electric power plant wastewater discharges to surface waters	Direct contact with surface water	Toxic effects on aquatic organisms[a]	Water quality impacts analysis (quantitative)—see Sections 4.1.1 and 4.3
	Ingestion of surface water	Degradation of surface water quality used as intake to drinking water plants	
	Direct contact with sediment	Toxic effects on benthic organisms[a]	Wildlife impacts analysis (quantitative)—see Sections 4.1.2 and 4.3
	Consumption of aquatic organisms	Bioaccumulation of contaminants and resulting toxic effects on wildlife[a]	
		Toxic effects on humans consuming contaminated fish[a]	Human health impacts analysis (quantitative)—see Sections 4.1.3 and 4.3
		Degradation of fish availability for recreational and subsistence fishers	Human health impacts analysis (quantitative)—see Sections 4.1.3 and 4.2
Uncollected CRL infiltration to nearby surface waters from combustion residual landfill	Direct contact with surface water or sediment	Toxic effects on humans and aquatic wildlife[a]	Groundwater quality impacts (qualitative)—see Section 2.2.3
Uncollected CRL entering groundwater from combustion residual landfill	Ingestion of groundwater	Changes in groundwater quality	
		Contaminated private drinking water wells	
Combustion residual surface impoundment	Direct contact with or ingestion of surface water	Toxic effects on wildlife[a]	Attractive nuisances (qualitative)—see Section 2.2.4
		Bioaccumulation of contaminants in wildlife	

a—The term "toxic effects" refers to impacts upon exposure, ingestion, inhalation, or assimilation into any organism, either directly from the environment or indirectly by ingestion through food chains. These effects can include death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), or physical deformations, in receptors (*e.g.*, aquatic organisms, wildlife, humans) or their offspring.

3.3 Environmental Impacts Selected for Qualitative and Quantitative Assessments in the EA

The EPA used both qualitative and quantitative assessments to describe the potential environmental impacts of the evaluated wastestreams (*i.e.*, FGD wastewater, BA transport water, CRL, and legacy wastewater) from steam electric power plants:

- Qualitative analysis focused on the impacts of uncollected CRL on groundwater quality and the potential for combustion residual surface impoundments to serve as attractive nuisances. Section 2.2.3 describes the EPA's findings on the potential for uncollected CRL to cause changes in groundwater quality and contaminate drinking water sources. Section 2.2.4 presents the EPA's findings on the potential toxic effects and bioaccumulation of contaminants in wildlife exposed to combustion residual surface impoundments.
- Quantitative analyses focused on the surface water exposure pathway. The EPA conducted a proximity analysis to determine whether evaluated wastestreams discharge into sensitive environments. See Section 3.5.

The EPA also evaluated the following wildlife and human health impacts caused by discharges of the evaluated wastestreams to surface waters under baseline as well as the potential reductions in those impacts under the regulatory options:

- Wildlife impacts:
  - Potential toxic effects to aquatic life based on changes in surface water quality—specifically, exceedances of the acute and chronic National Recommended Water Quality Criteria (NRWQC) for freshwater aquatic life.
  - Potential toxic effects on sediment biota based on changes in sediment quality within surface waters—specifically, exceedances of threshold effect concentrations (TECs) for sediment biota.
  - Bioaccumulation of contaminants and potential toxic effects on wildlife from consuming contaminated aquatic organisms—specifically, exceedances of no effect hazard concentrations (NEHCs), indicating a potential risk of reduced reproduction rates in piscivorous wildlife.

- Human health impacts:
  - Exceedances of the human health NRWQC based on two standards: (1) the standard for the consumption of water and organisms and (2) the standard for the consumption of organisms only.
  - Exceedances of drinking water maximum contaminant levels (MCLs). Although MCLs apply to drinking water produced by public water systems and not surface waters themselves, the EPA identified the extent to which immediate receiving waters exceeded an MCL as an indication of the degradation of the overall water quality following exposure to the evaluated wastestreams.
  - Elevated cancer risk due to consuming fish caught from contaminated receiving waters—specifically, instances where the calculated lifetime excess cancer risk due to inorganic arsenic is greater than one excess cancer case risk per one million lifetimes (also expressed as 10^{-6}).
  - Elevated noncancer health risks (*e.g.*, reproductive or neurological impacts) due to consuming fish caught from contaminated receiving waters—specifically, instances where the calculated average daily dose of a pollutant exceeds the oral reference dose (RfD) for that pollutant.

The EPA used its Immediate Receiving Water (IRW) Model to perform the quantitative assessment. Section 3.4 provides an overview of the modeling. Section 3 and Appendices C, D, and E of the 2020 EA (U.S. EPA, 2020a) provide more details on the IRW Model.

The EPA also evaluated additional wildlife and human health impacts resulting from changes in surface water quality, including impacts on threatened and endangered species, changes in ecosystem services, and neurological effects from exposure to lead and mercury. The methodologies and results of these analyses are presented in the BCA Report (U.S. EPA, 2024b). All analyses compare reductions under the regulatory options to baseline.

3.4 Overview of the IRW Model

The Immediate Receiving Water (IRW) Model is an integrated series of modules that utilize existing peer-reviewed methodologies and datasets to estimate environmental and human health risk resulting from wastewater releases. The EPA used the IRW Model to conduct the quantitative assessment of potential wildlife and human health impacts described in Section 3.3. This is the same model—including parameters and benchmark values—described in the 2020 EA (U.S. EPA, 2020a). It is a steady-state equilibrium-partitioning model that evaluates impacts within the immediate surface water[8] where discharges occur. An equilibrium-partitioning model assumes that dissolved and sorbed pollutants in a receiving water will quickly attain equilibrium in the immediate vicinity of the discharge point because they dissolve or sorb in the surface water faster than they can be transported or dispersed outside that area. The model also assumes that the equilibrium state for each pollutant can be represented by a partition coefficient that divides the total mass of a pollutant in the waterbody into four compartments:

- Constituents dissolved in the water column.
- Constituents sorbed onto suspended solids in the water column.
- Constituents sorbed onto sediments at the bottom of the waterbody.
- Constituents dissolved in pore water in the sediments at the bottom of the waterbody.

As described in Section 5 of the 2015 EA (U.S. EPA, 2015a), the EPA developed the IRW Model to quantify the environmental impacts to surface waters, wildlife, and human health from the wastestreams evaluated for the regulatory options. In developing the model, the EPA considered the type of receiving waters commonly affected by steam electric power plants and the pollutants typically found in the evaluated wastestreams. The IRW Model quantified the environmental risks within rivers/streams and lakes/ponds/reservoirs and evaluated impacts from nine toxic, bioaccumulative pollutants: arsenic, cadmium, copper, lead, mercury, nickel, selenium, thallium, and zinc. Section 4.1 presents the results of the IRW Model analyses based on baseline and regulatory option pollutant loadings for the evaluated wastestreams, along with the limitations and uncertainties of the IRW Model.

3.4.1 Structure of the IRW Model

The IRW Model has three interrelated modules: the Water Quality Module, the Wildlife Module, and the Human Health Module, which are described in further detail in this section. Figure 1 provides an overview of the model's inputs and the connections among the three modules.

- The Water Quality Module uses plant-specific input data (annual average pollutant loadings and cooling water flow rates) and receiving-water-specific input data (*e.g.*, annual average flow rate, lake volume) to calculate annual average total and dissolved pollutant concentrations in the water column

[8] The lengths of the immediate receiving waters for the EA, as defined in the National Hydrography Dataset Plus (NHDPlus) Version 2, range from about 0.20 to 18 miles. The upstream and downstream boundaries are defined in NHDPlus Version 2, and each plant outfall is located somewhere along the associated immediate receiving water (*i.e.*, the outfalls are not specifically indexed to the upstream end, midpoint, or downstream end). See the memorandum *Receiving Waters Characteristics Analysis and Supporting Documentation for the Environmental Assessment of the Final Supplemental Steam Electric Rule* (U.S. EPA, 2024f) for details on the immediate discharge zone and length of stream reach represented at each discharge location.

and sediment. The module compares these concentrations to selected water quality benchmark values (NRWQC and MCLs) as an indicator of potential impacts on aquatic life and human health.

- The Wildlife Module uses the annual average water column pollutant concentrations from the Water Quality Module to calculate the bioaccumulation of pollutants in fish tissue, providing results for both trophic level 3 (T3) and trophic level 4 (T4) fish.[9] The module compares these concentrations, and the sediment concentrations calculated by the Water Quality Module, to benchmark values that represent potential impacts on exposed sediment biota (TECs)[10] and piscivorous wildlife (NEHCs). The EPA chose minks and eagles as representative piscivorous wildlife that consume T3 and T4 fish, respectively.
- The Human Health Module uses the fish tissue concentrations from the Wildlife Module to calculate noncancer and cancer risks to human populations from consuming fish caught from contaminated receiving waters. The EPA performed this analysis using two sets of fish consumption rates:[11]
    - A "standard cohort" data set with consumption rates for recreational fishers and subsistence fishers (and their families), with separate age categories for adult and child fishers. Subsistence fishers are people who rely on self-caught fish for a larger share of their food intake than recreational fishers.
    - A data set with consumption rates for recreational and subsistence fishers in different race/ethnicity categories (non-Hispanic White; non-Hispanic Black; Mexican-American; other Hispanic; and other, including multiple races). The EPA used this data set to evaluate whether the human health impacts under baseline or reductions under the regulatory options (relative to baseline) will disproportionately affect minority groups.[12]

Appendices C, D, and E to the 2020 EA (U.S. EPA, 2020a) describe the IRW Model equations, input data, and environmental parameters in detail. The appendices also describe the limitations and assumptions for each module. Section 5.1 of the 2015 EA (U.S. EPA, 2015a) provides more information on the IRW Model, including a detailed discussion of the equilibrium-partition modeling methodology used in the Water Quality Module.

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[9] T3 fish (*e.g.*, carp, smelt, perch, catfish, sucker, bullhead, sauger) are those that primarily consume invertebrates and plankton, while T4 fish (*e.g.*, salmon, trout, walleye, bass) are those that primarily consume other fish.

[10] In the case of the TEC for selenium, exceedances of the TEC represent potential impacts on higher trophic levels due to consumption of sediment biota with elevated levels of selenium.

[11] See the memorandum *Fish Consumption Rates Used in the EA Human Health Module* (ERG, 2015b) for details on the selection of fish consumption rates for these analyses.

[12] The EPA also conducted an environmental justice (EJ) analysis using data from the EPA's EJScreen, the EA, and the benefits analysis. See *Environmental Justice Analysis for Final Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (U.S. EPA, 2024d) for more details.

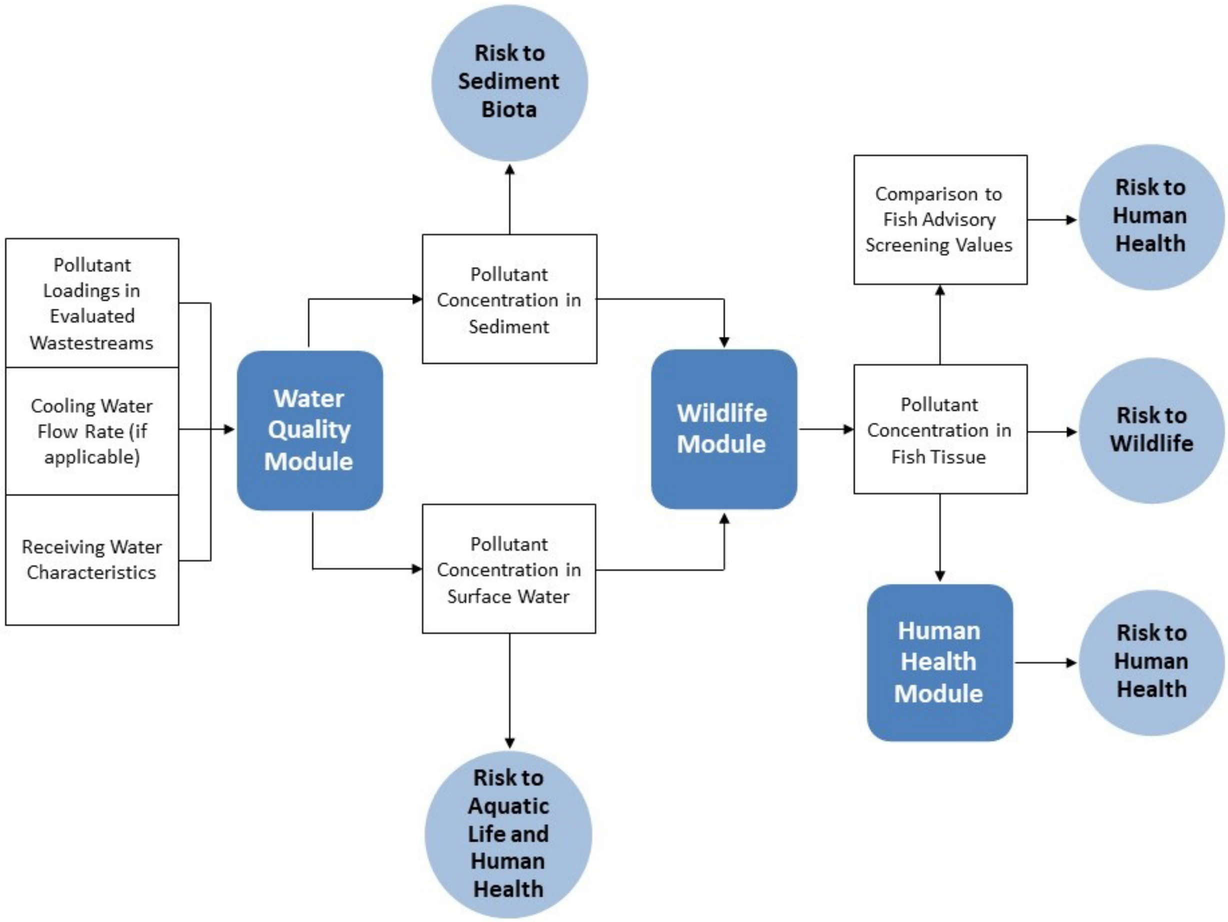

Figure 1. Overview of the IRW Model

3.4.2 Pollutants Evaluated by the IRW Model

The IRW Model analyzed nine toxic pollutants, all of which can bioaccumulate in fish and impact wildlife and human receptors via fish consumption. These pollutants were arsenic, cadmium, copper, lead, mercury, nickel, selenium, thallium, and zinc. The EPA evaluated the same pollutants in the 2020 EA. Table 4 through Table 6 include the benchmarks used in the IRW Model. The EPA identified two updates to benchmarks and incorporated these revised values in the IRW Model:

1. The EPA vacated the cadmium aquatic life criteria (freshwater, chronic) as documented in U.S. EPA (2016c). For the final rule EA, the EPA revised the benchmark as documented in U.S EPA (2001), which is also the value used in the 2015 EA.

2. The Agency for Toxic Substances and Disease Registry *Minimal Risk Levels (MRLs)* included an updated oral reference dose for copper. The EPA revised the benchmark to be 0.02 milligrams per kilogram body weight per day (mg/kg-day) (ATSDR, 2023).

Table 4. Water Quality Benchmarks: NRWQC and MCLs

Pollutant	FW Acute NRWQC[a,b,c] (mg/L)	FW Chronic NRWQC[a,b,c] (mg/L)	HH WO NRWQC[a,b] (mg/L)	HH O NRWQC[a,b] (mg/L)	MCL[a,d] (mg/L)
Arsenic	0.34	0.15	0.000018[e]	0.00014[e]	0.01
Cadmium	0.0018[f,g]	0.00025[f,g]	—	—	0.005
Copper	0.014[h]	0.009[h]	1.3	—	1.3 (action level); 1.0[i]
Lead	0.065[f]	0.0025[f]	—	—	0.015 (action level)
Mercury	0.0014	0.00077	—	—	0.002[e]
Nickel	0.47[f]	0.052[f]	0.61	4.6	—
Selenium	Lentic: 0.045[j] Lotic: 0.094[j]	Lentic: 0.0015[k] Lotic: 0.0031[k]	0.17	4.2	0.05
Thallium	—	—	0.00024	0.00047	0.002
Zinc	0.12[f]	0.12[f]	7.4	26	5[l]

Sources: U.S. EPA, 2001, 2009a, 2009b, 2016b, 2016c, and 2020c.

Abbreviations: FW (freshwater); HH O (human health organisms only); HH WO (human health water and organisms); MCL (maximum contaminant level); mg/L (milligrams per liter); NRWQC (National Recommended Water Quality Criteria).

a—"—" designates instances where a benchmark value does not exist for the pollutant.

b—Unless otherwise noted, pollutant concentrations were compared to NRWQC from the EPA's *National Recommended Water Quality Criteria* (U.S. EPA, 2009b).

c—Benchmark value is expressed in terms of the dissolved pollutant in the water column. For all pollutants except selenium, this is calculated using a total-to-dissolved conversion factor (U.S. EPA, 2009b).

d—Unless otherwise noted, pollutant concentrations were compared to the MCL from the EPA's *National Primary Drinking Water Regulations* (U.S. EPA, 2009a).

e—Benchmark value is for inorganic form of pollutant.

f—The FW NRWQC for this metal is expressed as a function of hardness (mg/L) in the water column. The values given here correspond to a hardness of 100 mg/L.

g—The cadmium benchmark values are from the EPA's *Aquatic Life Ambient Water Quality Criteria for Cadmium—2016* (U.S. EPA, 2016c) for FW acute NRWQC and the EPA's *Update of Ambient Water Quality Criteria for Cadmium* (U.S. EPA, 2001) for FW chronic NRWQC.

h—For this analysis, the EPA calculated FW NRWQC for copper using the Biotic Ligand Model and input water quality data that are representative of the ecoregions containing surface waters that receive discharges of the evaluated wastestreams (and their downstream waters) (U.S. EPA, 2020c).

i—The EPA evaluated both the action level of 1.3 mg/L and the secondary (nonenforceable) drinking water standard of 1.0 mg/L for copper (U.S. EPA, 2020d). The results presented in Section 4 and Attachment A are based on the number of immediate receiving waters with exceedances of the lower secondary drinking water standard (1.0 mg/L).

j—The selenium benchmark values are based on the NRWQC from the EPA's *Aquatic Life Ambient Water Quality Criteria for Selenium—Freshwater 2016* (U.S. EPA, 2016b). The selenium acute NRWQC, as calculated here, assumes a background selenium concentration of zero and an intermittent exposure duration of one day, which is the shortest exposure period to be used when applying the criterion. This serves as an intermittent exposure element of the chronic water quality criterion, intended to address short-term exposures that contribute to chronic effects through selenium bioaccumulation. "Lentic" pertains to still or slow-moving water, such as lakes or ponds. "Lotic" pertains to flowing water, such as streams and rivers.

k—The selenium benchmark values are based on the NRWQC from the EPA's *Aquatic Life Ambient Water Quality Criteria for Selenium—Freshwater 2016* (U.S. EPA, 2016b). The selenium chronic water column NRWQC applies only in the absence of fish tissue measurements. Use of this water column benchmark value may therefore over- or underestimate the number of exceedances.

l—The EPA has not defined an MCL or action level for zinc. This benchmark value represents the secondary (nonenforceable) drinking water standard for zinc (U.S. EPA, 2020d).

Table 5. Sediment Biota and Wildlife Benchmarks: TECs and NEHCs

Pollutant	TEC (mg/kg)[a]	NEHC for Minks (T3 Fish) (µg/g)[b]	NEHC for Eagle (T4 Fish) (µg/g)[b]
Arsenic	9.79	7.65	22.4
Cadmium	0.99	5.66	14.7
Copper	31.6	41.2	40.5
Lead	35.8	34.6	16.3
Mercury/methylmercury	0.18	0.37[c]	0.5[c]
Nickel	22.7	12.5	67.1
Selenium	2	1.13	4
Thallium	—[d]	—[d]	—[d]
Zinc	121	904	145

Abbreviations: mg/kg (milligrams per kilogram); NEHC (no effect hazard concentration); T3 (trophic level 3); T4 (trophic level 4); TEC (threshold effect concentration); µg/g (micrograms per gram).

a—Sources: Lemly (2018) for selenium; MacDonald et al. (2000) for all other pollutants.

b—Source: USGS, 2008.

c—No NEHC benchmark for methylmercury. The EPA compared the modeled methylmercury concentrations to the total mercury NEHC, which may underestimate the impact to wildlife.

d—No benchmark value identified; pollutant excluded from evaluation.

Table 6. Human Health Benchmarks: Oral RfDs and CSFs

Pollutant	Oral RfD (mg/kg-day)	CSF (mg/kg-day) $^{-1}$	Notes
Arsenic, inorganic	3.00×10^{-4}	1.50	Oral RfD and CSF for drinking water ingestion
Cadmium	1.00×10^{-3}	—[a]	Oral RfD for food consumption
Copper	2.00×10^{-2}	—[a]	Used the intermediate oral MRL as the oral RfD (ATSDR, 2023)
Lead, total	—[b]	—[a]	
Methylmercury	1.00×10^{-4}	—[a]	Oral RfD for fish consumption only
Nickel	2.00×10^{-2}	—[a]	Oral RfD for soluble salts; used for food consumption
Selenium	5.00×10^{-3}	—[a]	Oral RfD for food consumption
Thallium	1.00×10^{-5}	—[a]	Used value cited in U.S. EPA (2012), for soluble thallium as the oral RfD; used for chronic oral exposure
Zinc	3.00×10^{-1}	—[a]	Oral RfD for food consumption

Sources: ATSDR (2023) for copper, U.S. EPA (2012) for thallium, and U.S. EPA (2019) for all other pollutants.

Abbreviations: CSF (cancer slope factor); mg/kg-day (milligrams per kilogram body weight per day); MRL (minimal risk level); RfD (reference dose).

a—No benchmark value identified; pollutant excluded from evaluation.

b—As documented in IRIS (https://www.epa.gov/iris), the EPA concluded that it was inappropriate to develop an RfD as some of the effects from lead exposure, "particularly changes in the levels of certain blood enzymes and in aspects of children's neurobehavioral development, may occur at blood lead levels so low as to be essentially without a threshold." The CDC identified 10 micrograms per deciliter (µg/dL) as the blood lead level of concern in children; see the *BCA Report* (U.S. EPA, 2024b) for the EPA's analysis of lead impacts.

Like the 2020 EA, this EA did not use water quality modeling to assess the impacts associated with discharges of TDS, bromides, chlorides, or nutrients (total nitrogen and total phosphorus). The EPA did not have partition coefficients needed to model the pollutants in receiving water using the equilibrium-partition equations presented in Appendix C of the 2020 EA (U.S. EPA, 2020a). The EPA did include some of these pollutants in the surface water quality modeling of immediate and downstream waters, which was performed for the economic benefits analysis (see the BCA Report, U.S. EPA, 2024b).

3.5 Proximity Analysis

The pollutant loadings, ecological impacts, and human health concerns discussed in Section 2 and Section 3.2 are also of concern due to the proximity of many steam electric power plants to sensitive environments where the characteristics of plant wastewater may contribute to the impairment of water quality (*e.g.*, 303(d)-listed waters and waters with fish advisories) or pose a threat to threatened and endangered species (see the BCA Report, U.S. EPA, 2024b). The EPA identified the number of surface waters that receive discharges of the evaluated wastestreams and are located near the following sensitive environments:

- Immediate receiving waters that states, territories, and authorized tribes have identified, pursuant to section 303(d) of the Clean Water Act (CWA), as impaired waterbodies that can no longer meet their designated uses (*e.g.*, drinking, recreation, aquatic habitat) due to pollutant concentrations above water quality standards. These are also known as "CWA section 303(d)–listed waterbodies."
- Immediate receiving waters for which states, territories, and authorized tribes have issued fish consumption advisories, which indicates that pollutant concentrations in the tissues of fish inhabiting those waters are considered unsafe for human consumption at any or some consumption levels.
- Immediate receiving waters within five miles of drinking water resources, including intakes and reservoirs, public wells, and sole-source aquifers.

The EPA also assessed the potential for discharges of the evaluated wastestreams to cause or contribute to fish advisories, thereby posing a human health risk. The EPA compared the T4 fish tissue concentrations from the Wildlife Module to fish consumption advisory screening values. Screening values are concentrations of target analytes in fish or shellfish tissue that are of potential public health concern; they are used as threshold values to which levels of contamination in similar tissue collected from the ambient environment can be compared. Exceedance of screening values indicates that more intensive site-specific monitoring and/or evaluation of human health risks should be conducted (U.S. EPA, 2000, Table 5-3).[13]

The EPA's memorandum *Proximity Analyses and Supporting Documentation for the Environmental Assessment of the Final Supplemental Steam Electric Rule* (U.S. EPA, 2024j) describes the methodology used to evaluate the proximity of steam electric power plant discharges to sensitive environments. Section 4.2 of this report presents the results of the proximity analysis.

The EPA also performed further spatial analyses to identify public drinking water supply intakes downstream from discharges of the evaluated wastestreams. See the BCA Report (U.S. EPA, 2024b) for details on the methodology and results of that analysis.

3.6 Downstream Analysis

As part of the economic benefits analysis, the EPA used a separate pollutant fate and transport model (Downstream Fate and Transport Equations, or D-FATE) to calculate the concentrations of pollutants in surface waters downstream from the immediate receiving water for each plant that discharges the

[13] See the memorandum *IRW Model: Water Quality, Wildlife, and Human Health Analyses and Supporting Documentation for the Environmental Assessment of the Final Supplemental Steam Electric Rule* (U.S. EPA, 2024i) for documentation of the fish advisory screening level analysis.

evaluated wastestreams. See the BCA Report (U.S. EPA, 2024b) for a detailed discussion of the D-FATE model and the analysis, which uses annual average pollutant loadings and surface water flow rates.

The EPA used these downstream concentrations from D-FATE as inputs for an analysis that identified which downstream reaches would have at least one exceedance of a water quality, wildlife, or human health benchmark value under baseline or regulatory option loadings. The EPA used this approach to estimate the extent (in river miles) of impacts in downstream surface waters under baseline and the changes in these impacts under the regulatory options evaluated. Results are presented in Section 4.3 of this report. See the memorandum *Downstream Modeling Analysis and Supporting Documentation for the Environmental Assessment of the Final Supplemental Steam Electric Rule* (U.S. EPA, 2024l) for details on the methodology for this analysis.

3.7 Scope of the Evaluated Plants and Immediate Receiving Waters

The EPA estimates that 277 coal-fired electric generating units (EGUs) operated at 148 plants will be operating after December 31, 2028. Section 3 of the TDD (U.S. EPA, 2024a) describes how the EPA updated the industry profile to reflect changes since the 2020 rule. Section 5 and Section 6 of the TDD describe the population of plants and EGUs that the EPA estimated compliance costs and pollutant loadings under baseline (for 246 coal-fired EGUs operated at 110 plants)[14] and the regulatory options.

The scope of the EA includes the 110 plants and their discharges of one or more of the evaluated wastestreams (FGD wastewater, BA transport water, CRL, or legacy wastewater) directly or indirectly to surface waters under baseline and/or one or more regulatory options.[15] The EPA performed quantitative assessments to support the EA using its IRW Model, described in Section 3.4. The IRW Model, which excludes discharges to the Great Lakes and estuaries, encompasses 100 plants that discharge to 114 immediate receiving waters.[16] The IRW Model excludes Great Lake and estuarine immediate receiving waters because the specific hydrodynamics and scale of the analysis required to appropriately model and quantify pollutant concentrations in these types of waterbodies are more complex than can be represented in the IRW Model. The excluded waterbodies include Lake Erie, Lake Michigan (three stream reaches), Lake Superior, Escambia River, Hillsborough Bay, Big Lake, and Sutherland Reservoir. These nine immediate receiving waters (stream reaches) receive evaluated wastestream discharges from ten plants; see *Receiving Waters Characteristics Analysis and Supporting Documentation for the Environmental Assessment of the Final Supplemental Steam Electric Rule* (U.S. EPA, 2024f) for further details.

Table 7 presents the number of plants, generating units, and immediate receiving waters evaluated in the EA. Figure 2 shows the locations of the immediate receiving waters evaluated in the EA proximity analysis and indicates those that are included in the IRW Model. See the memorandum *Receiving Waters Characteristics Analysis and Supporting Documentation for the Environmental Assessment of the Final*

[14] The EPA made plant adjustments after running the final rule analyses, and two plants (and their respective receiving waters) were not included in the pollutant loadings presented in this report or in the IRW Model. The EPA did include the receiving waters in the proximity analysis. Both plants are expected to retire or undergo fuel conversion by 2034. See *Updates to Estimated Compliance Costs and Pollutant Loadings* (U.S. EPA, 2024n) and *Pollutant Loadings Analysis and Supporting Documentation for the Environmental Assessment of the Final Supplemental Steam Electric Rule* (U.S. EPA, 2024h).

[15] Of the 110 plants in the EA, 106 discharge directly to surface water, three discharge indirectly to POTWs, and one discharges wastestreams both directly and indirectly. The EPA excluded CRL discharges at one plant from the EA that indirectly discharges to a POTW that does not discharge to any receiving waters (U.S. EPA, 2024f). Discharges from two additional plants, not included in the count of 110 plants, were not included in the pollutant loadings analysis or IRW Model (only the proximity analysis); see U.S. EPA (2024h and 2024n). One plant is a direct discharging plant and the other is an indirect discharging plant.

[16] Ten of the 110 plants included in the EA discharge to more than one immediate receiving water.

Supplemental Steam Electric Rule (U.S. EPA, 2024f) for the list of immediate receiving waters and details on the EPA's methodology for identifying them.

The number of evaluated plants and generating units, and the number of the associated immediate receiving waters, vary across baseline and the regulatory options evaluated for the final rule. This is due to differences in the stringency of controls, applicability of these controls based on subcategorization, and estimates of the control technologies that plants would implement to meet requirements (see the preamble for details). Table 8 presents the number of plants, generating units, and immediate receiving waters with nonzero pollutant loadings for baseline and each regulatory option evaluated.

Table 7. Plants, Generating Units, and Immediate Receiving Waters Evaluated in the Environmental Assessment for the Final Supplemental Rule

Category	Number Evaluated in Pollutant Loadings Analysis	Number Evaluated in the Proximity Analysis	Number Evaluated in IRW Model[a]
Plants [b]	110	112	100
Electric generating units [b,c]	246	249	222
Immediate Receiving Waters			
River/stream [b]	98	100	98
Lake/pond/reservoir	16	16	16
Great Lakes	5[d]	5[d]	—
Estuary/bay/other	4	4	—
Total Immediate Receiving Waters	**123** [d,e]	**125** [d,e]	**114** [d,e]

Sources: U.S. EPA, 2024f and 2024h.

Abbreviations: IRW (immediate receiving water).

a—The IRW Model excludes discharges to nine immediate receiving waters that are one of the Great Lakes and or an estuary because the specific hydrodynamics and scale of the analysis required to appropriately model and quantify pollutant concentrations in these types of waterbodies are more complex than can be represented in the IRW Model.

b—The EPA made plant adjustments after running the final rule analyses, and two plants (and their respective receiving waters) were not included in the pollutant loadings presented in the report or in the IRW Model. The EPA did include the receiving waters in the proximity analysis. Both plants are expected to retire or undergo fuel conversion by 2034. See U.S. EPA (2024h and 2024n).

c—Legacy wastewater discharges at two plants are not associated with an active coal-fired generating unit.

d—Ten plants included discharge to more than one immediate receiving water. One Great Lake immediate receiving water receives discharges from two plants.

e—One plant discharges CRL to a zero-discharge publicly owned treatment works; therefore, no immediate receiving water is associated with the plant's pollutant loadings from that wastestream. The plant's legacy wastewater loadings are included in the EA analyses.

Table 8. Plants, Generating Units, and Immediate Receiving Waters with Pollutant Loadings Under Baseline and Regulatory Options for the Final Supplemental Rule

Category	Baseline	Option A	Option B	Option C
Downstream and Proximity Analyses[a]				
Plants	112	97	54	17
Electric generating units[b]	249	219	123	33
Immediate receiving waters	125	105	57	18
Subset Also Evaluated in Pollutant Loadings[a]				
Plants	110	97	54	17
Electric generating units[b]	246	219	123	33
Immediate receiving waters	123	105	57	18
Subset Also Evaluated in IRW Model[a,c]				
Plants	100	89	47	16
Electric generating units[b]	222	198	103	29
Immediate receiving waters	114	97	50	17

Sources: U.S. EPA, 2024f and 2024h.

Abbreviations: IRW (immediate receiving water).

a—The EPA made plant adjustments after running the final rule analyses, and two plants (and their respective receiving waters) are not included in the pollutant loadings presented in the report or in the IRW Model. The EPA did include the receiving waters in the proximity analysis. Both plants are expected to retire or undergo fuel conversion by 2034. See U.S. EPA (2024h and 2024n).

b—Legacy wastewater discharges at two plants are not associated with an active coal-fired generating unit.

c—The IRW Model excludes discharges to nine immediate receiving waters that are one of the Great Lakes and or an estuary because the specific hydrodynamics and scale of the analysis required to appropriately model and quantify pollutant concentrations in these types of waterbodies are more complex than can be represented in the IRW Model.

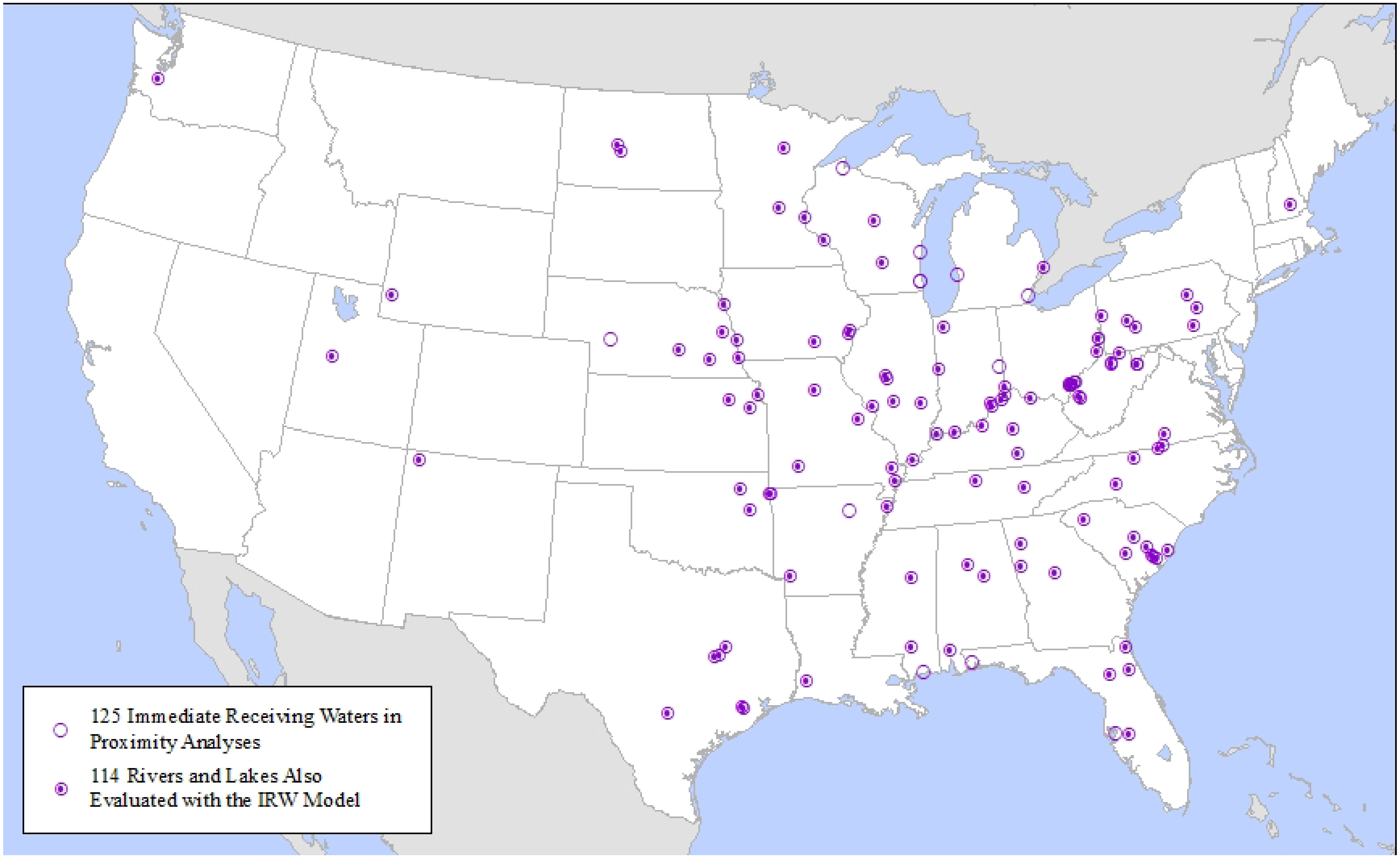

Figure 2. Locations of Immediate Receiving Waters Evaluated in the Environmental Assessment for the Final Supplemental Rule

4. Results of the Quantitative Environmental Assessment for the Final Supplemental Rule

The EPA used the plant-specific and receiving-water-specific pollutant loadings, described in Section 3.1, to determine the environmental impacts of the evaluated wastestreams—*i.e.*, flue gas desulfurization (FGD) wastewater, bottom ash (BA) transport water, combustion residual leachate (CRL), and legacy wastewater—from steam electric power plants. This section presents the results of the quantitative analyses described in Sections 3.3 through 3.6, which include the following:

- Use of the EPA's Immediate Receiving Water (IRW) Model to:
  - Estimate the annual average pollutant concentrations in immediate receiving waters due to discharges of the evaluated wastestreams under baseline and the regulatory options, estimate the bioaccumulation of pollutants in fish tissue within those waters, and estimate the daily and lifetime pollutant exposure doses among humans who consume those fish.
  - Compare the estimated concentrations and estimated exposure doses to various benchmark values as indicators of potential water quality, wildlife, and human health impacts.
  - Evaluate the estimated changes in those impacts under the regulatory options, as compared to baseline.
- A proximity analysis to identify immediate receiving waters that are designated as Clean Water Act (CWA) section 303(d)–listed impaired waterbodies; have been issued fish consumption advisories; or are within five miles of drinking water resources, including intakes and reservoirs, public wells, and sole-source aquifers.
- Use of pollutant fate and transport model (D-FATE) outputs to estimate potential water quality, wildlife, and human health impacts in downstream surface waters under baseline and evaluate the estimated changes in those impacts under the regulatory options.

The BCA Report (U.S. EPA, 2024b) discusses the EPA's evaluation of other impacts that were not quantified in the environmental assessment.

4.1 Environmental Impacts Identified by the IRW Model

The IRW Model includes modules assessing potential changes in impacts on water quality, wildlife, and human health in waters receiving discharges of the evaluated wastestreams from steam electric power plants.[17] See Section 3.4 of this document and Appendices C, D, and E of the 2020 environmental assessment (EA) (U.S. EPA, 2020a) for details on the IRW Model's structure and methodology, including equations, input data, and environmental parameters.

The following sections present the environmental impact results estimated from each module for the nine modeled pollutants: arsenic, cadmium, copper, lead, mercury, nickel, selenium, thallium, and zinc. The results identify modeled exceedances of water quality, wildlife, and human health benchmark values under baseline and the reduction in those exceedances under each regulatory option. Appendix A includes additional IRW Model outputs.

[17] The EA encompasses a total of 125 immediate receiving waters and 112 plants (some of which discharge to multiple receiving waters). The EPA made plant adjustments after running final rule analyses, and two plants and their respective receiving waters were only included in the proximity analysis. Both plants are expected to retire or undergo fuel conversion by 2034. See U.S. EPA (2024h and 2024n). The IRW Model, which excludes the Great Lakes and estuaries, analyzes a total of 114 immediate receiving waters and loadings from 100 plants.

4.1.1 *Water Quality Impacts*

The IRW Water Quality Module assesses the quality of surface waters that receive discharges of the evaluated wastestreams by comparing estimated pollutant concentrations in the water column to the National Recommended Water Quality Criteria (NRWQC) and drinking water maximum contaminant levels (MCLs)[18] under baseline and each regulatory option. The Water Quality Module results described in this section are based on estimated annual average pollutant loadings and flow rates. The module considers modeled exceedances of the freshwater acute NRWQC, freshwater chronic NRWQC, human health water and organism (HH WO) NRWQC, human health organism only (HH O) NRWQC, and drinking water MCL.

The EPA compared the modeled receiving water concentrations to the water quality benchmarks presented in Table 4. Table 9 summarizes the number of immediate receiving waters exceeding the water quality benchmarks. Table 10 presents the number of immediate receiving waters with exceedances of any NRWQC or MCL by pollutant. The EPA identified water quality benchmark exceedances for all nine pollutants evaluated for one or more immediate receiving waters. Pollutants with exceedances in multiple receiving waters included arsenic, cadmium, copper, lead, selenium, and thallium. Under baseline, the EPA estimated that 38 of the 114 immediate receiving waters (33 percent) exceeded one or more water quality benchmark. Under the final rule (Option B), the number of immediate receiving waters exceeding a benchmark will decrease by 24 immediate receiving waters.

Table 9. Modeled IRWs with Exceedances of NRWQC and MCLs Under Baseline and Regulatory Options

Water Quality Evaluation Benchmark	Pollutant	Number of Modeled IRWs Exceeding Benchmark Value (Difference Relative to Baseline)[a]			
		Baseline	Option A	Option B	Option C
Freshwater acute NRWQC	Any pollutant	3	2 (-1)	2 (-1)	2 (-1)
	Cadmium	3	2 (-1)	1 (-2)	1 (-2)
	Copper	1	1 (0)	0 (-1)	0 (-1)
	Nickel	1	1 (0)	0 (-1)	0 (-1)
	Selenium	1	1 (0)	1 (0)	1 (0)
	Zinc	1	1 (0)	0 (-1)	0 (-1)
Freshwater chronic NRWQC	Any pollutant	12	11 (-1)	5 (-7)	5 (-7)
	Cadmium	8	5 (-3)	2 (-6)	2 (-6)
	Copper	2	2 (0)	0 (-2)	0 (-2)
	Lead	1	1 (0)	0 (-1)	0 (-1)
	Mercury	1	1 (0)	0 (-1)	0 (-1)
	Nickel	1	1 (0)	0 (-1)	0 (-1)
	Selenium	12	11 (-1)	5 (-7)	5 (-7)
	Zinc	1	1 (0)	0 (-1)	0 (-1)
HH WO NRWQC	Any pollutant	38	28 (-10)	14 (-24)	7 (-31)
	Arsenic	38	28 (-10)	14 (-24)	7 (-31)
	Nickel	1	1 (0)	0 (-1)	0 (-1)
	Selenium	1	1 (0)	1 (0)	1 (0)
	Thallium	8	7 (-1)	4 (-4)	3 (-5)

[18] Table 4 in Section 3 presents the benchmarks values for the pollutants evaluated.

Table 9. Modeled IRWs with Exceedances of NRWQC and MCLs Under Baseline and Regulatory Options

Water Quality Evaluation Benchmark	Pollutant	Number of Modeled IRWs Exceeding Benchmark Value (Difference Relative to Baseline)[a]			
		Baseline	Option A	Option B	Option C
HH O NRWQC	Any pollutant	21	14 (-7)	4 (-17)	3 (-18)
	Arsenic	21	14 (-7)	4 (-17)	3 (-18)
	Selenium	1	1 (0)	1 (0)	1 (0)
	Thallium	7	5 (-2)	3 (-4)	3 (-4)
Drinking water MCL	Any pollutant	5	4 (-1)	3 (-2)	3 (-2)
	Arsenic	4	2 (-2)	2 (-2)	2 (-2)
	Cadmium	3	2 (-1)	1 (-2)	1 (-2)
	Lead	2	2 (0)	1 (-1)	1 (-1)
	Mercury	1	1 (0)	0 (-1)	0 (-1)
	Selenium	3	3 (0)	2 (-1)	2 (-1)
	Thallium	2	2 (0)	2 (0)	2 (0)
	Zinc	1	1 (0)	0 (-1)	0 (-1)
Total Number of Unique Immediate Receiving Waters[b]		38	28 (-10)	14 (-24)	7 (-31)

Source: U.S. EPA, 2024i.

Abbreviations: HH O (human health organism only); HH WO (human health water and organism); IRW (immediate receiving water); MCL (maximum contaminant level); NRWQC (National Recommended Water Quality Criteria).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

b—Total may not equal the sum of the individual values because some immediate receiving waters have multiple types of exceedances.

Table 10. Modeled IRWs with Exceedances of NRWQC and MCLs, by Pollutant, Under Baseline and Regulatory Options

Pollutant	Number of Modeled IRWs Exceeding Benchmark Value (Difference Relative to Baseline)[a]			
	Baseline	Option A	Option B	Option C
Arsenic	38	28 (-10)	14 (-24)	7 (-31)
Cadmium	8	5 (-3)	2 (-6)	2 (-6)
Copper	2	2 (0)	0 (-2)	0 (-2)
Lead	2	2 (0)	1 (-1)	1 (-1)
Mercury	1	1 (0)	0 (-1)	0 (-1)
Nickel	1	1 (0)	0 (-1)	0 (-1)
Selenium	12	11 (-1)	5 (-7)	5 (-7)
Thallium	8	7 (1)	4 (-4)	3 (-5)
Zinc	1	1 (0)	0 (-1)	0 (-1)
Any Pollutant[b]	38	28 (-10)	14 (-24)	7 (-31)

Source: U.S. EPA, 2024i.

Abbreviations: IRW (immediate receiving water); MCL (maximum contaminant level); NRWQC (National Recommended Water Quality Criteria).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

b—Total may not equal the sum of the individual values because some immediate receiving waters have multiple types of exceedances.

In the 2020 EA, the EPA conducted a water quality analysis using estimated monthly pollutant loadings and flow rates to assess the significance of monthly variability in the modeled water quality impacts. The results were similar to those using the annual average analysis, and the EPA determined the following key takeaways:

- Most worst-case months occur during the summer, whereas most best-case months occur during the winter and early spring.
- There is potential for impacts on aquatic life during certain periods characterized by low flows, high loadings, or a combination of the two.
- Certain geographic areas could experience adverse seasonal cumulative effects due to concurrent, or nearly concurrent, discharges of evaluated wastestreams from multiple plants.

These results suggest that seasonal water quality impacts from discharges of the evaluated wastestreams may be more prevalent than indicated by the annual average analysis. Seasonal cumulative effects in affected watersheds could be particularly pronounced during summer and early autumn. The EPA expects that swimming, fishing, and boating in local waterways are more common during these seasons, potentially increasing opportunities for exposure to degraded water quality conditions in the immediate receiving waters. In addition, fish species that spawn in the affected waterways during these periods (including federally threatened or endangered species) could have an increased potential for adverse impacts from pollutant exposure, since the timing of their sensitive life stages would align with worst-case water quality conditions. See the 2020 EA (U.S. EPA, 2020a) for more details.

Appendix C of the 2020 EA (U.S. EPA, 2020a) provides details on the following limitations and uncertainties of the IRW Water Quality Module:

- Estimated pollutant loadings are based on data from a subset of steam electric power plants.
- It uses annual-average pollutant loadings and flow rates.
- It does not consider temporal variability and pollutant speciation.
- It does not account for ambient background pollutant concentrations or contributions from other point and nonpoint sources.
- It assumes that equilibrium is quickly attained within the waterbody following discharge and is consistently maintained between the water column and surficial bottom sediments.
- It assumes that pollutants dissolved or sorbed within the water column and bottom sediments can be described by a partition coefficient and other calculation assumptions.
- It assumes that pollutants sorbed to bottom sediments are considered a net loss from the water column and assumes a pollutant burial rate of zero within the bottom sediment.

4.1.2 Wildlife Impacts

As described in Section 3.4, the IRW Wildlife Module assesses impacts to sediment biota, minks, and eagles. This analysis expands on the evaluation of potential wildlife impacts based on the Freshwater Chronic and Acute NRWQC in the Water Quality Module. Table 11 presents the number of immediate receiving waters with modeled exceedances of the threshold effect concentrations (TECs) and no effect hazard concentrations (NEHCs)[19] under baseline and reduction in those exceedances under the regulatory options. Results are presented for all pollutants in aggregate and individually for pollutants with exceedances. The EPA did not have benchmark data to compare thallium concentrations in the immediate receiving water; therefore, that pollutant is excluded from the wildlife impacts analysis.

Under baseline, the EPA estimated that all eight evaluated pollutants had one or more immediate receiving water that exceeded sediment TECs. Pollutants with exceedances in multiple receiving waters included arsenic, cadmium, copper, mercury, nickel, selenium, and zinc. Lead had an exceedance under baseline and all the regulatory options for one receiving water. Under the final rule (Option B), the number of immediate receiving waters with exceedances of TECs decreases by at least 70 percent for five of the eight pollutants (arsenic, cadmium, mercury, nickel, and zinc). Copper and selenium had smaller improvements under the final rule, with respective reductions of 50 and 54 percent of immediate receiving waters exceeding the TEC.

Four pollutants (cadmium, mercury, selenium, and zinc) exceeded the NEHCs for minks and eagles under baseline and the regulatory options. Under the final rule (Option B), the EPA calculated that the number of immediate receiving waters exceeding the NEHC for minks decreased by 14 immediate receiving waters for mercury and nine immediate receiving waters for selenium. The number of immediate receiving waters exceeding the NEHC for eagle decreased by 19 immediate receiving waters for mercury and nine immediate receiving waters for selenium under the final rule. Under baseline, cadmium and zinc exceeded NEHC for minks and eagles at one receiving water; the final rule will eliminate these exceedances.

[19] Table 5 in Section 3 presents the benchmarks values for the pollutants evaluated.

Table 11. Modeled IRWs with Exceedances of TECs and NEHCs Under Baseline and Regulatory Options

Wildlife Evaluation Benchmark	Pollutant[a]	Number of Modeled IRWs Exceeding Benchmark Value (Difference Relative to Baseline)[b]			
		Baseline	Option A	Option B	Option C
Sediment TEC	Any pollutant	24	24 (0)	11 (-13)	7 (-17)
	Arsenic	3	2 (-1)	0 (-3)	0 (-3)
	Cadmium	8	5 (-3)	2 (-6)	2 (-6)
	Copper	2	2 (0)	1 (-1)	1 (-1)
	Lead	1	1 (0)	1 (0)	1 (0)
	Mercury	19	9 (-10)	2 (-17)	2 (-17)
	Nickel	14	6 (-8)	2 (-12)	2 (-12)
	Selenium	24	24 (0)	11 (-13)	7 (-17)
	Zinc	7	4 (-3)	2 (-5)	2 (-5)
Fish ingestion NEHC for minks	Any pollutant	16	16 (0)	6 (-10)	5 (-11)
	Cadmium	1	1 (0)	0 (-1)	0 (-1)
	Mercury	16	7 (-9)	2 (-14)	2 (-14)
	Selenium	15	15 (0)	6 (-9)	5 (-10)
	Zinc	1	1 (0)	0 (-1)	0 (-1)
Fish ingestion NEHC for eagles	Any pollutant	22	17 (-5)	6 (-16)	5 (-17)
	Cadmium	1	1 (0)	0 (-1)	0 (-1)
	Mercury	22	15 (-7)	3 (-19)	2 (-20)
	Selenium	15	15 (0)	6 (-9)	5 (-10)
	Zinc	1	1 (0)	0 (-1)	0 (-1)
Any Wildlife Pollutant Benchmark for Any Pollutant[c]		24	24 (0)	11 (-13)	7 (-17)

Source: U.S. EPA, 2024i.

Abbreviations: IRW (immediate receiving water); TEC (threshold effect concentration); NEHC (no effect hazard concentration).

a—Thallium excluded from the analysis (no benchmarks for comparison). No immediate receiving waters exceeded the TEC for copper and lead. No immediate receiving waters exceeded NEHC benchmarks for arsenic, cadmium, copper, lead, nickel, or zinc.

b—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

c—Total may not equal the sum of the individual values because some immediate receiving waters have multiple types of exceedances.

Appendix D of the 2020 EA (U.S. EPA, 2020a) provides details on the following limitations and uncertainties of the IRW Wildlife Module:

- Impact estimates are based on an individual exposure pathway and individual pollutant exposure rather than cumulative risks across exposure pathways and the interaction of multiple pollutants.
- Bioaccumulation factors are not available for all pollutants (use of bioconcentration factors does not account for the accumulation of pollutants via the food web).
- It does not consider indirect ecological effects such as depletion of food sources.

- It assumes the selected receptor species and receiving water occur together (*i.e.*, all immediate receiving waters are habitats for the receptor species).
- It assumes the diet of the receptor species consists of fish inhabiting the immediate receiving water.
- It assumes all forms of a pollutant are equally bioavailable to ecological receptors.
- Modeling assumes that the receiving water is fully mixed; however, water in lakes might stratify and affect chemical speciation by stratum.

4.1.3 Human Health Impacts

The IRW Human Health Module evaluates noncancer and cancer human health impacts among various human cohorts (recreational and subsistence fishers; children and adults; and different race/ethnicity categories) from consuming fish caught from immediate receiving waters that are contaminated by discharges of the evaluated wastestreams. The module uses oral reference doses (RfDs) to evaluate changes in noncancer health risks and a lifetime excess cancer risk (LECR) benchmark value of one-in-a-million, or 10^{-6}, to evaluate changes in cancer risk. This analysis expands on the evaluation of potential human health impacts based on the NRWQC and MCLs in the Water Quality Module.

Under baseline, the EPA estimated the average daily dose of one or more individual pollutant from fish consumption among subsistence fishers exceed the oral RfDs (noncancer) in 31 to 39 (27 to 34 percent) of immediate receiving waters, depending on the age group evaluated. Average daily doses among recreational fishers exceeded oral RfDs in 26 to 28 (23 to 25 percent) of immediate receiving waters. The lower prevalence of exceedances among recreational fishers is primarily due to their lower average fish tissue consumption rates. These results suggest that fish in immediate receiving waters can have health effects on surrounding fisher populations.

As shown in Table 12, the exceedances are primarily driven by mercury (as methylmercury), selenium, and thallium. The EPA calculated no exceedances for arsenic (inorganic) or nickel (total) under baseline and the regulatory options. The EPA estimated that the number of immediate receiving waters contributing to oral RfD (noncancer) exceedances decreased for all standard cohorts (*i.e.*, cohorts that are not split into different race/ethnicity categories) under all regulatory options. Under the final rule (Option B), the EPA estimated the following decreases in number of immediate receiving waters with fish that, if consumed, would exceed oral RfDs:

- Methylmercury—decrease by at least 20 immediate receiving waters for all standard cohorts.
- Selenium—decrease by at least seven immediate receiving waters for all standard cohorts.
- Thallium—decrease by at least eight immediate receiving waters for all standard cohorts.

Although the EPA did not directly assess the potential health effects posed by lead in this EA, the final rule decreases the annual loadings of lead to the environment by 187 pounds per year compared to baseline.[20] The monetized human health effects associated with changes in lead discharges are discussed in the BCA Report (U.S. EPA, 2024b).

As part of this rulemaking, the EPA evaluated the joint toxic action of multiple pollutants discharged into the evaluated wastestreams from steam electric power plants to determine potential cumulative human health impacts at the immediate receiving waters. See the memorandum *Assessment of Human Health Impacts from Multiple Pollutants in Steam Electric Power Plant Discharges* (U.S. EPA, 2024k) for a summary of the results.

[20] For comparison, the 2015 rule reduced lead discharges by 19,200 pounds per year (U.S. EPA, 2015a).

Table 12. Modeled IRWs with Exceedances of Oral RfD (Noncancer Human Health Effects) Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Pollutant	Number of Modeled IRWs Exceeding Oral RfD (Difference Relative to Baseline)[a]			
		Baseline	Option A	Option B	Option C
Child—recreational	Any pollutant	28	22 (-6)	9 (-19)	6 (-22)
	Cadmium	3	2 (-1)	1 (-2)	1 (-2)
	Methylmercury	28	22 (-6)	8 (-20)	5 (-23)
	Selenium	15	15 (0)	6 (-9)	5 (-10)
	Thallium	16	15 (-1)	6 (-10)	5 (-11)
	Zinc	1	1 (0)	0 (-1)	0 (-1)
Child—subsistence	Any pollutant	39	28 (-11)	15 (-24)	8 (-31)
	Cadmium	4	4 (0)	2 (-2)	2 (-2)
	Copper	1	1 (0)	0 (-1)	0 (-1)
	Methylmercury	38	28 (-10)	15 (-23)	8 (-30)
	Selenium	22	22 (0)	8 (-14)	5 (-17)
	Thallium	24	19 (-5)	10 (-14)	7 (-17)
	Zinc	1	1 (0)	0 (-1)	0 (-1)
Adult—recreational	Any pollutant	26	18 (-8)	6 (-20)	5 (-21)
	Cadmium	1	1 (0)	1 (0)	1 (0)
	Methylmercury	25	17 (-8)	5 (-20)	4 (-21)
	Selenium	12	12 (0)	5 (-7)	4 (-8)
	Thallium	13	9 (-4)	5 (-8)	4 (-9)
	Zinc	1	1 (0)	0 (-1)	0 (-1)
Adult—subsistence	Any pollutant	31	23 (-8)	9 (-22)	6 (-25)
	Cadmium	4	3 (-1)	2 (-2)	2 (-2)
	Methylmercury	31	23 (-8)	9 (-22)	6 (-25)
	Selenium	15	15 (0)	6 (-9)	5 (-10)
	Thallium	16	15 (-1)	6 (-10)	5 (-11)
	Zinc	1	1 (0)	0 (-1)	0 (-1)
Any Pollutant and Age/Fishing Mode Cohort[b]		**39**	**28 (-11)**	**15 (-24)**	**8 (-31)**

Source: U.S. EPA, 2024i.

Abbreviations: IRW (immediate receiving water); RfD (reference dose).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

b—Total may not equal the sum of the individual values because some immediate receiving waters have multiple types of exceedances.

Under baseline, the EPA estimated that nine immediate receiving waters (eight percent) could contain fish contaminated with inorganic arsenic that present cancer risks greater than the LECR benchmark value of one-in-a-million for the most sensitive, standard cohort (adult subsistence fishers). Under the final rule (Option B), the number of immediate receiving waters whose fish exceed this cancer risk threshold will decrease by seven (78 percent) for this cohort. Table 13 presents the number of immediate receiving waters where the LECR for inorganic arsenic exceeds one-in-a-million.

Table 13. Modeled IRWs with LECR Greater Than One-in-a-Million (Cancer Human Health Effects) Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Number of Modeled IRWs with LECR Greater than One-in-a-Million (Difference Relative to Baseline)[a]			
	Baseline	Option A	Option B	Option C
Child—recreational	0	0 (0)	0 (0)	0 (0)
Child—subsistence	3	2 (-1)	1 (-2)	1 (-2)
Adult—recreational	4	2 (-2)	2 (-2)	2 (-2)
Adult—subsistence	9	3 (-6)	2 (-7)	2 (-7)
Total Number of Immediate Receiving Waters[b]	**9**	**3 (-6)**	**2 (-7)**	**2 (-7)**

Source: U.S. EPA, 2024i.

Abbreviations: IRW (immediate receiving water); LECR (lifetime excess cancer risk).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

b—Total may not equal the sum of the individual values because some immediate receiving waters have multiple types of exceedances.

The EPA also performed an analysis using fish consumption rates for recreational and subsistence fishers in different race/ethnicity categories to assess whether the steam electric power plant wastewater discharges disproportionately affect minority groups. Table 14 presents the number of immediate receiving waters in which the modeled average daily dose of any pollutant exceeds the oral RfD. Table 15 presents the number of immediate receiving waters that could contain fish contaminated with inorganic arsenic that present cancer risks greater than the LECR benchmark value of one-in-a-million. Results in the tables are presented by cohort (recreational and subsistence fisher) and race/ethnicity category.

As shown in Table 14, the number of immediate receiving waters where the average daily dose of at least one individual pollutant from fish consumption exceeds the oral RfDs is highest among subsistence fishers (child or adults) that fall in the "Other, Including Multiple Races" category. The increased prevalence of exceedances is primarily due to higher average fish tissue consumption rates for this category and fishing mode. Under the final rule, the EPA estimated reductions in the number of immediate receiving waters with exceedances of human health risk under the final rule to be between 19 and 23 immediate receiving waters, depending on the fisher type and cohort.

Inorganic arsenic concentrations in fish resulted in an estimated cancer risk greater than one-in-a-million to adult subsistence, minority fishers (*i.e.*, excluding the non-Hispanic white cohort) in nine to 11 immediate receiving waters under baseline. Four immediate receiving waters had inorganic arsenic concentrations in fish above the LECR threshold of one-in-a-million for adult recreational, minority fishers under baseline. Cancer risks for the child cohorts are lower. The estimated cancer risk among adult minority fishers is higher than the risk among adult nonminority fishers. The EPA estimated reductions in the number of immediate receiving waters with exceedances of cancer risk under the final rule to be up to eight immediate receiving waters, depending on the fisher type and cohort.

Appendix A presents the IRW Human Health Module results by pollutant for each age group and mode of fishing for both standard and race/ethnicity cohorts.

Table 14. Modeled IRWs with Exceedances of Oral RfDs by Race/Ethnicity Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Race/Ethnicity Category	Number of Modeled IRWs Exceeding Oral RfD (Difference Relative to Baseline)[a]			
		Baseline	Option A	Option B	Option C
Child—recreational	Non-Hispanic White	26	18 (-8)	6 (-20)	5 (-21)
	Non-Hispanic Black	26	19 (-7)	7 (-19)	5 (-21)
	Mexican-American	28	20 (-8)	8 (-20)	5 (-23)
	Other Hispanic	26	19 (-7)	7 (-19)	5 (-21)
	Other, Including multiple races	28	20 (-8)	8 (-20)	5 (-23)
Child—subsistence	Non-Hispanic White	29	23 (-6)	9 (-20)	6 (-23)
	Non-Hispanic Black	31	23 (-8)	9 (-22)	6 (-25)
	Mexican-American	32	25 (-7)	12 (-20)	7 (-25)
	Other Hispanic	32	23 (-9)	9 (-23)	6 (-26)
	Other, including multiple races	34	26 (-8)	14 (-20)	8 (-26)
Adult—recreational	Non-Hispanic White	26	18 (-8)	6 (-20)	5 (-21)
	Non-Hispanic Black	26	19 (-7)	7 (-19)	5 (-21)
	Mexican-American	28	20 (-8)	8 (-20)	5 (-23)
	Other Hispanic	26	19 (-7)	7 (-19)	5 (-21)
	Other, including multiple races	28	20 (-8)	8 (-20)	5 (-23)
Adult—subsistence	Non-Hispanic White	29	23 (-6)	9 (-20)	6 (-23)
	Non-Hispanic Black	31	23 (-8)	9 (-22)	6 (-25)
	Mexican-American	32	25 (-7)	12 (-20)	7 (-25)
	Other Hispanic	32	23 (-9)	9 (-23)	6 (-26)
	Other, including multiple races	34	26 (-8)	14 (-20)	8 (-26)

Source: U.S. EPA, 2024i.

Abbreviations: IRW (immediate receiving water); RfD (reference dose).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

Table 15. Modeled IRWs with LECR Greater Than One-in-a-Million (Cancer Human Health Effects) Race/Ethnicity Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Race/Ethnicity Category	Number of Modeled IRWs with LECR Above One-in-a-Million (Difference Relative to Baseline)[a]			
		Baseline	Option A	Option B	Option C
Child—recreational	Non-Hispanic White	0	0 (0)	0 (0)	0 (0)
	Non-Hispanic Black	0	0 (0)	0 (0)	0 (0)
	Mexican-American	0	0 (0)	0 (0)	0 (0)
	Other Hispanic	0	0 (0)	0 (0)	0 (0)
	Other, including multiple races	0	0 (0)	0 (0)	0 (0)
Child—subsistence	Non-Hispanic White	2	2 (0)	1 (-1)	0 (-2)
	Non-Hispanic Black	3	2 (-1)	1 (-2)	1 (-2)
	Mexican-American	3	2 (-1)	1 (-2)	1 (-2)
	Other Hispanic	3	2 (-1)	1 (-2)	1 (-2)
	Other, including multiple races	3	2 (-1)	1 (-2)	1 (-2)
Adult—recreational	Non-Hispanic White	4	2 (-2)	2 (-2)	2 (-2)
	Non-Hispanic Black	4	2 (-2)	2 (-2)	2 (-2)
	Mexican-American	4	2 (-2)	2 (-2)	2 (-2)
	Other Hispanic	4	2 (-2)	2 (-2)	2 (-2)
	Other, including multiple races	4	2 (-2)	2 (-2)	2 (-2)
Adult—subsistence	Non-Hispanic White	9	3 (-6)	2 (-7)	2 (-7)
	Non-Hispanic Black	9	3 (-6)	2 (-7)	2 (-7)
	Mexican-American	10	3 (-7)	2 (-8)	2 (-8)
	Other Hispanic	10	3 (-7)	2 (-8)	2 (-8)
	Other, including multiple races	11	4 (-7)	3 (-8)	2 (-9)

Source: U.S. EPA, 2024i.

Abbreviations: IRW (immediate receiving water); LECR (lifetime excess cancer risk).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

The EPA also compared trophic level 4 (T4) fish tissue pollutant concentrations to fish consumption advisory screening values to assess the potential for discharges of the evaluated wastestreams to cause or contribute to fish advisories and pose a human health risk.[21] Based on the modeling results, up to 32 immediate receiving waters (28 percent) may contain fish with contamination levels that could trigger advisories for recreational and/or subsistence fishers under baseline; this decreases to 10 immediate receiving waters (9 percent) under the final rule (Option B). Mercury and selenium are the pollutants

[21] For this analysis, the EPA used the fish consumption advisory screening values from the EPA's *Guidance for Assessing Chemical Contaminant Data for Uses in Fish Advisories, Volume 1* (U.S. EPA, 2000).

most likely to exceed screening values. Table 16 presents the number of immediate receiving waters where the modeled T4 fish tissue concentrations exceed screening values used for fish advisories.[22]

Table 16. Comparison of Modeled T4 Fish Tissue Concentrations to Fish Advisory Screening Values Under Baseline and Regulatory Options

Pollutant	Screening Value (ppm)	Number of IRWs with Modeled T4 Fish Tissue Concentrations Exceeding Screening Value (Difference Relative to Baseline)[a]			
		Baseline	Option A	Option B	Option C
Recreational Fishers					
Arsenic (as inorganic arsenic)[b]	0.026	0	0	0	0
Cadmium	4	1	1	0	0
Mercury (as methylmercury)	0.4	22	16	4	3
Selenium	20	8	7	3	3
Total for Any Pollutant in Evaluated Wastestreams[c]	—	**22**	**16**	**4**	**3**
Subsistence Fishers					
Arsenic (as inorganic arsenic)[b]	0.00327	0	0	0	0
Cadmium	0.491	4	3	2	2
Mercury (as methylmercury)	0.049	32	24	10	6
Selenium	2.457	18	18	8	5
Total for Any Pollutant in Evaluated Wastestreams[c]	—	**32**	**24**	**10**	**6**

Source: U.S. EPA, 2024i.

Abbreviations: IRW (immediate receiving water); ppm (parts per million); T4 (trophic level 4).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

b—Screening value presented is for carcinogenic effects (lower value than noncarcinogenic effects).

c—Total may not equal the sum of the individual values because some immediate receiving waters are impaired for multiple pollutants.

Appendix E of the 2020 EA (U.S. EPA, 2020a) details the following limitations and uncertainties of the IRW Human Health Module:

- Impact estimates are based on individual exposure pathway and individual pollutant exposure rather than cumulative risks across exposure pathways and the interaction of multiple pollutants.
- Exposure factors will vary by individual physical characteristics.
- The uncertainties associated with human health benchmark values are present, as described in the EPA's *Guidelines for Carcinogen Risk Assessment* (U.S. EPA, 2005) and Integrated Risk Information System (IRIS) (U.S. EPA, 2019).

[22] As described in Section 4.2.2, none of the immediate receiving waters are under fish consumption advisories for cadmium or selenium; each advisory screening value exceedance shown in Table 16 for these pollutants therefore indicates a "new" receiving water of concern that may warrant additional monitoring and/or evaluation of human health risk.

- The module assumes that the diet of the human health cohorts consists of fish inhabiting the immediate receiving water.
- It assumes all forms of a pollutant are equally bioavailable to human health cohorts.

4.2 Discharges to Sensitive Environments

As discussed in Section 3.5, the EPA evaluated pollutant discharges to sensitive environments (*i.e.*, impaired waters, fish consumption advisory waters, and drinking water resources). Discharges of the evaluated wastestreams to CWA section 303(d) impaired waters and fish consumption advisory waters[23] may contribute to water quality impairments, increased health risk associated with consuming fish, and a reduction in the extent of viable downstream fisheries. Discharges of pollutants in the evaluated wastestreams to drinking water resources would likely be reduced to safe levels as part of intake water treatment; however, these pollutants could affect the effectiveness of the treatment processes, which could increase public drinking water treatment costs.[24] Table 17 summarizes the number of immediate receiving waters that are classified as either CWA section 303(d) impaired waters, fish consumption advisory waters, or drinking water resources under baseline and each regulatory option. The EPA evaluated 125 immediate receiving waters that receive discharges of the evaluated wastestreams, either directly or indirectly via POTWs. Of these 125 immediate receiving waters, all 125 receive discharges of the evaluated wastestreams under baseline, 105 do under Option A, 57 do under Option B, and 18 do under Option C. Sections 4.2.1 through 4.2.3 present the results of the EPA's assessment of immediate receiving waters that are sensitive environments.[25]

Table 17. Modeled IRWs Identified as CWA Section 303(d) Impaired Waters, Fish Consumption Advisory Waters, or Drinking Water Resources Under Baseline and Regulatory Options

Sensitive Environment Category	Number of Modeled IRWs Receiving Discharges of the Evaluated Wastestreams (Difference Relative to Baseline)[a]			
	Baseline	Option A	Option B	Option C
IRWs receiving discharges of the evaluated wastestreams	125	105	57	18
Impaired water	64	55 (-9)	24 (-40)	8 (-56)
Subset impaired for one or more pollutants associated with the evaluated wastestreams[b]	43	37 (-6)	17 (-26)	6 (-37)
Fish consumption advisory water	72	60 (-12)	33 (-39)	12 (-60)
Subset with a fish consumption advisory for one or more pollutants associated with the evaluated wastestreams[c]	50	42 (-8)	23 (-27)	10 (-40)

[23] Fish consumption advisory waters are waterbodies for which states, territories, and authorized tribes have issued fish consumption advisories, indicating that pollutant concentrations in the tissues of fish inhabiting those waters are considered unsafe to consume.

[24] For more information on drinking water treatment processes used to reduce or eliminate metals commonly detected in the evaluated wastestreams from steam electric power plants, see the memorandum *Drinking Water Treatment Technologies That Can Reduce Metal and Selenium Concentrations Associated with Discharges from Steam Electric Power Plants* (ERG, 2013).

[25] See the memorandum *Proximity Analyses and Supporting Documentation for the Environmental Assessment of the Final Supplemental Steam Electric Rule* (U.S. EPA, 2024j) for a description of the methodology used to evaluate the proximity of plants to CWA section 303(d) impaired waters, fish consumption advisory waters, and drinking water resources.

Table 17. Modeled IRWs Identified as CWA Section 303(d) Impaired Waters, Fish Consumption Advisory Waters, or Drinking Water Resources Under Baseline and Regulatory Options

Sensitive Environment Category	Number of Modeled IRWs Receiving Discharges of the Evaluated Wastestreams (Difference Relative to Baseline)[a]			
	Baseline	Option A	Option B	Option C
Drinking water resource within five miles[d]	116	97 (-19)	54 (-62)	16 (-100)

Source: U.S. EPA, 2024j.

Abbreviations: IRW (immediate receiving water).

a—For this proximity analysis, the EPA evaluated 125 immediate receiving waters that receive discharges of the evaluated wastestreams, either directly or indirectly via a publicly owned treatment works. Of these 125 immediate receiving waters, all 125 receive discharges of the evaluated wastestreams under baseline, 105 do under Option A, 57 do under Option B, and 18 do under Option C.

b—The subset of immediate receiving waters that were impaired due to one or more of the following pollutants: arsenic, boron, cadmium, chlorides, chromium, copper, lead, manganese, mercury, metals (other than mercury), nitrogen (reported as ammonia, nitrate, or nitrite), nutrients, phosphorus, selenium, total dissolved solids, and zinc.

c—The subset of immediate receiving waters with a fish consumption advisory for one or more of the following pollutants: cadmium, lead, mercury, and selenium.

d—Drinking water resources include intakes and reservoirs, public wells, and sole-source aquifers.

4.2.1 Impaired Waters

The EPA estimated that more than half (64 of 125) of the immediate receiving waters analyzed in this EA are CWA Section 303(d) impaired waters.[26] As shown in Table 18, 18 of the immediate receiving waters under baseline are impaired for mercury, 16 are impaired for metals (other than mercury),[27] and eight are impaired for nutrients. Figure 3 through Figure 5 present the locations of immediate receiving waters that are classified as impaired by high concentrations of these three impairment categories. A total of 43 immediate receiving waters under baseline (34 percent) are impaired for a pollutant associated with the evaluated wastestreams.

Under the final rule (Option B), 40 immediate receiving waters listed as impaired (62.5 percent) will no longer receive discharges of the evaluated wastestreams.

[26] See the memorandum *Proximity Analyses and Supporting Documentation for the Environmental Assessment of the Final Supplemental Steam Electric Rule* (U.S. EPA, 2024j) for a complete list of the impairment categories identified in the EPA's CWA section 303(d) waters proximity analysis.

[27] The "metals (other than mercury)" impairment category in the EPA's national CWA section 303(d) impaired waters data set includes impairments caused by metalloids and nonmetals such as arsenic, boron, and selenium.

Table 18. Modeled IRWs Identified as CWA Section 303(d) Impaired Waters for Pollutants Present in the Evaluated Wastestreams Under Baseline and Regulatory Options

Pollutant Causing Impairment	Number of Modeled IRWs Receiving Discharges of the Evaluated Wastestreams (Difference Relative to Baseline)[a]			
	Baseline	Option A	Option B	Option C
Mercury	18	18 (0)	11 (-7)	3 (-15)
Metals, other than mercury[b]	16	12 (-4)	2 (-14)	2 (-14)
Nutrients	8	8 (0)	5 (-3)	1 (-7)
TDS	1	0 (-1)	0 (-1)	0 (-1)
Total for Pollutants Associated with the Evaluated Wastestreams[c]	**43**	**37 (-6)**	**17 (-26)**	**6 (-37)**
Total for Any Impairment Category	64	55 (-9)	24 (-40)	8 (-56)

Source: U.S. EPA, 2024j.

Abbreviations: CWA (Clean Water Act); IRW (immediate receiving water); TDS (total dissolved solids).

a—For this proximity analysis, the EPA evaluated 125 immediate receiving waters that receive discharges of the evaluated wastestreams, either directly or indirectly via a publicly owned treatment works. Of these 125 immediate receiving waters, all 125 receive discharges of the evaluated wastestreams under baseline, 105 do under Option A, 57 do under Option B, and 18 do under Option C.

b—Of the 16 immediate receiving waters classified as impaired for "metals, other than mercury" under baseline, five are specifically listed as impaired for one or more of the following individual pollutants evaluated in this environmental assessment: cadmium (1), copper (1), lead (2), manganese (2), selenium (1), and zinc (1). One additional immediate receiving water is impaired for boron (but not included in the "metals, other than mercury" impairment category).

c—Total may not equal the sum of the individual values because some immediate receiving waters are impaired for multiple pollutants.

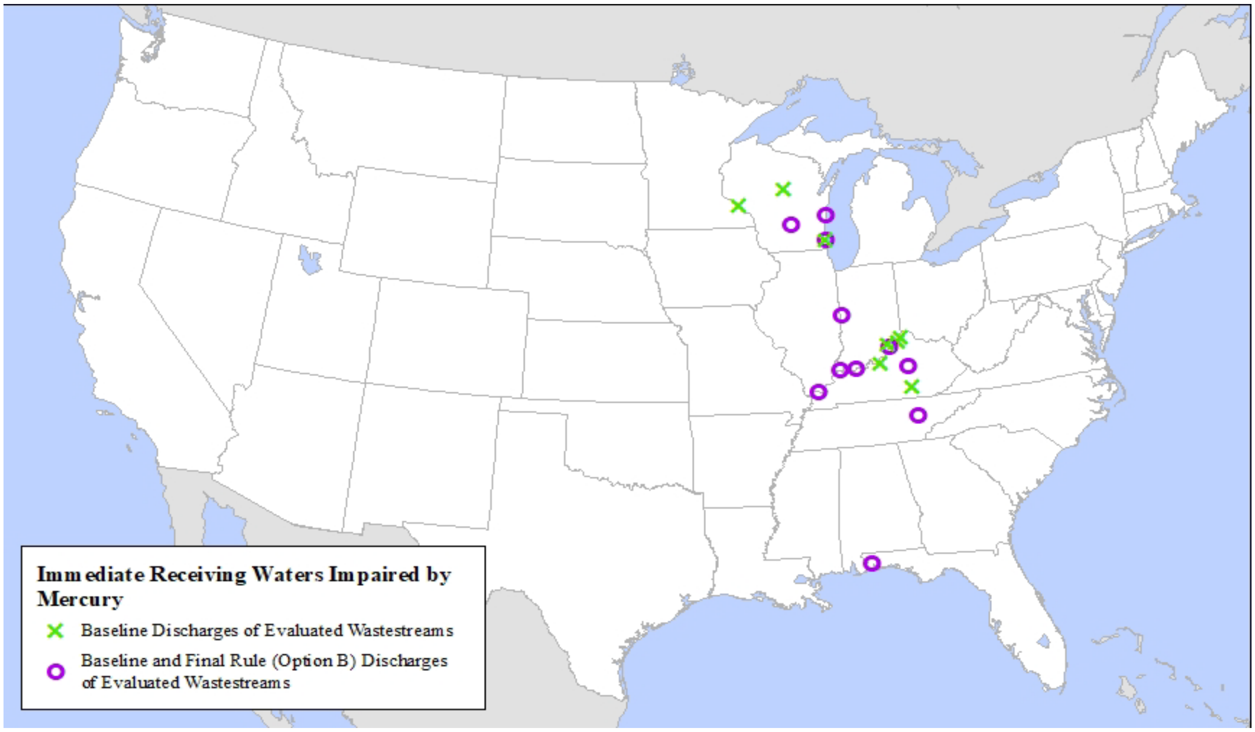

Figure 3. Immediate Receiving Waters Impaired by Mercury

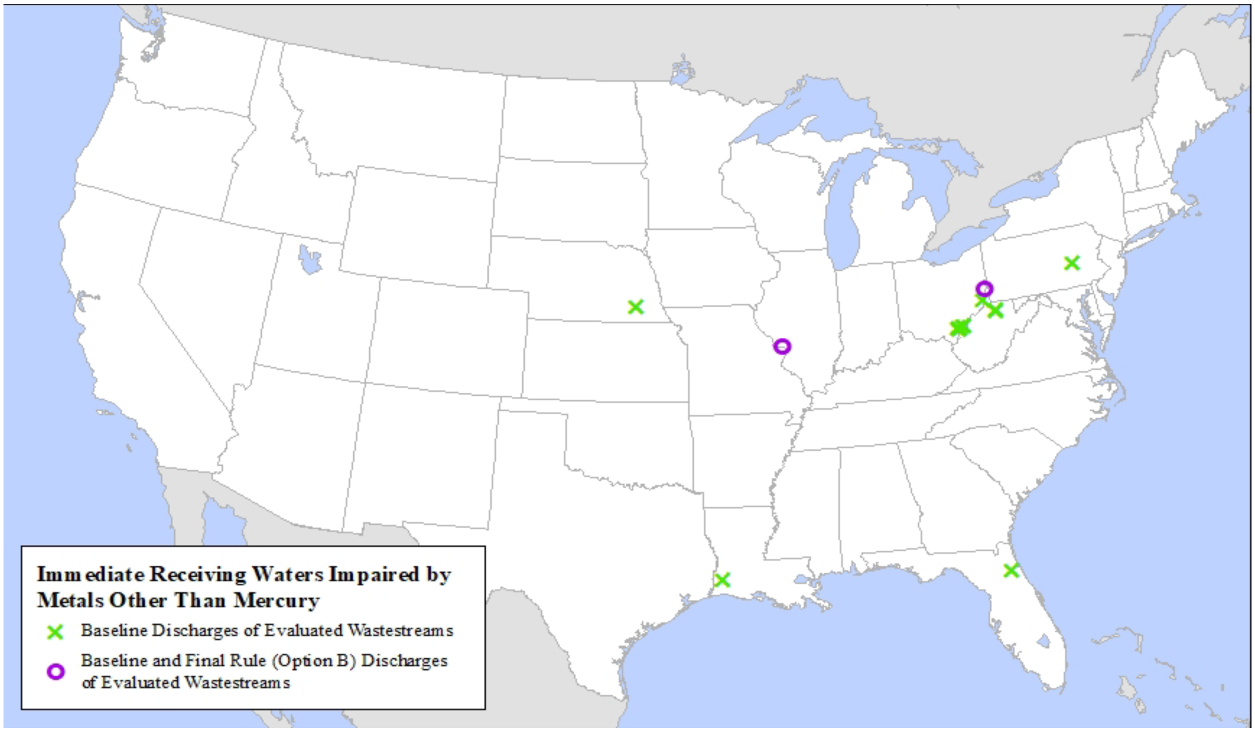

Figure 4. Immediate Receiving Waters Impaired by Metals Other Than Mercury

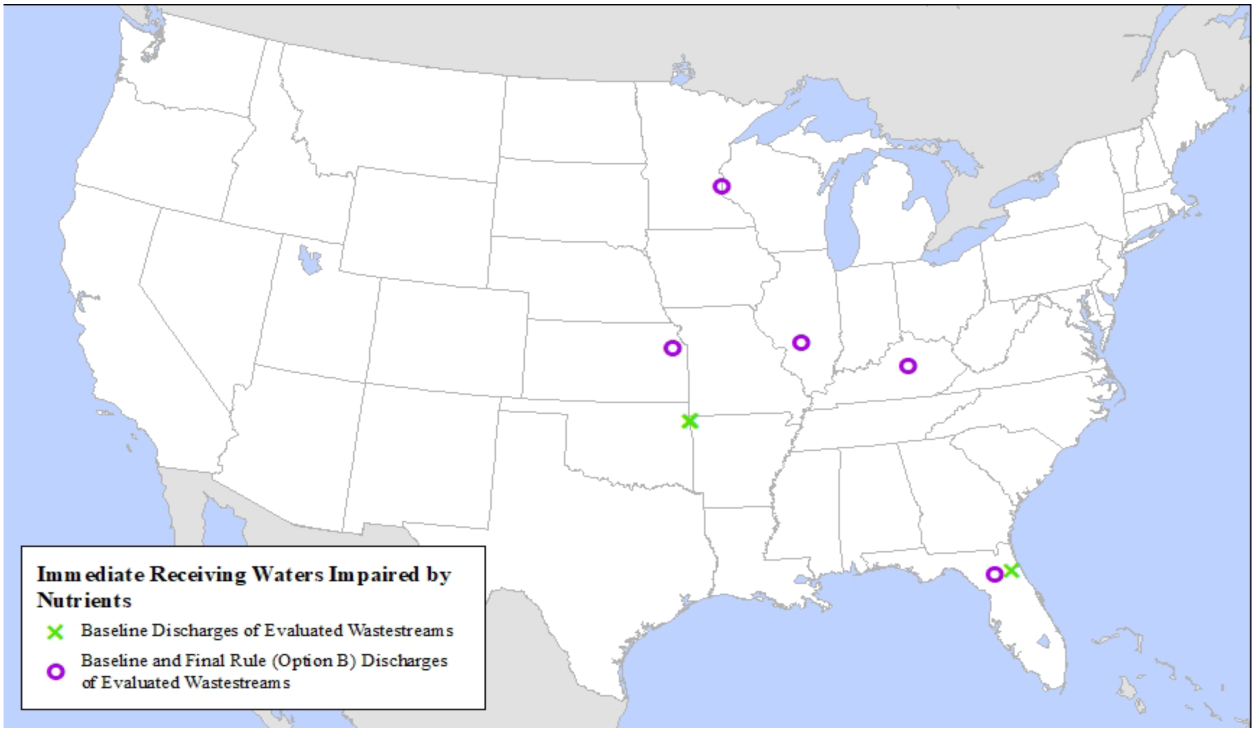

Figure 5. Immediate Receiving Waters Impaired by Nutrients

As shown in Table 2 of this report, the final rule (Option B) results in a decrease in pollutant loadings to the immediate receiving waters, including sensitive environments. The reduction in loadings will help impaired waters to recover; decrease the bioaccumulation of toxic pollutants in fish, thereby reducing the number of fish advisories; and reduce stress on threatened and endangered species and sensitive watersheds such as drinking water resources. The final rule has a net decrease on the loadings of pollutants to waters that are already impaired for those pollutants. The EPA estimated the following net changes relative to baseline in pollutant loadings to impaired waters once requirements under the final rule have been met by the steam electric power plants discharging the evaluated wastestreams to the impaired waterbodies:

- Decrease in nitrogen and phosphorus loadings of 4,910 pounds per year (lb/year) and 220 lb/year, respectively, to nutrient-impaired waters.
- Decrease in phosphorus loadings of 23.0 lb/year to phosphorus-impaired waters.
- Decrease in mercury loadings of 5.90 lb/year to mercury-impaired waters.
- Decrease in loadings to receiving waters impaired for a metal (except mercury), including:
    - Aluminum decrease of 7,190 lb/year.
    - Arsenic decrease of 88.3 lb/year.
    - Boron decrease of 892,000 lb/year.
    - Cadmium decrease of 69.9 lb/year.
    - Chromium decrease of 2,660 lb/year.
    - Copper decrease of 42.8 lb/year.
    - Iron decrease of 37,400 lb/year.
    - Lead decrease of 25.6 lb/year.
    - Magnesium decrease of 12,700,000 lb/year.
    - Manganese decrease of 80,700 lb/year.
    - Nickel decrease of 419 lb/year.
    - Selenium decrease of 267 lb/year.
    - Thallium decrease of 43.2 lb/year.
    - Vanadium decrease of 2,490 lb/year.
    - Zinc decrease of 809 lb/year.
- Decrease in TDS loadings of 135,000 lb/year to one TDS-impaired waterbody.

4.2.2 Fish Consumption Advisories

The EPA estimated that 58 percent (72 of 125) of the immediate receiving waters analyzed in this EA are under a fish consumption advisory.[28] As shown in Table 19, 50 of the immediate receiving waters under baseline (40 percent) are under an advisory for a pollutant associated with the evaluated wastestreams. All of these immediate receiving waters are under a fish consumption advisory for mercury, and one is under a fish advisory for lead. Figure 6 presents the locations of immediate receiving waters with fish consumption advisories for mercury.

Under the final rule (Option B), 39 immediate receiving waters with a fish consumption advisory (54 percent reduction) will no longer receive discharges of the evaluated wastestreams. Under the final rule,

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[28] See the memorandum *Proximity Analyses and Supporting Documentation for the Environmental Assessment of the Final Supplemental Steam Electric Rule* (U.S. EPA, 2024j) for a complete list of the types of advisories identified in the EPA's fish consumption advisories proximity analysis, including advisories due to pollutants that are not associated with the evaluated wastestreams.

the EPA estimated a decrease in the annual mercury loadings of 22.8 lb/year to immediate receiving waters with a fish consumption advisory for mercury.

Table 19. Modeled IRWs Identified as Fish Consumption Advisory Waters for Pollutants Present in the Evaluated Wastestreams Under Baseline and Regulatory Options

Pollutant Causing Fish Consumption Advisory	Number of Modeled IRWs Receiving Discharges of the Evaluated Wastestreams (Difference Relative to Baseline)[a]			
	Baseline	Option A	Option B	Option C
Lead	1	1 (0)	1 (0)	0 (-1)
Mercury	50	42 (-8)	23 (-27)	10 (-40)
Total for Pollutants Associated with the Evaluated Wastestreams[b]	50	42 (-8)	23 (-27)	10 (-40)
Total for Any Fish Advisory	72	60 (-12)	33 (-39)	12 (-60)

Source: U.S. EPA, 2024j.

Abbreviations: IRW (immediate receiving water).

a—For this proximity analysis, the EPA evaluated 125 immediate receiving waters that receive discharges of the evaluated wastestreams, either directly or indirectly via a publicly owned treatment works. Of these 125 immediate receiving waters, all 125 receive discharges of the evaluated wastestreams under baseline, 105 do under Option A, 57 do under Option B, and 18 do under Option C.

b—Total may not equal the sum of the individual values because some immediate receiving waters are under a fish advisory for multiple pollutants.

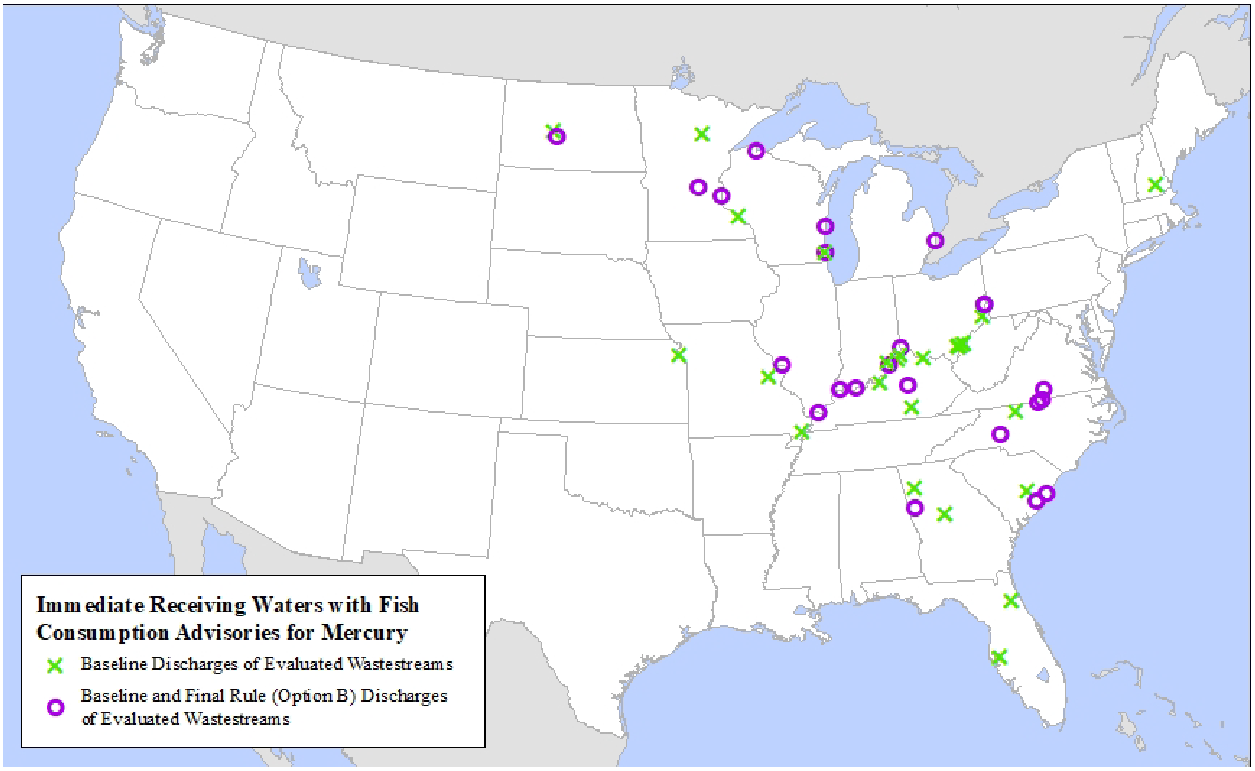

Figure 6. Immediate Receiving Waters with Fish Consumption Advisories for Mercury

4.2.3 Drinking Water Resources

The EPA estimated that 93 percent (116 of 125) of the immediate receiving waters analyzed in this EA are located within 5 miles of a drinking water resource. Under baseline, 103 of the immediate receiving waters (82 percent) are located near public wells, 38 immediate receiving waters (30 percent) are located near drinking water intakes/reservoirs, and two immediate receiving waters (less than 2 percent) are located near sole-source aquifers. Table 20 presents the number of immediate receiving waters evaluated under baseline and the regulatory options and the number of those immediate receiving waters located within 5 miles of a drinking water resource.

Under the final rule (Option B), 62 immediate receiving waters located within 5 miles of a drinking water resource (53 percent reduction) will no longer receive discharges of the evaluated wastestreams.

As discussed in Section 2.2, drinking water supplies can be degraded by pollutants in steam electric power plant wastewater (Cross, 1981), and bromide and iodine discharges are of particular concern due to the formation of disinfection byproducts at drinking water treatment plants and their distribution systems. Under the final rule, the EPA estimated a decrease in bromide loadings of 945,000 to 6.17 million lb/year and a decrease in iodine loadings of 66,900 to 241,000 lb/year to immediate receiving waters located within five miles of drinking water resources.

Table 20. Modeled IRWs Identified as Located Within 5 Miles of a Drinking Water Resource Under Baseline and Regulatory Options

Type of Drinking Water Resource	Number of Modeled IRWs Receiving Discharges of the Evaluated Wastestreams (Difference Relative to Baseline)[a]			
	Baseline	Option A	Option B	Option C
Intakes and reservoirs	38	33 (-5)	24 (-14)	5 (-33)
Public wells	104	87 (-16)	49 (-54)	15 (-88)
Sole-source aquifers	2	2 (0)	1 (-1)	0 (-2)
Total for Any Immediate Receiving Water[b]	116	97 (-19)	54 (-62)	16 (-100)

Source: U.S. EPA, 2024j.

Abbreviations: IRW (immediate receiving water).

a—For this proximity analysis, the EPA evaluated 125 immediate receiving waters that receive discharges of the evaluated wastestreams, either directly or indirectly via a publicly owned treatment works. Of these 125 immediate receiving waters, all 125 receive discharges of the evaluated wastestreams under baseline, 105 do under Option A, 57 do under Option B, and 18 do under Option C.

b—Total may not equal the sum of the individual values because some immediate receiving waters are within five miles of multiple drinking water resource types.

4.3 Impacts in Downstream Surface Waters

The EPA performed an analysis of surface waters downstream from the immediate receiving water for each plant that discharges the evaluated wastestreams. The downstream analysis uses the outputs from a separate pollutant fate and transport model (see the BCA Report, U.S. EPA, 2024b, for a description) to assess potential water quality, wildlife, and human health impacts in approximately 17,000 river miles of downstream surface waters. The methodology, which uses estimated annual average pollutant loadings and surface water flow rates, is summarized in Section 3.6 of this report and presented in further detail in the memorandum *Downstream Modeling Analysis and Supporting Documentation for the Environmental Assessment of the Final Supplemental Steam Electric Rule* (U.S. EPA, 2024l).

Table 21 presents the results of this downstream analysis. This table lists each of the water quality, wildlife, and human health benchmark values used in the IRW Model[29] and indicates the total length of downstream surface waters for which the EPA calculated an exceedance of a benchmark value for at least one of the modeled pollutants. Based on the results of the downstream modeling, 777 downstream river miles are affected by steam electric power plant discharges under baseline. Under the final rule (Option B), pollutant concentrations exceeding water quality, wildlife, and/or human health benchmarks will decrease to 411 river miles (47 percent reduction).

Table 21. Modeled Downstream River Miles with Exceedances of Any Pollutant Evaluation Benchmark Value Under Baseline and Regulatory Options

Evaluation Benchmark	Modeled Downstream River Miles Exceeding Benchmark Value (Difference Relative to Baseline)[a]			
	Baseline	Option A	Option B	Option C
Water Quality Results				
Freshwater acute NRWQC	0	0 (0)	0 (0)	0 (0)
Freshwater chronic NRWQC	16.7	16.1 (-0.607)	2.51 (-14.2)	0 (-16.7)
Human health water and organism NRWQC	363	213 (-149)	104 (-258)	78.0 (-285)
Human health organism only NRWQC	121	29.5 (-91.7)	6.38 (-115)	0 (-121)
Drinking water MCL	1.23	1.23 (0)	0 (-1.23)	0 (-1.23)
Wildlife Results				
Fish ingestion NEHC for minks	40.4	27.5 (-12.9)	4.37 (-36.0)	0 (-40.4)
Fish ingestion NEHC for eagles	121	27.5 (-93.7)	4.37 (-117)	0 (-121)
Human Health Results—Noncancer				
Oral RfD for child (recreational)	289	186 (-103)	86.0 (-203)	65.1 (-224)
Oral RfD for adult (recreational)	203	94.8 (-108)	54.0 (-149)	41.5 (-162)
Oral RfD for child (subsistence)	688	469 (-219)	333 (-355)	301 (-387)
Oral RfD for adult (subsistence)	420	294 (-126)	193 (-226)	167 (-253)
Human Health Results—Cancer				
LECR for child (recreational)	0	0 (0)	0 (0)	0 (0)
LECR for adult (recreational)	1.23	0 (-1.23)	0 (-1.23)	0 (-1.23))
LECR for child (subsistence)	1.23	0 (-1.23)	0 (-1.23)	0 (-1.23)
LECR for adult (subsistence)	13.0	1.23 (-11.8)	0 (-13.0)	0 (-13.0)
Total for Any Benchmark[b]	**777**	**547 (-230)**	**411 (-366)**	**379 (-398)**

Source: U.S. EPA, 2024l.

Abbreviations: LECR (lifetime excess cancer risk); MCL (maximum contaminant level); NEHC (no effect hazard concentration); NRWQC (National Recommended Water Quality Criteria); RfD (reference dose).

a—River miles are rounded to three significant figures. As part of this analysis, the EPA evaluated approximately 17,000 river miles of surface waters downstream of immediate receiving waters. For this analysis, the EPA estimated pollutant concentrations in the immediate receiving water and the downstream receiving waters using the D-FATE model.

b—Total may not equal the sum of the individual values because some river miles exceed multiple benchmarks.

[29] The water quality outputs used in the downstream analysis were derived from a pollutant fate and transport model that does not simulate pollutant partitioning to the benthic layer; therefore, this analysis does not include comparisons to the sediment TEC.

4.4 Summary of Key Environmental and Human Health Improvements

The EPA estimated that the reduced discharges of pollutants to the immediate receiving waters expected from the final rule will translate into improvements in water quality and reduction in pollutant exposures for wildlife and human health in the immediate receiving waters and further downstream from steam electric power plant discharges. The final supplemental rule will result in the following environmental improvements as estimated by the EA:

- 63 percent reduction in the number of immediate receiving waters exceeding an NRWQC for the protection of human health.
- Over 85 percent reduction in the number of immediate receiving waters that support fish whose tissue pollutant concentrations exceed mercury benchmarks for the protection of piscivorous wildlife (represented by minks and eagles).
- 69 percent reduction in the number of immediate receiving waters that support fish whose tissue pollutant concentrations exceed fish consumption advisories.
- 62 percent reduction in the number of immediate receiving waters that support fish whose tissue pollutant concentrations pose a risk of noncancer health effects in exposed populations.
- 78 percent reduction in the number of immediate receiving waters that support fish whose arsenic tissue concentrations pose a cancer risk to exposed populations.

As shown in the downstream modeling analysis, discharges of the evaluated wastestreams affect surface waters beyond the immediate receiving waters. Pollutant removals associated with the final rule will improve environmental and human health for communities beyond the area immediately surrounding steam electric power plants.

The environmental improvements quantified in the EA do not encompass the full range of improvements that will result from the final supplemental rule. For example, the following improvements are not quantified (or have only limited analysis) in this EA:

- Reducing the loadings of bioaccumulative pollutants to the broader ecosystem, resulting in decrease in long-term exposures and sublethal ecological effects.
- Reducing sublethal chronic effects of toxic pollutants on aquatic life not captured by the NRWQC.
- Mitigating impacts to the population diversity and community structures of aquatic and aquatic-dependent wildlife.
- Reducing loadings of pollutants for which the EPA did not perform water quality modeling in support of the EA (*e.g.*, aluminum, boron, iron, manganese, nutrients, TDS, and vanadium).
    - Reducing loadings of bromide and iodine to drinking water resources.

The EPA expects secondary improvements, associated directly or indirectly, as a result of the final supplemental rule. Pollutant removals not only improve water quality in surface waters but also enhance their aesthetics (*e.g.*, by improving clarity and decreasing odor and discoloration). Improvements in surface water quality may improve the quality of source water for downstream drinking water treatment plants and wells that are influenced by surface water. Such improvements may also improve the quality of water used for irrigation or for industrial uses (lower contaminant levels). Recreational benefits from water quality improvements include more enjoyment from swimming, fishing, and boating and potentially increased revenue from more people partaking of recreational activities. The final rule may also reduce economic impacts such as cleanup and treatment costs for contamination, reduce water usage, reduce potential for algal blooms, and decrease air emissions. The BCA Report (U.S. EPA, 2024b) provides further details on these secondary improvements and other benefits.

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Attachment A. Additional IRW Model Results

This appendix presents pollutant loadings and additional model outputs for all pollutants included in the Immediate Receiving Water (IRW) Model (arsenic, cadmium, copper, lead, mercury, nickel, selenium, thallium, and zinc) beyond those discussed in Section 4 of this environmental assessment. It includes the following tables:

- Table A-1. Modeled IRWs with Exceedances of Benchmark Values for One or More Pollutants Under Baseline and Regulatory Options
- Table A-2. Modeled IRWs with Exceedances of Arsenic Benchmark Values Under Baseline and Regulatory Options
- Table A-3. Modeled IRWs with Exceedances of Cadmium Benchmark Values Under Baseline and Regulatory Options
- Table A-4. Modeled IRWs with Exceedances of Copper Benchmark Values Under Baseline and Regulatory Options
- Table A-5. Modeled IRWs with Exceedances of Lead Benchmark Values Under Baseline and Regulatory Options
- Table A-6. Modeled IRWs with Exceedances of Mercury Benchmark Values Under Baseline and Regulatory Options
- Table A-7. Modeled IRWs with Exceedances of Nickel Benchmark Values Under Baseline and Regulatory Options
- Table A-8. . Modeled IRWs with Exceedances of Selenium Benchmark Values Under Baseline and Regulatory Options
- Table A-9. Modeled IRWs with Exceedances of Thallium Benchmark Values Under Baseline and Regulatory Options
- Table A-10. Modeled IRWs with Exceedances of Zinc Benchmark Values Under Baseline and Regulatory Options
- Table A-11. Modeled IRWs with Exceedances of Arsenic Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options
- Table A-12. Modeled IRWs with Exceedances of Cadmium Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options
- Table A-13. Modeled IRWs with Exceedances of Copper Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options
- Table A-14. Modeled IRWs with Exceedances of Mercury (as Methylmercury) Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options
- Table A-15. Modeled IRWs with Exceedances of Nickel Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options
- Table A-16. Modeled IRWs with Exceedances of Selenium Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options
- Table A-17. Modeled IRWs with Exceedances of Thallium Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options
- Table A-18. Modeled IRWs with Exceedances of Zinc Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options
- Table A-19. Modeled IRWs with Lifetime Excess Cancer Risk for Inorganic Arsenic Exceeding One-in-a-Million by Race/Ethnicity Category Under Baseline and Regulatory Options

Table A-1. Modeled IRWs with Exceedances of Benchmark Values for One or More Pollutants Under Baseline and Regulatory Options

Pollutant Loadings Basis	Industry Pollutant Loadings (lb/year)[a]			
	Baseline	Option A	Option B	Option C
Mass loadings for the nine modeled pollutants from 110 steam electric power plants in pollutant loadings analysis[b]	17,600	13,400	3,550	3,200
Evaluation Benchmark	**Number of Modeled IRWs Exceeding Benchmark Value[c]**			
	Baseline	Option A	Option B	Option C
Water Quality Results				
Freshwater acute NRWQC	3	2	2	2
Freshwater chronic NRWQC	12	11	5	5
HH WO NRWQC	38	28	14	7
HH O NRWQC	21	14	4	3
Drinking water MCL	5	4	3	3
Wildlife Results				
Sediment TEC	24	24	11	7
Fish ingestion NEHC for minks	16	16	6	5
Fish ingestion NEHC for eagles	22	17	6	5
Human Health Results—Fish Consumption Advisories				
T4 fish tissue concentration screening value (recreational)	22	16	4	3
T4 fish tissue concentration screening value (subsistence)	32	24	10	6
Human Health Results—Noncancer				
Oral RfD for child (recreational)	28	22	9	6
Oral RfD for child (subsistence)	39	28	15	8
Oral RfD for adult (recreational)	26	18	6	5
Oral RfD for adult (subsistence)	31	23	9	6
Human Health Results—Cancer				
LECR for child (recreational)	0	0	0	0
LECR for child (subsistence)	3	2	1	1
LECR for adult (recreational)	4	2	2	2
LECR for adult (subsistence)	9	3	2	2

Sources: U.S. EPA, 2024h and 2024i.

Abbreviations: HH O (human health organism only); HH WO (human health water and organism); IRW (immediate receiving water); lb/year (pounds per year); LECR (lifetime excess cancer risk); MCL (maximum contaminant level); NEHC (no effect hazard concentration); NRWQC (National Recommended Water Quality Criteria); RfD (reference dose); TEC (threshold effect concentration); T4 (trophic level 4).

a—Values represent the industry loadings and the IRW Model outputs for the following nine evaluated pollutants: arsenic, cadmium, copper, lead, mercury, nickel, selenium, thallium, and zinc. Pollutant loadings are rounded to three significant figures.

b—The pollutant loadings analysis includes discharges from 110 plants to 123 immediate receiving waters (some plants discharge to multiple receiving waters). Of these 123 immediate receiving waters, all 123 receive discharges of the evaluated wastestreams under baseline, 105 do under Option A, 57 do under Option B, and 18 do under Option C.

c—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

Table A-2. Modeled IRWs with Exceedances of Arsenic Benchmark Values Under Baseline and Regulatory Options

Pollutant Loadings Basis	Industry Arsenic Loadings (lb/year)[a]			
	Baseline	Option A	Option B	Option C
Mass loadings from 110 steam electric power plants in pollutant loadings analysis[b]	777	264	77.1	50.8
Evaluation Benchmark[c]	**Number of Modeled IRWs Exceeding Benchmark Value[d]**			
	Baseline	**Option A**	**Option B**	**Option C**
Water Quality Results				
Freshwater acute NRWQC[e]	0	0	0	0
Freshwater chronic NRWQC[e]	0	0	0	0
HH WO NRWQC[f]	38	28	14	7
HH O NRWQC[f]	21	14	4	3
Drinking water MCL	4	2	2	2
Wildlife Results				
Sediment TEC	3	2	0	0
Fish ingestion NEHC for minks	0	0	0	0
Fish ingestion NEHC for eagles	0	0	0	0
Human Health Results—Fish Consumption Advisories				
T4 fish tissue concentration screening value (recreational)[f,g]	0	0	0	0
T4 fish tissue concentration screening value (subsistence)[f,g]	0	0	0	0
Human Health Results—Noncancer				
Oral RfD for child (recreational)[f]	0	0	0	0
Oral RfD for child (subsistence)[f]	0	0	0	0
Oral RfD for adult (recreational)[f]	0	0	0	0
Oral RfD for adult (subsistence)[f]	0	0	0	0
Human Health Results—Cancer				
LECR for child (recreational)[f]	0	0	0	0
LECR for child (subsistence)[f]	3	2	1	1
LECR for adult (recreational)[f]	4	2	2	2
LECR for adult (subsistence)[f]	9	3	2	2

Sources: U.S. EPA, 2024h and 2024i.

Abbreviations: HH O (human health organism only); HH WO (human health water and organism); IRW (immediate receiving water); lb/year (pounds per year); LECR (lifetime excess cancer risk); MCL (maximum contaminant level); NEHC (no effect hazard concentration); NRWQC (National Recommended Water Quality Criteria); RfD (reference dose); TEC (threshold effect concentration); T4 (trophic level 4).

a—Pollutant loadings are rounded to three significant figures.

b— The pollutant loadings analysis includes discharges from 110 plants to 123 immediate receiving waters (some plants discharge to multiple receiving waters). Of these 123 immediate receiving waters, all 123 receive discharges of the evaluated wastestreams under baseline, 105 do under Option A, 57 do under Option B, and 18 do under Option C.

c—All benchmark values are based on total arsenic concentration, unless otherwise stated.

d—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

e—Benchmark value is based on dissolved arsenic.

f—Benchmark value is based on inorganic arsenic.

g—Values represent number of immediate receiving waters exceeding either the noncarcinogenic or carcinogenic screening values.

Table A-3. Modeled IRWs with Exceedances of Cadmium Benchmark Values Under Baseline and Regulatory Options

Pollutant Loadings Basis	Industry Cadmium Loadings (lb/year)[a]			
	Baseline	Option A	Option B	Option C
Mass loadings from 110 steam electric power plants in pollutant loadings analysis[b]	553	401	41.1	23.8
Evaluation Benchmark[c]	**Number of Modeled IRWs Exceeding Benchmark Value[d]**			
	Baseline	**Option A**	**Option B**	**Option C**
Water Quality Results				
Freshwater acute NRWQC[e]	3	2	1	1
Freshwater chronic NRWQC[e]	8	5	2	2
HH WO NRWQC	[f]	[f]	[f]	[f]
HH O NRWQC	[f]	[f]	[f]	[f]
Drinking water MCL	3	2	1	1
Wildlife Results				
Sediment TEC	8	5	2	2
Fish ingestion NEHC for minks	1	1	0	0
Fish ingestion NEHC for eagles	1	1	0	0
Human Health Results—Fish Consumption Advisories				
T4 fish tissue concentration screening value (recreational)	1	1	0	0
T4 fish tissue concentration screening value (subsistence)	4	3	2	2
Human Health Results—Noncancer				
Oral RfD for child (recreational)	3	2	1	1
Oral RfD for child (subsistence)	4	4	2	2
Oral RfD for adult (recreational)	1	1	1	1
Oral RfD for adult (subsistence)	4	3	2	2
Human Health Results—Cancer				
LECR for child (recreational)	[f]	[f]	[f]	[f]
LECR for child (subsistence)	[f]	[f]	[f]	[f]
LECR for adult (recreational)	[f]	[f]	[f]	[f]
LECR for adult (subsistence)	[f]	[f]	[f]	[f]

Sources: U.S. EPA, 2024h and 2024i.

Abbreviations: HH O (human health organism only); HH WO (human health water and organism); IRW (immediate receiving water); lb/year (pounds per year); LECR (lifetime excess cancer risk); MCL (maximum contaminant level); NEHC (no effect hazard concentration); NRWQC (National Recommended Water Quality Criteria); RfD (reference dose); TEC (threshold effect concentration); T4 (trophic level 4).

a—Pollutant loadings are rounded to three significant figures.

b— The pollutant loadings analysis includes discharges from 110 plants to 123 immediate receiving waters (some plants discharge to multiple receiving waters). Of these 123 immediate receiving waters, all 123 receive discharges of the evaluated wastestreams under baseline, 105 do under Option A, 57 do under Option B, and 18 do under Option C.

c—All benchmark values are based on total cadmium concentration, unless otherwise stated.

d—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

e—Benchmark value is based on dissolved cadmium.

f—A benchmark value is not yet established for this pollutant or was not included in the EPA's analyses.

Table A-4. Modeled IRWs with Exceedances of Copper Benchmark Values Under Baseline and Regulatory Options

Pollutant Loadings Basis	Industry Copper Loadings (lb/year)[a]			
	Baseline	Option A	Option B	Option C
Mass loadings from 110 steam electric power plants in pollutant loadings analysis[b]	398	217	49.4	32.9
Evaluation Benchmark[c]	**Number of Modeled IRWs Exceeding Benchmark Value[d]**			
	Baseline	**Option A**	**Option B**	**Option C**
Water Quality Results				
Freshwater acute NRWQC[e]	1	1	0	0
Freshwater chronic NRWQC[e]	2	2	0	0
HH WO NRWQC	0	0	0	0
HH O NRWQC	f	f	f	f
Drinking water MCL	0	0	0	0
Wildlife Results				
Sediment TEC	2	2	1	1
Fish ingestion NEHC for minks	0	0	0	0
Fish ingestion NEHC for eagles	0	0	0	0
Human Health Results—Fish Consumption Advisories				
T4 fish tissue concentration screening value (recreational)	f	f	f	f
T4 fish tissue concentration screening value (subsistence)	f	f	f	f
Human Health Results—Noncancer				
Oral RfD for child (recreational)	0	0	0	0
Oral RfD for child (subsistence)	1	1	0	0
Oral RfD for adult (recreational)	0	0	0	0
Oral RfD for adult (subsistence)	0	0	0	0
Human Health Results—Cancer				
LECR for child (recreational)	f	f	f	f
LECR for child (subsistence)	f	f	f	f
LECR for adult (recreational)	f	f	f	f
LECR for adult (subsistence)	f	f	f	f

Sources: U.S. EPA, 2024h and 2024i.

Abbreviations: HH O (human health organism only); HH WO (human health water and organism); IRW (immediate receiving water); lb/year (pounds per year); LECR (lifetime excess cancer risk); MCL (maximum contaminant level); NEHC (no effect hazard concentration); NRWQC (National Recommended Water Quality Criteria); RfD (reference dose); TEC (threshold effect concentration); T4 (trophic level 4).

a—Pollutant loadings are rounded to three significant figures.

b— The pollutant loadings analysis includes discharges from 110 plants to 123 immediate receiving waters (some plants discharge to multiple receiving waters). Of these 123 immediate receiving waters, all 123 receive discharges of the evaluated wastestreams under baseline, 105 do under Option A, 57 do under Option B, and 18 do under Option C.

c—All benchmark values are based on total copper concentration, unless otherwise stated.

d—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

e—Benchmark value is based on dissolved copper.

f—A benchmark value is not yet established for this pollutant or was not included in the EPA's analyses.

Table A-5. Modeled IRWs with Exceedances of Lead Benchmark Values Under Baseline and Regulatory Options

Pollutant Loadings Basis	Industry Lead Loadings (lb/year)[a]			
	Baseline	Option A	Option B	Option C
Mass loadings from 110 steam electric power plants in pollutant loadings analysis[b]	230	91.6	42.9	29.5
Evaluation Benchmark[c]	**Number of Modeled IRWs Exceeding Benchmark Value[d]**			
	Baseline	**Option A**	**Option B**	**Option C**
Water Quality Results				
Freshwater acute NRWQC[e]	0	0	0	0
Freshwater chronic NRWQC[e]	1	1	0	0
HH WO NRWQC	f	f	f	f
HH O NRWQC	f	f	f	f
Drinking water MCL	2	2	1	1
Wildlife Results				
Sediment TEC	1	1	1	1
Fish ingestion NEHC for minks	0	0	0	0
Fish ingestion NEHC for eagles	0	0	0	0
Human Health Results—Fish Consumption Advisories				
T4 fish tissue concentration screening value (recreational)	f	f	f	f
T4 fish tissue concentration screening value (subsistence)	f	f	f	f
Human Health Results—Noncancer				
Oral RfD for child (recreational)	f	f	f	f
Oral RfD for child (subsistence)	f	f	f	f
Oral RfD for adult (recreational)	f	f	f	f
Oral RfD for adult (subsistence)	f	f	f	f
Human Health Results—Cancer				
LECR for child (recreational)	f	f	f	f
LECR for child (subsistence)	f	f	f	f
LECR for adult (recreational)	f	f	f	f
LECR for adult (subsistence)	f	f	f	f

Sources: U.S. EPA, 2024h and 2024i.

Abbreviations: HH O (human health organism only); HH WO (human health water and organism); IRW (immediate receiving water); lb/year (pounds per year); LECR (lifetime excess cancer risk); MCL (maximum contaminant level); NEHC (no effect hazard concentration); NRWQC (National Recommended Water Quality Criteria); RfD (reference dose); TEC (threshold effect concentration); T4 (trophic level 4).

a—Pollutant loadings are rounded to three significant figures.

b— The pollutant loadings analysis includes discharges from 110 plants to 123 immediate receiving waters (some plants discharge to multiple receiving waters). Of these 123 immediate receiving waters, all 123 receive discharges of the evaluated wastestreams under baseline, 105 do under Option A, 57 do under Option B, and 18 do under Option C.

c—All benchmark values are based on total lead concentration, unless otherwise stated.

d—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

e—Benchmark value is based on dissolved lead.

f—A benchmark value is not yet established for this pollutant or was not included in the EPA's analyses.

