U.S. House Committee on Energy and Commerce
Subcommittee on Environment
"A Decade Later: A Review of Congressional Action, Environmental Protection Agency Rules, and Beneficial Use Opportunities for Coal Ash."
Documents for the Record
June 26, 2025

1. A letter from the American Cement Association addressed to Chairman Guthrie, Ranking Member Pallone, Chairman Griffith, and Ranking Member Tonko, submitted by the Majority.
2. Testimony of James Kenney to the U.S. House Committee on Appropriations, Subcommittee on Interior, Environment, and Related Agencies, submitted by Rep. Tonko.
3. An article from Inside EPA entitled, "North Dakota DEQ Chief Eager to Work with EPA Amid Budget Cut Worry," submitted by Rep. Tonko.
4. An article from the Paducah Sun entitled, "It's American Ingenuity: TVA Transforms McCracken Coal Ash Site into Innovative Solar Farm," submitted by the Majority.
5. A fact sheet from the Tennessee Valley Authority (TVA) entitled, "Burden vs. Benefit: Optimizing CCR Regulation to Unleash American Energy," submitted by the Majority.
6. A fact sheet from TVA entitled, "TVA Draft Programmatic Environmental Assessment for Beneficiation Facilities," submitted by the Majority.
7. An article from the New York Times entitled, "How Black Lung Came Roaring Back to Coal Country," submitted by the Minority.
8. A report from the Environmental Protection Agency entitled, "Risk Assessment of Coal Combustion Residuals: Legacy Impoundments and CCR Management Units," submitted by the Minority.
9. An article from the Environmental Protection Agency entitled "Radioactive Wastes From Coal-fired Power Plants," submitted by the Majority.
10. A letter from the American Public Power Association, addressed to Chairman Guthrie, Ranking Member Pallone, Chairman Griffith, and Ranking Member Tonko, submitted by the Majority.

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June 26, 2025

The Honorable Brett Guthrie
Chair
Committee on Energy and Commerce
U.S. House of Representatives
Washington, D.C. 20150

The Honorable Frank Pallone
Ranking Member
Committee on Energy and Commerce
U.S. House of Representatives
Washington, D.C. 20150

The Honorable Morgan Griffith
Chair
Committee on Energy and Commerce
Subcommittee on Environment
U.S. House of Representatives

The Honorable Paul Tonko
Ranking Member
Committee on Energy and Commerce
Subcommittee on Environment
U.S. House of Representatives

Dear Chair Guthrie, Ranking Member Pallone, Chair Griffith, and Ranking Member Tonko:

On behalf of the American Cement Association (ACA), I write in support of your hearing, *A Decade Later: A Review of Congressional Action, Environmental Protection Agency Rules, and Beneficial Use Opportunities for Coal Ash*.

Cement is essential to building and maintaining the nation's infrastructure – from highways and bridges to airports, mass transit systems, and water facilities. Our products enhance energy efficiency in buildings, improve fuel efficiency on roads, and contribute to the resilience of critical infrastructure. Cement and concrete manufacturing supports over 600,000 American jobs and contributes more than $100 billion to the U.S. economy annually.

Over the past decade, legislation and regulation have paved the way for limited use of coal combustion residuals (CCRs), but significant opportunities remain to promote innovation and the industriousness of cement manufacturers to maximize their value. As you examine legacy CCR impoundments, we urge Congress and the Environmental Protection Agency (EPA) to promote the responsible beneficial use of CCRs—an approach that protects public health and the environment while strengthening domestic cement manufacturing and capturing the associated economic benefits.

Coal Combustion Residuals in Cement

ACA supports the responsible beneficial reuse of CCRs that have historically been disposed of at impoundments and landfills. CCRs are chemically stable and decarbonated. When used as kiln feedstock, they displace virgin raw materials like limestone and reduce emissions from cement production.

Further, CCRs enhance the strength and durability of cement. The U.S. Department of Transportation and many state DOTs recognize CCRs as essential supplementary cementitious materials, particularly in concrete for critical infrastructure. Coal ash has unique properties that drives a chemical reaction with cement during the hardening process, ultimately allowing for concrete production that is similarly dense, less porous, and more resistant to erosion. As the industry works to expand domestic production to meet our nation's infrastructure and energy dominance goals, continued access to CCRs is vital.

Beneficial Use Policy

To that end, the ACA is concerned by the existing regulatory framework that EPA finalized in May 2024, following a flawed rulemaking process that relied on inadequate evaluations and risk assessments.

Specifically, the EPA did not properly evaluate the environmental and economic advantages of removing and reusing CCRs for industrial applications like cement manufacturing. The EPA further failed to provide a reasonable explanation of its decision as to why the rule does not provide flexibility to allow for beneficial use. By restricting access to harvestable CCRs, the rule limits the industry's ability to enhance energy security, reduce emissions, reuse industrial byproducts, and eliminate legacy impoundments altogether.

EPA's rule misses the mark on creating a win-win scenario whereby material is removed from environmentally-sensitive sites *and* that same material provides sustainable and domestically sourced raw materials to industry. EPA could have incorporated flexibility and oversight mechanisms, such as groundwater monitoring, to allow safe removal and beneficial use. Instead, the agency's failure to evaluate this option renders the rule both short-sighted and, arguably, arbitrary and capricious under administrative law standards.

Lastly, EPA seemed to have also neglected to consider that CCRs can cause an increase in environmental contamination far into the future. America's local communities will bear the burden of this overly restrictive rule if industry were to be hamstrung in its endeavor to better mitigate, or even eliminate, such risks. Ultimately, EPA's rule will fail to meet the Resource Conservation and Recovery Act (RCRA)'s broad goal to protect groundwater if it restricts the availability and beneficial use of CCRs.

Conclusion

EPA should revise its policies to support responsible CCR reuse, especially from legacy sites. This approach would allow for continued oversight while promoting environmental stewardship, resource efficiency, and industrial competitiveness. Providing sufficient time prior to final closure of impoundments would enable safe, beneficial use of CCRs, helping to meet energy needs, emissions goals, and infrastructure demands.

We appreciate the Committee's efforts to examine this issue. We encourage bipartisan support for pragmatic, economically-viable solutions that tackle the complexities of coal ash use and storage while simultaneously protecting human health, advancing sustainability, and strengthening domestic manufacturing. Thank you for your consideration of this letter. If you have any questions, please contact me at soneill@cement.org or (202)719-1974.

Sincerely,

Sean O'Neill
Senior Vice President, Government Affairs
American Cement Association

Testimony of James Kenney,
Cabinet Secretary, New Mexico Environment Department
and President, Environmental Council of the States,
to the U.S. House Committee on Appropriations,
Subcommittee on Interior, Environment, & Related Agencies
Addressing the FY26 Budget Request for the U.S. Environmental Protection Agency

FY26 Funding to States. The Environmental Council of the States (ECOS) – the national nonprofit, nonpartisan association of state, territorial, and District of Columbia environmental agency leaders (hereinafter referred to as "states") – appreciates the opportunity to submit written testimony on the Fiscal Year 2026 (FY26) U.S. Environmental Protection Agency (EPA) budget. For FY26, states request robust funding for state-led implementation of the nation's environmental programs, including not less than $683.097M for four specific Categorical Grant programs using FY24 enacted levels as the minimum funding amount – **State and local air quality management (Sec. 103, 105, and 106) at $235.922M, Resource Recovery and Hazardous Waste Grants at $105.5M (FY20 levels for hazardous waste and FY24 levels for coal combustion residuals or CCR and recycling), Water Pollution Control (Sec. 106) at $225.685M, and Public Water System Supervision (PWSS) at $115.99M.** These funds directly support the implementation of our nation's environmental programs at the state-level of government. Moreover, this funding level improves and sustains cooperative federalism by ensuring decisions related to state economies and environmental issues occur at the state level of government as opposed to the federal level. States support funding above the FY24 minimum levels for the four Categorical Grants – essentially state implementation grants – to reflect increased business, municipal, and community needs. For example, ensuring safe drinking water from emerging contaminants like per- and polyfluoroalkyl substances (PFAS) while hardening our drinking water infrastructure from cybersecurity threats demands a PWSS grant investment of a greater amount, such as **$200M**. In addition, states request appropriations at the fully authorized amount of **$3.25B each for the Clean Water (CW) and Drinking Water (DW) State Revolving Funds (SRFs)**. With such funding, states can increase investment in municipal infrastructure and leverage private sector investments to address the pressing issues impacting their economies and environment.

Critical Funding Juncture. States carry out more than 90% of the nation's federal environmental laws in communities around the United States, and states, state legislatures, and the business community depend on Congress to fund our efforts through grants and partnerships with EPA, including with its science labs and research and development functions. Dramatic budget cuts to EPA that are passed along to states will incapacitate state environmental programs while creating massive uncertainty for state legislatures and businesses across the United States. If that occurs, states, in cooperation with their legislatures, would need to evaluate the fiscal impact of passing these program implementation costs to their industry or taxpayers. Candidly, states may elect to terminate primacy, delegation, or authorization agreements and return full program

implementation to EPA. In addition, state primacy, delegation, or authorizations were approved by EPA and published in the Federal Register following public notice and comment. Such primacy, delegation, or authorization agreements are predicated on resource demonstrations that include a federal and state cost share. A reduction or elimination of the federal cost share will create implementation issues resulting in legal liabilities that may contribute to a state's decision to return a program to EPA for implementation within a state.

Cooperative Federalism Model. Our nation's environmental laws establish a process whereby Congress establishes the law, EPA sets national minimum standards for the designated pollutant or technology, and states implement these regulations through primacy, delegation, or authorization of federal programs to achieve the standards.

Congress established a required state match of federal funding, for instance requiring a 25% match of total project costs for the PWSS /drinking water and hazardous waste management programs, as well as a 40% or maintenance of effort match for Section 105 air pollution control programs. However, states invest funds far beyond the statutory requirements to meet the needs of businesses and our communities.

EPA's 18 categorical grants, funded by Congress through EPA to states support regulatory and competitive grant programs, have been stagnant or declined over the past 20 years. Categorical grants were funded at $1.143B in FY2003 and $1.106B in 2025 - $37M less in real dollars before inflation. Without sufficient federal funding, states may risk losing their primacy, delegation, or authorization agreements and be subject to increasing risks from third-party claims and petitions.

One of the most important things Congress can do for state constituencies is to provide increased federal funding directly to states. Through funding partnerships, states spend federal funding to deliver legally defensible permits that further invest in our communities, assure permits are being followed, conduct modeling to safeguard air and water quality, timely respond to natural disasters that impact our residents, and provide many other necessary services to boost local and national economies.

Meeting State Capacity Needs. As ECOS President, I issued a January 3, 2025 letter detailing top ECOS priorities. At a March 24, 2025 National Governors Association-ECOS Congressional Briefing on Environmental Protection, Idaho Department of Environmental Quality Director Jess Byrne noted, "Our state is working hard to support economic development but is having a hard time keeping up. A lack of funding to competitively compensate permit writers has resulted in significant turnover. It used to take an average of 89 days for an air quality permit to construct. Now, it takes 165 days for the same permit. We are working with our Governor, stakeholders, and legislature on additional funding, but our efforts will be undone if federal categorical grant funding is reduced."

The air is cleaner due to reductions in air emissions from regulated facilities, but this may also mean a reduction in fees collected based on tons emitted – essentially cutting funding

to state environmental agency programs as a result of their success. Core, ongoing program management does not end. States incur costs to implement new regulations or repeal existing ones and to communicate the implications with community members, businesses and their trade associations, and elected officials. The federal government must remain committed to implementing the laws Congress has passed so our communities can grow, and environmental and human health protections continue.

In addition to funding the named core categorical grants at levels not less than the enacted FY24 amounts, states continue to seek flexibility so that any increase in funding for State and Local Air Quality Management Categorical Grant be provided as CAA §103 awards to avoid match requirements and allow agencies that do not have sufficient matching general funds to still obtain grants. Reducing any unnecessary federal processes, such as administrative and reporting burdens on states, supports faster, better permits to facilitate economic growth while protecting public health and the environment.

Federal Programs. Currently, my state of New Mexico is pursuing becoming the 48th state to receive National Pollutant Discharge Elimination System (NPDES) authorization. My state fully understands the importance of federal funds when taking on a new federal program. Congress continues to signal its interest in state implementation of federal programs.

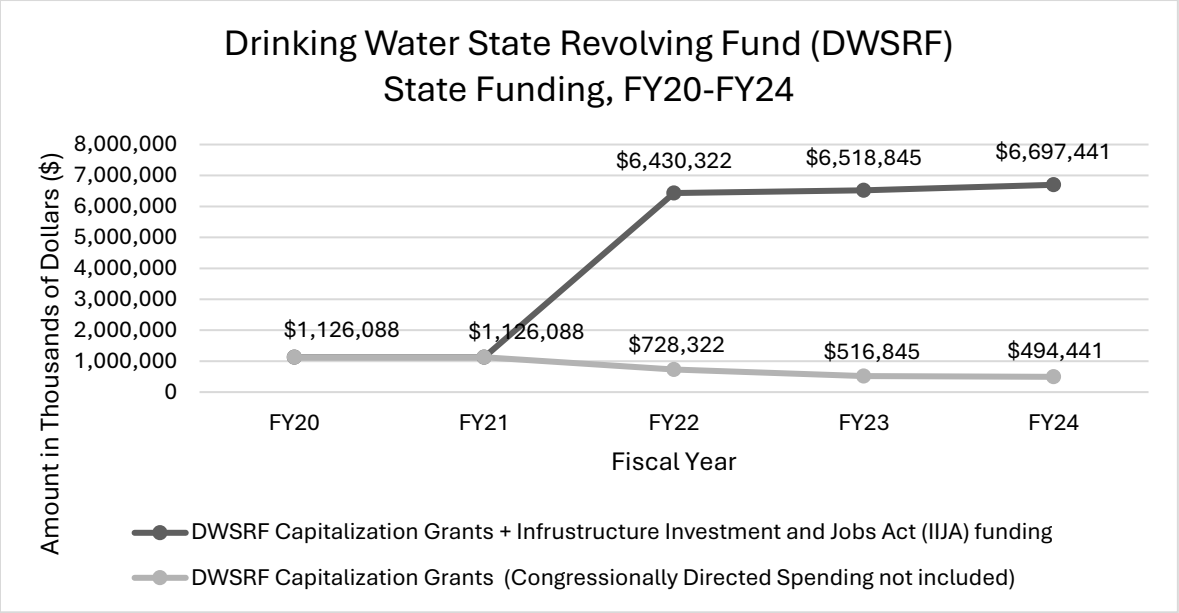
In FY21, Congress provided funding for CCR state program implementation. Congress passed the Save Our Seas 2.0 Act in December 2020 and the Infrastructure Investment and Jobs Act (IIJA) in November 2021, providing recycling infrastructure support through the Solid Waste Infrastructure for Recycling grant program. In FY24, Congress provided recycling infrastructure support through annual appropriations. In February 2025, Congress held a hearing to consider Underground Injection Control Class VI permitting for Carbon Capture, Utilization, and Storage and the potential for a new state authorized program. States appreciate and rely on new funding for new programs.

In FY24, the now-renamed Resource Recovery and Hazardous Waste Categorical Grant provided funding for CCR at $4M, Recycling at $5M, and Hazardous Waste program implementation at $92.5M – a drop to core state hazardous waste programs from $96.5M in FY20. If multiple programs are combined in a single Categorical Grant, states request that Congress provide adequate funding for each program and not at the expense of other grants. States request that Congress provide in FY26 not less than $96.5M – FY20 enacted funding level - for hazardous waste programs in addition to funding for CCR at $4M and recycling programs at $5M which are FY24 enacted levels.

Advancing Water and Energy Infrastructure. According to the Council of Infrastructure Financing Authorities, the subsidized loans offered by the CWSRF and DWSRF nationwide to build clean water and drinking water infrastructure can save communities up to 75% in interest payments. In 2022, the average interest rate was 1.25%, compared to market rates that exceeded 3% and are among the highest interest rates in decades. Lower interest rates

achieved through SRFs result in more affordable water rates, a more favorable platform for business development, and cleaner water.

IIJA SRF funding substantially increased federal investments for communities and for clean, affordable water for five years, ending in FY26. IIJA supplemental appropriations helped cover the across-the-board state capitalization grant cuts for most states due to Community Project Funding/ Congressionally Directed Spending (CPF/CDS). In FY24, CPF/CDS made up approximately half of the SRF appropriation, and a funding cliff looms after FY26 – or sooner – if Congress adjusts IIJA investments (see example chart on DWSRF state funding). States encourage Congress to support reauthorization of the CWSRF and DWSRF, which expire in 2026, and to support appropriations at authorized levels for FY26 of $3.25B each.



ECOS also continues to advocate that funding for CPF/CDS projects and project administration be kept separate from SRF funding. CPF/CDS funding should be additive, not decrease SRF funding, and allow for voluntary participation by states in its management.

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North Dakota DEQ Chief Eager To Work With EPA Amid Budget Cut Worry

June 16, 2025 Post

Dave Glatt, director of North Dakota's Department of Environmental Quality (DEQ), says he is happy to be working with the Trump EPA, which he expects will "let states run with a lot of things," though he continues to worry over the impact of dramatic proposed budget cuts from the agency for crucial state grant programs.

In a June 6 interview with *Inside EPA*, Glatt says he is extremely concerned about EPA's plan to slash state grant programs under Administrator Lee Zeldin's proposed budget, warning that the effort to zero out $1 billion in categorical grants and billions for water infrastructure will "have a very negative impact on the states," which do 90 percent of the work.

Even so, he sees a world of difference between the Trump and Biden EPAs, noting that he expects respect for state decisions from the first Trump term to carry over again. "I appreciated that. We have technical staff. We do the lion's share of the work in the field. We live here and know our own backyard. We still look to EPA for some guidance as a partner, a cooperative federalism partner."

Glatt was named DEQ chief in 2019 by then-North Dakota Gov. Doug Burgum (R), who is now Interior Secretary. Before that, he was chief of the environmental health section of the North Dakota Department of Health, a position he held since May 2002.

During the Biden administration, North Dakota sued EPA over many of its rules because, "they got too prescriptive" and were "trying to mandate states to take a certain path that didn't make sense, based on our knowledge of the state. And that's where the problems began," problems that were "manifested by challenges in court," that cost a lot of money.

Conversely, during the first few months of the Trump administration, Glatt is working with a completely different EPA. For example, the agency has already **approved the state's long-pending coal ash plan**.

It is also reconsidering its regional haze proposal, which the Biden administration partially disapproved because the state's "conclusion, at the end, was not what they thought it should be," according to Glatt.

The DEQ director says North Dakota has been trying to get its coal combustion residuals (CCR) program approved since 2002 and toward the end of the Biden administration a frustrated Glatt told EPA that it must either approve the plan or not, and if it were to issue a disapproval the state would sue, after years of hemming and hawing.

"And then, as soon as Trump got in, we got a phone call from his appointee saying, 'We looked at the program. It's good. We're going to move forward with approval.'"

Now, "I get the feeling that as long as we follow the law and the science, they'll approve it," he says.

Under Biden, "you got the feeling after a while that because you are a fossil fuel state, there was nothing we could do short of shutting down coal-fired power plants that could please the last administration," which acknowledged the state was in compliance with its federal requirements but wanted it to "do more."

"If we're in compliance, why do more? We have standards for a reason," Glatt argues.

'Too Far With Industry'

Additionally, during Trump 1.0 the state "had issues" with EPA "trying to go too far with industry, and we said no. The states have been pretty good about walking down the middle of the road and weathering the regulatory pendulums that

go back and forth. We stay in the middle and are consistent, and we made it clear to industry we're not changing because of the administration."

One example of tension in the first Trump term included when EPA tried to give too many concessions to the oil industry regarding spills. "And we said, 'No,' this is a state issue and we will handle it." After "very pointed discussions," EPA backed off, and industry was "appreciative of our approach because it means they don't have to guess."

So far during Trump 2.0, North Dakota has had minimal communications with EPA, which is "going through chaotic changes . . . and the dust really hasn't settled," Glatt says, adding this is true at both Region 8 and headquarters.

During the last administration, Glatt says headquarters made the "big decisions," while the region was often "stepped over."

On enforcement, Glatt is not worried that EPA plans to back off and **put far fewer resources** toward those efforts, noting that it should be "up to the state to decide what type of enforcement should be taken. We're fine with that. We have a very active enforcement program," with a different philosophy than the feds.

North Dakota wants companies to "get in compliance first and we'll see what the impact on the environment was, how bad noncompliance was, was it willful, was it an accident, who is impacted?"

In-state companies "self report at a pretty high level, and that is good." Some incidents are "no fault of their own. . . Things happen, so let's fix it."

'EPA Has To Change'

However, even as Glatt remains extremely concerned about Zeldin's effort to dramatically reduce state funding, he notes that even if Congress were to reinstate all of those proposed cuts, "EPA has to change. It has to interact with the states differently," along the lines of the "back-to-basics" approach Zeldin has touted.

He wants EPA to partner with states to deliver clean air, water and land without having a "top-down approach" and recognize that the agency "doesn't have all the answers. . . . If we have a cooperative relationship, things will be better. The last four years we were in 13 or 14 different lawsuits, spending millions of dollars on attorneys. Imagine if we could have used that money for environmental protection."

Glatt adds that individual EPA staffers are "nice and have good intentions," and that the political leaders have "shown some good steps forward," such as the planned approval of the state's long-pending CCR program. "But the rank-and-file are still waiting to see who is going to be here in six months, and that is what reorganization looks like. Once that settles, then we can get to the task of working on cooperative federalism, and I think we can."

The proposed dramatic reduction in EPA staff could also be a concern, depending on how personnel is reorganized. "The last several years we have not interacted with EPA that much unless it is them telling us what to do," he says.

Glatt is not opposed to a reorganization and staff reduction, noting, "I believe you have to punch reset sometimes and reorganize and sometimes have less staff." States do that all the time. "EPA needs to go through that and I think they'll do that and come out [just fine] on the other end." -- *Dawn Reeves* (**dreeves@iwpnews.com**)

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'It's American ingenuity': TVA transforms McCracken coal ash site into innovative solar farm

- By CARLY DICK | The Sun CDICK@PADUCAHSUN.COM

  Jun 19, 2025

The Tennessee Valley Authority's solar project is under construction in McCracken County, with nearly 30,000 solar panels out of 240,000 already in place. It is expected to enter service in 2028.

A first-of-its kind solar field being built on a closed coal ash site at the Shawnee Fossil Plant in McCracken County will use innovative technology to create energy on land that would otherwise be unusable, officials with the Tennessee Valley Authority said Wednesday.

The field, called Project Phoenix, is under construction, with nearly 30,000 solar panels out of 240,000 already in place. It is expected to enter service in 2028.

TVA said Project Phoenix will meet its customers' growing demand for power while maximizing the company's assets, such as the decommissioned coal ash site.

"We can generate energy in a new way, but within the same footprint that we've occupied for decades," TVA Civil Projects Group General Manager for Strategy and Engineering Patrick Kiser said. "Part of that is capitalizing on being so close to the transmission infrastructure, so we have the plant here, and our switchyard for the plant there, and us being so close just reduces the cost that it takes for us to generate the power here and then get it on the bulk grid for distribution."

Kiser described the project as a product of American innovation, reclaiming unusable land for productivity.

"In this case, this is really the coalescence of some new technologies that allow us to make use of this landfill property that you really couldn't make much use of before," he said. "We have to maintain our regulatory requirements, but we have to do it in a way that's efficient for power production."

To maximize the solar field's energy production, TVA worked with its technology partners, who designed and developed a specialized racking system. The system allows for panels to be closer to the ground, while still receiving maximum sunlight. Other solar fields position panels at an angle and higher off of the ground to avoid shading, which reduces the number of panels that can fit in one area.

"The low profile allows us to have a high energy density there, right? That really kind of maximizes what you can generate from a smaller footprint," Kiser said.

The high-density array means the solar field will produce 1 megawatt per 3 acres, compared to other solar fields that average 1 megawatt every 10 acres. The 270-acre field will generate 100 megawatts of solar power — enough to power approximately 58,000 homes.

The coal ash site underneath the solar field is covered in synthetic turf, which TVA said minimizes groundwork costs, is lower maintenance than grass and allows TVA to continue to access the coal ash, which can be used for building materials.

"In the future, if a need arises…you could move it aside, cut the turf, roll it back, harvest for the purpose that you intend to, reshape it, roll it back, seal it back up and redeploy the solar," Kiser said.

Now that the coal ash site is closed, TVA is depositing its coal ash in a modern lined landfill on the other side of the Shawnee Fossil Plant. Kiser said the site has potential to become another solar field if desired.

“Its initial design from the start considered the long-term development of solar. So, whereas here we had to reshape the ground to optimize it for solar, we’ve kind of designed it to build it out as we go with the ash that the plant’s currently producing to optimize that solar whether we do it or not,” he explained.

Project Phoenix is a leading example of how the company could expand solar energy to its other power plants.

“We’re looking across our fleet for needs and the right fit and so we’re in the planning stages now, and as this project continues to advance and mature, and we get a better understanding, and we understand how that fits into our overall generation scheme for reliability, we’ll make those decisions,” Kiser said.

He said Project Phoenix positions TVA as a utility that is helping drive the solar industry forward.

“It’s American ingenuity. It’s American innovation that’s driving a new way of thinking and providing opportunity for us to expand the potential for solar development,” Kiser said.

TENNESSEE VALLEY AUTHORITY

Burden vs. Benefit: Optimizing CCR Regulations to Unleash American Energy

April 2025

Background

In 2015, the EPA issued the Coal Combustion Residuals (CCR) rule, which authorized two methods for closing a CCR unit based on site conditions, while confirming the classification of CCR as non-hazardous solid waste. EPA Administrators from both political parties acknowledged that closure methods should be determined by facility owners/operators to best meet environmental and structural standards.

The 2015 CCR Rule aimed to:

- Authorize units to Close In Place or Close by Removing/Relocating the CCR based on site conditions; The EPA acknowledged most units would close in place.
- Ensure closed CCR units would meet groundwater protection standards (GWPS).
- Ensure structural stability and public oversight.
- Honor a cooperative approach between the federal government and states, allowing states to set stricter rules for closing waste facilities (through 2016 WIIN Act).

EPA's New Rule: A Costly Shift in Policy

In 2022, the EPA for the first time stated that closure in place is prohibited when CCR is in contact with groundwater. This was seven years after the CCR rule had been in effect.

In 2024, the EPA introduced sweeping changes to CCR regulations and industry precedent interpretations, expanding regulations to historical ("legacy") CCR sites and other units which were previously excluded from regulation. For TVA, most of these newly regulated legacy sites have been safely regulated under state oversight well before the issuance of the Legacy CCR Rule.

In Contrast: Based on site-specific risk considerations, EPA routinely approves closure scenarios in hazardous and solid waste corrective action and cleanup, where waste is left in place in direct contact with groundwater and other media. CCR is the only self-implementing regulatory scheme that does not rely upon site-specific risk considerations driving closure decisions, stripping States of critical legal authority to make risk-based considerations when approving site-specific closure scenarios in their state.

Why It Matters

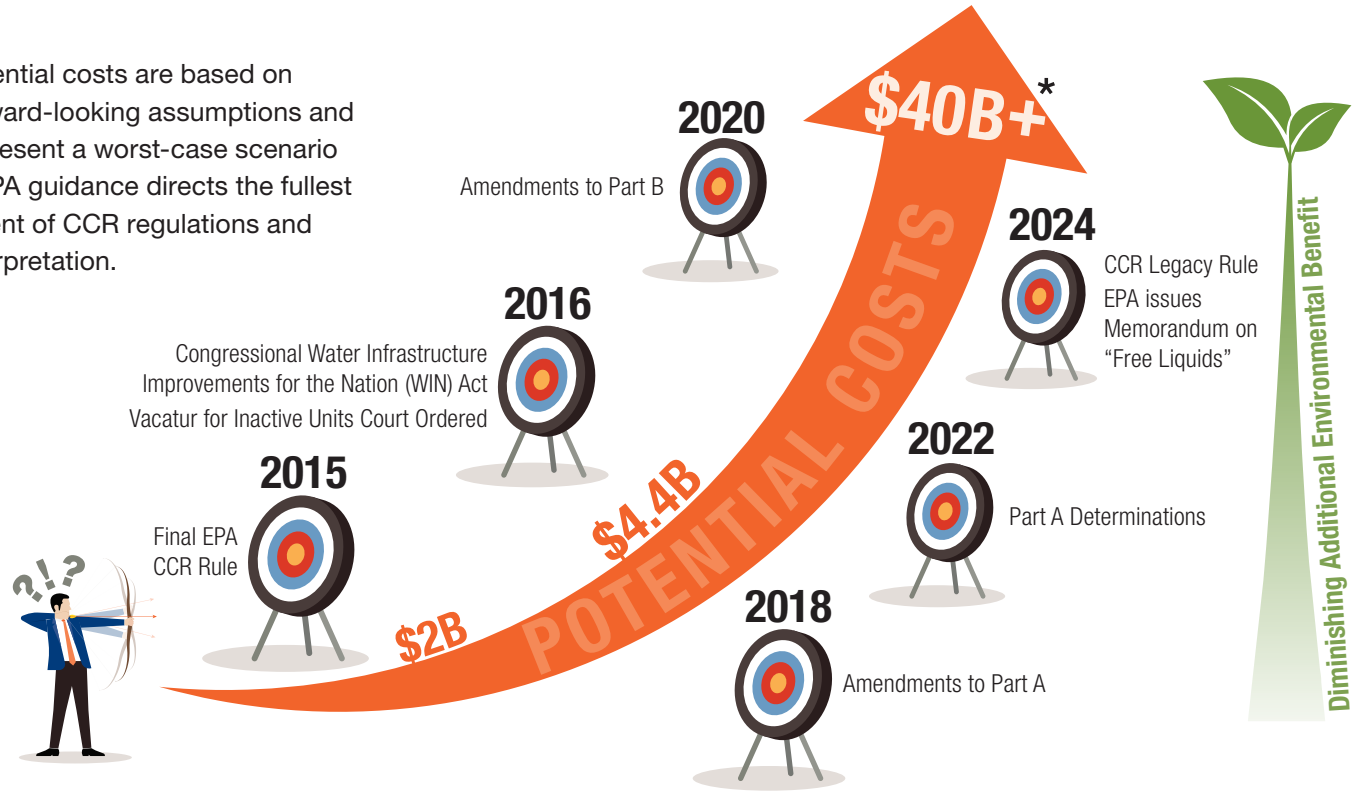
Typically, site-specific risk drives cleanup and closure decisions for remediation of solid and hazardous waste. The 2015 CCR Rule interpretations and 2024 Legacy Rule depart from this approach, imposing a rigid, one-size-fits-all approach, without relying on critical science and data to inform a unit's closure standard. This new approach will have significant financial and operational consequences for utilities and the communities they serve by:

- **Forcing the re-opening of safely closed and monitored sites**.
- **Diverting critical investments** away from new energy infrastructure.
- **Multiplying closure compliance costs for utilities**, directly affecting electricity rates.
- **Providing negligible to no measurable additional improvements** to environmental or public health protections.
- **Drastically increasing truck traffic** on local roads hauling materials to landfills.
- **Extending project durations** and creating unnecessary disruption to communities.
- **Taking up limited municipal landfill space**.

The Impact of Evolving Regulations

EVOLVING REGULATIONS DRIVE UP COST WITH MINIMAL ENVIRONMENTAL IMPROVEMENTS

* Potential costs are based on forward-looking assumptions and represent a worst-case scenario if EPA guidance directs the fullest extent of CCR regulations and interpretation.

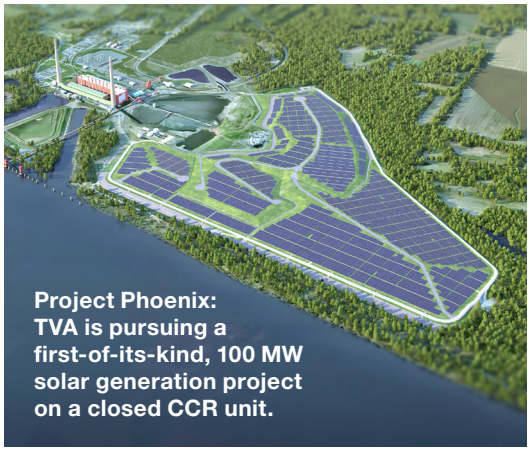


Graph is based on TVA facilities and may or may not be representative of other utility sites.




