Repairing the Damage

Cleaning Up Hazardous Coal Ash Can Create Jobs and Improve the Environment

Appendix A: Coal Combustion Residual Cleanup and Closure: Cost and Jobs Analysis

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1. Introduction

1.1. Background and Problem Statement

This report provides an analysis of closure and cleanup of coal combustion residuals (CCR) located at two coal-fired steam electricity generating stations in the United States, evaluating the environmental benefits, cost, and direct job creation under two distinct site-specific closure plans for each facility. In this report we evaluate cleanup and closure options at J. M. Stuart Electric Generating Station in Ohio and Sebree Generating Station in Kentucky.

CCR is generated from the combustion of coal and include fly ash and bottom ash, boiler slag, and flue gas desulfurization materials. CCR is historically one of the largest industrial waste streams generated in the United States. The U.S. Environmental Protection Agency (EPA) estimated in 2012 that more than 470 coal-fired electric utilities burn more than 800 million tons of coal, generating approximately 110 million tons of CCR annually in the United States.[1] CCR disposal was not federally regulated until promulgation of the federal CCR Rule (40 CFR Part 257, Subpart D) in 2015. Prior to this, disposal of CCR was commonly only regulated by states permitting the power station facility. Given the lack of regulatory standards for constructing CCR disposal areas and monitoring CCR waste, both the construction and condition of CCR waste units and pollution caused by the CCR were widely unreported until recently.

Historically, much of the CCR generated has been disposed of in unlined or poorly lined surface impoundments often referred to as coal ash “ponds.” CCR surface impoundments hold a mixture of CCR and process water by design, because CCR is commonly managed as a slurry at power stations to allow it to be piped to typically unlined basins. Where power stations were constructed adjacent to rivers and lakes for access to cooling water, the surface impoundments were often also sited adjacent to those rivers and lakes. It is also common for impoundments to be located in the floodplain and/or in areas of shallow groundwater.

Groundwater pollution is common from unlined and poorly lined surface impoundments as shown in the groundwater quality analytical data that have been required to be collected since the federal CCR rule came into effect (40 CFR § 257.90). Contact between groundwater and CCR provides one mechanism that leaches contaminants from CCR to groundwater. Seepage of both CCR slurry process water and precipitation in the impoundment provides another mechanism by which CCR leachate may impact groundwaters. CCR leachate is commonly high in arsenic, boron, lithium, cobalt, manganese, molybdenum, sulfate, and other chemical elements that either are toxic or otherwise render water unusable for drinking because of salinity and taste.[2] CCR-contaminated groundwater may flow to drinking water wells or pollute nearby surface water.

[1] Environmental Protection Agency. 2015. 40 CFR Parts 257 and 261 [EPA–HQ–RCRA–2009–0640; FRL–9919–44–OSWER] RIN–2050–AE81. Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities. Federal Register Vol. 80, No. 74, Friday, April 17, 2015, Rules and Regulations.

[2] See, for instance, 40 CFR Appendix III to Part 257—Constituents for Detection Monitoring, and Appendix IV to Part 257—Constituents for Assessment Monitoring.

In addition to disposal in surface impoundments, other common CCR management practices include beneficial reuse and landfill disposal. CCR disposal in engineered landfills constructed under the standards found at §257.70 for new and laterally expanded landfills typically provides superior environmental protection to surface impoundments, because the CCR is drained and stored relatively dry and because the landfills have liners, have leachate collection systems, and are constructed above the water table. Not all older landfills have these modern construction methods, and the federal CCR Rule grandfathers in many existing unlined landfills. A substantial volume of CCR is also beneficially reused as a raw material in products such as concrete and drywall. CCR reused in these types of applications is "encapsulated," meaning it is bound with other materials that limit the exposure to and leaching potential of contaminants contained in the CCR.

At both of the power stations evaluated in this report, CCR was disposed of in unlined surface impoundments that are in contact with groundwater. Each site also has documented groundwater pollution resulting from leaching of the CCR by both groundwater contact and seepage from the impoundments. The Sebree Station is home to the Green Landfill, an older unlined CCR landfill that both leaks to groundwater and forms surface seeps that flowed to the Green River. The J. M. Stuart Station also has two modern, lined CCR landfills. Given the various disposal methods used at these two sites, they are representative of both CCR disposal and contamination issues prevalent in the United States and the opportunities to provide robust cleanup CCR sites.

Regulatory agencies in the United States and the public are faced with evaluating electric power industry plans to address groundwater pollution and choose appropriate closure methods for surface impoundments at hundreds of power stations nationwide. The number of impoundments undergoing closure has significantly increased in recent years as electric utilities have retired coal-fired power stations because they are uneconomical to operate due to a combination of competition from power generated from renewables and low-priced natural gas, and due to the cost required to retrofit coal-fired power stations to comply with current environmental regulations. In addition, the 2015 federal CCR rule requires most coal ash surface impoundments (including all unlined impoundments and those whose bases are located within five feet of groundwater) to initiate closure by April 2021, unless they receive a specific extension to operate from the EPA. The result is that decisions are being made today that will determine the long-term human and environmental risks as well as permanence of the closure methods used for surface impoundments.

The closure method used for a CCR surface impoundment determines to a large degree whether the source of pollution to groundwater is eliminated. The electric power industry has shown a preference for cap-in-place closure of CCR impoundments, because it is relatively easy to implement as well as relatively low cost. Cap-in-place involves dewatering the impoundment of its surface liquid and then grading the top of the CCR to provide drainage and installing a low-permeability over-liner or "cap" typically made of a combination of plastic geomembrane, soil, and drainage layers. Cap-in-place eliminates most of the precipitation percolation leaching of contaminants from the CCR but does not prevent leaching by groundwater contact with CCR underneath the cap if the ash in the impoundment is in contact with the aquifer. Cap-in-place may also leave CCR surface impoundments vulnerable to catastrophic failure due to floods or cap failure during extreme storms. The risk of impoundment failure is exacerbated by the fact that impoundments are commonly constructed adjacent to surface water features and in floodways. Several high-profile, catastrophic surface impoundment failures have occurred, for instance, the 2008 Kingston coal ash spill in Tennessee and 2014 Dan River coal ash spill in North Carolina.

Other common closure methods for surface impoundments include excavation and removal of CCR either to a CCR landfill or to be beneficiated to produce raw materials for reuse; both are commonly referred to as "clean closure." Removal of CCR to landfills or the beneficial reuse market typically mitigates both the source of groundwater pollution and risk of catastrophic release from impoundment dike failure due to floods or other extreme events.

1.2. Study Goals and Objectives

The goal of our analysis for each power station is to evaluate the site conditions and impacts to groundwater and to assess the potential for differing corrective measure and closure options to address groundwater pollution and provide safe permanent storage of CCR at the site. We then provide an accounting of the potential cost and job creation for cleanup and closure activities.

For each power station we compare two alternatives for closure and groundwater corrective action, as follows:

> **Alternative 1: Utility cleanup and closure plan**
> The first closure alternative that we evaluate for each power station is the proposed plan that the utility has described in closure and corrective action documents that were prepared to comply with federal and state regulations that apply to groundwater cleanup and CCR waste unit closure.
>
> **Alternative 2: Comprehensive cleanup and closure plan**
> The second alternative for each power station represents a comprehensive cleanup plan that removes all CCR that poses a long-term threat to water quality. Excavated CCR is disposed of in CCR landfills and appropriate controls are constructed at each landfill to limit leachate and flooding hazards. This alternative is designed to eliminate the source of pollution to groundwater and surface water and provide a permanent and effective remedy of the source of groundwater contamination.

Both CCR waste unit closure (capping, removal, etc.) and groundwater corrective action needs are considered for each alternative; for simplicity we will refer to both as "closure" in the discussion of cost and jobs created. We evaluate the relative benefits and drawbacks to the two closure alternatives, estimate the direct cost of each closure alternative, and evaluate the potential jobs created during closure and post-closure construction and related activities. The cost and jobs are of interest because power stations often provide significant employment and tax base to communities located near power stations, and when the power station is retired, the economic impact to the community can be devastating. The closure and cleanup activities can provide an economic engine for these communities at exactly the time when the jobs and expenditures for power generation cease.

1.3. Report Organization

The report is organized as follows:

> **Section 1** provides an introductory background of CCR disposal issues and a summary of the goals and objectives and methods of this study.

Sections 2 and 3 provide discussion and results of the closure analysis for each power station. The section for each power station begins with a site overview of the power station facility, a summary of existing extent of contamination and special considerations therein, a description of the two closure plan alternatives evaluated, and cost and jobs analysis results. **Section 2** covers the J. M. Stuart Electric Generating Station in Ohio, and **Section 3** covers the Sebree Generating Station in Kentucky.

1.4. Methods Used to Estimate Cost and Jobs

We conducted an analysis to quantify the direct cost and job creation for two closure alternatives for each facility. Our analysis included developing cost and job schedules that illustrate capital and operation and maintenance (O&M) expenditures and construction and O&M-related jobs over the course of the cleanup and 30-year post-closure timeline, depending on the nature of the proposed alternative. Jobs quantified as part of this analysis are denoted as full-time equivalent (FTE), which represents the number of jobs per position per year. Our analysis was conducted under a set of assumptions made based on the data available for each site and the scope of the analysis, which was limited to direct costs and jobs. Cost and jobs indirectly linked to a particular cleanup effort (e.g., service industry costs or jobs catering to the cleanup workforce, rental equipment suppliers, etc.) were not considered as part of this evaluation. A second analysis conducted by a separate consulting firm evaluated the secondary jobs and economic impacts from the two cleanup scenarios at each facility based on the direct jobs and costs estimated here (see Appendix B).

Our analysis focuses on site closure and groundwater corrective action and post-closure O&M. We limited our cost and jobs analysis to the type and quantity of CCR contaminants and waste identified in the site closure plans and the site characterization and investigative reports completed by the utility pursuant to state or federal requirements. No estimates were made for handling of additional contaminants that could be discovered during closure activities (e.g., asbestos, polychlorinated biphenyls (PCBs), fuel tanks and hydrocarbon-contaminated soil, or other hazardous material). Reclamation activities evaluated were limited to grading and vegetation of caps and do not include detailed reuse and redevelopment plans or institutional controls needed for specific reuse options. Plant decommissioning (building removal, demolition, salvage net costs, etc.) was not part of the evaluation. Post-closure O&M costs begin the year following closure of a CCR waste unit and run for 30 years, to follow the requirements of 40 CFR §257.104. Where post-closure O&M includes some of the same activities as operational O&M, such as CCR landfill leachate and stormwater management, we only estimate jobs and costs for post-closure activities to differentiate closure cost and job creation from operational costs and jobs during the active life of the waste unit, because the focus of this study is to compare closure and cleanup economics.

Our analysis used a variety of methods and sources to quantify the capital costs and jobs associated with a particular cleanup effort. Fundamentally, our analysis determined cost using the material quantities for a particular activity (cubic yards of material excavated, gallons of water pumped, area of surface impoundment capped, etc.) combined with production rates and operational costs of a particular piece of equipment and labor rates. Similar to capital costs, the number of jobs were determined on a per-unit area or volume basis based on production rates of equipment and other references such as contractor quotes or professional judgment. Some jobs, such as annual O&M jobs in landfill and impoundment maintenance and water management, were determined on a cost basis based on an assumed percentage of the capital cost contributed to labor and the median salary of a particular job position, with an additional multiplier to account for taxes, benefits, space, and materials to better represent a full-time position. The types of jobs produced are categorized as skilled labor, unskilled labor, and professional. A specific list of jobs and roles would be developed prior to actual cleanup of a facility, but our analysis provides a representative comparison between cleanup alternatives. The results of the analysis are outlined in the following sections.

2. J. M. Stuart Electric Generating Station

2.1. Site Overview

The J. M. Stuart Electric Generating Station was a coal-fired power plant located adjacent to the Ohio River near the community of Aberdeen, Ohio. The power plant began operation in 1970 and had four generating units with a capacity of 2,318 megawatts (MW). The plant was operated for most of its life by Dayton Power & Light. The plant operated until 2018, when it was retired by then-operator AES Ohio Generation due to declining market conditions for coal power,[3] and an agreement by part owner American Electric Power to transition production to solar and wind power. In December 2019, the plant site was sold to Kingfisher Development, which intends to complete closure, cleanup, and redevelopment. To our knowledge, redevelopment plans have not been announced at this time.

The J. M. Stuart Station was constructed adjacent to the Ohio River for use as cooling water. Figure A1 shows the layout of the facility. The layout of the facility is complex, with numerous former surface impoundments buried under existing impoundments and landfills. The impoundments and landfills contain more than 26 million cubic yards of CCR, the total of which is uncertain because volumes are not reported for impoundments that were closed prior to the 2015 federal CCR rule.

[3] See https://www.aes-ohio.com/About-DPL/Newsroom/News-Archives/2018/DPL-Inc--announces-the-retirement-of-the-J-M--Stuart-and-Killen-Station-power-plants.

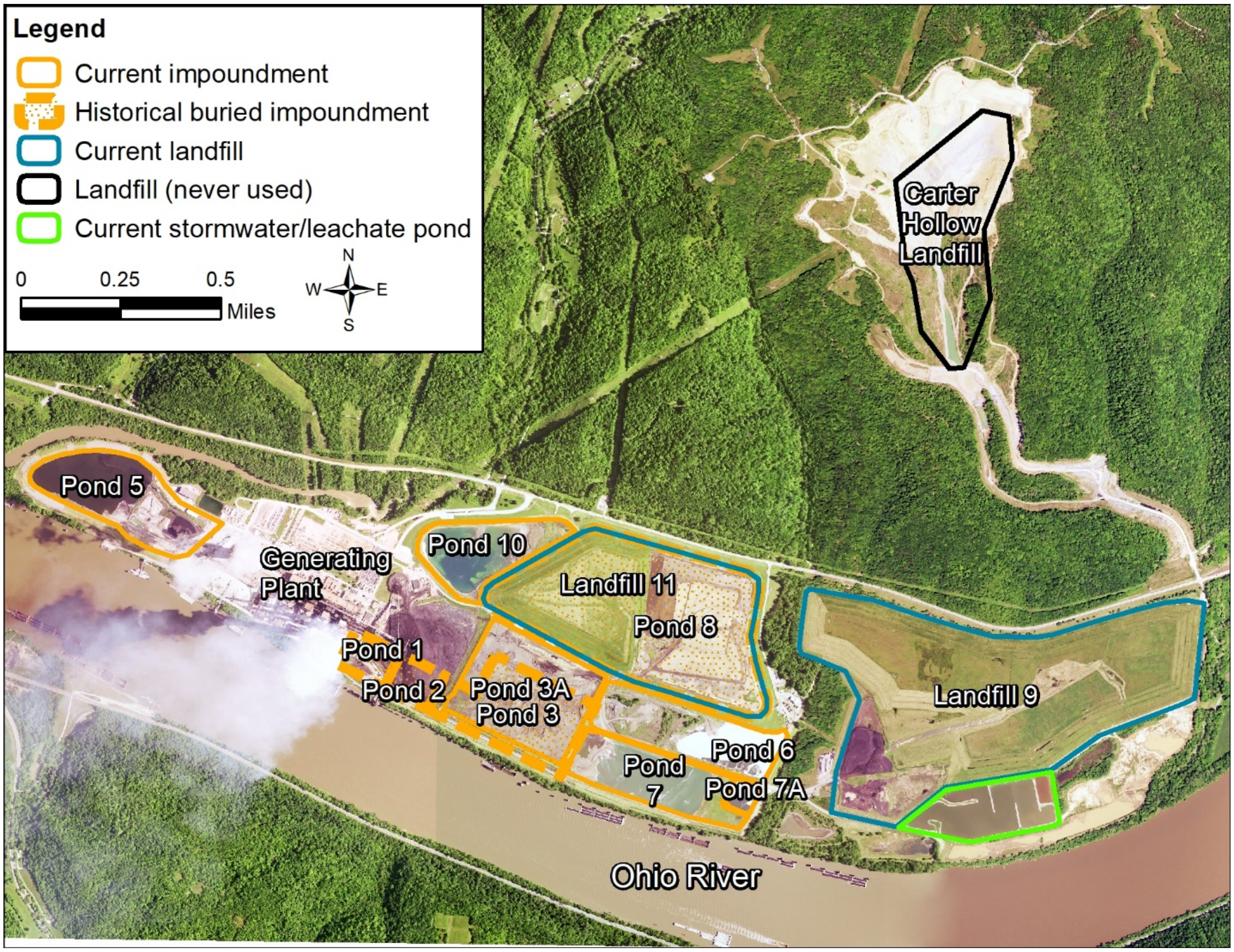

Figure A1. Current Site Layout of J. M. Stuart Electric Generating Station

The three original coal ash impoundments (Ponds 1, 2, and 3) were short-lived unlined impoundments that are currently buried under the plant coal yard and under the current Pond 3A.[4] Another former unlined impoundment, Pond 8, is buried underneath the current Landfill 11.

