Repairing the Damage

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

Union of Concerned Scientists

Ohio River Valley Institute

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Jeremy Richardson
Eric Dixon
Ted Boettner

September 2021

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Jeremy Richardson is a senior energy analyst in the UCS Climate and Energy Program.

Eric Dixon is an independent consultant working with the Ohio River Valley Institute.

Ted Boettner is a senior researcher at the Ohio River Valley Institute.

The Union of Concerned Scientists puts rigorous, independent science to work to solve our planet's most pressing problems. Joining with people across the country, we combine technical analysis and effective advocacy to create innovative, practical solutions for a healthy, safe, and sustainable future.

The Ohio River Valley Institute's mission is to support communities in the region working to advance a more prosperous, sustainable, and equitable Appalachia. The Institute produces data-driven research and proposes policies to improve the economic performance and standards of living for the greater Ohio River Valley, with a focus on shared prosperity, clean energy, and equitable democracy.

This report is available online at:
- www.ucsusa.org/resources/coal-ash-cleanup-benefits
- www.ohiorivervalleyinstitute.org/coal-ash-report/
- doi.org/10.47923/2021.14314

Designed by: Tyler Kemp-Benedict

Cover photo: Michael Patrick/AP Photo/Knoxville News Sentinel
Cleanup operations from the 2008 coal ash spill at the Kingston Fossil Plant in Tennessee, November 8, 2012.

Printed on recycled paper.

[CONTENTS]

v Figures, Tables, and Boxes
vi Acknowledgments

1 **EXECUTIVE SUMMARY**

CHAPTER 1
4 **One of the Nation's Largest Waste Streams**
4 Coal Ash in the Ohio River Valley States
5 The Many Benefits of Coal Ash Cleanup

CHAPTER 2
6 **Pollution from Coal Ash**
7 Impacts of Coal Ash Pollution
8 Higher Risks in the Ohio River Valley States

CHAPTER 3
11 **Weak Federal Coal Ash Regulations**
11 Inadequacies of the EPA's 2015 Coal Combustion Residuals Rule
14 How Coal Ash Is Regulated in Ohio River Valley States

CHAPTER 4
15 **Coal Ash Cleanup Methods**

CHAPTER 5
18 **Coal Ash Cleanup as Economic Opportunity**

CHAPTER 6
20 **Two Case Studies in the Ohio River Valley States**
20 Methodology
21 Case Study: Sebree Generating Station
24 Case Study: J. M. Stuart Station

CHAPTER 7
27 **Policy Recommendations**

29 References

[FIGURES, TABLES, AND BOXES]

FIGURES

2 Figure ES.1. Total Economic Output over Project Lifetime for Case Study Cleanup Options

22 Figure 1. Site Layout of the Sebree Generating Station

24 Figure 2. Total Job Creation per Year During the Construction Phase of Sebree Closure

24 Figure 3. Economic Output for Kentucky for the Two Sebree Generating Station Closure Options

25 Figure 4. Site Layout of the J. M. Stuart Station

26 Figure 5. Total Job Creation per Year During the Construction Phase of J. M. Stuart Closure

26 Figure 6. Economic Output for Ohio for the Two J. M. Stuart Station Closure Options

TABLES

2 Table ES.1. Projected Job Creation per Year in Kentucky and Ohio from Cleanup Options

9 Table 1. Overview of Coal Ash Disposal Sites in the Ohio River Valley

9 Table 2. Summary of Disposal Site Hazard Ratings for the Ohio River Valley States

10 Table 3. Higher Contamination Rates in the Five States in the Ohio River Valley Than the Nation as a Whole

18 Table 4. Total Jobs Created from Closure Options in Previous Case Studies

21 Table 5. Comparison of the Physical Characteristics of Disposal Sites Evaluated in Case Studies

BOXES

7 Box 1. Kingston’s Cautionary Tale

13 Box 2. A Big Wake-Up Call Leads to the Nation’s Largest Coal Ash Cleanup

16 Box 3. When Is Coal Ash Reuse Truly “Beneficial”?

17 Box 4. Can Coal Ash Help Meet Growing Demand for Rare Earth Elements?

23 Box 5. Why Coal Ash Pollution Is an Environmental Justice Issue

[ACKNOWLEDGMENTS]

This report was made possible by the generous support of the Heising-Simons Foundation, the Joyce Foundation, the John D. and Catherine T. MacArthur Foundation, the Rauch Foundation, and members of the Union of Concerned Scientists. The Just Transition Fund supported the economic analysis of cleanup options for the two sites.

The authors are grateful to Ian Magruder and Peter Haun with WWC Engineering for conducting the engineering analysis of the two case studies, as well as to Dale Shannon with Downstream Strategies for conducting the economic analysis of the two case studies. The authors would also like to thank Lisa Evans from Earthjustice, Frank Holleman from the Southern Environmental Law Center, and Abel Russ from the Environmental Integrity Project for their thoughtful and insightful review of this manuscript. Additional thanks to Karin Matchett for thorough and helpful editing; Julie McNamara, Juan Declet-Barreto, L. Delta Merner, and Steve Clemmer for reviewing; and Cynthia DeRocco and Heather Tuttle for expert publications and layout support.

Organizational affiliations are listed for identification purposes only. The opinions expressed herein do not necessarily reflect those of the individuals who reviewed the work or the funding organizations. The Union of Concerned Scientists and the Ohio River Valley Institute bear sole responsibility for the report's contents.

Although coal has powered the nation for generations and today offers well-paying jobs—often the best opportunities in more rural areas—coal negatively affects human health and the environment at every point in its life cycle: when it is mined, processed, transported, burned, and discarded (Freese, Clemmer, and Nogee 2008). Local communities—often low-income communities and/or communities of color—have for decades borne the brunt of these negative impacts, including air pollution, water pollution, and workplace injuries, illnesses, and fatalities.

One of the Nation's Largest Waste Streams

When coal is burned to produce electricity, not all of its components combust, leaving ash behind—massive amounts of it. Coal ash is one of the two largest industrial waste streams in the United States: From 1966 to 2017, US electric utility companies generated a total of 4.5 billion tons of coal ash and from 2015 to 2019 produced an average of 101 million tons of coal ash every year (ACAA 2021; Earthjustice 2019).

Coal ash is often mixed with water and stored in large impoundments, commonly called coal ash ponds. It can also be stored in dry form in landfills or reused in products like concrete. Many of the elements that make up coal ash—arsenic, boron, cadmium, chromium, lead, radium, and selenium, to name a few—are toxic, and exposure can cause a variety of severe health issues, including cancer, heart disease, reproductive failure, stroke, and even brain damage in children (Earthjustice 2020). Many coal ash constituents are also toxic to aquatic life, and disposal sites pose a risk of catastrophic spills that can contaminate soil, waterways, and groundwater. Despite being such a large waste stream with demonstrated serious impacts on human health and the environment (Gottlieb, Gilbert, and Evans 2010), only in 2015 did the Environmental Protection Agency (EPA) adopt monitoring standards and closure requirements for coal ash disposal sites under the Resource Conservation and Recovery Act (*Federal Register* 2015).

Coal Ash in the Ohio River Valley States

Coal-fired power plants are often located along major rivers because large amounts of water are needed for cooling, and many are concentrated along the Ohio River. Of the 738 coal ash disposal sites nationwide, 161 (more than one out of five) are found in the five states that make up the Ohio River Valley: Indiana, Kentucky, Ohio, Pennsylvania, and West Virginia. One assessment of documented groundwater contamination from coal ash disposal sites put two coal-fired power plants in the Ohio River Valley on the list of the top 10 most contaminated nationwide: the New Castle Generating Station in Pennsylvania (#5) and the Ghent Generating Station in Kentucky (#10) (Russ, Bernhardt, and Evans 2019).

These 161 disposal sites are located at 57 operating or retired coal-fired power plants in these five states. At 33 of the plants (58 percent), the surrounding community is considered low-income, meaning that the residents within a three-mile radius have an average income level at or below twice the federal poverty level in their state. Six of the 57 plants (nearly 11 percent) are located within three miles of a community with a disproportionate number of people of color; half are in Indiana (Earthjustice 2020). Nationally, 52 percent of communities near operating or retired coal-fired power plants are low-income—meaning that the Ohio River Valley disposal sites are more likely to affect low-income communities relative to the national average.

Case Studies Explore the Costs and Benefits of Complete Cleanup

Generalizing the costs of coal ash cleanup nationally is difficult because the cleanup needs are site-specific, but case studies are useful in understanding costs and needs under specific conditions and in providing context for the problem nationally. New analysis by the Union of Concerned Scientists and the Ohio River Valley Institute evaluates the cleanup costs and job creation potential for two coal ash sites—the first two such case studies in the Ohio River Valley. One, the J. M. Stuart coal-fired power plant in Appalachian Ohio, closed in 2018, along with another nearby coal plant, dealing a blow to the local economy (MacGillis 2018). The other, the Sebree Generating Station, consists of three coal-fired power plants (one still in operation but slated for retirement) in western Kentucky. Our analysis evaluates site owners' plans for cleanup activities (both of which are in violation of federal regulations) and proposes a more complete "clean closure" plan for both. These case studies illustrate how investing in cleanup of coal ash can create jobs in exactly the places where jobs are being lost as coal continues its decline. Clean closure simultaneously mitigates the harm caused by pollution begun in decades past and continuing to the present day by providing communities in the Appalachian region—and nationwide—a pathway forward as the shift toward clean energy continues.

TABLE ES.1. Projected Job Creation per Year in Kentucky and Ohio from Cleanup Options

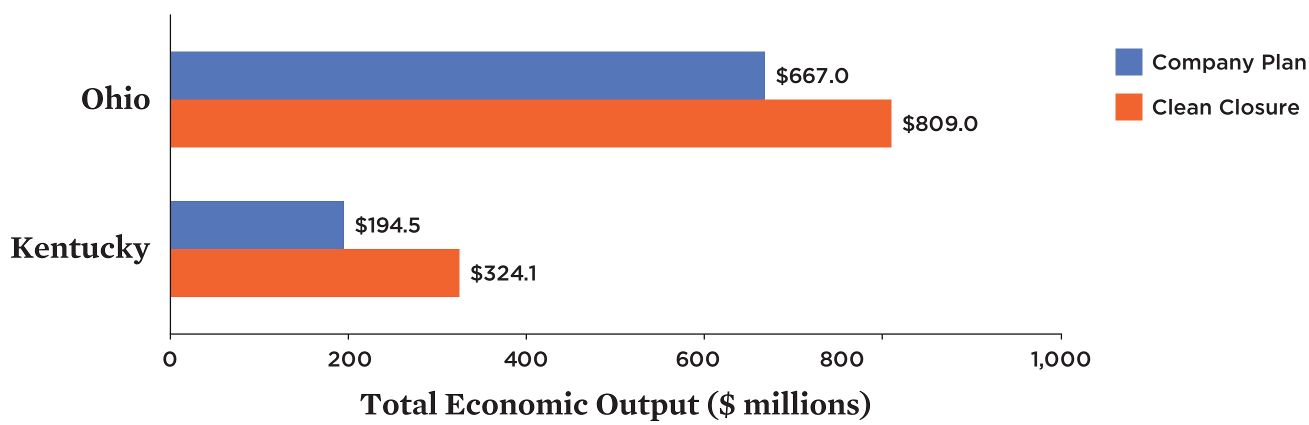
Construction Phase Job Creation per Year		
	Clean Closure	Company Plan
Kentucky	282	144
Ohio	314	252

During the construction phase, more jobs will be created per year with the clean closure plans compared to the owners' plans—in the case of Sebree, nearly twice as many. The construction phase is four years for Sebree and nine years for J. M. Stuart. The numbers represent the total jobs created (direct, indirect, and induced) including both full- and part-time employment.

Case Study Findings

Our analysis consists of an engineering assessment of each site and a cost analysis of two cleanup options—the owner's plan for closing the disposal sites and a proposed clean closure scenario that represents a complete set of actions to fully remediate the site, including excavation of coal ash ponds. Based on the cost estimates and direct job creation from the cleanup projects, we conducted an economic analysis of the impacts of the projects for each state's economy. We found that the clean closure of coal ash disposal sites offers superior protection for public health and ecosystems while offering better opportunities for local jobs and associated economic activity, consistent with similar evaluations for other sites in previous reports. The additional costs of clean closure are justified by the higher number of jobs, the wider economic benefits, and the potential for redevelopment that flow to the local communities. This is especially true for the Sebree plant, where the clean closure plan would generate nearly twice as many jobs as the utility's proposal during the project's construction phase, which refers to initial investments in infrastructure needed to excavate and safely store the coal ash waste. As shown in Table ES.1, the clean closure options would lead to the creation of 282 jobs in Kentucky during the four-year construction phase and 314 jobs in Ohio during the nine-year construction phase. At both sites, the clean closure scenario would drive significant economic impacts that would ripple through each state's economy, as shown in Figure ES.1. Relative to the owners' cleanup plans, the clean closure plans drive more than $100 million in additional economic output in each state.

FIGURE ES.1. Total Economic Output over Project Lifetime for Case Study Cleanup Options



For both projects, the clean closure plans would result in more than $100 million in additional economic activity in each state. Project lifetime is the construction phase plus 30 years of ongoing operations and maintenance. Output is an overall measure in dollars of the impact on the economy due to the investments in the project.

Recommendations

In addition to the job creation and local economic growth from cleaning up these two coal ash disposal sites, state and federal policymakers can take a number of actions to strengthen rules and increase funding to ensure that coal ash is cleaned up nationally.

- **Hold utilities and owners responsible for the clean closure of coal ash disposal sites.** Cleanup decisions are governed by state regulators, and rate-regulated utilities typically petition state public utility commissions for cost recovery—meaning ratepayers are on the hook to pay for the cleanup. Regulators should consider the long-term economic value of cleanup options to the local community—ratepayers should not bear the costs without reaping the economic value of full cleanup.
- **Robustly fund existing EPA programs that support communities.** EPA programs must be robustly funded to ensure that polluting coal ash disposal sites are identified and cleaned up. These programs include the Brownfields programs, enforcement divisions, and the Corrective Action Program within the Resource Conservation and Recovery Act.
- **Strengthen the enforcement of existing regulations that prohibit cap-in-place closure.** The EPA already has enforcement authority, and it can and should follow the plain language of the 2015 Coal Combustion Residuals Rule, requiring excavation when coal ash is in contact with groundwater or when coal ash ponds would remain in a floodplain when capped in place. States should also require excavation under state laws and regulations, as is being done in North Carolina, South Carolina, Virginia, and Illinois.
- **Ensure that frontline communities have a voice in cleanup decisions.** Residents and community leaders are often the strongest voices in holding utilities and site owners accountable for cleanup, and robust stakeholder processes are needed to ensure meaningful engagement. For example, the EPA's Technical Assistance Services for Communities Program offers grants that can empower fenceline communities and residents to participate in discussions about closure options. It is a valuable resource that should be robustly funded to drive better local outcomes, and additional programs supporting environmental justice communities may also be brought to bear.
- **Ensure strong labor standards and safety protections for cleanup workers and prioritize dislocated workers in hiring.** Local hiring requirements should be implemented to ensure that dislocated workers have access to cleanup jobs, and prevailing wages should be required to ensure that workers are paid fairly for their work. Because coal ash is toxic, workers must be protected during cleanup activities.
- **Prevent damage to communities and the environment from reuse of coal ash.** The EPA should cease classifying unencapsulated coal ash as an acceptable "beneficial use" and instead treat unencapsulated uses as a form of disposal.
- **Ensure that the extraction of rare earth elements is safe and is coupled with clean disposal of remaining coal ash.** A holistic assessment of risks and benefits should be applied to rare earth element extraction, and extraction programs should be informed by the community and unions.
- **Leverage existing federal programs or consider establishing new financial institutions or grant programs to ensure that all disposal sites nationally are fully cleaned up.** Existing federal programs like the Superfund program could be augmented through polluter-pays fees. Additional public financing may be needed to ensure complete removal of coal ash. These resources are critical for ensuring a fair transition to clean energy for communities and workers formerly dependent on coal-fired electricity production.

[CHAPTER 1]

One of the Nation's Largest Waste Streams

Although coal has powered the nation for generations and today offers well-paying jobs—often the best opportunities in more rural areas—coal negatively affects human health and the environment at every point in its life cycle: when it is mined, processed, transported, burned, and discarded (Freese, Clemmer, and Nogee 2008). Communities where coal-fired power plants are located—often low-income communities and/or communities of color—have for decades borne the brunt of these negative impacts, including air pollution, water pollution, and workplace injuries and fatalities. When coal is burned to produce electricity, not all of its components combust, and ash is left behind—massive amounts of it. Coal ash is one of the two largest industrial waste streams in the United States: From 1966 to 2017, US electric utility companies generated a total of 4.5 billion tons of coal ash and from 2015 to 2019 produced an average of 101 million tons of coal ash every year (ACAA 2021; Earthjustice 2019).

Coal Ash in the Ohio River Valley States

Coal ash is often mixed with water and stored in large surface impoundments, commonly called coal ash ponds. It can also be stored in dry form in landfills or reused in products like concrete. Many of the elements that make up coal ash—arsenic, boron, cadmium, chromium, lead, radium, and selenium, to name a few—are toxic, and exposure can cause a variety of severe health issues, including cancer, heart disease, reproductive failure, stroke, and even brain damage in children (Earthjustice 2020). Many coal ash constituents are also toxic to aquatic life, and coal ash ponds pose a risk of catastrophic spills that can contaminate soil, waterways, and groundwater. However, despite its being such a large waste stream with demonstrated serious impacts on human health and the environment (Gottlieb, Gilbert, and Evans 2010), only in 2015 did the Environmental Protection Agency (EPA) adopt rules under the Resource Conservation and Recovery Act that specifically address coal ash (*Federal Register* 2015).

Coal-fired power plants are often located along major rivers, because large amounts of water are needed for cooling (Rogers et. al. 2013), with many concentrated along the Ohio River. Of the 738[1] coal ash disposal sites nationwide, 161 (more than one out of five) can be found at operating or retired coal-fired power plants in the five states that make up the Ohio River Valley: Indiana, Kentucky, Ohio, Pennsylvania, and West Virginia.[2] One assessment of documented groundwater contamination from coal ash disposal sites put two coal-fired power plants in the Ohio River Valley on the list of the top 10 most contaminated nationwide: the New Castle Generating Station in Pennsylvania (#5) and the Ghent Generating Station in Kentucky (#10) (Russ, Bernhardt, and Evans 2019).

These 161 disposal sites are located at 57 operating or retired coal-fired power plants in these five states. At 33 of the plants (58 percent), the surrounding community is considered low-income, meaning that the residents within a three-mile

1 *This figure includes only coal ash disposal sites where the owner is required to report information on groundwater contamination, which excludes "legacy" coal ash ponds that closed prior to 2015 as well as sites that are regulated but have received exemptions from reporting requirements.*

2 *Both operating and retired power plants often include multiple coal ash ponds and landfills, referred to in this report as coal ash disposal sites.*

> ***Cleaning up coal ash can create jobs in exactly the places where jobs are being lost while simultaneously mitigating the harm caused by ongoing pollution and providing communities a pathway forward.***

radius have an average income level at or below twice the federal poverty level in their state. Six of the 57 plants (nearly 11 percent) are located within three miles of a community with a disproportionate number of people of color; half are in Indiana (Earthjustice 2020). Nationally, 52 percent of communities near operating or retired coal-fired power plants are low-income—meaning that the Ohio River Valley disposal sites are more likely to affect low-income communities than the national average.

The Many Benefits of Coal Ash Cleanup

With the advent of cheap and abundant natural gas and the dramatic decrease in costs of renewable energy like wind and solar, coal-fired power plants have become increasingly uneconomic in the last decade. Coal-fired generation dropped from providing more than half of electricity generation in 2008 to about 20 percent in 2020, and around 90 gigawatts (GW) of coal-fired generating capacity was retired over that time (Storrow 2020). But the soil and water pollution often remains and continues to affect human health and the environment. As the transition away from coal accelerates, coal ash cleanup is a critical component of dealing with the legacy of coal-fired electricity generation. The good news is that remediating coal ash sites can drive multiple positive outcomes: creating jobs for workers facing job losses at retiring coal plants, correcting a serious and ongoing threat to human health and the environment, increasing the potential for redevelopment of the sites, and helping diversify local economies. Pollution cleanup is essential to ensuring that these areas are places where people want to live and work.

Generalizing the costs of coal ash cleanup nationally is difficult because the cleanup needs are site-specific, but case studies are useful in understanding costs and needs under specific conditions and in providing context for the problem nationally. New analysis by the Union of Concerned Scientists and the Ohio River Valley Institute evaluates the cleanup costs and job creation potential for two coal ash sites—the first two such case studies in the Ohio River Valley. One site, the J. M. Stuart plant in Appalachian Ohio, closed in 2018, along with another nearby coal plant, dealing a blow to the local economy (MacGillis 2018). The other site, the Sebree Generating Station, consists of three coal-fired power plants (one still in operation but slated for retirement) in western Kentucky. Our analysis evaluates site owners' plans for cleanup activities (both of which are in violation of federal regulations) and proposes a more complete "clean closure" plan for both. We find that clean closure would generate more economic activity and create more jobs. This is especially true for Sebree, where the clean closure plan would generate nearly *twice* as many jobs as the utility's proposed plan during the project's construction phase, which refers to initial investments in infrastructure needed to excavate and safely store the coal ash waste. Relative to the owners' cleanup plans, the clean closure plans drive more than $100 million in additional economic output in each state.

These case studies illustrate how investing in cleanup of coal ash can create jobs in exactly the places where jobs are being lost, while simultaneously mitigating the harm caused by ongoing pollution and providing communities in the Appalachian region—and nationwide—a pathway forward as the shift toward clean energy continues.

[CHAPTER 2]

Pollution from Coal Ash

The combustion of coal yields a variety of waste streams including fly ash, bottom ash, boiler slag, and material from flue gas desulfurization, which are commonly called coal ash or coal combustion residuals (CCR) (EPA 2020). While coal ash can be diverted for reuse in products like concrete, it is typically disposed of on site at power plants, often mixed with water to create a slurry and piped for disposal to a nearby coal ash pond. Intended to contain many decades' worth of waste, coal ash ponds are typically large, averaging more than 50 acres in size and more than 20 feet deep (EPA 2018). Some are much larger. The McElroy's Run coal ash pond at the Pleasants Power Station in West Virginia, for example, is 253 acres—the area of about 192 football fields—and nearly 150 feet deep (Tetra Tech 2019). Coal ash can also be disposed of in dry form in landfills.

The unsafe disposal of coal ash is common given the historical lack of oversight and can lead to ongoing air and water pollution. Depending on how the ponds were constructed and where they were sited, coal ash ponds may allow toxic materials to seep into the groundwater and/or waterways. For coal-fired power plants located along rivers, the corresponding coal ash ponds are often located in the floodplain and often in places with shallow groundwater, increasing risk to aquatic life and drinking water. Furthermore, more than 95 percent of coal ash ponds are unlined or poorly lined, offering little to no barrier between the coal ash slurry and the groundwater below. Based on federal groundwater monitoring and reporting requirements that became mandatory after 2015, more than 90 percent of the 738 coal ash disposal sites nationwide are leaking at levels that render the underlying groundwater unsafe for drinking (Earthjustice 2020). And sometimes structural elements of coal ash impoundments can fail, leading to spills with catastrophic consequences for nearby residents, property, the environment, and cleanup workers (see Box 1).

Coal ash landfills are often similarly unlined, allowing precipitation to filter through the coal ash pile and leach contaminants directly into groundwater and into surrounding waterways through runoff. For example, on multiple occasions Kentucky state inspectors reported coal ash waste flowing from the Green Landfill at Sebree at rates of 60 gallons per minute (Van Velzer 2019). Just as with coal ash ponds, contamination from landfills can also occur when the ash is buried under the water table in direct contact with groundwater. Finally, wind can disperse coal ash dust if the landfill is uncapped, allowing uptake by soil and vegetation and inhalation by humans.

[***More than 90 percent of the 738 coal ash disposal sites nationwide are leaking at levels that render the underlying groundwater unsafe for drinking.***]

Impacts of Coal Ash Pollution

The EPA conducted an exhaustive assessment of the risks of coal ash to humans and ecological systems, evaluating a long list of contamination exposure mechanisms from both landfills and surface ponds and through soil, nearby flora and fauna, groundwater, drinking water, and air. The agency found risks to human health "primarily from exposures to arsenic and molybdenum in ground water used as a source of drinking water, but additional risks from boron, cadmium, cobalt, fluoride, mercury, and thallium were identified for specific subsets of national disposal practices." It also found risks to ecological systems "from exposures to aluminum, arsenic, barium, beryllium, boron, cadmium, chloride, chromium, selenium, and vanadium through direct exposure to impoundment wastewater" (EPA 2014c).

Other coal ash constituents can pose health risks, too. In its 2015 CCR Rule, the EPA defined a long list of constituents subject to monitoring based on their known risks to human health. Humans can come into contact with these pollutants by drinking contaminated water; swimming, boating, or fishing in contaminated lakes and rivers; eating animals and fish that have ingested the pollutants; and coming into direct contact with contaminated soil (Locke et al. 2020).

Contamination from coal ash can harm wildlife and have ecosystem-level impacts, such as reducing species abundance and diversity and even eliminating entire species (Lemly and Skorupa 2012; Rowe, Hopkins, and Congdon 2002). Trace elements from coal ash have been detected in algae, plankton, plants, insects, mollusks, crayfish, fish, amphibians, reptiles, birds, and mammals, and chronic exposure can cause reduced growth rates, deformities, and reproductive failure in some wildlife populations (Locke et al. 2020). Selenium is particularly dangerous because it is toxic to aquatic life even at low levels and has been detected at all levels of the food chain (Gottlieb, Gilbert, and Evans 2010).