Table A-6. Modeled IRWs with Exceedances of Mercury Benchmark Values Under Baseline and Regulatory Options

Pollutant Loadings Basis	Industry Mercury Loadings (lb/year)[a]			
	Baseline	Option A	Option B	Option C
Mass loadings from 110 steam electric power plants in pollutant loadings analysis[b]	40.0	28.5	1.53	1.21
Evaluation Benchmark[c]	**Number of Modeled IRWs Exceeding Benchmark Value[d]**			
	Baseline	**Option A**	**Option B**	**Option C**
Water Quality Results				
Freshwater acute NRWQC[e]	0	0	0	0
Freshwater chronic NRWQC[e]	1	1	0	0
HH WO NRWQC	[f]	[f]	[f]	[f]
HH O NRWQC	[f]	[f]	[f]	[f]
Drinking water MCL[g]	1	1	0	0
Wildlife Results				
Sediment TEC	19	9	2	2
Fish ingestion NEHC for minks[h]	16	7	2	2
Fish ingestion NEHC for eagles[h]	22	15	3	2
Human Health Results—Fish Consumption Advisories				
T4 fish tissue concentration screening value (recreational)[h]	22	16	4	3
T4 fish tissue concentration screening value (subsistence)[h]	32	24	10	6
Human Health Results—Noncancer				
Oral RfD for child (recreational)[h]	28	22	8	5
Oral RfD for child (subsistence)[h]	38	28	15	8
Oral RfD for adult (recreational)[h]	25	17	5	4
Oral RfD for adult (subsistence)[h]	31	23	9	6
Human Health Results—Cancer				
LECR for child (recreational)	[f]	[f]	[f]	[f]
LECR for child (subsistence)	[f]	[f]	[f]	[f]
LECR for adult (recreational)	[f]	[f]	[f]	[f]
LECR for adult (subsistence)	[f]	[f]	[f]	[f]

Sources: U.S. EPA, 2024h and 2024i.

Abbreviations: HH O (human health organism only); HH WO (human health water and organism); IRW (immediate receiving water); lb/year (pounds per year); LECR (lifetime excess cancer risk); MCL (maximum contaminant level); NEHC (no effect hazard concentration); NRWQC (National Recommended Water Quality Criteria); RfD (reference dose); TEC (threshold effect concentration); T4 (trophic level 4).

a—Pollutant loadings are rounded to three significant figures.

b—The pollutant loadings analysis includes discharges from 110 plants to 123 immediate receiving waters (some plants discharge to multiple receiving waters). Of these 123 immediate receiving waters, all 123 receive discharges of the evaluated wastestreams under baseline, 105 do under Option A, 57 do under Option B, and 18 do under Option C.

c—All benchmark values are based on total mercury concentration, unless otherwise stated.

d—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

e—Benchmark value is based on dissolved mercury.

f—A benchmark value is not yet established for this pollutant or was not included in the EPA's analyses.

g—Benchmark value is based on inorganic mercury.

h—Benchmark value is based on methylmercury.

Table A-7. Modeled IRWs with Exceedances of Nickel Benchmark Values Under Baseline and Regulatory Options

Pollutant Loadings Basis	Industry Nickel Loadings (lb/year)[a]			
	Baseline	Option A	Option B	Option C
Mass loadings from 110 steam electric power plants in pollutant loadings analysis[b]	3,430	2,740	113	79.4
Evaluation Benchmark[c]	**Number of Modeled IRWs Exceeding Benchmark Value[d]**			
	Baseline	**Option A**	**Option B**	**Option C**
Water Quality Results				
Freshwater acute NRWQC[e]	1	1	0	0
Freshwater chronic NRWQC[e]	1	1	0	0
HH WO NRWQC	1	1	0	0
HH O NRWQC	0	0	0	0
Drinking water MCL	[f]	[f]	[f]	[f]
Wildlife Results				
Sediment TEC	14	6	2	2
Fish ingestion NEHC for minks	0	0	0	0
Fish ingestion NEHC for eagles	0	0	0	0
Human Health Results—Fish Consumption Advisories				
T4 fish tissue concentration screening value (recreational)	[f]	[f]	[f]	[f]
T4 fish tissue concentration screening value (subsistence)	[f]	[f]	[f]	[f]
Human Health Results—Noncancer				
Oral RfD for child (recreational)	0	0	0	0
Oral RfD for child (subsistence)	0	0	0	0
Oral RfD for adult (recreational)	0	0	0	0
Oral RfD for adult (subsistence)	0	0	0	0
Human Health Results—Cancer				
LECR for child (recreational)	[f]	[f]	[f]	[f]
LECR for child (subsistence)	[f]	[f]	[f]	[f]
LECR for adult (recreational)	[f]	[f]	[f]	[f]
LECR for adult (subsistence)	[f]	[f]	[f]	[f]

Sources: U.S. EPA, 2024h and 2024i.

Abbreviations: HH O (human health organism only); HH WO (human health water and organism); IRW (immediate receiving water); lb/year (pounds per year); LECR (lifetime excess cancer risk); MCL (maximum contaminant level); NEHC (no effect hazard concentration); NRWQC (National Recommended Water Quality Criteria); RfD (reference dose); TEC (threshold effect concentration); T4 (trophic level 4).

a—Pollutant loadings are rounded to three significant figures.

b— The pollutant loadings analysis includes discharges from 110 plants to 123 immediate receiving waters (some plants discharge to multiple receiving waters). Of these 123 immediate receiving waters, all 123 receive discharges of the evaluated wastestreams under baseline, 105 do under Option A, 57 do under Option B, and 18 do under Option C.

c—All benchmark values are based on total nickel concentration, unless otherwise stated.

d—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

e—Benchmark value is based on dissolved nickel.

f—A benchmark value is not yet established for this pollutant or was not included in the EPA’s analyses.

Table A-8. Modeled IRWs with Exceedances of Selenium Benchmark Values Under Baseline and Regulatory Options

Pollutant Loadings Basis	Industry Selenium Loadings (lb/year)[a]			
	Baseline	Option A	Option B	Option C
Mass loadings from 110 steam electric power plants in pollutant loadings analysis[b]	4,810	4,600	2,840	2,730
Evaluation Benchmark[c]	**Number of Modeled IRWs Exceeding Benchmark Value[d]**			
	Baseline	**Option A**	**Option B**	**Option C**
Water Quality Results				
Freshwater acute NRWQC[e]	1	1	1	1
Freshwater chronic NRWQC[e]	12	11	5	5
HH WO NRWQC	1	1	1	1
HH O NRWQC	1	1	1	1
Drinking water MCL	3	3	2	2
Wildlife Results				
Sediment TEC	24	24	11	7
Fish ingestion NEHC for minks	15	15	6	5
Fish ingestion NEHC for eagles	15	15	6	5
Human Health Results—Fish Consumption Advisories				
T4 fish tissue concentration screening value (recreational)	8	7	3	3
T4 fish tissue concentration screening value (subsistence)	18	18	8	5
Human Health Results—Noncancer				
Oral RfD for child (recreational)	15	15	6	5
Oral RfD for child (subsistence)	22	22	8	5
Oral RfD for adult (recreational)	12	12	5	4
Oral RfD for adult (subsistence)	15	15	6	5
Human Health Results—Cancer				
LECR for child (recreational)	[f]	[f]	[f]	[f]
LECR for child (subsistence)	[f]	[f]	[f]	[f]
LECR for adult (recreational)	[f]	[f]	[f]	[f]
LECR for adult (subsistence)	[f]	[f]	[f]	[f]

Sources: U.S. EPA, 2024h and 2024i.

Abbreviations: HH O (human health organism only); HH WO (human health water and organism); IRW (immediate receiving water); lb/year (pounds per year); LECR (lifetime excess cancer risk); MCL (maximum contaminant level); NEHC (no effect hazard concentration); NRWQC (National Recommended Water Quality Criteria); RfD (reference dose); TEC (threshold effect concentration); T4 (trophic level 4).

a—Pollutant loadings are rounded to three significant figures.

b— The pollutant loadings analysis includes discharges from 110 plants to 123 immediate receiving waters (some plants discharge to multiple receiving waters). Of these 123 immediate receiving waters, all 123 receive discharges of the evaluated wastestreams under baseline, 105 do under Option A, 57 do under Option B, and 18 do under Option C.

c—All benchmark values are based on total selenium concentration, unless otherwise stated.

d—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

e—Benchmark value is based on dissolved selenium.

f—A benchmark value is not yet established for this pollutant or was not included in the EPA's analyses.

Table A-9. Modeled IRWs with Exceedances of Thallium Benchmark Values Under Baseline and Regulatory Options

Pollutant Loadings Basis	Industry Thallium Loadings (lb/year)[a]			
	Baseline	Option A	Option B	Option C
Mass loadings from 110 steam electric power plants in pollutant loadings analysis[b]	781	536	117	85.5
Evaluation Benchmark[c]	**Number of Modeled IRWs Exceeding Benchmark Value[d]**			
	Baseline	**Option A**	**Option B**	**Option C**
Water Quality Results				
Freshwater acute NRWQC	e	e	e	e
Freshwater chronic NRWQC	e	e	e	e
HH WO NRWQC	8	7	4	3
HH O NRWQC	7	5	3	3
Drinking water MCL	2	2	2	2
Wildlife Results				
Sediment TEC	e	e	e	e
Fish ingestion NEHC for minks	e	e	e	e
Fish ingestion NEHC for eagles	e	e	e	e
Human Health Results—Fish Consumption Advisories				
T4 fish tissue concentration screening value (recreational)	e	e	e	e
T4 fish tissue concentration screening value (subsistence)	e	e	e	e
Human Health Results—Noncancer				
Oral RfD for child (recreational)	16	15	6	5
Oral RfD for child (subsistence)	24	19	10	7
Oral RfD for adult (recreational)	13	9	5	4
Oral RfD for adult (subsistence)	16	15	6	5
Human Health Results—Cancer				
LECR for child (recreational)	e	e	e	e
LECR for child (subsistence)	e	e	e	e
LECR for adult (recreational)	e	e	e	e
LECR for adult (subsistence)	e	e	e	e

Sources: U.S. EPA, 2024h and 2024i.

Abbreviations: HH O (human health organism only); HH WO (human health water and organism); IRW (immediate receiving water); lb/year (pounds per year); LECR (lifetime excess cancer risk); MCL (maximum contaminant level); NEHC (no effect hazard concentration); NRWQC (National Recommended Water Quality Criteria); RfD (reference dose); TEC (threshold effect concentration); T4 (trophic level 4).

a—Pollutant loadings are rounded to three significant figures.

b— The pollutant loadings analysis includes discharges from 110 plants to 123 immediate receiving waters (some plants discharge to multiple receiving waters). Of these 123 immediate receiving waters, all 123 receive discharges of the evaluated wastestreams under baseline, 105 do under Option A, 57 do under Option B, and 18 do under Option C.

c—All benchmark values are based on total thallium concentration, unless otherwise stated.

d—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

e—A benchmark value is not yet established for this pollutant or was not included in the EPA's analyses.

Table A-10. Modeled IRWs with Exceedances of Zinc Benchmark Values Under Baseline and Regulatory Options

Pollutant Loadings Basis	Industry Zinc Loadings (lb/year)[a]			
	Baseline	Option A	Option B	Option C
Mass loadings from 110 steam electric power plants in pollutant loadings analysis[b]	6,570	4,530	265	174
Evaluation Benchmark[c]	**Number of Modeled IRWs Exceeding Benchmark Value[d]**			
	Baseline	**Option A**	**Option B**	**Option C**
Water Quality Results				
Freshwater acute NRWQC[e]	1	1	0	0
Freshwater chronic NRWQC[e]	1	1	0	0
HH WO NRWQC	0	0	0	0
HH O NRWQC	0	0	0	0
Drinking water MCL	1	1	0	0
Wildlife Results				
Sediment TEC	7	4	2	2
Fish ingestion NEHC for minks	1	1	0	0
Fish ingestion NEHC for eagles	1	1	0	0
Human Health Results—Fish Consumption Advisories				
T4 fish tissue concentration screening value (recreational)	[f]	[f]	[f]	[f]
T4 fish tissue concentration screening value (subsistence)	[f]	[f]	[f]	[f]
Human Health Results—Noncancer				
Oral RfD for child (recreational)	1	1	0	0
Oral RfD for child (subsistence)	1	1	0	0
Oral RfD for adult (recreational)	1	1	0	0
Oral RfD for adult (subsistence)	1	1	0	0
Human Health Results—Cancer				
LECR for child (recreational)	[f]	[f]	[f]	[f]
LECR for child (subsistence)	[f]	[f]	[f]	[f]
LECR for adult (recreational)	[f]	[f]	[f]	[f]
LECR for adult (subsistence)	[f]	[f]	[f]	[f]

Sources: U.S. EPA, 2024h and 2024i.

Abbreviations: HH O (human health organism only); HH WO (human health water and organism); IRW (immediate receiving water); lb/year (pounds per year); LECR (lifetime excess cancer risk); MCL (maximum contaminant level); NEHC (no effect hazard concentration); NRWQC (National Recommended Water Quality Criteria); RfD (reference dose); TEC (threshold effect concentration); T4 (trophic level 4).

a—Pollutant loadings are rounded to three significant figures.

b—The pollutant loadings analysis includes discharges from 110 plants to 123 immediate receiving waters (some plants discharge to multiple receiving waters). Of these 123 immediate receiving waters, all 123 receive discharges of the evaluated wastestreams under baseline, 105 do under Option A, 57 do under Option B, and 18 do under Option C.

c—All benchmark values are based on total zinc concentration, unless otherwise stated.

d—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

e—Benchmark value is based on dissolved zinc.

f—A benchmark value is not yet established for this pollutant or was not included in the EPA's analyses.

Table A-11. Modeled IRWs with Exceedances of Arsenic Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Race/Ethnicity Category	Number of Modeled IRWs Exceeding Oral RfD[a,b]			
		Baseline	Option A	Option B	Option C
Child—recreational	Non-Hispanic White	0	0	0	0
	Non-Hispanic Black	0	0	0	0
	Mexican-American	0	0	0	0
	Other Hispanic	0	0	0	0
	Other, including multiple races	0	0	0	0
Child—subsistence	Non-Hispanic White	0	0	0	0
	Non-Hispanic Black	0	0	0	0
	Mexican-American	0	0	0	0
	Other Hispanic	0	0	0	0
	Other, including multiple races	0	0	0	0
Adult—recreational	Non-Hispanic White	0	0	0	0
	Non-Hispanic Black	0	0	0	0
	Mexican-American	0	0	0	0
	Other Hispanic	0	0	0	0
	Other, including multiple races	0	0	0	0
Adult—subsistence	Non-Hispanic White	0	0	0	0
	Non-Hispanic Black	0	0	0	0
	Mexican-American	0	0	0	0
	Other Hispanic	0	0	0	0
	Other, including multiple races	0	0	0	0

Source: U.S. EPA, 2024i.

Abbreviations: IRW (immediate receiving water); RfD (reference dose).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

b—Benchmark value is based on inorganic arsenic.

Table A-12. Modeled IRWs with Exceedances of Cadmium Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Race/Ethnicity Category	Number of Modeled IRWs Exceeding Oral RfD[a,b]			
		Baseline	Option A	Option B	Option C
Child—recreational	Non-Hispanic White	1	1	1	1
	Non-Hispanic Black	1	1	1	1
	Mexican-American	2	2	1	1
	Other Hispanic	1	1	1	1
	Other, including multiple races	2	2	1	1
Child—subsistence	Non-Hispanic White	3	2	1	1
	Non-Hispanic Black	4	3	2	2
	Mexican-American	4	4	2	2
	Other Hispanic	4	4	2	2
	Other, including multiple races	4	4	2	2
Adult—recreational	Non-Hispanic White	1	1	1	1
	Non-Hispanic Black	1	1	1	1
	Mexican-American	2	2	1	1
	Other Hispanic	1	1	1	1
	Other, including multiple races	2	2	1	1
Adult—subsistence	Non-Hispanic White	3	2	1	1
	Non-Hispanic Black	4	3	2	2
	Mexican-American	4	4	2	2
	Other Hispanic	4	4	2	2
	Other, including multiple races	4	4	2	2

Source: U.S. EPA, 2024i.

Abbreviations: IRW (immediate receiving water); RfD (reference dose).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

b—Benchmark value is based on dissolved cadmium.

Table A-13. Modeled IRWs with Exceedances of Copper Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Race/Ethnicity Category	Number of Modeled IRWs Exceeding Oral RfD[a,b]			
		Baseline	Option A	Option B	Option C
Child—recreational	Non-Hispanic White	0	0	0	0
	Non-Hispanic Black	0	0	0	0
	Mexican-American	0	0	0	0
	Other Hispanic	0	0	0	0
	Other, including multiple races	0	0	0	0
Child—subsistence	Non-Hispanic White	0	0	0	0
	Non-Hispanic Black	0	0	0	0
	Mexican-American	0	0	0	0
	Other Hispanic	0	0	0	0
	Other, including multiple races	0	0	0	0
Adult—recreational	Non-Hispanic White	0	0	0	0
	Non-Hispanic Black	0	0	0	0
	Mexican-American	0	0	0	0
	Other Hispanic	0	0	0	0
	Other, including multiple races	0	0	0	0
Adult—subsistence	Non-Hispanic White	0	0	0	0
	Non-Hispanic Black	0	0	0	0
	Mexican-American	0	0	0	0
	Other Hispanic	0	0	0	0
	Other, including multiple races	0	0	0	0

Source: U.S. EPA, 2024i.

Abbreviations: IRW (immediate receiving water); RfD (reference dose).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

b—Benchmark value is based on total copper.

Table A-14. Modeled IRWs with Exceedances of Mercury (as Methylmercury) Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Race/Ethnicity Category	Number of Modeled IRWs Exceeding Oral RfD[a]			
		Baseline	Option A	Option B	Option C
Child—recreational	Non-Hispanic White	25	17	5	4
	Non-Hispanic Black	26	19	6	4
	Mexican-American	27	20	8	5
	Other Hispanic	26	19	7	5
	Other, including multiple races	27	20	8	5
Child—subsistence	Non-Hispanic White	29	23	9	5
	Non-Hispanic Black	31	23	9	6
	Mexican-American	32	24	10	6
	Other Hispanic	32	23	9	6
	Other, including multiple races	33	26	14	8
Adult—recreational	Non-Hispanic White	25	17	5	4
	Non-Hispanic Black	26	19	6	4
	Mexican-American	27	20	8	5
	Other Hispanic	26	19	7	5
	Other, including multiple races	27	20	8	5
Adult—subsistence	Non-Hispanic White	29	23	9	5
	Non-Hispanic Black	31	23	9	6
	Mexican-American	32	24	10	6
	Other Hispanic	32	23	9	6
	Other, including multiple races	33	26	14	8

Source: U.S. EPA, 2024i.

Abbreviations: IRW (immediate receiving water); RfD (reference dose).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

Table A-15. Modeled IRWs with Exceedances of Nickel Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Race/Ethnicity Category	Number of Modeled IRWs Exceeding Oral RfD[a,b]			
		Baseline	Option A	Option B	Option C
Child—recreational	Non-Hispanic White	0	0	0	0
	Non-Hispanic Black	0	0	0	0
	Mexican-American	0	0	0	0
	Other Hispanic	0	0	0	0
	Other, including multiple races	0	0	0	0
Child—subsistence	Non-Hispanic White	0	0	0	0
	Non-Hispanic Black	0	0	0	0
	Mexican-American	0	0	0	0
	Other Hispanic	0	0	0	0
	Other, including multiple races	0	0	0	0
Adult—recreational	Non-Hispanic White	0	0	0	0
	Non-Hispanic Black	0	0	0	0
	Mexican-American	0	0	0	0
	Other Hispanic	0	0	0	0
	Other, including multiple races	0	0	0	0
Adult—subsistence	Non-Hispanic White	0	0	0	0
	Non-Hispanic Black	0	0	0	0
	Mexican-American	0	0	0	0
	Other Hispanic	0	0	0	0
	Other, including multiple races	0	0	0	0

Source: U.S. EPA, 2024i.

Abbreviations: IRW (immediate receiving water); RfD (reference dose).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

b—Benchmark value is based on total nickel.

Table A-16. Modeled IRWs with Exceedances of Selenium Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Race/Ethnicity Category	Number of Modeled IRWs Exceeding Oral RfD[a,b]			
		Baseline	Option A	Option B	Option C
Child—recreational	Non-Hispanic White	12	12	5	4
	Non-Hispanic Black	12	12	5	4
	Mexican-American	13	13	5	4
	Other Hispanic	13	13	5	4
	Other, including multiple races	13	13	5	4
Child—subsistence	Non-Hispanic White	15	15	6	5
	Non-Hispanic Black	15	15	6	5
	Mexican-American	19	19	8	5
	Other Hispanic	17	17	7	5
	Other, including multiple races	19	19	8	5
Adult—recreational	Non-Hispanic White	12	12	5	4
	Non-Hispanic Black	12	12	5	4
	Mexican-American	13	13	5	4
	Other Hispanic	13	13	5	4
	Other, including multiple races	13	13	5	4
Adult—subsistence	Non-Hispanic White	15	15	6	5
	Non-Hispanic Black	15	15	6	5
	Mexican-American	19	19	8	5
	Other Hispanic	17	17	7	5
	Other, including multiple races	19	19	8	5

Source: U.S. EPA, 2024i.

Abbreviations: IRW (immediate receiving water); RfD (reference dose).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

b—Benchmark value is based on total selenium.

Table A-17. Modeled IRWs with Exceedances of Thallium Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Race/Ethnicity Category	Number of Modeled IRWs Exceeding Oral RfD[a,b]			
		Baseline	Option A	Option B	Option C
Child—recreational	Non-Hispanic White	13	9	5	4
	Non-Hispanic Black	13	12	5	4
	Mexican-American	15	12	5	4
	Other Hispanic	13	12	5	4
	Other, including multiple races	15	12	5	4
Child—subsistence	Non-Hispanic White	16	15	6	5
	Non-Hispanic Black	16	15	6	5
	Mexican-American	20	18	8	6
	Other Hispanic	20	17	6	5
	Other, including multiple races	21	19	10	7
Adult—recreational	Non-Hispanic White	13	9	5	4
	Non-Hispanic Black	13	12	5	4
	Mexican-American	15	12	5	4
	Other Hispanic	13	12	5	4
	Other, including multiple races	15	12	5	4
Adult—subsistence	Non-Hispanic White	16	15	6	5
	Non-Hispanic Black	16	15	6	5
	Mexican-American	20	18	8	6
	Other Hispanic	20	17	6	5
	Other, including multiple races	21	19	10	7

Source: U.S. EPA, 2024i.

Abbreviations: IRW (immediate receiving water); RfD (reference dose).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

b—Benchmark value is based on total thallium.

Table A-18. Modeled IRWs with Exceedances of Zinc Oral Reference Dose Values by Race/Ethnicity Category Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Race/Ethnicity Category	Number of Modeled IRWs Exceeding Oral RfD[a,b]			
		Baseline	Option A	Option B	Option C
Child—recreational	Non-Hispanic White	1	1	0	0
	Non-Hispanic Black	1	1	0	0
	Mexican-American	1	1	0	0
	Other Hispanic	1	1	0	0
	Other, including multiple races	1	1	0	0
Child—subsistence	Non-Hispanic White	1	1	0	0
	Non-Hispanic Black	1	1	0	0
	Mexican-American	1	1	0	0
	Other Hispanic	1	1	0	0
	Other, including multiple races	1	1	0	0
Adult—recreational	Non-Hispanic White	1	1	0	0
	Non-Hispanic Black	1	1	0	0
	Mexican-American	1	1	0	0
	Other Hispanic	1	1	0	0
	Other, including multiple races	1	1	0	0
Adult—subsistence	Non-Hispanic White	1	1	0	0
	Non-Hispanic Black	1	1	0	0
	Mexican-American	1	1	0	0
	Other Hispanic	1	1	0	0
	Other, including multiple races	1	1	0	0

Source: U.S. EPA, 2024i.

Abbreviations: IRW (immediate receiving water); RfD (reference dose).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

b—Benchmark value is based on total zinc.

Table A-19. Modeled IRWs with Lifetime Excess Cancer Risk for Inorganic Arsenic Exceeding One-in-a-Million by Race/Ethnicity Category Under Baseline and Regulatory Options

Age and Fishing Mode Cohort	Race/Ethnicity Category	Number of Modeled IRWs Exceeding LECR[a]			
		Baseline	Option A	Option B	Option C
Child—recreational	Non-Hispanic White	0	0	0	0
	Non-Hispanic Black	0	0	0	0
	Mexican-American	0	0	0	0
	Other Hispanic	0	0	0	0
	Other, including multiple races	0	0	0	0
Child—subsistence	Non-Hispanic White	2	2	1	0
	Non-Hispanic Black	3	2	1	1
	Mexican-American	3	2	1	1
	Other Hispanic	3	2	1	1
	Other, including multiple races	3	2	1	1
Adult—recreational	Non-Hispanic White	4	2	2	2
	Non-Hispanic Black	4	2	2	2
	Mexican-American	4	2	2	2
	Other Hispanic	4	2	2	2
	Other, including multiple races	4	2	2	2
Adult—subsistence	Non-Hispanic White	9	3	2	2
	Non-Hispanic Black	9	3	2	2
	Mexican-American	10	3	2	2
	Other Hispanic	10	3	2	2
	Other, including multiple races	11	4	3	2

Source: U.S. EPA, 2024i.

Abbreviations: IRW (immediate receiving water); LECR (lifetime excess cancer risk).

a—The IRW Model, which excludes the Great Lakes and estuaries, analyzes 114 total immediate receiving waters and loadings from 100 plants (some of which discharge to multiple receiving waters). Of these 114 immediate receiving waters, all 114 receive discharges of the evaluated wastestreams under baseline, 97 do under Option A, 50 do under Option B, and 17 do under Option C.

Exhibit 15

DECLARATIONS

TABLE OF CONTENTS

Clean Water Action

DECLARATION OF LYNN THORP

I, Lynn Thorp, declare as follows:

1. I am the National Campaigns Director for Clean Water Action. I have worked for Clean Water Action in this position for over 25 years.

2. In my role, I oversee all of Clean Water Action's national campaigns, which include policy research and advocacy around national environmental and public health laws, with an emphasis on the Clean Water Act and Safe Drinking Water Act.

3. Clean Water Action is a national, non-profit membership organization incorporated under the laws of the District of Columbia, with its principal place of business in Washington, D.C. We conduct campaigns on the national level as well as state and local campaigns in offices around the country.

4. Clean Water Action's mission includes prevention of pollution in the nation's water, protection of natural resources, creation of environmentally-safe jobs and businesses, and empowerment of people to make democracy work. Our activities include policy research and advocacy, public education and grassroots mobilization. We have been involved with the Clean Water Act since our founding in 1972 and with implementation activities throughout the Act's history. Our core programs have always included efforts to strengthen the Act's implementation and enforcement and to work toward the Act's goal of zero discharge pollution into waters of the United States.

5. For over a decade, one of Clean Water Action's priority campaigns has been advocating for the U.S. EPA to finalize a rule establishing stringent revised Effluent Limitation Guidelines for steam electric power plants ("the ELG Rule"). During the 2013 public comment period for the proposed ELG Rule, Clean Water Action filed comments signed by over 200 national, state, and local public interest organizations and collected nearly 45,000 comments from our members and other supporters, which called on EPA to finalize an ELG Rule that would require steam electric power plants to eliminate discharges of bottom ash, fly ash, and flue gas desulfurization wastewater. That same year, Clean Water Action contributed to and co-released a major report on the extent of water pollution coming from steam electric power plants across the country, *Closing the Floodgates: How the Coal Industry is Poisoning Our Water and How We Can Stop it.*

6. Since 2013, Clean Water Action has continued advocating for a strong ELG Rule. For example, Clean Water Action joined comments filed on January 21, 2020 on the proposed amendments to the ELG Rule (84 Fed. Reg. 64,620 (Nov. 22, 2019)) and subsequently joined a petition for review of those amendments when they were finalized in 2020 (85 Fed. Reg. 64,650 (Oct. 13, 2020)). We also joined comments filed on May 30, 2023 on the most recent proposed amendments to the ELG Rule (88 Fed. Reg. 18,824 (Mar. 29, 2023)), which are at issue in the present litigation. In addition, we have contributed to other reports and

communicated with members and the public about the importance of this issue. In particular, Clean Water Action has been focused on the impacts of power plant water pollution on our drinking water, including the impacts on municipal drinking water utilities that are forced to invest in additional treatment of source waters due to the impacts of upstream power plant pollution.

7. Since EPA published the most recently revised ELG Rule, at issue in this litigation, Clean Water Action has begun analyzing how the rule may be implemented and what role our organization will play to ensure the rule is implemented effectively. We believe the recently revised ELG rule—which requires steam electric power plants to upgrade wastewater treatment technology to achieve zero discharge of pollutants from bottom ash transport wastewater, flue gas desulfurization scrubber sludge, and combustion residual leachate—will result in significant improvements in water quality and public health.

8. We are aware that the Utility Water Act Group and two of its members (NRG Texas Power and Southwestern Electric Power Co.), as well as several states, have filed petitions challenging the recently revised ELG Rule. Based on those petitioners' prior comments and advocacy efforts on the ELG Rule, we expect they are seeking to overturn or significantly weaken the recently revised ELG Rule.

9. The interests of Clean Water Action and its members would be adversely affected if those petitioners' challenges were to succeed. Overturning or weakening the recently revised ELG Rule would eliminate or delay water quality and public health protections from which our members would benefit, and pollution from steam electric power plants would continue to harm waters of the United States that our members use and enjoy.

10. When an individual becomes a member of Clean Water Action, his or her current residential address is recorded in our membership database. This database is regularly updated to add new members, reflect address changes, and change membership status for those who are no longer active members.

11. Clean Water Action currently has more than 154,000 members nationwide.

I declare under the penalty of perjury that, to the best of my knowledge, the foregoing is true and correct.

Dated June 25, 2024.

Lynn W. Thorp

Lynn Thorp

DEC003

DECLARATION OF BECKY SMITH

I, Becky Smith, declare as follows:

1. My name is Becky Smith. I am over 18 years old. The information in this declaration is based on my personal experience and my review of publicly available information.

2. I live in Houston, Harris County, Texas, 77098 with my spouse and my daughter, who is in elementary school. I have lived at my current address since 2018.

3. I am employed by Clean Water Action. I serve as the organization's Texas State Director. My responsibilities in this role include directing and conducting campaign work to protect water quality and working to prevent pollution from myriad sources. Campaign work includes participation in coalitions and educating our members about opportunities to weigh in on public input processes regarding issues such as water permitting at the state level and also delivering testimony on behalf of our membership to decision-making bodies such as the Texas Legislature. I have been in this role since 2022.

4. In addition to my current role, I have worked for, and been a member of, Clean Water Action on and off since 2001. I am a member of Clean Water Action today.

5. I joined Clean Water Action because I care about protecting and preserving our environment and keeping waters flowing and clean for all flora and fauna. This includes protecting waters for human use and recreation. I want safe water for myself, my family, and everyone around us. As a person that uses nature to soothe myself, it is important to me to have healthy outdoor spaces to visit.

6. I regularly spend time outdoors in the Brazos River Basin in Brazos Bend State Park. I visit the Park at least a couple of times a year, at all different times of the year. I often go with my family. While there, I enjoy observing the wildlife in the river, including alligators and turtles, as well as migratory birds. I also like to hike along the river and climb the lookout tower to see the riverscape.

7. My family and I also visit the Brazos River Basin about once a year with other families who are members of the Scouts BSA. My child is going into her fourth-grade year of BSA. We join her and other families on camping trips in the Brazos Bend State Park. A lifelong goal for me as a parent is to build a sense of wonder for nature in my child. Every minute she's out in nature is a huge victory. I think it is setting her on a life-long course of discovery and joy. Having healthy outdoor spaces to visit, and healthy plant and animal life to observe, is important to me as a parent.

8. I am aware that the W.A. Parish power plant discharges its coal ash wastewater into Smithers Lake, which is part of the Brazos River Basin located upstream of Brazos Bend State Park. I am also aware that coal ash wastewater includes toxic contaminants, like mercury, arsenic, lead, and selenium.

9. I am concerned about mercury and other heavy metals that build up in fish and the impact those contaminants could have on my health and my family's health. As a woman of childbearing age, I've strictly limited my fish consumption because of mercury poison concerns. I also really try to limit my child's exposure to polluted water. Where we go for recreation and what waters we eat from are affected by my knowledge of where pollution sources are, including the W.A. Parish plant.

10. I am also concerned about heavy metals impacting species, including threatened and endangered species. I am especially fond of Whooping Cranes, which I sometimes see and like to observe when I visit the Park. I understand that heavy metals in water can negatively affect their eggs. As a mom, that feels personal, and it makes me wonder how it affects human reproduction.

11. My concerns about the impact of heavy metals on my health, my family's health, and the health of the species I like to observe affects my aesthetic and recreational enjoyment of the Brazos Bend State Park and Brazos River Basin.

12. I know that the U.S. EPA recently issued a new rule that will require the W.A. Parish plant to eliminate its discharge of two large wastewater streams. I am aware that those wastewater streams are significant sources of water pollution, including the heavy metals I am concerned about, and I am glad that the new rule requires W.A. Parish to eliminate them.

13. If the new rule is implemented, I would feel safer recreating in the Brazos River Basin in Brazos Bend State Park. I also would have a more positive experience in the Park knowing that the rule is positively impacting the species I like to observe by reducing water pollution.

14. By contrast, if the new rule is not implemented and W.A. Parish is allowed to keep discharging large amounts of polluted water, I worry that there will be less wildlife to see in the Park. We would visit the Park less if there were fewer healthy species to observe. The Scouts would probably visit less frequently too.

I declare under the penalty of perjury that, to the best of my knowledge, the foregoing is true and correct.

Dated June 26, 2024.

Becky Smith

Becky Smith

Sierra Club

DECLARATION OF HUDA FASHHO

I, Huda Fashho, state and declare as follows:

1. I am over 18 years old and have personal knowledge of the matters set forth in this declaration.

2. I am a Sierra Club employee. My current title is Senior Managing Director, Member Care. I have held this position for approximately five and a half years.

3. In that role, I manage aspects of Sierra Club's customer service, including maintaining an accurate list of members and managing the organization's member databases.

4. When a person becomes a member of Sierra Club, that person's current residential address or contact information is recorded in our membership database. This database is regularly updated to add new members, reflect address changes and contact information, and update membership status.

5. Sierra Club is a national non-profit member-based public interest organization incorporated under the laws of the State of California, with its principal place of business in Oakland, CA. It is a recognized not-for-profit corporation under Section 501(c)(3) and (c)(4) of the U.S. Internal Revenue Code. Sierra Club is further subdivided into local chapters, groups, committees, and task forces, with a presence in every state in the Nation.

6. The Sierra Club's mission is to explore, enjoy, and protect the wild places of the earth; to practice and promote the responsible use of the Earth's resources and ecosystems; to educate and enlist humanity to protect and restore the quality of the natural and human environment; and to use all lawful means to carry out those objectives. Its activities also include public education, advocacy, and litigation to enforce environmental laws, including advocacy and litigation to protect public health and air and water quality in the communities where our

members live, work, and recreate. Sierra Club has a longstanding commitment to ensuring that the Clean Water Act is fully enforced, properly implemented and ultimately used to ensure Clean Water for all Americans, including Sierra Club members, who live, work, recreate, and drink water that can be impacted by industrial pollution.

7. Sierra Club currently has 662,165 active, dues-paying members. As noted, when a person becomes a member of the Sierra Club, that person's contact information is recorded in our membership database, which is regularly updated to add new members, reflect changes to contact information, and change membership status for those who are no longer active members.

8. Membership in Sierra Club is granted to any person who provides Sierra Club with a membership application providing their name and pays a membership fee of at least $15. A person is a member from the date that Sierra Club receives their membership fee.

9. Sierra Club's membership database shows that Richard Hill, a resident of 230 S Paine Street in Hanover Indiana, is a Sierra Club member. According to the database, Sierra Club first received Mr. Hill's membership fee and added him to the membership list on October 1, 2009.

10. Sierra Club's membership database shows that Lori McKiernan, a resident of 1504 S Whittier Avenue in Springfield, Illinois is also a Sierra Club member. According to the database, Sierra Club first received Ms. McKiernan's membership fee and added her to the membership list on December 1, 2016.

11. Sierra Club's membership database shows that James Kotcon, a resident of 414 Tyrone Avery Road in Morgantown, West Virginia is a lifetime Sierra Club member. According to the database, Sierra Club first received Mr. Kotcon's lifetime membership fee and added him to the membership list on December 1, 1985.

Pursuant to 28 U.S.C. § 1746, I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge and belief.

Executed on June 25, 2024.

Huda Fashho

DECLARATION OF RICHARD HILL

I, Richard Hill, do declare as follows:

1. My name is Richard Hill. I am over 18 years of age, and I am competent to give this declaration. The information in this declaration is based on my personal knowledge, information, and belief. If called to testify I would testify to the facts as stated in this declaration.

2. I have been a member of Sierra Club since 2009. I currently serve on the Energy Committee for the Hoosier Chapter of the Sierra Club and previously served as Chair of the Executive Committee.

3. My concern for environmental issues – and in particular the pollution from power plants – grows out of my time working on a nuclear submarine in the Navy. After the issues with construction of the Marble Hill nuclear facility in Madison, Indiana, and the reports of pollution from the Love Canal accident and Three Mile Island, I became active in environmental issues in my region. In addition to my membership and roles within the Sierra Club, I have been involved in other environmental organizations dedicated to protecting water quality around the Clifty Creek power plant. Previously I served as President and as a member of the Board of Save the Valley, an all-volunteer environmental organization dedicated to protecting the air, water, and land of the Ohio River Valley in southeastern Indiana and northern Kentucky between Cincinnati and Louisville.

4. I am also a current member of the Hoosier Environmental Council and have been since 1997. Between 1998 and 2001, I was a member of the Hoosier Environmental Council Board. During the course of my time working to protect air and water quality with Sierra Club, Save the Valley, and the Hoosier Environmental Council, I have gained experience and knowledge of water quality, groundwater contamination, and permitting issues involving coal-burning power plants, including Clifty Creek.

5. I reside at 230 S. Paine St. in Hanover, Indiana and have lived here for five years. From 1990 until 2019, I lived approximately two miles from my current address, in Madison, Indiana.

6. I live less than two miles from the coal-burning Clifty Creek power plant.

7. Based on years of advocacy and publicly available data, including my participation in water quality and groundwater permit challenges involving the

Clifty Creek power plant, I understand that the Clifty Creek power plant historically dumped coal ash into impoundments adjacent to the plant, and still disposes of coal ash into a landfill next to the facility. The facility also discharges water from the power plant itself and from wastewater collected at the these impoundments and landfill into the Ohio River. It is also my understanding that the facility built a new landfill, which was installed directly over an existing unlined coal ash disposal impoundment. I understand that Water from the landfill is collected and discharged into the Ohio River.

8. I know that coal ash wastewater from power plants and ash impoundments can have high levels of heavy metals and toxic pollution, including mercury, arsenic, selenium, and other toxic pollutants. In fact, I understand that the owner and operator of the Clifty Creek power plant has acknowledged elevated levels of groundwater contamination, including molybdenum, lithium, and boron, from one or more of the coal ash ponds or landfills at the facility.

9. I am concerned about unsafe levels of surface and groundwater contamination from the coal ash impoundments and direct wastewater discharges from the Clifty Creek power plant, in part, because drinking water in my home is provided by the City of Madison water company. I understand, based on publicly available documents from the Indiana Department of Natural Resources, that the City of Madison owns five wells less than two miles the Clifty Creek power plant and coal ash ponds.

10. As part of my volunteer work with Sierra Club and other organizations, I have reviewed publicly available hydrological maps that indicate the wells from which the City of Madison draws its drinking water pull from aquifers that are adjacent to the Clifty Creek impoundments and other disposal areas and are likely hydrologically connected to aquifers beneath the impoundments, as well as the Ohio River. I am concerned that these wells drawn from groundwater that is contaminated by coal ash in the Clifty Creek ponds.

11. Because we obtain our water supply from the City of Madison, I am concerned that the water I drink, cook and bathe with may be contaminated with coal ash constituents that have either been discharged or leached into groundwater from the Clifty Creek power plant, including molybdenum, lithium, and boron. I am concerned about the adverse effects drinking this water may have on my health.

12. I understand that the U.S. EPA recently issued a rule limiting the amount of toxic pollution contained in wastewater discharged by coal plants like Clifty Creek. As I understand it, the rule would prohibit Clifty Creek from further

discharges of scrubber and boiler slag wastewater, and it would require treatment or elimination of the wastewater that leaches or percolates through Clifty Creek's coal ash impoundments or landfills and is then discharged into the Ohio River watershed. I support these aspects of the rule because they will result in reductions of coal ash pollution in the Ohio River watershed and the aquifers from which we obtain our water supply, and would therefore reduce our exposure to toxic water pollution.

13. It's also my understanding that several states and regulated power plants have challenged aspects of EPA's new rule because it requires those power plants to take additional steps to clean up their water pollution. A court order overturning EPA's new rule would negatively affect my family because it would negate the rule's promised water quality improvements and pollution reductions. For that reason, I support Sierra Club's efforts to defend the rule.

Pursuant to 28 U.S.C. § 1746, I declare under penalty of perjury that, to the best of my knowledge, all of the foregoing is true and correct.

Executed this 24 day of June, 2024.

[signature]

Richard Hill

DECLARATION OF JAMES KOTCON

I, James Kotcon, declare and state as follows:

1. My name is James Kotcon. I am over the age of 18 and am competent to give this declaration. I have personal knowledge of the matters stated herein and, if called as a witness, could testify thereto.

2. I am a lifetime member of the Sierra Club. I have been a member since 1986. I currently serve as Chair of the West Virginia Chapter. In my position, I work with other Chapter volunteers to plan and implement programs, and develop policy on local issues. I joined the Sierra Club initially to get involved with the Outings program but quickly became concerned with the prevalent conservation issues in West Virginia, especially those around clean air and clean water.

3. My professional background is in plant pathology. I earned my PhD from University of Wisconsin—Madison. I am an Associate Professor of Plant Pathology at West Virginia University where I teach students on a variety of subjects, including environmental impact assessments and water quality inspection.

4. I've lived in Morgantown, West Virginia since 1985. My wife and I moved into our current residence at 414 Tyrone Avery Road in 1986 and we have lived here ever since.

5. My residence is approximately 6 miles from the Fort Martin Power Station, a coal-fired power plant located on the Monongahela River, operated by Monongahela Power Company ("MonPower").

6. I enjoy outdoor recreational activities. I have canoed the upstream parts of the Monongahela River, with my wife or friends, every few years and plan to continue to do so in the future. I have enjoyed fishing on the Monongahela River, and I hope to resume that hobby in the near future.

7. I am aware of the harmful public health and environmental impacts of water pollution from coal-fired power plants. I understand that the wastewater discharged from the Fort Martin power plant into the river is comprised of a mix of substances that contain many toxic pollutants, including arsenic, mercury, selenium, and lead, among others. I understand that these toxic chemicals can cause cancer and other adverse health impacts including reproductive, neurological, respiratory, and developmental problems. I also understand that toxic pollutants such as selenium can be extremely harmful to fish and other aquatic life in high concentrations. For these reasons, I consciously avoid recreational activities on the Monongahela River that are downstream from the Fort Martin coal plant.

8. My wife and I became aware of West Virginia's water quality issues as soon as we moved into the area. It is an issue that deeply concerns me. I was born and raised on a dairy farm in Wisconsin, where we assumed water was always clean.

When I moved to West Virginia, I quickly learned that is not always the case. The major fish kill at Dunkard Creek in 2009 from coal mining pollution still troubles me. I worry about the health of streams and rivers for the many organisms that are sensitive to the toxic discharges. I've also heard anecdotally of grade school children coloring rivers orange instead of blue in their classrooms, which I find deeply upsetting.

9. I am deeply concerned about the discharges from Fort Martin and the impacts that this toxic pollution has on the Monongahela River and tributaries, surrounding riparian habitats, and aquatic life generally. I am concerned that there are not sufficient measures being taken to keep these contaminants from entering the river. I would fish and canoe in the downstream parts of the Monongahela River if I could be assured that Fort Martin is not discharging toxic pollutants into the river system.

10. I am also very concerned about the impacts of these toxic pollutants on the health of nearby communities. The river is a water source for several communities downstream of the Fort Martin plant all the way to Pittsburgh, Pennsylvania.

11. I understand that the U.S. EPA has recently issued a rule limiting the amount of toxic wastewater effluence coal plants are permitted to discharge. As I understand it, Fort Martin will be prohibited from further discharges of scrubber wastewater and bottom ash transport water, and would be required to treat or

eliminate wastewater that leaches through coal ash impoundments. I understand that this rule will reduce the discharge of toxic effluence into the Monongahela River.

12. If MonPower was required under the new rule to significantly reduce Fort Martin discharges, I believe it would help preserve the river's health, wildlife and reduce the environmental and public health risks associated with toxic water pollution from the power plant. If the Fort Martin power plant's discharges are properly controlled, I would feel safer, and more frequently partake in, fishing, canoeing, and rafting along the river.

I declare under penalty of perjury that, to the best of my knowledge, the foregoing is true and correct.

Dated June 25, 2024

James Kotcon

____
James Kotcon

DECLARATION OF LORI MCKIERNAN

I, Lori McKiernan, declare as follows:

1. My name is Lori McKiernan. I am over 18 years old. The information in this declaration is based on my personal experience and my review of publicly available information.

2. I live on South Whittier Avenue in Springfield, Illinois, about 3.5 miles northwest of City Water, Light, and Power's ("CWLP") Dallman coal-fired power plant. I have lived there for two-and-a-half years. I am retired.

3. I have been a member of Sierra Club for about a year. My membership is current. I joined because I care about water pollution, eliminating fossil fuels, and transitioning to renewable energy. I serve on the Executive Committee for the Club's Sangamon Valley Group and lead the clean transportation work for the Club's Illinois Chapter. I am also very involved in advocacy related to Dallman Unit 4. The Sierra Sangamon Valley Group monitors CWLP ordinances that involve water, the Dallman coal plant, and a transition to clean energy. We research and assess the proposals and speak out at City Council meetings when we have concerns about the requested actions. One of the environmental issues I am most focused on is clean water. That's in part because I know Dallman Unit 4 discharges its wastewater into our drinking water supply. The toxins in the wastewater that is discharged from Dallman 4 is a concern to our group.

4. I like to hike and observe nature around Lake Springfield and the Sangamon River. I do so about 4-6 times a year. I especially enjoy bird watching; I'm trying to learn about the birds that frequent Central Illinois. I always keep an eye and ear out for birds during those events. I'm aware of the impact of polluted water on our local wildlife. The impact of this pollution on the health and diversity of wildlife impacts humans. This is always on my mind as a problem during my hikes.

5. I am aware that CWLP sends some of its wastewater to the water reclamation district, and I am aware that some of its coal ash pollution seeps into the groundwater. I know this pollution contains toxic contaminants. I know about this water pollution from being part of Sierra Club and from following information abut the issue. I know this water pollution is a threat to our drinking water and that something needs to be done about it. I am extremely frustrated that CWLP and the City of Springfield aren't doing more to protect Springfield's citizens from environmental pollution.

6. I am concerned about how Dallman's water pollution impacts me and my community. It is stressful thinking about the potential impacts of all these toxic chemicals. I don't have much choice over my water supply. I am concerned about the presence of toxic contaminants in my water. I pay attention to any incident that could cause a failure in the City's water treatment system. I also worry about the people who live on Lake Springfield and spend time in the water.

7. In addition, I am concerned about how Dallman's water pollution impacts our ecosystem. I would not eat fish from the Sangamon River because of my concerns about water pollution. Additionally, I care about a healthy population of birds—both because I like to observe them and because I believe biodiversity is important. When I go hiking near Lake Springfield and the Sangamon River, concerns about water pollution diminish my enjoyment of bird watching. I worry about how pollution could impact them.

8. I am aware that the U.S. EPA recently issued a new rule that will require the Dallman plant to eliminate its discharge of two wastewater streams (FGD wastewater and managed coal ash leachate) and reduce its discharge of one wastestream (unmanaged coal ash leachate). I know these wastestreams contain toxic pollution. It's very concerning to me that CWLP isn't willing to go along with these new regulations.

9. If the new rule is implemented, and Dallman is required to eliminate its wastewater pollution, I would be less stressed about the potential impact to my drinking water supply, my health, and the health of my community. I would definitely get out and enjoy Lake Springfield and the Sangamon River more, especially because I would be better able to enjoy bird watching at those water bodies.

10. By contrast, if the new rule is not implemented and Dallman is allowed to keep discharging large amounts of polluted water, it would not reduce my concerns. Without this rule and its strong requirements, I do not believe CWLP will be held accountable for its pollution. I find that very frustrating and stressful. I also worry about how continued contamination of Lake Springfield and the Sangamon River could impact wildlife. Wildlife is part of the basis of our environmental system. If our environmental system is being damaged, it damages all of us.

I declare under the penalty of perjury that, to the best of my knowledge, the foregoing is true and correct.

Dated June 25, 2024.

Lori McKiernan

Lori McKiernan

Waterkeeper Alliance, Inc.

DECLARATION OF DANIEL E. ESTRIN

I, Daniel E. Estrin, hereby declare and state:

1. I have personal knowledge of the matters stated herein. I am over the age of 18 and suffer from no legal incapacity. I submit this declaration in support of Waterkeeper Alliance, Inc.'s ("Waterkeeper Alliance") participation as a respondent-intervenor in petitions filed by 22 State Attorneys General (collectively, "State Petitioners"), and the Utility Water Act Group and two of its members, Southwestern Electric Power Company and the NRG Texas Power, LLC, as well as a separate petition filed by the City Utilities of Springfield, Missouri (collectively, "Industry Petitioners"), challenging the United States Environmental Protection Agency's ("EPA") final rule entitled *Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category*, 89 Fed. Reg. 40,198 (May 9, 2024) (to be codified at 40 C.F.R. Pt. 423) (the "2024 Steam Electric ELG Rule").

2. I am General Counsel and Legal Director of Waterkeeper Alliance. I have held this position for over eight years and I have worked in various capacities with and for the Waterkeeper movement for more than 30

years. My business address is 180 Maiden Lane, Suite 603, New York, New York 10038.

3. In my role at Waterkeeper Alliance, I am responsible for supervising all of Waterkeeper's legal work, including all litigation to which Waterkeeper is a party.

4. Waterkeeper Alliance is a not-for-profit membership corporation organized under the laws of the State of New York, and a charitable corporation under section 501(c)(3) of the Internal Revenue Code, that strengthens and grows a global network of grassroots leaders protecting everyone's right to clean water. Waterkeeper Alliance currently comprises approximately 300 member Waterkeeper groups on 6 continents.

5. There are approximately 150 member Waterkeeper groups based in the United States. Waterkeeper Alliance has interests in the matters addressed herein that are aligned with the interests of these members groups and their individual members. Every case that Waterkeeper Alliance brings is brought to support or on behalf of Waterkeeper member groups.

6. West Virginia Rivers Coalition is a Waterkeeper member group in good standing. *See* the accompanying Declaration of Heather Sprouse dated June 26, 2024, submitted in support of our Motion for Intervention.

7. Waterkeeper Alliance's organizational model emphasizes grassroots advocacy. To become a member of Waterkeeper Alliance, prospective Waterkeeper groups must demonstrate that they will meet organizational quality standards. Each Waterkeeper group is associated with a particular body of water or watershed, which represents that group's "jurisdiction." Waterkeeper groups seek to protect and preserve the quality of the water resources within their respective jurisdictions by advocating for compliance with environmental laws, responding to citizen complaints, identifying problems that negatively affect their waterbodies, and devising appropriate remedies to address those issues.

8. Waterkeeper Alliance advances its own interests and the interests of its member Waterkeeper groups and their individual members through a variety of means, including identifying noncompliance with federal and state environmental laws and regulations, and bringing that noncompliance to the attention of regulatory authorities. Waterkeeper Alliance also brings litigation on behalf of itself and its member

Waterkeeper groups to enforce federal and state environmental laws and regulations when necessary to ensure compliance and to protect aquatic ecosystems and communities from pollution.

9. Through my educational and professional experience, I have gained extensive knowledge about a wide range of environmental topics. These topics include the harmful effects of pollution associated with coal extraction and combustion on aquatic ecosystems and human health.

10. Through my educational and professional experience I have learned that coal combustion wastewater – including bottom ash, combustion residual leachate ("CRL"), and flue gas desulfurization ("FGD") wastewater – discharged by coal-burning power plants can contain mercury, arsenic, manganese, selenium, chromium, and other toxic pollutants that are harmful to human health and aquatic ecosystems.

11. To achieve its organizational mission of strengthening and growing a global network of grassroots leaders protecting everyone's right to clean water, Waterkeeper Alliance concentrates its work on certain issues that most strongly affect that mission, especially when an issue affects a large number of Waterkeeper groups. One such issue is water pollution resulting from the extraction, transportation, combustion, and disposal of coal and

its byproducts. Waterkeeper Alliance staff work with Waterkeeper groups and other partners to investigate coal-related pollution sources and to implement strategies to abate such pollution. The Clean Water Act, and federal and state regulations implementing the Act, are primary tools that Waterkeeper Alliance and its Waterkeeper groups rely on to protect waterways from coal pollution.

12. Waterkeeper Alliance and its member Waterkeeper groups have frequently participated in administrative processes before state and federal agencies, including EPA, concerning proposed Clean Water Act National Pollutant Discharge Elimination System ("NPDES") permits for coal-burning power plants, to urge those agencies to require discharge limits in NPDES permits for coal-burning power plants that are consistent with Clean Water Act requirements.

13. In addition, Waterkeeper Alliance and its member Waterkeeper groups have frequently participated in citizen enforcement suits under the Clean Water Act, including citizen suits against the owners or operators of coal-burning power plants who violate the discharge limits or other terms and conditions of their NPDES permits.

14. I am aware that many of the surface waters that Waterkeeper Alliance aspires to protect, including many surface waters associated with particular Waterkeeper groups such as West Virginia Rivers Coalition, receive discharges from power plants containing coal combustion wastewater, including bottom ash, CRL, and FGD wastewater.

15. I understand that, cumulatively, current discharge limits in NPDES permits for coal-burning power plants allow discharges of billions of pounds of toxic pollution to waterways in the United States each year.

16. I am aware that EPA has adopted a new final rule further strengthening the Steam Electric ELGs after first updating them in 2015. When EPA first proposed to update the Steam Electric ELGs in 2013, Waterkeeper Alliance worked with Waterkeeper groups and partner organizations on comments urging EPA to finalize a strong rule consistent with Clean Water Act requirements. Waterkeeper Alliance also took other steps to advocate for a strong final ELG rule, including working with partner organizations to issue reports on the rulemaking and meeting with the White House Office of Management and Budget and other decision-makers.

17. Since EPA first updated the Steam Electric ELGs in 2015, Waterkeeper Alliance has continued to work closely with Waterkeeper groups and partner organizations to defend the stronger provisions of the rule while also continuing to advocate and litigate for EPA to further strengthen the Steam Electric ELGs consistent with Clean Water Act requirements. Waterkeeper Alliance's advocacy has included moving to intervene in industry challenges to the 2015 rule, working with partner organizations to successfully litigate a challenge to the 2015 rule's CRL and legacy wastewater provisions, and providing comments and pursuing further litigation on both the 2020 and 2024 Steam Electric ELG rules.

18. I understand that the new 2024 Steam Electric ELG Rule will require more stringent treatment, and in some cases complete elimination of discharges, of coal combustion wastewater, including bottom ash, CRL, and FGD wastewater. I also understand that this increased treatment and/or elimination of discharges will prevent significant amounts of toxic water pollution from entering waterways around the country, including in Waterkeeper groups' jurisdictions.

19. I am aware that 22 State Attorneys General have filed petitions for review challenging the 2024 Steam Electric ELG Rule, in addition to petitions for

review filed by the Utility Water Act Group and individual utilities in Arkansas and Texas, as well as a separate petition filed by City Utilities of Springfield, Missouri. Based on the comments filed by these petitioners during the public comment period on the proposed rule in 2023, it appears that these petitioners' aim through this litigation will be to weaken or overturn the 2024 Steam Electric ELG rule's new, more stringent requirements for CRL, bottom ash, and FGD wastewater discharges.

20. If industry challenges to the 2024 Steam Electric ELG Rule were to succeed, much or all the pollution reduction required by the rule would be undone, and damaging water pollution from coal-burning power plants would continue around the United States. This continued damage to waterways would harm the interests of Waterkeeper Alliance, many of our member Waterkeeper groups, and their members.

I declare under the penalty of perjury that the foregoing is true and correct.

Executed on June 27, 2024 in New York, New York.

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Daniel E. Estrin

DECLARATION OF HEATHER SPROUSE

I, Heather Sprouse, declare and state as follows:

1. My name is Heather Sprouse. I am over the age of 18. The information in this declaration is based on my personal experience and my review of publicly available information.

2. I live in the Curry District of Putnam County, West Virginia, between the towns of Huntington and Charleston and just over the Kanawha County line. My home is about 11 miles away from the John E. Amos power plant and about 6.5 miles from the banks of the Kanawha River. I have lived at my current home since 2013, and in this area since most of my life. My family has been in West Virginia for at least five generations.

3. I am the Community Engagement Manager for the West Virginia Rivers Coalition, also called WV Rivers, which is part of Waterkeeper Alliance, Inc. Our mission is to conserve and restore West Virginia's exceptional rivers and streams. I have been in my role for just over two years. In this role, I manage WV Rivers organizers; help to develop an organization-wide approach to community engagement; serve as one of the organization's media contacts for representing community voices; and develop training materials about how the public can more easily engage with environmental permitting processes and agencies.

4. I have also been a member of WV Rivers since May 2023. My membership is current. I got involved with WV Rivers because of my long-standing interest in environmental issues, especially concerns about water pollution. When I was a teenager, I became very concerned about mountaintop removal. Mining issues remain deepest in my heart. More recently, I've become concerned about PFAS. At the core of these concerns is my belief that all West Virginians should have access to safe and clean water.

5. I enjoy outdoor recreational activities, including fishing, kayaking, and swimming. I have been fishing and kayaking recreationally for about 8 years. Today, I fish and kayak about 6 times a year and plan to continue doing so in the future.

6. Currently, I have to drive quite far away from my home in order to find safe areas to fish and kayak, even though I am very close to the Kanawha River. For example, we sometimes kayak on the Coal River, which is about 20 miles from our

house. However, because that river also has significant water quality issues related to coal mining, we do not swim or fish for consumption from that river. Instead, we travel out of state where we can feel safe eating what we fish—for example, we have traveled to tributaries of the Great Lakes as well as the Pine Island area of Florida. We go to Florida every year to kayak, boat, and fish, and we are able to eat the fish year. We go yearly in large part because we feel we can't do those activities safely in West Virginia.

7. I grew up in this area, and I have never felt safe recreating in the part of the Kanawha River close to my home, near the John E. Amos power plant. The plant is huge and notorious, and you can see it from almost anywhere near here. I can see it from the grass fields of my in-laws' farm, which is about 14 miles away from the plant, where my family and I often spend time. My daughter grew up calling the plant the "cloud factory" because of seeing the steam coming from the plant's smokestacks. It's unpleasant to even walk near or drive past the power plant. I am constantly concerned about how pollution from the plant, including water pollution, impacts ecology and aquatic life. I'm also very worried for my neighbors who live downstream from the plant. Flooding is an increasing concern in the area, and I think a lot about what it would mean for homes to flood with water contaminated by pollution from the John E. Amos plant.

8. To date, I would never consider fishing downstream of the John E. Amos plant because of my concerns about water pollution from the plant. Not even catch-and-release feels safe, let alone fishing for subsistence. Similarly, swimming downstream of the plant has never been an option. Because of my concerns about water pollution, I feel unsafe recreating in the stretch of the Kanawha even many miles downstream of the power plant, down to the point where it flows into the Ohio River.

9. I would love to have a relationship with the Kanawha River, especially the part of the river that is near my home. It would be incredible to feel safe recreating there. I am envious of the communities that can go out and enjoy their water resources. That has never been an option where I live. Instead, you always have to drive somewhere to get access to waterbodies that are safe to recreate in. Knowing other communities are taking steps to clean up and protect their ecosystems makes me feel frustrated about the situation where I live. I feel robbed of this resource—access to the Kanawha River to use and enjoy—all the time. I live in an area where there are broad concerns about water quality, and water pollution from the John E. Amos plant specifically is a huge piece of the puzzle.

10. When I think about the John E. Amos plant, what concerns me most is water pollution. I know that the plant has unlined ponds of coal ash slurry and leachate, and I know they've been unlined for years and years. Pollution from the plant's unlined slurry pond is top of my mind. I am aware that pollution is discharged directly into the Kanawha River.

11. I am aware that the U.S. EPA recently issued a new rule that will require the John E. Amos plant to eliminate its discharge of three of its toxic wastewater streams into the Kanawha River and to reduce its discharge of a fourth toxic wastestream. I understand that these wastestreams contain pollutants like arsenic, mercury, selenium, and lead, among others. These pollutants, and my concerns about how they can impact human health, are why I don't feel safe recreating in the Kanawha River downstream of the John E. Amos plant.

12. If the new rule is implemented, and John E. Amos is required to eliminate its major discharges of wastewater pollution, I would feel safer kayaking and catch-and-release fishing in the part of the Kanawha River downstream of the John E. Amos plant. I would definitely use and enjoy that stretch of the river more.

13. By contrast, if the new rule is not implemented and John E. Amos is allowed to keep discharging large amounts of polluted water, it would not reduce my concerns. I would have to continue traveling far away from my home in order to feel safe fishing and kayaking. I also would continue to feel worried about how the plant's pollution is impacting our ecology and aquatic life, and how flood waters contaminated by John E. Amos's water pollution could impact my community.

I declare under penalty of perjury that, to the best of my knowledge, the foregoing is true and correct.

Dated June 26, 2024.

Heather N. Sprouse

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Heather Sprouse

Natural Resources Defense Council, Inc.

DECLARATION OF GINA TRUJILLO

I, Gina Trujillo, declare as follows:

1. I am the Director of Membership at the Natural Resources Defense Council, Inc. (NRDC). I have been in that position since January 1, 2015, and have worked at NRDC in the membership department for more than 30 years.

2. My duties include supervising the preparation of materials that NRDC distributes to members and prospective members. Those materials describe NRDC and identify its mission.

3. NRDC is a membership organization incorporated under the laws of the State of New York. It is recognized as a not-for-profit corporation under section 50l(c)(3) of the United States Internal Revenue Code. NRDC's headquarters are located at 40 West 20th Street, New York, NY 10011.

4. NRDC's mission statement declares that "The Natural Resources Defense Council's purpose is to safeguard the Earth: its people, its plants and animals, and the natural systems on which all life depends." The mission statement goes on to declare that NRDC works "to restore the integrity of the elements that sustain life - air, land, and water - and to defend endangered natural places." NRDC's mission includes the prevention and mitigation of water pollution, to protect NRDC's members' use and enjoyment of natural resources and their own health and safety.

5. Through the Freshwater Ecosystems Team within its Nature Program, NRDC pursues federal and state policies to curb water pollution and protect surface water resources for the benefit of people and wildlife.

6. As a part of these efforts to protect freshwater, NRDC has participated in administrative rulemaking processes and litigation aimed at strengthening pollution discharge standards for steam electric power plants through the effluent limitations guidelines (ELGs). For instance, on January 21, 2020, NRDC joined comments on the amendments to the steam electric ELGs proposed in 2019, 84 Fed. Reg. 64,620 (Nov. 22, 2019). NRDC likewise joined a petition for review to challenge the amendments to the steam electric ELGs finalized in 2020, 85 Fed. Reg. 64,650 (Oct. 13, 2020). And, NRDC joined comments on the amendments to the steam electric ELGs proposed in 2023, 88 Fed. Reg. 18,824 (Mar. 29, 2023), and at issue in the present litigation.

7. When an individual becomes a member of NRDC, his or her current residential address is recorded in NRDC's membership database. When a member renews his or her membership or otherwise makes a contribution to NRDC, the database entry reflecting the member's residential address is verified or updated.

8. NRDC currently has approximately 483,972 members. There are NRDC members residing in each of the fifty United States and in the District of Columbia and Puerto Rico.

9. When an individual becomes a member of NRDC, he or she authorizes NRDC to take legal action on his or her behalf to protect the environment and public health.

10. According to NRDC's membership records, Karen Cairns is a current member of NRDC, and her household has regularly donated since 2002.

I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge and belief.

Gina Trujillo

Gina Trujillo

Signed on June 27, 2024

<u>**Declaration of Karen Cairns**</u>

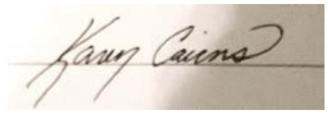
I, Karen Cairns, declare as follows:

1. My name is Karen Cairns. I am over 18 years old (I am 78). The information in this declaration is based on my personal experience and my review of publicly available information.
2. I live in Louisville, Kentucky. I have lived at my current address since March 2018. Before that, I lived in the Louisville area from 1984 until 2007 (in Louisville 1984-1989, then directly across the Ohio river in Indiana in 1989, then in Louisville 2002-2007).
3. I am retired from my careers as a registered nurse and environmental educator. I was a nurse for 20 years until I retired from that career in 2001. I attended the University of Louisville where I received a Doctorate in Environmental Education in 2001 and worked there for several years. I still do a lot of environmental education in my neighborhood and work with native plant groups.
4. I am a member of the Natural Resources Defense Council ("NRDC"), and my household has donated regularly to NRDC since 2002.
5. I am also a member of Sierra Club and have been a Life Member since the 1970s.
6. In addition, I was a member of the Salt River Watershed Watch, where I did water quality testing for the rivers and creeks that empty into the Ohio River, and I worked with the Louisville Urban Environmental Leadership group.
7. One of the main reasons I joined NRDC and Sierra Club was because I have always been aware of environmental issues. I grew up in a family of biologists who were very concerned about environmental issues. My father, Dr. John Cairns, Jr, was a member of NRDC until he died in 2017. Throughout his career as a limnologist, he worked on issues related to water quality, including problems with effluent or wastewater.
8. I enjoy walking along the Ohio River and Louisville's waterfront every week. We have a waterfront association here and there is a public greenway near my house to the Ohio River. I can walk along the Ohio River to downtown Louisville, and I do that regularly.
9. I am very concerned about environmental justice issues, and we have a number of those in Louisville. I am concerned about air pollution because I had severe asthma from the time I was a child until I was 56 years old. I no

longer have severe asthma but my lungs are hyper-reactive to air quality, so this is very important to me.

10. I am also concerned about water pollution. I worry that the Ohio River is highly contaminated due to power plants, like the Trimble County Generating Station, factories and other industrial sources of pollution in the area. When I go walking along the Ohio River, my concerns about the water pollution diminish my use and enjoyment.
11. I used to enjoy kayaking, but I am no longer able to do so. Even if I were able to do so, I would not kayak or even get into the water in the Ohio River near where I live and recreate because I am concerned about contamination from upstream sources of pollution like the Trimble County Generating Station.
12. I am also concerned about the ways water pollution from the Trimble County Generating Station impacts our ecosystem. I know that people fish downstream in the Ohio River near where I recreate and that they consume the fish that they catch. However, even though I do not fish, I would never consume fish caught in the Ohio River because I am too concerned that it has been contaminated by pollution.
13. I am aware that the U.S. EPA recently issued a new rule that will require the Trimble County Generating Station to eliminate its discharge of FGD wastewater. I know this wastewater contains toxic pollution.
14. If the new rule is implemented, and the Trimble County Generating Station is required to reduce its contamination of the Ohio River, it would absolutely impact me. I would enjoy recreating around the Ohio River more. Implementation of the new rule would also reduce my concerns about how the Trimble County Generating Station's water pollution is impacting my health, my community, and our ecosystem.
15. By contrast, if the new rule is not implemented and the Trimble County Generating Station is allowed to keep discharging large amounts of polluted water, this would actually increase my level of concern, as it would be difficult to understand why this was allowed to happen when there was a substantial opportunity to protect our water quality.

I declare under penalty of perjury that the foregoing statements are true and correct to the best of my knowledge, information, and belief.

Date: June 27, 2024 Signed: 

Environmental Integrity Project

DECLARATION OF JENNIFER DUGGAN

I, Jennifer Duggan, declare and state as follows:

1. My name is Jennifer Duggan, and I am the Executive Director of the Environmental Integrity Project ("EIP"). I am over 18 years of age and suffer from no impairment or disability affecting my ability to give truthful testimony.

2. I have worked for EIP for approximately ten years and currently serve as EIP's Executive Director.

3. EIP is a non-profit organization based in Washington, D.C. dedicated to ensuring the effective enforcement of state and federal environmental laws to protect public health and the environment. EIP's main office is located at 888 17th St. NW, Suite 810, Washington, DC 20006.

4. EIP's mission is to protect public health and our natural resources by holding polluters and government agencies accountable under the law, advocating for tough but fair environmental standards, and empowering communities fighting for clean air and clean water. EIP's goals are (1) to illustrate through objective facts and figures how the failure to enforce or implement environmental laws increases pollution and harms public health; (2) to hold federal and state agencies, as well as individual corporations, accountable for failing to enforce or comply with environmental laws; and (3) to help local communities obtain the protections of environmental laws.

5. To further this mission, EIP advocates for laws to protect public health and the environment from air and water pollution from coal-fired power plants and other large sources of pollution. As part of its efforts to ensure effective enforcement of environmental laws, EIP participates in federal and state rulemakings related to water pollution from the utility industry and brings lawsuits to enforce the Clean Water Act on behalf of community and environmental groups that are harmed by coal plant pollution. In addition, EIP uses public data obtained through public records requests to develop reports, media materials, and litigation briefs that educate the public and decision-makers.

6. I am aware that the EPA revised federal regulations related to the discharge of pollutants from the Steam Electric Industry, known as the "Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category" ("ELG Rule") in April 2024. The ELG Rule primarily regulates wastewater from the storage and disposal of the byproducts of coal combustion, generally known as "coal ash."

7. EIP invests substantial time and effort in documenting ground and surface water pollution caused by coal ash disposal. EIP uses this information to help ensure that coal-burning power plants comply with state and federal environmental laws, and to advocate for improvements to existing laws to protect human health and the environment from the unsafe disposal of coal ash. For

example, in 2013, EIP published a report with the Sierra Club and other organizations detailing how coal-burning power plants were frequently discharging wastewater without monitoring of, or limits on, toxic pollution, often into waterways that were impaired for coal ash pollutants. In 2015, EIP published a report with Physicians for Social Responsibility and other organizations explaining that the EPA had underestimated the monetary value of the human health benefits of the proposed ELG Rule. EIP has also published a series of reports documenting coal ash "damage cases," which include many cases of surface water impacts from coal ash.

8. In addition to informing the public about discharges of pollution from power plants and other industrial facilities through reports, EIP represents citizens and groups, on a pro bono basis, whose health, recreational, aesthetic and other environmental interests are harmed by coal-burning power plants and other industrial sources in their communities. Among other things, EIP advocates on behalf of these citizens and groups by reviewing permits required under the Clean Water Act and challenging them when necessary, and by bringing enforcement actions when sources violate conditions of state-issued permits or federal law.

9. Our ability to carry out our mission, and specifically our ability to provide legal assistance to people affected by coal ash pollution, is directly dependent on the extent to which EPA carries out its statutory mandate under the

Clean Water Act, including the extent to which EPA regulations protect human health and the environment consistent with the Clean Water Act's requirements.

10. The revised ELG Rule imposes new limits on toxic coal ash pollutants in unmanaged leachate and some so-called "legacy wastewater" that was, until recently, only subject to case-by-case limits derived using permit writers' best professional judgment. The ELG Rule's establishment of uniform, national effluent limitations based on best available technology that must be incorporated into all power plant permits creates a "floor" of protections that will allow EIP to make more effective use of its limited resources, because we will not have to review or challenge case-by-case determinations of best available technology, or the lack thereof, when advocating for greater protections for downstream communities.

11. Because our ability to carry out our mission depends on EPA's adherence to its Clean Water Act mandate, EIP invested substantial time and effort to push EPA to issue a strong ELG Rule. In 2009, EIP notified EPA of our intent to sue the Agency for failing to meet its statutory obligation to review and, as appropriate, revise, the Effluent Limitations Guidelines for the Steam Electric Power Generating Category. We then participated in litigation and negotiations that resulted in a consent decree establishing a deadline for EPA to promulgate a final ELG Rule.

12. During subsequent ELG rulemakings, EIP submitted comments on proposed rules, released public reports about the significance, strengths, and weaknesses of the proposed rules, and met with EPA and other government actors to advocate for a strong regulations with stringent limits.

13. EIP has an organizational interest in federal regulations that require the use of the best available technology, as required by the Clean Water Act – not just for the coal industry, but for all industries. EIP's interests would be harmed if the Steam Electric ELGs were weakened, providing potential precedent for weaker ELGs in other industries; conversely, EIP's ability to advocate for stronger ELGs in other industries would be strengthened if EPA were required to fully implement its mandate under the Clean Water Act with respect to the Steam Electric industry.

I declare, under penalty of perjury, that the foregoing is true and correct.

Executed on this 23rd day of June, 2024.

Jennifer Duggan, Executive Director
Environmental Integrity Project

PennEnvironment, Inc.

DECLARATION OF DAVID MASUR

I, David Masur, declare and state as follows:

1. I am over 18 years of age and competent to give truthful testimony. I have personal knowledge of the facts provided below.

2. I am the Executive Director of PennEnvironment, and have been since 2002. I am responsible for staff management, strategic planning, direct advocacy on our environmental agenda, and the day-to-day operations of the organization. I also oversee any environmental litigation in which PennEnvironment is involved.

3. PennEnvironment is a Pennsylvania non-profit corporation organized for the purpose of conducting public interest research, policy development and analysis, public education, litigation, and advocacy to protect the environment and people of Pennsylvania, including the quality of Pennsylvania's water. Its principal place of business is 1528 Walnut Street, Suite 1400, Philadelphia PA 19102. PennEnvironment was formed in 2002 to carry on the environmental work previously conducted by the Pennsylvania Public Interest Research Group. PennEnvironment currently has approximately 15,000 members in Pennsylvania.

4. Protecting the quality of Pennsylvania's waters has been one of PennEnvironment's lead environmental priorities. PennEnvironment

regularly engages the Pennsylvania Department of Environmental Protection ("DEP") regarding Clean Water Act issues, reviews DEP and U.S. Environmental Protection Agency ("EPA") files on Pennsylvania facilities that have National Pollutant Discharge Elimination System ("NPDES") permits, and releases reports on water quality in Pennsylvania. In 2007, PennEnvironment filed a successful suit in federal court alleging thousands of illegal discharges of pollutants including metals such as selenium from the Conemaugh Generating Station. In 2011, we won our case and the court ordered the Conemaugh Plant's to pay $3.75 million, $3.5 million to restore the Conemaugh River and an additional $250,000 in civil penalties.

5. PennEnvironment undertakes its clean water programs on behalf of its members. Its efforts to promote clean water are directly responsive to the interests of its members, who have indicated repeatedly that this is a high priority for them. Because many of its members become citizen activists in support of PennEnvironment's programs, PennEnvironment works to keep its members informed and to hear their concerns. Through PennEnvironment, individual citizens are able to act collectively and to speak with a more powerful voice.

6. People often decide to join PennEnvironment after a canvasser comes to their door to discuss the organization and to offer them the

opportunity to become a member, or after they hear a PennEnvironment staffer speak about the organization's campaigns or projects at a local meeting. PennEnvironment members join by paying a membership fee, and they are asked to renew that financial commitment each year. PennEnvironment regularly communicates with its members to inform them about new developments, to encourage them to become engaged in its work, and to solicit their feedback. Such communication takes the form of door-to-door canvassing, newsletters, annual reports, interactive email action alerts, member appreciation events, member surveys, advisory committees, and events where members interact with experts from the environmental, labor, business, or political fields. PennEnvironment relies on the input of its members in shaping its policy priorities, and the pursuit of litigation to enforce the Clean Water Act has always received strong member support.

7. Many of PennEnvironment's members live, fish, swim, kayak, and enjoy the wildlife along the waterways immediately downstream from coal plants in Pennsylvania. Our members are concerned about the quality of the fish they eat, the quality of the water they swim in, and the health of the environment that they are a part of.

8. I, like many of PennEnvironment's members, am concerned about the pollutants in coal ash wastewater, including heavy metals like

mercury and selenium, and other pollutants, that can be toxic to humans and wildlife. I know that many of these pollutants bioaccumulate, making fish unsafe to eat.

9. I am aware the EPA finalized a regulation limiting water pollution from power plants in April 2024. I know that the rule would require new limits on discharges of coal combustion residual leachate from the Conemaugh Plant.

10. I am concerned that any weakening of the rule will inevitably expose PennEnvironment members to more pollution than they would otherwise be exposed to. This will lead to an increased risk of cancer and other health effects to PennEnvironment members who eat fish from affected waterways, an increased risk to the health of the wildlife that PennEnvironment members regularly enjoy, and a general degradation of the environment that I and my organization work so hard to protect, including in the areas downstream of the Conemaugh Plant.

I declare under penalty of perjury, this 26TH day of June, 2024, that the foregoing is true and correct.

David Masur

DECLARATION OF KURT LIMBACH

I, Kurt Limbach, declare and state as follows:

1. I am over 18 years of age. The information in this declaration is based on my personal knowledge and my review of publicly available information.
2. I live at 350 Creek Road, Bolivar, PA. I have lived at this address since 1990.
3. My home is located on approximately 295 acres of land, portions of which overlook the Conemaugh River. I chose to make this part of Western Pennsylvania my home because of the quality of life that living here provides me. In particular, I value the opportunities for outdoor recreation and connection with the natural environment.
4. I have been a PennEnvironment member since 2002. I joined PennEnvironment because they work to limit pollution and uphold the law in Pennsylvania. I worked with PennEnvironment on a successful suit in 2007 against the Conemaugh Plant, which was violating its discharge limits for metals in the Conemaugh River so PennEnvironment and Sierra Club sued them.
5. I have been a Sierra Club member since 1996. I joined Sierra Club because of my interest in environmental activism and because I see the tremendous environmental destruction from pollution in Western Pennsylvania. I know there's another, better way to do things and to generate electricity, and I

appreciate the fact that Sierra Club fights for that and for the protection of our natural resources.

6. My home is located less than four (4) miles from the Conemaugh Generating Station.

7. I am aware that water pollution and effluent discharges from coal-fired power plants contribute to a wide range of negative public health and environmental effects. I know that pollutants such as arsenic, mercury, and selenium have been linked to adverse health impacts and that these and numerous other harmful pollutants are discharged into the Conemaugh River from the Conemaugh power plant. I am deeply concerned about water pollution from this large source and about the health effects of exposure to toxins in its discharges.

8. In the past, I have regularly kayaked on the Conemaugh River downstream of the Conemaugh Generating Station. I enjoy kayaking this stretch of the river given its close proximity to my home, because of the Class 1, 2, and 3 rapids that make for enjoyable paddling, and because of the natural beauty surrounding that part of the river. I plan to spend time this summer kayaking this section of the river; I generally kayak between May and July when river water levels are sufficiently high. I often would like to get out of my kayak and go for a swim when it's hot outside, however, I avoid swimming in the river because of my concerns with the polluted effluent discharges from the

Conemaugh plant and so as to limit the levels of pollution to which I am potentially exposed. It would be nice to spend more time on the Conemaugh River near my house; it's such a beautiful area, but the river itself is so damaged and polluted it degrades my experience.

9. Although I enjoy fishing, I avoid doing so on the Conemaugh River because of the water pollution and my concern that the fish will be polluted with toxins. In fact, because of the pollution in my stretch of river—only a couple miles downstream of the Conemaugh plant, there are limited fishing opportunities; the river is basically dead for aquatic life, even bugs you would expect to see on the water are largely nonexistent. There are pockets here and there where you may find a couple fish (for instance where cleaner feeder streams hit the main branch of the Conemaugh) but, for most stretches of the river, you could go three or four miles and not see any fish. In addition, I know that some of the pollutants discharged from the Conemaugh power plant, such as selenium and mercury, are bioaccumulative and, therefore, I would not feel comfortable eating fish from the river downstream of the plant. I am the Secretary and on the Board of Directors of a local fish club, the Tubville Trout Club Unlimited, a 501(c)(3), and we operate in one of the waters that feeds into the Conemaugh doing activities such as teaching children how to fish. I would like to do some of the

same activities in the Conemaugh, but I cannot because there is no fishing opportunity—I would not eat the fish that are there.

10. I am aware that in April 2024 the U.S. Environmental Protection Agency ("EPA") revised the Steam Electric Effluent Limitations and Guidelines ("ELG") rule to add new limits on the amount of toxic metals and other harmful pollutants that facilities such as Conemaugh can discharge into our rivers and other waterways. I understand that the 2024 ELG rule would reduce water pollution in the Conemaugh River, thereby improving environmental and public health. Such improvements would also increase opportunities for ecotourism in my area and likewise positively impact property values in my community. I am also aware that the ELG rule requires plants including the Conemaugh Plant to comply with limits on toxic discharges by a certain date and that the Pennsylvania Department of Environmental Protection ("DEP") would have to include these limits in Conemaugh's next National Pollutant Discharge Elimination System ("NPDES") permit.

11. The 2024 ELG rule would require DEP to incorporate new limits on coal ash pollution – specifically, coal combustion residual leachate – when it next renews the NPDES permit for the Conemaugh Generating Station, which would benefit me. I would worry less about my health and the health of my friends and family and would be able to more fully enjoy the stretch of Conemaugh River

near my home with stricter limits in place for this plant's discharges. I would kayak more, fish more, and my property would likely be worth more. I, and my whole community, would benefit from the resulting improvement in water quality and from knowing that Conemaugh's permit would be renewed with additional limits for toxic metals and pollutants known to be discharged by coal-fired power plants.

Pursuant to 28 U.S.C. § 1746, I declare under penalty of perjury that the foregoing is true and correct. Executed this 27 day of June, 2024.

Kurt Limbach

Prairie Rivers Network

DECLARATION OF DON DAVIS

I, Don Davis, declare and state as follows:

1. I am over 21 years of age and suffer from no impairment or disability affecting my ability to give truthful testimony. I have personal knowledge of the facts set forth below.

2. I am a member of Prairie Rivers Network. I have been a member since 2014. I joined Prairie Rivers Network in 2014 because I am a landowner on the Sangamon River floodplain and I am concerned about mercury and other toxic metals accumulating in the food web of the local environment. I have been involved in conservation efforts since the 1970s and I also recreate and fish on Illinois rivers, so I have an interest in preserving the integrity of natural ecosystems and also in making them safe for fishing and other uses.

3. I reside at 6363 Stagecoach Road, Pleasant Plains, IL, 62677. I have lived at this address since 1994. I have lived in the Springfield area my whole life.

4. My wife and I are co-owners, along with two other couples, of a land right on 185 acres along the Sangamon River, roughly 20 miles downstream from where Sugar Creek enters the Sangamon. We have been co-owners since 2002. The 185 acres have been under a conservation easement since before we became co-owners. We have managed the land as part of the Conservation Reserve

Enhancement Program, which is a state and federal cooperative effort to improve water quality and reduce sediment and nutrient loads on the Sangamon River.

5. I know that the coal plant known as Dallman Station, also known as City, Water, Light and Power, discharges wastewater into Sugar Creek and, indirectly, to the Sangamon River. I know that the wastewater from Dallman Station contains heavy metals and other pollutants from coal ash. Water pollution from Dallman Station flows through Sugar Creek into the Sangamon River, and ultimately through the 185 acres that I co-own. Our land is in a floodplain. Sediment in the river, which includes pollution from Dallman Station, frequently redeposits on our land. Pollutants in the river and in sediment also accumulate up the aquatic and terrestrial foodchains into the fish and game that my family eats.

6. Of the co-owners of the land right, I get the most recreational use of the area. My family and I all fish in the Sangamon River. We fish within the 185-acre area that we co-own, and we also fish further upstream, as far upstream as the Route 29 bridge. I do not fish closer to Sugar Creek because I am concerned about the mercury, lead, cadmium, and other heavy metals from coal ash that are in the water.

7. My family and I also hunt in the area. We hunt and eat deer, turkey, and squirrels that use the Sangamon River as a water supply. Since we are on a

food chain that starts with the Sangamon River, I am concerned about the heavy metals and other pollutants that I am being exposed to.

8. I know that the Environmental Protection Agency set new pollution limits for coal plants in April, 2024. I oppose any weakening of the new pollution limits because I believe that any weakening will directly harm my family, my community and myself by increasing the amount of pollution that we might be exposed to.

I declare, under penalty of perjury, that the foregoing is true and correct.

Executed on this 26 day of June, 2024.

Donald D. Davis

Don Davis

DECLARATION OF MAGGIE BRUNS

I, Maggie Bruns, declare and state as follows:

1. I am over 21 years of age and suffer from no impairment or disability affecting my ability to give truthful testimony. I have personal knowledge of the facts set forth below.

2. I am the Executive Director of Prairie Rivers Network (PRN), serving in this position since 2023. PRN advocates for clean water and healthy rivers for the people, fish and wildlife of Illinois and is the independent state affiliate for Illinois of the National Wildlife Federation.

3. PRN works to protect water, heal land, and inspire change. Using the creative power of science, law, and collective action, PRN protects and restores our rivers, returns healthy soils and diverse wildlife to our lands, and transforms how we care for the earth and for each other. We work to protect water quality and river health from the impacts of coal waste pollution and the toxic chemicals which can leach from coal ash ponds into groundwater, lakes and river, polluting drinking water supplies and threatening fish and wildlife.

4. PRN helped develop and is engaging in the implementation of Illinois's coal ash rules (called Part 845). We submitted comments and attended the hearing of the first Part 845 hearing in Powerton. PRN regularly submits comments to ensure that National Pollution Discharge Elimination System (NPDES) permit renewals for

major polluters comply with the law. PRN has also brought lawsuits on behalf of its members to combat illegal and unsafe discharges of water pollutants from fossil-fuel-burning facilities. For example, we've commented on NPDES permits for many Illinois coal-fired power plants, including Springfield, Newton, Meredosia, Powerton, Vermilion, Coffeen and Waukegan. We've brought lawsuits against coal-fired polluters, such as our groundwater violation case against four Midwest Generation plants, a Clean Water Act lawsuit at the Vermilion site, and an Environmental Protection Act lawsuit at the Vermilion site.

5. Prairie Rivers Network is a membership based non-profit organization, with members across Illinois. PRN's over 1000 members use Illinois' many rivers for fishing, swimming, boating, drinking, and enjoying wildlife. Many of our members live and recreate downstream of plants that would need to update limits for the ELG rule, and would be adversely affected by the discharge of pollutants that degrade water quality.

6. I am aware that in April, 2024 the U.S. Environmental Protection Agency (EPA) promulgated revisions to the Steam Electric Effluent Limitations and Guidelines (ELG) rule to limit the amount of toxic metals and other harmful pollutants that facilities such as Dallman in Springfield, IL can discharge into our rivers and other waterways.

7. I know that many of the pollutants in coal ash wastewater bio-accumulate, building up to unsafe levels in fish and other species. These pollutants, and other coal ash pollutants, threaten the health of PRN members who fish in Illinois waterways, and who drink water from Illinois waterways, and also threaten the wildlife that PRN members regularly enjoy while recreating on Illinois waterways. A weakening of the ELG rule would allow coal plants to release more toxic pollution into the water, exposing PRN members and wildlife to higher levels of pollution than they would otherwise be exposed to if the rule was allowed to go into effect as written (or strengthened). This, in turn, would increase the likelihood that PRN members will experience adverse health effects and a diminished ability to enjoy Illinois' ecological wealth.

I declare under penalty of perjury that the foregoing is true and correct, to the best of my knowledge, belief, and recollection, pursuant to 28 U.S.C. § 1746.

Executed on this 21st day of June, 2024.

Maggie Bruns

Exhibit 16

United States Environmental Protection Agency | Office of Water Washington, DC 20460 | EPA-821-R-24-006 April 18, 2024

Benefit and Cost Analysis for Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category

United States
Environmental Protection
Agency

Benefit and Cost Analysis for Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category

EPA-821-R-24-006

April 18, 2024

U.S. Environmental Protection Agency
Office of Water (4303T)
Engineering and Analysis Division
1200 Pennsylvania Avenue, NW
Washington, DC 20460

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Table of Contents

List of Figures

List of Tables

Abbreviations

ACS	American Community Survey
ADD	Average daily dose
ALE	Action level exceedance
As	Arsenic
ATSDR	Agency for Toxic Substances and Disease Registry
BA	Bottom ash
BAT	Best available technology economically achievable
BCA	Benefit-cost analysis
BEA	Bureau of Economic Analysis
BenMAP-CE	Environmental Benefits Mapping and Analysis Program—Community Edition
BLL	Blood lead level
BLS	Bureau of Labor Statistics
BMP	Best management practices
BOD	Biochemical oxygen demand
BW	Body weight
CAMx	Comprehensive Air Quality Model with Extensions
CBG	Census Block Group
CCI	Construction Cost Index
CCME	Canadian Council of Ministers of the Environment
CCR	Coal combustion residuals
CDC	Center for Disease Control
CFR	Code of Federal Regulations
CIL	Climate Impact Lab
CO_2	Carbon dioxide
COD	Chemical oxygen demand
COI	Cost-of-illness
COPD	Chronic obstructive pulmonary disease
CPI	Consumer Price Index
CWA	Clean Water Act
CWS	Community Water System
CWWS	Community Water System Survey
D-FATE	Downstream Fate and Transport Equations
DBP	Disinfection byproduct
DBPR	Disinfectants and Disinfection Byproduct Rule
DCN	Document Control Number
DICE	Dynamic Integrated Climate and Economy
DO	Dissolved oxygen
DSCIM	Data-driven Spatial Climate Impact Model
E2RF1	Enhanced River File 1
EA	Environmental Assessment
EC	Elemental carbon
ECI	Employment Cost Index

ECOS	Environmental Conservation Online System
EG	Emissions guidelines
EGU	Electricity generating unit
EJ	Environmental justice
ELGs	Effluent limitations guidelines and standards
EO	Executive Order
EPA	United States Environmental Protection Agency
EROM	Enhanced Runoff Method
ESA	Endangered Species Act
FaIR	Finite Amplitude Impulse Response
FC	Fecal coliform
FCA	Fish consumption advisories
FGD	Flue gas desulfurization
FUND	Climate Framework for Uncertainty, Negotiation, and Distribution
FR	Federal Register
FrEDI	Framework for Evaluating Damages and Impacts
GDP	Gross Domestic Product
GHG	Greenhouse gas
GIS	Geographic Information System
GIVE	Greenhouse Gas Impact Value Estimator
GMSL	Global mean sea level
GWP	Global warming potential
HAP	Hazardous air pollutant
HCl	Hydrogen chloride
Hg	Mercury
HRTR	High Residence Time Reduction
HUC	Hydrologic unit code
IAM	Integrated assessment model
IBI	Index of biotic integrity
IEUBK	Integrated Exposure, Uptake, and Biokinetics
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Planning Model
ISA	Integrated science assessment
ISI	Influential Scientific Information
IRIS	Integrated Risk Information System
IQ	Intelligence quotient
LADD	Lifetime average daily dose
LML	Lowest measured level
LRTR	Low Residence Time Reduction
MATS	Mercury and Air Toxics Standards
MCL	Maximum contaminant level
MCLG	Maximum contaminant level goal
MDA1	Maximum daily 1-hour average
MDA8	Maximum daily 8-hour average

MGD	Million gallons per day
MRM	Meta-regression model
NAAQS	National Ambient Air Quality Standards
NARS	National Aquatic Resources Survey
NEI	National Emissions Inventory
NERC	North American Electric Reliability Corporation
NHD	National Hydrography Dataset
NLCD	National Land Cover Dataset
NLFA	National Listing Fish Advisory
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No observed adverse effect level
NO_X	Nitrogen oxides
NPDES	National Pollutant Discharge Elimination System
NRSA	National Rivers and Streams Assessment
NRWQC	National Recommended Water Quality Criteria
NSPS	New source performance standard
NTU	Nephelometric turbidity units
NWIS	National Water Information System
O3	Ozone
O3V	Ozone formed in VOC-limited chemical regimes
O3N	Ozone formed in NO_X-limited chemical regimes
OA	Organic aerosol
O&M	Operation and maintenance
OMB	Office of Management and Budget
OSAT/APCA	Ozone Source Apportionment Technique/Anthropogenic Precursor Culpability Assessment
OWTP	Willingness-to-pay for a one-point WQI improvement (one-point WTP)
PACE	Policy Analysis of the Greenhouse Gas Effect
Pb	Lead
$PM_{2.5}$	Particulate matter (fine inhalable particles with diameters 2.5 μm and smaller)
PM_{10}	Particulate matter (inhalable particles with diameters 10 μm and smaller)
ppm	parts per million
PSAT	Particulate Source Apportionment Technique
PSES	Pretreatment Standards for Existing Sources
PV	Present value
PWS	Public water system
QA	Quality assurance
QC	Quality control
RIA	Regulatory Impact Analysis
RFF	Resources for the Future
SAB-HES	Science Advisory Board Health Effect Subcommittee
SBREFA	Small Business Regulatory Enforcement Fairness Act
SC-CO_2	Social cost of carbon
SDWIS	Safe Drinking Water Information System
Se	Selenium

SO_2	Sulfur dioxide
SPARROW	SPAtially Referenced Regressions On Watershed attributes
SSC	Suspended solids concentration
SWFSC	Southwest Fisheries Science Center
T&E	Threatened and endangered
TDD	Technical Development Document
TDS	Total dissolved solids
TEC	Threshold effect concentration
TN	Total nitrogen
TP	Total phosphorus
TRI	Toxics Release Inventory
TSD	Technical support document
TSS	Total suspended solids
TTHM	Total trihalomethanes
TWTP	Total willingness-to-pay
U.S. FWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VIP	Voluntary Incentive Program
VOC	Volatile organic compounds
VSL	Value of a statistical life
WBD	Watershed Boundary Dataset
WQ	Water quality
WQI	Water quality index
WQI-BL	Baseline water quality index
WQI-PC	Post-technology implementation water quality index
WQL	Water quality ladder
WTP	Willingness-to-pay

Executive Summary

The U.S. Environmental Protection Agency (EPA) is finalizing revisions to the technology-based effluent limitations guidelines and standards (ELGs) for the steam electric power generating point source category, 40 Code of Federal Regulations (CFR) part 423, which EPA promulgated in October 2020 (85 FR 64650). The final rule revises certain best available technology economically achievable (BAT) effluent limitations and pretreatment standards for existing sources (PSES) for three wastestreams: flue gas desulfurization (FGD) wastewater, bottom ash (BA) transport water, and combustion residual leachate (CRL). EPA also sets new source performance standards and pretreatment standards for new sources for CRL.[1]

Regulatory Options

EPA analyzed three regulatory options, summarized in Table ES-1. The options are labeled Option A through Option C according to increasing stringency. All options include the same general technology basis for FGD wastewater and BA transport water (zero discharge) and for CRL (chemical precipitation) but differ in terms of the technology basis applicable to certain subcategories. For example, all three options use surface impoundments as the basis for units retiring by 2028, and options A and B use chemical precipitation with biological treatment for FGD wastewater or High Recycle Rate Systems (HRR) for BA transport water as the bases for units retiring by 2034. Options B and C also use chemical precipitation as the basis for legacy wastewater. EPA is finalizing ELGs based on Option B.

The baseline for the benefit and social cost analyses reflects existing ELG requirements in absence of this EPA action, *i.e.*, the 2020 ELG. As detailed in this report, EPA calculated the difference between the baseline and regulatory Options A through C to determine the net incremental effect of the regulatory options. In general, the regulatory options are estimated to result in smaller pollutant loads, improved environmental conditions, and net benefits.

Benefits of Regulatory Options

EPA estimated the potential social welfare effects of the regulatory options and, where possible, quantified and monetized the benefits (see Chapters 3 through 9 for details of the methodology and results). Table ES-2 summarizes the benefits that EPA quantified and monetized.

EPA quantified but did not monetize other welfare effects of the regulatory options and discusses other effects only qualitatively. Chapter 2 presents additional information on these welfare effects

1 EPA does not expect, and is not aware of, any planned new sources that would be subject to the requirements of this final rule.

Table ES-1: Regulatory Options Analyzed for the Final Rule

Wastestream	Subcategory	Technology Basis for BAT/PSES Regulatory Options[a]			
		Baseline (2020 Rule)	Option A	Option B (Final Rule)	Option C
FGD Wastewater	NA (default unless in subcategory)[b]	CP + Bio	ZLD	ZLD	ZLD
	Boilers permanently ceasing the combustion of coal by 2028	SI	SI	SI	SI
	Boilers permanently ceasing the combustion of coal by 2034	NS	CP + Bio	CP + Bio	NS
	High FGD Flow Facilities or Low Utilization Boilers	CP	NS	NS	NS
BA Transport Water	NA (default unless in subcategory)[b]	HRR	ZLD	ZLD	ZLD
	Boilers permanently ceasing the combustion of coal by 2028	SI	SI	SI	SI
	Boilers permanently ceasing the combustion of coal by 2034	NS	HRR	HRR	NS
	Low Utilization Boilers	BMP Plan	NS	NS	NS
CRL	NA (default)[b]	BPJ	CP	ZLD	ZLD
	Discharges of unmanaged CRL	NA	NS	CP	CP
	Boilers permanently ceasing the combustion of coal by 2034	NA	CP	CP	NS
Legacy Wastewater	Operate after 2024	NA	NS	CP	CP

Abbreviations: BMP = Best Management Practice; CP = Chemical Precipitation; HRR = High Recycle Rate Systems; SI = Surface Impoundment; ZLD = Zero Liquid Discharge; NS = Not subcategorized (default technology basis applies); NA = Not applicable

a. See TDD for a description of these technologies (U.S. EPA, Agency for Toxic Substances and Disease Registry, 2009; Grandjean et al., 2014; Hollingsworth & Rudik, 2021; Mergler et al., 2007; 2024f).

b. The table does not present existing subcategories included in the 2015 and 2020 rules as EPA did not reopen the existing subcategorization of oil-fired units or units with a nameplate capacity of 50 MW or less.

Source: U.S. EPA Analysis, 2024

Table ES-2: Summary of Total Annualized Benefits for Regulatory Options, Compared to Baseline (Millions of 2023$; 2 Percent Discount)

Benefit Category	Option A	Option B (Final Rule)	Option C
Human Health			
Changes in IQ losses in children from exposure to lead via fish ingestion[a]	<$0.01	<$0.01	<$0.01
Changes in cardiovascular disease premature mortality from exposure to lead via fish ingestion	$0.16 – $0.43	$0.16 – $0.43	$0.16 – $0.45
Changes in IQ losses in children from exposure to mercury via fish ingestion	$1.71	$1.98	$2.00
Changes in cancer risk from disinfection by-products in drinking water	$13.37	$13.37	$14.27
Ecological Conditions and Recreational Uses Changes			
Use and nonuse values for water quality changes[b]	$0.79	$1.24	$1.68
Market and Productivity Effects[a]			
Changes in drinking water treatment costs	$0.45 – $0.54	$0.46 – $0.55	$0.59 – $0.71
Changes in dredging costs[a]	<$0.01	<$0.01	<$0.01
Air Quality-Related Effects			
Climate change effects from changes in greenhouse gas emissions[c]	$1,200	$1,600	$1,900
Human health effects from changes in NO_X, SO_2, and $PM_{2.5}$ emissions[c,d]	$1,200	$1,600	$2,000
Total[e]	**$2,417**	**$3,217**	**$3,919**
Additional non-monetized benefits	Other avoided adverse health effects (cancer and non-cancer) from reduced exposure to pollutants discharged to receiving waters; improvements in T&E species habitat and potential effects on T&E species populations; changes in property value from water quality improvements; changes in ecosystem effects, visibility impairment, and human health effects from direct exposure to NO_2, SO_2, and hazardous air pollutants.		

a. "<$0.01" indicates that monetary values are greater than $0 but less than $0.01 million.

b. Value reflects the main willingness-to-pay estimates. See Chapter 6 for details.

c. Values for air-quality related effects are rounded to two significant figures. EPA estimated the air quality-related benefits for Option B. EPA extrapolated estimates of air quality-related benefits for Options A and C from the estimate for Option B that is based on IPM outputs. See Chapter 8 for details.

d. The values reflect the LT estimates of human health effects from changes in $PM_{2.5}$ and ozone levels. See Chapter 8 for details.

e. Values for individual benefit categories may not sum to the total due to independent rounding.

Source: U.S. EPA Analysis, 2024

Social Costs of Regulatory Options

Table ES-3 (below) presents the incremental social costs attributable to the regulatory options, calculated as the difference between each option and the baseline. The regulatory options generally result in additional costs across regulatory options and discount rates. Chapter 11 describes the social cost analysis. The compliance costs of the regulatory options are detailed in the Regulatory Impact Analysis (RIA) (U.S. EPA, 2023k).

Comparison of Benefits and Social Costs of Regulatory Options

In accordance with the requirements of Executive Order (E.O.) 12866: *Regulatory Planning and Review*, as amended by E.O. 13563: *Improving Regulation and Regulatory Review* and E.O. 14094: *Modernizing Regulatory Review*. EPA compared the benefits and costs of each regulatory option. Table ES-4 presents the monetized benefits and social costs attributable to the regulatory options, calculated as the difference between each option and the baseline. The total social costs are presented as a range to reflect uncertainty regarding the costs to meet limits for unmanaged CRL.

Table ES-3: Total Annualized Benefits and Social Costs by Regulatory Option and Discount Rate (Millions of 2023$; 2 Percent Discount)

Regulatory Option	Total Monetized Benefits[a, b]	Total Social Costs[a]	
		Lower Bound	Upper Bound
Option A	$2,417	$433.2	$960.9
Option B (Final Rule)	$3,217	$536.2	$1,063.9
Option C	$3,919	$622.4	$1,150.1

a. EPA's benefits analysis did not account for the effects of loading reductions associated with limits for unmanaged CRL and legacy wastewater, whereas the total costs account for outlays for meeting these limits. See Chapter 11 for details on the lower and upper bound cost scenarios.

b. EPA estimated the air quality-related benefits for the final rule (Option B) only. EPA extrapolated estimates of air quality-related benefits for Options A and C from the estimate for Option B that is based on IPM outputs. See Chapter 8 for details.

Source: U.S. EPA Analysis, 2024.

1 Introduction

EPA is finalizing revisions to the technology-based ELGs for the steam electric power generating point source category, 40 CFR part 423, which EPA previously proposed in March 29, 2023 (88 FR 18824). The final rule revises certain effluent limitations promulgated in October 2020 (85 FR 64650) based on BAT and pretreatment standards for existing sources for four wastestreams: flue gas desulphurization (FGD) wastewater, bottom ash (BA) transport water, combustion residual leachate (CRL), and legacy wastewater. EPA also sets new source performance standards and pretreatment standards for new sources for CRL.[2]

This document presents an analysis of the benefits and social costs of the regulatory options and complements other analyses EPA conducted in support of this final rule, described in separate documents:

- *Environmental Assessment for Supplemental Effluent Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (EA; U.S. EPA, 2024b). The EA summarizes the potential environmental and human health impacts that are estimated to result from the regulatory options.

- *Technical Development Document for Supplemental Effluent Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (TDD; U.S. EPA, 2024f). The TDD summarizes the technical and engineering analyses supporting the final rule. The TDD presents EPA's updated analyses supporting the revisions to limitations and standards applicable to discharges of FGD wastewater, BA transport water, leachate, and legacy wastewater. These updates include additional data collection that has occurred since publication of the 2023 proposed rule, updates to the industry (*e.g.*, retirements, treatment updates), cost methodologies, pollutant removal estimates, and explanations for the calculation of the effluent limitations and standards.

- *Regulatory Impact Analysis for Supplemental Revisions to the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category* (RIA; U.S. EPA, 2024e). The RIA describes EPA's analysis of the costs and economic impacts of the regulatory options. This analysis provides the basis for social cost estimates presented in Chapter 11 of this document. The RIA also provides information pertinent to meeting several legislative and administrative requirements, including the Regulatory Flexibility Act of 1980 (as amended by the Small Business Regulatory Enforcement Fairness Act [SBREFA] of 1996), the Unfunded Mandates Reform Act of 1995, Executive Order (E.O.) 13211 on *Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution, or Use*, and others.

- *Environmental Justice Analysis for Supplemental Revisions to the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category (*EJA; U.S. EPA, 2024c). This report presents a profile of the communities and populations potentially impacted by this final rule and an analysis of the distribution of impacts in the baseline and final rule changes.

The rest of this chapter discusses aspects of the regulatory options that are salient to EPA's analysis of the benefits and social costs of the final rule and summarizes key analytic inputs used throughout this document.

[2] EPA does not expect, and is not aware of, any planned new sources that would be subject to the requirements of this final rule.

The analyses of the regulatory options are based on data generated or obtained in accordance with EPA's Quality Policy and Information Quality Guidelines. EPA's quality assurance (QA) and quality control (QC) activities for this rulemaking include the development, approval and implementation of Quality Assurance Project Plans for the use of environmental data generated or collected from all sampling and analyses, existing databases and literature searches, and for the development of any models which used environmental data. Unless otherwise stated within this document, the data used and associated data analyses were evaluated as described in these quality assurance documents to ensure they are of known and documented quality, meet EPA's requirements for objectivity, integrity and utility, and are appropriate for the intended use.

1.1 Steam Electric Power Plants

The ELGs for the Steam Electric Power Generating Point Source Category apply to a subset of the electric power industry, namely those plants "with discharges resulting from the operation of a generating unit by an establishment whose generation of electricity is the predominant source of revenue or principal reason for operation, and whose generation of electricity results primarily from a process utilizing fossil-type fuel (coal, oil, or gas), fuel derived from fossil fuel (*e.g.*, petroleum coke, synthesis gas), or nuclear fuel in conjunction with a thermal cycle employing the steam water system as the thermodynamic medium" (40 Code of Federal Regulations [CFR] 423.10).

As described in the RIA, of the 858 steam electric power plants in the universe identified by EPA, only those coal-fired power plants that discharge FGD wastewater, BA transport water, CRL or legacy wastewater may incur compliance costs under the regulatory options analyzed for this final rule. After accounting for planned retirements and fuel conversions, EPA estimated that 185 power plants will have coal-fired generating units operating after December 31, 2028 and/or generate FGD wastewater, BA transport water, CRL or legacy wastewater. Of those plants, an estimated 110 steam electric power plants generate the relevant wastestreams and may incur costs to meet the effluent limits under one or more regulatory options. See TDD and RIA for details (U.S. EPA, 2024e; 2024f).

1.2 Baseline and Regulatory Options Analyzed

EPA presents three regulatory options (see Table 1-1). These options differ in the stringency of controls and applicability of these controls to generating units or plants based on generation capacity utilization, and retirement or repowering status (see TDD for a detailed discussion of the options and the associated treatment technology bases).

The baseline for this analysis reflects applicable requirements (in absence of the rule). The baseline includes the 2020 rule (85 FR 64650). As discussed further in Section 2.2.2 of the RIA, the baseline for this analysis also includes the effects of the 2020 CCR Part A rule.

The Agency estimated and presents in this report the water quality and other environmental effects of FGD wastewater, BA transport water, leachate, and legacy wastewater discharges under both the 2020 rule baseline and regulatory options A through C presented in Table 1-1. The Agency calculated the difference between the baseline and the regulatory options to determine the net effect of each regulatory option. EPA is finalizing Option B.

Table 1-1: Regulatory Options Analyzed for the Final Rule

Wastestream	Subcategory	Technology Basis for BAT/PSES Regulatory Options[a]			
		Baseline (2020 Rule)	Option A	Option B (Final Rule)	Option C
FGD Wastewater	NA (default unless in subcategory)[b]	CP + Bio	ZLD	ZLD	ZLD
	Boilers permanently ceasing the combustion of coal by 2028	SI	SI	SI	SI
	Boilers permanently ceasing the combustion of coal by 2034	NS	CP + Bio	CP + Bio	NS
	High FGD Flow Facilities or Low Utilization Boilers	CP	NS	NS	NS
BA Transport Water	NA (default unless in subcategory)[b]	HRR	ZLD	ZLD	ZLD
	Boilers permanently ceasing the combustion of coal by 2028	SI	SI	SI	SI
	Boilers permanently ceasing the combustion of coal by 2034	NS	HRR	HRR	NS
	Low Utilization Boilers	BMP Plan	NS	NS	NS
CRL	NA (default)[b]	BPJ	CP	ZLD	ZLD
	Discharges of unmanaged CRL	NA	NS	CP	CP
	Boilers permanently ceasing the combustion of coal by 2034	NA	CP	CP	NS
Legacy wastewater	Operate after 2024	NA	NS	CP	CP

Abbreviations: BMP = Best Management Practice; CP = Chemical Precipitation; HRR = High Recycle Rate Systems; SI = Surface Impoundment; ZLD = Zero Liquid Discharge; NS = Not subcategorized (default technology basis applies); NA = Not applicable

a. See TDD for a description of these technologies (U.S. EPA, 2024f).

b. The table does not present existing subcategories included in the 2015 and 2020 rules as EPA did not reopen the existing subcategorization of oil-fired units or units with a nameplate capacity of 50 MW or less.

Source: U.S. EPA Analysis, 2024

1.3 Analytic Framework

The analytic framework of this benefit-cost analysis (BCA) includes basic components used consistently throughout the analysis of benefits and social costs[3] of the regulatory options:

1. All values are presented in 2023 dollars;
2. Future benefits and costs are discounted at 2 percent back to 2024;
3. Benefits and costs are analyzed over a 25-year period (2025 to 2049) which covers the years when plants implement wastewater treatment technologies to meet the revised ELGs (2025-2029) and the subsequent life of these technologies (20 years);
4. Technology installation and the resulting pollutant loading changes occur at the end of the estimated wastewater treatment technology implementation year;
5. Benefits and costs are annualized over 25 years, based on the period of analysis described above;
6. Positive values represent net benefits (*e.g.*, improvements in environmental conditions or social welfare) compared to baseline; and
7. Future values account for annual U.S. population and income growth, unless noted otherwise.

These components are discussed in the sections below.

As was the case for the 2023 proposed rule, EPA's analysis of the regulatory options generally follows the methodology the Agency used previously to analyze the 2015 and 2020 rules and the 2023 proposed rule (U.S. EPA, 2015a, 2020b, 2024a). In analyzing the regulatory options, however, EPA made several changes relative to the analysis of the 2020 rule and 2023 proposed rule:

- EPA used revised inputs that reflect the costs and loads estimated for each of the three regulatory options (see TDD and RIA for details; U.S. EPA, 2024e; 2024f). Like the analysis of the 2020 final rule and 2023 proposed rule, EPA estimated loading reductions for two periods (2025-2029 and 2030-2049) during the overall period of analysis (2025-2049) to account for transitional conditions when different plants are in the process of installing technologies to meet the ELGs.
- EPA updated the baseline industry information to incorporate changes in the universe and operational characteristics of steam electric power plants such as electricity generating unit retirements and fuel conversions since the analysis of the 2020 final rule and 2023 proposed rule. EPA also incorporated updated information on the technologies and other controls that plants employ. See the TDD for details on the changes (U.S. EPA, 2024f).
- Finally, EPA made certain changes to the methodologies to be consistent with approaches used by the Agency for other rules and/or incorporate recent advances in environmental assessment, health risk, and resource valuation research.

These changes are described in the relevant sections of this document, and summarized in Appendix A.

[3] Unless otherwise noted, costs represented in this document are social costs.

1.3.1 Constant Prices

This BCA applies a year 2023 constant price level to all future monetary values of benefits and costs. Some monetary values of benefits and costs are based on actual past market price data for goods or services, while others are based on other measures of values, such as household willingness-to-pay (WTP) surveys used to monetize ecological changes resulting from surface water quality changes. This BCA updates market and non-market prices using the Consumer Price Index (CPI), Gross Domestic Product (GDP) implicit price deflator, or Construction Cost Index (CCI). To update the value of a Statistical Life (VSL), EPA used the GDP deflator and the elasticity of VSL with respect to income of 0.4, as recommended in EPA's Guidelines for preparing Economic Analysis (U.S. EPA, 2010, updated 2014). EPA used the GDP deflator to update the value of an IQ point, the CPI to update the WTP for surface water quality improvements and cost of illness (COI) estimates, and the CCI to update the cost of dredging navigational waterways and reservoirs.

1.3.2 Discount Rate and Year

This BCA estimates the annualized value of future benefits and costs using a discount rate of 2 percent, following current Office of Management and Budget (OMB) guidance in Circular A-4 (U.S. Office of Management and Budget, 2023).[4] Climate benefits are monetized using social cost of greenhouse gas (SC-GHG) estimates calculated with near-term Ramsey discount rates of 1.5 percent, 2 percent, and 2.5 percent. To calculate the annualized value of climate benefits, EPA uses the same discount rate as the near-term Ramsey rate used to discount the climate benefits from future GHG changes. That is, future climate benefits estimated with the SC-GHG at the near-term 2 percent Ramsey rate are discounted to the base year of the analysis using a 2 percent rate. Section 8.2 provides additional details on the discounting of climate benefits.

All future cost and benefit values are discounted back to 2024, the rule promulgation year.[5]

In Appendix B, EPA presents the benefits and costs of the final rule using the discount rates used in the proposal BCA, which followed the guidance applicable at the time the prior analysis was conducted (OMB, 2003).[6]

1.3.3 Period of Analysis

The rule benefits are projected to begin accruing when each plant implements the control technologies needed to comply with any applicable BAT effluent limitations or pretreatment standards. As described in greater

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4 The social costs presented in this BCA differ from the annualized pre-tax compliance costs described in Chapter 3 of the RIA or the compliance costs modeled in IPM (Chapter 5 of the RIA) which use the estimated weighted average cost of capital for the power sector of 3.76 percent to discount and annualize costs.

5 In its analysis of the 2015 rule, EPA presented benefits in 2013 dollars and discounted these benefits and costs to 2015 (see U.S. Environmental Protection Agency. (2015a). *Benefit and Cost Analysis for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category*. (EPA-821-R-15-005).), whereas the analysis of the 2020 rule used 2018 dollars and discounted benefits and costs to 2020 (see U.S. Environmental Protection Agency. (2020b). *Benefit and Cost Analysis for Revisions to the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category*. (EPA-821-R-20-003).).

6 In the prior version of Circular A-4, the OMB recommended that 3 percent be used when a regulation affects private consumption, and 7 percent in evaluating a regulation that would mainly displace or alter the use of capital in the private sector (U.S. Office of Management and Budget. (2003). *Circular A-4: Regulatory Analysis*. Retrieved from https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/circulars/A4/a-4.pdf). OMB has long recognized that climate effects should be discounted only at appropriate consumption-based discount rates. Because the SC-GHG estimates reflect net climate change damages in terms of reduced consumption (or monetary consumption equivalents), the use of the social rate of return on capital (7 percent under ibid.) to discount damages estimated in terms of reduced consumption would inappropriately underestimate the impacts of climate change for the purposes of estimating the SC-GHG.

detail in the NPRM, EPA is establishing availability timing for BAT limitations that is "as soon as possible" after the effective date of any final rule but "no later than" five years from the effective date (*i.e.*, a 2029 deadline). As discussed in the RIA (in Chapter 3), for the purpose of the economic impact and benefit analysis, EPA generally estimates that plants will implement control technologies to meet the applicable rule limitations and standards as their permits are renewed, and no later than December 31, 2029. This schedule recognizes that control technology implementation is likely to be staggered over time across the universe of steam electric power plants.

The period of analysis extends to 2049 to capture the estimated life of the compliance technology at any steam electric power plant (20 or more years), starting from the year of technology implementation, which can be as late as 2029.

The different compliance years between options, wastestreams, and plants means that environmental changes may occur in a staggered fashion over the analysis period as plants implement control technologies to meet applicable limits under each option. To analyze environmental changes from the baseline and resulting benefits, EPA used the annual average of loadings or other environmental changes (*e.g.*, air emissions, water withdrawals) projected during two distinct periods (2025-2029 and 2030-2049) within the overall analysis period (2025-2049). Section 3.2 provides further details on the breakout of the analysis periods.

1.3.4 Timing of Technology Installation and Loading Reductions

For the purpose of the analysis of benefits and social costs, EPA estimates that plants meet revised applicable limitations and standards by the end of their estimated technology implementation year and that any resulting changes in loadings will be in effect at the start of the following year.

1.3.5 Annualization of future costs and benefits

Consistent with the timing of technology installation and loading reductions described above which is modeled to occur at the end of the year, EPA uses the following equation to annualize the future stream of costs and benefits:

Equation 1-1.

$$AV = \frac{r(PV)}{(1+r)[1-(1+r)^{-n}]}$$

Where *AV* is the annualized value, *PV* is the present value, *r* is the discount rate (2 percent), and *n* is the number of years (25 years) over which non-zero costs and benefits are modeled.

1.3.6 Population and Income Growth

To account for future population growth or decline, EPA used Woods & Poole population forecasts for the United States (Woods & Poole Economics Inc., 2021). EPA used the growth projections for each year to adjust affected population estimates for future years (*i.e.*, from 2025 to 2049).