The current impoundments (Ponds 3A, 5, 6, 7, 7A, and 10) contained 4.9 million cubic yards of fly ash when the plant shut down. The total amount of CCR in the impoundments is lower now, because the owner has begun excavating these impoundments and moving the CCR to one of the landfills as part of its closure plan.

The facility has two active CCR landfills constructed with lined bottoms and leachate collection systems. Landfill 9 was originally permitted and constructed in 1984 with expansions permitted by the Ohio Environmental Protection Agency in 1986 and 1995. As of October 2020, Landfill 9 contained 15.5 million cubic yards, out of a 29.3 million cubic yard capacity. Landfill 11 was permitted by the agency in 2003 and began receiving CCR in 2006. As of October 2020, Landfill 11 contained 4.6 million cubic yards

[4] Key Environmental, Inc. February 2021. Closure By Removal Pond 3A, Pond 10, Coal Yard Former Stuart Station Manchester, Adams County, Ohio. Prepared on behalf of Kingfisher Development, Inc.

of CCR; there is a discrepancy in the utility documents about whether the capacity is 7.8 or 9 million cubic yards. Regardless, these active landfills have capacity to handle the volume of CCR stored in unlined impoundments if the impoundments are closed by removal of CCR.

The newest landfill at the plant, the Carter Hollow Landfill, was permitted in 2012 and is currently partially constructed, but it has never received any CCR waste because the plant closed prior to its use. The Carter Hollow Landfill has a permitted capacity of approximately 15 million cubic yards of CCR. To our knowledge, the facility owner has not announced future plans for this landfill.

Groundwater near the impoundments is contaminated by arsenic, boron, cobalt, barium, lithium, molybdenum, selenium, and radium. Issues with the groundwater contaminants are discussed further in section 2.2. Kingfisher Development has not formally selected groundwater corrective action measures but has indicated preference for an alternative that combines CCR waste unit closure (either pond removal or landfill cap in place) with monitored natural attenuation (MNA) of groundwater.[5] MNA is a passive remediation method that allows natural physical and chemical processes to lower concentrations over time to meet groundwater protection standards. These processes typically consist of dispersion, dilution, precipitation/coprecipitation, sorption, and radioactive decay for inorganic CCR contaminants.

The closure plans for the site have been in flux as ownership has changed in recent years. Originally, Dayton Power & Light's closure plans relied almost entirely on cap in place, with Ponds 5, 6, 7/7A, and 10 to be capped,[6] and only Pond 3A to be closed by removal to one of the landfills.[7] Since acquiring the site, Kingfisher Development has indicated that it is changing the closure plans and intends to also close Ponds 5, 6, 7/7A, and 10 by removal.[8] Kingfisher Development intends to submit final closure design for

[5] Key Environmental, Inc. July 2020. Revised Corrective Measures Assessment Report. Multiunit Groundwater Monitoring System, Former Stuart Station, Adams County, Ohio.

Haley & Aldrich. October 2019. Report on Corrective Measures Assessment, JM Stuart Station—Pond 5, Manchester, Ohio.

Key Environmental, Inc. July 2020. Groundwater Remedy Selection, Semiannual Progress Report, Pond 5, Pond 7/7A, Pond 10, and Landfill 11, Former Stuart Electric Generating Station. Kingfisher Development, LLC. Manchester, Adams County, Ohio.

[6] Haley & Aldrich, Inc. October 2016. CCR Conceptual Closure Plan, Pond 5, Dayton Power & Light Company, J. M. Stuart Electric Generating Station, Aberdeen, Ohio.

Haley & Aldrich, Inc. October 2016. CCR Conceptual Closure Plan, Pond 6, Dayton Power & Light Company, J. M. Stuart Electric Generating Station, Aberdeen, Ohio.

Haley & Aldrich, Inc. October 2016. CCR Conceptual Closure Plan, Pond 7, Dayton Power & Light Company, J .M. Stuart Electric Generating Station, Aberdeen, Ohio.

Haley & Aldrich, Inc. October 2016. CCR Conceptual Closure Plan, Pond 10, Dayton Power & Light Company, J. M. Stuart Electric Generating Station, Aberdeen, Ohio.

[7] Haley & Aldrich, Inc. October 2016. CCR Conceptual Closure Plan. Pond 3A. Dayton Power & Light Company. J. M. Stuart Electric Generating Station, Aberdeen, Ohio.

[8] Key Environmental, Inc. January 2021. 2020 Annual Dam Inspection Report, Pond 5, ODNR No. 8535-003, Former Stuart Station Manchester, Adams County, Ohio.

those ponds to the Ohio Environmental Protection Agency in December 2021. Because the plans are not finalized, we refer to this as Kingfisher Development's preference for closure by removal in this report and not as a firm closure plan. Kingfisher Development has also submitted plans to remove buried CCR in Ponds 1 and 2 located in the coal yard area,[9] but they have not indicated plans to remove or otherwise address CCR located in former Ponds 3 or 8.

Both Landfills 9 and 11 will be closed by capping in place.[10] The closure plan for the Carter Hollow Landfill is to cap in place;[11] however, it is unknown whether the Carter Hollow Landfill will be used to store CCR now that the J. M. Stuart Plant and nearby Killen Generating Station are shut down.

2.2. Contamination Summary and Cleanup Considerations

Groundwater Contamination

Groundwater at the site is contaminated by arsenic, cobalt, barium, lithium, molybdenum, selenium, and radium. Following the federal CCR rule, the utility prepared annual groundwater monitoring reports and corrective measure assessments that attempt to identify the source of contaminants. The utility also produced several Alternative Source Demonstrations (per §257.95 (g)(3)(ii)) to show that sources of contaminations in some wells were due to either natural causes or upgradient ponds and landfills. Our opinion is it would be difficult to positively determine the sources of all contamination due to the large number of potential CCR sources, which are adjacent to and built on top of one another. It is likely that all CCR, both in the current impoundments and in the buried former impoundments, contribute to groundwater contamination to some degree. What is known is that the groundwater is contaminated with federal CCR rule Appendix IV parameters throughout the area of the ponds. The landfills appear to have less groundwater contamination associated with them. For instance, groundwater downgradient of Landfill 9 has elevated levels of Appendix III parameters, including boron, but does not have exceedances of Appendix IV parameters.

The utility produced several Alternative Source Demonstrations to make the case that arsenic in groundwater is the result of natural arsenic found in fine-grained sediment underneath the ponds.[12] In

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Key Environmental, Inc. January 2021. 2020 Annual Dam Inspection Report, Pond 6, ODNR No. 8535-013, Former Stuart Station Manchester, Adams County, Ohio.

Key Environmental, Inc. January 2021. 2020 Annual Dam Inspection Report, Pond 7/7A, ODNR No. 8535-002, Former Stuart Station Manchester, Adams County, Ohio.

Key Environmental, Inc. February 2021. Closure by Removal Pond 3A, Pond 10, Coal Yard Former Stuart Station.

[9] Key Environmental, Inc. February 2021. Closure by Removal Pond 3A, Pond 10, Coal Yard Former Stuart Station.

[10] Haley & Aldrich, Inc. October 2016. CCR Conceptual Closure Plan, Landfill 9, Dayton Power & Light Company, J. M. Stuart Electric Generating Station, Aberdeen, Ohio.

Haley & Aldrich, Inc. October 2016. CCR Conceptual Closure Plan, Landfill 11, Dayton Power & Light Company, J. M. Stuart Electric Generating Station Aberdeen, Ohio.

[11] Civil & Environmental Consultants, Inc. October 2016. CCR Closure Plan: Version 1 Carter Hollow Landfill, Dayton Power & Light Company, J. M. Stuart Electric Generating Station, Sprigg Township, Adams County, Ohio.

[12] See, for instance, Haley & Aldrich, Inc., Jan 2020, 2019 Annual Groundwater Monitoring and Corrective Action Report for Pond 5, Pond 7/7A, Landfill 9, Pond 10, and Landfill 11, J. M. Stuart Station, Manchester, Ohio.

our opinion the demonstration does not prove that the arsenic found in that sediment was not caused by seepage from the ponds. The demonstration also does not address whether the geochemical conditions identified as causing arsenic release from sediment are caused by pond seepage. In particular, the demonstration for Pond 5 does not explain potential connections between high concentrations of arsenic measured in porewater in that pond and arsenic in sediment and groundwater. The cause of the arsenic contamination may be irrelevant as far as choosing a remedy, because other contaminants which are definitively from CCR will require a remedy which should also address arsenic.

The utility additionally produced Alternative Source Demonstrations for Ponds 3A and 6 to show that contamination at those ponds is due to upgradient sources, such as Landfill 11 and former Pond 8. It is unclear why the owner would want to attribute contaminants to these sources given they have not proposed a plan to address Landfill 11 and former Pond 8 other than capping the landfill. Regardless, after completing the Alternative Source Demonstration the utility stopped considering Ponds 3A and 6 in assessment monitoring and corrective action plans.

As part of its groundwater corrective measure assessment, Dayton Power & Light provided a risk evaluation where it determined that there are "no adverse effects on human health or the environment currently or under reasonably anticipated future uses."[13] This conclusion is based on their analysis that there are no offsite drinking water wells within one-half mile of the site and because the groundwater is greatly diluted when it reaches the Ohio River. We cannot confirm their risk evaluation regarding drinking water in part because the utility has not produced the semi-annual groundwater flow direction data required by federal CCR rule,[14] and has not to our knowledge provided maps of drinking water wells. It is therefore unclear whether groundwater flow is consistent or whether flooding of the Ohio River causes significant changes in flow direction and contaminant transport which could impact offsite drinking water wells. Additionally, risk assessments are not recognized under the federal CCR rule; instead, the rule requires groundwater to be remedied to meet groundwater protection standards established pursuant to § 257.95(h).

Regarding potential impacts to the Ohio River, we agree that the river likely provides sufficient dilution of CCR contaminants in water. Potential contaminant impacts to river sediment have not been evaluated to our knowledge. As described previously, the Alternative Source Demonstrations for arsenic may show that arsenic from pond seepage has accumulated in fine-grained sediment under the ponds. The requirement pursuant to §257.95(g) to characterize the nature and extent of the CCR release may require testing of river and stream sediment downgradient of the ponds to determine if those are impacted.

[13] Key Environmental Inc. July 2020. Revised Corrective Measures Assessment Report, Multiunit Groundwater Monitoring System, Former Stuart Station, Adams County, Ohio.

[14] 2017 is the only year that groundwater elevation data were published for each sampling event. 40 CFR §257.93 (c) states: "Groundwater elevations must be measured in each well immediately prior to purging, each time groundwater is sampled. The owner or operator of the CCR unit must determine the rate and direction of groundwater flow each time groundwater is sampled."

Contact between CCR and groundwater is another important consideration when evaluating groundwater cleanup needs. Dayton Power & Light reports that Ponds 3A and 10 meet the 5 feet separation requirements at §257.60(a), while Ponds 5, 6, 7/7A do not.[15] The owner has not reported aquifer separation data for buried Ponds 1, 2, 3, and 8 because they are not subject to the federal CCR rule. The available data do not allow us to evaluate groundwater contact with CCR, because the owner has not followed reporting requirements for groundwater elevations in the federal CCR rule as previously discussed and because construction details of Ponds 1, 2, 3, and 8 have not been published, since these impoundments were closed long before the effective date of the federal CCR rule. To evaluate groundwater contact with these older impoundments, we compared the elevation of buried fly ash in Pond 3 shown in boring logs,[16] showing that the lowest elevation of buried fly ash is 500 feet. The top of the uppermost aquifer below Pond 3A is reported by Dayton Power & Light to be 488 feet.[17] The groundwater level likely rises during flooding of the Ohio River, which typically reaches flood stage above an elevation of 500 feet annually.[18] This indicates that buried CCR in Pond 3 is typically above the highest groundwater but may have intermittent contact during river floods. We assume the same to be true for Ponds 1 and 2. Buried Pond 8 appears to have adequate separation from groundwater given drawings provided in the Pond 6 and Landfill 11 location restriction demonstrations[19] and the groundwater elevations that the utility has reported. Both active landfills appear to have adequate separation from groundwater.

Given the difficulty in identifying the contribution of each pond and landfill to the widespread groundwater contamination at the site, a reasonable approach to groundwater cleanup would be to pursue removal of all CCR in current and former ponds to remove the source of contamination. This combined with adequate caps and maintenance of the landfills should mostly eliminate CCR leachate as an ongoing source of pollution. All current and former buried impoundments can be reasonably excavated, except for Pond 8, which is inaccessible because it is located underneath the existing Landfill 11. The two active landfills have adequate capacity for all accessible CCR that would be excavated.

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[15] Haley & Aldrich, Inc. 2018. CCR Rule Location Restrictions Evaluation—Pond 3A.

Haley & Aldrich, Inc. 2018. CCR Rule Location Restrictions Evaluation—Pond 5.

Haley & Aldrich, Inc. 2018. CCR Rule Location Restrictions Evaluation—Pond 6.

Haley & Aldrich, Inc. 2018. CCR Rule Location Restrictions Evaluation—Pond 7.

Haley & Aldrich, Inc. 2018. CCR Rule Location Restrictions Evaluation—Pond 10, J. M. Stuart Electric Generating Station.

[16] Haley & Aldrich, Inc. 2018. CCR Rule Location Restrictions Evaluation—Pond 3A. See subsurface exploration logs in Attachment 5.

[17] Ibid., Attachment 1.

[18] Stage record for USGS 03238000.

[19] Haley & Aldrich, Inc. October 2018. CCR Rule Location Restrictions Evaluation—Pond 6. J. M. Stuart Electric Generating Station, Aberdeen, Ohio. See Attachment 1.

Haley & Aldrich, Inc. October 2018. CCR Rule Location Restrictions Evaluation—Landfill 11. J. M. Stuart Electric Generating Station, Aberdeen, Ohio. See Figure 4 of Attachment 1.

Pond and Landfill Construction

Ponds 5, 6, 7, and 7A are unlined impoundments. Ponds 3A and 10 have compacted soil liners that do not meet federal CCR Rule liner requirements §257.71(a)(1) and are therefore considered unlined. The unlined impoundments are at particular risk of continued leaching where they are continually or intermittently in contact with groundwater. The groundwater separation described above suggests that Ponds 1, 2, 3, 5, 6, and 7/7A likely have intermittent or continual contact with groundwater. Removal of these ponds would eliminate what we anticipate is the most significant source of groundwater contamination at the site.

Both Landfills 9 and 11 were constructed according to the Ohio Environmental Protection Agency's regulations and have 18-inch compacted clay liners with 1×10^{-7} centimeters per second maximum permeability, leachate collection systems, and separation from the uppermost aquifer of greater than 5 feet.[20] The landfills lack geomembrane liners that would be required of a new landfill (§257.70(b) and (c)). The landfill final cover systems will consist of 24 inches of compacted clay with a 6-inch vegetated erosion control layer on top.[21] This final cover conforms with federal standards for closure of existing landfills (§257.102(d)(3)), which require the permeability of the final cover to be less than that of the bottom liner. We anticipate that the design will provide adequate protection from infiltration of precipitation and runoff if maintained properly.