A Path to Build Tomorrow Out of Yesterday

OPPORTUNITY TO SUPPORT RISK REDUCTION AND UNLEASH AMERICAN ENERGY



Project Phoenix: TVA is pursuing a first-of-its-kind, 100 MW solar generation project on a closed CCR unit.

- **Support cooperative federalism** with a framework for state regulatory autonomy.
- Utilize **site-specific data and science** to inform closure decisions through state implementation.
- Address multiple guidance documents (ex: liquids memo) regarding **CCR in contact with groundwater.**
- Provide **post-closure flexibility** supporting long term beneficial reuse and **Closure by Harvesting.**
- Exclude **historically closed CCR landfills** and **state-approved sites** from the legacy rule.
- Promote the **repurposing of closed CCR units** for new power generation.

TENNESSEE VALLEY AUTHORITY

TVA Draft Programmatic Environmental Assessment for Beneficiation Facilities

April 2025

Background

The Tennessee Valley Authority (TVA) has released a draft Programmatic Environmental Assessment (PEA) to evaluate the potential environmental impacts of constructing and operating special processing facilities called Beneficiation Processing Facilities (BPFs) at one or more of our coal plant sites. This is part of TVA's innovative and industry-leading management of coal combustion residuals (CCR) and to further expand our beneficial reuse program.

This assessment complies with the National Environmental Policy Act (NEPA), which requires federal agencies to carefully consider environmental impacts before taking major actions. TVA's draft PEA outlines two possible paths forward—one where no action is taken, and one where CCR processing facilities are built and operated.

TVA beneficially reuses CCR as part of its mission of environmental stewardship to reduce the amount of material that must be stored and managed in a landfill. In the past five years, TVA has beneficially reused nearly 70% of the CCR produced.

What Is a Beneficiation Processing Facility?

A **Beneficiation Processing Facility** is a site where CCR materials—like fly ash, bottom ash, and gypsum—are processed so they can be reused rather than stored in landfills. There are two main types:

- **Thermal beneficiation** – uses heat to improve the quality of the material, often reducing carbon content so it can be used in concrete or other products.
- **Nonthermal beneficiation** – uses physical or chemical methods (not heat) to process CCR for reuse.

These facilities can transform previously unusable material into valuable resources for manufacturing industries.

Why Is This Important?

Environmental Benefits

Reusing CCR reduces the amount that needs to be stored in landfills.

Supports a Circular Economy

Beneficiation turns waste into usable materials for products like concrete, drywall, roofing shingles, and blasting abrasives.

Reduces the Need for Long-term Storage

TVA has about 236 million tons of CCR currently stored across its coal plants. Much of this material could be reused with proper processing.

What's Next?

Public Comment Period

A 30-day public comment period is to begin on **April 11, 2025**. TVA welcomes public input on the draft assessment during this time.

Sites Under Consideration

Ten TVA coal plants are included in the environmental review: Bull Run, Colbert, Cumberland, Gallatin, John Sevier, Johnsonville, Kingston, Paradise, Shawnee, and Widows Creek.

Next Steps

Following the public comment period, TVA will review feedback and determine how best to move forward with any site-specific plans for BPF construction and operation.

Learn More

Visit **www.tva.com/NEPA** to learn more about the draft environmental assessment and how to submit your comments during the public comment period.

Visit **www.tva.com/coalash** to learn more about TVA's industry-leading coal ash management practices.

How Black Lung Came Roaring Back to Coal Country

Once nearly eradicated, the “old man’s disease” is back and suffocating younger miners. Federal cuts risk putting a solution further out of reach.

By Kate Morgan

Photographs by Jared Hamilton

Kate Morgan lives in Pennsylvania. She traveled across central Appalachia to visit rural clinics and miners’ homes and spoke with doctors, researchers and black lung patients for this story.

Published June 19, 2025 Updated June 20, 2025

Denver Brock and his son Aundra used to spend early mornings hunting rabbits in the wooded highlands of Harlan County, Ky. But they don’t get out there much these days. They both get too breathless trying to follow the baying hounds.

Instead, they tend a large garden alongside Denver Brock’s home. Even that can prove difficult, requiring them to work slowly and take frequent breaks.

“You get so dizzy,” Denver Brock said, “you can’t hardly stand up.”

The Brocks followed a long family tradition when they became Appalachian coal miners. For it, they both now have coal workers’ pneumoconiosis, a debilitating disease characterized by masses and scarred tissue in the chest, and better known by its colloquial name: black lung.

Mr. Brock, 73, wasn’t all that surprised when he was diagnosed in his mid-60s. In coal mining communities, black lung has long been considered an “old man’s disease,” one to be almost expected after enough years underground.

But his son was diagnosed much younger, at just 41. Like his father, he has progressive massive fibrosis, the most severe form of the disease. And today, at 48, he’s even sicker.

When he followed his father into mining, he thought he was entering a safer industry than the one prior generations had worked in. By the 1990s, safety standards and miner protections had nearly consigned the disease to history.

But now, black lung is back.

Modern miners are contracting it at younger ages and at rates not seen since the 1970s. For 20th-century miners, it could take decades to develop severe black lung. For men of Aundra Brock's generation, just a few years can be enough. Nationwide, one in 10 working miners is now estimated to have black lung. In the heart of the central Appalachian coal fields, it's one in five. Often, their disease is more severe, the progression faster. Doctors are seeing larger masses and more scarring in the lungs. Transplants, disability claims and deaths are all on the rise.

In an old industry, the reasons are modern. Centuries of extraction have altered the landscape, making the mountains more dangerous to mine, researchers say, and the men beneath them vulnerable not just to black lung, but to another lung disease called silicosis.

Experts say it should be possible to reverse the trend. "The entire thing about this whole disease is it's 100 percent preventable," said Dr. Robert Cohen, a pulmonologist at the University of Illinois Chicago who has studied the disease for decades. "It's not an act of God or an act of nature. It's not something out of our control. In a wealthy country with a wealthy economy, we should be able to do better."

From an industry perspective, miner health and safety "is always an area that can be improved," said Ashley Burke, a spokeswoman for the National Mining Association, which represents more than 250 companies. Ms. Burke said the association has supported mandatory screenings, research into technologies that could protect miners and an expedited government approval process for new equipment.

But as President Trump aims to revitalize the mining industry, doctors and researchers like Dr. Cohen also worry that federal government cuts are hampering efforts to find a solution.

A Shocking Revelation

When Dr. Brandon Crum, 50, opened his radiology clinic in Coal Run Village, Ky., in 2013, he didn't expect to encounter many grave cases of black lung.

Rates had fallen in the years after Congress passed the Coal Mine Health and Safety Act of 1969, which put limitations on acceptable levels of dust and established a federal program for black lung benefits. During the 1990s, the government documented only a few dozen cases, a low number even when accounting for the steep decline in mining jobs. Progressive massive fibrosis, the type of black lung the Brocks have, was nearly eradicated.

Dr. Crum, a Kentucky native, was well aware of the trends. Before attending medical school, he had worked at his family's mine as a teenager until the coal reserves ran out.

But quickly, Dr. Crum began seeing a shocking amount of progressive massive fibrosis: 60 cases over about 18 months. And the patients were often younger. One was just 44.

Progressive massive fibrosis occurs when dust settles in the lungs, and over time the resulting inflammation turns to hardened tissue. Eventually, patients can't get enough air to allow them to climb a set of stairs or carry groceries. Trying to eat, tying their shoes or taking a shower leaves them short of breath. Coughing can bring up mucus that might be black or bloody.

Medication can sometimes slow the disease's progression, but there is no cure. Hearts fail. People can struggle to breathe as their chests fill with fluid, a slow death by suffocation. By the time the lungs are examined at autopsy, they are often the color of coal.

In 2016, Dr. Crum attended a black lung conference in West Virginia in hopes of speaking to Scott Laney, an epidemiologist at the National Institute for Occupational Safety and Health and the chief scientist of the institute's health surveillance program for coal workers. Dr. Crum explained what he was seeing, but Dr. Laney was skeptical.

"I said, 'Slow down, cowboy,'" Dr. Laney said. "People call my desk every day and say, 'I've got this, I've got that,' and we investigate, and it's nothing."

But Dr. Crum was persuasive enough that Dr. Laney agreed to travel to the clinic in Coal Run from his home in Morgantown, W.Va. There, Dr. Laney viewed one X-ray after another of the worst black lung he had ever seen.

"I was sick to my stomach," he said. "I could not believe my eyes."

Around the same time, Dr. Cohen, the pulmonologist, noticed something was amiss, too. Since the late 1980s, Dr. Cohen's work has focused on mining safety issues. He watched as rates of black lung plunged, which was why he was so surprised when clinics began sending him a number of severe cases to review.

When Dr. Cohen and his colleagues analyzed the lung tissue of 13 miners from West Virginia, Kentucky and Pennsylvania, they were alarmed to find that only one had a classic coal-based form of black lung. The others all had a form of silicosis, a lung disease more closely associated with stonecutters.

Silicosis is caused by inhaling a mineral called crystalline silica that is typically found in sand, stone and concrete. It is a building block of the Appalachians. But in the air, it is dangerous, able to create much worse scarring in the lungs than coal dust alone. Breathing the coal and silica dust together can create a kind of hybrid disease that quickly leads to progressive massive fibrosis.

Scientists and miners alike have long understood the dangers of the rock dust. "You can tell there's silica when you see the flicker in it," said Charles Thacker, a 69-year-old former miner from Norton, Va., who now has black lung. "It looks like bits of glass flashing in the light. It's almost pretty. But that's what gets in your lungs and cuts you up."

For that reason, in 1974, the occupational health institute tried to limit miners' exposure to silica by recommending mine operators ensure that their workers weren't breathing more than 50 micrograms of silica per cubic meter of air. Instead, regulators set the exposure limit twice as high, where it remained for half a century.

Through further research, Dr. Cohen's group and others repeatedly showed that miners' lungs were filling with more silica than before. There were a number of factors that were likely to have increased silica exposure, including longer hours in the mines and the advent of powerful modern machinery that created finer silica dust that could easily penetrate the lungs.

But the experts settled on one reason as the most likely: Back when Denver Brock's career began in 1969, it was typical to be working along an underground wall of coal that reached above a miner's head. Today, many of those large coal deposits have been mined out of central Appalachia. The coal that remains is encased in thick layers of quartz and sandstone. Contemporary miners have to get through more rock, and when they drill, cut and blast it apart, that rock turns to dangerous crystalline silica dust, which is exactly what doctors found in Aundra Brock's lungs.

Legal Fights, X-rays and Dashed Dreams

St. Charles, Va., is a hollowed-out place. Boarded-up buildings loom alongside the road. Wedged between the creek and the railroad tracks sits a former hardware store that now houses the nation's largest federally funded black lung clinic.

After seeing the case files collected by Dr. Crum, Dr. Laney's team reached out to a network of federally funded black lung clinics, looking for more evidence of a growing problem. Within 48 hours, Stone Mountain Health Services, which runs the clinic, had gotten in touch. Here, federal investigators documented 416 additional cases, many in men who had first felt sick in their 30s and 40s.

At the University of Virginia, Dr. Drew Harris, a pulmonologist, read the report and wanted to help. Now, once a month, he drives the 300-plus miles from his office in Charlottesville, Va., to see patients who have black lung — or might soon.

The time he spends in St. Charles is packed with appointments. He's the only pulmonologist for Stone Mountain Health Services, which runs two black lung clinics in southwest Virginia. His patients, including Mr. Thacker and the Brocks, often drive more than an hour to see him.

Dr. Harris administers breathing tests and looks over CT scans to monitor disease progression in established patients, the sickest of whom arrive with portable oxygen units. Miners who have come for an initial exam — the first step in the process to prove they have black lung and are owed benefits — get an X-ray and a breathing test and then climb on a treadmill or an exercise bike to determine their blood oxygen level.

Dr. Harris's desire to do this work makes him a rarity. Many are unwilling to get involved, because treating the disease often requires wading into the complex and contentious benefit system. When miners are deemed eligible, one of their former employers, not the government, typically provides a monthly stipend and covers the cost of treatment. Coal companies often fight a decision that doesn't go their way, and doctors frequently have to go through depositions.

The legal fights can take years and prove arduous. Denver Brock had to appeal his own case after being initially denied federal benefits, and it was years before he saw any money. Still, he said he loved mining and would do it all again. His son would still be mining, too, if he were able. When Aundra Brock finished high school, he wanted to be a husband and a homeowner. His mining salary soon paid for a tidy house in a quiet hollow, just across the road from his parents.

But today, the masses in the younger Mr. Brock's lungs have grown so large that his doctors have begun talking about a lung transplant. Even if he gets one, and the risky procedure goes well, many black lung patients live for only a few more years. Aundra Brock is resistant. Two of his own friends had the surgery and died not long afterward, he said.

Ms. Burke of the National Mining Association said that work conditions had improved over the last decade but that the benefits had yet to be reflected in the disease data, arguing that they could take 10 years to become clear. She said strict adherence to ventilation plans and compliance with a 2014 rule that lowered the acceptable amount of airborne dust had reduced dust levels.

But more than a decade out from the rule's implementation, Dr. Laney said he had been seeing more black lung, not less.

"You don't get 30- and 40-something-year-old men on bilateral lung transplant evaluations if they aren't breathing toxic dust," Dr. Laney said. And increasingly, he added, he is concerned "that young men entering the work force as coal miners will not have the same health system afforded them that their dads and their dads' dads had."

Federal Cuts and Rule Delays

On April 1, more than 800 people at the National Institute for Occupational Safety and Health, including Dr. Laney, received notices that their jobs had been eliminated as part of broader federal cuts. After a federal judge issued an injunction, Dr. Laney and others in the coal workers' health surveillance program got their jobs back. But many other government scientists focused on solving the black lung problem did not.

Among them was the entire Pittsburgh mining research division. The division had been developing technology to monitor silica dust exposure in real time, potentially preventing miners from getting sick in the first place. "These cuts are going to endanger and kill miners in this country," said Brendan Demich, an engineer at the Pittsburgh division who represents his government colleagues as vice president of their union.

Emily Hilliard, a spokeswoman for the U.S. Department of Health and Human Services, said in a statement that the most essential services for miners would continue despite cuts at the department. “Ensuring the health and safety of our work force remains a top priority for the department,” Ms. Hilliard said.

But the cuts have had a ripple effect. For more than a decade, an agency within the Department of Labor, the Mine Safety and Health Administration, had been using the occupational health institute’s data, as well as the research of Dr. Cohen and others, to develop a case for lowering the silica exposure threshold. Last year, the agency finally issued a new standard, reducing the limit to the 50 micrograms that was recommended decades ago. It was set to go into effect this April.

But in the wake of “unforeseen NIOSH restructuring,” the agency announced it would pause implementation of the rule. The announcement came less than a week before enforcement was set to begin, and on the same day Mr. Trump signed executive orders aimed at bolstering what he called the “beautiful clean coal industry.”

Even if every coal operation in central Appalachia closed tomorrow, Dr. Crum said, miners who have taken in enough of the toxic mix of silica and coal dust would need decades of care. “Then they’ll die,” he said, “and we’ll have a lot more widows and children and grandchildren whose fathers were taken much earlier than they should have been.”

One of those widows is likely to be Denver Brock’s 67-year-old wife, Loretta. A coal miner’s daughter, she can now only watch as the health of both her husband and her son deteriorates. The breaks in the garden are longer now. On cold days, the men can barely step outside without their lungs burning.

“It’s hard to watch,” Ms. Brock said. “It takes a lot of prayer to get through this.”

Audio produced by Sarah Diamond.

Read by Kate Morgan

Kate Morgan is a journalist in central Pennsylvania and a media fellow at The Nova Institute for Health.

RISK ASSESSMENT OF COAL COMBUSTION RESIDUALS:

LEGACY IMPOUNDMENTS AND CCR MANAGEMENT UNITS

April 2024

Final

Prepared By:

United States Environmental Protection Agency
Office of Land and Emergency Management
Office of Resource Conservation and Recovery

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Table of Contents

List of Tables

List of Figures

Acronyms and Abbreviations

ACAA	American Coal Ash Association
ACI	Active Carbon Injection
ARAR	Applicable or Relevant and Appropriate Requirements
ASTM	American Association of Techniques and Methods
BEIR	Biological Effects of Ionizing Radiation
CCR	Coal Combustion Residuals
CCRMU	Coal Combustion Residual Management Unit
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COALQUAL	Coal Quality Database
CTE	Central Tendency Exposure
Eco-SSL	Ecological Soil Screening Level
EIA	Energy Information Association
EPA	Environmental Protection Agency
EPACMTP	EPA Composite Model for Leachate Migration with Transformation Products
ESP	Electrostatic Precipitator
FGD	Flue Gas Desulfurization
GWPS	Groundwater Protection Standards
HELP	Hydrologic Evaluation of Landfill Performance
HQs	Hazard Quotients
HSWA	Hazardous and Solid Waste Amendments of 1984
LANL	Los Alamos National Laboratory
LEAF	Leaching Evaluation Assessment Framework
LOI	Loss on Ignition
Mgal	Millions of Gallons
MODFLOW-USGT	Modular Three-Dimension Finite-Difference Ground-Water Flow Model - Unstructured Grid Transport
NAICS	North American Industry Classification System
NOAA	National Oceanic and Atmospheric Administration

NRC	National Research Council
OLEM	Office of Land and Emergency Management
OPP	Office of Pesticide Programs
ORNL	Oak Ridge National Laboratory
PRG	Primary Remediation Goal
RCRA	Resource Conservation and Recovery Act
RESRAD	RESidual RADiation
RME	Reasonable Maximum Exposure
RSL	Regional Screening Level
TENORM	Technologically Enhanced Naturally Occurring Radioactive Material
USCHEM	United States geoCHEMical Database
U.S.	United States
USGS	United States Geologic Survey
USWAG	Utility Solid Waste Activities Group
WIIN	Water Infrastructure Improvements for the Nation

1 Introduction

The United States (U.S.) Environmental Protection Agency (EPA or the Agency) has taken many steps toward characterizing the risks that may result from disposal of coal combustion residuals (CCR) and developing regulations necessary to protect human health and the environment. This characterization of risk is conducted in support of the Resource Conservation and Recovery Act of 1976 (RCRA), as amended by both the Hazardous and Solid Waste Amendments (HSWA) of 1984 and Water Infrastructure Improvements for the Nation (WIIN) Act of 2016. A full timeline and summary of regulatory actions related to CCR disposal can be found on the Agency website.[1]

This revised risk assessment presented in this document builds on and supplements the two most recently completed analyses in that timeline, the Final Human and Ecological Risk Assessment of Coal Combustion Residuals (U.S. EPA, 2014a) and the Draft Risk Assessment of Coal Combustion Residuals: Legacy Impoundments and CCR Management Units (U.S. EPA, 2023). Specifically, EPA has revised the Draft 2023 Risk Assessment to incorporate additional information and to address the comments received from the public. This document does not aim to directly summarize or respond to the specific comments received. That is provided in a separate response to comment document available in the docket for the final rule.

1.1 Regulatory Background

In 2015, EPA finalized national regulations for management of CCR generated at coal-fired electric utilities.[2] This rule established minimum national standards under Subtitle D of RCRA for the design, operation, and closure of landfills and surface impoundments that accept CCR after the effective date of the rule on October 19, 2015. These requirements were designed to address the potential risks EPA identified through environmental modeling documented in "Human and Ecological Risk Assessment of Coal Combustion Residuals" ("2014 Risk Assessment") (U.S. EPA, 2014a) and through a review of relevant damage cases.

The 2015 Rule was challenged by multiple parties, including a coalition of environmental advocacy groups. Among the issues raised by these petitioners was their contention that the scope of the rule violated the RCRA statute. Specifically, they argued exclusion of inactive surface impoundments at inactive facilities from the regulation ("legacy impoundments") could result in unmonitored leaks to groundwater and catastrophic structural failures, which violated a baseline requirement of RCRA that promulgated criteria for solid waste disposal pose "no reasonable probability of adverse effects on health or the environment." 42 U.S.C. 6944(a). On August 21, 2018, the U.S. Court of Appeals for the D.C. Circuit issued its opinion in the case of *Utility Solid Waste Activities*

1) Available online at: https://www.epa.gov/coalash/coal-ash-rule

2) 80 FR 21302, April 17, 2015.

Group v. EPA, 901 F.3d 414 (per curiam) (hereafter "*USWAG* decision"). This decision upheld the 2015 CCR Rule on most counts but agreed with the environmental petitioners on the issue of legacy impoundments, holding EPA acted "arbitrarily and capriciously and contrary to RCRA." As a result, the Court vacated the exemption for legacy impoundments and remanded the issue back to EPA.

In 2023, EPA proposed to revise the CCR Rule in response to the *USWAG* decision and to address additional issues that have arisen since that decision as a result of mandated facility reporting.[3] The Agency first proposed a set of requirements for management of CCR in legacy impoundments that would apply to the inactive facilities where these impoundments are located ("legacy facilities"), which include the same requirements as active units with the exception of certain design requirements and location restrictions. These requirements build off the existing risk record and respond to the *USWAG* decision. The Agency also proposed a separate set of requirements for management practices that result in placement of CCR on the land outside regulated disposal units, referred to as CCR management units ("CCRMU"), which would apply to both active facilities and legacy facilities. This would extend a subset of the requirements for CCR units to CCRMU, including groundwater monitoring, corrective action, closure, post-closure care, and reporting and recordkeeping. These requirements respond to 42 alternate source demonstrations or assessment of corrective measure documents that attribute identified groundwater contamination to these units.

1.2 Purpose and Scope of the Risk Assessment

The 2014 Risk Assessment previously addressed the potential risks from disposal of CCR in landfills and surface impoundments operating onsite at electric utilities (U.S. EPA, 2014a). This assessment utilized site-specific data, where available, supplemented by more regional and national data sets, to best reflect the variability of disposal practices, environmental conditions, and receptor behavior across the country. This assessment considered a range of exposure pathways that were modeled in a stepwise fashion, culminating in national-scale, probabilistic modeling. Based on the results of this probabilistic analysis, the Agency identified potential risks to groundwater from long-term leakage that warranted regulatory action.

The purpose of the current risk assessment is to evaluate the potential for risk from placement of CCR in legacy impoundments and CCRMU, which both fell outside the scope of the 2014 Risk Assessment. Because the 2014 Risk Assessment previously identified a subset of contaminants most likely to drive risk from leakage to groundwater, the current assessment of groundwater focuses on that list of contaminants. EPA started from the same methodology and data sources detailed in the 2014 Risk Assessment for selecting appropriate data and characterizing facility environmental

3) 88 FR 31982, May 18, 2023.

setting, CCR waste properties, contaminant leaching behavior and transport, and exposure. EPA found the same methodology and data sources were sufficient to support conclusions about the risks from the landfills and surface impoundments covered in this rulemaking. EPA adjusted the methodology as necessary to better reflect an updated conceptual model for smaller CCRMU placed for purposes other than disposal and to incorporate more recent data. Finally, EPA considered the potential for additional, non-groundwater exposures specific to these smaller CCRMU.

The regulatory scope of the current rulemaking is limited to management of CCRs generated by coal-fired electric utilities and independent power producers covered by the North American Industry Classification System (NAICS) Code 22111.[4] The scope of this risk assessment is limited to the disposal or other placement of CCR on the land at active and inactive electric utilities.

1.3 Overview of Assessment Methodology

The current risk assessment is divided into eight main sections and three appendices. The main sections summarize the different data sources relied upon, analyses performed, model results, and final conclusions. The appendices provide a more detailed discussion of the data and model results underlying the analyses summarized in the main text. The remainder of this subsection provides further information about the contents of each section and appendices.

- **Section 2, Problem Formulation:** describes the conceptual models used to identify relevant exposure pathways and summarizes new data sources used to characterize these pathways.
- **Section 3, Disposal Unit Groundwater Risk:** describes the review of available data conducted to characterize how risks from historical and inactive landfills and surface impoundments compare with those previously reported in 2014.
- **Section 4, CCRMU Fill Groundwater Risk:** describes modeling approach used to 1) estimate the magnitude of leakage from smaller CCRMU to groundwater, 2) model contaminant fate and transport through underlying soil and aquifer, and 3) calculate the magnitude of resulting exposure and corresponding risk.
- **Section 5, CCRMU Fill Soil Risk:** describes the modeling approach used to 1) estimate the rate at which gamma radiation and radon gas are released from smaller CCRMU placed within the soil, 2) model contaminant fate and transport through the overlying soil, and 3) calculate the magnitude of resulting exposure and corresponding risk.
- **Section 6, Uncertainty and Sensitivity Analyses:** describes the results of various analyses conducted to identify new sources of uncertainty and sensitive parameters that exert the greatest influence on modeled risks. To the extent possible, these sources are quantitatively

4) See: https://www.naics.com/naics-code-description/?code=22111

and qualitatively characterized to identify the potential for higher or lower risks than those previously modeled.

- **Section 7, Summary and Conclusions:** synthesizes available information from all sections of the risk assessment to reach final conclusions about the risks that may result from different CCR management practices.
- **Section 8, References:** provides citations for all documents referenced throughout the text.

2 Problem Formulation

The primary purpose of this section is to describe the conceptual models developed for legacy impoundments and different types of CCRMU, which form the basis for this risk assessment. This section also provides a summary of major data sources that have been updated since the 2014 Risk Assessment was finalized. These data on facility conditions and environmental setting are applied to the conceptual models to characterize the potential risks associated with placement of CCR on the land.

2.1 Overview of Coal Combustion and Residuals

CCR is a broad term that refers to a range of byproducts generated directly by coal combustion or as a result of applying certain pollution control devices to emissions from coal-fired combustion units. CCR may be generated wet or dry, but this can change after generation. Some CCR are dewatered after generation, while others are later mixed with water to facilitate transport. When multiple types of CCR are generated at the same facility, mixing and co-disposal may occur.

- **Fly ash** is the fraction of combusted coal that becomes suspended in plant flue gases. It is a very fine, powdery material composed primarily of silica. Fly ash is removed from the plant exhaust gases primarily by electrostatic precipitators (ESPs) or baghouses that contain fabric filters. In facilities that use activated carbon injection (ACI) before fly ash collection, the fly ash waste stream will also contain the carbon, along with other mercury control wastes. However, where ACI occurs after fly ash collection, a separate waste stream may result.
- **Bottom ash** consists of ash particles that are too large to become entrained in the flue gas during combustion. It is coarse, with grain sizes that range from fine sand to fine gravel, and quite angular, with a porous surface structure. Bottom ash is collected from the furnace after it collides with and agglomerates to furnace walls or falls through open grates to an ash hopper beneath the furnace.
- **Boiler slag** is molten bottom ash that has been quenched with water. When the molten ash comes in contact with the water, it crystallizes, fractures and forms pellets that are hard with a smooth, glassy appearance. Boiler slag is collected from the base of either slag tap or cyclone type furnaces.
- **Flue Gas Desulfurization (FGD) materials** are produced through a process used to reduce sulfur dioxide (SO_2) emissions from the exhaust gas system of a coal-fired boiler. The physical nature of these materials varies from a wet sludge to a dry powdered material, depending on the pollution control technology, and the composition consists of sulfites, sulfates, or a mixture thereof.

Figure 2-1 provides the layout of a generic coal-fired plant. This simplified layout is intended to demonstrate some major pollution control technologies, waste streams, and points of generation associated with coal combustion. It is intended to be illustrative and so does not capture all possible technologies or plant layouts.

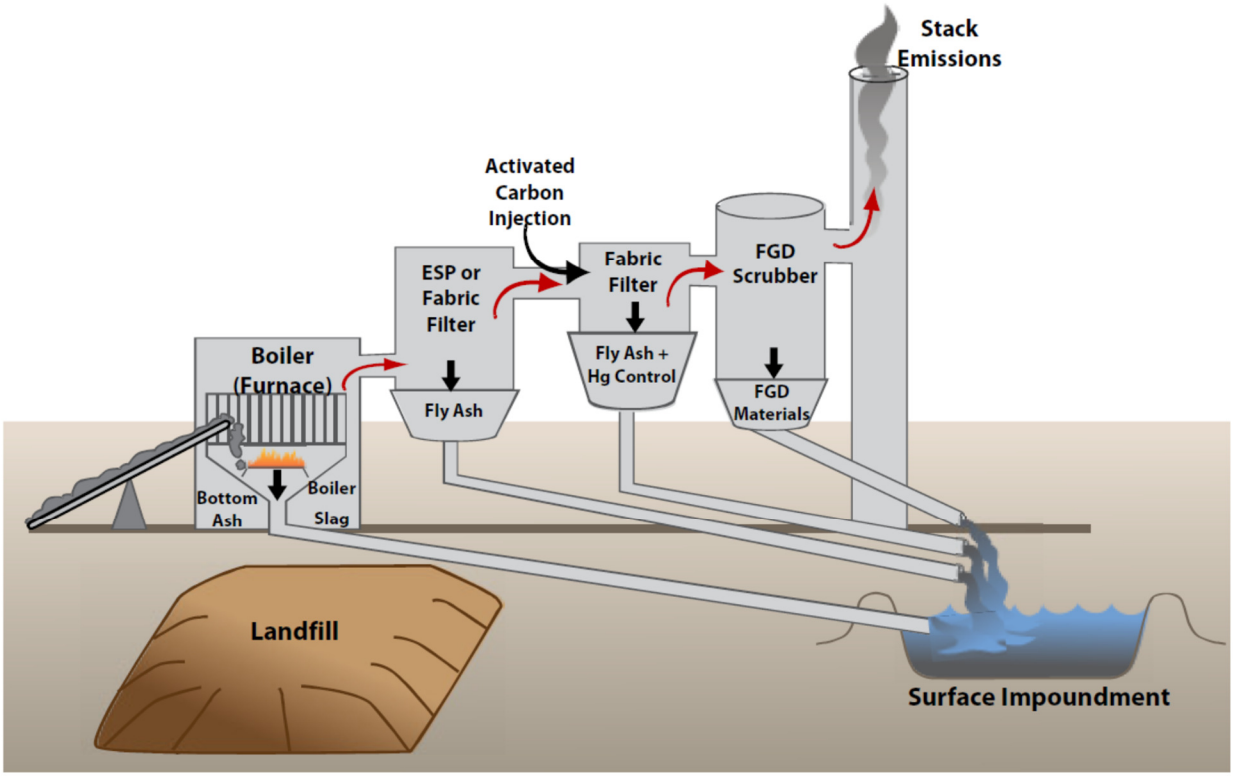

Figure 2-1. Generalized coal-fired power plant layout.

Since promulgation of the 2015 CCR Rule, the rates at which different CCR types are generated and the prevalence of various management practices may have shifted. However, the general descriptions provided here are still valid. For example, while there has been an increasing trend toward dry handling of CCR and landfill disposal, impoundments still operate across the country.

2.2 Conceptual Models

Once placed on the land, the chemical constituents present in CCR may leach or otherwise be released into the surrounding environment. To evaluate the potential for risk associated with such releases in the absence of regulatory action, EPA developed conceptual models with the intent to broadly depict the relevant characteristics of different management practices considered in the proposed rule. Thus, these definitions and conceptual models do not reflect any specific facility or unit. Nor are they intended to mirror distinctions made in the regulatory text. Instead, they form the basis for identification of complete exposure pathways and subsequent data collection efforts for use in this risk assessment.

2.2.1 Historical and Inactive Landfills

Historical landfills are defined for purposes of this document as landfills that ceased receipt of CCR prior to the effective date of the 2015 Rule and have installed some form of cover system over the remaining ash with the intent to close the unit. The steps taken toward closure may or may not be consistent with the requirements of 40 CFR § 257.102(d). Inactive landfills are defined for purposes of this document as landfills that ceased receipt of CCR prior to the effective date of the 2015 Rule and have taken no formal steps toward closure. These units may remain open to the air or have some limited soil cover for purposes such as dust control.

EPA believes the national-scale risks from historical and inactive landfills are best characterized using the same conceptual model as the 2014 Risk Assessment (U.S. EPA, 2014a). EPA modeled only one stage of the landfill lifecycle at the time because the groundwater model required a static unit configuration. The primary difference among landfill lifecycle stages is the presence of a cover system over the CCR following closure, which can reduce infiltration to some degree. Yet a cover constructed exclusively with natural soil is still expected to be relatively permeable and allow for infiltration. Given the prevalence of unlined units, EPA previously modeled all active landfills as closed under the assumption this stage of the landfill lifecycle contributes the most to long-term risk as a result of the longer time period that releases can occur. This conceptual model accurately identified potential risks from active landfills and is expected be equally applicable to historical and inactive landfills.

