Assessment of Duke Energy's Coal Ash Basin Closure Options Analysis in North Carolina

For Submission to the North Carolina Department of Environmental Quality

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1. EXECUTIVE SUMMARY

In 2018, Duke Energy submitted to the North Carolina Department of Environmental Quality its analysis of options for the closure of eight of its coal ash basins spread over six sites. The Southern Environmental Law Center commissioned Synapse Energy Economics, Inc. to review Duke's Summary Reports and the Company's analysis on trucking impacts, community and regional impacts, environmental impacts, and the estimated closure costs and schedules. Below, we provide a summary of our findings.

- Duke's coal ash basin site closure analysis is skewed heavily towards the options that the utility claims have the lowest cost and the shortest closure timelines. Duke recommends the Closure-in-Place option at seven out of the eight ash basins, and it ranks Closure-by- Removal as the least favorable option at all sites.

- The inclusion of environmental and other local impacts never affects the outcome of Duke's option analysis. At each site, Duke made the same recommendations that it would have made if it ignored environmental and community impacts and considered only its own costs and construction requirements. Duke admits that the Closure-by-Removal scenario will reduce the size of the boron plume at nearly all sites faster than other options, but this concern is effectively treated as secondary to cost drivers. Duke also selectively utilizes, and generally ignores, the environmental (non-groundwater) and regional impact findings from the Community Impact Analysis reports. Duke's claim that environmental considerations are weighted higher than cost considerations is false and misleading.

- The three major groundwater criteria were scored identically at each site except Marshall across all closure options: Closure-in-Place, Closure-by-Removal, or a Hybrid Option. The judgement that the closure option makes no difference for these key indicators of groundwater pollution rejects the concerns that have motivated much of the discussion of ash disposal methods. The identical groundwater scoring (on the three main criteria) across all closure options for all but one site means that the groundwater scoring has zero impact on the final choice among these options.

- The trucking miles reported for several scenarios are illogically small or large, and for Roxboro West Ash Basin the trucking miles calculations were carried out incorrectly.

- Duke's 0 to 10 ranking scale simultaneously fails to distinguish between or properly reflect impacts that differ by orders of magnitude (both within and across sites) while also improperly distinguishing between impacts that are on the same order of magnitude. Additionally, the large range between 0 and 10 skews the results towards the options the Company favors.

- Duke ranks its Rough Order of Magnitude (ROM) cost estimates as though the Company has a high degree of confidence in the scenario cost differences. Yet "rough" is an apt description of these estimates: At some sites, even the relative ranking of options by cost has not been confidently established. Duke reports all construction and Operation, Maintenance and Monitoring (OM&M) costs as though they are incurred at a single point in

time regardless of when the construction and OM&M actually happens or how the costs will impact the revenue requirement.

- The risk and associated costs from an ash-pond breach and spill are totally absent from the analysis, despite the number of spills that have occurred at Duke sites and in the surrounding region over the past years.

2. INTRODUCTION / CONTEXT

2.1. Sites Reviewed

Synapse reviewed Duke Energy's Coal Ash Basin closure option analysis submittals to the North Carolina Department of Environmental Quality for eight coal ash basins at six of the Company's sites in North Carolina. These sites are Roxboro Steam Electric Plant West Ash Basin (WAB), Roxboro Steam Electric Plant East Ash Basin (EAB), Mayo Plant Ash Basin, Belews Creek Steam Station Ash Basin, Allen Steam Station Ash Basin, Cliffside Steam Station Active Ash Basin at the Rogers Energy Complex, Cliffside Steam Station Unit 5 Inactive Ash Basin at the Rogers Energy Complex, and Marshall Station Ash Basin.

Synapse reviewed in detail the summary analysis reports that Duke prepared, including the multi-criteria analysis framework and all input assumptions and methodological decisions. We looked closely at the groundwater impacts, the trucking calculations, the community impact analysis, project costs, and the estimated closure schedule.

2.2. Studies, Analysis, and Reports Referenced

For each site, Duke Energy submitted to the DEQ Groundwater Modeling reports, Community Impact Analysis, and a Closure Options Analysis Summary Report. Synapse reviewed the latter two sets of reports for each site. Synapse found that Duke selectively utilized the results from the community impact reports when the findings matched the Company's desired recommendation and discounted them otherwise.

Closure Options Analysis Summary Reports

The Closure Options Analysis Summary Reports were prepared by Duke Energy. Each report provides a summary of the site, an overview of the closure options considered, an explanation of the multi-criteria evaluation used to score each closure option, a summary of the cost and schedule inputs, a discussion of the results, and a final recommendation on which closure options the utility recommends. Duke's analysis in these reports, and specifically the multi-criteria analysis used to rank sites, is discussed in depth in the remainder of this report.

Community Impact Analysis

The Community Impact Analysis reports were prepared by an outside consulting firm, Exponent. These reports utilized a Net Environmental Benefit Analysis (NEBA) framework to evaluate how well each closure option met each of five community impact objectives:

1. Protect human health from Coal Combustion Residuals (CCR) constituent exposure
2. Protect ecological health from CCR constituent exposure
3. Minimize risk and disturbances to humans from closure

4. Minimize risk and disturbances to the local environment from closure

5. Maximize local environmental services

The reports evaluate the impacts on both humans and local ecosystems, and thus include criteria that fall under Duke's regional impacts and environmental impacts categories. Synapse identified many shortcomings in the analysis and results in the Exponent report. However, it is still surprising how minimally Duke utilized the results. There is little correlation between the recommendations made in the Exponent reports and the closure options that receive the highest environmental and regional scores in Duke's scoring system (see Section 3.2). The disconnect between the community impact evaluations in the Exponent reports and the regional and environmental scores used by Duke calls into question whether Duke's ranking and weightings are based on sound research and analysis.

Exponent Report Assumptions and Metrics

The Exponent reports make questionable assumptions about the value of the existing habitat at the coal ash basins. Based on observations of aquatic vegetation in some open water areas of the ash basins, the reports count the ash ponds as supporting habitat. The ash ponds are assumed to have a net primary productivity (NPP) that is 25 percent as much as a natural freshwater habitat. In one of the sensitivities considered in the reports, the ash basin open water areas are assumed to have the same NPP as natural open water habitats. These assumptions are unjustified.

The use of the NEBA analysis more broadly also has shortcomings. The consideration of environmental disturbance analyzes the changes in discounted service acre-years (DSAYs) under the closure options. This analysis answers the question, what NPP services would have been produced at the current ash basin site and future landfill site but for the project closure. The result is the net gain or loss of natural land area expressed as a percentage of the baseline scenario.