Because WTP is expected to increase as income increases, EPA accounted for income growth for estimating the value of avoided premature mortality based on the value of a statistical life (VSL) and WTP for water quality improvements. To develop income adjustment factors, EPA calculated income growth factors using historical and projected "real disposable personal income" estimates (U.S. Energy Information Administration, 2021). For the VSL calculations, EPA used the VSL value in 1990 dollars ($4.8 million) and adjusted for inflation using the U.S. Bureau of Labor Statistics' (2023) CPI and adjusted for income growth using real GDP per capita and an income elasticity of 0.4 (U.S. EPA, 2010, updated 2014). Adjusted VSL values ranged from $13.5 million in 2025 to $16.4 million in 2049. For the WTP for water quality improvements, EPA multiplied income estimates by the income growth rate, relative to 2021, for the applicable analysis period year (*i.e.*, from 2025 to 2049).[7]

1.4 Organization of the Benefit and Cost Analysis Report

This BCA report presents EPA's analysis of the benefits of the regulatory options, assessment of the total social costs, and comparison of the social costs and monetized benefits.

The remainder of this report is organized as follows:

- Chapter 2 provides an overview of the main benefits expected to result from the implementation of the three regulatory options analyzed for this proposal.
- Chapter 3 describes EPA's estimates of the environmental changes resulting from the regulatory options, including water quality modeling that underlays the Agency's estimates of several categories of benefits.
- Chapters 4 and 5 details the methods and results of EPA's analysis of human health benefits from changes in pollutant exposure via the drinking water and fish ingestion pathways, respectively.
- Chapter 6 discusses EPA's analysis of the nonmarket benefits of changes in surface water quality resulting from the regulatory options.
- Chapter 7 discusses EPA's analysis of benefits to threatened and endangered (T&E) species.
- Chapter 8 describes EPA's analysis of benefits associated with changes in emissions of air pollutants associated with energy use, transportation, and the profile of electricity generation for the regulatory options.
- Chapter 9 describes benefits from changes in costs for drinking water treatment and dredging costs to maintain navigational channels and reservoirs.
- Chapter 10 summarizes monetized benefits across benefit categories.
- Chapter 11 summarizes the social costs of the regulatory options.
- Chapter 12 compares the benefits and social costs of its actions in accordance with executive order E.O. 12866: Regulatory Planning and Review (58 FR 51735, October 4, 1993), as amended by E.O. 13563: Improving Regulation and Regulatory Review (76 FR 3821, January 21, 2011) and E.O. 14094: Modernizing Regulatory Review (88 FR 21879, April 11, 2023).
- Chapter 13 provides references cited in the text.

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[7] There is a relatively strong consensus in economic literature that income elasticities of approximately "1" are appropriate for adjusting WTP for water quality improvements in future years (Johnston, R. J., Besedin, E. Y., & Holland, B. M. (2019). Modeling Distance Decay within Valuation Meta-Analysis. *Environmental and resource economics*, *72*(3), 657-690. https://doi.org/https://doi.org/10.1007/s10640-018-0218-z ; Tyllianakis, E., & Skuras, D. (2016). The income elasticity of Willingness-To-Pay (WTP) revisited: A meta-analysis of studies for restoring Good Ecological Status (GES) of water bodies under the Water Framework Directive (WFD). *Journal of environmental management*, *182*, 531-541. https://doi.org/10.1016/j.jenvman.2016.08.012). Therefore, EPA used an income elasticity of "1" in this analysis.

Several appendices provide additional details on selected aspects of analyses described in the main text of the report.

2 Benefits Overview

This chapter provides an overview of the estimated welfare effects to society resulting from changes in pollutant loadings due to implementation of the main regulatory options analyzed for the final rule. EPA expects the regulatory options to change discharge loads of various categories of pollutants when fully implemented. The categories of pollutants include conventional pollutants (such as suspended solids, biochemical oxygen demand (BOD), and oil and grease), priority pollutants (such as mercury [Hg], arsenic [As], and selenium [Se]), and non-conventional pollutants (such as total nitrogen [TN], total phosphorus [TP], chemical oxygen demand [COD] and total dissolved solids [TDS]).

Table 2-1 presents estimated annual pollutant loads in the baseline and changes in pollutant loads under full implementation of the effluent limitations and standards for the regulatory options. The TDD provides further detail on the loading changes (U.S. EPA, 2024f). As described in Section 3.2, EPA anticipates a transition period and estimated loadings during interim years before all plants have implemented control technologies to meet the applicable final ELGs under the regulatory options may differ from these values. EPA also anticipates loading reductions for legacy wastewater to occur only when facilities dewater and close their existing ponds, which may happen after the end of the period of analysis.

Table 2-1: Estimated Baseline Annual Pollutant Loadings and Changes in Loadings for Regulatory Options Under Technology Implementation

Pollutant	Estimated Baseline Total Pollutant Loadings[a] (pounds per year)	Estimated Changes in Pollutant Loadings[a] from Baseline (pounds per year)		
		Option A	Option B (Final Rule)	Option C
Antimony	245	-179	-225	-245
Arsenic	742	-480	-667	-691
Barium	7,260	-4,500	-5,680	-6,180
Beryllium	31	-27	-27	-31
Boron	6,270,000	-4,590,000	-4,910,000	-5,620,000
Bromide	6,160,000	-5,730,000	-5,730,000	-6,160,000
Cadmium	534	-134	-494	-510
Chemical oxygen demand	117,000	-112,000	-112,000	-117,000
Chromium	20,500	-20,300	-20,400	-20,400
Copper	379	-164	-331	-346
Cyanide	21,900	-18,900	-18,900	-21,900
Lead	215	-124	-172	-185
Manganese	600,000	-253,000	-516,000	-557,000
Mercury	40	-11	-38	-38
Nickel	3,390	-654	-3,280	-3,310
Total nitrogen	492,000	-165,000	-165,000	-189,000
Total phosphorus	10,800	-7,670	-7,670	-8,710
Selenium	4,750	-181	-1,930	-2,020
Thallium	743	-207	-626	-657
Total dissolved solids	712,000,000	-496,000,000	-563,000,000	-640,000,000
Total suspended solids	878,000	-547,000	-767,000	-803,000
Zinc	6,440	-1,920	-6,180	-6,270

Note: Pollutant loadings and removals are rounded to three significant figures. See TDD for additional details on estimated loads (U.S. EPA, 2024f).

Table 2-1: Estimated Baseline Annual Pollutant Loadings and Changes in Loadings for Regulatory Options Under Technology Implementation

Pollutant	Estimated Baseline Total Pollutant Loadings[a] (pounds per year)	Estimated Changes in Pollutant Loadings[a] from Baseline (pounds per year)		
		Option A	Option B (Final Rule)	Option C

a. Industry-wide pollutant loadings reflect full implementation of ELGs. Values shown in this table do not account for generating unit retirements or conversions during the period of analysis which are estimated to reduce total industry loadings under the baseline and regulatory options.

Source: U.S. EPA Analysis, 2024

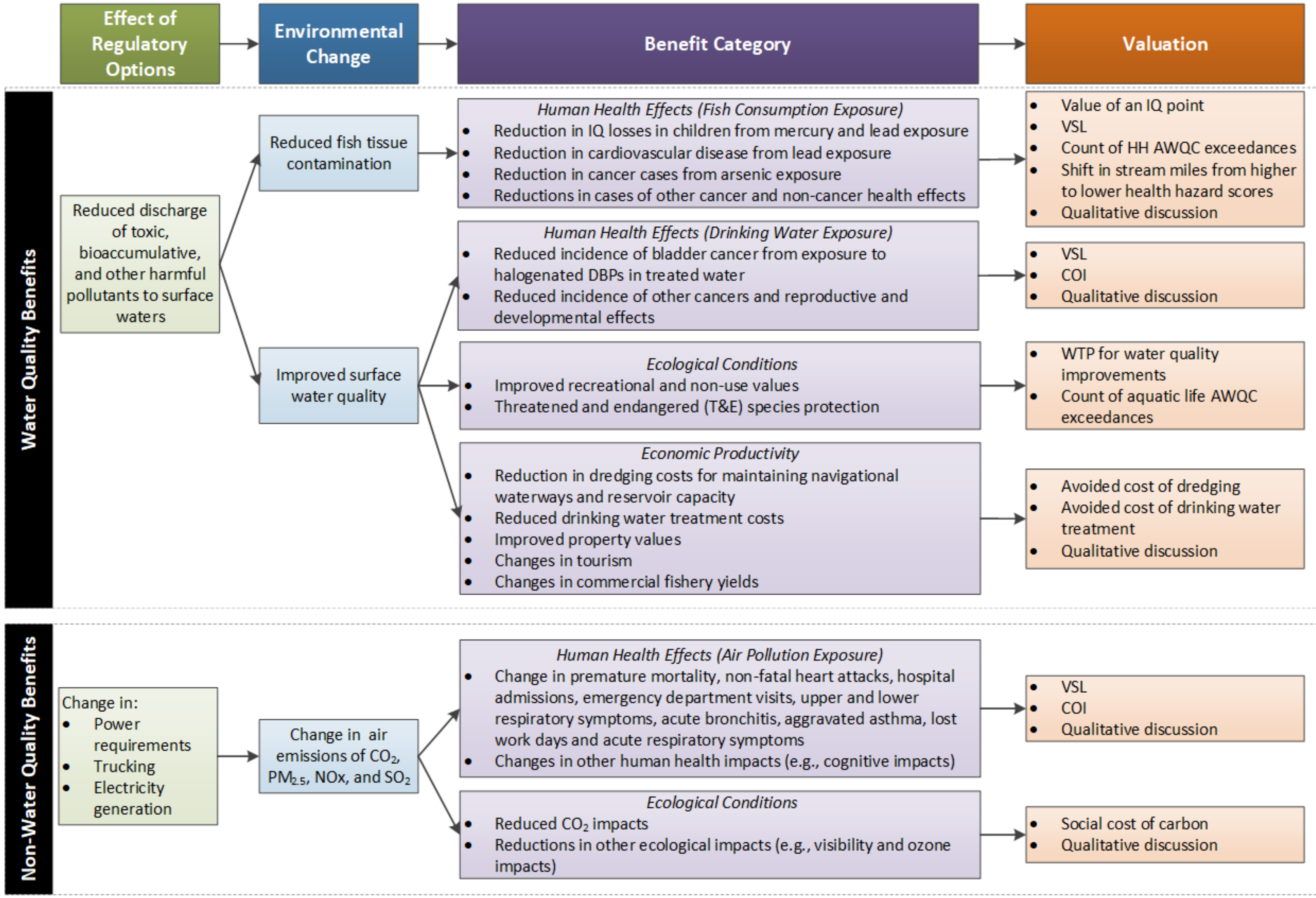
In addition to water quality changes, effects of the regulatory options in comparison to the 2020 rule also include other effects of the implementation of control technologies and changes in plant operations, such as changes in emissions of air pollutants (*e.g.*, carbon dioxide [CO_2], fine particulate matter [$PM_{2.5}$], nitrogen oxides [NO_X], and sulfur dioxide [SO_2]) which result in benefits to society in the form of changes in morbidity and mortality and CO_2 impacts on environmental quality and economic activities.

This chapter also briefly discusses the effects of pollutants found in FGD wastewater, BA transport water, CRL, and legacy wastewater and provides a framework for understanding the benefits expected to be achieved under by the regulatory options. For a more detailed description of steam electric wastewater pollutants, their fate, transport, and impacts on human health and environment, see the EA (U.S. EPA, 2024b).

Figure 2-1 summarizes the potential effects of the regulatory options, the expected environmental changes, and categories of social welfare effects as well as EPA's approach to analyzing those welfare effects.

EPA was not able to bring the same depth of analysis to all categories of social welfare effects because of imperfect understanding of the link between discharge changes or other environmental effects of the regulatory options and welfare effect categories, and how society values some of these effects. EPA was able to quantify and monetize some welfare effects, quantify but not monetize other welfare effects, and assess still other welfare effects only qualitatively. The remainder of this chapter provides a qualitative discussion of the social welfare effects applicable to the final rule, including human health effects, ecological effects, economic productivity, and changes in air pollution. Some estimates of the monetary value of social welfare changes presented in this document rely on models with a variety of limitations and uncertainties, as discussed in more detail in Chapters 3 through 9 for the relevant benefit categories.

Figure 2-1: Summary of Estimated Benefits Resulting from the Regulatory Options.



DBP = Disinfection byproducts; VSL = Value of Statistical Life; HH AWQC= human health ambient water quality criteria; COI = Cost of illness; WTP = Willingness to Pay; AWQC= ambient water quality criteria

Source: U.S. EPA Analysis, 2024.

2.1 Human Health Impacts Associated with Changes in Surface Water Quality

Pollutants present in steam electric power plant wastewater discharges can cause a variety of adverse human health effects. Chapter 3 describes the approach EPA used to estimate changes in pollutant levels in waters. More details on the fate, transport, and exposure risks of steam electric pollutants are provided in the EA (U.S. EPA, 2024b).

Human health effects are typically analyzed by estimating the change in the expected number of adverse human health events in the exposed population resulting from changes in effluent discharges. While some health effects (*e.g.*, cancer) are relatively well understood and can be quantified in a benefits analysis, others are less well characterized and cannot be assessed with the same rigor, or at all.

The regulatory options affect human health risk by changing exposure to pollutants in water via two principal exposure pathways discussed below: (1) treated water sourced from surface waters affected by steam electric power plant discharges and (2) fish and shellfish taken from waterways affected by steam electric power plant discharges. The regulatory options also affect human health risk by changing air emissions of pollutants via shifts in the profile of electricity generation, changes in auxiliary electricity use, and transportation; these effects are discussed separately in Section 2.5.

2.1.1 Drinking Water

Pollutants discharged by steam electric power plants to surface waters may affect the quality of water used for public drinking supplies. People may then be exposed to harmful constituents in treated water through ingestion, as well as inhalation and dermal absorption (*e.g.*, showering, bathing). The pollutants may not be removed adequately during treatment at a drinking water treatment plant, or constituents found in steam electric power plant discharges may interact with drinking water treatment processes and contribute to the formation of disinfection byproducts (DBPs).

Public drinking water supplies are subject to legally enforceable maximum contaminant levels (MCLs) established by EPA (U.S. EPA, 2018b). As the term implies, an MCL for drinking water specifies the highest level of a contaminant that is allowed in drinking water. The MCL is based on the MCL Goal (MCLG), which is the level of a contaminant in drinking water below which there is no known or expected risk to human health. EPA sets the MCL as close to the MCLG as possible, with consideration for the best available treatment technologies and costs. Table 2-2 shows the MCL and MCLG for selected constituents or constituent derivatives of steam electric power plant effluent.

Table 2-2: Drinking Water Maximum Contaminant Levels and Goals for Selected Pollutants in Steam Electric FGD Wastewater, BA Transport Water, CRL, and Legacy Wastewater Discharges

Pollutant	MCL (mg/L)	MCLG (mg/L)
Antimony	0.006	0.006
Arsenic	0.01	0
Barium	2.0	2.0
Beryllium	0.004	0.004
Bromate	0.010	0
Cadmium	0.005	0.005
Chromium (total)	0.1	0.1
Copper[a]	1.3	1.3
Cyanide (free cyanide)	0.2	0.2
Lead[a]	0.015	0

Table 2-2: Drinking Water Maximum Contaminant Levels and Goals for Selected Pollutants in Steam Electric FGD Wastewater, BA Transport Water, CRL, and Legacy Wastewater Discharges

Pollutant	MCL (mg/L)	MCLG (mg/L)
Mercury	0.002	0.002
Nitrate-Nitrite as N	10 (Nitrate); 1 (Nitrite)	10 (Nitrate); 1 (Nitrite)
Selenium	0.05	0.05
Thallium	0.002	0.0005
Total trihalomethanes[b]	0.080	Not applicable
bromodichloromethane	Not applicable	0
bromoform	Not applicable	0
dibromochloromethane	Not applicable	0.06
chloroform	Not applicable	0.07

a. MCL value is based on action level.

b. Bromide, a constituent found in steam electric power plant effluent, is a precursor for Total Trihalomethanes and three of its subcomponents. Additional trihalomethanes may also be formed in the presence of iodine, a constituent also found in steam electric power plant wastewater discharges.

Source: 40 CFR 141.53 as summarized in U.S. EPA (2018b): National Primary Drinking Water Regulation, EPA 816-F-09-004

Pursuant to MCLs, public drinking water supplies are tested and treated for pollutants that pose human health risks. In analyzing the human health benefits of the regulatory options, EPA assumes that treated water meets applicable MCLs in the baseline. Table 2-2 shows that for arsenic, bromate, lead, and certain trihalomethanes, the MCLG is zero. For these pollutants and for those that have an MCL above the MCLG (thallium), there may be incremental benefits from reducing concentrations even where they are below the MCL.

EPA used a mass balance approach to estimate the changes in halogen (bromide) levels in surface waters downstream from steam electric power plant outfalls. Halogens can be precursors for halogenated disinfection byproduct formation in treated drinking water, including trihalomethanes addressed by the total trihalomethanes (TTHM) MCL. The occurrence of TTHM and other halogenated disinfection byproducts in downstream drinking water depends on a number of environmental factors and site-specific processes at drinking water treatment plants. There is some evidence of associations between adverse human health effects, including bladder cancer, and exposure to sufficient levels of halogenated disinfection byproducts in drinking water (Hrudey et al., 2015; Regli et al., 2015; U.S. EPA, 2005b; 2016c; Villanueva et al., 2004; Villanueva et al., 2003). EPA quantitatively estimated the marginal effect of changes in surface water bromide levels on drinking water TTHM levels and bladder cancer incidence in exposed populations. EPA also monetized associated changes in human mortality and morbidity. EPA relied on the COI approach to monetize the estimated reduction in non-fatal bladder cancer cases and the VSL to monetize benefits from avoided fatal cancer cases (see Section 4.3.3). The COI approach allows valuation of a particular type of non-fatal illness by placing monetary values on measures, such as lost productivity and the cost of health care and medications, that can be monetized.

To assess potential for changes in health risk from exposure to arsenic, lead, and thallium in drinking water, EPA estimated changes in pollutant levels in source waters downstream from steam electric power plants under each regulatory option. This analysis is discussed in Section 4.3.2.3. EPA did not quantify or monetize benefits from reduced exposure to arsenic, lead, and thallium via drinking water due to the relatively small concentration changes in source waters downstream from steam electric plants. EPA however notes that coal ash effluents can make water more corrosive by increasing the conductivity of source waters used by downstream water systems and, as a result, increase lead leaching from water distribution infrastructure.

2.1.2 Fish Consumption

Recreational and subsistence fishers (and their household members) who consume fish caught in the reaches downstream of steam electric power plants may be affected by changes in pollutant concentrations in fish tissue. EPA analyzed the following direct measures of change in risk to human health from exposure to contaminated fish tissue:

- Neurological effects to children ages 0 to 7 from exposure to lead;
- Incidence of premature cardiovascular mortality in adults from exposure to lead;
- Neurological effects to infants from in-utero exposure to mercury;
- Incidence of skin cancer from exposure to arsenic[8]; and
- Reduced risk of other cancer and non-cancer toxic effects.

The Agency evaluated potential changes in intellectual impairment, or intelligence quotient (IQ), resulting from changes in childhood and in-utero exposures to lead and mercury. EPA also estimated changes in the incidence of cardiovascular premature mortality from exposure to lead and the number of avoided skin cancer cases exposure to arsenic.

For constituents with human health ambient water quality criteria or oral reference dose (RfD),[9] the change in the risk of other cancer and non-cancer toxic effects from fish consumption is addressed indirectly in EPA's assessment of changes in exceedances of these thresholds (see Section 5.8 and Section 4 and Appendix A of the EA; U.S. EPA, 2024b).

EPA relied on VSL to estimate the value of avoided cardiovascular premature mortality and a COI approach to estimate the value of changes in the incidence of skin cancer, which are generally non-fatal (see Section 5.6). Some health effects of changes in exposure to steam electric pollutants, such as neurological effects to children and infants exposed to lead and mercury, are measured based on avoided IQ losses. Changes in IQ cannot be valued based on WTP approaches because the available economic research provides little empirical data on society's WTP to avoid IQ losses. Instead, EPA calculated monetary values for changes in neurological and cognitive damages based on the impact of an additional IQ point on an individual's future earnings and the cost of compensatory education for children with learning disabilities. These estimates represent only one component of society's WTP to avoid adverse neurological effects and therefore produce a partial measure of the monetary value from changes in exposure to lead and mercury. Employed alone, these monetary values would underestimate society's WTP to avoid adverse neurological effects. See Sections 5.3 and 5.4 for applications of this method to valuing health effects in children and infants from changes in

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8 In 2023, EPA released an update to the IRIS inorganic arsenic protocol. "U.S. EPA. IRIS Toxicological Review of Inorganic Arsenic (Public Comment and External Review Draft)" to reflect new data on internal cancers including bladder, liver, kidney, and lung cancers associated with arsenic exposure via ingestion (U.S. Environmental Protection Agency. (2023i). *IRIS Toxicological Review of Inorganic Arsenic (Public Comment and External Review Draft)*. (EPA/635/R-23/166). Retrieved from https://iris.epa.gov/Document/&deid=253756). Because cancer slope factors for internal organs have not been finalized, the Agency did not consider these effects in the analysis of the final rule.

9 An RfD is defined as an estimate of a daily oral exposure that likely would not result in the occurrence of adverse health effects in humans, including sensitive individuals, during a lifetime. An RfD is typically established by applying uncertainty factors to the lowest- or no observed adverse effect level (NOAEL) for the critical toxic effect of a pollutant.

exposure to lead and mercury. This is the same approach EPA used in its analysis of the 2023 Proposed Lead and Copper Rule Improvements (U.S. EPA, 2023f).

EPA received comments on the analysis of the 2023 proposed supplemental ELG that it did not evaluate potential health impacts via the fish consumption pathway arising from changes in discharges of other steam electric pollutants, such as aluminum, boron, cadmium, hexavalent chromium, manganese, selenium, thallium, and zinc. Analyses of these health effects require data and information on the relationships between ingestion rate and potential adverse health effects and on the economic value of potential adverse health effects. Following a review of the available data, for the final rule EPA again did not quantify, nor was it able to monetize, changes in health effects associated with exposure to these pollutants under the regulatory options due to data limitations and uncertainty in the quantitative relationships. Despite numerous studies conducted by EPA and other researchers, dose-response functions are available for only a subset of health endpoints associated with steam electric wastewater pollutants. In addition, the available research does not always allow complete economic evaluation, even for quantifiable health effects. For example, sufficient data are not available to evaluate and monetize the following potential health effects from fish consumption: neonatal mortality from in-utero exposure to lead and other impacts to children from exposure to lead, such as decreased postnatal growth in children ages one to 16, delayed puberty, immunological effects, and decreased hearing and motor function (Cleveland et al., 2008; NTP, 2012; U.S. EPA, 2024d; 2019e); effects to adults from exposure to lead such as decreased kidney function, reproductive effects, immunological effects, cancer and nervous system disorders (Aoki et al., 2016; Chowdhury et al., 2018; Clay, Portnykh & Severnini, 2021; Grossman & Slusky, 2019; Lanphear et al., 2018; Navas-Acien, 2021; NTP, 2012; U.S. EPA, 2024d; 2019e; 2023f); neurological effects to children from exposure to mercury after birth (Grandjean et al., 2014); effects to adults from exposure to mercury, including vision defects, hand-eye coordination, hearing loss, tremors, cerebellar changes, premature mortality, and others (Hollingsworth & Rudik, 2021; Mergler et al., 2007; Center for Disease Control and Prevention (CDC), 2009); and other cancer and non-cancer effects from exposure to other steam electric pollutants (*e.g.,* kidney, liver, and lung damage from exposure to cadmium,[10] reproductive and developmental effects from exposure to arsenic, boron, and thallium, liver and blood effects from exposure to hexavalent chromium, and neurological effects from exposure to manganese) (California EPA, 2011; Oulhote et al., 2014; Roels et al., 2012; U.S. Department of Health and Human Services, 2012; U.S. EPA, 2020g; Ginsberg, 2012).

In some cases, EPA did not quantify or monetize health effects because the estimated changes in pollutant loadings and fish tissue concentrations are small and, combined with the available concentration-response or valuation functions, unlikely to result in tangible benefits. For example, concentration-response functions are available to characterize reductions in blood lead levels (caused by changes in lead exposure) and to translate these reductions into changes in birth weight and avoided cases of attention deficit hyperactivity disorder (ADHD). The corresponding COI estimates are also available. However, past analyses have shown that these benefits account for a small portion of total benefits associated with reducing adult and children exposure to

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[10] Although dose response relationships between a dietary exposure to cadmium and adverse effects in kidney functions have been developed for a cadmium exposure range of 0.003 to 0.014 mg/kg BW/d) (Ginsberg, G. L. (2012). Cadmium risk assessment in relation to background risk of chronic kidney disease. *Journal of Toxicology and Environmental Health, Part A, 75*(7), 374-390.), dose response relationships are not available for lower exposure ranges. Since exposure to cadmium associated with fish consumption caught in the reaches affected by steam electric discharges is below 0.001 mg/kg BW/d (RfD for cadmium) in 99.8 percent of the affected reaches (11,078 out of 11,080 reaches) in the baseline, EPA did not quantify changes in adverse health effects associated with reduced exposure to cadmium via fish consumption.

lead (*e.g.*, see U.S. EPA, 2023f). EPA therefore focused its quantitative analysis on the health effects that have been associated with the largest share of the benefits.

EPA recognizes that there may be cumulative or synergistic effects of pollutants that share the same toxicity mechanism, affect the same body organ or system, or result in the same health endpoint. For example, exposure to several pollutants discharged by steam electric plants (*i.e.*, lead, mercury, manganese, and aluminum) is associated with adverse neurological effects, in particular in fetuses and small children (Agency for Toxic Substances and Disease Registry (ATSDR), 2009; Grandjean et al., 2014; NTP, 2012; Oulhote et al., 2014; U.S. EPA, 2024d). However, data and resource limitations preclude a full analysis of such cumulative or synergistic effects. A weight of evidence approach is typically used in qualitatively evaluating the cumulative effect of a chemical mixture. Cumulative effects often depend on exposure doses as well as potential threshold effects (ATSDR, 2004; 2009). While there are no existing methods to fully analyze and monetize these effects, EPA quantified some of these effects in the EA (U.S. EPA, 2024b).

Due to these limitations, the total monetary value of changes in human health effects included in this analysis represents only a subset of the potential health benefits that are expected to result from the regulatory options.

2.1.3 Complementary Measure of Human Health Impacts

EPA quantified, but did not monetize, changes in pollutant concentrations in excess of human health-based national recommended water quality criteria (NRWQC). This analysis provides an approximate indication of the change in cancer and non-cancer health risk by comparing the number of receiving reaches exceeding health-based NRWQC for steam electric pollutants in the baseline to the number exceeding NRWQC under the regulatory options (Section 5.8).

Because the NRWQC in this analysis are set at levels to protect human health through ingestion of water and aquatic organisms, changes in the frequency at which human health-based NRWQC are exceeded could translate into changes in risk to human health. This analysis should be viewed as an indirect indicator of changes in risk to human health because it does not reflect the magnitude of human health risk changes or the population over which those changes would occur.

In addition, EPA assessed the risk of non-cancer health effects from exposure to steam electric pollutants by comparing the estimated exposure to the pollutant to the pollutant's RfD. To estimate a hazard quotient for a given pollutant EPA divided an individual's oral exposure to the pollutant by the pollutant's oral RfD. A hazard quotient less than one means that the pollutant dose to which an individual is exposed is less than the RfD. For assessing exposures to mixtures of pollutants, EPA developed distributions of non-cancer health hazard indices (HI) under the baseline and regulatory options by summing the individual hazard quotients for those pollutants in the mixture that affect the same target organ or system (*e.g.*, the kidneys, the respiratory system).[11] The shift in the affected stream miles from higher to lower hazard score values between the baseline and regulatory options is the measure of benefit from reduced non-cancer health hazards (See Section 4 of the EA; U.S. EPA, 2024b).

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11 HI values are interpreted similarly to hazard quotients. Values below one are generally considered to suggest that exposures are not likely to result in appreciable risk of adverse health effects during a lifetime, and values above one are generally cause for concern,

2.2 Ecological and Recreational Impacts Associated with Changes in Surface Water Quality

The regulatory options may affect the value of ecosystem services provided by surface waters through changes in the habitats or ecosystems (aquatic and terrestrial) that receive steam electric power plant discharges.

The composition of steam electric power plant wastewater depends on a variety of factors, such as fuel properties, air pollution control technologies, and wastewater management techniques. Wastewater often contains toxic pollutants such as aluminum, arsenic, boron, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, thallium, vanadium, molybdenum, and zinc (U.S. EPA, 2024b). Discharges of these pollutants to surface water can have a wide variety of environmental effects, including fish kills, reduction in the survival and growth of aquatic organisms, behavioral and physiological effects in wildlife, and degradation of aquatic habitat in the vicinity of steam electric power plant discharges (U.S. EPA, 2024b). As presented in Table 2-1, steam electric plants discharge an estimated 492,000 pounds of nitrogen and 10,800 pounds of phosphorus each year in the baseline. Excess nutrients in surface water contribute to eutrophication which can also cause algal blooms and depress oxygen levels, further reducing the habitability for game fish and other aquatic life (U.S. EPA, 2000; U.S. EPA, 2001; Li et al., 2013; Mallin & Cahoon, 2020). The adverse effects associated with releases of steam electric pollutants depend on many factors such as the chemical-specific properties of the effluent, the mechanism, medium, and timing of releases, and site-specific environmental conditions. The modeled changes in environmental impacts are small relative to the changes estimated for the 2015 rule. Still, EPA expects the ecological impacts from the regulatory options could include improved habitat conditions for fresh- and saltwater plants, invertebrates, fish, and amphibians, as well as terrestrial wildlife and birds that prey on aquatic organisms exposed to steam electric pollutants. The change in pollutant loadings has the potential to enhance ecosystem productivity in waterways and the health of resident species, including T&E species. Loading reductions projected under the regulatory options have the potential to impact the general health of fish and invertebrate populations, their propagation to waters, and fisheries for both commercial and recreational purposes. Water quality improvements also have the potential to enhance recreational activities such as swimming, boating, fishing, and water skiing. Finally, the final rule has the potential to impact nonuse values (*e.g.*, option, existence, and bequest values) of the waters that receive steam electric power plant discharges.

Society values changes in ecosystem services by a number of mechanisms, including increased frequency of use and improved quality of recreational activities (*e.g.*, fishing, swimming, and boating). Individuals also value the protection of habitats and species that may reside in waters that receive steam electric plant discharges, even when those individuals do not use or anticipate future use of such waters for recreational or other purposes, resulting in nonuse values. The sections below discuss selected categories of benefits associated with changes in ecosystem services (additional economic productivity benefits associated with changes in ecosystem services are discussed in Section 2.4).

EPA's analysis is intended to isolate possible effects of the regulatory options on aquatic ecosystems and organisms, including T&E species; however, it does not account for the fact that the National Pollutant Discharge Elimination System (NPDES) permit for each steam electric power plant, like all NPDES permits, is required to have limits more stringent than the technology-based limits established by an ELG wherever necessary to protect water quality standards. In cases where a NPDES permit would already provide for more stringent limits in the baseline than those that would be required under the final ELG, the improvements attributable to the rule will be less than estimated in this analysis.

2.2.1 Changes in Surface Water Quality

EPA quantified potential environmental impacts from the regulatory options by estimating in-waterway concentrations of FGD wastewater, BA transport water and CRL pollutants and translating water quality estimates into a single numerical indicator, a water quality index (WQI). EPA used the estimated change in WQI as a quantitative estimate of changes in aquatic ecosystem conditions for this regulatory analysis. Section 3.4 of this report provides details on the parameters used in formulating the WQI and the WQI methodology and calculations. In addition to estimating changes using the WQI, EPA compared estimated pollutant concentrations to freshwater NRWQC for aquatic life (see Section 3.4.1.1). The EA details comparisons of the estimated concentrations in immediate receiving and downstream reaches to the freshwater acute and chronic NRWQC for aquatic life for individual pollutants (U.S. EPA, 2024b).

A variety of primary methods exist for estimating recreational use values, including both revealed and stated preference methods (Freeman III, 2003). Where appropriate data are available or can be collected, revealed preference methods can represent a preferred set of methods for estimating use values. Revealed preference methods use observed behavior to infer users' values for environmental goods and services. Examples of revealed preference methods include travel cost, hedonic pricing, and random utility (or site choice) models.

In contrast to direct use values, nonuse values are considered more difficult to estimate. Stated preference methods, or benefit transfer based on stated preference studies, are the generally accepted techniques for estimating these values (U.S. EPA, 2010, updated 2014; OMB, 2023; Johnston, Boyle, et al., 2017). Stated preference methods rely on carefully designed surveys, which either (1) ask people about their WTP for particular environmental improvements, such as increased protection of aquatic species or habitats with particular attributes, or (2) ask people to choose between competing hypothetical "packages" of environmental improvements and household cost (Bateman et al., 2006; Johnston, Boyle, et al., 2017). In either case, values are estimated by statistical analysis of survey responses.

Although the use of primary research to estimate values is generally preferred because it affords the opportunity for the valuation questions to closely match the policy scenario, the realities of the regulatory process often dictate that benefit transfer is the only option for assessing certain types of non-market values (Rosenberger & Johnston, 2008; Johnston et al., 2021). Benefit transfer is described as the "practice of taking and adapting value estimates from past research … and using them … to assess the value of a similar, but separate, change in a different resource" (Smith, Van Houtven & Pattanayak, 2002, p. 134). It involves adapting research conducted for another purpose to estimate values within a particular policy context (Bergstrom & De Civita, 1999; Johnston et al., 2021). Among benefit transfer methods, meta-analyses are often more accurate compared to other types of transfer approaches due to the data synthesis from multiple source studies (Rosenberger and Phipps, 2007; Johnston et al., 2021). However, EPA acknowledges that there is still a potential for transfer errors (Shrestha, Rosenberger & Loomis, 2007) and no transfer method is always superior (Johnston et al., 2021).

EPA followed the same methodology used in analyzing the 2015 and 2020 rules and the 2023 proposal (U.S. EPA, 2015a, 2020b, 2023b) and relied on a benefit transfer approach based on an updated meta-analysis of surface water valuation studies to estimate the use and non-use benefits of improved surface water quality under the regulatory options. The updates consisted of incorporating WTP estimates from more recent peer reviewed studies into EPA's existing econometric model.[12] This analysis is presented in Chapter 6.

2.2.2 Impacts on Threatened and Endangered Species

For T&E species, even minor changes to reproductive rates and small mortality levels may represent a substantial portion of annual population growth. By reducing discharges of steam electric pollutants to aquatic habitats, the regulatory options have the potential to impact the survivability of some T&E species living in these habitats. These T&E species may have both use and nonuse values. However, given the protected nature of T&E species and the fact that use activities, such as fishing or hunting, generally constitute "take" which is illegal unless permitted, the majority of the economic value for T&E species comes from nonuse values.[13]

EPA quantified but did not monetize the potential benefits of the regulatory options on T&E species. EPA constructed databases to determine which species have habitat ranges that intersect waters downstream from steam electric power plants. EPA then queried these databases to identify "affected areas" of those habitats where 1) receiving waters do not meet aquatic life-based NRWQC under the baseline conditions; and 2) receiving waters do meet aquatic life-based NRWQC under the regulatory options.[14] Because NRWQC are set at levels to protect aquatic organisms, reducing the frequency at which aquatic life-based NRWQC are exceeded should translate into reduced effects to T&E species and potential improvement in species populations. EPA's analysis does not account for the potential for the NPDES permit issuance process to establish more stringent site-specific controls to meet applicable water quality standards (*i.e.*, water quality-based effluent limits issued under Section 301(b)(1)(C)). The analysis may therefore overestimate any potential impacts to T&E species and associated benefits.

EPA was unable to monetize the final rule's benefits on T&E species due to challenges in quantifying the response of T&E populations to changes in water quality. Although numerous economic studies have estimated WTP for T&E protection, these studies focused on estimating WTP to avoid species loss or extinction, increase in the probability of survival, or an increase in species population levels (Subroy et al., 2019; Richardson & Loomis, 2009). These studies, as summarized in Subroy et al. (2019), suggest that people attach economic value to protection of T&E species ranging from $12.6 per household (in 2023$) for Colorado pikeminnow to $208.5 (in 2023$) for lake sturgeon (both fish species).[15] In addition, T&E species may serve as a focus for eco-tourism and provide substantive economic benefit to local communities. For example, Solomon, Corey-Luse and Halvorsen (2004) estimate that manatee viewing provides a net benefit (tourism revenue minus the cost of manatee protection) of $14.1 million to $15.5 million (in 2023$) per year for Citrus County, Florida.[16]

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12 See ICF. (2022b). *Revisions to the Water Quality Meta-Data and Meta-Regression Models after the 2020 Steam Electric Analysis through December 2021* [Memorandum]. for additional detail on updating the meta-analysis.

13 The U.S. Endangered Species Act (ESA) defines "take" to mean "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." 16 U.S. Code § 1532

14 Because the regulatory options reduce pollutant loads, the opposite (receiving waters meet aquatic life-based NRWQC under the baseline conditions but do not meet the NRWQC under the regulatory options) does not apply to this analysis.

15 Values adjusted from $8.32 and $138 per household per year (in 2006$), respectively, using the CPI.

16 Range adjusted from $8.2 million to $9 million (in 2001$), using the CPI.

2.2.3 Changes in Sediment Contamination

Effluent discharges from steam electric power plants can also contaminate waterbody sediments. For example, sediment adsorption of arsenic, selenium, and other pollutants found in FGD wastewater, BA transport water, CRL and legacy wastewater discharges can result in accumulation of contaminated sediment on stream and lake beds (Ruhl et al., 2012), posing a particular threat to benthic (*i.e.*, bottom-dwelling) organisms. These pollutants can later be re-released into the water column and enter organisms at different trophic levels. Concentrations of selenium and other pollutants in fish tissue of organisms of lower trophic levels can bio-magnify through higher trophic levels, posing a threat to the food chain at large (Ruhl et al., 2012).

In waters receiving direct discharges from steam electric power plants, EPA examined potential exposures of ecological receptors (*i.e.*, sediment biota) to pollutants in contaminated sediment. Benthic organisms can be affected by pollutant discharges such as mercury, nickel, selenium, and cadmium (U.S. EPA, 2024b). The pollutants in steam electric power plant discharges may accumulate in living benthic organisms that obtain their food from sediments and pose a threat to both the organism and humans consuming the organism. As discussed in the EA, EPA modeled sediment pollutant concentrations in immediate receiving waters and compared those concentrations to threshold effect concentrations (TECs) for sediment biota (U.S. EPA, 2024b). In 2015, EPA also evaluated potential risks to fish and waterfowl that feed on aquatic organisms with elevated selenium levels and found that steam electric power plant selenium discharges elevated the risk of adverse reproduction impacts among fish and mallards in immediate receiving waters (U.S. EPA, 2015b).

By reducing discharges of pollutants to receiving reaches, the final rule may reduce the contamination of waterbody sediments, impacts to benthic organisms, and the probability that pollutants could later be released into the water column and affect surface water quality and the waterbody food chain. Due to data limitations, EPA did not quantify or monetize the associated benefits.

2.3 Water Supply and Use

The regulatory options are projected to reduce loadings of steam electric pollutants to surface waters relative to the baseline, and thus they may affect the uses of these waters for drinking water supply and agriculture. EPA implemented a treatment cost elasticity approach to quantify avoided drinking water treatment costs from reductions in total nitrogen and total suspended solids. This analysis is summarized in this section and described in more detail in Chapter 9 (see Section 9.1).

2.3.1 Drinking Water Treatment Costs

The regulatory options have the potential to affect drinking water treatment costs. Numerous studies have shown an unequivocal link between higher treatment costs and lower source water quality (see Heberling et al. (2022) for a non-exhaustive list of studies). Using data from 24 U.S. and non-U.S. studies, Price and Heberling (2018) developed elasticities for various water quality parameters, including nitrogen concentrations, phosphorus and sediment loadings, TOC, turbidity, and pH. EPA used these elasticities for turbidity and nitrogen to estimate potential drinking water treatment cost savings. The effects of reductions in other pollutants such as phosphorus, halogens, metals, and toxic chemicals are described qualitatively due to uncertain elasticities between these parameters and drinking water treatment costs, the lack of information on baseline concentrations of these pollutants at source water intakes, and to avoid the possibility of double-counting treatment cost savings.

2.3.1.1 Nutrients

Eutrophication, which is most commonly caused by an overabundance of nitrogen and phosphorus, is one of the main causes of taste and odor impairment in drinking water and can have a major negative impact on public perceptions of drinking water safety. The incremental cost of treating drinking water to address foul tastes and odors due to excess nutrients and the presence of algal blooms can be substantial (Mosheim & Ribaudo, 2017). Treatment may involve filtration, chemical treatment, or other processes (see Khera, Ransom and Speth (2013) for more information on treatment practices that may be employed by small drinking water systems). Recent work has estimated that drinking water systems nationwide incur nutrient pollution treatment costs in excess of $225 million annually (Andarge, 2022). Price and Heberling (2018) combined prior studies of the effect of nutrients on drinking water treatment costs, showing that a 1 percent change in nitrogen (as nitrate) concentration in source water leads to lead to a 0.05 to 0.06 percent change in drinking water treatment costs among all U.S. and non-U.S. studies. The one U.S. study with key controls for possible confounders yielded an elasticity of 0.06, but EPA instead employed a range of elasticity values of 0.05 to 0.06 to incorporate uncertainty. EPA combines the range of elasticities with estimates of baseline drinking water treatment costs to estimate the cost savings that are anticipated to accrue from this regulatory action. Given the uncertainty in the treatment cost elasticity for phosphorus, EPA did not calculate cost changes with respect to phosphorus. From nitrogen pollution reductions alone, EPA estimated annualized drinking water treatment cost savings from $357,000 to $552,000 across all regulatory options assuming a 2 percent discount rate. See details in Section 9.1.

2.3.1.2 Total Suspended Solids

Drinking water treatment costs associated with fluctuations in TSS have been quantified in prior EPA regulatory analyses including the 2004 Meat and Poultry Products Effluent Limitation Guidelines and the 2009 Effluent Limitation Guidelines and Standards for the Construction and Development Industry (U.S. EPA, 2004b, 2009b). Water systems address TSS using chemical treatment with coagulants such as alum or ferrous sulfate. Coagulant application varies in dosage depending on the influent concentrations of TSS, and thus water systems accrue variable costs in the form of coagulant purchases that vary with TSS in source water. Treatment for TSS also produces coagulated sediment in proportion to the influent concentration of TSS and the quantity of coagulant added, and disposal of this coagulated sediment results in additional variable costs for drinking water systems. Elasticity estimates for TSS in Price and Heberling (2018) are based on three studies, two of which date to 1987 and 1988. Only one of these studies included key controls, suggesting that a 1 percent change in sediment loads results in drinking water treatment cost changes of 0.05 percent. The elasticity estimates for turbidity in Price and Heberling (2018) are more precisely estimated across twelve studies, and the five studies controlling for key confounders suggest that a 1 percent increase in turbidity increases drinking water treatment costs by 0.10 to 0.12 percent. EPA therefore converts TSS measurements to turbidity levels and applies the turbidity elasticity from Price and Heberling (2018) to derive treatment cost savings from TSS reductions. The approach of converting TSS to turbidity was also applied for this benefit category in the 2009 Effluent Limitation Guidelines and Standards for the Construction and Development Industry (U.S. EPA, 2009b). EPA estimates that annualized treatment cost savings from TSS loading reductions are between $92,000 and $160,000 at a 2 percent discount rate. See details in Section 9.1.

2.3.1.3 Metals and Toxic Chemicals

EPA conducted a screening-level assessment to evaluate the potential for changes in costs incurred by public drinking water systems from changes in metal and toxic concentrations in source waters and concluded that such changes, while they may exist, are likely to be negligible. The assessment involved identifying the pollutants for which treatment costs may vary depending on source water quality, estimating changes in downstream concentrations of these pollutants at the location of drinking water intakes, and determining whether modeled water quality changes have the potential to affect drinking water treatment costs. Based on this analysis, EPA determined that there are no drinking water systems drawing water at levels that exceed an MCL for metals and other toxics[17] listed in Table 2-2 such as selenium and cyanide under either the baseline or the regulatory options (see Section 4.3.2.3 for details). EPA estimated no changes in MCL exceedances under the regulatory options. Accordingly, EPA did not conduct an analysis of changes in treatment costs incurred by public water systems (PWS) given the relatively small changes in source water quality expected under the final rule and data gaps regarding effects on treatment system operations.

2.3.1.4 Halogens

Halogens found in source water can react during routine drinking water treatment to generate harmful DBPs at levels that vary with site-specific conditions (Good & VanBriesen, 2017, 2019; Regli et al., 2015; U.S. EPA, 2016c). EPA estimated the costs of controlling DBP levels to the MCL in treated water as part of the Stage 2 Disinfectants and Disinfection Byproduct Rule (DBPR). These costs include treatment technology changes as well as non-treatment costs such as routine monitoring and operational evaluations. PWS may adjust their operations to control DBP levels, such as changing disinfectant dosage, moving the chlorination point, or enhancing coagulation and softening. These changes carry "negligible costs" (U.S. EPA, 2005c, pages 7-19). Where low-cost changes are insufficient to meet the MCL, PWS may need to incur irreversible capital costs to upgrade their treatment process to use alternative disinfection technologies such as ozone, ultraviolet light, or chloride dioxide; switch to chloramines for residual disinfection; or add a pre-treatment stage to remove DBP precursors (*e.g.*, microfiltration, ultrafiltration, aeration, or increased chlorine levels and contact time). Some drinking water treatment facilities have already upgraded their treatment systems as a direct result of halogen discharges from steam electric power plants (*United States of America v. Duke Energy*, "United States of America v. Duke Energy," 2015; Rivin, 2015). However, not all treatment technologies remove sufficient organic matter to control DBP formation to required levels (Watson, Farré & Knight, 2012). Thus, increased halogens levels in raw source water could translate into permanently higher drinking water treatment costs at some plants, in addition to posing increased human health risk. Conversely, reducing halogen levels in source waters can reduce the health risk, even where treatment changes have already occurred.[18] In some cases, operation and maintenance (O&M) costs may also be reduced.

EPA quantified halogen treatment cost elasticities using estimated operation and maintenance cost changes presented in Chen et al. (2010). According to the estimates in that study, a one percent change in bromide concentration in source waters leads to 0.14 and 0.86 percent change in drinking water operation and maintenance costs in small and large water systems, respectively, in California. However, EPA did not estimate PWS-level avoided treatment costs from bromide reductions resulting from this regulatory action due to significant uncertainty in these elasticities. To start, existing treatment technologies at the majority of PWS are not designed to remove halogens from raw surface waters, and so the coastal drinking water systems

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17 Modeled drinking water concentrations reflect discharged pollutant loads from steam electric plants and from other facilities reporting to the Toxics Resources Inventory (TRI).

18 Regli, S., Chen, J., Messner, M., Elovitz, M. S., Letkiewicz, F. J., Pegram, R. A., Pepping, T. J., . . . Wright, J. M. (2015). Estimating potential increased bladder cancer risk due to increased bromide concentrations in sources of disinfected drinking waters. *Environmental Science & Technology*, *49*(22), 13094-13102. estimated benefits of reducing bromide across various types of water treatment systems.

studied in Chen et al. (2010), which already contend with issues of seawater intrusion, are likely not representative of other drinking water systems. In addition, there are other environmental sources of halogens, and EPA has insufficient data on baseline bromide concentrations at source waters affected by this regulatory action. While significant uncertainty prevented an analysis of avoided treatment costs from bromide, the Agency assessed the changes in levels of halogens downstream from steam electric power plant outfalls and estimated health outcomes (avoided bladder cancer cases) associated with reduced DBP formation at downstream PWS (see Section 2.1.1 for a discussion of this benefit category and Chapter 4 for details of the analysis).[19]

2.3.1.5 Chloride and Dissolved solids

Finally, excess chloride and TDS can corrode distribution system pipes and lead to the buildup of scale (a mineral deposit), reducing water flow (U.S EPA, 2023m). Increased corrosion in water distribution systems can also increase the leaching of lead and copper. Stets et al. (2018) found a strong statistical connection between source water chemistry (*i.e.*, the chloride-sulfate mass ratio) and the probability of lead action level exceedances (ALEs) in drinking water facilities. Because corrosion in water distribution systems is a costly problem, the regulatory options have the potential to reduce costs to drinking water systems by reducing chloride and TDS loadings and, as a result, corrosivity of source water.

2.3.2 Effects on Household Averting Expenditure

Households who perceive their tap water as unsafe frequently buy bottled water or engage in other averting behaviors (*e.g.*, use filtration systems) aimed at reducing potential exposure to harmful pollutants, and these actions have associated costs. For example, Javidi and Pierce (2018) estimate the minimum expenditures on bottled water by all U.S. households who perceive their tap water as unsafe at $7.0 billion (2023$) annually.[20] In particular, frequent algal blooms are generating growing public concern due to their impact on drinking water safety. A study by Liu and Klaiber (2023) found that averting behavior in response to a 3-day water advisory due to a harmful algal bloom outbreak in 2014 in Toledo, Ohio persisted for up to a month with total averting costs for each household averaging approximately $4.60.[21] The regulatory options have the potential to affect source water quality and, as a result, to affect households' perception of tap water safety and reliance on bottled water to meet their consumption standards.

2.3.3 Irrigation and Other Agricultural Uses

Irrigation accounts for 42 percent of the total U.S. freshwater withdrawals and approximately 80 percent of the Nation's consumptive water use. Irrigated agriculture provides important contributions to the U.S. economy accounting for approximately 40 percent of the total farm sales (Hellerstein, Vilorio & Ribaudo, 2019). Pollutants in steam electric power plant discharges can affect the quality of water used for irrigation and livestock watering. Although elevated nutrient concentrations in irrigation water would not adversely

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[19] EPA's separate proposed rulemaking to regulate discharges of per- and polyfluoroalkyl substances in drinking water could result in implementation of drinking water treatment technologies that would reduce DBP levels during the analysis period.

[20] Values adjusted from $5.65 billion per year (in 2017$), using the CPI.

[21] The study relied on household level data for bottled water purchases to estimate household effect models of averting behavior. The average increase in bottled water expenditures was calculated across all households in the affected areas, of which only some households purchased bottled water after the 3-day advisory. Between 12 percent and 20 percent of households purchased bottled water before the drinking water advisory. The share increased to 34 percent in the two weeks following the 3-day drinking water advisory (66 percent did not purchase bottled water after the 3-day advisory). Values adjusted from $3.60 per household per year (in 2014$), using the CPI.

affect its usefulness for plants, other steam electric pollutants, such as arsenic, mercury, lead, cadmium, and selenium have the potential to affect soil fertility and enter the food chain (National Research Council, 1993; Zhang et al., 2018). For example, the same heavy metals found in oilfield produced waters (including barium, lead, and chromium) have been shown to accumulate in soil, plants, and oranges (Zhang et al., 2018). Additionally, nutrients can increase eutrophication, promoting cyanobacteria blooms that can kill livestock and wildlife that drink the contaminated surface water. TDS can impair the utility of water for both irrigation and livestock use. EPA did not quantify or monetize effects of quality changes in agricultural water sources arising from the regulatory options due to data limitations on how costs vary with relatively small estimated changes in water quality.

2.4 Other Economic Effects

The regulatory options may have other economic effects stemming from changes in sediment deposition in reservoirs and navigational waterways; changes in tourism, commercial fish harvests, and property values.[22] EPA estimated the changes in sediment deposition in reservoirs and navigational waterways. Chapter 9 discusses the associated benefits. Other benefit categories (*e.g.*, effects on property values) are discussed qualitatively in the following sections.

2.4.1 Reservoir Capacity

Reservoirs serve many functions, including storage of drinking and irrigation water supplies, flood control, hydropower supply, and recreation. Streams can carry sediment into reservoirs, where it can settle and build up over time, reducing reservoir capacity and the useful life of reservoirs (Graf et al., 2010; Palinkas & Russ, 2019; Rahmani et al., 2018). Reservoir capacity has been diminishing over time. At a national scale, Randle et al. (2021) found that total reservoir storage capacity has dropped from a peak of 850 Gm^3 to 810 Gm^3. At a state scale, Rahmani et al. (2018) found that all 24 federally operated reservoirs in Kansas have collectively lost 17 percent of their original capacity with the highest single-reservoir loss of 45 percent. Dredging and other sediment management strategies can be used to reclaim capacity (Hargrove et al., 2010; Miranda, 2017; Morris, 2020; Randle et al., 2021; Winkelman. M.O., Sens & Marcus, 2019).[23] EPA expects that changes in suspended solids discharges under the regulatory options could affect reservoir maintenance costs by changing the frequency or volume of dredging activity. Changes in sediment loads could result in a modest decrease in dredging costs in reservoirs under all regulatory options. See Section 9.2 for details.

2.4.2 Sedimentation Changes in Navigational Waterways

Navigable waterways, including rivers, lakes, bays, shipping channels and harbors, are an integral part of the United States' transportation network (Clark, Haverkamp & Chapman, 1985). Navigable channels are prone to reduced functionality due to sediment build-up, which can reduce the navigable depth and width of the waterway (Clark, Haverkamp & Chapman, 1985; Ribaudo & Johansson, 2006). For many navigable waters,

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22 EPA estimated changes in the marketability of coal combustion ash as a benefit of the 2015 rule (U.S. Environmental Protection Agency. (2015a). *Benefit and Cost Analysis for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category*. (EPA-821-R-15-005).). However, based on the baseline for this rule which already requires ash to be handled dry, EPA does not expect incremental changes in the amount of ash handled dry vs. wet and benefits from increased marketing of coal combustion ash under any of the regulatory options.

23 Other sedimentation management strategies may be used instead of, or in combination with, dredging. This includes reducing sediment yield through watershed management practices and routing sediments through or around reservoirs (Morris, G. L. (2020). Classification of Management Alternatives to Combat Reservoir Sedimentation. *Water*, *12*(3). https://doi.org/10.3390/w12030861 ; Randle, T. J., Morris, G. L., Tullos, D. D., Weirich, F. H., Kondolf, G. M., Moriasi, D. N., Annandale, G. W., . . . Wegner, D. L. (2021). Sustaining United States reservoir storage capacity: Need for a new paradigm. *Journal of Hydrology*, *602*, 126686. https://doi.org/https://doi.org/10.1016/j.jhydrol.2021.126686).

periodic dredging is necessary to remove sediment and keep them passable. For example, the U.S. Army Corps of Engineers (USACE) maintains the Southwest Pass[24], the most highly utilized commercial deep-draft waterway in the country, and its rapid-onset shoaling has led to prolonged periods of draft restrictions for transiting vessels (*e.g.*, reductions in the amount of cargo that can be transported per voyage). To counteract channel shoaling, the USACE has dredged an annual average 25 million cubic yards of sediment since 2015 (Hartman et al., 2022). Dredging navigable waterways can be costly. Following the previous example, total dredging expenditures in the Southwest Pass for the 2019 fiscal year amounted to $147.8 million (dredging expenditures between the 2015 and 2018 fiscal years ranged from $66.0 million to $65.4 million) (Hartman et al., 2022).

EPA estimated that all regulatory options would reduce sediment loadings to surface waters and reduce dredging of navigational waterways. EPA quantified and monetized these benefits based on the avoided cost for projected changes in future dredging volumes. Section 9.2 describes this analysis.

2.4.3 Commercial Fisheries

Pollutants in steam electric power plant discharges can reduce fish populations by inhibiting reproduction and survival of aquatic species. These changes may negatively affect commercial fishing industries as well as consumers of fish, shellfish, and fish and seafood products. Estuaries are particularly important breeding and nursery areas for commercial fish and shellfish species (Alkire, Silldorff & Wang, 2020; Brame et al., 2019; Beck et al., 2001). In some cases, excessive pollutant loadings can lead to the closure of shellfish beds, thereby reducing shellfish harvests and causing economic losses from reduced harvests (Jin, Thunberg & Hoagland, 2008; Trainer et al., 2007; Islam & Masaru, 2004). Improved water quality due to reduced discharges of steam electric pollutants would enhance aquatic life habitat and, as a result, contribute to reproduction and survival of commercially harvested species and larger fish and shellfish harvests, which in turn could lead to an increase in producer and consumer surplus. Conversely, an increase in pollutant loadings could lead to negative impacts on fish and shellfish harvest.

EPA did not quantify or monetize impacts to commercial fisheries under the regulatory options. EPA estimated that eight steam electric power plants discharge BA transport water, FGD wastewater, CRL or legacy wastewater directly to the Great Lakes or to estuaries. Large distances and stream flows greatly reduce the relative impact of steam electric power plants discharging upstream from these systems. Although estimated decreases in annual average pollutant loads under the regulatory options may benefit local fish populations and commercial harvest, the overall effects to commercial fisheries arising from the regulatory options are difficult to quantify but are likely to be relatively small. Commercial species potentially affected by steam electric discharges account for approximately 1 percent of total landings value in the United States.[25]

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24 This is the entrance channel for a port system which encompasses waters ranging from the Mississippi River in Baton Rouge, Louisiana to the Gulf of Mexico Project (Hartman, M. A., Mitchell, K. N., Dunkin, L. M., Lewis, J., Emery, B., Lenssen, N. F., & Copeland, R. (2022). Southwest Pass Sedimentation and Dredging Data Analysis. *Journal of Waterway, Port, Coastal, and Ocean Engineering*, *148*(2), 05021017. https://doi.org/doi:10.1061/(ASCE)WW.1943-5460.0000684).

25 Based on U.S. commercial fisheries landing values in 2019. EPA obtained commercial fisheries landing data for areas that may be affected by steam electric discharges (Mississippi (Big Lake, connected to Biloxi Bay), Tampa, FL area (closest port to Hillsborough Bay), Lake Eerie, and Lake Michigan) and compared the potentially affected commercial fisheries landing value to total U.S. commercial fisheries landing value (marine and Great Lakes). EPA obtained commercial fishery landing value for Mississippi and the U.S. from NOAA Fisheries (National Oceanic and Atmospheric Administration. (2022). *NOAA Fisheries - U.S. Commercial Fish Landings*. https://www.fisheries.noaa.gov/foss/f?p=215:200:1735541630262:Mail:NO:::), for the Tampa area from the Florida Fish and Wildlife Conservation Commission (Florida Fish and Wildlife Conservation Commission. (2022). *Commercial Fisheries Landings Summaries*. https://app.myfwc.com/FWRI/PFDM/ReportCreator.aspx), and for the Great Lakes

Moreover, most species of fish have numerous close substitutes. The economic literature suggests that when there are plentiful substitute fish products (*e.g.*, chicken is substitute for fish) the measure of consumer welfare (consumer surplus) is unlikely to change as a result of small changes in fish landings, such as those EPA expects under the regulatory options.

2.4.4 Tourism

Discharges of pollutants may also affect the tourism and recreation industries (*e.g.*, boat rentals, sales at local restaurants and hotels) and, as a result, local economies in the areas surrounding affected waters due to changes in recreational opportunities (U.S. Bureau of Economic Analysis, 2021; Mojica & Fletcher, 2020; Highfill & Franks, 2019). The effects of water quality on tourism are likely to be highly localized. Moreover, since substitute tourism locations may be available, increased tourism in one location (*e.g.*, the vicinity of steam electric power plants) may lead to a reduction in tourism in other locations or vice versa. Due to the relatively small water quality changes expected from the regulatory options (see Section 3.4 for details) and availability of substitute sites, the overall effects on tourism and, as a result, social welfare is likely to be negligible. Therefore, EPA did not quantify or monetize this benefit category.

2.4.5 Property Values

Discharges of pollutants may affect the aesthetic quality of water resources by altering water clarity, odor, and color in the receiving and downstream reaches. Technologies implemented by steam electric power plants to comply with the regulatory options remove nutrients and sediments to varying degrees and have varying effects on water eutrophication, algae production, water turbidity, and other surface water characteristics. Several studies (*e.g.*, Austin, 2020; Bin & Czajkowski, 2013; Cassidy, Meeks & Moore, 2023; Gibbs et al., 2002; Guignet et al., 2022; Irwin & Wolf, 2022; Kemp, Ng & Mohammad, 2017; Kuwayama, Olmstead & Zheng, 2022; Leggett & Bockstael, 2000; Liu, Opaluch & Uchida, 2017; Mamun et al., 2023; Moore et al., 2020; Netusil, Kincaid & Chang, 2014; Tang, Heintzelman & Holsen, 2018; Tuttle & Heintzelman, 2014; Walsh, Milon & Scrogin, 2011; Walsh et al., 2017; Wolf, Klaiber & Gopalakrishnan, 2022) suggest that both waterfront and non-waterfront properties are more desirable when located near unpolluted water. For example, a meta-analysis of 18 hedonic studies (Guignet et al., 2022) suggests that, on average, a one-percent increase in water clarity leads to a 0.19 percent increase in waterfront home prices and 0.04 percent increase in non-waterfront homes prices within 500 meters of the waterbody.[26] The authors also found that site specific effects on home prices are likely to be influenced by the baseline water clarity and vary by region. A hedonic analysis of property values across six Ohio counties (Wolf & Klaiber, 2017) found a decline in property values from increased frequency of algal blooms in lakes between 11 percent and 17 percent for near lake homes and 22 percent for lake adjacent homes. Public perception of potential health risks associated with toxic pollutant discharges from steam electric plants may also have a negative impact on nearby property values. For example, Austin (2020) finds that, in North Carolina, negative impacts of coal ash discharges on drinking water led to a 12 to 14 percent decline in sale price for homes within one mile of a coal ash pond after potential risks were made more salient by a state regulation. Therefore, the value of properties located in

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from the Great Lakes Fishery Commission (Great Lakes Fishery Commission. (2022). *Commercial fish production in the Great Lakes 1867–2020*. http://www.glfc.org/great-lakes-databases.php). EPA assumed that all fish species in Lake Eerie and Lake Michigan may be affected by steam electric discharges. For commercial fishery landings in Tampa and Mississippi, EPA removed deep sea fish species (*e.g.*, tuna, sharks, jacks, and octopus) from consideration of fish potentially affected by steam electric power plant discharges since they are unlikely to use the estuarine areas where discharges occur.

[26] These elasticities are based on the base meta-regression (see Model 1 in Table 3 on page 204, Guignet, D., Heberling, M. T., Papenfus, M., & Griot, O. (2022). Property values, water quality, and benefit transfer: A nationwide meta-analysis. *Land Economics, 050120-0062R1*.).

proximity to waters affected by steam electric plant discharges may increase due to reductions in discharges of FGD wastewater, BA transport water, CRL, and legacy wastewater.

EPA did not quantify or monetize the potential change in property values associated with the regulatory options because the water quality metrics or pollutants addressed in existing studies do not provide a good match to the list of pollutants covered by the steam electric ELG. As shown in Guignet et al. (2022), water clarity is the most common water quality measure analyzed in the hedonic literature, followed by fecal coliform and *chlorophyll a*.[27] The magnitude of the potential effect on property values from reducing steam electric discharges is uncertain. It depends on many factors, including the number of housing units located in the vicinity of the affected waterbodies,[28] community characteristics (*e.g.*, residential density), housing stock (*e.g.*, single family or multiple family), and the effects of steam electric pollutants on the aesthetic quality of surface water. Because changes in the aesthetic quality of surface waters (*e.g.*, clarity) that may result from the relatively small changes in pollutant concentrations under the regulatory options are difficult to quantify, EPA did not estimate the impacts of the final rule on property values. In addition, there may be an overlap between shifts in property values and the estimated total WTP for surface water quality changes discussed in Section 2.2.1.

2.5 Changes in Air Pollution

The final rule is expected to affect air pollution through three main mechanisms: 1) changes in energy use by steam electric power plants to operate wastewater treatment and other systems needed to comply with the final rule; 2) changes in transportation-related emissions due to changes in trucking of CCR and other waste to on-site or off-site landfills; and 3) the change in the profile of electricity generation due to relatively higher cost to generate electricity at plants incurring ELG compliance costs. The three mechanisms can produce changes in different directions. For example, increased energy use by power plant tend to increase air emissions associated with power generation, but those changes are relatively small when compared to the changes resulting from shifts in the electricity generation mix away from coal-fired generation and toward sources with lower emission factors. These shifts in generation mix result tend to reduce overall emissions at the national level, although the localized changes in air pollutant emissions may be positive or negative depending on which electricity generating units produce more or less electricity as a result of these shifts.

As described in Chapter 5 of the RIA, EPA used the Integrated Planning Model (IPM®), a comprehensive electricity market optimization model that can evaluate impacts within the context of regional and national electricity markets, to analyze impacts of the final rule (*i.e.*, Option B). Electricity market analyses using IPM project that the final rule (Option B) will expand on the baseline trend by shifting away from coal fired electric power generation toward generation from other energy sources, such as natural gas and renewables. Relative to the baseline, IPM projects coal-fired generation to decline as a result of the final rule. These changes are offset in part by an increase in natural gas generation, nuclear generation, and generation by renewables. Differences in emissions factors across energy sources generally results in net reductions in air

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27 The majority of recently published studies that were not included in ibid. also analyzed impacts on water clarity on home prices (e.g., Irwin, N., & Wolf, D. (2022). Time is money: Water quality's impact on home liquidity and property values. *Ecological economics*, *199*, 107482. , Mamun, S., Castillo-Castillo, A., Swedberg, K., Zhang, J., Boyle, K. J., Cardoso, D., Kling, C. L., . . . Phaneuf, D. (2023). Valuing water quality in the United States using a national dataset on property values. *Proceedings of the National Academy of Sciences*, *120*(15), e2210417120.).

28 In a review of 36 hedonic studies that focus on the impact of water quality on housing values, Guignet, D., Heberling, M. T., Papenfus, M., & Griot, O. (2022). Property values, water quality, and benefit transfer: A nationwide meta-analysis. *Land Economics*, *050120-0062R1*. note that some studies have detected property value impacts up to a mile away from impacted waterways.

emissions from electricity generating units across all modeled pollutants at the national level (CO_2, SO_2, NO_X, direct $PM_{2.5}$, PM_{10}, Hg, and hydrogen chloride (HCl)). Overall for the three mechanisms (auxiliary services, transportation, and market-level generation), EPA estimates net reductions in CO_2, SO_2, and NO_X emissions as compared to the baseline at the national level. EPA also estimated small increases in methane (CH_4) emissions from transportation, but these increases are much smaller than the net reductions in CO_2 emissions. However, the distribution of the changes may result in localized increases even as the overall changes nationwide are decreases, and air emissions of some pollutants may increase in some years and decrease in others. See the RIA for details (U.S. EPA, 2024e).

CO_2 is the most prevalent of the greenhouse gases, which are air pollutants that EPA has determined endanger public health and welfare through their contribution to climate change. EPA used estimates of the social cost of greenhouse gases (SC-GHG) – specifically, the social cost of carbon (SC-CO_2) and of the social cost of methane (SC-CH_4) – to monetize the benefits of changes in CO_2 and CH_4 emissions as a result of the final rule.. The SC-GHG is the monetary value of the net harm to society associated with emitting a metric ton of the GHG in question into the atmosphere in a given year, or the benefit of avoiding that increase. In principle, the SC-GHG includes the value of all climate change impacts, including (but not limited to) changes in net agricultural productivity, human health effects, property damage from increased flood risk and natural disasters, disruption of energy systems, risk of conflict, environmental migration, and the value of ecosystem services. Chapter 8 details this analysis.

NO_X, and SO_2 are known precursors to $PM_{2.5}$, a criteria air pollutant that has been associated with a variety of adverse health effects, including premature mortality and hospitalization for cardiovascular and respiratory diseases (*e.g.*, asthma, chronic obstructive pulmonary disease [COPD], and shortness of breath). EPA quantified changes in direct $PM_{2.5}$ emissions and in emissions of $PM_{2.5}$ and ozone[29] precursors NO_X and SO_2 and assessed impacts of those emission changes on air quality changes across the country using the Comprehensive Air Quality Model with Extensions (CAMx) (Ramboll Environ International Corporation, 2016). EPA then used spatial fields of baseline and post-compliance air pollutant concentrations as input to Benefits Mapping and Analysis Program—Community Edition (BenMAP-CE) to estimate incremental human health effects (including the potential for premature mortality and morbidity) from changes in ambient air pollutant concentrations (U.S. EPA, 2018a). Chapter 8 details this analysis.

The final rule may also affect air quality through changes in electricity generation units emissions of larger particulate matter (PM_{10}) and hazardous air pollutants (HAP) including mercury and hydrogen chloride. The health effects of mercury are detailed in the EA (U.S. EPA, 2024b). Hydrogen chloride is a corrosive gas that can cause irritation of the mucous membranes of the nose, throat, and respiratory tract. For more information about the impacts of mercury and hydrogen chloride emissions, see the Mercury and Air Toxics Standards (MATS) for Power Plants,[30] including the 2023 proposed *National Emission Standards for Hazardous Air Pollutants: Coal- and Oil-Fired Electric Utility Steam Generating Units Review of the Residual Risk and Technology Review* (88 FR 24854).

The final rule may also affect air quality if steam electric power plants alter their coal storing and handling practices, since Jha and Muller (2018) found that a 10 percent increase in coal stockpiles held by U.S. power

29 Emissions of nitrogen oxides (NOx) lead to formation of both ozone and $PM_{2.5}$ while SO_2 emissions lead to formation of $PM_{2.5}$ only.

30 See https://www.epa.gov/stationary-sources-air-pollution/mercury-and-air-toxics-standards.

plants results in a 0.09 percent increase in average $PM_{2.5}$ concentration levels within 25 miles of these plants. In addition to health effects from air emissions, air pollution can create a haze that affects visibility. Reduced visibility could impact views in national parks by softening the textures, fading colors, and obscuring distant features and therefore reduce the value of recreational activities (*e.g.*, Boyle et al., 2016; Pudoudyal, Paudel & Green, 2013). A number of studies (*e.g.*, Bayer, Keohane & Timmins, 2006; Beron, Murdoch & Thayer, 2001; Chay & Greenstone, 1998) also found that reduced air quality and visibility can negatively affect residential property values.

2.6 Summary of Benefits Categories

Table 2-3 summarizes the potential social welfare effects of the regulatory options analyzed for the final rule and the level of analysis applied to each category. As indicated in the table, only a subset of potential effects can be quantified and monetized. The monetized welfare effects include reductions in some human health risks, use and non-use values from surface water quality improvements, reduced costs for dredging reservoirs and navigational waterways, and changes in air emissions. Other welfare effect categories, including changes in waters exceeding NRWQC, were quantified but not monetized. Although EPA was not able to quantify or monetize other welfare effects, including some other human health risks and impacts to commercial fisheries, those unquantified benefits may be relatively small compared to other monetized benefits.[31] EPA evaluated these effects qualitatively as discussed above in Section 2.1 through Section 2.5.

Table 2-3: Estimated Welfare Effects of Changes in Pollutant Discharges from Steam Electric Power Plants

Category	Effect of Regulatory Options	Benefits Analysis		
		Quantified	Monetized	Methods (Report Chapter where Analysis is Detailed)
Human Health Benefits from Surface Water Quality Improvements				
Changes in human health effects (*e.g.*, bladder cancer) associated with halogenated DBP exposure via drinking water	Changes in exposure to halogenated DBPs in drinking water	✓	✓	VSL and COI (Chapter 4)
IQ losses to children ages 0 to 7	Changes in childhood exposure to lead from consumption of self-caught fish[a]	✓	✓	IQ point valuation (Chapter 5)
Need for specialized education	Changes in childhood exposure to lead from consumption of self-caught fish[a]	✓	✓	Qualitative discussion (Chapter 5)
Incidence of cardiovascular disease in adults	Changes in exposure to lead from consumption of self-caught fish[a]	✓	✓	VSL (Chapter 5)
IQ losses in infants	Changes in in-utero mercury exposure from maternal consumption of self-caught fish[a]	✓	✓	IQ point valuation (Chapter 5)
Incidence of skin cancer	Changes in exposure to arsenic from consumption of self-caught fish[a]	✓	✓	COI (Chapter 5); Qualitative discussion (Chapter 2)

31 The 2015 and 2020 rules, which are included in the baseline for this analysis, significantly reduced toxic pollutant and nutrient loadings, making additional reductions estimated for this final rule smaller, particularly when compared to the benefits that can be quantified and monetized.

Table 2-3: Estimated Welfare Effects of Changes in Pollutant Discharges from Steam Electric Power Plants

Category	Effect of Regulatory Options	Benefits Analysis		
		Quantified	Monetized	Methods (Report Chapter where Analysis is Detailed)
Other adverse health effects (cancer and non-cancer)	Changes in exposure to toxic pollutants (lead, cadmium, thallium, etc.) via fish consumption or drinking water	✓		Human health criteria exceedances (Chapter 5); Exposure above non-cancer health thresholds (Chapter 4, EA; U.S. EPA, 2024b); Qualitative discussion (Chapter 2)
Reduced adverse health effects (*e.g.*, rash and irritation from dermal exposure to toxins in HABs)	Changes in exposure to pollutants from recreational water uses			Qualitative discussion (Chapter 2)
Ecological Condition and Recreational Use Effects from Surface Water Quality Changes				
Aquatic and wildlife habitat[b]	Changes in ambient water quality in receiving reaches	✓	✓	Benefit transfer (Chapter 6); Qualitative discussion (Chapter 2)
Water-based recreation[b]	Changes in swimming, fishing, boating, and near-water activities from water quality changes			
Aesthetics[b]	Changes in aesthetics from shifts in water clarity, color, odor, including nearby site amenities for residing, working, and traveling			
Non-use values[b]	Changes in existence, option, and bequest values from improved ecosystem health			
Protection of T&E species	Changes in T&E species habitat and potential effects on T&E species populations	✓		Habitat range intersecting with reaches with NRWQC exceedances (Chapter 7); Qualitative discussion (Chapter 2)
Sediment contamination	Changes in deposition of toxic pollutants to sediment			Qualitative discussion (Chapter 2)
Water Supply and Use				
Water treatment costs for drinking water	Changes in quality of source water used for drinking	✓	✓	Avoided cost of drinking water treatment (Chapter 9); Qualitative discussion (Chapter 2)
Water treatment costs for irrigation and other agricultural uses	Changes in quality of source water used for irrigation and other agricultural uses			Qualitative discussion (Chapter 2)
Other Economic Effects				
Dredging costs	Changes in sedimentation and costs for maintaining navigational waterways and reservoir capacity	✓	✓	Avoided cost of dredging (Chapter 9); Qualitative discussion (Chapter 2)

Table 2-3: Estimated Welfare Effects of Changes in Pollutant Discharges from Steam Electric Power Plants

Category	Effect of Regulatory Options	Benefits Analysis		
		Quantified	Monetized	Methods (Report Chapter where Analysis is Detailed)
Commercial fisheries	Changes in fisheries yield and harvest quality due to aquatic habitat changes			Qualitative discussion (Chapter 2)
Tourism industries	Changes in participation in water-based recreation			Qualitative discussion (Chapter 2)
Property values	Changes in property values from changes in water quality			Qualitative discussion (Chapter 2)
Air Quality-Related Effects				
Air emissions of $PM_{2.5}$, NO_X and SO_2	Changes in mortality and morbidity from exposure to particulate matter ($PM_{2.5}$) emitted directly or linked to changes in NO_X and SO_2 emissions (precursors to $PM_{2.5}$ and ozone)	✓	✓	VSL and COI (Chapter 8); Qualitative discussion (Chapter 2)
Air quality effects of coal stockpiles	Air quality effects of storing and handling coal at steam electric power plants			Qualitative discussion (Chapter 2)
Air emissions of NO_X and SO_2	Changes in ecosystem effects; visibility impairment; and human health effects from direct exposure to NO_2, SO_2, and hazardous air pollutants.			Qualitative discussion (Chapters 2 and 8)
Air emissions of CO_2 and CH_4	Changes in climate change effects	✓	✓	Social cost of greenhouse gases (SC-GHG) (Chapter 8)

a. Reductions in discharges of lead, mercury, and other toxic pollutants may reduce concentrations of these pollutants in open seas, thus reducing levels of pollutants in high trophic level fish harvested commercially. There are unquantified benefits associated with all of these end points for those who consume commercially harvested fish, but these benefits are very difficult to estimate.

b. These values are implicit in the total WTP for water quality improvements.

Source: U.S. EPA Analysis, 2024

3 Water Quality Effects of Regulatory Options

Changes in the quality of surface waters, aquatic habitats and ecological functions under the regulatory options depend on several factors, including the operational characteristics of steam electric power plants, treatment technologies implemented to control pollutant levels, the timing of treatment technology implementation, and the hydrography of reaches receiving steam electric pollutant discharges, among others. This chapter describes the surface water quality changes projected under the regulatory options. EPA modeled water quality based on loadings estimated for the baseline and for each of the three regulatory options (Option A through Option C). The differences in concentrations between the baseline and option scenarios represent the changes attributable to the regulatory options. These changes inform the analysis of several of the benefits described in Chapter 2 and detailed in later chapters of this report.

The analyses use pollutant loading estimates detailed in the TDD (U.S. EPA, 2024f) and expand upon the analysis of immediate receiving waters described in the EA (U.S. EPA, 2024b) by estimating changes in both receiving and downstream reaches. The EA provides additional information on the effects of steam electric power plant discharges on surface waters and how they may change under the regulatory options.

3.1 Waters Affected by Steam Electric Power Plant Discharges

EPA estimates the regulatory options potentially affect 232 steam electric power plants with coal-fired generating units after December 31, 2028 and/or CRL or legacy wastewater discharges. EPA used the United States Geological Survey (USGS) medium-resolution National Hydrography Dataset (NHD) (USGS, 2018) to represent and identify waters affected by steam electric power plant discharges, and used additional attributes provided in version 2 of the NHDPlus dataset (U.S. EPA, 2019g) to characterize these waters.

Of the plants represented in the analysis, EPA estimated that 110 plants have non-zero pollutant discharges under the baseline or the regulatory options for the wastestreams modeled for the benefits analyses (FGD wastewater, BA transport water, CRL, or legacy wastewater).[32, 33] In the aggregate, the 110 plants discharge to 126 waterbodies (as categorized in NHDPlus), including lakes, rivers, and estuaries.[34] Receiving reaches that lack NHD classification for both waterbody area type and stream order generally correspond to reaches that do not have valid flow paths[35] for analysis of the fate and transport of steam electric power plant discharges (see Section 3.3). Eleven steam electric power plants discharge FGD wastewater, BA transport water, CRL or legacy wastewater to tidal reaches or the Great Lakes directly or through immediate tributaries or to waters not connected to the hydrographic network.[36] EPA did not assess pollutant loadings and water quality changes

32 The benefits analyses do not include loadings from unmanaged CRL and therefore omit some plants that are estimated to have only this wastestream. These plants may incur compliance costs to comply with limits for unmanaged CRL for any discharge that a permitting authority deems is the functional equivalent of a direct discharge and require a permit, but changes in unmanaged CRL loads were not modeled explicitly. Costs are included, however, in the social costs presented in Chapters 11 and 12.

33 Of these 110 plants, 12 plants discharge to more than one waterbody. Also, of the 110 plants, 104 plants have non-zero pollutant discharges under the baseline or the regulatory options for FGD wastewater, BA transport water, or CRL (6 plants have estimated loads for legacy wastewater only).

34 Some plants discharge waste streams to multiple (two or three) different receiving waters.

35 In NHDPlus, the flow path represents the distance traveled as one moves downstream from the reach to the terminus of the stream network. An invalid flow path suggests that a reach is disconnected from the stream network.

36 Four plants (Edgewater, Elm Road, JH Campbell, and Oak Creek) discharge non-zero loads to Lake Michigan, one plant (Monroe) discharges to Lake Erie, one plant (Bay Front) discharges to Lake Superior, and four plants (Big Bend, Jack Watson, Crist, and Winyah) discharge to estuaries or other tidal waters either directly or through immediate tributaries. Because Great

associated with these waterbodies because of the lack of a defined flow path in NHDPlus, and in the case of Great Lakes and esturaries the complexity of flow patterns and the relatively small changes in concentrations expected.[37] Thus, EPA estimated changes in water quality downstream from 101 steam electric plants associated with a total of 114 receiving reaches representing the waterbodies in NHDPlus.[38]

3.2 Changes in Pollutant Loadings

EPA estimated post-technology implementation pollutant loadings for each plant under the baseline and the regulatory options. The TDD details the methodology (U.S. EPA, 2024f). The sections below discuss the approach EPA used to develop a profile of loading changes over time under the baseline and each regulatory option and summarize the results.

3.2.1 Implementation Timing

Benefits analyses account for the temporal profile of environmental changes as the public values changes occurring in the future less than those that are more immediate (OMB, 2023). As discussed in Section 1.3.3, for the purpose of the economic impact and benefit analysis, EPA generally estimates that plants will implement control technologies to meet the applicable rule limitations and standards as their permits are renewed, and no later than December 31, 2029. This schedule recognizes that control technology implementation is likely to be staggered over time across the universe of steam electric power plants. This in turn can translate into variations in pollutant loads to waters over time.

To estimate the benefits of the regulatory options, EPA first developed a time profile of loadings for each scenario (*i.e.*, baseline and each regulatory option), electricity generating unit (EGU), wastestream, and pollutant that reflects the baseline loadings, the estimated loadings under the applicable technology basis, the estimated technology implementation year for the plant, and the timing of any retirements or repowerings. Specifically, EPA used baseline loadings starting in 2025 through the applicable technology implementation year, applicable technology-based loadings corresponding to the analyzed scenario (baseline or regulatory option) for all years following a plant's modeled implementation year, and zero loadings following a unit's retirement or repowering (where applicable).

EPA then used this year-explicit time profile to calculate the annual average loadings discharged by each plant for two distinct periods within the overall period of analysis of 2025 through 2049:[39]

Lakes and estuaries are complex waterbodies accurately modeling water quality impacts to these waters would require the application of more complex models that was not feasible within this rulemaking. Finally, one plant (Gerald Gentleman) discharges to a reservoir not connected to the stream network.

37 EPA looked at the changes in pollutant loadings and impacts to these systems in selected case studies as part of the analysis of the 2015 rule. See 2015 EA for details; U.S. Environmental Protection Agency. (2015b). *Environmental Assessment for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category*. (EPA 821-R-15-006).

38 EPA analyzed a total of 185 plants with plants with coal-fired generating units after December 31, 2028 and/or that generate the wastestreams within the scope of the final rule. Not all these plants have costs and/or loads under the baseline or regulatory options, so while the modeling scope is all 185 plants, as discussed in this section, some plants have zero loads whereas others discharge to waters that lack a valid flow path (*e.g.*, Great Lakes and estuaries), leaving 104 plants for which EPA analyzed changes in downstream water quality.

39 EPA had initially analyzed regulatory options for which the technology implementation deadline was set to of 2030 and the average loads calculated for two periods that reflected that deadline (*i.e.*, 2026-2030 and 2031-2050). While EPA later revised the compliance deadline to 2029, the Agency did not recalculate the average loads but instead shifted the periods and the associated loading reductions by one year (*i.e.*, 2025-2029 and 2030-2049). Because of the timing of the retirement of some generating units

- Period 1, which extends from 2025 through 2029, when the universe of plants would transition from current (baseline) treatment practices to practices that achieve the revised limits, and

- Period 2, which extends from 2030 through 2049 and is the post-transition period during which the full universe of plants is projected to employ treatment practices that achieve the revised limits.

The analysis accounts for each plant's technology implementation year(s) and for announced unit retirements or repowerings. Using average annual values for two distinct periods instead of a single average over the entire period of analysis enables EPA to better represent the rule implementation and capture the transitional effects of the regulatory options. While using an annual average does not show the differences between the baseline and regulatory options for individual years within Period 1, EPA considers that the average provides a reasonable measure of the transitional effects of the regulatory options given the categories of benefits that EPA is analyzing, which generally result from changes in multi-year processes.

As discussed in the RIA (U.S. EPA, 2024e), there is uncertainty in the exact timing of when individual steam electric power plants would be implementing technologies to meet the final rule or the other regulatory options. This benefits analysis uses the same plant- and wastestream-specific technology installation years used in the cost and economic impact analyses. To the extent that technologies are implemented earlier or later, the annualized loading values presented in this section may under- or overstate the annual loads during the analysis period.

3.2.2 Results

Differences in the stringency of effluent limits and pretreatment standards and the timing of their applicability to steam electric power plants (and the resulting treatment technology implementation) mean that changes in pollutant loads between the regulatory options and the baseline vary over the period of analysis. Within the period of analysis, the years 2025-2029 represent a period of transition as plants implement treatment technologies to meet the revised limits under the regulatory options, whereas years 2030 through 2049 have steady state loadings that reflect implementation of technologies across all plants.[40]

Table 3-1 summarizes the average annual reductions during Period 1 and Period 2 in FGD wastewater, BA transport water, CRL, legacy wastewater,[41] and total loads for selected pollutants that inform EPA's analysis of the benefits discussed in Chapters 4 through 7 and Chapters 9 and 10. The regulatory options are estimated to result in either no change or in *reductions* in pollutant loadings under an option as compared to the baseline, with the reductions generally increasing as one progresses from Option A to Option C. Further, loading reductions are largest during Period 2 when all steam electric plants have implemented the treatment technologies associated with the limits, as compared to the transition period represented by Period 1.

relative to technology installation, the loading reductions reflected in analysis for Period 2 are smaller than would have been obtained had EPA recalculated the average loads to reflect the earlier compliance year. The difference ranges between 0 percent and 7 percent, depending on the pollutant and regulatory option, with an average across pollutants of 2 percent for the final rule (Option B).

40 This steady state reflects unit retirements and repowerings. EPA accounted for unit retirements and repowerings by zeroing out the loadings starting in the year following the change in status.

41 Loading reductions associated with legacy wastewater limits will occur only as plants close and dewater their existing ponds. There is uncertainty on when plants may do so. For the purpose of this benefits analysis, EPA conservatively assumed that pond closures will occur after 2049 and therefore estimated no loading reductions during the period of analysis for Options B and C. To the extent that facilities close their ponds earlier, then the analysis understates the benefits of these two options.

Legacy wastewater discharges and loading reductions achieved by the legacy wastewater limits in the final rule would occur only as plants close and dewater their existing ponds. Given the uncertainty on when plants may do so, for the purpose of this analysis EPA estimated no loading reductions during the period of analysis. Similarly, certain plants could be required to treat unmanaged CRL discharged from landfills, surface impoundments, or other features to meet the limits in the final rule. These limits would apply only in cases where a permitting authority deems, on a case-by-case basis, that the discharge is functionally equivalent to a direct discharge and requires a permit. Because these discharges are uncertain, EPA did not include changes in pollutant loads from unmanaged CRL in the main analysis. Because the cost analysis detailed in the RIA (U.S. EPA, 2024e) and the social costs presented in Chapters 11 and 12 of this document includes these costs (based on the assumption that plants treat legacy wastewater discharges in 2049 and comply with the unmanaged CRL limits in the same year as limits for other wastestreams), the benefits of the final rule are understated when compared to the social costs.

Table 3-1: Annual Average Reductions in Total Pollutant Loading in Period 1 (2025-2029) and Period 2 (2030-2049) for Selected Pollutants in Steam Electric Power Plant Discharges, Compared to Baseline (lb/year)

Pollutant	Option A[a]					Option B (Final Rule)[a]					Option C[a]				
	BA[b]	CRL[c]	FGD	Legacy	Total[d]	BA[b]	CRL[c]	FGD	Legacy[e]	Total[d]	BA[b]	CRL[c]	FGD	Legacy[e]	Total[d]
Period 1 (2025-2029)															
Antimony	39	0	48	0	88	39	21	48	0	108	41	22	55	0	117
Arsenic	21	143	66	0	230	21	175	66	0	263	22	177	75	0	274
Barium	238	512	1,600	0	2,350	238	805	1,600	0	2,640	251	819	1,810	0	2,880
Beryllium	0	0	15	0	15	0	0	15	0	15	0	0	17	0	17
Boron	11,900	0	2,600,000	0	2,610,000	11,900	121,000	2,600,000	0	2,730,000	12,500	127,000	2,930,000	0	3,070,000
Bromide	2,430,000	11,400	0	0	2,440,000	2,430,000	11,400	0	0	2,440,000	2,670,000	12,000	0	0	2,690,000
Cadmium	2	22	48	0	71	2	45	48	0	94	2	46	54	0	101
Chromium	11	9,180	73	0	9,260	11	9,220	73	0	9,300	12	9,220	83	0	9,310
Copper	9	31	43	0	82	9	52	43	0	103	9	53	48	0	110
Cyanide	0	0	10,800	0	10,800	0	0	10,800	0	10,800	0	0	12,200	0	12,200
Lead	23	0	39	0	62	23	0	39	0	62	25	0	43	0	68
Manganese	342	672	143,000	0	144,000	342	15,600	143,000	0	159,000	361	16,400	161,000	0	178,000
Mercury	0	4	1	0	5	0	5	1	0	6	0	5	1	0	6
Nickel	39	198	72	0	309	39	247	72	0	358	41	250	81	0	372
TN	5,900	0	85,800	0	91,700	5,900	0	85,800	0	91,700	6,220	0	96,800	0	103,000
TP	496	0	3,690	0	4,190	496	0	3,690	0	4,190	523	0	4,160	0	4,680
Selenium	27	0	66	0	93	27	497	66	0	590	29	522	74	0	625
Thallium	3	2	112	0	117	3	9	112	0	123	3	9	126	0	138
TSS	29,900	137,000	99,300	0	267,000	29,900	185,000	99,300	0	314,000	31,500	187,000	112,000	0	330,000
Zinc	76	614	226	0	916	76	724	226	0	1,030	80	729	256	0	1,060
Period 2 (2030-2049)															
Antimony	56	1	59	0	116	56	47	59	0	161	56	50	61	0	167
Arsenic	30	314	81	0	425	30	385	81	0	496	30	390	83	0	503
Barium	343	1,120	1,950	0	3,410	343	1,770	1,950	0	4,060	345	1,810	2,010	0	4,170
Beryllium	0	0	19	0	19	0	0	19	0	19	0	0	19	0	19
Boron	17,100	0	3,170,000	0	3,180,000	17,100	269,000	3,170,000	0	3,450,000	17,200	286,000	3,260,000	0	3,570,000
Bromide	4,600,000	16,400	0	0	4,620,000	4,600,000	16,400	0	0	4,620,000	4,630,000	16,600	0	0	4,650,000
Cadmium	2	47	58	0	107	2	99	58	0	159	2	102	60	0	164
Chromium	16	20,100	89	0	20,200	16	20,200	89	0	20,300	17	20,200	92	0	20,300
Copper	13	67	52	0	132	13	114	52	0	178	13	117	54	0	183
Cyanide	0	0	13,100	0	13,100	0	0	13,100	0	13,100	0	0	13,500	0	13,500
Lead	34	0	47	0	80	34	0	47	0	80	34	0	48	0	82
Manganese	493	1,470	174,000	0	176,000	493	34,700	174,000	0	209,000	496	36,900	180,000	0	217,000
Mercury	0	10	1	0	11	0	11	1	0	12	0	11	1	0	12
Nickel	56	433	88	0	577	56	542	88	0	686	57	549	90	0	696
TN	8,490	0	104,000	0	113,000	8,490	0	104,000	0	113,000	8,550	0	108,000	0	116,000

Table 3-1: Annual Average Reductions in Total Pollutant Loading in Period 1 (2025-2029) and Period 2 (2030-2049) for Selected Pollutants in Steam Electric Power Plant Discharges, Compared to Baseline (lb/year)

Pollutant	Option A[a]					Option B (Final Rule)[a]					Option C[a]				
	BA[b]	CRL[c]	FGD	Legacy	Total[d]	BA[b]	CRL[c]	FGD	Legacy[e]	Total[d]	BA[b]	CRL[c]	FGD	Legacy[e]	Total[d]
TP	714	0	4,500	0	5,210	714	0	4,500	0	5,210	719	0	4,630	0	5,350
Selenium	40	0	80	0	119	40	1,060	80	0	1,180	40	1,140	82	0	1,260
Thallium	4	5	136	0	144	4	19	136	0	159	4	20	140	0	164
TSS	43,000	301,000	121,000	0	465,000	43,000	406,000	121,000	0	570,000	43,300	413,000	125,000	0	581,000
Zinc	109	1,340	276	0	1,730	109	1,590	276	0	1,970	110	1,600	284	0	2,000

TN = Nitrogen, total (as N); TP = Phosphorus, total (as P); TSS = Total suspended solids

a. All numbers presented with three significant figures.

b. EPA did not estimate changes in ammonia, beryllium, and cyanide loadings associated with BA transport water.

c. EPA did not estimate changes in ammonia, beryllium, bromide, cyanide, lead, nitrogen, and phosphorus associated with CRL. Additionally, the unmanaged CRL loadings presented in this table do not include unmanaged CRL discharged from landfills, surface impoundments, or other features which a permitting authority could deem, on a case-by-case basis, to be functionally equivalent to a direct discharge. These loadings are not included in the benefits analyses, but costs for treating the unmanaged CRL discharges are included in the social costs presented in Chapters 11 and 12.

d. FGD, BA, CRL and legacy wastewater loadings may not add up to the total due to independent rounding.

e. The loading reductions from legacy wastewater under Options B and C are estimated to occur only as plants close and dewater their ponds. For the purpose of this analysis, pond closures are estimated to occur after 2049 (*i.e.,* outside of the period of analysis) and therefore the loading reductions are zero across all pollutants for both options. Note that no legacy wastewater loading reductions are anticipated under Option A irrespective of the assumed pond closure year.

Source: U.S. EPA Analysis, 2024.

3.3 Water Quality Downstream from Steam Electric Power Plants

EPA used the estimated annual average changes in total pollutant loadings for Periods 1 and 2 to estimate concentrations downstream from each plant. Using the same approach as for the analysis of the 2020 rule and 2023 proposal, EPA applied two models to estimate downstream concentrations from each plant for each period:

- The D-FATE dilution model to estimate pollutant concentrations downstream from the plants. D-FATE (Downstream Fate And Transport Equations) calculates concentrations in each downstream medium-resolution NHD reach using annual average Enhanced Runoff Method (EROM) flows from NHDPlus v2 and mass conservation principles.

- USGS's SPAtially Referenced Regressions On Watershed attributes (SPARROW) to estimate flow-weighted nutrient (TN and TP) and suspended sediment concentrations. The SPARROW models provide baseline and regulatory option concentrations of TN, TP, and suspended solids concentration (SSC). EPA used the calibrated regional models published by the USGS (Ator, 2019; Hoos & Roland Ii, 2019; Robertson & Saad, 2019; Wise, 2019; Wise, Anning & Miller, 2019). These models define the stream network using the same medium-resolution NHD reaches used in D-FATE.

The models represent discharges to reaches represented in the NHD. As discussed in Section 3.1, EPA omitted wastestreams discharged by 11 steam electric power plants to the Great Lakes, estuaries or other waters that lack a valid flowpath.

In the D-FATE model, EPA used stream routing and flow attribute information from the medium-resolution NHDPlus v2 to track masses of pollutants from steam electric power plant discharges and other pollutant sources as they travel through the hydrographic network. For each point source discharger, the D-FATE model estimates pollutant concentrations for the receiving reach and all downstream reaches based on NHD mean annual flows. In-stream flows are kept constant (*i.e.*, discharges have no effect on flows). EPA notes that steam electric power plant discharges frequently constitute a return of flow withdrawn for plant use from the same surface water. In addition, FGD and BA wastewater discharges generally comprise a very small fraction of annual mean flows in the NHDPlus v2 dataset.[42]

Following the approach used in the analysis of the 2015 and 2020 rules and the 2023 proposal (U.S. EPA, 2015a, 2020b, 2023c) to estimate pollutant concentrations, EPA also included loadings from major dischargers (in addition to the steam electric power plants) that reported to the Toxics Release Inventory (TRI). EPA used loadings reported to the TRI in 2021.[43] TRI data were available for a subset of toxics: arsenic, barium, chromium, copper, lead, manganese, mercury, nickel, selenium, thallium, and zinc. EPA summed reach-specific concentrations from TRI dischargers and concentration estimates resulting from steam electric power plant loadings to represent water quality impacts from multiple sources. The pollutant concentrations calculated in the D-FATE model are used to derive fish tissue concentrations used to analyze human health effects from consuming self-caught fish (see Chapter 5), analyze nonmarket benefits of water

42 Steam electric power plant FGD discharge rates are typically approximately 1 million gallons per day (MGD), whereas the annual mean stream flows in receiving waters average approximately 15,000 MGD.

43 EPA had used 2019 TRI loadings for the analysis of the 2023 proposed rule. According to EPA TRI National Analysis, TRI releases to water reported in 2021 were approximately 2 percent lower, in the aggregate, than releases reported in 2019 (196.4 million pounds versus 200.9 million pounds) (U.S. Environmental Protection Agency. (2023r, March 15, 2023). *TRI National Analysis: Water Releases*. Retrieved November 28, 2023 from https://www.epa.gov/trinationalanalysis/water-releases).

quality improvements (see Chapter 6), and assess potential impacts to T&E species whose habitat ranges intersect with waters affected by steam electric plant discharges (see Chapter 7).

3.4 Overall Water Quality Changes

Following the approach used in the analysis of the 2015 and 2020 rules and 2023 proposal (U.S. EPA, 2015a; 2020b, 2023c), EPA used a WQI to link water quality changes from reduced toxics, nutrient and sediment discharges to effects on human uses and support for aquatic and terrestrial species habitat. The WQI translates water quality measurements, gathered for multiple parameters (*e.g.*, dissolved oxygen [DO], nutrients) that are indicative of various aspects of water quality, into a single numerical indicator. The WQI ranges from 10 to 100 with low values indicating poor quality and high values indicating good water quality.

As detailed in U.S. EPA (2015a), the WQI includes seven parameters: DO, BOD, fecal coliform (FC), TN, TP, suspended solids, and one aggregate subindex for toxics. The pollutants considered in the aggregate subindex for toxics are those that are discharged by modeled steam electric power plants or 2021 TRI dischargers and that have chronic aquatic life-based NRWQC. Pollutants that meet these qualifications include arsenic, cadmium, hexavalent chromium, copper, lead, mercury, nickel, selenium, and zinc. See the EA for details on NRWQC (U.S. EPA, 2024b). The subindex curve for toxics assigns the lowest WQI value of 0 to waters where exceedances are observed for the *nine* toxics analyzed, and a maximum WQI value of 100 to waters where there are no exceedances. Intermediate values are distributed between 100 and 0 in proportion to the number of exceedances.

3.4.1 WQI Data Sources

To calculate the WQI, EPA used modeled NRWQC exceedances for toxics (using concentrations from D-FATE) and modeled concentrations for TN, TP, and total suspended solids (TSS) from the respective SPARROW regional models. Following the approach used for the 2020 rule and 2023 proposal analyses, the USGS National Water Information System (NWIS) provided concentration data for three parameters that are held constant between the baseline and regulatory options: 1) fecal coliform, 2) dissolved oxygen, and 3) biochemical oxygen demand (see Section 3.4.1.2).[44, 45]

3.4.1.1 Exceedances of Water Quality Standards and Criteria

For each regulatory option, EPA identified reaches that do not meet NRWQC for aquatic life in Periods 1 and 2.[46] Table 3-2 summarizes the number of reaches with estimated exceedances of NRWQC in the baseline and

44 USGS's NWIS provides information on the occurrence, quantity, quality, distribution, and movement of surface and underground waters based on data collected at approximately 1.5 million sites in all 50 States, the District of Columbia, and U.S. territories. More information on NWIS can be found at http://waterdata.usgs.gov/nwis/.

45 The 2020 rule and 2023 proposal analysis used data ranging from 2007-2017. This dataset was updated for this analysis to include data ranging from 2007-2022.

46 Aquatic life criteria are the highest concentration of pollutants in water that are not expected to pose a significant risk to the majority of species in a given environment. For most pollutants, aquatic NRWQC are more stringent than human health NRWQC and thus provide a more conservative estimate of potential water quality impairment. Chronic criteria are derived using longer term (7-day to greater than 28-day) toxicity tests if available, or an acute-to-chronic ratio procedure where the acute criteria is derived using short term (48-hour to 96-hour) toxicity tests (U.S. Environmental Protection Agency. (2017a). *Chapter 3: Water Quality Criteria. Water Quality Standards Handbook*. (EPA 823-B-17-001). Retrieved from https://www.epa.gov/sites/production/files/2014-10/documents/handbook-chapter3.pdf). More information on aquatic NRWQC can be found at https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table and in the *EA* (U.S. Environmental Protection Agency. (2023g). *Environmental Assessment for Proposed Supplemental Revisions to the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category*.).

under the regulatory options. In Period 2, the final rule (Option B) is estimated to eliminate all exceedances of chronic criteria for 5 reaches (of 40 reaches with at least one exceedance), and eliminate all exceedances of acute criteria for all four reaches with baseline exceedances.

Table 3-2: Estimated Exceedances of National Recommended Water Quality Criteria under the Baseline and Regulatory Options

Regulatory Option	Number of Reaches with at Least One NRWQC Exceedance	
	Chronic	Acute
Period 1 (2025-2029)		
Baseline	42	4
Option A	42	2
Option B (Final Rule)	40	2
Option C	40	2
Period 2 (2030-2049)		
Baseline	40	4
Option A	40	2
Option B (Final Rule)	35	0
Option C	35	0

Source: U.S. EPA Analysis, 2024

Refer to the EA for additional discussion of comparisons of receiving and downstream water pollutant concentrations to acute and chronic aquatic NRWQC (U.S. EPA, 2024b).

3.4.1.2 Sources for Ambient Water Quality Data

Following the approach used for the analysis of the 2020 rule and 2023 proposal, EPA used average monitoring values for fecal coliform, dissolved oxygen, and biochemical oxygen demand for 2007-2022 where available. EPA used a successive average approach to assign average values for the three WQI parameters not explicitly modeled (*i.e.*, DO, BOD, fecal coliform). The approach, which adapts a common sequential averaging imputation technique, involves assigning the average of ambient concentrations for a given parameter within a hydrologic unit to reaches within the same hydrologic unit with missing data, and progressively expanding the geographical scope of the hydrologic unit (Hydrologic unit code (HUC8, HUC6, HUC4, and HUC2) to fill in all missing data.[47] This approach is based on the assumption that reaches located in the same watershed generally share similar characteristics. Using this estimation approach, EPA compiled ambient water quality data and/or estimates for all analyzed NHD reaches. As discussed below, the values of the three WQI parameters not explicitly modeled are kept constant for the baseline and regulatory policy scenarios. This approach has not been peer reviewed, but it has been used by EPA for several prior rules and reviewed by the public during the associated comment periods.

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[47] Hydrologic Unit Codes (HUCs) are cataloguing numbers that uniquely identify hydrologic features such as surface drainage basins. The HUCs consist of 8 to 14 digits, with each set of 2 digits giving more specific information about the hydrologic feature. The first pair of values designate the region (of which there are 22), the next pair the subregion (approximately 245), the third pair the basin or accounting unit (approximately 405), and the fourth pair the subbasin, or cataloguing unit (approximately 2,400) (U.S. Geological Survey. (2007). *National Hydrography Dataset (NHD)*. Retrieved from http://nhd.usgs.gov/data.html, U.S. Geological Survey. (2022). *Federal Standards and Procedures for the National Watershed Boundary Dataset (WBD)*. Retrieved from https://pubs.usgs.gov/tm/11/a3/pdf/tm11-a3_5ed.pdf). Digits after the first eight offer more detailed information at the watershed and subwatershed levels. In this discussion, a HUC level refers to a set of waters that have that number of HUC digits in common. For example, the HUC6 level includes all reaches for which the first six digits of their HUC are the same.

The water quality analysis included a total of 11,607 medium-resolution NHD reaches that are potentially affected by steam electric power plants under the baseline. Of these 11,607 NHD reaches, EPA estimated concentrations for 11,080 reaches from steam electric power plants. Table 3-3 summarizes the data sources used to estimate baseline and regulatory option values by water quality parameter.

Table 3-3: Water Quality Data used in Calculating WQI for the Baseline and Regulatory Options

Parameter	Baseline	Regulatory Option
TN	Concentrations calculated using SPARROW (baseline run)	Concentrations calculated using SPARROW (regulatory option run)
TP	Concentrations calculated using SPARROW (baseline run)	Concentrations calculated using SPARROW (regulatory option run)
TSS	Concentrations calculated using SPARROW (baseline run)	Concentrations calculated using SPARROW (regulatory option run)
DO	Observed values averaged at the WBD watershed level	No change. Regulatory option value set equal to baseline value
BOD	Observed values averaged at the WBD watershed level	No change. Regulatory option value set equal to baseline value
Fecal Coliform	Observed values averaged at the WBD watershed level	No change. Regulatory option value set equal to baseline value
Toxics	Baseline exceedances calculated using D-FATE model	Regulatory option exceedances calculated using D-FATE model

WBD = Watershed Boundary Dataset. The WBD is a companion dataset to the NHD

Source: U.S. EPA Analysis, 2022.

3.4.2 WQI Calculation

EPA used the approach described in the BCA for the 2015 and 2020 rules and 2023 proposal (U.S. EPA, 2015a, 2020b, 2023c) to estimate WQI values for each reach under the baseline and each option. EPA used updated subindex curves for TN, TP, and TSS previously used for the 2023 proposed revisions to the ELGs for the Meat and Poultry Products Point Source Category (U.S. EPA, 2023d) and reflect data from the 2013-2014 and 2018-2019 National Rivers and Streams Assessments (NRSA) (U.S. EPA, 2020e, 2023j).[48]

Implementing the WQI methodology involves three key steps: 1) obtaining water quality levels for each of seven parameters included in the WQI; 2) transforming parameter levels to subindex values expressed on a common scale; and 3) aggregating the individual parameter subindices to obtain an overall WQI value that reflects waterbody conditions across the seven parameters. These steps are repeated for each reach to calculate the WQI value for the baseline, and for each analyzed regulatory option. See details of the calculations in Appendix C, including the subindex curves used to transform levels of individual parameters. The scope of this analysis is the same as that for the analysis of nonmarket benefits of water quality

48 The NRSA is a component of EPA's National Aquatic Resources Survey (NARS). The NRSA provides information on the conditions of the nation's rivers and streams and is conducted at regular intervals (2008-2009, 2013-2014, and 2018-2019) using a consistent approach. This enables comparison of stream conditions over time. The NRSA has several interesting features to support the development of a water quality index: it is based on a statistical representation of rivers and streams, it provides data for key indicators of biological, chemical and physical conditions, and includes both measured data and a categorical assessment of the conditions (poor, fair, good) for selected indicators. In particular, the 2013-2014 and 2018-2019 surveys provide categorical assessments of chemical conditions related to TN and TP.

improvements discussed in Chapter 6, which focuses on reaches within 300 km of a steam electric plant outfall.[49]

3.4.3 Baseline WQI

The WQI value can be related to suitability for potential uses. Vaughan (1986) developed a water quality ladder (WQL) that can be used to indicate whether water quality is suitable for various human uses (*i.e.*, boating, rough fishing, game fishing, swimming, and drinking without treatment). Vaughan identified "minimally acceptable parameter concentration levels" for each of the five potential uses. Vaughan used a scale with a top value of 10 instead of the WQI scale with a top value of 100 to classify water quality based on its suitability for potential uses. Therefore, the WQI value corresponding to a given water quality use classification equals the WQL value multiplied by 10.

Based on the estimated WQI value under the baseline scenario (WQI-BL), EPA categorized each of the 11,080 NHD reaches using five WQI ranges (WQI < 25, 25≤WQI<45, 45≤WQI<50, 50≤WQI<70, and 70≤WQI) (Table 3-4). WQI values of less than 25 indicate that water is not suitable for boating (the recreational use with the lowest associated WQI on the WQL), whereas WQI values greater than 70 indicate that waters are swimmable (the recreational use with the highest associated WQI on the WQL).[50]

Table 3-4: Estimated Percentage of Potentially Affected Reach Miles by WQI Classification: Baseline Scenario

Water Quality Classification	Baseline WQ	Number of Reaches	Percent of Affected Reaches	Number of Reach Miles	Percent of Affected Reach Miles
Period 1 (2025-2029)					
Unusable	WQI<25	4	0.0%	10	0.1%
Suitable for Boating	25≤WQI<45	199	1.8%	352	3.0%
Suitable for Rough Fishing	45≤WQI<50	212	1.9%	214	1.8%
Suitable for Game Fishing	50≤WQI<70	4,231	38.2%	4,304	37.1%
Suitable for Swimming	70≤WQI	6,434	58.1%	6,734	58.0%
Total		**11,080**	**100.0%**	**11,613**	**100.0%**
Period 2 (2030-2049)					
Unusable	WQI<25	4	0.0%	10	0.1%
Suitable for Boating	25≤WQI<45	197	1.8%	349	3.0%
Suitable for Rough Fishing	45≤WQI<50	209	1.9%	211	1.8%
Suitable for Game Fishing	50≤WQI<70	4,236	38.2%	4,309	37.1%
Suitable for Swimming	70≤WQI	6,434	58.1%	6,734	58.0%
Total		**11,080**	**100.0%**	**11,613**	**100.0%**

Source: U.S. EPA Analysis, 2024

3.4.4 Estimated Changes in Water Quality (ΔWQI) from the Regulatory Options

To estimate the benefits of water quality improvements resulting from the regulatory options, EPA calculated the change in WQI for each analyzed regulatory option as compared to the baseline. This analysis was done

49 There are an estimated 16,832 NHD reaches on the downstream flow path of steam electric plant outfalls, of which 11,607 NHD reaches are within 300 km of any outfall. A subset of these reaches lack valid annual average flow data to estimate pollutant concentrations, leaving a total of 11,080 NHD reaches with the data needed to estimate WQI values.

50 EPA did not separately categorize waters where the WQI was greater than or equal to 90 (drinkable water) because surface waters are generally treated before distribution for potable use. Pollutant specific impacts on drinking water are addressed separately in Chapter 4.

for each reach and for each of the two periods. As discussed in Section 1.1, EPA estimated changes in ambient concentrations of TN, TP and TSS using the USGS's SPARROW models and toxics concentrations using the D-FATE model. Although the regulatory options would also indirectly affect levels of other WQI parameters, such as BOD and DO, these other parameters were held constant in this analysis for all regulatory options, due to methodological and data limitations.

The difference in the WQI between baseline conditions and a given regulatory option (hereafter denoted as ΔWQI) is a measure of the change in water quality attributable to the regulatory option. Table 3-5 presents water quality change ranges for the analyzed regulatory options under each analysis period.

Table 3-5: Ranges of Estimated Water Quality Changes for Regulatory Options, Compared to Baseline

Regulatory Option	Minimum ΔWQI	Maximum ΔWQI	25th Percentile ΔWQI	Median ΔWQI	75th Percentile ΔWQI	ΔWQI Interquartile Range
Period 1 (2025-2029)						
Option A	0	1.70	0	7.90×10^{-6}	3.39×10^{-4}	3.39×10^{-4}
Option B (Final Rule)	0	1.70	0	7.91×10^{-6}	3.39×10^{-4}	3.39×10^{-4}
Option C	0	1.70	0	7.91×10^{-6}	4.69×10^{-4}	4.69×10^{-4}
Period 2 (2030-2049)						
Option A	0	10.17	0	1.83×10^{-5}	4.02×10^{-4}	4.02×10^{-4}
Option B (Final Rule)	0	10.17	0	1.89×10^{-5}	4.54×10^{-4}	4.54×10^{-4}
Option C	0	10.17	0	2.67×10^{-5}	4.97×10^{-4}	4.97×10^{-4}

Source: U.S. EPA Analysis, 2024

3.5 Limitations and Uncertainty

The methodologies and data used in the estimation of the environmental effects of the regulatory options involve limitations and uncertainties. Table 3-6 summarizes the limitations and uncertainties and indicates the direction of the potential bias. Uncertainties associated with some of the input data are covered in greater detail in other documents. Regarding the uncertainties associated with use of the NHDPlus attribute data, see the NHDPlus v2 documentation (U.S. EPA, 2019g). Regarding the uncertainties associated with estimated loads, see the TDD (U.S. EPA, 2024f).

Table 3-6: Limitations and Uncertainties in Estimating Water Quality Effects of Regulatory Options

Uncertainty/Limitation	Effect on Water Quality Effects Estimation	Notes
Limited data are available to validate water quality concentrations estimated in D-FATE	Uncertain	The modeled concentrations reflect only a subset of pollutant sources (*e.g.*, steam electric power plant discharges and TRI releases) whereas monitoring data also reflect other sources such as bottom sediments, air deposition, and other point and non-point sources of pollution. TRI releases are also reported by the facilities and could potentially suffer from misreporting or faulty estimation techniques. EPA comparisons of D-FATE estimates to monitoring data available for selected locations and parameters (*e.g.*, bromide concentrations downstream of steam electric power plant discharges) confirmed that D-FATE provides reasonable values. Also refer to the 2015 EA for discussion of model validation for selected case studies (U.S. EPA, 2015b)
Steam electric power plant discharges have no effects on reach annual average or seasonal flows	Overestimate	The degree of overestimation in the estimation of pollutant concentrations, if any, would be small given that steam electric power plant discharge flows tend to be very small as compared to flows in modeled receiving and downstream reaches. Further, EPA acknowledges that the effect of steam electric power plant discharges on reach flows may vary seasonally due to low- and high-flow periods.
Ambient water toxics concentrations are based only on loadings from steam electric power plants and other TRI discharges.	Uncertain	Concentration estimates do not account for background concentrations of these pollutants from other sources, such as legacy pollution in sediments, non-point sources, point sources that are not required to report to TRI, air deposition, etc. Not including other contributors to background toxics concentrations in the analysis is likely to result in understatement of baseline concentrations of these pollutants and therefore of NRWQC exceedances. The effect on WQI calculations is uncertain.
Annual loadings are estimated based on EPA's estimated plant-specific technology implementation years	Uncertain	To the extent that technologies are implemented earlier or later, the Period 1 annualized loading values presented in this section may under- or overstate the annual loads during the analysis period. The effect of this uncertainty is limited to Period 1 since loads reach a steady-state level by the technology implementation deadlines applicable to the regulatory options (*e.g.*, by the end of 2029)

Table 3-6: Limitations and Uncertainties in Estimating Water Quality Effects of Regulatory Options

Uncertainty/Limitation	Effect on Water Quality Effects Estimation	Notes
Changes in WQI reflect only reductions in toxics, nutrient, and sediment concentrations.	Underestimate	The estimated changes in WQI reflect only water quality changes resulting directly from changes in toxics, nutrient and sediment concentrations. They do not include changes in other water quality parameters (*e.g.*, BOD, dissolved oxygen) that are part of the WQI and for which EPA used constant values. Because the omitted water quality parameters are also likely to respond to changes in pollutant loads (*e.g.*, dissolved oxygen levels respond to changes in nutrient levels), the analysis underestimates the water quality changes.
EPA used regional averages of monitoring data from 2007-2022 for fecal coliform, dissolved oxygen, and biochemical oxygen demand, when location-specific data were not available.	Uncertain	The monitoring values were averaged over progressively larger hydrologic units to fill in any missing data. As a result, WQI values may not reflect certain constituent fluctuations resulting from the various regulatory options and/or may be limited in their temporal and spatial relevance. Note that the analysis keeps these parameters constant under both the baseline and regulatory options. Modeled changes due to the regulatory options are not affected by this uncertainty.
Use of nonlinear subindex curves	Uncertain	The methodology used to translate sediment and nutrient concentrations into subindex scores (see Section 3.4.2 and Appendix C) employs nonlinear transformation curves. Water quality changes that fall outside of the sensitive part of the transformation curve (*i.e.*, above/below the upper/lower bounds, respectively) yield no change in the analysis and no benefits in the analysis described in Chapter 6.

4 Human Health Benefits from Changes in Pollutant Exposure via the Drinking Water Pathway

EPA expects that the changes in pollutant loadings from the regulatory options relative to the 2020 rule could affect several aspects of human health by changing bromide and other pollutant discharges to surface waters and, as a result, pollutant concentrations in the reaches that serve as sources of drinking water. The EA provides details on the health effects of steam electric pollutants (U.S. EPA, 2024b).

As described in Section 2.1, human health benefits deriving from changes in pollutant loadings to receiving waters include those associated with changes in exposure to pollutants via treated drinking water use and fish consumption. This chapter addresses the first exposure pathway: drinking water. Chapter 5 addresses the fish consumption pathway.

The changes in pollutant loadings from the regulatory options relative to the 2020 rule could affect human health by changing halogen and other pollutant discharges to surface waters and, as a result, pollutant concentrations in the reaches that serve as sources of drinking water. The EA presents background information regarding the potential impacts of halogen discharges on drinking water quality and human health (U.S. EPA, 2024b). Section 4.1 provides background information on trihalomethane precursor development. Sections 4.2 through 4.4 present EPA's analysis of human health effects from changes in bromide discharges. Section 4.5 summarizes potential impacts on source waters from changes in other pollutant discharges. Section 4.6 discusses uncertainty and limitations associated with the analysis presented in this chapter.