Floodplain

The Federal Emergency Management Agency (FEMA)–mapped 100-year floodplain and 500-year flood boundary is shown in Figure A2. Ponds 1, 2, 3A, 5, and 7/7A and Landfill 9 are constructed on the 100-year floodplain. These same waste units and Pond 6 are within the 500-year flood boundary. Flooding is a consideration for closure and cleanup because floodwaters may both rewet CCR causing increased leaching and destabilize caps.

[20] Dayton Power & Light Company, August 1994. Permit to Install Application for the Expansion of a Non-toxic Ashfill at the J. M. Stuart Electric Generating Station, Aberdeen, Ohio. Prepared by Woolpert Consultants.

URS. September 2002. Permit to Install Application, Dayton Power and Light, J. M. Stuart Electric Generating Station, Fly Ash Landfill 11, Volumes 1-3.

[21] Ibid.

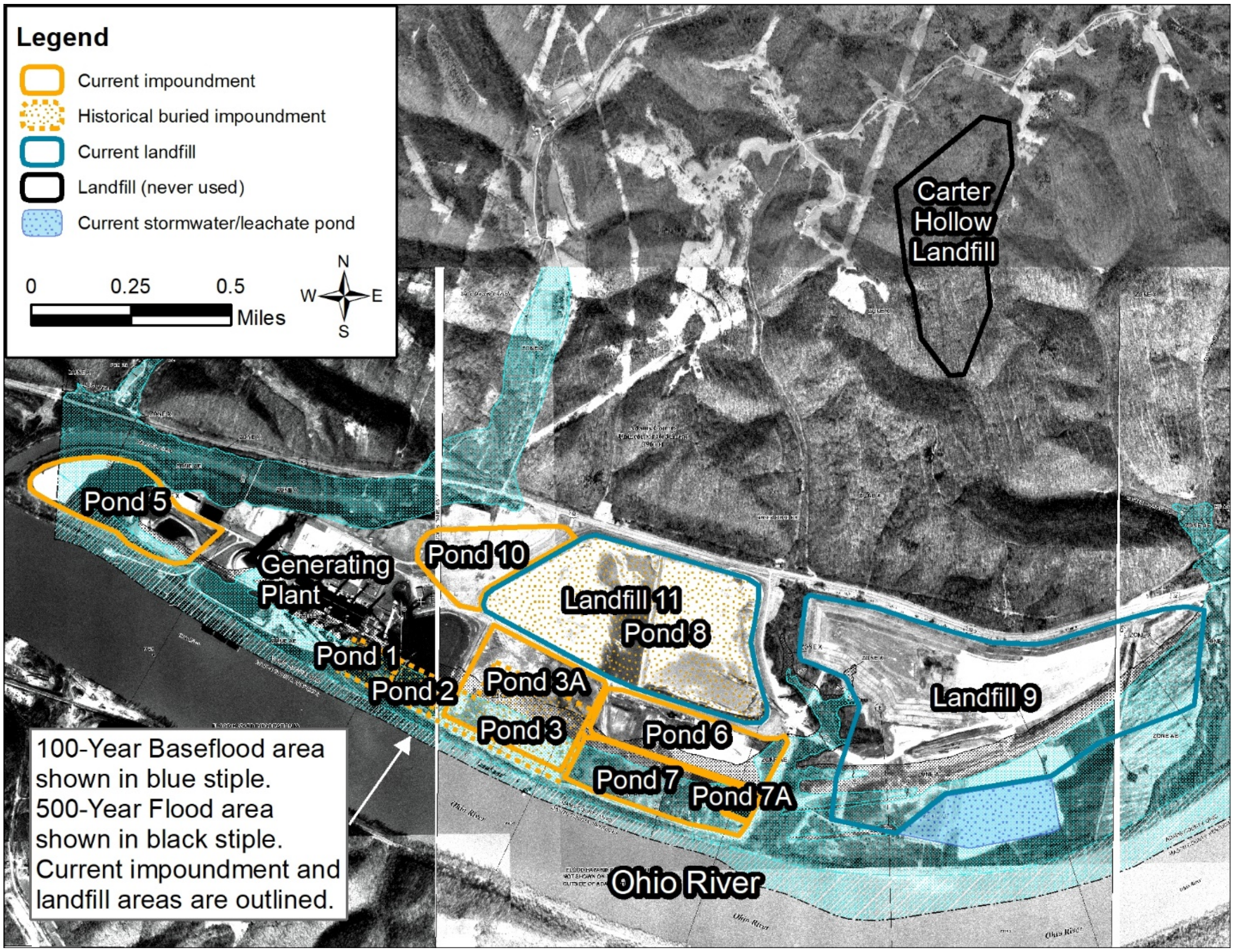

Figure A2. FEMA Floodplain Mapping at the J. M. Stuart Generating Station

Kingfisher has indicated a preference for closure by removal of the ponds that are located within the 100- and 500-year flood boundaries except for the buried former Pond 3. Landfill 9 is proposed to remain in the floodplain, capped in place. Landfill 9 flood design protections that are described in the Ohio Environmental Protection Agency permit application[22] are limited to a requirement that the utility install the final cover below the 100-year FEMA flood elevation of 518 feet within 120 days after the first lift of CCR is placed. Additional flood protections beyond these minimal cap installation requirements would reduce the risk of releases from Landfill 9. A flood-control levee, designed for the 500-year flood, is included in Alternative 2: Clean Closure.

[22] Dayton Power & Light Company. August 1994. Permit to Install Application for the Expansion of a Non-toxic Ashfill at the J. M. Stuart Electric Generating Station, Aberdeen, Ohio. Prepared by Woolpert Consultants.

2.3. Description of Closure Plan Alternatives

Alternative 1: Kingfisher Development Closure

This alternative follows Kingfisher Development's proposals as laid out in the most recent documents available (referenced in section 2.1).[23] The major elements of the closure and post-closure plan include the following:

- Ponds 3A, 5, 6, 7/7A, and 10: closure by removal with CCR material transported to Landfills 9 and 11
- Coal yard area: excavation of CCR from former Ponds 1 and 2, backfill and grading with clean fill
- Pond 3A berm: removal of the west portion of the berm to eliminate dam regulatory purview for the impoundment and to provide clean fill for coal yard backfill
- Pond 10: removal of berms that have a bottom ash core to Landfill 9 or 11, creation of a pond weir outlet to eliminate dam classification
- Landfills 9 and 11: cap in place; long-term cap maintenance, stormwater, and leachate management
- Carter Hollow Landfill: no action
- MNA of groundwater

A schedule of Kingfisher Development's closure activities is provided in Table A1**.**

Table A1. Activity Schedule for Kingfisher Development Closure

Activity	**Year**								
	2018	2019	2020	2021	2022	2023	2024	2025	2026
Planning/Permitting	■			■					
Mobilization	■								
Pond 3A CCR Excavation		■	■						
Pond 3A Berm Removal				■					
Pond 10 CCR Excavation		■	■						
Pond 10 Bottom Ash Berm Removal				■					
Coal Yard CCR Excavation		■	■						
Coal Yard Backfill and Grading				■					
Pond 5 CCR Excavation					■	■			
Pond 6 CCR Excavation					■	■	■	■	
Pond 7/7A CCR Excavation					■	■	■	■	■
Landfills 9&11 Closure									■

[23] The original closure plans developed by Dayton Power & Light which call for capping Ponds 5, 6, 7/7A, and 10 in place are still posted to Kingfisher Development's publicly accessible internet site (ccrstuart.com), which means those remain their official closure plan. For the sake of our analysis, we have assumed that Kingfisher Development will follow through on their indicated preference to close those ponds by removal.

The closure plans for each CCR waste unit are shown in Figure A3.

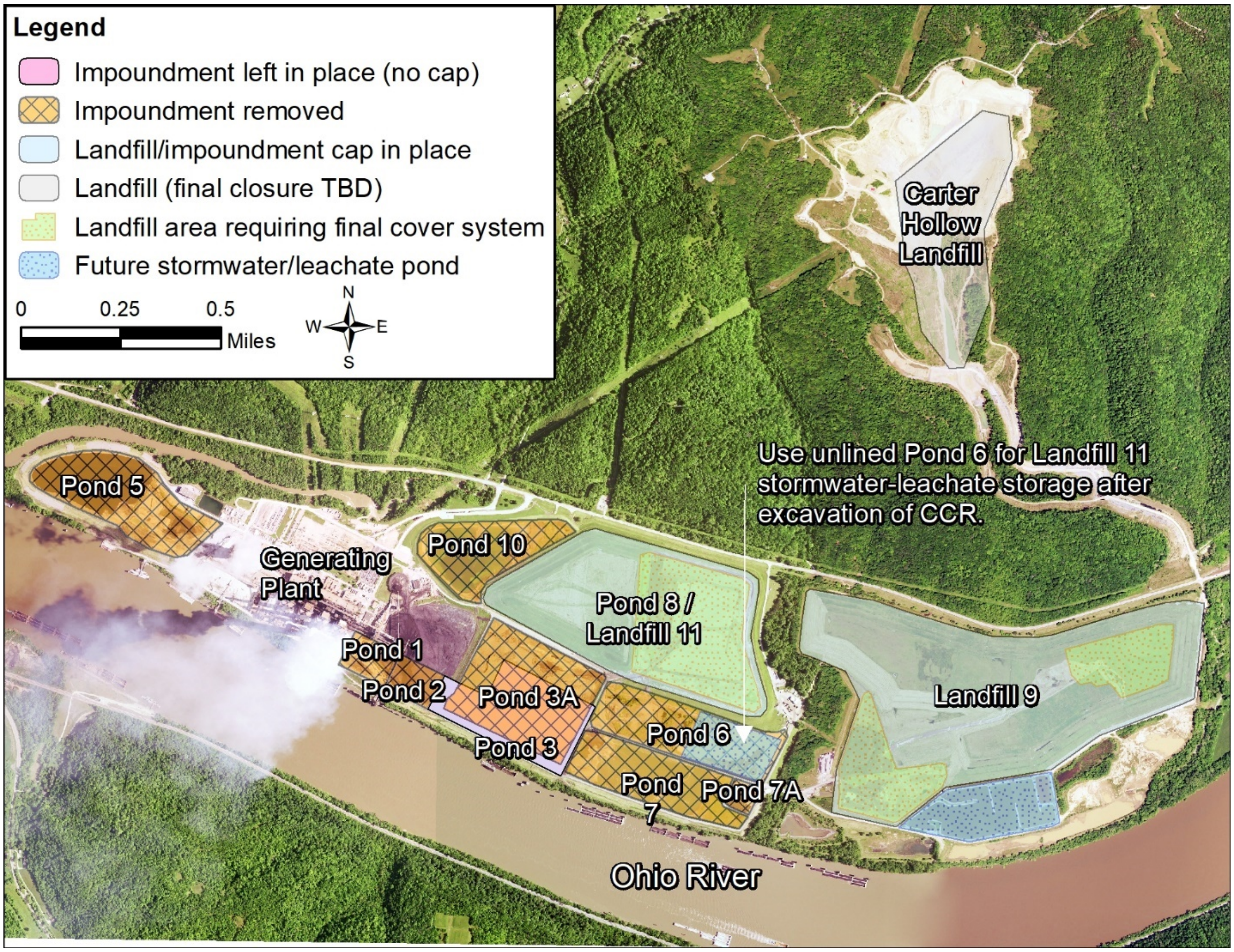

Figure A3. Kingfisher Development Closure Plan for the J. M. Stuart Generating Station

This alternative would leave CCR buried in place in former Ponds 3 and 8. Because these ponds were closed long before the effective date of the federal CCR rule, they are not regulated by its closure requirements. In Pond 3, the buried CCR would be left in place without a cap, which may lead to continued leaching by precipitation and storm runoff infiltrating the ground surface. In Pond 8, the former pond is capped by Landfill 11 and appears to be well above the water table. This may provide adequate protection of the CCR buried in Pond 8 from infiltration if the landfill is properly operated and maintained to minimize leachate that could pass through the landfill bottom into Pond 8.

The caps for this alternative are Dayton Power & Light's proposed federal CCR Rule–compliant (§257.102(d)(3)) cover system consisting of 24 inches of compacted clay with a 6-inch vegetated topsoil erosion protection layer.

Under Kingfisher Development's proposal, landfill stormwater and leachate would continue to be contained in the existing Landfill 9 Retention Basin and in Ponds 6 and 7A for Landfill 11 after the CCR contents are removed. The facility discharges the combined stormwater and leachate streams into the

Ohio River under a National Pollutant Discharge Elimination System. A copy of the current permit was not available for review, and the closure plans do not describe how discharge standards would be met during closure by removal of Ponds 6 and 7A. We assume that water management ponds can be alternated during closure by removal so that closure construction occurs on one pond without affecting water management and treatment needed for discharge.

This alternative includes cap maintenance, surface water management, and leachate system maintenance at Landfills 9 and 11 for the duration of the 30-year post-closure period. We assume that no further action occurs at Carter Hollow Landfill, given it is unclear whether that landfill could be used to store CCR from other sources such as closure activities at the nearby Killen Generating Station, which is also owned by Kingfisher Development.

The Kingfisher Development alternative relies on MNA for groundwater pollutants. Long-term groundwater monitoring is required to show that the groundwater contaminant plume is stable and not expanding toward human or environmental receptors. An MNA approach to groundwater contamination may require institutional controls such as deed restrictions that would prevent the withdrawal and use of contaminated groundwater and prevent other activities that would affect the contaminant plume. Our cost and jobs analysis assumes that five years after closure the removal remedy has eliminated groundwater standard exceedances except for Pond 3, where buried fly ash would remain. After five years, MNA is assumed to continue at Pond 3/3A with monitoring for federal CCR rule Appendix III and IV parameters for the duration of the 30-year post-closure period. After five years, Landfill 9 and 11 monitoring is limited to Appendix III parameters.

Alternative 2: Clean Closure

This alternative takes Kingfisher Development’s proposed closure and adds several improvements to the closure plan. It adds excavation of all accessible buried CCR by including former Pond 3 in the removal. It also adds construction of a lined stormwater and leachate pond for Landfill 11 and construction of a 500-year flood levee for Landfill 9. The major elements of the closure and post-closure plan include the following.

Improvements added in Alternative 2:

- Pond 3: complete removal of the Pond 3A berm to allow excavation of former Pond 3. Berm material is used for coal yard backfill and Landfill 9 flood levee
- Construction of a 15.5-acre lined stormwater and leachate pond for Landfill 11
- Construction of a 500-year flood levee for Landfill 9

Elements carried over from Alternative 1:

- Ponds 3A, 5, 6, 7/7A, and 10: closure by removal with CCR material transported to Landfills 9 and 11
- Coal yard area: excavation of CCR from former Ponds 1 and 2, backfill and grading with clean fill
- Pond 10: remove berms which have a bottom ash core to Landfill 9 or 11, creation of a pond weir outlet to eliminate dam classification
- Landfills 9 and 11: cap in place; long-term cap maintenance, stormwater, and leachate management
- Carter Hollow Landfill: no action

- MNA of groundwater

A schedule of the clean closure activities is provided in Table A2**.**

Table A2. Activity Schedule for Clean Closure

Activity	**Year**								
	2018	2019	2020	2021	2022	2023	2024	2025	2026
Planning/Permitting	■			■					
Mobilization	■								
Pond 3/3A CCR Excavation		■	■	■					
Pond 3A Berm Removal		■							
Pond 10 CCR Excavation		■	■						
Pond 10 Bottom Ash Berm Removal				■					
Coal Yard CCR Excavation		■	■						
Coal Yard Backfill and Grading				■					
Landfill 9 Levee		■							
Pond 5 CCR Excavation					■	■			
Pond 6 CCR Excavation					■	■	■	■	
Pond 6 Lining									■
Pond 7/7A CCR Excavation					■	■	■	■	■
Landfills 9&11 Closure									■

The closure plans for each CCR waste unit are shown in Figure A4.