BOX 1.

Kingston's Cautionary Tale

The structural elements containing the coal ash pond can sometimes fail, with catastrophic consequences that often compound burdens of environmental justice and systemic racism faced by low-income communities and communities of color. In late December of 2008, an earthen dike ruptured at the Tennessee Valley Authority's Kingston coal-fired power plant in Tennessee, spilling 1.1 billion gallons of coal ash waste—enough to fill 1,652 Olympic-sized swimming pools (Bourne 2019). The Kingston coal ash spill stands as the largest industrial disaster in US history, 10 times the size of the Deepwater Horizon oil spill in the Gulf of Mexico (Bourne 2019). In addition to the Kingston spill's destroying homes, devastating ecological systems, and contaminating the Emory and Clinch Rivers—the source of drinking water for hundreds of thousands of residents—in its immediate aftermath, workers were not provided any protective equipment during cleanup operations (Gaffney 2020). Of the nearly 900 workers who cleaned up the site, many became sick and at least 53 have died as a result of working on cleanup activities—a number that may grow (Knisley 2020; Sullivan 2019).

Short-term cleanup efforts led to the removal of almost 707 million gallons of waste from the river and surrounding areas. The next phase of cleanup relied on allowing the pollutants to dissipate naturally in the river ("monitored natural recovery") (SACE 2012), at least in part because dredging of the riverbed was stirring up additional contaminants from the history of nuclear testing at nearby Oak Ridge National Laboratory (Gaffney 2020). Most of the waste from the initial cleanup of the spill (to the tune of 4 million tons) was put on trains and trucks and shipped to a landfill in Uniontown, a small town in Perry County, Alabama. No modifications were made to the landfill to contain the coal ash; the ash was simply piled up in mounds as high as 60 feet (SACE 2013). Even today, residents report dust blowing from the coal ash piles and coating nearby homes, and runoff from the landfill pollutes local waterways (Engelman-Lado et al. 2021). Uniontown's population of just under 2,000 is predominantly Black, and more than half of its residents live below the poverty level.

The total cost of the Kingston cleanup was estimated to be $1.134 billion (Oak Ridge Today 2017). And that figure does not include the incalculable value of the cleanup workers who lost their lives or continue to suffer from chronic disease, the residents of Uniontown who face the lasting public health impacts of the waste and who saw their property values drop, or the effects of the spill and its disposal on the environment (Engelman-Lado et al. 2021). The legacy of the Tennessee Valley Authority's Kingston disaster, combined with decisions by the Alabama Department of Environmental Management and the Perry County Commission, which failed to properly protect or even consult with local residents, stands as a powerful example of the need to address environmental justice concerns in coal ash disposal.

J. Miles Cary/AP Photo/Knoxville News Sentinel

The largest industrial disaster in US history, the Kingston coal ash spill on December 22, 2008, destroyed homes, devastated ecological systems, and contaminated the Emory and Clinch Rivers. The spill was caused by the failure of a dike containing the coal ash pond, underscoring the threat of coal ash waste to human health and the environment.

Higher Risks in the Ohio River Valley States

In the five Ohio River Valley states, more than 162 billion gallons of coal ash waste is held in the 161 disposal sites (landfills or coal ash ponds) that are subject to the reporting requirements set forth by the EPA's CCR Rule. These sites are located at 57 operating or retired coal-fired power plants (see Table 1). Pennsylvania reported the highest volume of CCR waste of any of the five states, and Indiana has the most coal ash sites subject to reporting requirements. It is important to note that these totals do not include all coal ash sites in these states, because the numbers do not reflect coal ash sites that were closed prior to 2015 and therefore are not currently subject to EPA's coal ash regulations and reporting requirements; one analysis found dozens of additional unreported disposal sites in these states (Colman 2019).

The EPA has assigned hazard ratings to coal ash ponds based on the same criteria used by the Federal Emergency Management Agency and the Army Corps of Engineers to assess dam safety (ICDS 2004). The rating does not assess the likelihood of failure, but rather the potential for loss of life and damage if such a failure were to occur. A rating of "high" means that loss of life would likely occur in the event of failure; "significant" means that loss of life is not likely, but that a failure would result in economic losses and environmental damage. The five states have 16 sites rated as high hazard and

[*In the five Ohio River Valley states, more than 162 billion gallons of coal ash waste is held in the 161 disposal sites that are subject to EPA reporting requirements.*]

TABLE 1. Overview of Coal Ash Disposal Sites in the Ohio River Valley

State	Power Plants	Disposal Sites	Landfills	Coal Ash Ponds	Total CCR Volume (cubic yards)	Above Average Proportion of Residents Who Are People of Color	Above Average Proportion of Residents Who Are Low-Income
Indiana	16	50	9	41	49,995,320	3	8
Kentucky	15	43	15	28	173,881,205	2	10
Ohio	10	33	11	22	153,173,418	0	7
Pennsylvania	9	21	8	13	257,037,684	0	6
West Virginia	7	14	8	6	169,141,078	1	2
Total	**57**	**161**	**51**	**110**	**803,228,705**	**6**	**33**

The Ohio River Valley states host 57 operating or retired coal-fired power plants that are subject to EPA reporting requirements (a number that does not include unregulated disposal sites). The rightmost columns list the number of disposal sites where the surrounding community within a three-mile radius is above the state average for people of color or low-income households.

SOURCES: RUSS, BERNHARDT, AND EVANS 2019; EARTHJUSTICE 2020.

58 rated as significant (see Table 2). In West Virginia, five of the six coal ash ponds are rated as high or significant hazards, and in Ohio, 19 of the 22 are rated as either high or significant.

Published analysis of utility data required by the CCR rule indicates that 91 percent of coal-fired power plants nationally are contributing to unsafe groundwater via contamination from coal ash, where "unsafe groundwater" is defined as having at least one of the 17 substances subject to monitoring exceeding health-based standards (Russ, Bernhardt, and Evans 2019; Earthjustice 2020). Nationally, 54 percent of the sites exceed health-based thresholds of at least four of these pollutants, and the Ohio River Valley states show higher contamination rates than the nation as a whole. Of the 55 coal-fired power plants subject to monitoring requirements in the five states, 96 percent (53 plants) exceed the threshold for at least one pollutant, and 65 percent (36 plants) exceed standards for at least four pollutants (see Table 3, p. 10). In Ohio, eight out of the 10 plants show contamination above safe levels for at least four pollutants. Indiana has the greatest number of plants showing contamination of at least four pollutants, at 12. In three states, all coal plants in the state exceed safe levels of at least one pollutant.

TABLE 2. Summary of Disposal Site Hazard Ratings for the Ohio River Valley States

State	Total Sites	Hazard: High	Hazard: Significant	Total, High Plus Significant	% High or Significant
Indiana	50	1	26	27	54%
Kentucky	43	7	13	20	47%
Ohio	33	5	14	19	58%
Pennsylvania	21	1	2	3	14%
West Virginia	14	2	3	5	36%
Total	**161**	**16**	**58**	**74**	**46%**

Nearly half of the coal ash disposal sites in the Ohio River Valley states could lead to a loss of life ("high risk") or economic losses and environmental damage ("significant risk") in the event of structural failure.

Note: One site in Pennsylvania is rated "high/significant" and is counted in the "significant" column.

SOURCES: RUSS, BERNHARDT, AND EVANS 2019; EARTHJUSTICE 2020.

TABLE 3. Higher Contamination Rates in the Five States in the Ohio River Valley Than the Nation as a Whole

Substance	IN	KY	OH	PA	WV	Total
Antimony	2	1	0	0	0	**3**
Arsenic	14	7	8	3	4	**36**
Barium	0	0	2	1	1	**4**
Beryllium	1	2	1	0	1	**5**
Boron	11	8	9	3	3	**34**
Cadmium	2	0	0	0	0	**2**
Chromium	0	2	1	0	0	**3**
Cobalt	7	5	8	5	3	**28**
Fluoride	1	1	3	0	0	**5**
Lead	0	1	2	1	0	**4**
Lithium	12	12	8	6	3	**41**
Mercury	0	1	0	0	1	**2**
Molybdenum	12	9	8	4	5	**38**
Radium	2	3	4	0	1	**10**
Selenium	1	2	1	0	0	**4**
Sulfate	10	12	8	6	3	**39**
Thallium	3	2	1	0	0	**6**
Any Substance	**14**	**14**	**10**	**8**	**7**	**53**
At Least 4 Substances	**12**	**8**	**8**	**3**	**5**	**36**
Total Plants*	15	14	10	9	7	**55**
% Plants with at least 1	93%	100%	100%	89%	100%	**96%**
% Plants with at least 4	80%	57%	80%	33%	71%	**65%**

These 17 pollutants are subject to monitoring requirements and/or health-based standards by the CCR Rule. The values in the table indicate the number of current or former coal-fired power plant sites in each state that have exceeded health-based thresholds of each pollutant. Nationally, 54 percent of coal-fired power plants reported exceedances of at least four pollutants, and 91 percent reported exceedances of at least one, compared to 65 percent and 96 percent, respectively, for the Ohio River Valley states.

* Note: One plant in Indiana and one in Kentucky are excluded from the plant totals because contamination levels are unknown.

SOURCE: RUSS, BERNHARDT, AND EVANS 2019.

[CHAPTER 3]

Weak Federal Coal Ash Regulations

Although coal ash is one of the largest industrial waste streams in the United States and has been produced for many decades, the EPA did not adopt specific regulations governing it until recently. Spurred in part by the Tennessee Valley Authority's Kingston disaster (see Box 1, p. 7) and recognizing the potential for groundwater contamination from surface coal ash ponds and landfills, the EPA conducted a risk assessment that kicked off a rulemaking process to regulate the disposal of coal ash waste, concluding that it does pose a threat to human health and the environment (EPA 2018; 2014c). The agency finalized the Coal Combustion Residuals Rule in 2015 (*Federal Register* 2015).

The initial 2015 CCR Rule aimed to reduce risks of groundwater contamination, airborne transport of coal ash dust, and structural failure of surface coal ash ponds (EPA 2018). It established minimum criteria for new and existing coal ash ponds and landfills that include location restrictions, design and operating criteria, requirements for groundwater monitoring and corrective action, closure requirements, and public disclosures (EPA 2020). The rule regulates coal ash under the Resource Conservation and Recovery Act, the primary federal statute governing both hazardous and nonhazardous solid waste disposal.

The 2015 CCR Rule placed a first-time federal requirement on owners and operators of coal ash disposal sites to monitor groundwater. As noted above, the EPA's comprehensive risk assessment identified a set of constituents present in coal ash that pose significant risks to human health or ecosystems (EPA 2014c), and the 2015 CCR Rule identified pollutants for detection and assessment (*Federal Register* 2015). Importantly, the risk assessment found that composite liners installed in landfills and surface ponds provide the best protection, reducing risks to human health and ecological impacts by maintaining contaminant levels well within a safe range. Unlined disposal sites present the greatest risk, while clay-lined sites, although safer than unlined sites, can still allow contaminant levels that exceed the risk criteria (EPA 2014c).

The rule requires the closure of any unlined coal ash pond that is leaking toxic contaminants at levels above federal standards or any pond that cannot meet location restrictions or minimum structural requirements. Nearly all coal ash ponds are unlined or poorly lined (having been constructed at lowest cost and prior to federal oversight), and, based on subsequent disclosures from groundwater monitoring, 91 percent are leaking (Earthjustice 2020). However, during the Trump administration the EPA weakened the rule by extending the deadline for closure of these coal ash ponds under some circumstances. Also, although the 2015 CCR Rule required that all new disposal sites install composite liners, during the Trump administration the EPA amended the rule to allow some existing unlined and clay-lined impoundments to continue receiving coal ash, provided they are not contaminating groundwater (EPA 2018).

Inadequacies of the EPA's 2015 Coal Combustion Residuals Rule

Even before the rollbacks by the Trump administration, the original 2015 rule was widely considered inadequate by environmental and public health advocates as well as community groups (Earthjustice, n.d.). First and foremost, both cap-in-place and excavation are allowable closure methods under the rule, even though cap-in-place provides inferior protection from contamination relative to excavation because unlined ponds can continue to contaminate groundwater even when covered (see below for more on closure methods). Utilities can also apply for waivers to delay compliance and can avoid cleanup of groundwater by inappropriately attributing coal ash contamination to other sources and avoiding monitoring requirements (*Federal Register* 2015). Advocates argued that coal ash should be subject to more stringent rules applied to hazardous waste.

In addition, the EPA chose to exempt landfills that closed prior to 2015 and inactive ash ponds at facilities no longer generating electricity, leaving many potentially harmful sites unregulated. This also created a perverse incentive that led many utilities to close disposal sites before the rule was finalized and thus escape regulation and monitoring requirements. There is little information and no comprehensive database of these legacy ponds and landfills, many of which continue to pose threats to human health and the environment. Nearby residents are not able to ascertain whether or to what extent their drinking water is affected, and the absence of monitoring data hinders any efforts to initiate citizen enforcement.

The current federal regulations require monitoring groundwater only at the coal ash pond, not at nearby sources of drinking water. The extent of groundwater pollution was not well understood until after utilities were required to monitor for pollution (*Federal Register* 2015); therefore, we do not have comprehensive data about groundwater contamination at a distance from the pollution source. But despite the lack of comprehensive data, at least 24 sites have been identified where private wells were contaminated by coal ash; two are in Indiana, and two are in Pennsylvania (Earthjustice 2020). And finally, more than 100 coal ash ponds and landfills (including both unregulated legacy sites and those subject to current reporting requirements) are sited in locations considered at a high risk for flooding (Colman 2019). Hurricanes Matthew and Florence in 2016 and 2018 demonstrated the danger of flooding to coal ash ponds in

Rick Dove/Waterkeeper Alliance

The rupture of a stormwater pipe at a former coal-fired power plant owned by Duke Energy spilled 27 million gallons of contaminated water and 39,000 tons of coal ash into the Dan River in February 2014. The disaster exposed the utility's negligence and drove policymakers to ensure all coal ash ponds in the state close safely by 2029.

North and South Carolina, and this threat will only increase with more frequent extreme weather events driven by climate change (Colman 2019; Hayhoe et al. 2018; Northey and Wittenberg 2018).

Given the rule's inadequacy from an environmental and public health perspective, litigation followed the finalization of the initial CCR Rule, and in 2018, the United States Court of Appeals for the District of Columbia Circuit vacated and rejected three important parts of the 2015 rule, affirming some of the claims presented by environmental advocates. The court found that (1) the EPA had no grounds to allow only non-leaking unlined ponds to continue to receive waste (because of the risk of continued contamination); (2) the EPA had no grounds to classify "clay-lined" ponds as lined, as these liners still pose a risk of contamination; and (3) the EPA had no grounds to exempt legacy coal ash ponds from the requirements outlined in the rule (Kirn 2020). Instead of addressing these deficiencies, the Trump-era EPA weakened the rule by providing compliance extensions and making it easier for owners and operators to delay compliance. On the question of legacy ponds, the agency delayed and simply issued another request for information instead of amending the rule, sidestepping the required revisions to the rule in response to the court ruling (Frank and Maloney 2020). Litigation is ongoing (EELP 2017).

In one of his executive orders his first day in office, President Biden designated 50 EPA rules for review, including the regulations weakening the CCR Rule promulgated by the Trump administration. The agency is now headed by the former head of North Carolina's Department of Environmental Quality, who is credited for issuing directives and entering into an agreement that required Duke Energy to fully clean up coal ash ponds by excavation (see Box 2) (Marshall 2021). However, the Biden EPA chose not to challenge the Trump EPA's weakening of the rule, instead concluding that the most environmentally responsible action was to implement the rules rather than risk delay through additional rulemaking (Yohannan 2021).

BOX 2.

A Big Wake-Up Call Leads to the Nation's Largest Coal Ash Cleanup

On February 2, 2014, a stormwater pipe burst at a coal ash pond owned by Duke Energy in Eden, North Carolina, at the site of a retired coal-fired power plant. The breach, which took more than a week to repair and stem the flow of contaminated water, ultimately spilled 39,000 tons of coal ash and 27 million gallons of contaminated water into the Dan River near the border with Virginia (Appalachian Voices 2021). The spill reached more than 70 miles downstream and is the third-largest coal ash spill in US history. And yet it could have been much worse; Duke's problems were widespread, and the Eden coal ash pond was the company's smallest in the state, holding only 1 percent of the company's waste stored in 14 sites statewide (Wireback 2015). In just the six months following the spill, one estimate of the costs of the ecological damage, recreational impacts, and effects on human health totaled almost $300 million (Lemly 2015).

Political interference at the state's environmental regulator, the Department of Environment and Natural Resources (now the Department of Environmental Quality), resulted in lax enforcement prior to the spill and weak penalties in the immediate aftermath (Gabriel 2014). Ultimately, the Justice Department prosecuted Duke Energy. The company was found to be criminally negligent for the disaster and Clean Water Act violations at other coal ash sites in the state and agreed to pay $103 million in fines (CBS/AP 2015). The company also agreed to pay $3 million in cleanup costs to the EPA (EPA 2014a), and the North Carolina Department of Environmental Quality eventually fined the company $6.6 million (CBS/AP 2016). Even though community groups had fought for years to force Duke Energy to clean up leaks from coal ash ponds, the disaster provided the needed leverage to hold the company accountable.

The spill's impact reverberated through state politics, leading to legislation that forced the closure of all coal ash ponds in North Carolina by 2029 (Smith 2014). Litigation and negotiations continued for years, but eventually Duke Energy agreed to excavate waste from all of its coal ash ponds at 14 plants rather than cap the ponds in place, and transferred almost 126 million tons of coal ash to lined landfills or for recycling into concrete (Bonner 2020). And finally, the utility agreed to cover a portion of the costs of coal ash cleanup through 2030, saving electricity users more than $1 billion (Weinstein 2021).

North Carolina exemplifies how pressure from community groups can lead to positive outcomes—though, in this case, only after years of litigation and in the wake of a major environmental disaster that exposed both the utility's negligence and the state government's failure to hold the utility accountable.

How Coal Ash Is Regulated in Ohio River Valley States

Prior to the 2015 CCR Rule, states applied different levels of stringency to regulating coal ash ponds. In the five Ohio River Valley states, coal ash regulations ranged from inadequate to nonexistent. Four states had no groundwater monitoring requirements, and no states required composite lining to protect leaching of contaminants into the water table. Indiana and Ohio were among the worst in the nation: Indiana did not even require dams containing coal ash ponds to be designed by a professional engineer, and Ohio exempted coal ash from its solid waste definition that applies to most industrial waste streams and household garbage.

Following the finalization of the 2015 CCR Rule, only a handful of states have passed laws that require owners and operators of coal ash ponds to excavate the coal ash and dispose of it in a lined landfill. In North Carolina, litigation settlements and agency directives under the state's 2014 Coal Ash Management Act included requirements that all coal ash ponds be excavated, and in South Carolina, litigation settlements and utility decisions have resulted in excavation of all coal ash ponds. Virginia passed laws requiring its utilities to excavate unlined ponds near waterways (Frank and Maloney 2020). However, Kentucky regulators are hamstrung by state law that prevents regulations more stringent than federal requirements (Blau 2019). Pennsylvania adopted the initial CCR Rule and amended water pollution permits to require stronger standards for 10 coal-fired power plants in the state, but the weakened requirements at the federal level and ongoing litigation have thrown those requirements into question (Frazier 2020). Indiana, the state with the most coal ash ponds, requires excavation for coal ash ponds covered by the 2015 rule that are in contact with groundwater, but allows capping in place for older ponds not currently regulated (Frank and Maloney 2020). West Virginia similarly declined to enforce the federal standards, sticking with its own weaker groundwater standards (Chambers 2016).

Coal Ash Cleanup Methods

When a coal-fired power plant is retired, the utility must decide what to do with the leftover coal ash waste, and its choices have implications for the potential for ongoing pollution, human health impacts, and future economic development opportunities. With the disposal method called cap-in-place, once the coal ash pond is full or no longer needed, the surface liquid is removed, the top edge of the pond structure is graded to provide for drainage, and a low-permeability covering is placed over it and sealed. This largely prevents precipitation from leaching contaminants into the surrounding soil, but it cannot prevent leaching due to direct groundwater contact with the coal ash under the covering (Russ, Bernhardt, and Evans 2019). Since most coal ash ponds are unlined and many have millions of tons of ash sitting in groundwater, this leaching problem is common, and the risk of pollution continues indefinitely. At a minimum, cap-in-place closure requires long-term monitoring systems to detect groundwater contamination and guide cleanup activities.

Another disposal solution is excavation—draining the pond and removing the coal ash for disposal in a properly designed landfill. From an environmental standpoint, disposal in properly designed landfills is a better solution than capping in place because there is much lower risk of leaching into groundwater. Proper design includes ensuring the landfill is sited above the water table, lining the landfill, installing collection systems to capture any pollution runoff or leaching, installing groundwater monitoring systems, and capping the landfill to prevent fugitive dust, precipitation infiltration, and runoff (*Federal Register* 2015). Properly sited landfills also eliminate the risk of catastrophic structural failures from remaining coal ash ponds, as happened at Kingston (see Box 1, p. 7), that lead to massive pollution of adjacent rivers, streams, and lakes.

Finally, coal ash can be diverted or removed from coal ash ponds and from landfills for reuse. Trade groups suggest that a majority of coal ash is reused for beneficial purposes (ACAA 2021), but the reality is more complicated. Some applications for coal ash reuse are not truly beneficial, and some are themselves harmful (see Box 3, p. 16). The EPA has developed a methodology for assessing whether an application qualifies as a "beneficial use" (EPA 2016). An emerging reuse concept is to extract rare earth elements (REEs) for use in the manufacturing of clean energy components and electronics (see Box 4, p. 17). While extracting REEs may have some utility in reducing shortages of critical minerals, many elements of the coal ash will remain after the REEs are extracted. Reusing REEs will not significantly reduce the volume of coal ash waste, and its potential is therefore limited.

Although some coal ash may be diverted for legitimate beneficial uses, excavation is needed to ensure "clean

> ***Disposal of coal ash in properly designed landfills is a better solution than capping in place, because there is a much lower risk of leaching into groundwater.***

> **_Extracting and reusing rare earth minerals from coal ash will not significantly reduce the volume of coal ash waste._**

closure." Utilities often propose cap-in-place as a solution for closure of coal ash ponds because it is generally the least expensive and easiest solution. However, although draining the ponds and moving the coal ash waste to landfills can be more expensive, it ensures safer disposal that protects groundwater and surface waters and eliminates the risks posed by waterfront and floodplain coal ash storage—risks that are increasing due to more frequent and severe flooding and extreme weather (Hayhoe et al. 2018). Excavation is also more labor intensive and thus leads to more job creation and local economic activity. And the removal of coal ash and clean closure of the site provides greater development and/or recreational opportunities for the local community and can allow the restoration of the ecosystem.

BOX 3.

When Is Coal Ash Reuse Truly "Beneficial"?

Reuse is categorized by the form of the coal ash—encapsulated or unencapsulated. Encapsulated coal ash is defined as reuse that "binds CCR into a solid matrix that minimizes its mobilization into the surrounding environment" (EPA 2016). According to the EPA, beneficial use of encapsulated coal ash must (1) provide a functional benefit, (2) replace virgin material, and (3) meet existing civil society or governmental production or design standards relevant to the reuse application (*Federal Register* 2015). The EPA has determined two beneficial uses of encapsulated coal ash: the use of fly ash (fine particles that are carried off in the gases released from coal combustion and captured by pollution control devices) in concrete, and the use of synthetic gypsum (flue gas desulfurization sludge) in drywall. Fly ash can create measurably stronger, more durable, and more pumpable concrete than that made with Portland cement alone and avoids emissions of heat-trapping gases by reducing the production of Portland cement. Reusing synthetic gypsum in drywall avoids mining virgin gypsum (Gardner and Greenwood 2017; Seidler and Malloy 2020). These represent the two most common reuse applications, but only accounted for approximately 29 percent of coal ash waste in 2019 (ACAA 2021; USGS 2014).

Unencapsulated coal ash can be used for mine reclamation and for structural fills, and these types of reuse are much more controversial. The EPA defines unencapsulated coal ash as being in "a loose or unbound particulate or sludge form and involves the direct placement of the secondary material on the land" (EPA 2016). The EPA does not disallow unencapsulated applications from qualifying as beneficial uses per se, but an application of unencapsulated coal ash greater than 12,400 tons must meet a fourth criterion under the EPA's test for beneficial reuse: It must not result in more environmental releases than analogous material that does not contain coal ash (i.e., clean fill). Any pollutant releases must be below relevant human health and ecological benchmarks (EPA 2014b; Seidler and Malloy 2020).

When coal ash is used as a filler for mine pits, contouring landscapes, and leveling uneven surfaces for transportation or construction projects, there is risk of leaching into groundwater or surface water, as well as a concern that unencapsulated reuse as filler is a backdoor means of coal ash disposal that avoids regulation (Seidler and Malloy 2020; Earthjustice 2019). For example, unencapsulated coal ash was widely used as construction fill in the Town of Pines, Indiana; the entire town was later declared a Superfund site after high levels of boron and molybdenum linked to coal ash reuse were found in drinking water wells (EPA 2021). Earthjustice and other environmental groups argue that the use of coal ash as fill should be banned (Earthjustice 2019). More detail on coal ash reuse can be found in Appendix C, online at www.ucsusa.org/resources/coal-ash-cleanup-benefits.

BOX 4.

Can Coal Ash Help Meet Growing Demand for Rare Earth Elements?

