OUR WATERS AT RISK

PART 2

The Impact of Coal Ash on Indiana's Water Resources

Hoosier Environmental Council

CELEBRATING 37 YEARS OF EDUCATING & ADVOCATING

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The Hoosier Environmental Council is the voice of the people for the environment in Indiana — the organization with the passion and the plan to tackle our environmental challenges and help make our state a healthier, better place to live and do business.

Our Vision: We aim to set a new path for Indiana, where the people of our state embrace practices and policies that dramatically reduce the footprint of industry, commerce and agriculture on the environment. Following this path, Indiana will ascend to new heights in our public health, economic well-being, and in our preservation of nature for generations to come.

Executive Summary

Coal ash is the material left after burning coal. It contains heavy metals that can contaminate water. Indiana has been producing millions of tons of coal ash per year much of which is now stored in massive open-air impoundments[1]. Indiana has more coal ash impoundments than any other state in the nation.

This report is a follow up to the 2014 Hoosier Environmental Council report *Our Waters at Risk.* In the years since the publication of *Our Waters at Risk,* the regulatory framework for coal ash has changed completely with the first ever federal rule on coal ash disposal, the Coal Combustion Residuals Rule or CCR Rule as well as the Effluent Limitations Guidelines, or ELG Rule.

The CCR Rule requires groundwater monitoring at coal ash disposal sites, so for the first time in 2018 comprehensive data on the groundwater impact became available. For this report, the Hoosier Environmental Council reviewed all of the most recent groundwater data submitted under the CCR Rule for coal ash impoundments in Indiana. It shows that all but one of Indiana's monitored coal ash sites have contaminated the groundwater rendering it unfit for use as drinking water. Fourteen of the 15 sites exceed drinking water limits for molybdenum and lithium, 12 for boron, 11 for arsenic, 10 for sulfate, 6 for cobalt, 4 each for antimony and radium and 2 each for lead, selenium and thallium. The maximum concentrations detected often exceeded drinking water standards by many-fold.

Coal ash disposal can also threaten surface water, like lakes and rivers. This happens when water used to manage coal ash is discharged to waterways carrying coal ash contaminants with it. Lakes and rivers also receive the groundwater that has been contaminated by coal ash. If containment structures fail, coal ash can spill forming massive mudslide-like devastation. The risk to surface water is highest when coal ash is disposed of in the floodplain where aquifers are often shallow and flooding can induce a spill.

It is possible to dispose of coal ash in a manner that protects water resources. The key is to keep the ash from having contact with water. Using the ash in a manner that encapsulates it, such as in concrete, is safe. For the ash that must go for disposal, a well engineered landfill at a site on high ground, out of the floodplain, with an impermeable liner and leachate collection system under the ash and an impermeable cover over the ash is the best method of disposal.

Water-protective disposal of coal ash is happening in other states. In North Carolina and South Carolina all coal ash in impoundments is being moved to lined landfills or recycled. Virginia passed a law requiring removal of coal ash from unlined impoundments adjacent to major waterways. Leaking impoundments are being excavated in Tennessee, Georgia, and Florida, as well.

Indiana stands in stark contrast. It is the state with the most coal ash impoundments, and the majority of them are in the floodplain, yet only three sites in Indiana are planning to close coal ash impoundments by removing the ash to landfills on high ground. At ten other sites plans have been submitted by Indiana's electric utilities to the Indiana Department of Environmental Management (IDEM) for closing coal ash impoundments by leaving the ash in place and building a cap over it. This leaves the groundwater beneath the ash at risk, and at most of them, leaves the ash in the floodplain. The state has started approving these "cap-in-place" plans, including at sites where the coal ash would not just be threatening the groundwater, it would actually be left sitting in the groundwater.

Indiana can do much better to protect water resources for the future – for the sake of our public health and for the protection of our precious groundwater, rivers, and Lake Michigan. Coal ash impoundments that are in the floodplain or that are a threat to the groundwater need to be excavated and the ash recycled or taken to a lined landfill on high ground. Coal ash should no longer be used as fill material where it can come into contact with water. Where coal ash has contaminated groundwater, sound cleanup methods are needed to restore the groundwater.

Synopsis of *Our Waters at Risk*

In 2014 the Hoosier Environmental Council published *Our Waters at Risk* about the impact of coal ash on Indiana's water resources. This report will provide an update on what has been learned about coal ash and water in Indiana since then.

Coal ash is the waste material left behind after burning coal. There are four different types of coal ash: fly ash, bottom ash, flue gas desulfurization waste, and boiler slag. While coal contains traces of a variety of metals, those metals are more highly concentrated in the ash once the carbon has been burned off. When coal ash is in contact with water, those metals can leach into the water and contaminate it.

Millions of tons of coal ash have been produced in Indiana every year for decades. Indiana produced 6,849,800 tons of coal ash in 2018, the most recent year for which data are available[2]. Despite a number of Indiana power plants moving away from coal in recent years[3], the production of coal ash has dropped very little. In 2014, Indiana produced 7,306,400 tons of coal ash, so 2018 production was only 6% less.

There are beneficial uses for some coal ash, though only encapsulated uses, like using coal ash to make cement, are protective of water resources. The rest is disposed of either in a landfill or a surface impoundment.

Our Waters at Risk discussed the coal ash spills in Indiana to date and what was known at the time about coal ash contaminating groundwater. It also summarized the almost complete lack of regulation regarding coal ash disposal in Indiana and provided recommendations for strong federal regulation and for safe disposal of ash.

Since 2014

Since HEC's 2014 report, a lot has happened and we know a good deal more about the impact of coal ash on Indiana's drinking water resources and rivers.

Prior to 2015 the states had the option of adopting requirements for safe coal ash disposal. Indiana had landfill rules that applied to coal ash landfills and rules on impoundment closure that applied if a coal ash impoundment was closed[4]. It had no rules regarding where coal ash impoundments were built, how they were built, or whether they monitored for groundwater contamination.