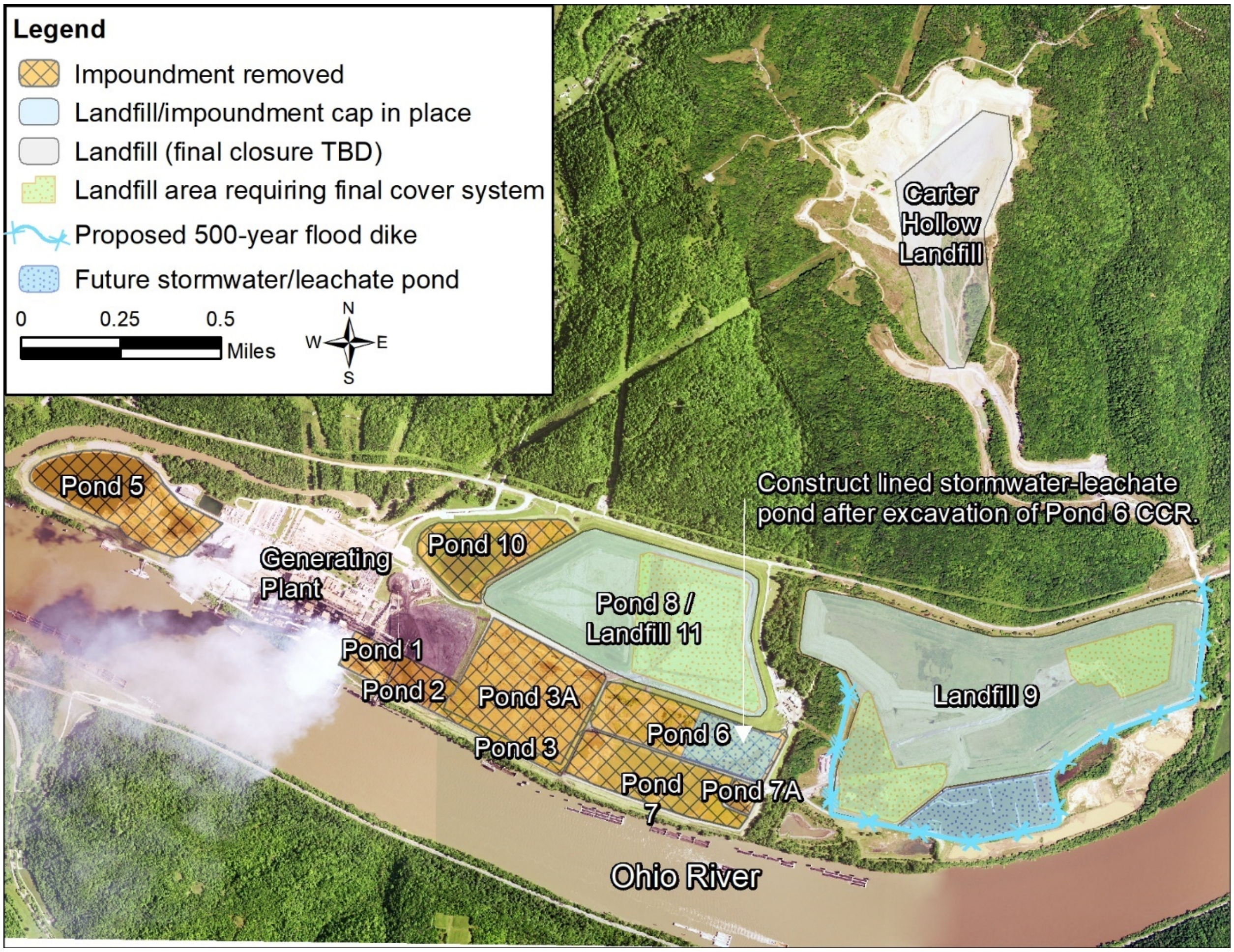

Figure A4. Clean Closure Plan for the J. M. Stuart Generating Station

This alternative removes all accessible CCR to provide further protection of groundwater over Kingfisher Development's plans, which would leave buried CCR uncapped in former Pond 3. This alternative leaves CCR buried in place in former Pond 8, which is inaccessible because it is located under Landfill 11. We assume this option to be protective of groundwater, because Pond 8 is not in contact with groundwater and Landfill 11 should provide a sufficient cap for Pond 8 if the landfill is properly operated and maintained to minimize leachate that could pass through the landfill bottom into Pond 8.

The caps for the clean closure alternative are the same as those proposed by Kingfisher Development, a federal CCR Rule–compliant (§257.102(d)(3)) cover system consisting of 24 inches of compacted clay with a 6-inch vegetated topsoil erosion protection layer. We assume that the proposed cap will be adequate, meaning that a lower permeability composite cap is not required, because the landfill leachate collection system will be used to protect groundwater.

The 500-year flood levee as proposed will provide a compacted soil levee with an elevation 3 feet above the FEMA 500-year flood elevation to provide a safe freeboard. The levee will protect Landfill 9, which is in both the 100-year and 500-year flood boundary, from floods that may rewet the dry CCR held in the landfill or otherwise destabilize the cap. We chose the 500-year flood height in order to be conservative, because the landfill will be expected to protect the CCR in perpetuity. The soil fill volume required to construct the levee was estimated assuming 2.5:1 side slope (horizontal: vertical) and using current topography provided by Google Earth terrain data available via Carlson Civil Software.

Under this alternative, landfill 9 stormwater and leachate would continue to be contained in the existing Landfill 9 Retention Basin, and for Landfill 11 a new lined pond would be constructed in Pond 6 after CCR contents are excavated.

Like the Kingfisher Development alternative, this one includes cap maintenance, surface water management, and leachate system maintenance at Landfills 9 and 11 for the duration of the 30-year post-closure period. We assume that no further action occurs at Carter Hollow Landfill, given it is unclear whether that landfill could be used to store CCR from other sources such as closure activities at the nearby Killen Generating Station, which is also owned by Kingfisher Development.

Like Kingfisher Development's proposal, this alternative relies on MNA for groundwater pollutants but with the added benefit of additional CCR excavation. Our cost and jobs analysis assumes that five years after closure the removal remedy has eliminated groundwater standard exceedances in all remaining monitoring wells. After five years, groundwater monitoring continues at Landfill 9 and 11 to comply with the federal CCR rule requirement but is limited to Appendix III parameters.

2.4. Cost Analysis

Cost Summary

Table A3 summarizes the estimated total capital cost for each alternative and the annual long-term post-closure O&M cost as described in Section 1.4. Long-term means the O&M costs that are incurred once the site is fully closed and all sites that will require long-term O&M are receiving those expenditures. Capital costs are inclusive of all construction activities, disposal cost, construction-related infrastructure and equipment, site grading, engineering design, planning, and project management.

Table A4 provides the estimated capital cost and post-closure O&M cost for both alternatives each year. Figure A5 shows the sum of the total capital cost and total annual O&M cost for the two alternatives from Table A4.

Table A3. Total Estimated Cost Comparison of the Two Closure Alternatives for the J. M. Stuart Generating Station

Alternative	**Summary of Closure Plan and Groundwater Corrective Action**	**Total Estimated Capital Cost (2022 USD)**	**Long-Term O&M Annual Cost (2022 USD)**
Kingfisher Development proposal	Excavation of CCR in all existing and former buried ponds with exception of Ponds 3 and 8. Partial berm removal and grading. Cap in place Landfill 9 and 11. MNA for groundwater.	$224,368,000	$1,119,000
Clean closure plan	Excavation of CCR in all existing and former buried ponds with exception of Pond 8. Partial berm removal and grading. Construction of a lined stormwater and leachate pond for Landfill 11. Construction of a 500-year flood levee for Landfill 9. Cap in place Landfill 9 and 11. MNA for groundwater.	$279,282,000	$1,113,000

Table A4. Estimated Annual Capital Cost and the Annual Post-Closure O&M Costs for Each Alternative for the J. M. Stuart Generating Station

Year	Kingfisher Development			Clean Closure		
	Total Capital Cost ($)	Total Annual O&M Cost ($)	Total Cost ($)	Total Capital Cost ($)	Total Annual O&M Cost ($)	Total Cost ($)
2018	$3,066,650	$103,240	$3,169,890	$4,701,388	$103,240	$4,804,628
2019	$10,866,182	$103,240	$10,969,422	$30,363,084	$103,240	$30,466,324
2020	$10,866,182	$103,240	$10,969,422	$22,598,459	$103,240	$22,701,699
2021	$11,080,666	$103,240	$11,183,906	$29,143,636	$103,240	$29,246,876
2022	$43,252,887	$103,240	$43,356,127	$43,269,149	$103,240	$43,372,389
2023	$43,252,887	$103,240	$43,356,127	$43,269,149	$103,240	$43,372,389
2024	$25,967,184	$103,240	$26,070,424	$25,983,446	$103,240	$26,086,686
2025	$25,967,184	$103,240	$26,070,424	$25,983,446	$103,240	$26,086,686
2026	$50,048,601	$103,240	$50,151,841	$53,970,220	$103,240	$54,073,460
2027		$1,183,882	$1,183,882		$1,183,882	$1,183,882
2028		$1,183,882	$1,183,882		$1,183,882	$1,183,882
2029		$1,183,882	$1,183,882		$1,183,882	$1,183,882
2030		$1,183,882	$1,183,882		$1,183,882	$1,183,882
2031		$1,183,882	$1,183,882		$1,183,882	$1,183,882
2032		$1,118,922	$1,118,922		$1,113,122	$1,113,122
2033		$1,118,922	$1,118,922		$1,113,122	$1,113,122
2034		$1,118,922	$1,118,922		$1,113,122	$1,113,122
2035		$1,118,922	$1,118,922		$1,113,122	$1,113,122
2036		$1,118,922	$1,118,922		$1,113,122	$1,113,122
2037		$1,118,922	$1,118,922		$1,113,122	$1,113,122
2038		$1,118,922	$1,118,922		$1,113,122	$1,113,122
2039		$1,118,922	$1,118,922		$1,113,122	$1,113,122
2040		$1,118,922	$1,118,922		$1,113,122	$1,113,122
2041		$1,118,922	$1,118,922		$1,113,122	$1,113,122
2042		$1,118,922	$1,118,922		$1,113,122	$1,113,122
2043		$1,118,922	$1,118,922		$1,113,122	$1,113,122
2044		$1,118,922	$1,118,922		$1,113,122	$1,113,122
2045		$1,118,922	$1,118,922		$1,113,122	$1,113,122
2046		$1,118,922	$1,118,922		$1,113,122	$1,113,122
2047		$1,118,922	$1,118,922		$1,113,122	$1,113,122
2048		$1,118,922	$1,118,922		$1,113,122	$1,113,122
2049		$1,118,922	$1,118,922		$1,113,122	$1,113,122
2050		$1,118,922	$1,118,922		$1,113,122	$1,113,122
2051		$1,118,922	$1,118,922		$1,113,122	$1,113,122
2052		$1,118,922	$1,118,922		$1,113,122	$1,113,122
2053		$1,118,922	$1,118,922		$1,113,122	$1,113,122
2054		$1,118,922	$1,118,922		$1,113,122	$1,113,122
2055		$1,118,922	$1,118,922		$1,113,122	$1,113,122
2056		$1,118,922	$1,118,922		$1,113,122	$1,113,122
Total	$224,368,423	$34,821,605	$259,190,028	$279,281,977	$34,676,605	$313,958,582

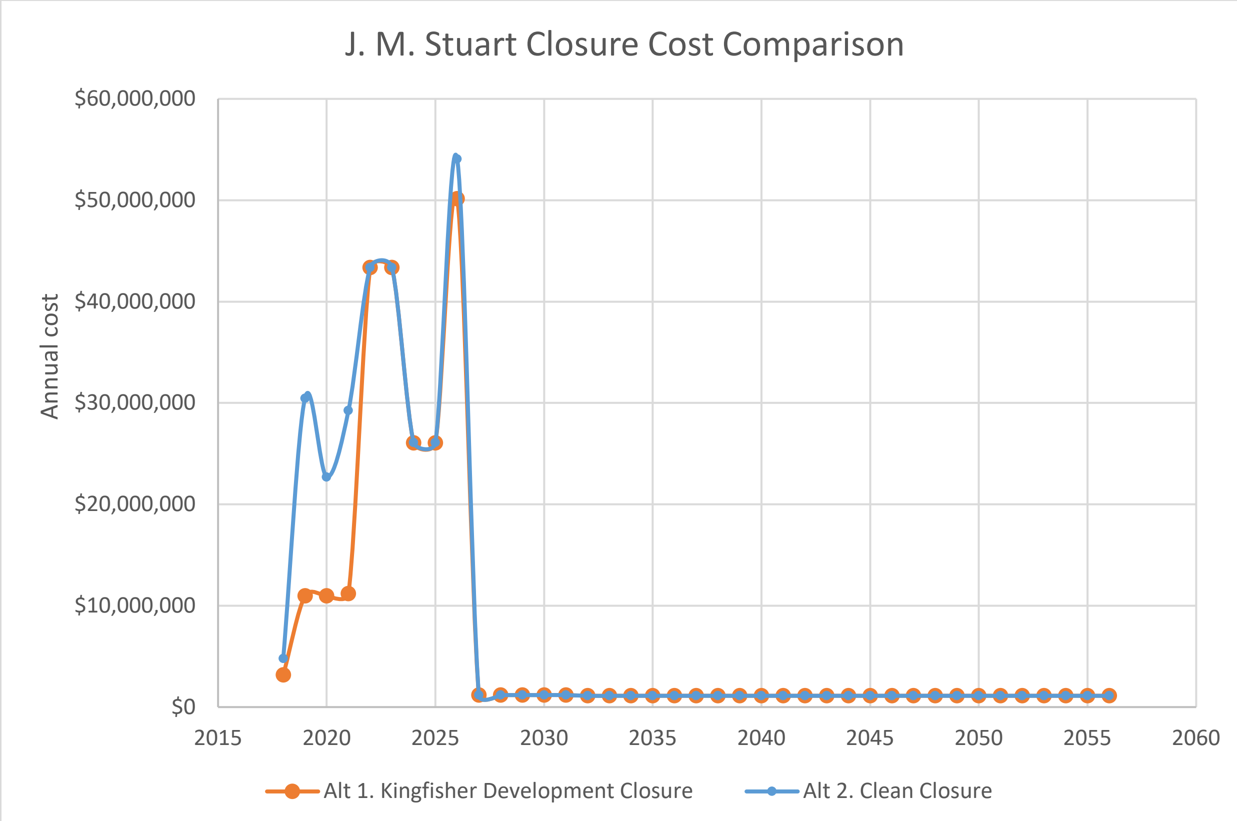

Figure A5 Closure Costs over Time for each Cleanup Alternative for the J. M. Stuart Generating Station (2022 dollars)

The capital costs of the clean closure plan are 19 percent higher than the Kingfisher Development plan due to the costs associated with additional CCR removal from Pond 3, construction of a lined water management pond for stormwater and leachate from Landfill 11, and construction of the flood levee for Landfill 9 in the clean closure plan.

Long-term O&M costs are very similar for the two alternatives, with slightly higher costs for the Kingfisher Development plan because we assume that the groundwater problems are not resolved at Pond 3A where CCR would be left in place uncapped in the buried former Pond 3. We assume that continued monitoring would be needed throughout the 30-year post-closure period under Kingfisher Development's proposed MNA approach for groundwater corrective action. If residual groundwater contamination near Pond 3A does not show progress toward meeting standards under Kingfisher Development's plans, additional groundwater remedy or CCR removal would likely be needed. However, those potential future costs are not considered because our analysis is limited to the closure plan as proposed.

2.5. Jobs Analysis

Jobs Summary

Table A5 summarizes the estimated direct job creation (FTE) for each alternative and the annual long-term post-closure O&M FTEs. Total estimated closure and corrective action FTEs represent the sum of FTEs created each year during closure design, permitting, and construction; long-term annual O&M FTEs represent the long-term jobs created for post-closure activities. Table A6 provides the estimated FTEs for each alternative each year.