EPA previously established the following conceptual model for closed landfills. During closure, waste is left in place and a cover is installed with a permeability equivalent to that of the underlying liner or native soil. Landfills may contain one or more of the different CCR types, as well as other wastes such as coal refuse. For purposes of modeling, landfills are assumed to be constructed with a square footprint and located anywhere from entirely above grade to entirely below the ground surface. **Figure 2-2** depicts a conceptual model for one potential configuration of a closed landfill.

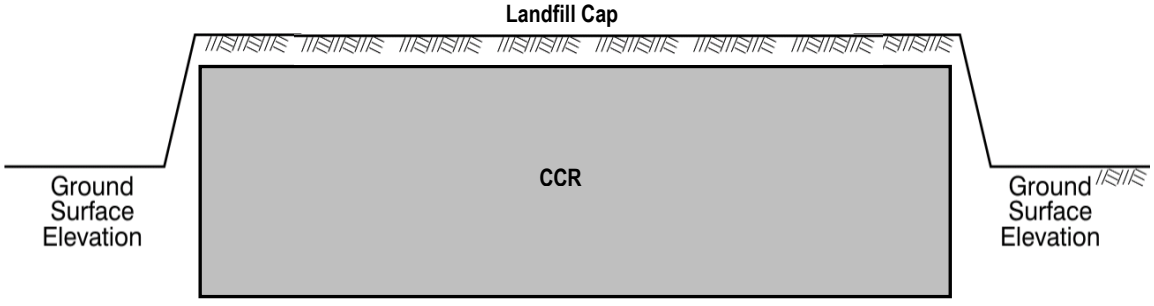

Figure 2-2. Cross-section view of closed landfill constructed above grade.

The 2014 Risk Assessment evaluated the potential risks to offsite receptors up to a mile away that result from disposal of CCR in landfills located at active facilities (U.S. EPA, 2014a). It considered multiple exposure pathways as part of a national-scale, probabilistic analysis, which included

human ingestion of impacted groundwater and fish caught from impacted streams, as well as ecological exposure to impacted surface water and sediment. On a national scale, the evaluation found potential for risk to human health from impacted groundwater to occur within the range the EPA Office of Land and Emergency Management (OLEM) typically considers to warrant regulation.[5] In particular, unlined landfills that account for a majority of regulated units were found to result in cancer risks up to 2×10^{-5} for arsenic. Based on these results, groundwater exposure is considered the principal risk driver for regulated landfills. Given the similar design and siting of historical and inactive units, the same exposure pathway will be the focus of further analysis for these units. **Figure 2-3** depicts the different exposure pathways considered for impoundments.

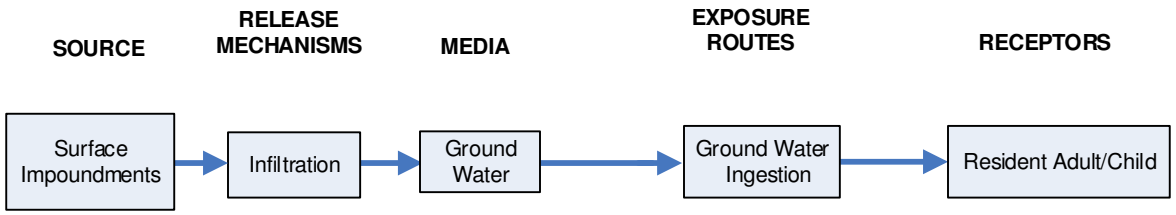

Figure 2-3. Surface impoundment conceptual exposure model.

2.2.2 Historical and Legacy Impoundments

Historical surface impoundments are defined for purposes of this document as impoundments that ceased receipt of CCR prior to the effective date of the 2015 Rule and have moved to drain the unit and install some form of cover system over the remaining ash with the intent to close the unit. The steps taken toward closure may or may not be consistent with the requirements of 40 CFR § 257.102(d). Legacy (i.e., inactive) impoundments are defined for purposes of this document as impoundments located at inactive electric utilities that ceased receipt of CCR prior to the effective date of the 2015 Rule, but still contain both CCR and free liquids. These liquids may take the form of wastewater ponded above the ash, excess porewater that can freely drain, or groundwater that saturates the ash. These units might be open to the air or have some form of soil accumulation on top of the ash for purposes such as dust control.

EPA believes the national-scale risks from historical and legacy impoundments are best characterized with the same conceptual model as the 2014 Risk Assessment (U.S. EPA, 2014a). EPA modeled only one stage of the impoundment lifecycle at that time because the groundwater model required a static unit configuration. The most significant difference among impoundment lifecycle stages is the presence of water ponded above the ash during unit operation. The hydraulic head from this water forces leachate into subsurface soils at a higher rate than would occur from gravity alone. EPA chose to model all surface impoundments during the active stage of their lifecycle under the assumption the sustained presence of this hydraulic head would result in the highest releases (U.S. EPA, 2014a). Although the current configuration of the historical and legacy

5) See, 80 FR 21449

impoundments may vary, both sets of units held ponded water during the active stage of their lifecycle. In the case of legacy impoundments, that ponded water may still be present. Regardless of whether the ponded water is still present, the impoundment would have gone through the same lifecycle which included a stage of ponded water. Thus, EPA believes the long-term risks from both historical and legacy impoundments are best characterized using the same conceptual model developed for active impoundments.

EPA previously established the following conceptual model for active surface impoundments. During operation, surface impoundment wastewater may be lost to a combination of infiltration to subsurface soils, evaporation to the atmosphere, and direct discharge to adjacent impoundments or nearby water bodies. CCR may accumulate until the surface impoundment's capacity is reached or the ash may be periodically dredged for disposition elsewhere. Impoundments may contain one or more of the different CCR types, as well as other wastes like coal refuse. To reflect that a majority of impoundments are dredged during operation, the conceptual model assumes that dredging losses are balanced out by continued loading from the facility, resulting in a constant ash thickness and water depth over the active life of the unit. For the purposes of modeling, surface impoundments are assumed to be constructed with a square footprint and located anywhere from entirely above grade to entirely below ground surface. **Figure 2-4** depicts a conceptual model for one potential configuration of an active impoundment.

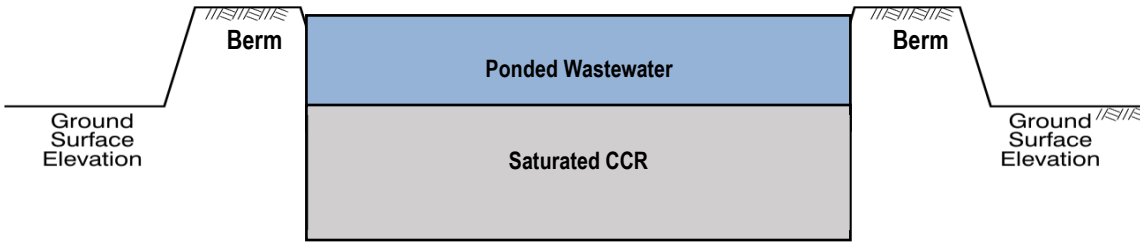

Figure 2-4. Cross-section view of active surface impoundment constructed above grade.

The 2014 Risk Assessment evaluated the potential risks to offsite receptors up to a mile away that result from disposal of CCR in surface impoundments located at active facilities (U.S. EPA, 2014a). It considered multiple exposure pathways as part of a national-scale, probabilistic analysis, which include human ingestion of impacted groundwater and fish caught from impacted streams, as well as ecological exposure to impacted surface water and sediment. On a national scale, the evaluation found potential for risk to human health from impacted groundwater to occur within the range that OLEM typically considers to warrant regulation.[6] In particular, unlined impoundments that account for a majority of regulated units were found to result in cancer risks up to 3×10^{-4} for arsenic and noncancer hazard quotients (HQs) up to 8, 3, 4, and 2 for arsenic, lithium, molybdenum, and thallium, respectively. Based on these results, groundwater exposure is considered the principal

6) See, 80 FR 21449

risk driver for regulated impoundments. Given the similar design and siting of legacy and historical units, the same exposure pathway will be the focus of further analysis for these units. **Figure 2-5** depicts the different exposure pathways considered for impoundments.

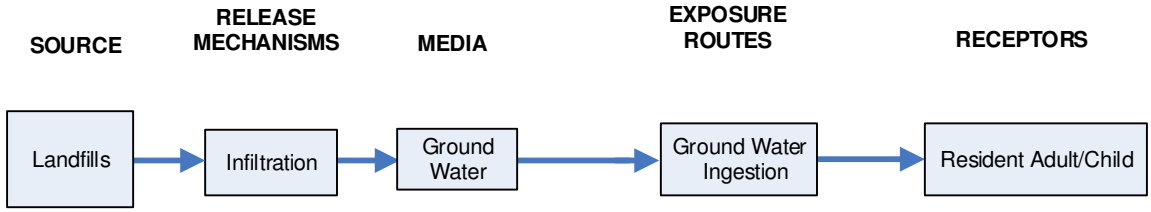

Figure 2-5. Landfill conceptual exposure model.

2.2.3 CCRMU Fills

The CCR Rule defines a CCRMU as any area of land on which non-containerized accumulations of CCR are received, placed, or otherwise managed, and is not otherwise regulated as a landfill or surface impoundment under the 2015 Rule. These units would include historical impoundments and landfills, inactive landfills, and other areas where CCR has been managed directly on the land. The intent of this broad definition is to capture management practices that fall outside the scope of the 2015 CCR Rule, but still have demonstrated potential to contaminate groundwater. As a result, CCRMU consist of a broad array of units unified by a single set of regulatory requirements.

As previously discussed, historical and inactive units have direct counterparts in the landfills and impoundments subject to the 2015 CCR Rule and so are best understood through the conceptual models for those regulated units. Therefore, a separate conceptual model was developed for the subset of CCRMU placed on the land outside of a new or existing landfill or impoundment and intended for a purpose other than disposal. It is anticipated the vast majority of such placement is associated with subsurface fills or similar uses. For clarity, this subset is hereafter referred to as "CCRMU fill(s)." This definition does not include placement in roadways, which are outside the scope of the rule, or piles and other placement on the land that have previously been established as forms of disposal. Nor does it include other diffuse placements, such as spreading for snow and ice control, for which there is little data available to characterize the manner or frequency of these placements across different sites.

CCRMU fill involves placement of dry CCR on or within the soil. In this way, the conceptual model for these fills also mirrors that of a landfill. During construction, a specified amount of CCR is placed in the fill. CCRMU fills are generally anticipated to be constructed with a fly ash, bottom ash, or boiler slag. FGD solids tend to be far more soluble than other CCR types and so are generally not anticipated to be suitable as fill. The timeframe for construction of a CCRMU fill is anticipated to be far shorter than for landfills and so is more likely to reflect ash from the single coal source. At the end of construction, waste is left in place and some form of cover is assumed to be initially placed over the ash. This cover may be native soil, concrete, or another material based on project

specifications. However, in the absence of routine inspection and maintenance, it cannot be assumed that any engineered cover will remain intact. Thus, the conceptual model considers a fill that has been disturbed and original cover disrupted. For the purposes of modeling, CCRMU fills are assumed to be constructed with a square footprint and located anywhere from entirely above grade to entirely below the ground surface. **Figure 2-6** depicts the conceptual model for one potential configuration of a CCRMU fill.

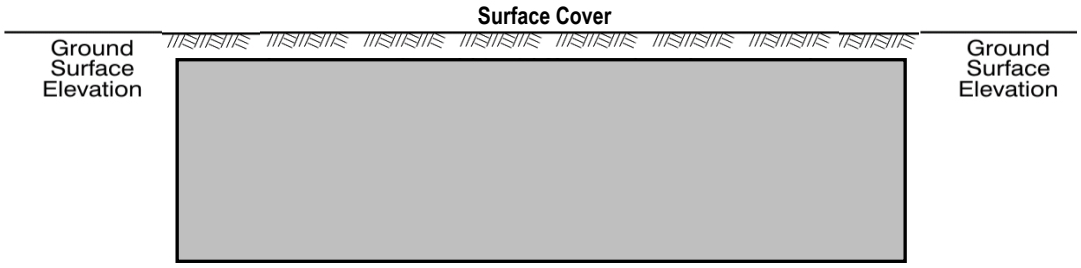

Figure 2-6. Cross-sectional view of generic CCRMU fill below grade.

CCRMU fills are located at the same facilities as historical and inactive disposal units. However, the exposure pathways for CCRMU fills can diverge from landfills and surface impoundments because facilities have not historically regarded such placements as a form of disposal. There is no indication facilities have reliably tracked or maintained these placements over time, as is required for disposal units. As a result, it is anticipated that, in the absence of further regulation, these fills will remain in place when ownership of the property changes.

EPA is concerned the potential risks from CCRMU fills have not been adequately characterized for all the stages of the fill lifecycle. The presence of engineering controls, such as an impervious structure constructed on top of the fill, might limit exposures while the facility is active. Yet, in the absence of land use restrictions, there is no guarantee these engineering controls will remain in place after the property transfers ownership. Disturbance of a fill may bring ash closer to the surface and create new pathways through which receptors may be exposed. For these reasons, EPA identified future land use as the point at which CCRMU fills are most likely to pose risk.

The Risk Assessment Guidance for Superfund and subsequent Agency policy directives instruct EPA to "assume future residential land use if it seems possible based on the evaluation of available information" (U.S. EPA, 1989; 2010). None of these facilities are expected to operate as electric utilities forever. Indeed, review of the U.S. Energy Information Administration (EIA) Form EIA-860 identified at least 85 utilities that burned coal and have closed since 2015 (U.S. EIA, 2022). EPA estimates that these facilities have an average of 1,000 to 40,000 individuals living within a one- to five-mile radius. 90th percentile population counts are closer to 2,300 to 94,000 individuals

living within a one- to five-mile radius.[7] Many of these facilities are also located along water bodies. While neither factor guarantees future residential use, both serve to make the land more attractive to such development opportunities. Indeed, EPA is aware of 22 examples in which former electric utilities have been proposed for residential development, 19 of which are known to have burned coal.[8] Therefore, EPA finds that consideration of future residential land use is relevant and appropriate when identifying potential exposure pathways.

Some state or local regulations may place restrictions on future land uses. However, the existence, scope, and enforcement of such restrictions can be inconsistent across the country. This is further complicated by the fact that waste disposal is not the primary activity at these facilities and there can be considerable tracts of land beyond permitted disposal units that could be considered for redevelopment if the presence of CCR is not known. As such, this baseline risk assessment aims to provide "…an analysis of potential adverse health effects (current or future) caused by hazardous substance releases from a site in the absence of any actions to control or mitigate these releases (i.e., under an assumption of no action)" (U.S. EPA, 1989). This approach provides a consistent frame of reference for EPA to understand the risk potential of such placements and to ensure any standards established under RCRA provide protection on a national basis.

EPA identified three potentially complete exposure pathways for future receptors that warrant further investigation. These pathways are not intended to represent a comprehensive list of all possible pathways. Instead, the focus is on those anticipated to result in the greatest risks and so to be the primary basis for regulatory action. First, chemical constituents present in CCRMU fill can be released by dissolution into precipitation and other water that comes in contact with the CCR. Dissolved constituents can infiltrate down to the underlying water table and migrate through the aquifer to downgradient wells where residents are exposed through ingestion of drinking water. Even in cases where groundwater is not anticipated to be the main source of drinking water, this type of exposure represents the maximum beneficial use of groundwater resources that the Agency seeks to protect wherever practicable. Second, radioisotopes present in CCRMU fill can decay and release radiation in the form of either gamma rays or radon gas. Gamma rays can pass through soil and other materials to reach the ground surface where residents are exposed directly to ionizing radiation. Radon gas may migrate through the soil and accumulate in nearby buildings, where residents are exposed through inhalation of indoor air. Finally, CCR may become intermingled with surface soils, where residents and wildlife are exposed through incidental ingestion of soil and dust present outdoors and tracked into the home. **Figure 2-7** depicts the different exposure pathways considered for CCRMU fills.

7) Data for total population collected according to the similar procedures as outlined in Appendix B of the 2014 Risk Assessment.

8) See: Memorandum to the Docket: Compilation of News Articles on Future Land Uses for Electric Utilities

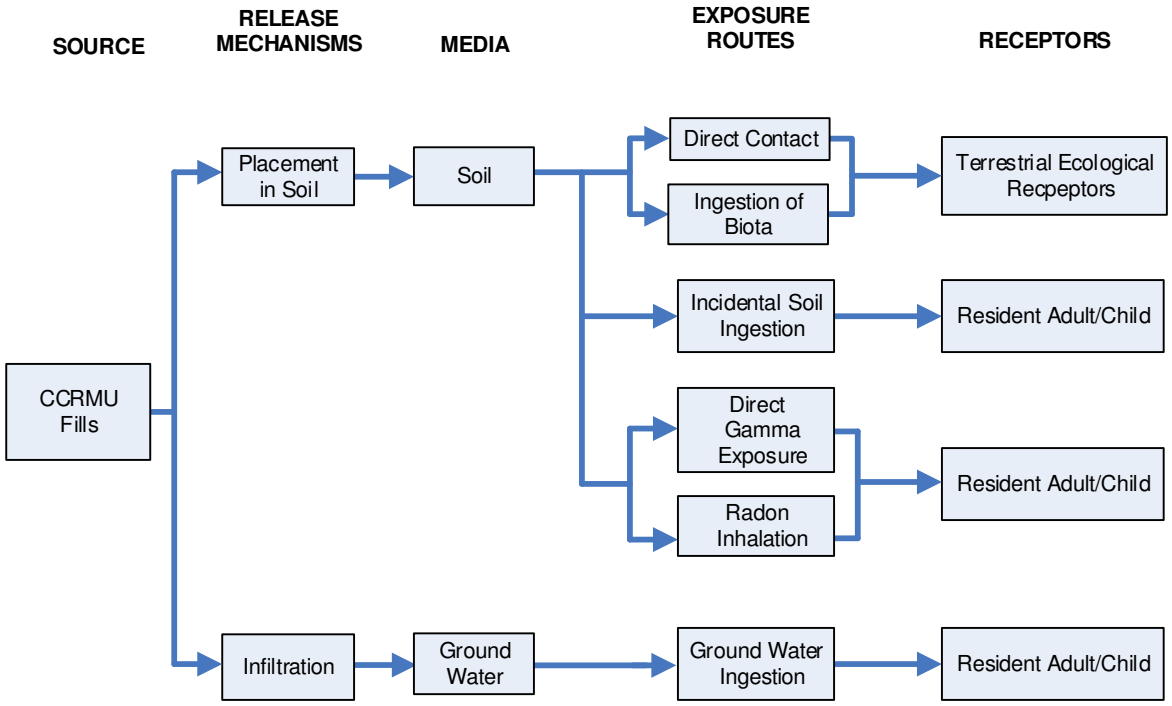

Figure 2-7. CCRMU fill conceptual exposure model.

2.3 Data Sources

The current assessment builds on the 2014 Risk Assessment and incorporates many of the same data sources previously applied to characterize facility environmental setting, waste composition and release potential, fate and transport through groundwater, and contaminant toxicity (U.S. EPA, 2014a). Many of these data sources and the associated approach to selecting these data for individual groundwater model runs are unchanged from the 2014 Risk Assessment and were previously discussed in detail as part of that previous assessment. These data sources were made available for public comment and external peer review and were found to represent the best available data. Therefore, EPA focuses subsequent discussion in this document on updated data sources that are relied upon in the current assessment. The following text details the major data sources relied upon in the current assessment that differ from or expand upon previous modeling.

2.3.1 Facility Data

The 2014 Risk Assessment relied on two EPA surveys conducted in 2009 and 2010 to identify the location of facilities with onsite disposal units ("EPA Surveys"). These surveys include data on 952 surface impoundments and 431 landfills located across 383 facilities. EPA ultimately determined that 218 of the surface impoundments and 122 of the landfills fell outside the scope of the final CCR Rule for one of the following reasons and so were not incorporated in the final risk model:

- The facility was no longer a coal-fired electric utility according to the 2012 EIA database;

- The landfill or surface impoundment was found to be inactive or retired; or
- The impoundment was not designed to accumulate CCR (e.g., cooling water ponds).

Since 2014, EPA has identified 3 additional facilities subject to the 2015 Rule that were not modeled in the 2014 Risk Assessment. These facilities were identified as a result of rule reporting requirements. Therefore, these regulated facilities were considered as part of current assessment. A list of all regulated facilities included in the model is provided in **Appendix A**.

In 2020, EPA published an Advance Notice of Proposed Rulemaking requesting information on legacy impoundments. Review of the comments received resulted in initial identification of 156 such impoundments not regulated under the 2015 CCR Rule. EPA conducted desktop research to supplement its understanding of each such unit and excluded impoundments found to not contain liquids after 2015 and those closed by removal between 2015 and 2022. The resulting universe relied upon in the Proposed Rule represented 127 legacy impoundments. In 2023, EPA received additional comments on the universe of facilities through both the Proposed Rule and subsequent Notice of Data Availability. These comments provided information on both newly identified units and previously identified units that no that no longer existed or otherwise did not meet the definition of a legacy impoundment. Following supplemental site research and verification, EPA identified a final list of 195 legacy impoundments and 204 CCRMU not regulated under the 2015 CCR Rule.[9] The current assessment used the information made available for these units to identify corresponding facility locations and associated environmental conditions. A list of 92 additional active and inactive facilities identified for this risk assessment is provided in **Appendix A**.

2.3.2 Meteorological Data

The 2014 Risk Assessment relied on the Hydrologic Evaluation of Landfill Performance (HELP) Model Version 3.0 to characterize meteorological conditions in the vicinity of modeled landfills and impoundments (U.S. EPA, 1994). HELP v3.0 provides data on precipitation, temperature, and solar radiation from a 30-year period between 1961 and 1990 at up to 183 meteorological stations at cities across the United States. Each disposal unit was assigned to the closest meteorological station to identify relevant data for environmental modeling.

Since the 2015 Rule was finalized, EPA released HELP Version 4.0 (U.S. EPA, 2020). This model update incorporates a meteorological dataset developed by the EPA Office of Pesticide Programs (OPP) with National Oceanic and Atmospheric Administration (NOAA) data. The OPP dataset is a grid of over 13,000 points distributed evenly across the country on a 0.25 × 0.25 degree grid (latitude/longitude) across the conterminous United States. Meteorological data are available for a 30-year period between 1985 and 2014 at each point on this grid. The current version of the HELP

9) Of the 204 CCRMU identified, a total of 9 were located at facilities that actively produced power as of 10/19/25, but had ceased on-site disposal of CCR before that date.

model is available for download on the EPA website.[10] Further information on how the OPP dataset was developed is described in Frye et al. (2016).

HELP v4.0 provides more recent data at a finer spatial resolution. Thus, the current risk assessment relied on the updated model to assign meteorological data to individual facilities. Once assigned, meteorological data drawn from HELP was applied to modeling of groundwater fate and transport in the same way as in the 2014 Risk Assessment. A list of the grid location assigned to each facility is provided in **Appendix A**.

2.3.3 Bulk Concentration Data

The 2014 Risk Assessment relied on a constituent dataset consisting of all the bulk concentration data for CCR that EPA had identified since 1998. These data were drawn from various public comments, state submissions, Agency studies, and peer-reviewed journal articles. Because these sources all had different goals in collecting the data, the amount of data available for each CCR type and chemical constituent varies. In particular, there is limited data for radionuclides present in CCR. Therefore, EPA has continued to review other data sources in order to expand upon the existing dataset.

EPA identified the U.S. Geological Survey (USGS) coal quality (COALQUAL) database as a new source of data that could be used to characterize radionuclide in the resulting CCR. COALQUAL contains information on nearly 7,500 samples of coal and associated rocks collected between 1973 and 1989. It was initially published in 1994 as part of the U.S. geoCHEMical (USCHEM) database. The current Version 3.0 was released as a standalone database in 2015 (USGS, 2015). COALQUAL contains data on up to 136 parameters for each sample, which include coal source, elemental composition, and ash yield. EPA used this information to estimate the bulk activity of different radionuclides in coal ash remaining after combustion. The full COALQUAL database is provided in **Appendix B**.

COALQUAL is believed to provide a valuable source of data for several reasons. First, the database includes a large number of geographically diverse samples collected from across 36 states. From these data, EPA incorporated as many as 6,100 samples across 25 states in the current analysis. This provides information on the variability of coal quality from across the country. Second, the samples represent a composite of entire coal beds weighted by the thickness of each discrete interval of minable coal (or "bench"). This is believed to provide information on the broader composition of coal that may be mined over time. Finally, USGS has undertaken extensive data verification and validation efforts to ensure consistency and reliability of the database.

10) Available online at: https://www.epa.gov/land-research/hydrologic-evaluation-landfill-performance-help-model

2.3.4 Leachate Concentration Data

The 2014 Risk Assessment relied on a constituent dataset consisting of all the CCR leachate data EPA had identified since 1998. These data were drawn from state submissions, public comments, Agency studies, and peer-reviewed journal articles. These data include porewater samples and leaching test data collected with SW-846 Methods, including extraction procedure toxicity test (Method 1310), toxicity characteristic leaching procedure (Method 1311), synthetic precipitation leaching procedure (Method 1312), and the leaching evaluation assessment framework (LEAF) methods (Methods 1313-1316). Following a review of the available data, EPA determined it was most appropriate to use porewater data to model leakage from surface impoundments and LEAF data to model leakage from landfills in the 2014 Risk Assessment.

EPA has since identified LEACHXS Lite as a source of new leachate data. LEACHXS Lite is a free data management and visualization tool that was developed by Vanderbilt University and others in partnership with EPA.[11] The LEACHXS Lite database contains all the LEAF data relied upon in the 2014 Risk Assessment, as well as LEAF data from other sources and for other materials. Review of the database identified one additional sample of fly ash leachate (Sample FA39), so EPA incorporated this sample into the larger constituent dataset. The additional leachate data is provided in **Appendix B**.

11) Available online at: https://www.vanderbilt.edu/leaching/leach-xs-lite/

3 Disposal Unit Groundwater Risk

As previously discussed, all landfills and surface impoundments progress through similar lifecycle stages during and after operation. The fact that some historical and inactive units may no longer contain ponded wastewater or may have installed a soil cover places these units in a different stage of their lifecycles. However, as noted during development of conceptual models, that alone does not necessarily differentiate the long-term risks from those of previously modeled active units. The potential for risk, and thus the need for groundwater monitoring and other requirements, must be considered over the full lifecycle of the unit. The risks associated with legacy impoundments and CCRMU disposal units can be understood in relation to those previously modeled in the 2014 Risk Assessment. EPA reviewed these previous model results and other available data about these historical and inactive units to understand any differences between these units that might affect modeled risks. The purpose of this section is to summarize the results of this review.

3.1 Previously Excluded Units

The 2014 Risk Assessment relied on data from the EPA Surveys. These surveys include data on 431 landfills and 952 impoundments located across 383 facilities. Of these units, EPA ultimately determined that 122 landfills and 218 surface impoundments fell outside the scope of the 2015 CCR Rule for one of the following reasons, and so even though EPA modeled the risks associated with these units, the results were not incorporated in the final risk results:

- The facility was no longer a coal-fired electric utility according to the 2012 EIA database;
- The landfill or surface impoundment was found to be inactive or retired; or
- The impoundment was not designed to accumulate CCR (e.g., cooling water ponds).

After removing impoundments not designed to contain CCR, there remained 122 landfills and 163 surface impoundments that represent either historical or inactive disposal units. As noted, EPA previously modeled the risks associated with these units prior to excluding them from the final risk results. Therefore, these model results provide the most direct comparison of risks between regulated and previously excluded units. EPA reviewed these results to understand how the risks associated these specific units compare with the active units previously reported in the 2014 Risk Assessment.

Table 3-1 presents the 90th percentile risks modeled for offsite human receptors who are exposed to groundwater. This value was selected in line with Agency policy to represent highly exposed individuals, defined as those with risks somewhere between the 90th and 99.9th percentile of the exposed population (U.S. EPA, 2004a). EPA selected the lower end of this range for use in the 2014 Risk Assessment because it provides the greatest confidence in the occurrence of any identified risks. Both cancer and noncancer risks are presented for the most sensitive age cohort modeled.

For drinking water ingestion, highest cancer risks were for adults (Ages > 21 years), while highest noncancer risks were for infants (Age < 1 year). Differences in most sensitive cohort are a result of the longer duration that adults are exposed that drives cancer risk and greater water consumption per pound of body weight for children that drives non-cancer risk (U.S. EPA, 2011). However, differences between the modeled adult and most sensitive child receptor are typically less than a factor of two. All values are rounded to the nearest whole number. Values that exceed the selected risk criteria (i.e., cancer risk > 1×10^{-5} or HQ > 1) are shown in **bold**. In instances where a value was found above the associated benchmark prior to rounding (e.g., HQ = 1.4), it was retained as an exceedance.

Table 3-1. 90th Percentile Nationwide Risks for Human Health from Excluded Units

Constituent	Surface Impoundments	Landfills
Carcinogenic Effects		
Arsenic III	**8×10^{-5}**	7×10^{-6}
Arsenic V	4×10^{-6}	3×10^{-7}
Noncarcinogenic Effects		
Arsenic III	**2**	0.2
Arsenic V	0.1	< 0.01
Molybdenum	**1**	< 0.01
Lithium	**2**	--*
Thallium	0.5	0.2

* Method 1313 data were not available to model this constituent for landfills.

For impoundments, the 90th percentile risks associated with ingestion of ground water are above cancer criteria for arsenic III (risk = 8×10^{-5}) and noncancer criteria for arsenic III (HQ = 2), lithium (HQ = 2), and molybdenum (HQ = 1). For landfills, the 90th percentile risks are below the cancer criteria for arsenic III, but still within OLEM risk range (risk = 7×10^{-6}). The risks associated with this set of excluded units vary somewhat from those previously reported, with slightly higher risks for landfills and slightly lower risks for impoundments. Yet there is general agreement on the overall magnitude of risk.

Of units reported in the 2014 Risk Assessment, approximately 42% of landfills and 65% of surface impoundments were modeled as having no engineered liner system based on facility self-reporting. For these unlined regulated impoundments, the 90th percentile risks are above cancer criteria for arsenic III (risk = 3×10^{-4}) and noncancer criteria for arsenic III (HQ = 8), lithium (HQ = 3), molybdenum (HQ = 4), and thallium (HQ = 2). For unlined regulated landfills, the 90th percentile risks are above cancer criteria for arsenic III (risk = 2×10^{-5}). Of the previously excluded units summarized above, approximately 71% of landfills and 57% of surface impoundments were

modeled as having had no engineered liner system. For these unlined excluded impoundments, the 90th percentile risks are above cancer criteria for arsenic III (risk = 2×10^{-4}) and noncancer criteria for arsenic III (HQ = 5), lithium (HQ = 3), molybdenum (HQ = 2), and thallium (HQ = 1). For unlined excluded landfills, the 90th percentile risks are just above cancer criteria for arsenic III (risk = 1×10^{-5}). Thus, EPA finds that a primary difference between the national risks modeled for regulated and excluded units is the prevalence of liners. Since finalization of 2015 CCR Rule, facility reporting has revealed a greater percentage of regulated units are unlined than previously modeled. EPA is not aware of any evidence that even older units have been lined at higher rates, particularly those constructed prior to the promulgation of minimum standards for disposal in RCRA subtitle D landfills in 1991. Thus, EPA concludes that the national risks for regulated and previously excluded units both fall closer to those modeled for unlined units.

3.2 Facility Locations

Facility location is a useful proxy for the environmental conditions to which a unit may be exposed. Nearby facilities are likely to be subject to a similar range of weather and hydrogeologic conditions. Therefore, EPA reviewed the locations of facilities that were modeled in 2014 and that have since been identified to understand any differences in the geographic distribution of these facilities. **Figure 3-1** provides a map of the locations of different facility identified as having onsite disposal. The 2014 Risk Assessment modeled disposal units at 383 facilities across the conterminous United States, as well as two additional facilities in Alaska and Puerto Rico not depicted here.