In 2015, the US Environmental Protection Agency (EPA) finalized the first nation-wide rule on coal ash disposal, the Coal Combustion Residuals Rule or CCR Rule. The Rule sets standards for the location and structure of coal ash impoundments to reduce the risk of catastrophic failure including prohibitions on coal ash impoundments in seismic areas, wetlands, unstable areas, on a geologic fault, or too close to an underlying aquifer. The CCR Rule required that impoundments be inspected yearly for structural stability, that utilities make documents regarding coal ash disposal available on the internet, and that utilities test the underlying groundwater and take corrective measures if the coal ash has contaminated it. If an impoundment failed location or structural integrity requirements or it contaminated groundwater, then the utility was required to stop placing coal ash in it and close it permanently. The Rule had requirements for safe closure of an impoundment.[5]

The EPA wrote the CCR Rule to be "self implementing", which meant the EPA would not be enforcing it. If a utility is not following the rule, the only legal mechanism for obtaining compliance is a citizen lawsuit. The Rule established deadlines for the utilities to come into compliance with the various parts of the Rule, so the utilities have taken a series of steps since 2015.

Legal challenges to the 2015 CCR Rule have come from both sides. Environmental groups challenged portions of the Rule they considered weak and the utilities challenged provisions they felt were too stringent. These challenges were consolidated and the D.C. Circuit Court of Appeals issued two rulings in this case. In 2016, the Court granted EPA's motion to vacate and remand a challenged provision of the 2015 rule that exempted from certain requirements those coal ash impoundments that the utilities had stopped using by October of 2015[6]. In August 2018, the D.C. Circuit ruled on the remaining issues, deciding that all unlined impoundments had to close, given the evidence of the risks they pose to human health and the environment. It also ruled that the EPA could not exempt coal ash impoundments at sites that no longer had active power plants, so-called 'legacy ponds', because they are just as likely as other ash impoundments to be environmental hazards[7]. The EPA waited until October 2020 to begin to act on the legacy pond decision and did so by issuing a request for information, rather than a proposed rule revision[8].

Between 2018 and the time of this writing, the EPA issued four additional proposals for revising the CCR Rule. Some of the proposals changed reporting requirements, but most weakened the Rule by adding lengthy extensions for cleanups and putting political appointees in charge of certifying aspects of ash disposal rather than professional engineers [9].

In the spring of 2016, Indiana's Environmental Rules Board adopted the federal CCR Rule language on impoundments directly into Indiana rules at the request of Indiana's electric utilities. The Indiana Department of Environmental Management (IDEM) considers the adopted coal ash rule language to be self-implementing, so they do not enforce it, though they have the authority to do so under Indiana law. However, based on long-standing state rules about impoundments of all types, that predate the CCR Rule, IDEM reviews plans for closure of coal ash impoundments and issues approvals or requires improvements in those plans[10].

In 2015, the EPA issued a companion rule to the CCR rule regarding the release of water that had been in contact with coal ash[11]. Titled the "Effluent Limitation Guidelines and Standards for the Steam Electric Power Generating Point Source Category" and known as the ELG Rule, this rule was issued under the Clean Water Act and put limits for the first time on the coal ash contaminants that could be released into waterways as point source discharges. In 2017, the Administration issued a stay on the rule's implementation[12], and in 2020 finalized a revision of the ELG Rule that allows more contaminants to be released and delays in compliance[13].

As a result of the original CCR and ELG Rules, most Indiana utilities that continued to burn coal stopped disposing of coal ash in impoundments and started using dry handling systems and landfills. Many of the existing coal ash impoundments have failed the CCR Rule location requirements or violated its standards for groundwater protection and will have to close.

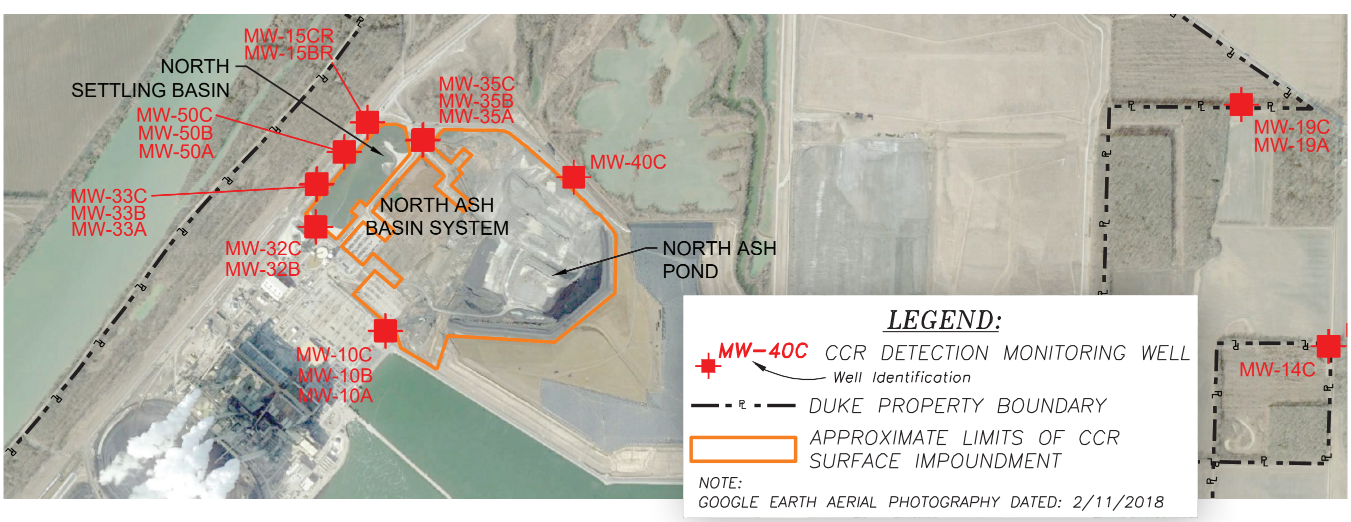
Impact on Groundwater

Groundwater is water found beneath the Earth's surface typically in saturated soil or fractures in rock[14]. Approximately two-thirds of Indiana's population receives their drinking water from groundwater resources[15].

Groundwater can be contaminated by coal ash. In a process called 'leaching', water in contact with the ash can pick up contaminants from the ash and carry them downward into the ground and into groundwater. The fact that coal ash can contaminate groundwater via leaching has been known for many years. Important studies clearly demonstrating leaching from coal ash were published by the industry's own Electric Power Research Institute (EPRI) in 2006[16] and by the U.S. EPA in 2009[17].