While this metric may seem reasonable, the magnitude of change is absent from consideration. Duke's focus on percentage changes in DSAYs can be misleading. Some closure options have relatively small gross DSAY losses, and if the baseline is also low, the percentage change will appear large. This will communicate an outsized environmental disturbance from the closure option, even if the magnitude of change is quite small.

Exponent Report Omissions

The reports also neglect the risk of coal ash seeps, which if included could change the results of the analysis. Seeps are left out because Duke has entered a Special Order by Consent (SOC) with the North Carolina Environmental Management Commission. The agreement requires Duke to address coal ash seeps by accelerating schedules for decanting. It is unclear why avoidance of seeps is not considered by the reports.

Treatment of the risk of coal ash spills is also absent from the reports. By ignoring the risks of seeps and spills, the reports arrive at the conclusion that there is a "lack of meaningful risk [to humans of CCR

exposure] under current conditions." The result is that the closure option selected has no impact on CCR exposure, because all closure options are safer than current conditions. Concluding that there is no risk to humans of CCR exposure from coal ash basins ignores the important reasons for closing the basins. High impact risks, even if relatively low probability, should be included in an analysis of the safety and environmental impact of the closure options.

2.3. Closure Options Considered

Duke utilized a pre-screening process to whittle down a longer list of closure options for each site to three options for final evaluation.[1] While it is reasonable for Duke to limit the universe of options considered, at the Roxboro sites, for example, the Company only provided a vague explanation for the prescreening process: The Company stated that it was done based on "optimized design," "excessive schedule/cost,", and "availability of on-site landfill space."[2]

The three closure options evaluated for each site are:

- Cap-in-Place: The Company will decant the impoundment to remove excess water and cover the coal ash in the existing unlined site with a low-permeability cap.
- Closure-by-Removal: The Company will decant the impoundment to remove excess water, removal all ash from the original site, and transport the ash to a new lined landfill. Duke will then restore and close the original site.
- Hybrid Closure Option: The Company will decant the impoundment to remove excess water, consolidate the ash in the existing basin footprint, and then cap and cover it within the unlined basin (at the East Roxboro Basin, the hybrid option involves removing some of the ash from the existing basin for disposal off-site).

3. MULTI-CRITERIA EVALUATION FRAMEWORK

3.1. Criteria and Considerations

Duke utilizes a multi-criteria framework to evaluate the three[3] closure options for each site. The multi-criteria evaluation framework relies on elaborate and at times complex calculations to produce a score for each closure option. However, the framework is highly flawed and produces a result that routinely favors the lowest cost, shortest timeline options. Synapse evaluated Duke's application of the multi-criteria framework and found that the Company would have achieved the same final ranking at each site

[1] Only two closure options are considered for the Cliffside Inactive Basin: Closure-in-Place and excavation closure.

[2] Duke Energy, Roxboro Steam Electric Plan West Ash Basin (WAB) Closure Options Analysis Summary Report.

[3] Cliffside Inactive considers only two closure options, and Allen Steam station considers four closure options

if the Company had only considered cost and construction schedule. Stated another way, the inclusion of environmental criteria and local impacts *never* affects the outcome.

Duke claims that the Company strongly weighs environmental considerations, saying: "the environmental considerations have a slightly higher weight than cost with the inclusion of certain regional / community factors (transportation impact, noise impact, view impact) which are effectively environmental considerations."[4] However, this claim is false and misleading. Even the Company's own language, and its choice of the term *effectively*, essentially admits that it is stretch to call regional impact and constructability evaluation environmental considerations.

The framework covers 18 distinct criteria which measure cost, schedule, construction and engineering requirements, environmental impacts, and other local and regional impacts. Each criterion is converted to a 0 to 10 scale, where the worst outcome is ranked 0 and the best outcome is ranked 10, and then all criteria are assigned weights in the final score. Cost and schedule are weighted most heavily, with environmental and regional impacts carrying lesser importance.[5] The criteria fall into four broad categories:

- Project cost and construction considerations (4 criteria): construction cost, OM&M cost, project start time, and total construction time together account for 50 percent of the total score.
- Groundwater pollution (4 criteria): surface and ground water impacts, and analysis of the boron plume account for just over 25 percent of the total score.
- Trucking impacts (3 criteria): air emissions from trucking both on- and off-site, and transportation impacts from off-site trucking account for around 13 percent of the total score.
- Other regional and environmental factors (7 criteria): greenfield disturbance, soil needs, beneficial reuse potential of both the CCR and the site, noise and visual disturbance, and other construction considerations account for the remaining 12 percent of the total score.

The heavy weighting of cost and construction considerations skews the results towards the less expensive and shorter duration options. Duke's final rankings by site are displayed in Table 1. Closure-by-Removal with complete removal of all ash is ranked worst by a wide margin at all eight sites. The Hybrid Option to consolidate or remove some of the existing coal ash ranks highest at Belews Creek, and Closure-in-Place ranks the highest for the remaining coal ash basins.

[4] Mayo Plant Ash Basin Closure Options Analysis Summary Report, page 5.

[5] The list of criteria and weights are nearly identical across all sites, however there are some small unexplained differences between the weights for some sites.

Table 1: Duke's Scenario Ranking by Site

Site	Highest Ranking	Middle Ranking	Lowest Ranking
Allen	Closure-in-Place	Hybrid Option	Closure-by-Removal
Belews Creek	Hybrid Option	Closure-in-Place	Closure-by-Removal
Cliffside (Active)	Closure-in-Place	Hybrid Option	Closure-by-Removal
Cliffside (Inactive)	Closure-in-Place	Hybrid Option	Closure-by-Removal
Marshall	Closure-in-Place	Hybrid Option	Closure-by-Removal
Mayo	Closure-in-Place	Hybrid Option	Closure-by-Removal
Roxboro (East Ash Basin)	Closure-in-Place	Hybrid Option	Closure-by-Removal
Roxboro (West Ash Basin)	Closure-in-Place	Hybrid Option	Closure-by-Removal

3.2. Community Impact Reports and Duke's Recommendations

The analysis in the community impact reports covers many of the regional and non-groundwater environmental factors that Duke evaluates as part of its scoring matrix. Based on just these factors, Exponent recommends against Closure-in-Place at all but one site (see Table 2). Despite this, Duke states in a summary of the impact analysis for the DEQ that, while the community impact analysis varies by site, "in all cases cap-in-place closure may be performed without adversely impacting the community."[6] This statement is false and misleading.