Table A5. Total Comparison of the Estimated Direct Job Creation and the Annual Long-Term Post-Closure O&M for Each Alternative for the J. M. Stuart Generating Station

Alternative	**Total Estimated FTEs for Closure and Corrective Action**	**Estimated Long-Term Annual O&M FTEs**
Kingfisher Development plan	223	4.2
Clean closure plan	277	4.2

Table A6. Estimated Direct Job Creation and the Annual Post-Closure O&M FTEs for Each Alternative for the J. M. Stuart Generating Station

Year	Kingfisher Development			Clean Closure		
	Total Annual Construction FTE	Total Annual O&M FTE	Total Annual FTE	Total Annual Construction FTE	Total Annual O&M FTE	Total Annual FTE
2018	3	0.2	3.7	8	0.2	8
2019	12	0.2	12.2	30	0.2	30
2020	12	0.2	12.2	23	0.2	23
2021	25	0.2	25.5	42	0.2	42
2022	41	0.2	41.1	41	0.2	41
2023	41	0.2	41.1	41	0.2	41
2024	26	0.2	26.0	26	0.2	26
2025	26	0.2	26.0	26	0.2	26
2026	37	0.2	37.4	41	0.2	41
2027		4.3	4.3		4.3	4.3
2028		4.3	4.3		4.3	4.3
2029		4.3	4.3		4.3	4.3
2030		4.3	4.3		4.3	4.3
2031		4.3	4.3		4.3	4.3
2032		4.2	4.2		4.2	4.2
2033		4.2	4.2		4.2	4.2
2034		4.2	4.2		4.2	4.2
2035		4.2	4.2		4.2	4.2
2036		4.2	4.2		4.2	4.2
2037		4.2	4.2		4.2	4.2
2038		4.2	4.2		4.2	4.2
2039		4.2	4.2		4.2	4.2
2040		4.2	4.2		4.2	4.2
2041		4.2	4.2		4.2	4.2
2042		4.2	4.2		4.2	4.2
2043		4.2	4.2		4.2	4.2
2044		4.2	4.2		4.2	4.2
2045		4.2	4.2		4.2	4.2
2046		4.2	4.2		4.2	4.2
2047		4.2	4.2		4.2	4.2
2048		4.2	4.2		4.2	4.2
2049		4.2	4.2		4.2	4.2
2050		4.2	4.2		4.2	4.2
2051		4.2	4.2		4.2	4.2
2052		4.2	4.2		4.2	4.2
2053		4.2	4.2		4.2	4.2
2054		4.2	4.2		4.2	4.2
2055		4.2	4.2		4.2	4.2
2056		4.2	4.2		4.2	4.2
Total	223	129	352	277	129	405

Figure A6 shows the sum of the total annual closure and corrective action FTE and total annual O&M FTE for the two alternatives from Table A6.

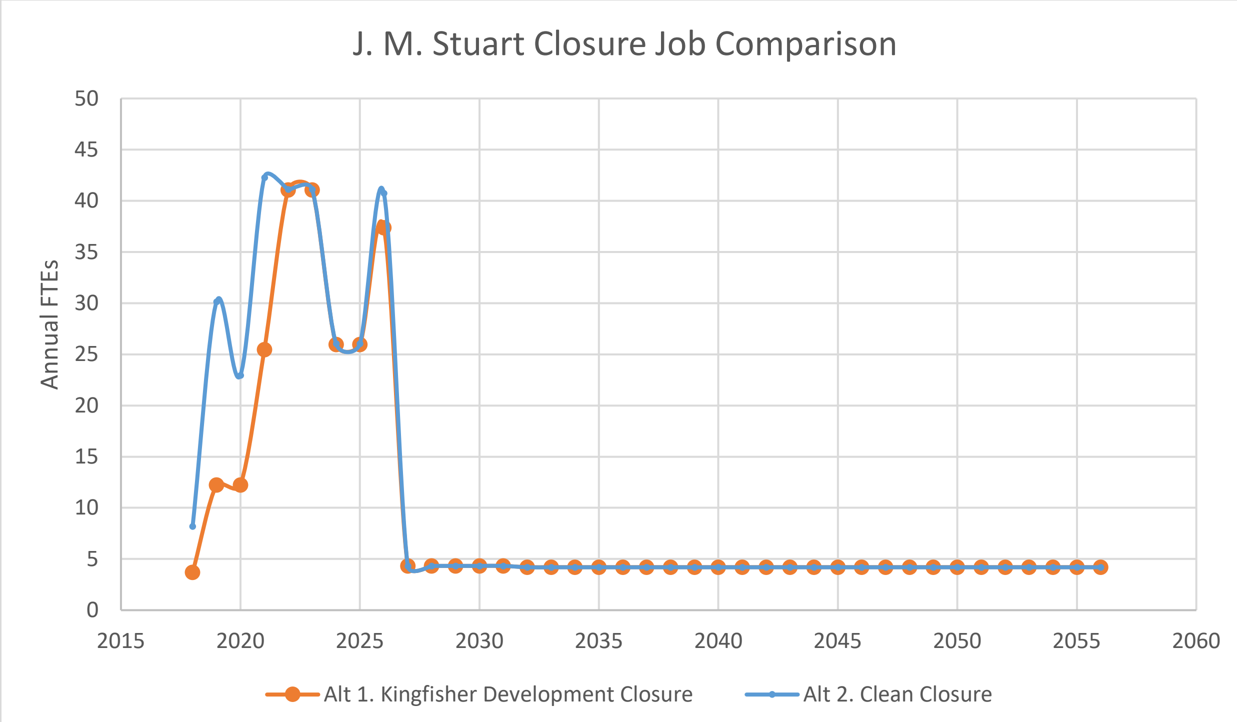

Figure A6. Direct Jobs over Time for each Cleanup Alternative for the J. M. Stuart Generating Station

Clean closure creates 54 more FTEs during closure construction due to the larger volume of CCR that is excavated and the jobs associated with building the 500-year flood levee and the lined stormwater and leachate pond for Landfill 11.

The long-term O&M jobs are virtually the same for both alternatives, because they include the same O&M activities for the two landfills and groundwater monitoring, with the slight additional labor required for the continued Pond 3A groundwater sampling under Kingfisher Development's plan, estimated to be only 0.01 FTE. If residual groundwater contamination near Pond 3A does not show progress toward meeting standards under Kingfisher Development's plans, additional groundwater remedy or CCR removal would likely be needed. However, those potential future jobs in groundwater remediation are not considered because our analysis is limited to their closure plan as proposed.

3. Sebree Generating Station

3.1. Site Overview

Sebree Generating Station is an informal name given to a collection of three operating and retired coal-fired power plants in Webster County, Kentucky: the currently operating 454 MW Robert D. Green Generating Station that burns coal, the Robert A. Reid Generating Station, a 46 MW combustion turbine that was converted from coal to natural gas in 2016, and Henderson Station Two, a 365 MW coal-fired plant that closed in May 2019. The plants are owned by Big Rivers Electric Corporation (BREC), a joint organization created by three Kentucky rural electric cooperatives.

The Sebree station was constructed adjacent to the Green River for use as cooling water. Figure A7 shows the layout of the facility. The Sebree site houses three coal ash disposal sites that together contain 24.4 million cubic yards of coal ash. Most of this waste (22.8 million cubic yards) is held in the Green Landfill, which has received attention from news media due to contaminated seeps that flowed into the Green River[24] and from the Kentucky Energy and Environment Cabinet Division of Waste Management for both the river seeps and other unauthorized discharges related to the landfill. The unlined Green Landfill uses a patented technique to stabilize fly ash called Poz-o-Tec® that is a mixture of lime, flue gas desulfurization scrubber sludge, and coal fly ash. In 1980, when the landfill was permitted and constructed, Poz-o-Tec was believed to produce a non-leachable, stabilized product.[25] Despite this, leachate is generated at the Green Landfill, and the lack of liner and leachate collection systems means the seepage has polluted groundwater and created contaminated surface seeps. There are also two coal ash ponds, the Green Impoundment and the Reid/Henderson Municipal Power & Light (HMP&L) Impoundment, that are unlined and are in contact with groundwater.

[24] See https://wfpl.org/coal-ash-is-still-polluting-kentuckys-green-river/

[25] Environmental Protection Agency. 1978. Trimble County Generating Station Permit: Environmental Impact Statement. Washington, DC.

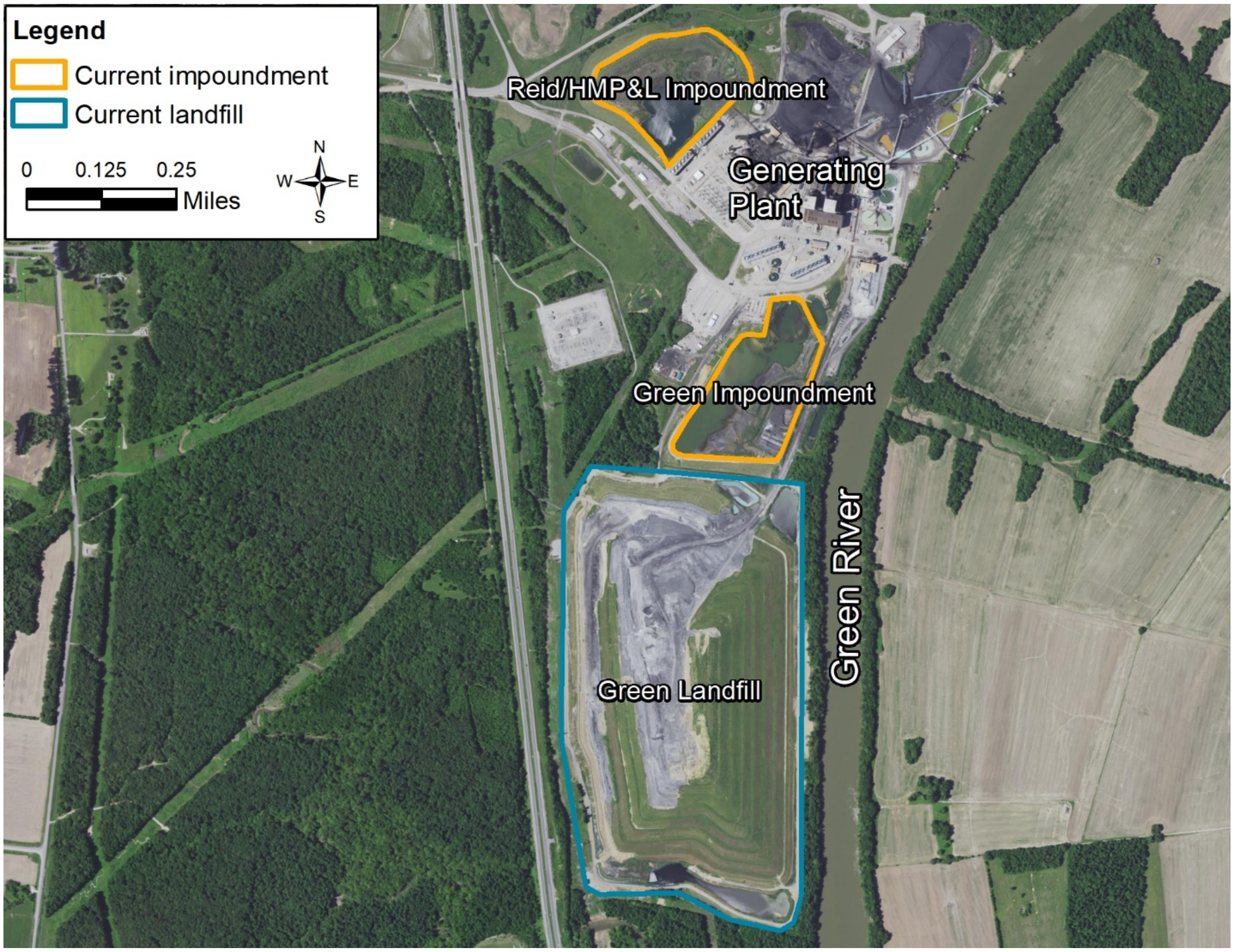

Figure A7. Sebree Plant Site Layout

Groundwater at the site is impacted by a wide range of contaminants associated with coal ash. It is difficult to identify exactly which parameters exceed standards in groundwater at Sebree, because the background well at the Green Impoundment appears to be contaminated by seepage from the pond, rendering the comparison of upgradient (background) and downgradient (below the CCR unit) water quality unreliable. The utility's monitoring reports, groundwater impact analysis (pursuant to 40 CFR § 257.94 (e)), and corrective action plans are all affected by the apparently contaminated background well. Additionally, all monitoring wells are all completed in geologic units that are deeper than the shallowest groundwater, meaning the groundwater directly under the waste units is not directly sampled. At the Green Landfill, BREC divides the groundwater impacts into what it calls "groundwater releases" and "non-groundwater releases." According to BREC, the non-groundwater releases are what feed the seeps around the perimeter of the Green Landfill. In any hydrogeologic interpretation the non-groundwater releases certainly are groundwater but represent shallower groundwater than that monitored by the monitoring well network. The landfill seeps show the full impact of the landfill leachate on groundwater, with concentrations of arsenic, cadmium, chloride, cobalt, lithium, molybdenum, radium, and selenium higher than groundwater protection standards. Issues with groundwater contamination and monitoring are discussed further in section 3.2.

In December 2019, BREC signed an Agreed Order with the Kentucky Division of Waste Management to address unpermitted discharges related to the Green Landfill including the seeps. This resulted in BREC constructing large-scale hydraulic controls that capture contaminated groundwater[26] and a landfill perimeter seep collection system that collects leachate around the landfill.[27] The system functions as a post facto leachate collection system for the landfill, albeit much less efficiently than a modern lined landfill with leachate collection. The most recent remedy progress reports available from fourth quarter 2020 show the controls are alleviating seepage, but the Agreed Order requirement that no seep be identified for four quarters had not been achieved yet.[28] Our professional judgment is that the remedy is a good approach for the site, and it is reasonable to assume that the groundwater and seep remedy will be effective once the landfill is closed and capped, thereby reducing precipitation infiltration and leachate generation in the landfill.

BREC plans to close the Green Landfill and both surface impoundments using cap in place during 2022–2024.[29] BREC eliminated excavation from the remedy selection options for the Green Landfill due both to cost and because, it states, a removal of the large landfill does not align with the one of the fundamental goals of the Resource Conservation and Recovery Act, that is, conserving energy and natural resources. However, BREC's interpretation of Resource Conservation and Recovery Act is inconsistent and contrary to the spirit of the act, which is intended to ensure that wastes are managed properly. We agree that excavation is more costly. Given the information available to us, we also agree that groundwater corrective action may not require full removal if the landfill is capped and closed properly, seep hydraulic control and perimeter drain collection systems are operated as intended, and these systems and the landfill are adequately maintained in the long term.

BREC's corrective measure plan for groundwater at the Green Landfill is to continue to operate the seep hydraulic control and perimeter drain collection systems, pumping the captured water to a new water treatment pond followed by discharge to the Green River under a Kentucky Pollutant Discharge

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[26] AECOM Technical Services. November 2020. Final Groundwater and Non-Groundwater Corrective Action Remedy Selection Report, Green Landfill, Sebree Station, Webster County, Kentucky.

[27] AECOM Technical Services. June 2020. Big Rivers Electric Corporation Sebree Generating Station, Green Landfill Perimeter Seep Control Design.

[28] Big Rivers Electric Corporation. January 2021. Fourth Quarter Progress Report, Non-Groundwater Collection Trenches, Reporting Period: October 1, 2020, through December 31, 2020.

[29] Associated Engineers, Inc. October 2016. Green Station CCR Landfill Disposal of Coal Combustion Residuals (CCR) from Electric Utilities, Final Rule Closure and Post-Closure Care Plan.

Burns & McDonnell Engineering Company, Inc. November 2020. Closure Plan for the Green Station CCR Surface Impoundment.

Associated Engineers, Inc. October 2016. Reid/HMP&L Station CCR Surface Impoundment Disposal of Coal Combustion Residuals (CCR) from Electric Utilities, Final Rule Closure and Post-Closure Care Plan.