Some of Indiana's coal ash is perpetually below the water table and soaking in the groundwater. Prior to initiating closure, nine of Indiana's coal ash disposal sites[18] had coal ash impoundments dug deep enough into the ground that the bottom of the ash was constantly in the groundwater, exacerbating the leaching.

Figure 1. Monitoring well map for the North Ash Basin System at Gibson Generating Station in SW Indiana[19]



With the CCR Rule in 2015, the utilities were required for the first time to systematically monitor groundwater at coal ash disposal sites. Monitoring is done by installing wells around the disposal site, periodically drawing water from the wells, and testing it in a lab. To give an example, Figure 1 is a map showing the location of groundwater monitoring wells at the Gibson Generating Station. There is an orange line around the ash impoundments, and red squares indicate the location of the wells. The Wabash River is on the left side of the figure.

Most of the wells are close to the impoundments, while three of them - wells MW-19C, MW-19A, and MW-14C on the right-hand side of figure 1 - are further away where they can sample groundwater unaffected by coal ash. Tests of the unaffected groundwater show the background concentrations of constituents in the local aquifer. The background samples are compared to samples near the ash impoundments to help determine what impact the ash is having. For example, coal ash can contaminate groundwater with arsenic, but at some locations arsenic can get into groundwater from the local geology. If arsenic is found in the groundwater at a coal ash disposal site and the same concentration of arsenic is present in the background samples, that would indicate that the arsenic came from the local geology. If the arsenic concentration is higher in the sample near the ash disposal than in the background sample, that would indicate that the arsenic came from the coal ash. Similar comparisons to background are done for all of the monitored constituents in the groundwater.

Groundwater monitoring needs to account for the movement of the groundwater in order to compare groundwater impacted by the coal ash to groundwater that has not been impacted. Groundwater flows by gravity from areas with a higher water table to areas with a lower water table – known as the "gradient". Figure 2 helps to illustrate this point. In monitoring well MW-33A the top of the groundwater is at an elevation of 381.33 feet above sea level, and in MW-35A on the right-hand side of the figure, the water is higher at 382.91 feet. Since the groundwater is more than a foot higher in MW-35A, it is flowing under the influence of gravity toward the lower point at MW-33A. The figure includes light blue lines along which the groundwater is at approximately the same elevation and a dark blue arrow indicating the expected direction of flow based on the water levels. Monitoring wells are typically placed so some of them sample the groundwater before it moves under the ash impoundment and others sample it after it has moved under the impoundment. The wells sampling water before are referred to as 'upgradient' and those sampling after are 'downgradient'. All monitoring wells, whether they are upgradient or downgradient, are located on the physical premises of the coal plant site.

Figure 2. Example of groundwater levels and movement, Gibson North Ash Basin[20]

The CCR Rule requires the utilities to publish annual groundwater monitoring reports on disposal sites subject to the Rule[21]. The first of these reports had to be posted publicly no later than March 2, 2018, covering the first two years of groundwater data. Two more annual reports have been released since then, so as of this writing, there are four years of data on groundwater at most coal ash disposal sites. Seven coal ash impoundments in Indiana were exempted under the original 2015 CCR Rule but brought under the Rule by the court decision in 2016, so they are on a delayed compliance schedule. Some of Indiana's many out-of-service coal ash impoundments, meaning impoundments that were no longer in use or located where the power plant stopped generating electricity before the CCR Rule became effective in 2015, remain outside the CCR rule as of this writing. These impoundments may have groundwater monitoring under other state regulations, but this report will focus on those that are reporting under the federal CCR Rule.

The Hoosier Environmental Council has examined the groundwater data from Indiana's coal ash sites that are currently publishing data pursuant to the CCR Rule. We compiled the data from the annual groundwater reports the utilities issued under the CCR Rule, relying on the most recent data for each impoundment. The question we sought to answer at each site was whether coal ash had rendered the groundwater at that site unfit for use as drinking water. Our analysis differs somewhat from the analysis required under the CCR Rule. If more than one ash impoundment had groundwater monitoring at a site, we considered the results from all of the impoundments' downgradient wells together since we were interested in the condition of the site overall, rather than separately as utilities might choose to do under the Rule.

For our analysis, we compared the downgradient well results to upgradient wells only if the upgradient wells reflected the local groundwater where it was not impacted by coal ash. If the upgradient wells showed clear evidence of being impacted by coal ash, we left them out of our analysis and looked only at the downgradient wells. Evidence that wells labeled by the electric utility as upgradient were impacted by coal ash included being located downgradient from coal ash; being built in areas with coal ash used as fill; seasonal changes in groundwater flow changing whether a well was up- or downgradient; and having the same typical coal ash contaminants that were in the downgradient wells.

Under the CCR Rule, the utilities are required to compare downgradient results to upgradient wells that *"Accurately represent the quality of background groundwater that has not been affected by leakage from a CCR unit"*[22], but in several instances we saw utilities inappropriately using upgradient wells impacted by coal ash to measure background water quality.

To answer the question of whether the groundwater at a site was unfit for use as drinking water, we compared the downgradient well results to standards for drinking water. Table 1 lists the standards we used and their sources. For chemicals that have a Maximum Contaminant Level (MCL) under the U.S. Safe Drinking Water Act, we used the MCL. For those without an MCL, we used the Safe Drinking Water Act Health Advisory, if there was one[23]. If there was neither an MCL nor a Health Advisory for a chemical, we used EPA's Risk-Based Screening Level for Tapwater[24]. While these standards have different names, they are all limits on contaminant levels in drinking water intended to help protect human health. The health-based limits we used for comparison were the same as those used under the CCR Rule as Groundwater Protection Standards, with the exception of molybdenum. For molybdenum, we chose to use the Health Advisory under the Safe Drinking Water Act while the CCR Rule uses the slightly higher Screening Level for Tapwater.

The groundwater at all of Indiana's coal ash disposal sites is unfit for human consumption[25]. At two of the sites, Rockport and Culley, some of the contamination may be due to sources other than the coal ash.