Synapse evaluated Duke's rankings on regional and environmental factors alone, which we would expect to qualitatively resemble the Exponent report results for community impacts.[7] There is significant divergence between the results recommended by Exponent and the rankings that Duke assigns to each criterion. Table 2 shows that based on regional and non-groundwater environmental impacts alone, Duke would rank Closure-in-Place highest for four sites, either the Hybrid Closure Option or Closure-in-Place highest for an additional three sites, and the Hybrid Option highest for the last site. Overall, Duke's scores reflect more favorable evaluations of Closure-in-Place than do the qualitative evaluations in the Exponent reports.

[6] Roxboro Steam Electric Plant letter to the Assistant Secretary for Environment, Date November 15, 2018.

[7] We excluded scores for groundwater-specific environmental impacts, as Duke relied on separate groundwater analysis modeling and reporting to rank these criteria.

Table 2: Closure recommendations based on regional and non-groundwater environmental criteria

Site	Exponent recommendations from Community Impact Assessment Reports	Highest scored option based on Duke's ranking for regional and non-groundwater environmental impacts
Allen	Hybrid Option	Hybrid Option or Closure-in-Place
Belews Creek	Hybrid Option	Hybrid Option or Closure-in-Place
Cliffside (Active)	NOT Closure-in-Place	Closure-in-Place
Cliffside (Inactive)	NOT Closure-in-Place	Closure-in-Place
Marshall	Hybrid Option	Hybrid Option or Closure-in-Place
Mayo	NOT Closure-in-Place	Hybrid Option
Roxboro (East Ash Basin)	Closure-in-Place or Hybrid Option	Closure-in-Place
Roxboro (West Ash Basin)	Hybrid Option	Closure-in-Place

At Mayo and the two Cliffside Ash Basins, the Exponent report recommends against the Closure-in-Place option based on community impacts. However, Duke's scoring system appears to disregard these recommendations. Specifically:

- Mayo Ash Basin: Exponent recommends against the Closure-in-Place option, based on community impacts. However, Duke assigns Closure-in-Place a higher regional and environmental score (1.42 out of 1.95) than Closure-by-Removal (0.14 out of 1.95), and Duke assigns an even higher score to the Hybrid Option (1.57 out of 1.95), clearly ignoring the results from the community impact study.
- Cliffside Active and Inactive Basins: Exponent again recommends against Closure-in-Place. Duke does exactly the opposite, assigning the highest regional and environmental score to the Closure-in-Place options.

Duke also appears to ignore the Exponent reports when selecting specific inputs for its scoring matrix. For example, at the Mayo site the Exponent report finds total off-site road miles driven to be the least for the Closure-by-Removal option. This means that if Duke was considering Exponent's report, the Company would rank Closure-by-Removal highest for off-site trucking.

However, Duke asserts in its scoring matrix for Mayo that none of the closure options result in any significant off-site road miles driven. The Company then assigns Closure-by-Removal two miles of off-site driving and the other options 0 miles without any explanation. Duke than scores Closure-by-Removal a 0 and assigns the other options a 10 based on this unexplained and unsourced two miles of travel.

Overall, Duke appears to disregard, and at times contradict, the findings and recommendations from Exponent's community impact analysis reports. While there are significant shortcomings with the Exponent reports (discussed in Section 2.2), it is still surprising how minimally Duke explains or justifies its selective use of the Exponent results.

3.3. Critique of the Framework

Quantitative Evaluation Frameworks

Quantitative evaluation frameworks are important for allowing distinct and otherwise non-additive criteria to be evaluated together. However, the design of the framework is as important as its application in ensuring the analysis is straightforward and objective.

There are two parts to the framework that must both be designed carefully: ranking the closure options under each criterion; and weighting the criteria to combine them into a single score.

- *Ranking:* The ranking scale applied to criteria (cost, schedule, groundwater impacts, trucking distance, etc.) should reflect the difference in impacts measured by each criterion for each closure option. Rankings should distinguish between meaningful and trivial differences in results. Ideally, it should be possible to compare the results across sites.

- *Weighting:* The weighting of criteria assigns a relative importance to each factor that is evaluated; the weights for all factors add up to 100 percent. The weighting should reflect each criterion's importance in the decision-making process.

Duke's Scoring System

Duke's multi-criteria evaluation framework is skewed and appears to have been engineered to produce the results that the Company wanted. Duke relies on seemingly benign, but unsupported, assumptions to rank the criteria across sites, and then erratically weighs all the criteria together to get a final score. The result is a framework that provides no useful information about the merits of the various disposal options.

Ranking the Criterion Across Sites

Table 3 below summarizes the scoring system that Duke used to rank each criterion across sites. The Company applied two general scoring systems to the 18 criteria – quantitatively ranking systems, and subjective scoring systems.

Quantitative Ranking

- Interpolation ranking: For 10 of the criteria, the Company set the maximum value to 0, and the minimum value to 10 at each site. The middle value was interpolated based on its magnitude relative the established min and max values. The 0 to 10 ranking was applied regardless of the range of values considered at each site.

- Quantitively ranking based on modeling results: Three of the groundwater criteria were ranked based on the number of years that an impact could be expected (10 years, 100 years, 200 years). The ranking was based on groundwater modeling results, and Duke used interpolation here as well to assign values on the scale between 10 years, 100 years, and 200 years.

Subjective Scoring

- Subjective ranking: For three of the criteria, the Company used a subjective 0 to 10 scale, ranking the scenario that minimized community impact or utilized the least complicated solution with the highest score, and ranking the scenario that had the largest community impacts or required the most complicated solution with the lowest score. The 0 to 10 scale was applied to subjectively rank each criterion, regardless of the actual range of impacts considered. It is unclear how the middle range of values were established.

- Subjective evaluation: Two of the criteria were ranked based on purely subjective and minimally explained criteria and evaluation decisions. It is not clear how these criteria were bounded, or how the middle values were established.

Table 3: Scoring system used for each criterion

	Scoring System	Criterion
Quantitative Ranking	Interpolation. Min value scores 10. Max value scores 0.	• Closure Cost • OM&M Cost • Initiation Time • Construction Duration • Air Emissions off-site • Air emission on-site • Transportation impacts off-site • Avoidance of greenfield disturbance • Soil needs • Beneficial CCR reuse (% of CCR, scale is reversed)
	Ranking based on 10 year, 100 year, and 200 year modeled impact.	• Surface water impacts from plume • Groundwater impacts beyond compliance boundary • Groundwater impacts off-site
Subjective Ranking	Subjective 0 to 10. 10 is lowest impact / least complicated, 0 is highest impact/most complicated	• Noise impacts • View Impacts • Stormwater management, geotechnical and dewatering
	Subjective ranking	• Beneficial site reuse • Visual interpretation of modeled boron plume

Duke did not provide clear quantitative or qualitative explanation for the scoring and ranking systems. The Company applied the 0-10 scale without justifying the range of meaningful outcomes. This large range skewed the results towards the options the Company favored. The Company also applied the ranking scale in a subjective and inconsistent manner across sites, resulting in equal rankings for impacts that were orders of magnitude different. For example:

- Trucking miles: The Company awarded the same full credit (worth 9.8 percent of the total score) for avoiding 1 or 2 miles of trucking at Belews Creek or Mayo as it did for avoiding 33 million miles (or a corrected 21 million miles) of trucking at the Roxboro West Ash Basin. The inability to distinguish the impacts of 1 or 2 miles of driving from the impacts of 33 million miles of driving shows a critical flaw in the inflexible multi-criteria framework.