The potential of reusing rare earth elements (REEs) in coal ash has garnered significant attention in recent years. REEs refer to 16 elemental metals (the lanthanide series plus scandium and yttrium) that are found abundantly but generally in low concentrations and non-isolated forms throughout Earth's crust (Seidler and Malloy 2020). REEs require considerable energy to extract and process for commercial applications, but their magnetic, phosphorescent, and catalytic properties make them critical for clean energy and electronics end uses. The manufacture of Apple's iPhone, for example, requires nine REEs (Seidler and Malloy 2020).

The concentration of REEs found in coal ash from US coal basins is two orders of magnitude lower than that found in conventional ore (Taggart et al. 2016). However, *critical* REEs—which are rarer and more commercially useful—make up a much larger share of the total REE content in coal ash. This could be advantageous because REEs that are abundant in conventional ore but not commercially useful are a significant waste stream of conventional mining operations; extracting critical REEs from coal ash would therefore reduce the waste generated per unit of critical REEs (Taggart et al. 2016). Extracting REEs from coal ash avoids environmental damage from new mining and reduces production costs by avoiding processing steps such as crushing ore.

Large-scale extraction of REEs from coal ash is currently uneconomical, and only small-scale projects have been operational thus far, but that could change with advances in extraction technology or increasing prices in existing REE markets (Gaffney 2021). In recent years, the Department of Energy has invested at least $19 million in projects to research and support the production and separation of REEs from coal ash, coal waste, acid mine drainage, and coal refuse. Extracting REEs from coal ash is most likely to be economical when paired with commercial reuse of other minerals in coal ash.

There are other potential benefits to extracting REEs from coal ash: While REEs are a small share of total coal ash content, and thus extracting them will have a negligible impact on reducing the total volume of coal ash waste, REE extraction could generate economic value for coal dependent communities (Seidler and Malloy 2020). Extracting REEs will not be universally viable, because the specific REEs in coal ash depend on both the geologic makeup of the source coal and the emissions controls of the power plant where it was burned. However, according to one analysis, coal in the Appalachian basin has the greatest REE concentration of the US coal basins (Taggart et al. 2016), although the same analysis suggests that extracting REEs from Appalachian coal ash may require more intensive chemical processes, thus raising concerns about introducing new chemical waste streams into nearby communities.

It remains an open question whether benefits of the extraction of REEs would accrue to nearby communities and to workers. The process of extraction is an industrial process that could present risks of environmental contamination and risks to worker health and safety. Depending on the technology, it may require toxic chemicals to isolate REEs, and, once REEs are extracted, most of the coal ash waste will still remain. Strong stakeholder processes that include local unions and nearby residents are critical to ensuring good outcomes.

[CHAPTER 5]

Coal Ash Cleanup as Economic Opportunity

Case studies help paint a picture of the national needs for coal ash cleanup by considering different kinds of problems at different coal ash disposal sites. Prior analyses of coal ash cleanup have compared the two closure methods (cap-in-place and excavation) to evaluate the estimated costs and potential for job creation. Since it is difficult to generalize cleanup costs (especially if they involve groundwater remediation), case studies such as these are a solid approach to addressing these questions. Each coal ash pond or landfill has a different set of issues, including the location (arid vs. dry, in the floodplain or not), whether there is contact with groundwater, and the design standards of the site. Case studies offer a glimpse of the costs of clean closure and the potential for job creation and resulting economic activity. Previous case studies of coal ash disposal sites have included an independent analysis of utility plans for closure and have armed advocates with alternative plans that quantify both the environmental and economic benefits of the different options (Evans and French 2021). Each of these case studies has shown greater job creation and positive impacts to the economy from clean closure plans (see Table 4).

The seminal reports on coal ash cleanup focused on the Colstrip Steam Electric Station, located in rural Rosebud County, Montana. The town of Colstrip is home to one of the largest coal-fired generating stations in the west, with two generating units that retired in early 2020 and two remaining units with a combined generating capacity of 1,480 megawatts (MW). The Colstrip coal ash pond complex is enormous: 20 ponds hold 38 million cubic yards of coal ash waste and cover more than 800 acres (Evans and French 2021), and groundwater contamination is widespread (Montana DEQ 2016; NPRC and IBEW 2018). Researchers found that a comprehensive cleanup—fully excavating the coal ash ponds that remain in contact with groundwater, moving the dry ash to properly designed landfills, and aggressively remediating the groundwater contamination—would lead to the creation of 218 direct jobs (full-time equivalents) each year over the first 10 years (2020–2029) and that ongoing operations and maintenance would create 66 jobs annually for 40 years beyond that initial construction phase (2030–2069) (French 2019). While the cost of the plan was higher than the plant operator's (Talen Montana's) originally proposed plan, which would have simply capped the ponds in place (NPRC and IBEW 2018), the analysis was so compelling that the Montana

TABLE 4. Total Jobs Created from Closure Options in Previous Case Studies

Previous Case Study	Clean Closure (# jobs)	Cap-in-Place (# jobs)
Colstrip (2020–2029)	404	158
Michigan City (2021–2034)	70	10
Grainger (2013–2020)	97	24

The three previous case studies of coal ash cleanup found that clean closure plans created from 2.5 to 7 times more jobs than the original cap-in-place plans.

Note: Jobs reported are in terms of full-time equivalents. The numbers above are not directly comparable to our new results presented below because a full-time equivalent is calculated using the total hours needed to complete the work, whereas our results represent total jobs, which includes both full- and part-time positions.

SOURCE: EVANS AND FRENCH 2021, FIGURE 3.

Department of Environmental Quality ultimately adopted the plan to excavate the five ash ponds associated with the two generating units that have already been taken out of service (Kohn 2020).

Two additional sites have been assessed for economic opportunities of clean closure options: the Grainger Generating Station in South Carolina and the Michigan City Generating Station in Indiana (Evans and French 2021). Grainger was a 170 MW coal-fired power plant that closed in 2012, leaving behind two 40-acre unlined coal ash ponds. After pressure from the community and litigation, the utility agreed to excavate the ponds and restore the area to wetlands. Analysis of the clean closure plan compared to a potential cap-in-place plan showed that the clean closure led to four to five times greater economic benefits to the surrounding area (Evans and French 2021). The Michigan City Generating Station currently hosts a 469 MW coal-fired power plant scheduled to close in 2028, but the site has been home to coal-fired power plants—and coal ash ponds—since 1931. An analysis of a clean closure option—one that includes excavating all historical coal ash fill and ponds in addition to the most recent and active ones—shows that clean closure would produce eight times the economic benefits of the utility's less comprehensive proposal that does not adequately protect public health and the environment (Evans and French 2021).

Two Case Studies in the Ohio River Valley States

The present analysis looks at two sites in the Ohio River Valley and uses a similar methodology. The sites evaluated here represent different physical characteristics and geology than previous case studies and include the first landfill remediation considered (see Table 5). The chosen locations help to quantify the benefits of cleanup in Appalachia and the Ohio River Valley, places that are reeling from the decline of coal over the last decade. Site selection criteria included availability of utility closure plans, volume of CCR waste publicly reported, known contamination problem or problematic location (i.e., floodplain or groundwater contact), non-compliance with aquifer requirements, and potential for community engagement. The two sites are the J. M. Stuart Station in Ohio and the Sebree Generating Station in Kentucky.

Methodology

Our analysis has two parts. First, using public documents typically available from utility closure plans and mandatory reporting required by the federal CCR Rule and state regulatory agencies, we assessed the site conditions at the two generating stations, including the sources and extent of contamination and the status and condition of coal ash ponds and landfills on site. Based on this evaluation we identified those disposal sites that, if no or inadequate remediation were completed, pose a long-term risk of ongoing groundwater pollution or even catastrophic failure. We then developed alternative closure plans that address those problems in a comprehensive way. For each location we quantified and compared the two alternatives for corrective action (the owner's proposal and the clean closure option), providing estimates of the cleanup costs and direct jobs required for each option. In contrast to the Colstrip study, our study does not evaluate the cost of cleaning up groundwater pollution (French 2019; NPRC and IBEW 2018).

Second, using the estimated direct jobs and costs from the first part of the analysis, we conducted an economic impact analysis of the two cleanup alternatives at each site using the IMPLAN input-output model.[3] We refined the existing industry definitions in the IMPLAN model to align with the type of economic activity created by the cleanup scenarios. The model uses the estimated direct effects (from the investment in the projects) to quantify the total impacts on the economy, which include indirect and induced effects from the investment specified. Direct effects are the costs and jobs required by the actual projects, indirect effects are regional upstream activities (e.g., purchases of goods and services needed to conduct the projects), and induced effects are follow-on impacts on the regional economy (such as workers spending their wages and state and local governments spending the additional fees and tax revenues). For each of these effects, the model estimates full- and part-time employment, economic output, and four measures of gross regional product: employee compensation, proprietor's income, indirect business taxes, and other profits. For more details on the methodology and assumptions for the two analyses, see Appendix A and Appendix B, online at www.ucsusa.org/resources/coal-ash-cleanup-benefits.

3 IMPLAN is an input-output model, which is a form of economic analysis based on the interdependencies between economic sectors. Input-output models are commonly used to estimate the impacts of "shocks" to an economy and to analyze their resulting ripple effects. See IMPLAN.com.

Proper cleanup of coal ash sites creates jobs as well as improves health and safety for people who live and work near the disposal sites.

Coal ash cleanup creates jobs for skilled laborers including heavy equipment operators and truck drivers, as well as professional jobs including environmental engineers and project managers. Some workers at the coal plant will be able to transfer into the skilled laborer positions needed for cleanup activities (e.g., heavy equipment operators), but others may require training. Cleanup projects also have knock-on effects in the regional economy, creating more jobs in wholesale and retail trade as well as transportation, for example, and boosting spending in restaurants and health care. Proper cleanup also addresses longstanding environmental justice concerns and improves health and safety for communities of color and low-income residents near the disposal sites (see Box 5, p. 23). All of this leads to greater tax revenue to support state and local budgets.

Case Study: Sebree Generating Station

The Sebree Generating Station is an informal name given to a collection of three operating or 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

TABLE 5. Comparison of the Physical Characteristics of Disposal Sites Evaluated in Case Studies

Facility	State	Total Number of Disposal Sites*	Volume of CCR Waste (cubic yards)	Surrounding Community Disproportionately People of Color	Surrounding Community Disproportionately Low-Income	Pollution Exceedances**	Additional Characteristics
Colstrip	Montana	13	18,351,212	No	No	7	Extensive groundwater contamination, ~200 million gal of leakage per year; arid location
Grainger	South Carolina	2	Unknown	Yes	Yes	1	Previously closed; cleanup is an example of positive environmental and economic outcomes
Michigan City	Indiana	2	49,000	Yes	Yes	2	Decades of legacy coal ash from previously closed ponds; located on shore of Lake Michigan
J. M. Stuart	Ohio	12	26,000,000	No	Yes	9	Recent, high-profile coal plant closures in rural area; along Ohio River
Sebree	Kentucky	3	23,977,238	Yes	Yes	4	Public attention to pollution in Green River; only case study to date that evaluates improvements to a coal ash landfill

The characteristics of the five coal ash cleanup case studies conducted to date, including the two new ones described in this report. The volume of CCR waste is uncertain in part because previously closed sites do not report data.

* These numbers represent the number of disposal sites subject to federal reporting requirements and exclude unregulated legacy sites.

** Number of pollutants whose levels exceed health-based standards (see Table 3, p. 10)

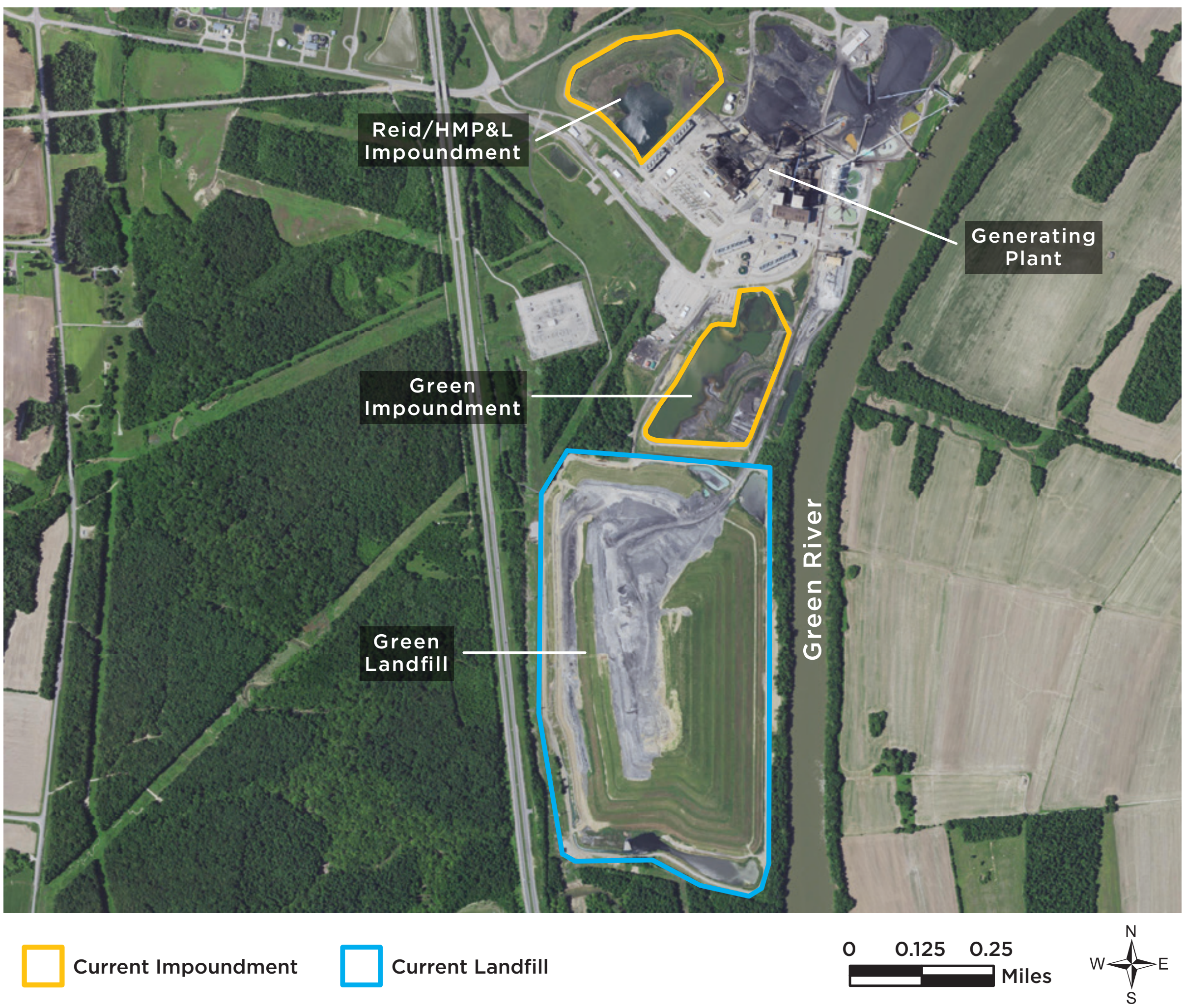
SOURCES: EARTHJUSTICE 2020, FRENCH 2019, AND NPRC AND IBEW 2018 (COLSTRIP); EVANS AND FRENCH 2021 (GRAINGER AND MICHIGAN CITY).

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, a joint organization created by three Kentucky rural electric cooperatives (BREC 2017).

In addition to suffering the loss of jobs from the retirement of the coal-fired power plants, Webster County has also been affected by the decline of the coal mining industry, with a drop in coal production of about 78 percent from 2015 to 2019 and the loss of 475 coal mining jobs over that time (Richardson and Anderson 2021). Coal mining and coal-fired power plant jobs represented 2 percent of jobs in the county of almost 13,000 residents in 2019 (Richardson and Anderson 2021). Webster County's unemployment rate and poverty rate were above the national average from 2015 to 2019, with a five-year average unemployment rate of 4.9 percent and a five-year average poverty rate of 23 percent (Richardson and Anderson 2021). The residents living within a three-mile radius of Sebree are both disproportionately low-income and disproportionately people of color relative to Kentucky as a whole (Earthjustice 2020).

As shown in Figure 1, the Sebree Generating Station houses three coal ash disposal sites that together contain 24.4 million cubic yards of coal ash. The vast majority of this waste (22.8 million cubic yards) is held in in the Green

FIGURE 1. Site Layout of the Sebree Generating Station



This aerial view of the Sebree Generating Station shows the locations of the plants' landfill and coal ash ponds along the Green River.

IMAGE CREDIT: WWC ENGINEERING.

Landfill, which has received attention from the media and the Kentucky Energy and Environment Cabinet's Division of Waste Management due to contaminated seeps that flowed into the Green River (Van Velzer 2019).[4] The two coal ash ponds, the Green and Reid Impoundments, are unlined, rated as significant hazards (see Table 2, p. 9), and in non-compliance with location restrictions for contact with the aquifer (Earthjustice 2020).

THE UTILITY'S MONITORING AND MITIGATION ACTIONS

Groundwater at the site is polluted by a wide range of contaminants associated with coal ash. It is difficult to identify exactly which parameters exceed standards at the individual monitoring wells at Sebree because Big Rivers has not complied with requirements for monitoring and reporting groundwater quality. To determine whether contamination exists requires a comparison between a monitoring well at the site of potential contamination and an uncontaminated well located nearby. The utility argues that there are no groundwater impacts from the Green coal ash pond; however, the well to which it compares its measurements, located in close proximity to the site of potential contamination, appears likely to itself be contaminated by the coal ash pond. By claiming no contamination, the utility is not required to monitor the Green coal ash pond for toxic CCR contaminants or to evaluate the need for groundwater corrective action.

A similar story plays out for the Green Landfill. Here, the utility has chosen not to consider the uppermost (shallow) groundwater to be "usable." Because only the uppermost usable groundwater is subject to federal monitoring requirements, the utility monitors only next highest groundwater level, within the deeper bedrock below. However, the shallow groundwater is directly underneath the landfill, is highly contaminated, and is the source of contaminated seeps and runoff.

Big Rivers has begun to address some of these issues after media scrutiny of the pollution flowing into the Green River. Kentucky regulators required action to address the source of pollution to the river, which led to the construction of large-scale hydraulic controls and landfill perimeter drains that capture contaminated groundwater and seepage around the landfill. If the landfill is closed with an adequate final cover system and seepage of precipitation into the landfill is mostly eliminated, the groundwater and seep remedy will likely be effective.

The utility plans to close the Green Landfill and both coal ash ponds using cap-in-place between 2022 and 2024. Under its closure plan, it will finish capping the landfill with a low-permeability clay cover, which is likely less effective in preventing seepage of precipitation into the landfill than the protection provided by a composite liner. Groundwater and seepage capture from the landfill will continue and will be treated and discharged to the Green River in line with state permitting. However, capping in place the two coal ash ponds will not address the groundwater contamination issues described above, and is illegal because the CCR Rule prohibits capping in place when coal ash is in contact with groundwater. The contamination from the ponds will continue indefinitely, and without proper monitoring, corrective action will not be required. Lastly, Big Rivers' delay in selecting a remedy and initiating groundwater cleanup for the Reid Impoundment violates the CCR Rule.

BOX 5.

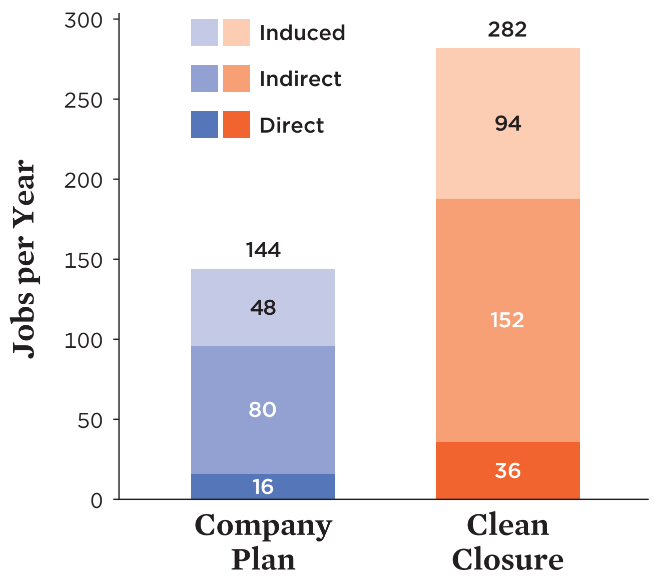
Why Coal Ash Pollution Is an Environmental Justice Issue

Historical and ongoing air pollution from burning coal harms public health, particularly in overburdened and underserved communities—fenceline communities whose residents are often people of color or have low incomes (Johnston and Cushing 2020; Sergi et al. 2020; Thind et al. 2019). These same communities face the detrimental impacts and risks from coal ash disposal and improper cleanup, and, worse, often cope with pollution from other industries, lack access to medical care and legal help, and do not have resources to test groundwater for contamination (Evans and French 2021).

Nationally, 52 percent of communities near coal-fired plants are low-income, and almost 24 percent are disproportionately people of color. The Ohio River Valley states overall have a greater proportion of low-income communities near these plants (at 58 percent), but a lower proportion of communities of color nearby (at nearly 11 percent) (Earthjustice 2020). Both of our case studies are in low-income communities, and the Sebree Generating Station is also located in a community whose residents are disproportionately people of color.

4 *The unlined Green Landfill, constructed in 1980, uses a patented technique to stabilize fly ash called Poz-o-Tec™ involving a mixture of lime, flue gas desulfurization scrubber sludge, and coal fly ash. The makers of Poz-o-Tec™ claimed that it produced a non-leachable, stabilized product. But the landfill sits as one example that the process is not capable of preventing leaching and other impacts to groundwater.*

FIGURE 2. Total Job Creation per Year During the Construction Phase of Sebree Closure



The bars represent the total number of jobs created (full- and part-time positions) for both cleanup options. The totals include direct jobs created by the project as well as secondary jobs (indirect and induced jobs in the economy).

Note: These numbers exclude operations and maintenance.

ALTERNATIVE CLEAN CLOSURE PLAN

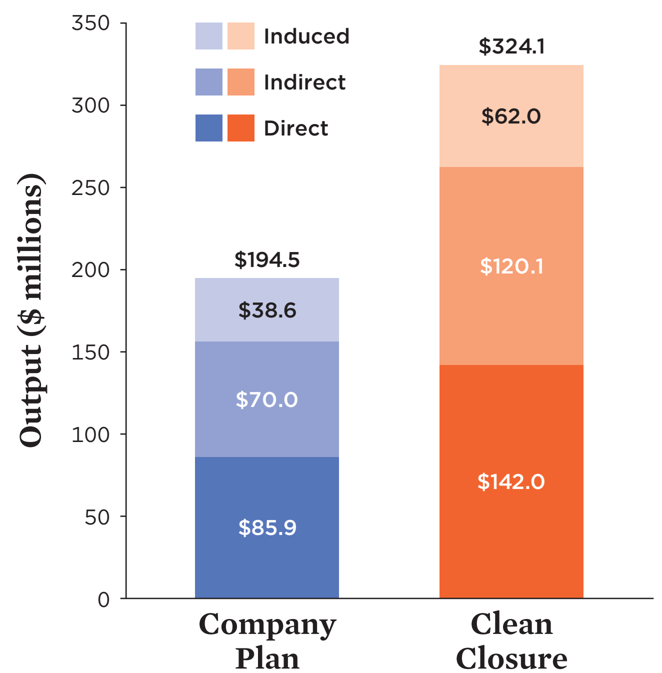
Our proposed alternative clean closure plan includes complete excavation of the Green and Reid coal ash ponds and improvements to the Green Landfill, including the construction of a composite cap that includes a geomembrane that should further reduce infiltration and leachate generation, and a flood control levee to protect the landfill from rising floodwater in the Green River (see Appendix A).

We found that the clean closure plan leads to almost double the economic impact of the utility owner's plan. Total costs over 34 years (four years of construction plus 30 years of continued operations) amount to $145 million for the clean closure option compared to $88 million for the utility's plan; however, the clean closure option leads to significantly more job creation. During the four-year construction phase, clean closure creates an average of 282 jobs per year, compared to 144 for the utility's plan. The impact on Kentucky's economy would be approximately $324 million in output over 34 years, compared to $195 million for the utility's plan. See Figures 2 and 3.

Case Study: J. M. Stuart Station

The J. M. Stuart coal-fired power plant is located in Adams County, Ohio, along the Ohio River in rural Appalachia, home to approximately 27,700 people in 2019. All 3,100 MW of coal-fired generating capacity supplied by the J. M. Stuart plant and the nearby Killen plant went offline in 2018. The closures led to the loss of at least 400 jobs (up to as many as 800, including contractors), hurting the local economy and sending workers scrambling to find new work in a region where the power plants were the largest employers and provided significant municipal tax revenue (MacGillis 2018). The five-year average unemployment rate from 2015 to 2019 was 7.3 percent, and the average poverty rate over the same time was 20.7 percent, both of which are above the national average (Richardson and Anderson 2021). Residents living within a three-mile radius of the plant are disproportionately low-income relative to Ohio as a whole (Earthjustice 2020).