4.1 Background

FGD wastewater and BA transport water discharges contain variable quantities of bromide due to the natural presence of bromide in coal feedstock and from additions of halogens, including bromide-containing salts, and use of brominated activated carbon products to enhance air emissions control (Kolker et al., 2012). Wastewater treatment technologies employed at steam electric power plants vary widely in their ability to remove bromide. A number of studies have documented elevated bromide levels in surface water due to steam electric power plant discharges (*e.g.*, Cornwell et al., 2018; Good & VanBriesen, 2016, 2017; McTigue et al., 2014; Ruhl et al., 2012; States et al., 2013; U.S. EPA, 2017c; 2019c) and have attributed measured increases in bromide levels to the increasing number of installed wet FGD devices at steam electric power plants. FGD wastewaters have been shown to contain relatively high levels of bromide relative to other industrial wastewaters. Modeling studies have sought to quantify the potential for drinking water sources to be affected by FGD wastewater discharges (Good & VanBriesen, 2019).

Bromide does not undergo significant physical (*e.g.*, sorption, volatilization), chemical or biological transformation in freshwater environments and is commonly used as a tracer in solute transport and mixing field studies. Surface waters transport bromide discharges to downstream drinking water treatment facility intakes where they are drawn into the treatment systems.

Although the bromide ion has a low degree of toxicity (World Health Organization, 2009), it can contribute to the formation of brominated DBPs during drinking water disinfection processes, including chlorination, chloramination, and ozonation. Bromate, a regulated DBP under the Safe Drinking Water Act (SDWA), forms when bromine reacts directly with ozone. Chlorine reacts with bromide to produce hypobromite (BrO^-), which reacts with organic matter to form brominated and mixed chloro-bromo DBPs, including three of the four regulated trihalomethanes[51] (THM4, also referred to as total trihalomethanes (TTHM) in this discussion) and two of the five regulated haloacetic acids[52] (HAA5). Additional unregulated brominated DBPs have been cited as an emerging class of water supply contaminants that can potentially pose health risks to humans (Richardson et al., 2007; NTP, 2018; U.S. EPA, 2016c).

There is a substantial body of literature on trihalomethane precursor occurrence, trihalomethane formation mechanisms in drinking water treatment plants, and relationships between source water bromide levels and TTHM levels in treated drinking water. The formation of TTHM in a particular drinking water treatment plant is a function of several factors including chlorine, bromide, organic material, temperature, and pH levels as well as system residence times. There is also substantial evidence linking TTHM exposure to bladder cancer incidence (U.S. EPA, 2016c). Bromodichloromethane and bromoform are likely to be carcinogenic to humans by all exposure routes and there is evidence suggestive of dibromochloromethane's carcinogenicity (NTP, 2018; U.S. EPA, 2016c). The relationships between exposure to DBPs, specifically TTHMs and other halogenated compounds resulting from water chlorination, and bladder cancer are further discussed in Section 4.3.3.2 and U.S. EPA (2019b).

4.2 Overview of the Analysis

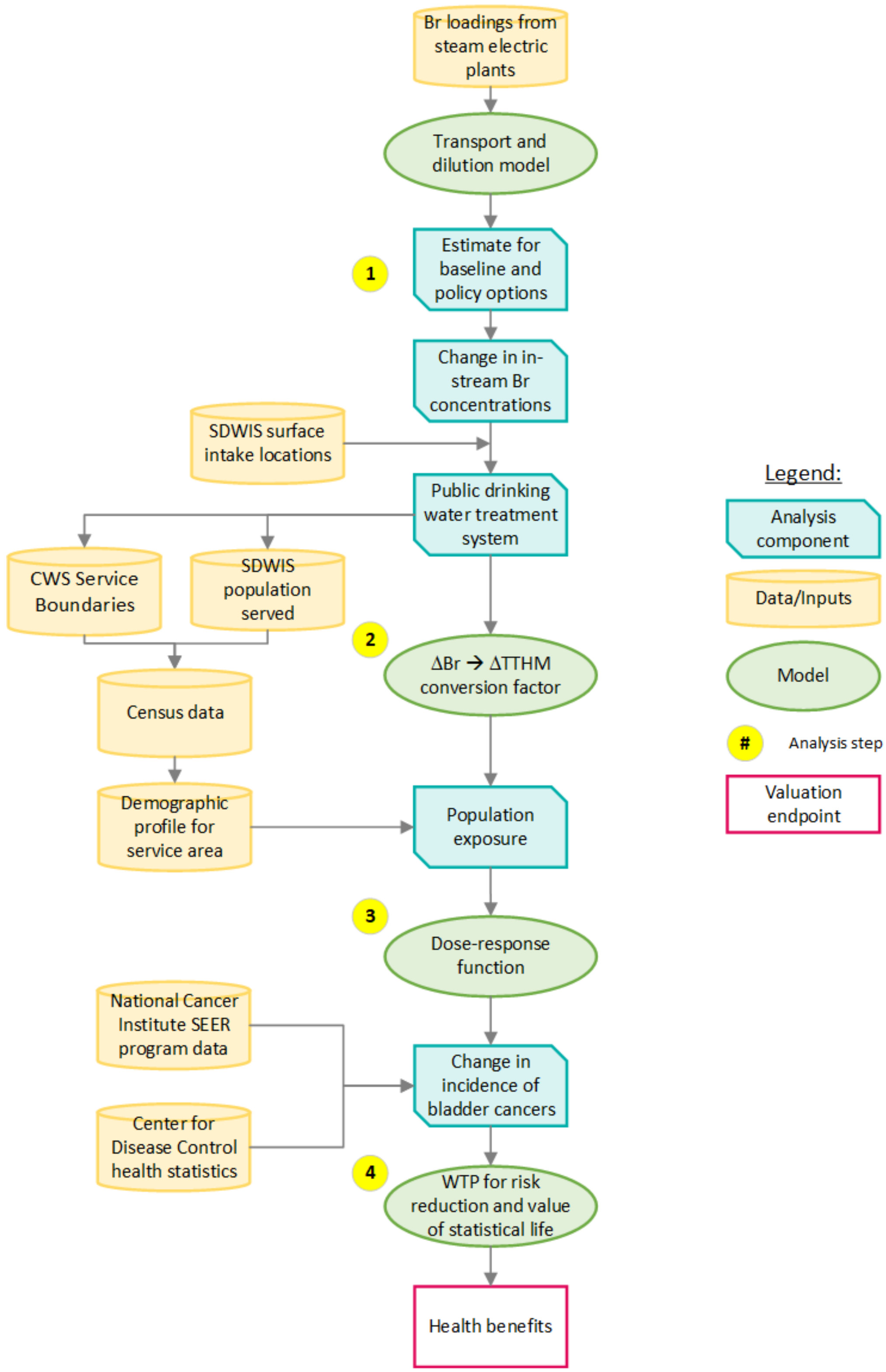
Figure 4-1 illustrates EPA's approach for quantifying and valuing the human health effects of altering bromide discharges from steam electric power plants. The analysis entails estimating in-stream changes in bromide levels between conditions under the baseline and each of the three regulatory options (Step 1); estimating the change in source water bromide levels and corresponding changes in TTHM concentrations in treated water supplies (Step 2); relating these estimated changes to changes in exposure and the subsequent changes in the incidence of bladder cancers[53] in the exposed population (Step 3); and estimating the associated monetary value of benefits (Step 4). This approach was implemented in EPA's 2019 proposed rule and the 2023 proposal (U.S. EPA, 2019b, 2023c) and relies on findings from a peer-reviewed paper by Regli et al. (2015) that built on the approach taken in the Stage 2 Disinfectants and Disinfection Byproduct Rule (DBPR) (U.S. EPA, 2005c) to derive a slope factor to relate changes in lifetime bladder cancer risk to changes in TTHM exposure. This analysis also incorporates National Cancer Institute's Surveillance, Epidemiology, and End Results (SEER) program data to model incidence of bladder cancers by age and sex, cancer stage, changes in lifetime cancer risk attributable to the regulatory options, and survival outcomes. The life-table modeling approach used by EPA to estimate changes in health outcomes is a widely used method in public health, insurance, medical research, and other studies and was used for analysis of lead-associated health effects in the 2015 rule. The main advantage of this approach is that it allows for explicitly accounting for age and cancer stage-specific patterns in cancer outcomes, as well as for other causes of mortality in the affected population.

[51] The four regulated trihalomethanes are bromodichloromethane, bromoform, chloroform, and dibromochloromethane.

[52] The five regulated haloacetic acids are dibromoacetic acid, dichloroacetic acid, monobromoacetic acid, monochloroacetic acid, and trichloroacetic acid.

[53] Regli, S., Chen, J., Messner, M., Elovitz, M. S., Letkiewicz, F. J., Pegram, R. A., Pepping, T. J., . . . Wright, J. M. (2015). Estimating potential increased bladder cancer risk due to increased bromide concentrations in sources of disinfected drinking waters. *Environmental Science & Technology*, *49*(22), 13094-13102. estimated the additional lifetime risk from a 1 µg/L increase in TTHM. This relationship holds over the TTHM range expected for systems in compliance with the Stage 2 Disinfectants and Disinfection Byproduct Rule.

Figure 4-1: Overview of Analysis of Estimated Human Health Benefits of Reducing Bromide Discharges.



Source: U.S. EPA Analysis, 2024.

4.3 Estimates of Changes in Halogen Concentrations in Source Water

EPA estimated the change in halogen levels in the source water for PWS that have intakes downstream from steam electric power plants. Halogens such as bromide are precursors for halogenated disinfection byproduct formation in treated drinking water, including certain trihalomethanes addressed by the TTHM MCL. Higher halogen levels in PWS source waters have been associated with higher levels of halogenated DBPs in treated drinking water. The formation of DBPs varies with site-specific factors. *In vitro* toxicology studies with bacteria and mammalian cells have documented evidence of genotoxic (including mutagenic), cytotoxic, tumorigenic, and developmental toxicity properties of iodinated DBPs, but the available data are insufficient at this time to determine the extent of iodinated DBP's contribution to adverse human health effects from exposure to treated drinking water (Richardson et al., 2007; U.S. EPA, 2016c; National Toxicology Program, 2018). Populations exposed to changes in halogenated disinfection byproduct levels in their drinking water under the regulatory options could experience changes in the incidence of adverse health effects, and in turn the total counts of these health effects.

In this section, the Agency presents the number of PWS with modeled changes in bromide concentration in their source water, the magnitude and direction of these changes, and the PWS service population estimated to experience a change in DBP exposure levels due to changes in source water bromide levels.

4.3.1 Step 1: Modeling Bromide Concentrations in Surface Water

EPA estimated steam electric power plant-level bromide loadings associated with FGD wastewater and BA transport water for the baseline and the regulatory options.[54] This chapter presents EPA's best estimate of changes in bromide loadings under each of the regulatory options.

EPA used the D-FATE model described in Section 3.3 to estimate in-stream bromide concentrations downstream from 38 steam electric power plants that EPA estimated have non-zero bromide loads (*i.e.*, discharge FGD wastewater and/or BA transport water) under the baseline or regulatory options. EPA first estimated the annual average bromide loads in Period 1 and Period 2 (see Section 3.2.1). EPA then estimated concentrations in the receiving reach and each downstream reach in Period 1 and Period 2, using conservation of mass principles, until the load reaches the hydrographic network terminus (*e.g.*, Great Lake, estuary).[55] EPA summed individual contributions from all plants to estimate total in-stream concentrations under the baseline and the regulatory options in Period 1 and Period 2. Finally, EPA estimated the change in bromide concentrations in each reach as the difference between each regulatory option and the baseline. The modeled change is not dependent on bromide contributions from other sources (*e.g.*, waterbody background levels).

As summarized in Table 4-1, regulatory options A and B are estimated to result in the same bromide loading reductions, whereas bromide loading reductions are slightly higher under Option C. The reductions are higher in Period 2 than in Period 1 under all regulatory options.

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[54] EPA did not estimate bromide loadings associated with CRL discharges.

[55] As discussed in Section 3.1, EPA did not estimate concentration changes in the Great Lakes or estuaries.

Table 4-1: Estimated Bromide Loading Reductions by Analysis Period and Regulatory Option

Regulatory Option	Number of Steam Electric Plants with non-Zero Changes	Total Bromide Load Reduction (lbs/year)
Period 1 (2025-2029)		
Option A	32	2,444,904
Option B (Final Rule)	32	2,444,904
Option C	32	2,686,485
Period 2 (2030-2049)		
Option A	37	4,615,175
Option B (Final Rule)	37	4,615,175
Option C	38	4,647,249

Source: U.S. EPA Analysis, 2024

4.3.2 Step 2: Modeling Changes in Trihalomethanes in Treated Water Supplies

4.3.2.1 Affected Public Water Systems

For the final rule, EPA updated the universe of PWS potentially affected by steam electric plant discharges to reflect adjustments to the universe of plants projected to be subject to the rule and their associated receiving and downstream reaches. EPA also collected more recent information about the operating characteristics of the water systems (*e.g.*, population served, facility status, wholesale water purchases). EPA used Safe Drinking Water Information System (SDWIS) fourth quarter data for 2022.

EPA's SDWIS database[56] provides the latitude and longitude of surface water facilities[57], including source water intakes for public drinking water treatment systems. To identify potentially affected PWS, the Agency georeferenced each permanent surface water facility associated with non-transient community water systems to the NHD medium-resolution stream network used in D-FATE.[58] Appendix F describes the methodology EPA used to identify the NHD water feature for each facility. The SDWIS database also includes information on PWS primary sources (*e.g.*, whether a PWS relies primarily on groundwater or surface water for their source water), operational status, and population served, among other attributes. For this analysis, EPA used the subset of facilities that identify surface water as their primary water source (specifically surface water intakes and reservoirs) and are categorized as "active" and "permanent" in SDWIS. This subset of facilities corresponds to PWS that are more likely to be affected by upstream bromide releases on an ongoing basis, as compared to other systems that may use surface water sources only sporadically. This approach identifies populations most likely to experience changes in long-term halogenated DBP exposures and associated health effects due to the regulatory options.

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56 EPA used intake locations and PWS data from the fourth quarter report for 2022. Intake location data are protected from disclosure due to security concerns. SDWIS public data records are available from the Federal Reporting Services system at https://ofmpub.epa.gov/apex/sfdw/.

57 Surface water facilities include any part of a PWS that aids in obtaining, treating, and distributing drinking water. Facilities in the SDWIS database may include groundwater wells, consecutive connections between buyer and seller PWS, pump stations, reservoirs, and intakes, among others.

58 This analysis does not include intakes that draw from the Great Lakes or other water bodies not analyzed in the D-FATE model.

PWS can be either directly or indirectly affected by steam electric power plant discharges. Directly affected PWS are systems with surface water intakes drawing directly from reaches downstream from steam electric power plants discharging bromide.[59] Other PWS are indirectly affected because they purchase their source water from another PWS via a "consecutive connection" instead of withdrawing directly from a surface water or groundwater source. For these systems, SDWIS provides information on the PWS that supplies the purchased water. EPA used SDWIS data to identify PWS that may be indirectly affected by steam electric power plant discharges because they purchase water from a directly affected PWS. The total potentially exposed population consists of the people served by either directly or indirectly affected systems.

Table 4-2 summarizes the number of intakes, PWS, and total populations potentially affected by steam electric power plant discharges via the drinking water pathway, and the subset of those intakes and PWS affected by bromide discharges. In this analysis, the average distance from the steam electric power plant discharge point to the drinking water treatment plant intake is 71 miles and approximately 19 percent of the intakes are located within 30 miles of a steam electric power plant outfall. A subset of these PWS is downstream of FGD wastewater and BA transport water discharges containing bromide,[60] specifically 118 affected reaches have intakes used by 151 PWS serving a total of 15.7 million people, directly or indirectly.

Table 4-2: Estimated Reaches, Surface Water Intakes, Public Water Systems, and Populations Potentially Affected by Steam Electric Power Plant Discharges

PWS Impact Category	Number of Reaches with Drinking Water Intakes	Number of Intakes Downstream of Steam Electric Power Plants	Number of PWS	Total Population Served (Million People)
Reaches downstream from steam electric plant discharges				
Direct[a]	223	283	234	18.4
Indirect	Not applicable	Not applicable	682	10.8
Total	**223**	**283**	**916**	**29.2**
Reaches downstream from steam electric plant with non-zero bromide loads				
Direct[b]	118	151	131	11.5
Indirect	Not applicable	Not applicable	366	4.1
Total	**118**	**151**	**497**	**15.7**

a. Includes 16 systems with both intakes downstream of steam electric power plant discharges and that purchase water from other systems with intakes downstream of steam electric power plant discharges.

b. Includes 7 systems with both intakes downstream of steam electric power plant discharges and that purchase water from other systems with intakes downstream of steam electric power plant discharges.

Source: U.S. EPA Analysis, 2024

4.3.2.2 System-Level Changes in Bromide Concentrations in Source Water

EPA estimated the change in bromide concentrations in the source water for each PWS that could result from the regulatory options. In this discussion, the term "system" refers to PWS and their associated drinking water

59 To identify potentially affected PWS, EPA looked at all downstream reaches starting from the immediate reach receiving the steam electric power plant discharge to the reach identified as the terminus of the stream network.

60 Note that when plants retire, bromide may still be present in CRL. The present analysis considers bromide discharges from FGD wastewater and BA transport water only.

treatment operations, whereas the term "facility" refers to the intake that is drawing untreated water from a source reach for treatment at the PWS level.

To estimate changes in bromide concentrations at the PWS level, EPA obtained the number of active permanent surface water sources used by each PWS based on SDWIS data. SDWIS does not provide information on respective source flow contributions from surface water and groundwater facilities for a given PWS. For drinking water treatment systems that have both surface water and groundwater facilities, EPA assessed changes from surface water sources only. This approach is reasonable given that the analysis is limited to the PWS for which SDWIS identifies surface water as primary source.

For intakes located on reaches modeled in D-FATE, EPA calculated the reach-level change in bromide concentration as the difference between the regulatory option and the baseline conditions. Some PWS rely on a single intake facility for their source water supply. If the source water reach associated with this single intake is affected by steam electric power plant bromide discharges, the system-level changes in bromide concentration at the PWS would equal the estimated change in bromide concentration of the source water reach. Other PWS rely on multiple intake facilities that may be located along different source water reaches. System-level changes in bromide concentrations at these PWS are an average of the estimated changes in bromide concentrations associated with each source water reach. For any additional intakes not located on the modeled reaches and for intakes relying on groundwater sources, EPA estimated zero change in bromide concentration. Because SDWIS does not provide information on source flows contributed by intake facilities used by a given PWS, EPA calculated the system-level change in bromide concentration assuming each active permanent source facility contributes equally to the total volume of water treated by the PWS. For example, the PWS-level change in bromide concentration for a PWS with three intakes, of which one intake is directly affected by steam electric power plant discharges, is estimated as one third of the modeled reach concentration change ($[\Delta Br + 0 + 0]/3$).

EPA addressed water purchases similarly, but with the change in bromide concentration associated with the consecutive connection set equal to the PWS-level change estimated for the seller PWS instead of a reach-level change. For facilities affected only indirectly by steam electric power plant discharges, EPA assumed zero change in bromide concentrations for any other unaffected source facility associated with the buyer. EPA also assumed that each permanent source facility contributes an equal share of the total volume of water distributed by the buyer. For the seven PWS classified as both directly and indirectly affected by steam electric power plant bromide discharges, EPA assessed the total change in bromide concentration as the average of the change in concentration from both directly-drawn and purchased water.

Table 4-3 summarizes the distribution of changes in bromide concentrations under the regulatory options for the two analysis periods. The changes depends on the Period, option, source water reach, and PWS but are generally consistent with the changes in bromide loadings associated with FGD and bottom ash transport wastewaters under each regulatory option (see Table 3-1). During Periods 1 and 2, all options show either reductions or no changes in bromide concentrations for all source waters and PWS. For all options, the magnitude and scope (the number of reaches, PWS, and population served) of the bromide reductions are larger during Period 2 than during Period 1.

Table 4-3: Estimated Distribution of Changes in Source Water and PWS-Level Bromide Concentrations by Period and Regulatory Option, Compared to Baseline

ΔBr Range (µg/L)	Number of Source Water Reaches		Number of PWS[a]		Population Served by PWS	
	Reduction ΔBr	No ΔBr (ΔBr = 0)	Reduction ΔBr	No ΔBr (ΔBr = 0)	Reduction ΔBr	No ΔBr (ΔBr = 0)
Period 1 (2025-2029)						
Option A						
0 to 10	109	13	451	65	13,539,103	3,380,007
10 to 30	1	0	2	0	2,521	0
50 to 75	1	0	3	0	123,386	0
Option B (Final Rule)						
0 to 10	109	13	451	65	13,539,103	3,380,007
10 to 30	1	0	2	0	2,521	0
50 to 75	1	0	3	0	123,386	0
Option C						
0 to 10	109	13	451	65	13,539,103	3,380,007
10 to 30	1	0	2	0	2,521	0
50 to 75	1	0	3	0	123,386	0
Period 2 (2030-2049)						
Option A						
0 to 10	117	1	473	36	15,095,692	1,669,547
10 to 30	5	0	9	0	156,392	0
>75	1	0	3	0	123,386	0
Option B (Final Rule)						
0 to 10	117	1	473	36	15,095,692	1,669,547
10 to 30	5	0	9	0	156,392	0
>75	1	0	3	0	123,386	0
Option C						
0 to 10	118	0	485	24	15,598,789	1,166,450
10 to 30	5	0	9	0	156,392	0
>75	1	0	3	0	123,386	0

a. Includes systems potentially directly and/or indirectly affected by steam electric power plant discharges.

Source: U.S. EPA Analysis, 2024.

4.3.2.3 Changes in TTHM Concentration in Treated Water Supplies

The prior step provides the estimated PWS-level change in bromide concentration in the blend of source waters used by a given system. The step described in this section provides the estimated PWS-level change in TTHM concentration associated with this change in bromide concentration.

Regli et al. (2015) applied the Surface Water Analytical Tool (SWAT) version 1.1, which models TTHM concentrations in drinking water treatment plants as a function of precursor levels, source water quality (*e.g.*, bromide and organic material levels), water temperature, treatment processes (*e.g.*, pH, residence time), and disinfectant dose (*e.g.*, chlorine levels) to predict the distribution of changes in TTHM concentrations in finished water associated with defined increments of changes in bromide concentration in source waters. That study estimated the distribution of increments of change in TTHM concentration for a subset of the population of PWS characterized in the 1997-1998 Information Collection Rule (ICR) dataset. Table 4-4 summarizes the results from the Regli et al. (2015) analysis.

Table 4-4: Estimated Increments of Change in TTHM Levels (µg/L) as a Function of Change in Bromide Levels (µg/L)

Change in bromide concentration (µg/L)	Change in TTHM concentration (µg/L)					
	Minimum	5th Percentile	Median	Mean	95th Percentile	Maximum
10	0.0	0.1	1.1	1.3	3.4	10.1
30	0.0	0.3	2.6	3.2	8.3	23.7
50	0.0	0.5	3.7	4.6	11.6	33.2
75	0.0	0.6	4.9	6.0	14.8	42.1
100	0.0	0.8	5.8	7.1	17.5	49.3

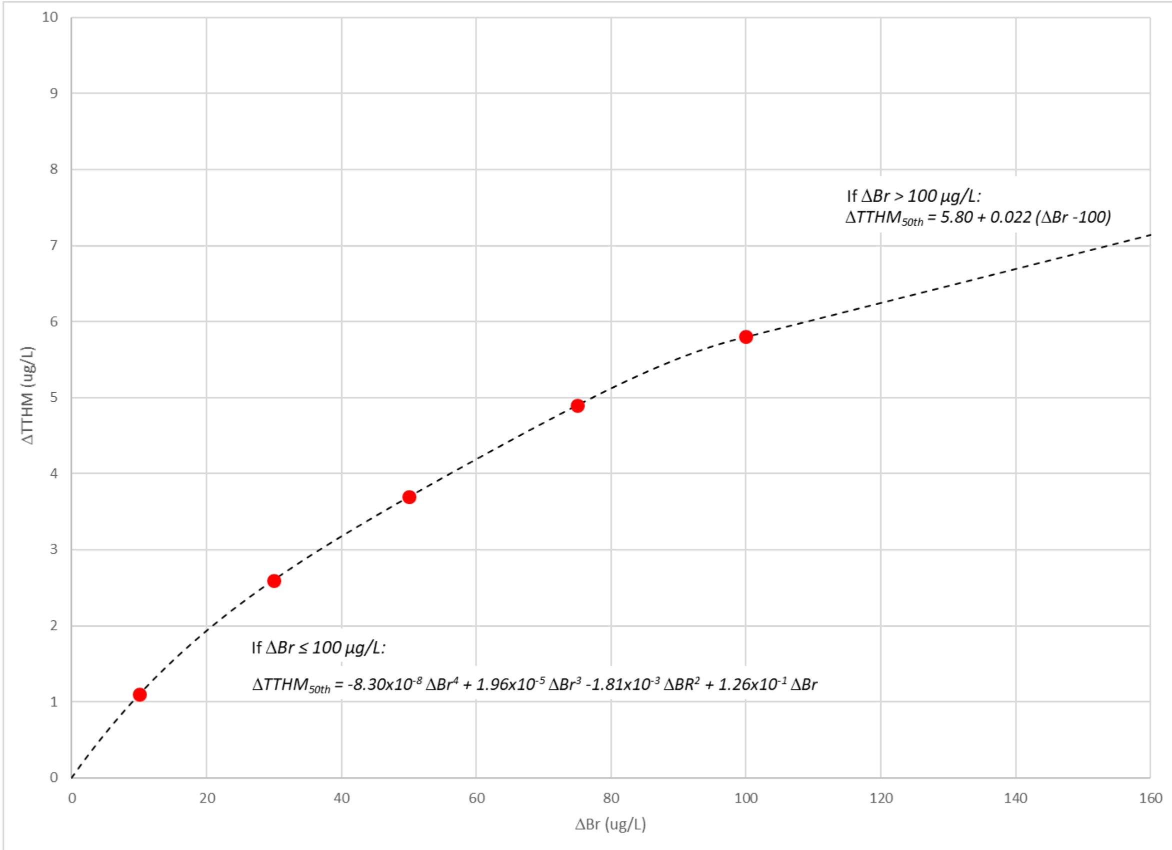
Source: Regli et al. (2015), Table 2.

For this analysis, EPA used the results from Regli et al. (2015) to predict TTHM concentration changes for each water treatment plant with changes in bromide concentrations in their source water due to the regulatory options. Figure 4-2 shows the relationship (dashed line) between the change in bromide concentration and the change in TTHM concentration based on fitting a polynomial curve through the median estimates from Table 4-4 (circular markers). EPA used the equation of the best-fit curve[61] to estimate changes in TTHM concentration as a function of changes in bromide concentration within the bromide concentration range presented in Regli et al. (2015) (0 to 100 µg/L). Estimates of TTHM concentration changes presented in the remainder of this section reflect median changes from Regli et al. (2015).[62] EPA evaluated the sensitivity of benefits estimates to the relationship between changes in bromide and changes in TTHM using the 5th and 95th percentile estimates in Table 4-4 in the 2019 and 2023 proposed rules (U.S. EPA, 2019b, 2023b).

[61] The polynomial curve fits observations in Table 4-4 with residuals of zero over the range of observations.

[62] While Regli, S., Chen, J., Messner, M., Elovitz, M. S., Letkiewicz, F. J., Pegram, R. A., Pepping, T. J., . . . Wright, J. M. (2015). Estimating potential increased bladder cancer risk due to increased bromide concentrations in sources of disinfected drinking waters. *Environmental Science & Technology*, *49*(22), 13094-13102. show similar mean and median changes in TTHM concentrations across the range of changes in bromide concentrations, EPA used the median to minimize potential influence of outlier values or skew in the distribution. Mean changes in TTHM for changes in bromide levels of 10, 30, 50, 75, and 100 µg/L were 1.3, 3.2, 4.6, 6.0 and 7.1 µg/L, respectively. Median changes in TTHM for changes in bromide levels of 10, 30, 50, 75, and 100 µg/L were 1.1, 2.6, 3.7, 4.9, and 5.8 µg/L, respectively.

Figure 4-2: Modeled Relationship between Changes in Bromide Concentration and Changes in TTHM Concentrations based on Median Values in Regli et al. (2015).



Source: U.S. EPA Analysis, 2024, based on Regli et al. (2015).

Table 4-5 shows the distribution of modeled absolute changes in TTHM concentrations and the potentially exposed populations under each of the regulatory options. As shown in the table, the magnitude of estimated bromide concentration changes is generally less than 10 µg/L, corresponding to estimated changes in TTHM concentrations of less than 1.1 µg/L. Compared to the baseline, all options are estimated to reduce TTHM concentrations in treated water.

Table 4-5: Distribution of Estimated Changes in TTHM Concentration by the Number of PWS and Population Served

Absolute ΔBr range[a] (µg/L)	Absolute ΔTTHM range[a] (µg/L)	Number of PWS[b]	Total population served (million people)[c]
Period 1 (2025-2029)			
Option A			
>0 to 10	0.00 to 1.09	451	13.54
10 to 30	1.81 to 1.81	2	0.00
30 to 50	3.82 to 3.82	3	0.12
Option B (Final Rule)			
>0 to 10	0.00 to 1.09	451	13.54
10 to 30	1.81 to 1.81	2	0.00
30 to 50	3.82 to 3.82	3	0.12

Table 4-5: Distribution of Estimated Changes in TTHM Concentration by the Number of PWS and Population Served

Absolute ΔBr range[a] (µg/L)	Absolute ΔTTHM range[a] (µg/L)	Number of PWS[b]	Total population served (million people)[c]
Option C			
>0 to 10	0.00 to 1.09	451	13.54
10 to 30	1.81 to 1.81	2	0.00
30 to 50	3.82 to 3.82	3	0.12
Period 2 (2030-2049)			
Option A			
>0 to 10	0.00 to 0.95	473	15.10
10 to 30	1.23 to 1.82	9	0.16
30 to 50	N/A	0	0.00
50 to 75	N/A	0	0.00
>75	6.48 to 6.48	3	0.12
Option B (Final Rule)			
>0 to 10	0.00 to 0.95	473	15.10
10 to 30	1.23 to 1.82	9	0.16
30 to 50	N/A	0	0.00
50 to 75	N/A	0	0.00
>75	6.48 to 6.48	3	0.12
Option C			
>0 to 10	0.00 to 0.95	485	15.60
10 to 30	1.23 to 1.82	9	0.16
30 to 50	N/A	0	0.00
50 to 75	N/A	0	0.00
>75	6.48 to 6.48	3	0.12

N/A: Not applicable (*i.e.*, there are no observations within the specified ΔBr range)

Source: U.S. EPA Analysis, 2024.

4.3.3 Step 3: Quantifying Population Exposure and Health Effects

EPA used the following steps to quantify changes in human health resulting from changes in TTHM levels in drinking water supplies:

- Characterize the exposed populations;
- Estimate changes in individual health risk; and
- Quantify the changes in adverse health outcomes.

4.3.3.1 Exposed Populations

The exposed populations consist of people served by each affected PWS. SDWIS provides the total population served by each PWS but does not provide detailed information about the geographic extent of the service area. For the final rule, EPA determined the service area of each PWS using a multi-tiered approach based on data availability. EPA first used service areas (SA) identified in the Hydroshare Community Water

Systems Service Boundaries (CWSSB) dataset (SimpleLab EPIC, 2022),[63] then 2022 TIGER ZIP code tabulated areas (ZCTAs), and finally county boundaries when no other data were available.[64] Over 95 percent of PWS with facilities downstream from steam electric plants had boundaries defined in the CWSBB dataset. Three percent of the PWS service areas were matched based on the ZIP code, and approximately one percent were matched based on the county.

EPA overlaid the service area boundaries to the Census block group (CBG) data in the 2021 American Community Survey (U.S. Census Bureau, 2021) to distribute the total population served by each PWS by age group to model health effects as described in Section 4.3.3.3.

EPA assumed that all individuals served by a given PWS are exposed to the same modeled changes in TTHM levels for the PWS, *i.e.*, there are no differences in TTHM concentrations in different parts of the water distribution system.

4.3.3.2 Health Impact Function

The relationship between exposure to DBPs, specifically trihalomethanes and other halogenated compounds resulting from water chlorination, and bladder cancer has been the subject of multiple epidemiological studies (Cantor et al., 2010; U.S. EPA, 2005c; NTP, 2018), a meta-analysis (Villanueva et al., 2003; Costet et al., 2011), and pooled analysis (Villanueva et al., 2004). The relationship between trihalomethane levels and bladder cancer in the Villanueva et al. (2004) study was used to support the benefits analysis for EPA's Stage 2 DBP Rule[65] which specifically aimed to reduce the potential health risks from DBPs (U.S. EPA, 2005c).

Regli et al. (2015) conducted an analysis of potential bladder cancer risks associated with increased bromide levels in surface source water. To estimate risks associated with modeled TTHM levels, they built on the approach taken in EPA's Stage 2 DBP Rule, *i.e.*, deriving a slope factor from the pooled analysis of Villanueva et al. (2004). They showed that the overall pooled exposure-response relationship for TTHM is linear over a range of relevant doses. The linear relationship predicted an incremental lifetime cancer risk of 1 in ten thousand exposed individuals (10^{-4}) per 1 µg/L increase in TTHM. The linear model proposed by Regli et al. (2015) provides a basis for estimating the dose-response relationship associated with changes in TTHM levels estimated for the regulatory options. The linear slope factor enables estimates of the total number of cancer cases associated with lifetime exposures to different TTHM levels.

EPA used the relationship estimated by Regli et al. (2015) to model the impact of changes in TTHM concentration in treated water on the lifetime bladder cancer risk:

Equation 4-1. $$O(x) = O(0) \cdot \exp\,(0.00427 \cdot x),$$

where $O(x)$ are the odds of lifetime bladder cancer incidence for an individual exposed to a lifetime average TTHM concentration in residential water supply of x µg/L and $O(0)$ are the odds of lifetime bladder cancer in

63 The CWSSB dataset uses a 3-tiered approach to assign more specific boundaries to PWS service areas. Tier 1 includes all PWS with explicit water service boundaries provided by states. Tier 2 assigns a boundary based on a match with a TIGER place name. Any PWS not in tier 1 or 2 is assigned a circular boundary around provided water system centroids based on a statistical model trained on explicit water service boundary data.

64 This is compared to the 2019 and 2023 analyses which used counties and ZIP codes, respectively, to determine the demographic and socioeconomic characteristics of the population served.

65 See DBP Rule documentation at https://www.epa.gov/dwreginfo/stage-1-and-stage-2-disinfectants-and-disinfection-byproducts-rules

the absence of exposure to TTHM in residential water supply. The log-linear relationship (Equation 4-1) has the advantage of being independent from the baseline TTHM exposure level, which is highly uncertain for most affected individuals due to lack of historical data.

4.3.3.3 Health Risk Model and Data Sources

EPA estimated changes in lifetime bladder cancer cases due to estimated changes in lifetime TTHM exposure using a dynamic microsimulation model that estimates affected population life tables under different exposure conditions. Life table approaches are standard among practitioners in demography and risk sciences and provide a flexible method for estimating the probability and timing of health impacts during a defined period (Miller & Hurley, 2003; Rockett, 2010).[66] In this application, the life table approach estimates age-specific changes in bladder cancer probability and models subsequent bladder cancer mortality, which is highly dependent on the age at the time of diagnosis. This age-specific cancer probability addresses variability in age-specific life expectancy across the population alive at the time the change occurs. This model allows for quantification of relatively complex policy scenarios, including those that involve variable contaminant level changes over time.

For this analysis, EPA assumed that the population affected by estimated changes in bromide discharges from steam electric power plants is exposed to baseline TTHM levels prior to implementation of the regulatory options – *i.e.*, prior to 2025 – and to alternative TTHM levels from 2025 through 2049. As described in Section 1.3.3, the period of analysis is based on the approximate life span of the longest-lived compliance technology for any steam electric power plant (20 or more years) and the final year of implementation (2029). The change in TTHM exposure affects the risk of developing bladder cancer beyond this period, however, because the majority of cancer cases manifest during the latter half of the average individual life span (Hrudey *et al.*, 2015). To capture these effects while being consistent with the framework of evaluating costs and benefits incurred from 2025-2049, EPA modeled changes in health outcomes resulting from changes in exposure in 2025-2049. Since changes in cancer incidence occur long after exposure, EPA modeled associated changes in cancer incidence through 2125, though only for the changes attributable to changed exposures in the 2025-2049 timeframe.

Lifetime health risk model data sources, detailed in Table 4-6 (next page), include EPA SDWIS and UCMR 4, ACS 2021 (U.S. Census Bureau, 2019, 2021), the Surveillance, Epidemiology, and End Results (SEER) program database (National Cancer Institute), and the Center for Disease Control (CDC) National Center for Health Statistics.

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66 EPA has used life table approaches to estimate health risks associated with radon in homes, formaldehyde exposure, and Superfund and RCRA site chemicals exposure, among others (Pawel, D. J., & Puskin, J. S. (2004). The US Environmental Protection Agency's assessment of risks from indoor radon. *Health physics*, *87*(1), 68-74. ; Munns, W. R., & Mitro, M. G. (2006). *Assessing risks to populations at Superfund and RCRA sites: Characterizing effects on populations*. Ecological Risk Assessment Support Center, Office of Research and …. ; National Research Council. (2011). *Review of the Environmental Protection Agency's Draft IRIS Assessment of Formaldehyde* (978-0-309-21193-2). https://www.nap.edu/catalog/13142/review-of-the-environmental-protection-agencys-draft-iris-assessment-of-formaldehyde).

Table 4-6: Summary of Data Sources Used in Lifetime Health Risk Model

Data element	Modeled variability	Data source	Notes
Number of persons in the affected population in 2025	Age: 1-year groups (ages 0 to 100) Sex: males, females Location: PWS service areas identified based on available Hydroshare CWSSB data, zip codes for PWS from SDWIS[a] and the fourth Unregulated Contaminant Monitoring Rule (UCMR 4) database[b], or the county.	2021 American Community Survey (ACS) (data on age- and sex-specific zip code-level population [U.S. Census Bureau, 2019, 2021] and age- and sex-specific population projections from Woods & Poole Economics Inc. (2021).	ACS data were in 5-year age groups. EPA assumed uniform distribution within each age interval to represent data as 1-year age groups. EPA then grew the age- and sex-specific CBG population data to the beginning of the analysis period (2025) using corresponding county-specific growth rates calculated using the Woods & Poole Economics Inc. (2021) complete demographic database. EPA then computed relevant age- and sex- population shares and used them to distribute location-specific affected population.
Bladder cancer incidence rate (IR) per 100,000 persons	Age at diagnosis: 1-year groups (ages 0 to 100) Sex: males, females	SEER 21 (Surveillance Research Program - National Cancer Institute, 2020b)[c]	Distinct SEER 21 IR data were available for ages 0, 1-4, 5-9, 10-14, 15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69, 70-74, 75-79, 80-84, 85+ years. EPA assumed that the same IR applies to all ages within each age group.
General population mortality rate	Age: 1-year groups (ages 0 to 100) Sex: males, females	Center for Disease Control (CDC)/National Center for Health Statistics (NCHS) United States Life Tables, 2017	EPA used age- and sex-specific probabilities of dying within the integer age intervals.
Share of bladder cancer incidence at specific cancer stage	Age at diagnosis: 1-year groups (ages 0 to 100) Sex: males, females Cancer stage: localized, regional, distant, unstaged	SEER 21 distribution of bladder cancer incidence over stages by age and sex at diagnosis	Distinct SEER 21 data were available for ages 0-14, 15-39, 40-64, 65-74, 75+. EPA assumed that the same cancer incidence shares by stage apply to all ages within each age group.
Share of cancer deaths among all-cause deaths	Age at diagnosis: 1-year groups (ages 0 to 100) Sex: males, females Cancer type: Malignant neoplasm of bladder	Underlying Cause of Death, 1999-2019 on CDC WONDER Online Database (Centers for Disease Control and Prevention, 2020)	EPA calculated share of cancer deaths among all-cause deaths by age and sex by dividing the number of cancer deaths during 1999-2019 with the number of all-cause deaths during 1999-2019.
Relative bladder cancer survival by cancer stage	Age at diagnosis: 1-year groups (ages 0 to 100) Sex: males, females Duration: 1-year groups (durations 0 to 100 years) Cancer stage: localized, regional,	SEER 18 relative bladder cancer survival by age at diagnosis, sex, cancer stage and duration with diagnosis for 2000-2017 (Surveillance Research Program - National Cancer Institute, 2020a)	Distinct SEER 18 data were available for ages at diagnosis 0-14, 15-39, 40-64, 65-74, 75+. EPA assumed that the same cancer relative survival patterns apply to all ages within each age group. SEER 18 contained data on relative survival among persons that had bladder cancer for 0, 1, 2, 3, 4, 5, 6,

Table 4-6: Summary of Data Sources Used in Lifetime Health Risk Model

Data element	Modeled variability	Data source	Notes
	distant, unstaged Cancer type: Urinary Bladder (Invasive & In Situ) Cancer		7, 8, 9, and 10 years. For disease durations longer than 10 years EPA applied 10-year relative survival rates.

[a] EPA's Safe Drinking Water Information System SDWIS: https://www3.epa.gov/enviro/facts/sdwis/search.html

[b] Where Hydroshare CWSSB data were not available, ICF matched zip-code level populations from the 2021 ACS data (U.S. Census Bureau, 2019, 2021) to zip codes associated with PWS in the SDWIS 2022 Q4 dataset (U.S. EPA, 2022) or the UCMR 4 dataset (U.S. EPA, 2016a). The SDWIS dataset often contains a one-to-many relationship between PWS and zip codes served, whereas the UCMR 4 dataset provides a one-to-one relationship between PWS and zip codes.

[c] SEER program, National Cancer Institute, National Institute of Health

Source: U.S. EPA Analysis, 2024.

Table 4-7 summarizes sex- and age group-specific general population mortality rates and bladder cancer incidence rates used in the model simulations, as well as the sex-specific share of the affected population for each age group. Appendix D summarize sex- and age group-specific distribution of bladder cancer cases over four analyzed stages as well as the age of onset-specific relative survival probability for each stage.

Using available data on cancer incidence and mortality, EPA calculated changes in bladder cancer cases resulting from the regulatory options using the relationship between the change in TTHM concentrations and the change in lifetime bladder cancer risk estimated by Regli et al. (2015) (see Section 4.3.3.2). The analysis accounts for the gradual changes in lifetime exposures to TTHM following estimated changes in annual average bromide discharges and associated TTHM exposure under the regulatory options compared to the baseline.

Table 4-7: Summary of Sex- and Age-specific Mortality and Bladder Cancer Incidence Rates

Sex	Age group	Sex-specific share of the affected population[a]	General population mortality rate (per 100,000)[b]	General population bladder cancer incidence rate (per 100,000)[b,c]
Female	<1	0.006	579	0.000
Female	1-4	0.024	25	0.000
Female	5-9	0.029	12	0.000
Female	10-14	0.030	13	0.000
Female	15-19	0.031	33	0.000
Female	20-24	0.035	47	0.174
Female	25-29	0.040	60	0.264
Female	30-34	0.039	80	0.498
Female	35-39	0.035	113	0.891
Female	40-44	0.032	168	1.540
Female	45-49	0.030	254	2.856
Female	50-54	0.031	378	6.551
Female	55-59	0.032	558	11.381
Female	60-64	0.032	833	18.160
Female	65-69	0.027	1,256	29.084
Female	70-74	0.021	1,997	42.848
Female	75-79	0.015	3,271	57.612
Female	80-84	0.010	5,550	71.083
Female	85+	0.010	13,559	76.378
Male	<1	0.006	702	0.000
Male	1-4	0.025	31	0.000
Male	5-9	0.031	14	0.000
Male	10-14	0.030	19	0.000
Male	15-19	0.031	78	0.112
Male	20-24	0.032	136	0.298
Male	25-29	0.035	148	0.508
Male	30-34	0.040	165	1.103
Male	35-39	0.039	204	2.078
Male	40-44	0.035	281	4.153
Male	45-49	0.032	419	8.823
Male	50-54	0.030	631	18.898
Male	55-59	0.030	933	37.562
Male	60-64	0.030	1,361	67.458
Male	65-69	0.030	1,963	114.313
Male	70-74	0.023	2,977	175.990

Table 4-7: Summary of Sex- and Age-specific Mortality and Bladder Cancer Incidence Rates

Sex	Age group	Sex-specific share of the affected population[a]	General population mortality rate (per 100,000)[b]	General population bladder cancer incidence rate (per 100,000)[b,c]
Male	75-79	0.018	4,704	244.517
Male	80-84	0.011	7,623	315.335
Male	85+	0.006	15,543	357.071

[a] Shares calculated for the total population served by potentially affected PWS, based on Hydroshare service areas data.

[b] Based on the general population of the United States.

[c] Single age-specific rates were aggregated up to the age groups reported in the table using the individual age-specific number of affected persons as weights.

Source: U.S. EPA analysis (2024) of 2021 ACS data (U.S. Census Bureau, 2019, 2021).

4.3.3.4 Model Implementation

EPA analyzed effects of the regulatory options using the dynamic microsimulation model and data sources described in Section 4.3.3.3. As described above, EPA models TTHM changes (ΔTTHM) due to the regulatory options as being in effect for the years 2025 through 2049. After 2049, EPA does not attribute costs or changes in bromide loadings to the rule, and therefore does not model incremental changes in exposures to TTHM.[67]

To estimate changes in bladder cancer incidence, EPA defined and quantified a set of 31,108 unique combinations[68] of the following parameters:

- *Location and TTHM changes*: 154 PWS groups;[69]
- *Age*: age of the population at the start of the evaluation period (2025), ranging from 0 to 100;
- *Sex*: population sex (male or female).

4.3.4 Step 4: Quantifying the Monetary Value of Benefits

EPA estimated total monetized benefits from avoided morbidity and mortality (also referred to as avoided cancer cases and avoided cancer deaths, respectively, in this discussion) from estimated changes in bromide discharges, and estimated changes in TTHM exposure and the resulting estimated bladder cancer incidence rate using a 2 percent discount rate for each of the three regulatory options.[70]

- *Morbidity*: To value changes in the economic burden associated with cancer morbidity EPA relied on base willingness-to-pay (WTP) estimates from Bosworth, Cameron and DeShazo (2009) for colon/bladder cancer in monetizing bladder cancer benefits. The base estimate of WTP per illness avoided based on an affected population of 50,000 for a duration of ten years is $400,000 for

67 In other words, costs after 2049 = $0 and Δbromide after 2049 is zero (hence ΔTTHM after 2049 is zero).

68 The set of 31,108 combinations was determined by multiplying the number of PWS groups by the number of ages and sexes considered (154 x 101 x 2).

69 The PWS groups represent unique combinations of ΔTTHM values and typically consist of a directly affected PWS and other PWSs serving populations located in the same county and purchasing water from the directly affected PWS. The number of PWS in each PWS group ranges from 1 to 41.

70 In some cases, benefits are derived from a delay in cancer morbidity and mortality.

colon/bladder cancer (2009 dollars). The value was adjusted for income growth using an assumed elasticity of 0.45, the central elasticity estimate for severe and chronic health effects (U.S. EPA, 2023h); it ranged from $635,947 per case in 2025 to $786,916 per case in 2049. The product of this value and the estimated aggregate reduction in risk of bladder cancer in a given year represents the affected population's aggregate WTP to reduce its probability of bladder cancer in one year.

- *Mortality*: To value changes in excess mortality from bladder cancer EPA extrapolated the default central tendency of the VSL distribution recommended for use in EPA's regulatory impact analyses, $4.8 million (1990 dollars, 1990 income year), to future years, ranging from $13.54 million per death in 2025 to $16.36 million per death in 2049 (U.S. EPA, 2010). The product of VSL and the estimated aggregate reduction in risk of death in a given year represents the affected population's aggregate WTP to reduce its probability of death in one year.

4.4 Results of Analysis of Human Health Benefits from Estimated Changes in Bromide Discharges Analysis

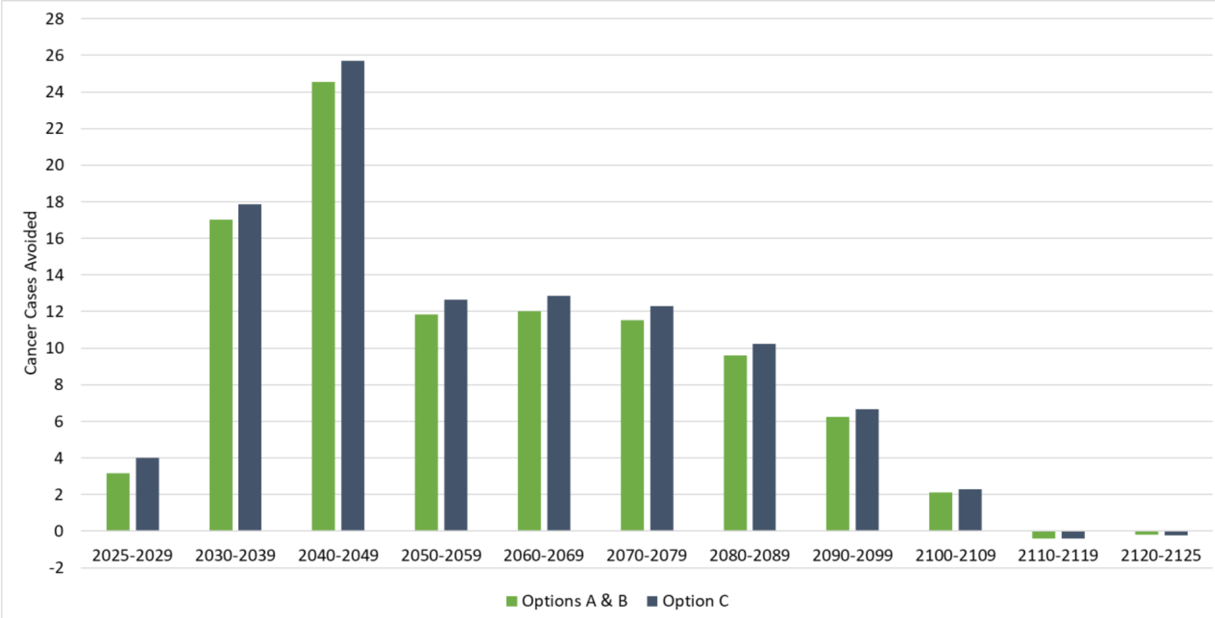
Using the data EPA assembled on cancer incidence and mortality, the Agency estimated changes in bladder cancer cases for the regulatory options using the relationship between TTHM concentrations and the lifetime bladder cancer risk estimated by Regli et al. (2015). Figure 4-3 and Figure 4-4 show the estimated number of bladder cancer cases and premature deaths avoided, respectively, under the three regulatory options by decade. In each decade, the estimated number of bladder cancer cases is never in excess of 26 cases and the estimated number of premature deaths avoided is never in excess of seven deaths avoided.

Options A and B provide the same reductions in bromide loadings and the same benefits, whereas Option C provides additional loading reductions and consequently larger benefits. More than 50 percent of the modeled avoided bladder cancer incidence associated with the regulatory options occurs between 2025 and 2059. This pattern is consistent with existing cancer cessation lag models (*e.g.*, Hrubec & McLaughlin, 1997, Hartge et al., 1987, and Chen & Gibb, 2003) that show between 61 and 94 percent reduction in cancer risk in the first 25 years after exposure cessation (see Appendix D for detail). After 2059, the benefits attributable to exposures incurred under the regulatory options in 2025-2049 decline due to comparably fewer people surviving to mature ages.[71] In the years after 2099, the avoided cases decline considerably and in the last two decades considered in the analysis, the cancer incidences increase relative to baseline incidences.[72]

[71] In the period between 2060 and 2099, the estimated avoided cases decline slowly as the living people exposed to the estimated changes in TTHM levels reach 70 years (the age at which the highest annual incidence of bladder cancer is observed). According to American Cancer Society, about 9 out of 10 people diagnosed with bladder cancer are over the age of 55. The average age at the time of diagnosis is 73 (American Cancer Society. (2019). *Key Statistics for Bladder Cancer*. Retrieved 2019 from https://www.cancer.org/cancer/bladder-cancer/about/key-statistics.html).

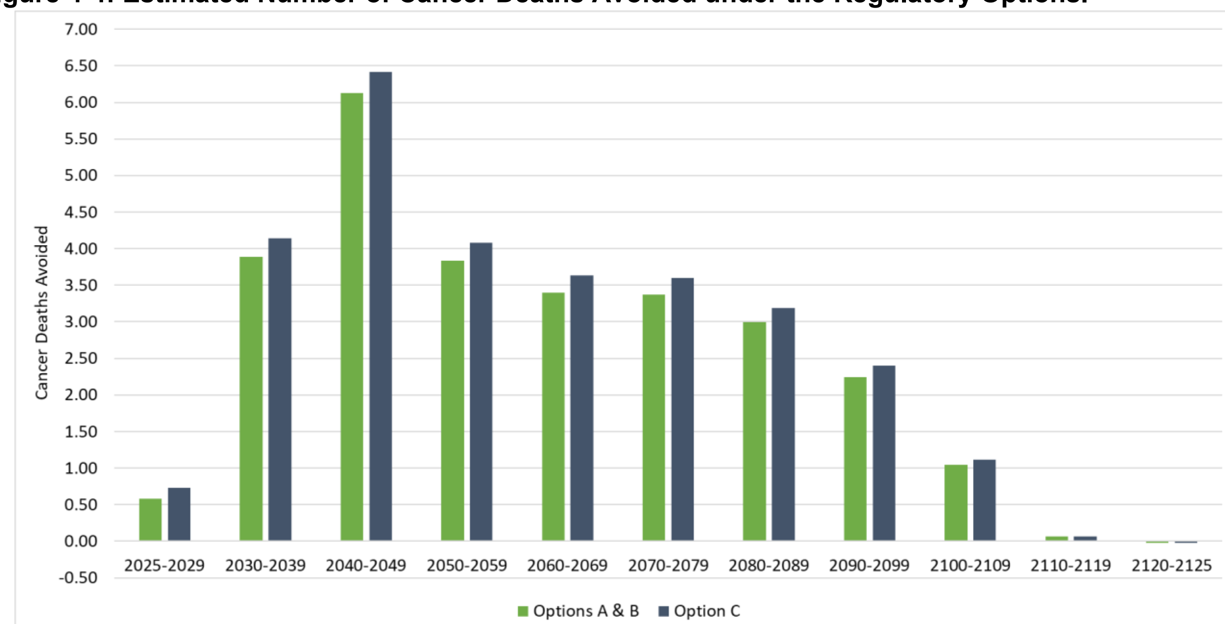
[72] The increase in cancer cases in the last decade is due to the connection between survival and cancer incidence. Lower estimated TTHM exposure due to reductions in bromide loadings under certain regulatory options reduces the estimated number of people developing bladder cancer during the earlier years of the analysis and increases overall survival rates. Higher estimated rates of survival lead to longer life spans and more people developing cancer later in life. This effect becomes more apparent closer to the end of the evaluation period, at which point there are fewer people estimated to be alive in the baseline population compared to the estimated number of people alive under certain regulatory option scenarios.

Figure 4-3: Estimated Number of Bladder Cancer Cases Avoided under the Regulatory Options.



Source: U.S. EPA Analysis, 2024.

Figure 4-4: Estimated Number of Cancer Deaths Avoided under the Regulatory Options.



Source: U.S. EPA Analysis, 2024.

Table 4-8 summarizes the estimated changes in the incidence of bladder cancer from exposure to TTHM due to the regulatory options and the value of benefits from avoided cancer cases, including avoided mortality and morbidity. The table provides the present value of benefits from changes in TTHM exposure in 2025-2049 for the period of analysis (2025-2049) and for the entire period with attributable benefits (through 2125).

Table 4-8: Estimated Bromide-related Bladder Cancer Mortality and Morbidity Monetized Benefits

Regulatory Option	Changes in cancer cases[a] from changes in TTHM exposure 2025-2049		Present value of discounted benefits[a] (million 2023$, discounted to 2024 at 2 percent)			Annualized[b] benefits (million 2023$, discounted to 2024 at 2 percent)		
	Total bladder cancer cases avoided	Total cancer deaths avoided	Avoided mortality	Avoided morbidity	Total	Avoided mortality	Avoided morbidity	Total
Option A	98	28	$225.8	$40.4	$266.2	$11.3	$2.0	$13.4
Option B (Final Rule)	98	28	$225.8	$40.4	$266.2	$11.3	$2.0	$13.4
Option C	104	29	$241.0	$43.1	$284.1	$12.1	$2.2	$14.3

[a] The values account for the persisting health effects (up until 2125) from changes in TTHM exposure during the period of analysis (2025-2049).

[b] Benefits are annualized over 25 years. The annualized benefits account for avoided mortality and morbidity during the period of analysis (2025-2049) as well as persisting health effects (up until 2125) from reduced TTHM exposure through 2049.

Source: U.S. EPA Analysis, 2024

4.5 Additional Measures of Human Health Effects from Exposure to Steam Electric Pollutants via Drinking Water Pathway

The regulatory options may result in relatively small changes to source water quality for additional parameters that can adversely affect human health (see Section 2.1.1). Many pollutants in steam electric power plant discharges have MCLs that set allowable levels in treated water. For some pollutants that have an MCL above the MCLG, there may be incremental benefits from reducing concentrations below the MCL. In addition to certain brominated DBPs discussed in the previous sections, there are no "safe levels" for lead and arsenic and therefore any reduction in exposure to these pollutants is expected to yield benefits.[73]

Estimated concentrations of arsenic and lead in downstream reaches that serve as drinking water sources do not exceed typical detection limits for these contaminants. The results show thallium concentrations in source waters that exceed levels detectable by standard methods (0.005 µg/L) in one source water reach during Period 1 but are below 0.005 µg/L in all other modeled source waters. Relative to baseline concentrations, the changes in arsenic, lead, and thallium concentrations are small (*e.g.*, less than 0.005 µg/L in Period 1 and less than 0.007 µg/L in Period 2 in source waters). Table 4-9 summarizes the direction of changes in arsenic, lead, and thallium concentrations under the regulatory options for the two analysis periods. The magnitude of the changes depends on the Period, regulatory option, source water reach, and PWS but is generally consistent with the changes in halogen loadings associated with FGD wastewater and bottom ash transport water under each analyzed regulatory option (see Table 3-1). During Period 1, all Options show either reductions or no changes in arsenic, lead, and thallium concentrations for all source waters and PWS. During Period 2, the three regulatory options also show estimated reductions in arsenic, lead, and thallium concentrations with both the magnitude and scope (the number of reaches, PWS, and population served) of the reductions larger than during Period 1.

[73] Even in cases where the MCLG is equal to the MCL, there may be incremental health-related benefits associated with changes in concentrations arising from the regulatory options since detection of the pollutants is subject to imperfect monitoring and treatment may not remove all contaminants from the drinking water supplies, as evidenced by reported MCL violations for inorganic and other contaminants at community water systems (U.S. Environmental Protection Agency. (2013b). *Fiscal year 2011: Drinking water and ground water statistics*. (EPA 816-R-13-003). Washington, DC: U.S. Environmental Protection Agency, Office of Water).

To assess potential additional drinking water-related health benefits, EPA estimated the changes in the number of receiving reaches with drinking water intakes that have modeled pollutant concentrations exceeding MCLs or MCLGs. EPA did this analysis for all of the pollutants listed in Table 2-2, except bromate and TTHM.[74] This analysis showed no changes in the number of MCL or MCLG exceedances under the regulatory options during Period 1, when compared to the baseline. In addition, EPA found no reaches with drinking water intakes that had modeled lead, arsenic, or thallium concentrations in excess of MCLs or MCLGs under either the baseline or the regulatory options during Period 1, even where concentrations increased as summarized in Table 4-9.[75]

During Period 2, EPA found 182 reaches with drinking water intakes that had modeled arsenic concentrations in excess of the MCLG and 23 reaches with modeled lead concentrations in excess of the MCLG that showed improvements under at least one of the regulatory options. The Agency concluded, based on these screening analyses, that any additional benefits from changes in exposure to the pollutants examined in this analysis via the drinking water pathway would be relatively small.

Table 4-9: Estimated Distribution of Changes in Source Water and PWS-Level Arsenic, Lead, and Thallium Concentrations by Period and Regulatory Option, Compared to Baseline

Regulatory Option	Number of Source Water Reaches		Number of PWS[a]		Population Served by PWS (Millions)	
	Reduction	No Change	Reduction	No Change	Reduction	No Change
Period 1 (2025-2029)						
Arsenic						
Option A	215	13	849	67	28.0	1.1
Option B (Final Rule)	217	11	866	50	28.6	0.5
Option C	217	11	866	50	28.6	0.5
Lead						
Option A	118	26	464	79	13.8	3.1
Option B (Final Rule)	118	26	464	79	13.8	3.1
Option C	118	26	464	79	13.8	3.1
Thallium						
Option A	215	13	849	67	28.0	1.1
Option B (Final Rule)	217	11	866	50	28.6	0.5
Option C	217	11	866	50	28.6	0.5
Period 2 (2030-2049)						
Arsenic						
Option A	222	6	889	27	29.0	0.2
Option B (Final Rule)	223	5	894	22	29.1	0.1
Option C	223	5	894	22	29.1	0.1
Lead						
Option A	130	14	493	50	15.5	1.4
Option B (Final Rule)	130	14	493	50	15.5	1.4
Option C	131	13	505	38	16.0	0.9

74 EPA did not consider MCL or MCLG exceedances for bromate and TTHM because the background data on these contaminants in source waters is not readily available (*e.g.*, these contaminants are not included in the TRI dataset). Additionally, modeled discharges of bromate from steam electric plant effluent do not exceed EPA's MCL of 0.01 mg/L, but all exceed the MCLG of zero.

75 EPA also found that there are no reaches with drinking water intakes that have pollutant concentrations exceeding human health ambient water quality criteria for either the consumption of water and organism or the consumption of organism only.

Table 4-9: Estimated Distribution of Changes in Source Water and PWS-Level Arsenic, Lead, and Thallium Concentrations by Period and Regulatory Option, Compared to Baseline

Regulatory Option	Number of Source Water Reaches		Number of PWS[a]		Population Served by PWS (Millions)	
	Reduction	No Change	Reduction	No Change	Reduction	No Change
Thallium						
Option A	222	6	889	27	29.0	0.2
Option B (Final Rule)	223	5	894	22	29.1	0.1
Option C	223	5	894	22	29.1	0.1

a. Includes systems potentially directly and/or indirectly affected by steam electric power plant discharges.

Source: U.S. EPA Analysis, 2024.

4.6 Limitations and Uncertainties

Table 4-10 summarizes principal limitations and sources of uncertainties associated with the estimated changes in pollutant levels in source waters downstream from steam electric power plant discharges. Additional limitations and uncertainties are associated with the estimation of pollutant loadings (see U.S. EPA, U.S. EPA, 2020g). Note that the effect on benefits estimates indicated in the second column of the table refers to the magnitude of the benefits rather than the direction (*i.e.*, a source of uncertainty that tends to underestimate benefits indicates expectation for either larger forgone benefits or larger realized benefits).

Table 4-10: Limitations and Uncertainties in the Analysis of Human Health Benefits from Changes in Discharges of Halogens and Other Pollutants Via the Drinking Water Pathway

Uncertainty/Limitation	Effect on Benefits Estimate	Notes
Analysis does not account for births within the exposed population.	Underestimate	The analysis does not account for people born after 2025. This likely leads to an underestimate of benefits.
Analysis does not account for migration within the exposed population.	Uncertain	The analysis does not account for people leaving or moving into the service area. The overall effect of this factor on the estimated benefits is uncertain.
Bladder cancer risks are estimated for populations for which changes in TTHM exposures relative to baseline exposures start at different ages, including children.	Uncertain	The relative cancer potency of TTHM in children is unknown, which may bias benefits estimates either upward or downward. Past reviews found no clear evidence that children are at greater risk of adverse effects from bromoform or dibromochloromethane exposure (U.S. EPA, 2005a) although certain modes of action and health effects may be associated with exposure to TTHM during childhood (U.S. EPA, 2016c). Because bladder cancer incidence in children is very small, EPA assesses any bias to be negligible.
For PWS with multiple sources of water, the analysis uses equal contributions from each source.	Uncertain	Data on the flow rates of individual source facilities are not available and EPA therefore estimated that all permanent active sources contribute equally to a PWS's total supply. Effects of the regulatory option may be greater or smaller than estimated, depending on actual supply shares.

Table 4-10: Limitations and Uncertainties in the Analysis of Human Health Benefits from Changes in Discharges of Halogens and Other Pollutants Via the Drinking Water Pathway

Uncertainty/Limitation	Effect on Benefits Estimate	Notes
Changes in bromide concentrations are analyzed for active permanent surface water intakes and reservoirs only.	Underestimate	The analysis includes only permanent active surface water facilities associated with non-transient PWS classified as "community water systems" that use surface water as primary source. To the extent that PWS using surface waters as secondary source or other non-permanent surface water facilities are affected, this approach understates the effects of the regulatory options.
Changes in TTHM formation depends only on changes in bromide levels.	Uncertain	The regulatory options are expected to affect bromide levels in source water. Other factors such as disinfection method, pH, temperature, and organic content affect TTHM formation. EPA assumes that PWS and source waters affected by steam electric power plant discharges have similar characteristics as those modeled in Regli et al. (2015).
Use of a national relationship from Regli et al. (2015) to relate changes in bromide concentration to changes in TTHM concentration.	Uncertain	EPA did not collect site-specific information on factors affecting TTHM formation at each potentially affected drinking water treatment plant, but instead used the median from a sample population of approximately 200 drinking water treatment systems. Use of the national relationship from Regli et al. (2015) could either understate or overstate actual changes in TTHM concentrations for a given change in bromide concentrations at any specific drinking water treatment system.
Change in risk is based on changes in exposure to TTHMs rather than to brominated trihalomethanes specifically.	Underestimate	Brominated species play a prominent role in the overall toxicity of DBP exposure. Given that the regulatory options predominantly affect the formation of brominated DBPs, the estimated changes in cancer risk resulting from regulatory options could be biased downward. EPA report provides additional information about health effects of DBPs (U.S. EPA, 2016c).
The analysis relies on public-access SEER 18 5-year relative bladder cancer survival data to model mortality patterns in the bladder cancer population.	Uncertain	Reliance on these data generates both a downward and an upward bias. The downward bias is due to the short, 5-year excess mortality follow-up window. Survival rates beyond 5 years following the initial diagnosis are likely to be lower. The upward bias comes from the inability to determine how many of the excess deaths were deaths from bladder cancer.
The dose-response function used to estimate risk assumes causality of bladder cancer from exposure to disinfected drinking water.	Overestimate	While the evidence supporting causality has increased since EPA's Stage 2 DBP Rule, the weight of evidence is still not definitive (see Regli et al. (2015)).

Table 4-10: Limitations and Uncertainties in the Analysis of Human Health Benefits from Changes in Discharges of Halogens and Other Pollutants Via the Drinking Water Pathway

Uncertainty/Limitation	Effect on Benefits Estimate	Notes
The relationship from Regli et al. (2015) is a linear approximation of the odds ratios reported in Villanueva et al. (2004).	Uncertain	Given the uncertainty about the historical, location-specific TTHM baselines, Regli et al. (2015) provides a reasonable approximation of the risk. However, depending on the baseline TTHM exposure level, the impact computed based on Regli et al. (2015) may be larger or smaller than the impact computed using the Villanueva et al. (2004)-reported odds ratios directly.
The analysis does not account for the relationship between TTHM exposure and bladder cancer within certain subpopulations.	Overestimate	Epidemiological literature suggests that TTHM effects could be greatest for the smoker population, whose members are already at higher risk for bladder cancer. Smoking prevalence has declined in the United States and relationships estimated with data from the 1980s and 1990s may overestimate future bladder cancer impact. Robust synthesis estimates of the relationship between TTHM and bladder cancer in the smoker population are lacking, limiting EPA's ability to account for smoking when modeling health effects.
The change in risk for a given change in TTHM is uncertain for changes in TTHM concentrations that are less than 1 µg/L.	Uncertain	EPA notes that the majority of the regulatory options benefits are associated with PWS for which predicted changes in TTHM concentration are greater than 1 µg/L. Although there is greater uncertainty in the estimated changes in health risk associated with changes in TTHM concentrations less than 1 µg/L, EPA included these changes in the estimated benefits. Benefits from the regulatory options may be greater or smaller than estimated, depending on actual risk changes.
Health effects associated with DBP exposure other than bladder cancer are not quantified in this analysis.	Uncertain	An EPA report discusses potential linkages between DBP exposures and other health endpoints, *e.g.*, developmental effects (with a short-term exposure) and cancers other than bladder cancers (with a long-term exposure), but there is insufficient data to fully evaluate these endpoints (U.S. EPA, 2016c).
Discharge monitoring data for bromide from steam electric power plants are limited and demonstrate significant variability based on site-specific factors.	Uncertain	Limited bromide monitoring data are available to assess bromide source water concentration estimates.
The analysis does not consider pollutant sources beyond those associated with steam electric power plants or TRI dischargers.	Underestimate	The analysis of other pollutants does not account for natural background and anthropogenic sources that do not report to TRI. This results in a potential underestimate of the number of waters exceeding the MCL or MCLG.

Table 4-10: Limitations and Uncertainties in the Analysis of Human Health Benefits from Changes in Discharges of Halogens and Other Pollutants Via the Drinking Water Pathway

Uncertainty/Limitation	Effect on Benefits Estimate	Notes
The analysis does not account for populations that consume bottled water as their primary drinking water source or populations that practice averting behaviors such as purchasing bottled water and filters in response to drinking water violations.	Uncertain	Studies indicate that between 13 percent and 33 percent of the U.S. population consumes bottled water as their primary drinking water source (Hu, Morton & Mahler, 2011; Rosinger et al., 2018; Vieux et al., 2020). Recent research also documents a relationship between sales of bottled water and violations of the SDWA (Allaire et al., 2019). The benefits models do not consider populations who consume bottled water as their primary drinking water source or populations that practice averting behaviors in response to poor drinking water quality. The overall effect of not considering these populations on the estimated benefits is uncertain.

5 Human Health Effects from Changes in Pollutant Exposure via the Fish Ingestion Pathway

EPA expects the regulatory options to affect human health risk by changing effluent discharges to surface waters and, as a result, ambient pollutant concentrations in the receiving reaches. The EA provides details on the health effects of steam electric pollutants (U.S. EPA, 2024b). Recreational and subsistence fishers (and their household members) who consume fish caught[76] in the reaches receiving steam electric power plant discharges could benefit from reduced pollutant concentrations in fish tissue. This chapter presents EPA's analysis of human health effects resulting from changes in exposure to pollutants in bottom ash transport water, FGD wastewater and CRL via the fish consumption pathway. The analyzed health effects include:

- Changes in exposure to lead: This includes changes in neurological and cognitive damages in children (ages 0-7) based on the impact of an additional IQ point on an individual's future earnings, and changes in cardiovascular disease (CVD) premature mortality for adults.
- Changes in exposure to mercury: Changes in neurological and cognitive damages in infants from exposure to mercury *in-utero* based on the impact of an additional IQ point on an individual's future earnings.
- Changes in exposure to arsenic: Changes in incidence of cancer cases and the COI associated with treating skin cancer.

The total quantified human health effects included in this analysis represent only a subset of the potential health effects estimated to result from the regulatory options. While additional adverse health effects are associated with pollutants in bottom ash transport water and FGD wastewater (such as kidney damage from cadmium or selenium exposure, gastrointestinal problems from zinc, thallium, or boron exposure, and others), the lack of data on dose-response relationships[77] between ingestion rates and these effects precluded EPA from quantifying the associated health effects.

EPA's analysis of the monetary value of human health effects utilizes data and methodologies described in Chapter 3 and in the EA (U.S. EPA, 2024b). The relevant data include the set of immediate and downstream reaches that receive steam electric power plant discharges (*i.e.*, affected reaches), as defined by the NHD COMID,[78] the estimated ambient pollutant concentrations in receiving reaches, and estimated fish consumption rates among different age and ethnic cohorts for affected recreational and subsistence fishers.

Section 5.1 describes how EPA identified the population potentially exposed to pollutants from steam electric power plant discharges via fish consumption. Section 5.2 describes the methods for estimating fish tissue pollutant concentrations and potential exposure via fish consumption in the affected population. Section 5.3 to Section 5.6 describe EPA's analysis of various human health endpoints potentially affected by the regulatory

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[76] As detailed in Section 5.2 and Section 5.9, for the subset of recreational and subsistence fishers who consume catch from affected reaches (*i.e.*, do not practice catch-and-release), EPA assumed that all fish consumed consists of self-caught fish. EPA assumed no exposure via fish consumption for all other households, including recreational and subsistence fishers who consume catch from other reaches.

[77] A dose response relationship is an increase in incidences of an adverse health outcome per unit increase in exposure to a toxin.

[78] A COMID is a unique numeric identifier for a given waterbody (reach), assigned by a joint effort of the United States Geological Survey and EPA.

options, which are then summarized in Section 5.7. Section 5.8 provides additional measures of human health benefits. Section 5.9 describes limitations and uncertainties.

5.1 Population in Scope of the Analysis

The population in scope of the analysis (*i.e.*, individuals potentially exposed to steam electric pollutants via consumption of contaminated fish tissue) includes recreational and subsistence fishers who fish reaches affected by steam electric power plant discharges (including receiving and downstream reaches), as well as their household members.[79] EPA estimated the number of people who are likely to fish affected reaches based on typical travel distances to a fishing site and presence of substitute fishing locations. EPA notes that the universe of sites potentially visited by recreational and subsistence fishers includes reaches subject to fish consumption advisories (FCA).[80] EPA expects that recreational fishers' responses to FCA presence are reflected in their catch and release practices, as discussed below.

Since fish consumption rates vary across different age, racial and ethnic groups, and fishing mode (recreational versus subsistence fishing), EPA estimated potential health effects separately for a number of age-, ethnicity-, and mode-specific cohorts. For each Census Block Group (CBG) within 50 miles of an affected reach, EPA assembled 2021 American Community Survey data on the number of people in 7 age categories (0 to 1, 2, 3 to 5, 6 to 10, 11 to 15, 16 to 21, and 21 years or higher) for the analysis of benefits to children from reductions in lead and mercury, and for cancer benefits from reductions in arsenic, and in 41 age categories for the analysis of adult lead benefits. EPA then subdivided each group according to 7 racial/ethnic categories:[81] 1) White non-Hispanic; 2) African-American non-Hispanic; 3) Tribal/Native Alaskan non-Hispanic; 4) Asian/Pacific Islander non-Hispanic; 5) Other non-Hispanic (including multiple races); 6) Mexican Hispanic; and 7) Other Hispanic.[82] Within each racial/ethnic group, EPA further subdivided the population according to recreational and subsistence fisher groups. The Agency assumed that the 95th percentile of the general population fish consumption rate is representative of the subsistence fisher consumption rate. Accordingly, the Agency assumed that 5 percent of the total fishers population practices subsistence fishing.[83] EPA also subdivided the affected population by income into poverty and non-poverty

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79 The in-scope population excludes recreational and subsistence fishers who fish other reaches or certain affected waterbodies not covered by the water quality models (*i.e.*, Great Lakes and estuaries).

80 Based on EPA's review of studies documenting fishers' awareness of FCA and their behavioral responses to FCA, 57.0 percent to 61.2 percent of fishers are aware of FCA, and 71.6 percent to 76.1 percent of those who are aware ignore FCA (Burger, J. (2004). Fish consumption advisories: knowledge, compliance and why people fish in an urban estuary. *Journal of Risk Research*, *7*(5), 463-479. , Jakus, P. M., Downing, M., Bevelhimer, M. S., & Fly, J. M. (1997). Do sportfish consumption advisories affect reservoir anglers' site choice? *Agricultural and Resource Economics Review*, *26*(2), 196-204. ; Jakus, P. M., McGuinness, M., & Krupnick, A. J. (2002). *The benefits and costs of fish consumption advisories for mercury*. ; Williams, R. L., O'Leary, J. T., Sheaffer, A. L., & Mason, D. (2000). An examination of fish consumption by Indiana recreational anglers: an on-site survey. *West Lafayette, IN: Purdue University*.). Therefore, only 17.4 percent of fishers may adjust their behavior in response to FCA (U.S. Environmental Protection Agency. (2015a). *Benefit and Cost Analysis for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category*. (EPA-821-R-15-005).). The analysis reflects EPA's expectations that fishers responses to FCA are reflected in their catch and release practices.

81 The racial/ethnic categories are based on available fish consumption data as well as the breakout of ethnic/racial populations in Census data, which distinguishes racial groups within Hispanic and non-Hispanic categories.

82 The Mexican Hispanic and Hispanic block group populations were calculated by applying the Census tract percent Mexican Hispanic and Hispanic to the underlying block-group populations, since these data were not available at the block-group level.

83 Data are not available on the share of the fishing population that practices subsistence fishing. EPA assumed that 5 percent of people who fish practice subsistence fishing, based on the assumed 95th percentile fish consumption rate for this population in EPA's Exposure Factors Handbook (see U.S. Environmental Protection Agency. (2011). *Exposure Factors Handbook, 2011 Edition (Final)*. (EPA-600-R-09-025F). U.S. Environmental Protection Agency, Washington, DC).

groups, based on the share of people below the federal poverty line.[84] After subdividing population groups by age, race, fishing mode, and poverty indicator, each CBG has 196 unique population cohorts (7 age groups × 7 ethnic/racial groups × 2 fishing modes [recreational versus subsistence fishing] × 2 poverty status designations) for the analysis of benefits to children from reductions in lead and mercury and cancer benefits from reductions in arsenic, and each CBG has 1,148 unique population cohorts (41 age groups × 7 ethnic/racial groups × 2 fishing modes [recreational versus subsistence fishing] × 2 poverty status designations) for the analysis of adult lead benefits.

EPA distinguished the exposed population by racial/ethnic group and poverty status to support analysis of potential environmental justice (EJ) considerations from baseline exposure to pollutants in steam electric power plant discharges, and to allow evaluation of the effects of the regulatory options on mitigating any EJ concerns. See EJA document for details of the EJ analysis. As noted below, distinguishing the exposed population in this manner allows the Agency to account for differences in exposure among demographic groups, where supported by available data.

Equation 5-1 shows how EPA estimated the population potentially exposed to steam electric pollutants, *ExPop(i)(s)(c)*, for CBG *i* in state *s* for cohort *c*.

Equation 5-1. $$\boldsymbol{ExPop(i)(s)(c)} = \boldsymbol{Pop(i)(c)} \times \boldsymbol{\%Fish(s)} \times \boldsymbol{CaR(c)}$$

Where:

Pop(i)(c) = Total CBG population in cohort c. Age and racial/ethnicity-specific populations in each CBG are based on data from the 2021 American Community Survey, which provides population numbers for each CBG broken out by age and racial/ethnic group. To estimate the population in each age- and ethnicity/race-specific group, EPA calculated the share of the population in each racial/ethnic group and applied those percentages to the population in each age group.

%Fish(s) = Fraction of people who live in households with fishers. To estimate what percentage of the total population participates in fishing, EPA used region-specific U.S. Fish and Wildlife Service (U.S. FWS, 2023) estimates of the population 16 and older who fish.[85] EPA assumed that the share of households that includes fishers is equal to the fraction of people over 16 who participate in recreational fishing.

CaR(c) = Adjustment for catch-and-release practices. According to U.S. FWS (U.S. FWS, 2006) data, approximately 23.3 percent of recreational fishers release all the fish they catch ("catch-and-release" fishers). Fishers practicing "catch-and-release" would not be exposed to steam electric pollutants via consumption of contaminated fish. For all recreational fishers, EPA reduced the affected population by 23.3 percent. EPA assumed that subsistence fishers do not practice "catch-and-release" fishing.

84 Poverty status is based on data from the Census Bureau's American Community Survey which determines poverty status by comparing annual income to a set of dollar values called poverty thresholds that vary by family size, number of children, and the age of the householder.

85 The share of the population who fishes ranges from 10 percent in the Pacific region to 22 percent in the West North Central region. Other regions include the Middle Atlantic (12 percent), New England (12 percent), Mountain (15 percent), South Atlantic (16 percent), East North Central (17 percent), West South Central (17 percent), and East South Central (20 percent).

Table 5-1 summarizes the population living within 50 miles of reaches affected by steam electric power plant discharges (see Section 5.2.1 for a discussion of this distance buffer) and EPA's estimate of the population potentially exposed to the pollutants via consumption of subsistence- and recreationally-caught fish (based on 2021 population data and not adjusted for population growth during the analysis period). Of the total population, 17 percent live within 50 miles of an affected reach and participate in recreational and/or subsistence fishing, and 13 percent are potentially exposed to fish contaminated by steam electric pollutants in bottom ash transport water, FGD wastewater, CRL, and legacy wastewater discharges.

Table 5-1: Summary of Population Potentially Exposed to Contaminated Fish Living within 50 Miles of Affected Reaches (as of 2021)

Total population	126,726,686
Total fishers population[a]	21,532,470
Population potentially exposed to contaminated fish[b, c]	16,766,257

a. Total population living within 50 miles of an affected reach multiplied by the state-specific share of the population who fishes based on U.S. FWS (2023; 2018; between 10 percent and 22 percent, depending on the state).

b. Total fishers population adjusted to remove fishers practicing catch-and-release and who therefore do not consume self-caught fish.

c. Analysis accounts for projected population growth so that the average population in scope of the analysis over the period of 2025 through 2049 is 10.8 percent higher than the population in 2021 presented in the table, or 18.6 million people. The analysis estimates that the fraction of the U.S. population engaged in recreational and subsistence fishing remains constant from 2025 through 2049.

Source: U.S. EPA Analysis, 2024

5.2 Pollutant Exposure from Fish Consumption

EPA calculated an average fish tissue concentration for each pollutant for each CBG based on a length-weighted average concentration for all reaches within 50 miles. Depending on the health endpoint used in the analysis, EPA calculated either the average daily dose (ADD) or lifetime average daily dose (LADD) for each combination of pollutant, cohort and CBG.

5.2.1 Fish Tissue Pollutant Concentrations

The set of reaches that may represent a source of contaminated fish for recreational and subsistence fishers in each CBG depends on the typical distance fishers travel to fish. EPA assumed that fishers typically travel up to 50 miles to fish,[86] and used this distance to estimate the relevant fishing sites for the population of fishers in each CBG.

Fishers may have several fishable sites to choose from within 50 miles of travel. To account for the effect of substitute sites, EPA assumed that fishing efforts are uniformly distributed among all the available fishing sites within 50 miles from the CBG (travel zone). For each CBG, EPA identified all fishable reaches within 50 miles (where distance was determined based on the Euclidean distance between the centroid of the CBG and the midpoint of the reach) and the reach length in miles.

86 Studies of fishers behavior and practices have made similar observations (*e.g.*, Sohngen, B., Zhang, W., Bruskotter, J., & Sheldon, B. (2015). Results from a 2014 survey of Lake Erie anglers. *Columbus, OH: The Ohio State University, Department of Agricultural, Environmental and Development Economics and School of Environment & Natural Resources*. and Sea Grant - Illinois-Indiana. (2018). Lake Michigan anglers boost local Illinois and Indiana economies. Retrieved 2019, from https://iiseagrant.org/lake-michigan-anglers-boost-illinois-and-indiana-local-economies/).

EPA then calculated, for each CBG within the 50-mile buffer of a fishable reach, the fish tissue concentration of As, Hg, and lead (Pb). Appendix E in U.S. EPA (2020b) describes the approach used to calculate fish tissue concentrations of steam electric pollutants in the baseline and under each of the regulatory options.

For each CBG, EPA then calculated the reach length ($Length_i$) weighted fish fillet concentration (C_{Fish_Fillet} *(CBG))* based on all fishable reaches within the 50-mile radius according to Equation 5-2. See Appendix E for additional details about the derivation of fish tissue concentration values.

Equation 5-2. $$C_{Fish_{Fillet_e}}(CBG) = \frac{\sum_{i=1}^{n} C_{Fish_{Fillet}}(i) * Length_i}{\sum_{i=1}^{n} Length_i}$$

5.2.2 Average Daily Dose

Exposure to steam electric pollutants via fish consumption depends on the cohort-specific fish consumption rates. Table 5-2 summarizes the average fish consumption rates, expressed in daily grams per kilogram of body weight (BW), according to the race/ethnicity and fishing mode. The rates reflect recommended values for consumer-only intake of finfish in the general population from all sources, based on EPA's Exposure Factors Handbook (U.S. EPA, 2011). For more details on these fish consumption rates, see the EA (U.S. EPA, 2024b) and the uncertainty discussion in Section 5.9.

Table 5-2: Summary of Group-specific Consumption Rates for Fish Tissue Consumption Risk Analysis

Race/ Ethnicity[a]	EA Cohort Name[b]	Consumption Rate (g/kg BW/day)	
		Recreational	Subsistence
White (non-Hispanic)	Non-Hispanic White	0.67	1.9
African American (non-Hispanic)	Non-Hispanic Black	0.77	2.1
Asian/Pacific Islander (non-Hispanic)	Other, including Multiple Races	0.96	3.6
Tribal/Native Alaskan (non-Hispanic)	Other, including Multiple Races	0.96	3.6
Other non-Hispanic	Other, including Multiple Races	0.96	3.6
Mexican Hispanic	Mexican Hispanic	0.93	2.8
Other Hispanic	Other Hispanic	0.82	2.7

a. Each group is also subdivided into seven age groups (0-1, 2, 3-5, 6-10, 11-15, 16-20, Adult [21 or higher] and two income groups [above and below the poverty threshold]).

b. See EA for details (U.S. EPA, 2024b).

Source: U.S. EPA Analysis, 2024

Equation 5-3 and Equation 5-4 show the cohort- and CBG-specific ADD and LADD calculations based on fish tissue concentrations, consumption rates, and exposure duration and averaging periods detailed in the EA (U.S. EPA, 2024b.

Equation 5-3. $$\boldsymbol{ADD(c)(i) = \frac{C_{fish\_fillet}(i) \times CR_{Fish}(c) \times F_{Fish}}{1000}}$$

Where:

$ADD(c)(i)$ = average daily dose of pollutant from fish consumption for cohort c in CBG i (milligrams[mg] per kilogram [kg] body weight [BW] per day)

$C_{fish\_fillet}(i)$ = average fish fillet pollutant concentration consumed by humans for CBG i (mg per kg)

$CR_{fish}(c)$ = consumption rate of fish for cohort c (grams per kg BW per day); see Table 5-2

F_{fish} = fraction of fish from reaches within the analyzed distance from the CBG (percent; estimated value of 100%)

Equation 5-4. $$LADD(c)(i) = \frac{ADD(c)(i) \times ED(c) \times EF}{AT \times 365}$$

Where:

LADD (*c*)(*i*) = lifetime average daily dose (mg per kg BW per day) for cohort *c* in CBG *i*

ADD (*c*)(*i*) = average daily dose (mg per kg BW per day) for cohort *c* in CBG *i*

ED(*c*) = exposure duration (years) for cohort *c*

EF = exposure frequency (days; set to 350)

AT = averaging time (years; set to 70)

EPA used the doses of steam electric pollutants as calculated above from fish caught through recreational and subsistence fishing in its analysis of benefits associated with the various human health endpoints described below.

5.3 Health Effects in Children from Changes in Lead Exposure

Lead is a highly toxic pollutant that can cause a variety of adverse health effects in children of all ages. In particular, elevated lead exposure may induce a number of adverse neurological effects in children, including decline in cognitive function, conduct disorders, attentional difficulties, internalizing behavior,[87] and motor skill deficits (see NTP, 2012; ATSDR, 2020; U.S. EPA, 2024d, 2019e, 2020g, and 2024d). Elevated blood lead level (BLL) in children may also slow postnatal growth in children ages one to 16, delay puberty in 8- to 17-year-olds, and decrease hearing and motor function (NTP, 2012; ATSDR, 2020; U.S. EPA, 2019e and 2024d). Lead exposure is also associated with adverse health outcomes related to the immune system, including atopic and inflammatory responses (*e.g.*, allergy and asthma) and reduced resistance to bacterial infections. Studies have also found a relationship between lead exposure in expectant mothers and lower birth weight in newborns (NTP, 2012; ATSDR, 2020; U.S. EPA, 2019e and 2024d; Zhu et al., 2010). For this final rule, EPA estimated the effects of changes in neurological and cognitive damages to children ages 0 to 7 using the dose-response relationship for IQ decrements (Crump et al., 2013).[88]

EPA estimated health effects from changes in exposure to lead to preschool children using BLL as a biomarker of lead exposure. EPA modeled BLL under the baseline and regulatory option scenarios, and then used a concentration-response relationship between BLL and IQ loss to estimate changes in IQ losses in the affected population of children and changes in incidences of extremely low IQ scores (less than 70, or two standard deviations below the mean). EPA calculated the monetary value of changes in children's health effects based on the impact of an additional IQ point on an individual's future earnings.

EPA used the methodology described in Section 5.1 to estimate the population of children from birth to age seven who live in recreational fisher and subsistence fisher households and are potentially exposed to lead via

87 Behavioral difficulties in children may include both externalizing behavior (*e.g.*, inattention, impulsivity, conduct disorders), and internalizing behaviors (*e.g.*, withdrawn behaviors, symptoms of depression, fearfulness, and anxiety).

88 EPA also evaluated estimating the effects of changes in lead exposure on ADHD in children and low birthweight in infants, but given the small magnitude of IQ point effects for the final rule and the fact that regulatory analyses for other rules have shown avoided IQ losses to be larger than ADHD and birthweight effects, EPA did not quantify these additional benefits. For example, the 2023 Lead and Copper Rule Improvements (LCRI) proposed rulemaking showed the cognitive development benefits from avoided IQ losses to be 3 to 13 times ADHD benefits and 150 to 1,000 times low-birthweight benefits, depending on the scenario and discount rate (U.S. Environmental Protection Agency. (2023f). *Economic Analysis for the Proposed Lead and Copper Rule Improvements*.).

consumption of contaminated fish tissue. EPA notes that fish tissue is not the only route of exposure to lead among children. Other routes of exposure may include drinking water, dust, and other food. EPA used reference exposure values for these other routes of lead exposures and held these values constant for the baseline and regulatory options scenarios. Since this health effect applies to children up to the seventh birthday only, EPA restricted the analysis to the relevant age cohorts of fisher household members.

5.3.1 Data and Methodology

This analysis considers children who are born after implementation of the regulatory options and live in recreational fisher and subsistence fisher households. It relies on EPA's Integrated Exposure, Uptake, and Biokinetics (IEUBK) Model for Lead in Children (version 2; U.S. EPA, 2021a), which uses lead concentrations in a variety of media – including soil, dust, air, water, and diet – to estimate total exposure to lead for children in seven one-year age cohorts from birth through the seventh birthday. Based on the estimated total exposure, the model generates a predicted geometric mean BLL for a population of children exposed to similar lead levels. See the 2013 BCA report (U.S. EPA, 2013a) for details.

For each CBG, EPA used the cohort-specific ADD based on Equation 5-3. EPA then multiplied the cohort-specific ADD by the average body weight for each age group[89] to calculate the "alternative source" dietary input for the IEUBK model, which varied by option relative to the baseline. All other sources of lead were held constant. Lead bioavailability and uptake after consumption vary for different chemical forms. Many factors complicate the estimation of bioavailability, including nutritional status and timing of meals relative to lead intake. For this analysis, EPA used the default media-specific bioavailability factor for the "alternative source" provided in the IEUBK model, which is 50 percent for oral ingestion.

EPA used the IEUBK model to generate the geometric mean BLL for each cohort in each CBG under the baseline and post-technology implementation scenarios. The IEUBK model processes daily intake to two decimal places (μg/day). For this analysis, this means that some of the change between the baseline and regulatory options is not accounted for by using the model (*i.e.*, IEUBK treats these very small changes as zero). This aspect of the model contributes to potential underestimation of the lead-related health effects in children arising from the regulatory options, since the estimated changes in health effects are driven by small changes across large populations.

EPA used the Crump et al. (2013) dose-response function to estimate changes in IQ losses between the baseline and regulatory options. Comparing the baseline and regulatory option results provides the changes in IQ loss per child. Crump et al. (2013) concluded that there was statistical evidence that the exposure-response is non-linear over the full range of BLL. Equation 5-5 shows an exposure-response function that represents this non-linearity:

89 The average body weight values are 11.4 kg for ages 0 to 2, 13.8 kg for ages 2 to less than 3, 18.6 kg for ages 3 to less than 6, and 31.8 kg for ages 6 to 7.

Equation 5-5. $$\Delta \boldsymbol{IQ} = \beta_1 \times \boldsymbol{ln}(\boldsymbol{BLL} + \mathbf{1})$$

Where:

β_1 = -3.315 (log-linear regression coefficient on the lifetime blood lead level[90])

Multiplying the result by the number of affected pre-school children yields the total change in the number of IQ points for the affected population of children for the baseline and each regulatory option.

The IEUBK model estimates the mean of the BLL distribution in children, assuming a continuous exposure pattern for children from birth through the seventh birthday. The 2021 American Community Survey indicates that children ages 0 to 7 are approximately evenly distributed by age. To get an annual estimate of the number of children that would benefit from implementation of the regulatory options, EPA divided the estimated number of affected children by 7. This division adjusts the equation to apply only to children age 0 to 1. The estimated changes in IQ loss represent an annual value (*i.e.*, it would apply to the cohort of children born each year after implementation).[91] Equation 5-6 shows this calculation for the annual increase in total IQ points.

Equation 5-6. $$\Delta \boldsymbol{IQ}(\boldsymbol{i})(\boldsymbol{c}) = \left(\mathbf{ln}\big(\Delta \boldsymbol{GM}(\boldsymbol{i})(\boldsymbol{c})\big) \times \mathbf{CRF} \times \left(\frac{\boldsymbol{ExCh}(\boldsymbol{i})(\boldsymbol{c})}{\mathbf{7}}\right)\right)$$

Where:

ΔIQ(i)(c) = the difference in total IQ points between the baseline and regulatory option scenarios for cohort *c* in CBG *i*

Ln(ΔGM(i)(c)) = the log-linear change in the average BLL in affected population of children (μg/dL) for cohort *c* in CBG *i*

CRF = -3.315, the log-linear regression coefficient from Crump et al. (2013)

ExCh(i)(c) = the number of affected children aged 0 to 7 for cohort *c* in CBG *i*

The available economic literature provides little empirical data on society's overall WTP to avoid a decrease in children's IQ. To estimate the value of avoided IQ losses, EPA used estimates of the changes in a child's future expected lifetime earnings per one IQ point reduction using the methodology presented in Salkever (1995) but with more recent data from the 1997 National Longitudinal Survey of Youth (U.S. EPA, 2019d). Updated results based on Salkever (1995) indicate that a one-point IQ reduction reduces expected lifetime earnings by 2.63 percent. Table 5-3 summarizes the estimated values of an IQ point based on the updated Salkever (1995) analysis using a 2 percent discount rate. For the lead analysis, the value is discounted to the third year of life to represent the midpoint of the exposed children population. For the mercury analysis (Section 5.5), the value of an IQ point is discounted to birth to better align the benefits of reducing exposure

90 The lifetime blood lead level in children ages 0 to 7 is defined as a mean from six months of age to present (Crump, K. S., Van Landingham, C., Bowers, T. S., Cahoy, D., & Chandalia, J. K. (2013). A statistical reevaluation of the data used in the Lanphear et al. pooled-analysis that related low levels of blood lead to intellectual deficits in children. *Critical reviews in toxicology*, *43*(9), 785-799.).

91 Dividing by seven undercounts overall benefits. Children from ages 1 to 7 (*i.e.*, born prior to the base year of the analysis) are not accounted for in the analysis, although they are also affected by changes in lead exposure.

to mercury with in-utero exposure (U.S. EPA, 2019f). EPA also used an alternative value of an IQ point from Lin, Lutter and Ruhm (2018) in a sensitivity analysis (see Appendix G).

Table 5-3: Value of an IQ Point (2023$) based on Expected Reductions in Lifetime Earnings, 2 Percent Discount Rate

Discount Age	Value of an IQ Point[a,b] (2023$)
Discounted to Age 3 (Lead)	$39,930
Discounted to Birth (Mercury)	$37,627

a. Values are adjusted for the cost of education.

b. EPA adjusted the value of an IQ point to 2023 dollars using the GDP deflator.

Source: U.S. EPA (2019d) re-analysis of data from Salkever (1995); 2 percent estimates calculated for U.S. EPA (2023f)

5.3.2 Results

Table 5-4 shows the benefits associated with changes in IQ losses from lead exposure via consumption of self-caught fish. Avoided IQ point losses over the entire in-scope population of children with changes in lead exposure is approximately 1 point. Estimated annualized benefits from avoided IQ losses are less than $0.01 million.

Table 5-4: Estimated Benefits from Avoided IQ Losses for Children Exposed to Lead under the Regulatory Options, Compared to Baseline

Regulatory Option	Average Annual Number of Children 0 to 7 in Scope of the Analysis[b]	Total Avoided IQ Point Losses, 2025 to 2049 in All Children 0 to 7 in Scope of the Analysis[c]	Annualized Value of Avoided IQ Point Losses[a] (Millions 2023$; 2% Discount Rate)
Option A	1,555,558	1	<$0.01
Option B (Final Rule)	1,555,558	1	<$0.01
Option C	1,555,558	1	<$0.01

a. Based on estimate that the loss of one IQ point results in the loss of 2.63 percent of lifetime earnings, following updated Salkever (1995) values from U.S. EPA (2019d).

b. The number of children in scope of the analysis is based on reaches analyzed across the regulatory options. Some of the children included in this count see no changes in exposure under some options.

c. EPA notes that the IEUBK model does not analyze BLL changes beyond two decimal points and therefore the analysis omits benefits from very small changes in lead exposure and resulting BLL changes.

Source: U.S. EPA Analysis, 2024

5.4 Health Effects in Adults from Changes in Lead Exposure

As described in Chapter 2 of this document and in the EA (U.S. EPA, 2024b), exposure to lead can result in numerous adverse health effects in adults, including increasing the incidence of cardiovascular disease premature mortality (*e.g.*, Aoki et al., 2016; Lanphear et al., 2018; Navas-Acien, 2021; U.S. EPA, 2023f; 2024d).

To analyze the benefits of reducing exposure to lead from the consumption of self-caught fish, EPA adapted the methodology used in the Agency's analysis of the 2023 Lead and Copper Rule Improvements (LCRI) proposed rulemaking (U.S. EPA, 2023f) to reflect differences in exposure and affected populations. This methodology relies on concentration-response functions relating adult BLL level to CVD mortality.

5.4.1 Data and Methodology

The affected population is derived from that described in Section 5.1 and consists of adults aged 40 to 80 who live in recreational and subsistence fisher households near reaches affected by steam electric power plant discharges and who are potentially exposed to lead via consumption of contaminated fish tissue. To estimate total exposure to lead for individuals from 40 to age 80, EPA relied on the All Ages Lead Model (AALM),[92] which uses lead concentrations in a variety of media, including soil, dust, air, water, and food to predict lead concentration in body tissues and organs of hypothetical individuals based on a simulated lifetime of lead exposure (U.S. EPA, 2019a). EPA only varied lead intake via food to account for varying levels of lead exposure caused by consuming exposed fish and left all other media at their recommended default value. To estimate the "food" input for the AALM, EPA first estimated the cohort-specific ADD for each CBG based on Equation 5-3. EPA then multiplied the cohort-specific ADD by the average body weight for each age group in Table 5-5. Based on the estimated total exposure to lead, the model generates a predicted BLL geometric mean for a population of adults.

Table 5-5: Estimated Average Body Weights (kg) by Age and Gender

Age	Males	Females	Age	Males	Females
0 to 1	9.30	9.30	43 to 44	89.48	71.59
1 to 2	11.30	11.50	44 to 45	87.00	74.86
2 to 3	13.70	13.30	45 to 46	84.61	81.15
3 to 4	16.40	15.20	46 to 47	93.27	74.94
4 to 5	18.80	18.10	47 to 48	80.87	68.24
5 to 6	20.20	20.70	48 to 49	85.58	82.10
6 to 7	22.90	22.00	49 to 50	88.84	75.55
7to 8	28.10	26.00	50 to 51	90.09	83.22
8 to 9	31.90	30.80	51 to 52	90.63	76.89
9 to 10	36.10	36.00	52 to 53	90.62	80.89
10 to 11	39.50	39.40	53 to 54	92.42	76.12
11 to 12	42.00	47.20	54 to 55	90.51	75.19
12 to 13	49.40	51.60	55 to 56	84.84	79.87
13 to 14	54.90	59.80	56 to 57	84.48	80.68
14 to 15	65.10	59.90	57 to 58	86.02	73.07
15 to 16	68.20	63.40	58 to 59	89.11	71.21
16 to 17	72.50	63.40	59 to 60	83.82	76.28
17 to 18	75.40	59.90	60 to 61	89.53	75.97
18 to 19	74.80	65.00	61 to 62	86.04	77.01
19 to 20	80.10	68.70	62 to 63	84.46	75.78
20 to 21	80.00	66.30	63 to 64	86.51	77.95
21 to 22	73.84	65.89	64 to 65	91.45	76.75
22 to 23	89.62	67.27	65 to 66	89.46	72.95
23 to 24	83.39	73.58	66 to 67	90.40	79.00
24 to 25	80.26	71.81	67 to 68	85.34	77.76
25 to 26	87.47	71.64	68 to 69	84.48	73.28
26 to 27	72.11	78.09	69 to 70	92.35	69.94
27 to 28	85.78	72.48	70 to 71	81.91	70.50
28 to 29	88.04	76.18	71 to 72	79.65	66.22
29 to 30	84.02	71.88	72 to 73	84.67	76.89
30 to 31	80.10	74.00	73 to 74	89.70	72.75

[92] The AALM is an outgrowth of the IEUBK model used in the analysis described in Section 5.3.

Table 5-5: Estimated Average Body Weights (kg) by Age and Gender

Age	Males	Females	Age	Males	Females
31 to 32	84.65	79.12	74 to 75	80.85	69.21
32 to 33	90.99	77.53	75 to 76	84.26	68.61
33 to 34	90.90	76.60	76 to 77	86.13	67.42
34 to 35	79.09	73.26	77 to 78	81.68	78.35
35 to 36	91.15	79.91	78 to 79	81.99	72.30
36 to 37	88.96	72.10	79 to 80	80.18	67.95
37 to 38	84.62	70.75	80 to 81	75.90	60.97
38 to 39	80.52	80.86	81 to 82	73.77	68.76
39 to 40	84.77	78.08	82 to 83	81.01	62.93
40 to 41	92.21	73.87	83 to 84	76.07	66.24
41 to 42	83.11	75.91	84 to 85	73.06	66.29
42 to 43	91.94	82.03	85+	74.10	59.68

Note: Data converted from ages in months to ages in years (*e.g.*, age 1–2 year represents ages from 12 to 23 months).

Source: Adapted from Table 8-24 in U.S. EPA (2011)

Because the AALM assumes a linear relationship between lead intake from food ingestion and BLL, EPA calculated age- and sex-specific slopes that approximate the linear relationship between lead intake from food ingestion and BLL, instead of running the AALM for each CBG and cohort-specific lead intakes.[93] EPA used the age- and sex-specific slopes to scale a cohort's BLL given their lead intake from fish ingestion for the two periods under the baseline and each regulatory option. EPA estimated small BLL changes during the period of analysis, ranging between zero and 0.001 µg/dL and with an average of 0.0007 µg/dL across the exposed population under Option C.

EPA relied on the relationship between BLL and CVD mortality from Aoki et al. (2016) and Lanphear et al. (2018) to link the estimated BLL to changes in CVD mortality. Both studies use regression models to relate log-transformed BLL to CVD mortality, as shown in Equation 5-7. To estimate the annual number of avoided CVD mortality cases, EPA multiplied the estimated change in CVD mortality risk by the affected population (Equation 5-8). Consistent with the methodology used in LCRI (U.S. EPA, 2023f), EPA assumed a 10-year window of exposure. Therefore, the BLL (x_2 and x_1 in Equation 5-7 and Equation 5-8) represent an individual's average BLL over the past ten years. EPA assumed that the change in lead intake, and resulting change in BLL, occur instantaneously.[94] Since the change in lead intake and BLL realistically occurs over time, this assumption tends to overstate the benefits from the change in exposure to lead in fish tissue.

Equation 5-7.

$$\Delta CVD\ Mortality = y_1 \left(1 - e^{\beta log_z\left(\frac{x_2}{x_1}\right)}\right)$$

Equation 5-8.

$$Deaths\ Avoided = y_1 \left(1 - e^{\beta log_z\left(\frac{x_2}{x_1}\right)}\right) * pop$$

93 This approach enables the analysis to remain sensitive to very small changes in BLL from changes in lead exposure.

94 In the LCRI analysis, EPA assumed that lead intake, and resulting BLL, changed gradually.

Where:

y_1 = Hazard rate of CVD mortality in baseline scenario (*i.e.*, without the rule)

β = Beta coefficient, which represents the change in CVD mortality per unit change in BLL

Log_z = Log transformation to the base z (*i.e.*, $\log_{10}$)

x_2 = BLL associated with the regulatory option

x_1 = BLL associated with the baseline

pop = population for whom the change in BLL occurs

EPA obtained the baseline hazard rates of CVD mortality (y_1) used in Equation 5-7 and Equation 5-8 from the CDC's Wonder database (see Table 5-6).

Table 5-6: Baseline Hazard Rates of CVD Mortality by Age and Gender

Age	Male	Female
40-49	0.000786	0.000377
50-59	0.002186	0.000972
60-69	0.004598	0.002211
70-80	0.010802	0.006751

Source: U.S. EPA, 2023f, originally obtained from Centers for Disease Control and Prevention, 2014

EPA calculated low and high estimates of the effect of BLL on CVD mortality to reflect the uncertainty over the best functional form that describes the relationship between BLL and CVD mortality. The low estimate (β = 0.36) is based on Aoki et al. (2016) and the high estimate (β = 0.96) is based on Lanphear et al. (2018). Using these beta coefficients in Equation 5-7 and Equation 5-8, EPA calculated high and low estimates of the change in CVD mortality risk and the number annual deaths avoided under each regulatory option.

To value changes in CVD mortality, EPA used the VSL described in Section 4.3.4. The product of VSL and the estimated population level reduction in risk of CVD mortality in a given year represents the affected population's aggregate WTP to reduce the probability of CVD-related death in one year.

5.4.2 Results

Table 5-7 summarizes estimated benefits from avoided CVD mortality from reducing lead exposure via consumption of self-caught fish under each regulatory option. The estimated benefits of the final rule range from \$0.16 million to \$0.43 million.

Table 5-7: Estimated Benefits from Avoided CVD Deaths for Adults Aged 40-80 For All Regulatory Options, Compared to Baseline

Regulatory Option	Number of Adults in Scope of the Analysis[a]	Total CVD Deaths Avoided[b] 2025 to 2049 in All Adults in Scope of Analysis		Annualized Value of Avoided CVD Deaths (2% Discount Rate; Millions 2023$)	
		Low	High	Low	High
Option A	21,684,921	0.42	1.13	$0.16	$0.43
Option B (Final Rule)	21,684,921	0.42	1.13	$0.16	$0.43
Option C	21,684,921	0.45	1.20	$0.17	$0.45

a. The number of adults in scope of the analysis is based on reaches analyzed across the regulatory options. Some of the adults included in this count see no changes in exposure under some options. Benefits accrue to the subset of adults that experience changes in exposure under one or more options (576,537 adults in 2025). Under the assumption that fishers would share their catch with members of their household, EPA included household members in this subset.

b. Assumes that the distribution for the individuals experiencing lead-related CVD mortality is the same as the distribution of CVD mortality irrespective of the cause.

Source: U.S. EPA Analysis, 2024

5.5 Heath Effects in Children from Changes in Mercury Exposure

Mercury can have a variety of adverse health effects on adults (*e.g.*, vision defects, tremors, cerebellar changes, and mortality) and children (*e.g.*, neurological effects) (U.S. EPA, 2024b; Grandjean et al., 2014; Hollingsworth & Rudik, 2021; Mergler et al., 2007; CDC, 2009). The regulatory options may change the discharge of mercury to surface waters by steam electric power plants and therefore affect a range of human health outcomes. Due to data limitations, however, EPA estimated only the monetary value of the changes in IQ losses among children exposed to mercury *in-utero* as a result of maternal consumption of contaminated fish.

EPA identified the population of children exposed *in-utero* starting from the CBG-specific population in scope of the analysis described in Section 5.1. Therefore, this analysis only reflects health effects from consumption of self-caught fish by households. Also, because this analysis focuses only on infants born after implementation of the regulatory options, EPA further limited the analyzed population by estimating the number of women between the ages of 15 and 44 potentially exposed to contaminated fish caught in the affected waterbodies and multiplying the result by ethnicity-specific average fertility rates.[95] This yields the cohort-specific annual number of births for each CBG.

The U.S. Department of Health and Human Services provides fertility rates by race for 2021 in the National Vital Statistics Report (Osterman et al., 2023). The fertility rate measures the number of births occurring per 1,000 women between the ages of 15 and 44 in a particular year. Fertility rates were highest for Hispanic women at 63.4, followed by African Americans at 57.4, other race/ethnicities at 56.3, Caucasians at 54.4, Native Americans at 50.8, and Asians at 49.6.

5.5.1 Data and Methodology

EPA used the ethnicity- and mode-specific consumption rates shown in Table 5-2 and calculated the CBG- and cohort-specific mercury ADD based on Equation 5-3. As EPA is not aware of consumption rates specific

95 EPA acknowledges that fertility rates vary by age. However, the use of a single average fertility rate for all ages is not expected to bias results because the average fertility rate reflects the underlying distribution of fertility rates by age.

to pregnant women, the analysis uses the same consumption rates as in the general population within each analyzed cohort.

In this analysis, EPA used a linear dose-response relationship between maternal mercury hair content and subsequent childhood IQ loss from Axelrad et al. (2007). Axelrad et al. (2007) developed a dose-response function based on data from three epidemiological studies in the Faroe Islands, New Zealand, and Seychelle Islands. According to their results, there is a 0.18-point IQ loss for each 1 part-per-million (ppm) increase in maternal hair mercury.

To estimate maternal hair mercury concentrations based on the daily intake (see Section 5.2.2), EPA used the median conversion factor derived by Swartout and Rice (2000), who estimated that a 0.08 µg/kg body weight increase in daily mercury dose is associated with a 1 ppm increase in hair concentration. Equation 5-9 shows EPA's calculation of the total annual IQ changes for a given receiving reach.

Equation 5-9. $$\boldsymbol{IQL}(\boldsymbol{i})(\mathbf{c}) = \boldsymbol{InExPop}(\boldsymbol{i})(\boldsymbol{c}) * \boldsymbol{MADD}(\boldsymbol{i})(\boldsymbol{c}) * \left(\frac{\mathbf{1}}{\boldsymbol{Conv}}\right) * \boldsymbol{DRF}$$

Where:

IQL(i)(c) = IQ changes associated with *in-utero* exposure to mercury from maternal consumption of fish contaminated with mercury for cohort *c* in CBG *i*

InExPop(i)(c) = population of infants in scope of the analysis for cohort *c* in CBG *i* (the number of births)

MADD(i)(c) = maternal ADD for cohort *c* in CBG *i* (µg/kg BW/day)

Conv = conversion factor for hair mercury concentration based on maternal mercury exposure (0.08 µg/kg BW/day per 1 ppm increase in hair mercury)

DRF = dose response function for IQ decrement based on marginal increase in maternal hair mercury (0.18-point IQ decrement per 1 ppm increase in hair mercury)

Summing estimated IQ changes across all analyzed CBGs yields the total changes in the number of IQ points due to *in-utero* mercury exposure from maternal fish consumption under each analyzed regulatory option. The benefits of the regulatory options are calculated as the change in IQ points between the baseline and modeled post-technology implementation conditions under each of the regulatory options.

The available economic literature provides little empirical data on society's overall WTP to avoid a decrease in children's IQ. To estimate the value of avoided IQ losses, EPA used estimates of the changes in a child's future expected lifetime earnings per one IQ point reduction, discounted to birth (Table 5-3). EPA also used an alternative value of an IQ point from Lin, Lutter and Ruhm (2018) in a sensitivity analysis (see Appendix G).

5.5.2 Results

Table 5-8 shows the estimated changes in IQ point losses for infants exposed to mercury in-utero and the corresponding monetary values. The final rule (Option B) results in 1,377 avoided IQ point losses over the entire in-scope population of infants with changes in mercury exposure. The annualized benefits of avoided IQ point losses are $1.98 million.

Table 5-8: Estimated Benefits from Avoided IQ Losses for Infants from Mercury Exposure under the Regulatory Options, Compared to Baseline

Regulatory Option	Number of Infants in Scope of the Analysis per Year[b]	Total Avoided IQ Point Losses, 2025 to 2049 in All Infants in Scope of the Analysis	Annualized Value of Avoided IQ Point Losses[a] (Millions 2023$; 2% Discount Rate)
Option A	201,850	1,190	$1.71
Option B (Final Rule)	201,850	1,377	$1.98
Option C	201,850	1,393	$2.00

a. Based on the estimate that the loss of one IQ point results in the loss of 2.63 percent of lifetime earnings discounted to birth, following updated Salkever (1995) values from U.S. EPA (2019f).

b. The number of infants in scope of the analysis is based on reaches analyzed across the regulatory options. Some of the children included in this count see no changes in exposure under some options.

Source: U.S. EPA Analysis, 2024

5.6 Estimated Changes in Cancer Cases from Arsenic Exposure

Among steam electric pollutants that can contaminate fish tissue and are analyzed in the EA, arsenic is the only confirmed carcinogen with a published dose response function (see U.S. EPA, 2010).[96] EPA used the methodology presented in Section 3.6 of the 2015 BCA (U.S. EPA, 2015a) to estimate the number of annual skin cancer cases associated with consumption of fish contaminated with arsenic from steam electric power plant discharges under the baseline and the change corresponding to each regulatory option and the associated monetary values. EPA's analysis shows negligible changes in skin cancer cases from exposure to arsenic via consumption of self-caught fish under the regulatory options.[97] Accordingly, the estimated benefits are also negligible under all regulatory options and are not included in the total monetized benefits.

5.7 Monetary Values of Estimated Changes in Human Health Effects

Table 5-9 presents the estimated benefits under the regulatory options of changes in adverse human health outcomes associated with the consumption of self-caught fish. The estimated benefits of the final rule (Option B) range from $2.14 million to $2.41 million. Changes in mercury exposure for children account for the majority of total monetary values from increases in adverse health outcomes.

Table 5-9: Estimated Benefits of Changes in Human Health Outcomes Associated with Fish Consumption under the Regulatory Options, Compared to Baseline (Millions of 2023$; 2% Discount Rate)

Regulatory Option	Changes in Lead Exposure for Children	Changes in Lead Exposure for Adults		Changes in Mercury Exposure for Children	Total	
		Low	High		Low	High
Option A	<$0.01	$0.16	$0.43	$1.71	$1.87	$2.14
Option B (Final Rule)	<$0.01	$0.16	$0.43	$1.98	$2.14	$2.41
Option C	<$0.01	$0.17	$0.45	$2.00	$2.17	$2.45

Source: U.S. EPA Analysis, 2024

96 Although other pollutants, such as cadmium, are also likely to be carcinogenic (see U.S. Department of Health and Human Services. (2012). *Toxicological Profile for Cadmium*.), EPA did not identify dose-response functions to quantify the effects of changes in these other pollutants.

97 The analysis estimated a reduction in the incidence of arsenic-related skin cancer cases of 0.01 cases between 2025 and 2049 for all three regulatory options.

5.8 Additional Measures of Potential Changes in Human Health Effects

As noted in the introduction to this chapter, untreated pollutants in steam electric power plant discharges have been linked to additional adverse human health effects. EPA compared immediate receiving water concentrations to human health-based NRWQC in U.S. EPA (2020g). To provide an additional measure of the potential health effects of the regulatory options, EPA also estimated the changes in the number of receiving and downstream reaches with pollutant concentrations in excess of human health-based NRWQC. This analysis compares pollutant concentrations estimated for the baseline and each analyzed regulatory option in receiving reaches and downstream reaches to criteria established by EPA for protection of human health. EPA compared estimated in-water concentrations of antimony, arsenic, barium, cadmium, chromium, cyanide, copper, lead, manganese, mercury, nitrate-nitrite as N, nickel, selenium, thallium, and zinc to EPA's NRWQC protective of human health used by states and tribes (U.S. EPA, 2018c) and to MCLs.[98] Estimated pollutant concentrations in excess of these values indicate potential risks to human health. This analysis and its findings are not additive to the preceding analyses in this chapter, but instead represent another way of characterizing potential health effects resulting from changes in exposure to steam electric pollutants.