- Initiation time (the time required before the project can start): The Company converted closure schedule data to the 0 to 10 scale. Duke awarded full credit to the closure option with the quickest start time at each site, even though start times at Roxboro differed by only 4 months across closure options, whereas start times at Belews Creek differed by 24 months.

Weighing the Criteria

Duke's weighting system, which ranks the relative importance of each criterion, heavily favors the criteria that the utility values most (cost and schedule). The selected weightings ensure that the analysis will always favor the least-cost option regardless of environmental or community impacts. The Company provides no rationale or justification for how the weighting system was developed and why it should be viewed as acceptable. Table 4 below summarizes the weighting system.

Table 4: Duke's criterion weighting by site

	Belews Creek, Mayo, Marshall	Allen, Cliffside Active, Cliffside Inactive	Roxboro West, Roxboro East
Environmental Protection and Impact			
Modeled plume intersecting surface water	**7.14%**	**7.20%**	**7.20%**
Modeled groundwater impact beyond the current compliance boundary	**7.14%**	**7.20%**	**7.20%**
Modeled off-site groundwater impact	**7.14%**	**7.20%**	**7.20%**
Rank based on visual interpretation of modeled boron plume	**4.08%**	**3.90%**	**3.90%**
Air emissions off-site (hauling CCR and contaminated soil)	1.5%	1.5%	1.5%
Air emissions on-site	1.5%	1.5%	1.5%
Avoidance of greenfield disturbance	1.5%	1.5%	1.5%
Cost			
Closure cost	28.0%	28.0%	28.0%
Operation, maintenance, and monitoring cost	7.0%	7.0%	7.0%
Schedule			
Initiation time	4.5%	4.5%	4.5%
Construction duration	10.5%	10.5%	10.5%
Regional Factors			
Plan or potential for beneficial reuse of site	0.75%	0.75%	0.75%
Imported soil needs	0.75%	0.75%	0.75%
Beneficial reuse of CCR	**2.25%**	**2.25%**	**0.00%**
Transportation impact (hauling CCR and contaminated soil)	9.75%	9.75%	9.75%
Noise impact due to on-site activity	0.75%	0.75%	0.75%
View impact	**0.75%**	**0.75%**	**3.00%**
Constructability			
Stormwater management, geotechnical, and dewatering	5.00%	5.00%	5.00%

*Note: Values in **bold** are for criteria weighted differently at different sites. The Company provides no explanation for its weighting decisions, and why different sites require different weighting systems.*

As shown in the table above. Duke used three slightly different weighting systems which ranked six of the 18 criteria differently at some sites. Specifically:

- View impacts are weighted four times as high at the Roxboro sites as they are at the other six sites
- Beneficial reuses of CCR receives no weighting at the Roxboro sites, but receives 2.25 percent weighting at the other six sites
- The four groundwater criteria are weighted slightly differently at the Mayo and Allen site than they are at the other six sites.

It is unclear why the Company would come up with a purportedly straightforward quantitative ranking system, and then change how it weighs the criteria across sites. This discrepancy calls into question the

legitimacy and accuracy of Duke's entire scoring system, and once again demonstrates that there is nothing systematic and objective about the scoring process.

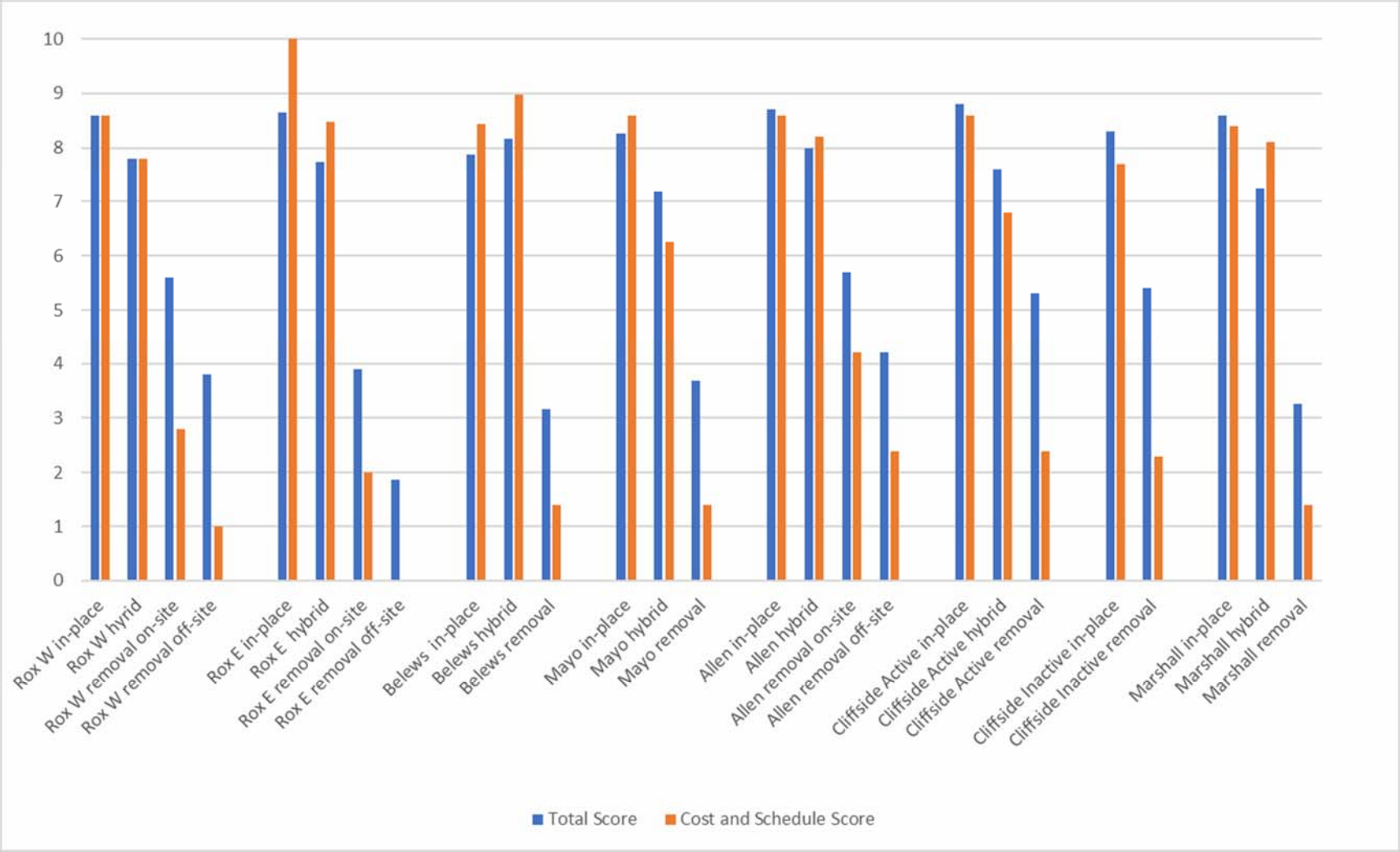
3.4. Does the Framework Even Matter?