FIGURE 3. Economic Output for Kentucky for the Two Sebree Generating Station Closure Options

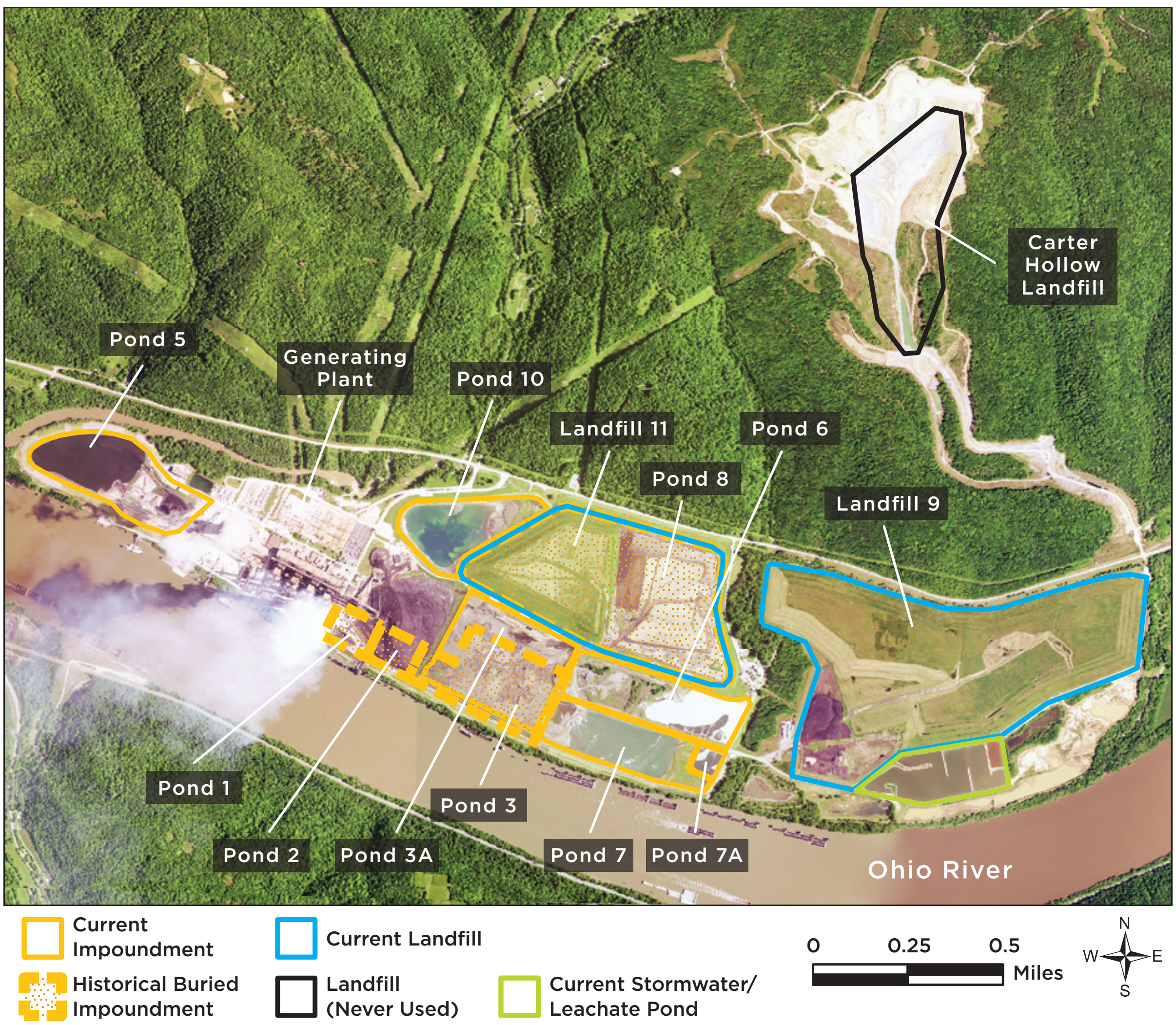


These numbers represent the value of construction, cleanup, and monitoring activities for the four-year construction phase and an additional 30 years of operations and maintenance. Output is an overall measure in dollars of the impact on the economy due to the investments in the project. The clean closure option leads to $324 million in economic output over 34 years, compared to $195 million for the owner's plan.

THE OWNER'S MONITORING AND MITIGATION ACTIONS

At J. M. Stuart, more than 26 million cubic yards of CCR waste (the majority of the waste) is held in two landfills and five remaining coal ash ponds (none of which meet the liner criteria of the federal CCR rule and all of which are rated as significant hazards) (Earthjustice 2020), and four older ponds that are buried under current features at the site (see Figure 4). Three of the ponds are in non-compliance with location restrictions based on their proximity to the aquifer. Groundwater reporting from 2017 indicates contamination from the following substances at levels higher than the maximum allowable to protect public health: arsenic, barium, boron, cobalt, lithium, molybdenum, radium, selenium, and sulfate (Russ, Bernhardt, and Evans 2019). However, non-compliance with monitoring requirements has resulted in critical data gaps on the rate and direction of groundwater flow and uncertainty about the nature and extent of onsite and offsite contamination. The owner assessed groundwater cleanup measures and closure options and originally proposed to cap-in-place all coal ash ponds except one. In 2019, the

FIGURE 4. Site Layout of the J. M. Stuart Station

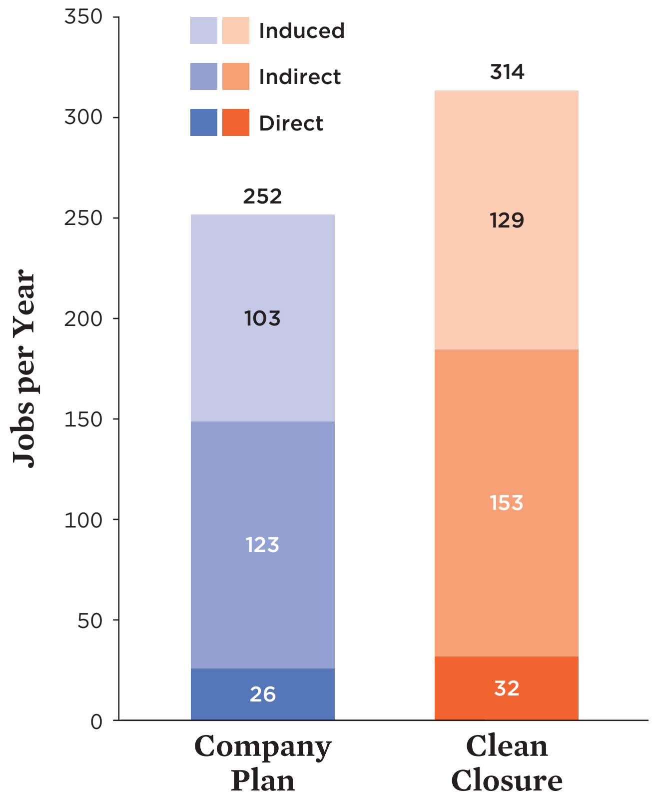


This aerial view of the J.M Stuart Station shows the locations of the plants' landfills and coal ash ponds along the Ohio River.

Note: Ponds 1, 2, 3, and 8 (dotted lines) are buried. Landfill 9 is located in the floodplain of the Ohio River.

IMAGE CREDIT: WWC ENGINEERING.

FIGURE 5. Total Job Creation per Year During the Construction Phase of J. M. Stuart Closure



The bars represent the total number of jobs created (full- and part-time positions) for both cleanup options. The totals include direct jobs created by the project as well as secondary jobs (indirect and induced jobs in the economy).

Note: These numbers exclude operations and maintenance.

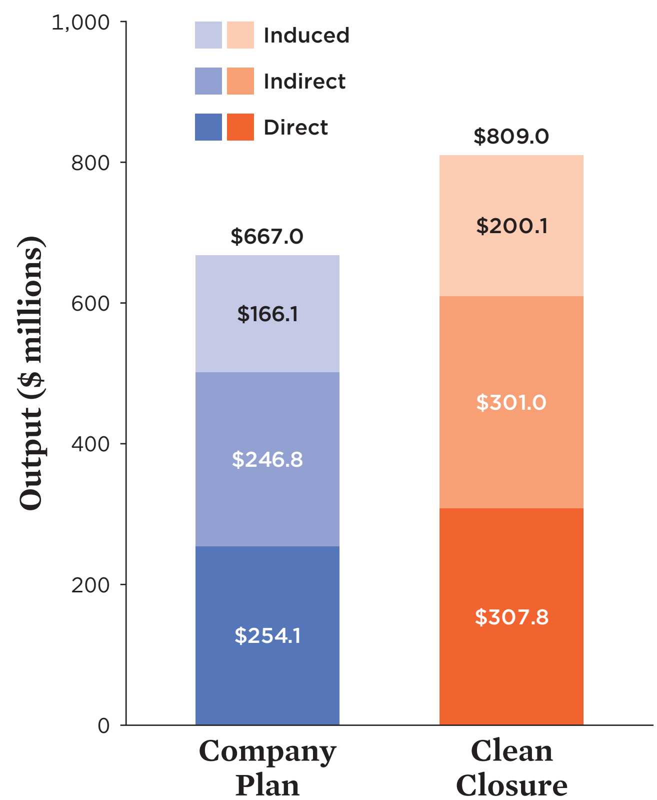
utility sold the site along with the cleanup and closure liability. Although the new owner has not yet finalized overdue cleanup plans, it has indicated a preference for a more comprehensive cleanup and closure, including excavating all five current coal ash ponds, removing only a portion of the buried coal ash from past ponds, and using one of the landfills for disposal. Updated groundwater cleanup assessments by the owner would rely on removal of coal ash along with "monitored natural attenuation" as the groundwater remedy. Pursuant to the CCR Rule, the plant should have initiated groundwater cleanup, but the owner has not yet selected a remedy.

ALTERNATIVE CLEAN CLOSURE PLAN

Our proposed alternative (the clean closure plan) includes excavation of all accessible coal ash (including portions underground) to more fully protect groundwater from contamination, and construction of a flood-control levee to protect the landfill that is located within the floodplain of the Ohio River (see Appendix A).

The economic impacts and job creation are better for the clean closure scenario, although the owner's current closure proposal is relatively robust. We estimate construction costs at $224 million over nine years for the owner's plan compared to $279 million over nine years for the clean closure plan. During the nine-year construction phase, we estimate the clean closure plan would create 314 jobs per year, compared to 252 jobs per year for the owner's plan. The clean closure plan would lead to $809 million in additional economic output in the state over 39 years, compared to $667 million for the utility's plan (see Figures 5 and 6).

FIGURE 6. Economic Output for Ohio for the Two J. M. Stuart Station Closure Options



These numbers represent the value of construction, cleanup, and monitoring activities for the four-year construction phase and an additional 30 years of operations and maintenance. Output is an overall measure in dollars of the impact on the economy due to the investments in the project. The clean closure plan would lead to $809 million in additional economic output in the state, compared to $667 million for the utility's plan.

[CHAPTER 7]

Policy Recommendations

Our analysis of two case studies in Ohio and Kentucky shows that the clean closure of coal ash disposal sites offers superior protection for public health and ecosystems while offering better opportunities for local jobs and associated economic activity. This analysis is consistent with similar evaluations for other sites in previous reports (Evans and French 2021; French 2019). The costs of clean closure are somewhat higher than the costs of owners' cleanup plans, but these costs are justified by the substantial benefits that flow to the local communities. Based on our findings, we offer the following recommendations to federal and state policymakers to ensure effective and complete cleanup of coal ash sites.

- **Hold utilities and owners responsible for the clean closure of coal ash disposal sites.** Cleanup decisions are governed by state regulators, and rate-regulated utilities typically petition state public utility commissions for cost recovery—meaning ratepayers are on the hook to pay for the cleanup. Regulators should consider the long-term economic value of cleanup options to the local community—ratepayers should not bear the costs without reaping the economic value of full cleanup.
- **Robustly fund existing EPA programs that support communities.** EPA programs must be robustly funded to ensure that polluting coal ash disposal sites are identified and cleaned up. These programs include the Brownfields programs, enforcement divisions, and the Corrective Action Program within the Resource Conservation and Recovery Act.
- **Strengthen the enforcement of existing regulations that prohibit cap-in-place closure.** The EPA already has enforcement authority, and it can and should follow the plain language of the 2015 CCR Rule, requiring excavation when coal ash is in contact with groundwater or when coal ash ponds would remain in a floodplain when capped in place. States should also require excavation under state laws and regulations, as is being done in North Carolina, South Carolina, Virginia, and Illinois.
- **Ensure that frontline communities have a voice in cleanup decisions.** Residents and community leaders are often the strongest voices in holding utilities and site owners accountable for cleanup, and robust stakeholder processes are needed to ensure meaningful engagement. For example, the EPA's Technical Assistance Services for Communities Program offers grants that can empower fenceline communities and residents to participate in discussions about closure options. It is a valuable resource that should be robustly funded to drive better local outcomes, and additional programs supporting environmental justice communities may also be brought to bear.
- **Ensure strong labor standards and safety protections for cleanup workers and prioritize dislocated workers in hiring.** Local hiring requirements should be implemented to ensure that dislocated workers have access to cleanup jobs, and prevailing wages should be required to ensure that workers are paid fairly for their work. Because coal ash is toxic, workers must be protected during cleanup activities.

- **Prevent damage to communities and the environment from reuse of coal ash.** The EPA should cease classifying unencapsulated coal ash as an acceptable “beneficial use” and instead treat unencapsulated uses as a form of disposal.
- **Ensure that the extraction of rare earth elements is safe and is coupled with clean disposal of remaining coal ash.** A holistic assessment of risks and benefits should be applied to rare earth element extraction, and extraction programs should be informed by the community and unions.
- **Leverage existing federal programs or consider establishing new financial institutions or grant programs to ensure that all disposal sites nationally are fully cleaned up.** Existing federal programs like the Superfund program could be augmented through polluter-pays fees. Additional public financing may be needed to ensure complete removal of coal ash. These resources are critical for ensuring a fair transition to clean energy for communities and workers formerly dependent on coal-fired electricity production.

When coal plants close, nearby communities face the fallout from lost jobs, lost local tax revenue, and an economic slump. Many of these communities are disproportionately low-income or communities of color and have faced the negative public health impacts of coal-fired electricity generation for decades. When coal ash disposal sites are not sufficiently and safely cleaned up, these communities continue to bear the ongoing costs—lower property values, persistent water pollution, and the risk of catastrophic failures of inadequate containment structures—but receive no economic benefits. Remediation of coal ash ponds and landfills is an essential element of a fair transition to a clean energy economy.

Ensuring that the disposal of coal ash is complete and as safe as possible not only protects human health and the environment but also creates jobs—in the very places where jobs are being lost as coal continues its decline. Comprehensive cleanup increases property values, eliminates pollution, and positions communities to diversify their economies, helping attract new industries that will not inherit the cleanup liability and making these communities places where more people want to live and work.

[REFERENCES]

ACAA (American Coal Ash Association). 2021. "Coal Combustion Products Production and Use Reports." Denver, CO. https://acaa-usa.org/publications/production-use-reports/

Appalachian Voices. 2021. "Coal Ash Disasters: Appalachian Voices." Boone, NC. https://appvoices.org/coalash/disasters/

BREC (Big Rivers Electric Corporation). 2017. "Introduction." Henderson, KY. https://www.bigrivers.com/introduction/

Blau, Max. 2019. "Southern States Split in Response to EPA's Coal Ash Rule Rollbacks." *Stateline* (blog), December 2, 2019. https://pew.org/2rwP1p2

Bonner, Lynn. 2020. "Duke Energy Will Dig up Most of Its Coal Ash under a Settlement with North Carolina." *Raleigh News & Observer*, January 2, 2020. https://www.newsobserver.com/news/politics-government/article238898708.html

Bourne, Joel K. 2019. "Neglected Threat: Kingston's Toxic Ash Spill Shows the Other Dark Side of Coal." *National Geographic*, February 19, 2019. https://www.nationalgeographic.com/environment/article/coal-other-dark-side-toxic-ash

CBS/AP. 2015. "Duke Energy Fined $102 Million in Coal Ash Spill." *CBS News*, May 14, 2015. https://www.cbsnews.com/news/duke-energy-fined-102-million-in-coal-ash-spill/

———. 2016. "Duke Energy Corporation Agrees to $6 Million Fine for Coal Ash Spill, North Carolina Says." September 25, 2016. https://www.cbsnews.com/news/duke-energy-corporation-agrees-6-million-fine-coal-ash-spill-north-carolina/

Chambers, William. 2016. "Coal Ash Disposal: Coal Combustion Residuals in West Virginia." *The National Law Review* 6 (61). https://www.natlawreview.com/article/coal-ash-disposal-coal-combustion-residuals-west-virginia

Colman, Zack. 2019. "The Toxic Waste Threat That Climate Change Is Making Worse." *POLITICO*, August 26, 2019. https://politi.co/2Pepc8K

Earthjustice. 2019. "Comments of Earthjustice, et al. on EPA-HQ-OLEM-2018-0524." October 15, 2019. San Francisco, CA. https://earthjustice.org/sites/default/files/files/101519-env-comments_phase-2-proposal-epa-hq-olem-2018-0524.pdf

———. 2020. "Mapping the Coal Ash Contamination." San Francisco, CA. October 6, 2020. https://earthjustice.org/features/map-coal-ash-contaminated-sites

———. n.d. "EPA Continues to Gut Coal Ash Rule by Delaying Closure of Leaking Toxic Ponds." Fact sheet. San Francisco, CA. Accessed September 8, 2021. https://earthjustice.org/sites/default/files/files/CCR-Rule-Fact-Sheet_11-05.pdf

EELP (Environmental and Energy Law Program). 2017. "Coal Ash Rule." December 15, 2017. Cambridge, MA: Harvard Law School. http://eelp.law.harvard.edu/2017/12/coal-ash-rule/

Engelman-Lado, Marianne, Camila Bustos, Haley Leslie-Bole, and Perry Leung. 2021. "Environmental Injustice in Uniontown, Alabama, Decades after the Civil Rights Act of 1964: It's Time for Action." *Human Rights*, May 21, 2021. Chicago: IL. American Bar Association. https://www.americanbar.org/groups/crsj/publications/human_rights_magazine_home/vol--44--no-2--housing/environmental-injustice-in-uniontown--alabama--decades-after-the/

EPA (Environmental Protection Agency). 2014a. "Case Summary: Duke Energy Agrees to $3 Million Cleanup for Coal Ash Release in the Dan River." November 23, 2014. Washington, DC. https://www.epa.gov/enforcement/case-summary-duke-energy-agrees-3-million-cleanup-coal-ash-release-dan-river

———. 2014b. "Coal Ash Reuse." December 11, 2014. Washington, DC. https://www.epa.gov/coalash/coal-ash-reuse

———. 2014c. *Human and Ecological Risk Assessment of Coal Combustion Residuals*. Washington, DC. https://www.regulations.gov/document/EPA-HQ-OLEM-2019-0173-0008

———. 2016. "Methodology for Evaluating Beneficial Uses of Industrial Non-Hazardous Secondary Materials." EPA 530-R-16-011. Washington, DC: Office of Resource Conservation and Recovery and Office of Land and Emergency Management. https://www.epa.gov/smm/methodology-evaluating-beneficial-uses-industrial-non-hazardous-secondary-materials-and

———. 2018. "Frequent Questions About the 2015 Coal Ash Disposal Rule." November 2, 2018. Washington, DC. https://www.epa.gov/coalash/frequent-questions-about-2015-coal-ash-disposal-rule

———. 2020. "Revisions to the Coal Combustion Residuals (CCR) Closure Regulations." Washington, DC. https://www.epa.gov/coalash/fact-sheet-revisions-several-coal-ash-closure-requirements-and-provisions-enhance-public

———. 2021. "Superfund Site: Town of Pines Groundwater Plume." Washington, DC. https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.Cleanup&id=0508071#bkground

Evans, Lisa, and Kate French. 2021. *Cleaning Up Coal Ash for Good*. San Francisco, CA: Earthjustice. https://earthjustice.org/sites/default/files/feature/2021/report-coalash/coal-ash-cleanup-report-earthjustice.pdf

Federal Register. 2015. *Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals From Electric Utilities. 40 CFR Parts 257 and 261*. Vol. 80 FR 21301. Washington, DC. https://www.federalregister.gov/documents/2015/04/17/2015-00257/hazardous-and-solid-waste-management-system-disposal-of-coal-combustion-residuals-from-electric

Frank, Indra, and Tim Maloney. 2020. "Our Waters at Risk, Part 2: The Impact of Coal Ash on Indiana's Water Resources." Indianapolis, IN: Hoosier Environmental Council. https://www.hecweb.org/issues/environmental-health-justice/coal-ash/

Frazier, Reid. 2020. "For Now, Latest Federal Rollback of Coal Regs Won't Affect PA Plants." *StateImpact Pennsylvania*, September 3, 2020. https://stateimpact.npr.org/pennsylvania/2020/09/03/for-now-latest-federal-rollback-of-coal-regs-wont-affect-pa-plants/

Freese, Barbara, Steve Clemmer, and Alan Nogee. 2008. *Coal Power in a Warming World: A Sensible Transition to Cleaner Energy Options.* Cambridge, MA: Union of Concerned Scientists. https://www.ucsusa.org/resources/coal-power-warming-world

French, Kate. 2019. "Doing It Right II: Job Creation Through Colstrip Cleanup." Billings, MT: Northern Plains Resource Council. http://www.worc.org/doing-it-right-means-more-jobs-for-colstrip-and-around-the-united-states/

Gabriel, Trip. 2014. "Ash Spill Shows How Watchdog Was Defanged." *New York Times*, February 28, 2014. https://www.nytimes.com/2014/03/01/us/coal-ash-spill-reveals-transformation-of-north-carolina-agency.html

Gaffney, Austyn. 2020. "A Legacy of Contamination: How the Kingston Coal Ash Spill Unearthed a Nuclear Nightmare." *Grist*, December 15, 2020. https://grist.org/justice/tva-kingston-coal-ash-spill-nuclear/

———. 2021. "Can Harvesting Rare Earth Elements Solve the Coal Ash Crisis?" *Sierra*, February 3, 2021. https://www.sierraclub.org/sierra/2021-2-march-april/feature/can-harvesting-rare-earth-elements-solve-coal-ash-crisis

Gardner, Kevin H., and Scott Greenwood. 2017. *Beneficial Reuse of Coal Ash from Dominion Energy Coal Ash Sites: Feasibility Assessment*. Prepared for the Southern Environmental Law Center and the Potomac Riverkeeper Network. Charlottesville, VA, and Washington, DC.

Gottlieb, Barbara, Steven G. Gilbert, and Lisa Gollin Evans. 2010. "Coal Ash: The Toxic Threat to Our Health and Environment." Washington, DC: Physicians for Social Responsibility and Earthjustice. https://www.psr.org/wp-content/uploads/2018/05/coal-ash.pdf

Hayhoe, Katharine, Donald J. Wuebbles, David R. Easterling, David W. Fahey, Sarah Doherty, James P. Kossin, William V. Sweet, Russell S. Vose, and Michael F. Wehner. 2018. "Chapter 2 : Our Changing Climate. Impacts, Risks, and Adaptation in the United States." In *Fourth National Climate Assessment, Volume II*. Washington, DC: US Global Change Research Program. https://doi.org/10.7930/NCA4.2018.CH2

ICDS (Interagency Committee on Dam Safety). 2004. "Federal Guidelines for Dam Safety: Hazard Potential Classification System for Dams." Washington, DC: Department of Homeland Security and Federal Emergency Management Agency. https://archive.epa.gov/epawaste/nonhaz/industrial/special/fossil/web/html/indexi-2.html

Johnston, Jill, and Lara Cushing. 2020. "Chemical Exposures, Health, and Environmental Justice in Communities Living on the Fenceline of Industry." *Current Environmental Health Reports* 7 (1): 48–57. https://doi.org/10.1007/s40572-020-00263-8

Kirn, Jillian C. 2020. "The State of Coal Ash Regulation and Implications for the Commonwealth." *The Legal Intelligencer*, November 19, 2020. https://www.law.com/thelegalintelligencer/2020/11/19/the-state-of-coal-ash-regulation-and-implications-for-the-commonwealth/

Knisley, Brianna. 2020. "Fight Like Hell for the Living: Honoring Kingston Coal Ash Workers." *Front Porch* (blog), December 22, 2020. https://appvoices.org/2020/12/22/kingston-coal-ash-workers/

Kohn, Jay. 2020. "Montana Regulators Order Cleanup of Colstrip Ash Ponds." *KTVQ*, November 19, 2020. https://www.ktvq.com/news/local-news/montana-regulators-order-cleanup-of-colstrip-ash-ponds

Lemly, A. Dennis. 2015. "Damage Cost of the Dan River Coal Ash Spill." *Environmental Pollution* 197 (February): 55–61. https://doi.org/10.1016/j.envpol.2014.11.027

Lemly, A. Dennis, and Joseph P. Skorupa. 2012. "Wildlife and the Coal Waste Policy Debate: Proposed Rules for Coal Waste Disposal Ignore Lessons from 45 Years of Wildlife Poisoning." *Environmental Science & Technology* 46 (16): 8595–8600. https://doi.org/10.1021/es301467q

Locke, Randy, Laura Keefer, Trish Barker, Scott Elrick, Veronica Hemrich, Anne Huber, Walt Kelly, et al. 2020. *Coal Ash Response Team Final Report*. Champaign, IL: Prairie Research Institute, University of Illinois. https://www.ideals.illinois.edu/handle/2142/108384

MacGillis, Alec. 2018. "Forced to Choose Between a Job—and a Community." *ProPublica*, May 23, 2018. https://www.propublica.org/article/adams-county-ohio-coal-forced-to-choose-between-a-job-and-a-community

Marshall, James. 2021. "Michael Regan's Coal Ash Cleanups Set Template for EPA Regs." *Greenwire*, February 3, 2021. https://www.eenews.net/stories/1063724125

Montana DEQ (Department of Environmental Quality). 2016. "Colstrip Steam Electric Station Coal Ash Ponds." Helena, MT. http://deq.mt.gov/Portals/112/DEQAdmin/MFS/Colstrip/Aug2016_FactSheet.pdf

Northey, Hannah, and Ariel Wittenberg. 2018. "Greens See 'Tale of Two Utilities' in Florence Response." *Greenwire*, September 26, 2018. https://www.eenews.net/stories/1060099817

NPRC (Northern Plains Resource Council) and IBEW (International Brotherhood of Electrical Workers Local 1638). 2018. "Doing It Right: Colstrip's Bright Future with Cleanup." Billings, MT: Northern Plains Resource Council.