Arsenic is present in the Rockport groundwater above the drinking water standard[26], but similar concentrations are also present in background wells that are distant from the coal ash. Rockport has reported elevated boron, chloride, fluoride, pH, dissolved solids, and sulfate exceeding background, but not at levels that exceed drinking water standards[27].

At Rockport, the soil beneath the ash impoundments includes a 5 to 15 foot layer of dense clay[28]. The Raccoon Creek Group Aquifer System under Rockport is considered at low risk for contamination because of the low permeability clay layers above it[29]. Clay can be nearly impervious to water movement, so this thick layer of clay is likely limiting groundwater contamination by the Rockport coal ash.

Table 1. Drinking water standards for comparison to groundwater monitoring results

	Health-based limit	Reference for health-based limit	Potential health effects[30]
Antimony	6 ug/L	US Safe Drinking Water Act, Maximum Contaminant Level (MCL)	skin and eye irritation, may be a carcinogen, birth defects in animal studies
Arsenic	10 ug/L	US Safe Drinking Water Act, Maximum Contaminant Level (MCL)	toxic to the nervous system, carcinogenic
Boron	3000 ug/L	US Drinking Water Health Advisory Level	gut irritation, low birth weight, birth defects
Chromium (total)	100 ug/L	US Safe Drinking Water Act, Maximum Contaminant Level (MCL)	gut irritation, skin allergies
Cobalt	6 ug/L	EPA Risk-Based Screening Level for Tapwater	heart, lung, kidney, and liver effects
Lead	15 ug/L	US Safe Drinking Water Act, action level	toxic to the nervous system
Lithium	40 ug/L	EPA Risk-Based Screening Level for Tapwater	nervous system effects
Mercury	2 ug/L	US Safe Drinking Water Act, Maximum Contaminant Level (MCL)	toxic to the nervous system
Molybdenum	80 ug/L	US Drinking Water Health Advisory Level	damage to kidney, liver, and reproductive system
Radium 226 + 228	5 pCi/L	US Safe Drinking Water Act, Maximum Contaminant Level (MCL)	carcinogenic, anemia, cataracts
Selenium	50 ug/L	US Safe Drinking Water Act, Maximum Contaminant Level (MCL)	hair loss
Sulfate	500 mg/L	US Drinking Water Health Advisory Level	diarrhea
Thallium	2 ug/L	US Safe Drinking Water Act, Maximum Contaminant Level (MCL)	toxic to the nervous system

Key: ug=microgram, mg=milligram, pCi = pico-Curies, L = liter

Upgradient wells at Culley are distant from the coal ash impoundments, but on the utility property. They have concentrations of antimony, cobalt, lead and lithium that are similar to or higher than the concentrations of those contaminants in the downgradient wells. Arsenic is also present in some of the upgradient samples, but at concentrations much lower than in the downgradient wells[31, 32]. At Culley, the coal ash appears to be adding arsenic, boron, mercury, molybdenum, radium, and sulfate to the groundwater, but antimony, cobalt, lead and lithium are in the background groundwater. The land around Culley has been heavily industrialized for many years, and this may account for the background contamination.

Determining whether a site's groundwater is unfit for drinking water produces 'yes' or 'no' answer. If all the samples have chemical concentrations under the health-based limits, the groundwater would be a reasonable drinking water source. If some have elevated concentrations, then it would not.

The degree of contamination is another question. There are different ways to assess the degree of contamination. At any given coal ash site, there were multiple downgradient wells and multiple samples of groundwater from each well. Chemical concentrations varied from well to well and varied between samples taken at different times from the same well. Indiana's coal ash impoundment sites have between 4 and 34 downgradient wells, and the total number of samples at a site that were tested for a chemical varied from 5 to 132. The sites with higher numbers of samples were the ones that included an impoundment on the delayed compliance schedule, since their most recent groundwater report was their first report and included two years of data.

To answer the question, "how contaminated is the water", we chose to evaluate three indicators:

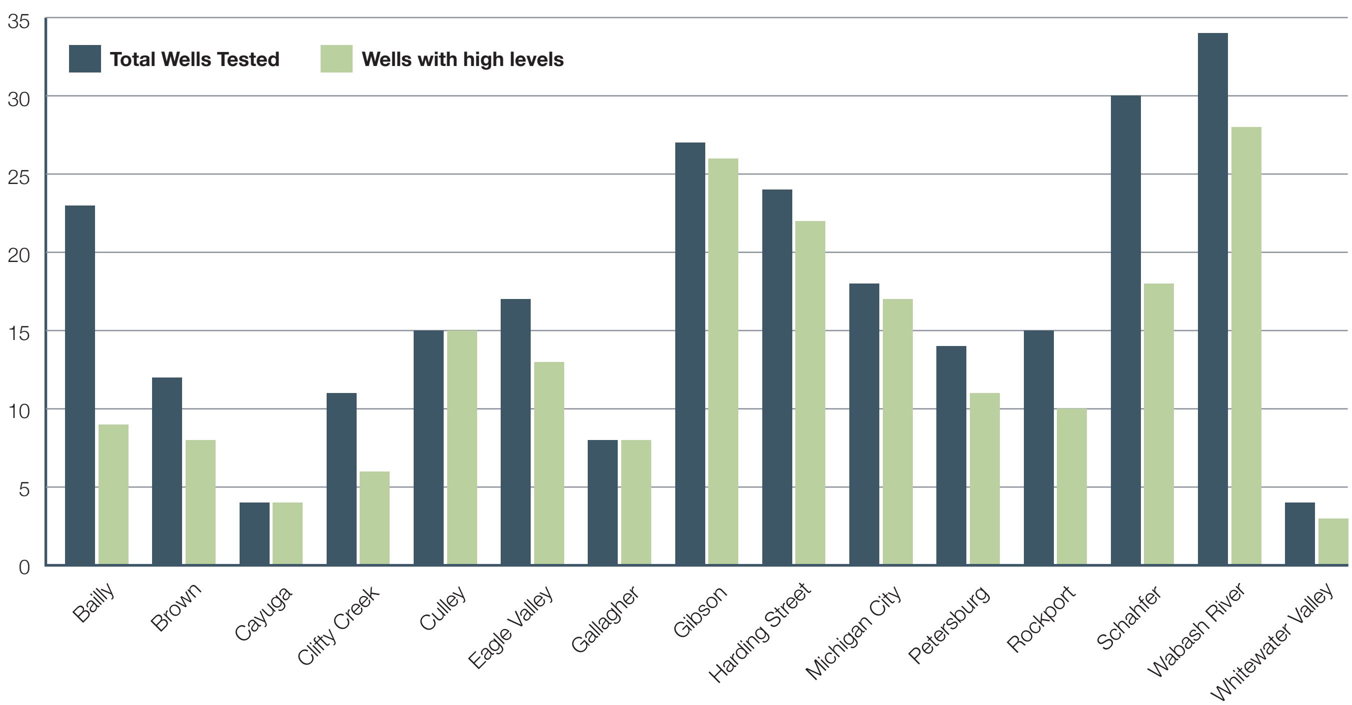
1. the percent of downgradient wells at the site with one or more chemicals above the health-based limit, in other words, the wells that could not be used for drinking water,
2. the percent of groundwater samples from downgradient wells with a chemical above the health-based limit, and
3. the highest concentration of the chemicals detected at each site.