Synapse evaluated whether Duke would have achieved the same results if the Company had simply ignored all criteria except cost and construction schedule. To do this, we calculated site rankings using just the four cost and scheduling criteria. We found that, as shown in Figure 1, the rankings of scenarios would be identical—and the numerical scores would be similar in many cases—if only the four cost and schedule criteria were used instead of all 18.

In all cases, the Closure-by-Removal option rank last,[8] the Hybrid Option is narrowly ranked highest at Belews Creek, and the Closure-in-Place option is ranked highest at the remaining seven sites. As Figure 1 demonstrates, this is equally true using Duke's entire 18-factor scoring, or using only the four cost and schedule criteria. This means that Duke has made the same recommendations that it would have reached if it ignored environmental and community impacts and considered only its own costs and construction requirements. Due to modeling choices, possible data entry errors (discussed in Section 4.2), and an implicit dismissal of environmental concerns, Duke's own costs and schedules always determine the winning scenario.

[8] At Roxboro East, removal literally scores zero on all the cost and schedule criteria.

Figure 1. Total score vs. cost + schedule components



Note: The blue bar shows the total score from Duke's multi-criteria evaluation, using all 18 criteria. The orange bar shows what the total score would be if only cost and schedule criteria were used, and their total weight were scaled up to 100 percent.

4. DUKE'S EVALUATION OF IMPACTS AND CRITERIA

4.1. Cost and Construction Considerations

As discussed above, Duke's site evaluation focuses heavily on cost and scheduling factors. The four cost and construction criteria scored in the matrix are: closure cost, worth 28 percent of the final score; OM&M costs, worth 7 percent; initiation time worth 4.5% of the final score; and project duration, worth 10.5 percent of the final score. Together, these four criteria account for 50 percent of the total score. There are three main issues with the Company's cost and scheduling treatment: first, the Company weighs construction spending and OM&M spending differently (and further distorts the result through its application of the 0-10 ranking scale); second, the Company improperly reports its Rough Order of Magnitude (ROM) cost estimates; and finally, the Company reports all costs as though they are incurred at a single point in time rather than as a stream of values.

Construction and OM&M Cost Weighting

Duke evaluates closure costs and OM&M costs separately. Separating the categories would make sense if Duke were evaluating each over a different time period. However, because the Company is viewing all costs as though they are incurred in the present, this treatment leads to arbitrary distinctions between the value of a dollar spent on different cost categories. One million dollars spent on closure costs at one site should be valued the same as one million dollars spent on OM&M costs at that site in the same year.

Compounding this issue, Duke distorts the scores by applying an arbitrary 0-10 ranking system across a wide range of construction and scheduling values at the eight basins. Large differences in costs should lead to scores that are farther apart, and small differences should lead to scores that are close together. Furthermore, if the costs associated with all closure options at a site fall within a small range, then all options should receive a similar cost ranking.

Instead, in Duke's scoring system, the higher cost option always receives a score of 0 and the lower cost option always receives a score of 10. A full 28 percent of each site's total score is determined in this manner. Since removal tends to have the higher construction cost, many of the Closure-by-Removal options score a 0 in this category, while most Closure-in-Place options score a full 10.

Meanwhile, the reverse is true for OM&M costs, which tend to be higher for the Closure-in-Place option. However, this category is worth only 7 percent of the total score. The result for several sites is that removal receives 0.7 points (a score of 10, with a 7 percent weighting) for having lower OM&M costs, while Closure-in-Place receives 2.8 (a score of 10, with a 28 percent weighting) for having lower closure costs, regardless of any of the actual dollar values. At the Cliffside Inactive Basin, for example, the total estimated cost of Closure-by-Removal is only slightly more expensive than the cost of Closure-in-Place

($72,727,940 for removal, $62,454,352 for in place).[9] In this case, savings of $39 million in construction costs is worth 2.8 points for Closure-in-Place, while savings of $29 million in OM&M costs is worth just 0.7 points for Closure-by-Removal.

Order of Magnitude Estimates

All the reported cost values are referred to as rough order of magnitude (ROM) cost estimates, meaning they are not exact figures. By reporting so many digits (significant figures), as is done in the Cliffside costs described above, the utility is misleading the audience into believing that it is confident in the cost estimates down to the last dollar, when in fact the utility is only confident to within a much larger margin of error, perhaps in the tens of millions of dollars.

Additionally, when ROM rankings are used to estimate cost, rankings should be especially careful not to differentiate between options with similar costs. In the case of Cliffside, cost estimates for Closure-in-Place and Closure-by-Removal are on the same order of magnitude, and if the actual numbers turn out to be just a few percentage points different from Duke's estimates, Closure-by-Removal could turn out to be less expensive. These options should be scored similarly for total cost. The approximate nature of the cost estimates exacerbates the flaws in Duke's scoring system. As described above, Duke's scoring matrix magnifies even small differences between the estimated costs by assigning a score of 0 to the higher cost and a score of 10 to the lower cost, regardless of how different the costs are. This method is particularly absurd when the rough estimates of the costs for the closure options are relatively close.