Table 5-10 shows the results of this analysis.[99] During Period 1, EPA estimates that with baseline steam electric pollutant discharges, concentrations of steam electric pollutants exceed human health criteria for at least one pollutant in 375 reaches based on the "consumption of water and organism" criteria, and 112 reaches based on the "consumption of organism only" criteria nationwide. During Period 2, concentrations of steam electric pollutants exceed human health criteria for at least one pollutant in 326 reaches based on the "consumption of water and organism" criteria, and 112 reaches based on the "consumption of organism only" criteria nationwide under the baseline scenario. The estimated number of reaches with exceedances of "consumption water and organism" criteria and with exceedances of "consumption of organism only" criteria during both Period 1 and Period 2 decreases under all regulatory options.[100] For example, Option C eliminates exceedances in 271 reaches (326-55) and reduces the number of exceedances in 237 reaches.

Table 5-10: Estimated Number of Reaches Exceeding Human Health Criteria for Steam Electric Pollutants

Regulatory Option	Number of Reaches with Ambient Concentrations Exceeding Human Health Criteria for at Least One Pollutant[a]		Number of Reaches with Lower Number of Exceedances, Relative to Baseline[b]	
	Consumption of Water + Organism	Consumption of Organism Only	Consumption of Water + Organism	Consumption of Organism Only
Period 1 (2025-2029)				
Baseline	375	112	Not applicable	Not applicable
Option A	308	70	73	42
Option B (Final Rule)	298	68	90	52
Option C	274	68	117	52

98 For pollutants that do not have NRWQC protective of human health, EPA used MCLs. These pollutants include cadmium, chromium, lead, and mercury.

99 Only reaches designated as fishable (*i.e.*, Strahler Stream Order larger than 1) were included in the NRWQC exceedances analysis.

100 EPA's analysis does not account for the fact that the NPDES permit for each steam electric power plant, like all NPDES permits, is required to have limits more stringent than the technology-based limits established by an ELG, wherever necessary to protect water quality standards. Because this analysis does not project where a permit will have more stringent limits than those required by the ELG, it may overestimate any negative impacts to aquatic ecosystems and T&E species, including impacts that will not be realized at all because the permits will be written to include limits as stringent as necessary to meet water quality standards as required by the CWA.

Table 5-10: Estimated Number of Reaches Exceeding Human Health Criteria for Steam Electric Pollutants

Regulatory Option	Number of Reaches with Ambient Concentrations Exceeding Human Health Criteria for at Least One Pollutant[a]		Number of Reaches with Lower Number of Exceedances, Relative to Baseline[b]	
	Consumption of Water + Organism	Consumption of Organism Only	Consumption of Water + Organism	Consumption of Organism Only
Period 2 (2030-2049)				
Baseline	326	112	Not applicable	Not applicable
Option A	180	38	140	67
Option B (Final Rule)	78	8	222	79
Option C	55	0	237	84

a. Pollutants for which there was at least one exceedance in the baseline or regulatory options include antimony, arsenic, chromium, cyanide, manganese, and thallium in Period 1 and arsenic, chromium, cyanide, manganese, and thallium in Period 2.

b. Pollutants for which there was at least one reach with lower number of exceedances relative to baseline include arsenic and chromium in Period 1 and arsenic, chromium, cyanide, manganese, and thallium in Period 2.

Source: U.S. EPA Analysis, 2024

5.9 Limitations and Uncertainties

The analysis presented in this chapter does not include all possible human health effects associated with post-technology implementation changes in pollutant discharges due to lack of data on a dose-response relationship between ingestion rates and potential adverse health effects. Therefore, the total quantified human health effects included in this analysis represent only a subset of the potential health effects estimated to result from the regulatory options. Section 2.1 provides a qualitative discussion of health effects omitted from the quantitative analysis.

The methodologies and data used in the analysis of adverse health outcomes due to consumption of fish contaminated with steam electric pollutants involve limitations and uncertainties. Table 5-11 summarizes the limitations and uncertainties and indicates the direction of the potential bias. Additional limitations and uncertainties associated with the environmental assessment analyses and data are discussed in the EA (see U.S. EPA, 2024b).

Table 5-11: Limitations and Uncertainties in the Analysis of Human Health Effects via the Fish Ingestion Pathway

Uncertainty/Limitation	Effect on Benefits Estimate	Notes
Fishers are estimated to evenly distribute their activity over all available fishing sites within the 50-mile travel distance.	Uncertain	EPA estimated that all fishers travel up to 50 miles and distribute their visits over all fishable sites within the area. In fact, recreational and subsistence fishers may have preferred sites (*e.g.*, a site located closer to their home) that they visit more frequently. The characteristics of these sites, notably ambient water concentrations and fishing advisories, affects exposure to pollutants, but EPA does not have data to support a more detailed analysis of fishing visits. The impact of this approach on monetary estimates is uncertain since fewer/more fishers may be exposed to higher/lower fish tissue concentrations than estimated by EPA.

Table 5-11: Limitations and Uncertainties in the Analysis of Human Health Effects via the Fish Ingestion Pathway

Uncertainty/Limitation	Effect on Benefits Estimate	Notes
The exposed population is estimated based on households in proximity to affected reaches and the fraction of the general population who fish.	Uncertain	EPA estimated the share of households that includes fishers to be equal to the fraction of people over 16 who are fishers. This may double-count households with more than one fisher over 16. However, the exposed population may also include non-household members who also consume the catch.
Fish intake rates used in estimating exposure are based on recommended values for the general consumer population.	Uncertain	The fish consumption rates used in the analysis are based on the general consumer population, which may understate or overstate the amount of fish consumed by fishers who may consume fish at higher or lower rates than the general population (*e.g.*, Burger, 2013; U.S. EPA, 2011, 2013c)
Fish intake rates used in estimating exposure do not reflect potential lower fish consumption by pregnant women.	Overestimate	To the degree that pregnant women reduce their consumption of self-caught fish when compared to women in the general population, then exposure in the baseline would be less and the final rule benefits from reduced exposure to mercury correspondingly lower.
100 percent of fish consumed by recreational fishers is self-caught.	Overestimate	The fish consumption rates used in the analysis account for all fish sources (*i.e.*, store-bought or self-caught fish). Assuming that recreational fishers consume only self-caught fish may overestimate exposure to steam electric pollutants from fish consumption. The degree of the overestimate is unknown as the fraction of fish consumed that is self-caught varies significantly across different locations and population subgroups (*e.g.*, U.S. EPA, 2013c).
The number of subsistence fishers was set to equal 5 percent of the total number of fishers fishing the affected reaches.	Uncertain	The magnitude of subsistence fishing in the United States or individual states is not known. Using 5 percent may understate or overstate the overall number of potentially affected subsistence fishers (and their households) and ignores potential variability in subsistence fishing rates across racial/ethnic groups and different geographic locations.
Value of an IQ point used to quantify benefits health effects from changes in lead and mercury exposure	Uncertain	EPA used two alternative estimates of the value of an IQ point in its analysis, following the methodology in U.S. EPA (2019d; 2019e, 2020b). EPA acknowledges recent research indicating higher IQ point values than those calculated based on Salkever (1995) and Lin, Lutter and Ruhm (2018). However, because the recent research was based on either non-U.S. populations (*e.g.*, Grönqvist, Nilsson & Robling, 2020) or unrepresentative subsets of the U.S. population (Hollingsworth et al., 2020; Hollingsworth & Rudik, 2021),EPA continued to use IQ point values based on Salkever (1995) and Lin, Lutter and Ruhm (2018).
There is a 0.18-point IQ loss for each 1 ppm increase in maternal hair mercury (*i.e.*, the relationship is assumed to be linear).	Uncertain	The exact form of the relationship between maternal body mercury burden and IQ losses is uncertain. Using a linear relationship may understate or overstate the IQ losses resulting from a given change in mercury exposure.

Table 5-11: Limitations and Uncertainties in the Analysis of Human Health Effects via the Fish Ingestion Pathway

Uncertainty/Limitation	Effect on Benefits Estimate	Notes
For the mercury- and lead-related health impact analyses, EPA assessed IQ losses to be an appropriate endpoint for quantifying adverse cognitive and neurological effects resulting from childhood or in-utero exposures to lead and mercury (respectively).	Underestimate	IQ may not be the most sensitive endpoint. Additionally, there are deficits in cognitive abilities that are not reflected in IQ scores, including increased incidence of attention-related and problem behaviors (NTP, 2012; U.S. EPA, 2005d). To the extent that these impacts create disadvantages for children exposed to mercury and lead in the absence of (or independent from) measurable IQ losses, this analysis may underestimate the social welfare effects of the regulatory options of changes in lead and mercury exposure.
The IEUBK model processes daily intake from “alternative sources” to 2 decimal places (µg/day).	Underestimate	Since the fish-associated pollutant intakes are small, some variation is missed by using this model (*i.e.*, it does not capture very small changes between the baseline and regulatory options).
For the lead analysis in adults EPA assumed that fishers would share their catch with household members.	Overestimate	EPA used CBG-specific estimates of persons per household which range from 1.0 to 13.6 and average 2.6 members. Not all individuals within a household may be adults.
The AALM only models BLL from birth to age 60.	Uncertain	BLL for ages 61-80 were extrapolated, but because the simulation of BLL levels off and becomes very predictable after age 30 confidence in the extrapolation is high.
CVD mortality studies use a single measurement of adult BLL.	Uncertain	The CVD studies used to derive the beta coefficients used in Equation 5-7 and Equation 5-8 use a single measurement of adult BLL.
EPA does not adjust BLLs for hematocrit when using the Aoki CVD mortality function.	Overestimate	Based on example calculations conducted in Abt Associates (2023), which compared the two approaches using a hypothetical scenario, the use of whole blood BLLs appears to reasonable for scenarios such as the one in this analysis, where BLLs changes are expected to be small.
EPA estimates avoided CVD premature mortality impacts for adults ages 40 through 80 only.	Underestimate	EPA did not estimate avoided premature CVD deaths for populations younger than 40 or older than 80. This will underestimate benefits because benefits are directly proportional to the size of the affected population and baseline mortality rates.
Uncertainty in the shape of the dose-response function for CVD premature mortality.	Uncertain	The mathematical form of the dose-response function for lead CVD impacts is based on models that best fit the data from the selected epidemiological studies. However, uncertainty remains about the true shape of the function, particularly at very low blood lead levels, for which there are fewer historic data points. Estimating health impacts using alternative mathematical functions that reflect these alternative shapes is beyond the scope of this analysis. Depending on the shape tested, benefit results could be higher or lower.
Baseline CVD rates used in the analysis of lead-related CVD premature mortality in adults did not consider cause.	Uncertain	EPA assumed that the distribution for the age of the individuals experiencing lead-related CVD premature mortality is the same as the distribution of CVD mortality by age and sex for CVD premature mortality irrespective of the cause.

Table 5-11: Limitations and Uncertainties in the Analysis of Human Health Effects via the Fish Ingestion Pathway

Uncertainty/Limitation	Effect on Benefits Estimate	Notes
EPA assumed that changes in lead intake for adults and the resulting change in BLL occur instantaneously.	Overestimate	Because change in BLL in adults resulting from reduction in lead intake realistically occurs over time, assuming an instantaneous change in BLL is likely to overestimate reduction in lead-related CVD premature mortality.
EPA did not monetize the health effects associated with changes in adult exposure to mercury.	Underestimate	The scientific literature suggests that exposure to mercury may have significant adverse health effects for adults (*e.g.*, Hollingsworth & Rudik, 2021; Mergler et al., 2007; Center for Disease Control and Prevention (CDC), 2009). If measurable effects are occurring at current exposure levels, excluding the effects of increased adult exposure results in an underestimate of benefits.
EPA did not quantify other health effects in children from exposure to lead or mercury.	Underestimate	As discussed in Section 2.1, exposure to lead could result in additional adverse health effects in children (*e.g.*, low birth weight and neonatal mortality from in-utero exposure to lead, or neurological effects in children exposed to lead after age seven) (NTP, 2012; U.S. EPA, 2024d; U.S. EPA, 2019e; U.S. EPA, 2023f). Additional neurological effects could also occur in children from exposure to mercury after birth (Mergler et al., 2007; CDC, 2009). If measurable effects are occurring at current exposure levels, excluding additional health effects of increased children exposure results in an underestimate of benefits.
EPA did not assess combined health risk of multiple pollutants.	Uncertain	The combined health risk of exposure to multiple pollutants could be greater than that to a single pollutant (Evans, Campbell & Naidenko, 2020). However, quantifying cumulative risk is challenging because a mixture of pollutants could affect a wide range of target organs and endpoints (ATSDR, 2004, 2009). For example, different carcinogens found in steam electric power plant discharges may affect different organs (*e.g.*, arsenic is linked to skin cancer while cadmium is linked to kidney cancer). Other synergistic effects may increase or lessen the risk. While there are no existing methods to fully analyze and monetize these effects, EPA quantified some of these effects in the EA (U.S. EPA, 2024b).

6 Nonmarket Benefits from Water Quality Changes

As discussed in the EA (U.S. EPA, 2024b), heavy metals, nutrients, and other pollutants discharged by steam electric power plants can have a wide range of effects on water resources downstream from the plants. These environmental changes affect environmental goods and services valued by humans, including recreation; commercial fishing; public and private property ownership; navigation; water supply and use; and existence services such as aquatic life, wildlife, and habitat designated uses. Some environmental goods and services (*e.g.*, commercially caught fish) are traded in markets, and thus their value can be directly observed. Other environmental goods and services (*e.g.*, recreation and support of aquatic life) are not bought or sold directly and thus do not have observable market values. This second type of environmental goods and services are classified as "nonmarket." The estimated changes in the nonmarket values of the water resources affected by the regulatory options (hereafter nonmarket benefits) are additive to market values (*e.g.*, avoided costs of producing various market goods and services).

The analysis of the nonmarket value of water quality changes resulting from the regulatory options follows the same approach EPA used in the analysis of the 2015 and 2020 rules and 2023 proposal (U.S. EPA, 2015a, 2020b, 2023c). This approach, which is briefly summarized below, involves:

1. Characterizing the change in water quality under the regulatory options relative to the baseline using a WQI and linking these changes to ecosystem services or potential uses that are valued by society (see Section 3.4.2), and

2. Monetizing changes in the nonmarket value of affected water resources under the regulatory options using a meta-analysis of surface water valuation studies that provide data on the public's WTP for water quality changes (see Section 6.1).

The analysis accounts for improvements in water quality resulting from changes in nutrient, sediment, and toxics concentrations in reaches potentially affected by bottom ash transport water and FGD wastewater discharges. The assessment uses the CBG as the geographic unit of analysis, assigning a radial distance of 100 miles from the CBG centroid. EPA estimates that households residing in a given CBG value water quality changes in all modeled reaches within this range, with all unaffected reaches being viable substitutes for affected reaches within the area around the CBG. Appendix E in U.S. EPA (2020b) provides additional details on EPA's approach.

6.1 Estimated Total WTP for Water Quality Changes

EPA estimated economic values of water quality changes at the CBG level using results of a meta-analysis of 189 estimates of total WTP (including both use and nonuse values) for water quality improvements, provided by 59 original studies conducted between 1981 and 2017.[101] The estimated econometric model allows calculation of total WTP for changes in a variety of environmental services affected by water quality and valued by humans, including changes in recreational fishing opportunities, other water-based recreation, and

[101] Although the potential limitations and challenges of benefit transfer are well established (Desvousges, W. H., Smith, V. K., & Fisher, A. (1987). Option price estimates for water quality improvements: a contingent valuation study for the Monongahela River. *Journal of Environmental Economics and Management, 14*, 248-267. https://doi.org/https://doi.org/10.1016/0095-0696(87)90019-2), benefit transfers are a nearly universal component of benefit cost analyses conducted by and for government agencies. As noted by Smith, V. K., Van Houtven, G., & Pattanayak, S. K. (2002). Benefit transfer via preference calibration:"Prudential algebra" for policy. *Land Economics, 78*(1), 132-152. , "nearly all benefit cost analyses rely on benefit transfers, whether they acknowledge it or not."

existence services such as aquatic life, wildlife, and habitat designated uses. The model also allows EPA to adjust WTP values based on the core geospatial factors predicted by theory to influence WTP, including: scale (the size of affected resources or areas), market extent (the size of the market area over which WTP is estimated), and the availability of substitutes. The meta-analysis regression is based on two models: Model 1 provides EPA's main estimate of non-market benefits, and Model 2 is used in a sensitivity analysis to develop a range of estimates that account for uncertainty in the estimated WTP values (see Section 6.2 for Model 2 results). Appendix H provides details on how EPA used the meta-analysis to predict household WTP for each CBG and year as well as the estimated regression equation, intercept and variable coefficients for the two models used in this analysis. The appendix also provides names and definitions of the independent variable and assigned values.

Based on the meta-analysis results, EPA multiplied the coefficient estimates for each variable (see Model 1 and Model 2 in Table H-3) by the variable levels calculated for each CBG or fixed at the levels indicated in the "Assigned Value" column in Table H-3. The sum of these products represents the predicted natural log of the WTP for a one-point improvement on the WQI (*ln_OWTP*) for a representative household in each CBG. Equation 6-1 provides the equation used to calculate household benefits for each CBG.

Equation 6-1.

$$HWTP_{Y,B} = OWTP_{Y,B} \times \Delta WQI_B$$

where:

$HWTP_{Y,B}$ = Annual household WTP in 2023$ in year *Y* for households located in the CBG (*B*),

$OWTP_{Y,B}$ = WTP for a one-point improvement on the WQI for a given year (*Y*) and the CBG (*B*), estimated by the meta-analysis function and evaluated at the midpoint of the range over which water quality is changed,

ΔWQI_B = Estimated annual average water quality change for the CBG (*B*). See Section 3.4 and Appendix C for details about the WQI calculation methodology.

To estimate WTP for water quality improvements under the regulatory options, EPA first estimated water quality improvements for each year within Period 1 and Period 2 (see Section 3.2.1 for details) and then applied the meta-regression model (MRM) to estimate per household WTP for water quality improvements for each year in the analysis period (2024-2049). As summarized in Table 6-1, average annual household WTP estimates for the regulatory options, based on the main estimates from Model 1, range from $0.01 under Option A to $0.03 under Option C.

To estimate total WTP (TWTP) for water quality changes for each CBG, EPA multiplied the per-household WTP values for the estimated water quality change by the number of households within each CBG in a given year and calculated the present value (PV) of the stream of WTP over the 25 years in EPA's period of analysis. EPA then calculated annualized total WTP values for each CBG using a 2 percent discount rate as shown in Equation 6-2.

Equation 6-2.

$$TWTP_B = \left(\sum_{T=2025}^{2049} \frac{HWTP_{Y,B} \times HH_{Y,B}}{(1+i)^{Y-2024}} \right) \times \left(\frac{i \times (1+i)^n}{(1+i)^{n+1} - 1} \right)$$

where:

$TWTP_B$	=	Annualized total household WTP in 2023$ for households located in the CBG (*B*),
$HWTP_{Y,B}$	=	Annual household WTP in 2023$ for households located in the CBG (*B*) in year (*Y*),
$HH_{Y,B}$	=	the number of households residing in the CBG (*B*) in year (*Y*),
T	=	Year when benefits are realized
i	=	Discount rate (2 percent)
n	=	Duration of the analysis (25 years)[102]

EPA generated annual household counts for each CBG through the period of analysis based on projected population growth following the method described in Section 1.3.6. Table 6-1 presents the main analysis results, based on Model 1. For the final rule (Option B), the total annualized values of water quality changes resulting from changes in toxics, nutrient and sediment discharges in these reaches are $1.24 million.

Table 6-1: Estimated Household and Total Annualized Willingness-to-Pay for Water Quality Improvements under the Regulatory Options, Compared to Baseline (Main Estimates)

Regulatory Option	Number of Affected Households (Millions)[a]	Average Annual WTP Per Household (2023$)[b]	Total Annualized WTP (Millions 2023$; 2% Discount Rate)[b]
Option A	58.7	$0.01	$0.79
Option B (Final Rule)	58.9	$0.02	$1.24
Option C	59.6	$0.03	$1.68

a. The number of affected households varies across options because of differences in the number of reaches that have non-zero changes in water quality.

b. Estimates based on Model 1, which provides EPA's main estimate of non-market benefits.

Source: U.S. EPA Analysis, 2024

6.2 Sensitivity Analysis

Table 6-2 presents sensitivity analysis results produced from Model 2, including average annual household WTP and total annualized values, for water quality improvements resulting from all regulatory options. For the final rule (Option B), average annual household WTP estimates range from $0.02 to $0.05. Total annualized values range from $1.31 million to $2.68 million.

102 See Section 1.3.3 for details on the period of analysis.

Table 6-2: Estimated Household and Total Annualized Willingness-to-Pay for Water Quality Changes under the Regulatory Options, Compared to Baseline (Sensitivity Analysis)

Regulatory Option	Number of Affected Households (Millions)[a]	Average Annual WTP Per Household (2023$)[b]		Total Annualized WTP (Millions 2023$; 2% Discount Rate)[b]	
		Low	High	Low	High
Option A	58.7	$0.01	$0.03	$0.86	$1.76
Option B (Final Rule)	58.9	$0.02	$0.05	$1.31	$2.68
Option C	59.6	$0.03	$0.07	$1.78	$3.65

a. The number of affected households varies across options because of differences in the number of reaches that have non-zero changes in water quality.

b. Estimates based on Model 2, which provides a range of estimates that account for uncertainty in the WTP estimates as a sensitivity analysis. For the ∆WQI variable setting in Model 2-based sensitivity analysis, EPA used values of 20 units to develop low estimates and 7 units to develop high estimates (see Appendix H for details).

Source: U.S. EPA Analysis, 2024

6.3 Limitations and Uncertainties

Table 6-3 summarizes the limitations and uncertainties in the analysis of benefits associated with changes in surface water quality and indicates the direction of any potential bias.

Table 6-3: Limitations and Uncertainties in the Analysis of Nonmarket Water Quality Benefits

Uncertainty/Limitation	Effect on Benefits Estimate	Notes
Use of 100-mile buffer for calculating water quality benefits for each CBG	Underestimate	The distance between surveyed households and the affected waterbodies is not well measured by any of the explanatory variables in the MRM. EPA would expect values for water quality changes to diminish with distance (all else equal) between the household and affected waterbody. The choice of 100 miles is based on typical driving distance to recreational sites (*i.e.*, 2 hours or 100 miles; Viscusi, Huber & Bell, 2008), which captures approximately 80 percent of recreational uses. However, it does not capture the full extent of recreational use or recreational use for multiday trips. It also does not capture the extent of market or population willingness to pay for nonuse value. EPA used 100 miles to approximate the distance decay effect on WTP values but acknowledges that distance decay effects could occur at varying distances (*i.e.,* closer or further than 100 miles) and may exhibit more complex spatial patterns than a simple radius approach. The analysis recognizes further uncertainty for people living farther than 100 miles and does not assign any value for water quality improvements in waters affected by this rulemaking despite literature that shows that while WTP tends to decline with distance from the waterbody, people value the quality of waters outside their region.

Table 6-3: Limitations and Uncertainties in the Analysis of Nonmarket Water Quality Benefits		
Uncertainty/Limitation	**Effect on Benefits Estimate**	**Notes**
Selection of the *lnquality_ch* variable value in Model 2 for estimating a range of WTP values (sensitivity analysis)	Uncertain	The value of an additional one-point improvement in WQI is expected to decline as the magnitude of the water quality change increases. To account for variability in WTP due to the magnitude of the valued water quality changes, EPA estimated a range of WTP values for a one-point improvement on the WQI using alternative settings for *lnquality_ch* (ΔWQI= 20 and 7 units, respectively). These values were based on the 25th and 75th percentile of water quality changes included in the meta-data. To ensure that the benefit transfer function satisfies the adding-up condition, this variable is treated as a methodological (fixed) variable. The negative coefficient for *lnquality_ch* implies that larger value settings produce smaller WTP estimates for a one-point improvement, which is consistent with economic theory; smaller value settings produce larger WTP estimates for a one-point improvement. The selected values may bias the estimated WTP values either upward or downward.
Potential hypothetical bias in underlying stated preference results	Uncertain	Following standard benefit transfer approaches, this analysis proceeds under the assumption that each source study provides a valid, unbiased estimate of the welfare measure under consideration (cf. Moeltner, Boyle & Paterson, 2007; Rosenberger and Phipps, 2007). To minimize potential hypothetical bias underlying stated preference studies included in meta-data, EPA set independent variable values to reflect best practices for stated preference (*e.g.*, the payment vehicle variable is set to a non-voluntary value because use of voluntary donations is prone to issues of free-riding).
Use of different water quality measures in the underlying meta-data	Uncertain	The estimation of WTP may be sensitive to differences in the presentation of water quality changes across studies in the meta-data. Studies that did not use the WQI were mapped to the WQI, so a comparison could be made across studies. To account for potential effects of the use of a different water quality metric (*i.e.*, index of biotic integrity (IBI)) on WTP values for a one-point improvement on the WQI, EPA used a dummy variable in the MRM (see Appendix H for details). In benefit transfer applications, the IBI variable is set to zero, which is consistent with using the WQI.
Transfer error	Uncertain	Transfer error may occur when benefit estimates from a study site are adopted to forecast the benefits of a policy site. Rosenberger and Stanley (2006) define transfer error as the difference between the transferred and actual, generally unknown, value. Although meta-analyses are often more flexible and accurate compared to other types of transfer approaches (*e.g.*, value transfers and benefit function transfers) due to the data synthesis from multiple source studies (Rosenberger and Phipps, 2007; Johnston et al., 2021), there is still a potential for transfer errors (Shrestha, Rosenberger & Loomis, 2007) and no transfer method is always superior relative to other benefit transfer methods (Johnston et al., 2021).
Omission of Great Lakes and estuaries from analysis of benefits from water quality changes	Underestimate	Five out of 92 (5 percent) steam electric power plants discharge to the Great Lakes or estuaries. Due to limitations of the water quality models used in the analysis of the regulatory options, these waterbodies were excluded from the analysis. This omission likely underestimates benefits of water quality changes from the regulatory options.

Table 6-3: Limitations and Uncertainties in the Analysis of Nonmarket Water Quality Benefits

Uncertainty/Limitation	Effect on Benefits Estimate	Notes
The water quality model accounts for only a subset of sources of toxic pollutants contributing to baseline concentrations	Uncertain	The overall impact of this limitation on the estimated WTP for water quality changes is uncertain but is expected to be small. Toxic pollutants are grouped into one parameter out of the seven parameters included the WQI. Therefore, the effect of including additional toxic pollutants on the estimated change in WQI is likely to be small.

7 Impacts and Benefits to Threatened and Endangered Species

7.1 Introduction

T&E species are species vulnerable to future extinction or at risk of extinction in the near future, respectively. These designations reflect low or rapidly declining population levels, loss of essential habitat, or life history stages that are particularly vulnerable to environmental alteration or other stressors. In many cases, T&E species are given special protection due to inherent vulnerabilities to habitat modification, disturbance, or other impacts of human activities. This chapter examines the projected change in environmental impacts of steam electric power plant discharges on T&E species and the estimated benefits associated with the projected changes resulting from the regulatory options.

As described in the EA (U.S. EPA, 2024b), the untreated chemical constituents of steam electric power plant wastestreams can pose serious threats to ecological health due to the bioaccumulative nature of many pollutants, high concentrations, and high loadings. Pollutants such as selenium, arsenic and mercury have been associated with fish kills, disruption of growth and reproductive cycles and behavioral and physiological alterations in aquatic organisms. Additionally, high nutrient loads can lead to the eutrophication of waterbodies. Eutrophication can lead to increases in the occurrence and intensity of water column phytoplankton, including harmful algal blooms (*e.g.*, nuisance and/or toxic species), which have been found to cause fatal poisoning in other animals, fish, and birds. Eutrophication may also result in the loss of critical submerged rooted aquatic plants (or macrophytes), and reduced DO levels, leading to anoxic or hypoxic waters.

For species vulnerable to future extinction, even minor changes to growth and reproductive rates and small levels of mortality may represent a substantial portion of annual population growth. To quantify the estimated effects of the regulatory options compared to baseline, EPA conducted a screening analysis using as indicator of benefits the changes in projected attainment of freshwater NRWQC. Specifically, EPA identified the reaches that are projected to see changes in achievement of freshwater aquatic life NRWQC, assuming no more stringent controls are established to meet applicable water quality standards (*i.e.*, water-quality-based effluent limits issued under Section 301(b)(1)(C))). Using these projections, EPA then estimated the number of T&E species whose recovery could be affected based on the species' habitat range. Because NRWQC are recommended at levels to protect aquatic organisms, reducing the frequency at which aquatic life-based NRWQC are exceeded could translate into reduced risk to T&E species and potential improvements in species populations.[103]

In this chapter, EPA examines the current conservation status of species belonging to freshwater taxa and identifies the extent to which the regulatory options, independent of consideration of additional water quality-based controls, may benefit or adversely impact T&E species. The analysis generally follows the approach EPA used for the analyses of the 2015 and 2020 rules and 2023 proposal (U.S. EPA, 2015a, 2020b, 2023b), including updates EPA made over time to the methodology, assumptions, and inputs to address comments or

[103] Criteria are developed based on the 1985 Guidelines methods (U.S. Environmental Protection Agency. (1985). *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection Of Aquatic Organisms and Their Uses*. (PB85-227049). Retrieved from https://www.epa.gov/sites/production/files/2016-02/documents/guidelines-water-quality-criteria.pdf) and generally reflect high quality toxicity data from at least eight different taxa groups that broadly represent aquatic organisms. To the extent that more stringent levels are required to protect organisms in a particular location, that is addressed during the water quality standard development process for that location.

incorporate more recent data. As for the earlier analyses, this analysis provides a quantitative, but unmonetized proxy for the benefits associated with the regulatory options.

7.2 Baseline Status of Freshwater Fish Species

Reviews of aquatic species' conservation status over the past three decades have documented the effect of cumulative stressors on freshwater aquatic ecosystems, resulting in a significant decline in the biodiversity and condition of indigenous communities (Deacon et al., 1979; Williams et al., 1989; Williams et al., 1993; Taylor et al., 1996; Taylor et al., 2007; Jelks et al., 2008). Overall, aquatic species may be disproportionately imperiled relative to terrestrial species. For example, while 39 percent of freshwater and diadromous fish species are imperiled (Jelks et al., 2008), a similar status review found that only 7 percent of North American bird and mammal species are imperiled (Wilcove & Master, 2005). More recent studies of threats and extinction trends in freshwater taxa also concluded that biodiversity is much more at risk in freshwater compared to marine ecosystems (Winemiller, 2018).

Approximately 39 percent of described fish species in North America are imperiled, with 700 fish taxa classified as vulnerable (230), threatened (190), or endangered (280) in addition to 61 taxa presumed extinct or functionally extirpated from nature (Jelks et al., 2008). These data show that the number of T&E species has increased by 98 percent and 179 percent when compared to similar reviews conducted by the American Fisheries Society in 1989 (Williams et al., 1989) and 1979 (Deacon et al., 1979), respectively. Despite conservation efforts, including the listing of several species under the Endangered Species Act (ESA), only 6 percent of the fish taxa assessed in 2008 had improved in status since the 1989 inventory (Jelks et al., 2008).

Several families of fish have high proportions of T&E species. Approximately 46 percent and 44 percent of species within families Cyprinidae (carps and true minnows) and Percidae (darters and perches) are imperiled, respectively. Some families with few, wide-ranging species have even higher rates of imperilment, including the Acipenseridae (sturgeons; 88 percent) and Polyodontidae (paddlefish; 100 percent). Families with species important to sport and commercial fisheries have imperilment levels ranging from a low of 22 percent for Centrarchidae (sunfishes) to a high of 61 percent for Salmonidae (salmon) (Jelks et al., 2008).

7.3 T&E Species Potentially Affected by the Regulatory Options

To assess the potential effects of the regulatory options on T&E species, EPA used the U.S. FWS Environmental Conservation Online System (ECOS) to construct a database of species that have habitats that overlap with waters projected to improve due to reductions in pollutant discharge from steam electric power plants under the regulatory options. The source data include all animal species currently listed or proposed for listing under the ESA (U.S. FWS, 2020d).

7.3.1 Identifying T&E Species Potentially Affected by the Regulatory Options

To estimate the effects of the regulatory options on T&E species, EPA first compiled data on habitat ranges for all species currently listed or under consideration for listing under the ESA. EPA obtained the geographical distribution of T&E species in geographic information system (GIS) format from ECOS (U.S. FWS, 2020b).

EPA constructed a screening database using the spatial data on species habitat ranges and all NHD reaches downstream from steam electric power plants. This database included all T&E species whose habitat ranges intersect reaches immediately receiving or downstream of steam electric power plant discharges. EPA used a 200-meter buffer on either side of each reach when estimating the intersection to account for waterbody widths and any minor errors in habitat maps. EPA removed several species previously included in the analysis of the 2023 proposal because they were delisted from the ESA due to extinction, according to the USFWS (U.S. Fish & Wildlife Service, 2023). The analysis retained a total of 184 T&E species.

EPA then classified these species on the basis of their vulnerability to changes in water quality for the purpose of assessing potential impacts of the regulatory options. EPA obtained species life history data from a wide variety of sources to assess T&E species' vulnerability to water pollution. For the purpose of this analysis, species were classified as follows:

- Higher vulnerability – species living in aquatic habitats for several life history stages and/or species that obtain a majority of their food from aquatic sources.
- Moderate vulnerability – species living in aquatic habitats for one life history stage and/or species that obtain some of their food from aquatic sources.
- Lower vulnerability – species whose habitats overlap bodies of water, but whose life history traits and food sources are terrestrial.

Table 7-1 summarizes the results of this assessment. Appendix I lists all T&E species whose habitat ranges intersect reaches immediately receiving or downstream of steam electric power plant discharges.

Table 7-1: Number of T&E Species with Habitat Range Intersecting Reaches Immediately Receiving or Downstream of Steam Electric Power Plant Discharges, by Group

Species Group	Species Vulnerability			Species Count
	Lower	Moderate	Higher	
Amphibians	3	2	4	9
Arachnids	6	0	0	6
Birds	17	4	5	26
Clams	0	0	56	56
Crustaceans	0	0	5	5
Fishes	0	0	28	28
Insects	10	0	0	10
Mammals	13	1	1	15
Reptiles	13	0	6	19
Snails	1	0	9	10
Total	**63**	**7**	**114**	**184**

Source: U.S. EPA Analysis, 2024.

To estimate the potential impacts of the regulatory options, EPA focused the analysis on species with higher vulnerability potentials based upon life history traits. EPA's further review of this subset of species resulted in the removal from further analysis of those species endemic to isolated headwaters and natural springs, as these waters are unlikely to receive steam electric power plant discharges in the scope of the final rule (see Appendix I for details). A review of life history data for the remaining species shows pollution or water quality issues as factors influencing species decline. This suggests that water quality issues may be important to species recovery even if not emphasized explicitly in species recovery plans.

7.3.2 Estimating Effects of the Rule on T&E Species

EPA used the results of the water quality model described in Chapter 3 to flag those reaches where estimated pollutant concentrations exceed the freshwater NRWQC under the baseline or the regulatory options (see

Section 3.4.1.1). EPA estimated exceedances for two distinct periods (2025-2029 and 2030-2049) within the overall analysis period (2025-2049). As described in Section 3.2.1, Period 1 corresponds to transition years when the steam electric power plants would be installing treatment technologies to comply with the revised limits, whereas Period 2 reflects post-technology implementation conditions when all plants meet applicable revised limits.

EPA then linked the water quality model outputs with the species database described in the section above to identify potentially “affected T&E species habitats” where the reaches intersecting the habitat range of a T&E species do not meet the NRWQC under baseline conditions but do meet the NRWQC under one or more of the regulatory options (*i.e.*, potential positive benefits). EPA compared dissolved concentration estimates for eight pollutants to the freshwater acute and chronic NRWQC values[104] to assess the exceedance status of the reaches under the baseline and each regulatory option. Appendix I provides details on the number of exceedances from steam electric power plants affecting T&E species of all vulnerability levels. Overall, EPA’s analysis indicates that 23 reaches intersecting the habitat ranges of 30 T&E species exceed NRWQC under the baseline conditions in Period 1 and 19 reaches intersecting the habitat ranges of 27 T&E species exceed NRWQC under the baseline conditions in Period 2. In Period 1 (2025-2029), exceedances improvements occur in four reaches under option A, and in 16 reaches under options B and C. In Period 2 (2030-2049), NRWQC exceedances are eliminated or reduced in two reaches under option A, in 16 reaches under option B, and in 19 reaches under option C.

Table 7-2, on the next page, provides additional details on the subset of species with higher vulnerability to water pollution for which the regulatory options reduce the number of exceedances in at least one Period and reach. EPA estimated that the improvements in water quality in Period 1 provide potential benefits to three T&E species under option A and ten T&E species under options B and C, as indicated by changes in the number of reaches with NRWQC exceedances. Improvements during Period 2 provide potential benefits to one T&E species under option A, 12 T&E species under option B, and 14 T&E species under option C.

While NRWQC do not translate into a quantifiable level of harm or improvement to wildlife species exposed to various contaminants, they may provide a useful proxy to indicate where significant improvements in water quality may occur, recognizing that these improvements may not necessarily benefit species to the same degree. Species have vastly different and unique life histories, and as a result, some may continue to face detrimental impacts even where NRWQC exceedances are eliminated, while other species may either not face detrimental impacts from water quality to begin with or may see benefits as the result of water quality improvements even without changes in exceedances. Furthermore, conditions that do not exceed NRWQC may still cause harm to species, especially those species with chronic exposure to contaminants such as heavy metals. Roughly 30 percent (56 of 184) of species with designated habitats intersecting reaches affected by steam electric power plant discharges are bivalves. Additionally, 15 percent (28 of 184) of species with designated habitats receiving steam electric power plant discharges are fish. Such taxonomic groups face consistent exposure to aquatic pollutants due to their entirely aquatic nature. Bivalves in particular fulfill vital ecological roles as ecosystem engineers (Hancock & Ermgassen, 2019). Freshwater bivalves are crucial filter feeders, removing metals, sediment, excess nutrients, and bacteria from surrounding water (Upper Midwest Environmental Sciences Center, 2020). Healthy populations of freshwater bivalve species help improve water quality and overall river/lake health by improving habitat for other aquatic invertebrates as well as finfish.

[104] The eight pollutants are arsenic, cadmium, copper, lead, mercury, nickel, selenium, and zinc. For more information about the aquatic life NRWQC, see the EA (U.S. Environmental Protection Agency. (2024b). *Environmental Assessment for Supplemental Effluent Guidelines and Standards for the Steam Electric Power Generating Point Source Category*. (821-R-24-005).).

Species in which pollutants bioaccumulate may face detrimental or lethal effects at lower pollution levels over time. For example, bivalves feed by filtering large amounts of water and face extended exposure to pollutants over longer time spans compared to other species. As a result, populations of these species may suffer over time as negative effects of chronic exposure add up. Table 7-2 shows the Snuffbox mussel (*Epioblasma triquetra*), Sheepnose mussel (*Plethobasus cyphyus*), Spectaclecase mussel (*Cumberlandia monodonta*), and Pink Mucket (*Lampsilis abrupta*) all seeing improvements across many reaches intersecting their habitat ranges under the final rule (Option B). Publications from the USFWS warn that pollution and contamination are key threats to survival for each of these four species due to both acute and chronic toxic effects (Butler, 2007; U.S. Fish & Wildlife Service, 1997, 2012a, 2012b). Such cumulative effects on these species could further negatively impact local ecosystems by disrupting the filtering function provided by bivalves (Hancock & Ermgassen, 2019). Non-bivalve species could see benefits from improvements as well. Water contaminants, including metals, are a known threat to the survival of the Colorado Pikeminnow (*Ptychocheilus lucius*), and although the impacts of many contaminants are not quantified for this species, it demonstrates that this species could benefit from improvements to water quality (U.S. Fish & Wildlife Service, 2022). While the number of reaches with improvements are indicative of the benefits to T&E species provided by each option, it remains a rough indicator. However, for T&E species dependent on aquatic systems for survival, such as bivalves and fishes, any level of improvement that increases the ability of the species to survive and reproduce could enhance conservation and recovery efforts.

Table 7-2: Higher Vulnerability T&E Species Whose Habitat May be Affected by the Regulatory Options Compared to Baseline (Shading Highlights Change from Baseline)

Species Name	State(s)	Number of Reaches with NRWQC Exceedances for at Least One Pollutant			
		Baseline	Option A	Option B (Final Rule)	Option C
Period 1 (2025-2029)					
Clubshell (*Pleurobema clava*)	Kentucky	1	1	1	1
Colorado pikeminnow (*Ptychocheilus lucius*)	New Mexico	6	3	3	3
Fanshell (*Cyprogenia stegaria*)	Kentucky/West Virginia	11	11	1	1
Frosted Flatwoods salamander (*Ambystoma cingulatum*)	Florida	1	1	0	0
Humpback chub (*Gila cypha*)	Arizona	3	3	3	3
Orangefoot pimpleback (pearlymussel) (*Plethobasus cooperianus*)	Kentucky	1	1	1	1
Pink mucket (pearlymussel) (*Lampsilis abrupta*)	Kentucky/Ohio/West Virginia	12	12	2	2
Razorback sucker (*Xyrauchen texanus*)	New Mexico	3	0	0	0
Ring pink mussel (*Obovaria retusa*)	Kentucky	1	1	1	1
Rough pigtoe (*Pleurobema plenum*)	Kentucky	1	1	1	1
Sheepnose mussel (*Plethobasus cyphyus*)	West Virginia/Ohio	11	11	1	1
Snuffbox mussel (*Epioblasma triquetra*)	West Virginia	10	10	0	0
Spectaclecase mussel (*Cumberlandia monodonta*)	West Virginia	10	10	0	0
Topeka shiner (*Notropis topeka*)	Kansas	3	2	2	2
West Indian manatee (*Trichechus manatus*)	Florida	1	1	0	0

Table 7-2: Higher Vulnerability T&E Species Whose Habitat May be Affected by the Regulatory Options Compared to Baseline (Shading Highlights Change from Baseline)

Species Name	State(s)	Number of Reaches with NRWQC Exceedances for at Least One Pollutant			
		Baseline	Option A	Option B (Final Rule)	Option C
Period 2 (2030-2049)					
Clubshell (*Pleurobema clava*)	Kentucky	1	1	0	0
Colorado pikeminnow (*Ptychocheilus lucius*)	New Mexico	3	3	3	0
Fanshell (*Cyprogenia stegaria*)	Kentucky/West Virginia	11	11	0	0
Frosted Flatwoods salamander (*Ambystoma cingulatum*)	Florida	1	1	0	0
Humpback chub (*Gila cypha*)	Arizona	3	3	3	0
Orangefoot pimpleback (pearlymussel) (*Plethobasus cooperianus*)	Kentucky	1	1	0	0
Pink mucket (pearlymussel) (*Lampsilis abrupta*)	Kentucky/Ohio/West Virginia	12	12	0	0
Ring pink mussel (*Obovaria retusa*)	Kentucky	1	1	0	0
Rough pigtoe (*Pleurobema plenum*)	Kentucky	1	1	0	0
Sheepnose mussel (*Plethobasus cyphyus*)	West Virginia/Ohio	11	11	0	0
Snuffbox mussel (*Epioblasma triquetra*)	West Virginia	10	10	0	0
Spectaclecase mussel (*Cumberlandia monodonta*)	West Virginia	10	10	0	0
Topeka shiner (*Notropis topeka*)	Kansas	2	0	0	0
West Indian manatee (*Trichechus manatus*)	Florida	1	1	0	0

Source: U.S. EPA Analysis, 2024

7.4 Limitations and Uncertainties

One limitation of EPA's analysis of the regulatory options' impacts on T&E species and their habitat is the lack of data necessary to quantitively estimate population changes of T&E species and to monetize these effects. The data required to estimate the response of T&E species populations to improved habitats are rarely available. In addition, understanding the contribution of T&E species to ecosystem functions can be challenging because: (1) it is often difficult to locate T&E species, (2) experimental studies including rare or threatened species are limited; and (3) ecologists studying relationships between biodiversity and ecosystem functions typically focus on overall species diversity or estimate species contribution to ecosystem functions based on abundance (Dee et al., 2019). Finally, much of the wildlife economic literature focuses on recreational benefits (*i.e.*, use values) that are not relevant for many protected species and the existing T&E valuation studies tend to focus on species that many people consider to be "charismatic" (*e.g.*, spotted owl, salmon) (Richardson & Loomis, 2009). Although a relatively large number of economic studies have estimated WTP for T&E protection, these studies focused on estimating WTP to avoid species loss/extinction, reintroduction, increase in the probability of survival, or a substantial increase in species population (Subroy et al., 2019; Richardson & Loomis, 2009). In addition, use of the MRMs developed by Subroy et al. (2019) and Richardson and Loomis (2009) is not feasible for this analysis due to the challenges associated with estimating T&E population changes from the final rule.

Table 7-3 summarizes limitations and uncertainties known to affect EPA's assessment of the impacts of the final rule on T&E species. Note that the effect on benefits estimates indicated in the second column of the table refers to the direction and magnitude of the benefits (*i.e.*, a source of uncertainty that tends to underestimate benefits indicates expectation for larger realized benefits).

Table 7-3: Limitations and Uncertainties in the Analysis of T&E Species Impacts and Benefits

Uncertainty/Limitation	Effect on Benefits Estimate	Notes
The analysis does not account for water quality based effluent limits	Overestimate	This screening analysis is intended to isolate possible effects of the regulatory options on T&E species, however, it does not consider the fact that the NPDES permits for each steam electric power plant, like all NPDES permits, are required to have limits more stringent than the technology-based limits established by an ELG wherever necessary to protect water quality standards. Because this analysis does not project where a permit will have more stringent limits than those required by the ELG, it may overestimate any negative impacts to T&E species in the baseline, and therefore overestimate benefits under the regulatory options.
Intersection of T&E species habitat with reaches affected by steam electric plant discharges is used as proxy for exposure to steam electric pollutants	Overestimate	EPA used the habitat range as the basis for assessing the potential for impacts to the species from water quality changes. This approach is reasonable given the lack of reach-specific population data to support a national-level analysis, but the Agency acknowledges that the habitat range of a species does not necessarily indicate that the species is found in individual reaches within the habitat range.
The change in T&E species populations due to improvement in water quality under the regulatory options is uncertain	Uncertain	Data necessary to quantitatively estimate population changes are unavailable. Therefore, EPA used the methodology described in Section 7.3.1 as a screening-level analysis to estimate whether the regulatory options could contribute to a change in the recovery of T&E species populations.
Only those T&E species listed as threatened or endangered under the ESA are included in the analysis	Underestimate	The databases used to conduct this analysis include only species protected under the ESA. Additional species may be considered threatened or endangered by scientific organizations but are not protected by the ESA (*e.g.*, the American Fisheries Society [Williams et al., 1993; Taylor et al., 2007; Jelks et al., 2008]). The magnitude of the underestimate is unknown. Although the proportion of imperiled freshwater fish and mussel species is high (*e.g.*, Jelks et al., 2008; Taylor et al., 2007), the geographic distribution of these species may or may not overlap with reaches affected by steam electric discharges.
The potential for impact to T&E species is also present for changes in pollutant concentrations that don't result in changes in NRWQC exceedances	Underestimate	EPA's analysis quantifies changes in whether a NRWQC is exceeded in a given reach that intersects T&E species habitat ranges. However, changes in pollutant concentrations have the potential to result in impacts to T&E species even where they do not result in changes in NRWQC exceedance status. There are also potential impacts to T&E species from changes in pollutants for which freshwater NRWQC are not available (*e.g.*, salinity).

Table 7-3: Limitations and Uncertainties in the Analysis of T&E Species Impacts and Benefits

Uncertainty/Limitation	Effect on Benefits Estimate	Notes
EPA's water quality model does not capture all sources of pollutants with a potential to impact aquatic T&E species	Uncertain	EPA's water quality model focuses on toxic pollutant discharges from steam electric power plants and certain other point sources, but does not account for other pollution sources (*e.g.*, historical contamination) or background levels. Adding these other sources or background levels could result in additional NRWQC exceedances under the baseline and/or regulatory options, but it is uncertain how the regulatory options would change the exceedance status of the intersected reaches. Additionally, the water quality model does not capture synergistic relationships between pollutants, which may exacerbate adverse effects on T&E species.

8 Air Quality-Related Benefits

The regulatory options evaluated may affect air quality through three main mechanisms: 1) changes in energy used by steam electric power plants to operate wastewater treatment, ash handling, and other systems needed to meet the limitations and standards under the regulatory options; 2) transportation-related emissions due to the changes in trucking of CCR and other waste to on-site or off-site landfills; and 3) changes in the electricity generation profile from increases in wastewater treatment costs compared to the baseline and the resulting changes in EGU relative operating costs.

EPA estimated the climate-related benefits of changes in CO_2 and methane (CH_4) emissions, as well as the human health benefits resulting from changes in particulate matter and ozone ambient exposure due to net changes in emissions of NO_X, SO_2, and directly emitted fine particulate matter ($PM_{2.5}$), also referred to as primary $PM_{2.5}$ emissions.

8.1 Changes in Air Emissions

With respect to the third mechanism mentioned in the introduction and as discussed in the RIA, EPA used the Integrated Planning Model (IPM) to estimate the electricity market-level effects of the final rule (Option B). IPM projects generation from coal to decrease in all model years as a result of the final rule. Over the period of analysis, the reductions are largest in run years 2028 and 2035 (18.1 thousand GWh and 21.2 thousand GWh, respectively), are somewhat smaller in 2030 and 2040 (10.6 thousand GWh and 6.7 thousand GWh), and smallest in the last two run years of 2045 and 2050 (1.1 thousand GWh and 0.7 thousand GWh, respectively). These changes are offset in part by an increase in generation from natural gas, nuclear, and renewables. See details in Chapter 5 of the RIA (U.S. EPA, 2024e). The net effects of these changes in the generation mix are reductions in air emissions that reflect differences in EGU emissions rates for these other fuels or sources of energy, as compared to coal.

IPM outputs include estimated CO_2, NO_X, and SO_2 emissions to air from EGUs.[105] EPA also used IPM outputs to estimate EGU emissions of primary $PM_{2.5}$ based on the methodology described in U.S. EPA (2020c). Specifically, EPA estimated primary $PM_{2.5}$ emissions by multiplying the generation predicted for each IPM plant type (ultrasupercritical coal without carbon capture and storage, combined cycle, combustion turbine, etc.) by a type-specific empirical emission factor derived from the 2019 National Emissions Inventory (NEI) and other data sources. The emission factors reflect the fuel type (including coal rank), FGD controls, and state emission limits for each plant type, where applicable.

Comparing emissions projected under Option B to those projected for the baseline provides an assessment of the changes in air emissions resulting from changes in the profile of electricity generation under the final rule.[106] EPA used six of the seven IPM run years, shown in Table 8-1, to represent the period of analysis. IPM provides outputs starting in 2028 and EPA therefore estimated no changes in air emissions from changes in electricity generation in 2025 through 2027. The last run year (2055) falls outside of the analysis period of 2025-2049 and EPA does not include results for that year when estimating benefits.

[105] EPA also estimated Hg, HCl and PM_{10} emissions but does not use these estimates for the benefits analysis.

[106] While EPA only ran IPM for the final rule (Option B), the Agency extrapolated the benefits estimated using these IPM outputs to Option A and Option C to provide insight on the potential air quality-related effects of the other regulatory options. See Section 8.4 for details.

Table 8-1: IPM Run Years	
IPM Run Year	**Years Represented**
2028	2028-2029
2030	2030-2031
2035	2032-2037
2040	2038-2041
2045	2042-2047
2050	2048-2052
2055	2053-2059
Source: U.S. EPA, 2023e	

As part of its analysis of non-water quality environmental impacts, EPA developed separate estimates of changes in energy requirements for operating wastewater treatment and ash handling systems, and changes in transportation needed to landfill solid waste and CCR (see TDD for details; U.S. EPA, 2024f). EPA estimated CO_2, NO_X, and SO_2 emissions associated with changes in energy requirements to power wastewater treatment systems by multiplying plant-specific changes in electricity consumption by plant- or North American Electric Reliability Corporation (NERC)-specific emission factors obtained from IPM for the baseline in run year 2035.[107] EPA estimated the changes in air emissions associated with changes in transportation by multiplying the increase in the number of miles traveled to dispose of CCR by average emission factors.

Table 8-2 and Table 8-3 respectively summarize the estimated changes in emissions associated with changes in power requirements to operate treatment systems and with the incremental transportation of CCR and solid waste under the regulatory options. For consistency, the tables present estimates for selected IPM model years. EPA modeled emissions in each year based on when each plant is estimated to implement technologies for each wastestream and any announced unit retirements. EPA estimates that changes in power requirements and transportation will increase emissions slightly, relative to the baseline. The variations across regulatory options reflect differences in treatment technologies and affected steam electric plants, whereas variations across model years for a given regulatory option reflect the timing of technology implementation and announced EGU retirements.[108]

Table 8-2: Estimated Changes in Air Pollutant Emissions Due to Increase in Power Requirements at Steam Electric Power Plants 2025-2049, Compared to Baseline

Year	CO_2 (Million Tons/Year)[a]	NOx (Thousand Tons/Year)[a]	SO_2 (Thousand Tons/Year)[a]	Primary $PM_{2.5}$ (Thousand Tons/Year)[a]	CH_4 (Million Tons/Year)[a]
Option A					
2028	0.034	0.015	0.020	Not estimated	Not estimated
2030	0.069	0.044	0.049	Not estimated	Not estimated
2035	0.069	0.044	0.049	Not estimated	Not estimated
2040	0.068	0.044	0.049	Not estimated	Not estimated
2045	0.068	0.044	0.049	Not estimated	Not estimated
2050	0.068	0.041	0.047	Not estimated	Not estimated

107 Applying grid emission factors developed for run year 2035 to the entire period of analysis may overstate emissions associated with power requirements for operating treatment systems since emission factors decline during the period of analysis.

108 For the purpose of this analysis, EPA developed a time profile of air emissions changes based on plants' estimated technology implementation years during the period of 2025 through 2029, as well as announced EGU retirements during the period of analysis. For EGUs that retire during the analysis period, incremental power requirements and trucking associated with BA transport water and FGD wastewater treatment cease, but those associated with CRL continue even after the unit retires.

Table 8-2: Estimated Changes in Air Pollutant Emissions Due to Increase in Power Requirements at Steam Electric Power Plants 2025-2049, Compared to Baseline

Year	CO_2 (Million Tons/Year)[a]	NOx (Thousand Tons/Year)[a]	SO_2 (Thousand Tons/Year)[a]	Primary $PM_{2.5}$ (Thousand Tons/Year)[a]	CH_4 (Million Tons/Year)[a]
Option B (Final Rule)					
2028	0.073	0.043	0.066	Not estimated	Not estimated
2030	0.14	0.088	0.12	Not estimated	Not estimated
2035	0.14	0.088	0.12	Not estimated	Not estimated
2040	0.14	0.088	0.12	Not estimated	Not estimated
2045	0.14	0.087	0.12	Not estimated	Not estimated
2050	0.14	0.083	0.11	Not estimated	Not estimated
Option C					
2028	0.085	0.052	0.070	Not estimated	Not estimated
2030	0.16	0.10	0.12	Not estimated	Not estimated
2035	0.16	0.10	0.12	Not estimated	Not estimated
2040	0.16	0.10	0.12	Not estimated	Not estimated
2045	0.16	0.098	0.12	Not estimated	Not estimated
2050	0.16	0.094	0.12	Not estimated	Not estimated

a. Values rounded to two significant figures. Positive values indicate an increase in emissions.

Source: U.S. EPA Analysis, 2024

Table 8-3: Estimated Changes in Air Pollutant Emissions Due to Increase in Trucking at Steam Electric Power Plants 2025-2049, Compared to Baseline

Year	CO_2 (Million Tons/Year)[a]	NOx (Thousand Tons/Year)[a]	SO_2 (Thousand Tons/Year)[a]	Primary $PM_{2.5}$ (Thousand Tons/Year)[a]	CH_4 (Million Tons/Year)[a]
Option A					
2028	0.00041	0.00083	0.0000014	Not estimated	0.0000036
2030	0.00074	0.0016	0.0000025	Not estimated	0.0000070
2035	0.00074	0.0016	0.0000025	Not estimated	0.0000070
2040	0.00074	0.0016	0.0000025	Not estimated	0.0000070
2045	0.00074	0.0016	0.0000025	Not estimated	0.0000070
2050	0.00070	0.0015	0.0000024	Not estimated	0.0000066
Option B (Final Rule)					
2028	0.00047	0.00097	0.0000016	Not estimated	0.0000042
2030	0.00087	0.0019	0.0000029	Not estimated	0.0000083
2035	0.00087	0.0019	0.0000029	Not estimated	0.0000083
2040	0.00087	0.0019	0.0000029	Not estimated	0.0000083
2045	0.00087	0.0019	0.0000029	Not estimated	0.0000083
2050	0.00083	0.0018	0.0000028	Not estimated	0.0000079
Option C					
2028	0.00055	0.0012	0.0000019	Not estimated	0.0000050
2030	0.0012	0.0025	0.0000039	Not estimated	0.000011
2035	0.0012	0.0025	0.0000039	Not estimated	0.000011
2040	0.0012	0.0025	0.0000039	Not estimated	0.000011
2045	0.0011	0.0025	0.0000039	Not estimated	0.000011
2050	0.0011	0.0024	0.0000037	Not estimated	0.000010

a. Values rounded to two significant figures. Positive values indicate an increase in emissions.

Source: U.S. EPA Analysis, 2024

Table 8-4 summarizes the estimated changes in pollutant emissions from electricity generation under the final rule (*i.e.*, Option B).[109] Projected changes in the profile of electricity generation under Option B, compared to the baseline, generally lead to national-level reductions in emissions for all air pollutants modeled. The pattern of change follows the decline in coal generation described above. Thus, the largest declines in CO_2, NO_X, SO_2 and $PM_{2.5}$ emissions occur in model years 2028 through 2035 before tapering off in the latter run years of the analysis. Thus, at the national level, CO_2 emissions are estimated to decrease by between 11 million and 16 million tons during run years 2028 through 2035 under the final rule when compared to the baseline. Reductions in run years 2040 through 2050 are much smaller (0.7 million to 2.1 million tons per year). In relative terms, the largest effect is SO_2 emissions for the final rule is estimated to reduce baseline emissions by approximately 5 percent in model year 2035.

The impact on emissions varies across regions and by pollutant with emissions increasing in some and decreasing in other NERC regions, as detailed in the RIA (Table 5-4; U.S. EPA, 2024e).

Table 8-4: Estimated Changes in Pollutant Emissions Due to Changes in Electricity Generation Profile, Compared to Baseline

Regulatory Option	Year	CO_2 (Million Tons/Year)[a]	NOx (Thousand Tons/Year)[a]	SO_2 (Thousand Tons/Year)[a]	Primary $PM_{2.5}$ (Thousand Tons/Year)[a]	CH_4 (Million Tons/Year)[a]
Option B (Final Rule)	2028	-16	-8.9	-11	-0.63	Not estimated
	2030	-11	-7.4	-2.5	-0.38	Not estimated
	2035	-13	-8.8	-13	-0.25	Not estimated
	2040	-2.1	-3.2	-2.3	-0.16	Not estimated
	2045	-1.4	-0.7	-1.0	-0.093	Not estimated
	2050	-0.72	-0.45	-0.78	-0.12	Not estimated

a. Values rounded to two significant figures. Negative values indicate a reduction in emissions.

Source: U.S. EPA Analysis, 2024; See Chapter 5 in RIA for details on IPM (U.S. EPA, 2024e).

A comparison of estimated changes in emissions across the three mechanisms (Table 8-2, Table 8-3 and Table 8-4) for the final rule (Option B) shows that the largest effect on projected air emissions comes from the change in the emissions profile of electricity generation at the market level. Table 8-5 presents the net changes in emissions of the four pollutants compared to baseline. The next two sections quantify the climate change and human health benefits associated with changes in emissions under the final rule (Option B).

Table 8-5: Estimated Net Changes in Air Pollutant Emissions Due to Changes in Power Requirements, Trucking, and Electricity Generation Profile, Compared to Baseline

Regulatory Option	Year	CO_2 (Million Tons/Year)[a]	NOx (Thousand Tons/Year)[a]	SO_2 (Thousand Tons/Year)[a]	Primary $PM_{2.5}$ (Thousand Tons/Year)[a]	CH_4 (Million Tons/Year)[a]
Option B (Final Rule)	2028	-16	-8.9	-11	-0.63	0.0000042
	2030	-11	-7.3	-2.4	-0.38	0.0000083
	2035	-13	-8.7	-13	-0.25	0.0000083
	2040	-1.9	-3.1	-2.2	-0.16	0.0000083
	2045	-1.3	-0.63	-0.85	-0.093	0.0000083
	2050	-0.58	-0.37	-0.67	-0.12	0.0000079

a. Values rounded to two significant figures. Negative values indicate a net reduction in emissions.

109 EPA did not run IPM for Option A and Option C.

Table 8-5: Estimated Net Changes in Air Pollutant Emissions Due to Changes in Power Requirements, Trucking, and Electricity Generation Profile, Compared to Baseline

Regulatory Option	Year	CO_2 (Million Tons/Year)[a]	NOx (Thousand Tons/Year)[a]	SO_2 (Thousand Tons/Year)[a]	Primary $PM_{2.5}$ (Thousand Tons/Year)[a]	CH_4 (Million Tons/Year)[a]

Source: U.S. EPA Analysis, 2024

8.2 Climate Change Benefits

8.2.1 Data and Methodology

EPA estimated the climate benefits of the net CO_2 and CH_4 emission changes expected from this final rule using the estimates of the social cost of greenhouse gases (SC-GHG) – specifically, the social cost of carbon (SC-CO_2) and social cost of methane (SC-CH_4)[110] – that reflect recent advances in the scientific literature on climate change and its economic impacts and incorporate recommendations made by the National Academies of Science, Engineering, and Medicine (National Academies, 2017). EPA published and used these estimates in the RIA for the December 2023 Final Oil and Gas New Source Performance Standards (NSPS)/Emissions Guidelines (EG) Rulemaking, "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review". EPA solicited public comment on the methodology and use of these estimates in the RIA for the agency's December 2022 Oil and Gas NSPS/EG Supplemental Proposal (U.S. EPA, 2023l) and has conducted an external peer review of these estimates, as described further below.

The SC-GHG is the monetary value of the net harm to society associated with emitting a metric ton of the GHG in question into the atmosphere in a given year, or the net benefit of avoiding that increase. In principle, the SC-GHG includes the value of all climate change impacts (both negative and positive), including (but not limited to) changes in net agricultural productivity, human health effects, property damage from increased flood risk and natural disasters, disruption of energy systems, risk of conflict, environmental migration, and the value of ecosystem services. The SC-GHG therefore reflects the societal value of reducing emissions of the gas in question by one metric ton and is the theoretically appropriate value to use in conducting benefit-cost analyses of policies that affect greenhouse gas emissions. In practice, data and modeling limitations restrain the ability of SC-GHG estimates to include all physical, ecological, and economic impacts of climate change, implicitly assigning a value of zero to the omitted climate damages. The estimates are, therefore, a partial accounting of climate change impacts and likely underestimate of the marginal benefits of abatement.

EPA and other Federal agencies began regularly incorporating SC-GHG estimates in their benefit-cost analyses conducted under E.O. 12866[111] since 2008, following a Ninth Circuit Court of Appeals remand of a rule for failing to monetize the benefits of reducing greenhouse gas emissions in that rulemaking process. The values used by EPA from 2009 to 2016, and since 2021 – including in the proposal for this rulemaking – have been consistent with those developed and recommended by the Interagency Working Group on the SC-GHG

[110] Estimates of the social cost of greenhouse gases are gas specific (*e.g.*, social cost of carbon (SC-CO_2), social cost of methane (SC-CH_4), social cost of nitrous oxide (SC-N_2O)), but collectively they are referenced as the social cost of greenhouse gases (SC-GHG).

[111] E.O. 12866, released in 1993 and still in effect today, requires that for all economically significant regulatory actions, an agency provide an assessment of the potential costs and benefits of the regulatory action, and that this assessment include a quantification of benefits and costs to the extent feasible. For purposes of this action, monetized climate benefits are presented for purposes of providing a complete benefit-cost analysis under EO 12866 and other relevant executive orders. The estimates of change in GHG emissions and the monetized benefits associated with those changes play no part in the record basis for this action.

(IWG); and the values used from 2017 to 2020 were consistent with those required by E.O. 13783, which disbanded the IWG. During 2015-2017, the National Academies conducted a comprehensive review of the SC-CO_2 and issued a final report in 2017 recommending specific criteria for future updates to the SC-CO_2 estimates, a modeling framework to satisfy the specified criteria, and both near-term updates and longer-term research needs pertaining to various components of the estimation process (National Academies, 2017). The IWG was reconstituted in 2021 and E.O. 13990 directed it to develop a comprehensive update of its SC-GHG estimates, recommendations regarding areas of decision-making to which SC-GHG should be applied, and a standardized review and updating process to ensure that the recommended estimates continue to be based on the best available economics and science going forward.

EPA is a member of the IWG and is participating in the IWG's work under E.O. 13990. As noted in previous EPA RIAs, including in the proposal for this rulemaking, while that process continues, EPA is continuously reviewing developments in the scientific literature on the SC-GHG, including more robust methodologies for estimating damages from emissions, and looking for opportunities to further improve SC-GHG estimation [112] In the December 2022 Oil and Gas NSPS/EG Supplemental Proposal RIA, the Agency included a sensitivity analysis of the climate benefits of the Supplemental Proposal using a new set of SC-GHG estimates that incorporates recent research addressing recommendations of the National Academies (National Academies, 2017) in addition to using the interim SC-GHG estimates presented in the Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990 (IWG, 2021) that the IWG recommended for use until updated estimates that address the National Academies' recommendations are available.

EPA solicited public comment on the sensitivity analysis and the accompanying draft technical report, External Review Draft of Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances, which explains the methodology underlying the new set of estimates, in the December 2022 Supplemental Oil and Gas Proposal. The response to comments document can be found in the docket for that action.

To ensure that the methodological updates adopted in the technical report are consistent with economic theory and reflect the latest science, EPA also initiated an external peer review panel to conduct a high-quality review of the technical report, completed in May 2023. See 88 FR at 26075/2 noting this peer review process. The peer reviewers commended the agency on its development of the draft update, calling it a much-needed improvement in estimating the SC-GHG and a significant step toward addressing the National Academies' recommendations with defensible modeling choices based on current science. The peer reviewers provided numerous recommendations for refining the presentation and for future modeling improvements, especially with respect to climate change impacts and associated damages that are not currently included in the analysis. Additional discussion of omitted impacts and other updates have been incorporated in the technical report to address peer reviewer recommendations. Complete information about the external peer review, including the peer reviewer selection process, the final report with individual recommendations from peer reviewers, and EPA's response to each recommendation is available on EPA's website.[113]

The remainder of this section provides an overview of the methodological updates incorporated into the SC-GHG estimates used in this analysis. A more detailed explanation of each input and the modeling process is

[112] EPA strives to base its analyses on the best available science and economics, consistent with its responsibilities, for example, under the Information Quality Act.

[113] See https://www.epa.gov/environmental-economics/scghg

provided in the technical report, *Supplementary Material for the RIA: EPA Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances* (U.S. EPA, 2023n). Appendix B shows the climate benefits of the final rule using the interim SC-GHG (IWG, 2021) estimates presented in the proposal BCA for comparison purposes.

The steps necessary to estimate the SC-GHG with a climate change integrated assessment model (IAM) can generally be grouped into four modules: socioeconomics and emissions, climate, damages, and discounting. The emissions trajectories from the socioeconomic module are used to project future temperatures in the climate module. The damage module then translates the temperature and other climate endpoints (along with the projections of socioeconomic variables) into physical impacts and associated monetized economic damages, where the damages are calculated as the amount of money the individuals experiencing the climate change impacts would be willing to pay to avoid them. To calculate the marginal effect of emissions, *i.e.*, the SC-GHG in year *t*, the entire model is run twice—first as a baseline and second with an additional pulse of emissions in year *t*. After recalculating the temperature effects and damages expected in all years beyond *t* resulting from the adjusted path of emissions, the losses are discounted to a present value in the discounting module. Many sources of uncertainty in the estimation process are incorporated using Monte Carlo techniques by taking draws from probability distributions that reflect the uncertainty in parameters.

The SC-GHG estimates used by EPA and many other federal agencies since 2009 have relied on an ensemble of three widely used IAMs: Dynamic Integrated Climate and Economy (DICE) (W. D. Nordhaus, 2010); Climate Framework for Uncertainty, Negotiation, and Distribution (FUND) (Anthoff & Tol, 2013a, 2013b); and Policy Analysis of the Greenhouse Gas Effect (PAGE) (Hope, 2013). In 2010, the IWG harmonized key inputs across the IAMs, but all other model features were left unchanged, relying on the model developers' best estimates and judgments. That is, the representation of climate dynamics and damage functions included in the default version of each IAM as used in the published literature was retained.

The SC-GHG estimates in U.S. EPA (2023l) no longer rely on the three IAMs (*i.e.*, DICE, FUND, and PAGE) used in previous SC-GHG estimates. Instead, EPA uses a modular approach to estimating the SC-GHG, consistent with the National Academies' near-term recommendations (National Academies, 2017). That is, the methodology underlying each component, or module, of the SC-GHG estimation process is developed by drawing on the latest research and expertise from the scientific disciplines relevant to that component. Under this approach, each step in the SC-GHG estimation improves consistency with the current state of scientific knowledge, enhances transparency, and allows for more explicit representation of uncertainty.

The socioeconomic and emissions module relies on a new set of probabilistic projections for population, income, and GHG emissions developed under the Resources for the Future (RFF) Social Cost of Carbon Initiative (Rennert et al., 2021). These socioeconomic projections (hereafter collectively referred to as the RFF-SPs) are an internally consistent set of probabilistic projections of population, GDP, and GHG emissions (CO_2, CH_4, and N_2O) to 2300. Based on a review of available sources of long-run projections necessary for damage calculations, the RFF-SPs stand out as being most consistent with the National Academies' recommendations. Consistent with the National Academies' recommendation, the RFF-SPs were developed using a mix of statistical and expert elicitation techniques to capture uncertainty in a single probabilistic approach, taking into account the likelihood of future emissions mitigation policies and technological developments, and provide the level of disaggregation necessary for damage calculations. Unlike other sources of projections, they provide inputs for estimation out to 2300 without further extrapolation assumptions. Conditional on the modeling conducted for the SC-GHG estimates, this time horizon is far enough in the future to capture the majority of discounted climate damages. Including damages beyond 2300 would increase the estimates of the SC-GHG. As discussed in U.S. EPA (2023n), the use of the RFF-SPs allows for capturing economic growth uncertainty within the discounting module.

The climate module relies on the Finite Amplitude Impulse Response (FaIR) model (IPCC, 2021b; Millar et al., 2017; Smith et al., 2018), a widely used Earth system model which captures the relationships between GHG emissions, atmospheric GHG concentrations, and global mean surface temperature. The FaIR model was originally developed by Richard Millar, Zeb Nicholls, and Myles Allen at Oxford University, as a modification of the approach used in IPCC AR5 to assess the GWP and GTP (Global Temperature Potential) of different gases. It is open source, widely used (*e.g.*, IPCC (2018, 2021a)), and was highlighted by the National Academies (2017) as a model that satisfies their recommendations for a near-term update of the climate module in SC-GHG estimation. Specifically, it translates GHG emissions into mean surface temperature response and represents the current understanding of the climate and GHG cycle systems and associated uncertainties within a probabilistic framework. The SC-GHG estimates used in this RIA rely on FaIR version 1.6.2 as used by the IPCC (2021a). It provides, with high confidence, an accurate representation of the latest scientific consensus on the relationship between global emissions and global mean surface temperature, offers a code base that is fully transparent and available online, and the uncertainty capabilities in FaIR 1.6.2 have been calibrated to the most recent assessment of the IPCC (which importantly narrowed the range of likely climate sensitivities relative to prior assessments). See U.S. EPA (2023n) for more details.

The socioeconomic projections and outputs of the climate module are inputs into the damage module to estimate monetized future damages from climate change.[114] The National Academies' recommendations for the damage module, scientific literature on climate damages, updates to models that have been developed since 2010, as well as the public comments received on individual EPA rulemakings and the IWG's February 2021 TSD, have all helped to identify available sources of improved damage functions. The IWG (*e.g.*, IWG, 2010; 2016b, 2021), the National Academies (2017), comprehensive studies (*e.g.*, Rose et al. (2014)), and public comments have all recognized that the damages functions underlying the IWG SC-GHG estimates used since 2013 (taken from DICE 2010 (W.D. Nordhaus, 2010); FUND 3.8 (Anthoff & Tol, 2013a, 2013b); and PAGE 2009 (Hope, 2012)) do not include all of important physical, ecological, and economic impacts of climate change. The climate change literature and the science underlying the economic damage functions have evolved, and DICE 2010, FUND 3.8, and PAGE 2009 now lag behind the most recent research.

The challenges involved with updating damage functions have been widely recognized. Functional forms and calibrations are constrained by the available literature and need to extrapolate beyond warming levels or locations studied in that literature. Research focused on understanding how these physical changes translate into economic impacts is still developing, and has received less public resources, relative to the research focused on modeling and improving our understanding of climate system dynamics and the physical impacts from climate change (Auffhammer, 2018). Even so, there has been a large increase in research on climate

114 In addition to temperature change, two of the three damage modules used in the SC-GHG estimation require global mean sea level (GMSL) projections as an input to estimate coastal damages. Those two damage modules use different models for generating estimates of GMSL. Both are based off reduced complexity models that can use the FaIR temperature outputs as inputs to the model and generate projections of GMSL accounting for the contributions of thermal expansion and glacial and ice sheet melting based on recent scientific research. Absent clear evidence on a preferred model, the SC-GHG estimates presented in this chapter retain both methods used by the damage module developers. See U.S. Environmental Protection Agency. (2023n). *Supplementary Material for the Regulatory Impact Analysis for the Final Rulemaking, "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review": EPA Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances*. Retrieved from https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf for more details.

impacts and damages in the time since DICE 2010, FUND 3.8, and PAGE 2009 were published. Along with this growth, there continues to be variation in methodologies and scope of studies, such that care is required when synthesizing the current understanding of impacts or damages. Based on a review of available studies and approaches to damage function estimation, EPA uses three separate damage functions to form the damage module. They are:

1. a subnational-scale, sectoral damage function (based on the Data-driven Spatial Climate Impact Model (DSCIM) developed by the Climate Impact Lab (Carleton et al., 2022; Climate Impact Lab (CIL), 2023; Rode et al., 2021),
2. a country-scale, sectoral damage function (based on the Greenhouse Gas Impact Value Estimator (GIVE) model developed under RFF's Social Cost of Carbon Initiative (Rennert et al., 2022), and
3. a meta-analysis-based damage function (based on Howard & Sterner, 2017).

The damage functions in DSCIM and GIVE represent substantial improvements relative to the damage functions underlying the SC-GHG estimates used by EPA to date and reflect the forefront of scientific understanding about how temperature change and sea level rise lead to monetized net (market and nonmarket) damages for several categories of climate impacts. The models' spatially explicit and impact-specific modeling of relevant processes allows for improved understanding and transparency about mechanisms through which climate impacts are occurring and how each damage component contributes to the overall results, consistent with the National Academies' recommendations. DSCIM addresses common criticisms related to the damage functions underlying current SC-GHG estimates (*e.g.*, Pindyck (2017)) by developing multi-sector, empirically grounded damage functions. The damage functions in the GIVE model offer a direct implementation of the National Academies' near-term recommendation to develop updated sectoral damage functions that are based on recently published work and reflective of the current state of knowledge about damages in each sector. Specifically, the National Academies noted that "[t]he literature on agriculture, mortality, coastal damages, and energy demand provide immediate opportunities to update the [models]" (National Academies, 2017, p. 199), which are the four damage categories currently in GIVE. A limitation of both models is that the sectoral coverage is still limited, and even the categories that are represented are incomplete. Neither DSCIM nor GIVE yet accommodate estimation of several categories of temperature driven climate impacts (*e.g.*, morbidity, conflict, migration, biodiversity loss) and only represent a limited subset of damages from changes in precipitation. For example, while precipitation is considered in the agriculture sectors in both DSCIM and GIVE, neither model takes into account impacts of flooding, changes in rainfall from tropical storms, and other precipitation related impacts. As another example, the coastal damage estimates in both models do not fully reflect the consequences of sea level rise-driven salt-water intrusion and erosion, or sea level rise damages to coastal tourism and recreation. Other missing elements are damages that result from other physical impacts (*e.g.*, ocean acidification, non-temperature-related mortality such as diarrheal disease and malaria) and the many feedbacks and interactions across sectors and regions that can lead to additional damages.[115] See U.S. EPA (2023n) for more discussion of omitted damage categories and other modeling limitations. DSCIM and GIVE do account for the most commonly cited benefits associated with CO_2 emissions and climate change—CO_2 crop fertilization and declines in cold related mortality. As such, while the GIVE- and DSCIM-based results provide state-of-the-science assessments of

[115] The one exception is that the agricultural damage function in DSCIM and GIVE reflects the ways that trade can help mitigate damages arising from crop yield impacts.

key climate change impacts, they remain partial estimates of future climate damages resulting from incremental changes in CO_2, CH_4, and N_2O.[116]

Finally, given the still relatively narrow sectoral scope of the recently developed DSCIM and GIVE models, the damage module includes a third damage function that reflects a synthesis of the state of knowledge in other published climate damages literature. Studies that employ meta-analytic techniques offer a tractable and straightforward way to combine the results of multiple studies into a single damage function that represents the body of evidence on climate damages that pre-date CIL and RFF's research initiatives.[117] The first use of meta-analysis to combine multiple climate damage studies was done by Tol (2009) and included 14 studies. The studies in Tol (2009) served as the basis for the global damage function in DICE starting in version 2013R (Nordhaus, 2014). The damage function in the most recent published version of DICE, DICE 2016, is from an updated meta-analysis based on a review of existing damage studies and included 26 studies published over 1994-2013 (Nordhaus & Moffat, 2017). Howard and Sterner (2017) provide a more recent published peer-reviewed meta-analysis of existing damage studies (published through 2016) and account for additional features of the underlying studies. This study addresses differences in measurement across studies by adjusting estimates such that the data are relative to the same base period. They also eliminate double counting by removing duplicative estimates. Howard and Sterner's final sample is drawn from 20 studies that were published through 2015. Howard and Sterner (2017) present results under several specifications, and their analysis shows that the estimates are somewhat sensitive to defensible alternative modeling choices. As discussed in detail in U.S. EPA (2023n), the damage module underlying the SC-GHG estimates in this analysis includes the damage function specification (that excludes duplicate studies) from Howard and Sterner (2017) that leads to the lowest SC-GHG estimates, all else equal.

The discounting module discounts the stream of future net climate damages to its present value in the year when the additional unit of emissions was released. Given the long time horizon over which the damages are expected to occur, the discount rate has a large influence on the present value of future damages. Consistent with the findings of National Academies (2017), the economic literature, OMB Circular A-4's guidance for regulatory analysis, and IWG recommendations to date (IWG, 2010, 2013; 2016a, 2016b, 2021), EPA continues to conclude that the consumption rate of interest is the theoretically appropriate discount rate to discount the future benefits of reducing GHG emissions and that discount rate uncertainty should be accounted for in selecting future discount rates in this intergenerational context. OMB's Circular A-4 points out that "the analytically preferred method of handling temporal differences between benefits and costs is to adjust all the benefits and costs to reflect their value in equivalent units of consumption before discounting them." (OMB, 2023)[118] The damage module described above calculates future net damages in terms of

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116 One advantage of the modular approach used by these models is that future research on new or alternative damage functions can be incorporated in a relatively straightforward way. DSCIM and GIVE developers have work underway on other impact categories that may be ready for consideration in future updates (*e.g.*, morbidity and biodiversity loss).

117 Meta-analysis is a statistical method of pooling data and/or results from a set of comparable studies of a problem. Pooling in this way provides a larger sample size for evaluation and allows for a stronger conclusion than can be provided by any single study. Meta-analysis yields a quantitative summary of the combined results and current state of the literature.

118 The previous version of OMB's Circular A-4 similarly pointed out that "the analytically preferred method of handling temporal differences between benefits and costs is to adjust all the benefits and costs to reflect their value in equivalent units of consumption and to discount them at the rate consumers and savers would normally use in discounting future consumption benefits" (U.S. Office of Management and Budget. (2023). *Circular A-4: Regulatory Analysis*. Retrieved from https://www.whitehouse.gov/wp-content/uploads/2023/11/CircularA-4.pdf, ibid.).

reduced consumption (or monetary consumption equivalents), and so an application of this guidance is to use the consumption discount rate to calculate the SC-GHG.[119]

For the SC-GHG estimates used in this analysis, EPA relies on a dynamic discounting approach that more fully captures the role of uncertainty in the discount rate in a manner consistent with the other modules. Based on a review of the literature and data on consumption discount rates, the public comments received on individual EPA rulemakings, and the February 2021 TSD (IWG, 2021), and the National Academies (2017) recommendations for updating the discounting module, the SC-GHG estimates rely on discount rates that reflect more recent data on the consumption interest rate and uncertainty in future rates. Specifically, rather than using a constant discount rate, the evolution of the discount rate over time is defined following the latest empirical evidence on interest rate uncertainty and using a framework originally developed by Ramsey (1928) that connects economic growth and interest rates. The Ramsey approach explicitly reflects (1) preferences for utility in one period relative to utility in a later period and (2) the value of additional consumption as income changes. The dynamic discount rates used to develop the SC-GHG estimates applied in this analysis have been calibrated following the Newell, Pizer and Prest (2022) approach, as applied in Rennert et al. (2022). This approach uses the Ramsey (1928) discounting formula in which the parameters are calibrated such that (1) the decline in the certainty-equivalent discount rate matches the latest empirical evidence on interest rate uncertainty estimated by Bauer and Rudebusch (2020, 2023) and (2) the average of the certainty-equivalent discount rate over the first decade matches a near-term consumption rate of interest. Uncertainty in the starting rate is addressed by using three near-term target rates (1.5, 2.0, and 2.5 percent) based on multiple lines of evidence on observed market interest rates.

The resulting dynamic discount rate provides a notable improvement over the constant discount rate framework used for SC-GHG estimation in EPA regulatory impact analyses to date. Specifically, it provides internal consistency within the modeling and a more complete accounting of uncertainty consistent with economic theory (Arrow et al., 2013; Cropper et al., 2014) and the National Academies' (2017) recommendation to employ a more structural, Ramsey-like approach to discounting that explicitly recognizes the relationship between economic growth and discounting uncertainty. This approach is also consistent with the National Academies (2017) recommendation to use three sets of Ramsey parameters that reflect a range of near-term certainty-equivalent discount rates and are consistent with theory and empirical evidence on consumption rate uncertainty. Finally, the value of aversion to risk associated with net damages from GHG emissions is explicitly incorporated into the modeling framework following the economic literature. See U.S. EPA (2023n) for a more detailed discussion of the entire discounting module and methodology used to value risk aversion in the SC-GHG estimates.

Taken together, the methodologies adopted in this SC-GHG estimation process allow for a more holistic treatment of uncertainty than in past estimates by EPA. The updates incorporate a quantitative consideration of uncertainty into all modules and use a Monte Carlo approach that captures the compounding uncertainties across modules. The estimation process generates nine separate distributions of discounted marginal damages per metric ton — the product of using three damage modules and three near-term target discount rates — for each gas in each emissions year. These distributions have long right tails reflecting the extensive evidence in

[119] See the discussion of the inappropriateness of discounting consumption-equivalent measures of benefits and costs using a rate of return on capital in Circular A-4 (ibid., ibid.). Note that under the previous version of OMB's Circular A-4 EPA also concluded that the use of the social rate of return on capital (7 percent under the 2003 OMB Circular A-4 guidance), which does not reflect the consumption rate, to discount damages estimated in terms of reduced consumption would inappropriately underestimate the impacts of climate change for the purposes of estimating the SC-GHG.

the scientific and economic literature that shows the potential for lower-probability but higher-impact outcomes from climate change, which would be particularly harmful to society. The uncertainty grows over the modeled time horizon. Therefore, under cases with a lower near-term target discount rate – that give relatively more weight to impacts in the future – the distribution of results is wider. To produce a range of estimates that reflects the uncertainty in the estimation exercise while also providing a manageable number of estimates for policy analysis, EPA combines the multiple lines of evidence on damage modules by averaging the results across the three damage module specifications. The full results generated from the updated methodology for methane and other greenhouse gases (SC-CO_2, SC-CH_4, and SC-N_2O) for emissions years 2020 through 2080 are provided in U.S. EPA (2023n).

Table 8-6 presents the resulting averaged certainty-equivalent SC-CO_2 and SC-CH_4 estimates for emissions occurring in 2025 to 2049 under each near-term discount rate that are used to estimate the climate benefits of the CO_2 and CH_4 changes expected from the final rule. These estimates are reported in 2023 dollars but are otherwise identical to those presented in U.S. EPA (2023l). The SC-GHG increases over time within the models — *i.e.*, the societal harm from one metric ton emitted in 2030 is higher than the harm caused by one metric ton emitted in 2025 — because future emissions produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change, and because GDP is growing over time and many damage categories are modeled as proportional to GDP. EPA estimated the climate benefits of the net CO_2 and CH_4 emission changes for each analysis year between 2025 and 2049 by applying the annual SC-CO_2 and SC-CH_4 estimates, shown in Table 8-6, to the estimated changes in CO_2 and CH_4 emissions in the corresponding year under the regulatory options.

Table 8-6: Estimates of the Social Cost of Greenhouse Gas by Year and Near-Term Ramsey Discount Rate, 2025–2049

Year	Social Cost of CO2 (2023$/Metric Tonne CO_2)			Social Cost of CH_4 (2023$/Metric Tonne CH_4)		
	1.5%	2.0%	2.5%	1.5%	2.0%	2.5%
2025	$150	$250	$430	$1,800	$2,300	$3,200
2026	$150	$250	$420	$1,900	$2,400	$3,300
2027	$160	$250	$430	$2,000	$2,500	$3,400
2028	$160	$260	$440	$2,100	$2,600	$3,500
2029	$160	$260	$440	$2,200	$2,700	$3,600
2030	$170	$270	$450	$2,200	$2,800	$3,700
2031	$170	$270	$450	$2,300	$2,900	$3,800
2032	$170	$270	$460	$2,400	$3,000	$3,900
2033	$180	$280	$460	$2,500	$3,100	$4,000
2034	$180	$280	$470	$2,600	$3,200	$4,100
2035	$180	$290	$470	$2,700	$3,300	$4,300
2036	$190	$290	$480	$2,800	$3,400	$4,400
2037	$190	$300	$480	$2,900	$3,500	$4,500
2038	$190	$300	$490	$3,000	$3,600	$4,600
2039	$200	$310	$490	$3,000	$3,700	$4,700
2040	$200	$310	$500	$3,100	$3,800	$4,800
2041	$200	$310	$510	$3,200	$3,900	$5,000
2042	$210	$320	$510	$3,300	$4,000	$5,100
2043	$210	$320	$520	$3,400	$4,100	$5,200
2044	$220	$330	$520	$3,500	$4,200	$5,300
2045	$220	$330	$530	$3,600	$4,400	$5,500
2046	$220	$340	$540	$3,700	$4,500	$5,600
2047	$230	$340	$540	$3,800	$4,600	$5,700
2048	$230	$350	$550	$3,900	$4,700	$5,900

Table 8-6: Estimates of the Social Cost of Greenhouse Gas by Year and Near-Term Ramsey Discount Rate, 2025–2049

Year	Social Cost of CO2 (2023$/Metric Tonne CO_2)			Social Cost of CH_4 (2023$/Metric Tonne CH_4)		
	1.5%	2.0%	2.5%	1.5%	2.0%	2.5%
2049	$230	$350	$550	$4,000	$4,800	$6,000

Note: Values shown are rounded to two significant figures, but the unrounded values were used in the calculations and are available in the Appendix to U.S. EPA (2023n). These SC-GHG values are identical to those reported in U.S. EPA (2023n) adjusted for inflation to 2023 dollars using the annual GDP Implicit Price Deflator values in the U.S. Bureau of Economic Analysis' (BEA) National Income and Product Accounts Table 1.1.9 (U.S. BEA, 2023; U.S. BEA, 2024), which are 122.262 and 105.381, respectively for 2023 and 2020. SC-CO_2 and SC-CH_4 values are stated in $/metric tonne CO_2 and CH_4, respectively (1 metric tonne equals 1.102 short tons) and vary depending on the year of emissions.

Source: U.S. EPA Analysis, 2024 based on U.S. EPA (2023l; U.S. EPA (2023n).

The methodological updates incorporated in U.S. EPA (2023l) and summarized above represent a major step forward in bringing SC-GHG estimation closer to the frontier of climate science and economics and address many of the near-term recommendations by the National Academies (2017). Nevertheless, the SC-GHG estimates presented in Table 8-6 still have several limitations, as would be expected for any modeling exercise that covers such a broad scope of scientific and economic issues across a complex global landscape. There are still many categories of climate impacts and associated damages that are only partially or not reflected yet in these estimates and sources of uncertainty that have not been fully characterized due to data and modeling limitations. For example, the modeling omits most of the consequences of changes in precipitation, damages from extreme weather events, the potential for nongradual damages from passing critical thresholds (*e.g.*, tipping elements) in natural or socioeconomic systems, and non-climate mediated effects of GHG emissions. The SC-CH_4 estimates do not account for the direct health and welfare impacts associated with tropospheric ozone produced by methane. Importantly, the updated SC-GHG methodology does not yet reflect interactions and feedback effects within, and across, Earth and human systems. For example, it does not explicitly reflect potential interactions among damage categories, such as those stemming from the interdependencies of energy, water, and land use. These, and other, interactions and feedbacks were highlighted by the National Academies as an important area of future research for longer-term enhancements in the SC-GHG estimation framework.

8.2.2 Results

Table 8-7 presents the undiscounted annual monetized climate benefits in selected years for Option B, the final rule. Benefits are calculated using the three different estimates of the SC-GHG from Table 8-6 based on the near-term Ramsey discount rates. EPA first mapped IPM emissions changes to corresponding years within the period of analysis 2025-2049 based on Table 8-1 and assuming no changes in air emissions from electricity generation between 2025 and 2027. For trucking and energy use, EPA estimated changes in air emissions corresponding to the year each plant is estimated to implement changes in technology. Net CO_2 and CH_4 changes each year are then multiplied by the SC-CO_2 or SC-CH_4 estimates for that year. EPA calculated the present value of climate benefits as of the expected rule promulgation year of 2024 by discounting each year-specific value to the year 2024 using the same near-term Ramsey discount rate used to calculate the corresponding SC-GHG. [120] That is, future climate benefits estimated with the SC-GHG at the 2.5 percent,

[120] As discussed in U.S. Environmental Protection Agency. (2023n). *Supplementary Material for the Regulatory Impact Analysis for the Final Rulemaking, "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review": EPA Report on the Social Cost of Greenhouse Gases: Estimates*

2 percent, and 1.5 percent Ramsey rate are discounted to the base year of the analysis using a constant 2.5, 2, and 1.5 percent rate, respectively.

The profile of benefits is the result of both ELG effects and other factors. Thus, the larger benefits beginning in 2028 coincide with the timing of compliance with the revised ELGs and impacts of the rule on the generation mix, whereas the decline starting around 2038 coincide with emissions reductions already projected in Base Case due to factors external to the revised ELGs. See Chapter 5 in the RIA for details on IPM Base Case projections (U.S. EPA, 2024e).

Table 8-7: Estimated Undiscounted and Total Present Value of Climate Benefits from Changes in CO_2 and CH_4 Emissions under the Final Rule, Compared to Baseline (Millions of 2023$)

Regulatory Option	Year	Climate Benefits[a, b]		
		SC-GHG based on 1.5% near term Ramsey discount rate	SC-GHG based on 2% near-term Ramsey discount rate	SC-GHG based on 2.5% near-term Ramsey discount rate
Option B (Final Rule)	2025	$0.0	$0.0	$0.0
	2026	-$5.7	-$9.2	-$15.7
	2027	-$8.4	-$13.5	-$22.9
	2028	$2,393.4	$3,839.8	$6,457.1
	2029	$2,424.2	$3,885.6	$6,533.2
	2030	$1,642.7	$2,623.8	$4,380.6
	2031	$1,677.0	$2,669.4	$4,437.7
	2032	$1,993.3	$3,149.4	$5,235.7
	2033	$2,033.2	$3,202.6	$5,288.9
	2034	$2,059.8	$3,255.7	$5,355.4
	2035	$2,099.6	$3,295.6	$5,421.8
	2036	$2,139.5	$3,348.8	$5,475.0
	2037	$2,179.4	$3,401.9	$5,541.4
	2038	$340.5	$528.2	$860.5
	2039	$346.7	$536.3	$868.7
	2040	$352.8	$544.5	$878.9
	2041	$358.9	$552.7	$889.2
	2042	$242.4	$372.3	$597.1
	2043	$246.4	$377.8	$603.9
	2044	$251.9	$383.2	$610.7
	2045	$255.9	$388.6	$617.5
	2046	$260.0	$394.1	$625.7
	2047	$264.2	$401.0	$632.7
	2048	$121.7	$183.5	$288.7
	2049	$123.6	$186.0	$291.9
	Total present value	**$18,774.7**	**$31,019.9**	**$53,649.9**
	Annualized value	**$994.1**	**$1,557.7**	**$2,551.0**

a. Values rounded to two significant figures.

Incorporating Recent Scientific Advances. Retrieved from https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf, the error associated with using a constant discount rate rather than the certainty-equivalent rate path to calculate the present value of a future stream of monetized climate benefits is small for analyses with moderate time frames (*e.g.*, 30 years or less). Ibid. also provides an illustration of the amount that climate benefits from reductions in future emissions will be underestimated by using a constant discount rate relative to the more complicated certainty-equivalent rate path.

Table 8-7: Estimated Undiscounted and Total Present Value of Climate Benefits from Changes in CO_2 and CH_4 Emissions under the Final Rule, Compared to Baseline (Millions of 2023$)

Regulatory Option	Year	Climate Benefits[a, b]		
		SC-GHG based on 1.5% near term Ramsey discount rate	SC-GHG based on 2% near-term Ramsey discount rate	SC-GHG based on 2.5% near-term Ramsey discount rate

b. Climate benefits are based on changes in CO_2 and CH_4 emissions and are calculated using three different estimates of the SC-GHG (1.5 percent, 2 percent, and 2.5 percent near-term Ramsey discount rates).

Source: U.S. EPA Analysis, 2024

Table 8-8 shows the annualized climate benefits associated with changes in CO_2 and CH_4 emissions over the 2025-2049 period under each discount rate for the final rule by category of emissions. EPA annualized the climate benefits to enable consistent reporting across benefit categories (*e.g.*, benefits from improvement in water quality). As noted above, the IPM model run provides outputs starting in 2028. For the years 2025 through 2027, EPA assumed no change in air emissions from changes in the profile of electricity generation. For trucking and energy use, EPA estimated changes in air emissions corresponding to the year each plant is estimated to implement changes in technology. For each SC-GHG estimate, EPA then calculated the annualized benefits from the perspective of 2024 by discounting each year-specific value to the year 2024 using the same near-term discount rate used to calculate the SC-GHG. Using the SC-GHG values for the 2 percent near-term discount rate and using a 2 percent discount to annualize the benefits yields annualized benefits of $1,558 million.

Table 8-8: Estimated Annualized Climate Benefits from Changes in CO_2 and CH_4 Emissions under the Final Rule during the Period of 2025-2049 by Categories of Air Emissions and SC-GHG Estimates, Compared to Baseline (Millions of 2023$)

Regulatory Option	Category of Air Emissions	Annualized Climate Benefits[a,b]		
		1.5% Discount Rate	2.0% Discount Rate	2.5% Discount Rate
Option B (Final Rule)	Electricity generation	$1,014.0	$1,589.1	$2,602.8
	Trucking	-$0.1	-$0.2	-$0.3
	Energy use	-$19.7	-$31.2	-$51.4
	Total	**$994.2**	**$1,557.7**	**$2,551.1**

a. Values rounded to two significant figures. Negative values indicate forgone benefits whereas positive values indicate positive benefits.

b. Climate benefits are based on changes CO_2 and CH_4 emissions and are calculated using three different estimates of the SC-CO_2 and SC-CH_4 (1.5 percent, 2.0 percent, and 2.5 percent near-term Ramsey discount rates).

Source: U.S. EPA Analysis, 2024

Unlike many environmental problems where the causes and impacts are distributed more locally, GHG emissions are a global externality making climate change a true global challenge. GHG emissions contribute to damages around the world regardless of where they are emitted. Because of the distinctive global nature of climate change, in the BCA for this final rule EPA centers attention on a global measure of climate benefits from GHG reductions. Consistent with all IWG recommended SC-GHG estimates to date, the SC-GHG values presented in Table 8-6 above provide a global measure of monetized damages from GHG emissions and Tables 8-7 and 8-8 present the monetized global climate benefits of the GHG emission changes expected from the final rule. This approach is the same as that taken in EPA regulatory analyses from 2009 through 2016 and since 2021. It is also consistent with guidance in Circular A-4 (OMB, 2003) that recommends reporting of important international effects.[121] EPA also notes that EPA's cost estimates in RIAs, including the cost estimates contained in this BCA, regularly do not differentiate between the share of compliance costs expected to accrue to U.S. firms versus foreign interests, such as to foreign investors in regulated entities.[122] A global perspective on climate effects is therefore consistent with the approach EPA takes on costs. There are many reasons, as summarized in this section – and as articulated by OMB and in IWG assessments (IWG, 2010, 2013; 2016a, 2016b, 2021), the 2015 Response to Comments (IWG, 2015) and in detail in U.S. EPA (2023n) and in Appendix A of the Response to Comments document for the December 2023 Final Oil and Gas NSPS/EG Rulemaking – why EPA focuses on the global value of climate change impacts when analyzing policies that affect GHG emissions.

International cooperation and reciprocity are essential to successfully addressing climate change, as the global nature of greenhouse gases means that a ton of GHGs emitted in any other country harms those in the United States just as much as a ton emitted within the territorial United States. Assessing the benefits of U.S. GHG mitigation activities requires consideration of how those actions may affect mitigation activities by other countries, as those international mitigation actions will provide a benefit to U.S. citizens and residents by mitigating climate impacts that affect U.S. citizens and residents. This is a classic public goods problem because each country's reductions benefit everyone else, and no country can be excluded from enjoying the benefits of other countries' reductions. The only way to achieve an efficient allocation of resources for emissions reduction on a global basis — and so benefit the United States and its citizens and residents — is for all countries to base their policies on global estimates of damages. A wide range of scientific and

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121 The 2003 version of OMB Circular A-4 states when a regulation is likely to have international effects, "these effects should be reported"; while OMB Circular A-4 recommends that international effects we reported separately, the guidance also explains that "[d]ifferent regulations may call for different emphases in the analysis, depending on the nature and complexity of the regulatory issues." (U.S. Office of Management and Budget. (2003). *Circular A-4: Regulatory Analysis*. Retrieved from https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/circulars/A4/a-4.pdf). The 2023 update to Circular A-4 states that "In certain contexts, it may be particularly appropriate to include effects experienced by noncitizens residing abroad in your primary analysis. Such contexts include, for example, when:

- assessing effects on noncitizens residing abroad provides a useful proxy for effects on U.S. citizens and residents that are difficult to otherwise estimate;
- assessing effects on noncitizens residing abroad provides a useful proxy for effects on U.S. national interests that are not otherwise fully captured by effects experienced by particular U.S. citizens and residents (e.g., national security interests, diplomatic interests, etc.);
- regulating an externality on the basis of its global effects supports a cooperative international approach to the regulation of the externality by potentially inducing other countries to follow suit or maintain existing efforts; or
- international or domestic legal obligations require or support a global calculation of regulatory effects" (U.S. Office of Management and Budget. (2023). *Circular A-4: Regulatory Analysis*. Retrieved from https://www.whitehouse.gov/wp-content/uploads/2023/11/CircularA-4.pdf).
- Due to the global nature of the climate change problem, the OMB recommendations of appropriate contexts for considering international effects are relevant to the CO_2 emission reductions expected from the final rule. For example, as discussed in this RIA, a global focus in evaluating the climate impacts of changes in CO_2 emissions supports a cooperative international approach to GHG mitigation by potentially inducing other countries to follow suit or maintain existing efforts, and the global SC-CO_2 estimates better capture effects on U.S. citizens and residents and U.S. national interests that are difficult to estimate and not otherwise fully captured.

122 For example, in the RIA for the 2018 Proposed Reconsideration of the Oil and Natural Gas Sector Emission Standards for New, Reconstructed, and Modified Sources, EPA acknowledged that some portion of regulatory costs will likely "accru[e] to entities outside U.S. borders" through foreign ownership, employment, or consumption (U.S. Environmental Protection Agency. (2018d). *Regulatory Impact Analysis for the Proposed Reconsideration of the Oil and Natural Gas Sector Emission Standards for New, Reconstructed, and Modified Sources*. (EPA-452/R-18-001). Retrieved from https://www.epa.gov/sites/default/files/2018-09/documents/oil_and_natural_gas_nsps_reconsideration_proposal_ria.pdf, p. 3-13). In general, a significant share of U.S. corporate debt and equities are foreign-owned, including in the oil and gas industry.

economic experts have emphasized the issue of international cooperation and reciprocity as support for assessing global damages of GHG emission in domestic policy analysis. Using a global estimate of damages in U.S. analyses of regulatory actions allows the U.S. to continue to actively encourage other nations, including emerging major economies, to also assess global climate damages of their policies and to take steps to reduce emissions. For example, many countries and international institutions have already explicitly adapted the global SC-GHG estimates used by EPA in their domestic analyses (*e.g.*, Canada, Israel) or developed their own estimates of global damages (*e.g.*, Germany), and recently, there has been renewed interest by other countries to update their estimates since the draft release of the updated SC-GHG estimates presented in the December 2022 Oil and Gas NSPS/EG Supplemental Proposal RIA.[123] Several recent studies have empirically examined the evidence on international GHG mitigation reciprocity, through both policy diffusion and technology diffusion effects. See U.S. EPA (2023n) for more discussion.

For all of these reasons, EPA believes that a global metric is appropriate for assessing the climate benefits of avoided GHG emissions in this final RIA. In addition, as emphasized in the National Academies' recommendations, "[i]t is important to consider what constitutes a domestic impact in the case of a global pollutant that could have international implications that impact the United States." (National Academies, 2017) The global nature of GHG pollution and its impacts means that U.S. interests are affected by climate change impacts through a multitude of pathways and these need to be considered when evaluating the benefits of GHG mitigation to U.S. citizens and residents. The increasing interconnectedness of global economy and populations means that impacts occurring outside of U.S. borders can have significant impacts on U.S. interests. Examples of affected interests include direct effects on U.S. citizens and assets located abroad, international trade, and tourism, and spillover pathways such as economic and political destabilization and global migration that can lead to adverse impacts on U.S. national security, public health, and humanitarian concerns. Those impacts point to the global nature of the climate change problem and are better captured within global measures of the social cost of greenhouse gases.

In the case of these global pollutants, for the reasons articulated in this section, the assessment of global net damages of GHG emissions allows EPA to fully disclose and contextualize the net climate benefits of GHG emission changes expected from this final rule. EPA disagrees with public comments received on the December 2022 Oil and Gas NSPS/EG Supplemental Proposal that suggested that EPA can or should use a metric focused on benefits resulting solely from changes in climate impacts occurring within U.S. borders. The global models used in the SC-GHG modeling described above do not lend themselves to be disaggregated in a way that could provide sufficiently robust information about the distribution of the rule's climate benefits to citizens and residents of particular countries, or population groups across the globe and within the U.S. Two of the models used to inform the damage module, the GIVE and DSCIM models, have spatial resolution that allows for some geographic disaggregation of future climate impacts across the world. This permits the calculation of a partial GIVE and DSCIM-based SC-GHG measuring the damages from four or five climate impact categories projected to physically occur within the U.S., respectively, subject to caveats. As discussed at length in U.S. EPA (2023n), these damage modules are only a partial accounting and do not capture all of the pathways through which climate change affects public health and welfare. Thus, they only cover a subset of potential climate change impacts. Furthermore, the damage modules do not capture

123 In April 2023, the government of Canada announced the publication of an interim update to their SC-GHG guidance, recommending SC-GHG estimates identical to EPA's updated estimates presented in the December 2022 Supplemental Proposal RIA. The Canadian interim guidance will be used across all Canadian federal departments and agencies, with the values expected to be finalized by the end of the year. https://www.canada.ca/en/environment-climate-change/services/climate-change/science-research-data/social-cost-ghg.html.

spillover or indirect effects whereby climate impacts in one country or region can affect the welfare of residents in other countries or regions—such as how economic and health conditions across countries will impact U.S. business, investments, and travel abroad.

Additional modeling efforts can and have shed further light on some omitted damage categories. For example, the Framework for Evaluating Damages and Impacts (FrEDI) is an open-source modeling framework developed by EPA[124] to facilitate the characterization of net annual climate change impacts in numerous impact categories within the contiguous U.S. and monetize the associated distribution of modeled damages (Sarofim et al., 2021; U.S. EPA, 2021c). The additional impact categories included in FrEDI reflect the availability of U.S.-specific data and research on climate change effects. As discussed in U.S. EPA (2023n) results from FrEDI show that annual damages resulting from climate change impacts within the contiguous U.S. (CONUS) (*i.e.*, excluding Hawaii, Alaska, and U.S. territories) and for impact categories not represented in GIVE and DSCIM are expected to be substantial. As discussed in U.S. EPA (2021c), results from FrEDI show that annual damages resulting from climate change impacts within the contiguous U.S. (CONUS) (*i.e.*, excluding Hawaii, Alaska, and U.S. territories) and for impact categories not represented in GIVE and DSCIM are expected to be substantial. For example, FrEDI estimates a partial SC-CO_2 of \$47/mtCO_2 for damages physically occurring within CONUS for 2030 emissions, under a 2 percent near-term Ramsey discount rate)[125] (Hartin et al., 2023), compared to a GIVE and DSCIM-based U.S.-specific SC-CO_2 of \$19/mtCO2 and \$21/mtCO_2, respectively, for 2030 emissions.[126]

While the FrEDI results help to illustrate how monetized damages physically occurring within CONUS increase as more impacts are reflected in the modeling framework, they are still subject to many of the same limitations associated with the DSCIM and GIVE damage modules, including the omission or partial

[124] The FrEDI framework and Technical Documentation have been subject to a public review comment period and an independent external peer review, following guidance in EPA Peer-Review Handbook for Influential Scientific Information (ISI). Information on the FrEDI peer-review is available at EPA Science Inventory (https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryID=360384&Lab=OAP).

[125] As explained in U.S. Environmental Protection Agency. (2023n). *Supplementary Material for the Regulatory Impact Analysis for the Final Rulemaking, "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review": EPA Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances*. Retrieved from https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf, Hartin, C., McDuffie, E. E., Noiva, K., Sarofim, M., Parthum, B., Martinich, J., Barr, S., . . . Fawcett, A. (2023). Advancing the estimation of future climate impacts within the United States. *Earth Syst. Dynam.*, *14*(5), 1015-1037. https://doi.org/10.5194/esd-14-1015-2023 present partial SC-CO2, SC-CH4, and SC-N2O estimates for a 2020 emissions pulse year. This same methodology was applied in U.S. Environmental Protection Agency. (2023n). *Supplementary Material for the Regulatory Impact Analysis for the Final Rulemaking, "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review": EPA Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances*. Retrieved from https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf to calculate the FrEDI-based partial SC-GHG values for 2030 emissions. Updated the values from ibid. to 2023 dollars using the GDP deflator.

[126] Updated the values from U.S. Environmental Protection Agency. (2023n). *Supplementary Material for the Regulatory Impact Analysis for the Final Rulemaking, "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review": EPA Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances*. Retrieved from https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf to 2023 dollars using the GDP deflator. FrEDI estimates a partial SC-CH_4 of \$684/mtCH_4 for damages physically occurring within CONUS for 2030 emissions (under a 2 percent near-term Ramsey discount rate) (Hartin, C., McDuffie, E. E., Noiva, K., Sarofim, M., Parthum, B., Martinich, J., Barr, S., . . . Fawcett, A. (2023). Advancing the estimation of future climate impacts within the United States. *Earth Syst. Dynam.*, *14*(5), 1015-1037. https://doi.org/10.5194/esd-14-1015-2023) compared to a GIVE and DSCIM-based U.S.-specific SC-CH_4 of \$321/mtCH_4 and \$87/mtCH_4, respectively, for 2030 emissions.

modeling of important damage categories.[127] Finally, none of these modeling efforts – GIVE, DSCIM, and FrEDI – reflect non-climate mediated effects of GHG emissions experienced by U.S. populations (other than CO_2 fertilization effects on agriculture). As one example of new research on non-climate mediated effects of methane emissions, McDuffie et al. (2023) estimate the monetized increase in respiratory-related human mortality risk from the ozone produced from a marginal pulse of methane emissions. Using the socioeconomics from the RFF-SPs and the 2 percent near-term Ramsey discounting approach, this additional health risk to U.S. populations is on the order of approximately $417/mt$CH_4$ for 2030 emissions.[128]

Applying the U.S.-specific partial SC-GHG estimates derived from the multiple lines of evidence described above to the GHG emissions changes expected under the final rule would yield substantial benefits. For example, the present value of the climate benefits of the final rule over 2025-2049 as measured by FrEDI from climate change impacts in CONUS are estimated to be $4.8 billion (under a 2 percent near-term Ramsey discount rate). However, the numerous explicitly omitted damage categories and other modeling limitations discussed above and throughout U.S. EPA (2023n) make it likely that these estimates underestimate the benefits to U.S. citizens and residents of the GHG reductions from the final rule; the limitations in developing a U.S.-specific estimate that accurately captures direct and spillover effects on U.S. citizens and residents further demonstrates that it is more appropriate to use a global measure of climate benefits from GHG reductions. EPA will continue to review developments in the literature, including more robust methodologies for estimating the magnitude of the various damages to U.S. populations from climate impacts and reciprocal international mitigation activities, and explore ways to better inform the public of the full range of GHG impacts.

8.3 Human Health Benefits

8.3.1 Data and Methodology

As summarized in Table 8-5, the final rule is estimated to influence the level of pollutants emitted in the atmosphere that adversely affect human health, including directly emitted $PM_{2.5}$, as well as SO_2 and NO_X, which are both precursors to ambient $PM_{2.5}$. NO_X emissions are also a precursor to ambient ground-level ozone. The change in emissions alters the ambient concentrations, which in turn leads to changes in

127 Another method that has produced estimates of the effect of climate change on U.S.-specific outcomes uses a top-down approach to estimate aggregate damage functions. Published research using this approach include total-economy empirical studies that econometrically estimate the relationship between GDP and a climate variable, usually temperature. As discussed in U.S. Environmental Protection Agency. (2023n). *Supplementary Material for the Regulatory Impact Analysis for the Final Rulemaking, "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review": EPA Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances*. Retrieved from https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf the modeling framework used in the existing published studies using this approach differ in important ways from the inputs underlying the SC-GHG estimates described above (*e.g.*, discounting, risk aversion, and scenario uncertainty). Hence, we do not consider this line of evidence in the analysis for this RIA. Updating the framework of total-economy empirical damage functions to be consistent with the methods described in this RIA and ibid. would require new analysis. Finally, because total-economy empirical studies estimate market impacts, they do not include any non-market impacts of climate change (*e.g.*, heat related mortality) and therefore are also only a partial estimate. EPA will continue to review developments in the literature and explore ways to better inform the public of the full range of GHG impacts.

128 See ibid. for more details. Updated to 2023 dollars using the GDP deflator.

population exposure. EPA estimated the changes in the human health impacts associated with $PM_{2.5}$ and ozone.[129]

This section summarizes EPA's approach to estimating the incidence and economic value of the $PM_{2.5}$ and ozone-related benefits estimated for the final rule (Option B). The approach entails two major steps: (1) developing baseline and Option B spatial fields of air quality across the U.S. using nationwide photochemical modeling and related analyses; and (2) using these spatial fields in BenMAP-CE[130] to quantify the benefits under Option B as compared to the baseline. In this approach, EPA used IPM projections of EGU air emissions for the baseline and Option B (final rule).

8.3.1.1 Air Quality Modeling Methodology

As described in Appendix J, spatial fields of annual ozone and $PM_{2.5}$ concentrations representing the baseline and Option B were obtained from ozone source and PM source apportionment modeling. These $PM_{2.5}$ and ozone spatial fields were used as input to BenMAP-CE which, in turn, was used to quantify the benefits from this rule.

EPA prepared spatial fields of air quality for the baseline and for Option B for two health-impact metrics: annual mean $PM_{2.5}$ and April through September seasonal average 8-hour daily maximum (MDA8) ozone (AS-MO3). The EGU emissions for the baseline and Option B, consisting of total NO_X, SO_2, and primary $PM_{2.5}$ emissions summarized by year and state, were obtained from the outputs of the IPM run, as described above and in Chapter 5 of the RIA (U.S. EPA, 2024e). As such, the spatial fields do not account for changes in emissions associated with power requirements to operate treatment systems or with transportation. See Section 8.3.1 regarding limitations and uncertainty associated with the analysis of air quality related benefits.

The basic methodology for determining air quality changes is the same as that used in the RIAs from multiple previous rules (U.S. EPA, 2019i; 2020b; 2020a, 2021b; 2022c). Appendix J provides an overview of the air quality modeling and the methodologies EPA used to develop spatial fields of seasonal ozone and annual $PM_{2.5}$ concentrations. The appendix also provides selected figures showing the geographical and temporal distribution of air quality changes.

EPA used air quality modeling to estimate health benefits associated with changes in ozone and $PM_{2.5}$ concentrations that may occur because of Option B of the final rule relative to the baseline. Air quality surfaces of the baseline reflect projected 2026 emission from all sources other than EGUs but reflect year-specific projected emissions for EGUs for 2028, 2030, 2035, 3040, 2045 and 2050.[131] While the CAMx air quality modeling includes a range of pollution sources, contributions from non-EGU point sources, on-road vehicles, non-road mobile equipment and marine vessels are held constant in this analysis, and the only

[129] Ambient concentrations of both SO_2 and NO_X also pose health risks independent of $PM_{2.5}$ and ozone, though EPA does not quantify these impacts in this analysis (U.S. Environmental Protection Agency. (2016b). *Integrated Science Assessment for Oxides of Nitrogen: Health Criteria*. (EPA/600/R-15/068). Retrieved from http://ofmpub.epa.gov/eims/eimscomm.getfile?p_download_id=526855, U.S. Environmental Protection Agency. (2017b). *Integrated Science Assessment for Sulfur Oxides: Health Criteria*. (EPA/600/R-17/451). Retrieved from http://ofmpub.epa.gov/eims/eimscomm.getfile?p_download_id=533653)

[130] The Environmental Benefits Mapping and Analysis Program - Community Edition (BenMAP-CE) is described and found at: https://www.epa.gov/benmap.

[131] The air quality modeling techniques used for this analysis reflect non-EGU emissions as of 2026, so implementation or effects of any changes in non-EGU emissions expected to occur after 2026 are not accounted for in this analysis. However, the effect of non-EGU emissions on changes in pollution concentrations due to the final rule is likely to be small.

changes are those associated with the projected impacts of the rule on the profile of electricity generation and EGU emissions, as compared to the baseline. The modeled air quality changes do not include other potential effects of the rule, such as changes in power requirements to run treatment systems or changes in CCR transportation, which were estimated separately as described in Section 8.1 and were found to be negligible as described in section 8.4.

8.3.1.2 $PM_{2.5}$ and Ozone Related Health Impacts

EPA estimated the benefits of Option B using the open-source environmental Benefits Mapping and Analysis Program—Community Edition (BenMAP-CE) (Sacks et al., 2018). The *Estimating $PM_{2.5}$- and Ozone-Attributable Health Benefits* Technical Support Document (TSD) fully describes the Agency's approach for identifying those health endpoints to evaluate as well as quantifying their number and value (U.S. EPA, 2023p). In the TSD, the reader can find the rationale for selecting health endpoints to quantify; the demographic, health and economic data used; modeling assumptions; and our techniques for quantifying uncertainty.

Estimating the health benefits of reductions in $PM_{2.5}$ and ozone exposure begins with estimating the change in exposure for each individual and then estimating the change in each individual's risks for those health outcomes affected by exposure. The dollar benefit of reducing the risk of each adverse effect is based on the exposed individual's willingness to pay (WTP) for the risk change, assuming that each outcome is independent of one another. The greater the magnitude of the risk reduction from a given change in concentration, the greater the individual's WTP, all else equal. The social benefit of the change in health risks equals the sum of the individual WTP estimates across all of the affected individuals residing in the United States. We conduct this analysis by adapting primary research—specifically, air pollution epidemiology studies and economic value studies—from similar contexts. This approach is sometimes referred to as "benefits transfer." Below we describe the procedure we follow for: (1) selecting air pollution health endpoints to quantify; (2) calculating counts of air pollution effects using a health impact function; (3) specifying the health impact function with concentration-response parameters drawn from the epidemiological literature.