Table 2 shows the proportion of the downgradient wells at each site that were over the health-based limit for at least one chemical. It varies from 39% of the downgradient wells at Bailly to 100% at Cayuga, Culley, and Gallagher. Figure 3 shows the numbers of wells and numbers with elevated levels in graphic form.

Table 2. Percent of downgradient wells with one or more chemicals above the health-based limit

Site	Number of downgradient wells tested	Percent of downgradient wells with 1 or more chemicals above the health-based limit	Chemicals exceeding health-based limits
Bailly	23	39.1%	arsenic, lithium, molybdenum, selenium, thallium,
Brown	12	66.7%	arsenic, boron, lithium, molybdenum, sulfate, thallium
Cayuga	4	100%	antimony, boron, chromium cobalt, lithium, molybdenum, sulfate
Clifty Creek	11	54.5%	boron, lithium, molybdenum
Culley	15	100%	antimony, arsenic, boron, cobalt, lead, lithium, mercury, molybdenum, radium, sulfate
Eagle Valley	17	76.5%	arsenic, boron, lithium, molybdenum
Gallagher	8	100%	arsenic, boron, cobalt, lithium, molybdenum, radium, sulfate
Gibson	27	96.3%	arsenic, boron, chromium, cobalt, lead, lithium, molybdenum, radium, sulfate, thallium
Harding Street	24	91.7%	antimony, arsenic, boron, lithium, molybdenum, sulfate
Michigan City	18	94.4%	arsenic, boron, lithium, molybdenum, selenium, sulfate, thallium
Petersburg	14	78.6%	boron, cobalt, lithium, molybdenum, sulfate
Rockport	15	66.7%	arsenic
Schahfer	30	60%	arsenic, boron, cobalt,lithium, molybdenum, sulfate
Wabash River	34	82.4%	arsenic, boron, chromium, cobalt, lead, lithium, molybdenum, radium, sulfate
Whitewater Valley	4	75%	boron, lithium, molybdenum, sulfate

Figure 3. Numbers of downgradient wells and number with at least one chemical above the health-based limit



At all 15 sites with monitored coal ash impoundments in Indiana, there were 256 downgradient wells, of which 198 (or 77%) had at least one chemical above the health-based limit. Only 23% were completely free of coal ash contaminants. The pie chart in figure 4 helps illustrate those proportions.

Figure 4. Percent of all downgradient wells at all Indiana coal ash sites with one or more chemicals above the health-based limit

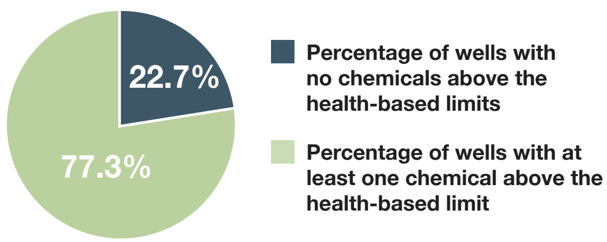
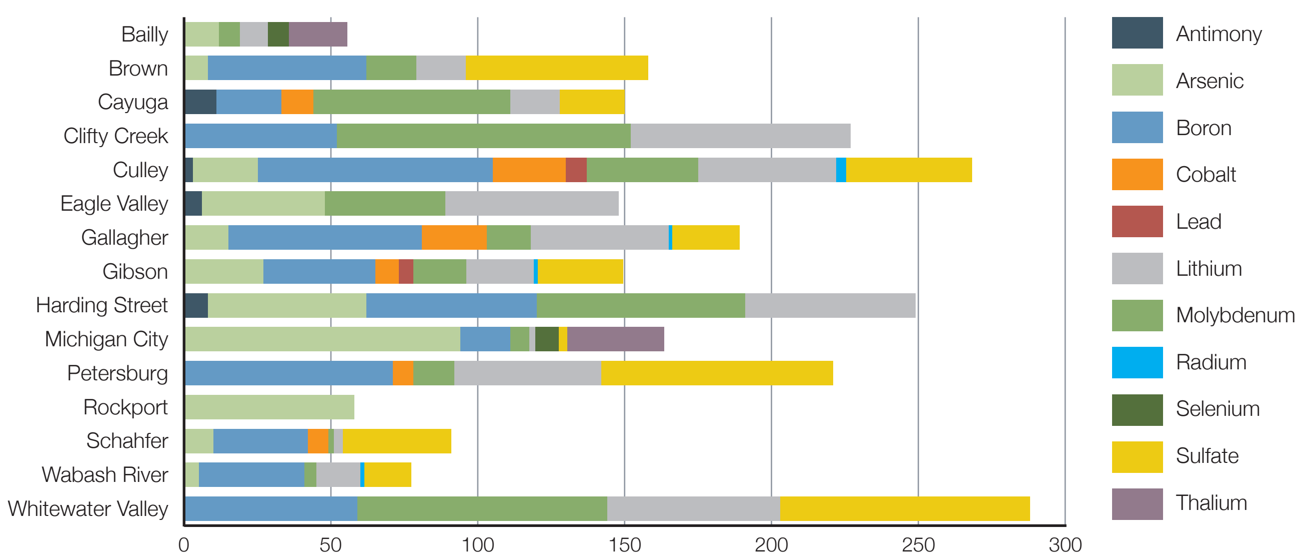


Table 2 also lists the chemicals that exceeded health-based limits in at least one sample at each site. Lithium and molybdenum were elevated at 14 of the 15 sites. Boron was the next most common contaminant with 12 sites having concentrations above the EPA's Health Advisory. Arsenic was high at 11 and sulfate at 10. Six sites had high cobalt, 4 had antimony, 4 had radium, and there were 2 each for lead, selenium and thallium.