Elimination System permit.[30] At the Green Landfill BREC also proposes to use institutional controls as necessary to prevent ingestion of contaminated groundwater. Institutional controls are not specified, but environmental covenants and groundwater use restrictions are listed as examples. BREC also proposes to monitor groundwater until standards are met. The groundwater remedy for the Reid/HMP&L Impoundment has not been finalized, which §257.97(a) requires to be done as soon as feasible. BREC has narrowed the possible remedy options to a similar plan as for the landfill: cap in place closure, institutional controls, and monitoring with the possibility of also using hydraulic controls (pumping) or physical containment (funnel-gate system) along with treatment of captured water.[31]

3.2. Contamination Summary and Cleanup Considerations

Groundwater Contamination

Shallow groundwater at Sebree has more significant CCR pollution than deeper groundwater. This is expected, given that shallow groundwater is directly underneath the landfill and in contact with CCR at the two impoundments. Despite this, the monitoring well network is not installed in the shallowest groundwater. To understand why shallow groundwater is not currently monitored by BREC, a description of the local geology and understanding of BREC's interpretation of the language of the federal CCR rule is needed.

The geologic formations include a layer of loess (wind-deposited sandy and clayey silt) near the surface that is up to 25 feet thick. Below the loess is sandstone and shale bedrock of the Carbondale and Shelburn formations. Both the loess and sandstone-shale bedrock contain groundwater. A hydraulic connection exists between the loess and bedrock, but horizontal permeability is much greater than vertical, meaning contaminated groundwater in the loess will predominantly flow horizontally with less flow vertically into the bedrock.

Leachate seepage from the Green Landfill flows downward, where it enters and contaminates groundwater in the loess. Some loess groundwater is perched on lower-permeability layers, which cause the groundwater to flow horizontally to the ground surface where it creates seeps.[32] Some of the contaminated groundwater continues to flow downward into the bedrock, as shown by the chemical parameters typical of CCR impacts, such as chloride, sulfate, total dissolved solids, and lithium that are elevated in the bedrock aquifer.[33] Groundwater in the loess has higher levels of contamination because it receives the direct seepage from the landfill. The deeper bedrock groundwater has lower concentrations of CCR contaminants because vertical seepage is limited and because it is diluted by the

[30] AECOM Technical Services. November 2020. Final Groundwater and Non-Groundwater Corrective Action Remedy Selection Report, Green Landfill.

[31] AECOM Technical Services. December 2020. Semi-Annual Remedy Selection Progress Report, Reid/HMP&L Surface Impoundment, Sebree Generating Station, Webster County, Kentucky.

[32] AECOM Technical Services. July 2020. Status Report Corrective Measures East Non-Groundwater Releases, Green Landfill, Sebree Station, Robards, Kentucky.

[33] AECOM Technical Services. January 2019. 2018 Annual Groundwater Monitoring and Corrective Action Report, Coal Combustion Residuals (CCR) Rule, Green Station Landfill, Green Station CCR Surface Impoundment, Reid/HMP&L Station CCR Surface Impoundment, Webster County, Kentucky.

ambient groundwater flow in the bedrock aquifer. A similar situation likely exists at the two impoundments, which are earthen basins excavated into the loess.

The monitoring well network is completed entirely within the bedrock because BREC has concluded that the bedrock groundwater is the “uppermost aquifer.” The uppermost aquifer is subject to the federal CCR rule monitoring requirements at §257.91. However, there is no definition of “aquifer” in the rule. Definitions for the word aquifer typically state that it is a body of rock or strata that yields “usable” or “economic” quantities of water, which is a subjective determination. BREC has made the conclusion that the loess does not yield “usable” quantities of water,[34] and therefore it only monitors the bedrock groundwater. This is the basis for BREC’s distinction between “groundwater releases” to bedrock groundwater and “non-groundwater releases” to loess groundwater.

What their interpretation means is that the monitoring wells miss the highest concentrations of CCR contaminants in groundwater, and it is this groundwater that is hydraulically connected to the seeps and to the Green River. It is also worth noting that in 1982 when the original monitoring wells were installed for the Green Landfill, several wells were completed in silt and clay directly underneath the landfill.[35] Those monitoring wells were abandoned and sealed in 1996 when the current monitoring well network was installed. To our knowledge, reasons for abandoning the original monitoring network have not been identified in any publicly available document, but it seems plausible that sampling of those wells showed impacts of landfill leachate.

We have recent data on the loess groundwater contamination from seep samples that have been taken under requirement of the Kentucky Division of Waste Management.[36] The seep samples that have been reported are limited to a single sampling event which showed groundwater exceeding site-specific standards developed per §257.95(d)(3) for arsenic, cadmium, cobalt, lithium, molybdenum, radium 226 and radium 228.[37] The seep samples also exceed Kentucky Warm Water Aquatic Habitat criteria for chronic exposure for arsenic, cadmium, chloride, and selenium. Sampling of the Green River did not show exceedances, but these groundwater concentrations could impact aquatic life if seeps flow into small tributaries of the river or if stream sediments are contaminated.

In comparison to what is considered non-groundwater, BREC reports that lithium is the sole parameter in groundwater that exceeds the site-specific standards at a statistically significant level at both the Green Landfill and Reid/HMP&L Impoundment.

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[34] AECOM Technical Services. June 2019. Assessment of Corrective Measures under the CCR Rule, Green Station CCR Landfill, Green Station, Webster County, Kentucky.

AECOM Technical Services. June 2019. Assessment of Corrective Measures under the CCR Rule, CCR Surface Impoundment, Reid/HMP&L Station, Webster County, Kentucky.

[35] Well logs available from Kentucky Geological Survey, Water Well and Spring Records Database, Kentucky Groundwater Data Repository.

[36] AECOM Technical Services. June 2019. Assessment of Corrective Measures Non-Groundwater Releases under the CCR Rule, Green Station CCR Landfill, Green Station, Webster County, Kentucky.

[37] Ibid., Appendix A, Technical Memorandum—River and Seep Sampling and Analysis.

As stated in Section 3.1, the background monitoring well at the Green Impoundment and possibly also the background well at the Green Landfill appear to be sited too close to the CCR waste units to represent clean background water. The Green Impoundment background well is significantly elevated in parameters indicative of CCR leachate when compared to water quality at the Reid/HMP&L Impoundment background well, which appears to be truly upgradient. For instance, background levels of chloride are reported to be 358 times higher at the Green Impoundment than at Reid/HMP&L Impoundment; sulfate is 54 times higher.[38] Potential contamination of the Green Landfill background well is more difficult to discern, although concentrations of Appendix III parameters are higher than in the Reid/HMP&L Impoundment background well. For instance, boron is approximately six times higher in the Green Landfill background samples, and total dissolved solids are approximately twice as high.[39]

BREC uses the apparently contaminated background data from the Green Impoundment to determine that there are no statistically significant increases of Appendix III CCR parameters in downgradient groundwater. The result is that the more toxic Appendix IV parameters are not sampled at the Green Impoundment and BREC does not include the impoundment in its corrective action plans.

At the Reid/HMP&L Impoundment, BREC reports that groundwater exceeds standards for lithium. It is likely that additional CCR pollutants impact shallow groundwater at this impoundment.

Contact between CCR and groundwater is an additional consideration when evaluating groundwater corrective action plans. Both surface impoundments are well below the water table as reported by BREC.[40] Potential contact between the Green Landfill and groundwater is harder to discern, because utilities are not required by the federal CCR rule to report placement above the uppermost aquifer for landfills, although landfills are typically designed to be above the water table. As previously stated, the monitoring network is completed in the bedrock aquifer and not the shallowest groundwater that directly underlies the landfill. There are no reported groundwater level measurements for the shallowest groundwater. The shallow groundwater is hydraulically connected to the Green River and is likely recharged by the river at higher stage, which could raise shallow groundwater levels. Given the data available, we cannot determine conclusively whether the Green Landfill is always above the highest groundwater, and the risk may exist for groundwater to intermittently contact the bottom of the landfill.

To summarize, CCR held in the two surface impoundments and landfill impact shallow groundwater and to a lesser extent deep groundwater. The deeper bedrock aquifer requires corrective action for lithium under the federal CCR rule. BREC has already constructed seep hydraulic control and perimeter drain

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[38] AECOM Technical Services, Inc. 2018 Annual Groundwater Monitoring and Corrective Action Report, Coal Combustion Residuals (CCR) Rule, Green Station CCR Landfill, Green Station CCR Surface Impoundment, Reid/HMP&L Station CCR Surface Impoundment, Webster County, Kentucky.

[39] Ibid., Attachment C, Statistical Evaluations.

[40] AECOM. October 2018. Existing Green CCR Surface Impoundment Disposal of Coal Combustion Residuals (CCR) from Electric Utilities Final Rule Placement above the Uppermost Aquifer Demonstration for Coal Combustion Residuals (CCR)

AECOM. October 2018. Existing Reid/HMP&L CCR Surface Impoundment Disposal of Coal Combustion Residuals (CCR) from Electric Utilities, Final Rule Placement above the Uppermost Aquifer Demonstration for Coal Combustion Residuals (CCR).

collection systems at the Green Landfill, which capture contaminated groundwater and landfill leachate. Treated water from the landfill is discharged to the Green River under a Kentucky Pollutant Discharge Elimination System permit. The water treatment method used depends on the outfall the water is routed to, and includes settling, neutralization, or dilution capacity of the Green River and an unnamed tributary of the river.[41] We have not performed a detailed review of BREC's permit application and whether the water treatment methods are appropriate for the concentrations of contaminants present in the shallow groundwater and landfill seepage. It appears that BREC is not required to sample these outfalls for most of the CCR contaminants that are present in the seep samples that BREC reports; additional investigation of the fate of those contaminants may be warranted.

At the Green Landfill, progress reports show that the newly constructed hydraulic controls are working to dry up the seeps; but the remedy has not fully achieved the Agreed Order requirement of eliminating all seeps for one year.[42] Our professional judgment is that this groundwater remedy is likely to be effective in eliminating the landfill seeps. The hydraulic controls may reduce but will likely not eliminate the vertical seepage of contaminated shallow groundwater into the bedrock aquifer. Further reduction in leachate generation will be afforded by capping the landfill. The existing groundwater hydraulic controls have the secondary benefit that they can be used to limit any flood-related rise in the water table, should that be needed.

The surface impoundments are both unlined and constructed below the water table. This will lead to continuing leaching of contaminants by groundwater flow if CCR is capped in place. The impoundments should undergo clean closure to prevent perpetual releases to groundwater.

Pond and Landfill Construction

Information on the construction of the surface impoundments is limited in BREC's history of construction reports, and it does not appear to provide all construction details required by 257.73(c)(1)(vii).[43] The reports indicate detailed engineering drawings were reviewed, but instead of including the drawings as required by rule, they indicate they are "maintained at Big Rivers Electric Corporation corporate office in Henderson, Kentucky." BREC's impoundment liner assessment reports do not provide further construction detail, although they do indicate that the liners in both

[41] Kentucky Department for Environmental Protection, Division of Water. October 2019. Kentucky Pollutant Discharge Elimination System Fact Sheet, KPDES No. KY0001929, AI No. 4196, Green/Reid/Henderson Station II Power Plant, 9000 Highway 2096, Robards, Webster County, Kentucky.

[42] Big Rivers Electric Corporation. January 2021. Fourth Quarter Progress Report, Non-Groundwater Collection Trenches, Reporting Period: October 1, 2020, through December 31, 2020.

[43] Associated Engineers, Inc. October 2016. Green Station CCR Surface Impoundment Disposal of Coal Combustion Residuals (CCR) from Electric Utilities, Final Rule Structural Integrity Criteria for Existing CCR Surface Impoundments History of Construction.

Associated Engineers, Inc. October 2016. Reid/HMP&L Station, CCR Surface Impoundment Disposal of Coal Combustion Residuals (CCR) from Electric Utilities, Final Rule Structural Integrity Criteria for Existing CCR Surface Impoundments History of Construction.

impoundments do not meet the federal CCR rule definition for a liner at §257.71.[44] Given limited information, we assume both impoundments are completely unlined, earthen impoundments.

Construction details on the Green Landfill are limited in BREC's federal CCR rule reporting, because the regulations do not require the same construction details as for impoundments. Reports obtained from the Kentucky Division of Waste Management indicate that the Green Landfill is unlined, constructed on native clay and silt soils.[45] The landfill also includes vertical expansion walls, a special design which allowed the landfill to expand within limited space.[46] The vertical walls are a consideration for long-term maintenance needs, because they require additional O&M compared to standard sloping landfills. A design life of 60 to 75 years is discussed for the anchored soldier pile retaining wall,[47] indicating that significant maintenance costs will be incurred beyond the 30-year post-closure timeframe.

Floodplain

The FEMA-mapped 100-year floodplain and 500-year flood boundary are shown in Figure A8. The Green Landfill and Green Impoundment are constructed on the 100-year floodplain and within the 500-year flood boundary. Flooding is a consideration for closure and cleanup because floodwaters may rewet CCR, causing increased leaching, and may also destabilize caps.

Additional flood protections would reduce the risk of releases from these waste units within the flood area. A flood-control levee for the Green Landfill, designed for the 500-year flood, is included in the clean closure alternative.

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[44] Associated Engineers, Inc. June 2016. Big Rivers Electric Corporation Disposal of Coal Combustion Residuals (CCR) from Electric Utilities, Final Rule CCR Impoundment Liner Assessment Report.

[45] Terracon Consultants, Inc. December 2013. Subsurface Exploration Report—Revision I, Green Station Landfill Combination Wall, Sebree, Kentucky.

[46] Big Rivers Electric Corporation. October 2010. Application for a Special Waste Landfill Permit.

HDR Engineering, Inc. January 2014. Reid HMP&L Station 2 / Green Station Landfill (Special Waste Facility) Vertical Expansion Using a Combination Wall, Revised Engineering Report for Construction Level Design.

[47] Pinnacle Design/Build Group, Inc. January 2014. Anchored Soldier Pile Retaining Wall, Big Rivers Electric—Sebree Landfill Power Plant Ash Berm, Robards, Kentucky.