The BenMAP-CE tool quantifies the number and value of air pollution-attributable premature deaths and illnesses resulting from changes in $PM_{2.5}$ and ozone concentrations. Table 8-9 reports the ozone and $PM_{2.5}$-related human health impacts effects EPA quantified and those the Agency did not quantify in this analysis of the final rule. The list of benefit categories not quantified is not exhaustive. And, among the effects quantified, it might not have been possible to quantify completely either the full range of human health impacts or economic values.

Table 8-9: Human Health Effects of Ambient Ozone and $PM_{2.5}$

Category	Effect	Effect Quantified	Effect Monetized	More Information
Premature mortality from exposure to $PM_{2.5}$	Adult premature mortality based on cohort study estimates and expert elicitation estimates (age 65-99 or age 30-99)	✓	✓	PM ISA
	Infant mortality (age <1)	✓	✓	PM ISA
Morbidity from exposure to $PM_{2.5}$	Heart attacks (age > 18)	✓	✓	PM ISA
	Hospital admissions—cardiovascular (ages 65-99)	✓	✓	PM ISA
	Emergency department visits— cardiovascular (age 0-99)	✓	✓	PM ISA
	Hospital admissions—respiratory (ages 0-18 and 65-99)	✓	✓	PM ISA
	Emergency room visits—respiratory (all ages)	✓	✓	PM ISA

Table 8-9: Human Health Effects of Ambient Ozone and $PM_{2.5}$

Category	Effect	Effect Quantified	Effect Monetized	More Information
	Cardiac arrest (ages 0-99; excludes initial hospital and/or emergency department visits)	✓	✓	PM ISA
	Stroke (ages 65-99)	✓	✓	PM ISA
	Asthma onset (ages 0-17)	✓	✓	PM ISA
	Asthma symptoms/exacerbation (6-17)	✓	✓	PM ISA
	Lung cancer (ages 30-99)	✓	✓	PM ISA
	Allergic rhinitis (hay fever) symptoms (ages 3-17)	✓	✓	PM ISA
	Lost work days (age 18-65)	✓	✓	PM ISA
	Minor restricted-activity days (age 18-65)	✓	✓	PM ISA
	Hospital admissions—Alzheimer's disease (ages 65-99)	✓	✓	PM ISA
	Hospital admissions—Parkinson's disease (ages 65-99)	✓	✓	PM ISA
	Other cardiovascular effects (*e.g.*, other ages)	—	—	PM ISA[b]
	Other respiratory effects (*e.g.*, pulmonary function, non-asthma ER visits, non-bronchitis chronic diseases, other ages and populations)	—	—	PM ISA[b]
	Other nervous system effects (*e.g.*, autism, cognitive decline, dementia)	—	—	PM ISA[b]
	Metabolic effects (*e.g.*, diabetes)	—	—	PM ISA[b]
	Reproductive and developmental effects (*e.g.*, low birth weight, pre-term births)	—	—	PM ISA[b]
	Cancer, mutagenicity, and genotoxicity effects	—	—	PM ISA[b]
Mortality from exposure to ozone	Premature mortality based on short-term study estimates (age 0-99)	✓	✓	Ozone ISA
	Premature mortality based on long-term study estimates (age 30–99)	✓	✓	Ozone ISA[a]
Morbidity from exposure to ozone	Hospital admissions—respiratory causes (ages 0-99)	✓	✓	Ozone ISA
	Emergency department—respiratory (ages 0-99)	✓	✓	Ozone ISA
	Asthma onset (0-17)	✓	✓	Ozone ISA
	Asthma symptoms/exacerbation (asthmatics age 2-17)	✓	✓	Ozone ISA
	Allergic rhinitis (hay fever) symptoms (ages 3-17)	✓	✓	Ozone ISA
	Minor restricted-activity days (age 18–65)	✓	✓	Ozone ISA
	School absence days (age 5–17)	✓	✓	Ozone ISA
	Decreased outdoor worker productivity (age 18–65)	—	—	Ozone ISA[b]
	Metabolic effects (*e.g.*, diabetes)	—	—	Ozone ISA[b]
	Other respiratory effects (*e.g.*, premature aging of lungs)	—	—	Ozone ISA[b]
	Cardiovascular and nervous system effects	—	—	Ozone ISA[b]
	Reproductive and developmental effects	—	—	Ozone ISA[b,c]

a. EPA assesses these benefits qualitatively due to data and resource limitations for this analysis. In other analyses EPA quantified these effects as a sensitivity analysis.

b. EPA assesses these benefits qualitatively because of insufficient confidence in available data or methods.

c. EPA assesses these benefits qualitatively because current evidence is only suggestive of causality or there are other significant concerns over the strength of the association.

Source: EPA Analysis, 2024

Counts of attributable effects are quantified using a health impact function, which combines information regarding the: concentration-response relationship between air quality changes and the risk of a given adverse outcome; population exposed to the air quality change; baseline rate of death or disease in that population; and air pollution concentration to which the population is exposed. When used to quantify $PM_{2.5}$- or ozone-related effects, the functions combine effect estimates (*i.e.*, the β coefficients) from epidemiological studies, which portray the relationship between a change in air quality and a health effect, such as mortality, associated with changes in estimated $PM_{2.5}$ or ozone concentrations (supplied using the IPM market model simulations described above), population data, and baseline death rates for each county in each year. After having quantified $PM_{2.5}$- and ozone-attributable cases of premature death and illness, EPA estimated the economic value of these cases using willingness to pay (WTP) and cost of illness (COI) measures.

EPA estimated the number of $PM_{2.5}$-attributable premature deaths using effect estimates from two epidemiology studies examining two large population cohorts: an analysis of Medicare beneficiaries (Wu et al., 2020) and the National Health Interview Survey (NHIS) (Pope et al., 2019). For ozone-related premature deaths, EPA uses one epidemiological study that examines the relationship between long-term exposure to ozone and mortality (Turner et al., 2016) and two studies that examine the relationship between short-term exposure to ozone and mortality (Katsouyanni et al., 2009; Zanobetti & Schwartz, 2008).

EPA quantifies and monetizes effects the Integrated Science Assessment (ISA) identifies as having either a causal or likely-to-be-causal relationship with the pollutant. Relative to the 2015 ISA, the 2020 ISA for Ozone reclassified the casual relation between short-term ozone exposure and total mortality, changing it from "likely to be causal" to "suggestive of, but not sufficient to infer, a causal relationship." The 2020 Ozone ISA separately classified short-term O3 exposure and respiratory outcomes as being "causal" and long-term exposure as being "likely to be causal." When determining whether there existed a causal relationship between short- or long-term ozone exposure and respiratory effects, EPA evaluated the evidence for both morbidity and mortality effects. The ISA identified evidence in the epidemiologic literature of an association between ozone exposure and respiratory mortality, finding that the evidence was not entirely consistent and there remained uncertainties in the evidence base.

EPA continues to quantify premature respiratory mortality attributable to both short- and long-term exposure to ozone because doing so is consistent with: (1) the evaluation of causality noted above; and (2) EPA's approach for selecting and quantifying endpoints described in the TSD "Estimating PM2.5- and Ozone-Attributable Health Benefits," which was recently reviewed by the U.S. EPA Science Advisory Board (U.S. EPA, 2023p; U.S. EPA Science Advisory Board, 2024).

Projected impacts of the final rule (Option B) show both decreased and increased levels of $PM_{2.5}$ and ozone, depending on the year and location, compared to the baseline (see maps in Appendix J for details). Some portion of the air quality and health benefits from the final rule occur in areas not attaining the $PM_{2.5}$ or Ozone National Ambient Air Quality Standards (NAAQS). The analysis does not account for possible interactions between NAAQS compliance and the final rule, which introduces uncertainty into the benefits (and forgone benefits) estimates. If the final rule increases or decreases primary $PM_{2.5}$, SO_2 and NO_X emissions and consequentially $PM_{2.5}$ and/or ozone concentrations, these changes may affect compliance with existing NAAQS standards and subsequently affect the actual benefits (and forgone benefits) of the final rule.

8.3.2 Results

EPA reports below the estimated number of avoided $PM_{2.5}$ and ozone-related premature deaths and illnesses in each year for Option B, the final rule, relative to the baseline along with the 95 percent confidence interval (see Table 8-10). The number of avoided premature deaths and illnesses under the final rule are calculated from the sum of individual reduced mortality and illness risk across the population in a given year. Table 8-11 reports the estimated economic value of avoided premature deaths and illness for each analysis year relative to the baseline.

Table 8-10: Estimated Avoided $PM_{2.5}$ and Ozone-Related Premature Deaths and Illnesses by Year for the Final Rule (Option B), Compared to Baseline (95 Percent Confidence Interval)

Category and Basis		2028[a]	2030[a]	2035[a]	2040[a]	2045[a]	2050[a]
Avoided premature death among adults[b]							
$PM_{2.5}$	Wu et al. (2020)	67	19	100	29	8.5	8.2
		(59 to 75)	(16 to 21)	(91 to 120)	(25 to 32)	(7.5 to 9.5)	(7.2 to 9.1)
	Pope III et al. (2019)	140	38	210	57	17	16
		(100 to 180)	(27 to 48)	(150 to 270)	(41 to 73)	(12 to 22)	(12 to 21)
Avoided infant mortality							
$PM_{2.5}$	Woodruff, Darrow & Parker, 2008	0.16	0.034	0.2	0.052	0.016	0.015
		(-0.10 to 0.42)	(-0.022 to 0.088)	(-0.12 to 0.51)	(-0.033 to 0.13)	(-0.010 to 0.041)	(-0.0092 to 0.037)
Ozone (O_3)	Katsouyanni et al. (2009)[c,d] and Zanobetti et al. (2008)[d] pooled	2.1	2	2.9	1.3	0.38	0.18
		(0.83 to 3.3)	(0.80 to 3.1)	(1.2 to 4.5)	(0.52 to 2.0)	(0.15 to 0.60)	(0.074 to 0.29)
	Turner et al. (2016)[c]	46	44	63	29	8.4	4.1
		(32 to 59)	(31 to 57)	(44 to 82)	(20 to 37)	(5.8 to 11)	(2.8 to 5.3)
All other morbidity effects							
Acute Myocardial Infarcation		2.3	0.57	3.5	0.95	0.29	0.29
		(1.3 to 3.2)	(0.33 to 0.79)	(2.0 to 4.9)	(0.55 to 1.3)	(0.17 to 0.40)	(0.17 to 0.40)
Hospital admissions—cardiovascular ($PM_{2.5}$)		9.9	2.7	15	4.2	1.3	1.2
		(7.2 to 13)	(2.0 to 3.4)	(11 to 19)	(3.0 to 5.3)	(0.91 to 1.6)	(0.89 to 1.6)
Hospital admissions—respiratory ($PM_{2.5}$)		6.9	1.5	9.6	2.6	0.81	0.82
		(2.4 to 11)	(0.50 to 2.5)	(3.2 to 16)	(0.87 to 4.3)	(0.28 to 1.3)	(0.28 to 1.3)
Hospital admissions—respiratory[d] (O_3)		6	5.7	8.1	3.6	1.1	0.59
		(-1.6 to 13)	(-1.5 to 13)	(-2.1 to 18)	(-0.95 to 8.1)	(-0.29 to 2.5)	(-0.15 to 1.3)
Hospital admissions—Alzheimer's Disease ($PM_{2.5}$)		37	8	57	16	5	5.2
		(28 to 46)	(5.9 to 9.9)	(42 to 71)	(12 to 20)	(3.8 to 6.3)	(3.9 to 6.5)
Hospital admissions— Parkinson's Disease ($PM_{2.5}$)		4.6	1.3	6.6	1.8	0.51	0.51
		(2.3 to 6.7)	(0.66 to 1.9)	(3.4 to 9.8)	(0.90 to 2.6)	(0.26 to 0.75)	(0.26 to 0.75)
ED visits—cardiovascular ($PM_{2.5}$)		21	5.3	30	8.3	2.6	2.5
		(-8.0 to 48)	(-2.0 to 12)	(-12 to 70)	(-3.2 to 19)	(-0.99 to 6.0)	(-0.97 to 5.9)
ED visits—respiratory ($PM_{2.5}$)		41	11	56	15	4.8	4.6
		(8.1 to 86)	(2.1 to 23)	(11 to 120)	(2.9 to 31)	(0.95 to 10)	(0.91 to 9.7)
ED visits—respiratory[f] (O_3)		110	96	140	62	20	9.7
		(31 to 240)	(26 to 200)	(38 to 290)	(17 to 130)	(5.6 to 43)	(2.7 to 20)
Cardiac Arrest ($PM_{2.5}$)		1	0.28	1.5	0.39	0.12	0.12
		(-0.42 to 2.3)	(-0.11 to 0.63)	(-0.59 to 3.3)	(-0.16 to 0.89)	(-0.050 to 0.28)	(-0.048 to 0.27)
Stroke ($PM_{2.5}$)		4.2	1.2	6	1.6	0.48	0.47
		(1.1 to 7.1)	(0.30 to 2.0)	(1.5 to 10)	(0.41 to 2.7)	(0.13 to 0.83)	(0.12 to 0.81)

Table 8-10: Estimated Avoided $PM_{2.5}$ and Ozone-Related Premature Deaths and Illnesses by Year for the Final Rule (Option B), Compared to Baseline (95 Percent Confidence Interval)

Category and Basis	2028[a]	2030[a]	2035[a]	2040[a]	2045[a]	2050[a]
Lung Cancer ($PM_{2.5}$)	4.7	1.3	7	2	0.61	0.59
	(1.4 to 7.8)	(0.39 to 2.2)	(2.1 to 12)	(0.59 to 3.3)	(0.18 to 1.0)	(0.18 to 0.98)
Hay Fever/Rhinitis ($PM_{2.5}$)	1,000	250	1,300	370	120	110
	(240 to 1,700)	(60 to 430)	(320 to 2,300)	(89 to 640)	(28 to 200)	(27 to 190)
Hay Fever/Rhinitis[g] (O_3)	2,000	1,700	2,300	1,000	320	150
	(1,000 to 2,900)	(900 to 2,500)	(1,200 to 3,400)	(550 to 1,500)	(170 to 470)	(78 to 220)
Asthma Onset ($PM_{2.5}$)	160	38	200	56	18	17
	(150 to 160)	(36 to 39)	(200 to 210)	(54 to 58)	(17 to 19)	(16 to 18)
Asthma onset[e] (O_3)	340	290	400	180	55	25
	(300 to 390)	(250 to 330)	(340 to 450)	(150 to 200)	(48 to 63)	(22 to 29)
Asthma symptoms-- Albuterol use ($PM_{2.5}$)	29,000	7,200	40,000	11,000	3,400	3,300
	(-14,000 to 71,000)	(-3,500 to 18,000)	(-19,000 to 96,000)	(-5,200 to 26,000)	(-1,700 to 8,300)	(-1,600 to 8,000)
Asthma symptoms (O_3)	64,000	55,000	74,000	33,000	10,000	4,700
	(-7,900 to 130,000)	(-6,800 to 110,000)	(-9,100 to 150,000)	(-4,100 to 69,000)	(-1,300 to 21,000)	(-580 to 9800)
Minor restricted-activity days ($PM_{2.5}$)	45,000	11,000	61,000	17,000	5,400	5,200
	(37,000 to 53,000)	(9,200 to 13,000)	(49,000 to 72,000)	(13,000 to 20,000)	(4,300 to 6,300)	(4,300 to 6,200)
Minor restricted-activity days[d,f] (O_3)	30,000	26,000	35,000	16,000	5,000	2,400
	(12,000 to 47,000)	(10,000 to 40,000)	(14,000 to 55,000)	(6,300 to 25,000)	(2,000 to 8,000)	(950 to 3,800)
Lost work days ($PM_{2.5}$)	7,700	1,900	10,000	2,800	910	890
	(6,500 to 8,800)	(1,600 to 2,200)	(8,700 to 12,000)	(2,400 to 3,200)	(760 to 1,000)	(750 to 1,000)
School absence days (O_3)	23,000	20,000	27,000	12,000	3,700	1,700
	(-3,200 to 48,000)	(-2,800 to 41,000)	(-3,800 to 56,000)	(-1,700 to 25,000)	(-520 to 7,700)	(-240 to 3,600)

a. Values rounded to two significant figures. Negative values indicate forgone benefits (*i.e.*, the number of avoided cases under the final rule is smaller than in the baseline). Lower bound of confidence interval represents the 95 percent confidence estimate that is lower in value than the point estimate, while upper bound represents the estimate that is higher in value than the point estimate.

b. EPA also quantified changes in premature infant mortality from exposure to $PM_{2.5}$ but the estimated change was less than 1 for all years analyzed.

c. Applied risk estimate derived from April-September exposures to estimates of ozone across the May-September warm season.

d. Converted ozone risk estimate metric from MDA1 to MDA8.

e. Applied risk estimate derived from June-August exposures to estimates of ozone across the May-September warm season.

f. Applied risk estimate derived from full year exposures to estimates of ozone across the May-September warm season.

g. Converted ozone risk estimate metric from DA24 to MDA8

Source: U.S. EPA Analysis, 2024

Table 8-11: Estimated Discounted Economic Value of Avoided Ozone and $PM_{2.5}$-Attributable Premature Mortality and Illness for Option B (millions of 2023$)

Year	2% Discount Rate[a]		
2028	$1,100	*and*	$2,600
2030	$390	*and*	$1,200
2035	$1,600	*and*	$3,900
2040	$500	*and*	$1,300
2045	$150	*and*	$380
2050	$140	*and*	$310

[a] Values rounded to two significant figures. The two benefits estimates are separated by the word "and" to signify that they are two separate estimates. The estimates do not represent lower- and upper-bound estimates and should not be summed.

Source: U.S. EPA Analysis, 2024

8.4 Annualized Air Quality-Related Benefits of Regulatory Options

EPA calculated the present value (discounted to 2024) of estimated air quality-related benefits over the analysis period of 2025-2049 and annualized these values to provide a measure that is comparable to the way other benefit categories and social costs are reported.

Section 8.2.1 provides benefit estimates for Option B, the final rule, based on the changes in the electricity generation profile projected in IPM. EPA mapped changes in emissions due to changes in electricity generation for each IPM run year to individual years within the analysis period of 2025-2049 (see Table 8-1). Because IPM outputs are available only for 2028 onward, EPA conservatively assumed no benefits associated with changes in the profile of electricity generation between 2025 and 2027. However, changes in the profile of electricity generation and EGU emissions are likely to occur as steam electric power generating plants start incurring costs to comply with the revised ELG between 2025 and 2029, and assuming no emission reductions for the first three years of this period understates the air quality-related benefits of the final rule.

For energy use and trucking, EPA estimated changes in air emissions corresponding to the year each plant is estimated to implement changes in technology. These emissions are included in the analysis of climate change benefits. As discussed in Section 8.3.1.1, however, the analysis of human health benefits does not account for other changes in pollutant emissions associated with power requirements to operate wastewater treatment systems or transport CCR or other solid waste. EPA considered adjusting the estimated benefits in proportion to the average ratio between total air emissions of NO_X and SO_2 (Table 8-5) and EGU emissions associated with changes in the electricity generation profile (Table 8-4) but concluded that such an adjustment would have a negligible effect on the estimated human health benefit estimates given the comparably small emissions changes associated with power requirements and trucking. Therefore, EPA is presenting unadjusted values for the final rule below.

For the climate change benefits, EPA used the same discount rate used to develop SC-GHG values. For the human health benefits, EPA used the LT mortality benefit estimate at a 2 percent discount rate from Table 8-11.

Table 8-12: Total Annualized Air Quality-Related Benefits of Final Rule (Option B), Compared to the Baseline, 2025-2049 (Millions of 2023$)

SC-GHG near-term discount rate	Climate Change Benefits[a]	$PM_{2.5}$ and Ozone Related Human Health Benefits at 2% Discount Rate[a]	Total[a]
1.5%	$990	$1,600	$2,600
2.0%	$1,600	$1,600	$3,200
2.5%	$2,600	$1,600	$4,200

a. Values rounded to two significant figures.

b. Values calculated based on the LT mortality benefits estimates at a 2 percent discount rate.

Source: U.S. EPA Analysis, 2024

Because EPA did not run IPM for Options A and C, EPA did not analyze climate and human health benefits for these regulatory options. To provide insight into the potential air quality-related benefits across regulatory options, EPA estimated benefits for Options A and C by scaling Option B benefits in proportion to the total social costs of the respective options (see Chapter 11 in this document). Specifically, EPA calculated the ratio of the benefits to total social costs for Option B, then multiplied total social costs for Options A and C by this ratio. The scaling factor provides an order of magnitude approximation of the benefits by assuming proportionality between air-related benefits and total social costs.[132] While air-related benefits are expected to be driven primarily by changes in the profile of electricity generation (see Table 8-4 and Table 8-5) and the generation profile is affected most directly by the incremental technology implementation costs, the effects may not be linear.

Table 8-13 summarizes the annualized air quality-related benefits of the regulatory options for the climate change benefits estimated using the SC-GHG under the 2 percent near-term Ramsey discount rate and for human health benefits discounted using a 2 percent discount rate.

Table 8-13: Total Annualized Air Quality-Related Benefits of Regulatory Options Based on Extrapolation from Option B, Compared to the Baseline, 2025-2049 (Millions of 2023$)

Regulatory Option	Climate Change Benefits (SC-GHG 2% near-term discount rate)[a]	$PM_{2.5}$ and Ozone Related Human Health Benefits at 2% Discount Rate[a,b]	Total[a]
Option A[c]	$1,200	$1,200	$2,400
Option B (Final Rule)	$1,600	$1,600	$3,200
Option C[c]	$1,900	$2,000	$3,900

a. Values rounded to two significant figures.

b. These values reflect the air-related human health benefits based on the LT mortality benefits estimates from changes in $PM_{2.5}$ and ozone levels.

c. EPA estimated air quality-related benefits for Options A and C by multiplying the total social costs for each option (see Section 11.2) by the ratio of [air quality-related benefits / total social costs] for Option B. For the purpose of scaling benefits, EPA used the subset of social costs associated with the wastestreams modeled in the benefits analyses.

Source: U.S. EPA Analysis, 2024

132 For the 2015 final rule, EPA analyzed two options using IPM and therefore had air-related benefits for both options. Using the benefit/cost ratio of one option to estimate benefits of the other option resulted in benefits that were ±7 percent than benefits derived from the IPM outputs.

8.5 Limitations and Uncertainties

Table 8-14 summarizes the limitations and uncertainties associated with the analysis of the air quality-related benefits. The second column of the table provides a conclusion of how the limitation affects the magnitude of the benefits estimate relative to expected actual benefits (*i.e.*, a source of uncertainty that has the effect of underestimating benefits indicates an expectation that expected actual benefits are larger than the estimate). The analysis also incorporates uncertainties associated with IPM modeling, which are discussed in Chapter 5 in the RIA (U.S. EPA, 2024e). See Appendix J for additional discussions of the uncertainty associated with the air quality modeling methodology.

Table 8-14: Limitations and Uncertainties in Analysis of Air Quality-Related Benefits

Uncertainty/Limitation	Effect on Benefits Estimate	Notes
EPA extrapolated Option B benefits to Options A and C.	Uncertain	EPA ran IPM only for the final rule (Option B) and used the results to extrapolate benefits of Options A and C, based on the ratios of annualized benefits and annualized social costs. Air emissions and air quality changes are unlikely to follow differences in social costs in a linear fashion, however, given how marginal changes in operating costs for individual units may affect dispatch of EGUs within the broader regional and national electricity markets. Because benefits are dependent on magnitude and, for human health benefits, the spatial distribution of emissions changes, projected benefits for Options A and C are uncertain.
EPA assumed no changes in air emissions associated with shifts in the mix of electricity generation in 2025-2027 relative to baseline	Underestimate	The first IPM year is 2028. Changes in the profile of electricity generation and EGU emissions are likely to occur as steam electric power generating plants start incurring costs to comply with the revised ELG between 2025 and 2029, and assuming no emission reductions for the first three years of this technology implementation period understates the air quality-related benefits of the final rule. This is even though the changes in air emissions predicted in IPM are modest in 2028.
The modeled air quality assumes a static apportionment of EGU sources and static emissions from other sources.	Uncertain	As discussed in Appendix J, the source apportionment contributions are informed by the spatial and temporal distribution of the emissions from each source tag as they occur in the future year modeled case. Thus, the contribution modeling results do not consider the effects of any changes to spatial distribution of EGU emissions within a state-fuel tag between the future year modeled case and the baseline and final rule scenarios analyzed in this RIA.
The modeled air quality surfaces used in the analysis of human health benefits only reflect changes in emissions associated with changes in the electricity generation profile.	Uncertain	EPA developed the spatial fields based on IPM projected emissions changes for Option B. These projections do not include additional changes in NO_X and SO_2 emissions associated with power requirements to operate wastewater treatment systems or trucking to transport CCR and other solid waste. While these emissions changes could affect human health benefit estimates, such effects are expected to be small overall given that these emissions generally represent less than 2 percent of total NO_X and SO_2 emissions changes.

Table 8-14: Limitations and Uncertainties in Analysis of Air Quality-Related Benefits

Uncertainty/Limitation	Effect on Benefits Estimate	Notes
The methodology used to create ozone and $PM_{2.5}$ Air Quality surfaces do not account for nonlinear impacts of precursor emissions changes	Uncertain	Appendix J provides further details on this limitation.
All fine particles, regardless of their chemical composition, are equally potent in causing premature mortality.	Uncertain	The PM ISA concluded reaffirmed the conclusion reached in the 2009 ISA that "many PM2.5 components and sources are associated with many health effects and that the evidence does not indicate that any one source or component is consistently more strongly related with health effects than PM2.5 mass." (U.S. EPA, 2009c, 2022d).
Assumed "Cessation" lag between the change in $PM_{2.5}$ and ozone exposures and the total realization of changes in long-term mortality effects.	Uncertain	The approach distributes the incidences of premature mortality related to $PM_{2.5}$ exposures over the 20 years following exposure based on the advice of EPA's Science Advisory Board Health Effect Subcommittee (SAB-HES) (U.S. EPA, 2004a). This distribution is also assumed for long-term mortality from ozone exposure. This distribution affects the valuation of mortality benefits at different discount rates. The actual distribution of effects over time is uncertain.
Climate changes may affect ambient concentrations of pollutants.	Uncertain	Estimated health benefits do not account for the influence of future changes in the climate on ambient concentrations of pollutants (U.S. Global Change Research Program, 2016). For example, recent research suggests that future changes to climate may create conditions more conducive to forming ozone; the influence of changes in the climate on $PM_{2.5}$ concentrations are less clear (Fann et al., 2015). The estimated health benefits also do not consider the potential for climate-induced changes in temperature to modify the relationship between ozone and the risk of premature death (Jhun et al., 2014; Ren, Williams, Mengersen, et al., 2008; Ren, Williams, Morawska, et al., 2008). Modeling used to estimate air quality changes from this final rule used meteorological fields representing conditions that occurred in 2016.
EPA did not analyze all benefits of changes in exposure to NO_X, SO_2, and other pollutants emitted by EGUs.	Underestimate	The analysis focused on adverse health effects related to $PM_{2.5}$ and ozone levels. There are additional benefits from changes in levels of NO_X, SO_2 and other air pollutants emitted by EGUs (*e.g.*, mercury, HCl). These include health benefits from changes in ambient NO_2 and SO_2 exposure, health benefits from changes in mercury deposition, ecosystem benefits associated with changes in emissions of NO_X, SO_2, PM, and mercury, and visibility impairment.

9 Estimated Changes in Drinking Water Treatment and Dredging Costs

By reducing pollutant loads in receiving and downstream waters, the regulatory options have the potential to reduce costs associated with uses of these waters. For example, numerous studies have shown an unequivocal link between source water quality and the cost of drinking water treatment and changes in sediment deposition has the potential to affect the cost of maintaining reservoirs and navigational waterways. This chapter provides EPA's analysis of the changes in drinking water treatment and dredging costs associated with the regulatory options.

9.1 Changes in Drinking Water Treatment Costs

As summarized in Chapter 2, the regulatory options have the potential to affect drinking water treatment costs by reducing loadings of steam electric pollutants to surface waters used for drinking water supply. EPA implemented a treatment cost elasticity approach to quantify avoided treatment costs from reductions in total nitrogen (TN) and total suspended solids (TSS). The treatment cost elasticity approach has been used in recent research estimating the social cost of nutrient pollution (Andarge, 2022), and it is supported by the economics literature on drinking water treatment costs (see Price and Heberling (2018) for a review of 15 U.S. and 9 non-U.S. studies that estimate quantitative relationships between source water quality and drinking water treatment costs).

The treatment cost elasticity approach differs from the work breakdown structure models that are more frequently used to estimate changes in drinking water treatment costs as part of EPA regulatory analysis (Khera, Ransom & Speth, 2013). In comparison to treatment cost elasticity approaches, work breakdown structure models require more information on drinking water system treatment practices, source water parameters, and how treatment process costs vary with changes in source water characteristics at different production levels. In contrast, treatment cost elasticities are based on empirical studies of water system behavior and observed costs, and thus they make fewer assumptions on how water systems respond to changes in source water characteristics.

Given the relatively small drinking water treatment savings expected to accrue from this rule, EPA implemented the more straightforward treatment cost elasticity approach to estimate the magnitude of impacts to drinking water systems. The use of a treatment cost elasticity approach in regulatory analysis may provide a rationale for academic researchers to develop additional treatment cost elasticities for application in future regulatory impact assessments.

9.1.1 Data and Methodology

EPA applied the following steps to calculate avoided drinking water treatment costs associated with reductions in TN and TSS:

1. Identify water systems with surface water intakes downstream of steam electric power plant discharges.

2. Estimate TN and TSS baseline levels and reductions in source waters using SPARROW modelling.

3. Convert TSS levels and reductions to turbidity levels and reductions following U.S. EPA (2009b).

4. Compute the percent change in TN and turbidity for each regulatory option and all regulatory periods.

5. Estimate drinking water treatment costs at affected water systems using the median cost by system size and source type according to responses to the 2006 Community Water System Survey.

6. Estimate the percent change in drinking water treatment costs associated with reductions in TN and turbidity levels using the elasticities in Price and Heberling (2018).

Further detail on the identification of water systems with affected intakes and SPARROW modelling is provided in Chapter 3. For this analysis, EPA excludes water systems that purchase their water from affected systems to avoid potentially double-counting benefits, although this assumption likely underestimates true cost savings across all affected systems as discussed in the limitations section of this chapter. In addition, EPA assumes that the blending ratio across intakes is uniform, such that a water system with multiple affected intakes will see the average loadings change across all intakes. Intakes that are not affected by steam electric power plant discharges in the baseline are assumed to have loadings changes of zero. Table 9-1 summarizes the average annual changes in TSS, TN, and TP loadings at 233 directly affected water systems.

Table 9-1: Average Percent Change in Source Water Concentrations of TN, TP, and TSS Compared to Baseline

Regulatory Option	Period 1 (2025-2029)			Period 2 (2030 -2049)		
	TSS	TN	TP	TSS	TN	TP
Option A	-0.0006	-0.008	-0.004	-0.0012	-0.009	-0.004
Option B (Final Rule)	-0.0006	-0.008	-0.004	-0.0013	-0.009	-0.004
Option C	-0.0009	-0.010	-0.005	-0.0015	-0.009	-0.005

Source: U.S. EPA Analysis, 2024.

Next, EPA incorporated expenditure data from the 2006 Community Water System Survey (CWWS, U.S. EPA, 2009a) to assign drinking water systems baseline treatment expenditures. The CWSS was specifically designed to support regulatory and policy analysis. It collected revenue and expenditure information from 1,314 community water systems using a stratified random sampling procedure to ensure representativeness across water system types; the surveyors ensured data accuracy by sending experts to smaller systems to assist completion of certain information fields (U.S. EPA, 2009a). The 2006 CWSS is the most recently available survey of water systems that collected information needed to estimate drinking water treatment costs separately from other types of expenditure category that are unlikely to vary with source water characteristics. In addition, the survey data has been used in the academic literature to assess the importance of source-water characteristics on drinking water treatment costs (Price & Heberling, 2020).

EPA uses only variable treatment cost expenditures in this analysis because the regulatory options are anticipated to reduce loadings of pollutants that affect ongoing treatment costs rather than all system cost categories. In particular, while systems may have already invested in costly capital equipment to address baseline pollutant loadings from steam electric power plant effluents, EPA assumes that these capital expenditures are largely irreversible. For example, some systems may have already invested in ion exchange treatment processes to contend with nitrates (Khera et al., 2021). The assumption of irreversibility of certain costs leads to an underestimate of true cost savings, as discussed in the limitations section of this chapter.

After removing observations with missing values, treatment cost information was available in the CWSS for 418 drinking water systems. Treatment expenditure information was updated from 2006 to 2023 price levels using the Consumer Price Index. Treatment costs are presented across system source type and population served category in Table 9-2, which also lists the count of systems affected by the regulation.

Table 9-2: Median Drinking Water Treatment Expenditures by System Size and Source Category

System Size	Groundwater		Surface Water		Affected Systems Count
	Median Treatment Cost	CWSS System Count	Median Treatment Cost	CWSS System Count	
Population <100	$27,740	14	$20,890	18	11
Population 101–500	$19,272	10	$279,412	21	8
Population 501–3,300	$49,137	19	$436,572	24	27
Population 3,301–10,000	$840,203	11	$1,679,000	27	47
Population 10,001–50,000	$660,920	25	$3,108,194	36	80
Population 50,001–100,000	$3,237,274	14	$2,263,000	38	23
Population 100,001–500,000	$9,927,596	16	$11,101,192	104	27
Population >500,00	$16,371,051	2	$90,992,030	39	10

Notes: Surface-water systems include systems sourcing from groundwater under the influence of surface water. Dollars estimated to 2023$

Source: 2006 CWWS, U.S. EPA, 2009a.

The treatment cost information for 418 systems in Table 9-2 with available cost data in the CWSS demonstrate that water systems sourcing from surface water tend to have higher treatment costs than water systems that source from groundwater. In addition, for every system size category there are at least 18 water systems that source from surface water with which to infer cost data for systems affected by this regulation. In general, median treatment costs tend to increase with system size, with the exception of surface-water systems serving a population of 50,001-100,000. The CWSS masks identifiers for specific water systems, and so it is not possible to link any surveyed systems to the systems that are affected by this regulatory action. As such, EPA assigns median cost values to water systems based on their size and source category. All directly affected systems source primarily from surface water. Median treatment costs are used instead of average treatment costs to reduce the influence of outlier observations.

Finally, EPA computes avoided drinking water treatment costs $\Delta Cost_{itp}$ for drinking water system *i*, period *t*, and each water quality parameter *p* as:

$$\Delta Cost_{itp} = \eta_p * \frac{\Delta Concentration_{itp}}{Concentration_{itp}} * Cost_{it}$$

Where η_p represents the elasticity between source water concentrations of water quality parameter *p* and drinking water treatment costs. EPA uses a range of total nitrogen elasticity values from 0.05 to 0.06 to represent average elasticity values in Price and Heberling (2018). The elasticity of 0.05 is derived from a non-U.S. study without key controls, but it is included as a possible low-range elasticity estimate to better characterize uncertainty. For TSS, EPA uses the range of turbidity elasticity estimates of 0.10 to 0.12 from the same study to represent low and high estimates, where these values are derived exclusively from studies with controls for key confounders.

9.1.2 Results

Annualized avoided costs across all drinking water systems affected by the regulatory options for TN, TSS, and both parameters combined are summarized at the 2 percent discount rate in Table 9-3 (EPA provides summaries at the 3 percent and 7 percent discount rates in Appendix B). Annualized cost savings related to TN loadings reductions under the final rule range from $357,000 to $429,000. For TSS, annualized cost savings range from $103,000 to $124,000 under the final rule (Option B). Under the final rule, total cost savings to drinking water systems range from $460,000 to $552,000. Further details on methods specific to TN and TSS are described in turn below.

Table 9-3: Annualized Estimated Drinking Water Treatment Cost Savings under the Regulatory Options, Compared to Baseline (Million 2023$, 2 Percent Discount Rate)

Regulatory Option	TN		TSS		Combined	
	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate
Option A	$0.357	$0.429	$0.092	$0.111	$0.449	$0.539
Option B (Final Rule)	$0.357	$0.429	$0.103	$0.124	$0.460	$0.552
Option C	$0.460	$0.552	$0.133	$0.160	$0.592	$0.711

Source: U.S. EPA Analysis, 2024.

9.1.2.1 Nutrients

As described in Chapter 2, the incremental cost of treating drinking water to address excess nutrients can be substantial. Price and Heberling (2018) combined prior studies of the effect of nutrients on drinking water treatment costs, showing that a 1 percent change in nitrogen (as nitrate) concentration in source water leads to a 0.05 - 0.06 percent change in drinking water treatment costs, depending on whether the studies control for key confounders. Similarly, the authors show that a 1 percent increase in phosphorus loadings increases drinking water treatment costs by 0 – 0.02 percent, where findings of zero represent a null statistical relationship between phosphorus loadings and drinking water treatment costs. Given the uncertainty in the treatment cost elasticities for phosphorus and the possibility of double-counting cost savings across nitrogen and phosphorus, EPA does not calculate cost changes with respect to phosphorus loading reductions. To characterize uncertainty in the relationship between source water TN and drinking water treatment costs, EPA employed a low elasticity estimate of 0.05 and a high elasticity estimate of 0.06, representing the range of values reported in Price and Heberling (2018).

Table 9-4 presents illustrative average cost savings from reductions in TN across all years in the regulatory analysis and for all drinking water systems in each size category. These values are intended to illustrate the magnitude of impacts across system size, and as such they are only averaged across all years in the regulatory period and not annualized or discounted. For most system size categories, the average annual cost savings are relatively small both in absolute terms and in relation to annual drinking water treatment costs, ranging from roughly 0.01 percent to 0.03 percent of drinking water treatment costs. These small impacts are in part due to the small impacts of the regulatory options on source water concentrations of TN as reported in Table 9-1.

Table 9-4: Estimated Average System-Level Annual Changes in Drinking Water Treatment Costs for TN under the Regulatory Options, Compared to Baseline (2023$)

System Size	Low Estimate			High Estimate		
	Option A	Option B (Final Rule)	Option C	Option A	Option B (Final Rule)	Option C
Population <100	-5	-5	-8	-6	-6	-9
Population 101–500	-57	-57	-93	-69	-69	-111

Table 9-4: Estimated Average System-Level Annual Changes in Drinking Water Treatment Costs for TN under the Regulatory Options, Compared to Baseline (2023$)

System Size	Low Estimate			High Estimate		
	Option A	Option B (Final Rule)	Option C	Option A	Option B (Final Rule)	Option C
Population 501–3,300	-353	-353	-387	-423	-423	-464
Population 3,301–10,000	-481	-481	-482	-578	-578	-578
Population 10,001–50,000	-1,527	-1,527	-1,692	-1,833	-1,833	-2,030
Population 50,001–100,000	-230	-230	-430	-276	-276	-516
Population 100,001–500,000	-914	-914	-1,338	-1,097	-1,097	-1,606
Population >500,00	-17,526	-17,526	-23,804	-21,031	-21,031	-28,565

Notes: The presented annual cost changes by system size are not discounted or annualized and represent only changes to system treatment costs averaged over each year of the regulatory analysis period. Treatment costs include only ongoing operation and maintenance costs and exclude investments in irreversible capital equipment.

Source: U.S. EPA Analysis, 2024.

9.1.2.2 Total Suspended Solids

Reducing TSS from steam electric power plant effluent is expected to affect the turbidity of source waters used by drinking water systems. Water systems address TSS using chemical treatment with coagulants such as alum or ferrous sulfate. Coagulant application varies in dosage depending on the influent concentrations of TSS, and thus water system variable costs for coagulant purchases vary with TSS in source water. Treatment for TSS also produces coagulated sediment in proportion to the influent concentration of TSS and the quantity of coagulant added, and disposal of this coagulated sediment results in additional variable costs for drinking water systems.

The impacts of TSS on drinking water treatment costs have been quantified in prior EPA regulatory analyses including the 2004 Meat and Poultry Products Effluent Limitation Guidelines as well as the 2009 Effluent Limitation Guidelines and Standards for the Construction and Development Industry (see U.S. EPA, 2004b, 2009b). To calculate the changes in drinking water treatment costs associated with TSS, EPA first converts TSS to turbidity and then applies the elasticity for turbidity from Price and Heberling (2018).

EPA uses the elasticity associated with turbidity in Price and Heberling (2018) instead of TSS because the elasticity with respect to TSS is based on only one study with key controls and three studies overall. In addition, two of the underlying studies informing the TSS elasticity date from 1987 and 1988, and this relationship may have changed significantly since these studies were conducted. Further, the range of elasticity values for TSS is more disperse and less certain, suggesting that a 1 percent change in sediment loads could lead to a 0.05 to 0.24 percent change in treatment costs. In contrast, Price and Heberling (2018) calculate an elasticity with respect to turbidity that is much more precisely estimated across twelve studies; these studies suggest that a 1 percent increase in turbidity leads to an increase in drinking water costs of 0.10 to 0.14 percent. Aside from quality of underlying elasticity estimates, EPA follows the precedent set in in U.S. EPA (2009b) by estimating TSS-related changes to drinking water costs via changes in turbidity.

EPA converted TSS concentrations into nephelometric turbidity units (NTUs) using the method employed in U.S. EPA (2009b). In the prior analysis, TSS was converted to turbidity using Equation 9-1.

Equation 9-1.

$$Turbidity = \frac{TSS}{b}$$

Where turbidity is measured in NTUs and TSS is measured in mg/L. In U.S. EPA (2009b), *b* was set to a constant equal to 0.8, 1.5, or 2.2 to reflect low, medium, and high estimates of the relationship between TSS and turbidity. For this analysis, EPA produces a range of plausible TSS-turbidity conversions using only the low and high constants of 0.8 and 2.2. EPA also selected a range of elasticities of 0.10 and 0.12 based on studies that include key controls for confounding variables as reported in Price and Heberling (2018).

Table 9-5 presents illustrative average cost savings from reductions in TSS and associated turbidity across all years in the regulatory analysis and for all drinking water systems in each size category. These values are intended to illustrate the magnitude of impacts across system size, and as such they are only averaged across all years in the regulatory period and not annualized or discounted. The average annual system-level cost changes are relatively small in comparison to typical system-level treatment costs across all size categories.

Table 9-5: Estimated Average System-Level Annual Changes in Drinking Water Treatment Costs for TSS under the Regulatory Options, Compared to Baseline (2023$)

System Size	Low Estimate			High Estimate		
	Option A	Option B (Final Rule)	Option C	Option A	Option B (Final Rule)	Option C
Population<100	-1	-1	-1	-1	-2	-2
Population 101–500	-17	-21	-22	-20	-26	-27
Population 501–3,300	-67	-81	-82	-80	-97	-99
Population 3,301–10,000	-406	-415	-531	-487	-498	-638
Population 10,001–50,000	-258	-291	-308	-309	-349	-370
Population 50,001–100,000	-78	-90	-110	-94	-107	-133
Population 100,001–500,000	-628	-697	-932	-754	-838	-1,119
Population >500,00	-3,291	-3,821	-5,312	-3,970	-4,610	-6,401

Notes: The presented annual cost changes by system size are not discounted or annualized and represent only changes to system treatment costs averaged over each year of the regulatory analysis period. Treatment costs include only ongoing operation and maintenance costs and exclude investments in irreversible capital equipment.

Source: U.S. EPA Analysis, 2024.

9.2 Changes in Dredging Costs

As summarized in Chapter 2 and in Table 3-1, the regulatory options could result in relatively small changes in suspended solid discharges by steam electric power plants, which could have an impact on the rate of sediment deposition in affected reaches, including navigable waterways and reservoirs that require dredging for maintenance.

Navigable waterways, including rivers, lakes, bays, shipping channels and harbors, are an integral part of the United States' transportation network. They are prone to reduced functionality due to sediment build-up, which can reduce the navigable depth and width of the waterway (Clark, Haverkamp & Chapman, 1985; Ribaudo, 2011). In many cases, costly periodic dredging is necessary to keep them passable. The regulatory options could increase or reduce costs for government and private entities responsible for maintenance of navigable waterways by changing the need for dredging.

Reservoirs serve many functions, including water storage for drinking, irrigation, and hydropower uses, flood control, and recreation. Streams and rivers carry sediment into reservoirs, where it can settle and build up at a recorded average rate of 1.2 billion kilograms per reservoir every year (USGS, 2009). Sedimentation reduces reservoir capacity (Graf et al., 2010) and the useful life of reservoirs unless measures such as dredging are taken to reclaim capacity (Clark, Haverkamp & Chapman, 1985; Hargrove et al., 2010; Miranda, 2017).

9.2.1 Data and Methodology

In this analysis, EPA followed the same general methodology for estimating changes in costs associated with changes in sediment depositions in navigational waterways and reservoirs that EPA used in the 2020 rule and 2023 proposal (U.S. EPA, 2020b, 2023b).[133] The methodology utilizes information on historic dredging locations, frequency of dredging, the amount of sediment removed, and dredging costs in conjunction with the estimated changes in net sediment deposition (sedimentation minus erosion) in dredged waterways and reservoirs under the regulatory options. Benefits are equal to avoided costs, calculated as the difference from historical averages in total annualized dredging costs due to changes between the baseline and the regulatory options.

9.2.2 Results

9.2.2.1 Estimated Changes in Navigational Dredging Costs

EPA identified 128 unique dredging jobs and 400 dredging occurrences[134] within the affected reaches. This corresponds to approximately 8 percent of the dredging occurrences with coordinates reported in the Dredging Information System (U.S. Army Corps of Engineers, 2013). The recurrence interval for dredging jobs ranged from one to 17 years across affected reaches and averaged 13 years. Dredging costs vary considerably across geographic locations and dredging jobs from less than $1 per cubic yard at the Ohio River (open channel)[135] in Louisville, Kentucky to $534 per cubic yard at Herculaneum in St. Louis, Missouri.[136] The median unit cost of dredging for the entire conterminous United States is $3.75 per cubic yard.

Table 9-6 presents low and high estimates of dredged sediment volume and dredging costs during the period of 2025 through 2049 in navigational waterways that may be affected by steam electric plant discharges, based on historical averages. EPA generated low and high estimates for navigational dredging by varying the projected future dredging occurrence, including dredging frequency and job start as well as cost of dredging for locations that did not report location specific costs (see U.S. EPA, 2015a, Appendix K for details). Estimated total navigational dredging costs based on historical averages range from $57.3 million to $130.8 million per year.

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[133] For the 2020 rule analysis, EPA made two improvements to the methodology used in 2015. First, dredging occurrences were considered part of a single dredging job if the latitude and longitude coordinates were identical to within two decimal places. Second, the 10th percentile and 90th percentile of costs and sediment dredged for dredging occurrences within USACE districts were used to fill in missing values in the Low and High scenarios. EPA also made one change to the methodology used to estimate net sediment deposition at any given location in the reach network by using the *TOTAL_YIELD* output variable from the SPARROW models instead of *INC_TOTAL_YIELD*. This change was implemented to be more inclusive of the upstream impacts to affected COMIDs (*INC_TOTAL_YIELD* excluded upstream impacts).

[134] Dredging jobs refer to unique sites/locations defined by the U.S. Army Corps of Engineers where dredging was conducted, whereas dredging occurrences are unique instances when dredging was conducted and may include successive dredging at the same location.

[135] The cost per cubic yard at the Ohio River (open channel) is $0.37.

[136] The second most expensive dredging job was $55.30 per cubic yard also in St. Louis.

Table 9-6: Estimated Annual Average Navigational Dredging Quantities and Costs at Affected Reaches Based on Historical Averages

Total Sediment Dredged (Millions Cubic Yards)		Annual Costs (Millions of 2023$)	
Low	High	Low	High
544.8	974.9	$57.3	$130.8

Source: U.S. EPA Analysis, 2024.

The difference between the estimated dredging costs using historical averages and costs resulting from the reduction in sediment deposition under a regulatory option as compared to baseline represents the avoided costs under the regulatory option. Table 9-7 presents estimated changes in navigational dredging costs for the three regulatory options. Annualized benefits range from $3,800 to $4,700 under Option A and from $4,400 to $5,500 under Options B and C.

Table 9-7: Estimated Annualized Changes in Navigational Dredging Costs under the Regulatory Options, Compared to Baseline

Regulatory Option	Total Reduction in Sediment Dredged (Thousands Cubic Yards)		Annualized Avoided Costs (Millions of 2023$, 2% Discount Rate)[a]	
	Low	High	Low	High
Option A	7.1	9.3	<$0.01	$0.01
Option B (Final Rule)	8.3	10.8	<$0.01	$0.01
Option C	8.5	11.0	<$0.01	$0.01

a. Positive values represent cost savings.

Source: U.S. EPA Analysis, 2024.

9.2.2.2 Estimated Changes in Reservoir Dredging Costs

EPA identified 2,009 reservoirs within the affected reaches with changes in sediment loads under at least one of the regulatory options, corresponding to approximately one percent of the reservoirs represented in the SPARROW models (Ator, 2019; Hoos & Roland Ii, 2019; Robertson & Saad, 2019; Wise, 2019; Wise, Anning & Miller, 2019). EPA used USACE district regional estimates of average dredging costs to calculate changes in reservoir dredging costs under the regulatory options. The median cost per cubic yard ranges from $0.37 in the Louisville USACE District (Kentucky) to $52.42 in the Rock Island USACE District (Illinois), with a median value of $8.99 for USACE districts which contain affected reservoirs. Table 9-8 presents low and high estimates of the projected volume of sediment to be dredged during the period of 2025 through 2049 from these reservoirs as well as estimated annualized dredging costs, based on historical averages. The estimated reservoir dredging costs based on historical averages range between $771.4 million and $836.7 million.

Table 9-8: Estimated Annualized Reservoir Dredging Volume and Costs based on Historical Averages

Total Sediment Dredged (Millions Cubic Yards)		Annual Costs (Millions of 2023$)	
Low	High	Low	High
5,675.5	34,052.9	$771.4	$4,836.7

Source: U.S. EPA Analysis, 2024.

The difference between the estimated dredging costs using historical averages and costs resulting from the reduction in sediment deposition under a regulatory option as compared to baseline represents the avoided costs for that regulatory option. Table 9-9 presents avoided costs for reservoir dredging under the regulatory options, including low and high estimates. Annualized benefits are approximately $300 under Option A and range from $300 to $400 under Options B and C.

Table 9-9: Estimated Total Annualized Changes in Reservoir Dredging Volume and Costs under the Regulatory Options, Compared to Baseline

Regulatory Option	Total Reduction in Sediment Dredged (Thousands Cubic Yards)		Annualized Avoided Costs[a] (Millions of 2023$ per Year, 2% Discount Rate)	
	Low	High	Low	High
Option A	1.0	1.1	<$0.01	<$0.01
Option B (Final Rule)	1.2	1.3	<$0.01	<$0.01
Option C	1.2	1.4	<$0.01	<$0.01

a. Positive values represent cost savings.

Source: U.S. EPA Analysis, 2024.

9.3 Limitation and Uncertainty

Table 9-10 summarizes key uncertainties and limitations in the analysis of sediment dredging benefits. A more detailed description is provided in Appendix K of the 2015 BCA (U.S. EPA, 2015a). Note that the effect on benefits estimates indicated in the second column of the table refers to the magnitude of the benefits rather than the direction (*i.e.*, a source of uncertainty that tends to underestimate benefits indicates expectation for larger forgone benefits or for larger realized benefits). Uncertainties and limitations associated with SPARROW model estimates of sediment deposition are discussed in the respective regional model reports (Ator, 2019; Hoos & Roland Ii, 2019; Robertson & Saad, 2019; Wise, 2019; Wise, Anning & Miller, 2019).

Table 9-10: Limitations and Uncertainties in Analysis of Changes in Dredging Costs

Uncertainty/Limitation	Effect on Benefits Estimate	Notes
EPA includes only TSS and TN in the estimation of drinking water treatment cost savings.	Underestimate	Drinking water systems may experience cost savings due to TSS, nutrients, halogens, and metals, although EPA lacks statistically reliable treatment cost elasticities for parameters other than TSS and TN.
EPA assumes that only water systems with surface water intakes that are directly affected by steam electric effluents have cost savings, and so water purchasers indirectly affected by the regulation do not accrue cost savings.	Underestimate	Water systems that purchase water from directly-affected systems may realize cost savings in the form of lower water prices. These water systems are excluded from the analysis due to uncertainties surrounding price setting behavior among water retailers.
EPA selects elasticity estimates in Price and Heberling (2018) based on models with complete controls.	Uncertain	Estimated relationships between source water turbidity and TN levels are generally slightly higher when including studies that did not incorporate key controls for confounding variables.

Table 9-10: Limitations and Uncertainties in Analysis of Changes in Dredging Costs

Uncertainty/Limitation	Effect on Benefits Estimate	Notes
EPA imputes costs for all affected systems based on a subset of public systems available in the Community Water System Survey (2006) and uses median values rather than average costs within size category.	Uncertain	The 2006 CWSS was designed to be a representative sample of US drinking water systems, but it is possible that drinking water systems sourcing from surface waters affected by this regulation may have different characteristics and higher or lower drinking water treatment costs, on average. To the extent that systems affected by the regulation differ in their treatment costs from the 2006 CWSS systems, EPA may over or under-estimate true cost savings.
EPA considers drinking water treatment capital costs to be fully realized and not recoverable, so treatment cost savings only vary by ongoing operations & maintenance treatment costs.	Underestimate	Some capital expenditures can be reduced with improvements in source water quality. For example, water systems may be able to switch to less costly treatment processes while still maintaining their water quality objectives. These possible changes in capital expenditures would result in an underestimate of true cost savings.
Disposal costs for coagulated sediment sludge may be significantly higher if the sediment sludge also contains other hazardous chemicals.	Underestimate	To the extent that sediment sludge from drinking water systems affected by steam electric effluents have more toxic chemicals than typical systems, EPA expects that disposal costs for the sludge would be higher.
The analysis of dredging cost savings scales dredging volumes and costs in proportion to the percent change in sediment deposition in navigational waterways and reservoirs.	Uncertain	EPA estimated a linear relationship between changes in sediment deposition and dredging volumes and costs which may not capture non-linear dynamics in the relationships between sediment deposition and dredging volumes and between dredging volumes and costs.
The frequency of navigational dredging is based on the proximity of nearby dredging occurrences.	Uncertain	Because data in the U.S. Army Corps of Engineers Database does not indicate whether different dredging occurrences are part of a single dredging job, EPA determined whether dredging occurrences are part of a single dredging job by comparing their latitudinal and longitudinal coordinates to two decimal places. Changes in the precision of a job's coordinates would affect the number of occurrences that are considered part of the same dredging job. When precision is changed to a single decimal place, the number of occurrences that would be considered part of a single dredging job increases (and vice-versa). A larger (smaller) number of occurrences for a single dredging job would increase (decrease) the frequency of dredging and, as a result, total dredging costs over the period of analysis.
The analysis of navigational waterways includes only jobs reported for 1998 through 2015.	Underestimate	Because some dredging jobs included in the U.S. Army Corps of Engineers Database lack latitude and longitude and the database does not use standardized job names, EPA was only able to map approximately 64 percent of all recorded dredging occurrences. This may lead to potential underestimation of historical costs and changes in dredging costs under the regulatory options.

Table 9-10: Limitations and Uncertainties in Analysis of Changes in Dredging Costs

Uncertainty/Limitation	Effect on Benefits Estimate	Notes
The analysis of reservoir dredging is limited to reservoirs identified on the NHD reach network.	Underestimate	The omission of other reservoirs could understate the magnitude of estimated historical costs and changes in reservoir dredging benefits if there are additional reservoirs located downstream from steam electric power plants.

10 Summary of Estimated Total Monetized Benefits

Table 10-1 summarizes the total annualized monetized benefits. Table 10-2 provides additional details on the time profile of the monetized benefits.

The monetized benefits presented in these two tables do not account for all effects of the regulatory options, including changes in certain cancer and non-cancer health risk (*e.g.*, effects of halogenated disinfection byproducts in drinking water, effects of cadmium on kidney functions and bone density), impacts of pollutant load changes on T&E species habitat, etc. See Chapter 2 for a discussion of categories of benefits EPA did not monetize. Chapter 4 through Chapter 9 provide more detail on the estimation methodologies for each benefit category.

Table 10-1: Summary of Estimated Total Annualized Benefits of the Regulatory Options, Compared to Baseline (Millions of 2023$; 2 Percent Discount)

Benefit Category	Option A	Option B (Final Rule)	Option C
Human Health			
Changes in IQ losses in children from exposure to lead via fish ingestion[a]	<$0.01	<$0.01	<$0.01
Changes in cardiovascular disease mortality from exposure to lead via fish ingestion	$0.16 – $0.43	$0.16 – $0.43	$0.16 – $0.45
Changes in IQ losses in children from exposure to mercury via fish ingestion	$1.71	$1.98	$2.00
Changes in cancer risk from disinfection by-products in drinking water	$13.37	$13.37	$14.27
Ecological Conditions and Recreational Uses Changes			
Use and nonuse values for water quality changes[b]	$0.79	$1.24	$1.68
Market and Productivity Effects[a]			
Changes in drinking water treatment costs	$0.45 – $0.54	$0.46 – $0.55	$0.59 – $0.71
Changes in dredging costs[a]	<$0.01	<$0.01	<$0.01
Air Quality-Related Effects			
Climate change effects from changes in greenhouse gas emissions[c]	$1,200	$1,600	$1,900
Human health effects from changes in NO_X, SO_2, and $PM_{2.5}$ emissions[c,d]	$1,200	$1,600	$2,000
Total[e]	**$2,417**	**$3,217**	**$3,919**
Additional non-monetized benefits	Other avoided adverse health effects (cancer and non-cancer) from reduced exposure to pollutants discharged to receiving waters; improvements in T&E species habitat and potential effects on T&E species populations; changes in property value from water quality improvements; changes in ecosystem effects, visibility impairment, and human health effects from direct exposure to NO_2, SO_2, and hazardous air pollutants.		

a. "<$0.01" indicates that monetary values are greater than $0 but less than $0.01 million.

b. Estimates based on Model 1, which provides EPA's main estimate of non-market benefits. See Chapter 6 for details.

c. Values for air-quality related effects are rounded to two significant figures. EPA estimated the air quality-related benefits for Option B. EPA extrapolated estimates of air quality-related benefits for Options A and C from the estimate for Option B that is based on IPM outputs. For the purpose of scaling the air quality-related benefits, EPA used the subset of social costs associated with the wastestreams modeled in the benefits analyses. See Chapter 8 for details.

d. The values reflect the LT estimates of human health effects from changes in $PM_{2.5}$ and ozone levels. See Chapter 8 for details.

Table 10-1: Summary of Estimated Total Annualized Benefits of the Regulatory Options, Compared to Baseline (Millions of 2023$; 2 Percent Discount)			
Benefit Category	Option A	Option B (Final Rule)	Option C

e. Values for individual benefit categories may not sum to the total due to independent rounding.

Source: U.S. EPA Analysis, 2024

Table 10-2: Time Profile of Monetized Benefits (Millions of 2023$)

Year	Option A[1, 2]	Option B (Final Rule)[2]	Option C[1,2]
2025	$3.2	$3.6	$4.5
2026	-$3.3	-$5.1	-$5.9
2027	-$5.9	-$9.5	-$11.4
2028	$4,904.4	$6,404.8	$7,906.1
2029	$4,904.7	$6,505.2	$7,906.5
2030	$2,908.1	$3,808.9	$4,709.9
2031	$3,008.8	$3,909.6	$4,710.6
2032	$5,409.5	$7,010.3	$8,611.3
2033	$5,410.1	$7,110.9	$8,711.9
2034	$5,510.7	$7,211.5	$8,812.6
2035	$5,511.3	$7,212.1	$8,813.1
2036	$5,511.7	$7,212.5	$8,913.6
2037	$5,612.2	$7,313.0	$8,914.1
2038	$1,412.6	$1,843.5	$2,214.5
2039	$1,413.1	$1,854.0	$2,315.0
2040	$1,413.6	$1,854.4	$2,315.5
2041	$1,414.0	$1,864.9	$2,316.0
2042	$584.5	$765.4	$936.5
2043	$594.9	$775.8	$947.0
2044	$595.4	$776.3	$957.5
2045	$605.9	$786.8	$958.0
2046	$606.4	$787.3	$968.6
2047	$616.8	$797.7	$979.0
2048	$397.2	$508.1	$619.5
2049	$397.6	$518.5	$629.9
Annualized Benefits Accounted in 2025-2049, 2%	**$2,410.6**	**$3,211.3**	**$3,912.4**
Annualized Value of Additional Benefits in 2050-2115, 2%[3]	**$6.3**	**$6.3**	**$6.7**
Total Annualized Benefits, 2%	**$2,417**	**$3,218**	**$3,919**

[1] EPA estimated the air quality-related benefits for Option B. EPA extrapolated estimates of air quality-related benefits for Options A and C from the estimate for Option B that is based on IPM outputs. For the purpose of scaling the air quality-related benefits, EPA used the subset of social costs associated with the wastestreams modeled in the benefits analyses.

[2] Values for air-quality related effects included in the total for each year are rounded to two significant figures.

[3] Accounts for avoided bladder cancer benefits in 2050-2115 from reductions in TTHM exposure in 2025-2049

Source: U.S. EPA Analysis, 2024.

11 Summary of Total Social Costs

This chapter discusses EPA's estimates of the costs to society under the regulatory options. Social costs include costs incurred by both private entities and the government (*e.g.*, in implementing the regulation). As described further in Chapter 10 of the RIA (U.S. EPA, 2024e), EPA did not evaluate incremental baseline costs, and associated cost savings to state governments which would no longer have to evaluate and incorporate best professional judgment into NPDES permits under the regulatory options. Consequently, the only category of costs used to calculate social costs are estimated technology implementation costs for steam electric power plants.

11.1 Overview of Costs Analysis Framework

The RIA (Chapter 3) presents EPA's development of costs for the estimated 858 steam electric power plants within the scope of the final rule (U.S. EPA, 2024e). These costs (pre-tax) are used as the basis of the social cost analysis.[137] A subset of these plants (between 141 and 170, depending on the regulatory option) incur non-zero incremental costs under the final rule (Option B), as compared to the baseline. The range corresponds to the lower and upper bound cost scenarios that reflect the uncertainty associated with costs for meeting limits for unmanaged CRL. As described in the RIA, the lower bound scenario reflects the sum of point estimates of costs to meet FGD wastewater, BA transport water, legacy wastewater, and CRL limits, plus the *lower* bound estimate of the cost to meet limits for unmanaged CRL, whereas the upper bound scenario reflects the sum of the point estimates for the four wastestreams plus the *upper* bound estimate of the cost to meet limits for unmanaged CRL.

As described earlier in Chapter 1, EPA estimated that steam electric power plants, in the aggregate, will implement control technologies to meet revised limits for FGD wastewater, BA transport water, and CRL between 2025 and 2029. EPA estimated that plants will implement control technologies to meet legacy wastewater limits in 2044. For the analysis of social costs, EPA estimated a plant- and year-explicit schedule of technology implementation cost outlays over the period of 2025 through 2049.[138] This schedule accounts for retirements and repowerings by zeroing-out O&M costs to operate BA and FGD treatment systems in years following unit retirement or repowering, but continued O&M costs for CRL since treatment of the CRL wastewater is expected to continue even after a unit ceases to generate electricity. After creating a cost-incurrence schedule for each cost component, EPA summed the costs expected to be incurred in each year for each plant, then aggregated these costs to estimate the total costs for each year in the analysis period. Specifically, EPA assumed that capital costs for compliance technology equipment, installation, site preparation, construction, and other upfront, non-annually recurring outlays associated with compliance with the regulatory options are incurred in the modeled compliance year for each plant. Annual fixed O&M costs, including regular annual monitoring, and annual variable O&M costs (*e.g.*, operating labor, maintenance labor and materials, electricity required to operate wastewater treatment systems, chemicals, combustion residual

137 As discussed in Section 3.1.1 of the RIA (U.S. Environmental Protection Agency. (2024e). *Regulatory Impact Analysis for Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category*. (821-R-24-007).), EPA did not select the lowest-cost technology for five plants to meet zero-discharge limits for CRL. This resulted in the estimated total compliance costs for Option B and Option C being overstated by approximately $6 million (1.5 percent of total costs) on an after-tax basis.

138 The period of analysis extends through 2049 to capture a substantive portion of the life of the wastewater treatment technology at any steam electric power plant (20 or more years), and the last year of technology implementation (2029).

waste transport and disposal operation and maintenance) are incurred each year. Other non-annual recurring costs are incurred at specified intervals of 5, 6, or 10 years. See Section 3.1.2 in the RIA for details.

Following the approach used for the analyses of the 2015 and 2020 rules, and 2023 proposal (U.S. EPA, 2015a, 2020b, 2023k), after technology implementation costs were assigned to the year of occurrence, the Agency adjusted these costs for change between 2023 (the year when costs were estimated) and the year(s) of their incurrence as follows:

- All technology costs, except planning, were adjusted to their incurrence year(s) using the Construction Cost Index (CCI) from McGraw Hill Construction and the Gross Domestic Product (GDP) deflator index published by the U.S. Bureau of Economic Analysis (BEA).
- Planning costs were adjusted to their incurrence year(s) using the Employment Cost Index (ECI) Bureau of Labor Statistics (BLS) and GDP deflator.

The CCI and ECI adjustment factors were developed only through the year 2031; after these years, EPA assumed that the real change in prices is zero – that is, costs are expected to change in line with general inflation. EPA judges this to be a reasonable approach, given that capital expenditures will occur by 2029 and the uncertainty of long-term future price projections.

After developing the year-explicit schedule of total costs and adjusting them for predicted real change to the year of their incurrence, EPA calculated the present value of these cost outlays as of the anticipated rule promulgation year by discounting the cost in each year back to 2024 using a 2 percent discount rates, following OMB regulatory analysis guidance in Circular A-4 (OMB, 2023). EPA calculated the constant annual equivalent value (annualized value), again using the 2 percent discount rate, over a 25-year social cost analysis period. EPA assumed no re-installation of wastewater treatment technology during the period covered by the social cost analysis, *i.e.*, upfront capital costs are incurred only once.

To assess the economic costs of the regulatory options to society, EPA relied first on the estimated costs to steam electric power plants for the labor, equipment, material, and other economic resources needed to comply with the regulatory options (see U.S. EPA, 2024e for details). In this analysis, the market prices for labor, equipment, material, and other compliance resources represent the opportunity costs to society for use of those resources in regulatory compliance. EPA assumed in its social cost analysis that the regulatory options do not affect the aggregate quantity of electricity that will be sold to consumers and, thus, that the rule's social cost will include no changes in consumer and producer surplus *from changes in electricity sales* by the electricity industry in aggregate. Given the small impact of the regulatory options on electricity production cost for the total industry (see RIA Chapter 5, U.S. EPA, 2024e) and relatively inelastic electricity demand with respect to price, at least in the short term (Burke & Abayasekara, 2018; Bernstein and Griffin (2005)), this approach is reasonable for the social cost analysis (for more details on the impacts of the regulatory options on electricity production cost, see RIA Chapter 5). The social cost analysis considers costs on an as-incurred, year-by-year basis — that is, this analysis associates each cost component to the year(s) in which they are assumed to occur relative to the assumed rule promulgation and technology implementation years.[139]

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[139] The specific assumptions of when each cost component is incurred can be found in Chapter 3 of the RIA (U.S. Environmental Protection Agency. (2024a). *Benefit and Cost Analysis for Supplemental Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category*. (821-R-24-006).).

Finally, as discussed in Chapter 10 of the RIA (U.S. EPA, 2024e; see Section 10.7: Paperwork Reduction Act of 1995), the regulatory options will not result in additional administrative costs for plants to implement, and state and federal NPDES permitting authorities to administer, the rule. The social cost analysis therefore focuses on the resource cost of compliance as the only direct cost incurred by society as a result of the final rule.

11.2 Key Findings for Regulatory Options

Table 11-1 presents annualized incremental costs for the analyzed regulatory options, as compared to the baseline.

Table 11-1: Summary of Estimated Incremental Annualized Costs for Regulatory Options (Millions of 2023$, 2 Percent Discount Rate)

Regulatory Option	Annualized Costs	
	Lower Bound	Upper Bound
Option A	$433.2	$960.9
Option B (Final Rule)	$536.2	$1,063.9
Option C	$622.4	$1,150.1

Source: U.S. EPA Analysis, 2024.

Table 11-2 and Table 11-3 provide additional detail on the social cost calculations for the lower bound and upper bound cost scenarios, respectively. The tables compile, for each regulatory option, the assumed time profiles of technology implementation costs incurred, relative to the baseline, as well as the annualized costs. The maximum technology implementation outlays differ across the options but are incurred over the years 2025 through 2029, *i.e.*, during the estimated window (defined as Period 1 in Section 3.2.1) when steam electric power plants are expected to implement wastewater treatment technologies for FGD wastewater, BA transport water, and CRL. Outlays increase in 2044 due to the implementation of treatment to meet legacy wastewater limits as plants are assumed to start dewatering ponds in that year.

Table 11-2: Time Profile of Costs to Society (Millions of 2023$) – Lower Bound

Year	Option A	Option B (Final Rule)	Option C
2025	$1,096.8	$1,240.0	$1,349.2
2026	$613.0	$748.9	$1,009.8
2027	$1,010.1	$1,123.4	$1,328.2
2028	$1,152.8	$1,448.5	$1,679.5
2029	$718.9	$852.0	$1,027.6
2030	$285.3	$345.3	$399.1
2031	$293.2	$353.2	$406.4
2032	$293.2	$352.6	$405.8
2033	$292.2	$352.2	$405.9
2034	$294.4	$353.0	$405.9
2035	$293.0	$352.4	$405.9
2036	$286.3	$347.2	$401.9
2037	$290.4	$350.4	$403.5
2038	$289.8	$349.2	$402.4
2039	$288.7	$348.7	$402.3
2040	$290.9	$349.5	$402.4
2041	$289.4	$348.9	$402.4
2042	$286.2	$347.1	$401.8
2043	$289.7	$349.7	$402.8

Table 11-2: Time Profile of Costs to Society (Millions of 2023$) – Lower Bound			
Year	Option A	Option B (Final Rule)	Option C
2044	$289.8	$803.7	$856.9
2045	$288.7	$376.6	$430.3
2046	$290.9	$377.5	$430.3
2047	$290.1	$377.5	$431.0
2048	$286.3	$375.2	$429.8
2049	$289.7	$377.6	$430.8
Annualized Costs, 2%	**$433.2**	**$536.2**	**$622.4**

Source: U.S. EPA Analysis, 2024.

Table 11-3: Time Profile of Costs to Society (Millions of 2023$) – Upper Bound			
Year	Option A	Option B (Final Rule)	Option C
2025	$1,853.6	$1,996.8	$2,106.0
2026	$1,011.7	$1,147.5	$1,408.5
2027	$1,772.3	$1,885.6	$2,090.4
2028	$2,967.8	$3,263.6	$3,494.5
2029	$1,649.2	$1,782.3	$1,957.9
2030	$692.3	$752.3	$806.1
2031	$709.9	$769.8	$823.0
2032	$708.5	$768.0	$821.2
2033	$707.6	$767.5	$821.2
2034	$710.1	$768.7	$821.5
2035	$709.0	$768.5	$822.0
2036	$699.7	$760.6	$815.3
2037	$707.0	$767.0	$820.1
2038	$705.1	$764.6	$817.7
2039	$704.1	$764.0	$817.7
2040	$706.6	$765.2	$818.0
2041	$705.5	$765.0	$818.5
2042	$699.6	$760.5	$815.2
2043	$706.4	$766.3	$819.5
2044	$705.1	$1,219.1	$1,272.2
2045	$704.1	$792.0	$845.6
2046	$706.6	$793.1	$846.0
2047	$706.2	$793.6	$847.1
2048	$699.7	$788.6	$843.2
2049	$706.4	$794.2	$847.4
Annualized Costs, 2%	**$960.9**	**$1,063.9**	**$1,150.1**

Source: U.S. EPA Analysis, 2024.

12 Benefits and Social Costs

This chapter compares total monetized benefits and costs for the regulatory options. Benefits and costs are compared on two bases: (1) incrementally for each of the options analyzed as compared to the baseline and (2) incrementally across options. The comparison of benefits and costs also satisfies the requirements of E.O. 12866: Regulatory Planning and Review (58 FR 51735, October 4, 1993), as amended by E.O. 13563: Improving Regulation and Regulatory Review (76 FR 3821, January 21, 2011) and E.O. 14094: Modernizing Regulatory Review (88 FR 21879, April 11, 2023). See Chapter 9 in the RIA for details (U.S. EPA, 2024e).

12.1 Comparison of Benefits and Costs by Option

Chapters 10 and 11 present estimates of the benefits and costs, respectively, for the regulatory options as compared to the baseline. Table 12-1 presents EPA's estimates of benefits and costs of the regulatory options, annualized over 25 years. The table provides an approximate comparison of total monetized benefits and total costs for the final rule due to differences in wastestreams included in the two analyses. Thus, the benefits analysis omits loading reductions associated with meeting limits for unmanaged CRL and legacy wastewater, even though the costs for meeting these limits are included in the total costs. EPA expects that including these wastestreams in the analysis of benefits would increase the monetized benefits.

Table 12-1: Total Estimated Annualized Benefits and Costs by Regulatory Option and Discount Rate, Compared to Baseline (Millions of 2023$, 2 Percent Discount Rate)

Regulatory Option	Total Monetized Benefits[a,b]	Total Costs[a]	
		Lower Bound	Upper Bound
Option A	$2,417	$433.2	$960.9
Option B (Final Rule)	$3,217	$536.2	$1,063.9
Option C	$3,919	$622.4	$1,150.1

a. EPA's benefits analysis did not account for the effects of loading reductions associated with limits for unmanaged CRL and legacy wastewater, whereas the total costs account for outlays for meeting these limits. See Chapter 11 for details on the lower and upper bound cost scenarios.

b. EPA estimated the air quality-related benefits for the final rule (Option B) only. EPA extrapolated estimates of air quality-related benefits for Options A and C from the estimate for Option B that is based on IPM outputs. See Chapter 8 for details.

Source: U.S. EPA Analysis, 2024.

12.2 Analysis of Incremental Benefits and Costs

In addition to comparing estimated benefits and costs for each regulatory option relative to the baseline, as presented in the preceding section, EPA also estimated the benefits and costs of the options on an incremental basis. The comparison in the preceding section addresses the simple quantitative relationship between estimated benefits and costs for each option and determines whether costs or benefits are greater for a given option and by how much. In contrast, incremental analysis looks at the differential relationship of benefits and costs across options and poses a different question: as increasingly more costly options are considered, by what amount do benefits, costs, and net benefits (*i.e.*, benefits minus costs) change from option to option? Incremental net benefit analysis provides insight into the net gain to society from imposing increasingly more costly requirements.

EPA conducted the incremental net benefit analysis by calculating the change in net benefits, from option to option, in moving from the least stringent option to successively more stringent options, where stringency is determined based on total pollutant loads. As described in Chapter 1, the regulatory options differ in the technology basis for different wastestreams. Thus, the difference in benefits and costs across the options derives from the characteristics of the wastestreams controlled by an option, the relative effectiveness of the control technology in reducing pollutant loads, the timing of control technology implementation, and the distribution and characteristics of steam electric power plants and of the receiving reaches. As was the case for the comparison in Table 12-1, the calculation of net benefits is also an approximation due to the differences in wastestreams included in the analysis of the benefits versus the costs.

As reported in Table 12-2, all options have positive net annual monetized benefits, meaning benefits exceed costs. This is true despite the omission of additional loading reductions from unmanaged CRL and legacy wastewater from the monetized benefits analysis. Net annual monetized benefit estimates range from $2,153 million under Option A to $2,681 million under Option C. Incremental net annual monetized benefit values are also positive across all options, which means that the increase in benefits under the more stringent options is larger than the increase in costs. The incremental net annual monetized benefits of moving from Option A to the final rule (Option B) is $698 million, whereas the incremental net benefits of moving the final rule (Option B) to Option C is $615 million.

Table 12-2: Analysis of Estimated Incremental Net Benefit of the Regulatory Options, Compared to Baseline and to Other Regulatory Options (Millions of 2023$, 2 Percent Discount Rate)

Regulatory Option	Net Annualized Monetized Benefits[a,b]		Incremental Net Annualized Monetized Benefits[c]	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
Option A	$1,983	$1,456	NA	NA
Option B (Final Rule)	$2,681	$2,153	$698	$698
Option C	$3,296	$2,769	$615	$615

NA: Not applicable for Option A

a. Net benefits are calculated by subtracting total annualized costs from total annual monetized benefits, where both costs and benefits are measured relative to the baseline.

b. EPA estimated the air quality-related benefits for the final rule (Option B) only. EPA extrapolated estimates of air quality-related benefits for Options A and C from the estimate for Option B that is based on IPM outputs. See Chapter 8 for details.

c. Incremental net benefits are equal to the difference between net benefits of an option and net benefits of the previous, less stringent option.

Source: U.S. EPA Analysis, 2024.

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A Changes to Benefits Methodology since 2020 Final Rule Analysis

The table below summarizes the principal methodological changes EPA made to analyses of the benefits of the final rule regulatory options, as compared to the analyses of the 2020 final rule (U.S. EPA, 2020b) and 2023 proposal (U.S. EPA, 2023c).

Table A-1: Changes to Benefits Analysis Since 2020 Final Rule

Benefits Category and Analysis Component	Analysis Component [2020 final rule analysis value]	Changes to Analysis for Proposed Rule, relative to 2020 Final Rule	Changes to Analysis for 2024 Final Rule, relative to 2023 Proposed Rule
General inputs and pollutant loads			
Universe of plants, EGUs, and receiving reaches	Analysis includes loadings for all coal-fired units operating as of 2020. The analysis also reflects other updates to the steam electric industry profile through the end of 2019, including the timing of projected retirements and refueling projects and existing treatment technologies.	Analysis includes updates to the steam electric industry profile through the end of 2021, including the timing of projected retirements and refueling projects and existing treatment technologies. See TDD for details (U.S. EPA, 2023o).	Analysis includes further updates to the steam electric industry profile through August 25, 2023, including the timing of projected retirements and refueling projects and existing treatment technologies. See TDD for details (U.S. EPA, 2024f).
General pollutant loadings and concentrations	Affected reaches based on immediate receiving reaches and flow paths in medium-resolution NHD.	Updated immediate receiving reaches (and associated downstream reaches) for selected plants. Discharges include CRL discharge outfalls.	Updated immediate receiving reaches (and associated downstream reaches) for selected plants. Discharges include legacy wastewater discharge outfalls.
	SPARROW modeling of nutrient and sediment concentrations in receiving and downstream reaches based on the most recent five regional SPARROW models that use the medium-resolution NHD stream network.	No change.	No change.

Table A-1: Changes to Benefits Analysis Since 2020 Final Rule

Benefits Category and Analysis Component	Analysis Component [2020 final rule analysis value]	Changes to Analysis for Proposed Rule, relative to 2020 Final Rule	Changes to Analysis for 2024 Final Rule, relative to 2023 Proposed Rule
	Uses the annual average loadings for two distinct periods during the analysis: 2021-2028 and 2029-2047, with pre-technology implementation loads set equal to current loads and post-retirement or repowering loads set to zero.	The two analysis periods are 2025-2029 and 2030-2049.	No change.
Water quality index	Expresses overall water quality changes using a seven-parameter index that includes subindex curve parameters for nutrients and sediment based on the regional SPARROW models.	No change.	EPA used updated subindex curves for TN, TP, and TSS derived using NARS water quality assessment data and defined at the level of the associated NARS ecoregions.
Population and socioeconomic characteristics	Based on 2017 ACS data.	Based on 2019 ACS data.	Based on 2021 ACS data.
Human health benefits from changes in exposure to halogenated disinfection byproducts in drinking water			
Public water systems affected by bromide discharges	Modeled changes in bromide concentrations in source water of public water systems.	Modeled changes in bromide concentrations in source water of public water systems and total trihalomethane concentrations in drinking water.	No change from 2023 proposal.
SDWIS database with PWS network and population served information	SDWIS 2020Q1 data	SDWIS 2021Q1 data	SDWIS 2022Q4 data

Table A-1: Changes to Benefits Analysis Since 2020 Final Rule

Benefits Category and Analysis Component	Analysis Component [2020 final rule analysis value]	Changes to Analysis for Proposed Rule, relative to 2020 Final Rule	Changes to Analysis for 2024 Final Rule, relative to 2023 Proposed Rule
Lifetime changes in incidence of bladder cancer	Qualitative discussion. EPA received public comments that further evaluation of certain DBPs should be completed and that the analysis at proposal should be subjected to peer review. EPA acknowledges that further study in this area should be conducted, including peer review of the model used at proposal. EPA will continue to evaluate the scientific data on the health impacts of DBPs.	Applied lifetime risk model to estimate changes in bladder cancer incidence in population served by public water systems. The modeling approach is generally the same EPA used for the 2019 proposed rule analysis. It is also consistent with that in a study by Weisman et al. (2022) which also applied the dose-response information from Regli et al. (2015) with more recent DBP data to estimate the potential number of bladder cancer cases associated with chlorination DBPs in drinking water. Weisman et al. (2022) found that the weight of evidence supporting causality further increased since Regli et al., 2015.	No change.
Monetization of changes in incidence of bladder cancer	Because EPA did not calculate changes in incidence of bladder cancer, the Agency was unable to monetize this effect.	Mortality valued using VSL (U.S. EPA, 2010, updated 2014). Morbidity valued based on COI (Greco et al., 2019).	Mortality valued using VSL (U.S. EPA, 2010, updated 2014). Morbidity valued based on WTP from Bosworth, Cameron and DeShazo (2009).

Table A-1: Changes to Benefits Analysis Since 2020 Final Rule			
Benefits Category and Analysis Component	**Analysis Component [2020 final rule analysis value]**	**Changes to Analysis for Proposed Rule, relative to 2020 Final Rule**	**Changes to Analysis for 2024 Final Rule, relative to 2023 Proposed Rule**
Non-market benefits from water quality improvements			
WTP for water quality improvements	Benefits valued using a MRM	EPA added 10 new studies to the 2015 meta-data, revised existing observations as needed to improve consistency within the dataset, and re-estimated the MRM (see ICF, 2022b for details). Similar to the 2015 MRM, the model includes spatial characteristics of the affected water resources: size of the market, waterbody characteristics (length and flow), availability of substitute sites, and land use type in the adjacent counties. Variables characterizing the availability of substitute sites, size of the market, and land-use were revised based on changes in the universe of receiving reaches and CBGs included in the analysis.	No change, except from updates to the model scope and variables to reflect changes in the universe of receiving reaches and CBGs.
Effects on T&E species	Categorical analysis based on designated critical habitat overlap/proximity to reaches with estimated changes in NRWQC exceedances.	EPA updated the list of species included in the analysis based on the 2020 ECOS online database (U.S. FWS, 2020d). EPA also relied on the habitat range of T&E species in determining whether reaches downstream from steam electric power plant outfalls intersect species habitat (U.S. FWS, 2020b), rather than "critical habitat" as the term is defined in the ESA. EPA included all species categorized as having higher vulnerability to water pollution in its analysis (see Chapter 7 and Appendix I for details). The only exception is species endemic to springs and headwaters.	EPA updated the list of species based on critical habitats as of January 4, 2024, as well as the scope of the analysis to reflect additional receiving waters. At this time, EPA also adjusted analysis to remove species delisted by the USFWS in 2023 due to extinction (U.S. Fish & Wildlife Service, 2023).

Table A-1: Changes to Benefits Analysis Since 2020 Final Rule

Benefits Category and Analysis Component	Analysis Component [2020 final rule analysis value]	Changes to Analysis for Proposed Rule, relative to 2020 Final Rule	Changes to Analysis for 2024 Final Rule, relative to 2023 Proposed Rule
Air quality-related effects			
Emissions changes	Emissions from changes in electricity generation profile from 2020 IPM runs. Energy use-associated emissions were updated to reflect emission factors estimated using the 2020 IPM runs.	Emissions from changes in electricity generation profile from 2022 IPM runs. Energy use-associated emissions were updated to reflect emission factors estimated using the 2022 IPM runs.	Emissions from changes in electricity generation profile from 2024 IPM runs. Energy use-associated emissions were updated to reflect emission factors estimated using the 2024 IPM runs.
Air quality changes	Used the ACE modeling methodology to estimate changes in air pollutant concentrations.	Updated methodology to reflect the most recent air quality surfaces.	Updated methodology to reflect the most recent air quality surfaces. See Appendix J for details.
Monetization of health effects	Used BenMAP-CE model to estimate associated human health benefits.	No change.	No change.
Monetization of changes in GHG emissions	Used E.O. 13783 domestic-only SC-GHG values at 3 and 7 percent discounts in main analysis. Presented results based on global SC-GHG values under 2.5, 3, and 7 percent discount rates in sensitivity analysis.	Used IWG (2021) recommended interim global SC-GHG values at 2.5, 3 (average and 95%), and 5 percent discount rates.	Used EPA (2023l) updated global SC-GHG values at 1.5 percent, 2.0 percent, and 2.5 percent near-term Ramsey discount rates. Presented results based on IWG (2021) interim SC-GHG values in Appendix.

B Estimated Costs and Benefits Using Discount Rates from the Proposal

This appendix provides costs and benefits of the final rule using the discount rates used in the proposal BCA to facilitate comparison with the benefits analysis presented at proposal (see 2023 BCA; U.S. EPA, 2023c). As is the case throughout the document, monetary values in this appendix are presented in 2023 dollars (as compared to 2021 dollars for values in the 2023 BCA (U.S. EPA, 2023c)).

B.1 Benefits

Table B-1: Estimated Bromide-related Bladder Cancer Mortality and Morbidity Monetized Benefits

Regulatory Option	Changes in cancer cases from changes in TTHM exposure 2025-2049[a]		Benefits (million 2023$, discounted to 2024)					
	Total bladder cancer cases avoided	Total cancer deaths avoided	Annualized[b] benefits from avoided mortality		Annualized[b] benefits from avoided morbidity		Total annualized[b] benefits	
			3%	7%	3%	7%	3%	7%
Option A	98	28	$9.5	$5.8	$1.7	$1.1	$11.3	$7.0
Option B (Final Rule)	98	28	$9.5	$5.8	$1.7	$1.1	$11.3	$7.0
Option C	104	29	$10.2	$6.3	$1.9	$1.2	$12.1	$7.5

[a] The analysis accounts for the persisting health effects (up until 2125) from changes in TTHM exposure during the period of analysis (2025-2049).

[b] Benefits are annualized over 25 years.

Source: U.S. EPA Analysis, 2024

Table B-2: Estimated Benefits from Avoided IQ Losses for Children Exposed to Lead under the Regulatory Options, Compared to Baseline

Regulatory Option	Average Annual Number of Children 0 to 7 in Scope of the Analysis[b]	Total Avoided IQ Point Losses, 2025 to 2049 in All Children 0 to 7 in Scope of the Analysis[c]	Annualized Value of Avoided IQ Point Losses[a] (Millions 2023$)	
			3% Discount Rate	7% Discount Rate
Option A	1,555,558	0.93	<$0.01	<$0.01
Option B (Final Rule)	1,555,558	0.93	<$0.01	<$0.01
Option C	1,555,558	0.93	<$0.01	<$0.01

a. Based on estimate that the loss of one IQ point results in the loss of 2.63 percent of lifetime earnings, following updated Salkever (1995) values from U.S. EPA (2019d).

b. The number of children in scope of the analysis is based on reaches analyzed across the regulatory options. Some of the children included in this count see no changes in exposure under some options.

c. EPA notes that the IQ point losses are very small. EPA further notes that the IEUBK model does not analyze blood lead level changes beyond two decimal points.

Source: U.S. EPA Analysis, 2024

Table B-3: Estimated Benefits from Avoided IQ Losses for Infants from Mercury Exposure under the Regulatory Options, Compared to Baseline

Regulatory Option	Number of Infants in Scope of the Analysis per Year[b]	Total Avoided IQ Point Losses, 2025 to 2049 in All Infants in Scope of the Analysis	Annualized Value of Avoided IQ Point Losses[a] (Millions 2023$)	
			3% Discount Rate	7% Discount Rate
Option A	201,850	1,190	$1.02	$0.18
Option B (Final Rule)	201,850	1,377	$1.18	$0.21
Option C	201,850	1,393	$1.19	$0.21

a. Based on the estimate that the loss of one IQ point results in the loss of 2.63 percent of lifetime earnings discounted to birth, following updated Salkever (1995) values from U.S. EPA (2019f).

b. The number of infants in scope of the analysis is based on reaches analyzed across the regulatory options. Some of the children included in this count see no changes in exposure under some options.

Source: U.S. EPA Analysis, 2024

Table B-4: Estimated Benefits from Avoided CVD Deaths for Adults (aged 40-80) under the Regulatory Options, Compared to Baseline

Regulatory Option	Number of Adults in Scope of the Analysis per Year[a]	Total CVD Deaths Avoided, 2025 to 2049 in All Adults in Scope of the Analysis[b]		Annualized Value of Avoided CVD Deaths[c] (Millions 2023$)			
				3% Discount Rate		7% Discount Rate	
		Low	High	Low	High	Low	High
Option A	19,571,228	0.42	1.13	$0.16	$0.42	$0.14	$0.37
Option B (Final Rule)	19,571,228	0.42	1.13	$0.16	$0.42	$0.14	$0.37
Option C	19,571,228	0.45	1.20	$0.16	$0.43	$0.14	$0.38

a. The number of adults in scope of the analysis is based on reaches analyzed across the regulatory options. Some of the adults included in this count see no changes in exposure under some options. Benefits accrue to the subset of adults that experience changes in exposure under one or more options (576,537 adults in 2025). Under the assumption that fishers would share their catch with members of their household, EPA included household members in this subset.
b. Assumes that the distribution for the individuals experiencing CVD premature mortality that is caused by lead is the same as the distribution of CVD premature mortality irrespective of the cause.

Source: U.S. EPA Analysis, 2024

Table B-5: Estimated Household and Total Annualized Willingness-to-Pay for Water Quality Improvements under the Regulatory Options, Compared to Baseline (Main Estimates)

Regulatory Option	Number of Affected Households (Millions)[a]	Average Annual WTP Per Household (2023$)[b]	Total Annualized WTP (Millions 2023$)[b]	
			3% Discount Rate	7% Discount Rate
Option A	58.7	$0.01	$0.77	$0.70
Option B (Final Rule)	58.9	$0.02	$1.21	$1.10
Option C	59.6	$0.03	$1.64	$1.50

a. The number of affected households varies across options because of differences in the number of reaches that have non-zero changes in water quality.

b. Estimates based on Model 1, which provides EPA's main estimate of non-market benefits.

Source: U.S. EPA Analysis, 2024

Table B-6: Estimated Household and Total Annualized Willingness-to-Pay for Water Quality Changes under the Regulatory Options, Compared to Baseline (Sensitivity Analysis)

Regulatory Option	Number of Affected Households (Millions)[a]	Average Annual WTP Per Household (2023$)[b]		Total Annualized WTP (Millions 2023$)[b]			
				3% Discount Rate[a,b]		7% Discount Rate[a]	
		Low	High	Low	High	Low	High
Option A	58.7	$0.01	$0.03	$0.84	$1.71	$0.74	$1.52
Option B (Final Rule)	58.9	$0.02	$0.05	$1.27	$2.60	$1.12	$2.30
Option C	59.6	$0.03	$0.07	$1.73	$3.55	$1.55	$3.17

a. The number of affected households varies across options because of differences in the number of reaches that have non-zero changes in water quality.

b. Estimates based on Model 2, which provides a range of estimates that account for uncertainty in the WTP estimates as a sensitivity analysis. For the ∆WQI variable setting in Model 2-based sensitivity analysis, EPA used values of 20 units to develop low estimates and 7 units to develop high estimates (see Appendix H for details).

Source: U.S. EPA Analysis, 2024

Table B-7: Estimated Annualized Climate Benefits from Changes in CO_2 and CH_4 Emissions under the Final Rule during the Period of 2025-2049 by Categories of Air Emissions and Interim SC-GHG Estimates, Compared to Baseline (Millions of 2023$)

Regulatory Option	Category of Air Emissions	Annualized Climate Benefits[a,b]			
		5.0% Average	3.0% Average	2.5% Average	3.0% 95th Percentile
Option B (Final Rule)	Electricity generation	$142.8	$435.9	$620.8	$1,323.6
	Trucking	-$0.0	-$0.1	-$0.1	-$0.2
	Energy use	-$2.6	-$8.2	-$11.8	-$25.1
	Total	**$140.2**	**$427.6**	**$608.9**	**$1,298.4**

a. Values rounded to two significant figures. Negative values indicate forgone benefits whereas positive values indicate positive benefits.

b. Climate benefits estimated using interim SC-GHG (IWG, 2021).

Source: U.S. EPA Analysis, 2024

Table B-8: Estimated Discounted Economic Value of Avoided Ozone and $PM_{2.5}$-Attributable Premature Mortality and Illness for Option B (95 Percent Confidence Interval; millions of 2023$)

Year	3% Discount Rate[a]			7% Discount Rate[a]		
2028	$1,000	*and*	$2,500	$890	*and*	$2,200
	($170 to $2500)		($300 to $6,500)	($120 to $2,200)		($240 to $5,800)
2030	$380	*and*	$1,200	$320	*and*	$1,000
	($77 to $890)		($150 to $3,000)	($51 to $770)		($110 to $2,700)
2035	$1,600	*and*	$3,700	$1,400	*and*	$3,300
	($240 to $4,000)		($430 to $9,800)	($180 to $3,500)		($350 to $8,800)
2040	$480	*and*	$1,200	$410	*and*	$1,100
	($78 to $1,200)		($140 to $3,200)	($57 to $1,000)		($120 to $2,900)
2045	$150	*and*	$370	$130	*and*	$330
	($24 to $360)		($44 to $970)	($17 to $320)		($36 to $870)
2050	$130	*and*	$300	$120	*and*	$260
	($19 to $330)		($34 to $790)	($15 to $290)		($28 to $700)

[a] Values rounded to two significant figures. The two benefits estimates are separated by the word "and" to signify that they are two separate estimates. The estimates do not represent lower- and upper-bound estimates and should not be summed.

Source: U.S. EPA Analysis, 2024

Table B-9: Estimated Annualized Changes in Navigational Dredging Costs under the Regulatory Options, Compared to Baseline

Regulatory Option	Total Reduction in Sediment Dredged (Thousands Cubic Yards)		3% Discount Rate (Millions of 2023$ per Year)[a]		7% Discount Rate (Millions of 2023$ per Year)[a]	
	Low	High	Low	High	Low	High
Option A	7.1	9.3	<$0.01	$0.01	<$0.01	<$0.01
Option B (Final Rule)	8.3	10.8	<$0.01	$0.01	<$0.01	$0.01
Option C	8.5	11.0	<$0.01	$0.01	<$0.01	$0.01

a. Positive values represent cost savings.

Source: U.S. EPA Analysis, 2024.

Table B-10: Estimated Total Annualized Changes in Reservoir Dredging Volume and Costs under the Regulatory Options, Compared to Baseline

Regulatory Option	Total Reduction in Sediment Dredged (Thousands Cubic Yards)		Costs at 3% Discount Rate[a] (Millions of 2023$ per Year)		Costs at 7% Discount Rate[a] (Millions of 2023$ per Year)	
	Low	High	Low	High	Low	High
Option A	1.0	1.1	<$0.01	<$0.01	<$0.01	<$0.01
Option B (Final Rule)	1.2	1.3	<$0.01	<$0.01	<$0.01	<$0.01
Option C	1.2	1.4	<$0.01	<$0.01	<$0.01	<$0.01

a. Positive values represent cost savings.

Source: U.S. EPA Analysis, 2024.

Table B-10: Summary of Estimated Total Annualized Benefits of the Regulatory Options, Compared to Baseline, at 3 Percent (Millions of 2023$)

Benefit Category	Option A	Option B (Final Rule)	Option C
Human Health			
Changes in IQ losses in children from exposure to lead[a]	<$0.01	<$0.01	<$0.01
Changes in cardiovascular disease premature mortality from exposure to lead	$0.16 - $0.42	$0.16 - $0.42	$0.16 - $0.43
Changes in IQ losses in children from exposure to mercury	$1.05	$1.21	$1.23
Changes in cancer risk from disinfection by-products in drinking water	$11.28	$11.28	$12.06
Ecological Conditions and Recreational Uses Changes			
Use and nonuse values for water quality changes[b]	$0.77	$1.21	$1.64
Market and Productivity Effects[a]			
Changes in drinking water treatment costs			
Changes in dredging costs[a]	<$0.01	<$0.01	<$0.01
Air Quality-Related Effects[c]			
Climate change effects from changes in greenhouse gas emissions[c,d]	$330	$430	$520
Human health effects from changes in NO_X, SO_2, and $PM_{2.5}$ emissions[c]	$1,200	$1,600	$2,000
Total[e]	**$1,544**	**$2,044**	**$2,536**

a. "<$0.01" indicates that monetary values are greater than $0 but less than $0.01 million.

b. Estimates based on Model 1, which provides EPA's main estimate of non-market benefits. See Chapter 6 for details.

Table B-10: Summary of Estimated Total Annualized Benefits of the Regulatory Options, Compared to Baseline, at 3 Percent (Millions of 2023$)

Benefit Category	Option A	Option B (Final Rule)	Option C

c. Values for air-quality related effects are rounded to two significant figures. EPA estimated the air quality-related benefits for the final rule (Option B). EPA extrapolated estimates of air quality-related benefits for Options A and C from the estimate for Option B that is based on IPM outputs. See Chapter 8 for details.

d. Climate change benefits are based on interim SC-GHG values for the 3 percent discount rate (IWG, 2021), discounted and annualized using a 3 percent discount.

e. Values for individual benefit categories may not sum to the total due to independent rounding.

Source: U.S. EPA Analysis, 2024

Table B-11: Summary of Estimated Total Annualized Benefits of the Regulatory Options, Compared to Baseline, at 7 Percent (Millions of 2023$)

Benefit Category	Option A	Option B (Final Rule)	Option C
Human Health			
Changes in IQ losses in children from exposure to lead[a]	<$0.01	<$0.01	<$0.01
Changes in cardiovascular disease premature mortality from exposure to lead	$0.14 - $0.37	$0.14 - $0.37	$0.14 - $0.38
Changes in IQ losses in children from exposure to mercury	$0.19	$0.22	$0.22
Changes in cancer risk from disinfection by-products in drinking water	$6.99	$6.99	$7.53
Ecological Conditions and Recreational Uses Changes			
Use and nonuse values for water quality changes[b]	$0.70	$1.10	$1.50
Market and Productivity Effects[a]			
Changes in drinking water treatment costs			
Changes in dredging costs[a]	<$0.01	<$0.01	<$0.01
Air Quality-Related Effects[c]			
Climate change effects from changes in greenhouse gas emissions[c,d]	$330	$430	$520
Human health effects from changes in NO_X, SO_2, and $PM_{2.5}$ emissions[c,e]	$1,100	$1,400	$1,700
Total[f]	**$1,438**	**$1,839**	**$2,230**

a. "<$0.01" indicates that monetary values are greater than $0 but less than $0.01 million.

b. Estimates based on Model 1, which provides EPA's main estimate of non-market benefits. See Chapter 6 for details.

c. Values for air-quality related effects are rounded to two significant figures. EPA estimated the air quality-related benefits for the final rule (Option B). EPA extrapolated estimates of air quality-related benefits for Options A and C from the estimate for Option B that is based on IPM outputs. See Chapter 8 for details.

d. Climate change benefits are based on interim SC-GHG values for the 3 percent discount rate (IWG, 2021), discounted and annualized using a 3 percent discount.

e. The values reflect the LT estimates of human health effects from changes in $PM_{2.5}$ and ozone levels. See Chapter 8 for details.

f. Values for individual benefit categories may not sum to the total due to independent rounding.

Source: U.S. EPA Analysis, 2024

B.2 Social Costs

Table B-12: Summary of Estimated Incremental Annualized Costs for Regulatory Options (Millions of 2023$)

Regulatory Option	Annualized Costs			
	3% Discount Rate		7% Discount Rate	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
Option A	$444.2	$974.7	$478.7	$1,028.7
Option B (Final Rule)	$544.8	$1,077.2	$580.1	$1,130.1
Option C	$633.0	$1,165.4	$676.5	$1,226.5

Source: U.S. EPA Analysis, 2024.

B.3 Social Benefits and Costs

Table B-14: Total Estimated Annualized Benefits and Costs by Regulatory Option and Discount Rate, Compared to Baseline (Millions of 2023$)

Regulatory Option	3% Discount			7% Discount		
	Total Monetized Benefits[a,b]	Total Costs		Total Monetized Benefits[a,b]	Total Costs	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound
Option A	$1,544	$444.2	$974.7	$1,244	$478.7	$1,028.7
Option B (Final Rule)	$2,044	$544.8	$1,077.2	$1,653	$580.1	$1,130.1
Option C	$2,536	$633.0	$1,165.4	$2,056	$676.5	$1,226.5

a. EPA estimated the air quality-related benefits for the final rule (Option B) only. EPA extrapolated estimates of air quality-related benefits for Options A and C from the estimate for Option B that is based on IPM outputs. See Chapter 8 for details.

b. Climate change benefits are based on interim SC-GHG values for the 3 percent discount rate (IWG, 2021), discounted and annualized using a 3 percent discount.

Source: U.S. EPA Analysis, 2024.

C WQI Calculation and Regional Subindices

C.1 WQI Calculation

The first step in the implementation of the WQI involves obtaining water quality levels for each parameter, and for each waterbody, under both the baseline conditions and each regulatory option. Some parameter levels are modeled values (TN, TP, TSS, arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, and zinc) and vary from the baseline depending on the regulatory option, while others are field measurements (FC, BOD, and DO) and are left unchanged between the baseline and regulatory options.

The second step involves transforming the parameter measurements into subindex values that express water quality conditions on a common scale of 10 to 100. EPA used the subindex transformation curves developed by Dunnette (1979) and Cude (2001) for the Oregon WQI for BOD, DO, and FC. For TSS, TN, and TP concentrations, EPA adapted the approach developed by Cude (2001) to account for the wide range of natural or background nutrient and sediment concentrations that result from variability in geologic and other region-specific conditions, and to reflect the national context of the analysis. TSS, TN, and TP subindex curves were developed for each of the nine ecoregions used for the 2013-2014 and 2018-2019 National Rivers and Stream Assessment (NRSA) (U.S. EPA, 2020e, 2023j). For each of the nine ecoregions, EPA derived the transformation curves by assigning a score of 100 to the 10th percentile of the observations within each ecoregion (*i.e.*, using the 10th percentile as a proxy for "reference" concentrations), and a score of 70 to the median concentration. An exponential equation was then fitted to the two concentration points following the approach used in Cude (2001).

For this analysis, EPA also used a toxics-specific subindex curve based on the number of NRWQC exceedances for toxics in each waterbody. National freshwater chronic NRWQC values are available for arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, and zinc. See the EA for details on the NRWQC (U.S. EPA, 2020g; U.S. EPA, 2024b). To develop this subindex curve, EPA used an approach developed by the Canadian Council of Ministers of the Environment (CCME, 2001). The CCME water quality index is based on three attributes of water quality that relate to water quality objectives: scope (number of monitored parameters that exceed water quality standard or toxicological benchmark); frequency (number of individual measurements that do not meet objectives, relative to the total number of measurements for the time period of interest) and amplitude (*i.e.*, amount by which measured values exceed the standards or benchmarks). Following the CCME approach, EPA's toxics subindex considers the number of parameters with exceedances of the relevant water quality criterion. With regards to frequency, EPA modeled long-term annual average concentrations in ambient water, and therefore any exceedance of an NRWQC may indicate that ambient concentrations exceed NRWQC most of the time (assumed to be 100 percent of the time). EPA did not consider amplitude, because if the annual average concentration exceeds the chronic NRWQC then the water is impaired for that constituent and the level of exceedance is of secondary concern. Using this approach, the subindex curve for toxics assigns the lowest subindex score of 0 to waters where exceedances are observed for all nine of the toxics analyzed, and a maximum score of 100 to waters where there are no exceedances. Intermediate values are distributed evenly between 0 and 100.

Table C-1 presents parameter-specific functions used for transforming water quality data into water quality subindices for freshwater waterbodies for the six pollutants with individual subindices. Table C-2 presents the subindex values for toxics. The equation parameters for each of the nine ecoregion-specific TSS, TN, and TP subindex curves are provided in the next section. The curves include threshold values below or above which the subindex score does not change in response to changes in parameter levels. For example, improving DO levels from 10.5 mg/L to 12 mg/L or from 2 mg/L to 3.3 mg/L would result in no change in the DO subindex score.

Table C-1: Freshwater Water Quality Subindices

Parameter	Concentrations	Concentration Unit	Subindex
Dissolved Oxygen (DO)			
DO saturation ≤100%			
DO	DO ≤ 3.3	mg/L	10
DO	3.3 < DO < 10.5	mg/L	$-80.29+31.88 \times DO-1.401 \times DO^2$
DO	DO ≥ 10.5	mg/L	100
100% < DO saturation ≤ 275%			
DO	NA	mg/L	$100 \times \exp((DOsat - 100) \times -1.197 \times 10^{-2})$
275% < DO saturation			
DO	NA	mg/L	10
Fecal Coliform (FC)			
FC	FC > 1,600	cfu/100 mL	10
FC	50 < FC ≤ 1,600	cfu/100 mL	$98 \times \exp((FC - 50) \times -9.9178 \times 10^{-4})$
FC	FC ≤ 50	cfu/100 mL	98
Total Nitrogen (TN)[a]			
TN	$TN > TN_{10}$	mg/L	10
TN	$TN_{100} < TN \leq TN_{10}$	mg/L	a × exp(TN×b); where a and b are ecoregion-specific values
TN	$TN \leq TN_{100}$	mg/L	100
Total Phosphorus (TP)[b]			
TP	$TP > TP_{10}$	mg/L	10
TP	$TP_{100} < TP \leq TP_{10}$	mg/L	a × exp(TP×b); where a and b are ecoregion-specific values
TP	$TP \leq TP_{100}$	mg/L	100
Suspended Solids[c]			
TSS	TSS > TSS 10	mg/L	10
TSS	TSS 100 < TSS ≤ TSS 10	mg/L	a × exp(TSS×b); where a and b are ecoregion-specific values
TSS	TSS ≤ TSS 00	mg/L	100
Biochemical Oxygen Demand, 5-day (BOD)			
BOD	BOD > 8	mg/L	10
BOD	BOD ≤ 8	mg/L	$100 \times \exp(BOD \times -0.1993)$

a. TN10 and TN100 are ecoregion-specific TN concentration values that correspond to subindex scores of 10 and 100, respectively. Use of 10 and 100 for the lower and upper bounds of the WQI subindex score follow the approach in Cude (2001)

b. TP10 and TP100 are ecoregion-specific TP concentration values that correspond to subindex scores of 10 and 100, respectively. Use of 10 and 100 for the lower and upper bounds of the WQI subindex score follow the approach in Cude (2001)

c. TSS10 and TSS100 are ecoregion-specific SSC concentration values that correspond to subindex scores of 10 and 100, respectively. Use of 10 and 100 for the lower and upper bounds of the WQI subindex score follow the approach in Cude (2001)

Source: EPA Analysis, 2024, based on methodology in Cude (2001).

Table C-2: Freshwater Water Quality Subindex for Toxics

Number of Toxics with NRWQC Exceedances	Subindex
0	100.0
1	88.9
2	77.8
3	66.7
4	55.6
5	44.4
6	33.3
7	22.2
8	11.1
9	0.0

The final step in implementing the WQI involves combining the individual parameter subindices into a single WQI value that reflects the overall water quality across the parameters. EPA calculated the overall WQI for a given reach using a geometric mean function and assigned all WQ parameters an equal weight of 0.143 (1/7th of the overall score). Unweighted scores for individual metrics of a WQI have previously been used in Cude (2001), CCME, 2001, and Carruthers and Wazniak (2003).

Equation C-1 presents EPA's calculation of the overall WQI score.

Equation C-1.

$$WQI_r = \prod_{i=1}^{n} Q_i^{Wi}$$

WQI_r	=	the multiplicative water quality index (from 0 to 100) for reach *r*
Q_i	=	the water quality subindex measure for parameter *i*
W_i	=	the weight of the *i*-th parameter (0.143)
n	=	the number of parameters (*i.e.*, seven)

C.2 Regional Subindices

The following tables provide the ecoregion-specific parameters used in estimating the TSS, TN, or TP water quality subindex, as follows:

- If [WQ Parameter] ≤ WQ Parameter 100	Subindex = 100
- If WQ Parameter 100 < [WQ Parameter] ≤ WQ Parameter 10	Subindex = a exp(b [WQ Parameter])
- If [WQ Parameter] > WQ Parameter 10	Subindex = 10

Where [WQ Parameter] is the measured concentration of either TSS, TN, or TP and WQ Parameter $_{10}$, WQ Parameter $_{100}$, a, and b are specified in Table C-3 for TSS, Table C-4 for TN, and Table C-5 for TP.

Table C-3: TSS Subindex Curve Parameters, by Ecoregion

Ecoregion	a	b	TSS_{100}	TSS_{10}
Coastal Plains	109.34	-0.015	5.86	156.84
Northern Appalachians	108.11	-0.061	1.29	39.27
Northern Plains	102.07	-0.001	18.10	2,049.20
Southern Appalachians	114.22	-0.012	10.88	199.43
Southern Plains	102.19	-0.001	15.53	1,667.06
Temperate Plains	114.02	-0.003	46.30	858.85
Upper Midwest	101.24	-0.021	0.59	111.70
Western Mountains	108.48	-0.018	4.51	131.95
Xeric	101.72	-0.003	6.53	887.38

Source: U.S. EPA Analysis, 2024

Table C-4: TN Subindex Curve Parameters, by Ecoregion

Ecoregion	a	b	TN_{100}	TN_{10}
Coastal Plains	148.67	-0.85	0.47	3.17
Northern Appalachians	128.25	-1.08	0.23	2.36
Northern Plains	124.98	-0.40	0.56	6.37
Southern Appalachians	178.79	-0.95	0.61	3.04
Southern Plains	113.00	-0.22	0.55	10.95
Temperate Plains	123.62	-0.13	1.57	18.65
Upper Midwest	119.92	-0.40	0.45	6.20
Western Mountains	121.28	-1.99	0.10	1.25
Xeric	130.03	-1.06	0.25	2.43

Source: U.S. EPA Analysis, 2024

Table C-5: TP Subindex Curve Parameters, by Ecoregion

Ecoregion	a	b	TP_{100}	TP_{10}
Coastal Plains	116.13	-5.33	0.03	0.46
Northern Appalachians	104.31	-5.75	0.01	0.41
Northern Plains	117.76	-13.58	0.01	0.18
Southern Appalachians	115.90	-1.02	0.15	2.41
Southern Plains	114.66	-4.37	0.03	0.56
Temperate Plains	103.46	-0.66	0.05	3.56
Upper Midwest	140.90	-1.58	0.22	1.67
Western Mountains	107.15	-3.89	0.02	0.61
Xeric	108.89	-9.72	0.01	0.25

Source: U.S. EPA Analysis, 2024

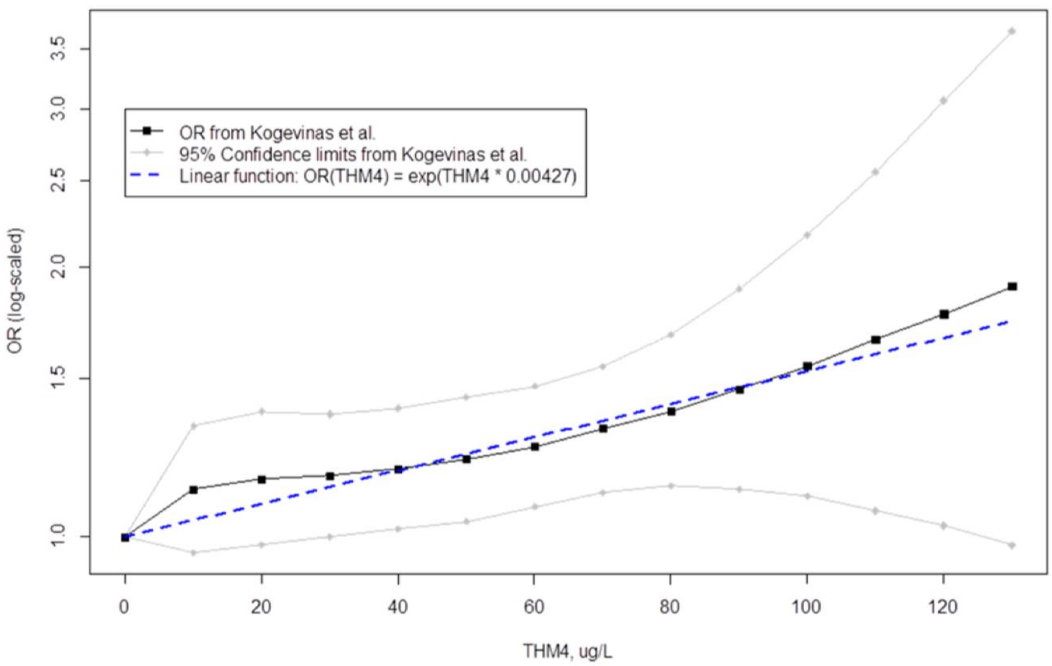
D Additional Details on Modeling Change in Bladder Cancer Incidence from Change in TTHM Exposure

D.1 Details on Life Table Approach

D.1.1 Health Impact Function

Figure D-1 shows the dependence between lifetime odds of bladder cancer and drinking water TTHM concentration as reported by Villanueva et al. (2004). These data were used by Regli et al. (2015) to estimate the log-linear relationship in Equation 4-1, which is also displayed in Figure D-1. As described in Chapter 4, Regli et al. (2015) showed that, while the original analysis deviated from linearity, particularly at low doses, the overall pooled exposure-response relationship for TTHM could be well-approximated by a linear slope factor that predicted an incremental lifetime cancer risk of 1 in ten thousand exposed individuals (10^{-4}) per 1 µg/L increase in TTHM.[140]

Figure D-1: Estimated Relationships between Lifetime Bladder Cancer Risk and TTHM Concentrations in Drinking Water



Source: Regli et al. (2015)

[140] Regli, S., Chen, J., Messner, M., Elovitz, M. S., Letkiewicz, F. J., Pegram, R. A., Pepping, T. J., . . . Wright, J. M. (2015). Estimating potential increased bladder cancer risk due to increased bromide concentrations in sources of disinfected drinking waters. *Environmental Science & Technology*, *49*(22), 13094-13102. addressed some of the limitations noted in the Hrudey, S. E., Backer, L. C., Humpage, A. R., Krasner, S. W., Michaud, D. S., Moore, L. E., Singer, P. C., . . . Stanford, B. D. (2015). Evaluating evidence for association of human bladder cancer with drinking-water chlorination disinfection by-products. *Journal of Toxicology and Environmental Health, Part B*, *18*(5), 213-241. analysis. They suggested that the seeming discrepancy between the slope factor derived from the pooled epidemiological data and that from animal studies was due primarily to (1) potentially high human exposures to DBPs by the inhalation route, and (2) that trihalomethanes were acting as proxies for other carcinogenic DBPs.

EPA used the Regli et al. (2015) relationship between the lifetime odds of bladder cancer and lifetime TTHM exposure from drinking water to derive a set of age-specific health impact functions. A person's lifetime TTHM exposure from drinking water by age a—denoted by x_a—is defined as:

Equation D-1. $$\boldsymbol{x_a = \frac{1}{a}\sum_{i=0}^{a-1} TTHM_i\,, x_0 = 0}.$$

See Table D-1 at the end of this section for definitions of all variables used in the equations in this appendix.

Assuming a baseline exposure of z_a and a regulatory option exposure of x_a (*i.e.*, exposure following implementation of a regulatory option), the relative risk (RR) of bladder cancer by age a under the option exposure relative to the baseline exposure can be expressed as:

Equation D-2 $$RR(x_a, z_a) = \max\left[1 - PAF, \left(\frac{O(x_a)}{O(z_a)}\right)^{-1} \cdot \left(LR_a \cdot \frac{O(x_a)}{O(z_a)} - LR_a + 1\right)\right]$$

where LR_a is the lifetime risk of bladder cancer within age interval $[0, a]$ (Fay et al. 2003) under baseline conditions and PAF is the environmental exposure-related population attributable fraction of bladder cancer incidence set at 0.0394. As such, this equation implies that EPA caps the magnitude of TTHM-related cumulative bladder cancer risk reduction at the PAF of 3.94 percent to ensure plausibility of the estimated bladder cancer benefits size. EPA developed this PAF estimate based on a review of literature on environmental contaminant-attributable risk estimates for cancers (ICF, 2022a).