Cost Reporting

Duke reports all construction and OM&M costs as though they are incurred at a single point in time regardless of when the construction and OM&M happens or how the costs will impact the revenue requirement. The Company should instead be reporting all costs based on their present value, to reflect how and when those costs will accrue to the Company. If there is uncertainty around cost treatment, then Duke should acknowledge that and report a range of possible costs. This is important because the costs associated with the Closure-by-Removal options are spread out over a longer period than the Closure-in-Place options. So the relevant financial assumptions, including discounting, weighted average cost of capital, inflation, amortization, depreciation, financing costs, and taxes will have a systematically greater impact on the Closure-by-Removal options than the Closure-in-Place options. The present value costs of the Closure-by-Removal option should be lower than the numbers presented in these documents, and closer to the comparable costs of Closure-in-Place.

4.2. Trucking Impacts

Duke's trucking analysis and estimation of vehicle miles travel is based on the amount of soil and ash that needs to be removed from the site, as well as the soil needed to be brought to the site to fill in

[9] The removal option does have higher construction costs compared to Closure-in-Place, but this is balanced out by lower OM&M costs. The present value cost of the removal option is likely much lower than what is presented by Duke Energy.

emptied coal ash basins and cover landfills. The three trucking criteria in the scoring matrix are transportation impact (based on miles driven), which is worth 9.8 percent of the final score, air emissions off-site (based on miles driven), and air emissions on-site (based on miles drive), which are each worth 1.5 percent of the score.

Duke's execution of the trucking analysis is problematic for several reasons: (1) the analysis relies on illogical and unsubstantiated data inputs; (2) there are errors in the Company's calculations; (3) there are data entry errors and inconsistencies in the analysis presented in the Company's scoring matrix for multiple sites.

Illogical Data Inputs

The miles driven inputs and calculations are so small as to be insignificant for several of the scenarios. Specifically, the removal scenarios for Belews Creek and Mayo are said to include only 1 or 2 miles of total off-site truck driving, while Marshall and Allen are reported to require only 10 and 50 miles of off-site trucking. It is difficult to picture a scenario making use of such precise, small amounts of trucking over a multi-year time scale. Duke should use a figure of zero if no real off-site trucking is involved rather than assigning a small but unsubstantiated number. This is significant because assigning a small, but non-zero, number of trucking miles to the hybrid or excavation option allows the Company to justify a ranking of zero for these options, versus a ranking of 10 (full credit) for the Company's preferred Closure-in-Place option.

None of the scenarios for these sites have significant trucking impacts according to Duke's community impacts analysis. But in addition, Duke disregards its own community impacts analysis, which estimates that cap in place will have a greater trucking impact than on-site ash removal.

Data Entry and Calculation Errors

The scoring spreadsheet has duplicate, often contradictory data entries for trucking miles associated with each scenario. Duke utilized the input of miles driven off-site twice for each scenario: once for calculating the transportation impact criterion, and a second time for calculating the air emissions off-site criterion. The number of miles utilized for these two pieces of analysis should be identical; however, the values reported on the scoring matrix differ for the two criteria at four of the sites.[10]

Additionally, at the Roxboro West Ash Basin, the mileage calculation was performed incorrectly. Duke reported a value of 34.5 million miles of off-site trucking associated with the Closure-by-Removal option, when the actual value should have been 20.7 million miles. The error appears to result from adding "Est Off-site Travel (Miles)" and "Total Est Off-site Haul Volume (CY)" in the Company's spreadsheet.[11]

Clearly these different categories, expressed in different units, should not be added together. "Est On-

[10] The scoring spreadsheet asks the user to enter miles driven off-site twice for each site, once for the transportation impact criterion, and again for the air emissions off-site criterion. The numbers entered are different for the two criteria at four of the sites.

[11] Duke Energy, "Roxboro Steam Electric Plant West Ash Basin (WAB) Closure Options Analysis Report 11-15-18," Table 2 – Estimated Quantity Analysis.

site Travel (Miles)" is zero for this option, so the correct total travel distance is the off-site travel, which is 20,699,857 miles.

The same error occurs for all three scenarios at Roxboro West, as shown by Table 5 below. Derivation of "Total Est Travel" is not shown – but the large number of digits presented for each data point by Duke makes it possible to confirm the mistake. All these issues mentioned above lead to major questions about data quality and quality control of Duke's inputs and analysis.

Table 5. Roxboro West travel calculations

Scenario	Total Est Off-site Haul Volume (CY)	Est Off-site Travel (Miles)	Total Est Travel (Miles)
Removal	13,799,905	20,699,857	34,499,762
Hybrid	782,972	1,174,459	1,957,431
Closure-in-Place	600,160	900,240	1,500,400

Source: Excerpted from Duke Energy, "Roxboro Steam Electric Plant West Ash Basin (WAB) Closure Options Analysis Report 1-18-19," Table 2 – Estimated Quantity Analysis.

4.3. Groundwater Pollution

The four main groundwater criteria cover the potential for the boron plume to intersect the surface water, groundwater impacts beyond the current compliance boundary, and any off-site groundwater impacts. Together, these criteria account for almost a quarter of the total score. These criteria address some of the leading concerns about the environmental impacts of coal ash disposal. However, at seven of the eight sites, three of the four groundwater criteria receive the same score under each of the three scenarios.[12] In short, Duke is asserting that the final choice of compliance methodology Closure-in-Place, Closure-by-Removal, or the Hybrid Closure Option – makes no difference for these key indicators of groundwater pollution. The identical scores on more than 20 percent of the final evaluation for each scenario effectively removes these issues from the decision about the preferable method for ash disposal.

Discounting Boron Plumes

In the summary report for the Mayo, Roxboro, and Belews Creek sites, Duke admits that the Closure-by-Removal scenario will reduce the boron plume within the immediate vicinity of the basin footprint faster than all other scenarios. However, the Company goes on to state that "the minor change in modeled plume size, within the immediate vicinity of the basin footprint, is not enough to justify the cost of the

[12] There is some variation among scenarios on a fourth groundwater criterion, given the lower weight of 4.1 percent of the final score (or 3.9 percent, depending on the site): "relative rank based on visual interpretation of modeled boron plume." However, this criterion is treated as less important than the three discussed in the text, which each account for 7.14 – 7.20 percent of the final score.

Closure-by-Removal scenario." This statement clearly demonstrates that cost, not environmental and health impacts, are driving Duke's site closure decisions

In the Cliffside Active Basin, Closure-by-Removal is anticipated to more quickly reduce boron concentrations beyond the compliance boundary, according to Duke's report. The Company states that in the Closure-by-Removal case "boron is predicted to exceed the 2L standard for approximately 100 years," while in the Closure-in-Place and Hybrid Options the standard is exceeded for 500 and 400 years, respectively. Despite centuries of additional pollution, all three options receive perfect scores for the three major groundwater impact criteria discussed above. In particular, they all receive a score of 10 for "Groundwater Impact Beyond the current Compliance Boundary," which seems to be exactly the indicator that Duke says would be improved under Closure-by-Removal. It is unclear why differences in pollutant levels that last for hundreds of years are essentially being ignored in Duke's cleanup plans.