Oak Ridge Today. 2017. "Watts Bar Reservoir Has Returned to Conditions before Kingston Coal Ash Spill, EPA Says." January 19, 2017. https://oakridgetoday.com/2017/01/18/watts-bar-reservoir-has-returned-to-conditions-before-kingston-coal-ash-spill-epa-says/

Richardson, Jeremy, and Lee Anderson. 2021. *Supporting the Nation's Coal Workers and Communities in a Changing Energy Landscape*. Cambridge, MA, and Washington, DC: Union of Concerned Scientists and Utility Workers Union of America. https://www.ucsusa.org/resources/support-coal-workers

Rogers, John, Kristen Averyt, Steve Clemmer, Michelle Davis, Francisco Flores-Lopez, Doug Kenney, Jordan Macknick, et al. 2013. *Water-Smart Power: Strengthening the U.S. Electricity System in a Warming Worl*d. A Report of the Energy and Water in a Warming World Initiative. Cambridge, MA: Union of Concerned Scientists. https://www.ucsusa.org/resources/water-smart-power

Rowe, Christopher L., William A. Hopkins, and Justin D. Congdon. 2002. "Ecotoxicological Implications of Aquatic Disposal of Coal Combustion Residues in the United States: A Review." *Environmental Monitoring and Assessment* 80 (3): 207–276. https://doi.org/10.1023/A:1021127120575

Russ, Abel, Courtney Bernhardt, and Lisa Evans. 2019. "Coal's Poisonous Legacy: Groundwater Contamination by Coal Ash Across the U.S." Washington, DC: Environmental Integrity Project. https://earthjustice.org/documents/legal-document/coal-s-poisonous-legacygroundwater-contaminated-by-coal-ash-across-the-u-s

SACE (Southern Alliance for Clean Energy). 2012. "Letting the Coal Ash Settle: The Kingston Disaster 4 Years Later." *Southern Alliance for Clean Energy* (blog), December 21, 2012. https://cleanenergy.org/blog/letting-the-coal-ash-settle-the-kingston-disaster-4-years-later/

———. 2013. "Five Years Since Kingston: Perry County, Alabama's Toxic Tragedy." *Southern Alliance for Clean Energy* (blog), December 22, 2013. https://cleanenergy.org/blog/five-years-since-kingston-perry-county-alabama-is-still-waiting-for-solutions/

Seidler, Maria, and Ken Malloy. 2020. "A Comprehensive Survey of Coal Ash Law and Commercialization: Its Environmental Risks, Disposal Regulation, and Beneficial Use Markets." Washington, DC: National Association of Regulatory Utility Commissioners.

Sergi, Brian J., Peter J. Adams, Nicholas Z. Muller, Allen L. Robinson, Steven J. Davis, Julian D. Marshall, and Inês L. Azevedo. 2020. "Optimizing Emissions Reductions from the U.S. Power Sector for Climate and Health Benefits." *Environmental Science & Technology* 54 (12): 7513–7523. https://doi.org/10.1021/acs.est.9b06936

Smith, Robin. 2014. "NC Coal Ash Bill Becomes Law." *SmithEnvironment Blog*, September 24, 2014. http://www.smithenvironment.com/n-c-coal-ash-bill-becomes-law/

Storrow, Benjamin. 2020. "More Coal Has Retired Under Trump than in Obama's 2nd Term." *E&E News*, June 22, 2020. https://www.eenews.net/stories/1063430425

Sullivan, J. R. 2019. "A Lawyer, 40 Dead Americans, and a Billion Gallons of Coal Sludge." *Men's Journal*, August 26, 2019. https://www.mensjournal.com/features/coal-disaster-killing-scores-rural-americans/

Taggart, Ross K., James C. Hower, Gary S. Dwyer, and Heileen Hsu-Kim. 2016. "Trends in the Rare Earth Element Content of U.S.-Based Coal Combustion Fly Ashes." *Environmental Science & Technology* 50 (11): 5919–5926. https://doi.org/10.1021/acs.est.6b00085

Tetra Tech, Inc. 2019. "CCR Rule Assessment of Corrective Measures (ACM) Report." Tetra Tech Project No. 212C-SW-00070. Greensburg, PA: FirstEnergy. http://ccrdocs.firstenergycorp.com/files/CCR%20Landfills/Pleasants%20Landfill/Groundwater%20Requirements/Pleasants%20CCR%20ACM%20Report_Oct%202019.pdf

Thind, Maninder P. S., Christopher W. Tessum, Inês L. Azevedo, and Julian D. Marshall. 2019. "Fine Particulate Air Pollution from Electricity Generation in the U.S.: Health Impacts by Race, Income, and Geography." *Environmental Science & Technology* 53 (23): 14010–14019. https://doi.org/10.1021/acs.est.9b02527

USGS (US Geological Survey). 2014. "Coal Combustion Products Statistics." In *Historical Statistics for Mineral and Material Commodities in the United States*, compiled by T. D. Kelly and G. R. Matos. U.S. Geological Survey Data Series 140. Washington, DC.

Van Velzer, Ryan. 2019. "Coal Ash Is Still Polluting Kentucky's Green River." *89.3 WFPL News Louisville*, December 4, 2019. https://wfpl.org/coal-ash-is-still-polluting-kentuckys-green-river/

Weinstein, Austin. 2021. "Duke Energy Customers to Save $1.1 Billion in Settlement over Coal Ash Cleanup Costs." *Charlotte Observer*, January 25, 2021. https://www.charlotteobserver.com/news/business/article248745190.html

Wireback, Taft. 2015. "Dan River Coal Ash Disaster: Environmental Impact Could Take Years to Determine." *Greensboro News and Record*, February 1, 2015. https://greensboro.com/news/dan-river-coal-ash-disaster-environmental-impact-could-take-years-to-determine/article_fed5e6e8-0150-528d-a35e-c4355ba8aa88.html

Yohannan, Suzanne. 2021. "EPA Backs Trump-Era Coal Ash Rules on Eve of Key Litigation Deadline." *Inside EPA*, July 6, 2021. Washington, DC. https://insideepa.com/daily-news/epa-backs-trump-era-coal-ash-rules-eve-key-litigation-deadline

Repairing the Damage

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

[Comprehensive coal ash cleanup can address longtime inequities, ensure lasting environmental benefits, generate new jobs for displaced workers, and broaden opportunities for community redevelopment.]

The burning of coal to produce electricity leaves behind coal ash, one of the largest industrial waste streams in the United States. Coal ash contains more than a dozen toxic substances that threaten human health and ecosystems, and weak regulations and lack of enforcement have allowed the ongoing pollution of our air, soil, and waterways. Disadvantaged communities, where many disposal sites are located, are disproportionately affected. The comprehensive cleanup of coal ash waste ensures long-lasting environmental benefits and addresses environmental justice issues, while driving local job creation in communities facing the closure of coal-fired power plants and improving opportunities for community redevelopment.

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EXECUTIVE SUMMARY

Repairing the Damage

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

HIGHLIGHTS

The burning of coal to produce electricity leaves behind coal ash, one of the largest industrial waste streams in the United States. Coal ash contains more than a dozen toxic substances that threaten human health and ecosystems, and weak regulations and lack of enforcement have allowed the ongoing pollution of our air, soil, and waterways. Disadvantaged communities, where many disposal sites are located, are disproportionately affected. The comprehensive cleanup of coal ash waste ensures long-lasting environmental benefits and addresses environmental justice issues, while driving local job creation in communities facing the closure of coal-fired power plants and improving opportunities for community redevelopment.

Although coal has powered the nation for generations and today offers well-paying jobs—often the best opportunities in more rural areas—coal negatively affects human health and the environment at every point in its life cycle: when it is mined, processed, transported, burned, and discarded. Local communities—often low-income communities and/or communities of color—have for decades borne the brunt of these negative impacts, including air pollution, water pollution, and workplace injuries, illnesses, and fatalities.

One of the Nation's Largest Waste Streams

When coal is burned to produce electricity, not all of its components combust, leaving ash behind—massive amounts of it. Coal ash is one of the two largest industrial waste streams in the United States: From 1966 to 2017, US electric utility companies generated a total of 4.5 billion tons of coal ash and from 2015 to 2019 produced an average of 101 million tons of coal ash every year.

Coal ash is often mixed with water and stored in large impoundments, commonly called coal ash ponds. It can also be stored in dry form in landfills or reused in products like concrete. Many of the elements that make up coal ash—arsenic, boron, cadmium, chromium, lead, radium, and selenium, to name a few—are toxic, and exposure can cause a variety of severe health issues, including cancer, heart disease, reproductive failure, stroke, and even brain damage in children.

J. Miles Cary/AP Photo/Knoxville News Sentinel

The largest industrial disaster in US history, the Kingston coal ash spill on December 22, 2008, destroyed homes, devastated ecological systems, and contaminated the Emory and Clinch Rivers. The spill was caused by the failure of a dike containing the coal ash pond, underscoring the threat of coal ash waste to human health and the environment.

> ***Comprehensive coal ash cleanup can address longtime inequities, ensure lasting environmental benefits, generate new jobs for displaced workers, and broaden opportunities for community redevelopment.***

Many coal ash constituents are also toxic to aquatic life, and disposal sites pose a risk of catastrophic spills that can contaminate soil, waterways, and groundwater. Despite being such a large waste stream with demonstrated serious impacts on human health and the environment, only in 2015 did the Environmental Protection Agency (EPA) adopt monitoring standards and closure requirements for coal ash disposal sites under the Resource Conservation and Recovery Act.

Coal Ash in the Ohio River Valley States

Coal-fired power plants are often located along major rivers because large amounts of water are needed for cooling, and many are concentrated along the Ohio River. Of the 738 coal ash disposal sites nationwide, 161 (more than one out of five) are found in the five states that make up the Ohio River Valley: Indiana, Kentucky, Ohio, Pennsylvania, and West Virginia. One assessment of documented groundwater contamination from coal ash disposal sites put two coal-fired power plants in the Ohio River Valley on the list of the top 10 most contaminated nationwide: the New Castle Generating Station in Pennsylvania (#5) and the Ghent Generating Station in Kentucky (#10).

These 161 disposal sites are located at 57 operating or retired coal-fired power plants in these five states. At 33 of the plants (58 percent), the surrounding community is considered low-income, meaning that the residents within a three-mile radius have an average income level at or below twice the federal poverty level in their state. Six of the 57 plants (nearly 11 percent) are located within three miles of a community with a disproportionate number of people of color; half are in Indiana. Nationally, 52 percent of communities near operating or retired coal-fired power plants are low-income—meaning that the Ohio River Valley disposal sites are more likely to affect low-income communities relative to the national average.

Case Studies Explore the Costs and Benefits of Complete Cleanup

Generalizing the costs of coal ash cleanup nationally is difficult because the cleanup needs are site-specific, but case studies are useful in understanding costs and needs under specific conditions and in providing context for the problem nationally. New analysis by the Union of Concerned Scientists and the Ohio River Valley Institute evaluates the cleanup costs and job creation potential for two coal ash sites—the first two such case studies in the Ohio River Valley. One, the J. M. Stuart coal-fired power plant in Appalachian Ohio, closed in 2018, along with another nearby coal plant, dealing a blow to the local economy. The other, the Sebree Generating Station, consists of three coal-fired power plants (one still in operation but slated for retirement) in western Kentucky. Our analysis evaluates site owners' plans for cleanup activities (both of which are in violation of federal regulations) and proposes a more complete "clean closure" plan for both. These case studies illustrate how investing in cleanup of coal ash can create jobs in exactly the places where jobs are being lost as coal continues its decline. Clean closure simultaneously mitigates the harm caused by pollution begun in decades past and continuing to the present day by providing communities in the Appalachian region—and nationwide—a pathway forward as the shift toward clean energy continues.

Case Study Findings

Our analysis consists of an engineering assessment of each site and a cost analysis of two cleanup options—the owner's plan for closing the disposal sites and a proposed clean closure scenario that represents a complete set of actions to fully remediate the site, including excavation of coal ash ponds. Based on the cost estimates and direct job creation from the cleanup projects, we conducted an economic analysis of the impacts of the projects for each state's economy. We found that the clean closure of coal ash disposal sites offers superior protection for public health and ecosystems while offering better opportunities for local jobs and associated economic activity, consistent with similar evaluations for other sites in previous reports. The additional costs of clean closure are justified by the higher number of jobs, the wider economic benefits, and the potential for redevelopment that flow to the local communities. This is especially true for the Sebree plant, where the clean closure plan would generate nearly twice as many jobs as the utility's proposal during the project's construction phase, which refers to initial investments in infrastructure needed to excavate and safely store the coal ash waste. As shown in Table ES.1, the clean closure options would lead to the creation of 282 jobs in Kentucky during the four-year construction phase and 314 jobs in Ohio during the nine-year construction phase. At both sites, the clean closure scenario would drive significant economic impacts that would ripple through each state's economy, as shown in Figure ES.1. Relative to the owners' cleanup plans, the clean closure plans drive more than $100 million in additional economic output in each state.

TABLE ES.1. Projected Job Creation per Year in Kentucky and Ohio from Cleanup Options

Construction Phase Job Creation per Year		
	Clean Closure	Company Plan
Kentucky	282	144
Ohio	314	252

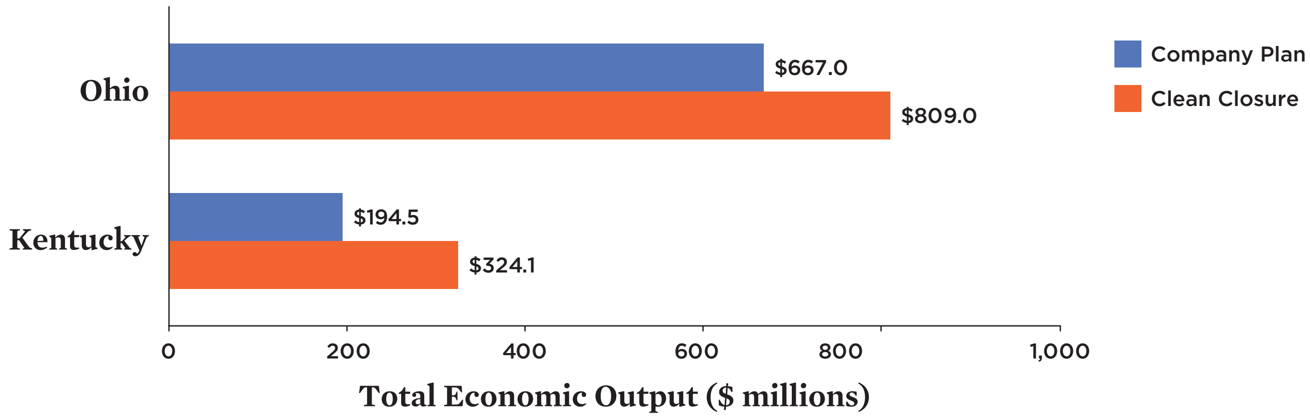
During the construction phase, more jobs will be created per year with the clean closure plans compared to the owners' plans—in the case of Sebree, nearly twice as many. The construction phase is four years for Sebree and nine years for J. M. Stuart. The numbers represent the total jobs created (direct, indirect, and induced) including both full- and part-time employment.

Recommendations

In addition to the job creation and local economic growth from cleaning up these two coal ash disposal sites, state and federal policymakers can take a number of actions to strengthen rules and increase funding to ensure that coal ash is cleaned up nationally.

- **Hold utilities and owners responsible for the clean closure of coal ash disposal sites.** Cleanup decisions are governed by state regulators, and rate-regulated utilities typically petition state public utility commissions for cost recovery—meaning ratepayers are on the hook to pay for the cleanup. Regulators should consider the long-term economic value of cleanup options to the local community—ratepayers should not bear the costs without reaping the economic value of full cleanup.
- **Robustly fund existing EPA programs that support communities.** EPA programs must be robustly funded to ensure that polluting coal ash disposal sites are identified and cleaned up. These programs include the Brownfields programs, enforcement divisions, and the Corrective Action Program within the Resource Conservation and Recovery Act.

FIGURE ES.1. Total Economic Output over Project Lifetime for Case Study Cleanup Options



For both projects, the clean closure plans would result in more than $100 million in additional economic activity in each state. Project lifetime is the construction phase plus 30 years of ongoing operations and maintenance. Output is an overall measure in dollars of the impact on the economy due to the investments in the project.

- **Strengthen the enforcement of existing regulations that prohibit cap-in-place closure.** The EPA already has enforcement authority, and it can and should follow the plain language of the 2015 Coal Combustion Residuals Rule, requiring excavation when coal ash is in contact with groundwater or when coal ash ponds would remain in a floodplain when capped in place. States should also require excavation under state laws and regulations, as is being done in North Carolina, South Carolina, Virginia, and Illinois.
- **Ensure that frontline communities have a voice in cleanup decisions.** Residents and community leaders are often the strongest voices in holding utilities and site owners accountable for cleanup, and robust stakeholder processes are needed to ensure meaningful engagement. For example, the EPA's Technical Assistance Services for Communities Program offers grants that can empower fenceline communities and residents to participate in discussions about closure options. It is a valuable resource that should be robustly funded to drive better local outcomes, and additional programs supporting environmental justice communities may also be brought to bear.
- **Ensure strong labor standards and safety protections for cleanup workers and prioritize dislocated workers in hiring.** Local hiring requirements should be implemented to ensure that dislocated workers have access to cleanup jobs, and prevailing wages should be required to ensure that workers are paid fairly for their work. Because coal ash is toxic, workers must be protected during cleanup activities.
- **Prevent damage to communities and the environment from reuse of coal ash.** The EPA should cease classifying unencapsulated coal ash as an acceptable "beneficial use" and instead treat unencapsulated uses as a form of disposal.
- **Ensure that the extraction of rare earth elements is safe and is coupled with clean disposal of remaining coal ash.** A holistic assessment of risks and benefits should be applied to rare earth element extraction, and extraction programs should be informed by the community and unions.
- **Leverage existing federal programs or consider establishing new financial institutions or grant programs to ensure that all disposal sites nationally are fully cleaned up.** Existing federal programs like the Superfund program could be augmented through polluter-pays fees. Additional public financing may be needed to ensure complete removal of coal ash. These resources are critical for ensuring a fair transition to clean energy for communities and workers formerly dependent on coal-fired electricity production.

__Jeremy Richardson__ is a senior energy analyst in the UCS Climate and Energy Program. __Eric Dixon__ is an independent consultant working with the Ohio River Valley Institute. __Ted Boettner__ is a senior researcher at the Ohio River Valley Institute.

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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

www.ucsusa.org/resources/coal-ash-cleanup-benefits

Ian Magruder

Peter Haun

Prepared for the Union of Concerned Scientists and the Ohio River Valley Institute By:

WWC ENGINEERING

wwcengineering.com
Helena, Montana

October 2021

Table of Contents

1. Introduction 1
1.1. Background and Problem Statement 1
1.2. Study Goals and Objectives 3
1.3. Report Organization 3
1.4. Methods Used to Estimate Cost and Jobs 4
2. J. M. Stuart Electric Generating Station 5
2.1. Site Overview 5
2.2. Contamination Summary and Cleanup Considerations 8
Groundwater Contamination 8
Pond and Landfill Construction 11
Floodplain 11
2.3. Description of Closure Plan Alternatives 13
2.4. Cost Analysis 18
2.5. Jobs Analysis 22
3. Sebree Generating Station 25
3.1. Site Overview 25
3.2. Contamination Summary and Cleanup Considerations 28
Groundwater Contamination 28
Pond and Landfill Construction 31
Floodplain 32
3.3. Description of Closure Plan Alternatives 33
3.4. Cost Analysis 38
3.5. Jobs Analysis 42

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.

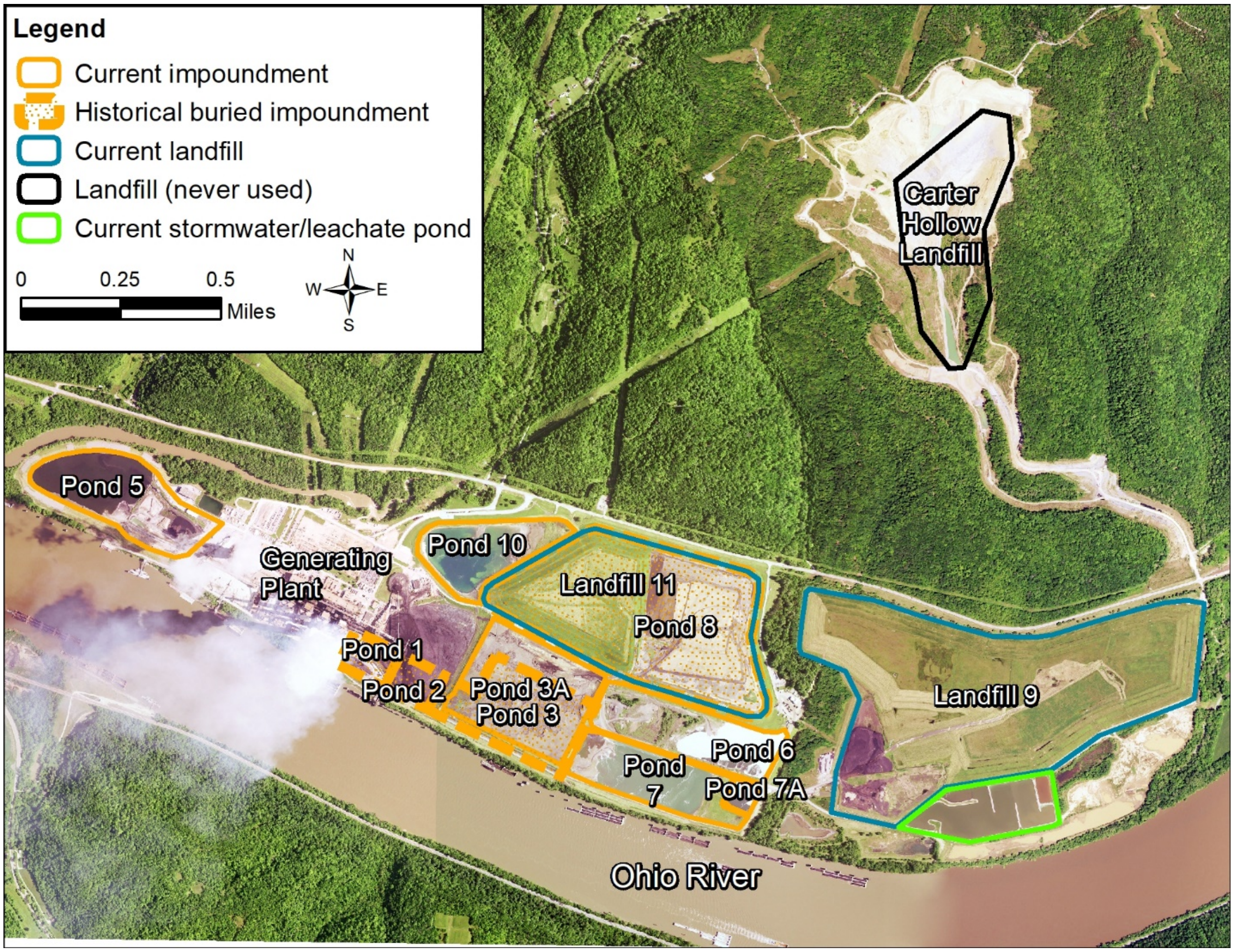

Figure A1. Current Site Layout of J. M. Stuart Electric Generating Station

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

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[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.

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[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.

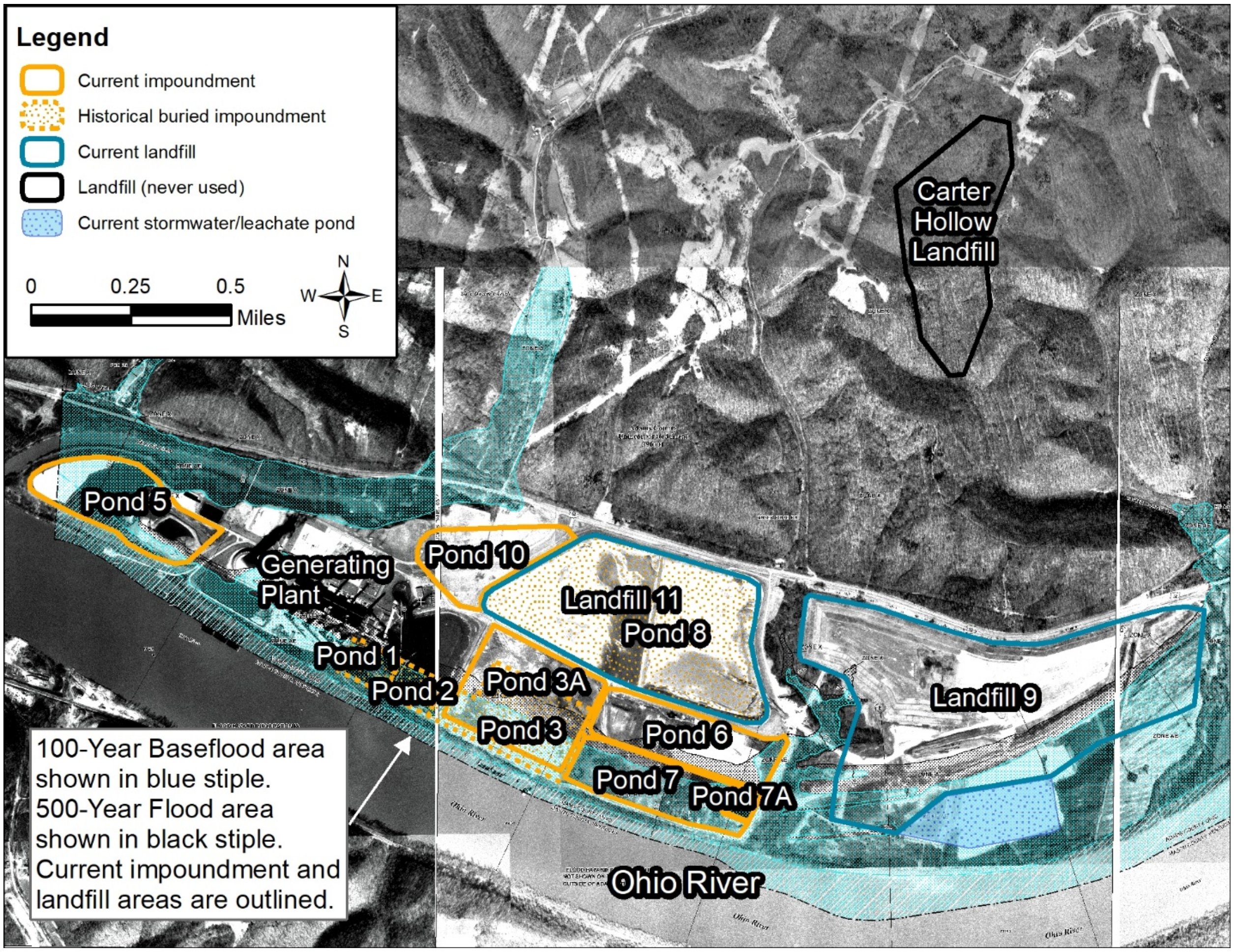

Figure A2. FEMA Floodplain Mapping at the J. M. Stuart Generating Station

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.