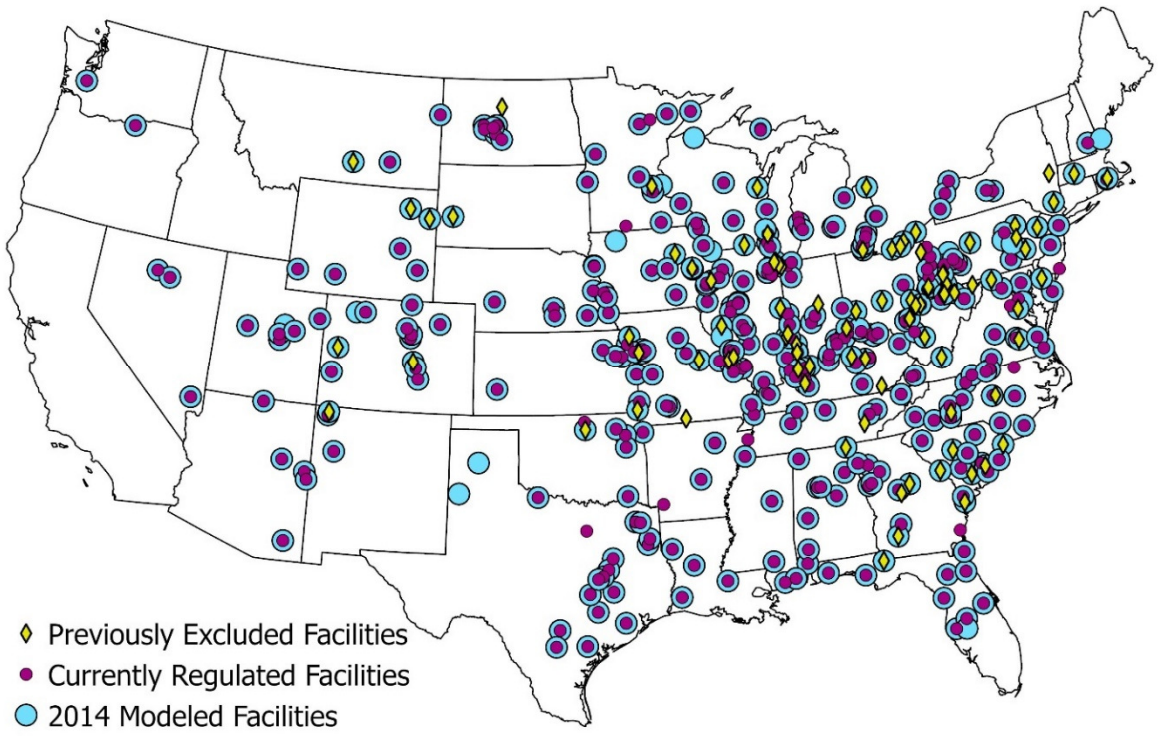

Figure 3-1. Identified facilities within the conterminous United States.

Of the 92 active and inactive facilities that were excluded from the original 2015 CCR Rule, a total of 76 had at least one unit that was previously modeled as part of the 2014 Risk Assessment. Thus, a vast majority of these facilities are already included in the model results summarized earlier in this section. The weather and hydrogeologic conditions modeled at these facilities are expected to be applicable to any onsite units that were not previously modeled. In some cases, these units will be located nearby or directly adjacent to those that were modeled. Additionally, EPA drew environmental data from over a mile around each modeled unit to best capture the prevalence of different conditions that could affect subsurface fate and transport at a site. As a result, it is unlikely that consideration of unit locations somewhere else on the same facility property would identify a dramatically different set of environmental conditions that would substantially alter probabilistic model results. The remaining 16 facilities that were excluded from the original 2015 CCR Rule are located an average distance of 26 miles from one or more facilities that were previously modeled. Thus, there is no indication the environmental conditions at these few facilities are not adequately captured by modeling of the surrounding facilities.

3.3 Unit Size

Public commenters have raised the potential for historical and inactive disposal units to be smaller in size than currently regulated units. These commenters contend that a smaller unit size would generate a lower volume of leakage and would not sustain plumes of the same magnitude as larger regulated units. EPA first reviewed available data from the EPA Surveys to understand the extent to which unit size may differ. **Figure 3-2** provides a comparison of the unit area modeled for both currently regulated and previously excluded units landfills (LFs) and surface impoundments (SIs).

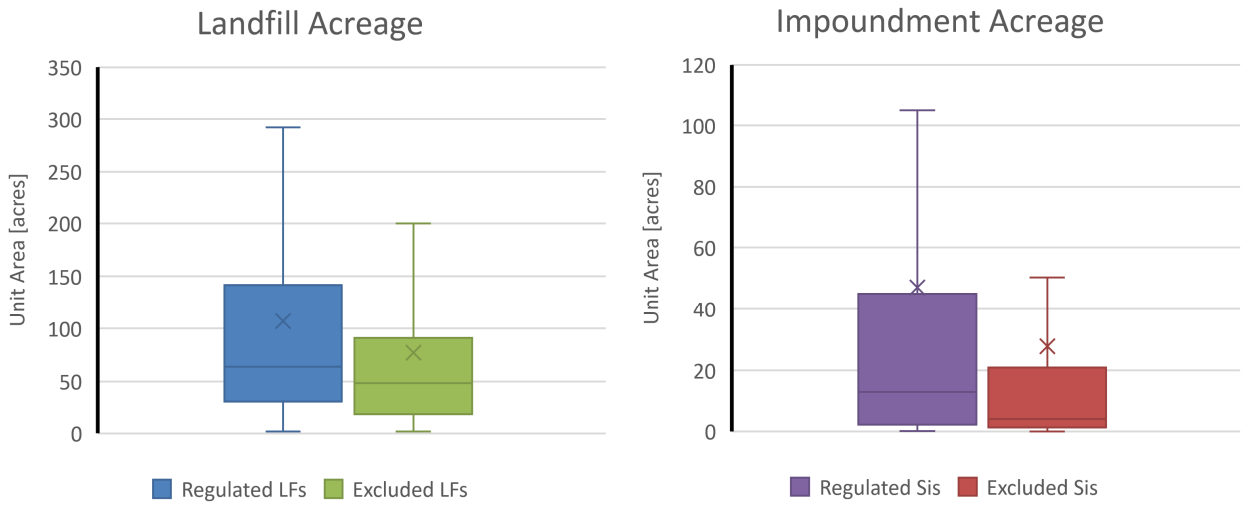

Figure 3-2. Comparison of regulated and excluded unit sizes.

This comparison indicates previously excluded units tend to be somewhat smaller than currently regulated units. The size of regulated units is a factor of anywhere between 1.3 to 3 times larger

across the range of calculated summary statistics. The median size of regulated units is 64 acres for landfills and 13 acres for impoundments. The median size of excluded units is 48 acres for landfills and 4 acres for impoundments. Despite these differences, there remains a great deal of overlap in the range of sizes modeled for both sets of units. Thus, there is no indication that previous modeling did not capture the existence or prevalence of smaller disposal units.

As described above, similar risks were identified for all regulated and previously excluded units. Thus, there is no indication that differences in the size of these units had an appreciable effect on national risks. EPA is not aware of evidence that any remaining units not captured in the EPA Surveys are substantially or consistently smaller than those modeled or that any differences in size that may exist are substantial enough to shift nationwide risk estimates. Therefore, EPA concludes that, based on available data, the 2014 Risk Assessment adequately captures the effects of unit size on risk.

Finally, EPA notes that individual unit size is not necessarily a reliable metric to draw conclusions about the overall risk from CCR disposal at electric utilities. The 2014 Risk Assessment modeled the risks from each landfill and impoundment separately because it was difficult to confirm the relative locations and orientations of different units with data from the EPA Surveys. However, the Agency is aware of many cases in which multiple units, both landfills and impoundments, are located immediately adjacent to one another. As such, even the smallest units can meaningfully contribute to broader groundwater contamination, both onsite and offsite. It is likely that the 2014 Risk Assessment underestimated site risk to some degree by not evaluating leakage over the full contributing area of these adjacent disposal units.

3.4 Conclusions

EPA previously modeled a number of historical and inactive disposal units. These model results were ultimately excluded from the 2014 Risk Assessment because these specific units were judged to not be subject to the 2015 CCR Rule. These model results provide direct, quantitative evidence of the relative risk between the currently regulated and previously excluded disposal units. This comparison found no evidence the risks from regulated units are meaningfully different from those of legacy impoundments or CCRMU disposal units. EPA further reviewed available information about the location and size of these excluded units to determine whether there exists any potential for conditions beyond those modeled to result in a substantially different risk profile. This review found that previous modeling efforts already capture a majority of the newly identified active and inactive facility locations, as well as potential unit sizes. There is no indication the risks associated with any remaining, unmodeled units are not already reflected in the previous national model. Thus, EPA concludes the results of the 2014 Risk Assessment are equally applicable to legacy impoundments and CCRMU disposal units.

The 2014 Risk Assessment modeled contaminant transport based on a national distribution of the closest residences anticipated to rely on groundwater as a source of drinking water up to a mile away from CCR units. These locations were defined using a combination of Census reports, satellite imagery, and other geographic data. This modeling approach assumed that, while the proximity of receptors around each unit may shift over time, the overall distribution of receptors across the country would remain the same. The risks identified based on these receptors provided a sufficient basis for national regulations. However, the fact the Agency did not need to consider risks to closer receptors to justify the rule does not mean these risks do not exist or warrant action. A broad goal of RCRA regulations is to protect groundwater. Thus, placements of CCR that does not allow for unrestricted future land use may warrant regulation now to ensure such placements are tracked and properly managed, so the site does not later become a Superfund site after responsible parties have dissolved. For these reasons, EPA conducted separate modeling of smaller CCRMU fills to understand the potential risks associated with these placements. The design and results of this modeling is documented in **Section 4 (CCRMU Fill Groundwater Risk)**.

4 CCRMU Fill Groundwater Risk

EPA conducted further modeling of the exposures that may result if contaminated groundwater is used as a source of drinking water by future residents. The goal of this modeling is to characterize the risks associated with smaller quantities of CCR and understand whether a lower limit exists below which even smaller placement pose no concerns. The section of the document describes the overarching framework for this modeling effort, as well as the specific models and inputs used to predict the fate and transport of constituents through subsurface soils and ground water.

4.1 Modeling Framework

The placement scenario considered for the current evaluation is CCRMU fills located onsite at both active and inactive facilities subject to this regulatory action. In the absence of any requirements to identify and track these smaller placements, it is assumed that the site will be redeveloped in the future for residential use. As part of redevelopment, it is assumed any current engineering controls have been disturbed (e.g., clay cap breached, overlying building demolished). It is assumed there will be some type of soil or other cover placed over the CCR so that it is not exposed to the open air. This is because CCR is not expected to support a robust vegetative cover and because exposed ash may require active measures for dust control. EPA used a combination of two models to characterize the potential impacts to groundwater quality and resulting risks to these residential receptors.

The first model is the EPA Composite Model for Leachate Migration with Transformation Products v2.22 (hereafter "EPACMTP") (U.S. EPA, 1996a, 1997a, 2003a,b,c). EPACMTP consists of two coupled modules: a one-dimensional module that simulates infiltration and dissolved constituent transport through unsaturated soils in the vadose zone and a three-dimensional module that simulates transport through groundwater. As described by the 2014 Risk Assessment, EPACMTP has undergone multiple rounds of internal and external review, including several by the EPA Science Advisory Board (Kool et al., 1994; U.S. EPA, 1996b, 1999a, 2004b). EPA used this model to calculate groundwater concentrations that result from waste disposal at specified locations and times. The outputs from EPACMTP were used to inform the second model.

The other model is Modular Three-Dimensional Finite-Difference Ground-Water Flow Model - Unstructured Grid Transport (hereafter "MODFLOW-USGT") Version 1.10 (USGS, 2013a; Panday, 2022). MODFLOW-USGT is a three-dimensional model capable of simulating groundwater flow and contaminant transport. This model allows for more direct consideration of transport in three dimensions by dividing the aquifer into a grid and assigning different values to each cell in that grid. This version of MODFLOW-USGT was chosen because it is a publicly available model; allows consideration of transport through unsaturated soils, which provides a more direct comparison for

EPACMTP; and has undergone extensive review and validation (e.g., U.S. EPA, 1997b, 2009a, 2015; Panday, 2022).

4.2 EPACMTP Setup

Model inputs for EPAMCTP were drawn from a range of site-based, regional, and national datasets based on a combination of government sources and peer-reviewed journal articles. Many of these sources are the same as previously used in the 2014 Risk Assessment (U.S. EPA, 2014a). These data sources were made available for public comment and external peer review and were found to represent the best available data. Therefore, subsequent discussion focuses on where the Agency incorporates new data sources or applies the same data sources in different ways. For example, when site-based data were not available for individual CCRMU fills, EPA drew data from more regional datasets.

4.2.1 CCRMU Fill Size

EPA has identified little available information on the total size of CCRMU fills present onsite at facilities. EPA believe it is unlikely that a consistent or reliable set of records could be identified for the purposes of characterizing CCRMU fill size. The available record indicates the location of such fills has not been closely tracked by facilities and the short timeframe for construction makes it unlikely these units would all be readily identified through aerial photography or similar means. Instead, EPA identified 74,800 tons as an upper limit of for the current assessment. This amount represents the smallest landfill size identified based on the EPA Surveys (Kastner, 2015). Despite potential for larger fills, a 74,800 ton upper bound is believed to provide a clear distinction between previously modelled landfills and CCRMU fills, and thus allow for a better understanding of potential risks associated with smaller placements of CCR not reflected in the 2014 Risk Assessment. Therefore, EPA modeled CCRMU fills based on a flat distribution ranging anywhere from 1 to 74,800 tons.

4.2.2 CCRMU Fill Dimensions

EPA has identified little available information on the relative dimensions of CCRMU fills present onsite at facilities. For purposes of modeling, EPA calculated possible dimensions of CCRMU fills by conceptualizing the fill as a conical pile. EPA then calculated the area of the most efficient piles possible based on the modeled tonnage and waste-specific range of values for density and angle of repose (i.e., friction angle of the ash) identified in the literature for fly and bottom ashes. Densities were sampled from across a range 910 kg/m^3 (Pandian, 2004) to 1,750 kg/m^3 (Kim et al., 2005). Angle of repose was sampled from across a range of 21 to 51 degrees (Muhanthan et al., 2004). EPA assumed the CCR is spread equally over the pile area to achieve a uniform thickness to establish a maximum thickness. EPA constrained the minimum thickness for all model runs to be one foot, intended to represent limited placement for grading or to promote drainage. The thickness for a model run was allowed to vary anywhere between these established minimum and maximum

values for that configuration. The area of the fill was then calculated based on the selected tonnage and thickness

4.2.3 Depth Below Grade

It is assumed CCRMU fills can be constructed anywhere from entirely below the ground surface (e.g., structural fill) to entirely above grade (e.g., embankment). However, even if the entire unit is constructed above grade, it is assumed for purposes of modeling that the fill will have a minimum of two feet of soil cover. It is also assumed the top of a fill will not begin more than 10 ft below the ground surface because of the compounding cost of thicker covers. The exact thickness of the soil above the CCR is not a sensitive parameter in the model and will not affect long-term infiltration. Instead, the selected maximum is intended to prevent the fills from being modeled at unrealistic depths and potentially intersecting with a deeper water table (e.g., a 10 ft thick fill located 100 ft below ground surface).

CCRMU Fills were not allowed to be placed in direct contact with the groundwater table in the modelling. This is due in part to the constraints inherent in EPACMTP resulting from assumptions made to allow efficient derivation of flow and transport equations. First, the model assumes that flow in the unsaturated zone is one-dimensional and directed down toward the water table. Second, the model assumes that flow in the unsaturated zone is driven only by leakage from a contaminant source and can be represented by a constant rate. Contact between the fill and water table may violate these assumptions as one-dimensional and steady vertical flow cannot be guaranteed, particularly in cases of groundwater mounding. Furthermore, contact between the waste and water may shift redox conditions in ways that alter leaching behavior, which cannot be accounted for with available leaching test methods. Therefore, if the random sampling of model inputs resulted in a scenario where the fill was in contact with groundwater, the inputs were discarded and resampled.

4.2.4 Leachate Concentration

Leachate pH is a primary factor used to define relevant leachate concentrations. The 2014 Risk Assessment relied on a pH distribution generated from 580 samples collected from 42 landfills to approximate overall waste properties within landfills (U.S. EPA, 2014a). However, landfill disposal can include disposal of CCR types not relevant to CCRMU fills (e.g., FGD wastes) and mixing with non-CCR wastes (e.g., coal refuse). Therefore, for the current assessment, EPA instead relied on available LEAF Method 1313 leachate data to identify the range of natural pH for fly ash (i.e., the final pH when the ash is exposed only to water) (U.S. EPA, 2009b). EPA then applied an error bar of 0.5 pH units to either end of the reported natural pH to better capture potential variability and ensure a more continuous distribution. **Figure 4-1** depicts the resulting distribution of leachate pH, expressed both as a cumulative frequency and as a number of samples captured in discrete pH bins.

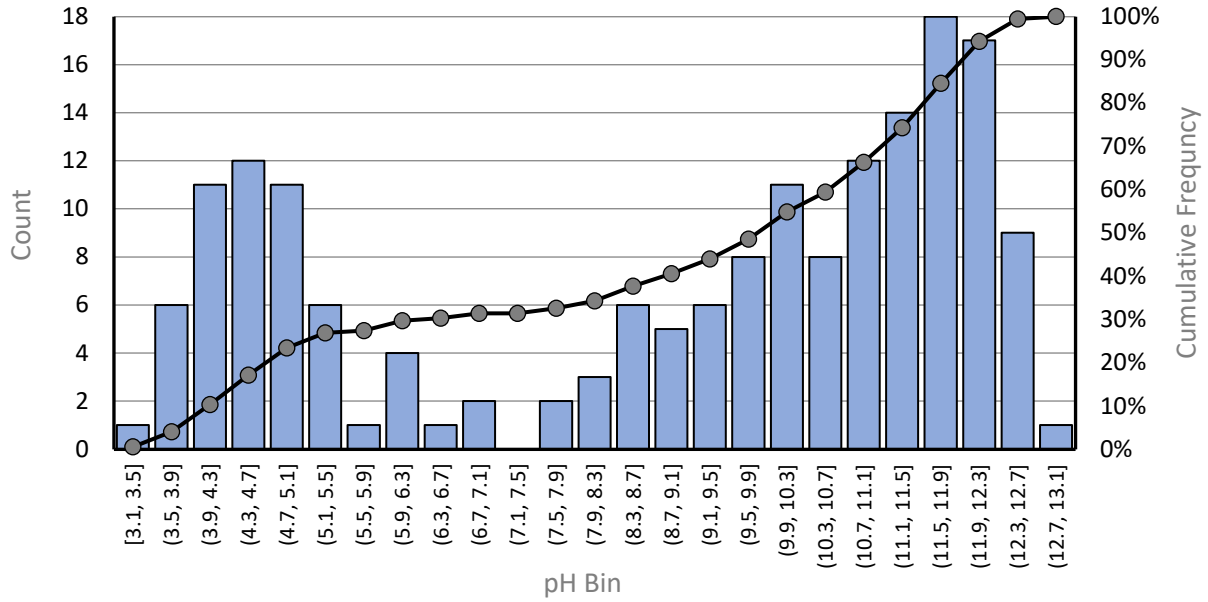

Figure 4-1. Modeled Leachate pH Distribution.

The current assessment relies on available data for fly ash measured with LEAF Method 1313 to characterize leachate concentrations from CCRMU fills. Data on mixed CCR were not used because of the potential inclusion of FGD scrubber sludge that is not considered relevant for this type of placement because of its high solubility. Method 1313 does not provide data at the exact same pH for every sample. Therefore, EPA first interpolated between measured leachate concentrations to obtain values at consistent 0.25 pH increments. EPA then sorted the interpolated values into bins of 0.5 pH increments shown in the **Figure 4-1**. Thus, each of these bins had two values for each ash sample. To identify the relevant leachate concentration for each model run, the pH distribution was probabilistically sampled and the associated pH bin was selected. Next, a sample ID from the bin was randomly selected. This ensured the model was not biased toward individual samples that had been analyzed under different conditions (i.e., ACI turned on and off). Finally, one of the leachate concentrations associated with the sample ID in that bin was randomly selected for use in the model.

4.2.5 Environmental Setting

As previously discussed, there is little information available on the exact locations of CCRMU fills onsite at facilities. These fills are placed for reasons other than disposal and so are not necessarily subject to the same siting considerations as landfills and impoundments (e.g., proximity to point of generation or surface water). As such, EPA assumed CCRMU fills could be located anywhere in the facility boundary. EPA generally drew a 1.2-mile (2.0-kilometer) radius around the centroid of each facility. In the rare case that the identified location of disposal units associated with a given facility were more than five miles apart and located in different hydrogeologic environments, EPA

drew environmental data from around each unit to better reflect this variability. Environmental data was extracted from within that area for use in EPACMTP as previously described in Appendix B of the 2014 Risk Assessment.

In the absence of periodic inspections and a well-maintained cap, it cannot be guaranteed that the any ash placed in the ground will remain undisturbed as a result of human or animal activity, natural settling or freeze-thaw cycles, flooding and other extreme weather-related events, or other unforeseen factors. Given the properties of the ash can be subject to change, it was not possible to develop a distribution of conductivities. Instead, EPA modeled conductivity based on the dominant megatexture of surrounding soils as described in Appendix B of the 2014 Risk Assessment. As such, the model assumes the ash has been subjected to a similar degree of compaction as the surrounding soils.

4.2.6 EPACMTP Sampling Location

EPACMTP requires users to specify a fixed point some distance downgradient of the contaminant source where the model will calculate resulting groundwater concentrations. This point may be conceptualized as a well location where water is drawn from the ground. The current assessment considers two types of wells. The first type is a downgradient compliance well similar to those required at landfills by the 2015 CCR Rule. This well is located at a fixed location as close to the waste boundary as feasible. In this case, a distance of 3 ft (1m) from the centerline of the waste boundary was chosen because a plume will be thinnest directly adjacent to the fill. Therefore, the well was placed a short distance away from the waste boundary to provide a chance for the plume to mix somewhat with groundwater and ensure the model did not miss evidence of contamination by inadvertently oversampling beneath the region of groundwater contamination. The second type is a monitoring well similar to those used to delineate contaminant plumes as part of corrective action. These wells were placed at a fixed locations of 500 and 1,000 ft away from the centerline of the waste boundary. **Figure 4-2** shows a schematic of the well locations relative to a CCRMU fill. Because these fills may be located anywhere at a facility and because the intent of this modeling is to understand the full potential for contamination to spread, the current assessment did not separately consider the effects of interception of groundwater by surface water. Instead, this pathway is further discussed in **Section 6 (Uncertainty and Sensitivity Analyses)**.

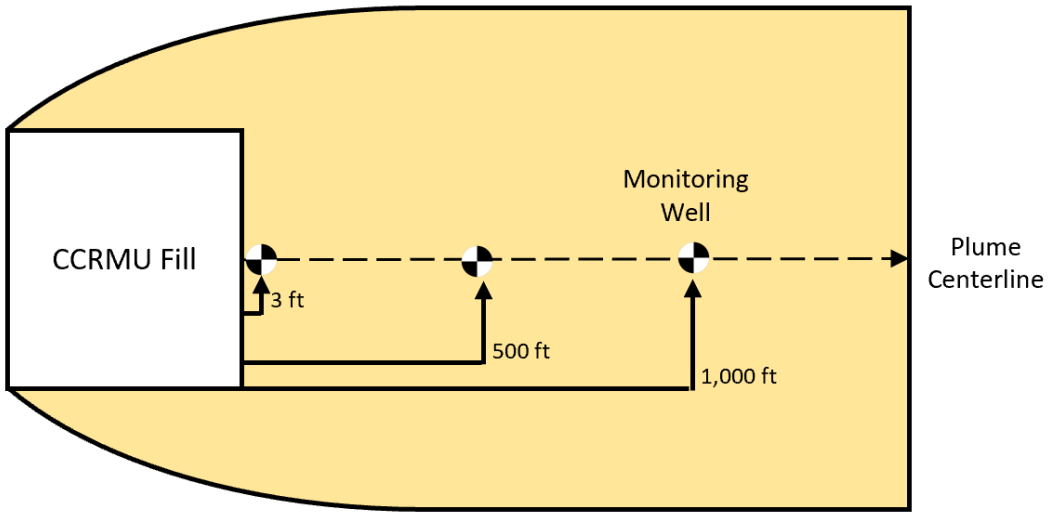

Figure 4-2. Aerial view of conceptual model for well locations.

For each model run and each well, a sample depth was randomly assigned within the top five feet of the surficial aquifer. The purpose of this interval is two-fold. First, it best reflects groundwater concentrations that would be measured by the low-flow sampling used in remedial investigations. Therefore, this interval is considered most appropriate to understand potential for exceedance of groundwater protection standard (GWPS). Second, it ensures a consistent frame of reference among the different wells. EPA has found that default of sampling in the top 30 ft of the aquifer can result in oversampling below the plume where it is thinnest, resulting in the appearance of lower concentrations at the wells closest to the unit.

4.2.7 Risk Benchmarks

For every model iteration, the groundwater concentration at each time step was identified. EPA ran the groundwater model until either the observed concentration at the well reached a maximum (i.e., peak) and then fell below a model-specified minimum concentration (1×10^{-16} mg/L), or the model had been run for a time period of 10,000 years. EPA selected these model horizons to ensure the peak and duration of any impacts to groundwater can be reliably identified across model runs despite the wide range of environmental conditions that may be encountered across the country (U.S. EPA, 2003d). Then the single year of highest concentration across all modeled time steps was identified. In cases where the ground water concentration was found to still be increasing after 10,000 years, EPACMTP stopped modeling and used the ground water concentration at that final year as the peak concentration. This does not mean it typically took that long for contamination be identified or that most model simulations continue for the full 10,000 years. Furthermore, the time to first exceedance of selected risk criteria is typically considerably less than the time to the greatest exceedance.

A time-weighted concentration was calculated by averaging the concentrations modeled for each time step over the specified exposure duration, centered around the year of highest concentration. The resulting concentrations were aggregated into probability distribution for that well location. Summary statistics were calculated from this distribution and compared against relevant risk benchmarks.

For the compliance well, the year of highest concentration was used to compare against GWPS. If the modeled concentrations at this location exceed promulgated GWPS, that indicates the CCRMU fills have potential to result in the same concentrations that would trigger corrective action in regulated landfills. This is relevant not only for the potential for CCRMU fills to directly impact groundwater quality, but also the potential for unmonitored releases to migrate from the CCRMU fills and interfere with groundwater monitoring at nearby regulated units.

For each of the monitoring wells, risk was calculated for a single reasonable maximum exposure (RME) residential receptor, relying on the Agency's approach to assessment of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites (U.S. EPA, 2014b). EPA chose this approach to ensure the full risk potential of individual sites is properly characterized, even if such high-end exposures ultimately occur at only a small percentage of sites nationwide. Because the future locations of these receptors are unknown and may occur relatively infrequently, the risk to this sensitive population may not be adequately captured by a nationwide assessment of receptor behavior. Including these considerations reflects the fact EPA is directed not only to issue nationwide rules, but also to issue site-specific permits.

For carcinogens, risk was calculated from modeled concentrations averaged over the 26 years bracketing the year of highest concentration, which represents the total time an individual lives at a residence and is exposed. For non-carcinogens, risk was calculated from the year of highest concentration. The reason for the separate approaches is differences in how cancer and non-cancer risks are evaluated. Cancer risk is calculated based on a slope factor and represents the increase in risk from all exposure spread out over the course of a lifetime. Therefore, cancer risk considers the cumulative exposure over time. Non-cancer risk is calculated based on a reference dose and represents the degree to which exposures exceed a threshold above which adverse health effects are anticipated to occur. Therefore, non-cancer risk usually considers the potential for exposures to exceed this threshold. If the modeled risks at the monitoring wells exceed either of these risk benchmarks, that indicates groundwater contamination has the potential to spread substantial distances at levels that may trigger further investigation or remedial action, such as source control, at a future cleanup site.

4.3 MODFLOW-USGT Setup

EPACMTP is designed to model groundwater concentrations at a single compliance location. Thus, it can be difficult to get a broader sense of full magnitude and extent of an individual plume over

time from those results alone. MODFLOW-USGT was selected for use in this evaluation because it is a fully three-dimensional model that can simulate the shape and volume of a contaminant plume over time when run under transient conditions (as opposed to steady-state). MODFLOW models were constructed using model parameters and numerical grid dimensions selected to be consistent with EPACMTP runs. However, MODFLOW-USGT is not designed to be run in the same iterative and probabilistic manner as EPACMTP. Running MODFLOW for the over 150,000 EPACMTP runs would quickly become time and resource prohibitive. Instead, EPA used MODFLOW-USGT for a more targeted analysis intended to represent the 90th percentile groundwater concentrations identified across all EPACMTP model runs.

EPA first identified the 90th percentile groundwater concentration at the 1,000 ft monitoring well of EPACMTP model runs. EPA then pulled all model runs within ± 0.5% of that concentration for further review. The approximately 1,600 model runs pulled represent those with potential for substantial transport away from the CCRMU fill. From these runs, EPA then selected 24 at random and confirmed that the median inputs across these runs roughly matched those of the full 1,600 model runs scenarios.

4.3.1 Model Inputs

Inputs for MODFLOW were drawn directly from selected EPACMTP runs without modification. This was done to ensure that the conditions captured by MODFLOW-USGT mirror those from EPACMTP. **Table 4-1** lists the input parameters drawn from EPACMTP and their equivalent in MODFLOW-USGT. Some inputs used by EPACMTP do not have direct equivalents in MODFLOW-USGT because that model calculates them from other data. A list of the 24 EPACMTP model runs for each constituent and the associated model inputs are provided in **Appendix C**.

Table 4-1. Comparison of EPACMTP and Corresponding MODFLOW-USGT Model Inputs

EPACMTP Input Name	MODFLOW-USGT Input Name	Parameter Description	Units	MODFLOW-USGT Package
AREA	Modeled, not specified	Area of fill	m^2	N/A
XW	Modeled, not specified	Length of fill in direction of groundwater flow	M	N/A
RECHRG	RECH	Infiltration rate outside fill footprint. Modeled same as inside.	m/yr	RCH
SINFIL	RECH	Infiltration rate inside fill footprint. Modeled same as outside.	m/yr	RCH
TSOURC	PERLEN	Duration of leaching	Yr	DISU
DEPTH	Modeled, not specified	Depth or thickness of fill	M	N/A
DGBS	Modeled, not specified	Depth of fill bottom below ground surface	M	N/A
CZERO	CONC	Constant leachate concentration over time	mg/L	RCH
POR	PRSITY	Effective porosity of saturated soils	-	BCT
BULKD	BULKD	Bulk density of saturated soils	g/cm^3	BCT
ZB	Modeled, not specified	Thickness of saturated zone	M	N/A

Table 4-1. Comparison of EPACMTP and Corresponding MODFLOW-USGT Model Inputs

EPACMTP Input Name	MODFLOW-USGT Input Name	Parameter Description	Units	MODFLOW-USGT Package
XKX	HK and VKA	Hydraulic conductivity of saturated zone (aquifer)	m/yr	LPF
GRADNT	Modeled, not specified	Regional hydraulic gradient in the aquifer	-	N/A
AL	DL	Longitudinal dispersivity in the aquifer	M	LPF
AT	DT	Transverse dispersivity in the aquifer	M	LPF
AV	DTYZ and DTXZ	Transverse and vertical dispersivity in the aquifer	M	LPF
SATK	KSAT	Saturated hydraulic conductivity of unsaturated soils	cm/hr	LPF
ALPHA	ALPHA	Moisture retention parameter (Van Genuchten) Alpha	cm^{-1}	LPF
BETA	BETA	Moisture retention parameter (Van Genuchten) Beta	-	LPF
WCR	SR	Residual water content	-	LPF
WCS	PRSITY	Saturated water content (effective porosity)	-	LPF
DSOIL	Modeled, not specified	Depth from ground surface to water table	M	N/A
DISPR	DL	Longitudinal dispersivity in unsaturated zone	M	LPF
RHOB	BULKD	Bulk density of unsaturated soil	g/cm^3	LPF
UFCOF	ADSORB	Kd of unsaturated zone	cm^3/g	LPF
SFCOF	ADSORB	Kd of saturated zone	cm^3/g	LPF

4.3.2 Model Design

MODFLOW-USGT is divided into a series of components called "packages." Each package performs a specific task, which can be added to or omitted from the model structure to represent the scenario of interest. For example, one package may define properties of individual soil layers, while another may introduce a point of groundwater withdrawal (e.g., pumping activities). **Table 4-2** describes the specific packages used in the current modeling effort.