Combining Equation D-1 and Equation D-2 shows that the relative risk of bladder cancer by age a based on Regli et al. (2015) depends only on the lifetime risk and on the magnitude of change in TTHM concentration from baseline concentration, $\Delta x_a = x_a - z_a$, but not on the baseline TTHM level:

Equation D-3. $$RR_{\text{Regli et al.}}(x_a, z_a) = \max\left[1 - PAF, \left(\frac{O(0)\cdot e^{0.00427\cdot x_a}}{O(0)\cdot e^{0.00427\cdot z_a}}\right)^{-1} \cdot \left(LR_a \cdot \frac{O(0)\cdot e^{0.00427\cdot x_a}}{O(0)\cdot e^{0.00427\cdot z_a}} - LR_a + 1\right)\right]$$
$$= \max\left[1 - PAF, e^{-0.00427\cdot(x_a - z_a)} \cdot \left(LR_a \cdot e^{0.00427\cdot(x_a - z_a)} - LR_a + 1\right)\right]$$
$$= \max\left[1 - PAF, e^{-0.00427\cdot\Delta x_a} \cdot \left(LR_a \cdot e^{0.00427\cdot\Delta x_a} - LR_a + 1\right)\right].$$

At the average baseline TTHM concentration level of 38.05 μg/L reported in Regli et al. (2015), the slope of the Regli et al. (2015) relationship appears to be a good approximation of the slope of the piece-wise linear relationship implied by the Villanueva et al. (2004) data. For baseline TTHM levels in the 20 μg/L to 60 μg/L range, the Regli et al. (2015) slope is steeper than the slopes of the piece-wise linear relationship whereas for baseline TTHM levels above 60 μg/L the Regli et al. (2015) slope is flatter. While this potentially has implications for the magnitude of the health effects EPA modeled,[141] the relationship based on Villanueva et

[141] If the piece-wise linear relationship based on Villanueva, C. M., Cantor, K. P., Cordier, S., Jaakkola, J. J. K., King, W. D., Lynch, C. F., Porru, S., . . . Kogevinas, M. (2004). Disinfection byproducts and bladder cancer: a pooled analysis. *Epidemiology*, 357-367. reported data had been used as the basis for health impact function, there would have been larger effect estimates for some individuals and smaller effect estimates for others relative to the estimates obtained using the Regli, S., Chen, J., Messner, M., Elovitz, M. S., Letkiewicz, F. J., Pegram, R. A., Pepping, T. J., . . . Wright, J. M. (2015). Estimating potential increased bladder cancer risk due to increased bromide concentrations in sources of disinfected drinking waters. *Environmental Science & Technology*, *49*(22), 13094-13102. linear approximation.

al. (2004) requires detailed information on the baseline TTHM exposure for the population of interest which is not available.

D.1.2 Health Risk Model

To estimate the health effects of changes in TTHM exposure, the health risk model tracks evolution of two populations over time — the bladder cancer-free population and the bladder cancer population. These two populations are modeled for both the baseline annual TTHM exposure scenario and for the regulatory options TTHM exposure scenarios. Populations in the scenarios are demographically identical but they differ in the TTHM levels to which they are exposed. The population affected by change in bromide discharges associated with a regulatory option is assumed to be exposed to baseline TTHM levels prior to the regulatory option implementation year (in this case 2024) and to alternative TTHM levels that reflect the impact of technology implementation under each regulatory option starting in 2025.

To capture these effects while being consistent with the remainder of the cost-benefit framework, EPA modeled changes in health outcomes resulting from changes in exposure between 2025 and 2049. For these exposures, EPA modeled effects out to 2124 to capture the resultant lagged changes in lifetime bladder cancer risk, but did not attribute changes in bromide loadings and TTHM exposures to the regulatory options beyond 2049.[142]

EPA tracks mortality and bladder cancer experience for a set of model populations defined by sex, location, and age attained by 2025, which is denoted by $A = 0,1,2,3, \ldots 100$. Each model population is followed from birth (corresponding to calendar year $2025 - A$) to age 100, using a one-year time step. Below, we first describe the process for quantifying the evolution of model population A under the baseline TTHM exposure assumptions. We then describe the process for quantifying the evolution of the population under the regulatory option TTHM exposures. Finally, we describe the process for estimating the total calendar year y-specific health benefits which aggregate estimates over all model populations ($A = 0,1,2,3, \ldots 100$).

<u>Evolution of Model Population *A* under Baseline TTHM Exposure</u>

Given a model population A, for each current age a and calendar year y, the following baseline exposure $z_{a,y} = \frac{1}{a}\sum_{i=0}^{a-1} \text{Baseline TTHM}_{i,y-a+i}$ dependent quantities are computed:

- $l_{C=0,a,y}(z_{a,y})$: The number of bladder cancer-free living individuals at the beginning of age a, in year y;
- $d_{C=0,a,y}(z_{a,y})$: The number of deaths among bladder cancer-free individuals aged a during the year y;
- $l_{C=1,a,y}(z_{a,y})$: The number of new bladder cancer cases among individuals aged a during the year y.

To compute each quantity above, EPA makes an assumption about the priority of events that terminate a person's existence in the pool of bladder cancer-free living individuals. These events are general population

[142] This approach is equivalent to assuming that TTHM levels revert back to baseline conditions at the end of the regulatory option costing period.

deaths that occur with probability[143] $q_{C=0,a}$ and new bladder cancer diagnoses that occur with probability γ_a, which is approximated by age-specific annual bladder cancer incidence rate $IR_a \cdot 10^{-5}$. In the model, EPA assumes that the new cancer diagnoses occur after general population deaths and uses the following recurrent equations for ages $a > 0$:[144]

Equation D-4.

$$l_{C=0,a,y}(z_{a,y}) = l_{C=0,a-1,y-1}(z_{a-1,y-1}) - d_{C=0,a-1,y-1}(z_{a-1,y-1}) - l_{C=1,a-1,y-1}(z_{a-1,y-1})$$

Equation D-5. $$d_{C=0,a,y}(z_{a,y}) = q_{C=0,a} \cdot l_{C=0,a,y}(z_{a,y})$$

Equation D-6. $$l_{C=1,a,y}(z_{a,y}) = \gamma_a \cdot \left(l_{C=0,a,y}(z_{a,y}) - d_{C=0,a,y}(z_{a,y})\right)$$

To initiate each set of recurrent equations, EPA estimates the number of cancer-free individuals at age $a = 0$, denoted by $l_{C=0,0,y-A}(z_{0,y-A})$, that is consistent with the number of affected persons of age A in 2025, denoted by P. To this end, Equation D-4, Equation D-5, and Equation D-6 are solved to find $l_{C=0,0,y-A}(z_{0,y-A})$ such that $l_{C=0,A,2025}(z_{A,2025}) = P$.

Consistent with available bladder cancer survival statistics, EPA models mortality experience in the bladder cancer populations $l_{C=1,a,y}(z_{a,y})$ as dependent on the age-at-onset a, disease duration k, and cancer stage s (for bladder cancer there are four defined stages: localized, regional, distant, unstaged). Given each age-specific share of new cancer cases $l_{C=1,a,y}(z_{a,y})$ and age-specific share of new stage s cancers $\delta_{S=s,a}$, EPA calculates the number of new stage s cancers occurring at age a in year y:

Equation D-7. $$\tilde{l}_{S=s,a,y,0}(z_{a,y}) = \delta_{S=s,a} \cdot l_{C=1,a,y}(z_{a,y})$$

For a model population aged A years in 2025 and cancer stage s, EPA separately tracks $100 - A + 1$ new stage-specific bladder cancer populations from age-at-onset a to age 100.[145] Next, a set of cancer duration k-dependent annual death probabilities is derived for each population from available data on relative survival rates[146] $r_{S=s,a,k}$ and general population annual death probabilities $q_{C=0,a+k}$ as follows:

143 The model does not index the general population death rates using the calendar year, because the model relies on the most recent static life tables.

144 EPA notes that this is a conservative assumption that results in a lower bound estimate of the policy impact (with respect to this particular uncertainty factor). An upper bound estimate of the policy impact can be obtained by assuming that new bladder diagnoses occur before general population deaths. In a limited sensitivity analysis, EPA found that estimates generated using this alternative assumption were approximately 5 percent larger than the estimates reported here.

145 In total, there are $4 \cdot (100 - A + 1)$ new cancer populations being tracked for each model population.

146 Note that $r_{S=s,a,k}$ is a multiplier that modifies the general probability of survival to age k to reflect the fact that the population under consideration has developed cancer k years ago.

Equation D-8. $\tilde{q}_{S=s,a,k} = 1 - \frac{r_{S=s,a,k+1}}{r_{S=s,a,k}}(1 - q_{C=0,a+k}).$

In estimating additional deaths in the cancer population in the year of diagnosis (*i.e.*, when $k = 0$), EPA accounts only for cancer population deaths that are in excess of the general population deaths. As such, the estimate of additional cancer population deaths is computed as follows:

Equation D-9. $\tilde{d}_{S=s,a,y,0}(z_{a,y}) = (\tilde{q}_{S=s,a,0} - q_{C=0,a}) \cdot \tilde{l}_{S=s,a,y,0}(z_{a,y}),$

In years that follow the initial diagnosis year (*i.e.*, $k > 0$), EPA uses the following recurrent equations to estimate the number of people living with bladder cancer and the annual number of deaths in the bladder cancer population:

Equation D-10. $\tilde{l}_{S=s,a,y,k}(z_{a,y-k}) = \tilde{l}_{S=s,a,y,k-1}(z_{a,y-k}) - \tilde{d}_{S=s,a,y,k-1}(z_{a,y-k}),$

Equation D-11. $\tilde{d}_{S=s,a,y,k}(z_{a,y-k}) = \tilde{q}_{S=s,a,k} \cdot \tilde{l}_{S=s,a,y,k}(z_{a,y-k}).$

Because EPA is interested in bladder cancer-related deaths rather than all deaths in the bladder cancer population, EPA also tracks the number of excess bladder cancer population deaths (*i.e.*, the number of deaths in the bladder cancer population over and above the number of deaths expected in the general population of the same age). The excess deaths are computed as:

Equation D-12. $\tilde{e}_{S=s,a,y,k}(z_{a,y-k}) = \tilde{q}_{S=s,a,k} \cdot \tilde{l}_{S=s,a,y,k}(z_{a,y-k}) - q_{C=0,a+k} \cdot \tilde{l}_{S=s,a,y,k}(z_{a,y-k})$

<u>Evolution of Model Population *A* under the Regulatory Option TTHM Exposure</u>

Under the baseline conditions when the change in TTHM is zero (*i.e.*, before 2025), EPA approximates the annual bladder cancer probability γ_a by age-specific annual bladder cancer incidence rate $IR_a \cdot 10^{-5}$. As described in Section 4, current empirical evidence links TTHM exposure to the lifetime bladder cancer risk, rather than annual bladder cancer probability. EPA computes the TTHM-dependent annual new bladder cancer cases under the regulatory option conditions, $l_{C=1,a,y}(x_{a,y})$, in three steps. First, EPA recursively estimates $LR_{a,y}(z_{a,y})$, the lifetime risk of bladder cancer within age interval $[0, a]$ under the baseline conditions:

Equation D-13. $LR_{a,y}(z_{a,y}) = \frac{1}{l_{C=0,0,y-A}(z_{0,y-A})} \cdot \sum_{j=0}^{a-1} l_{C=1,j}(z_{j,y-A+j}),\ a > 0$ **and** $LR_{0,y-A}(z_{0,y-A}) = 0$

Second, the result of Equation D-13 is combined with the relative risk estimate $RR(x_{a,y}, z_{a,y})$, based on Regli et al. (2015):

Equation D-14. $LR_{a,y}(x_{a,y}) = RR(x_{a,y}, z_{a,y})LR_{a,y}(z_{a,y})$

This results in a series of lifetime bladder cancer risk estimates under the option conditions. Third, EPA computes a series of new annual bladder cancer case estimates under the option conditions as follows:

Equation D-15.

$$l_{C=1,a,y}(x_{a,y}) = \left(LR_{a+1,y+1}(x_{a+1,y+1}) - LR_{a,y}(x_{a,y})\right) \cdot l_{C=0,0,y-A}(z_{0,y-A})$$

Health Effects and Benefits Attributable to Regulatory Options

To characterize the overall impact of the regulatory option in a given year y, for each model population defined by age a in 2025, sex, and location, EPA calculates three quantities: the incremental number of new stage s bladder cancer cases ($NC_{A,y,s}$), the incremental number of individuals living with stage s bladder cancer ($LC_{A,y,s}$), and the incremental number of excess deaths in the bladder cancer population ($ED_{A,y}$). The formal definitions of each of these quantities are given below:

Equation D-16.

$$NC_{A,y,s} = [0 \le y - 2025 + A \le 100] \cdot \left(\tilde{l}_{S=s,y-2025+A,y,0}(z_{y-2025+A,y}) - \tilde{l}_{S=s,y-2024+A,0}(x_{y-2025+A,y})\right)$$

Equation D-17.

$$LC_{A,y,s} = \sum_{k=1}^{100}[0 \le y - 2025 + A + k \le 100] \cdot \left(\tilde{l}_{S=s,y-2025+A-k,y,k}(z_{y-2025+A-k,y-k}) - \tilde{l}_{S=s,y-2025+A-k,y,k}(x_{y-2025+A-k,y-k})\right)$$

Equation D-18.

$$ED_{A,y} = \sum_{k=0}^{100}[0 \le y - 2025 + A + k \le 100] \sum_{s \in S} \left(\tilde{e}_{S=s,y-2025+A-k,y,k}(z_{y-2025+A-k,y-k}) - \tilde{e}_{S=s,y-2025+A-k,y,k}(x_{y-2025+A-k,y-k})\right)$$

These calculations are carried out to 2125, when those aged 0 years in 2025 attain the age of 100.

Table D-1: Health Risk Model Variable Definitions

Variable	Definition
$O(x)$	The odds of lifetime bladder cancer incident for an individual exposed to a lifetime average TTHM concentration in residential water supply of x (ug/L)
a	Current age or age at cancer diagnosis
x_a	A person's lifetime option TTHM exposure by age a
z_a	A person's lifetime baseline TTHM exposure by age a
LR_a	Lifetime risk of bladder cancer within age interval $[0, a)$ under the baseline conditions
IR_a	Age-specific baseline annual bladder cancer incidence rate
$RR(x_a, z_a)$	Relative risk of bladder cancer by age a given baseline exposure z_a and option exposure x_a
PAF	Population attributable fraction of bladder cancer incidence
A	Age in 2025 (years)
y	Calendar year
$x_{a,y}$	A person's lifetime option TTHM exposure by age a given that this age occurs in year y
$z_{a,y}$	A person's lifetime baseline TTHM exposure by age a given that this age occurs in year y
$l_{C=0,a,y}(z_{a,y})$	The baseline number of bladder cancer-free living individuals at the beginning of age a given that this age occurs in year y

Table D-1: Health Risk Model Variable Definitions

Variable	Definition
$d_{C=0,a,y}(z_{a,y})$	The baseline number of deaths among bladder cancer-free individuals at age a given that this age occurs in year y
$l_{C=1,a,y}(z_{a,y})$	The baseline number of new bladder cancer cases at age a given that this age occurs in year y
$q_{C=0,a}$	Probability of a general population death at age a
γ_a	Baseline probability of a new bladder cancer diagnosis at age a given
k	Bladder cancer duration in years
s	Cancer stage (localized, regional, distant, unstaged)
$\delta_{S=s,a}$	Age-specific share of new stage s bladder cancers
$\tilde{l}_{S=s,a,y,0}(z_{a,y})$	The baseline number of new stage s cancers occurring at age a given that this age occurs in year y
$r_{S=s,a,k}$	Relative survival rate k years after stage s bladder cancer occurrence at age a
$\tilde{q}_{S=s,a,k}$	Stage-specific probability of death in the bladder cancer population whose bladder cancer was diagnosed at age a and they lived k years after the diagnosis. Current age of these individuals is $a + k$.
$\tilde{d}_{S=s,a,y,0}(z_{a,y})$	The baseline number of deaths in the stage s cancer population in the year of diagnosis (*i.e.*, when $k = 0$), given the current age a and the corresponding year y.
$\tilde{l}_{S=s,a,y,k}(z_{a,y-k})$	The baseline number of living with the stage s cancer in the k-th year after diagnosis in year y, given the cancer diagnosis at age a and the cumulative exposure through to that age and year $y - k$.
$\tilde{d}_{S=s,a,y,k}(z_{a,y-k})$	The baseline number of deaths among those with the stage s cancer in the k-th year after diagnosis in year y, given the cancer diagnosis at age a and the cumulative exposure through to that age and year $y - k$.
$\tilde{e}_{S=s,a,y,k}(z_{a,y-k})$	The baseline number of excess bladder cancer deaths (*i.e.*, the number of deaths in the bladder cancer population over and above the number of deaths expected in the general population of the same age) among those with the stage s cancer in the k-th year after diagnosis in year y, given the cancer diagnosis at age a and the cumulative exposure through to that age and year $y - k$.
$LR_{a,y}(z_{a,y})$	Recursive estimate of the lifetime risk of bladder cancer within age interval [0, a) under the baseline conditions, given that age a occurs in year y
$RR(x_{a,y}, z_{a,y})$	Relative risk of bladder cancer by age a given that this age occurs in year y, baseline exposure $z_{a,y}$ and option exposure $x_{a,y}$
$LR_{a,y}(x_{a,y})$	Recursive estimate of the lifetime risk of bladder cancer within age interval [0, a) under the option conditions, given that age a occurs in year y
$NC_{A,y,s}$	The incremental number of new stage s bladder cancer cases in year y for the model population aged A in 2025.
$LC_{A,y,s}$	The incremental number of individuals living with stage s bladder cancer in year y for the model population aged A in 2025.
$ED_{A,y}$	The incremental number of excess in stage s bladder cancer population in year y for the model population aged A in 2025.

D.1.3 Detailed Input Data

As noted in Section 4, EPA relied on the federal government data sources including EPA SDWIS, ACS 2021 (U.S. Census Bureau, 2021), the Surveillance, Epidemiology, and End Results (SEER) program database (National Cancer Institute), and the Center for Disease Control (CDC) National Center for Health Statistics to characterize sex- and age group-specific general population mortality rates and bladder cancer incidence rates used in model simulations. All of these data are compiled by the relevant federal agencies and thus meet federal government data quality standards. These data sources are appropriate for this analysis based on the standards underlying their collection and publication, and their applicability to analyzing health effects of exposure to TTHM via drinking water. Table 4-7 in Section 4 summarizes the sex- and age group-specific share of general population mortality rates and bladder cancer incidence. Table D-2 below summarizes sex-and age group-specific distribution of bladder cancer cases over four analyzed stages as well as onset-specific relative survival probability for each stage.

Table D-2: Summary of Baseline Bladder Cancer Incidence Data Used in the Model

Age	Females					Males				
	Incidence per 100K	Percent of Incidence in Stage				Incidence per 100K	Percent of Incidence in Stage			
		Localized	Regional	Distant	Unstaged		Localized	Regional	Distant	Unstaged
<1	-	77	4.5	14	4.5	-	66	23	11	0
1-4	-	77	4.5	14	4.5	-	66	23	11	0
5-9	-	77	4.5	14	4.5	-	66	23	11	0
10-14	-	77	4.5	14	4.5	-	66	23	11	0
15-19	-	82	8.2	5.1	4.9	0.11	90	4.8	3.1	2.5
20-24	0.17	82	8.2	5.1	4.9	0.3	90	4.8	3.1	2.5
25-29	0.26	82	8.2	5.1	4.9	0.51	90	4.8	3.1	2.5
30-34	0.5	82	8.2	5.1	4.9	1.1	90	4.8	3.1	2.5
35-39	0.89	82	8.2	5.1	4.9	2.1	90	4.8	3.1	2.5
40-44	1.5	83	8.6	6.1	2.7	4.2	85	7.4	4.9	2.5
45-49	2.9	83	8.6	6.1	2.7	8.8	85	7.4	4.9	2.5
50-54	6.6	83	8.6	6.1	2.7	19	85	7.4	4.9	2.5
55-59	11	83	8.6	6.1	2.7	38	85	7.4	4.9	2.5
60-64	18	83	8.6	6.1	2.7	67	85	7.4	4.9	2.5
65-69	29	84	7.9	5.6	2.8	114	86	6.7	4.3	2.9
70-74	43	84	7.9	5.6	2.8	176	86	6.7	4.3	2.9
75-79	58	80	7.1	5.8	6.8	245	85	6.2	4.1	5.2
80-84	71	80	7.1	5.8	6.8	315	85	6.2	4.1	5.2
85+	76	80	7.1	5.8	6.8	357	85	6.2	4.1	5.2

Table D-3: Summary of Relative and Absolute Bladder Cancer Survival Used in the Model

Age at Diagnosis	Follow-Up Time	Females								Males							
		Relative Survival by Stage (Percent)				Absolute Survival (Average) by Stage (Percent)				Relative Survival by Stage (Percent)				Absolute Survival (Average) by Stage (Percent)			
		Localized	Regional	Distant	Unstaged	Localized	Regional	Distant	Unstaged	Localized	Regional	Distant	Unstaged	Localized	Regional	Distant	Unstaged
Ages 15-39	1 year	98	79	20	90	97	79	20	90	99	85	46	100	97	83	45	98
Ages 15-39	2 years	97	58	4	83	96	57	4	83	99	67	23	97	96	65	22	95
Ages 15-39	3 years	96	47	0	80	95	46	0	79	98	60	14	95	96	58	13	92
Ages 15-39	4 years	95	39	0	80	94	39	0	79	97	58	11	91	95	56	11	89
Ages 15-39	5 years	95	32	0	80	93	32	0	79	96	56	11	91	94	54	11	89
Ages 15-39	6 years	94	28	0	80	93	27	0	79	96	56	9	91	93	54	9	89
Ages 15-39	7 years	94	28	0	80	92	27	0	79	96	56	7	91	93	54	7	88
Ages 15-39	8 years	93	28	0	80	92	27	0	78	95	56	7	91	92	54	7	88
Ages 15-39	9 years	93	28	0	80	91	27	0	78	94	52	5	91	91	51	4	88
Ages 15-39	10 years	93	28	0	80	91	27	0	78	93	52	5	85	90	50	4	82
Ages 40-64	1 year	97	73	34	84	92	69	32	80	98	78	36	85	90	72	33	78
Ages 40-64	2 years	95	53	15	81	90	50	14	76	96	57	16	79	87	52	15	72
Ages 40-64	3 years	94	45	9	77	88	42	9	72	94	48	11	75	85	43	10	67
Ages 40-64	4 years	93	40	7	76	87	37	7	70	93	43	9	73	83	38	8	65
Ages 40-64	5 years	92	37	5	74	85	34	5	69	91	40	8	71	81	35	7	63
Ages 40-64	6 years	91	36	5	74	84	33	5	68	90	38	7	68	79	33	7	60
Ages 40-64	7 years	90	34	4	73	82	31	4	66	89	37	7	66	77	32	6	57
Ages 40-64	8 years	89	32	4	71	80	29	4	64	88	36	7	64	75	30	6	54
Ages 40-64	9 years	88	31	4	70	79	28	3	63	87	35	7	61	73	29	6	51
Ages 40-64	10 years	87	31	4	70	77	27	3	62	86	34	7	61	71	28	6	51
Ages 65-74	1 year	95	67	25	72	88	62	24	66	97	74	32	81	86	66	29	72
Ages 65-74	2 years	92	48	11	67	83	44	10	61	94	55	16	75	82	48	13	65
Ages 65-74	3 years	90	38	8	63	80	34	7	57	92	47	11	72	77	39	9	60
Ages 65-74	4 years	88	34	6	60	77	30	5	52	89	42	8	69	73	34	6	56
Ages 65-74	5 years	86	31	5	58	73	26	5	50	88	39	6	66	70	31	5	52
Ages 65-74	6 years	85	28	5	56	71	23	4	47	86	36	6	64	66	27	4	49

Table D-3: Summary of Relative and Absolute Bladder Cancer Survival Used in the Model

Age at Diagnosis	Follow-Up Time	Females								Males							
		Relative Survival by Stage (Percent)				Absolute Survival (Average) by Stage (Percent)				Relative Survival by Stage (Percent)				Absolute Survival (Average) by Stage (Percent)			
		Localized	Regional	Distant	Unstaged	Localized	Regional	Distant	Unstaged	Localized	Regional	Distant	Unstaged	Localized	Regional	Distant	Unstaged
Ages 65-74	7 years	84	27	4	54	68	22	3	44	84	34	5	61	62	25	4	45
Ages 65-74	8 years	82	25	4	52	64	20	3	41	82	32	5	57	58	23	4	40
Ages 65-74	9 years	81	25	3	51	61	19	2	39	80	30	4	56	54	20	3	38
Ages 65-74	10 years	79	25	3	51	58	18	2	37	79	29	4	56	50	19	3	36
Ages 75+	1 year	86	48	17	39	44	25	9	20	92	60	22	59	45	30	11	29
Ages 75+	2 years	81	36	8	32	40	18	4	16	87	44	10	51	42	21	5	24
Ages 75+	3 years	77	30	6	27	38	15	3	13	84	38	7	45	38	17	3	21
Ages 75+	4 years	76	28	5	24	36	13	2	11	81	35	5	40	35	15	2	17
Ages 75+	5 years	73	26	4	22	33	12	2	10	79	33	5	37	33	14	2	15
Ages 75+	6 years	71	24	4	22	31	11	2	9	76	32	4	34	30	13	2	13
Ages 75+	7 years	69	22	3	20	29	9	1	8	74	29	3	31	27	11	1	11
Ages 75+	8 years	68	21	3	18	27	8	1	7	72	28	3	29	25	10	1	10
Ages 75+	9 years	66	21	2	18	25	8	1	7	70	28	3	26	22	9	1	8
Ages 75+	10 years	65	18	2	18	23	6	1	6	68	28	3	23	20	8	1	7

Table D-4: Summary of All-Cause and Bladder Cancer Mortality Data Used in the Model

Age	Females			Males		
	Rate per 100K		Percent Bladder Cancer	Rate per 100K		Percent Bladder Cancer
	All-Cause	Bladder Cancer		All-Cause	Bladder Cancer	
<1	579	-	0	702	-	0
1-4	25	-	0	31	-	0
5-9	12	-	0	14	-	0
10-14	13	-	0	19	-	0
15-19	33	-	0	78	-	0
20-24	47	-	0	136	0.009	0.01
25-29	60	0.019	0.03	148	0.016	0.01
30-34	80	0.037	0.05	165	0.055	0.03
35-39	113	0.111	0.10	204	0.142	0.07
40-44	168	0.230	0.14	281	0.380	0.14
45-49	254	0.471	0.19	419	1.05	0.25
50-54	378	0.893	0.24	631	2.39	0.38
55-59	558	1.64	0.29	933	5.13	0.55
60-64	833	2.88	0.35	1,361	9.72	0.71
65-69	1,256	4.88	0.39	1,963	16.9	0.86
70-74	1,997	8.62	0.43	2,977	28.8	0.97
75-79	3,271	14.1	0.43	4,704	48.8	1.04
80-84	5,550	22.8	0.41	7,623	81.8	1.07
85+	13,559	40.6	0.30	15,543	151	0.97

D.2 Detailed Results from Analysis

The health impact model assumes that the regulatory changes begin in 2025 and end by 2049 and thus TTHM changes are in effect during this period. After 2049, TTHM levels return to baseline levels, *i.e.*, ΔTTHM is zero. Due to the lasting effects of changes in TTHM exposure, the benefits of the policies after 2049 were included in the final calculations for each option. Table D-5 summarizes the health impact and valuation results in millions of 2023 dollars for each regulatory option, as shown graphically and discussed in Section 4.4.

Table D-5: Number of Adverse Health Effects Avoided Over Time Starting from 2025

Option	Evaluation period											Total[d]
	2025-2029	2030-2039	2040-2049	2050-2059	2060-2069	2070-2079	2080-2089	2090-2099	2100-2109	2110-2119	2120-2125	
	Cancer morbidity cases avoided[a,c]											
Options A & B	3	17	25	12	12	12	10	6	2	0	0	98
Option C	4	18	26	13	13	12	10	7	2	0	0	104
	Excess cancer deaths avoided[b,c]											
Options A & B	1	4	6	4	3	3	3	2	1	0	0	28
Option C	1	4	6	4	4	4	3	2	1	0	0	29
	Value of morbidity avoided (million 2023 dollars, 2% discount rate)[c]											
Options A & B	$1.94	$9.48	$12.32	$5.15	$4.29	$3.38	$2.32	$1.24	$0.35	-$0.05	-$0.02	$40.39
Option C	$2.44	$9.95	$12.89	$5.51	$4.58	$3.61	$2.47	$1.33	$0.38	-$0.05	-$0.03	$43.07
	Value of mortality avoided (million 2023 dollars, 2% discount rate)[c]											
Options A & B	$7.52	$45.60	$64.14	$34.90	$25.20	$20.52	$14.97	$9.26	$3.59	$0.19	-$0.05	$225.84
Option C	$9.44	$48.58	$67.19	$37.12	$26.96	$21.92	$15.97	$9.88	$3.83	$0.21	-$0.05	$241.02

Notes:

a. Number of TTHM-attributable bladder cancer cases that are expected to be avoided under the policy in the calendar time period.

b. Number of excess deaths among the TTHM-attributable bladder cancer cases that are expected to be avoided under the policy in the calendar time period.

c. Number of attributable cases and deaths are rounded to the nearest digit. Values of avoided morbidity and mortality are rounded to the nearest cent. Negative values represent increases in the number of cases/deaths and morbidity/mortality costs.

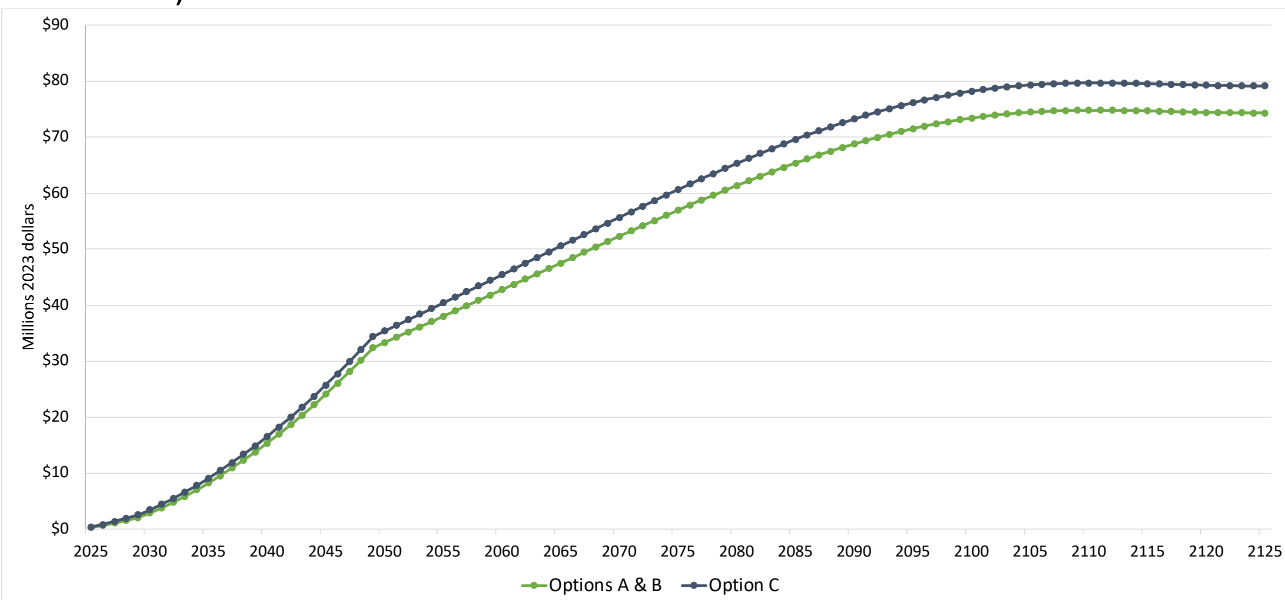
d. Total TTHM-attributable adverse health effects that are expected to be avoided between 2025 and 2125 as a result of the regulatory option changes in 2025-2049.

Source: U.S. EPA Analysis, 2024

D.3 Temporal Distribution of Benefits

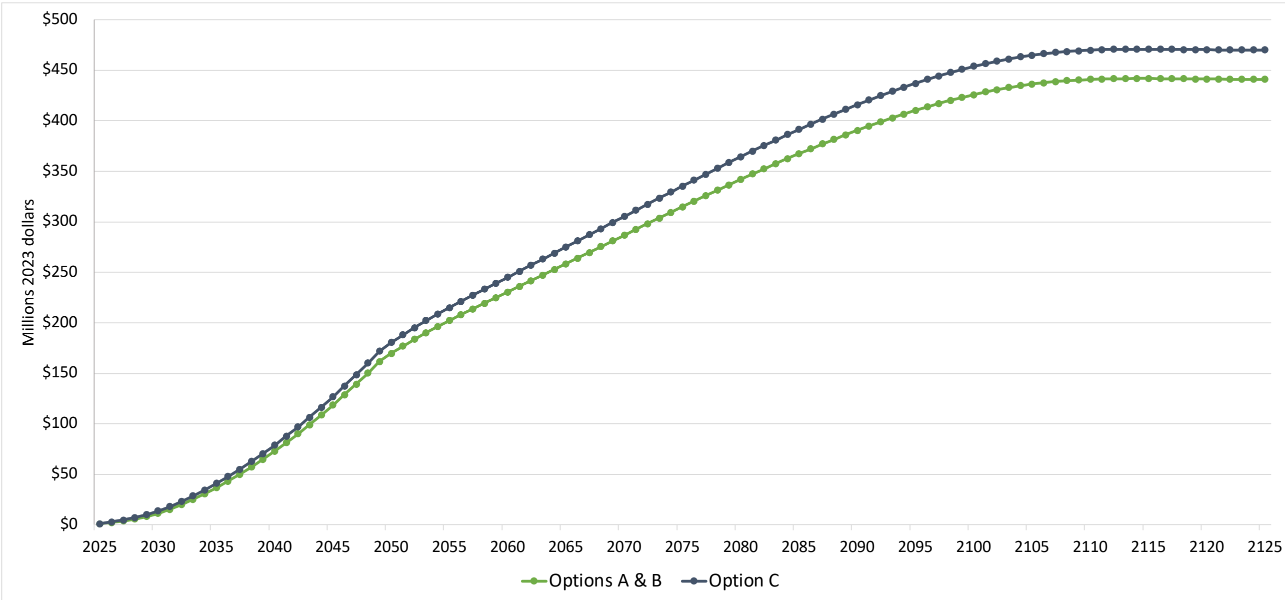
Figure D-2 and Figure D-3 illustrate patterns of changes in benefits for the three regulatory options for the 100-year simulation period of 2025 through 2125 based on the cumulative annual value of morbidity avoided and the cumulative annual value of mortality, respectively (values are undiscounted). These figures show the gradual increase in benefits for Options A, B, and C between 2025 and 2049, which continues but at a reduced rate after 2049 until levelling off around 2111. As discussed in Section 4.4, benefits decrease during the final decades for Options A, B, and C. The benefits associated with Options A and B are smaller than those of Option C.

Figure D-2: Cumulative Annual Value of Cancer Morbidity Avoided, 2025-2125 (Million 2023$ undiscounted).



Source: U.S. EPA Analysis, 2024.

Figure D-3: Cumulative Annual Value of Mortality Avoided, 2025-2125 (Million 2023$ undiscounted).



Source: U.S. EPA Analysis, 2024.

E Derivation of Ambient Water and Fish Tissue Concentrations in Downstream Reaches

This appendix describes the methodology EPA used to estimate water and fish tissue concentrations under the baseline and each of the regulatory options. The concentrations are used as inputs to estimate the water quality changes and human health benefits of the regulatory options. Specifically, EPA used ambient water toxics concentrations to derive fish tissue concentrations used to analyze human health effects from consuming self-caught fish (see Chapter 5) and to analyze non-use benefits of water quality changes (see Chapter 6). Nutrient and suspended solids concentrations are used to support analysis of non-use benefits from water quality changes (see Chapter 6).

The overall modeling methodology builds on data and methods described in the EA and TDD for the regulatory options (U.S. EPA, 2024b; 2024f). The following sections discuss calculations of the toxics concentrations in ambient water and fish tissue and nutrient and sediment concentrations in ambient water.

E.1 Toxics

E.1.1 Estimating Water Concentrations in each Reach

EPA first estimated the baseline and regulatory option toxics concentrations in reaches receiving steam electric power plant discharges and downstream reaches.

The D-FATE model (see Chapter 3) was used to estimate water concentrations. The model tracks the fate and transport of discharged pollutants through a reach network defined based on the medium resolution NHD.[147] The hydrography network represented in the D-FATE model consists of 11,607 reaches within 300 km of a steam electric power plant, 11,080 of which are estimated to be potentially fishable.[148]

The analysis involved the following key steps for the baseline and each of the regulatory options:

- **Summing plant-level loadings to the receiving reach**. EPA summed the estimated plant-level annual average loads for each unique reach receiving plant discharges from steam electric power plants in the baseline and under the regulatory options. For a description of the approach EPA used to identify the receiving waterbodies, see U.S. EPA, 2023g.
- **Performing dilution and transport calculations**. The D-FATE model calculates the concentration of the pollutant in a given reach based on the total mass transported to the reach from upstream sources and the EROM flows for each reach from NHDPlus v2. In the model, a plant is assumed to

147 The USGS's National Hydrology Dataset (NHD) defines a reach as a continuous piece of surface water with similar hydrologic characteristics. In the NHD each reach is assigned a reach code; a reach may be composed of a single feature, like a lake or isolated stream, but reaches may also be composed of several contiguous features. Each reach code occurs only once throughout the nation and once assigned a reach code is permanently associated with its reach. If the reach is deleted, its reach code is retired.

148 Reaches represented in the D-FATE model are those estimated to be potentially fishable based on type and physical characteristics. Because the D-FATE model calculates the movement of a chemical release downstream using flow data, reaches must have at least one downstream or upstream connecting reach and have a non-negative flow and velocity. The D-FATE model does not calculate concentrations for certain types of reaches, such as coastlines, treatment reservoirs, and bays; the downstream path of any chemical is assumed to stop if one of these types of reach is encountered.

release its annual load at a constant rate throughout the year. Each source-pollutant release is tracked throughout the NHD reach network until the terminal reach.[149]

- **Specifying concentrations in the water quality model**. The D-FATE model includes background data on estimated annual average pollutant concentrations to surface waters from facilities that reported to the TRI in 2019. EPA added background concentrations where available to concentration estimates from steam electric power plant dischargers.

EPA used the approach above to estimate annual average concentrations of ten toxics: arsenic, cadmium, hexavalent chromium, copper, lead, mercury, nickel, selenium, thallium, and zinc.

E.1.2 Estimating Fish Tissue Concentrations in each Reach

To support analysis of the human health benefits associated with water quality improvements (see Chapter 5), EPA estimated concentrations of arsenic, lead, and mercury in fish tissue based on the D-FATE model outputs discussed above.

The methodology follows the same general approach described in the EA for estimating fish tissue concentrations for receiving reaches (U.S. EPA, 2024b), but applies the calculations to the larger set of reaches modeled using D-FATE, which include not only the receiving reaches analyzed in the EA, but also downstream reaches. Further, the calculations use D-FATE-estimated concentrations as inputs, which account not only for the steam electric power plant discharges, but also other major dischargers that report to TRI.

The analysis involved the following key steps for the baseline and each of the regulatory options:

7. **Obtaining the relationship between water concentrations and fish tissue concentrations**. EPA used the results of the Immediate Receiving Water (IRW) model (see EA, U.S. EPA, 2023g) to parameterize the linear relationship between water concentrations in receiving reaches and composite fish tissue concentrations (representative of trophic levels 3 and 4 fish consumed) in these same reaches for each of the three toxics.

8. **Calculating fish tissue data for affected reaches**. For reaches for which the D-FATE model provides non-zero water concentrations (*i.e.*, reaches affected by steam electric power plants or other TRI dischargers), EPA used the relationship obtained in Step 1 to calculate a preliminary fish tissue concentration for each pollutant.

The analysis provides background toxic-specific composite fish fillet concentrations for each reach modeled in the D-FATE model (Table E-1).

Table E-1: Background Fish Tissue Concentrations, based on 10th Percentile

Parameter	Pollutant Concentration (mg/kg)
As	0.039
Hg	0.058
Pb	0.039

Source: U.S. EPA Analysis, 2024

149 For some analyses, EPA limits the scope of reaches to 300 km (186 miles) downstream from steam electric power plant outfalls.

E.2 Nutrients and Suspended Sediment

EPA used the USGS's regional SPARROW models to estimate nutrient and sediment concentrations in receiving and downstream reaches. The regional models used for this analysis are the five regional models developed for the Pacific, Southwest, Midwest, Southeast, and Northeast regions for flow, total nitrogen (TN), total phosphorus (TP), and suspended sediment (Ator, 2019; Hoos & Roland Ii, 2019; Robertson & Saad, 2019; Wise, 2019; Wise, Anning & Miller, 2019). EPA adjusted the models to include a variable for steam electric discharges using the following steps:

- **Specifying a source load parameter for steam electric discharges.** The regional SPARROW models do not include an explicit explanatory variable for point sources related to industrial dischargers (non publicly owned treatment works). EPA recalibrated the regional models by adding a variable for steam electric loadings, initially setting all loadings for this parameter equal to zero, assigning this new variable a calibration coefficient value of 1, and specifying zero land-to-water delivery effects associated with this new variable.
- **Appending steam electric TN, TP, and TSS loadings to regional input data.** Once the regional SPARROW models were recalibrated to include the steam electric loadings variable, EPA added the steam electric TN, TP, and TSS[150] loadings to the model input data and ran each regional model for each pollutant to obtain catchment-level TN, TP, and SSC predictions.

For Periods 1 and 2, the SPARROW models output predicted annual average baseline and regulatory option concentrations in each reach. EPA compared the baseline predictions to the predictions obtained for each of the regulatory options to estimate changes in concentrations.

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150 TSS loadings are converted to SSC values at this step by using location-specific relationships built into the SPARROW regional models.

F Georeferencing Surface Water Intakes to the Medium-resolution Reach Network

For the 2024 final rule analysis, EPA used the following steps to assign PWS surface water intakes to waters represented in the medium-resolution NHD Plus version 2 dataset and identify those intakes potentially affected by steam electric power plant discharges.

1. Identify the downstream flowpath via NHD Plus Version 2 Flowlines for all steam electric dischargers.
2. Identify intakes within a 5-kilometer buffer of the downstream flowpath. This distance is used to limit the set of points to be visually reviewed in the next step and provides an upper bound of the distance between an intake and its potential associated receiving water.
3. Visually review the location of each intake within the five-kilometer buffer to determine whether the intake is on a waterbody downstream of steam electric power plant discharges. The visual assessment accounts for hydrographic connectivity and flow direction.

EPA then paired the intakes that were confirmed to be impacted to the closest NHD COMID based on a simple cartesian distance.

G Sensitivity Analysis for IQ Point-based Human Health Effects

EPA monetized the value of an IQ point based on the methodology from Salkever (1995) but with more recent data from the 1997 National Longitudinal Survey of Youth (U.S. EPA, 2019d). As a sensitivity analysis of the benefits of changes in lead and mercury exposure, EPA used alternative, more conservative estimates provided in Lin, Lutter and Ruhm (2018), which indicate that a one-point IQ reduction reduces expected lifetime earnings by 1.39 percent, as compared to 2.63 percent based on Salkever (1995). As noted in Sections 5.3 and 5.4, values of an IQ point used in the analysis of health effects in children from lead exposure are discounted to the third year of life to represent the midpoint of the exposed children population, and values of an IQ point used in the analysis of health effects associated with in-utero exposure to mercury are discounted to birth. Table G-1 summarizes the estimated values of an IQ point based on Lin, Lutter and Ruhm (2018), using 2 percent, 3 percent, and 7 percent discount rates.

Table G-1: Value of an IQ Point (2023$) based on Expected Reductions in Lifetime Earnings

Discount Rate	Value of an IQ Point[a] (2023$)
Value of an IQ point Discounted to Age 3 (Lead)	
2 Percent	$21,653
3 percent	$13,718
7 percent	$2,885
Value of an IQ point Discounted to Birth (Mercury)	
2 Percent	$20,404
3 percent	$12,554
7 percent	$2,355

a. Values are adjusted for the cost of education.

Source: U.S. EPA, 2019d and 2019e analysis of data from Lin, Lutter and Ruhm (2018); 2 percent estimates calculated for U.S. EPA (2023f)

G.1 Health Effects in Children from Changes in Lead Exposure

Table G-2 shows the benefits associated with avoided IQ losses from lead exposure via fish consumption. The total net change in avoided IQ point losses over the entire population of children with reductions in lead exposure is approximately one point. Annualized benefits of avoided IQ losses from reductions in lead exposure, based on the Lin, Lutter and Ruhm (2018) IQ point value, range from approximately $100 (7 percent discount rate) to $800 (2 percent discount rate).

Table G-2: Estimated Benefits of Avoided IQ Losses for Children Exposed to Lead under the Regulatory Options, Compared to Baseline

Regulatory Option	Average Annual Number of Children 0 to 7 in Scope of the Analysis[b]	Total Avoided IQ Point Losses, 2025 to 2049, in All Children 0 to 7 in Scope of the Analysis	Annualized Value of Changes in IQ Point Losses[a] (Thousands of 2023$)		
			2% Discount Rate	3% Discount Rate	7% Discount Rate
Option A	1,555,558	0.93	$0.8	$0.5	$0.1
Option B (Final Rule)	1,555,558	0.93	$0.8	$0.5	$0.1
Option C	1,555,558	0.93	$0.8	$0.5	$0.1

Table G-2: Estimated Benefits of Avoided IQ Losses for Children Exposed to Lead under the Regulatory Options, Compared to Baseline

Regulatory Option	Average Annual Number of Children 0 to 7 in Scope of the Analysis[b]	Total Avoided IQ Point Losses, 2025 to 2049, in All Children 0 to 7 in Scope of the Analysis	Annualized Value of Changes in IQ Point Losses[a] (Thousands of 2023$)		
			2% Discount Rate	3% Discount Rate	7% Discount Rate

a. Based on estimates that the loss of one IQ point results in the loss of 1.39 percent of lifetime earnings (following Lin, Lutter and Ruhm (2018) values from U.S. EPA, 2019d).

b. The number of affected children is based on reaches analyzed across the regulatory options. Some of the children included in this count see no changes in exposure under some options.

Source: U.S. EPA Analysis, 2024

G.2 Heath Effects in Children from Changes in Mercury Exposure

Table G-3 shows the estimated changes in avoided IQ point losses for infants exposed to mercury in-utero and the corresponding monetary benefits, using 2 percent, 3 percent, and 7 percent discount rates. The final rule (Option B) results in 1,377 avoided IQ point losses over the entire in-scope population of infants with changes in mercury exposure. Annualized benefits of avoided IQ losses from reductions in mercury exposure, based on the Lin, Lutter and Ruhm (2018) IQ point value, range from $0.1 million (7 percent discount rate) to $1.1 million (2 percent discount rate) under the final rule (Option B).

Table G-3: Estimated Benefits of Avoided IQ Losses for Infants from Mercury Exposure under the Regulatory Options, Compared to Baseline

Regulatory Option	Average Annual Number of Infants in Scope of the Analysis[b]	Total Avoided IQ Point Losses, 2025 to 2049, in All Infants in Scope of the Analysis	Annualized Value of Changes in IQ Point Losses[a] (Millions 2023$)		
			2% Discount Rate	3% Discount Rate	7% Discount Rate
Option A	201,850	1,190	$0.9	$0.6	$0.1
Option B (Final Rule)	201,850	1,377	$1.1	$0.6	$0.1
Option C	201,850	1,393	$1.1	$0.7	$0.1

a. Based on estimates that the loss of one IQ point results in the loss of 1.39 percent of lifetime earnings (following Lin, Lutter and Ruhm (2018) values from U.S. EPA, 2019d and 2019e).

b. The number of affected children is based on reaches analyzed across the regulatory options. Some of the children included in this count see no changes in exposure under some options.

Source: U.S. EPA Analysis, 2024

H Methodology for Estimating WTP for Water Quality Changes

To estimate the nonmarket benefits of the water quality changes resulting from the regulatory options, EPA used updated results from a meta-analysis of stated preference studies described in detail in Appendix H in the 2015 BCA (U.S. EPA, 2015a). To update results of the 2015 meta-analysis, EPA first conducted a literature review and identified 10 new studies to augment the existing meta-data. EPA also performed quality assurance on the meta-data, identifying revisions that improved accuracy and consistency within the meta-data, and added or removed observations from existing studies, as appropriate. EPA then re-estimated the MRM and made additional improvements to the model by introducing explanatory variables to account for different survey methodologies, WTP estimation methodologies, payment mechanisms, and water quality metrics used in some of the added studies. A memorandum titled "Revisions to the Water Quality Meta-Data and Meta-Regression Models after the 2020 Steam Electric Analysis through December 2021" (ICF, 2022b) details changes to the meta-data and MRMs following the 2020 Steam Electric ELG analysis (U.S. EPA, 2020f), summarizes how the studies and observations included in the meta-data have changed from 2015 to 2020 to present, and compares the latest MRM results with those from 2015 (U.S. EPA, 2015a) and 2020 (U.S. EPA, 2020f).

Table H-1 summarizes studies in the revised meta-data, including number of observations from each study, state-level study location, waterbody type, geographic scope, and household WTP summary statistics. In total, the revised meta-data includes 189 observations from 59 stated preference studies that estimated per household WTP (use plus nonuse) for water quality changes in U.S. waterbodies. The studies address various waterbody types including, rivers, lakes, salt ponds/marshes, and estuaries. The ten studies added to the meta-data since 2015 are shaded in Table H-1.

Table H-1: Primary Studies Included in the Meta-data

Study	Obs. In Meta-data	State(s)	Waterbody Type(s)	Geographic Scope	WTP Per Household (2019$)		
					Mean	Min	Max
Aiken (1985)	1	CO	river/ stream and lake	Entire state	$238.19	$238.19	$238.19
Anderson and Edwards (1986)	1	RI	salt pond /marsh	Coastal salt ponds (South Kingstown, Charlestown, and Narragansett)	$222.82	$222.82	$222.82
Banzhaf et al. (2006)	2	NY	lake	Adirondack Park, New York State	$70.86	$66.69	$75.03
Banzhaf et al. (2016)	1	VA, WV, TN, NC, GA	river/ stream	Southern Appalachian Mountains region	$18.67	$18.67	$18.67
Bockstael, McConnell and Strand (1989)	2	MD, DC, VA	estuary	Chesapeake Bay (Baltimore-Washington Metropolitan Area)	$137.31	$93.30	$181.32
Borisova et al. (2008)	2	VA/WV	river/ stream	Opequon Creek watershed	$42.54	$22.25	$62.83
Cameron and Huppert (1989)	1	CA	estuary	San Francisco Bay	$61.07	$61.07	$61.07
Carson et al. (1994)	2	CA	estuary	Southern California Bight	$73.24	$50.81	$95.67

Table H-1: Primary Studies Included in the Meta-data

Study	Obs. In Meta-data	State(s)	Waterbody Type(s)	Geographic Scope	WTP Per Household (2019$)		
					Mean	Min	Max
Choi and Ready (2019)	6	PA	river/ stream	Three creek watersheds: Spring, Mahantango, and Conewago	$4.56	$1.73	$10.40
Clonts and Malone (1990)	2	AL	river/ stream	15 free-flowing rivers, AL	$112.28	$96.56	$128.00
Collins and Rosenberger (2007)	1	WV	river/ stream	Cheat River Watershed	$22.43	$22.43	$22.43
Collins, Rosenberger and Fletcher (2009)	1	WV	river/ stream	Deckers Creek Watershed	$229.82	$229.82	$229.82
Corrigan (2008)	1	IA	lake	Clear Lake	$152.03	$152.03	$152.03
Croke, Fabian and Brenniman (1986-1987)	6	IL	river/ stream	Chicago metropolitan area river system	$90.25	$75.60	$107.18
De Zoysa (1995)	1	OH	river/ stream	Maumee River Basin	$86.53	$86.53	$86.53
Desvousges, Smith and Fisher (1987)	12	PA	river/ stream	Monongahela River basin (PA portion)	$72.98	$24.46	$169.24
Downstream Strategies LLC (2008)	2	PA	river/ stream	West Branch Susquehanna River watershed	$15.70	$13.19	$18.21
Farber and Griner (2000)	6	PA	river/ stream	Loyalhanna Creek and Conemaugh River basins (western PA)	$93.91	$20.45	$183.21
Hayes, Tyrell and Anderson (1992)	2	RI	estuary	Upper Narragansett Bay	$490.05	$481.71	$498.38
Herriges and Shogren (1996)	1	IA	lake	Storm Lake watershed	$76.09	$76.09	$76.09
Hite (2002)	2	MS	river/ stream	Entire state	$74.09	$71.81	$76.36
Holland and Johnston (2017)	6	ME	river/ stream	Merriland, Branch Brook and Little River Watershed	$13.90	$8.16	$21.27
Huang, Haab. T.C. and Whitehead (1997)	2	NC	estuary	Albemarle and Pamlico Sounds	$318.92	$314.43	$323.40
Interis and Petrolia (2016)	10	AL/LA	estuary	Mobile Bay, AL; Barataria-Terrebonne estuary, LA	$87.91	$45.00	$140.47
Irvin, Haab and Hitzhusen (2007)	4	OH	river/ stream and lake	Entire state	$26.72	$24.22	$28.64

Table H-1: Primary Studies Included in the Meta-data

Study	Obs. In Meta-data	State(s)	Waterbody Type(s)	Geographic Scope	WTP Per Household (2019$)		
					Mean	Min	Max
Johnston and Ramachandran (2014)	3	RI	river/ stream	Pawtuxet watershed	$14.11	$7.05	$21.16
Johnston, Swallow and Bauer (2002)	1	RI	river/ stream	Wood-Pawcatuck watershed	$48.08	$48.08	$48.08
R. J. Johnston et al. (2017)	3	RI	river/ stream	Pawtuxet watershed	$4.79	$2.40	$7.19
Kaoru (1993)	1	MA	salt pond /marsh	Martha's Vineyard	$269.56	$269.56	$269.56
Lant and Roberts (1990)	3	IA/IL	river/ stream	Des Moines, Skunk, English, Cedar, Wapsipinicon, Turkey; Illinois: Rock, Edwards, La Moine, Sangamon, Iroquois, and Vermillion River basins	$177.47	$152.94	$190.26
Lant and Tobin (1989)	9	IA/IL	river/ stream	Edwards River, Wapsipinicon River, and South Skunk drainage basins	$68.59	$50.04	$83.40
Lichtkoppler and Blaine (1999)	1	OH	river/ stream and lake	Ashtabula River and Ashtabula Harbor	$51.69	$51.69	$51.69
Lindsey (1994)	8	MD	estuary	Chesapeake Bay	$82.37	$41.18	$126.02
Lipton (2004)	1	MD	estuary	Chesapeake Bay Watershed	$78.88	$78.88	$78.88
Londoño Cadavid and Ando (2013)	2	IL	river/ stream	Cities of Champaign and Urbana	$47.70	$44.30	$51.10
Loomis (1996)	1	WA	river/ stream	Elwha River	$114.75	$114.75	$114.75
Lyke (1993)	2	WI	river/ stream and lake	Wisconsin Great Lakes	$97.10	$73.68	$120.52
Mathews, Homans and Easter (1999)	1	MN	river/ stream	Minnesota River	$22.36	$22.36	$22.36
Moore et al. (2018)	2	MD, VA, DC, DE, NY, PA, WV, CT, FL, GA, ME, MA, NH, NJ, NC, RI, SC, VT	lake	Chesapeake Bay Watershed	$131.21	$77.75	$184.67
Nelson et al. (2015)	2	UT	river/ stream and lake	Entire state	$259.70	$167.07	$352.33

Table H-1: Primary Studies Included in the Meta-data

Study	Obs. In Meta-data	State(s)	Waterbody Type(s)	Geographic Scope	WTP Per Household (2019$)		
					Mean	Min	Max
Opaluch et al. (1998)	1	NY	estuary	Peconic Estuary System	$170.73	$170.73	$170.73
Roberts and Leitch (1997)	1	MN/SD	lake	Mud Lake	$10.30	$10.30	$10.30
Rowe et al. (1985)	1	CO	river/ stream	Eagle River	$165.95	$165.95	$165.95
Sanders, Walsh and Loomis (1990)	4	CO	river/ stream	Cache la Poudre, Colorado, Conejos, Dollores, Elk, Encampment, Green, Gunnison, Los Pinos, Piedra, and Yampa rivers	$198.13	$99.89	$258.99
Schulze et al. (1995)	4	MT	river/ stream	Clark Fork River Basin	$75.19	$56.62	$95.54
Shrestha and Alavalapati (2004)	2	FL	river/ stream and lake	Lake Okeechobee watershed	$192.92	$170.12	$215.72
Stumborg, Baerenklau and Bishop (2001)	2	WI	lake	Lake Mendota Watershed	$103.94	$82.28	$125.59
Sutherland and Walsh (1985)	1	MT	river/ stream and lake	Flathead River drainage system	$180.05	$180.05	$180.05
Takatsuka (2004)	4	TN	river/ stream	Clinch River watershed	$353.72	$224.28	$483.16
Van Houtven et al. (2014)	32	VA, NC, SC, AL, GA, KY, MS, TN	lake	Entire state (separate observations for each state)	$316.16	$260.91	$374.11
Wattage (1993)	2	IA	river/ stream	Bear Creek watershed	$53.68	$49.61	$57.76
Welle (1986)	4	MN	lake	Entire state	$175.44	$135.13	$227.59
Welle and Hodgson (2011)	3	MN	lake	Lake Margaret and Sauk River Chain of Lakes watersheds	$178.91	$13.06	$351.48
Wey (1990)	1	RI	salt pond /marsh	Great Salt Pond (Block Island)	$78.85	$78.85	$78.85
Whitehead (2006)	3	NC	river/ stream	Neuse River watershed	$230.79	$33.93	$450.72
Whitehead and Groothuis (1992)	2	NC	river/ stream	Tar-Pamlico River	$43.08	$39.33	$46.82
Whitehead et al. (1995)	1	NC	estuary	Albermarle-Pamlico estuary system	$115.56	$115.56	$115.56
Whittington (1994)	1	TX	estuary	Galveston Bay estuary	$240.09	$240.09	$240.09
Zhao, Johnston and Schultz (2013)	3	RI	river/ stream and lake	Pawtuxet watershed	$7.19	$3.59	$10.78

Table H-1: Primary Studies Included in the Meta-data

Study	Obs. In Meta-data	State(s)	Waterbody Type(s)	Geographic Scope	WTP Per Household (2019$)		
					Mean	Min	Max

Source: U.S. EPA Analysis, 2024

Similar to the 2015 MRM, the updated MRM satisfies the adding-up condition, a theoretically desirable property.[151] This condition ensures that if the model were used to estimate WTP for the cumulative water quality change resulting from several CWA regulations, the benefits estimates would be equal to the sum of benefits from using the model to estimate WTP for water quality changes separately for each rule (Moeltner, 2019; Newbold et al., 2018).

The meta-analysis is based on 189 observations from 59 stated preference studies, published between 1985 and 2021. The variables in the meta-data fall into four general categories:

- *Study methodology and year variables* characterize such features as the year in which a study was conducted, payment vehicle and elicitation formats, and publication type. These variables are included to explain differences in WTP across studies but are not expected to vary across benefit transfer for different policy applications.
- *Region and surveyed populations variables* characterize such features as the geographical region within the United States in which the study was conducted, the average income of respondent households, and the representation of users and nonusers within the survey sample.
- *Sampled market and affected resource variables* characterize features such as the geospatial scale (or size) of affected waterbodies, the size of the market area over which populations were sampled, as well as land cover and the quantity of substitute waterbodies.
- *Water quality (baseline and change) variables* characterize baseline conditions and the extent of the water quality change. To standardize the results across these studies, EPA expressed water quality (baseline and change) in each study using the 100-point WQI, if they did not already employ the WQI or WQL.

In the latest version of the MRM, EPA built upon published versions of the MRM (R. J. Johnston et al., 2017; Johnston, Besedin & Holland, 2019; U.S. EPA, 2020b; U.S. EPA, 2015a), with revisions to better account for methodological differences in the underlying studies (see ICF (2022b) for detail on changes in the meta-data and the explanatory variables used in the regression equation).

EPA also revised regional indicators to match the U.S. Census regions (U.S. Census Bureau, n.d.). To correct for heteroskedasticity, the model is estimated using weighted least squares with observations weighted by sample size and robust standard errors (Nelson & Kennedy, 2009). Detailed discussion of this approach can be found in Vedogbeton and Johnston (2020). A comprehensive review of these methods is provided by Stanley (2005).

[151] For a WTP function WTP (WQI_0, WQI_2, Y_0) to satisfy the adding-up property, it must meet the simple condition that $WTP(WQI_0, WQI_1, Y_0) + WTP(WQI_1, WQI_2, Y_0 - WTP(WQI_0, WQI_1, Y_0)) = WTP(WQI_0, WQI_2, Y_0)$ for all possible values of baseline water quality (WQI_0), potential future water quality levels (WQI_1 and WQI_2), and baseline income (Y_0).

Table H-2 provides definitions and presents descriptive statistics for variables included in the MRM, based on the meta-data studies.

Table H-2: Definition and Summary Statistics for Model Variables

Variable	Definition	Units	Mean	St. Dev.
Dependent Variable				
ln_OWTP	Natural log of WTP per unit (one point) of water quality improvement, per household.	Natural log of 2019$	1.873	1.391
OWTP[a]	WTP per unit of water quality improvement, per household.	2019$	15.931	23.595
Study Methodology and Year				
OneShotVal	Binary variable indicating that the study's survey only included one valuation question.	Binary (Value: 0 or 1)	0.534	0.500
tax_only[b]	Binary variable indicating that the payment mechanism used to elicit WTP is increased taxes.	Binary (Value: 0 or 1)	0.397	0.491
user_cost[b]	Binary variable indicating that the payment mechanism used to elicit WTP is increased user costs.	Binary (Value: 0 or 1)	0.021	0.144
volunt[b]	Binary variable indicating that WTP was estimated using a payment vehicle described as voluntary as opposed to, for example, property taxes.	Binary (Value: 0 or 1)	0.058	0.235
RUM	Binary variable indicating that the study used a Random Utility Model to estimate WTP.	Binary (Value: 0 or 1)	0.566	0.497
IBI	Binary variable indicating that the study used the index of biotic integrity as the water quality metric.	Binary (Value: 0 or 1)	0.079	0.271
lnyear	Natural log of the year in which the study was conducted (*i.e.*, data was collected), converted to an index by subtracting 1980.	Natural log of years (year ranges from 1981 to 2017).	2.629	0.979
non_reviewed	Binary variable indicating that the study was not published in a peer-reviewed journal.	Binary (Value: 0 or 1)	0.159	0.366
thesis	Binary variable indicating that the study is a thesis.	Binary (Value: 0 or 1)	0.079	0.271
lump_sum	Binary variable indicating that the study provided WTP as a one-time, lump sum or provided annual WTP values for a payment period of five years or less. This variable enables the policy analyst to estimate annual WTP values by setting *lump_sum*=0.	Binary (Value: 0 or 1)	0.180	0.385
Region and Surveyed Populations				
census_south[c]	Binary variable indicating that the affected waters are located entirely within the South Census region, which includes the following states: DE, MD, DC, WV, VA, NC, SC, GA, FL, KY, TN, MS, AL, AR, LA, OK, and TX.	Binary (Value: 0 or 1)	0.349	0.478
census_midwest[c]	Binary variable indicating that the affected waters are located entirely within the Midwest Census region, which includes the following states: OH, MI, IN, IL, WI, MN, IA, MO, ND, SD, NE, and KS.	Binary (Value: 0 or 1)	0.228	0.420

Table H-2: Definition and Summary Statistics for Model Variables

Variable	Definition	Units	Mean	St. Dev.
census_west[c]	Binary variable indicating that the affected waters are located entirely within the West Census region, which includes the following states: MT, WY, CO, NM, ID, UT, AZ, NV, WA, OR, and CA.	Binary (Value: 0 or 1)	0.090	0.287
nonusers	Binary variable indicating that the survey was implemented over a population of nonusers (default category for this variable is a survey of any population that includes both users and nonusers).	Binary (Value: 0 or 1)	0.058	0.235
lnincome	Natural log of the median income (in 2019$) for the sample area of each study based on historical U.S. Census data. It was designed to provide a consistent income variable given differences in reporting of respondent income across studies in the meta-data (*i.e.*, mean vs. median). Also, some studies do not report respondent income. This variable was estimated for all studies in the meta-data regardless of whether the study reported summary statistics for respondent income.	Natural log of income (2019$)	10.946	0.160
Sampled Market and Affected Resource				
swim_use	Binary variable indicating that the affected use(s) stated in the survey instrument include swimming.	Binary (Value: 0 or 1)	0.222	0.417
gamefish	Binary variable indicating that the affected use stated in the survey instrument is game fishing.	Binary (Value: 0 or 1)	0.190	0.394
ln_ar_agr[d]	Natural log of the proportion of the affected resource area that is agricultural based on National Land Cover Database, reflecting the nature of development in the area surrounding the resource. The affected resource area is defined as all counties that intersect the affected resource(s).	Natural log of proportion (Proportion Range: 0 to 1; km^2/km^2)	-1.648	0.912
ln_ar_ratio	The ratio of the sampled area, in km^2, relative to the affected resource area. When not explicitly reported in the study, the affected resource area is measured as the total area of counties that intersect the affected resource(s), to create the variable *ar_total_area*. From here, *ln_ar_ratio* = log(*sa_area* / *ar_total_area*), where *sa_area* is the size of the sampled area in km^2.	Natural log of ratio (km^2/km^2)	-0.594	2.408
sub_proportion[e]	The water bodies affected by the water quality change, as a proportion of all water bodies of the same hydrological type in the sampled area. The affected resource appears in both the numerator and denominator when calculating *sub_proportion*. The value can range from 0 to 1.	Proportion (Range: 0 to 1; km/km)	0.351	0.401

Table H-2: Definition and Summary Statistics for Model Variables

Variable	Definition	Units	Mean	St. Dev.
	Water Quality Baseline and Change			
ln_Q	Natural log of the mid-point of the baseline and policy water quality: Q = *(1/2)(WQI-BL + WQI-PC)*.	Natural log of WQI units	3.944	0.295
lnquality_ch	Natural log of the change in mean water quality (*quality_ch*), specified on the WQI.	Natural log of WQI units	2.552	0.801

a. Provided for informational purposes. Model uses the natural log version of the *OWTP* variable as the dependent variable.

b. The payment types omitted from the payment type binary variables are: (1) increased prices, (2) increased prices and/or taxes, (3) multiple methods, (4) earmarked fund, and (5) not specified/unknown.

c. The regions omitted from the regional binary variables are the Northeast Census region (ME, NH, VT, MA, RI, CT, NY, PA, and NJ) and the Chesapeake Bay (studies focused on the Chesapeake Bay or Chesapeake Bay Watershed since the Chesapeake Bay Watershed spans two Census regions).

d. In addition to the *ln_ar_agr* variable, EPA tested a variable for the proportion of the affected resource area that is developed, but it did not improve model fit.

e. The *sub_proportion* estimation method differs by waterbody type. For rivers, the calculation is the length of the affected river reaches as a proportion of all reaches of the same order. For lakes and ponds, the calculation is the area of the affected waterbody as a proportion of all water bodies of the same National Hydrography Dataset classification. For bays and estuaries, the calculation is the shoreline length of the waterbody as a proportion of all analogous (*e.g.*, coastal) shoreline lengths. To account for observations where multiple waterbody types are affected, the variable *sub_proportion* is defined as the maximum of separate substitute proportions for rivers, lakes, and estuaries/bays.

Source: U.S. EPA Analysis, 2024.

Using the updated meta-data, EPA developed MRMs that predict how WTP for a one-point improvement on the WQI (hereafter, one-point WTP) depends on a variety of methodological, population, resource, and water quality change characteristics. The estimated MRMs predict the one-point WTP values that would be generated by a stated preference survey with a particular set of characteristics chosen to represent the water quality changes and other specifics of the regulatory options where possible, and best practices in economic literature (*e.g.*, excluding outlier responses from estimating WTP). As with the 2015 meta-analysis, EPA developed two MRMs (U.S. EPA, 2015a). Model 1 is used to provide EPA's main estimate of non-market benefits. Model 2 provides alternative estimates by including an additional variable (*lnquality_ch*), which accounts for the magnitude of WQI changes (*e.g.*, low or high) and the associated effect on estimated WTP values. The two models differ only in how they account for the magnitude of the water quality changes presented to respondents in the original stated preference studies:

- Model 1 assumes that individuals' one-point WTP depends on the average level of water quality between the baseline and regulatory options. It does not depend on the magnitude of the water quality change specified in the surveys of studies included in the underlying meta-data. This restriction means that the meta-model satisfies the adding-up condition, a theoretically desirable property.
- Model 2 allows one-point WTP to depend not only on the average level of water quality but also on the magnitude of the water quality change specified in the surveys of studies included in the underlying meta-data. The model allows for the possibility that the WTP for a one-point improvement on the WQI depends on both the average level of water quality between the baseline and the regulatory options and the total water quality change that respondents were asked to value. Since

environmental quality is considered by economists to be a normal good,[152] one-point WTP is expected to decrease when the total WQI change increases according to the law of diminishing marginal utility. As indicated by a negative sign on the *lnquality_ch* coefficient, the estimated WTP for a one-point improvement on the WQI scale is larger when respondents were asked to value a 10-point improvement compared to a 20-point improvement. EPA used Model 2 to generate alternative estimates of non-market benefits. This model provides a better statistical fit to the meta-data, but it satisfies the adding-up condition only if the same magnitude of the water quality change is considered (*e.g.*, 10 points). To uniquely define the demand curve and satisfy the adding-up condition using this model, EPA treats the water quality change variable as a methodological variable and therefore must make an assumption about the size of the water quality change that would be appropriate to use in a stated preference survey designed to value water quality changes resulting from the regulatory options.

EPA used the two MRMs in a benefit transfer approach that follows standard methods described by Johnston et al. (2005), Shrestha, Rosenberger and Loomis (2007), and Rosenberger and Phipps (2007). Based on benefit transfer literature (*e.g.*, Stapler & Johnston, 2009; Boyle & Wooldridge, 2018), methodological variables are assigned values that either reflect "best practices" associated with reducing measurement errors in primary studies or set to their mean values over the meta-data. The literature also recommends setting variables representing policy outcomes and policy context (*i.e.*, resource and population characteristics) at the levels that might be expected from a regulation. The benefit transfer approach uses CBGs as the geographic unit of analysis.[153] This approach involves estimating benefits in each CBG and year, based on the following general benefit function:

Equation H-1.

$$\ln\left(OWTP_{Y,B}\right) = Intercept + \sum (coefficient_i) \times (independent\ variable\ value_i)$$

Where

$ln(OWTP_{Y,B})$	=	The predicted natural log of one-point household WTP for a given year (*Y*) and CBG (*B*).
coefficient	=	A vector of variable coefficients from the meta-regression.
independent variable values	=	A vector of independent variable values. Variables include baseline water quality level ($WQI\text{-}BL_{Y,B}$) and expected water quality under the regulatory option ($WQI\text{-}PC_{Y,B}$) for a given year and CBG.

152 Environmental quality, including water quality, is a "normal" good because people want more of it as their real incomes increase.

153 A Census Block Group is a group of Census Blocks (the smallest geographic unit for the Census) in a contiguous area that never crosses a State or county boundary. A block group typically contains a population between 600 and 3,000 individuals. There are 239,780 block groups in the United States based on the 2020 Census. See https://www.census.gov/geographies/reference-files/time-series/geo/tallies.html. http://www.census.gov/geo/maps-data/data/tallies/tractblock.html.

Here, $ln(OWTP_{Y,B})$ is the dependent variable in the meta-analysis—the natural log of an average WTP per one point improvement per household, in a given CBG *B* for water quality in a given year *Y*.[154] The baseline water quality level ($WQI\text{-}BL_{Y,B}$) and expected water quality under the regulatory option ($WQI\text{-}PC_{Y,B}$) were based on water quality in waterbodies within a 100-mile buffer of the centroid of each CBG. A buffer of 100 miles is consistent with Viscusi, Huber and Bell (2008) and with the assumption that the majority of recreational trips would occur within a 2-hour drive from home. Because one-point WTP is assumed to depend, according to Equation H-1, on both baseline water quality level ($WQI\text{-}BL_{Y,B}$) and expected water quality under the regulatory option ($WQI\text{-}PC_{Y,B}$), EPA estimated the one-point WTP for water quality changes resulting from the regulatory options at the mid-point of the range over which water quality was changed, $WQI_{Y,B} = (1/2)(WQI\text{-}BL_{Y,B} + WQI\text{-}PC_{Y,B})$.

In this analysis, EPA estimated WTP for the households in each CBG for waters within a 100-mile radius of that CBG's centroid. EPA chose the 100 mile-radius because households are likely to be most familiar with waterbodies and their qualities within the 100-mile distance. However, this assumption may be an underestimate of the distance beyond which households have familiarity with and WTP for waterbodies affected by steam electric power plant discharges and their quality. By focusing on a buffer around the CBG as a unit of analysis, rather than buffers around affected waterbodies, each household is included in the assessment exactly once, eliminating the potential for double-counting of households.[155] Total national WTP is calculated as the sum of estimated CBG-level WTP across all CBGs that have at least one affected waterbody within 100 miles. Using this approach, EPA is unable to analyze the WTP for CBGs with no affected waters within 100 miles. Appendix E in U.S. EPA (2020b) describes the methodology used to identify the relevant populations.

In each CBG and year, predicted WTP per household is tailored by choosing appropriate input values for the meta-analysis parameters describing the resource(s) valued, the extent of resource changes (*i.e.*, $WQI\text{-}PC_{Y,B}$), the scale of resource changes relative to the size of the buffer and relative to available substitutes, the characteristics of surveyed populations (*e.g.*, users, nonusers), and other methodological variables. For example, EPA projected that household income (an independent variable) changes over time, resulting in household WTP values that vary by year.

Table H-3 provides details on how EPA used the meta-analysis to predict household WTP for each CBG and year. The table presents the estimated regression equation intercepts and variable coefficients ($coefficient_i$) for the two models, and the corresponding independent variables names and assigned values. The MRM allows the Agency to forecast WTP based on assigned values for model variables that are chosen to represent a resource change in the context of the regulatory options.

In this instance, EPA assigned six study and methodology variables, (*thesis, volunt, non_reviewed, lump_sum, user_cost, IBI*) a value of zero. Three methodological variables (*OneShotVal*, *tax_only*, *RUM*) were included with an assigned value of 1. For the study year variable *(lnyear)*, EPA gave the variable a value of 3.6109 (or the ln(2017-1980)), which is the maximum value in the meta-data. This value assignment reflects a time trend interpretation of the variable. Model 2 includes an additional variable, water quality change (*ln_quality_ch*), which allows the benefit transfer function to reflect differences in one-point WTP based on the magnitude of

154 To satisfy the adding-up condition, as noted above, EPA normalized WTP values reported in the studies included in the meta-data so that the dependent variable is WTP for a one-point improvement on the WQI.

155 Population double-counting issues can arise when using "distance to waterbody" to assess simultaneous improvements to many waterbodies.

changes presented to survey respondents when eliciting WTP values. To ensure that the benefit transfer function satisfies the adding-up condition, the *ln_quality_ch* variable was treated as a demand curve shifter, similar to the methodological control variables, and held fixed for the benefit calculations. To estimate low and high sensitivity analysis values of WTP for water quality changes resulting from the regulatory options, EPA estimated one-point WTP using two alternative settings of the *ln_quality_ch* variable: ΔWQI = 7 units and ΔWQI = 20 units. These two values represent the 25th percentile and 75th percentile values of the meta-data.

All but one of the region and surveyed population variables vary based on the characteristics of each CBG. EPA set the variable *nonusers_only* to zero for all CBGs because water quality changes are expected to enhance both use and non-use values of the affected resources and thus benefit both users and nonusers (a nonuser value of 1 implies WTP values that are representative of nonusers only, whereas the default value of 0 indicates that both users and nonusers are included in the surveyed population). For median household income, EPA used CBG-level median household income data from the 2021 American Community Survey (5-year data) and accounted for projected income growth over the analysis period using the methodology described in Section 1.3.6.

The geospatial variables corresponding to the sampled market and scale of the affected resources (*ln_ar_agr*, *ln_ar_ratio*, *sub_proportion*) vary based on attributes of the CBG and attributes of the nearby affected resources. For all options, the affected resource is based on the 9,358 NHD reaches potentially affected by steam electric power generating plant discharges under baseline conditions. The affected resource for each CBG is the portion of the 9,358 reaches that falls within the 100-mile buffer of the CBG. Spatial scale is held fixed across regulatory options. The variable corresponding to the sampled market (*ln_ar_ratio*) is set to the mean value across all COMIDs within the scope of the analysis and thus does not vary across affected CBGs.

Because data on specific recreational uses of the water resources affected by the regulatory options are not available, the recreational use variables (*swim_use*, *gamefish*) are set to zero, which corresponds to "unspecified" or "all" recreational uses in the meta-data.[156] Water quality variables (*Q* and *lnquality_ch*) vary across CBGs and regulatory options based on the magnitude of the reach-length weighted average water quality changes in resources within scope of the analysis within the 100-mile buffer of each CBG.

Table H-3: Independent Variable Assignments for Surface Water Quality Meta-Analysis

Variable	Coefficient		Assigned Value	Explanation
	Model 1	Model 2		
Study Methodology and Year				
intercept	-2.823	-10.020		
OneShotVal	0.247	0.552	1	Binary variable indicating that the study's survey only included one valuation question. Set to one because one valuation scenario follows best practices for generating incentive-compatible WTP estimates (Carson, Groves & List, 2014; Johnston, Boyle, et al., 2017).

156 If a particular recreational use was not specified in the survey instrument, EPA assessed that survey respondents were thinking of all relevant uses.

Table H-3: Independent Variable Assignments for Surface Water Quality Meta-Analysis

Variable	Coefficient		Assigned Value	Explanation
	Model 1	Model 2		
tax_only	-0.177	-0.478	1	Binary variable indicating that the payment mechanism used to elicit WTP is increased taxes. Set to one because using taxes as the payment mechanism generates incentive-compatible WTP estimates and is inclusive of both users and nonusers.
user_cost	-0.873	-1.199	0	Binary variable indicating that the payment mechanism used to elicit WTP is increased user cost. Set to zero because user cost payment mechanisms are less inclusive of nonusers than tax-based payment mechanisms.
volunt	-1.656	-1.870	0	Binary variable indicating that WTP was estimated using a payment vehicle described as voluntary as opposed to, for example, property taxes. Set to zero because hypothetical voluntary payment mechanisms are not incentive compatible (Johnston, Boyle, et al., 2017).
RUM	0.901	0.680	1	Binary variable indicating that the study used a Random Utility Model to estimate WTP. Set to one because use of a Random Utility Model to estimate WTP is a standard best practice in modern stated preference studies.
IBI	-2.355	-2.185	0	Binary variable indicating that the study used the Index of Biotic Integrity as the water quality metric. Set to zero because the meta-regression uses the WQI as the water quality metric, not the Index of Biotic Integrity.
lnyear	-0.135	-0.362	ln(2017-1980)	Natural log of the year in which the study was conducted (*i.e.*, data were collected), converted to an index by subtracting 1980. Set to the natural log of the maximum value from the meta-data (ln(2017-1980)) to reflect a time trend interpretation of the variable.
non_reviewed	-0.233	-0.247	0	Binary variable indicating that the study was not published in a peer-reviewed journal. Set to zero because studies published in peer-reviewed journals are preferred.
thesis	0.431	0.580	0	Binary variable indicating that the study is a thesis or dissertation. Set to zero because studies published in peer-reviewed journals are preferred.
lump_sum	0.534	0.518	0	Binary variable indicating that the study provided WTP as a one-time, lump sum or provided annual WTP values for a payment period of five years or less. Set to zero to reflect that the majority of studies from the meta-data estimated an annual WTP, and to produce an annual WTP prediction.
Region and Surveyed Population				
census_south	0.693	0.990	Varies	Binary variable indicating that the affected waters are located entirely within the South Census region, which includes the following states: DE, MD, DC, WV, VA, NC, SC, GA, FL, KY, TN, MS, AL, AR, LA, OK, and TX. Set based on the state in which the CBG is located.
census_midwest	0.667	0.945	Varies	Binary variable indicating that the affected waters are located entirely within the Midwest Census region, which includes the following states: OH, MI, IN, IL, WI, MN, IA, MO, ND, SD, NE, and KS. Set based on the state in which the CBG is located.

Table H-3: Independent Variable Assignments for Surface Water Quality Meta-Analysis

Variable	Coefficient		Assigned Value	Explanation
	Model 1	Model 2		
census_west	0.393	0.400	Varies	Binary variable indicating that the affected waters are located entirely within the West Census region, which includes the following states: MT, WY, CO, NM, ID, UT, AZ, NV, WA, OR, and CA. Set based on the state in which the CBG is located.
nonusers	-0.283	-0.380	0	Binary variable indicating that the sampled population included nonusers only; the alternative case includes all households. Set to zero to estimate the total value for water quality changes for all households, including users and nonusers.
lnincome	0.478	1.199	Varies	Natural log of median household income values assigned separately for each CBG. Varies by year based on the estimated income growth in future years.
Sampled Market and Affected Resource				
swim_use	0.300	0.361	0	Binary variables indicating that the affected use(s) stated in the survey instrument include swimming and gamefishing. Set to zero, which corresponds to all recreational uses, since data on specific recreational uses of the reaches affected by steam electric power plant discharges are not available.
gamefish	0.871	0.531	0	
ln_ar_agr	-0.572	-0.654	Varies	Natural log of the proportion of the affected resource area which is agricultural based on the National Land Cover Database, reflecting the nature of development in the area surrounding the resource. Used Census county boundary layers to identify counties that intersect affected resources within the 100-mile buffer of each CBG. For intersecting counties, calculated the fraction of total land area that is agricultural using the National Land Cover Dataset. The *ln_ar_agr* variable was coded in the metadata to reflect the area surrounding the affected resources.
ln_ar_ratio	-0.157	-0.153	3.648	The natural log of the ratio of the sampled area (*sa_area*) relative to the affected resource area (defined as the total area of counties that intersect the affected resource[s]) (*ar_total_area*). In the context of the steam electric scenario, *sa_area* is set based on the total area within the 100-mile buffer from the COMIDs in scope of the analysis, while *ar_total_area* is set based on the area of counties intersecting each affected reach (COMID). *ln_ar_ratio* is set to the mean value from all COMIDs within the scope of the analysis.
sub_proportion	0.993	0.650	Varies	The size of the resources within the scope of the analysis relative to available substitutes. Calculated as the ratio of affected reaches miles to the total number of reach miles within the buffer that are the same or greater than the order(s) of the affected reaches within the buffer. Its value can range from 0 to 1.

Table H-3: Independent Variable Assignments for Surface Water Quality Meta-Analysis

Variable	Coefficient		Assigned Value	Explanation
	Model 1	Model 2		
Water Quality				
ln_Q	-0.666	-0.259	Varies	Because WTP for a one-point improvement on the WQI is assumed to depend on both baseline water quality and expected water quality under the regulatory option, this variable is set to the natural log of the mid-point of the range of water quality changes due to the regulatory options, $WQI_{Y,B} = (1/2)(WQI\text{-}BL_{Y,B} + WQI\text{-}PC_{Y,B})$. Calculated as the length-weighted average WQI score for all potentially affected reaches within the 100-mile buffer of each CBG.
lnquality_ch	NA	-0.683	ln(7) ln(20)	*ln_quality_ch* was set to the natural log of ΔWQI=7 or ΔWQI=20 for high and low estimates of the one-point WTP, respectively. These two values represent the 25th percentile and 75th percentile values of the meta-data.

I Identification of Threatened and Endangered Species Potentially Affected by the Final Rule Regulatory Options

As discussed in Chapter 7, EPA identified a total of 184 T&E species whose habitat range intersects reaches affected by steam electric power plant discharges. These species include amphibians, arachnids, birds, clams, crustaceans, fishes, insects, mammals, reptiles, and snails. Table I-1 summarizes the number of species within each group that have habitat ranges intersecting reaches with NRWQC exceedances for at least one pollutant under the baseline or regulatory options in Period 1 (2025-2029) or Period 2 (2030-2049). As shown in the table, several species of amphibians, birds, clams, fishes, mammals, and reptiles have habitat ranges overlapping reaches with baseline exceedances in Period 1. There are no additional exceedances under any of the regulatory options, but water quality improvements under each regulatory option reduce the number of exceedances from the baseline conditions.

Table I-1: Number of T&E Species with Habitat Range Intersecting Reaches Downstream from Steam Electric Power Plant Outfalls, by Species Group

Species Group	Number of Individual Species with NRWQC Exceedances for at Least One Pollutant in Reaches Intersecting their Habitat Range							
	Period 1				Period 2			
	Baseline	Option A	Option B (Final Rule)	Option C	Baseline	Option A	Option B (Final Rule)	Option C
Amphibians	1	1	0	0	1	1	0	0
Arachnids	0	0	0	0	0	0	0	0
Birds	6	6	6	6	5	5	5	0
Clams	9	9	9	9	9	9	0	0
Crustaceans	0	0	0	0	0	0	0	0
Fishes	4	4	4	4	3	3	3	0
Insects	0	0	0	0	0	0	0	0
Mammals	5	5	5	5	4	4	0	0
Reptiles	5	5	0	0	5	5	0	0
Snails	0	0	0	0	0	0	0	0
Total	**30**	**30**	**24**	**24**	**27**	**27**	**8**	**0**

Source: U.S. EPA Analysis, 2024

Table I-2 provides further details on the 184 T&E species whose habitat range intersects reaches affected by steam electric power plant discharges. The table denotes, for each species, the number of reaches with at least one reported exceedance of a NRWQC in the baseline or regulatory options in Period 1 and Period 2. The table also includes the results of EPA's assessment of species vulnerability to water pollution. As noted in Chapter 7, EPA classified species as follows:

- Higher vulnerability – species living in aquatic habitats for several life history stages and/or species that obtain a majority of their food from aquatic sources.
- Moderate vulnerability – species living in aquatic habitats for one life history stage and/or species that obtain some of their food from aquatic sources.
- Lower vulnerability – species whose habitats overlap bodies of water, but whose life history traits and food sources are terrestrial.

EPA obtained species life history data from a wide variety of sources to assess T&E species vulnerability to water pollution. These sources included: U.S. DOI, 2019; Froese and Pauly, 2019; NatureServe, 2020; NOAA Fisheries, 2020; Southwest Fisheries Science Center (SWFSC), 2019; U.S. FWS, 2019a, 2019b, 2019c, 2019d, 2019e, 2019f, 2019g, 2020a, 2020b, 2020c, 2020e, 2020f, 2020g, 2020h, 2020i, 2020j, 2020k; Upper Colorado River Endangered Fish Recovery Program, 2020.

Section 7.3.2 discusses impacts on selected higher vulnerability species whose habitat ranges intersect reaches with estimated changes in NRWQC exceedance status under the regulatory options.

Table I-2: T&E Species with Habitat Range Intersecting Reaches Downstream from Steam Electric Power Plant Outfalls (Shading Highlights Change from Baseline)

Species Group	Species Count	Species Name	Vulnerability	Number of Intersected Reaches Exceeding NRWQC for at Least One Pollutant							
				Period 1				Period 2			
				Baseline	Option A	Option B (Final Rule)	Option C	Baseline	Option A	Option B (Final Rule)	Option C
Amphibians	9	*Ambystoma bishopi*	Moderate	0	0	0	0	0	0	0	0
		Ambystoma cingulatum	Higher	1	1	0	0	1	1	0	0
		Bufo houstonensis	Moderate	0	0	0	0	0	0	0	0
		Cryptobranchus alleganiensis bishopi	Higher	0	0	0	0	0	0	0	0
		Necturus alabamensis	Higher	0	0	0	0	0	0	0	0
		Phaeognathus hubrichti	Lower	0	0	0	0	0	0	0	0
		Plethodon nettingi	Lower	0	0	0	0	0	0	0	0
		Rana pretiosa	Higher	0	0	0	0	0	0	0	0
		Rana sevosa	Lower	0	0	0	0	0	0	0	0
Arachnids	6	*Cicurina baronia*	Lower	0	0	0	0	0	0	0	0
		Cicurina madla	Lower	0	0	0	0	0	0	0	0
		Cicurina venii	Lower	0	0	0	0	0	0	0	0
		Cicurina vespera	Lower	0	0	0	0	0	0	0	0
		Tayshaneta microps	Lower	0	0	0	0	0	0	0	0
		Texella cokendolpheri	Lower	0	0	0	0	0	0	0	0
Birds	26	*Ammodramus savannarum floridanus*	Lower	0	0	0	0	0	0	0	0
		Aphelocoma coerulescens	Lower	0	0	0	0	0	0	0	0
		Brachyramphus marmoratus	Moderate	0	0	0	0	0	0	0	0
		Calidris canutus rufa	Lower	11	11	0	0	11	11	0	0
		Campephilus principalis	Lower	0	0	0	0	0	0	0	0
		Charadrius melodus	Moderate	3	2	2	2	2	0	0	0
		Coccyzus americanus	Lower	6	3	3	3	3	3	3	0
		Empidonax traillii extimus	Lower	3	0	0	0	0	0	0	0
		Eremophila alpestris strigata	Lower	0	0	0	0	0	0	0	0
		Falco femoralis septentrionalis	Lower	0	0	0	0	0	0	0	0
		Grus americana	Moderate	0	0	0	0	0	0	0	0
		Grus canadensis pulla	Higher	0	0	0	0	0	0	0	0
		Gymnogyps californianus	Lower	0	0	0	0	0	0	0	0
		Laterallus jamaicensis ssp. jamaicensis	Lower	0	0	0	0	0	0	0	0

Table I-2: T&E Species with Habitat Range Intersecting Reaches Downstream from Steam Electric Power Plant Outfalls (Shading Highlights Change from Baseline)

Species Group	Species Count	Species Name	Vulnerability	Number of Intersected Reaches Exceeding NRWQC for at Least One Pollutant							
				Period 1				Period 2			
				Baseline	Option A	Option B (Final Rule)	Option C	Baseline	Option A	Option B (Final Rule)	Option C
		Mycteria americana	Moderate	2	2	1	1	2	2	0	0
		Numenius borealis	Lower	0	0	0	0	0	0	0	0
		Picoides borealis	Lower	1	1	0	0	1	1	0	0
		Polyborus plancus audubonii	Lower	0	0	0	0	0	0	0	0
		Rallus obsoletus yumanensis	Higher	0	0	0	0	0	0	0	0
		Rostrhamus sociabilis plumbeus	Higher	0	0	0	0	0	0	0	0
		Setophaga chrysoparia	Lower	0	0	0	0	0	0	0	0
		Sterna antillarum browni	Higher	0	0	0	0	0	0	0	0
		Sterna dougallii dougallii	Higher	0	0	0	0	0	0	0	0
		Strix occidentalis caurina	Lower	0	0	0	0	0	0	0	0
		Strix occidentalis lucida	Lower	0	0	0	0	0	0	0	0
		Tympanuchus cupido attwateri	Lower	0	0	0	0	0	0	0	0
Clams	56	*Amblema neislerii*	Higher	0	0	0	0	0	0	0	0
		Arcidens wheeleri	Higher	0	0	0	0	0	0	0	0
		Cumberlandia monodonta	Higher	10	10	0	0	10	10	0	0
		Cyprogenia stegaria	Higher	11	11	1	1	11	11	0	0
		Dromus dromas	Higher	0	0	0	0	0	0	0	0
		Elliptio chipolaensis	Higher	0	0	0	0	0	0	0	0
		Elliptio lanceolata	Higher	0	0	0	0	0	0	0	0
		Elliptio spinosa	Higher	0	0	0	0	0	0	0	0
		Elliptoideus sloatianus	Higher	0	0	0	0	0	0	0	0
		Epioblasma brevidens	Higher	0	0	0	0	0	0	0	0
		Epioblasma capsaeformis	Higher	0	0	0	0	0	0	0	0
		Epioblasma obliquata obliquata	Higher	0	0	0	0	0	0	0	0
		Epioblasma rangiana	Higher	0	0	0	0	0	0	0	0
		Epioblasma triquetra	Higher	10	10	0	0	10	10	0	0
		Fusconaia cor	Higher	0	0	0	0	0	0	0	0
		Fusconaia cuneolus	Higher	0	0	0	0	0	0	0	0
		Fusconaia masoni	Higher	0	0	0	0	0	0	0	0
		Hamiota altilis	Higher	0	0	0	0	0	0	0	0
		Hamiota perovalis	Higher	0	0	0	0	0	0	0	0
		Hamiota subangulata	Higher	0	0	0	0	0	0	0	0
		Hemistena lata	Higher	0	0	0	0	0	0	0	0
		Lampsilis abrupta	Higher	12	12	2	2	12	12	0	0
		Lampsilis higginsii	Higher	0	0	0	0	0	0	0	0
		Lampsilis rafinesqueana	Higher	0	0	0	0	0	0	0	0
		Lampsilis virescens	Higher	0	0	0	0	0	0	0	0
		Lasmigona decorata	Higher	0	0	0	0	0	0	0	0
		Leptodea leptodon	Higher	0	0	0	0	0	0	0	0

Table I-2: T&E Species with Habitat Range Intersecting Reaches Downstream from Steam Electric Power Plant Outfalls (Shading Highlights Change from Baseline)

Species Group	Species Count	Species Name	Vulnerability	Number of Intersected Reaches Exceeding NRWQC for at Least One Pollutant							
				Period 1				Period 2			
				Baseline	Option A	Option B (Final Rule)	Option C	Baseline	Option A	Option B (Final Rule)	Option C
		Margaritifera hembeli	Higher	0	0	0	0	0	0	0	0
		Margaritifera marrianae	Higher	0	0	0	0	0	0	0	0
		Medionidus acutissimus	Higher	0	0	0	0	0	0	0	0
		Medionidus parvulus	Higher	0	0	0	0	0	0	0	0
		Medionidus penicillatus	Higher	0	0	0	0	0	0	0	0
		Obovaria retusa	Higher	1	1	1	1	1	1	0	0
		Parvaspina collina	Higher	0	0	0	0	0	0	0	0
		Plethobasus cicatricosus	Higher	0	0	0	0	0	0	0	0
		Plethobasus cooperianus	Higher	1	1	1	1	1	1	0	0
		Plethobasus cyphyus	Higher	11	11	1	1	11	11	0	0
		Pleurobema clava	Higher	1	1	1	1	1	1	0	0
		Pleurobema decisum	Higher	0	0	0	0	0	0	0	0
		Pleurobema furvum	Higher	0	0	0	0	0	0	0	0
		Pleurobema georgianum	Higher	0	0	0	0	0	0	0	0
		Pleurobema hanleyianum	Higher	0	0	0	0	0	0	0	0
		Pleurobema perovatum	Higher	0	0	0	0	0	0	0	0
		Pleurobema plenum	Higher	1	1	1	1	1	1	0	0
		Pleurobema pyriforme	Higher	0	0	0	0	0	0	0	0
		Pleurobema taitianum	Higher	0	0	0	0	0	0	0	0
		Pleuronaia dolabelloides	Higher	0	0	0	0	0	0	0	0
		Potamilus capax	Higher	0	0	0	0	0	0	0	0
		Potamilus inflatus	Higher	0	0	0	0	0	0	0	0
		Ptychobranchus greenii	Higher	0	0	0	0	0	0	0	0
		Ptychobranchus subtentus	Higher	0	0	0	0	0	0	0	0
		Quadrula cylindrica cylindrica	Higher	0	0	0	0	0	0	0	0
		Quadrula fragosa	Higher	0	0	0	0	0	0	0	0
		Theliderma intermedia	Higher	0	0	0	0	0	0	0	0
		Theliderma sparsa	Higher	0	0	0	0	0	0	0	0
		Villosa fabalis	Higher[a]	0	0	0	0	0	0	0	0
Crustaceans	5	*Antrolana lira*	Higher	0	0	0	0	0	0	0	0
		Cambarus aculabrum	Higher	0	0	0	0	0	0	0	0
		Cambarus zophonastes	Higher	0	0	0	0	0	0	0	0
		Orconectes shoupi [b]	Higher	0	0	0	0	0	0	0	0
		Palaemonias alabamae	Higher	0	0	0	0	0	0	0	0
Fishes	28	*Acipenser oxyrinchus (=oxyrhynchus) desotoi*	Higher	0	0	0	0	0	0	0	0
		Amblyopsis rosae	Higher	0	0	0	0	0	0	0	0
		Chrosomus saylori	Higher[a]	0	0	0	0	0	0	0	0
		Cyprinella caerulea	Higher	0	0	0	0	0	0	0	0

Table I-2: T&E Species with Habitat Range Intersecting Reaches Downstream from Steam Electric Power Plant Outfalls (Shading Highlights Change from Baseline)

Species Group	Species Count	Species Name	Vulnerability	Number of Intersected Reaches Exceeding NRWQC for at Least One Pollutant							
				Period 1				Period 2			
				Baseline	Option A	Option B (Final Rule)	Option C	Baseline	Option A	Option B (Final Rule)	Option C
		Elassoma alabamae	Higher[a]	0	0	0	0	0	0	0	0
		Etheostoma boschungi	Higher	0	0	0	0	0	0	0	0
		Etheostoma chienense	Higher	0	0	0	0	0	0	0	0
		Etheostoma etowahae	Higher	0	0	0	0	0	0	0	0
		Etheostoma nianguae	Higher	0	0	0	0	0	0	0	0
		Etheostoma phytophilum	Higher	0	0	0	0	0	0	0	0
		Etheostoma rubrum	Higher	0	0	0	0	0	0	0	0
		Etheostoma scotti	Higher	0	0	0	0	0	0	0	0
		Etheostoma trisella	Higher	0	0	0	0	0	0	0	0
		Gila cypha	Higher	3	3	3	3	3	3	3	0
		Gila elegans	Higher	0	0	0	0	0	0	0	0
		Macrhybopsis tetranema	Higher	0	0	0	0	0	0	0	0
		Notropis cahabae	Higher	0	0	0	0	0	0	0	0
		Notropis topeka (=tristis)	Higher	3	2	2	2	2	0	0	0
		Oncorhynchus apache	Higher	0	0	0	0	0	0	0	0
		Percina aurora	Higher	0	0	0	0	0	0	0	0
		Percina rex	Higher	0	0	0	0	0	0	0	0
		Percina tanasi	Higher	0	0	0	0	0	0	0	0
		Ptychocheilus lucius	Higher	6	3	3	3	3	3	3	0
		Salvelinus confluentus	Higher	0	0	0	0	0	0	0	0
		Scaphirhynchus albus	Higher	0	0	0	0	0	0	0	0
		Scaphirhynchus suttkusi	Higher	0	0	0	0	0	0	0	0
		Speoplatyrhinus poulsoni	Higher[a]	0	0	0	0	0	0	0	0
		Xyrauchen texanus	Higher	3	0	0	0	0	0	0	0
Insects	10	*Batrisodes venyivi*	Lower	0	0	0	0	0	0	0	0
		Bombus affinis	Lower	0	0	0	0	0	0	0	0
		Euphydryas editha taylori	Lower	0	0	0	0	0	0	0	0
		Hesperia dacotae	Lower	0	0	0	0	0	0	0	0
		Lycaeides melissa samuelis	Lower	0	0	0	0	0	0	0	0
		Neonympha mitchellii mitchellii	Lower	0	0	0	0	0	0	0	0
		Nicrophorus americanus	Lower	0	0	0	0	0	0	0	0
		Rhadine exilis	Lower	0	0	0	0	0	0	0	0
		Rhadine infernalis	Lower	0	0	0	0	0	0	0	0
		Somatochlora hineana	Lower	0	0	0	0	0	0	0	0
Mammals	15	*Antilocapra americana sonoriensis*	Lower	0	0	0	0	0	0	0	0
		Canis lupus	Lower	0	0	0	0	0	0	0	0
		Corynorhinus (=Plecotus) townsendii ingens	Lower	0	0	0	0	0	0	0	0

Table I-2: T&E Species with Habitat Range Intersecting Reaches Downstream from Steam Electric Power Plant Outfalls (Shading Highlights Change from Baseline)

Species Group	Species Count	Species Name	Vulnerability	Number of Intersected Reaches Exceeding NRWQC for at Least One Pollutant							
				Period 1				Period 2			
				Baseline	Option A	Option B (Final Rule)	Option C	Baseline	Option A	Option B (Final Rule)	Option C
		Corynorhinus (=Plecotus) townsendii virginianus	Lower	0	0	0	0	0	0	0	0
		Eumops floridanus	Lower	0	0	0	0	0	0	0	0
		Lynx canadensis	Lower	3	0	0	0	0	0	0	0
		Mustela nigripes	Lower	0	0	0	0	0	0	0	0
		Myotis grisescens	Moderate	1	1	1	1	1	1	0	0
		Myotis septentrionalis	Lower	16	15	5	5	15	13	0	0
		Myotis sodalis	Lower	12	12	2	2	12	12	0	0
		Puma (=Felis) concolor (all subsp. except coryi)	Lower	0	0	0	0	0	0	0	0
		Puma (=Felis) concolor coryi	Lower	0	0	0	0	0	0	0	0
		Thomomys mazama pugetensis	Lower	0	0	0	0	0	0	0	0
		Thomomys mazama yelmensis	Lower	0	0	0	0	0	0	0	0
		Trichechus manatus	Higher	1	1	0	0	1	1	0	0
Reptiles	19	*Alligator mississippiensis*	Higher	0	0	0	0	0	0	0	0
		Caretta caretta	Lower	1	1	0	0	1	1	0	0
		Chelonia mydas	Lower	1	1	0	0	1	1	0	0
		Crocodylus acutus	Higher	0	0	0	0	0	0	0	0
		Dermochelys coriacea	Lower	1	1	0	0	1	1	0	0
		Drymarchon couperi	Lower	1	1	0	0	1	1	0	0
		Eretmochelys imbricata	Lower	1	1	0	0	1	1	0	0
		Eumeces egregius lividus	Lower	0	0	0	0	0	0	0	0
		Glyptemys muhlenbergii	Higher	0	0	0	0	0	0	0	0
		Gopherus agassizii	Lower	0	0	0	0	0	0	0	0
		Gopherus polyphemus	Lower	0	0	0	0	0	0	0	0
		Graptemys flavimaculata	Higher	0	0	0	0	0	0	0	0
		Lepidochelys kempii	Lower	0	0	0	0	0	0	0	0
		Neoseps reynoldsi	Lower	0	0	0	0	0	0	0	0
		Pituophis melanoleucus lodingi	Lower	0	0	0	0	0	0	0	0
		Pituophis ruthveni	Lower	0	0	0	0	0	0	0	0
		Pseudemys alabamensis	Higher	0	0	0	0	0	0	0	0
		Sistrurus catenatus	Lower	0	0	0	0	0	0	0	0
		Sternotherus depressus	Higher	0	0	0	0	0	0	0	0
Snails	10	*Athearnia anthonyi*	Higher	0	0	0	0	0	0	0	0
		Campeloma decampi	Higher	0	0	0	0	0	0	0	0
		Elimia crenatella	Higher	0	0	0	0	0	0	0	0
		Leptoxis foremani	Higher	0	0	0	0	0	0	0	0
		Leptoxis taeniata	Higher	0	0	0	0	0	0	0	0
		Lioplax cyclostomaformis	Higher	0	0	0	0	0	0	0	0

Table I-2: T&E Species with Habitat Range Intersecting Reaches Downstream from Steam Electric Power Plant Outfalls (Shading Highlights Change from Baseline)

Species Group	Species Count	Species Name	Vulnerability	Number of Intersected Reaches Exceeding NRWQC for at Least One Pollutant							
				Period 1				Period 2			
				Baseline	Option A	Option B (Final Rule)	Option C	Baseline	Option A	Option B (Final Rule)	Option C
		Marstonia ogmorhaphe	Higher	0	0	0	0	0	0	0	0
		Pleurocera foremani	Higher	0	0	0	0	0	0	0	0
		Triodopsis platysayoides	Lower	0	0	0	0	0	0	0	0
		Tulotoma magnifica	Higher	0	0	0	0	0	0	0	0

[a] Species that could be categorized as highly vulnerable to water quality changes are endemic only to waters (headwater streams and springs) that are not likely to receive discharges from steam electric plants or be affected by upstream discharges. This may be reflected in a lower vulnerability rating for certain species.

[b] U.S. Fish and Wildlife Service proposed delisting this species on September 23, 2020. See notice of proposed rulemaking "Endangered and Threatened Wildlife and Plants: Removal of the Nashville Crayfish from the Federal List of Endangered and Threatened Wildlife." (85 FR 59732)

Source: U.S. EPA Analysis, 2024

J Methodology for Modeling Air Quality Changes for the Final Rule

As noted in Chapter 8, EPA used photochemical modeling to create air quality surfaces[157] that were then used in air pollution benefits calculations of the final rule. The modeling-based surfaces captured air pollution impacts resulting from changes in electricity generation profiles due to the incremental costs to generate electricity at plants incurring water treatment costs and did not simulate the impact of emissions changes resulting from changes in energy use by steam electric power plants or resulting from changes in trucking of CCR and other waste. This appendix describes the source apportionment modeling and associated methods used to create air quality surfaces for the baseline scenario and a scenario representing water treatment technology implementation-driven EGU profile changes for 7 analytic years: 2028, 2030, 2035, 2040, 2045, and 2050. EPA created air quality surfaces for the following pollutants and metrics: annual average $PM_{2.5}$; April-September average of 8-hr daily maximum (MDA8) ozone (AS-MO3).

New ozone and PM source apportionment modeling outputs were created to support analyses in the RIAs for multiple final EGU rulemaking efforts. The basic methodology for determining air quality changes is the same as that used in the RIAs from multiple previous rules (U.S. EPA, 2019i, 2020a, 2020b, 2021b, 2022c). EPA calculated baseline and Final Rule EGU emissions estimates of NO_x and SO_2 for all seven IPM model years from the Integrated Planning Model (IPM) (Chapter 5 of the RIA; U.S. EPA, 2024e). EPA also used IPM outputs to estimate EGU emissions of $PM_{2.5}$ based on the methodology described in U.S. EPA (2020c). This appendix provides additional details on the source apportionment modeling simulations and on the methods used to translate these emissions scenarios into air quality surfaces.

J.1 Air Quality Modeling Simulations

The air quality modeling utilized a 2016-based modeling platform which included meteorology and base year emissions from 2016 and projected future-year emissions for 2026 for all sectors other than EGUs and 2030 for EGUs. The air quality modeling included photochemical model simulations for a 2016 base year and a future year representing the combined 2026/2030 emissions described above to provide hourly concentrations of ozone and $PM_{2.5}$ component species nationwide. In addition, source apportionment modeling was performed for the future year to quantify the contributions to ozone from NO_X emissions and to $PM_{2.5}$ from NO_X, SO_2 and directly emitted $PM_{2.5}$ emissions from EGUs on a state-by-state and fuel-type basis. As described below, the modeling results for 2016 and the future year, in conjunction with EGU emissions data for the baseline and three illustrative scenarios in 2028, 2030, 2035, 2040, 2045, and 2050 were used to construct the air quality surfaces that reflect the influence of emissions changes between the baseline and the three illustrative scenarios in each year.

The air quality model simulations (*i.e.*, model runs) were performed using the Comprehensive Air Quality Model with Extensions (CAMx) version 7.10[158] (Ramboll Environ, 2020). The nationwide modeling domain (*i.e.*, the geographic area included in the modeling) covers all lower 48 states plus adjacent portions of Canada and Mexico using a horizontal grid resolution of 12 × 12 km shown in Figure J-1. CAMx requires a variety of input files that contain information pertaining to the modeling domain and simulation period. These include gridded, hourly emissions estimates and meteorological data, and initial and boundary concentrations. The meteorological data and the initial and boundary concentrations were identical to those described in U.S. EPA

157 "air quality surfaces" refers to continuous gridded spatial fields using a 12-km grid-cell resolution

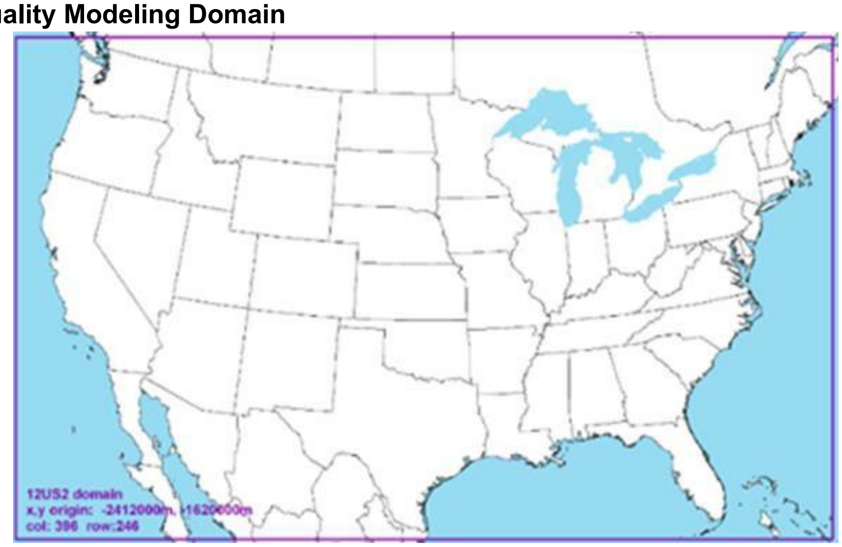
158 This CAMx simulation set the Rscale NH_3 dry deposition parameter to 0 which resulted in more realistic model predictions of $PM_{2.5}$ nitrate concentrations than using a default Rscale parameter of 1.

(2023a). Separate emissions inventories were prepared for the 2016 base year and the projected future year. All other inputs (*i.e.*, meteorological fields, initial concentrations, ozone column, photolysis rates, and boundary concentrations) were specified for the 2016 base year model application and remained unchanged for the projection-year model simulation.

2016 base year emissions are described in detail in U.S. EPA (2023q). The types of sources included in the emission inventory include stationary point sources such as EGUs and non-EGUs; non-point emissions sources including those from oil and gas production and distribution, agriculture, residential wood combustion, fugitive dust, and residential and commercial heating and cooking; mobile source emissions from onroad and nonroad vehicles, aircraft, commercial marine vessels, and locomotives; wild, prescribed, and agricultural fires; and biogenic emissions from vegetation and soils. Future year emissions from all sources other than EGUs were based on the 2026 emissions projections described in U.S. EPA (2023q) . The Post-IRA 2022 Reference Case of EPA's Power Sector Platform v6 using Integrated Planning Model (IPM), which includes the Final GNP, was also reflected[159]. The EGU projected inventory represents demand growth, fuel resource availability, generating technology cost and performance, and other economic factors affecting power sector behavior. It also reflects environmental rules and regulations, consent decrees and settlements, plant closures, and newly built units for the calendar year 2030. In this analysis, the projected EGU emissions include provisions of tax incentives impacting electricity supply in the Inflation Reduction Act of 2022 (IRA), Final GNP, 2021 Revised Cross-State Air Pollution Rule Update (RCU), the 2016 Standards of Performance for Greenhouse Gas Emissions from New, Modified, and Reconstructed Stationary Sources, the Mercury and Air Toxics Rule (MATS) finalized in 2011, and other finalized rules. Documentation and results of the Post-IRA 2022 Reference Case, where the Final GNP was also included for EGUs, are available at (https://www.epa.gov/power-sector-modeling/final-pm-naaqs).

Model predictions of ozone and $PM_{2.5}$ concentrations were compared against ambient measurements (U.S. EPA, 2022a; 2022b). Ozone and $PM_{2.5}$ model evaluations showed model performance that was adequate for applying these model simulations for the purpose of creating air quality surfaces to estimate ozone and $PM_{2.5}$ benefits.

Figure J-1: Air Quality Modeling Domain



[159] https://www.epa.gov/power-sector-modeling/post-ira-2022-reference-case

The contributions to ozone and $PM_{2.5}$ component species (*e.g.*, sulfate, nitrate, ammonium, elemental carbon (EC), organic aerosol (OA), and crustal material[160]) from EGU emissions in individual states and from each EGU-fuel type were modeled using the "source apportionment" tool. In general, source apportionment modeling quantifies the air quality concentrations formed from individual, user-defined groups of emissions sources or "tags". These source tags are tracked through the transport, dispersion, chemical transformation, and deposition processes within the model to obtain hourly gridded[161] contributions from the emissions in each individual tag to hourly modeled concentrations. For this RIA we used the source apportionment contribution data to provide a means to estimate the effect of changes in emissions from each group of emissions sources (*i.e.*, each tag) to changes in ozone and $PM_{2.5}$ concentrations. Specifically, we applied outputs from source apportionment modeling for ozone and $PM_{2.5}$ component species using the future year modeled case to obtain the contributions from EGUs emissions in each state and fuel-type to ozone and $PM_{2.5}$ component species concentrations in each 12 x 12 km model grid cell nationwide. Ozone contributions were modeled using the Anthropogenic Precursor Culpability Assessment (APCA) tool and $PM_{2.5}$ contributions were modeled suing the Particulate Matter Source Apportionment Technology (PSAT) tool.

(Ramboll Environ, 2020). The ozone source apportionment modeling was performed for the period April through September to provide data for developing spatial fields for the April through September maximum daily eight hour (MDA8) (*i.e.*, AS-MO3) average ozone concentration exposure metric. The $PM_{2.5}$ source apportionment modeling was performed for a full-year to provide data for developing annual average $PM_{2.5}$ spatial fields. Table J-1, Table J-2, and Table J-3 provide emissions that were tracked for each source apportionment tag.

Table J-1: Future-year Emissions Allocated to Each Modeled Coal State Source Apportionment Tag

State Tag	Ozone Season NO_X Emissions	Annual NO_X emissions	Annual SO_2 emissions	Annual $PM_{2.5}$ emissions
AL[5]	NA	5,046	1,929	700
AL+ MS[5]	2,541			
AR[4]	NA	304	331	51
AZ	1,005	2,536	4,515	609
CA	222	511	99	27
CO	19	269	287	21
CT	0	0	0	0
DC	0	0	0	0
DE	0	0	0	0
FL	1,110	1,401	7,163	277
GA	1,654	2,534	3,247	159
IA	8,354	18,776	9,656	1,203
ID	0	0	0	0
IL	1,639	3,742	6,773	270
IN	4,886	18,146	26,584	2,252
KS[1]	NA	214	121	NA
KY	3,551	7,333	7,127	560
LA[2,4]	NA	47	NA	NA
MA	0	0	0	0

160 Crustal material refers to elements that are commonly found in the earth's crust such as Aluminum, Calcium, Iron, Magnesium, Manganese, Potassium, Silicon, Titanium and the associated oxygen atoms.

161 Hourly contribution information is provided for each grid cell to provide spatial patterns of the contributions from each tag.