4.4. Other Regional and Environmental Factors

The seven criteria that cover non-groundwater regional, environmental, and community impacts include greenfield disturbance, soil needs, beneficial reuse potential of both the CCR byproduct and of the site more broadly, noise disturbance, and visual disturbance, and construction considerations for stormwater management and ash dewatering. These criteria together account for 12 percent of the total score.

The scoring for these criteria is informed by the Community Impact Analysis report, which was discussed in detail in Section 3.2.

4.5. What Is Missing from the Multi-Criteria Framework?

The risk of impacts from a breach and leak at a coal ash basin is completely absent from Duke's summary reports, evaluation framework, and the Community Impact Assessment Reports. This is surprising considering the increased occurrence of coal ash pond breaches that have occurred in the recent past, and the significant harm that has resulted.

The U.S. Environmental Protection Agency ranks coal ash ponds according to a National Inventory of Dams (NID) criteria based on the damage that would likely occur if there was a dam failure.[13] In the United States, there are 81 ponds that have a "high hazard" ranking, meaning dam failure would probably result in loss of life. An additional 250 ponds have a "significant hazard" ranking, meaning dam failure would result in economic loss, environmental damage, disruption of lifeline facilities, and other impacts—but not likely loss of human life. All the ash disposal ponds discussed here are ranked as high hazard sites.

[13] High and Significant Hazard Coal Ash Dump Sites. Earthjustice. https://earthjustice.org/features/high-and-significant-hazard-coal-ash-dump-sites.

Coal ash spills and contaminations are not a rare occurrence. As of 2014, there were 208 coal ash sites in the United States that had led to contamination or spills.[14] Duke Energy is a repeat offender with several spills on record in the past five years. A Duke Energy coal ash containment pond in Eden, North Carolina spilled into the Dan River in 2014, spilling 39,000 tons of coal ash. Costs in the first six months amounted to $295 million, and attempts to clean the river were largely unsuccessful.[15] In 2018, another Duke ash pond at the Sutton Power Plant near Wilmington spilled after sustaining damage from Tropical Storm Florence.[16]

Duke's multi-criteria analysis of ash disposal scenarios trivializes or ignores such risks–implicitly asserting that coal ash spills and leaks will never occur, even at "high hazard" disposal sites.

[14] Coal Ash Contaminated Sites. Earthjusticehttps://earthjustice.org/features/coal-ash-contaminated-sites.

[15] Lemly, A. Dennis. "Damage cost of the Dan River coal ash spill." *Environmental Pollution*, Volume 197, Pages 55-61. February 2015. Available at https://www.sciencedirect.com/science/article/pii/S0269749114004953.

[16] Ari Natter. Another Coal-Ash Spill Reported at Duke Site in North Carolina. Bloomberg, https://www.bloomberg.com/news/articles/2018-09-17/another-coal-ash-spill-reported-at-duke-site-in-north-carolina.

5. SITE HIGHLIGHTS

Table 6: Summary of Duke's cost and schedule rankings by site

	Total Cost (Construction and OM&M) $ Million			Schedule (from initiation to completion) Years		
	Closure-in-Place	Hybrid Option	Closure-by-Removal	Closure-in-Place	Hybrid Option	Closure-by-Removal
Belews Creek	$202	$174	$510	8.8	10.3	16.0
Mayo	$115	$141	$224	5.5	8.0	10.0
Roxboro East	$34	$58	$514 $768	6.5	7.3	19.4 19.4
Roxboro West	$97	$214	$412 $548	8.7	11.4	19.0 19.0
Marshall	$303	$456	$1,120	15.0	14.5	32.4
Allen*	$249	$326	$593 $1,231	8.8	10.3	22.0 19.7
Cliffside Active	$108	$119	$153	6.2	7.8	9.3
Cliffside Inactive	$62	NA	$73	4.2	NA	5.0

**Allen and the Roxboro sites each have two Closure-by-Removal scenarios – in all three cases the lower cost removal option is for on-site disposal and the higher cost option is for off-site removal.*

5.1. Belews Creek Steam Station Ash Basin

Duke's Site Ranking

1. **Hybrid Option**: $174 million project cost; 10.3 years project timeline.
2. Closure-in-Place: $202 million project cost; 8.8 years project timeline.
3. Closure-by-Removal: $510 million project cost; 16 years project timeline.

Community Impact Analysis Recommendation: Hybrid Option

Site Summary

Belews Creek is the only site where Duke recommends the Hybrid Closure Option. Belews Creek is also the only site where the Hybrid Option is less expensive than Closure-in-Place. The Closure-by-Removal option will utilize an on-site landfill (across Pine Hill Road from the existing Ash Basin) so the off-site trucking impacts and air emissions are negligible.

Indeed, Duke's Community Impact Analysis acknowledges that no option has significant trucking impacts. And the impacts Duke does identify are greater for cap in place than for ash removal. Specifically, Duke estimates that cap in place would cause a 12% increase in daily average truck traffic on community roads, compared to 11% for the hybrid option and 9% for excavation.

However, in scoring trucking impacts for the three closure scenarios, the Closure-by-Removal scenario is ranked worst, with 1 mile of driving (for which there is no source of justification), while the Closure-in-Place scenario is ranked best with no miles driven. The Closure-in-Place scenario gets full credit for minimizing driving, worth 9.8 percent of the final score, because it purportedly avoids the 1 or 2 miles of driving reported for the removal scenario. The avoidance of 1-2 miles of driving over a 10 plus year period should not affect any decision or calculations.

Duke acknowledges that the Closure-by-Removal scenario will reduce the boron plume within the immediate vicinity of the basin footprint faster than all other scenarios, yet the Company still ranks this option last. Additionally, there are data entry errors and inconsistencies in the Company's Summary Report. The Construction and OM&M costs reported in Duke's Summary report (REV 1) do not match the cost numbers reported in the scoring matrix.

5.2. Mayo Plant Ash Basin

Duke's Site Ranking

1) **Closure-in-Place:** $115 million project cost; 5.5 years project timeline.
2) Hybrid Option: $141 million project cost; 8 years project timeline.
3) Closure-by-Removal: $224 million project cost; 10 years project timeline.

Community Impact Analysis Recommendation: Not Closure-in-Place

Site Summary

Duke recommends Closure-in-Place for the Mayo Plant Ash Basin. The Closure-by-Removal option will utilize an on-site landfill (across Boston Road from the existing Ash Basin), so the off-site trucking impacts and air emissions are negligible.