For our second measure of the degree of contamination, we assessed the percent of groundwater samples that exceeded the health-based limit for each chemical at each site. We did this by adding up the total number of samples taken from downgradient wells at the site that were tested for each chemical. Out of those samples we found those that exceeded the health-based limit for that chemical and calculated their percentage. A full table of all 15 sites and their percent exceedances for 11 chemicals is included in Appendix A. Figure 5 presents the same data as a stacked bar graph. Each chemical is represented by a color, and the length of that color represents the percent of samples that exceed the health-based limit. For example, the red bar representing arsenic shows nearly 100% at Michigan City, but only around 10% at Bailly. At Brown the lavender bar on the end representing sulfate shows over 50%, while at Cayuga it is closer to 20%. The total length of each bar reflects both the number of chemicals with exceedances and the percent of samples with exceedances.

Our third measure of the degree of contamination was the maximum concentrations of the chemicals. Arguably the average concentration or median concentration across all samples at the site could be used. However, in looking at whether the groundwater was drinkable, we chose to look at the worst case scenario: an individual is taking a drink from a well at that site and is unlucky enough to select the well with the highest concentration. If drinking water were being drawn from the groundwater

Figure 5. Percent of groundwater samples that exceeded each health-based limit



at a site, it might be drawn from a single well, so the average concentration of the wells scattered across the site will not reflect the water a person might drink from a single well.

Table 3 shows the maximum concentrations of each of the 11 chemicals for all 15 coal ash sites. Blank spaces in the table indicate there were no samples exceeding the health-based limit for that chemical. The health-based limits are listed under the name of each chemical. Table 3 shows that

- All but one site exceeds the limit for molybdenum, half of which exceed it by 10-fold or more.
- 73% of sites have at least double the limit for lithium.
- 78% percent of sites have at least double the U.S. drinking water standard for arsenic
- Boron is elevated at 80% of sites all but one of which have at least double the Health Advisory.

The groundwater contamination from coal ash impoundments is not a surprise. Coal ash contains a long list of heavy metals. The metals are present in the coal in trace amounts, but when coal is burned, the carbon is burned off leaving the metals behind in much higher concentration. Studies in the early 2000's clearly demonstrated that when coal ash is in contact with water, the metals can leach out of coal ash into the water[33]. In unlined coal ash impoundments, the ash is mixed with water and there is nothing to stop that water from soaking downward into the ground.

Unlined coal ash landfills are also contaminating groundwater, but assessment of groundwater monitoring data at Indiana's coal ash landfills is beyond the scope of this paper.

Table 3. Maximum groundwater concentrations at Indiana Coal Ash Sites. For each chemical, the table shows the highest concentration detected at that site. A blank means none of the samples at a site exceeded the health-based limit for that chemical.

	Antimony	Arsenic	Boron	Chromium	Cobalt	Lead	Lithium	Molybdenum	Radium[34]	Selenium	Sulfate	Thallium
Health-based limit	0.006 mg/L	0.01 mg/L	3 mg/L	0.1 mg/L	0.006 mg/L	0.015 mg/L	0.04 mg/L	0.08 mg/L	5.0 pCi/L	0.05 mg/L	500 mg/L	0.002 mg/L
Bailly		0.083					0.063	0.63		0.09		0.013
Brown		0.023	14				0.1	1.9			4800	0.01
Cayuga	0.008		8.4		0.02		0.41	0.14			1280	
Clifty Creek			11				1.0	0.87				
Culley[35]	0.01	0.32	35		0.026	0.24	0.47	1.5	10.2		1400	
Eagle Valley		0.0796	7.86				0.116	0.198				
Gallagher		0.094[36]	29.2		0.019		0.069	1.6	5.2		834	
Gibson		0.21	58.3	0.21	0.057	0.12	0.15	1.4	9.73		1660	0.0034
Harding Street	0.0092	0.471	43.3				0.567	1.09			1690	
Michigan City		0.058	5.3				0.12	0.088		0.11	950	0.0056
Petersburg			26.4		0.295		0.0778	2.2			1710	
Rockport[37]		0.03										
Schahfer		0.026	14		0.0084		0.064	0.18			1500	
Wabash River		0.053	50.1	0.16	0.044	0.24	0.26	1.7	6.6		1660	
Whitewater Valley							0.0946	0.128			1460	

HEXAVALENT CHROMIUM IS A LIKELY BUT UNMEASURED GROUNDWATER CONTAMINANT

The groundwater at coal ash sites has not been tested for hexavalent chromium (CrVI), but it is likely there. The CCR Rule requires testing the groundwater at coal ash sites for total chromium but does not require differentiating between different forms of chromium.

Hexavalent chromium is common in coal ash leachate. The Electric Power Research Institute (EPRI) study of coal ash and FGD leachates found "Analysis of speciation samples indicated that ash leachate is usually dominated by As(V) and Cr(VI)" indicating that the chromium found in coal ash leachate is usually in the Cr(VI) or hexavalent form. The study found hexavalent chromium at concentrations up to 5090 ug/L in ash leachate with a median concentration of 0.7 ug/L. Of the samples in the EPRI study, the majority (60 - 64%) of samples had detectable hexavalent chromium[38].

Hexavalent chromium is highly toxic and carcinogenic. The International Agency for Research on Cancer (IARC) and the U.S. National Toxicology Program both designate it a known human carcinogen[39]. In drinking water, it is associated with oral and intestinal cancers. Hexavalent chromium readily enters human cells where it is reduced to Cr(III) which binds to DNA leading to genetic damage and mutations. The genetic damage is one mechanism of its carcinogenicity[40]. Cellular oxidative stress, a form of chemical damage, induced by hexavelent chromium is also believed to play a role[41].