Table 4-2. MODFLOW-USGT Packages Used

Model Package	Acronym	Reason for Use
BASIC	BAS	The package handles a number of administrative tasks for the model as a whole. It opens files and determines options that will be active. It declares and allocates memory for variables that can then be used by other packages to define parameters.
Block Centered Transport	BCT	This package simulates the transport of contaminant mass. It specifies dispersion and adsorption parameters and material properties (i.e., porosity, water content and bulk density)
Output Control	OC	This package was used to instruct the model when and how to save outputs.
Sparse Matrix Solver	SMS	This package was used to solve groundwater flow and transport equations. It incorporates nonlinear methods for conditions where conductance is a

Table 4-2. MODFLOW-USGT Packages Used

Model Package	Acronym	Reason for Use
		function of hydraulic head and linear solution schemes to solve for matrix equations
Recharge	RCH	This package was used to simulate the rate and location of infiltration into the soil and fill.
Transient Constant Head	CHD	This package was used to specify the water level in boundary cells and hydraulic gradient across cells.
Layer-Property Flow (LPF)	LPF	This package was used to simulate flow in the saturated zone. It specified layer types, grid dimensions, and material properties (i.e. hydraulic conductivity and storage).
Unstructured Discretization	DISU	This package is used to organize and interrelate the location of different cells within the grid and to define initial time steps for the numerical solution.
Adaptive Time Stepping	ATS	This package allows the model to determine the appropriate length of time (time step) between each set of calculations to ensure efficient computation. If the model fails to converge on a solution to transport equations for a given time step, it will attempt to correct the problem by reducing the time step and solving again. It can also increase a time step length if a time step is quickly solved.
Prescribed Concentration Boundary	PCB	This package is used to specify a constant set of boundary conditions upgradient and downgradient of the unit.

MODFLOW-USGT allows for greater consideration of complex hydrogeology in modeled scenarios than EPACMTP. However, there is no reasonable means for EPA to assemble the level of detailed, site-specific data necessary to incorporate additional complexities on a national scale. Indeed, EPA has raised concerns through Part A and B reviews that facilities have not adequately characterized site hydrogeology even in the immediate vicinity of the regulated units. Therefore, some additional assumptions are required to enforce consistency in the modeling approach. Below is a list of the major assumptions to ensure consistency in the overall modeling approach. Additional parameter values are identified below:

- EPACMTP is unable to model waste in contact with the water table. Thus, EPA established the top two grid layers of MODFLOW-USGT to represent the total unsaturated thickness of CCR and soil above the aquifer using the DISU package. The thickness of the first layer equals that portion of fill that extends below ground surface and the second layer represents the distance between the bottom of the fill and the water table.
- EPACMTP assumes the unsaturated soil and aquifer are both homogenous and isotropic. To mirror these conditions in MODFLOW-USGT, EPA specified identical aquifer properties (e.g., hydraulic conductivity, porosity) in the X- and Y- directions. EPA then set the vertical anisotropy ratio (Kx/Kz) in the Z-direction equal to 1.

- EPACMTP assumes there is a constant aquifer thickness across the modeled area. It derives flow boundary conditions along the edge of the modeled area based on specified hydraulic gradient, hydraulic conductivity, and recharge rate. MODFLOW-USGT allows the saturated thickness of an unconfined aquifer to vary. To prevent a scenario where the aquifer is discontinuous, fixed water table depths are applied to the upgradient and downgradient ends of the model based on the specified saturated thickness and flow gradient for that model run.
- EPACMTP simulates steady groundwater flow in which groundwater head elevations do not change over time. Transient transport simulations are required to model plume volume and average risk over time. Transient flow simulations are utilized in MODFLOW-USGT in addition to transient transport to estimate water volumes more accurately over time and therefore an additional input parameter is required, the specific yield (S_Y), to account for gravity drainage from unconfined aquifer media. Fixed boundary conditions applied to flow simulations result in nearly steady state flow fields that render long-term results insensitive to the initial value of S_Y. Therefore, a default value of 0.13 for S_Y was selected with the intent to reflect silt and clay soils (Morris and Johnson, 1967).
- MODFLOW-USGT requires a set of boundary conditions for concentration. EPA specified a zero-concentration boundary upgradient of the fill to ensure no contributions from background. A zero-concentration boundary was also set at the base of the aquifer to prevent contaminant mass from flowing through that confining layer. At the bottom of the fill, EPA specified a constant concentration boundary condition equal to the leachate concentration to serve as the contaminant source. That boundary condition was maintained throughout the leaching duration simulated by EPACMTP, after which the boundary value was set to zero. Finally, EPA set a boundary condition at the downgradient edge of the model domain equal to the concentration in the final cell, which allowed any contaminant mass to continue to flow beyond the downgradient distance that was explicitly modeled.

4.3.3 MODFLOW-USGT Sampling Location

EPACMTP models the unsaturated and saturated zones as distinct components, each defined by a single set of parameters. MODFLOW-USGT does not explicitly define separate unsaturated and saturated zones. Instead, it relies on boundary and initial conditions to determine which parts of the model domain are saturated at any given time. MODFLOW-USGT allows the domain to be subdivided into cells that can each accept different parameter values. For purposes of this risk assessment, the model grid consists of 286 grid columns in the direction of groundwater flow, 181 grid rows perpendicular to groundwater flow, and 12 layers. This results in a total of 621,192 cells across the entire model domain. The specific number of layers and cells were defined through sensitivity analyses that identified the lowest number of cells at which the calculated plume volume and concentration had stabilized for all model runs (i.e., adding more cells did not refine

the model outputs). **Figure 4-3** provides an example of how site hydrogeology is translated into a grid structure.

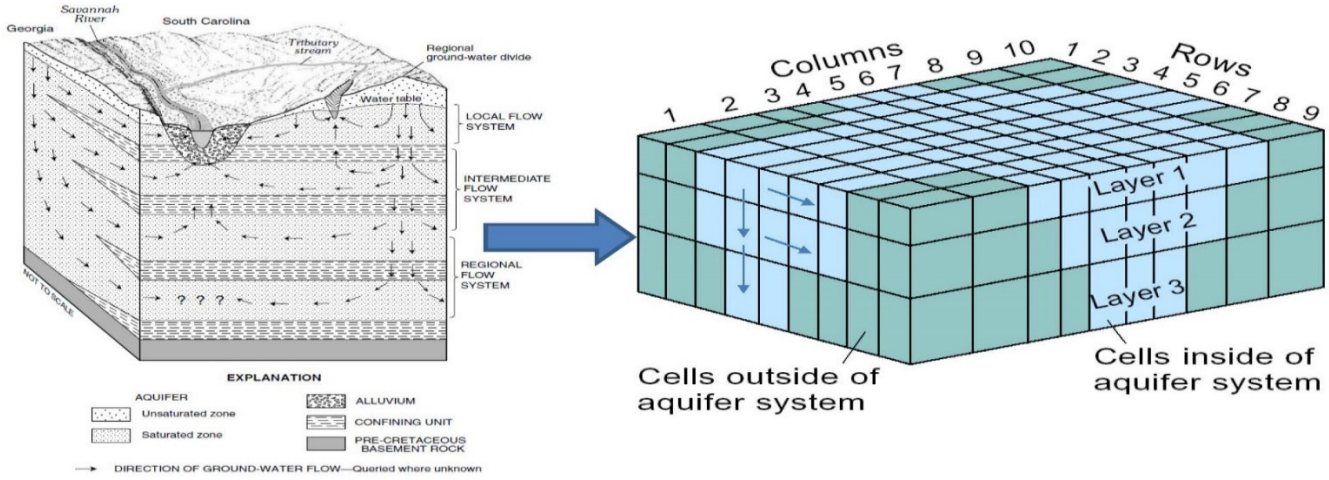

Figure 4-3. Conceptual model of three-dimensional groundwater flow.
(Adapted from USGS, 1996, 1997)

The model domain was set at 1,515 m (4,970 ft) in length, with the upgradient edge of the fill located 476 m (1,562 ft) away from the upgradient boundary. The model domain length of 1,515 m was selected to be greater than the model domain lengths estimated by EPACMTP for both sets of 24 model runs. EPACMTP estimates the model domain length based on consideration of the size of contaminant source, distance of receptor wells, and longitudinal dispersivity (U.S. EPA, 2003b). The model domain was set at 411 m (1,348 ft) in width, and rectangles, with a length that varies from 1 m at the smallest to 10 m at the largest. This layout was selected for several reasons: to allow finer resolution of calculations in the vicinity of the fill and along the plume flow path, to accommodate a range of fill sizes within the zone of higher resolution, and to reduce computational burden in areas furthest away from the plume. **Table 4-3** lists the sizes assigned to each cell within a layer. All layers in a run were assigned identical cell layouts. **Figure 4-3** shows an annotated screenshot of MODFLOW-USGT that depicts how different cell sizes are distributed within a modeled layer.

Table 4-3. Cell Layout in a MODFLOW-USGT Layer

Cell Length	Column Number	Row Number	Cell Aspect Ratio
10 m	1 to 39, 195 to 286	1 to 10, 171 to 181	1.5
6.5 m	40 to 41, 193 to 194,	11 to 12, 170 to 171	1.4
4.5 m	42 to 43, 191 to 192	13 to 14, 168 to 169	1.5
3 m	44 to 45, 189 to 190	15 to 16, 166 to 167	1.5
2 m	46 to 47, 187 to 188	17 to 18, 164 to 165	1.3
1.5 m	48 to 49, 185 to 186	19 to 20, 162 to 163	1.5
1 m	50 to 184	21 to 161	1.0

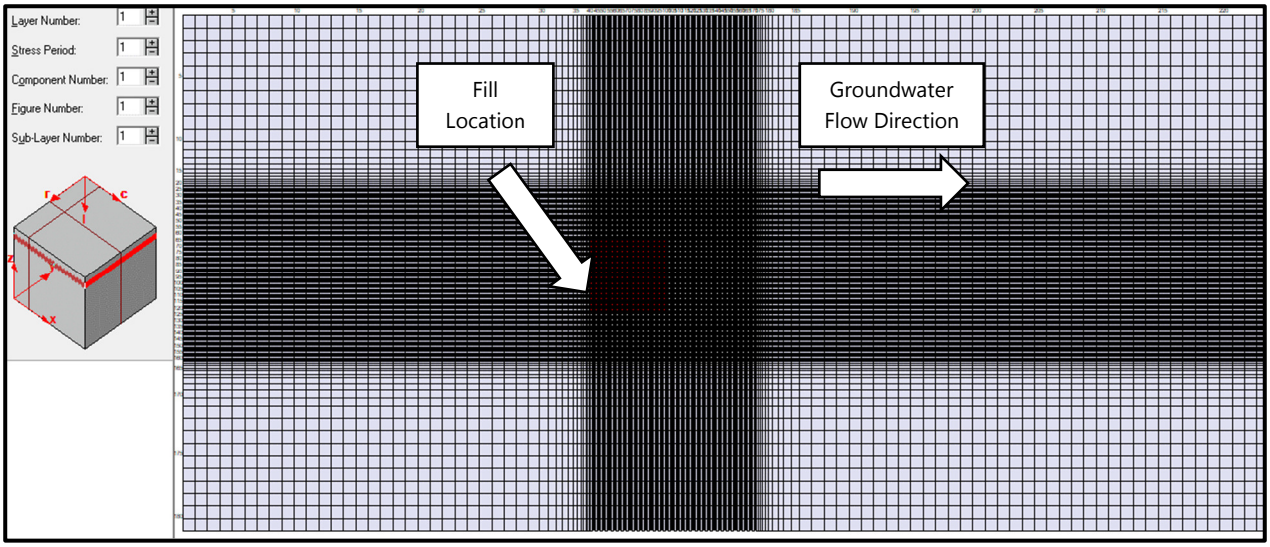

Figure 4-4. Depiction of grid layout for individual layer visualized within MODFLOW-USGT.

The top two layers represent 1) the depth of fill below ground surface and 2) the unsaturated soil between the fill and aquifer. These two layers were assigned properties corresponding to the unsaturated zone. The remaining 10 layers were assigned properties corresponding to the saturated aquifer. The aim of assigning thicknesses to these 10 layers was intended to maintain a thicknesses aspect ratio of less than 2.0 across all layers to ensure numerical convergence of the model. The purpose to the subdivision of layers is instead to refine the estimate of modeled plume volume. Details of grid dimensions for all scenarios are presented in **Appendix C**. All cells within the unsaturated and saturated layers are assigned corresponding parameter values from the EPACMTP runs. Contaminant concentrations are calculated as an average at the center node of each cell. Because a contaminant plume is typically curved, use of cells that are too large can result in underestimation of concentrations closer to the boundary.

For each model run, both the volume of groundwater above a specified concentration benchmark and average magnitude of exceedance of that benchmark over that volume were recorded at each time step. Benchmarks were separately established based on GWPS and the RME risk scenario described for EPACMTP with a cancer risk of 1×10^{-5} or HQ of 1. Use of these benchmarks provides a consistent frame of reference to identify the volume of affected groundwater over time. MODFLOW first determined which cells across the model domain were partially or fully below the water based on whether the calculated porewater pressure that was positive over some or all of the cell, indicating saturation of the soil. Next, the model identified which of saturated cells had an average groundwater concentration above relevant benchmarks. Finally, the model summed the volume of affected groundwater across these cells and calculated the average magnitude of exceedance over that total volume. These outputs across different points in time were used to

understand the magnitude and extent of the resulting plume, as well as the potential for sustained exposure for future receptors.

4.4 Model Results

Groundwater concentrations modeled with EPACMTP at the waste boundary were compared to respective GWPS to understand the potential for fills to impact groundwater quality to an extent that would trigger corrective action at regulated landfills. The 90th and 50th percentile exceedance of GWPS for each constituent modeled with EPACMTP at the waste boundary are presented in **Table 4-4**. Values represent the ratio of modeled concentrations and corresponding GWPS. All values are rounded to the nearest whole number. Values that exceed the respective GWPS are shown in **bold**.

Table 4-4. Modeled Exceedance of GWPS at Waste Boundary.

Constituent	GWPS (µg/L)	90th Percentile	50th Percentile
Arsenic III	10	**26**	0.2
Arsenic V	10	**19**	0.2
Molybdenum	100	**156**	**2**
Thallium	2	**19**	0.8

The 90th percentile groundwater concentrations exceeded GWPS by factors of 26 for arsenic III, 19 for arsenic V, 156 for molybdenum, and 19 for thallium. The 50th percentile concentrations exceeded GWPS by a factor of 2 for molybdenum. Based on these results, EPA finds that CCRMU fills can meaningfully contribute to groundwater contamination across a facility.

Groundwater concentrations modeled with EPACMTP at 500 and 1,000 feet away from the waste boundary were used calculate risks to individual RME receptors exposed to these concentrations. Exceedance of risk benchmarks at 90th and 50th percentile concentrations are presented in **Table 4-5** for each distance from the waste boundary. Both cancer and noncancer risks are presented for the associated RME receptors based on Agency policy. For drinking water ingestion, cancer risks are calculated for an individual who is exposed for 6 years as a child and 20 years as an adult, while noncancer risks were for a child. Differences in most sensitive age cohort are a result of the longer duration that adults are exposed that drives cancer risk and greater water consumption per pound of body weight for children that drives non-cancer risk (U.S. EPA, 2011). All values are rounded to the nearest whole number. Values that exceed the selected risk criteria (i.e., cancer risk > $1x10^{-5}$ or HQ > 1) are shown in **bold**. In instances where a values were above the benchmark prior to rounding (e.g., HQ = 1.4), it was retained as an exceedance.

Table 4-5. Modeled Risk at Different Distances from CCRMU Fill

Constituent	Risk for 90th Percentile Groundwater Concentration		Risk for 50th Percentile Groundwater Concentration	
	500 ft	1,000 ft	500 ft	1,000 ft
Carcinogenic Effects				
Arsenic III	**6×10^{-4}**	**3×10^{-4}**	7×10^{-6}	3×10^{-6}
Arsenic V	**5×10^{-4}**	**2×10^{-4}**	4×10^{-6}	1×10^{-6}
Noncarcinogenic Effects				
Arsenic III	0.7	0.4	0.01	< 0.01
Arsenic V	0.5	0.3	< 0.01	< 0.01
Molybdenum	**26**	**15**	0.3	0.1
Thallium	**33**	**18**	**1**	0.7

Risks decline further away from the fill as the plume has greater opportunity to mix within the aquifer and disperse. However, at 90th percentile concentrations all constituents still exceed at least one benchmark (cancer or noncancer) at 1,000 ft from the fill. At this distance, EPA identified cancer risks from arsenic (risk = 3×10^{-4} for trivalent and 2×10^{-4} for pentavalent) and noncancer risks from molybdenum (HQ = 15) and thallium (HQ = 18). At 50th percentile concentrations, the only identified exceedance of benchmarks was for thallium (HQ = 1). This indicates potential for the leakage from CCRMU fills to spread at environmentally significant concentrations.

Because EPACMTP runs represent concentrations at a fixed location, they do not provide broader information about the magnitude and extent of the plume. As a result, EPA does not rely primarily on these results to draw direct conclusions about overall risk. Instead, the Agency retained a subset of 24 model runs for both arsenic V and molybdenum drawn from around the 90th percentile concentrations at 1,000 ft. Altogether, these runs reflect a range of conditions that collectively resulted in high-end groundwater concentrations 1,000 feet from the fill. These corresponding placements of CCR range from around 3,500 to 70,000 tons placed over areas between 0.15 to 2.0 acres.

EPA calculated the median of modeled risks and volumes across these runs to define values representative of these high-end runs over time. For arsenic V, the model identified a peak risk of 1×10^{-4} averaged over 32 million gallons (Mgal) of groundwater and a peak volume of 147 Mgal with an average risk of 7×10^{-5}. The same leakage of arsenic V would result in a peak GWPS exceedance of 3 averaged over a plume volume of 1.2 Mgal and a peak plume volume of 8 Mgal with an average exceedance of 2. It takes around 2,300 years from the time of first exceedance for the plume to fully dissipate. For molybdenum, the peak exceedance of both risk benchmark and GWPS was 10 averaged over a plume volume of 27 Mgal and a peak plume volume of 80 Mgal with an average exceedance of 4. It takes around 100 years from the time of first exceedance for the

plume to fully dissipate. Results for each of the individual 24 model runs and the associated model inputs are presented in **Appendix C**. **Figure 4-5** presents a time series plot based on EPACMTP model run #94,263 for arsenic V and #33,662 for molybdenum. These runs were determined to fall closest to the overall median risk and volume results summarized above.

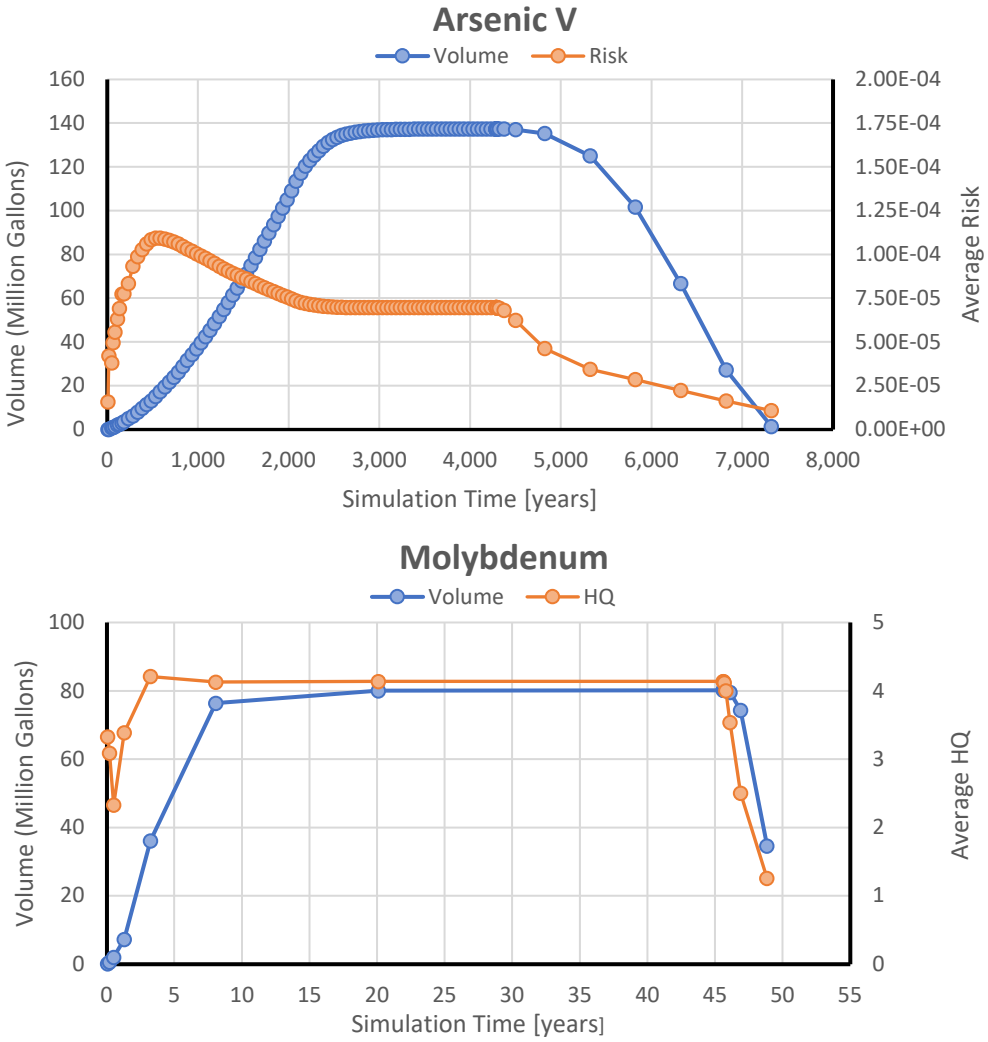

Figure 4-5. MODFLOW-USGT examples for arsenic V and molybdenum.

The average risk changes over time as the volume grows due to mixing with the aquifer and lateral dispersion. In both cases, the average risk across the plume eventually achieves a steady state until the leachable mass in the fill is depleted and the plume begins to shrink. However, not all model runs achieve a similar steady state conditions before the source is depleted. Plumes of these size and durations could readily sustain exposures for typical residential receptors anticipated to use around 80 gallons of water a day for all indoor household needs, resulting in less than 0.8 Mgal of use over the up to 26 years of exposure (USGS, 2018).

4.5 Conclusions

EPA modeled the potential magnitude and extent of groundwater contamination resulting from CCRMU fills with EPACMTP and MODFLOW-USGT. This modeling effort incorporated many of the same data sources previously used to characterize leakage from CCR in the 2014 Risk Assessment, applied to the conceptual model for smaller fills. EPACMTP model runs identified potential for these smaller fills to result in groundwater contamination under high-end and more moderate scenarios. In particular, high-end scenarios demonstrated potential for substantial plume spread. Therefore, MODFLOW-USGT was used to further model the full extent the plumes for a subset of high-end scenarios identified with EPACMTP. Based on these results, leakage of arsenic from smaller fills can still result in contamination that can extend over millions of gallons of groundwater and persist for a century or more. For all these reasons, EPA finds the potential for risk to future residential receptors to be within the range OLEM typically considers for regulation.

5 CCRMU Fill Soil Risk

CCR is recognized as a type of technologically enhanced naturally occurring radioactive material (TENORM).[12] "Technologically enhanced" in this context means naturally occurring radioactive material has been concentrated or altered, such as through combustion, in a way that increases the potential for exposure. Therefore, EPA conducted further modeling of the exposures to radiation that may result from living in a home built on or around a CCRMU fill. The goal of this modeling is to characterize the risks associated with placement of smaller quantities of CCR. The section of the document describes the overarching framework for this modeling effort, as well as the specific models and inputs used to predict risks from radiation.

5.1 Model Framework

The placement scenario considered for the current evaluation is CCRMU fills located onsite at both active and inactive facilities subject to this rulemaking. In the absence of requirements to identify and track these smaller placements, it is assumed that a site could be redeveloped in the future for residential use. It is also assumed there will initially be some type of soil layer placed over the CCR to support a lawn or similar vegetative cover.

This evaluation considered the potential for exposure to gamma radiation and radon gas from placement beneath the soil. Because the CCR is buried, EPA did not consider potential for direct exposure to the CCR or indirect exposure through uptake of contaminants by crops and livestock. Further, EPA did not separately consider leaching to groundwater due to a lack of data on leaching potential of these constituents from CCR. However, contributions from these additional pathways to overall exposures is expected to be lower than the modeled pathways.

EPA selected the Preliminary Remediation Goal (PRG) Calculator for the current evaluation.[13] The current version of the model calculates risk with cancer slope factors from Federal Guidance Report 13 (U.S. EPA, 1999b) with International Commission on Radiological Protection 107 decay data (ICRP, 2008), as outlined in the report "Calculation of Slope Factors and Dose Coefficients" (ORNL, 2014). The calculator was selected because it is a publicly available model that addresses relevant exposure scenarios, allows user specification of key parameters, and has undergone extensive review and validation both internally and externally (e.g., U.S. EPA, 2015; 2017; 2021; 2022). Further documentation of these reviews is available on the calculator webpage.

12) See: https://www.epa.gov/radiation/tenorm-coal-combustion-residuals

13) See: https://epa-prgs.ornl.gov/radionuclides/

5.2 Model Setup

For some parameters, the available data would not support development of continuous probability distributions. This precludes the type of fully probabilistic modeling conducted for groundwater exposures. Instead, model inputs for the PRG Calculator for direct gamma exposure were identified based on a review of model default values, EPA guidance, and the wider scientific literature. These inputs were used to conduct a more deterministic analysis intended to represent an RME exposure scenario. All values not discussed below were left as model defaults.

5.2.1 Bulk Activity

Activity is a measurement of the rate at which radioisotope mass within a sample disintegrates (or decays), expressed in units of picocuries per gram (pCi/g). One pCi is equal to 2.22 disintegrations per minute. Each disintegration releases ionizing radiation in the form of alpha particles, beta particles, or gamma waves that have the potential to damage genetic material and increase an individual's lifetime cancer risk. Activity determines the amount of each radioisotope present in that can release radiation into the surrounding environment.

EPA relied on the COALQUAL database to identify activity in coal ash. However, this data source reports chemical concentrations on a whole coal basis. Therefore, additional steps were required to estimate the activity of the resulting ash. COALQUAL reports two parameters in the datasheet that represent the amount of ash remaining after a coal sample has been burned. The parameter "STDAsh" in the "CQ_Prox_Ult" datasheet represents the percent ash yield as determined by the American Society for Testing and Materials (ASTM) Method D-3174 following combustion at 750 degrees Celsius (ºC), while the parameter "GSAsh Dry" in the "CQ_Trace" datasheet represents the percent ash yield determined by the USGS laboratories following combustion at 525 ºC. For some constituents in COALQUAL, USGS first measured concentrations in ash from combustion at 525 ºC and then back-calculated concentrations in the whole coal. One goal of combustion at a lower temperature was to limit loss of more volatile constituent mass from the ash and provide a more representative concentration in whole coal. As a result of the lower combustion temperature, the resulting ash yield for "GSAsh Dry" tends to be somewhat higher than "STDAsh." EPA selected "GSAsh Dry" to calculate concentrations in the resulting ash both because it was the basis for many USGS measurements and the higher residual ash yield reflects the reality that combustion of coal is not always complete.

After calculating ash concentrations, EPA filtered out any non-standard coal types listed under "Estimated Rank" in the "QC_Descript" sheet. For example, EPA removed samples listed as: "bone," "shale," "clay," "pyrite zone," "coal," and "carbonaceous to coaly shale." These samples might represent roof, floor, partings, or other non-coal samples.[14] This filtering removed only 89 samples

14) Roof, floor, and partings are non-coal rocks found above, below, and interbedded within minable coal deposits.

and so is not anticipated to have a substantial impact on concentrations. After filtering, remaining samples consisted of lignite, bituminous, sub-bituminous, semi-anthracite, and anthracite.

Not all coal deposits in the United States are mined in equal volumes. Therefore, EPA sampled the COALQUAL database in rough proportion to production statistics by county and coal rank. To represent changes in production over time, EPA drew data from a mixture of sources to represent each decade between the first and last years with reported data, 1983 and 2022. EPA pulled data from the EIA Coal Data Browser for the years 2022, 2013, and 2003 (U.S. EIA, 2024). The browser does not report a county for these years and so reported mine codes were used to assign locations for each mine based on data from U.S. Mine Safety and Health Administration (U.S. MSHA, 2024). EPA pulled data from the EIA-7A, Annual Survey of Coal Production and Preparation for the years 1993 and 1983 (U.S. EIA, 1993a; 1983). These surveys do not include information on coal rank for these years. Data from the 1993 Annual Coal Production Report were used to identify coal rank for each mine by matching production reported for individual mines with the coal rank production reported for the county (U.S. EIA, 1993b). A production report was not identified for 1983. Instead, EPA assigned coal rank to each mine based on data identified from other reported years. In the rare case that coal rank produced by a mine changed over time, the oldest value identified from across the reports was assigned.

EPA calculated the production for each combination of state, county, and coal rank across all years as a percentage of total production across all years. Both anthracite and lignite represent a small portion of coal mined and database samples, so these coals were grouped together with and sampled alongside bituminous coals. The calculated percentages are provided as part of **Appendix C**. EPA randomly sampled COALQUAL in proportion to these percentages. If fewer than three data points were available for a combination of county and rank, then samples were drawn from across the state to avoid biasing sampling toward a small number of data points. This process was repeated 150,000 times to provide coverage of all the samples in the database. This sampling resulted in a distribution of uranium and thorium bulk content. The calculated concentrations represent a "whole ash" concentration consisting of fly ash mixed with bottom ash or boiler slag.

All uranium and thorium mass is inherently radioactive and will eventually decay. However, this mass may consist of multiple different isotopes that decay at different rates and with different decay products. The primary radioisotopes of interest for the current assessment are uranium-238 (U-238) and thorium-232 (Th-232). These isotopes are both the most naturally abundant (99.27% and 99.98% of uranium and thorium, respectively) and serve as the starting point for their respective decay chains. EPA calculated the bulk activity of U-238 and Th-232 from the bulk content of uranium and thorium using the following **Equation 5-1**, adapted from U.S. EPA (2014d):

(5-1) $$A_B = \frac{(C_B)(NA)}{(2.8 \times 10^{-12})(M_A)(T_{1/2})}$$

Where:

A_B	=	Isotope Bulk Activity [pCi/g]
C_B	=	Element Bulk Content [mg/kg]
NA	=	Isotope Natural Abundance [%]
M_A	=	Isotope Atomic Mass [amu]
$T_{1/2}$	=	Isotope Half-Life [years]
2.8×10^{-12}	=	Unit Conversion Constant

Each measurement of uranium and thorium bulk content were converted to corresponding U-238 and Th-232 bulk activity prior to calculating summary statistics for the whole ash. Because these calculations rely on innate properties of the isotopes (e.g., half-life), it is unlikely these calculations introduced much additional uncertainty into the dataset. **Table 5-1** presents summary statistics used to characterize bulk activity of U-238 and Th-232.

Table 5-1. Calculated Bulk Activity (pCi/g)

Constituent	50th Percentile	90th Percentile
Uranium-238	3.6	7.8
Thorium-232	2.2	4.1

U-238 and Th-232 will both naturally decay through their respective chains of isotopes before reaching a stable end product. Each of these decays will release radiation into the surrounding environment. Of the isotopes in these decay chains, radium and its short-lived decay products are expected to contribute most to cancer risk. Thus, it is critical to understand the activity of these isotopes. COALQUAL does not report bulk content of radium in coal. The mass concentration of this element is typically very low, often on the order of picograms per kilogram, and so is typically reported only on the basis of bulk activity. Previous studies have found that U-238 and Th-232 are in approximate secular equilibrium with the respective radium isotopes, radium-226 (Ra-226) and radium-228 (Ra-228) (Beck and Miller, 1980; LANL, 1982; Lauer et al., 2015). Secular equilibrium is the state in which the mass of a radioisotope remains constant because its production rate (e.g., due to decay of a parent isotope) is equal to its decay rate. Under secular equilibrium, the activity of all isotopes in the decay chain is identical. Therefore, EPA used data on the activity of U-238 and Th-232 to also represent the activity of Ra-226 and Ra-228.