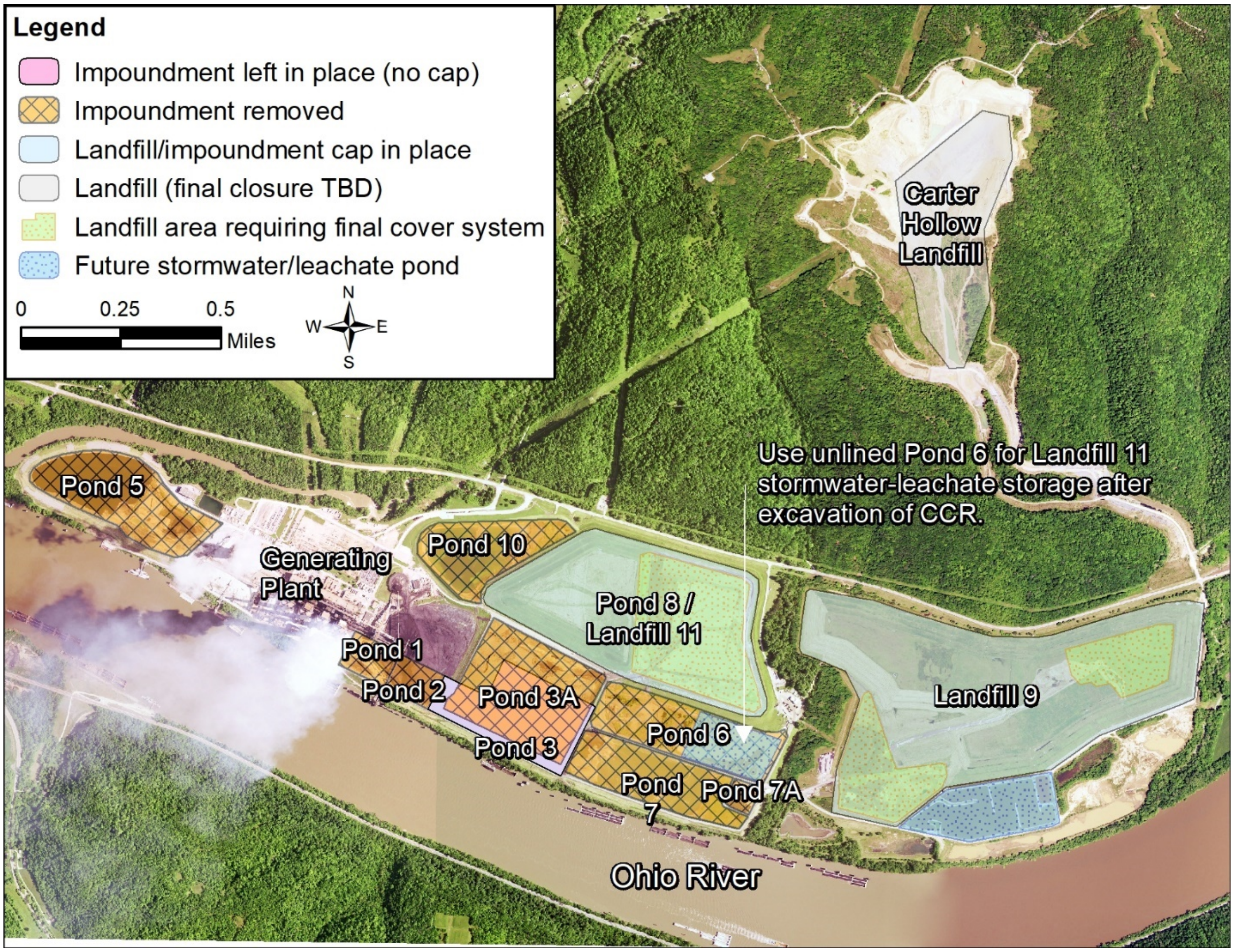

Figure A3. Kingfisher Development Closure Plan for the J. M. Stuart Generating Station

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.

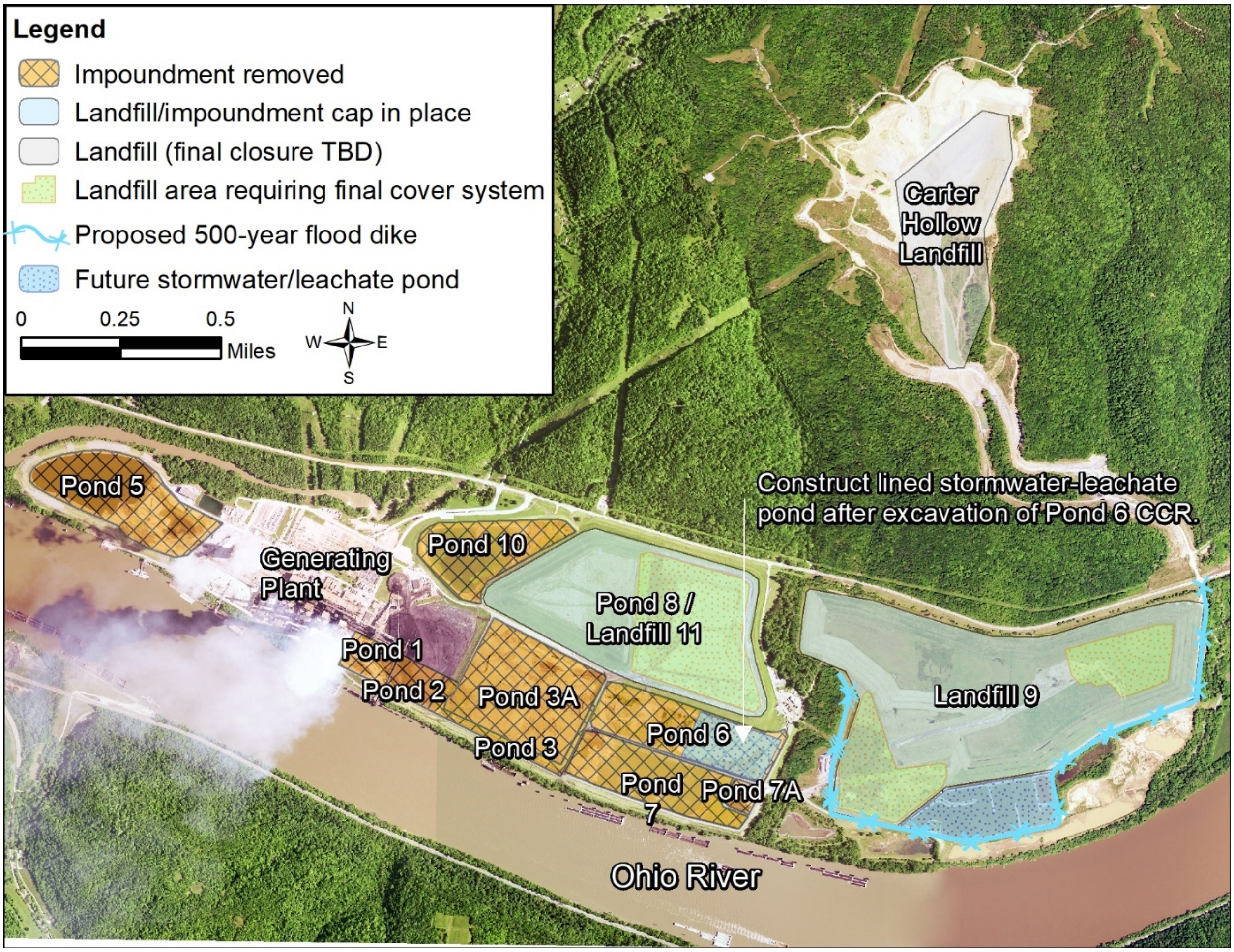

Figure A4. Clean Closure Plan for the J. M. Stuart Generating Station

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

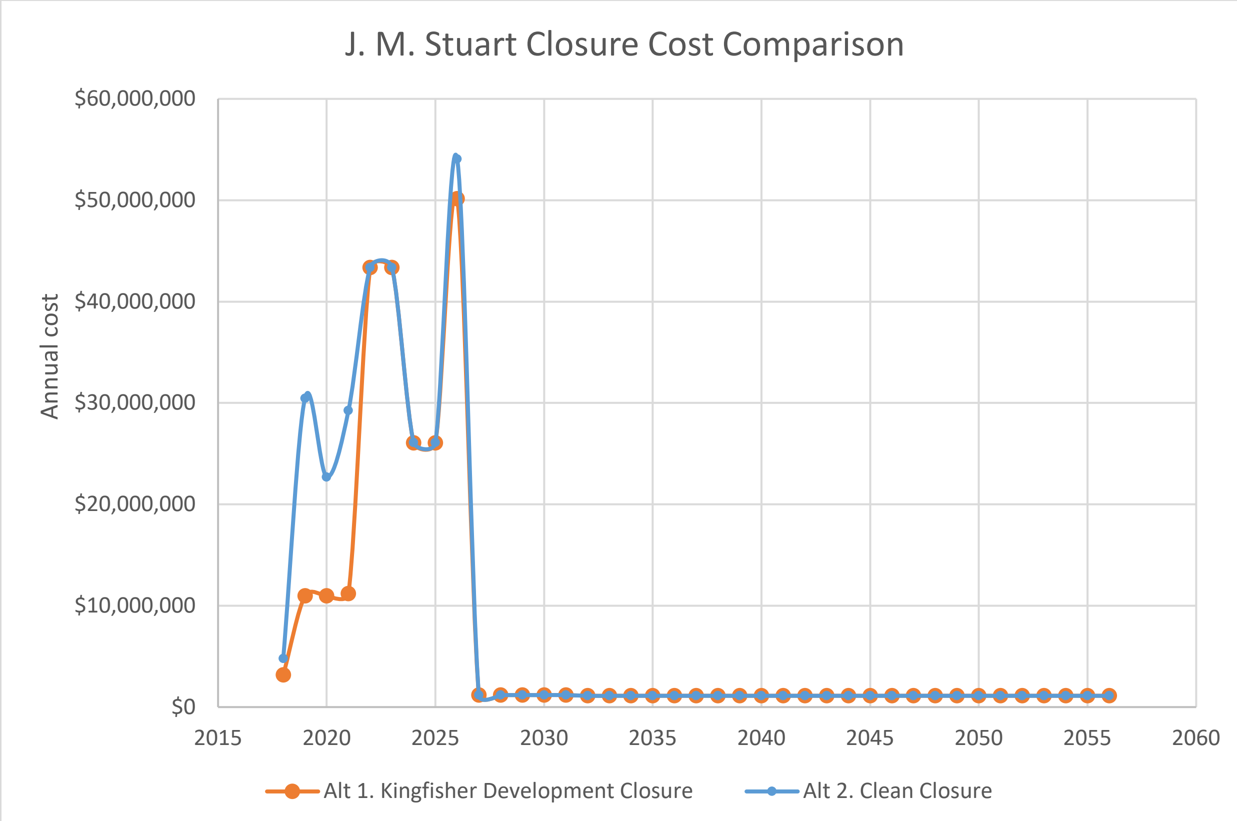

Figure A5 Closure Costs over Time for each Cleanup Alternative for the J. M. Stuart Generating Station (2022 dollars)

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.

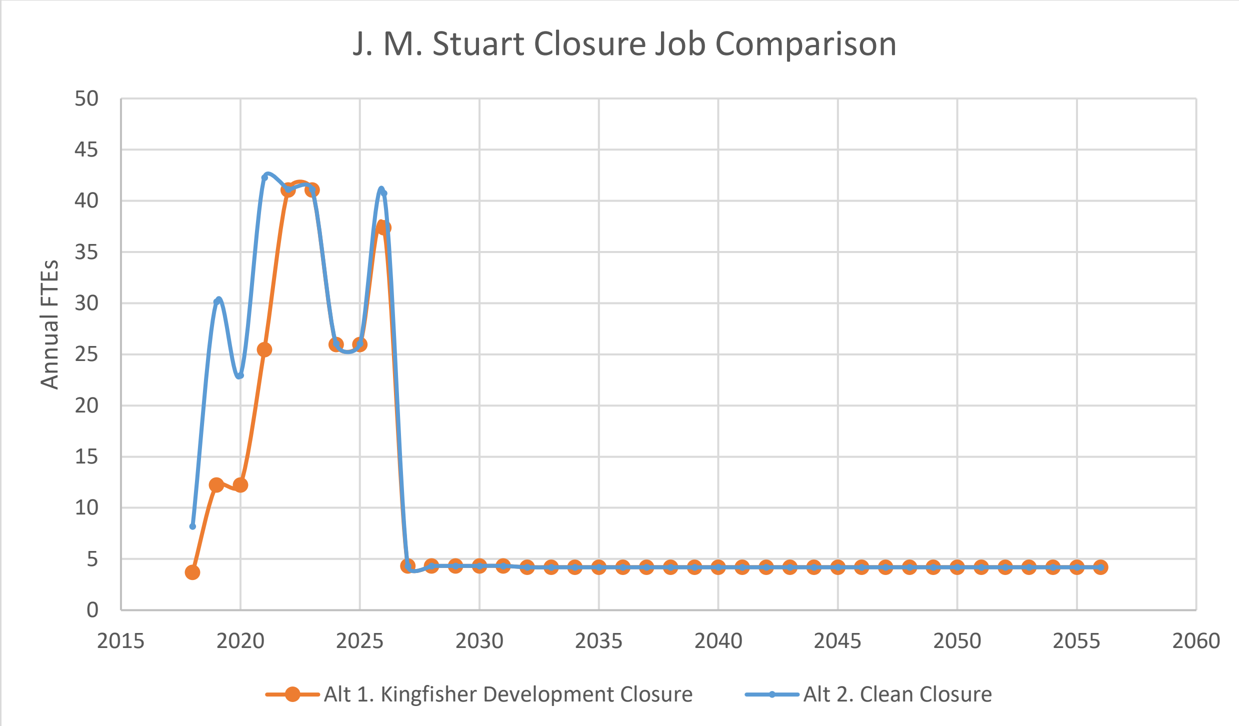

Figure A6. Direct Jobs over Time for each Cleanup Alternative for the J. M. Stuart Generating Station

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.

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[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.

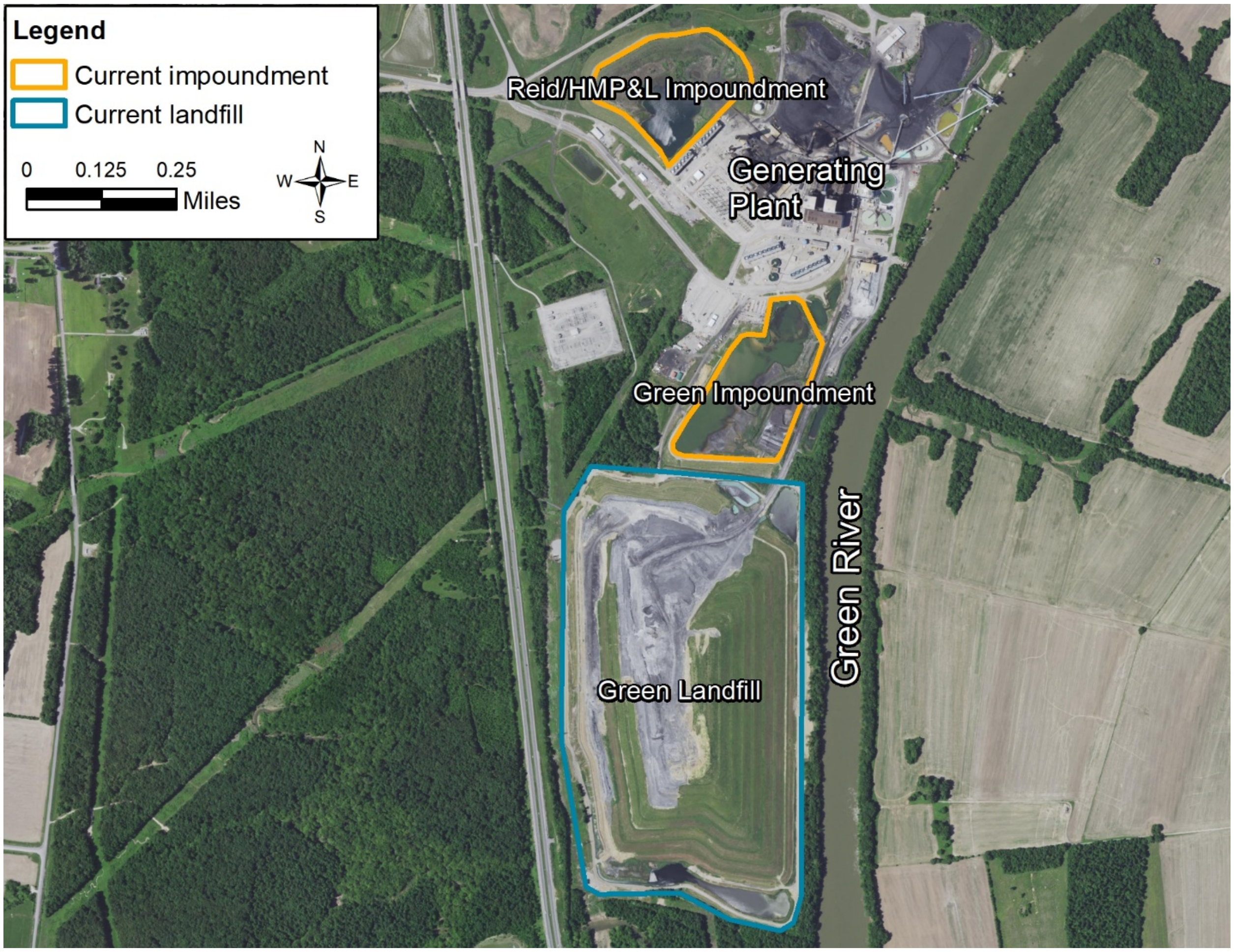

Figure A7. Sebree Plant Site Layout

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

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[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.

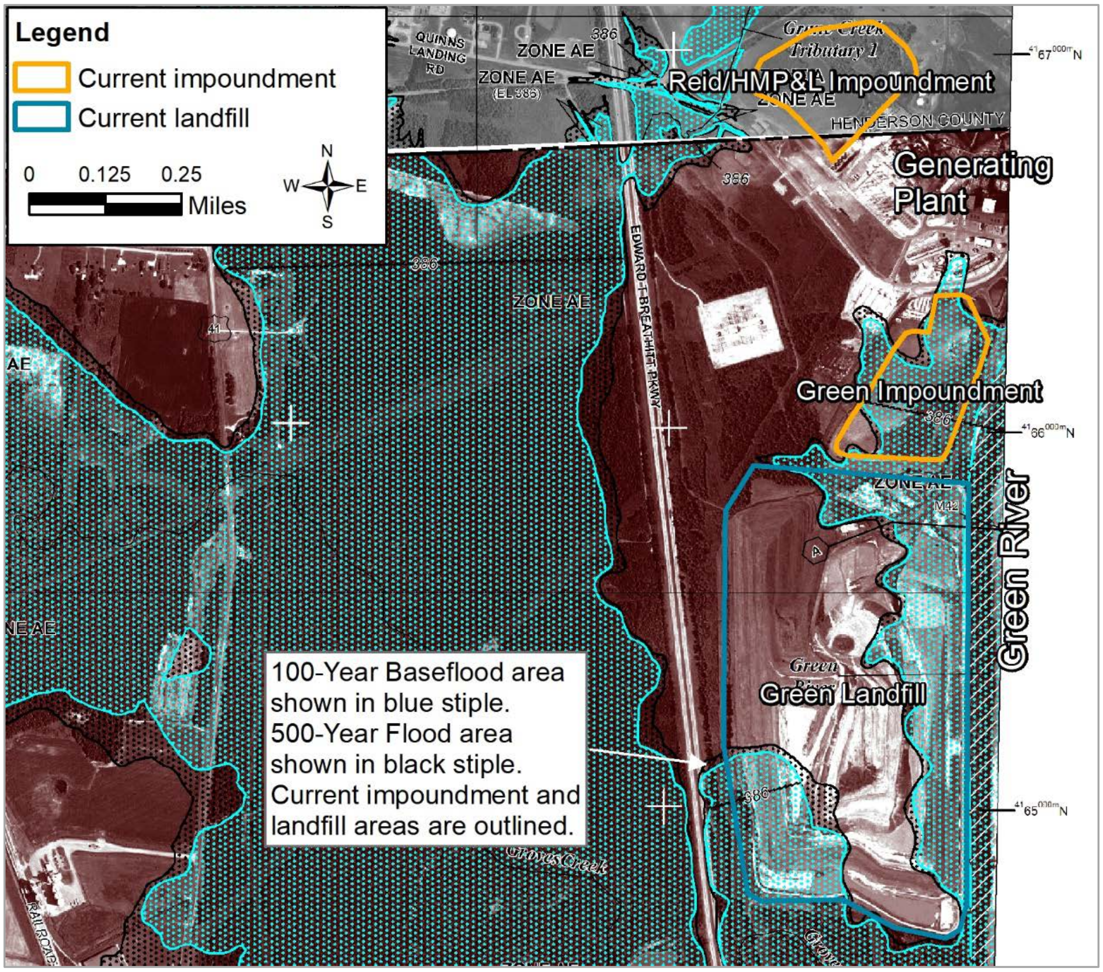


Figure A8. FEMA Floodplain Mapping at Sebree

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.