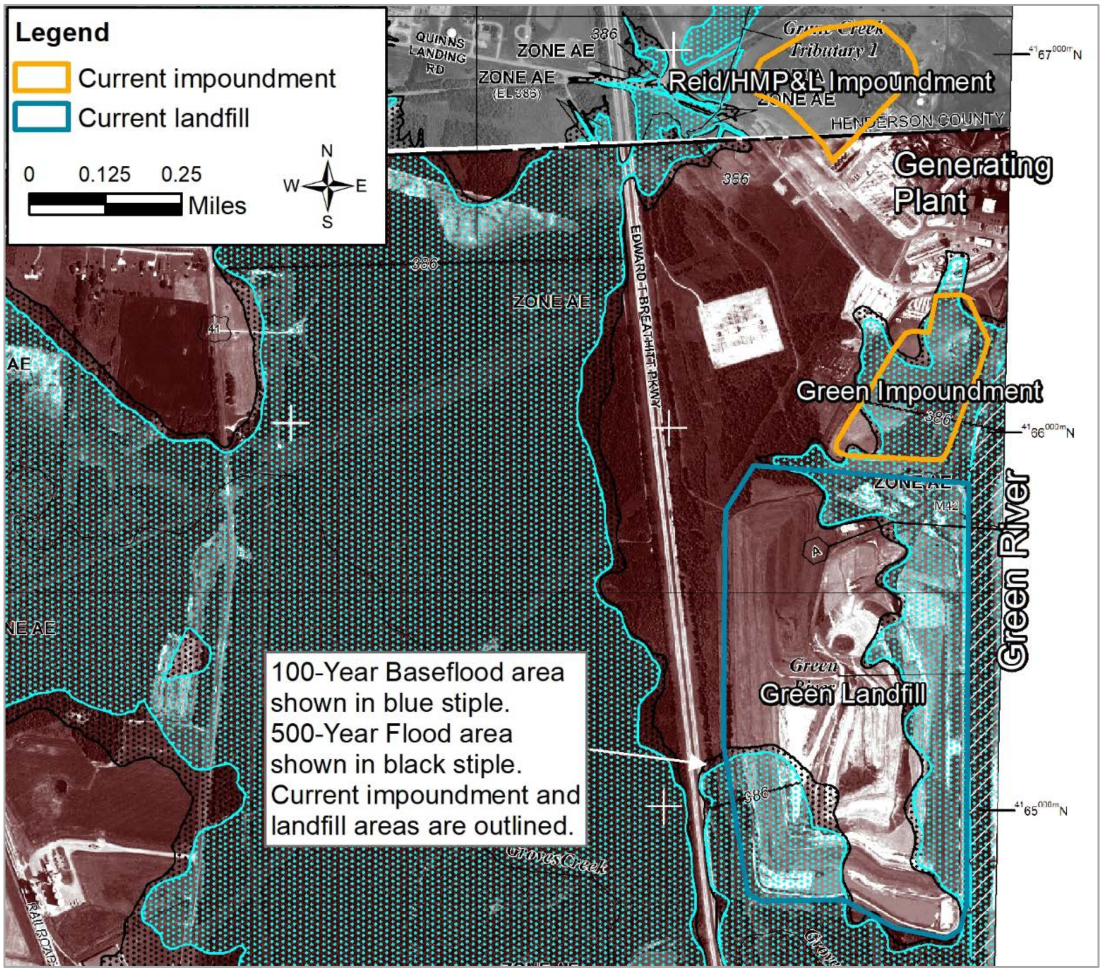

Figure A8. FEMA Floodplain Mapping at Sebree

3.3. Description of Closure Plan Alternatives

Alternative 1: BREC Closure

This alternative follows BREC's closure and corrective action plans and proposals as laid out in plans referenced in section 3.1. The major elements of the closure and post-closure plan include the following:

- Cap in place Green Landfill, Green Impoundment, and Reid/HMP&L Impoundment with compacted clay cover systems
- Continued operation of the Green Landfill seep hydraulic control and perimeter drain collection systems
- Construction of the lined water mass balance (WMB) water treatment pond
- Institutional controls for groundwater
- Groundwater monitoring
- Long-term cap maintenance
- Long-term landfill surface water management

A schedule of BREC's closure activities is provided in Table A7.

Table A7. Activity Schedule for BREC Closure

Activity	Year			
	2021	2022	2023	2024
Planning/Permitting	■			
Mobilization		■		
Green Impoundment Cut/Fill and Excavation of CCR		■	■	
WMB Pond Construction			■	
Green Impoundment Closure			■	
Reid Impoundment Closure			■	
Green Landfill Closure				■

BREC's closure plans for each CCR waste unit are shown in Figure A9.

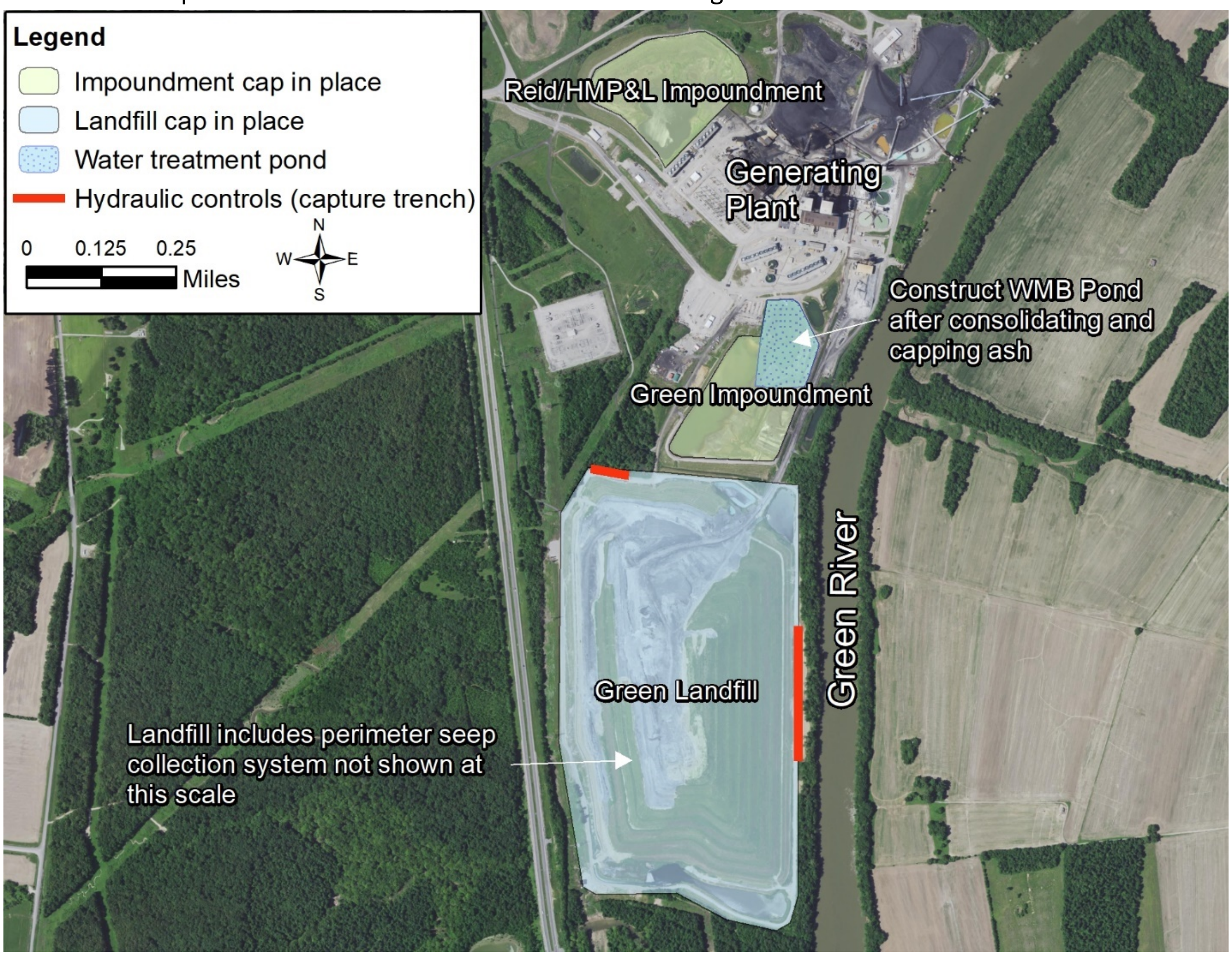

Figure A9. BREC Closure Plan for the Sebree Plant

Under this alternative, CCR is capped in place in both surface impoundments, which are unlined and are constructed below the current water table. This will likely lead to continuing release of CCR contaminants to shallow and deep groundwater and does not meet the impoundment drainage requirements at §257.102(d)(2). The Green Landfill would also be capped in place.

The Green Landfill cap described in BREC's closure plan consists of 18 inches of soil with permeability not more than 1 x 10^{-5} centimeters per second and a 6-inch vegetated erosion layer on top. The closure plan indicates a capped area of 85 acres. We assume the remainder of the 140-acre landfill was already capped with a similar cover system as the landfill was filled. For the impoundment caps, we assume that BREC will use the "typical final cover system" shown in the closure plans, which are the same cap proposed for Green Landfill. This alternative includes post-closure cap maintenance and surface water management for the duration of the 30-year post-closure period.

Hydraulic control and perimeter drain collection systems have already been constructed at the Green Landfill under an agreement with the Kentucky Division of Waste Management. The cost and jobs associated with construction of these capture systems are not included in our analysis, because, as described in BREC's corrective action plans, those actions were required to meet operating permit requirements, not closure. Continued O&M of the seep hydraulic control and perimeter drain collection systems are included in BREC's corrective action plans for groundwater and are included in the cost and job estimates here.

At the Green Impoundment, CCR will be excavated from a 10 acre portion of the 26 acre pond to create a basin for the new WMB pond. The excavated CCR will be consolidated in the remaining 16 acre area of the pond and capped in place. The WMB pond, a new lined water treatment pond, will be constructed and used to treat stormwater, as well as captured leachate and groundwater from the seep hydraulic control and perimeter drain collection systems.

There is no groundwater corrective action for the Green Impoundment, because BREC claims no increases in CCR Appendix III parameters downgradient of the pond, based on use of an apparently contaminated background well.

BREC has not finalized selection of groundwater corrective actions at the Reid/HMP&L Impoundment. We assume that BREC will choose its proposed alternative #2a, which includes cap in place of the impoundment, institutional controls to restrict the property to industrial use and to prohibit groundwater use for potable purpose, and monitoring. This is essentially an MNA remedy plan for groundwater, which is a common utility proposal.

Continued monitoring of the federal CCR rule groundwater monitoring system is included in this alternative. We also assume the Green Landfill seeps will continue to be monitored through 2023. Beginning in 2024 we assume that the seep hydraulic control and perimeter drain collection systems are functional, seeps have been eliminated, and monitoring will then be limited to wells as required under the federal CCR rule.

For this alternative, we assume that any institutional controls that are required to prevent ingestion of contaminated groundwater, such as deed notices preventing the drilling of drinking water wells, are a minor cost and thus are not included in the cost and job estimates.

Alternative 2: Clean Closure

This alternative takes BREC's proposed closure and adds several improvements to the closure plan. It adds clean closure of the Green and Reid/HMP&L Impoundments, a lower-permeability geomembrane composite cap for the Green Landfill, and a flood-control levee for the Green Landfill. The major elements of the closure and post-closure plan include the following.

Improvements added in the clean closure plan:

- Excavation and removal of Green and Reid/HMP&L Impoundments to the Green Landfill,
- Cap in place Green Landfill with composite cover system,
- Construction of a 500-year flood levee for Green Landfill,

Elements carried over from the BREC plan:

- Continued operation of the Green Landfill seep hydraulic control and perimeter drain collection systems
- Construction of the lined WMB water treatment pond
- Institutional controls for groundwater
- Groundwater monitoring
- Long-term cap maintenance
- Long-term landfill surface water management

A schedule of the clean closure activities is provided in Table A8**.**

Table A8. Activity Schedule for Clean Closure

Activity	**Year**			
	2021	**2022**	**2023**	**2024**
Planning/Permitting	■			
Mobilization		■		
Green Impoundment CCR Excavation		■	■	
WMB Pond Construction			■	
Levee Construction		■	■	
Reid Impoundment CCR Excavation		■	■	
Green Landfill Closure				■

The closure plans for each CCR waste unit are shown in Figure A10.

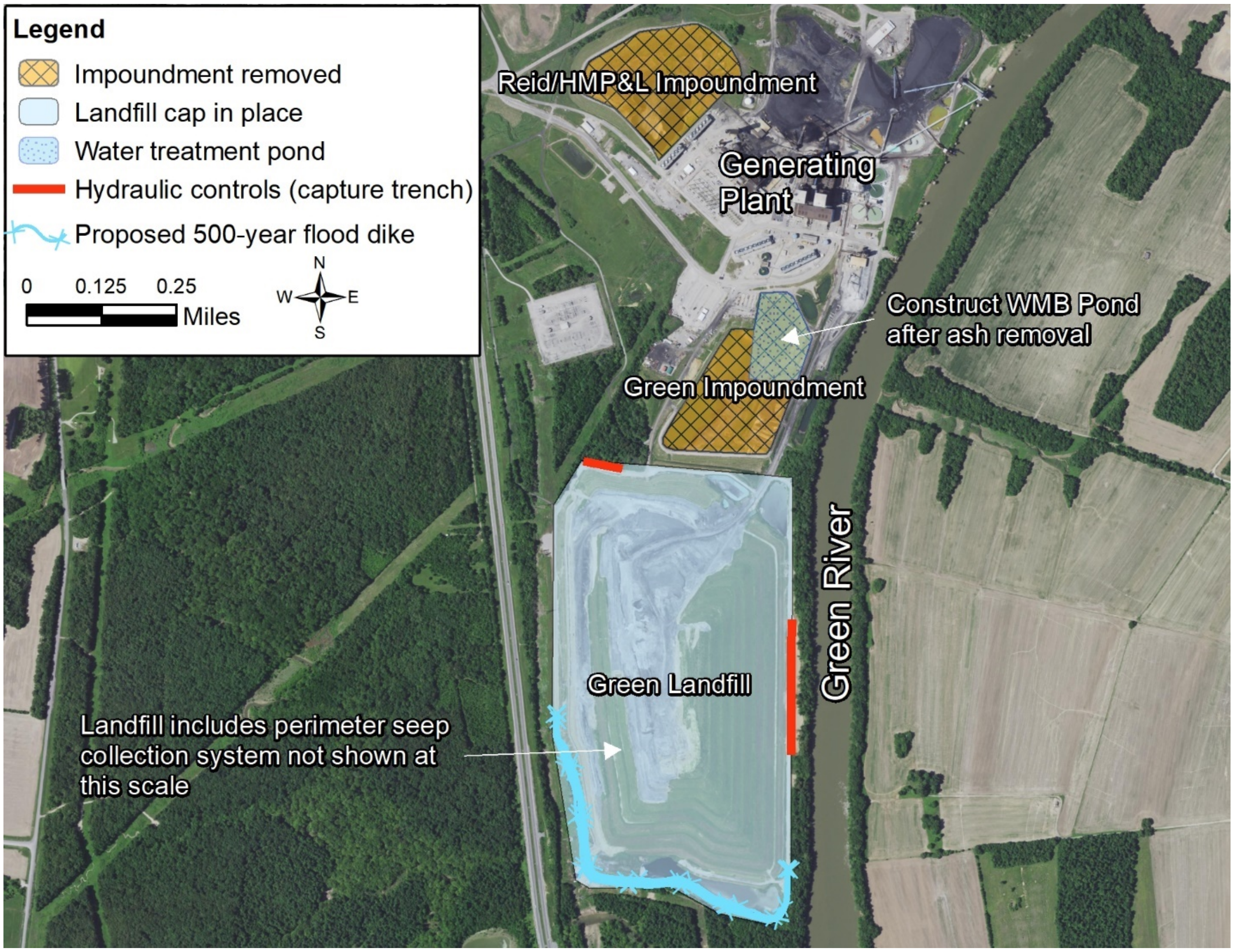

Figure A10. Clean Closure Plan for the Sebree Station

Under the clean closure plan, CCR is excavated from both surface impoundments to provide superior protection of groundwater over BREC's proposed cap-in-place closure plan. Both impoundments are unlined, and the CCR is currently in contact with groundwater.

A composite cover system would be constructed over the entire 140-acre Green Landfill to further reduce infiltration of precipitation and reduce leachate generation over BREC's planned cap. A composite cover system is proposed because the Green Landfill has no bottom liner; therefore, a lower permeability cap with a drainage layer provides a superior capping option for decreasing leachate generation. Groundwater will be further protected by the composite cap when combined with operation of the seep hydraulic control and perimeter drain collection systems. The composite final cover includes a 6-inch vegetated erosion layer on top, 18 inches of compacted clay fill, a geocomposite drainage layer, 60-mil high-density polyethylene (HDPE) geomembrane, and geotextile cushion over graded Poz-o-Tec CCR.

This alternative includes cap maintenance and surface water management at the Green Landfill. The Green Landfill seep hydraulic control and perimeter drain collection systems would continue to be operated and maintained to pump and treat existing groundwater releases and reduce further seepage to groundwater. The cost and jobs associated with construction of these capture systems are not included in our analysis, because, as described in BREC's corrective action plans, those actions were required to meet operating permit requirements, not closure. Continued O&M of the seep hydraulic control and perimeter drain collection systems are included in the cost and job estimates.

The 500-year flood levee as proposed will provide a compacted soil levee with an elevation three feet above the FEMA 500-year flood elevation to provide a safe freeboard.[48] The levee will protect the Green Landfill from floods that may rewet the dry CCR held in the landfill or otherwise destabilize the cap. We chose the 500-year flood height to be conservative, because the landfill will be expected to protect the CCR in perpetuity. The soil fill volume required to construct the levee was estimated assuming 2.5:1 side slope (horizontal: vertical) and using current topography provided by Google Earth terrain data available via Carlson Civil Software. We assume that the flood-control levee, when combined with the previously constructed groundwater hydraulic controls, will be capable of preventing CCR from being rewetted during flooding of the Green River by either floodwaters or rising groundwater levels.