A major benefit of the COALQUAL dataset is that it provides consistent reporting of each element across samples. This can allow identification of trends in relative constituent concentrations, which can be an important consideration for cumulative risk because a sample with the highest activity of one isotope may not have the highest of another. Therefore, EPA calculated summary

statistics for combined radium activity (Ra-226+228) across samples. **Table 5-2** presents summary statistics used to characterize combined activity of Ra-226+228.

Table 5-2. Combined Radium Bulk Activity (pCi/g)

Constituent	50th Percentile	90th Percentile
Radium 226 + 228	6.4	11.8

5.2.2 Radon Emanation Coefficient

The radon emanation coefficient (or "emanation power") is the fraction of generated radon able to escape from the ash and migrate into empty pore spaces between the ash particles. This parameter determines the fraction of radon that is available to migrate through the subsurface and enter overlying buildings. It is generally accepted that recoil is the dominant means by which radon gas is able to escape from solid particles. Recoil occurs because an alpha particle is ejected from the atom when radium decays to radon.[15] The force of ejection causes the newly formed radon atom to recoil in the opposite direction, which can result in release of radon from CCR if it occurs close enough to the surface of the ash particle. The distance radon can push through solid materials by recoil is small, typically on the order of a few micrometers. As a result, the radon emanation coefficient is influenced by waste properties, such as the size and shape of individual particles.

Sakoda et al. (2011) reported emanation coefficients from 46 samples of fly ash across six studies to derive an average emanation coefficient for Rn-222 of 3%. Other available data on CCR generated within the United States generally confirms the magnitude of that average. Beck et al. (1980) summarized data of fly ash and bottom ash samples from three power plants and reported average coefficients for both of less than 1%. Beck and Miller (1980) summarized data of 11 samples of fly ash and 10 samples of bottom ash or slag and reported an average emanation coefficient less than 2% and a maximum of 5%. The American Coal Ash Association, working with Laurence Berkley Laboratory, reported data on 20 samples of fly ash, with an average and maximum emanation of 1.2 and 3.5%, respectively (ACAA, 1981). The Los Alamos National Laboratory reported data on nine samples of both fly ash and bottom ash. The fly ash had average and maximum coefficients of 0.7 and 2.8%, while bottom ash had average and maximum coefficients of 0.2 and 0.4% (LANL, 1981). Based on these data, EPA assigned a moderate emanation coefficient to 1% for both Rn-220 and Rn-222. EPA applied factors of five to effectively bound the range of reported values and obtain low and high values of 0.2 and 5%, respectively.

The 50th and 90th percentile activities of Ra-226 in CCR of 4.0 and 7.5 pCi/g are higher than the corresponding values in background soil of 1.1 and 1.6 pCi/g, based on nation-wide data from Oak Ridge National Laboratory (ORNL, 1979). However, the range of radon emanation coefficients

15) An alpha particle is a positively charged subatomic particle that consists of two protons and two neutrons tightly bound together.

identified for CCR is substantially lower than for soils. The moderate values for CCR of 1% is over an order of magnitude lower than average values reported for soil around 20% (Sakoda et al., 2011). As a result, despite higher radium activities, radon emanation from CCR is generally expected to be lower than from background soil. Even with both the CCR radium activity and emanation coefficient set to higher values, radon emanation from CCR would fall within the range expected for soils. Thus, based on the available data, the radon risks from CCR are not distinguishable from background soil and highly unlikely to result in the radon accumulation within the range EPA recommends for remediation. Therefore, EPA did not retain radon for further consideration in this risk assessment and does not further discuss model parameters unique to this exposure pathway.

5.2.3 Cover Soil Depth

Cover soil depth is the thickness of uncontaminated soil separating CCRMU fill from the ground surface and the building foundation. A thicker cover will result in lower exposure because the soil serves as a shield that will absorb some of the gamma radiation and slow radon migration to allow for greater decay before either reaches the ground surface. It is generally assumed that placement of CCR will not extend up to the ground surface. However, EPA did not identify any data sources that could be used to define representative values for a cover that may be placed over fills. Instead, EPA considered multiple depths to define internal and external gamma shielding factors ranging from a maximum of 60 cm (2 feet), corresponding to the cover requirements for landfill closure, and down to 20 cm (0.65 feet) in increments of 20 cm.

5.2.4 Fill Size

The unit size is the land surface area over which the CCRMU fill extends. EPA set the unit size at 2,000 m^2 (0.5 acres), which is the closest available option in the PRG Calculator to the median unit size modeled for groundwater pathways of around 2,900 m^2 (0.72 acres) and so most representative of potential exposures. While larger amounts of CCR could be placed over smaller or larger areas, model results were not found to be particularly sensitive to areas within the range considered in this assessment.

5.2.5 Time Spent Indoors/Outdoors

The time spent indoors and outdoors is the fraction of a day a resident spends inside and outside around the home. This parameter determines the level of exposure to gamma radiation and radon. When inside, there is less exposure to gamma radiation because concrete and other building materials serve as shields that absorb some of the radiation before it can reach the resident. These parameters are expressed as a percent of a given 24-hour day. EPA selected the values for time spent indoors and outdoors as the PRG Calculator defaults of 68% and 7% of the day respectively. These values correspond to the 50th percentile values from Table 16-16 “indoors in a residence (all rooms)” and Table 16-20 “at home in the yard or other areas outside the house” in the 2011

Exposure Factors Handbook (US EPA, 2011). The remaining time not accounted for between these two fractions is assumed to be spent away from home and so not exposed.

5.2.6 Exposure Duration

Exposure duration is the number of years a receptor is expected to live at a single residence before moving away. It determines the total amount of time a receptor is near the waste and potentially exposed. EPA selected the value for exposure duration as the PRG Calculator default of 26 years. This value corresponds to the 90th percentile value from Table 16-108 in the 2011 Exposure Factors Handbook (U.S. EPA, 2011).

5.2.7 Risk Benchmarks

EPA calculated health-based benchmarks for direct gamma exposure to Th-232 and U-238 decay chains with the PRG Calculator. Contributions to exposure from incidental ingestion, inhalation, and consumption of produce were not included. Separate sets of values were calculated with the inputs identified throughout this section for each cover thickness. The benchmarks for a thickness of 20, 40, and 60 cm that correspond to a risk of 1×10^{-5} are 0.856, 4.02, and 16.7 pCi/g for the Th-232 decay chain and 1.34, 7.54, and 39.0 pCi/g U-238.

5.3 Results

For each cover thickness, EPA used the identified benchmarks to calculate the risk associated with each individual sample in the overall distribution of ash activity sampled from COALQUAL. The intent of this approach is to more accurately reflect the relative contributions from both decay chains. EPA then calculated the risks associated with the 90th and 50th activities from across the overall distribution. **Table 5-3** presents the results of this analysis. All values are rounded to the nearest whole number. Values that exceed the selected risk criteria (i.e., cancer risk > 1×10^{-5}) are shown in **bold**. In instances where a values were above the benchmark prior to rounding (e.g., risk = 1.4×10^{-5}), it was retained as an exceedance.

Table 5-3. Modeled Risk with Different Cover Thickness.

Cover Thickness	90th Percentile Activity	50th Percentile Activity
60 cm	4×10^{-6}	2×10^{-6}
40 cm	**2×10^{-5}**	**1×10^{-5}**
20 cm	**1×10^{-4}**	**6×10^{-5}**

High-end risks resulting from exposure to gamma radiation range from 4×10^{-6} at a cover thickness of 60 cm to 1×10^{-4} at a cover thickness of 20 cm. Risks associated with more moderate activity were approximately a factor of two lower, ranging from 2×10^{-6} at a cover thickness of 60 cm to 6×10^{-5} at a cover thickness of 20 cm.

5.4 Conclusions

CCR is a type of TENORM that contains radioisotopes at levels greater than typically observed in background soil. Available data indicate the potential for radon emanation and associated risk from CCR is not distinguishable from that of background soils. Therefore, this exposure route was not retained for further consideration. The remaining risks from gamma radiation for future residential receptors were modeled with the EPA PRG Calculator under the assumption that some level of cover separates the CCR and the receptor. Modeled high-end risks ranged from 4×10^{-6} at a cover thickness of 60cm to 1×10^{-4} at a cover thickness of 20 cm.

The parameter with the greatest influence on risk is the amount of cover soil separating the CCR and the receptor. This is because the soil serves as a shield and limits exposure to gamma radiation. However, this indicates the potential for even greater risks if CCR is located closer to the ground surface. While it is considered unlikely a future resident would live on top of an entirely uncovered CCRMU fill, there is real potential for the CCR to become mixed in with the surface soil if the fill is disturbed. Modeling such exposures would require additional assumptions about the degree of disturbance and mixing, which would introduce additional uncertainty into the calculated risks. Therefore, this scenario is discussed further in **Section 6 (Uncertainty and Sensitivity Analyses)**.

6 Uncertainty and Sensitivity Analyses

EPA reviewed the models used, as well as the data and assumptions input into the models, to better understand the potential sources of uncertainty inherent in the quantitative analyses. The Agency qualitatively and, to the extent possible, quantitatively analyzed these sources to understand the potential effects each may have on modeled risks. EPA also conducted further sensitivity analyses to understand how the modeled risks vary in response to changes in sensitive parameters and to evaluate the potential for risks through exposure pathways that could not be fully modeled on a national scale. The purpose of this section is to document the results of these additional analyses.

6.1 Uncertainty Analyses

Uncertainty exists to some degree in any quantitative evaluation, and can bias the calculated results higher or lower than actual values. It is important to understand both the direction and magnitude of uncertainties present in a risk assessment. The direction of uncertainty is the tendency for that uncertainty to push a predicted value higher or lower than the actual value, while the magnitude of uncertainty is the extent to which that uncertainty may push a predicted value away from the true value. Characterizing these uncertainties helps to ensure that the overall conclusions of the evaluation would not change with the consideration of additional information. There are three primary causes of uncertainty:

- Variability is the extent to which the characteristics of an environmental system are heterogeneous, and is reflected in the parameter distributions used as inputs for the models. Although variability can be better captured by collecting additional data, it cannot be eliminated and must be treated explicitly in the assessment.
- Data uncertainty is a description of the imperfection in knowledge of the true value of a particular parameter. Uncertainty is generally reducible through additional research and information-gathering.
- Model error occurs because models and their mathematical expressions are simplifications of reality that are used to approximate real-world conditions, processes, and their relationships. These assumptions are sometimes necessary to solve complex mathematical equations or to fill gaps in available knowledge. However, the simplification of complex systems may misrepresent real-world conditions to an unknown degree.

Uncertainties identified in the evaluation were managed to the extent practicable to minimize the potential effects on model results. Variability was addressed by compiling available data into probabilistic distributions for each parameter. Uncertainty about the exact range or distribution of a parameter was addressed through use of estimated point values or distributions to appropriately bound the true range, while ensuring protection of human health and the environment.

As previously documented in **Section 4.1** and **Section 5.1**, the publicly available models used in the current evaluation have undergone extensive review and validation. Together, these reviews verified that the mathematical formulation of the models is scientifically sound, the code executes properly, and the results can provide a reasonable representation of real-world conditions. Due to the extent of past review, EPA has a high degree of confidence in the design and functionality of these models. While some sources of uncertainty based on the model design are known to remain, such as the inability to fully quantify the effects of disposal below the water table, EPA aimed to constrain the scope of the evaluation to minimize the effects of such uncertainties on quantitative model results. Thus, EPA limited the discussion here to uncertainties associated with key inputs selected for use in the models. In particular, many inputs used to characterize groundwater fate and transport were drawn from the same sources as the 2014 Risk Assessment (U.S. EPA, 2014a). Uncertainties associated with these sources were previously discussed in the 2014 Assessment and these sources were found to represent the best available data available on a national scale. As a result, the focus of this uncertainty analysis is new sources of data incorporated in this evaluation.

6.1.1 Constituents Retained for Groundwater Modeling

The 2014 Risk Assessment identified potential for groundwater risk to receptors that live up to a mile away from landfills and surface impoundments (U.S. EPA, 2014a). For the current assessment, the Agency retained only those constituents found to pose risk from unlined impoundments. These constituents are those that have the demonstrated potential to spread furthest at environmentally significant concentrations and so are most likely to pose concern closer to smaller CCRMU fills. The 2014 Risk Assessment did identify other contaminants of concern, but these were all associated with specific CCR or management scenarios not considered relevant to CCRMU fills (i.e., FGD waste, codisposal with coal refuse). While there may be potential for these other constituents to result in more localized impacts to groundwater, consideration of these additional constituents was not necessary to establish the potential for risk from CCRMU fills. Therefore this uncertainty is unlikely to affect the final conclusions of the risk assessment.

6.1.2 Lithium

Lithium was previously identified as a risk driver for unlined surface impoundments in the 2014 Risk Assessment (U.S. EPA, 2014a), but was not retained for modeling in the current assessment because of the limited number of LEAF samples and associated a lack of information on leachable content. The inability to fully model this constituent may result in an underestimation of risk to groundwater. Lithium is a highly mobile constituent previously identified as posing similar risks as molybdenum based on impoundment porewater data. Available LEAF data indicate that lithium and molybdenum can both leach at similarly high concentrations when managed dry in landfills. Thus, it is anticipated that modeled lithium risks for CCRMU fills would be comparable to those identified for molybdenum. The exact magnitude of this uncertainty is not known.

6.1.3 Leachate pH

EPA modeled leaching from CCRMU fills with distribution of leachate pH based on measurements of the natural pH (or "own pH") of individual ash samples analyzed with LEAF methods. Sampling of this pH distribution resulted in a median pH of around 10 across all model runs. This aligns with the median pH modeled in the 2014 Risk Assessment, which relied on measurements of pH from landfill leachate (U.S. EPA, 2014a). However, the broader distribution of pH values has a greater prevalence of acidic conditions than previously modeled in 2014 Risk Assessment. It is reasonable that the pH conditions in landfills and CCRMU fills can differ. Landfills can contain a mixture of different CCR types and other related waste streams, resulting in a different overall pH from that of individual CCR. Smaller CCRMU fills are more likely to consist of a single ash type. Thus, EPA determined it is most appropriate to consider the pH of individual ash samples, rather than broader landfill conditions. To better understand the impact of pH on modeled risks, EPA parsed the 90th modeled groundwater concentrations at 1,000 feet from the waste boundary into bins representing acidic (pH < 7) and basic (pH > 7) conditions. **Table 6-1** presents the results of this comparison. Values that exceed the selected risk criteria (i.e., cancer risk > 1×10^{-5} or HQ > 1) are shown in **bold**.

Table 6-1. Modeled Risk for Different Leachate pH

Constituent	Acidic	Basic
Carcinogenic Effects		
Arsenic III	**1×10^{-4}**	**3×10^{-4}**
Arsenic V	**1×10^{-4}**	**3×10^{-4}**
Noncarcinogenic Effects		
Arsenic III	0.2	0.5
Arsenic V	0.1	0.3
Molybdenum	0.4	**20**
Thallium	**47**	**5.2**

This comparison shows that consideration of acidic leachate pH as low as 3.1 actually resulted in lower risks for most constituents. This is because the pH distribution does not include highly acidic conditions that are known to mobilize arsenic and other constituents. Only thallium had higher risks at an acidic pH. Thus, to the extent that basic pH conditions are more prevalent in the field, there is potential for the model to underestimate thallium risk to some degree. Yet thallium was still found to spread at concentrations of concern up to 1,000 ft away from the waste boundary under more basic conditions. Therefore, the magnitude of this uncertainty is considered to be small.

6.1.4 Chemical Speciation

The speciation of arsenic can alter the mobility of this constituent in the environment. Arsenic occurs most frequently in either a trivalent (arsenic III) or pentavalent (arsenic V) oxidation state,

with arsenic III as the more mobile form. The speciation of arsenic can change during transport through the subsurface soil and groundwater based on the prevailing geochemistry. There is not sufficient data available on a national scale to model changes in oxidation state during transport, particularly where the pH and redox conditions of a leachate plume may further alter groundwater chemistry. To account for this uncertainty, EPACMTP was run twice for both valence states of arsenic. The results from the two model runs bracket the full range of possible risks. Actual risks for arsenic on a national scale are anticipated to fall somewhere within this range. However, EPA notes that the current assessment identified potential for risk to groundwater from the less mobile arsenic V species. Therefore, this uncertainty is unlikely to affect the final conclusions of the risk assessment.

6.1.5 Landfill Cover

It is possible some historical landfills have been closed in a manner more consistent with the existing CCR regulations than modeled. However, this is unlikely to change the overall conclusions of the risk assessment. This is because, regardless of the cover that is ultimately installed, higher leakage can occur throughout the active life of the unit when the landfill face is open and able to intercept more precipitation. This conclusion is reinforced by the fact that facility monitoring reports document that around 20% of currently active landfills have already triggered corrective action. Additionally, EPA has seen no evidence to suggest closure of older historical and inactive units has been consistently more protective than previously modeled. The Agency's previous review of state programs prior to 2015 found that oversight of these wastes and the overall protectiveness of particular programs varied widely and raised concerns about adequacy. For these reasons, EPA believes the approach to modeling national risks in the 2014 Risk Assessment is equally applicable to historical landfills.

EPA also believes the 2014 Risk Assessment accurately represents the risk potential that remains for units that were closed consistent with the 2015 CCR Rule. If the cover system is not adequately maintained after closure, degradation over time from human or animal activity, natural settling, freeze-thaw cycles, flooding and other extreme weather events, and other factors can result in greater leakage from the unit than designed. In some cases, groundwater monitoring may provide the only clear evidence the cap is not performing as designed. Thus, the 2014 Risk Assessment accurately describes the risks that can result if these units are not adequately maintained and monitored in line with current regulatory requirements.

6.1.6 Fill Conditions

EPACMTP requires a fixed source term to model leakage and so cannot track changes to a unit over time. There is little information available on the current condition of these fills. However, in the absence of routine maintenance, it cannot be assumed any fill will remain undisturbed due to some combination of natural processes (e.g., erosion, freeze-thaw cycling, differential settling) or anthropogenic activity (e.g., construction, excavation). Therefore, to understand the risk potential

of these units in the absence of required maintenance, EPA assumed all CCRMU fills could become disturbed at some point. There is no information available that could be used to estimate the extent to which these fills may be disturbed. Therefore, EPA modeled the hydraulic conductivity of a disturbed fill as equivalent to that of the surrounding soil megatexture under the presumption that the ash would achieve a similar degree of natural compaction. This approach is considered to be reasonable, as there is substantial overlap in the range of reported conductivities for both fly and bottom ash (e.g., EPRI, 1993; Ramme and Tharanyil, 2013) and natural soils. This approach may overestimate the potential for long-term infiltration to some degree. For example, EPA is aware that some fly ash has the potential to self-cement when exposed to water, which would result in a lower conductivity. Yet, it is unclear how common it is for this type of ash to be placed in fills when it is a valuable commodity for use in concrete. Further, there is little information about the long-term performance of unamended ash left in the soil, particularly if that ash does not meet specifications for use in concrete. For these reasons, EPA believe the current modeling approach makes the best use of available information while remaining protective of human health.

6.1.7 Offsite Receptors

There is little information available about the specific locations of CCRMU fills. As a result, it is not possible to develop a probabilistic distribution of distances to the nearest offsite resident or model the potential for risk to these receptors. However, groundwater modeling with MODFLOW identified the potential for high-end plumes to extend approximately 3,000 feet (0.56 mile) from the waste boundary. EPA previously estimated that around 70% of the nearest residents identified in the 2014 Risk Assessment live within half a mile of a landfill (U.S. EPA, 2014a). Thus, to the extent that CCRMU fills tend to be located similar distances from the property boundary as disposal units, there is real potential for contamination to migrate offsite and for nearby receptors to be exposed. Further, there is potential for leakage from a fill to intersect with and exacerbate releases from any nearby disposal units or other fills, resulting in even greater risk from disposal units to offsite receptors than previously modeled. The inability to model exposure of offsite residential receptors to leakage from CCRMU fills will result in an underestimation of risk to some degree. However, the magnitude of this uncertainty is unknown.

6.1.8 Risks to Surface Water

The fact some contaminant plumes might discharge to surface water at a given site does not mean there is no potential for harm or no need for further action to account for impacts to nearby surface water bodies. Surface water bodies are large and highly interconnected systems that receive discharge from a diverse array of sources. EPA notes that the 2014 Risk Assessment modeled risks from each landfill and impoundment in isolation. However, facilities can have multiple disposal units located in close proximity, which may result in greater cumulative impacts to surface water than reported in the 2014 Assessment. There is also an unknown potential for multiple CCRMU fills to be located across the facility and further contribute to facility-wide discharge. Finally, there

can be any number of other industrial sources located along the banks of the water body, each with their own associated discharges. If all facilities along the water body were allowed to freely discharge to surface water solely because no individual unit posed risk, the cumulative impacts to surface water could be severe. The 2015 CCR Rule addressed this potential risk by specifying corrective action must "remove from the environment as much of the contaminated material that was released from the CCR unit as is feasible." 40 C.F.R. 257.97(b)(3). Thus, dilution of a groundwater plume into surface water could not be considered a presumptive remedy. This requirement is consistent with guidance for OLEM programs, which specify the need to prevent groundwater contamination above GWPS from contaminating other aquifers or environmental media (U.S. EPA, 2009c).

EPA reviewed model results for previously excluded impoundments to understand the potential for discharge of concentrations greater than GWPS to nearby surface water bodies. The Agency first combined and rearranged Equations J-1 and J-2 from the 2014 Risk Assessment, substituting parameters to obtain an equation solvable with only data reported in the EPACMTP Input/Output Database (**Appendix C**). The resulting **Equation 6-1** was then applied to back-calculate the average groundwater concentration for each constituent at the point of discharge to surface water.

$$\bar{C}(X = X_{SW}, t) = \frac{(\text{SWFlux})}{(BaseF)(Plume\_Width)\left(10^6 \frac{m^2}{km^2}\right)} \quad \textbf{(6-1)}$$

Where:

C = Groundwater concentration at $X = X_{SW}$ (g/m^3 or mg/L);
X = Specified distance downgradient of unit edge (m);
X_{SW} = Distance of stream from the downgradient unit edge (m);
t = Time of peak discharge (yr);
SWFlux = Averaged constituent mass loading to surface water (g/yr);
BaseF = Baseflow per unit length of stream (km^2/yr); and
Plume_Width = Width of impacted groundwater discharging to stream (m).

Equation 6-1 was applied to each model run for previously excluded surface impoundments. This was done for constituents previously found to pose groundwater risk from unlined impoundments. Calculated concentrations were then compared against relevant GWPS to calculate a percentage of model runs where average discharge exceed standards. **Table 6-2** lists the percentage of model runs for each contaminant that the average groundwater concentration over the area of discharge exceeded GWPS. Similar calculations were not done for lithium because benchmarks for ecological exposure to surface water or sediment and uptake by fish were not identified for lithium in 2014. Because a corresponding risk could not be calculated, SWFlux was not modeled at the time.

Table 6-2. Impoundment Exceedance of GWPS at Surface Water Boundary

Constituent	All Exceedance (%)	Unlined Exceedance (%)
Arsenic (III)	19.8	31.1
Arsenic (V)	5.5	8.9
Molybdenum	35.9	55.1
Thallium	1.3	2.1

Based on these results, a substantial fraction of these impoundments have the potential to discharge concentrations above GWPS to surface water. However, EPA notes these percentages are based on an average concentration over the entire area of discharge. If a discharge is broad and has wide regions of lower concentrations around the periphery, it can mask evidence of high concentrations closer to the center of the plume. As a result, it is expected the percentage of units that can result in discharges that exceed GWPS is somewhat higher than reported above.

6.1.9 Alternate Contaminant Sources

As part of the current risk assessment, EPA considered whether there might be a quantity of CCR small enough to pose no reasonable risk of adverse impacts to groundwater. Such an analysis might be feasible for individual placements of CCR. However, management of CCR onsite at electric utilities is considered unique from management offsite in part because there is far greater potential for placement of CCR at multiple discrete locations, both across the facility and in close proximity. The presence of unidentified accumulations of CCR are a particular concern for groundwater monitoring around currently regulated disposal units. There is presently limited data available on the size and extent of placement across these facilities and the available record indicates that documentation of past placement has not always been maintained. As such, EPA does not believe it is possible to compile a reliable record of such placements in the absence of further facility inspection and reporting.

The regulatory framework of the 2015 CCR Rule does not capture contamination arising from CCRMU (disposal units or fills). Therefore, at present, both previous and ongoing leakage from such placements can affect groundwater quality at wells installed around monitored CCR units without running afoul of the rule. The statistical methods used to identify statistically significant increases and statistically significant levels are formulated based on the assumption there is a common background that would be found both upgradient and downgradient of a CCR unit, provided that unit has not leaked. However, this assumption would not be valid if background wells have been affected by leakage from disposal of CCR further upgradient, which can leak all the same constituents as currently regulated units. If concentrations in background wells increase due to leakage from disposal further upgradient, then the resulting characterization of background

would not provide an accurate baseline for comparison against compliance wells. Any leakage from the regulated CCR unit would then need to progress even further and faster than from the upgradient disposal to be distinguished from the skewed background. At a minimum, this could delay identification of a release.

Leakage from CCR disposed further upgradient does not have to constitute a release by itself to confound groundwater monitoring at nearby CCR units. Elevated levels of the common ions and other constituents listed on Appendix III could still delay or prevent a monitored CCR unit from entering into assessment monitoring. Further, leakage from smaller sources can still contribute to overall risk by supplementing leakage from regulated CCR units, resulting in a larger downgradient plume than would have otherwise occurred.

EPA previously identified potential for risk to human health and the environment from operating landfills and surface impoundments. If identification of a release from these currently regulated CCR units is delayed or prevented by leakage from upgradient disposal, then previously identified risks from these CCR units to nearby receptors would remain. The longer that contamination is allowed to spread, the greater potential that full remediation will not be feasible as a result of complex site geology or other factors. Therefore, just because a particular CCRMU might not be expected to trigger corrective action in isolation does not mean there is no potential for concern. The Agency is unable to reliably identify a minimum quantity of CCR at which interference with groundwater monitoring is unlikely. This would depend on a number of factors such as the quantity of ash, the number and proximity of these placements, and the relative timeframe over which each has leaked. This represents a major source of uncertainty in the current assessment.

6.1.10 Bulk Activity

COALQUAL includes data on coal samples as-mined. These samples will all undergo processing and combustion prior to disposal as coal ash, both of which may alter the overall composition of the sample. Therefore, EPA considered the potential for these processes to result in either an over or underestimation of bulk contaminant concentrations in the resulting ash.

COALQUAL reports the weighted average of concentrations across multiple benches to provide an estimate of coal quality across the full bed and incorporate any vertical variation in coal quality. These full-bed averages provide estimates of overall coal quality, but there is potential that some portions of the bed may not ultimately be mined or delivered due to lower quality coal or other economic factors. Such selective mining practices might avoid some of the more pyrite- or clay-rich portions of the coal bed associated with higher concentrations of some contaminants. EPA anticipates that sampling of the COALQUAL database weighted toward states and counties with the highest production rates will blunt effects of this uncertainty to some degree. These represent the most productive regions of the country with large reservoirs of salable coal, making it less likely that poor quality deposits will represent a majority of the sampled bed. There is also no

evidence such mining practices consistently prevent mining of coal with higher contaminant concentrations. Specifically, empirical measurements of CCR bulk content demonstrate the potential for concentrations of a similar magnitude as estimated by COALQUAL. As a result, the magnitude of this uncertainty is believed to be small.

Coal naturally contains impurities, such as pyrite and quartz, which can contribute to undesirable residuals (i.e., ash) and air pollutants (e.g., sulfur dioxide) during combustion. Coal cleaning is the process by which impurities are removed to the extent practicable from coal prior to combustion. Coal cleaning is a longstanding practice because it can increase the heating value and improve fuel consistency. Today it is employed just as often to reduce emissions of sulfur dioxide and other air pollutants (U.S. EPA, 1977). Although a wide array of cleaning methods have been proposed, the most common approach is still washing (NRC, 2007). Washing is accomplished by first crushing the coal to expose impurities that are not chemically bound within the coal. Afterward, the coal is placed in water, where the impurities separate from the coal based on differences in specific gravity. A secondary benefit of washing is it can greatly reduce concentrations of certain trace elements closely associated with the impurities, particularly sulfur minerals. However, washing also reduces the overall amount of CCR generated by combustion. For example, one study found of eastern coals found an average 70% reduction in the residual ash remaining after cleaning (EPRI, 1998). Thus, reduction in constituent mass from cleaning will be counterbalanced to some degree by concentration back into a smaller amount of ash. EPA identified one study that compared concentrations of raw and clean coal on an ash basis (USGS, 2021). **Table 6-3** presents a comparison of reported thorium and uranium concentrations from coal beds before and after cleaning. Based on this comparison, typical ash from cleaned coal tends to have similar or higher concentrations of these elements. Thus, this uncertainty is considered unlikely to result in an underestimation of risk.

Table 6-3. Bulk Content of Raw and Clean Coals on Ash Basis (mg/kg).

Sample Number	Field Sample ID	Coal Bed	Sample Type	Thorium	Uranium	Median Thorium	Median Uranium
45	BR Dan 1-2	Danville #7	Raw Coal	16.8	6.1	16.8	6.1
46	BR Dan 4	Danville #7	Clean coal	17.8	22.9	17.8	22.9
26	IL 23-ER 1D	De Koven	Raw coal	7.8	5.4	7.8	5.4
27	IL 24-ER 2D	De Koven	Clean coal	15.5	12.0	15.5	12.0
14	IL 11-SM 1H	Herrin #6	Raw coal	13.0	10.4	13.0	7.2
21	IL 18-BH 2H	Herrin #6	Raw coal	17.9	8.4		
35	IL 32-MM 1H	Herrin #6	Raw coal	13.8	7.2		
39	IL 36-WH 1H	Herrin #6	Raw coal	11.6	4.9		
1	IL-1	Herrin #6	Raw Coal	5.6	5.2		

Table 6-3. Bulk Content of Raw and Clean Coals on Ash Basis (mg/kg).

Sample Number	Field Sample ID	Coal Bed	Sample Type	Thorium	Uranium	Median Thorium	Median Uranium
8	IL-8	Herrin #6	Final product	1.8	7.6	16.0	23.1
15	IL 12-SM 2H	Herrin #6	Clean coal	17.2	22.1		
20	IL 17-BH 1H	Herrin #6	Clean coal	11.8	4.7		
33	IL 30-PM 2H	Herrin #6	Clean coal	15.9	24.0		
36	IL 33-MM 2H	Herrin #6	Clean coal	16.1	17.2		
40	IL 37-WH 2H	Herrin #6	Clean coal	18.3	78.1		
42	IL 39-LG 2H	Herrin #6	Clean coal	13.2	24.6		
24	IL 21-CP 1M	Murphysboro	Raw coal	24.5	15.5	24.5	15.5
25	IL 22-CP 2M	Murphysboro	Clean coal	25.0	14.3	25.0	14.3
17	IL 14-V 1S	Springfield #5	Raw coal	10.4	7.7	13.2	8.2
22	IL 19-BH 1S	Springfield #5	Raw coal	15.9	8.7		
18	IL-15-V 2S	Springfield #5	Clean coal	11.7	14.5	15.4	11.8
23	IL 20-BH 2S	Springfield #5	Clean coal	19.0	9.1		

Coal combustion occurs at extremely high temperatures that can exceed 1,000 °C (1,832 °F). These temperatures are higher than the boiling points of many trace constituents. As a result, certain constituents can vaporize from the coal during combustion and escape from the boiler along with the flue gas. However, flue gas will not remain at such a high temperature. For example, at a plant equipped with an FGD unit, the flue gas will generally exit at temperature between 55 to 70°C (130 to 160°F) (NETL, 2016). That is below the boiling point of most elements and so it is expected the majority of constituent mass will condense out onto ash particulates and be captured in pollution control devices, such as baghouses. Therefore, EPA assumes the effects of volatilization on whole ash concentrations are negligible for the constituents considered in this evaluation. However, this may not be the case for highly volatile constituents, such as boron, mercury, and selenium.