Table J-1: Future-year Emissions Allocated to Each Modeled Coal State Source Apportionment Tag

State Tag	Ozone Season NO_X Emissions	Annual NO_X emissions	Annual SO_2 emissions	Annual $PM_{2.5}$ emissions
MD[3]	NA	139	272	31
MD + PA[3]	708	NA	NA	NA
ME	0	0	0	0
MI	1,532	4,071	12,478	380
MN	724	1,549	3,289	94
MO	2,947	23,480	38,989	853
MS[5]	NA	252	507	23
MT	3,771	8,842	4,056	1,252
NC	266	482	634	35
ND	8,583	19,562	25,398	1,923
NE[1]	NA	17,507	43,858	NA
NE + KS[1]	7,817	NA	NA	374
NH	0	0	0	0
NJ	0	0	0	0
NM	1,442	2,757	6,800	1,739
NV	0	1	1	0
NY	0	0	0	0
OH	3,152	10,485	21,721	901
OK[4]	NA	212	152	21
OR	0	0	0	0
PA[3]	NA	1,530	4,932	167
RI	0	0	0	0
SC	807	1,939	3,429	364
SD	418	1,100	1,022	27
TN	259	259	269	32
TX[2,4]	NA	7,031	NA	NA
TX + LA[2]	NA	NA	11,607	1,578
TX-reg[4]	2,698	NA	NA	NA
UT	2,702	4,236	7,625	232
VA	466	1,124	259	445
VT	0	0	0	0
WA	0	0	0	0
WI	866	2,137	838	90
WV	6,824	16,358	17,631	1,753
WY	6,066	13,222	11,754	1,024

[1]KS and NE emissions grouped into multi-state tag for direct $PM_{2.5}$ and ozone season NO_X

[2]LA and TX emissions grouped into multi-state tag for SO_2 and direct $PM_{2.5}$

[3]MD and PA emissions grouped into multi-state tag for ozone season NO_X

[4]AR, LA,OK and TX emissions grouped into multi-state tag (“TX-reg”) for ozone season NO_X

[5]AL and MS emissions group into multi-state tag for ozone season NOx

Table J-2: Future-year Emissions Allocated to Each Modeled Natural Gas EGU State Source Apportionment Tag

State Tag	Ozone Season NO_X Emissions	Annual NO_X emissions	Annual SO_2 emissions	Annual $PM_{2.5}$ emissions
AL	2,833	5,132	0	1,979
AR	1,651	2,957	0	632

Table J-2: Future-year Emissions Allocated to Each Modeled Natural Gas EGU State Source Apportionment Tag

State Tag	Ozone Season NO_X Emissions	Annual NO_X emissions	Annual SO_2 emissions	Annual $PM_{2.5}$ emissions
AZ	1,759	3,146	0	686
CA	1,960	5,773	0	1,964
CO	957	1,825	0	461
CT	461	778	0	160
DC	6	11	0	7
DE	383	502	0	134
FL	7,550	14,372	0	4,996
GA	2,279	4,182	0	1,740
IA	875	1,106	0	327
ID	336	513	0	185
IL	1,624	2,705	0	825
IN	1,180	2,166	0	955
KS	329	621	0	54
KY	980	2,806	0	699
LA	3,771	8,706	0	2,158
MA	482	725	0	244
MD	402	710	0	435
ME	232	273	0	21
MI	6,523	11,372	0	1,508
MN	661	928	0	87
MO	587	875	0	342
MS	1,926	3,860	0	1,140
MT	11	19	0	7
NC	1,803	3,426	0	1,213
ND	25	41	0	3
NE	13	47	0	4
NH	120	136	0	34
NJ	1,024	1,910	0	608
NM	733	1,128	0	131
NV	1,693	2,471	0	648
NY	2,793	5,125	0	1,270
OH	1,838	3,824	0	1,617
OK	1,558	2,448	0	546
OR	5	188	0	87
PA	6,811	12,386	0	3,280
RI	115	153	0	73
SC	1,092	2,090	0	917
SD	93	105	0	11
TN	464	1,107	0	388
TX	7,652	14,715	0	3,567
UT	1,189	1,779	0	514
VA	1,836	3,409	0	1,087
VT	4	8	0	6
WA	485	1,311	0	464
WI	847	1,447	0	369
WV	109	180	0	50
WY	203	206	0	28

Table J-3: Future-year Emissions Allocated to Each Other EGU Source Apportionment Tag

State Tag	Ozone Season NO_X Emissions	Annual NO_X emissions	Annual SO_2 emissions	Annual $PM_{2.5}$ emissions
US[a]	20,611	48,619	9,631	7,915

[a] Only includes US emissions from the contiguous 48 states.

Examples of the magnitude and spatial extent of ozone and $PM_{2.5}$ contributions are provided in Figure J-2 through Figure J-5 for EGUs in California, Georgia, Iowa, and Ohio. These figures show how the magnitude and the spatial patterns of contributions of EGU emissions to ozone and $PM_{2.5}$ component species depend on multiple factors including the magnitude and location of emissions as well as the atmospheric conditions that influence the formation and transport of these pollutants. For instance, NO_X emissions are a precursor to both ozone and $PM_{2.5}$ nitrate. However, ozone and nitrate form under very different types of atmospheric conditions, with ozone formation occurring in locations with ample sunlight and ambient VOC concentrations while nitrate formation requires colder and drier conditions and the presence of gas-phase ammonia. California's complex terrain that tends to trap air and allow pollutant build-up combined with warm sunny summer and cooler dry winters and sources of both ammonia and VOCs make its atmosphere conducive to formation of both ozone and nitrate. While the magnitude of EGU NO_X emissions from gas plus coal EGUs is substantially larger in Iowa than in California (Table J-1 and Table J-2), the emissions from California lead to larger maximum contributions to the formation of those pollutants due to the conducive conditions in that state. Georgia and Ohio both had substantial NO_X emissions. While maximum ozone impacts shown for Georgia and Ohio EGUs are similar order of magnitude to maximum ozone impacts from California EGUs, nitrate impacts are negligible in both Georgia and Ohio due to less conducive atmospheric conditions for nitrate formation in those locations. California EGU SO_2 emissions in the future year source apportionment modeling are several orders of magnitude smaller than SO_2 emissions in Ohio and Georgia (Table J-1) leading to much smaller sulfate contributions from California EGUs than from Ohio and Georgia EGUs. $PM_{2.5}$ organic aerosol EGU contributions in this modeling come from primary $PM_{2.5}$ emissions rather than secondary atmospheric formation. Consequently, the impacts of EGU emissions on this pollutant tend to occur closer to the EGU sources than impacts of secondary pollutants (ozone, nitrate, and sulfate) which have spatial patterns showing a broader regional impact. These patterns demonstrate how the model captures important atmospheric processes which impact pollutant formation and transport from emissions sources. Finally, Figure J-6 and Figure J-7 show EGU ozone and PM2.5 contributions from all contiguous U.S. EGUs split out by fuel type. The spatial differences between coal EGU, natural gas EGU, and other EGU contributions reflect the varying location and magnitude of emissions from each type of EGU.

Figure J-2: Maps of California EGU Tag contributions to a) April-September Seasonal Average MDA8 Ozone (ppb); b) Annual Average $PM_{2.5}$ Nitrate (µg/m^3); c) Annual Average $PM_{2.5}$ sulfate (µg/m^3); d) Annual Average $PM_{2.5}$ Organic Aerosol (µg/m^3)

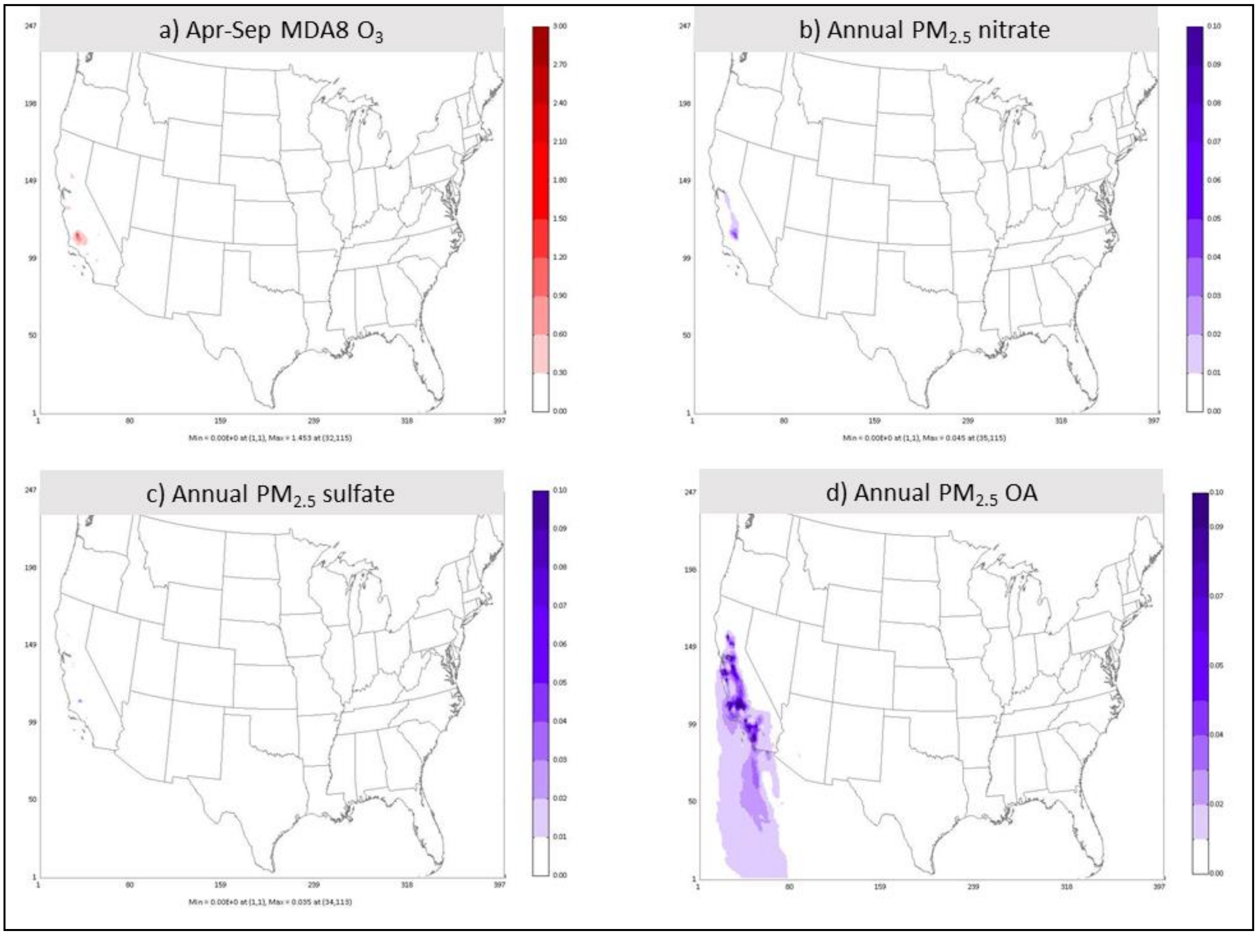


Figure J-3: Maps of Georgia EGU Tag contributions to a) April-September Seasonal Average MDA8 Ozone (ppb); b) Annual Average $PM_{2.5}$ Nitrate (µg/m³); c) Annual Average $PM_{2.5}$ sulfate (µg/m³); d) Annual Average $PM_{2.5}$ Organic Aerosol (µg/m³)

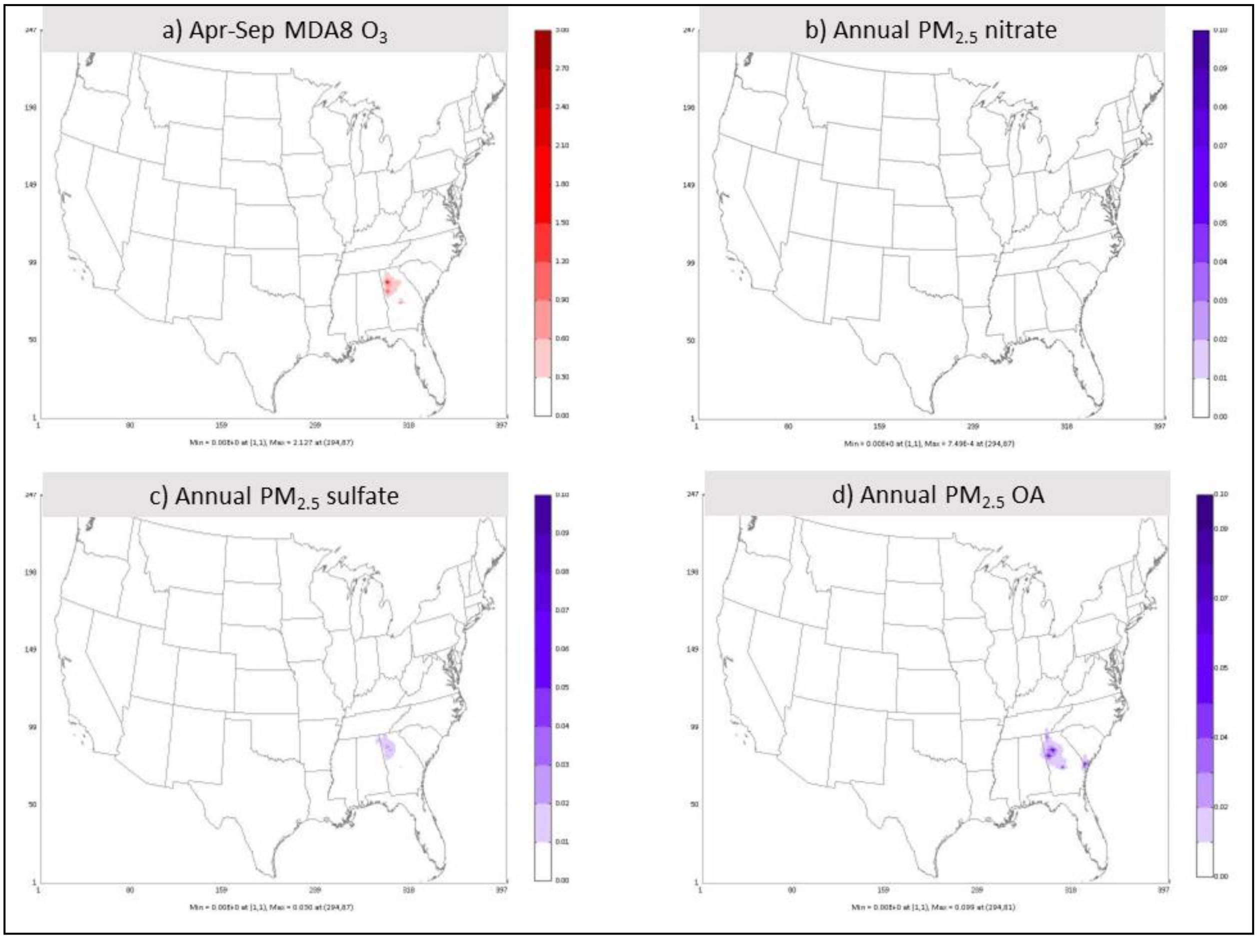


Figure J-4: Maps of Iowa EGU Tag contributions to a) April-September Seasonal Average MDA8 Ozone (ppb); b) Annual Average $PM_{2.5}$ Nitrate (μg/m^3); c) Annual Average $PM_{2.5}$ sulfate (μg/m^3); d) Annual Average $PM_{2.5}$ Organic Aerosol (μg/m^3)

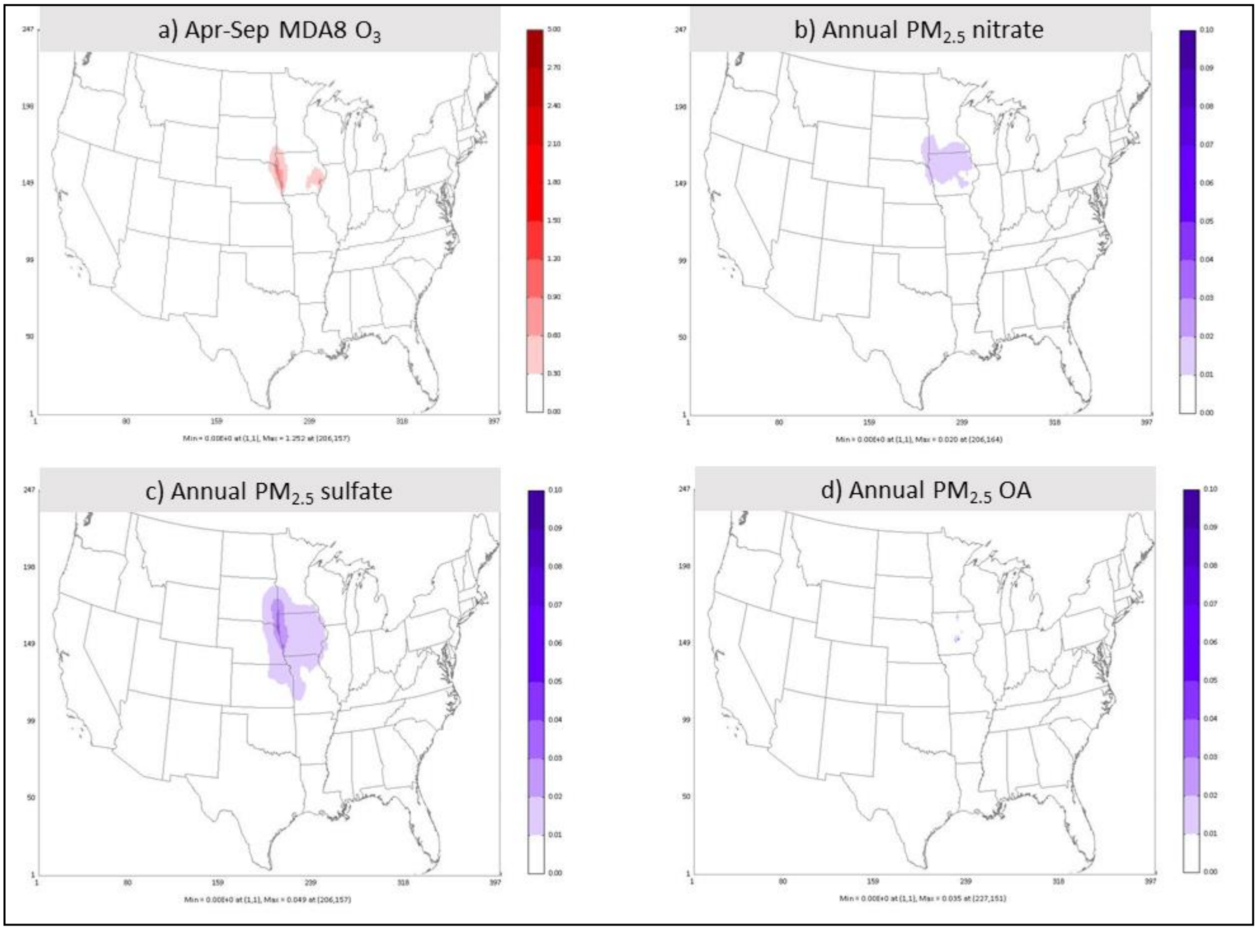


Figure J-5: Maps of Ohio EGU Tag contributions to a) April-September Seasonal Average MDA8 Ozone (ppb); b) Annual Average $PM_{2.5}$ Nitrate (µg/m^3); c) Annual Average $PM_{2.5}$ sulfate (µg/m^3); d) Annual Average $PM_{2.5}$ Organic Aerosol (µg/m^3)

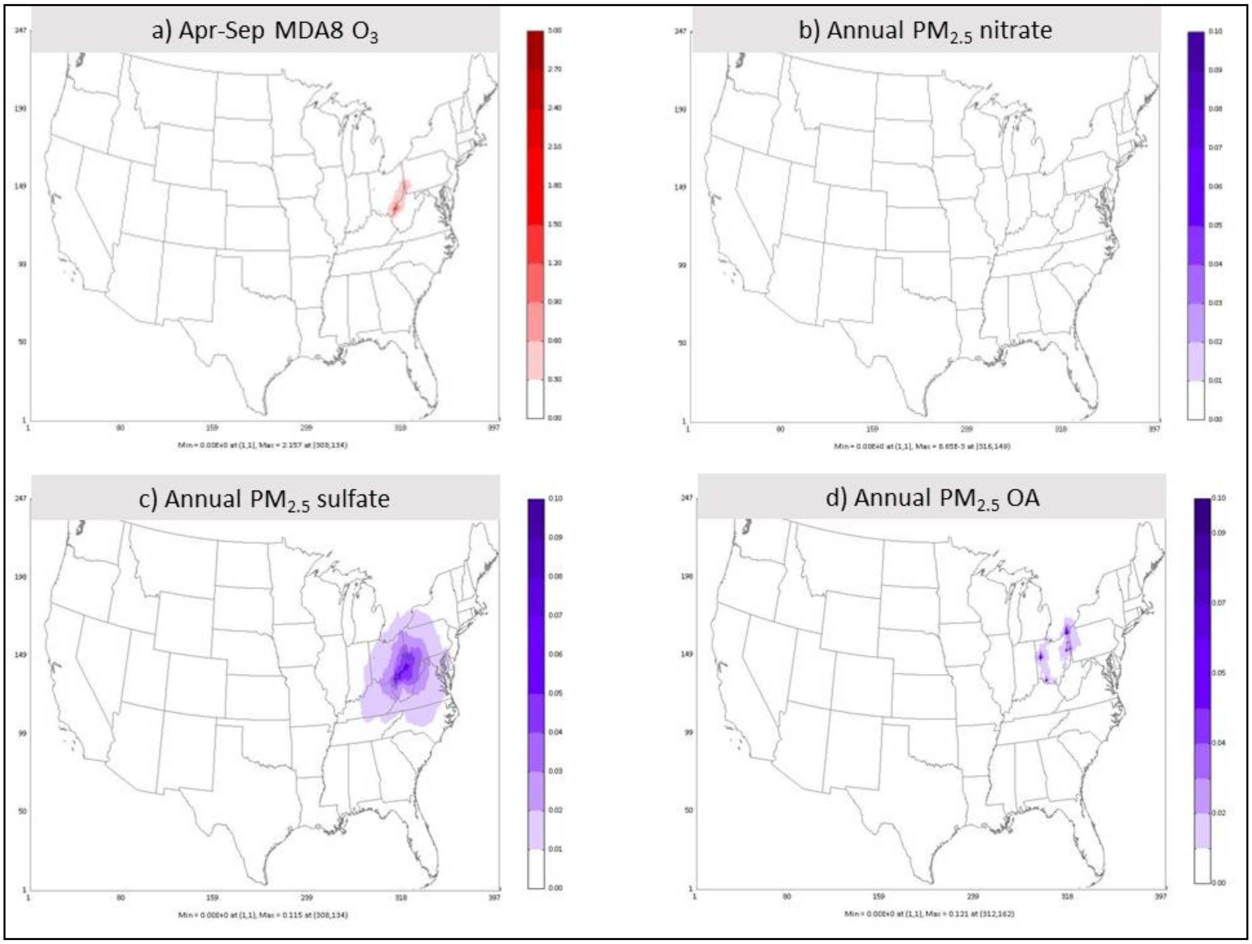


Figure J-6: Maps of National EGU Tag contributions to April-September Seasonal Average MDA8 ozone (ppb) by fuel for a) Coal EGUs; b) Natural Gas EGUs; c) All Other EGUs

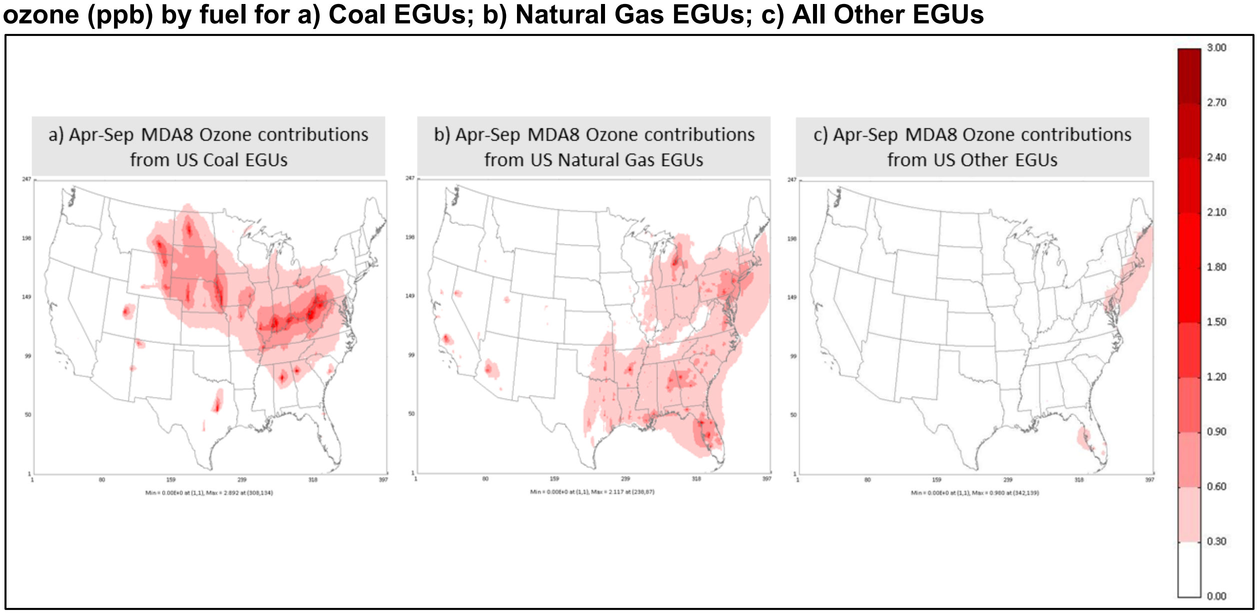
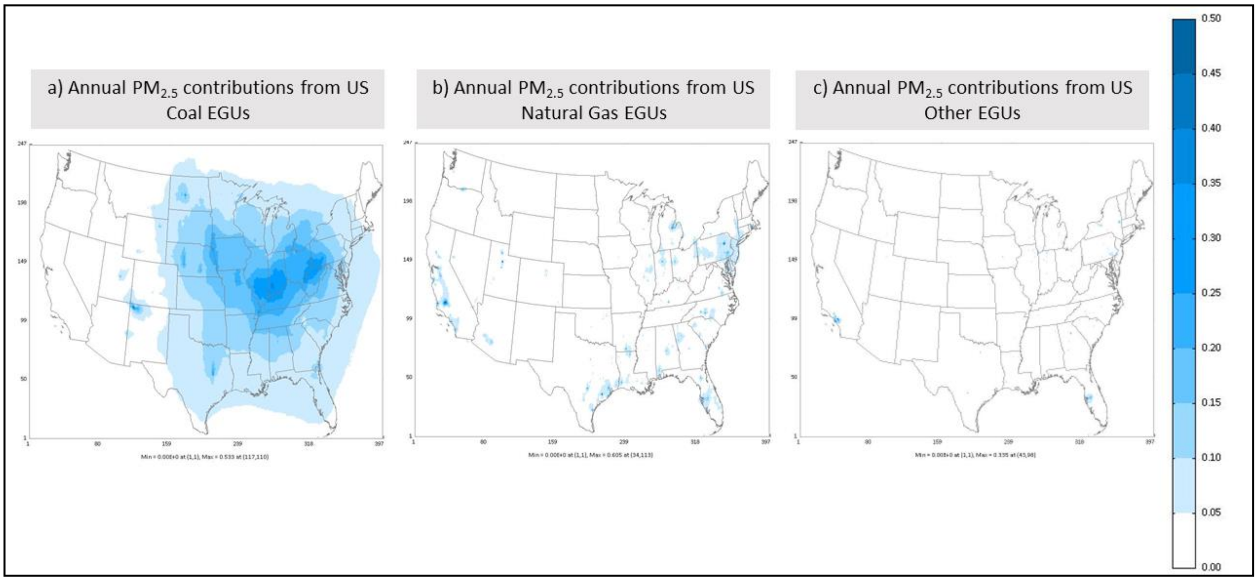


Figure J-7: Maps of National EGU Tag contributions to Annual Average $PM_{2.5}$ (µg/m3) by fuel for a) Coal EGUs; b) Natural Gas EGUs; c) All Other EGUs



J.2 Applying Modeling Outputs to Create Spatial Fields

In this section we describe the method for creating spatial fields of AS-MO3 and annual average $PM_{2.5}$ based on the 2016 and future year modeling. The foundational data include (1) ozone and speciated $PM_{2.5}$ concentrations in each model grid cell from the 2016 and the future year modeling, (2) ozone and speciated PM2.5 contributions in the future year of EGUs emissions from each state in each model grid cell[162], (3) future year emissions from EGUs that were input to the contribution modeling (Table J-1, Table J-2, and Table J-3), and (4) the EGU emissions from IPM for baseline and policy scenarios in year of analysis (2028, 2030, 2035, 2040, 2045, and 2050). The method to create spatial fields applies scaling factors to gridded source apportionment contributions based on emissions changes between future year projections and the baseline and the control cases to the modeled contributions. This method is described in detail below.

Spatial fields of ozone and $PM_{2.5}$ in the future year were created based on "fusing" modeled data with measured concentrations at air quality monitoring locations. To create the spatial fields for each future emissions scenario these fused future year model fields are used in combination with future year source apportionment modeling and the EGU emissions for each scenario and analytic year[163]. Contributions from each state and fuel EGU contribution "tag" were scaled based on the ratio of emissions in the year/scenario being evaluated to the emissions in the modeled future year scenario. Contributions from tags representing sources other than EGUs are held constant at 2026 levels for each of the scenarios and year. For each scenario and year analyzed, the scaled contributions from all sources were summed together to create a gridded surface of total modeled ozone and $PM_{2.5}$. The process is described in a step-by-step manner below starting with the methodology for creating AS-MO3 spatial fields followed by a description of the steps for creating annual $PM_{2.5}$ spatial fields.

162 Contributions from EGUs were modeled using projected emissions for the future year modeled scenario. The resulting contributions were used to construct spatial fields in 2028, 2030, 2035, 2040, 2045, and 2050.

163 *i.e.*, 2028, 2030, 2035, 2040, 2045, and 2050

J.2.1 Ozone

1. Create fused spatial fields of future year AS-MO3 incorporating information from the air quality modeling and from ambient measured monitoring data. The enhanced Voronoi Neighbor Average (eVNA) technique (Gold et al., 1997; US EPA, 2007; Ding et al., 2015) was applied to ozone model predictions in conjunction with measured data to create modeled/measured fused surfaces that leverage measured concentrations at air quality monitor locations and model predictions at locations with no monitoring data.
   1.1. The AS-MO3 eVNA spatial fields are created for the 2016 base year with EPA's software package, Software for the Modeled Attainment Test – Community Edition (SMAT-CE) using 3 years of monitoring data (2015-2017) and the 2016 modeled data.
   1.2. The model-predicted spatial fields (*i.e.*, not the eVNA fields) of AS-MO3 in 2016 were paired with the corresponding model-predicted spatial fields in the future year to calculate the ratio of AS-MO3 between 2016 and the future year in each model grid cell.
   1.3. To create a gridded future year eVNA surfaces, the spatial fields of 2016/future year ratios created in step (1.2) were multiplied by the corresponding eVNA spatial fields for 2016 created in step (1.1) to produce an eVNA AS-MO3 spatial field for the future year using equation 1.

$$eVNA_{g,future} = \left(eVNA_{g,2016}\right) \times \frac{Model_{g,future}}{Model_{g,2016}} \qquad \text{Eq-1}$$

- $eVNA_{g,future}$ is the eVNA concentration of AS-MO3 or $PM_{2.5}$ component species in grid-cell, g, in the future year
- $eVNA_{g,2016}$ is the eVNA concentration of AS-MO3 or $PM_{2.5}$ component species in grid-cell, g, in 2016
- $Model_{g,future}$ is the CAMx modeled concentration of AS-MO3 or $PM_{2.5}$ component species in grid-cell, g, in the future year
- $Model_{g,2016}$ is the CAMx modeled concentration of AS-MO3 or $PM_{2.5}$ component in grid-cell, g, in 2016

2. Create spatial fields of total EGU AS-MO3 contributions for each combination of scenario and analytic year evaluated.
   2.1. Use the EGU ozone season NOX emissions for the 2028 baseline and the corresponding future year modeled EGU ozone season emissions (Table J-1, Table J-2, and Table J-3) to calculate the ratio of 2028 baseline emissions to future year modeled emissions for each EGU tag (*i.e.*, an ozone scaling factor calculated for each state-fuel combination)[164]. These scaling factors are provided in Table J-4, Table J-5, and Table J-11.
   2.2. Calculate adjusted gridded AS-MO3 EGU contributions that reflect differences in state-fuel EGU NOX emissions between the modeled future year and the 2028 baseline by multiplying the ozone season NOX scaling factors by the corresponding gridded AS-MO3 ozone contributions from each state-fuel EGU tag.
   2.3. Add together the adjusted AS-MO3 contributions for each EGU-state tag to produce spatial

164 Preliminary testing of this methodology showed unstable results when very small magnitudes of emissions were tagged especially when being scaled by large factors. To mitigate this issue, in cases where state-fuel EGU tags were associated with no or very small emissions, tags were combined into multi-state regions.

fields of adjusted EGU totals for the 2028 baseline.[165]

2.4. Repeat steps 2.1 through 2.3 for the 2028 final rule scenario and for the baseline and final rule scenarios for each additional analytic year. The scaling factors for the baseline scenarios and the final rule scenarios are provided in Table J-4, Table J-5, and Table J-11.

3. Create a gridded spatial field of AS-MO3 associated with IPM emissions for the 2028 baseline by combining the EGU AS-MO3 contributions from steps (2.3) with the corresponding contributions to AS-MO3 from all other sources. Repeat for each of the EGU contributions created in step (2.4) to create separate gridded spatial fields for the rest of the baseline and final rule scenarios for each analytic year.

Steps 2 and 3 in combination can be represented by equation 2:

$$AS\text{-}MO3_{g,i,y} = eVNA_{g,y} \times \left(\frac{C_{g,BC}}{C_{g,Tot}} + \frac{C_{g,int}}{C_{g,Tot}} + \frac{C_{g,bio}}{C_{g,Tot}} + \frac{C_{g,fires}}{C_{g,Tot}} + \frac{C_{g,USanthro}}{C_{g,Tot}} + \sum_{t=1}^{T} \frac{C_{EGUVOC,g,t}}{C_{g,Tot}} + \sum_{t=1}^{T} \frac{C_{EGUNOx,g,t}\, S_{NOx,t,i,y}}{C_{g,Tot}} \right) \quad \text{Eq-2}$$

- $AS\text{-}MO3_{g,i,y}$ is the estimated fused model-obs AS-MO3 for grid-cell, "g", scenario, "i"[166], and year, "y"[167];
- $eVNA_{g,future}$ is the future year eVNA future year AS-MO3 concentration for grid-cell "g" calculated using Eq-1.
- $C_{g,Tot}$ is the total modeled AS-MO3 for grid-cell "g" from all sources in the future year source apportionment modeling
- $C_{g,BC}$ is the future year AS-MO3 modeled contribution from the modeled boundary inflow;
- $C_{g,int}$ is the future year AS-MO3 modeled contribution from international emissions within the modeling domain;
- $C_{g,bio}$ is the future year AS-MO3 modeled contribution from biogenic emissions;
- $C_{g,fires}$ is the future year AS-MO3 modeled contribution from fires;
- $C_{g,USanthro}$ is the total future year AS-MO3 modeled contribution from U.S. anthropogenic sources other than EGUs;
- $C_{EGUVOC,g,t}$ is the future year AS-MO3 modeled contribution from EGU emissions of VOCs from state, "t";

[165] The contributions from the unaltered O3V tags are added to the summed adjusted O3N EGU tags.

[166] Scenario "i" can represent either the baseline or the final rule scenario

[167] Analytic year "y" can represent 2028, 2030, 2035, 2040, 2045 or 2050

- $C_{EGUNOx,g,t}$ is the future year AS-MO3 modeled contribution from EGU emissions of NO_X from tag, "t"; and
- $S_{NOx,t,i,y}$ is the EGU NO_X scaling factor for tag, "t", scenario "i", and year, "y".

J.2.2 $PM_{2.5}$

4. Create fused spatial fields of future year annual $PM_{2.5}$ component species incorporating information from the air quality modeling and from ambient measured monitoring data. The eVNA technique was applied to $PM_{2.5}$ component species model predictions in conjunction with measured data to create modeled/measured fused surfaces that leverage measured concentrations at air quality monitor locations and model predictions at locations with no monitoring data.
   - 4.1. The quarterly average $PM_{2.5}$ component species eVNA spatial fields are created for the 2016 base year with EPA's SMAT-CE software package using 3 years of monitoring data (2015-2017) and the 2016 modeled data.
   - 4.2. The model-predicted spatial fields (*i.e.*, not the eVNA fields) of quarterly average $PM_{2.5}$ component species in 2016 were paired with the corresponding model-predicted spatial fields in the future year to calculate the ratio of $PM_{2.5}$ component species between 2016 and the future year in each model grid cell.
   - 4.3. To create a gridded future year eVNA surfaces, the spatial fields of 2016/future year ratios created in step (4.2) were multiplied by the corresponding eVNA spatial fields for 2016 created in step (4.1) to produce an eVNA annual average $PM_{2.5}$ component species spatial field for the future year using (Eq-1).
5. Create spatial fields of total EGU speciated $PM_{2.5}$ contributions for each year/scenario evaluated.
   - 5.1. Use the annual total NOX, SO2 and PM2.5 emissions for the 2028 baseline scenario and the corresponding future year modeled EGU NOX, SO¬2 and PM2.5 emissions to calculate the ratio of 2028 baseline emissions to future year modeled emissions for each EGU state-fuel contribution tag (*i.e.*, annual NOX, SO2 and PM2.5 scaling factors calculated for each state and fuel combination). These scaling factors are provided in Table J-6 through Table J-11.
   - 5.2. Calculate adjusted gridded annual $PM_{2.5}$ component species EGU contributions that reflect differences in state-EGU NO_X, SO_2 and primary $PM_{2.5}$ emissions between the modeled future year and the 2028 baseline by multiplying the annual NO_X, SO_2 and $PM_{2.5}$ scaling factors by the corresponding annual gridded $PM_{2.5}$ component species contributions from each state-fuel EGU tag[168].
   - 5.3. Add together the adjusted $PM_{2.5}$ contributions of for each EGU state-fuel tag to produce spatial fields of adjusted EGU totals for each $PM_{2.5}$ component species.
   - 5.4. Repeat steps 5.1 through 5.3 for the 2028 final rule scenario and for the baseline and final rule scenarios for each additional analytic year. The scaling factors for all $PM_{2.5}$ component species for the baseline and the final rule scenarios are provided in Table J-6 through Table J-11.
6. Create gridded spatial fields of each $PM_{2.5}$ component species for the 2028 baseline by combining the EGU annual $PM_{2.5}$ component species contributions from step (5.3) with the corresponding contributions

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[168] Scaling factors for components that are formed through chemical reactions in the atmosphere were created as follows: scaling factors for sulfate were based on relative changes in annual SO_2 emissions; scaling factors for nitrate were based on relative changes in annual NO_X emissions. Scaling factors for $PM_{2.5}$ components that are emitted directly from the source (OA, EC, crustal) were based on the relative changes in annual primary $PM_{2.5}$ emissions between the future year modeled emissions and the baseline and the final rule scenarios in each year.

to annual $PM_{2.5}$ component species from all other sources. Repeat for each of the EGU contributions created in step (5.4) to create separate gridded spatial fields for the rest of the baseline and policy scenarios and analytic years.

7. Create gridded spatial fields of total $PM_{2.5}$ mass by combining the component species surfaces for sulfate, nitrate, organic aerosol, elemental carbon and crustal material with ammonium, and particle-bound. Ammonium and particle-bound water concentrations are calculated for each scenario based on nitrate and sulfate concentrations along with the ammonium degree of neutralization in the base year modeling in accordance with equations from the SMAT-CE modeling software.

Steps 5 and 6 result in equation 3 for $PM_{2.5}$ component species: sulfate, nitrate, organic aerosol, elemental carbon and crustal material.

$$PM_{s,g,i,y} = eVNA_{s,g,y} \times \left(\frac{C_{s,g,BC}}{C_{s,g,Tot}} + \frac{C_{s,g,int}}{C_{s,g,Tot}} + \frac{C_{s,g,bio}}{C_{s,g,Tot}} + \frac{C_{s,g,fires}}{C_{s,g,Tot}} + \frac{C_{s,g,USanthro}}{C_{s,g,Tot}} + \sum_{t=1}^{T} \frac{C_{EGUs,g,t}\, S_{s,t,i,y}}{C_{s,g,Tot}} \right) \qquad \text{Eq-3}$$

- $PM_{s,g,i,y}$ is the estimated fused model-obs PM component species "s" for grid-cell, "g", scenario, "i"[169], and year, "y"[170];
- $eVNA_{s,g,future}$ is the future year eVNA PM concentration for component species "s" in grid-cell "g" calculated using Eq-1.
- $C_{s,g,Tot}$ is the total modeled PM component species "s" for grid-cell "g" from all sources in the future year source apportionment modeling
- $C_{s,g,BC}$ is the future year PM component species "s" modeled contribution from the modeled boundary inflow;
- $C_{s,g,int}$ is the future year PM component species "s" modeled contribution from international emissions within the modeling domain;
- $C_{s,g,bio}$ is the future year PM component species "s" modeled contribution from biogenic emissions;
- $C_{s,g,fires}$ is the future year PM component species "s" modeled contribution from fires;
- $C_{s,g,USanthro}$ is the total future year PM component species "s" modeled contribution from U.S. anthropogenic sources other than EGUs;

169 Scenario "i" can represent either baseline or the final rule scenario.

170 Analytic year "y" can represent 2028, 2030, 2035, 2040, 2045, or 2050

- $C_{EGUs,g,t}$ is the future year PM component species "s" modeled contribution from EGU emissions of NO_X, SO_2, or primary $PM_{2.5}$ from tag, "t"; and

- $S_{s,t,i,y}$ is the EGU scaling factor for component species "s", tag, "t", scenario "i", and year, "y". Scaling factors for nitrate are based on annual NO_X emissions, scaling factors for sulfate are based on annual SO_2 emissions, scaling factors for primary $PM_{2.5}$ components are based on primary $PM_{2.5}$ emissions.

Selected maps showing changes in air quality concentrations between the final rule and the baseline are provided later in this appendix.

J.3 Scaling Factors Applied to Source Apportionment Tags

Table J-4: Baseline and Final Rule Scenario Ozone Scaling Factors for Coal EGU Tags

State Tag	Baseline						Final Rule					
	2028	2030	2035	2040	2045	2050	2028	2030	2035	2040	2045	2050
ALMS[a]	1.40	1.65	1.47	1.47	0.38	0.38	1.19	1.65	1.47	1.47	0.38	0.38
AZ	0.01	1.43	1.13	0.00	0.00	0.98	0.01	1.40	1.15	0.00	0.00	0.98
CA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO	139.01	1.28	1.98	1.98	1.98	1.98	139.01	1.28	1.98	1.98	1.98	1.98
CT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FL	0.47	1.24	0.10	0.10	0.03	0.03	0.44	0.93	0.10	0.10	0.03	0.03
GA	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00
IA	1.17	1.18	0.77	0.46	0.42	0.81	1.17	1.18	0.72	0.46	0.42	0.81
ID	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IL	0.97	0.96	0.81	0.14	0.00	0.00	0.97	0.96	0.77	0.10	0.00	0.00
IN	1.35	0.76	0.19	0.19	0.00	0.00	1.35	0.77	0.19	0.19	0.00	0.00
KY	0.79	0.95	0.97	0.83	0.06	0.15	0.65	0.84	0.60	0.57	0.00	0.15
MA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MDPA[b]	3.14	3.17	2.58	1.06	1.30	1.31	3.07	3.07	2.53	1.06	1.30	1.37
ME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MI	0.75	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.00	0.00	0.00	0.00
MN	2.41	2.25	0.00	0.00	0.00	0.00	2.41	2.25	0.00	0.00	0.00	0.00
MO	2.72	1.57	0.67	0.31	0.27	0.56	2.68	1.59	0.66	0.28	0.26	0.52
MT	1.07	1.12	1.11	0.99	0.00	0.78	1.07	1.12	1.10	0.99	0.00	0.77
NC	9.89	6.41	2.86	1.50	2.86	3.98	12.69	9.43	2.86	0.00	2.57	3.98
ND	1.09	1.08	0.25	0.24	0.01	0.02	1.08	1.07	0.25	0.24	0.01	0.02
NEKS[c]	1.79	1.87	0.76	0.59	0.41	0.68	1.55	1.61	0.76	0.59	0.39	0.68
NH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NM	0.98	0.98	0.01	0.01	0.01	0.01	0.98	0.98	0.01	0.01	0.01	0.01
NV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OH	0.58	1.07	0.00	0.00	0.00	0.70	0.57	0.77	0.00	0.00	0.00	0.68
OR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SC	0.81	2.22	3.18	3.18	0.00	0.00	0.48	2.21	3.18	3.18	0.00	0.00
SD	0.87	1.33	0.00	0.00	0.00	0.00	0.87	1.33	0.00	0.00	0.00	0.00
TN	3.89	0.01	0.00	0.00	0.00	0.00	3.79	0.01	0.00	0.00	0.00	0.00
TX-reg[d]	2.69	2.03	1.54	0.95	0.44	1.40	2.64	2.15	1.56	0.95	0.44	1.39

Table J-4: Baseline and Final Rule Scenario Ozone Scaling Factors for Coal EGU Tags

State Tag	Baseline						Final Rule					
	2028	2030	2035	2040	2045	2050	2028	2030	2035	2040	2045	2050
UT	1.00	0.06	0.06	0.06	0.04	0.00	1.00	0.06	0.06	0.06	0.04	0.00
VA	0.65	0.45	0.00	0.00	0.00	0.00	0.65	0.41	0.00	0.00	0.00	0.00
VT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WI	1.66	2.16	0.36	0.00	0.00	0.66	1.66	2.16	0.36	0.00	0.00	0.66
WV	0.92	1.16	0.92	0.27	0.10	0.10	0.76	1.00	0.58	0.27	0.10	0.10
WY	1.26	1.12	1.12	0.61	0.53	0.52	1.26	1.12	1.12	0.61	0.53	0.52
ALMS	1.40	1.65	1.47	1.47	0.38	0.38	1.19	1.65	1.47	1.47	0.38	0.38

[a]ALMS: AL, MS

[b]MDPA: MD, PA

[c]NEKS: NE, KS

[d]TX-reg: AR, LA, OK, TX

Table J-5: Baseline and Final Rule Scenario Ozone Scaling Factors for Natural Gas EGU Tags

State Tag	Baseline						Final Rule					
	2028	2030	2035	2040	2045	2050	2028	2030	2035	2040	2045	2050
AL	0.53	0.61	0.49	0.39	0.27	0.37	0.52	0.50	0.49	0.38	0.27	0.36
AR	0.65	0.68	0.43	0.20	0.10	0.18	0.65	0.68	0.43	0.19	0.10	0.18
AZ	0.69	0.68	0.67	0.68	0.45	0.69	0.69	0.68	0.67	0.68	0.45	0.69
CA	0.92	0.94	0.85	0.52	0.02	0.04	0.92	0.94	0.85	0.51	0.02	0.04
CO	3.26	0.63	0.50	0.48	0.12	0.17	3.27	0.63	0.50	0.47	0.12	0.17
CT	1.04	0.98	0.89	0.00	0.01	0.01	1.05	0.98	0.89	0.00	0.01	0.01
DC	0.86	0.59	0.33	0.21	0.16	0.16	0.86	0.59	0.33	0.21	0.16	0.16
DE	0.79	0.80	0.38	0.37	0.38	0.43	0.77	0.78	0.38	0.37	0.32	0.42
FL	1.08	1.03	1.04	0.89	0.66	0.65	1.07	1.04	1.03	0.89	0.65	0.64
GA	0.58	0.54	0.52	0.42	0.38	0.41	0.58	0.53	0.52	0.41	0.38	0.41
IA	0.53	0.42	0.16	0.04	0.01	0.04	0.53	0.43	0.15	0.04	0.01	0.05
ID	0.60	0.90	0.90	0.90	0.04	0.09	0.59	0.90	0.88	0.88	0.03	0.09
IL	0.69	0.61	0.42	0.21	0.00	0.00	0.67	0.62	0.41	0.20	0.00	0.00
IN	0.75	0.63	0.38	0.20	0.15	0.21	0.74	0.64	0.38	0.20	0.16	0.21
KS	1.38	1.32	0.25	0.14	0.10	0.03	1.39	1.33	0.33	0.15	0.11	0.03
KY	0.87	0.81	0.69	0.57	0.38	0.49	0.96	0.90	0.83	0.66	0.45	0.59
LA	1.04	1.00	0.72	0.45	0.41	0.56	1.03	1.00	0.71	0.45	0.40	0.56
MA	0.60	0.67	0.66	0.84	0.47	0.64	0.59	0.68	0.66	0.80	0.45	0.64
MD	1.51	1.33	1.12	0.84	0.79	1.04	1.34	1.24	1.10	0.83	0.72	1.04
ME	1.16	1.15	0.59	0.63	0.36	0.56	1.16	1.15	0.59	0.64	0.36	0.56
MI	0.68	0.70	0.55	0.41	0.23	0.40	0.67	0.63	0.54	0.40	0.23	0.40
MN	0.92	0.84	0.34	0.17	0.13	0.21	0.85	0.78	0.34	0.17	0.13	0.21
MO	0.59	0.59	0.20	0.08	0.04	0.06	0.57	0.57	0.20	0.08	0.04	0.06
MS	0.64	0.62	0.50	0.45	0.29	0.34	0.63	0.59	0.50	0.44	0.26	0.33
MT	0.95	1.10	0.08	0.14	0.02	0.24	0.95	0.79	0.08	0.14	0.02	0.34
NC	0.77	0.59	0.68	0.63	0.51	0.59	0.73	0.55	0.69	0.62	0.48	0.59
ND	0.85	1.85	0.34	0.96	0.14	0.66	0.85	1.84	0.34	0.96	0.14	0.16
NE	5.91	5.92	0.28	0.87	0.02	1.02	5.80	5.98	0.33	0.87	0.05	1.02
NH	0.67	0.51	0.41	0.41	0.41	0.40	0.68	0.51	0.41	0.41	0.41	0.40
NJ	0.81	0.85	0.61	0.49	0.46	0.75	0.77	0.85	0.59	0.48	0.45	0.74
NM	1.00	0.84	0.77	0.35	0.47	0.40	1.00	0.84	0.77	0.33	0.48	0.40

Table J-5: Baseline and Final Rule Scenario Ozone Scaling Factors for Natural Gas EGU Tags

State Tag	Baseline						Final Rule					
	2028	2030	2035	2040	2045	2050	2028	2030	2035	2040	2045	2050
NV	0.33	0.25	0.19	0.21	0.12	0.09	0.33	0.25	0.19	0.21	0.11	0.09
NY	1.03	0.99	0.65	0.28	0.28	0.28	0.97	0.97	0.62	0.28	0.28	0.28
OH	1.02	0.97	0.84	0.71	0.62	0.80	1.11	1.07	0.94	0.80	0.71	0.81
OK	1.69	1.57	0.48	0.33	0.32	0.32	1.65	1.56	0.48	0.33	0.32	0.33
OR	63.29	0.00	0.00	0.00	0.00	0.00	63.38	0.00	0.00	0.00	0.00	0.00
PA	0.79	0.69	0.34	0.24	0.23	0.35	0.74	0.64	0.35	0.23	0.23	0.35
RI	0.69	0.75	0.71	0.88	0.89	0.46	0.69	0.75	0.72	0.88	0.89	0.46
SC	0.93	0.96	0.59	0.59	0.56	0.83	0.91	0.94	0.58	0.59	0.60	0.83
SD	0.59	0.59	0.17	0.06	0.03	0.07	0.54	0.59	0.16	0.06	0.02	0.07
TN	1.12	1.09	1.07	0.90	0.51	0.72	1.13	1.10	1.05	0.87	0.49	0.64
TX	0.99	0.89	0.47	0.28	0.15	0.32	0.98	0.88	0.47	0.28	0.15	0.32
UT	0.50	0.43	0.34	0.37	0.31	0.41	0.50	0.43	0.34	0.37	0.30	0.41
VA	0.89	0.85	0.54	0.32	0.26	0.12	0.84	0.83	0.54	0.31	0.17	0.12
VT	0.00	0.37	3.53	3.99	0.00	1.58	0.00	0.37	3.53	3.99	0.00	1.58
WA	0.08	0.23	0.79	0.74	0.02	0.02	0.08	0.23	0.85	0.74	0.02	0.02
WI	0.74	0.70	0.58	0.30	0.14	0.24	0.73	0.66	0.41	0.30	0.14	0.23
WV	1.19	1.12	0.33	0.13	0.07	2.97	1.25	1.18	0.39	0.16	0.11	2.99
WY	0.01	0.04	0.06	0.06	0.00	0.05	0.01	0.05	0.06	0.05	0.00	0.05

Table J-6: Baseline and Final Rule Scenario Nitrate Scaling Factors for Coal EGU Tags

State Tag	Baseline						Final Rule					
	2028	2030	2035	2040	2045	2050	2028	2030	2035	2040	2045	2050
AL	1.33	1.45	1.65	1.54	0.14	0.23	1.36	1.50	1.65	1.54	0.14	0.23
AR	39.93	8.30	3.83	0.71	0.28	2.49	39.48	8.53	3.83	0.71	0.28	2.51
AZ	0.47	0.97	0.59	0.20	0.15	0.69	0.47	0.97	0.60	0.19	0.15	0.69
CA	0.24	0.36	0.16	0.13	0.00	0.00	0.24	0.36	0.16	0.13	0.00	0.00
CO	25.56	0.97	0.37	0.41	0.37	0.40	25.64	0.97	0.37	0.41	0.37	0.40
CT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FL	0.89	1.20	0.26	0.26	0.14	0.18	0.76	1.01	0.26	0.26	0.14	0.18
GA	0.23	0.12	0.00	0.00	0.00	0.00	0.53	0.35	0.00	0.00	0.00	0.00
IA	1.20	1.16	0.68	0.28	0.19	0.57	1.20	1.19	0.65	0.27	0.19	0.57
ID	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IL	0.98	0.92	0.62	0.14	0.00	0.00	0.98	0.93	0.58	0.10	0.00	0.00
IN	1.29	0.64	0.11	0.11	0.00	0.00	1.36	0.68	0.11	0.11	0.00	0.00
KS	45.15	46.03	3.08	3.08	0.00	0.00	36.98	39.58	3.08	3.08	0.00	0.00
KY	1.38	1.12	1.15	1.00	0.07	0.16	1.19	1.01	0.77	0.70	0.05	0.16
LA	24.63	16.33	25.37	13.43	2.22	16.83	24.63	16.56	26.42	13.43	2.22	16.83
MA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MD	3.54	3.54	3.54	3.54	2.97	3.42	3.54	3.54	3.54	3.54	2.97	3.42
ME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MI	0.74	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.00	0.00	0.00	0.00
MN	2.97	2.31	0.00	0.00	0.00	0.00	2.97	2.25	0.00	0.00	0.00	0.00
MO	1.41	1.06	0.43	0.04	0.03	0.09	1.39	1.06	0.43	0.04	0.03	0.08
MS	4.02	3.60	1.06	1.00	1.00	1.00	1.94	3.60	1.06	1.00	1.00	1.00
MT	1.07	1.09	1.08	1.02	0.38	0.79	1.07	1.10	1.08	1.02	0.38	0.79
NC	19.19	11.95	3.66	3.51	3.84	4.16	21.30	11.96	3.68	2.58	3.69	4.16

Table J-6: Baseline and Final Rule Scenario Nitrate Scaling Factors for Coal EGU Tags

State Tag	Baseline						Final Rule					
	2028	2030	2035	2040	2045	2050	2028	2030	2035	2040	2045	2050
ND	1.03	1.03	0.25	0.25	0.01	0.02	1.03	1.03	0.26	0.25	0.01	0.02
NE	1.14	1.13	0.61	0.37	0.18	0.46	1.03	1.02	0.61	0.37	0.17	0.46
NH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NM	0.99	0.99	0.01	0.01	0.01	0.01	0.99	0.99	0.01	0.01	0.01	0.01
NV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OH	0.90	0.94	0.19	0.00	0.00	0.40	0.81	0.84	0.25	0.00	0.00	0.40
OK	12.10	5.08	3.11	3.11	1.03	1.03	11.50	5.19	3.11	3.11	1.03	1.03
OR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PA	3.05	2.94	2.61	1.19	1.16	1.23	2.98	2.88	2.56	1.20	1.15	1.22
RI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SC	1.15	1.92	2.98	2.98	0.00	0.00	0.98	1.91	2.98	2.98	0.00	0.00
SD	0.93	1.11	0.00	0.00	0.00	0.00	0.93	1.11	0.00	0.00	0.00	0.00
TN	7.49	1.00	0.00	0.00	0.00	0.00	7.39	1.00	0.00	0.00	0.00	0.00
TX	1.02	1.13	0.87	0.47	0.12	0.42	1.03	1.20	0.88	0.47	0.12	0.41
UT	3.50	0.09	0.09	0.09	0.06	0.04	3.50	0.09	0.09	0.09	0.06	0.04
VA	0.67	0.41	0.12	0.00	0.00	0.00	0.67	0.31	0.12	0.00	0.00	0.00
VT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WI	1.84	2.07	0.38	0.00	0.00	0.27	1.81	2.10	0.37	0.00	0.00	0.27
WV	1.25	1.30	0.97	0.27	0.09	0.10	1.06	1.16	0.61	0.27	0.09	0.10
WY	1.32	1.15	1.14	0.61	0.48	0.51	1.32	1.15	1.14	0.61	0.48	0.51

Table J-7: Baseline and Final Rule Scenario Nitrate Scaling Factors for Natural Gas EGU Tags

State Tag	Baseline						Final Rule					
	2028	2030	2035	2040	2045	2050	2028	2030	2035	2040	2045	2050
AL	0.59	0.60	0.45	0.27	0.16	0.23	0.58	0.53	0.46	0.27	0.16	0.23
AR	0.56	0.68	0.38	0.13	0.06	0.12	0.56	0.68	0.38	0.13	0.06	0.12
AZ	0.73	0.85	0.83	0.75	0.37	0.62	0.73	0.85	0.82	0.74	0.38	0.62
CA	0.76	0.88	0.97	0.67	0.16	0.19	0.76	0.89	0.97	0.67	0.15	0.19
CO	2.02	0.71	0.72	0.76	0.30	0.51	2.02	0.71	0.72	0.74	0.30	0.50
CT	0.92	0.81	0.66	0.00	0.01	0.01	0.92	0.81	0.66	0.00	0.01	0.01
DC	0.63	0.47	0.26	0.18	0.13	0.11	0.63	0.47	0.26	0.17	0.13	0.12
DE	0.79	0.76	0.33	0.29	0.30	0.42	0.77	0.70	0.33	0.29	0.26	0.41
FL	1.11	1.06	1.01	0.73	0.49	0.51	1.10	1.05	1.00	0.72	0.49	0.50
GA	0.68	0.63	0.54	0.29	0.22	0.26	0.67	0.62	0.54	0.29	0.22	0.26
IA	0.49	0.42	0.13	0.03	0.01	0.04	0.49	0.42	0.13	0.03	0.01	0.04
ID	1.02	1.36	1.39	1.24	0.60	0.84	1.00	1.35	1.36	1.21	0.59	0.84
IL	0.54	0.54	0.29	0.12	0.00	0.00	0.53	0.54	0.29	0.12	0.00	0.00
IN	0.67	0.59	0.34	0.12	0.08	0.12	0.65	0.59	0.34	0.12	0.09	0.12
KS	0.96	0.87	0.20	0.07	0.05	0.02	0.96	0.92	0.25	0.08	0.06	0.02
KY	0.81	0.76	0.46	0.25	0.15	0.22	0.88	0.80	0.55	0.30	0.17	0.27
LA	0.96	0.94	0.61	0.27	0.24	0.34	0.95	0.93	0.60	0.27	0.24	0.34
MA	0.64	0.66	0.54	0.61	0.33	0.52	0.63	0.67	0.54	0.58	0.32	0.52
MD	1.47	1.35	1.05	0.72	0.66	0.82	1.36	1.27	1.03	0.72	0.61	0.85
ME	1.64	1.34	0.63	0.58	0.34	0.55	1.64	1.37	0.63	0.60	0.34	0.55
MI	0.65	0.71	0.43	0.30	0.15	0.28	0.65	0.64	0.43	0.28	0.15	0.27

Table J-7: Baseline and Final Rule Scenario Nitrate Scaling Factors for Natural Gas EGU Tags

State Tag	Baseline						Final Rule					
	2028	2030	2035	2040	2045	2050	2028	2030	2035	2040	2045	2050
MN	1.02	0.95	0.36	0.15	0.09	0.18	0.97	0.90	0.36	0.15	0.09	0.18
MO	0.52	0.52	0.19	0.06	0.03	0.05	0.50	0.51	0.19	0.06	0.03	0.05
MS	0.61	0.56	0.36	0.24	0.15	0.19	0.58	0.53	0.35	0.23	0.13	0.18
MT	0.66	0.80	0.05	0.08	0.01	0.14	0.66	0.61	0.05	0.08	0.01	0.20
NC	0.89	0.67	0.72	0.55	0.47	0.62	0.85	0.64	0.72	0.54	0.45	0.62
ND	0.66	1.32	0.26	0.60	0.09	0.41	0.66	1.33	0.26	0.60	0.09	0.10
NE	2.05	1.80	0.13	0.31	0.01	0.28	2.04	1.84	0.14	0.30	0.01	0.28
NH	0.78	0.59	0.44	0.38	0.36	0.41	0.79	0.58	0.43	0.38	0.36	0.41
NJ	0.82	0.83	0.51	0.34	0.39	0.67	0.78	0.81	0.48	0.34	0.38	0.66
NM	0.74	0.66	0.64	0.33	0.39	0.36	0.74	0.66	0.64	0.32	0.39	0.37
NV	0.50	0.39	0.44	0.40	0.23	0.18	0.50	0.39	0.44	0.40	0.23	0.18
NY	0.91	0.89	0.55	0.16	0.16	0.17	0.88	0.89	0.54	0.16	0.16	0.17
OH	1.00	0.98	0.87	0.59	0.42	0.61	1.10	1.08	0.96	0.66	0.48	0.60
OK	1.43	1.20	0.34	0.21	0.20	0.21	1.38	1.18	0.34	0.21	0.20	0.21
OR	5.58	0.96	0.50	0.00	0.00	0.00	5.58	0.96	0.49	0.00	0.00	0.00
PA	0.69	0.61	0.35	0.21	0.18	0.31	0.66	0.57	0.35	0.20	0.18	0.31
RI	0.76	0.76	0.64	0.71	0.68	0.45	0.77	0.77	0.65	0.71	0.68	0.45
SC	0.94	0.96	0.67	0.56	0.55	0.83	0.88	0.94	0.67	0.56	0.55	0.83
SD	0.55	0.55	0.16	0.06	0.04	0.08	0.51	0.57	0.15	0.06	0.04	0.08
TN	1.02	0.97	0.79	0.41	0.23	0.34	1.02	0.96	0.77	0.40	0.22	0.30
TX	0.97	0.88	0.42	0.17	0.08	0.20	0.97	0.88	0.42	0.17	0.08	0.20
UT	0.52	0.62	0.56	0.58	0.46	0.61	0.52	0.62	0.55	0.57	0.46	0.61
VA	0.84	0.80	0.43	0.20	0.15	0.09	0.80	0.75	0.42	0.20	0.10	0.09
VT	0.10	0.16	1.53	1.73	0.00	0.68	0.10	0.16	1.53	1.73	0.00	0.68
WA	0.43	0.36	0.72	0.97	0.44	0.27	0.43	0.36	0.74	0.97	0.43	0.26
WI	0.66	0.67	0.45	0.18	0.08	0.14	0.65	0.63	0.34	0.18	0.08	0.14
WV	1.02	0.89	0.22	0.08	0.04	3.06	1.10	0.95	0.30	0.14	0.09	3.06
WY	0.01	0.04	0.06	0.06	0.00	0.05	0.01	0.05	0.06	0.05	0.00	0.05

Table J-8: Baseline and Final Rule Scenario Sulfate Scaling Factors for Coal EGU Tags

State Tag	Baseline						Final Rule					
	2028	2030	2035	2040	2045	2050	2028	2030	2035	2040	2045	2050
AL	4.96	5.39	7.07	5.96	0.34	0.55	5.29	5.56	6.77	6.49	0.34	0.55
AR	118.10	7.02	4.45	1.09	0.42	2.83	116.64	7.40	4.45	1.09	0.42	2.85
AZ	0.48	1.42	1.16	0.32	0.31	1.47	0.48	1.42	1.16	0.32	0.31	1.47
CA	0.33	0.50	0.26	0.19	0.00	0.00	0.33	0.50	0.26	0.19	0.00	0.00
CO	14.31	0.98	0.20	0.22	0.21	0.23	14.40	0.98	0.20	0.22	0.21	0.23
CT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FL	0.98	1.16	0.50	0.50	0.38	0.50	0.89	1.03	0.50	0.50	0.38	0.50
GA	0.04	0.09	0.00	0.00	0.00	0.00	0.10	0.23	0.00	0.00	0.00	0.00
IA	1.31	1.25	0.78	0.32	0.21	0.66	1.31	1.27	0.75	0.31	0.21	0.66
ID	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IL	1.01	0.73	0.48	0.10	0.00	0.00	1.01	0.74	0.46	0.08	0.00	0.00
IN	0.89	0.56	0.12	0.13	0.00	0.00	0.91	0.60	0.12	0.13	0.00	0.00
KS	52.35	51.92	11.39	11.39	0.00	0.00	43.14	45.52	11.39	11.39	0.00	0.00
KY	2.68	2.12	1.88	1.71	0.09	0.21	2.41	2.01	1.47	1.39	0.06	0.21

Table J-8: Baseline and Final Rule Scenario Sulfate Scaling Factors for Coal EGU Tags

State Tag	Baseline						Final Rule					
	2028	2030	2035	2040	2045	2050	2028	2030	2035	2040	2045	2050
MA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MD	3.54	3.54	3.54	3.54	2.97	3.42	3.54	3.54	3.54	3.54	2.97	3.42
ME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MI	0.85	0.00	0.00	0.00	0.00	0.00	0.85	0.00	0.00	0.00	0.00	0.00
MN	1.68	1.47	0.00	0.00	0.00	0.00	1.68	1.43	0.00	0.00	0.00	0.00
MO	2.20	1.08	0.71	0.10	0.12	0.36	2.17	1.09	0.70	0.09	0.11	0.35
MS	4.02	3.60	1.06	1.00	1.00	1.00	1.94	3.60	1.06	1.00	1.00	1.00
MT	1.85	2.06	1.92	1.30	0.39	0.86	1.85	2.07	1.89	1.30	0.39	0.86
NC	7.31	5.14	1.88	1.67	2.03	1.38	8.56	4.95	1.89	1.36	1.90	1.38
ND	0.94	1.00	0.94	0.93	0.03	0.03	0.94	1.01	0.94	0.93	0.03	0.03
NE	0.96	0.95	0.58	0.35	0.18	0.57	0.92	0.91	0.57	0.35	0.17	0.57
NH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NM	1.00	1.00	0.01	0.01	0.01	0.01	1.00	1.00	0.01	0.01	0.01	0.01
NV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OH	0.78	0.61	0.29	0.00	0.00	0.36	0.63	0.65	0.16	0.00	0.00	0.35
OK	37.84	4.77	2.54	2.54	1.68	1.68	37.24	4.85	2.54	2.54	1.68	1.68
OR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PA	4.25	4.06	3.94	1.63	1.83	1.72	4.26	4.15	4.02	1.67	1.85	1.73
RI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SC	0.73	1.22	1.76	1.76	0.00	0.00	0.65	1.22	1.76	1.76	0.00	0.00
SD	1.05	1.27	0.00	0.00	0.00	0.00	1.06	1.27	0.00	0.00	0.00	0.00
TN	20.55	1.57	0.00	0.00	0.00	0.00	20.19	1.57	0.00	0.00	0.00	0.00
TXLA[a]	1.86	2.39	2.25	1.61	0.42	1.29	1.86	2.45	2.28	1.60	0.42	1.28
UT	0.93	0.06	0.06	0.05	0.04	0.02	0.94	0.06	0.06	0.05	0.04	0.02
VA	0.11	0.07	0.02	0.00	0.00	0.00	0.11	0.05	0.02	0.00	0.00	0.00
VT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WI	3.50	3.83	1.15	0.00	0.00	0.69	3.93	3.88	1.11	0.00	0.00	0.69
WV	1.40	1.39	1.08	0.36	0.12	0.13	1.31	1.21	0.75	0.35	0.12	0.13
WY	1.26	0.98	0.97	0.49	0.37	0.37	1.26	0.98	0.97	0.49	0.37	0.37

Note: Emissions of Louisiana are less 10 tpy in the original source apportionment modeling. Air quality impacts and emissions from Texas and Louisiana were combined.

[a] TXLA: Louisiana and Texas

Table J-9: Baseline and Final Rule Primary $PM_{2.5}$ Scaling Factors for Coal EGU Tags

State Tag	Baseline						Final Rule					
	2028	2030	2035	2040	2045	2050	2028	2030	2035	2040	2045	2050
AL	1.20	1.31	1.43	1.33	0.14	0.22	1.21	1.36	1.43	1.33	0.14	0.22
AR	20.02	7.10	3.14	0.08	0.03	2.20	19.77	7.32	3.14	0.08	0.03	2.22
AZ	0.38	1.17	0.61	0.18	0.16	0.76	0.38	1.18	0.61	0.17	0.16	0.76
CA	0.24	0.36	0.16	0.13	0.00	0.00	0.24	0.36	0.16	0.13	0.00	0.00
CO	13.37	1.19	0.51	0.54	0.51	0.53	13.47	1.19	0.51	0.54	0.51	0.53
CT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FL	1.40	1.84	0.25	0.25	0.13	0.17	1.32	1.82	0.25	0.25	0.13	0.17

Table J-9: Baseline and Final Rule Primary $PM_{2.5}$ Scaling Factors for Coal EGU Tags

State Tag	Baseline						Final Rule					
	2028	2030	2035	2040	2045	2050	2028	2030	2035	2040	2045	2050
GA	0.03	0.06	0.00	0.00	0.00	0.00	0.06	0.14	0.00	0.00	0.00	0.00
IA	1.17	1.14	0.67	0.28	0.19	0.57	1.17	1.16	0.64	0.27	0.19	0.57
ID	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IL	1.17	0.95	0.57	0.03	0.00	0.00	1.17	0.95	0.56	0.02	0.00	0.00
IN	1.28	0.60	0.20	0.20	0.00	0.00	1.32	0.63	0.20	0.20	0.00	0.00
KY	1.30	1.19	0.77	0.36	0.16	0.36	1.03	1.07	0.42	0.34	0.10	0.36
MA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MD	3.54	3.54	3.54	3.54	2.97	3.42	3.54	3.54	3.54	3.54	2.97	3.42
ME	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MI	0.83	0.00	0.00	0.00	0.00	0.00	0.82	0.00	0.00	0.00	0.00	0.00
MN	3.50	2.70	0.00	0.00	0.00	0.00	3.51	2.62	0.00	0.00	0.00	0.00
MO	3.04	1.33	0.54	0.11	0.10	0.26	2.96	1.34	0.54	0.10	0.10	0.25
MS	4.02	3.60	1.06	1.00	1.00	1.00	1.94	3.60	1.06	1.00	1.00	1.00
MT	0.98	0.98	0.98	0.98	0.38	0.79	0.98	0.98	0.98	0.98	0.38	0.78
NC	21.57	17.32	6.08	6.14	6.26	8.67	19.27	14.75	6.12	4.19	6.10	8.67
ND	0.94	0.98	0.78	0.72	0.04	0.08	0.94	0.98	0.78	0.72	0.04	0.08
NEKS[a]	3.70	3.68	0.80	0.50	0.15	0.43	2.81	2.91	0.80	0.50	0.14	0.43
NH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NM	0.98	0.99	0.01	0.01	0.01	0.01	0.98	0.99	0.01	0.01	0.01	0.01
NV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OH	0.83	1.08	0.19	0.00	0.00	0.46	0.93	1.04	0.24	0.00	0.00	0.46
OK	14.75	8.14	8.94	8.94	1.00	1.00	14.17	8.57	8.94	8.94	1.00	1.00
OR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PA	3.12	3.04	2.28	1.14	1.14	1.10	2.74	2.71	1.91	1.05	1.03	1.01
RI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SC	1.03	2.17	3.78	3.78	0.00	0.00	0.91	2.16	3.78	3.78	0.00	0.00
SD	0.93	1.11	0.00	0.00	0.00	0.00	0.93	1.11	0.00	0.00	0.00	0.00
TN	16.88	1.00	0.00	0.00	0.00	0.00	16.63	1.00	0.00	0.00	0.00	0.00
TXLA[b]	1.10	1.30	1.15	0.65	0.14	0.55	1.11	1.37	1.16	0.65	0.14	0.54
UT	2.92	0.06	0.06	0.06	0.04	0.02	2.89	0.06	0.06	0.06	0.04	0.02
VA	0.46	0.29	0.08	0.00	0.00	0.00	0.46	0.21	0.08	0.00	0.00	0.00
VT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WI	2.11	2.36	0.46	0.00	0.00	0.33	2.10	2.39	0.45	0.00	0.00	0.33
WV	1.29	1.45	1.23	0.56	0.06	0.06	1.29	1.47	1.13	0.55	0.06	0.06
WY	1.03	1.10	1.08	0.54	0.44	0.43	1.03	1.10	1.08	0.54	0.44	0.43

Note: Emissions of Louisiana and Kansas are less 10 tpy in the original source apportionment modeling. Air quality impacts and emissions from those states were combined with nearby states.

[a] NEKS: Nebraska and Kansas

[b] TXLA: Louisiana and Texas

Table J-10: Baseline and Final Rule Primary $PM_{2.5}$ Scaling Factors for Natural Gas EGU Tags

State Tag	Baseline						Final Rule					
	2028	2030	2035	2040	2045	2050	2028	2030	2035	2040	2045	2050
AL	0.85	0.84	0.71	0.46	0.31	0.39	0.84	0.82	0.71	0.45	0.31	0.39
AR	0.63	0.82	0.43	0.10	0.07	0.10	0.63	0.81	0.43	0.10	0.06	0.10

Table J-10: Baseline and Final Rule Primary $PM_{2.5}$ Scaling Factors for Natural Gas EGU Tags

State Tag	Baseline						Final Rule					
	2028	2030	2035	2040	2045	2050	2028	2030	2035	2040	2045	2050
AZ	0.70	0.85	0.86	0.74	0.39	0.79	0.70	0.85	0.86	0.73	0.38	0.79
CA	0.96	1.06	0.98	0.77	0.20	0.24	0.96	1.07	0.97	0.77	0.20	0.24
CO	1.23	0.74	0.77	0.75	0.32	0.51	1.22	0.74	0.77	0.73	0.32	0.50
CT	0.78	0.67	0.60	0.00	0.00	0.03	0.78	0.67	0.60	0.00	0.00	0.03
DC	0.15	0.13	0.11	0.10	0.08	0.07	0.15	0.13	0.11	0.09	0.08	0.08
DE	0.62	0.64	0.31	0.27	0.30	0.48	0.59	0.53	0.30	0.26	0.26	0.47
FL	0.97	0.98	0.95	0.77	0.55	0.57	0.97	0.98	0.94	0.77	0.55	0.57
GA	0.84	0.81	0.72	0.41	0.30	0.37	0.84	0.80	0.72	0.41	0.30	0.37
IA	0.50	0.48	0.20	0.06	0.01	0.08	0.50	0.47	0.20	0.07	0.01	0.08
ID	1.22	1.65	1.68	1.49	0.76	1.04	1.21	1.63	1.65	1.47	0.74	1.03
IL	0.49	0.55	0.28	0.13	0.00	0.00	0.49	0.55	0.28	0.13	0.00	0.00
IN	0.67	0.67	0.44	0.15	0.10	0.15	0.66	0.67	0.43	0.15	0.11	0.15
KS	1.11	1.01	0.19	0.08	0.04	0.03	1.12	1.05	0.21	0.09	0.04	0.03
KY	0.75	0.72	0.49	0.34	0.18	0.30	0.90	0.86	0.66	0.45	0.24	0.37
LA	0.79	0.80	0.64	0.29	0.19	0.31	0.79	0.79	0.63	0.28	0.19	0.31
MA	0.48	0.46	0.34	0.28	0.19	0.26	0.48	0.46	0.34	0.28	0.18	0.26
MD	1.05	1.08	0.85	0.63	0.61	0.75	1.01	0.99	0.83	0.63	0.58	0.77
ME	1.75	1.44	0.51	0.50	0.29	0.45	1.74	1.49	0.52	0.52	0.29	0.44
MI	0.75	0.87	0.63	0.48	0.28	0.43	0.75	0.81	0.63	0.46	0.27	0.43
MN	0.57	0.52	0.21	0.08	0.05	0.09	0.53	0.49	0.21	0.08	0.05	0.09
MO	0.30	0.33	0.10	0.03	0.01	0.02	0.28	0.33	0.10	0.02	0.01	0.02
MS	0.88	0.84	0.51	0.32	0.18	0.24	0.86	0.79	0.50	0.31	0.16	0.23
MT	0.17	0.21	0.03	0.03	0.00	0.05	0.17	0.17	0.03	0.03	0.00	0.07
NC	0.87	0.70	0.76	0.60	0.55	0.73	0.86	0.68	0.76	0.59	0.54	0.74
ND	0.47	0.92	0.19	0.43	0.06	0.22	0.47	0.86	0.17	0.43	0.06	0.07
NE	2.35	2.21	0.30	0.78	0.01	0.74	2.32	2.24	0.36	0.78	0.05	0.74
NH	0.59	0.43	0.31	0.27	0.25	0.29	0.59	0.42	0.31	0.27	0.25	0.29
NJ	0.82	0.84	0.52	0.40	0.42	0.77	0.78	0.81	0.47	0.40	0.42	0.76
NM	0.52	0.52	0.89	0.99	0.86	1.34	0.52	0.53	0.89	1.00	0.89	1.36
NV	0.72	0.84	0.83	0.85	0.36	0.28	0.72	0.83	0.83	0.85	0.35	0.28
NY	0.86	0.85	0.59	0.26	0.27	0.28	0.85	0.86	0.58	0.26	0.27	0.28
OH	0.95	0.95	0.89	0.63	0.42	0.63	1.05	1.04	0.97	0.68	0.48	0.63
OK	1.00	0.79	0.22	0.07	0.06	0.06	0.97	0.78	0.22	0.07	0.06	0.06
OR	3.29	0.74	0.39	0.00	0.00	0.00	3.29	0.74	0.39	0.00	0.00	0.00
PA	0.83	0.80	0.60	0.37	0.33	0.51	0.83	0.80	0.61	0.36	0.33	0.51
RI	0.83	0.78	0.65	0.38	0.35	0.34	0.84	0.80	0.66	0.38	0.35	0.34
SC	0.80	0.86	0.64	0.51	0.53	0.77	0.77	0.85	0.63	0.52	0.54	0.77
SD	0.73	0.73	0.25	0.13	0.11	0.21	0.72	0.73	0.19	0.18	0.10	0.22
TN	1.08	1.05	0.88	0.46	0.26	0.39	1.08	1.04	0.86	0.45	0.26	0.35
TX	0.90	0.83	0.45	0.19	0.09	0.24	0.89	0.82	0.45	0.19	0.09	0.24
UT	0.66	0.87	0.84	0.88	0.69	0.92	0.66	0.87	0.84	0.88	0.68	0.92
VA	0.81	0.73	0.47	0.26	0.17	0.12	0.79	0.71	0.47	0.23	0.14	0.12
VT	0.00	0.00	0.03	0.03	0.00	0.01	0.00	0.00	0.03	0.03	0.00	0.01
WA	0.44	0.48	0.58	0.59	0.39	0.36	0.44	0.48	0.58	0.59	0.39	0.36
WI	0.56	0.66	0.43	0.18	0.08	0.15	0.55	0.64	0.36	0.18	0.08	0.15
WV	0.51	0.38	0.10	0.12	0.09	4.54	0.63	0.50	0.23	0.21	0.15	4.54
WY	0.01	0.04	0.03	0.03	0.00	0.01	0.01	0.05	0.03	0.01	0.00	0.01

Table J-11: Baseline and Final Rule Scaling Factors for Other EGU Tags

State Tag	Baseline						Final Rule					
	2028	2030	2035	2040	2045	2050	2028	2030	2035	2040	2045	2050
Seasonal NO_X	1.16	1.16	1.10	1.04	1.03	1.08	1.16	1.16	1.10	1.04	1.03	1.16
Annual NO_X	1.17	1.17	1.11	1.03	1.00	1.06	1.17	1.17	1.11	1.03	1.00	1.17
Annual SO_2	1.00	1.01	1.00	0.90	0.87	0.87	1.00	1.01	1.00	0.90	0.87	1.00
Annual $PM_{2.5}$	1.37	1.37	1.32	1.27	1.20	1.49	1.37	1.37	1.32	1.27	1.20	1.37

J.4 Air Quality Surface Results

The spatial fields of baseline AS-MO3 and Annual Average $PM_{2.5}$ in 2028 are presented in Figure J-8 and J-9, respectively. It is important to recognize that ozone is a secondary pollutant, meaning that it is formed through chemical reactions of precursor emissions in the atmosphere. As a result of the time necessary for precursors to mix in the atmosphere and for these reactions to occur, ozone can either be highest at the location of the precursor emissions or peak at some distance downwind of those emissions sources. The spatial gradients of ozone depend on a multitude of factors including the spatial patterns of NOx and VOC emissions and the meteorological conditions on a particular day. Thus, on any individual day, high ozone concentrations may be found in narrow plumes downwind of specific point sources, may appear as urban outflow with large concentrations downwind of urban source locations or may have a more regional signal. However, in general, because the AS-MO3 metric is based on the average of concentrations over more than 180 days in the spring and summer, the resulting spatial fields are rather smooth without sharp gradients, compared to what might be expected when looking at the spatial patterns of MDA8 ozone concentrations on specific high ozone episode days. $PM_{2.5}$ is made up of both primary and secondary components. Secondary $PM_{2.5}$ species sulfate and nitrate often demonstrate regional signals without large local gradients while primary $PM_{2.5}$ components often have heterogenous spatial patterns with larger gradients near emissions sources. Both secondary and primary $PM_{2.5}$ contribute to the spatial patterns shown in Figure J-9 as demonstrated by the extensive areas of elevated concentrations over much of the Eastern US which have large secondary components and hotspots in urban areas which are impacted by primary PM emissions.

Figure J-10 through Figure J-15 present the model-predicted changes in the AS-MO3 between the baseline and the final rule for 2028, 2030, 2035, 2040, 2045, and 2050 calculated as final rule minus the baseline. Figures J-16 to J-21 present the model-predicted changes in annual average $PM_{2.5}$ between the baseline and final rule for 2028, 2030, 2035, 2040, 2045, and 2050 calculated as the final rule minus the baseline. The spatial patterns shown in the figures are a result of (1) of the spatial distribution of EGU sources that are predicted to have changes in emissions and (2) of the physical or chemical processing that the model simulates in the atmosphere. While SO_2, NO_x and primary $PM_{2.5}$ emissions changes all contributed to the $PM_{2.5}$ changes depicted in Figures J-16 through J-21, the $PM_{2.5}$ component species with the larger changes was sulfate and consequently the SO_2 emissions changes have the largest impact on predicted changes in $PM_{2.5}$ concentrations through sulfate, ammonium and particle-bound water impacts. The spatial fields used to create these maps serve as an input to the benefits analysis.

Figure J-8: Map of AS-MO3 in the 2028 Baseline

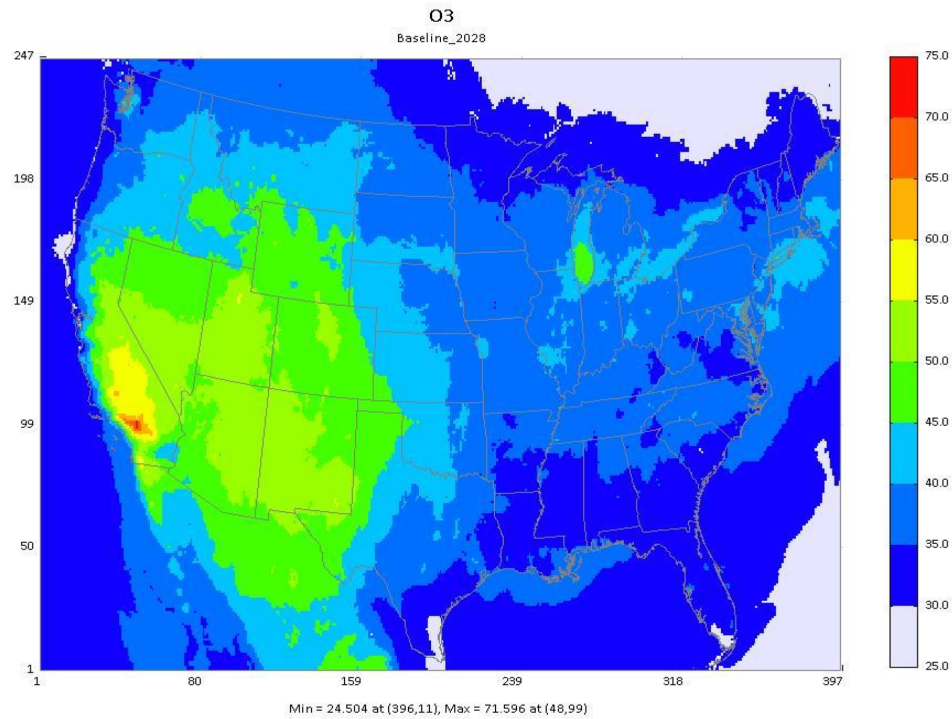


Figure J-9: Map of Annual Average $PM_{2.5}$ in the 2028 Baseline

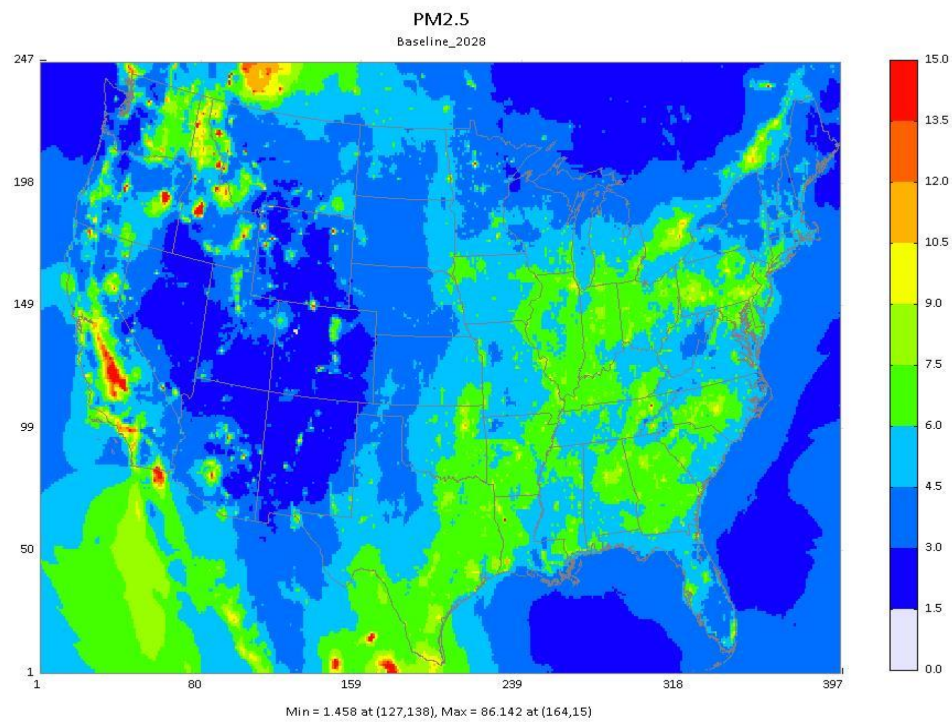


Figure J-10: Map of Change in Apr-September MDA8 Ozone (ppb): 2028 Final Rule – Baseline

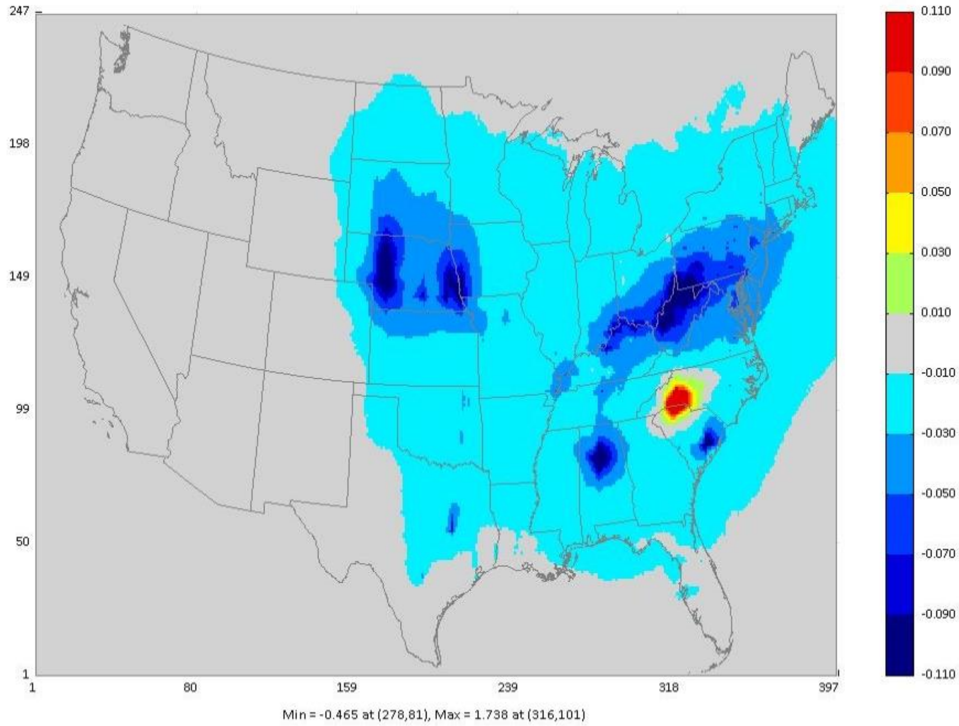


Figure J-11: Map of Change in Apr-September MDA8 Ozone (ppb): 2030 Final Rule – Baseline

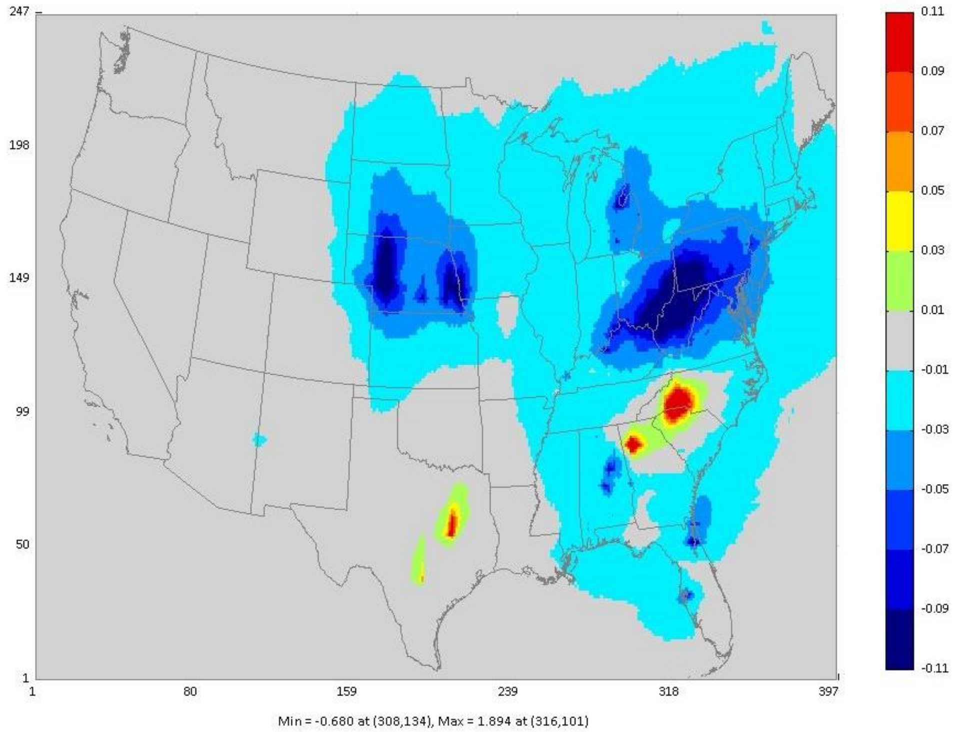


Figure J-12: Map of Change in Apr-September MDA8 Ozone (ppb): 2035 Final Rule – Baseline

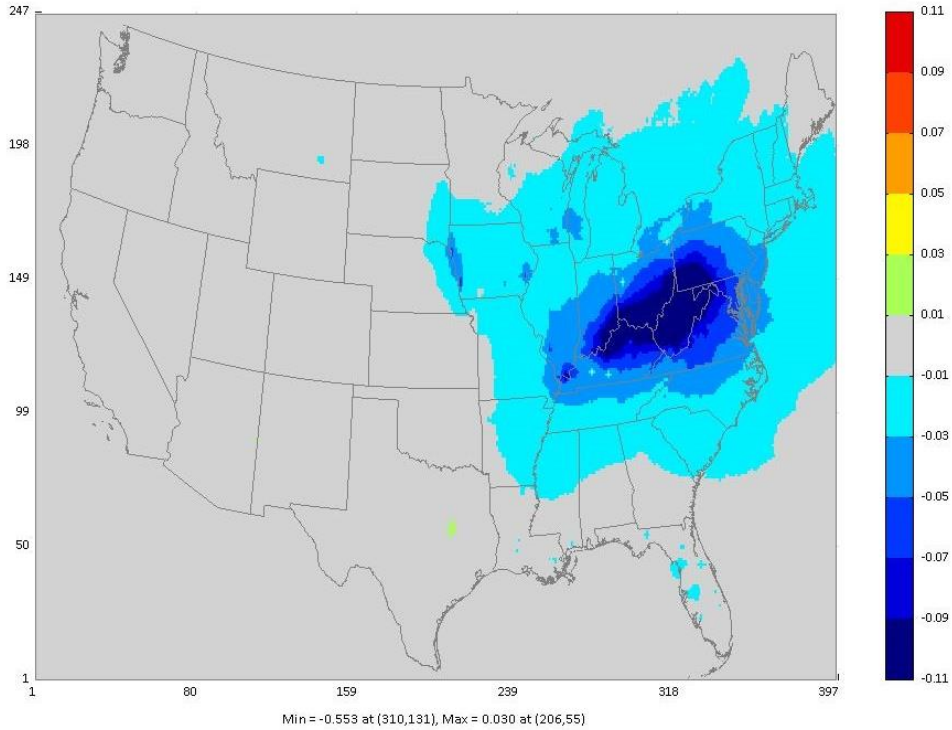


Figure J-13: Map of Change in Apr-September MDA8 Ozone (ppb): 2040 Final Rule – Baseline

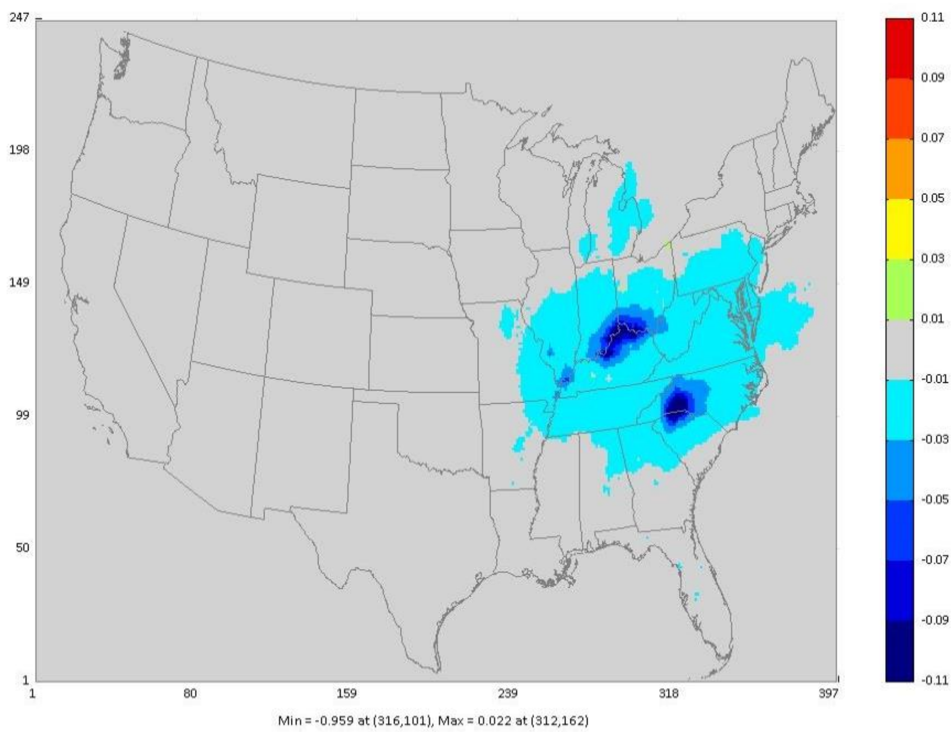


Figure J-14: Map of Change in Apr-September MDA8 Ozone (ppb): 2045 Final Rule – Baseline

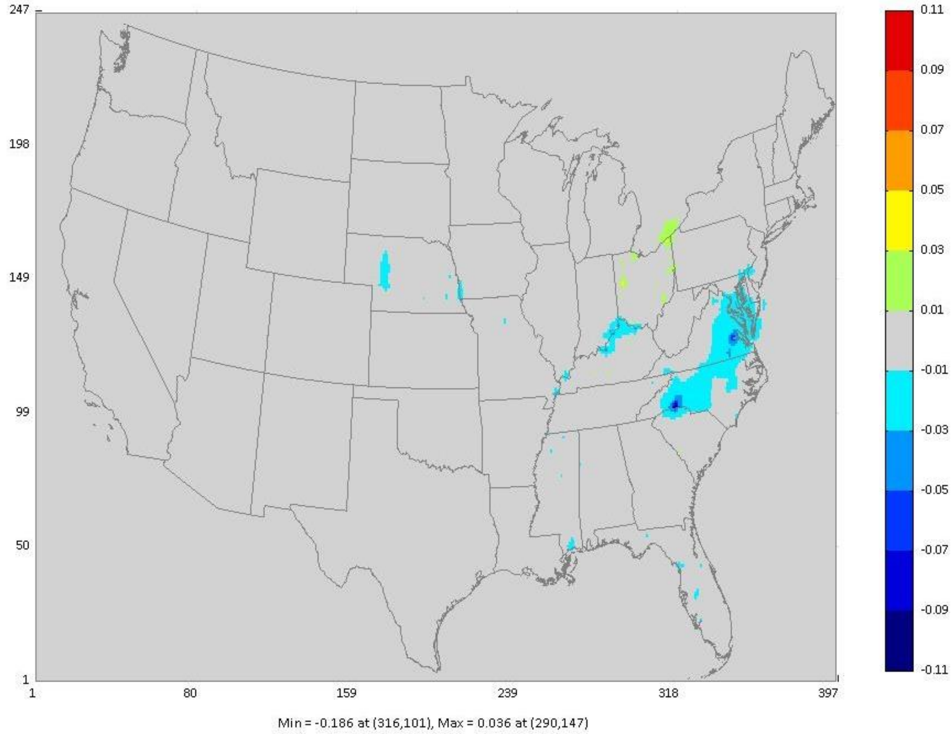


Figure J-15: Map of Change in Apr-September MDA8 Ozone (ppb): 2050 Final Rule – Baseline

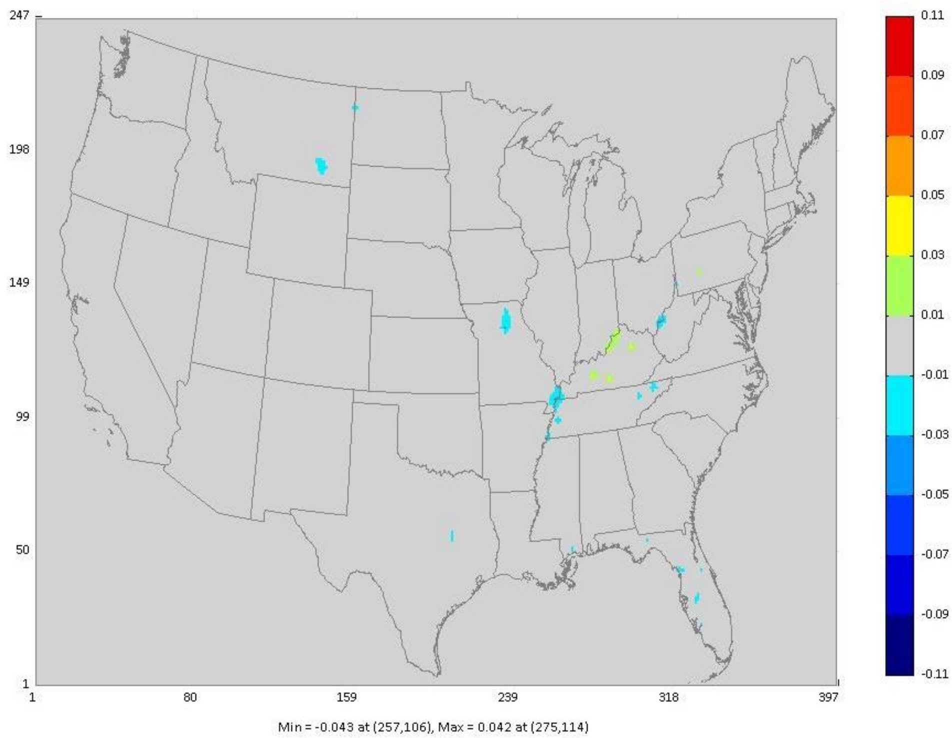


Figure J-16: Map of Change in Annual Mean $PM_{2.5}$ ($\mu g/m^3$): 2028 Final Rule – Baseline

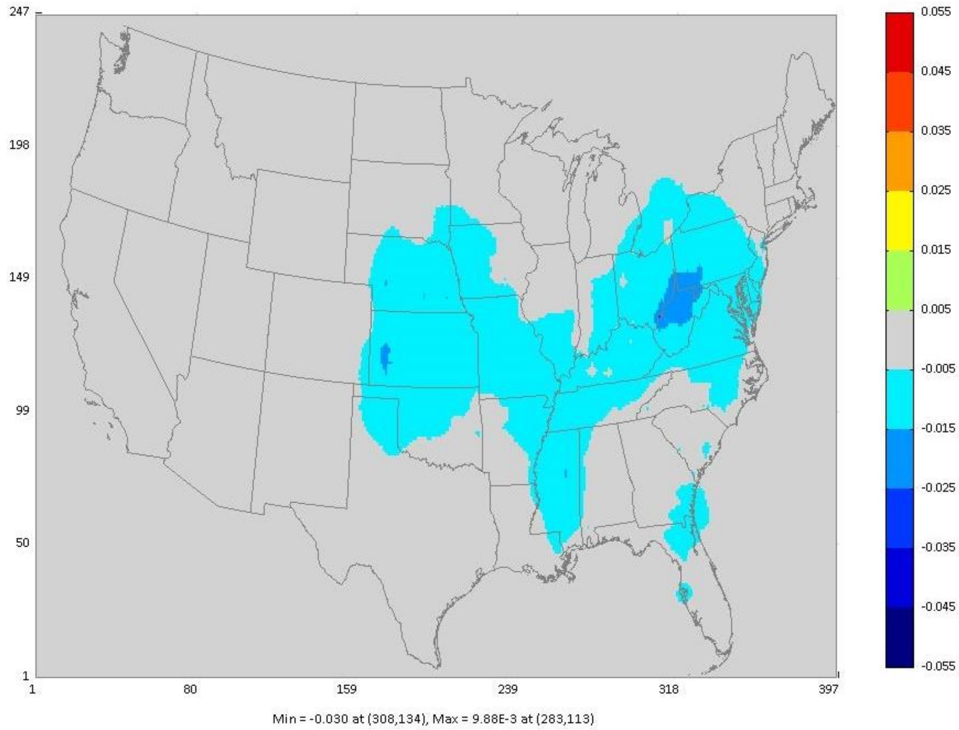


Figure J-17: Map of Change in Annual Mean $PM_{2.5}$ ($\mu g/m^3$): 2030 Final Rule – Baseline

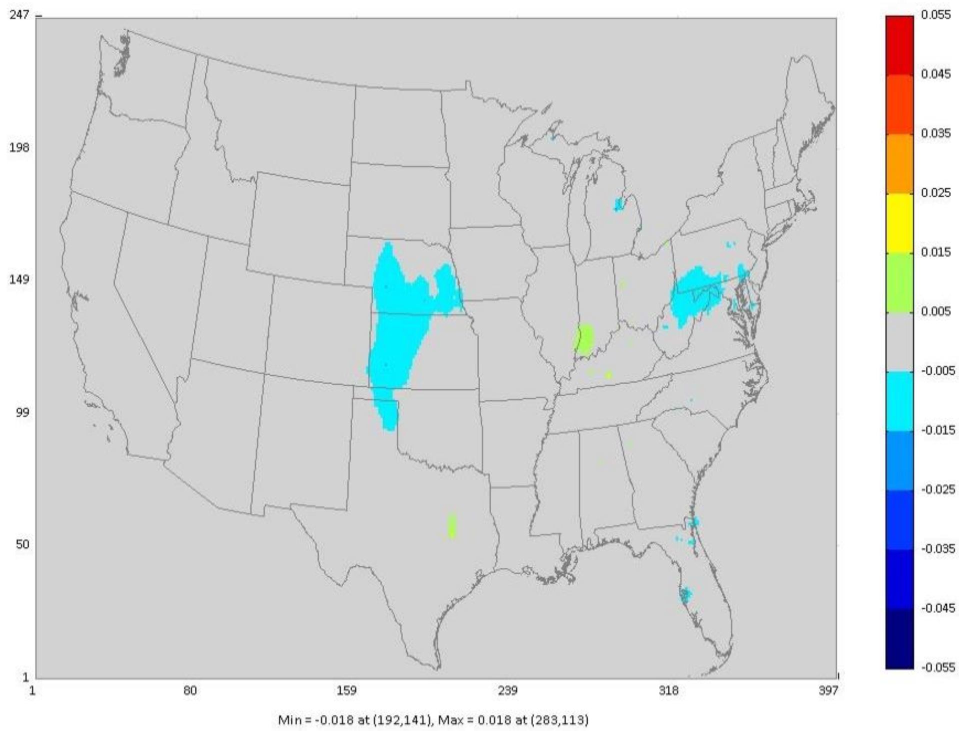


Figure J-18: Map of Change in Annual Mean $PM_{2.5}$ ($\mu g/m^3$): 2035 Final Rule – Baseline

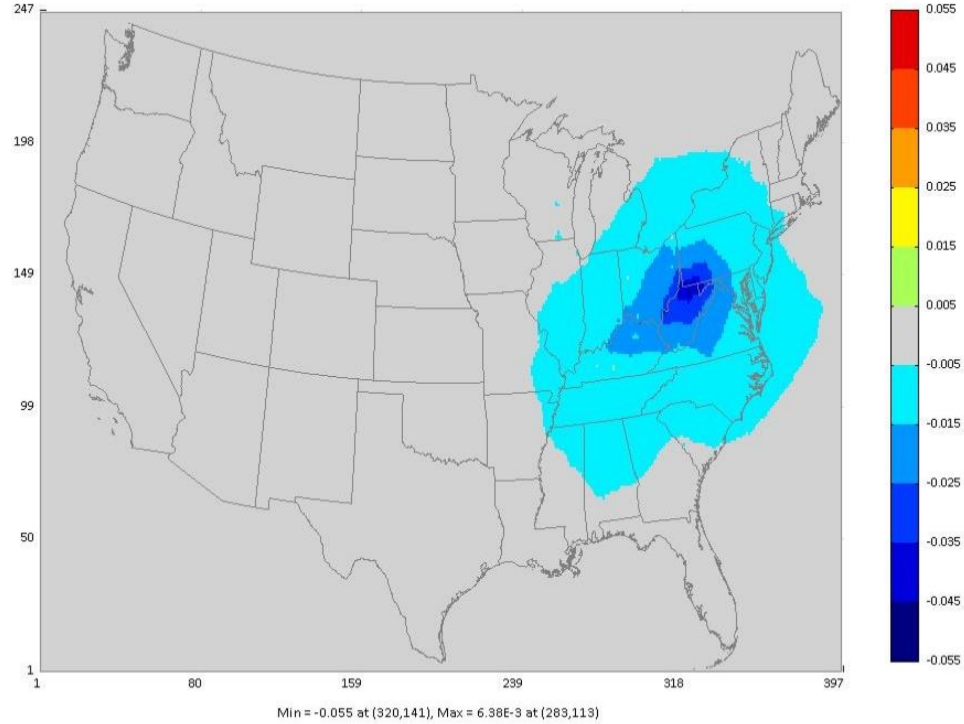


Figure J-19: Map of Change in Annual Mean $PM_{2.5}$ ($\mu g/m^3$): 2040 Final Rule – Baseline

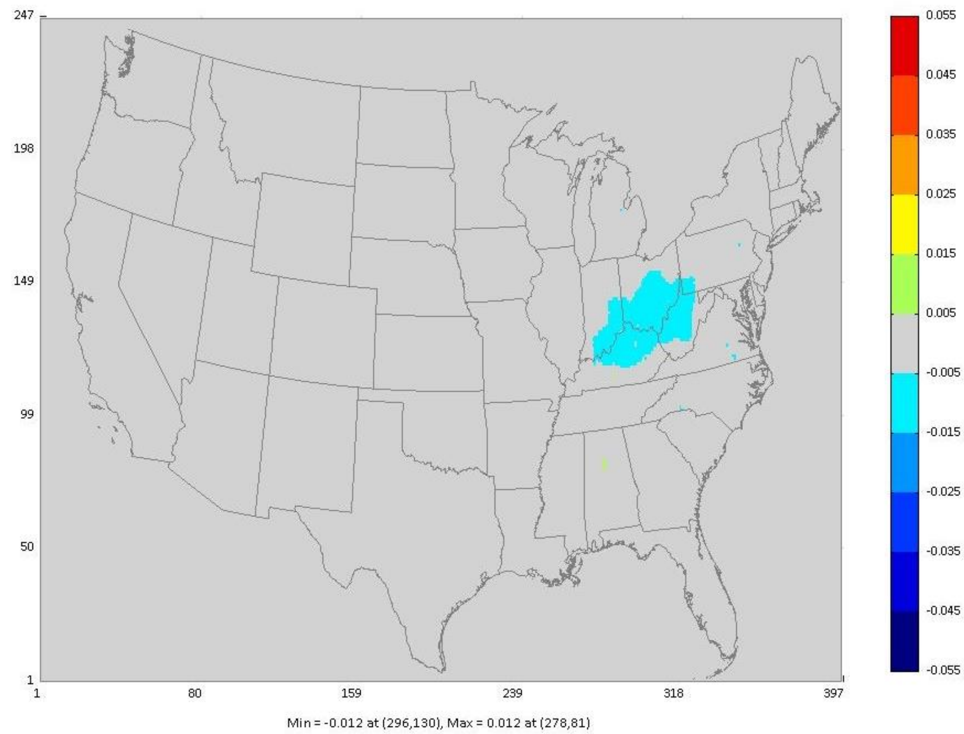


Figure J-20: Map of Change in Annual Mean $PM_{2.5}$ ($\mu g/m^3$): 2045 Final Rule – Baseline

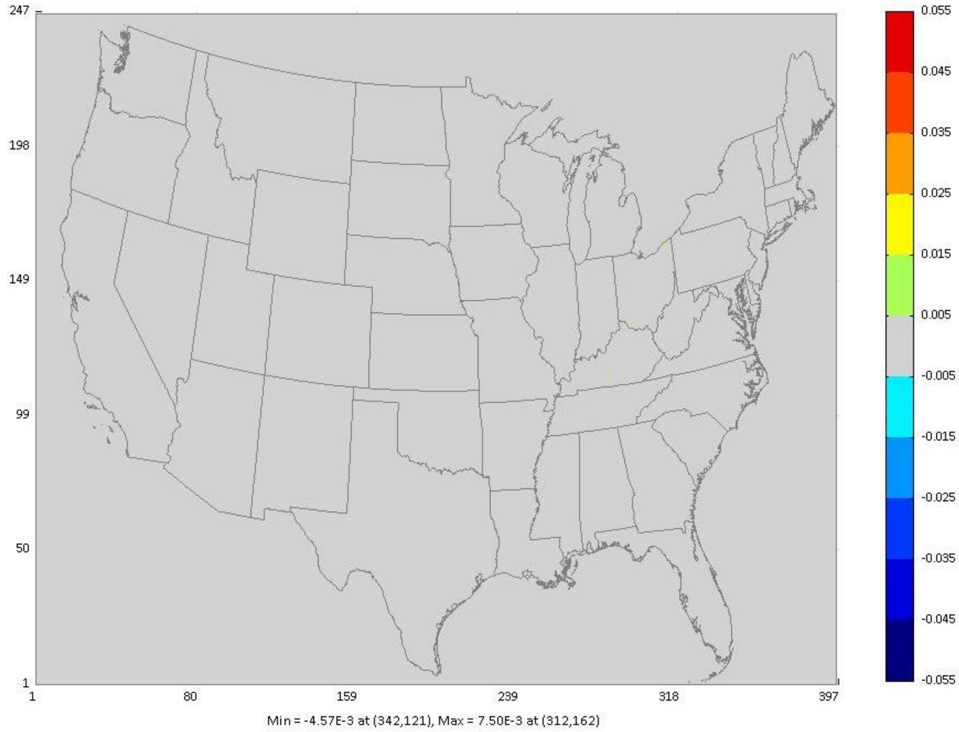
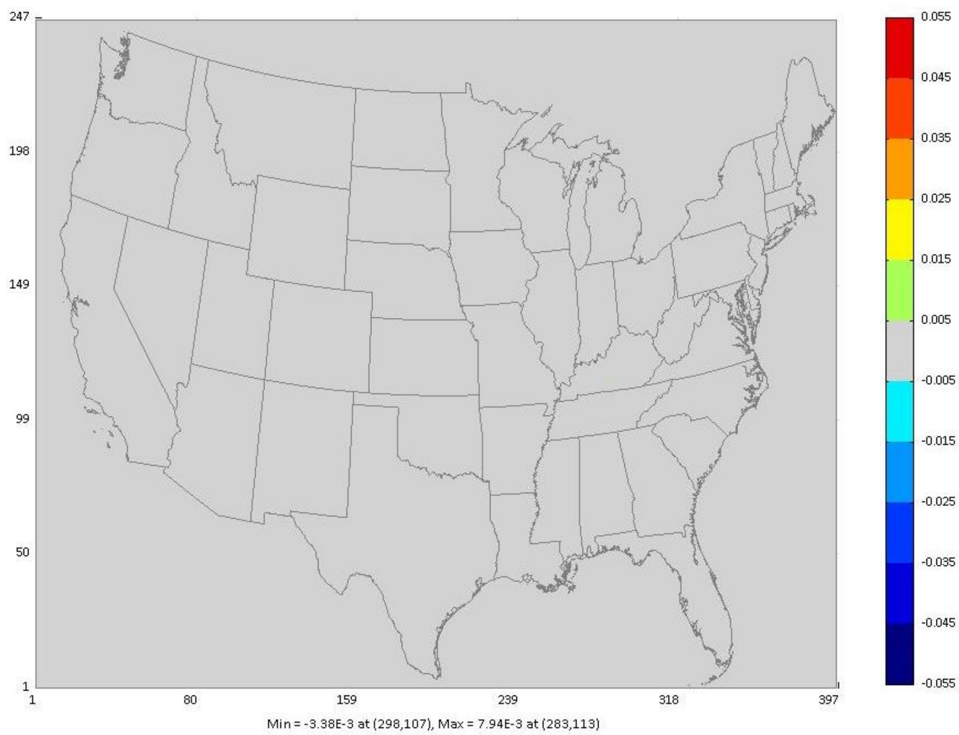


Figure J-21: Map of Change in Annual Mean $PM_{2.5}$ ($\mu g/m^3$): 2050 Final Rule – Baseline



J.5 Uncertainties and Limitations of the Air Quality Methodology

One limitation of the scaling methodology for creating ozone and $PM_{2.5}$ surfaces associated with the baseline or final rule scenarios described above is that the methodology treats air quality changes from the tagged sources as linear and additive. It therefore does not account for nonlinear atmospheric chemistry and does not account for interactions between emissions of different pollutants and between emissions from different tagged sources. The method applied in this analysis is consistent with how air quality estimations have been made in several prior regulatory analyses (U.S. EPA, 2012, 2019h, 2020d). We note that air quality is calculated in the same manner for the baseline and for the final rule, so any uncertainties associated with these assumptions is propagated through results for both the baseline and final rule scenarios in the same manner. In addition, emissions changes between baseline and the final rule are relatively small compared to modeled future year emissions that form the basis of the source apportionment approach described in this appendix. Previous studies have shown that air pollutant concentrations generally respond linearly to small emissions changes of up to 30 percent (Cohan & Napelenok, 2011; Cohan et al., 2005; Dunker et al., 2002; Koo, Dunker & Yarwood, 2007; Napelenok et al., 2006; Zavala et al., 2009). A second limitation is that the source apportionment contributions are informed by the spatial and temporal distribution of the emissions from each source tag as they occur in the future year modeled case. Thus, the contribution modeling results do not allow us to consider the effects of any changes to spatial distribution of EGU emissions within a state-fuel tag between the future year modeled case and the baseline and final rule scenarios analyzed in this RIA. Finally, the future year CAMx-modeled concentrations themselves have some uncertainty. While all models have some level of inherent uncertainty in their formulation and inputs, the base-year 2016 model outputs have been evaluated against ambient measurements and have been shown to adequately reproduce spatially and temporally varying concentrations.