Indeed, Duke's Community Impact Analysis acknowledges that no option has large trucking impacts. And the impacts Duke does identify are greater for cap in place than for ash removal. Duke estimates that cap in place would cause a 2.9% increase to daily average truck traffic on community roads, compared to 2.3% for the hybrid option and 0.01 % for excavation.

However, in scoring trucking impacts for the three closure scenarios at Mayo, the Closure-by-Removal scenario is ranked worst, with 2 miles driven. The Closure-in-Place scenario is ranked best with no miles driven. As with Belews Creek, the Closure-in-Place scenario gets full credit for minimizing driving, worth 9.8 percent of the final score, because it avoids 1-2 miles of driving reported for the Closure-by-Removal scenario.

Stormwater management was cited as a concern with the Closure-in-Place option. Duke acknowledges that long-term modeling indicates a quicker reduction in the boron plum within the immediate vicinity of the basin footprint by the Closure-by-Removal option.

5.3. Roxboro Ash Basins (East and West)

Duke's Site Ranking

East Ash Basin

1) **Closure-in-Place:** $34 million project cost; 6.5 years project timeline.
2) Hybrid Option: $58 million project cost; 7.3 years project timeline.
3) Closure-by-Removal on-site: $514 million project cost; 19.4 years project timeline.
4) Closure-by-Removal off-site: $768 million project cost; 19.4 years project timeline.

Community Impact Analysis Recommendation: Hybrid Option or Closure-in-Place

West Ash Basin

1) **Closure-in-Place:** $97 million project cost; 8.7 years project timeline.
2) Hybrid Option: $214 million project cost; 11.4 years project timeline.
3) Closure-by-Removal on-site: $412 million project cost; 19 years project timeline.
4) Closure-by-Removal off-site: $548 million project cost; 19 years project timeline.

Community Impact Analysis Recommendation: Hybrid Option

Site Summary

Duke recommends Closure-in-Place for both the Roxboro East and Roxboro West Ash Basin. The off-site Closure-by-Removal option and the Hybrid Option for Roxboro East Basin involve trucking the coal ash material to the Mayo landfill more than 15 miles away, as does the off-site Closure-by-Removal option for Roxboro West Basin. On-site Closure-by-Removal options are also considered for both Roxboro sites. The Mayo landfill will also receive coal ash waste from the Mayo Plant Ash Basin under the Closure-by-Removal and Hybrid Options, and Duke asserts that it would be infeasible to simultaneously process waste from all three sites at the Mayo landfill.

Once again, Duke acknowledges that long-term modeling indicates a quicker reduction in the boron plume size within the immediate vicinity of the basin footprints at both sites for the Closure-by-Removal options compared to the Closure-in-Place options.

5.4. Allen Steam Station Ash Basin

Duke's Site Ranking

1) **Closure-in-Place:** $249 million project cost; 8.8 years project timeline.
2) Hybrid Option: $326 million project cost; 10.3 years project timeline.
3) Closure-by-Removal on-site: $593 million project cost; 22 years project timeline.
4) Closure-by-Removal off-site: $1,231 million project cost; 19.7 years project timeline.

Community Impact Analysis Recommendation: Hybrid Option

Site Summary

Duke recommends Closure-in-Place for the Allen Steam Station. There are two ash basins at Allen—a retired / inactive ash basin and an active ash basin. The on-site Closure-by-Removal option constructs a new landfill on the site of the existing ash basin, while the off-site Closure-by-Removal option trucks the excavated ash to an existing (but currently unidentified) off-site, lined landfill. The Company assumes that the off-site landfill will be located within a 50-mile radius of the site, but no specific landfill is referenced. Unlike at Roxboro, Duke does not present the math or analysis on the total miles traveled and the associated air emissions. The Company simply enters 50 miles into the scoring matrix.

According to Duke's analysis, the trucking impacts of ash removal in the on-site Closure-by-Removal scenario are negligible, and are even less than Closure-in-Place: Excavation to onsite storage for the Closure-by-Removal scenario would add only two more trucks on community roads each day, compared to six more trucks on community roads for the duration of the Closure-in-Place scenario.

5.5. Marshall Station Ash Basin

Duke's Site Ranking

1) **Closure-in-Place:** $303 million project cost; 15 years project timeline.
2) Hybrid Option: $456 million project cost; 14.5 years project timeline.
3) Closure-by-Removal: $1,120 million project cost; 32.4 years project timeline.

Community Impact Analysis Recommendation: Hybrid Option

Site Summary

Duke recommends Closure-in-Place for the Marshall Station. The Hybrid Option involves building a new consolidated closure area within the existing ash basin footprint. The Closure-by-Removal option involves building a new lined landfill on-site, but outside the existing ash basin footprint. None of the closure options involve trucking material off-site or using public roads for movement of excavated ash. According to Duke's analysis, the trucking impacts of ash removal to the on-site landfill are negligible, and are even less than cap in place: Duke estimates that Closure-by-Removal would cause only a 4% increase in daily truck traffic on community roads, compared to a 7% increase for the Closure-in-Place scenario.

5.6. Cliffside Steam Station at the Rogers Energy Complex

Duke's Site Ranking

Active Ash Basin

1) **Closure-in-Place:** $108.5 million project cost; 6.2 years project timeline.
2) Hybrid Option: $119.5 million project cost; 7.75 years project timeline.
3) Closure-by-Removal: $153 million project cost; 9.25 years project timeline.

Community Impact Analysis Recommendation: Not Closure-in-Place

Unit 5 Inactive Ash Basin

1) **Closure-in-Place:** $62.5 million project cost; 4.2 years project timeline.
2) Closure-by-Removal: $73 million project cost; 5 years project timeline.

Community Impact Analysis Recommendation: Not Closure-in-Place

Site Summary

Duke recommends Closure-in-Place for both the Active Ash Basin and the Unit 5 Inactive Ash Basin at the Cliffside Steam Station. At the Active Basin, the Hybrid Option involves consolidating the coal ash into a smaller footprint in the existing basin (the Company did not report a Hybrid Option for the Inactive site). At both the Active and Inactive Basins, the Closure-by-Removal option involves moving all excavated ash to an on-site Coal Combustions Products landfill, so negligible off-site trucking is involved.

According to Duke's analysis, the trucking impacts of ash removal to the on-site landfill are negligible, and are even less than cap in place: Closure-by-Removal would add only nine more trucks on community roads each day, compared to 13 more trucks on community roads for the Closure-in-Place scenario.