The concentrations of hexavalent chromium found in coal ash leachate in the EPRI study are enough to pose a threat to human health. Hexavalent chromium is highly toxic even at exceedingly low concentrations. The EPA limit for total chromium in drinking water is 0.1 mg/L, but that was set in 1991 and did not distinguish the form of chromium[42]. In a recent effort to reassess the chromium limit in drinking water and whether hexavalent chromium should be regulated separately, the EPA required drinking water systems around the United States to test for hexavalent chromium with a limit of detection of 0.03 ug/L[43]. The EPA reassessment has not concluded, yet. The California Office of Environmental Health Hazard Assessment did an in-depth review of hexavalent chromium, published in 2011, which set a public health goal of 0.02 ug/L in drinking water based on the cancer risk[44]. This is 5,000-fold less than the current U.S. drinking water standard for total chromium. Indiana's 2020 screening level for hexavalent chromium in groundwater used for residential tap water (i.e., the state's tapwater standard for hexavalent chromium) is 0.35 ug/L[45]. The median concentration of hexavalent chromium that EPRI found in coal ash leachate is twice Indiana's tapwater standard, so the amount likely to be present in coal ash contaminated groundwater exceeds health-based limits.

The Indiana coal ash sites all tested groundwater samples for total chromium , but did not determine if any of it was in the hexavalent chromium form. Their total chromium concentrations ranged from 0.000469 to 0.21 mg/L (0.469 - 210 ug/L). If hexavalent chromium were a significant portion of the total chromium, as the EPRI study suggests it would be at 60% of coal ash sites, they could easily have exceeded the Indiana tapwater standard of 0.35 ug/L.

Eight of the 15 sites evaluated in this report did not detect total chromium in any of their groundwater samples, but this does not mean they were free of hexavalent chromium. The labs testing their groundwater had limits of detection for total chromium of either 0.002 mg/L or 0.01 mg/L (2 or 10 ug/L), except for Rockport which had a limit of 0.07 ug/L. Those with limits of 2 or 10 ug/L could not have detected chromium at the Indiana tapwater standard of 0.35 ug/L. Hexavalent chromium at or above 0.35 ug/L could have been present but undetected since the limits of detection were 5- to 28-fold higher than 0.35 ug/L.

Impact on drinking water

Two-thirds of Hoosiers get their drinking water from groundwater sources, either from their own private well or from a public water system that uses wells[46]. Groundwater is vulnerable to contamination by coal ash, and there are four known locations in Indiana where coal ash has contaminated drinking water wells. More than 260 private wells in the town of Pines, Indiana, were impacted by an unlined coal ash landfill used by NIPSCO known as Yard 520[47]. Coal ash had been used extensively as fill on properties in the Town of Pines, and the fill also contributed to the groundwater contamination[48]. NIPSCO paid to extend municipal water lines to many of those homes and businesses, and continues to provide bottled water to others[49]. Duke Energy provided municipal water lines to private well owners near their Cayuga plant and bottled water to others near their Gibson power plant because they were impacted by coal ash[50]. In 2017 residential wells near the Noblesville power plant were found to be impacted by coal ash, and Duke Energy began providing bottled water to the affected residents[51, 52].

At a fifth location, municipal drinking water wells are at risk of contamination by coal ash. The retired Tanners Creek Generating Station on the shoreline of the Ohio River has two legacy coal ash ponds[53], a coal ash landfill, and a large deposit of coal ash used as fill. There is a shallow sand and gravel aquifer at the site, and some of the coal ash is sitting in the groundwater[54, 55]. The Tanners Creek coal ash is known to be contaminating the groundwater with boron, arsenic, lithium, and manganese[56, 57]. Monitoring has shown the groundwater from the site moving west to northwest under typical conditions, pulled in that direction by a "cone of depression" created by pumping at municipal wells for the Lawrenceburg, Manchester and Sparta Conservancy District and the City of Aurora. The closest of these wells is located only about 500 feet from the edge of the Fly Ash Pond[58].

If the groundwater contamination continues at coal ash disposal sites in Indiana, then Indiana loses the opportunity to use that groundwater in the future. Coal ash contaminants are metals. Over time and depending on local conditions, they can undergo chemical reactions to other forms, like arsenic being oxidized from arsenite to arsenate, or they can be moved by wind or water, but they do not break down. Coal ash is essentially a forever pollutant.

Impact on Indiana's surface water

RISK OF SPILLS

When coal ash disposal structures fail, the coal ash spills can be catastrophic. The spilled ash is like a mud slide. When it enters a water body, it can both contaminate water and have a physical smothering effect on the aquatic ecosystem.

Figure 6a. Coal ash spill Kingston, Tennessee, aerial photo

Source: Tennessee Valley Authority (TVA) https://en.wikipedia.org/wiki/Kingston_Fossil_Plant_coal_fly_ash_slurry_spill#/media/File:Aerial_view_of_ash_slide_site_Dec_23_2008_TVA.gov_123002.jpg

In 2008, 5.4 million cubic yards of coal ash spilled from an impoundment in Kingston,Tennessee, because the dike holding the ash failed. The ash covered 300 acres and spilled into the Emory River[59, 60] which flows into the Tennessee River, a source of drinking water for Chattanooga. The spill did extensive damage to homes and local infrastructure and caused "a tremendous fish kill"[61]. Miraculously, no human lives were lost during the spill.

River samples were collected downstream from the Kingston spill just days after it happened and analyzed at Appalachian State University. They showed concentrations of arsenic, barium, cadmium, chromium, lead, mercury, nickel, and thallium exceeding drinking water standards near the spill, some exceeding it many

Figure 6b. Coal ash spill Kingston, Tennessee on-the-ground photo

Source: Brian Stansberry

Figure 7. Coal ash covering the bank of the Dan River after the 2014 spill.

Source: U.S. Environmental Protection Agency (EPA), Atlanta, GA. "Eden NC Coal Ash Spill."

times over. Arsenic, lead, and mercury were still elevated at 2 to 35 times drinking water standards at a sampling site nearly 2 miles downstream[62].