Coal combustion is often not a 100% efficient process, resulting in some amount of unburnt carbon mass, commonly referred to as loss on ignition (LOI), remaining in the residual ash. EPA could not explicitly incorporate LOI in calculations because that data is not available in COALQUAL. The presence of unburnt carbon would increase the overall mass of ash generated and may result in lower concentrations than calculated. Available estimates indicate that LOI for most ashes falls within a narrow range and is often less than 10% on a mass basis (Heidrich et al., 2013). That amount of unburnt carbon, while potentially significant from a chemical perspective, is expected to amount to a rounding error for calculation of mass concentrations. Additionally, EPA relied on the reported "GSash" to represent ash yield for the calculation of ash bulk content in part because it reflects combustion at a lower temperature and results in greater yield than "STDash." This

approach is expected to indirectly reflect the additional mass of ash resulting from LOI to some extent. As a result, the magnitude of this uncertainty is believed to be small.

To further understand the potential, EPA compared the bulk activity of both thorium and uranium calculated from COALQUAL with measurements of fly ash identified from government and industry reports, as well as peer-reviewed journal articles (**Appendix B**). Summary statistics were calculated after averaging samples from each study determined to represent the same facility burning the same coal source. **Table 6-4** summarizes this comparison of calculated and measured bulk content. Upper bound values represent a maximum reported value unless otherwise indicated.

Table 6-4. Comparison of CCR Bulk Activity Data.

Constituent	Data Source	Sample Count	50th Percentile (pCi/g)	90th Percentile (pCi/g)	Upper Bound (pCi/g)
Uranium-238 / Radium-226	COALQUAL[1]	6,104	3.6	7.8	21
	Appendix B Uranium-238	199	3.4	6.8	37
	Appendix B Radium-226	160	4.2	8.1	28
Thorium-232 / Radium-228	COALQUAL[1]	5,836	2.2	4.1	7.3
	Appendix B Thorium-232	108	2.4	5.4	24
	Appendix B Radium-228	61	2.1	3.1	3.8

NR – Not Reported

1) Upper bound is 99th percentile to exclude outlier values for purposes of comparison.

This comparison indicates there is generally good agreement between the values calculated from COALQUAL and empirical measurements reported in the broader literature. Values calculated from COALQUAL fall in the narrow range between those reported in the literature for the parent isotopes and radium progeny. This provides confidence the activities calculated from COALQUAL are reasonable. Use of these data would not result in substantially different conclusions about potential for exposure compared to other available data. EPA did not identify a strong regional influence on the variability of the calculated activities. The average activities of the COALQUAL samples used in this analysis from eastern and western production states without any further weighting are 2.7 vs 2.7 pCi/g for Th-232 and 4.7 vs 5.2 pCi/g for U-238. Thus, there is no indication that further refinement of the sampling methodology would yield substantially different results.

Based on these results, EPA sampled COALQUAL for other constituents evaluated in the current assessment using the methodology described in **Section 5 (CCRMU Fill Soil Risk).** EPA compared the calculated values with empirical measurements of fly ash from the 2014 Risk Assessment (U.S. EPA, 2014a) and other literature sources to understand how calculated values compared for other relevant constituents. Values were not calculated for thallium because the high number of non-

detects in COALQUAL database for this constituent. Insufficient empirical data was identified to conduct a comparison for lithium. **Table 6-5** summarizes the results of this comparison. Upper bound values represent a maximum reported value unless otherwise indicated.

Table 6-5. Comparison of CCR Bulk Concentration Data.

Constituent	Data Source	Count	50th Percentile (mg/kg)	90th Percentile (mg/kg)	Upper Bound (mg/kg)
Arsenic	COALQUAL[1]	6,102 Samples	35	251	1,197
	U.S. EPA (2014a)	36 Facilities	60	211	980
	EPRI (2008)	NR	50	NR	NR
Molybdenum	COALQUAL[1]	5,820 Samples	15	50	150
	U.S. EPA (2014a)	16 Facilities	14	62	260
	EPRI (2011)	81 Samples	16	NR	236

NR – Not Reported

1) Upper bound is 99th percentile to exclude outlier values for purposes of comparison.

These values also show general agreement across the distribution of concentrations for arsenic and molybdenum. This provides some confidence the concentrations calculated from COALQUAL are reasonable. Use of these data would not result in substantially different conclusions about the magnitude of potential exposures compared to other data sources. EPA did identify strong regional influence on the variability of calculated concentrations for arsenic. The average concentration of COALQUAL samples used in this analysis from eastern and western production states without any further weighting are 47 vs 310 mg/kg. As a result, there may be potential for calculated values to shift somewhat in response to further refinement of the sampling methodology. As a result, EPA does not further rely on COALQUAL at this time to draw conclusions about these constituents at this time.

6.1.11 Coal Combustion Residual Type

The bulk activity calculated with the COALQUAL database represents the whole ash generated by combustion, which is a mixture of fly ash and bottom ash or boiler slag. It is not possible to further break out the contributions from each type of CCR. In a typical boiler, the ratio of generated ash types falls somewhere around 80% fly ash to 20% bottom ash (U.S. EPA, 1981). This ratio has remained relatively consistent. Recent statistics on national generation rates show that fly ash accounts for 74% of the annual mass of these three ash types (ACAA, 2022). Thus, the whole ash can be understood as predominantly fly ash.

There are potential differences in the composition of fly ash and other CCR types that may result from differences in the volatility of individual constituents. As previously noted, more volatile constituents have a greater tendency to escape from the boiler and settle out onto fly ash. This may result in higher concentrations in fly ash compared to bottom ash and boiler slag. Generally, there are far less data available on constituent concentrations present in and released from bottom ash and boiler slag. This may be due in part to the smaller quantities of ash generated. The most recent

American Coal Ash Association (ACAA) report indicates that coal combustion across the United States results in 74% fly ash, 23% bottom ash, and 3% boiler slag (ACAA, 2022). Thus, from a waste management perspective, fly ash has historically been a dominant concern.

In 2014, EPA did not have sufficient data on bottom ash or boiler slag to separately model these CCR types. This was not considered a major source of uncertainty because of the prevalence of co-management of different CCR types in landfills and impoundments. Since then, the Agency has not identified any substantial new sources of data to further inform groundwater modeling for these CCR types. As a result, EPA was again unable to separately model these CCR types as part of the current evaluation. However, it is assumed that there is similar potential for co-management in CCRMU fills.

Despite the lack of waste characterization data for bottom ash and boiler slag, the monitoring data that the 2015 CCR Rule required facilities to report provides ample evidence that these two CCR types have similar potential to contaminate groundwater based on facility monitoring reports as of October 2023. A total of 26 of 81 units identified as dedicated to bottom ash have initiated corrective action (32%). A total of 5 of 13 units identified as dedicated to slag have initiated corrective action (38%). These rates of are comparable those for units that manage other or mixed ash types (41%). Thus, it appears that any differences in the composition of bottom ash and boiler slag are not substantial enough to prevent groundwater releases. As a result, the magnitude of the uncertainty as it related to groundwater exposure is considered low.

As part of the Agency's regular review of the available literature, EPA did identify a number of sources that characterized the bulk activity of bottom ash. Altogether, these sources are considered sufficient to characterize the anticipated bulk activity of this CCR type. **Table 6-6** provides a comparison of summary statistics for Ra-226 activity in fly and bottom ash. Summary statistics were calculated after averaging samples from each study that were collected from a single source. The underlying raw data are made available in **Appendix B.** Little data was identified for Ra-228 in bottom ash and so a similar comparison could not be conducted.

Table 6-6. Comparison of Fly and Bottom Ash Bulk Activity.

Constituent	Ash Type	Sample Count	50th Percentile (pCi/g)	90th Percentile (pCi/g)
Radium-226	Fly Ash	160	4.2	8.1
	Bottom Ash	42	4.4	8.8

Based on these data, there is no indication the Ra-226 activity of bottom ash will differ substantially from that of fly ash. Additionally, it has been previously reported that both thorium and uranium are expected to be similarly distributed between bottom ash and fly ash (Clarke and Sloss, 1992). Therefore, EPA concludes the use of COALQUAL data to also represent the bulk activity of bottom ash is appropriate. EPA is not aware of any reason the overall composition of boiler slag would

differ dramatically from that of bottom ash. As a result, the magnitude of the uncertainty as it relates to radiation exposure is considered low.

6.1.12 Radiation Model

The Agency considered both the RESRAD Onsite model and the EPA PRG Calculator for use in the current risk assessment to evaluate the risks from exposure to radiation. RESRAD was initially considered because it provides greater ability to directly adjust the model parameters that control radon fate and transport through subsurface soils. However, because it was found that emanation of radon from CCR is indistinguishable from background soils, the PRG Calculator was selected for ease of use and programmatic consistency. As previously documented in **Section 5.1**, the PRG Calculator has undergone extensive review and validation. To better understand the potential for this selection to affect modeled risk, EPA compared the results of the two models for a single scenario. The Agency considered an exposure scenario of direct exposure to gamma radiation and incidental ingestion of soil for a resident living on top of an uncovered fill containing 4.0 pCi/g Th-232 and 7.8 pCi/g U-238 in equilibrium with their respective decay chains. Under this scenario, both RESRAD and the PRG Calculator return a risk of 9×10^{-4}. Given the agreement between these results, EPA concludes the uncertainty associated with model selection is likely to be minimal.

6.1.13 Additional Soil Exposure Pathways

The current assessment of soil exposure focused on incidental ingestion of soil and direct exposure to gamma radiation because these are the two most direct exposure routes. There can be potential for additional exposure through other routes if CCRMU fills are disturbed. Not all of these other pathways are likely to be major contributors to overall risk. For example, based on default PRG Calculator inputs, the risk from inhalation of ash particles that become suspended in the air is three orders of magnitude less than from external exposure to gamma radiation. Therefore, consideration of this pathways is not expected to impact overall risk estimates. Other pathways have potential to result in greater risk but depend on a number of additional factors that introduce further variability and potential uncertainty into exposure estimates on a national scale. For example, based on default PRG Calculator inputs, the risk from consumption of a range of produce grown on impacted soil may be up to an order of magnitude greater than external exposure to gamma radiation. However, actual risk at a site will depend on a number of factors, such as the types of crops grown, the consumption rate for each crop, and how much of the diet is sourced from the garden. There is little data available for many of these factors to support modeling on a national scale and it is also unlikely this exposure scenario would occur at every site. The lack of quantitative evaluation for these additional pathways may result in some underestimation of risk. The magnitude of this uncertainty is unknown. However, risks associated with the more direct exposure pathways were already found to be substantial enough to warrant action. Therefore, this uncertainty is unlikely to alter the overall conclusions of the current assessment.

6.1.14 Background

EPA generally only considers contributions from disposed wastes to risk when conducting national risk assessments under RCRA. Background concentrations may contribute to risk when present and may sometimes be higher than the concentrations modeled in the risk assessment. Although constituent concentrations in undisturbed environmental media can be highly variable, they are often relatively low in concentration. As a result, consideration of these concentrations would generally have no impact on the overall conclusions of a national-scale risk assessment. Instead, consideration of background concentrations is more appropriate on a site-specific basis when risk managers are determining the need for and scope of corrective action. EPA recognizes that a focus on background is more common for discussion of radioactivity, particularly when providing context for the associated risks to the broader public. The 50th and 90th percentiles of Ra-226+228 in background surface soil are estimated to be 2.1 and 3.0 pCi/g (ORNL, 1979). EPA has found that activities of nearly half of fly and bottom ashes are likely to be greater than the standard of 5 pCi/g Ra-226+228 above background soil, which has been adopted as an applicable or relevant and appropriate requirement (ARAR) for some cleanups under Superfund and some state programs (U.S. EPA, 1998). Additionally, EPA has found that high-end Ra-226+228 activity in CCR has the potential to be around an order of magnitude higher than background soil. Thus, there is clear potential for mixing of CCR with soil to further increase any existing risk from background. Mixing of small quantities of CCR with soil may not result in total soil activity above the ARAR. For high-end CCR activity, this may require a roughly equal mixture of soil and ash. However, that does not mean that lower accumulations pose no concern. EPA has shown that unrestricted exposure to the high-end activity found in CCR can result in a cancer risk approaching 1×10^{-3}. Therefore, smaller accumulations in surface soil can still result in risks within the range EPA considers for regulation. As such, EPA has identified an ARAR of 5 pCi/g as equally applicable to subsurface contamination that may be disturbed at some point in the future and concluded that "it would not generally be appropriate to allow backfilling with material with concentration higher than 5 pCi/g." Therefore, further consideration of background is unlikely to alter the conclusions of the current assessment.

6.2 Sensitivity Analyses

Sensitivity analyses identify the parameters that exert the greatest influence on modeled risks. These analyses provide further insight as to whether specific waste management scenarios can result in risks substantially different than those modeled nationally. EPA relied on the findings of these analyses to draw additional conclusions about the potential risks associated with CCR management and to refine the scope of its proposed regulatory action.

6.2.1 Central Tendency Exposure for Groundwater

Consistent with EPA's long-standing practice under RCRA (as well as other agency programs), an RME individual provides the principal basis for evaluating potential human health risks. As such, the focus of groundwater modeling with MODFLOW was the risk to this RME receptor. However,

EPA also considers moderate, central tendency (CTE) exposures to provide broader understanding of the overall distribution of risk. Such information can provide useful information that can guide decision-making, such as prioritization of resources for cleanups across different sites. Therefore, EPA conducted an additional sensitivity analysis to evaluate the risks for a CTE individual from the high-end concentrations previously discussed in **Section 4.4**.

EPA updated the concentrations benchmarks used with MODFLOW to reflect a CTE scenario based on the most recent available data on median receptor characteristics and behavior from the 2011 Exposure Factors Handbook (U.S. EPA, 2011) for tap water ingestion rate (Table 3-33) and residence time (Table 16-88). This resulted in values for an adult receptor of 1 L/day for tap water ingestion and 9 years for residence time. EPA compared the CTE benchmark to the average concentration of arsenic V over the full volume of the plume at different points in time. This comparison identified a peak risk of 2×10^{-5} averaged over a volume of 32 Mgal and a risk of 9×10^{-6} averaged over a peak volume of 147 Mgal. A comparison of the RME and CTE risks for arsenic V associated with concentrations averaged over the volume of high-end plumes is presented in **Table 6-7**. Values that exceed a cancer risk of 1×10^{-5} are shown in **bold**. This indicates the high-end concentrations resulting from these units can also pose risk within the range EPA typically considers for regulation for a substantial portion of an exposed population.

Table 6-7. Comparison of RME and CTE Risk for High-End Groundwater Concentrations

Constituent	Groundwater Volume (Mgal)	RME Risk	CTE Risk
Arsenic V	32	**1×10^{-4}**	**2×10^{-5}**
	147	**7×10^{-5}**	9×10^{-6}

6.2.2 De Minimis Placements

In Section 4 (CCRMU Fill Groundwater Risk), EPA modeled groundwater concentrations at the boundary of smaller CCRMU fills to understand the potential for exceedance of GPWS that would trigger corrective action at landfills. On the whole, this analysis identified the potential for both moderate and high-end groundwater concentrations of molybdenum to exceed GWPS. Given that these results reflect the full range of evaluated fill sizes, EPA conducted further sensitivity analysis to better understand whether there is an amount below which there is no reasonable probability of adverse impacts to groundwater quality. To better understand the relationship of tonnage and modeled risk, EPA first organized all the individual model runs from the smallest to largest tonnage and binned the runs in increments of 2,000 runs (i.e., 1-2000, 2001-4000, etc.). This approach aims to identify broader trends across model runs while minimizing the range of tonnages summarized in each data point. A running 90th percentile was calculated for both the tonnage and risk for each group of samples. **Figure 6-1** presents the results of this review for molybdenum, which was found to exceed GWPS by the largest margin out of the modeled constituents, along with the best-fit trendline and associated 95th percentile confidence interval.

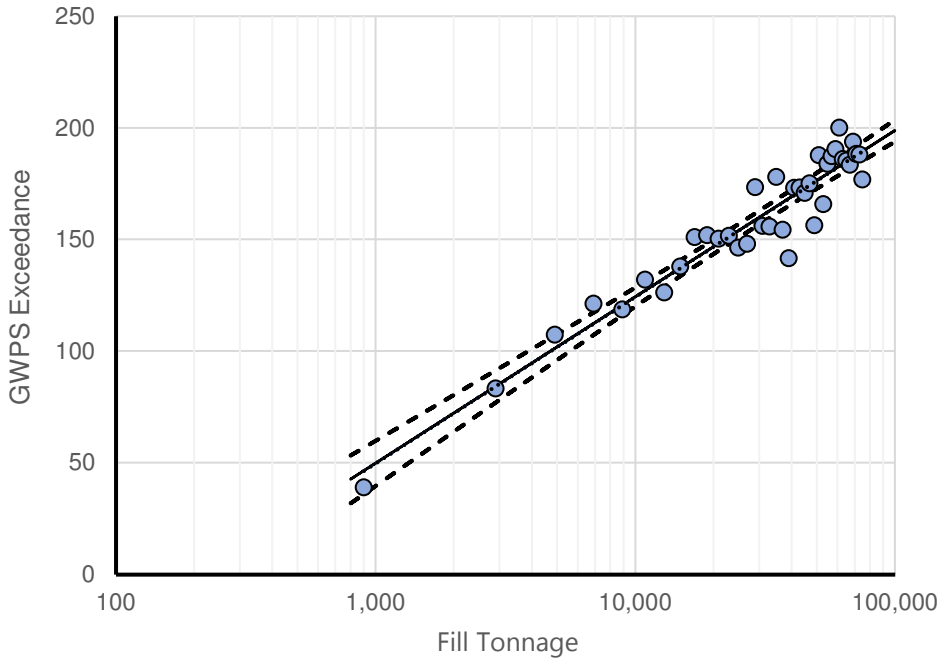

Figure 6-1. Magnitude of molybdenum GWPS exceedance as function of tonnage.

This graph shows there is a trend of decreasing groundwater concentrations along with decreasing tonnage. However, there remains potential for exceedance of GWPS at the waste boundary below 1,000 tons. EPA did not attempt to summarize results for tonnages lower than that because of the small number of runs conducted below that amount, which amount to about 1% of all model runs. As can be seen in the figure, there is already a fair amount of variability among the runs as plotted. Parsing the smaller number of runs below 1,000 tons could lead to erroneous conclusions because the smaller number of runs would allow the variability of individual runs to exert even greater influence on calculated summary statistics, leading to less reliable values. Nor did EPA extrapolate from plotted data to identify a lower mass limit below which no exceedances are expected. The graph provides strong evidence of a general magnitude of exceedances and existence of broader trends, but there remains uncertainty about the exact shape of the curve. For example, each data point on the curve summarizes results for a range of tonnages, with the very first ranging from 1 to 921 tons. With more model runs, that range could be further shrunk to provide a more precise estimate around a specific tonnage. Such refinement would be expected to shift the overall curve; however, the associated magnitude and direction of this shift is not known. Nor is it known how many additional model runs would be needed to support identification of a lower limit. Thus, EPA does not draw any final conclusions about the potential for adverse impacts from placements less than around 1,000 tons.

6.2.3 Additional Exposure Pathways

In **Section 5 (CCRMU Fill Soil Risk)**, EPA evaluated the risks associated with CCRMU fills assuming a scenario where the fills remained covered by some amount of soil. However, there is no guarantee

that any form of cover currently in place will be maintained into the future in the absence of land use restrictions or requirements for routine maintenance. Mixing of CCR with surface soil will result in increased exposures not only to radiation, but also to other chemical constituents present. There is substantial uncertainty about the degree of mixing that will occur at a national scale. Thus, EPA designed this sensitivity analysis to consider how risks would change as the quantity of ash mixed with surface soil increases.

To calculate cancer risk, EPA drew health-based benchmarks for ingestion and direct gamma exposure from both Regional Screening Level (RSL) Calculator for arsenic[16] and PRG Calculator for Th-232 and U-238 decay chains. The arsenic benchmark is based on default exposure for adult incidental ingestion. The Th-232 and U-238 benchmarks for are based on the same exposure scenario defined in **Section 5** with the exception of no soil cover. The benchmarks corresponding to 1×10^{-5} risk for residential exposures were 6.77 mg/kg arsenic, 0.113 pCi/g Th-232, and 0.145 pCi/g U-238. EPA first applied these benchmarks to calculate the risk associated with undiluted exposure to CCR. For arsenic, EPA used summary statistics for fly ash from the 2014 Risk Assessment summarized in **Table 6-5** to identify the 90th and 50th concentrations. For radionuclides, EPA calculated a combined Th-232 and U-238 risk for each individual sample from the COALQUAL database and then calculated an overall 90th and 50th percentile risk based on same national sampling of the database as described in **Section 5**. Finally, EPA scaled these risks based on different degrees of mixing with the surface soil. **Figure 6-2** depicts the risk from CCR as it becomes an increasing fraction of the overall surface soil.

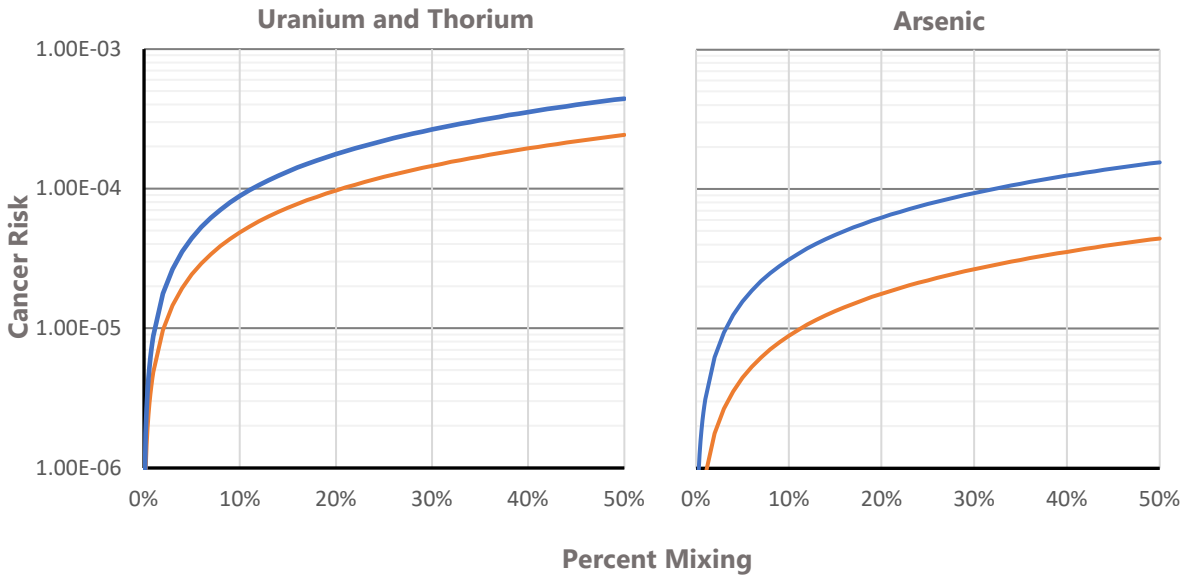

Figure 6-2. Human health risk from various degrees of ash mixing.

16) See: https://www.epa.gov/risk/regional-screening-levels-rsls

For radionuclides, cancer risks above 1×10^{-4} are possible for residential receptors with mixing of more than 11% for 90th percentile activity and 21% for 50th percentile activity. For arsenic, cancer risks above 1×10^{-4} are possible with mixing of more than 33% for 90th percentile concentration, but would not occur at any degree of mixing for 50th percentile concentration. Agency policy is to evaluate the risks from radionuclide exposures the same as for chemical contaminants (U.S. EPA, 2014c). Therefore, the cancer risks from concurrent exposure to radionuclides and arsenic are treated as additive. EPA did not calculate a cumulative risk here because the different data sources used to characterize arsenic and radionuclides levels do not allow for a one-to-one comparison. However, given the differences observed in the graphs, consideration of cumulative risk is expected to reduce the mixing required to exceed a risk of 1×10^{-4} by a few percentage points at most. Thus, cancer risks are driven generally by exposure to radionuclides and particularly by isotopes of radium and their immediate decay products.

Natural background soils can also contain radium at levels that pose risk. However, the activity of CCR has been found to be substantially higher. For example, the 90th percentile radium activity in background surface soil is estimated to be 3.0 pCi/g, with roughly equal contributions from the Ra-226 and Ra-228 (ORNL, 1979). After subtracting this background from the estimated 90th percentile activities in CCR of 7.8 pCi/g Ra-226 and 4.0 pCi/g Ra-228, it would require closer to 15% mixing to result in an incremental increase in cancer risk of 1×10^{-4}. This confirms that further consideration of background would not alter the overall conclusions of this analysis. It is not acceptable for waste disposal to substantially add to potential risk solely because background risks may already be elevated.

EPA separately considered a CTE scenario for radiation based on the most recent available data on median receptor characteristics and behavior from the 2011 Exposure Factors Handbook (U.S. EPA, 2011) for soil and dust ingestion (Table 5-1) and residence time (Table 16-88). This resulted in values for an adult receptor of 50 mg/day for soil and dust ingestion and 9 years for residence time. The benchmarks associated with this scenario are 0.333 pCi/g Th-232 and 0.445 pCi/g U-238, approximately a factor of three higher for each compared to the RME scenario. Changes in these values are driven primarily by differences in residence time. This would result in a risk of 1×10^{-4} occuring at mixing closer to 33% for 90th percentile activity. Thus, similar risks could be possible for a substantial fraction of the population at even lower mixtures.

6.2.4 Additional Ecological Exposures

In the previous sensitivity analysis, EPA evaluated the risks to human health associated with CCR mixed with surface soil. However, commenters raised scenarios in which other sensitive receptors may be present. Specifically, some commenters stated that facilities may become nature preserves. Therefore, EPA conducted an analysis of soil mixing for ecological exposures in the same manner as previously discussed for human exposure to arsenic. This analysis considered all constituents

with available ecological soil screening levels (Eco-SSLs) (U.S. EPA, 2005a). These benchmarks represent concentrations of contaminants in soil that are protective of ecological receptors derived separately for four groups of ecological receptors that commonly come into contact with soil or ingest biota that live in or on soil (i.e., plants, soil invertebrates, birds, and mammals). EPA selected the benchmark for the most sensitive receptor among these groups for use in this analysis. The Agency drew concentration data for fly ash from the 2014 Risk Assessment for comparison (U.S. EPA, 2014a). **Table 6-8** summarizes the risk from fly ash at 90th and 50th percentile concentrations as it becomes an increasing fraction of the overall surface soil. Constituents that exceed associated benchmarks with less than 10% mixing are highlighted in **bold**.

Table 6-8. Ecological Risk from Various Degrees of Ash Mixing.

Constituent	Eco-SSL (mg/kg)	Benchmark Source	50th Percentile		90th Percentile	
			Concentration (mg/kg)	Mixing (%)	Concentration (mg/kg)	Mixing (%)
Antimony[1]	0.27	U.S. EPA (2005b)	5.0	**5%**	39	**1%**
Arsenic	18	U.S. EPA (2005c)	60	30%	211	**9%**
Barium	330	U.S. EPA (2005d)	472	70%	6,067	**5%**
Beryllium	21	U.S. EPA (2005e)	10	> 100%	24	88%
Cadmium	0.36	U.S. EPA (2005f)	1.1	33%	8.1	**4%**
Chromium	26	U.S. EPA (2008)	82	32%	181	14%
Cobalt	13	U.S. EPA (2005g)	52	25%	99	13%
Copper	28	U.S. EPA (2007a)	82	34%	331	**8%**
Lead	11	U.S. EPA (2005h)	53	21%	140	**8%**
Manganese	220	U.S. EPA (2007b)	180	> 100%	369	60%
Nickel	38	U.S. EPA (2007c)	93	41%	263	14%
Selenium	0.52	U.S. EPA (2007d)	5.7	**9%**	22	**2%**
Silver	4.2	U.S. EPA (2006)	1.3	> 100%	4.0	> 100%
Vanadium	7.8	U.S. EPA (2005i)	312	**3%**	521	**1%**
Zinc	46	U.S. EPA (2007e)	144	32%	600	**8%**

1) One extreme outlier of 1,370 mg/kg was identified as more than an order of magnitude higher than any other reported value and excluded from calculations.

This analysis indicates potential for risk to sensitive ecological receptors from antimony, selenium, and vanadium with mixing of less than 10% for 90th and 50th percentile concentrations. Additional constituents with potential for risk with mixing of less than 10% for just the 90th percentile include arsenic, barium, cadmium, copper, lead, and zinc. As a result, these constituents are considered the most likely to drive further evaluation of ecological risk at sites where CCR has been disposed.

Eco-SSLs are screening benchmarks intended to protect sensitive ecological receptors. Unlike for human receptors, where Census and other population statistics can be used to locate receptors with

some accuracy, site-specific surveys are often needed to confirm the presence of and risk to specific ecological receptors. As a result, it is not possible to assign a likelihood of risk to the accumulations identified above. Nevertheless, identification of benchmark exceedances at such low mixing rates indicate the potential for risk and need for further evaluation, even where future land use is not residential.

Eco-SSLs do have the potential to be set lower than background soil concentrations. As such, EPA considered how background concentrations could affect the overall rate of accumulation in soil. This comparison found concentrations in fly ash can be substantially higher than background. For example, the 90th percentile vanadium concentration in background soil is estimated to be 107 mg/kg (USGS, 2013b). After subtracting this background from the estimated 90th percentile fly ash concentration of 521 mg/kg, it would require closer to 2% mixing to exceed the Eco-SSL. Similar results are obtained for antimony with a high-end background of 1.1 mg/kg and selenium with a high-end background of 0.6 mg/kg. Thus, further consideration of background is not expected to alter the overall conclusions of this analysis.

6.2.5 Post-Closure Exposures

The main model and sensitivity analyses identified potential risks resulting from gamma radiation and radon gas if CCRMU fills are disturbed. To ensure that current disposal standards are sufficient to mitigate the identified risks, EPA conducted a further analysis of closed disposal units. A major consideration is the fact that land use controls imposed on these units will prevent construction of habitable structures on top of the cover system. This will greatly limit the types of exposures and amount of time any individual will spend on top of the unit in a given day. In the absence of residential receptors, a RME scenario under a future land use might be an individual who uses the open area for recreation.

EPA has not established recommended exposure factors for this type of receptor, as actual behavior can vary widely across different sites. Instead, EPA considered a worst-case scenario equivalent to an outdoor worker who spends 8 hours a day, 225 days a year, over the course of 25 years in the open air standing on top of a soil cover with a maintained thickness of 0.6 m (2 ft). The benchmarks corresponding to 1×10^{-5} risk are 28.1 pCi/g Th-232, and 65.5 pCi/g U-238. EPA calculated the combined Th-232 and U-238 risk for each individual sample from the COALQUAL database and then overall the 90th risk based on same sampling of the database as described in **Section 5**. Under this worst-case scenario, the PRG Calculator identified a cancer risk attributed to gamma radiation of around 3×10^{-6}.

The scenario is expected to overestimate risk for multiple reasons. For example, it is highly unlikely any receptor would be present on top of a closed unit all day for over two decades. Additionally, many units will not contain ash with high-end activities. Based on these various considerations, it

is likely that the risks associated with release of gamma radiation from disposal units closed in a manner consistent with the requirements of the 2015 CCR Rule will fall outside the OLEM risk range.

6.3 Conclusions

EPA identified and reviewed major sources of uncertainty that have been identified since the 2014 Risk Assessment to understand the potential effects on modeled risks. The uncertainties associated with newer data sources are expected to have minimal effect on the conclusions of this assessment. Uncertainties associated with scenarios that could not be quantitatively modeled have the potential to result in underestimation of risk in some circumstances. To the extent practicable, EPA aimed to minimize the influence of such uncertainties by focusing on the most direct exposure pathways and applying best available data.

EPA also conducted several sensitivity analyses to understand the potential for substantially higher risk than was modeled on a national scale. One analysis identified potential for risk to future residents and ecological receptors from exposure to soil if CCRMU fills are disturbed and mixed with surface soil. Another affirmed that current regulatory requirements for closure of disposal units are adequate to protect human health and the environment from anticipated exposures to radiation.

The results of all these analyses reinforce the conclusions from previous modeling that disposal in historical and inactive landfills and surface impoundments, as well as placement in CCRMU fills, have the potential to result in risk to future receptors that warrant regulatory action.

7 Summary and Conclusions

The purpose of this document is to characterize the potential for risk on a national basis resulting from management of CCR in legacy impoundments and CCRMU. To accomplish this task, EPA drew on previous modeling to supplement available record for legacy impoundments and CCRMU disposal units. EPA also conducted further mathematical modeling to estimate the magnitude of environmental releases from smaller CCRMU fills, contaminant fate and transport through the environment, and the potential risk of adverse effects to human health and the environment. EPA then conducted additional sensitivity and uncertainty analyses to identify any potential for higher risks than those identified in through the main analysis. The following discussion summarizes the various analyses conducted and results obtained for different exposure pathways, provide further context for these results, and present the final Agency conclusions.