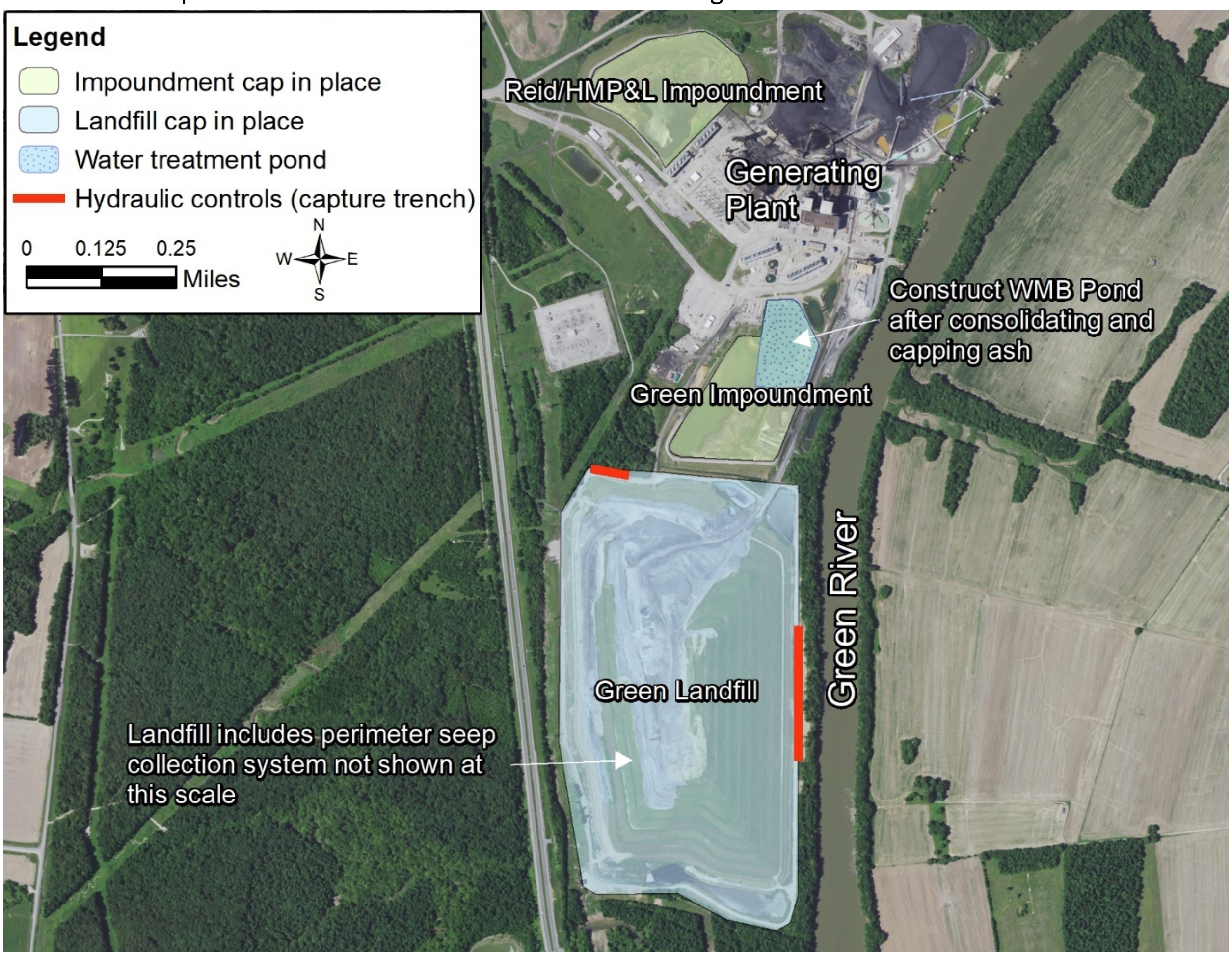


Figure A9. BREC Closure Plan for the Sebree Plant

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 1×10^{-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

<table>
<tr><th rowspan="2">Activity</th><th colspan="4">Year</th></tr>
<tr><th>2021</th><th>2022</th><th>2023</th><th>2024</th></tr>
<tr><td>Planning/Permitting</td><td bgcolor="#aaaaaa"></td><td></td><td></td><td></td></tr>
<tr><td>Mobilization</td><td></td><td bgcolor="#aaaaaa"></td><td></td><td></td></tr>
<tr><td>Green Impoundment CCR Excavation</td><td></td><td bgcolor="#aaaaaa"></td><td bgcolor="#aaaaaa"></td><td></td></tr>
<tr><td>WMB Pond Construction</td><td></td><td></td><td bgcolor="#aaaaaa"></td><td></td></tr>
<tr><td>Levee Construction</td><td></td><td bgcolor="#aaaaaa"></td><td bgcolor="#aaaaaa"></td><td></td></tr>
<tr><td>Reid Impoundment CCR Excavation</td><td></td><td bgcolor="#aaaaaa"></td><td bgcolor="#aaaaaa"></td><td></td></tr>
<tr><td>Green Landfill Closure</td><td></td><td></td><td></td><td bgcolor="#aaaaaa"></td></tr>
</table>

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

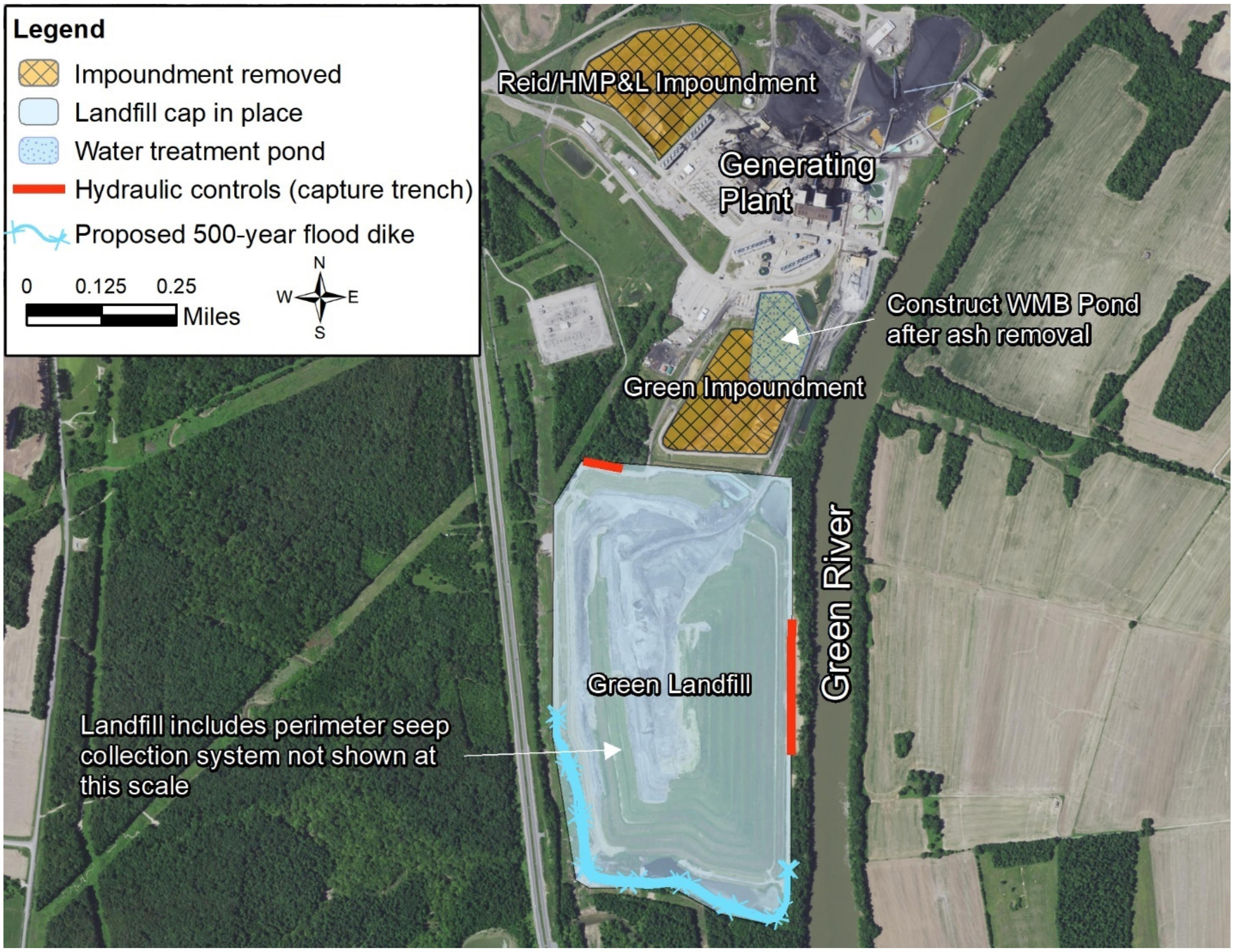


Figure A10. Clean Closure Plan for the Sebree Station

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.

[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

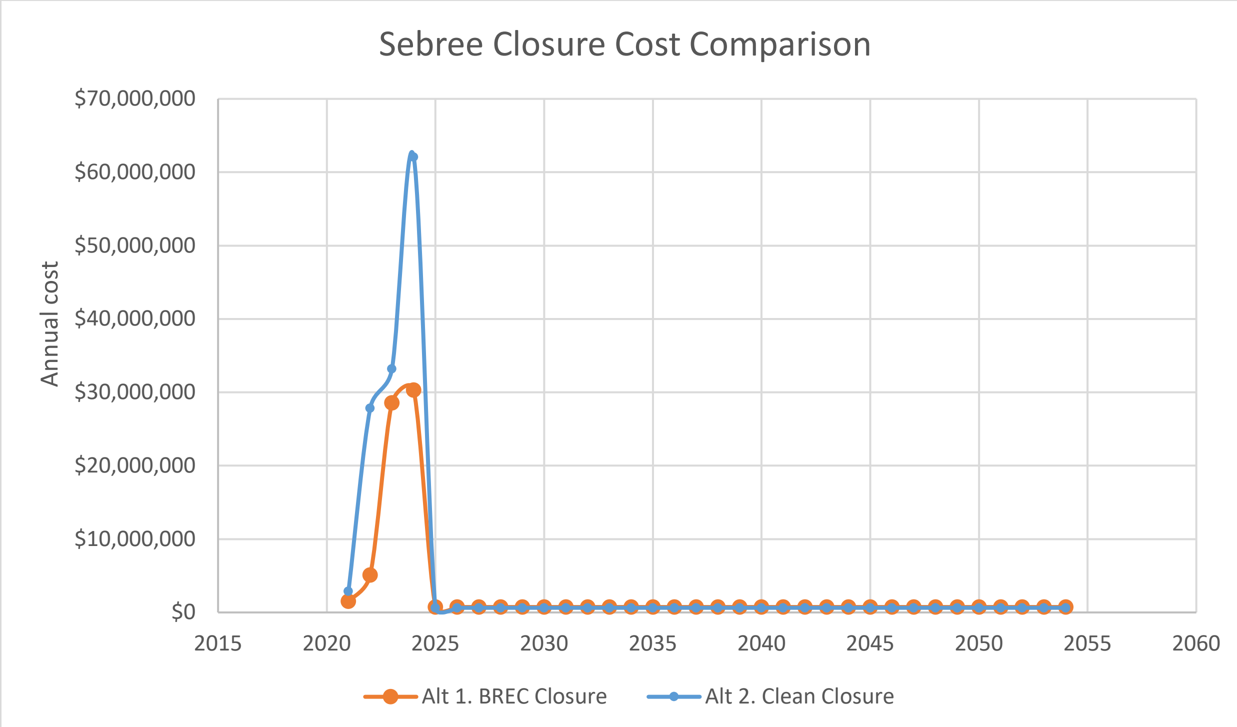


Figure A11. Closure Costs over Time for Each Cleanup Alternative for the Sebree Station (2022 dollars)

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

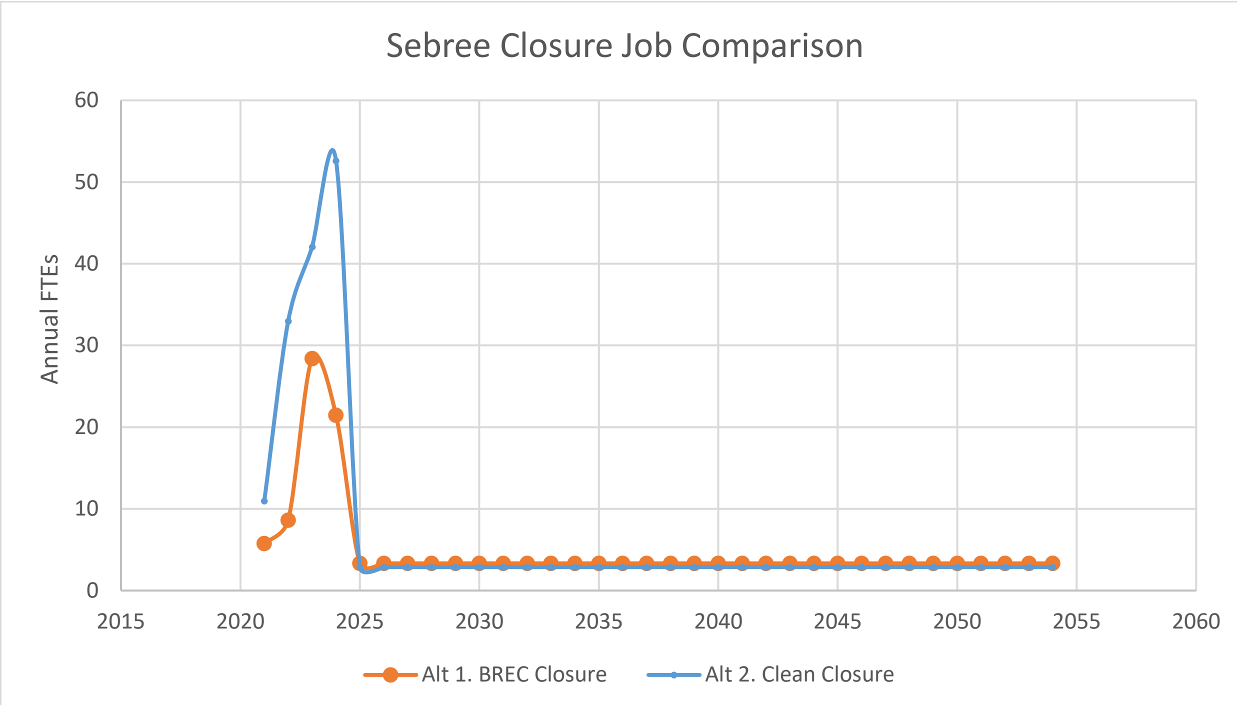


Figure A12. Direct Jobs over Time for Each Cleanup Alternative for the Sebree Station

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.

Repairing the Damage

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

Appendix B: Economic Impact Analysis of Closure Scenarios for Two Case Studies in the Ohio River Valley

www.ucsusa.org/resources/coal-ash-cleanup-benefits

Dale Shannon

Jeremy Richardson

Ted Boettner

October 2021

Prepared by Downstream Strategies for the Union of Concerned Scientists and the Ohio River Valley Institute

Downstream Strategies
Ideas that sustain.

Overview

Repairing the Damage: Cleaning up Hazardous Coal Ash Can Create Jobs and Improve the Environment is Part 4 in a series of reports exploring issues and opportunities of cleaning up legacy pollution from fossil fuel extraction in Appalachia. The report explores the issue of coal ash pollution and cleanup in the Ohio River Valley states of Indiana, Kentucky, Ohio, Pennsylvania, and West Virginia. It provides detailed case study analyses of two current or former coal-fired power plants: Sebree Generating Station in Kentucky and J. M. Stuart Generating Station in Ohio. Appendix A provides a detailed description and engineering analysis of each coal ash complex as well as cost estimates and direct job creation at each of the two current and former coal plants for two cleanup scenarios—the owner's proposal as well as a more comprehensive "clean closure" plan developed by the engineering firm. This appendix provides a detailed description of the economic analysis of the two cleanup scenarios for each case study based on the results of the engineering analysis.

Methodology

The economic impact analysis of the two proposed clean up alternatives done at the J.M. Stuart Station in Ohio and the Sebree Station in Kentucky used the Impact Analysis for Planning (IMPLAN) Pro state-level models for the appropriate states.[1] IMPLAN models are recognized internationally for providing consistent estimates of economic impacts for a specified geography. Economic impact analyses provide estimates of the economic activity that would result from specified activity or ongoing activity within a defined geography (region).[2]

For the analysis in this report, WWC Engineering, Inc., developed a detailed set of cost and employment estimates by year and activity for both the owner's plan and a clean closure proposal for both the J. M. Stuart Generating Station in Ohio and Sebree Generating Station in Kentucky (see Appendix A).[3] This economic analysis is based on the results of the engineering analysis.

[1] See IMPLAN.com.

[2] This analysis assumes that both Ohio and Kentucky establish policies to require preferences for intra-state goods and services (including labor). While this may reflect practical political reality, this assumption also recognizes that the state IMPLAN models do not include information about the specific location of the generating facilities and coal ash impoundments within the state boundaries. It is possible that goods and services for the cleanup of both facilities (especially the J. M. Stuart plant located along the Ohio River) could receive cross-border goods, services, and labor.

[3] The costs provided by the engineers were in 2022 dollars. To appropriately adjust these dollars and report all results in current year (2021 dollars), the deflators within the IMPLAN were used. These deflators include inflation rates for each of the 544 industries as well as an overall rate for gross domestic product for final demand. The net result of this adjustment for inflation is to reduce the total value of the activity by about 1.25 percentage points. Because both industry-level and national inflation rates come into play in the adjustment, the specific change from 2022 dollars to 2021 dollars depends on the activity being specified. Employment levels are not affected by deflation in the IMPLAN model.

INDUSTRY SPECIFICATIONS

As noted in other studies[4] of the remediation of coal ash disposal sites that are discussed in the report, the IMPLAN model does not have an industry that is readily identified with the type of construction activity required for this type of remediation work. Our solution was to employ a relatively common approach called an "analysis-by-parts." This creates the opportunity to specify the commodities and services used in each of the activities for each year, lets the model identify the employment that would be associated with those activities for the indirect effects, and uses the employment levels and costs provided by the engineers to define the direct effects. Direct effects are the costs and jobs required by the actual projects, indirect effects are regional upstream activities (e.g., purchases of goods and services needed to conduct the projects), and induced effects are follow-on impacts on the regional economy (such as workers spending their wages and state and local governments spending the additional fees and tax revenues).

The distribution of the spending pattern used the hard costs built from the industry spending patterns for the IMPLAN industries "maintenance and repair construction of highways, streets, bridges, and tunnels" (IMPLAN industry 62) and "water, sewage, and other systems" (IMPAN industry 49). For both states these two industries had relatively similar spending patterns, but each had specific concentrations that were viewed as appropriate for handing water, moving large quantities of coal ash, and cleaning up the sites after relocating the waste. After discussions with environmental engineers familiar with the activities involved in closing coal ash impoundments, the allocations of ready-mix concrete and other cement-related commodities were reduced to better reflect the purchases of the commodities associated with the cleanup. Additionally, the local purchasing shares were increased for a few commodities such as "sand and gravel mining," "truck transportation," "landscape and horticultural services," and a few other commodities with relatively minor contributions in order to reflect the likely local sources for those goods and services. Spending on soft costs such as "architectural, engineering, and related services" and "environmental and other technical consulting services" were zeroed out in the hard costs component and modeled separately to allocate the share of the costs going into those activities.

LABOR AND EMPLOYMENT SPECIFICATIONS

The analysis-by-parts methodology estimates the effect on the state economies associated with the indirect and induced effects generated from the spending necessary to clean up the coal ash disposal sites. However, the on-site employment (direct employment) that was specified by the engineers in Appendix A and the income associated with that employment is not specified in the direct effects in the IMPLAN model's analysis-by-parts approach. To correctly account for this activity, the labor costs were estimated and removed prior to setting the costs distributed to the spending patterns as noted above. Thus, the spending patterns were defined only for the materials and services purchased for the activity, while labor costs were addressed in a separate modeling exercise. The full time equivelent employment levels provided by the

[4] See Evans and French (2018), French (2019), and NPRC and IBEW (2018) in the reference list for the main report.

enigineers were converted to full- and part-time employment, the definition used by the IMPLAN model, using an IMPLAN industry level conversion.[5] .

Labor costs were estimated by state using a labor income per employee for the appropriate IMPLAN industry sector with a 25 percent adjustment to reflect fair wage rates for the employees. The total labor income was distributed to both employee compensation and proprietor incomes based on ratios within the model. Although a 25 percent wage premium reflects the necessity of a fair wage in regions with low aggregate incomes, the premium still results in the aggregate labor income being constrained at a level below the model's default given the overall construction costs. This constraint reflects the employment levels specified by the engineers with the result that fewer construction workers were employed and lower direct regional incomes were required than without this constraint. Economically, these specifications reflect a scenario that required that the average construction workers be more highly skilled than what would be assumed by the defaults for the industries initially modeled.

As a final step, the distribution between employee compensation and proprietor income for each state was based on the distribution for the appropriate industry, and a labor income change activity was specified for each year and each type of hard or soft construction activity. A change in labor income activity results in estimates for only the induced effects since that labor income is spent across the regional economy. Because direct effects (economic activity and employment) were specified separately from the engineers' results, they were added to the IMPLAN secondary effects to calculate total jobs and economic activity.

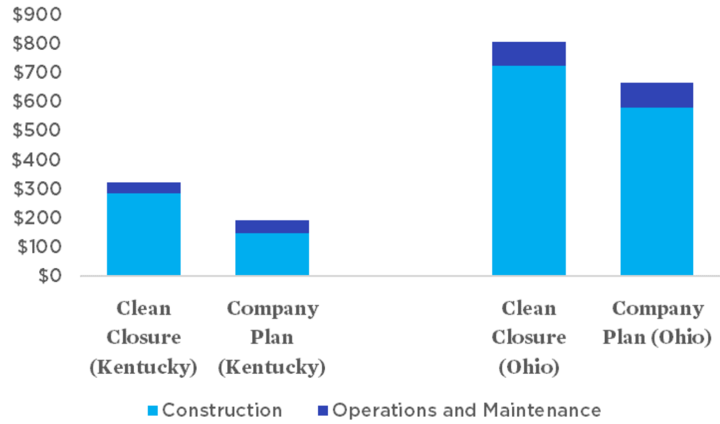
The net result for an aggregate activity for a given year thus includes estimates of the hard and soft costs for the secondary effects from the industry spending patterns, the secondary effects from the labor income changes, and the estimated direct effects on output, labor income, and employment.

Discussion

This section presents additional detail on the results of the IMPLAN analysis to accompany the main report. Figure B-1 shows the total statewide economic impact from the Sebree (Kentucky) and J. M. Stuart (Ohio) case studies, breaking out the impacts of the initial construction phase from those of the operations and maintenance activities. As noted in Figure B-1, the closure of the J. M. Stuart plant will create a larger economic impact because there are significantly larger cleanup needs. For both cleanup scenarios in both case studies, direct employment created by the cleanup activities is dominated by the initial construction phase when the coal ash waste is being removed and contained. See Figure B-2 for Sebree closure options and B-3 for J. M. Stuart closure options.

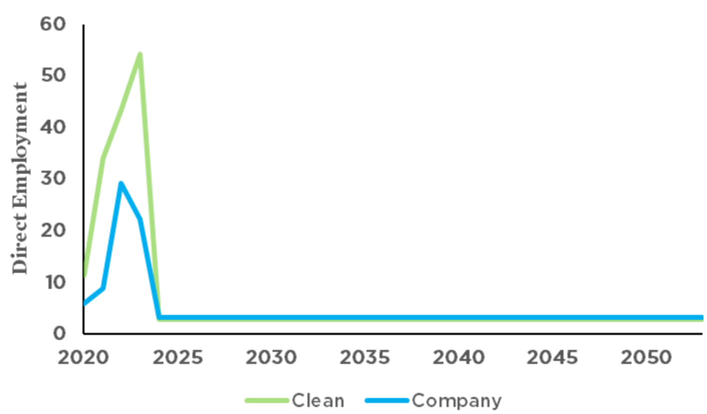
[5] An FTE is calculated using the total hours needed to complete the work, whereas our results represent total jobs, which includes both full- and part-time positions.

Figure B-1. Total Economic Output from Closure Scenarios in Kentucky and Ohio



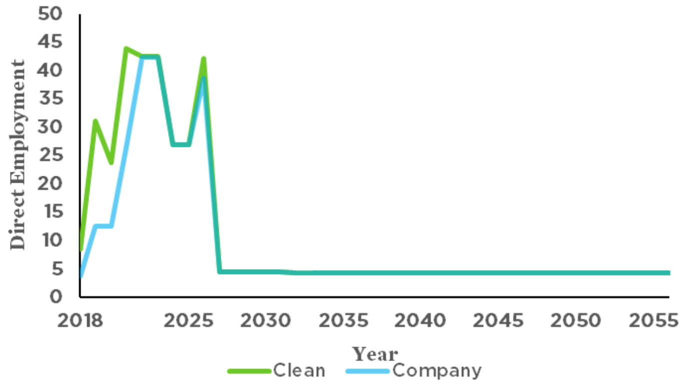
Our analysis found that the clean closure scenario leads to greater economic output than the company plan for both case studies. This chart shows the impacts from the construction phase (four years for Kentucky and nine years for Ohio) separately from the operations and maintenance phase (construction phase plus 30 years). The totals in Figures ES.1 in the executive summary and Figures 3 and 6 in the main report match the totals shown here but are split out by direct, indirect, and induced effects.

Figure B-2. Direct Employment per Year over Project Lifetime for Sebree Closure Options



Once the initial construction (excavation) phase is complete, ongoing operations and maintenance beginning in 2024 creates relatively few ongoing direct jobs when compared to the large impacts from the construction activity.

Figure B-3. Direct Employment per Year over Project Lifetime for J. M. Stuart Closure Options



Once the initial construction (excavation) phase is complete, ongoing operations and maintenance beginning in 2027 creates relatively few ongoing direct jobs when compared to the large impacts from the construction activity.

The following two tables compare details on the economic measures between the clean closures and the company closures by effect. The values for total economic output correspond to Figure B-1. Value added is a component of output, and labor income is a component of value added (see Figure B-4 for a graphical representation of the components of economic output). Results are shown for the direct, indirect, and induced effects. See Table B-1 for results for the Sebree closure options and Table B-2 for the results for the J. M. Stuart closure options. The tables explicitly show the difference between the closure options in each case. Details on definitions may be found in the "Overview of the IMPLAN Model" section below.

Table B-1. Total Economic Output and Selected Components of Output for Sebree Closure Options ($ millions)

	Total Output			Total Value Added			Total Labor Income		
	Clean Closure	Company Closure	Difference	Clean Closure	Company Closure	Difference	Clean Closure	Company Closure	Difference
Direct	$142.0	$85.9	$56.1	$23.9	$17.2	$6.7	$17.1	$12.5	$4.6
Indirect	$120.1	$70.0	$50.1	$62.1	$36.2	$25.9	$36.7	$22.0	$14.7
Induced	$62.0	$38.6	$23.3	$36.0	$22.4	$13.6	$21.8	$13.5	$8.3
Total	$324.1	$194.5	$129.5	$122.0	$75.8	$46.2	$75.7	$48.0	$27.7

This table breaks out the total economic impact (also called output) of both Sebree closure options by showing the direct, indirect, and induced effects (rows) and selected components of output (columns).

Table B-2. Total Economic Output and Selected Components of Output for J. M. Stuart Closure Options

	Total Output			Total Value Added			Total Labor Income		
	Clean Closure	Company Closure	Difference	Clean Closure	Company Closure	Difference	Clean Closure	Company Closure	Difference
Direct	$307.8	$254.1	$53.7	$45.6	$39.6	$6.0	$35.5	$30.8	$4.7
Indirect	$301.0	$246.8	$54.2	$163.1	$133.7	$29.3	$98.3	$80.8	$17.5
Induced	$200.1	$166.1	$34.0	$120.5	$100.0	$20.5	$71.2	$59.0	$12.2
Total	$809.0	$667.0	$141.9	$329.1	$273.3	$55.9	$205.0	$170.6	$34.4

This table breaks out the total economic impact (also called output) of both closure options for J. M. Stuart by showing the direct, indirect, and induced effects (rows) and selected components of output (columns).