The groundwater corrective actions for this alternative are the same as for the BREC closure plan, with the added benefit of CCR removal from the two impoundments that are in contact with groundwater and better source control at the Green Landfill through a lower-permeability cap. We assume that all of the current federal CCR rule monitoring network wells continue to be monitored through 2023. Beginning in 2024, following clean closure of the Green and Reid/HMP&L Impoundments, we assume that the removal remedy is effective for groundwater at these two impoundments and groundwater monitoring ceases. At the Green Landfill, we assume that the Green Landfill seeps continue to be monitored through 2023. Beginning in 2024, we assume that the seep hydraulic control and perimeter drain collection systems are functional, seeps have been eliminated, and that after this, monitoring is limited to the wells at Green Landfill.

For this alternative, we assume that any institutional controls that are required to prevent ingestion of contaminated groundwater, such as deed notices preventing the drilling of drinking water wells, are a minor cost, and thus are not included in the cost and jobs.

3.4. Cost Analysis

Cost Summary

Table A9 summarizes the estimated total capital cost for each alternative and the annual long-term post-closure O&M cost as described in Section 1.4. Long-term means the O&M costs that are incurred once the site is fully closed and all sites that will require long-term O&M are receiving those expenditures. Capital costs are inclusive of all construction activities, disposal cost, construction-related infrastructure and equipment, site grading, engineering design, planning, and project management.

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[48] Freeboard is additional height added to levee design to reduce the likelihood of overtopping.

Table A10 provides an annual comparison of the estimated capital cost and post-closure O&M cost for the two alternatives. Figure A11 shows the sum of the total capital cost and total annual O&M cost for the two alternatives from Table A10.

Table A9. Total Estimated Cost Comparison of the Two Closure Alternatives for the Sebree Facility

Alternative	Summary of Closure Plan and Groundwater Corrective Action	Total Estimated Capital Cost (2022 USD)	Long-Term O&M Annual Cost (2022 USD)
BREC closure plan	Cap in place the Green Landfill, Green Impoundment, and Reid/HMP&L Impoundment with compacted clay cover systems. Green Landfill groundwater corrective action includes capture, pumping, and treating contaminated shallow groundwater and landfill seepage; construction of the lined WMB pond; institutional controls; and continued groundwater monitoring. Reid/HMP&L Impoundment groundwater corrective action includes MNA and institutional controls.	$65,166,000	$736,000
Clean closure plan	Closure by removal of Green and Reid/HMP&L Impoundments. Cap in place Green Landfill with low-permeability composite cover system. Construction of a 500-year flood levee for Green Landfill. Green Landfill groundwater corrective action includes capture, pumping, and treating contaminated shallow groundwater and landfill seepage; construction of the lined WMB pond; institutional controls; and continued groundwater monitoring. Green Impoundment and Reid/HMP&L Impoundment groundwater corrective action includes closure by removal, MNA, and institutional controls.	$125,721,000	$629,000

Table A10. Estimated Annual Capital Cost and the Annual Post-Closure O&M Costs for Each Alternative for the Sebree Facility

Year	BREC Closure			Clean Closure		
	Total Capital Cost ($)	Total Annual O&M Cost ($)	Total Cost ($)	Total Capital Cost ($)	Total Annual O&M Cost ($)	Total Cost ($)
2021	$1,454,588	$69,600	$1,524,188	$2,806,277	$69,600	$2,875,877
2022	$5,050,983	$69,600	$5,120,583	$27,758,473	$69,600	$27,828,073
2023	$28,511,493	$69,600	$28,581,093	$33,101,260	$69,600	$33,170,860
2024	$30,148,490	$179,699	$30,328,189	$62,055,221	$24,360	$62,079,581
2025		$736,499	$736,499		$628,619	$628,619
2026		$736,499	$736,499		$628,619	$628,619
2027		$736,499	$736,499		$628,619	$628,619
2028		$736,499	$736,499		$628,619	$628,619
2029		$736,499	$736,499		$628,619	$628,619
2030		$736,499	$736,499		$628,619	$628,619
2031		$736,499	$736,499		$628,619	$628,619
2032		$736,499	$736,499		$628,619	$628,619
2033		$736,499	$736,499		$628,619	$628,619
2034		$736,499	$736,499		$628,619	$628,619
2035		$736,499	$736,499		$628,619	$628,619
2036		$736,499	$736,499		$628,619	$628,619
2037		$736,499	$736,499		$628,619	$628,619
2038		$736,499	$736,499		$628,619	$628,619
2039		$736,499	$736,499		$628,619	$628,619
2040		$736,499	$736,499		$628,619	$628,619
2041		$736,499	$736,499		$628,619	$628,619
2042		$736,499	$736,499		$628,619	$628,619
2043		$736,499	$736,499		$628,619	$628,619
2044		$736,499	$736,499		$628,619	$628,619
2045		$736,499	$736,499		$628,619	$628,619
2046		$736,499	$736,499		$628,619	$628,619
2047		$736,499	$736,499		$628,619	$628,619
2048		$736,499	$736,499		$628,619	$628,619
2049		$736,499	$736,499		$628,619	$628,619
2050		$736,499	$736,499		$628,619	$628,619
2051		$736,499	$736,499		$628,619	$628,619
2052		$736,499	$736,499		$628,619	$628,619
2053		$736,499	$736,499		$628,619	$628,619
2054		$736,499	$736,499		$628,619	$628,619
Total	$65,165,554	$22,483,454	$87,649,008	$125,721,231	$19,091,715	$144,812,946

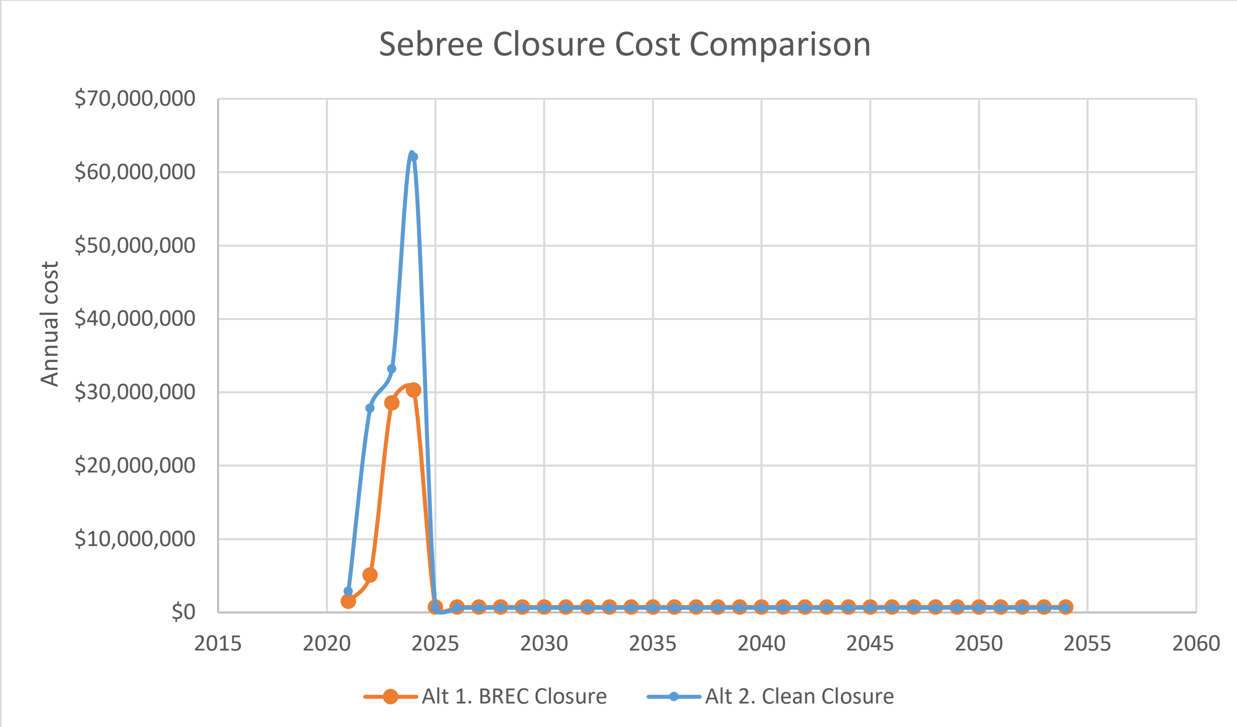

Figure A11. Closure Costs over Time for Each Cleanup Alternative for the Sebree Station (2022 dollars)

The clean closure plan is more expensive up front because excavation and removal of the CCR in the two impoundments would remove 1.6 million cubic yards of CCR to the landfill, versus the BREC closure proposal that would excavate and consolidate 400,000 cubic yards within the Green Impoundment. The clean closure plan is also more expensive because it includes construction of the 500-year flood levee from imported material, and it includes additional materials and construction costs for the composite geomembrane cover system for the Green Landfill.

The BREC closure leaves an estimated 1.6 million cubic yards of CCR capped in place in the two surface impoundments, where it is in contact with groundwater. Long-term O&M costs are estimated to be an additional $108,000 per year for the BREC closure because of the costs associated with O&M at the two surface impoundments that would remain. Long-term O&M costs are also higher for the BREC closure, because additional long-term groundwater monitoring will be required for the two impoundments that remain capped in place. If residual groundwater contamination near the two impoundments does not show progress toward meeting standards under BREC's plans, additional groundwater remedy or CCR removal would likely be needed. However, those potential future costs are not considered, because our analysis is limited to the closure plan as proposed.

3.5. Jobs Analysis

Jobs Summary

Table A11 summarizes the estimated direct job creation (FTE) for each alternative and the annual long-term post-closure O&M FTEs. Total estimated closure and corrective action FTEs represent the sum of FTEs created each year during closure design, permitting, and construction; long-term annual O&M FTEs represent the long-term jobs created for post-closure activities.

Table A12 provides an annual comparison of the estimated direct jobs created for the two alternatives for Sebree closure and corrective action. Figure A12 shows the sum of the total annual closure and corrective action FTE and total annual O&M FTE for the two alternatives from A12.

Table A11. Total Comparison of the Estimated Direct Jobs Created for the Two Alternatives for Sebree Closure and Corrective Action

Alternative	**Total Estimated Closure and Corrective Action FTE**	**Long-Term Annual O&M FTE**
BREC closure	63	3.3
Clean closure	138	2.9

Table A12. Estimated Direct Job Creation and the Annual Post-Closure O&M FTEs for Each Alternative for the Sebree Facility

Year	BREC Closure			Clean Closure		
	Total Construction FTE	**Total Annual O&M FTE**	**Total Annual FTE**	**Total Construction FTE**	**Total Annual O&M FTE**	**Total Annual FTE**
2021	5.6	0.2	5.8	11	0.2	11
2022	8.5	0.2	8.6	33	0.2	33
2023	28	0.2	28.4	42	0.2	42
2024	21	0.8	21.5	53	0.1	53
2025		3.3	3.3		2.9	2.9
2026		3.3	3.3		2.9	2.9
2027		3.3	3.3		2.9	2.9
2028		3.3	3.3		2.9	2.9
2029		3.3	3.3		2.9	2.9
2030		3.3	3.3		2.9	2.9
2031		3.3	3.3		2.9	2.9
2032		3.3	3.3		2.9	2.9
2033		3.3	3.3		2.9	2.9
2034		3.3	3.3		2.9	2.9
2035		3.3	3.3		2.9	2.9
2036		3.3	3.3		2.9	2.9
2037		3.3	3.3		2.9	2.9
2038		3.3	3.3		2.9	2.9
2039		3.3	3.3		2.9	2.9
2040		3.3	3.3		2.9	2.9
2041		3.3	3.3		2.9	2.9
2042		3.3	3.3		2.9	2.9
2043		3.3	3.3		2.9	2.9
2044		3.3	3.3		2.9	2.9
2045		3.3	3.3		2.9	2.9
2046		3.3	3.3		2.9	2.9
2047		3.3	3.3		2.9	2.9
2048		3.3	3.3		2.9	2.9
2049		3.3	3.3		2.9	2.9
2050		3.3	3.3		2.9	2.9
2051		3.3	3.3		2.9	2.9
2052		3.3	3.3		2.9	2.9
2053		3.3	3.3		2.9	2.9
2054		3.3	3.3		2.9	2.9
Total	63	101	164	138	87	225

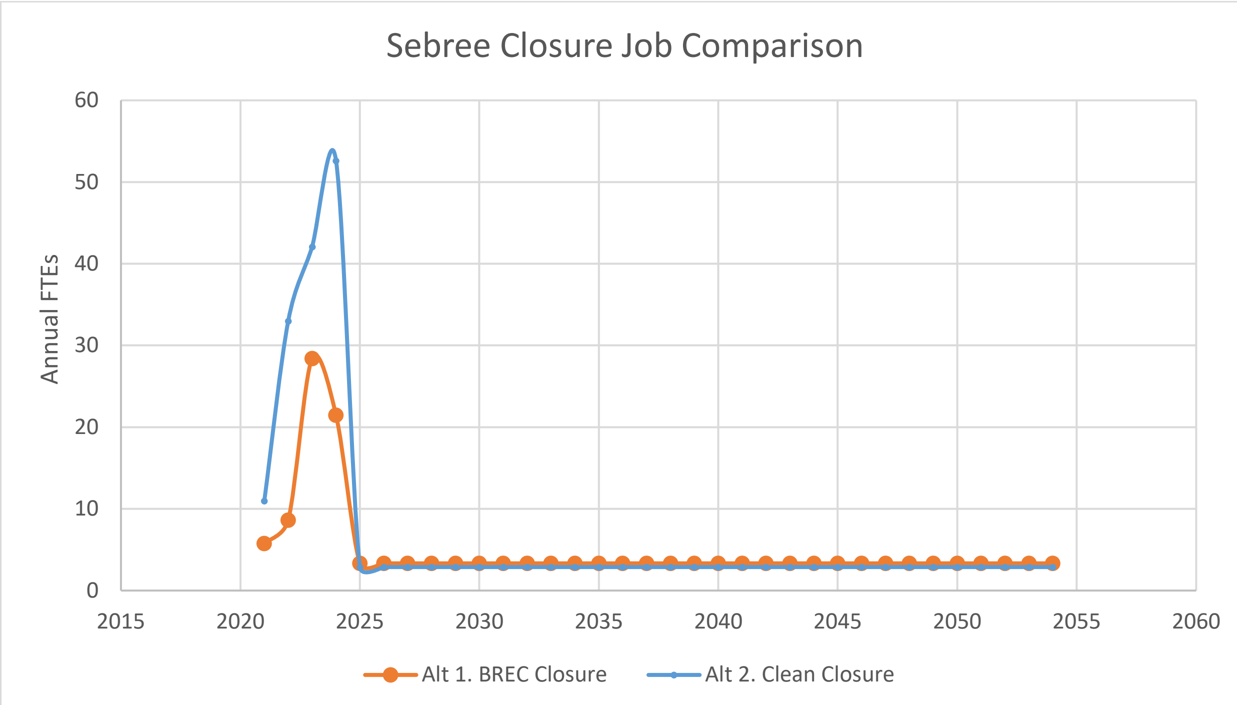

Figure A12. Direct Jobs over Time for Each Cleanup Alternative for the Sebree Station

The clean closure plan creates more jobs during the 2021–2024 closure and corrective action construction period due to jobs associated with the larger volume of CCR that is excavated, trucking of CCR to the landfill, trucking of levee construction fill material, levee construction, installation of a larger and more complex landfill cover system, and engineering, planning, and project management required for the additional remedy components.

Long-term O&M FTEs associated with both alternatives are similar. The BREC closure requires a slightly higher long-term O&M FTE because the two surface impoundments require O&M that is not required under clean closure. BREC closure also requires slightly more labor for long-term groundwater monitoring, because the monitoring wells at the surface impoundments would need to be sampled.