7.1 Problem Formation

EPA first developed conceptual models to illustrate a generalized layout of legacy impoundments and CCRMU, the different pathways through which constituents may be released from CCR and migrate through the environment, and the risks to human health and the environment that could result. The conceptual models for landfills and impoundments were the same as used in the 2014 Risk Assessment/ EPA determined that a second model was warranted for CCRMU because some smaller placements have not historically been regarded as disposal by facilities and so have not been reliably tracked or maintained over time. These smaller placements may be disturbed after land use changes, which can result in additional release pathways. Therefore, EPA prepared a second conceptual model for smaller units (i.e., CCRMU fills). These conceptual models provide the basis for subsequent modeling efforts.

When CCR are placed on the ground for any purpose, they may leach metals and other inorganic contaminants to groundwater. Once mixed with groundwater, contamination may migrate downgradient to private wells where it is ingested by receptors who rely on groundwater as their primary source of drinking water. But a receptor does not need to be presently exposed for there to be a reasonable probability of adverse effects on health or the environment. EPA evaluated this exposure pathway in the 2014 Risk Assessment and identified a set of constituents most likely to pose risk to offsite receptors living up to a mile away. The 2024 assessment builds on those model results and identifies arsenic, lithium, molybdenum, and thallium as constituents that warranted further evaluation. These are the constituents found in the 2014 Risk Assessment to pose the greatest risk for unlined surface impoundments and have the greatest demonstrated potential to spread and pose risk on a national scale. These 2014 model results therefore also provide a reasonable screen to identify the most likely risk drivers for receptors living even closer to these types of units.

When CCR is placed in fills and left unmonitored, the ash can be disturbed in the future when land use changes. In the absence of records of the presence of CCR, and in the absence of inspection and maintenance, any engineering controls currently present that might serve to limit exposure cannot reasonably be assumed to remain in place in perpetuity. For this reason, EPA considered the potential for additional exposure pathways that could occur under a future residential land use scenario. The 2014 Risk Assessment did not evaluate risks from direct placement of CCR in the soil. However, EPA previously identified radium as a constituent of concern in the 2015 CCR Rule and included two radioisotopes on the Appendix IV list for groundwater monitoring, radium-226 and radium-228. These radioisotopes are part of larger, naturally occurring decay chains that begin with uranium-238 and thorium-232, respectively. Even if some form of cover remains over the ash, future receptors who live on or around a fill may be exposed to radiation through direct exposure to gamma radiation or inhalation of radon gas. Therefore, EPA considered potential for exposure to the full decay chains of these radium isotopes as the primary risk driver for this pathway.

7.2 Disposal Unit Groundwater Risk

All disposal units pass through the same lifecycle stages, ranging from initial construction to final closure. As a result, there is potential for historical and inactive disposal units to result in the same types of environmental releases as currently regulated units over the course of their lifecycle. The fact some historical and inactive units may have since drained ponded wastewater or installed some form of cover system does nothing to remediate any prior releases. EPA conducted a review of the available data on these historical and inactive units to understand whether the associated risks would be expected to differ from those previously modeled for regulated units.

The 2014 Risk Assessment modeled risks for a total of 122 landfills and 163 impoundments that were ultimately excluded from the final summary of national risks because it was determined that these units fell outside the scope of the 2015 CCR Rule. These units were excluded because they were anticipated to cease receipt of waste prior to the effective date of the rule. Therefore, model results for these previously excluded units directly address the historical and inactive units subject to the current rulemaking. EPA reviewed model results for these previously excluded units to better understand whether the associated risks were any different from those of currently regulated units. For highly exposed individuals, landfills were estimated to pose cancer risks as high as 7×10-6 from arsenic III, while surface impoundments were estimated to pose cancer risks as high as 8×10-5 from arsenic III and noncancer HQs as high as 2 for arsenic III, 2 for lithium, and 1 for molybdenum.

Differences between these risks and those for currently regulated units are attributed primarily to differences in the prevalence of engineered liners modeled for the two sets of units. The previously excluded units were modeled as having no engineered liner at 71% of landfills and 57% of impoundments, compared to 42% of landfills and 65% of impoundments for currently regulated

units. For unlined units, the arsenic III risk from previously excluded units was 1×10-5 for landfills and 2×10-4 for surface impoundments, while corresponding risk from regulated units were 2×10-5 for landfills and 3×10-4 for surface impoundments. Since all of this modeling was completed in 2014, it has been discovered through facility reporting that a greater percentage of regulated units has no engineered liner than EPA previously modeled. For example, in the 2014 Risk Assessment, EPA estimated that 65% of impoundments had no engineered liner based on the EPA Surveys. It has since become clear that even fewer impoundments are actually lined. EPA's review of available liner demonstration documents posted on facilities' CCR websites indicates closer to 83% of have no engineered liner. EPA has seen no evidence that would indicate older historical and inactive units would be lined at any greater frequency. Thus, EPA concludes that the national risks for regulated and previously excluded units will fall closer to those modeled for unlined units.

EPA reviewed available data on facility location to understand whether environmental conditions (e.g., precipitation, soil type) at inactive and active facilities could be substantially different than previously modeled. Such conditions can affect the rate of leakage from a unit and subsequent transport of that leachate through the subsurface. This review found that around 8280% of the active and inactive facilities that were not subject to the 2015 CCR Rule had already been modeled as part of the 2014 Risk Assessment and so are already reflected in the risk results for those previously excluded units. The remaining 1820% of facilities are located an average distance of 25 26 miles from the nearest modeled facility. Therefore, EPA concludes that the 2014 Risk Assessment adequately captures the effects of facility location on national risk.

Commenters stated that the smaller size of historical and inactive disposal units would result in lower volumes of leakage and could not sustain plumes of the same magnitude as from larger regulated units. EPA reviewed data from the EPA Surveys to determine whether the sizes of previously excluded units are substantially different than EPA modeled for currently regulated units. This comparison indicates that excluded units do tend to be somewhat smaller. The average size modeled for excluded units was 77 acres for landfills and 28 acres for impoundments. The average size modeled for regulated units was 107 acres for landfills and 47 acres for impoundments. Despite these differences, there remains a great deal of overlap in the range of sizes for both sets of units. Further, as described above, similar risks were identified for both sets of units. Thus, there is no indication that size differences of this magnitude have any notable effect on national risk. Nor is there any information available about the units not captured in the EPA Surveys that would indicate these remaining units are significantly smaller. Therefore, EPA concludes that the 2014 Risk Assessment adequately captures the effects of unit size on national risk.

7.3 CCRMU Fill Groundwater Risk

EPA conducted national-scale modeling of CCRMU fills to understand the potential groundwater risks that could result from these smaller placements of CCR. The exposure route evaluated for was human ingestion of groundwater used as a source of drinking water. The evaluation incorporated

many of the same data sources used in the 2014 Risk Assessment to characterize the variability of site conditions. Two models were used to evaluate contaminant fate and transport, EPACMTP and MODFLOW-USG. EPACMTP was run first at specified distances along the centerline of the plume to understand the potential for releases to occur and spread further downgradient. MODFLOW-USG was then run for a subset of the conditions to understand the broader magnitude and extent of these plumes.

Groundwater concentrations modeled with EPACMTP at the waste boundary were first compared to respective GWPS to understand the potential for fills to impact groundwater quality to an extent that would trigger corrective action at regulated landfills. The 90th percentile concentrations exceeded GWPS by factors of 26 for arsenic III, 19 for arsenic V, 156 for molybdenum, and 19 for thallium. The 50th percentile concentrations exceeded GWPS by a factor of two for molybdenum. Based on these results, EPA finds that CCRMU fills can meaningfully contribute to groundwater contamination across a facility.

Groundwater concentrations modeled with EPACMTP at 500 and 1,000 feet away from the waste boundary were used calculate risks to individual RME receptors exposed to these concentrations. The 90th percentile concentration of each modeled constituent exceeded at least one risk benchmark at 1,000 feet. This indicates potential for leakage from fills to spread at environmentally significant concentrations. However, because these model runs represent concentrations at a fixed location, they do not provide broader information about the magnitude and extent of the plume. As a result, EPA does not rely primarily on these results to draw direct conclusions about overall risk. Instead, the Agency retained a subset of these model runs for both arsenic V and molybdenum from around the 90th percentile concentrations modeled at 1,000 ft. EPA selected pentavalent arsenic because it is the less mobile species and so provides a reasonable bounding on the high-end concentrations that can result for this contaminant. These runs were retained for further modeling with MODFLOW-USG to characterize the full magnitude and extent of each plume over time.

The MODFLOW-USG runs were designed with the same inputs as corresponding EPAMCTP runs. Altogether, these model runs reflect a range of conditions that collectively resulted in high-end groundwater concentrations 1,000 feet from the fill. These corresponding placements of CCR range from around 3,500 to 70,000 tons placed over areas between 0.15 to 2.0 acres. EPA calculated the midpoint across these runs to define values representative of the 90th percentile model runs. For arsenic V, the model identified a peak risk of 1×10-4 averaged over 32 million gallons (Mgal) of groundwater and a peak volume of 147 Mgal with an average risk of 7×10-5. The same leakage of arsenic V would result in a peak GWPS exceedance of three averaged over a plume volume of 1.2 Mgal and a peak plume volume of 8 Mgal with an average exceedance of 2 times GWPS. It would take around 2,300 years from the time of first exceedance for the plume to fully dissipate. For molybdenum, the peak exceedance of both risk benchmark and GWPS was 10 averaged over a plume volume of 27 Mgal and a peak plume volume of 80 Mgal with an average exceedance of 4

times GWPS. It would take around 100 years from the time of first exceedance for the plume to fully dissipate. Plumes of these size and duration could readily sustain exposures for a typical residential receptors that are anticipated to use around 80 gallons of water a day for all indoor household needs, resulting in less than 0.8 Mgal of use over 26 years of exposure.

7.4 CCRMU Fill Soil Risk

EPA modeled of CCRMU fills to understand the potential risks that could result from CCR present in the soil. Exposure routes initially considered for evaluation were human inhalation of radon gas and direct exposure to gamma radiation emitted from the CCR. However, based on a preliminary review of available data, EPA determined that radon emanation from CCR (i.e., fraction of radon able to escape into the surrounding air) is generally lower than from most soils. Despite the higher overall activity of CCR, the resulting radon emanation from the ash is not distinguishable from that of most surface soils. Therefore, EPA did not retain exposure to radon for further consideration.

Modeling of exposure to gamma radiation was conducted with the EPA PRG calculator. EPA evaluated the potential for direct exposure to gamma radiation from CCR under a soil cover ranging in thickness from 60 to 20 cm (2 to 0.66 feet). EPA compared the combined activity of the uranium-238 and thorium-232 decay chains in the CCR to the health benchmarks for each cover thickness to calculate the risks that could result from receptors living on or near the fill. Both 90th and 50th percentile activities have potential to result in cancer risks at or above $1\times10\text{-}5$ with a cover of 40 cm. The 90th percentile activity resulted in a cancer risk of $1\times10\text{-}4$ with a cover of 20 cm. This indicated the potential for even higher risk if the cover were to be disturbed and the CCR brought to the ground surface. However, evaluation of this scenario would require additional assumptions about the degree of mixing, which could be a major source of uncertainty on a national scale. Therefore, EPA retained this scenario for further consideration as part of a separate sensitivity analysis.

7.5 Uncertainty and Sensitivity Analyses

EPA reviewed the models used, as well as the data and assumptions input into the models, to better understand the potential sources of uncertainty inherent in the model results. The Agency qualitatively and, to the extent possible, quantitatively analyzed these sources to understand the potential effects each may have on modeled risks. EPA also conducted further sensitivity analyses to understand how the modeled national risks vary in response to changes in sensitive parameters and to evaluate the potential for risks through exposure pathways that could not be fully modeled on a national scale.

The major source of uncertainty identified for the groundwater model is the potential for greater risk from multiple units located in close proximity. The EPA Surveys did not provide information on the relative location or orientation of different landfills and impoundments at any given facility

and so the 2014 Risk Assessment modeled risks from each unit individually. However, the Agency is now aware of many instances where multiple units are located directly adjacent to one another, resulting in a larger total area over which leakage can occur. This could result in greater cumulative risk to offsite receptors than predicted based on contributions from each individual unit. Furthermore, there is potential for legacy impoundments and CCRMU (disposal units and fill) to confound groundwater monitoring programs when located upgradient of a regulated unit. Ongoing leakage from these unregulated units has the potential to skew the characterization of background groundwater quality. Under these circumstances, any leakage from a regulated unit would need to progress even further and faster to be distinguishable from that skewed background. This could delay or entirely prevent a regulated unit from entering into corrective action, resulting in risk to downgradient receptors.

EPA conducted a sensitivity analysis to determine whether there is a unit size below which adverse impacts to groundwater quality are unlikely and monitoring is not warranted. This analysis found exceedances of GWPS are possible for placements below 1,000 tons. Thus, such placements can meaningfully contribute to groundwater contamination at these facilities. It was not possible to identify a limit much lower than this tonnage because of the few model runs conducted at smaller amounts. Extrapolation beyond available model runs could introduce a great deal of uncertainty into any specific limit identified. The extent to which any identified limit could shift higher or lower in response to further modeling around these lowest tonnages is not known. Therefore, the Agency could not identify a lower limit based on the current modeling.

EPA conducted further sensitivity analyses to better characterize the risks to human health that may result from mixing of CCR with the soil. There is little data available to predict the likelihood of different degrees of mixing that could occur across the country. Instead, EPA considered the incremental contributions from CCR through increased mixing with soil to identify the point at which accumulation would raise concern. This analysis focused on radionuclides previously identified as potential risk drivers for soil, but also considered contributions from arsenic that may further contribute to cancer risk. The exposure pathways considered were incidental ingestion of the CCR and soil mixture and direct exposure to gamma radiation. For radionuclides, cancer risks above $1\times10\text{-}4$ are possible for residential receptors at mixing of more than 11% for 90th percentile activity and 21% for 50th percentile activity. For arsenic, cancer risks above $1\times10\text{-}4$ are possible at mixing of more than 33% for 90th percentile concentration, but would not occur at any degree of mixing for 50th percentile concentration. Both radionuclides and arsenic also occur naturally in soil; however, levels in CCR can be markedly higher than typical background levels. In particular, EPA has identified the potential for CCR to have a combined radium activity nearly 10 pCi/g above typical background soils. This is greater than the ARAR that has been applied at some cleanups for surface and subsurface soils under Superfund and State programs. As such, consideration of the incremental increase above background does not alter the overall results of this analysis. Therefore,

EPA concludes that accumulation of CCR within the soil column can result in risks within the range that EPA considers or regulation.

EPA separately considered the potential for risk to ecological receptors that may result from mixing of CCR with the soil based on comments received that a future use for these facilities could be as a nature preserve. EPA calculated the incremental contributions from CCR as described above and compared the resulting concentrations to available ecological benchmarks. This analysis focused on constituents for which ecological soil screening levels are available. This comparison indicates that antimony, selenium, and vanadium are most likely to drive risk and require further evaluation at both high-end and median ash concentrations. In some cases, ecological benchmarks are lower than typical background soil levels. However, consideration of the incremental increase above background does not alter overall results. Therefore, the potential for risk from accumulation of CCR within the soil column remains even if future residential land use is not anticipated.

7.6 Final Conclusions

Based on the analyses summarized in the current risk assessment, EPA concludes that there is a reasonable probability of adverse effects on health and the environment due to leakage from legacy CCR surface impoundments and CCRMU. EPA's assessment estimates that the risks that leakage from these units would adversely impact groundwater quality and pose risk to future receptors fall within the range EPA typically considers warrants regulation under section 4004(a) (i.e., cancer risks greater than 1×10^{-5} and non-cancer risks exceeding an HQ of 1). Older historical and inactive disposal units can pose risks to offsite receptors substantially the same as previously reported for currently regulated units. Smaller CCRMU fills can pose risk to onsite receptors and materially contribute to broader groundwater contamination across the facility. Depending on the location of these fills, they can also pose risk to offsite receptors. The risks identified for CCRMU fills are also believed to provide a bounding estimate on the risks posed by disposal units, as leakage from these larger units would generally be expected to result in more extensive releases than modeled for fills. Risks to human health from groundwater are anticipated to be driven by ingestion of arsenic, lithium, molybdenum, and/or thallium. Health effects associated with arsenic ingestion are an increase in the risk of cancer in the skin, liver, bladder, and lungs, as well as nausea, vomiting, abnormal heart rhythm, and damage to blood vessels. Health effects associated with ingestion of lithium are neurological and psychiatric effects, decreased thyroid function, renal effects, cardiovascular effects, skin eruptions, and gastrointestinal effects Health effects associated with molybdenum ingestion are higher levels of uric acid in the blood, gout-like symptoms, and anemia. Health effects associated with thallium ingestion are hair loss, ocular effects, and behavioral changes.

EPA also concludes the unmonitored accumulation of CCR in surface and subsurface soils has the potential to result in risk to future human and ecological receptors in the range OLEM typically considers for regulation. Potential human health risks are driven by incidental ingestion of ash

mixed with the soil and direct exposure to gamma radiation from radium and its associated decay chains. Health effects attributed to radium exposure include increased risk of several types of cancer, particularly lung and bone cancer. Potential ecological risks are driven by exposure to antimony for mammals, selenium for plants and mammals, and vanadium for birds from ash mixed with the soil. Health effects attributed to these exposures are decreased reproduction, growth, or survival. EPA did not seek to identify a comprehensive list of other contaminants that might also contribute to risk as part of the current assessment; however, any further risk would be equally addressed by controls put in place to mitigate the identified soil risks.

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Appendix A: Facility List

EPA has identified a number of facilities that are expected to be subject to the current rulemaking, but that were not previously modeled as part of the 2014 Risk Assessment. These include active facilities subject that are currently regulated and additional active or inactive facilities that were exempt from the 2015 CCR Rule. EPA incorporated all these additional facilities along with those previously modeled in current groundwater modeling for CCRMU fills. **Attachment A-1** provides a list of newly identified units and assigned facility locations. **Attachment A-2** provides a list of all facility locations modeled for CCRMU fills, the regulatory status of those facilities, whether they were modeled in 2014, and a summary of the environmental parameters assigned to that facility for purposes of fate and transport modeling.

Appendix B: New Characterization Data

Since finalization of the 2014 Risk Assessment, EPA has identified additional sources of data that were used in this risk assessment to supplement and corroborate the Agency's characterization of CCR composition and behavior. The COALQUAL database includes data on the composition of coal samples from across the country and was used to estimate CCR bulk composition and activity. **Attachment B-1** provides the 2015 COALQUAL database, as well as a the summary of frequency at which EPA sampled the different combinations of state, county, and coal rank from the database based on EIA coal production data. The LEACHXS Lite database includes a repository of LEAF leachate data on a range of materials. Recent review of this database identified additional CCR data that was used together with previously collected leachate data. **Attachment B-2** provides new leachate data drawn from LEACHXS Lite. The bulk activity dataset represents data compiled by the Agency from the broader literature. This dataset was used to corroborate the bulk activity calculated from COALQUAL. **Attachment B-3** provides the bulk activity data identified through a review of the literature.

Appendix C: Model Outputs

This risk assessment modeled the fate and transport of metallic and other inorganic constituents identified as constituents of concern for CCRs. As part of this effort, EPA applied multiple models to characterize the magnitude and extent of adverse impacts to different environmental media. EPACMTP is groundwater model designed to calculate concentrations at a specified distance away from the source. **Attachment C-1** provides Access databases that contain the EPACMTP inputs and associated outputs for landfills and impoundments previously modeled, but not incorporated in the results reported in the 2014 Risk Assessment. **Attachment C-2** provides Access databases that contain the EPACMTP inputs and corresponding outputs for CCRMU fills at three distances away from the waste boundary. MODFLOW-USGT is a groundwater model that can be used to calculate concentrations in three dimensions. **Attachment C-3** summarizes the MODFLOW-USGT model inputs and outputs for each model run conducted. **Attachment C-4** provides full output files for the two individual model runs discussed in the main text.

Radioactive Wastes From Coal-fired Power Plants

Coal is a fossil fuel used to produce power in the United States. Coal contains trace amounts of naturally-occurring radioactive elements. The process of burning coal at coal-fired power plants, called combustion, produces wastes that contain small amounts of naturally-occurring radioactive material (NORM).

On this page:

Radiation Facts

- The process of burning coal at coal-fired power plants, called combustion, creates wastes that contain small amounts of naturally-occurring radioactive material.

About Radioactive Wastes From Coal-fired Power Plants

Like all rocks, coal contains small amounts of radioactive elements that are found naturally in the environment. When coal is burned to create heat and steam to produce power it is called combustion. During coal combustion, natural radioactive material in coal concentrates in three main waste streams:

- **Fly ash** is a light colored, fine particle waste that resembles a powder. The majority of coal combustion wastes are fly ash.

- **Bottom ash** is a larger particle size than fly ash and is a heavier waste that resembles a mix of sand and small rocks. Just over 10% of coal combustion waste is bottom ash.
- **Boiler slag** is made when bottom ash melts under the intense heat of combustion. Boiler slag resembles the size of gravel. It makes up about 2% of coal combustion waste.

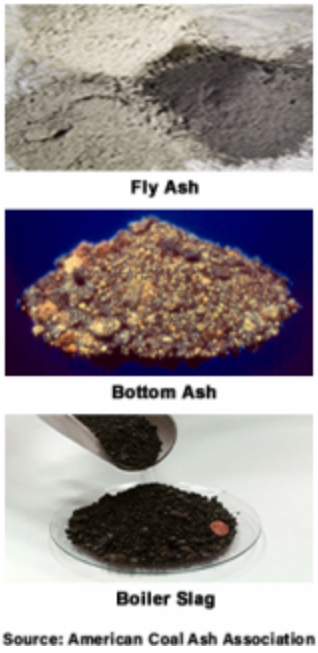


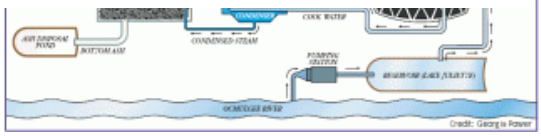
Image of different types of coal-fired power plant wastes.
Source: American Coal Ash Association

Generally, these wastes are only slightly more radioactive than the average soil in the United States. The amount of natural radiation in wastes from coal-fired power plants is so small that no precautions need to be taken.

While 99% of fly ash is captured by filters, small amounts (about 1%) can escape into the air. Government regulations require power plants to limit the amount of fly ash that escapes into the environment and to dispose of collected ash properly.

A survey by the American Coal Ash Association showed that more than 50% of all fly ash, bottom ash and boiler slag is reused in other products. Some ways that these wastes can be reused include: concrete, blended cement, to fill structures or embankments, as blasting grit or as roofing granules.

<https://epa.gov/sites/default/files/2019-02/coal_fired_power_plants_wss-wuse-thermoelectric-diagram.gif>



A diagram of how Georgia Power's Scherer Plant operates.
Source: United States Geological Survey (USGS)

What You Can Do

- **Know the regulations.** While the amount of radiation in wastes from coal-fired power plants is very small, there are other harmful emissions from power plants and industrial sources that are regulated. You can learn more about the EPA's air pollution standards by visiting the Plain English Guide to the Clean Air Act <https://epa.gov/clean-air-act-overview/plain-english-guide-clean-air-act>.

You can view air quality information for your area from any type of emission at the EPA's AirNow website <https://www.airnow.gov/>.

Where to Learn More

The U.S. Environmental Protection Agency (EPA)

The EPA develops standards for coal-fired power plants and has primary responsibility for setting federal radiation standards for exposure to naturally-occurring radioactive materials.

Clean Air Act (CAA) <https://epa.gov/clean-air-act-overview>
View an overview of the Clean Air Act and Air Pollution

Clean Water Act (CWA) <https://epa.gov/laws-regulations/summary-clean-water-act>
View a summary of the Clean Water Act.

Safe Drinking Water Act (SDWA) <https://epa.gov/sdwa>
This webpage provides information about the Safe Drinking Water Act and other drinking water standards and regulations.

Resource Conservation and Recovery Act (RCRA) <https://epa.gov/laws-regulations/summary-resource-conservation-and-recovery-act>
This webpage provides a summary of RCRA and lists links to additional information.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) <https://epa.gov/superfund/superfund-cercla-overview>
This webpage provides an overview of CERCLA, commonly known as Superfund.

The EPA also provides information about radioactivity in coal and the management and use of coal combustion wastes, or coal combustion residuals (CCR).

Coal Ash <https://epa.gov/coalash>
This webpage provides information about coal ash and coal combustion residuals (CCR).

TENORM: Coal Combustion Residuals <https://epa.gov/radiation/tenorm-coal-combustion-residuals>
This webpage provides a description of technologically enhanced naturally-occurring radioactive material (TENORM) and links to additional information.

Cleaner Power Plants <https://epa.gov/stationary-sources-air-pollution/mercury-and-air-toxics-standards>
This webpage provides information on setting standards for mercury and other toxic air emissions from power plants.

The States

Each state has one or more programs to address radiation protection, including naturally-occurring radioactive materials. Most states control public exposure to radioactive materials through programs implementing federal environmental laws such as the Clean Air Act and the Clean Water Act.

State Radiation Protection Programs <https://www.crcpd.org/mpage/map>
The Conference of Radiation Control Program Directors (CRCPD)
This webpage provides links and contact information for each state's Radiation Control Program office.

The U.S. Department of Energy (DOE)

The DOE provides grants for research on coal-fired plants and clean coal technologies.

Clean Coal Research <https://energy.gov/fe/science-innovation/clean-coal-research>
This webpage provides information on the DOE's clean coal research and development efforts.

Oak Ridge National Laboratory, UT Battelle for the U.S. Department of Energy

Oak Ridge National Laboratory is the largest US Department of Energy science and energy laboratory. ORNL conducts a broad range of research and development, primarily for the U.S. Department of Energy, but also for other federal agencies and both public and private sponsors.

Coal Combustion: Nuclear Resource or Danger (pdf) <https://www.ornl.gov/sites/default/files/ornl%20review%20v26n3-4%201993.pdf#page=26> (7.6 K)
This article discusses the radioactive pollution associated with the burning of coal.

American Coal Ash Association (ACA)

The ACA, established in 1968, is a nonprofit trade association devoted to recycling the materials created when we burn coal to generate electricity.

American Coal Ash Association (ACCA) Coal Combustion Production (CCP) & Use 2019 Survey Report <https://epa.gov//acaa-usa.org/wp-content/uploads/coal-combustion-products-use/2019-survey-results.pdf>
This chart contains the results of a survey of coal combustion companies about the amount of combustion residuals produced and the amount reused.

Last updated on June 24, 2025

AMERICAN PUBLIC POWER ASSOCIATION
Powering Strong Communities

June 26, 2025

The Honorable Brett Guthrie
Chairman
Committee on Energy and Commerce
U.S. House of Representatives
2125 Rayburn House Office Building
Washington, D.C. 20515

The Honorable Frank Pallone Jr.
Ranking Member
Committee on Energy & Commerce
U.S. House of Representatives
2322A Rayburn House Office Building
Washington, D.C. 20515

The Honorable Morgan Griffith
Chairman
Subcommittee on Environment
Committee on Energy & Commerce
U.S. House of Representatives
2125 Rayburn House Office Building
Washington, D.C. 20515

The Honorable Paul Tonko
Ranking Member
Subcommittee on Environment
Committee on Energy & Commerce
U.S. House of Representatives
2322A Rayburn House Office Building
Washington, D.C. 20515

Dear Chairmen Guthrie and Griffith and Ranking Members Pallone and Tonko:

The American Public Power Association (APPA) appreciates the opportunity to submit a statement for the record for the House Energy & Commerce Committee's Subcommittee on Environment's hearing, "A Decade Later: A Review of Congressional Action, Environmental Protection Agency Rules, and Beneficial Use Opportunities for Coal Ash." We applaud the subcommittee reviewing the implementation of the Environmental Protection Agency's (EPA) 2015 Coal Combustion Residuals (CCR) rule and subsequent CCR regulations.

APPA is the national trade organization representing the nation's 2,000 not-for-profit, community-owned electric utilities. Public power utilities are in every state except Hawaii. They collectively serve over 55 million people in 49 states and five U.S. territories. Public power utilities are load-serving entities, with the primary goal of providing their communities with safe, reliable electric service at the lowest reasonable costs, consistent with good environmental stewardship. While public power utilities serve some of the nation's largest cities, nearly 1,600 of the 2,000 in operation serve rural communities.

EPA's 2015 CCR rule established minimum standards for the disposal of CCR in existing and new landfills and surface impoundments. The rule applies directly to facilities, requiring utilities to implement the rule without the benefit of federal or state permit programs to demonstrate and ensure compliance. This self-implementing program has proven to be unworkable for many public power utilities. Since 2015, EPA has issued six rulemakings that have only further inhibited regulatory compliance and broadened the scope of federal CCR regulations. Further, a change in EPA's interpretation of key terms such as "contains liquids" and "beneficial use" in the federal CCR regulations has complicated compliance and injects uncertainty as our members plan projects.

In 2016, Congress passed the Water Infrastructure Improvements for the Nation (WIIN) Act (P.L. 114-322). The legislation requires EPA to approve state CCR permit programs that achieve compliance with the federal CCR rule or are as protective as those criteria. APPA was actively engaged in the development and passage of the WIIN Act, which had bipartisan support in the House and Senate. Specifically, we strongly supported the provisions allowing states to implement the federal CCR rule and consider site-specific factors and risks in these state permits. At the time of enactment, we believed that establishing a federal and state permit program would resolve many of our concerns with the self-implementing regulations.

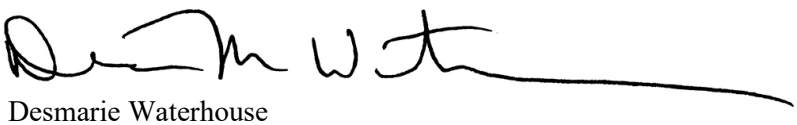
To date, EPA has only approved three state permit programs (Oklahoma, Georgia, and Texas), disapproved one (Alabama), and is proposing to approve North Dakota's permit program. The state of Wyoming filed a petition in the United States District Court for the District of Wyoming seeking to compel EPA action on its state CCR permit program application under the WIIN Act. The Wyoming Department of Environmental Quality submitted its state CCR permit application to EPA for approval on February 6, 2023. Under the WIIN Act, EPA is directed to decide on state CCR permit program applications within 180 days of submission (42 U.S.C. § 6945(d)(1)(B)). To resolve the lawsuit, we understand EPA is preparing to issue a decision on Wyoming's permit application soon. Several other states have shown interest in obtaining approval for their own permit programs under the WIIN Act, which would use a risk-based approach tailored to specific sites. Unfortunately, EPA's slow approval process for state permits, combined with repeated changes to the 2015 CCR rule, has effectively stalled the implementation of the WIIN Act. As a result, the CCR rule remains self-implementing and impractical for most regulated facilities. It would be improper—and inconsistent with Congressional intent—for EPA to proceed with developing further self-implementing CCR regulations.

The WIIN Act requires the EPA to develop a federal CCR permit program in collaboration with Congress. To date, Congress has appropriated $50 million for the agency to establish the program. EPA issued a proposed federal permit rule in 2020 but has yet to issue a final rule, nine years after the passage of the WIIN Act.

EPA's shifting interpretations and successive rulemakings have added complexity to the CCR program, increasing compliance costs without offering substantive guidance to ensure facilities can dispose of CCR consistent with EPA's requirements. Public power utilities operate as not-for-profit entities and do not have the capital budget for the considerably higher compliance costs that come with a one-size-fits-all approach that does not allow for site-specific considerations.

APPA welcomes the committee's review of EPA's CCR program. The current regulations impose substantial regulatory burdens on public power utilities and broaden the regulatory scope to include activities that exceed EPA's statutory authority and have traditionally been regulated by states. The combination of EPA's sluggish state permit approval process and an unstable regulatory environment has hindered effective WIIN Act implementation. EPA should focus its efforts and resources on proposing a new federal permitting program that fulfills the WIIN Act's requirements and facilitates the development and approval of state permit programs.

Sincerely,



Desmarie Waterhouse
Senior Vice President of Advocacy and Communications & General Counsel