Tables B-1 and B-2 show economic activity over the full project lifetime, to include both the initial construction (excavation) phase and 30 years of ongoing operations and maintenance. Annual employment estimates, however, are presented in Tables B-3 and B-4 separately for the two portions of each project: the short-term construction or excavation activity and the operations and maintenance activities that continue throughout the project. The bulk of the jobs created are in the construction phase, with only a few people needed to continue operating and maintaining the remediated site once the cleanup is complete, as shown in Figures B-2 and B-3. The initial construction phase is four years for Sebree cleanup and nine years for J. M. Stuart cleanup. The operations and maintenance activities include employment during the construction phase plus 30 years of monitoring required by federal regulations.

Table B-3. Annual Employment for Sebree Closure Options

	Total Annual Employment During Construction (4 years)			Total Annual Employment in Operations and Maintenance Activities (34 years)		
	Clean Closure	**Company Closure**	**Difference**	**Clean Closure**	**Company Closure**	**Difference**
Direct	35.7	16.3	19.4	2.6	3.1	-0.4
Indirect	151.8	79.5	72.3	2.5	3.0	-0.4
Induced	94.3	48.3	46.0	2.2	2.5	-0.4
Total	281.8	144.1	137.7	7.3	8.6	-1.3

Table B-4. Annual Employment for J.M. Stuart Closure Options

	Total Annual Employment During Construction (4 years)			Total Annual Employment in Operations and Maintenance Activities (34 years)		
	Clean Closure	**Company Closure**	**Difference**	**Clean Closure**	**Company Closure**	**Difference**
Direct	31.8	25.6	6.2	3.4	3.4	0.0
Indirect	153.2	123.0	30.2	4.0	4.0	0.0
Induced	128.7	103.4	25.3	4.4	4.5	0.0
Total	313.7	252.1	61.6	11.8	11.8	0.0

Overview of the IMPLAN Model

The estimates of impacts from the IMPLAN model are specified by activities. The unique activity associated with coal ash impoundment closures analyzed in this report were best modeled using an industry spending pattern, which is different from an industry change specification approach, probably the most-used impact specification type. The six types of activity specifications in the IMPLAN model are:

- **Industry change:** This is probably the most-used impact specification, usually specifying an output or employment level.
- **Commodity change:** This activity specification takes into account that commodities in IMPLAN can be produced in multiple industries.
- **Labor income change:** A labor income change activity is generated by changes in employee compensation and/or proprietor income and only creates induced effects from changes in spending.
- **Household income change:** Household income changes can be specified for any one of the nine different household income levels. Appropriate tax rates and spending patterns are applied.
- **Industry spending pattern:** Industry spending patterns specify the shares of spending on any of the commodities within the model. The pattern includes a regional coefficient.
- **Institutional spending pattern:** Institutional spending patterns specify a change in commodities demanded as complete goods produced for consumption. The institutions can include households, state and local governments, the federal government, and enterprises.

DEFINITIONS OF IMPACT EFFECTS

Depending on the specifications used by the analyst, the IMPLAN model reports on up to three different impact effects: the direct effects, the indirect effects, and the induced effects. The model also provides an aggregate, "total effects"—the sum of those three. For a typical (industry change) analysis, the direct effects are specified by the costs of the activity (as was done for this analysis). These costs are adjusted for goods and services that are procured from outside the specified region (in this case, the two states).

- **Direct effects:** The direct effects reflect the costs (sales) and employment levels that are being specified to measure or represent a given level of production.
- **Indirect effects:** Indirect effects are the measure of the effect on the regional economy generated as firms and proprietors in the economy change production to meet the requirements of the change in output specified in the direct activity.
- **Induced effects:** Induced effects are the measure of the effect on the regional economy generated from the changes in household income that resulted from both the changes

in labor to meet the increase in production specified in the direct effects and by the estimated regional inputs required in the indirect effects.

- **Iterative solution:** Both the indirect and induced effects (together sometimes referred to as secondary effects) are based on iteratively solving the initial specified direct effect as it ripples across the region and generates additional economic activity. For the indirect effect this activity is related to the production requirements addressing the question of what other industries within the region will be able or required to increase their production given the specified direct effect. The induced effect is related to spending, as the initial increase in regional spending will generate more spending activity. The IMPLAN model built for this analysis has been structured to estimate these changes as they ripple out to the last dollar.[6]

- **Economic multipliers:** Economic impact analyses often refer to an economic multiplier, the ratio of one effect over another effect or set of effects. One commonly used multiplier is the total effect divided by the direct effect. Thus, an employment multiplier of 3.0 would indicate that for every 100 direct jobs needed for a given activity, 200 additional jobs would be generated in all regional industries and governments. In this example, an employment multiplier of 3.0 refers to the total 300 jobs associated with all activity (200 indirect and induced jobs plus the 100 direct jobs) divided by the initial 100 direct jobs.

DEFINITIONS OF ECONOMIC VARIABLES

Impact results are estimated by the IMPLAN model for six different general economic measures as well as up to 75 state and local government tax categories and potentially 35 federal government categories. These variables are estimated for each impact effects identified above. The six general economic measures include the following.

- **Output:** This is a broad summary measure of production that primarily measures the change in sales but also includes the changes in inventories that would be associated with the changes in production.

- **Employment:** The IMPLAN model uses full- and part-time employment counts from the federal government.[7] IMPLAN uses this measure as opposed to full-time equivalent employment to be consistent in source definitions with the measures of value added provided by the same federal agencies (primarily the BEA as noted above but also the Census Bureau's State, County and Zip Code business patterns program.)

- **Value added** includes four components in the IMPLAN model:

[6] A reduction in economic activity can be modeled the same way, and these effects will account for the reduced economic activity.

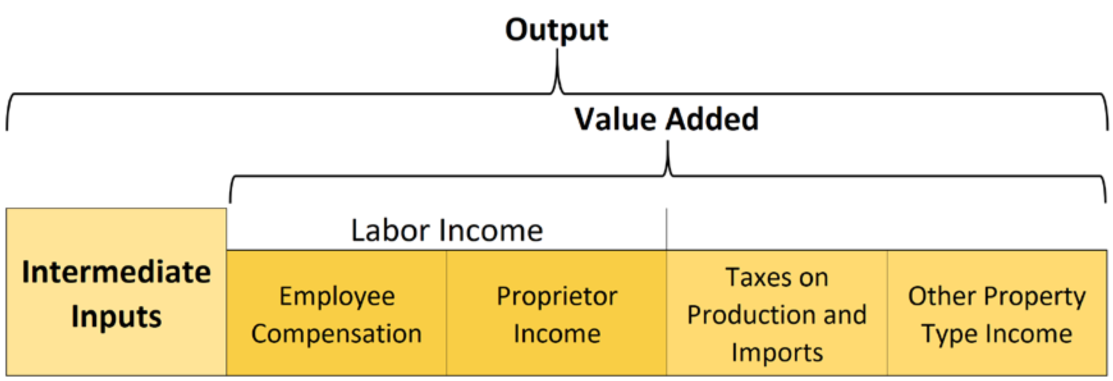
[7] Employment counts come from the Bureau of Labor Statistics and the Bureau of Economic Analysis.

- **Employee compensation:** This is a measure of employees' salaries and all benefits.
- **Proprietor income:** Proprietor income is a labor payment received by self-employed individuals and unincorporated business owners.
- **Other property type income**: Other property type income is gross operating surplus minus proprietor income, and includes consumption of fixed capital, corporate profits, and net business transfer payments.
- **Taxes on production and imports:** Indirect business taxes, or taxes on production and imports, include sales and excise taxes, customs duties, property taxes, motor vehicle licenses, severance taxes, other taxes, and special assessments.

- **Labor income:** Labor income, the value that initiates the induced effects, is the aggregate of the two components of value added that accrue directly to the region's households: employee compensation and proprietor income.

Each of these economic variables is estimated for each industry within the specified region for each impact effect the model estimates. Figure B-4 shows graphically how the economic variables are interrelated.

Figure B-4. Graphical Representation of Components of Economic Output as Defined by the IMPLAN Model



Repairing the Damage

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

Appendix C: Coal Ash Reuse

www.ucsusa.org/resources/coal-ash-cleanup-benefits

Eric Dixon

October 2021

The Scale of Coal Ash Reuse

Coal ash disposal—but not its reuse—is subject to regulation under the Resource Conservation and Recovery Act (Federal Register 2015; Seidler and Malloy 2020;[1]). For this reason, the 2015 Coal Combustion Residuals (CCR) rule distinguishes between coal ash disposal and reuse, and provides a method for assessing whether an application qualifies as reuse (Seidler and Malloy 2020; ORCR and OLEM 2016). Coal ash has been reused to some extent for decades—and specific coal combustion residuals are more common in certain reuse applications. Research on coal ash reuse stretches back to 1937, and by 1949 coal ash was used as a cement replacement in the construction of the Hungry Horse Dam in Montana (Seidler and Malloy 2020).

The American Coal Ash Association (ACAA) is a trade organization dedicated to the reuse of coal ash, and its members include many of the largest electric utilities in the country. ACAA conducts an annual voluntary survey among utilities to gather data on national coal ash production and reuse. Typically, the respondents to the survey represent only a portion of the total power capacity nationally. For example, ACAA reports that in 2009 respondents represented 59 percent of total generating capacity nationwide; in 2019 respondents represented 64 percent (ACAA 2021a).

QUANTITIES OF COAL ASH REUSED

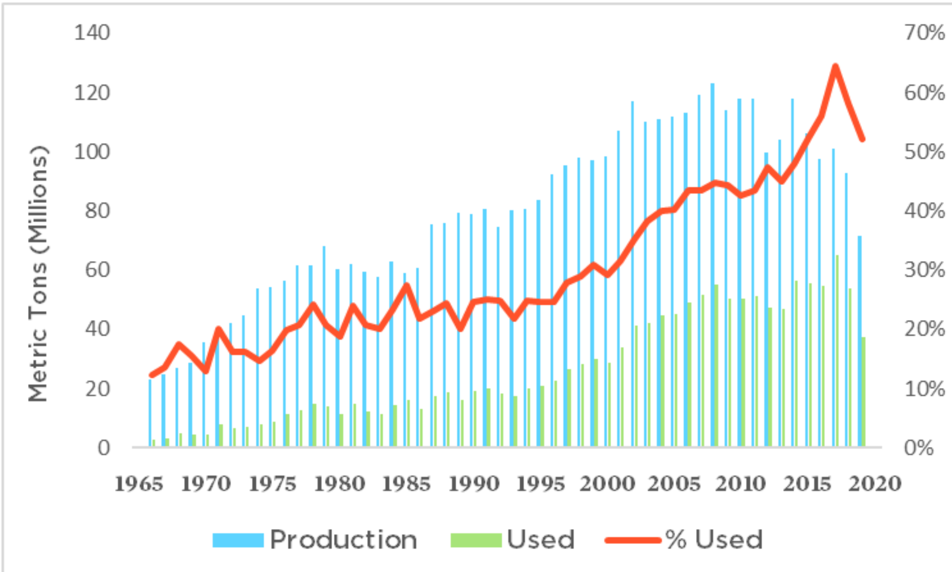
According to ACAA, approximately 52 percent of coal ash waste was reused in 2019, and 34 percent of coal ash has been reused in total since 1966 (ACAA 2021a). These estimates include both encapsulated and unencapsulated reuse applications. All of these applications are considered "beneficial" according to ACAA, but, as discussed below, some are controversial. Figure 1 shows the production and reuse of coal ash since 1966, the first year for which these data are available. The annual volume of coal ash produced has grown dramatically over the past half century: production in 2019 was over 2 times larger than in 1966.

The *portion* of coal ash that is reused annually also increased sharply over time. As of 2019, 52 percent of coal ash was reused—significantly higher than the 12 percent in 1966 and slightly lower than the 2017 peak of 64 percent. The combination of higher production and a higher reuse rate resulted in a 2019 reuse tonnage that was more than 12 times larger than in 1966 (37 million metric tons compared with 2.8 million metric tons). If we look at the entire 1966–2019 period in total, 4.3 billion metric tons of coal ash were produced. Only 34 percent (1.4 billion

[1] See pages 4 and 62 in Seidler and Malloy (2020): "Beneficial uses of coal ash, however, are not subject to regulation by [the Environmental Protection Agency] under [the Resource Conservation and Recovery Act]. Although [the act] was designed to 'conserve valuable material and energy resources by [promoting] . . . new and improved methods of collection, separation, and recovery, and recycling of solid wastes,' conservation activities are exempt from direct regulation. Consequently, in promulgating national minimum criteria for coal ash disposal, [the Environmental Protection Agency] promulgated a definition of beneficial use to differentiate those use activities that would not be classified as disposal from regulated disposal activities."

metric tons) were reused, meaning that in the past 54 years at least 2.8 billion metric tons of coal ash were disposed of.

Figure 1. Coal Ash Production and Use, 1966–2019.



Note: The production and use values for 1966 through 2015 are from the U.S. Geological Survey (USGS 2014), which relied on ACAA for the period 1966 through 1993, its own data for 1994 through 2001, and ACAA data for 2002 through 2015. The production and use values for 2016 through 2019 are from the annual ACAA survey. See USGS 2014 for notes on this data, including regarding early years when data for certain CCRs was unavailable and excluded.
Sources: USGS (2014); ACAA (2021a).

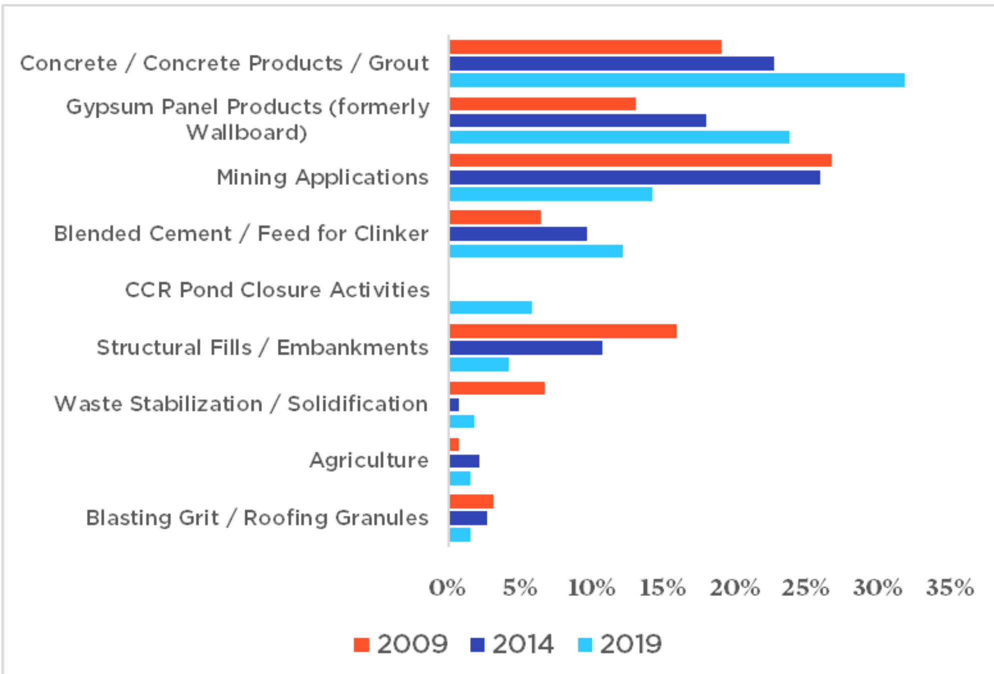
REUSE OF ENCAPSULATED COAL ASH

Figure 2 outlines the top nine reuse categories as of 2019, which represented 97 percent of total coal ash reused (by tonnage). About one-third of total coal ash that was reused in 2019 was reused in concrete products. Almost a quarter of total coal ash reused in 2019 was reused in wallboard, or drywall, as synthetic gypsum; the use of synthetic gypsum in wallboard avoids mining virgin gypsum (Seidler and Malloy 2020). It is common for wallboard manufacturers to locate adjacent to power plants in order to utilize directly the synthetic gypsum from coal ash (Seidler and Malloy 2020). These two reuse applications are the most common, and their use is growing. In 2019, these two categories represented 56 percent of total coal ash reused, up from 32 percent in 2009. Though, in 2019 the tonnage of coal ash reused in concrete products and wallboard was only 29% of total coal ash *production* (ACAA 2021a) Both applications are encapsulated and considered beneficial uses of coal ash according to the EPA.

In addition to improving the performance of materials, reusing coal ash instead of mining or producing virgin materials can yield considerable emissions reductions. According to ACAA, reusing a ton of fly ash[2] in concrete avoids roughly a ton of CO_2 emissions (Seidler and Malloy 2020). ACAA claims that 250 million tons of greenhouse gases have been avoided by reusing coal ash in cement production since 2000 (ACAA 2021b).

However, fly ash often has to undergo a "beneficiation" step to make it chemically suitable for use in concrete (Gardner and Greenwood 2017), which can increase the global warming emissions associated with this type of coal ash reuse. For example, typically there is too high a percentage of combustible content remaining in coal ash and it must undergo additional processing which utilizes energy (Gardner and Greenwood 2017). Beneficiation processes, as well as transporting the fly ash, require energy and thus emissions, and a full analysis of the lifecycle of reuse and its benefits should weigh the environmental impacts of beneficiation as well.

Figure 2. Reuse Category as Percent of Total Reuse Tonnage, 2009—2019



Note: This chart only includes categories that were at least 1 percent of total reuse tonnage in 2019; the top nine of the 17 reuse categories listed by ACAA are included

REUSE OF UNENCAPSULATED COAL ASH

Other common reuse applications—for mine reclamation and for structural fills—are much more controversial. Both of these reuse applications use unencapsulated coal ash. Loose coal

[2] Fly ash is coal ash that is expelled from the boiler with flue gases and is captured by pollution control systems.

ash has been used as filler for mine pits, contouring landscapes, and leveling uneven surfaces for transportation or construction projects.

When coal ash is used as a filler, there is risk of contaminants leachinginto groundwater or surface water, and a concern that unencapsulated reuse as filler is a backdoor means of coal ash disposal that avoids regulation. In a 2011 report, the inspector general of the Environmental Protection Agency acknowledged that “sand and gravel pits as well as large-scale fill operations, represent disposal rather than beneficial use” (OIG 2011). As of 2015, the agency’s test for “beneficial reuse” requires unencapsulated non-roadway projects above 12,500 tons—that is, projects large enough to be landfills—to not result in more environmental releases than analogous material that does not contain coal ash (ORCR and OLEM 2016; Ward 2019). Any pollutant releases must be below relevant human health and ecological benchmarks (EPA 2014b; Seidler and Malloy 2020).

Trade groups like ACAA argue that these applications are safe, noting that unencapsulated use as structural filler has a history stretching back to the 1970s and is governed by extensive industry and engineering standards (Ward 2019). The engineering benefits of using coal ash as fill are evident; however, the concern is that these applications are not worth the risk of contamination. For example, the Environmental Protection Agency determined that coal ash used as fill for a golf course in Virginia did not qualify as beneficial reuse (Seidler and Malloy 2020). In the Town of Pines, Indiana, unencapsulated coal ash was used as filler throughout the town, resulting in the contamination of water wells and the eventual declaration of the entire community as a Superfund site (Gottlieb, Gilbert, and Evans 2010).

NEW REUSES

In addition to these common reuse applications, utilities and other stakeholders are exploring new end uses for coal ash. Georgia Power and the Electric Power Research Institute opened the Ash Beneficial Use Center in 2020 to pilot new methods of coal ash reuse (Gaffney 2021). Some researchers are exploring the potential of reusing coal ash for carbon nanomaterials, which could be used for many applications, including making stronger materials (Seidler and Malloy 2020). Cenospheres—light, hollow spheres that can be separated from coal ash by water and then coated with metals—are also being pursued for their potential use in lightweight car manufacturing, battery casings, and other applications (Seidler and Malloy 2020).

The specific elements in coal ash can vary based on the location of the mined coal and the emissions controls at the specific power plants, and this variety in coal ash composition impacts the feasibility of different reuse applications (Seidler and Malloy 2020). This is especially the case with the potential of extracting rare earth elements from coal ash. The company Optimus, an extension of the University of Kentucky, and the Asian Coal Ash Association are partnering to develop an eco-industrial park model that would theoretically reuse coal ash in various processes and applications in adjacent locations (Seidler and Malloy 2020).[3]

The Need for Proper Regulation

Coal ash, if unregulated, poses considerable risk of contaminating water sources and thus harming public health (OIG 2011). Historically, the reuse of coal ash—particularly unencapsulated reuse as fill—has been utilized to dispose of coal ash in an unregulated way and has been promoted by the Environmental Protection Agency without proper examination of the risks. In 2011, a report by the Environmental Protection Agency inspector general found that the agency had promoted the "beneficial reuse" of coal ash but "did not follow accepted and standard practices in determining the safety of the 15 categories of CCR beneficial uses it promoted" (OIG 2011).

Given the considerable public health risk, the precautionary principle should be utilized in assessing new and future coal ash reuse applications: policymakers should be cautious about allowing the reuse of coal ash and should place a reasonable burden of proof on industry in demonstrating that applications are safe prior to approving reuse (Gottlieb, Gilbert, and Evans 2010). The environmental benefits of reuse can be considerable, but policymakers should remain diligent about weighing these against the risks, particularly as many stakeholders will continue to pursue reuse for its economic benefits. As an example, the cost of fly ash is roughly half the cost of Portland cement, making fly ash reuse in concrete a billion-dollar industry (Gardner and Greenwood 2017). Coal ash reuse in other applications could be similarly lucrative.

Reuse of coal ash in unencapsulated applications should demonstrate, according to research specific to the application and across a range of cases, that such reuse poses no greater public health risk than analogous materials (Federal Register 2015; Gottlieb, Gilbert, and Evans 2010). Unencapsulated reuse, given the inherit risk of its physical form and the history of mistreatment as disposal, should be treated legally as disposal, with the appropriate regulatory and monitoring controls (Gottlieb, Gilbert, and Evans 2010).

REFERENCES

ACAA (American Coal Ash Association). 2021a. "Coal Combustion Products Production and Use Reports." Denver, CO. https://acaa-usa.org/publications/production-use-reports/

———. 2021b. "Fact Sheet: Coal Ash Regulation and 'Unencapsulated' Beneficial Use." Denver, CO. https://docs.house.gov/meetings/IF/IF18/20210415/111450/HHRG-117-IF18-20210415-SD024.pdf

———. 2016. "2015 Coal Combustion Products Production and Use Reports." Denver, CO. https://acaa-usa.org/wp-content/uploads/coal-combustion-products-use/2015-Survey_Results_Table.pdf

———. 2012. "2011 Coal Combustion Products Production and Use Reports." Denver, CO. https://acaa-usa.org/wp-content/uploads/coal-combustion-products-use/Final2011CCPSurvey.pdf

Federal Register. 2015. *Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities. 40 CFR Parts 257 and 261*. Vol. 80 FR 21301. A Rule by the

[3] See pages 55 and 56 of Seidler and Malloy (2020), who cite David Harris, *Coal Combustion Products and the Circular Economy*, Asian Coal Ash Association, Optimus Mgmt. Ltd., at slide 12 (2017), http://unia-ups.pl/wp-content/uploads/2016/03/Harris.pdf.

Environmental Protection Agency on 4/17/2015. Washington, DC. https://www.federalregister.gov/documents/2015/04/17/2015-00257/hazardous-and-solid-waste-management-system-disposal-of-coal-combustion-residuals-from-electric

Gaffney, Austyn. 2021. "Can Harvesting Rare Earth Elements Solve the Coal Ash Crisis?" *Sierra*, February 3, 2021. https://www.sierraclub.org/sierra/2021-2-march-april/feature/can-harvesting-rare-earth-elements-solve-coal-ash-crisis

Gardner, Kevin H., and Scott Greenwood. 2017. "Beneficial Reuse of Coal Ash from Dominion Energy Coal Ash Sites: Feasibility Assessment." Prepared for Southern Environmental Law Center and the Potomac Riverkeeper Network.

Gottlieb, Barbara, Steven G. Gilbert, and Lisa Gollin Evans. 2010. "Coal Ash: The Toxic Threat to Our Health and Environment." Washington, DC: Physicians for Social Responsibility and Earthjustice. https://www.psr.org/wp-content/uploads/2018/05/coal-ash.pdf

OIG (Office of Inspector General). 2011. "EPA Promoted the Use of Coal Ash Products with Incomplete Risk Information." Report No. 11-P-0173. Washington, DC: Environmental Protection Agency.

ORCR and OLEM (Office of Resource Conservation and Recovery and Office of Land and Emergency Management). 2016. "Methodology for Evaluating Beneficial Uses of Industrial Non-hazardous Secondary Materials." EPA 530-R-16-011. Washington, DC: Environmental Protection Agency. https://www.epa.gov/smm/methodology-evaluating-beneficial-uses-industrial-non-hazardous-secondary-materials-and

Seidler, Maria, and Ken Malloy. 2020. "A Comprehensive Survey of Coal Ash Law and Commercialization: Its Environmental Risks, Disposal Regulation, and Beneficial Use Markets." Washington, DC: National Association of Regulatory Utility Commissioners.

USGS (U.S. Geological Survey). 2014. "Coal Combustion Products Statistics." In T. D. Kelly and G. R. Matos, Comps., *Historical Statistics for Mineral and Material Commodities in the United States*. U.S. Geological Survey Data Series 140. Washington, DC. http://minerals.usgs.gov/minerals/pubs/historical-statistics/

Ward, John. 2019. "Structural Fill: Conserving Natural Resources Through Projects Featuring Rigorous Engineering Standards." *Ash at Work: Applications, Science, and Sustainability of Coal Ash* No. 2, pp. 19-23.