In 2014, a pipe failed in an impoundment at the Dan River Generating Station in North Carolina releasing 39,000 tons of coal ash into the Dan River[63] which was carried as far as Kerr Lake in Virginia, 70 miles downstream[64]. The ash from the spill formed deposits on the river bottom from a few inches to 6 feet thick [65].

One study estimated the total ecological, recreational, human health, property value, and aesthetic cost of the Dan River spill at $295 million[66]. Duke Energy published its own study of monitoring water, sediment, and the ecosystem after the spill, and concluded there was no evidence of ecosystem damage[67]. However, assessments by the states of North Carolina and Virginia, as well as the federal government, found damage to natural resources that led them to file a suit against Duke Energy in 2019. The complaint they filed stated: "the release of hazardous substances resulting from the Dan River Coal Ash Spill injured or may have injured migratory birds, fish, aquatic insects, freshwater mussels, reptiles, amphibians, surface water, and sediment of the Dan River; human use of the Dan River; and general supporting habitat for all of these resources"[68].

In late 2007, an estimated 30 million gallons of coal ash spilled into the White River from impoundments at the Eagle Valley Generating Station in Martinsville, Indiana. The failed berm was repaired but then failed again releasing another 30 million gallons just the next year. None of the spilled ash was recovered[69]. Each of these spills released at least one-fifth of the ash stored in the affected ponds.[70]

Coal ash can also spill when flood waters carry the ash out of a disposal site. For example, rain from Hurricane Matthew in 2016 and Hurricane Florence in 2018 flooded coal ash impoundments in North Carolina carrying coal ash into nearby waterways[71, 72].

The risk of a coal ash spill is higher when the ash is stored in the floodplain. The majority of Indiana's coal ash has been disposed of on utility properties, and those properties are adjacent to sources of cooling water, either one of Indiana's major rivers or Lake Michigan. That means Indiana's coal ash impoundments and landfills are next to the Kankakee, Wabash, White, Whitewater, or Ohio Rivers or Lake Michigan (see figure 8). In fact, all but four of them—in other words, 76% of them—are in the hundred-year floodplain (Table 4). Along with impoundments and landfills, many of the utilities also disposed of large quantities of coal ash on their properties as fill material, so that coal ash resides in the floodplain, as well.

Figure 8. Indiana's Coal Ash Disposal Sites

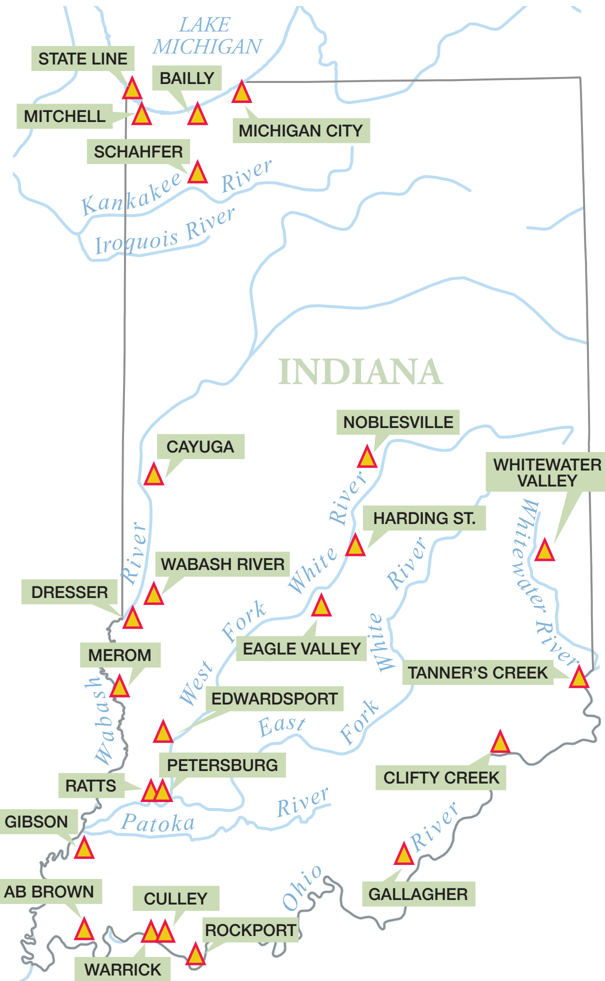


Figure 9 shows satellite photos of coal ash impoundments at Gallagher and Harding Street as examples of disposal in the floodplain. On the floodplain maps, the yellow and blue areas are the 100-year floodplain with the yellow indicating the floodway where flood waters will travel the fastest. The red areas are the estimated 500-year floodplain.

At Gallagher, the coal ash impoundments would all be under water during a 100-year flood. At Harding Street, the coal ash impoundments would be completely surrounded by water during a 100-year flood but the berms around the impoundments are just high enough to be above the floodwater. As a result the Harding Street impoundments appear to be surrounded by the flood and outlined by it on the floodplain map. The coal ash impoundments are at risk during flood events at both sites.

Table 4. Indiana power plants with coal ash disposal in the 100-year floodplain[73]

Bailly	No
Brown	No
Cayuga	Yes
Clifty Creek	Yes
Culley/Warrick	In floodplain, but berms surrounding the ash ponds exceed the height of the estimated 100-year flood
Eagle Valley	Yes
Gallagher	Yes
Gibson	Yes
Harding Street	In floodplain, but berms surrounding the ash ponds exceed the height of the estimated 100-year flood
Merom	No
Michigan City	Yes
Petersburg	Yes
Ratts	Yes
Rockport	Yes
Schahfer	Yes
Wabash River	Yes
Whitewater Valley	No

The risk of future flooding at coal ash sites may be higher than portrayed by the current floodplain maps, since those maps do not take climate change into account. Precipitation in Indiana is increasing and contributing to the risk of flooding. Data gathered by the Purdue Climate Change Research Center show that Indiana's annual average precipitation is 5.6 inches more than it was in 1895 when data were first collected. Current climate projections are that there will be a further 6 – 8 percent increase in annual precipitation in Indiana by 2050 and an increased frequency of extreme precipitation events[74]. The flood maps do not account for the climate projections, so the actual 100-year and 500-year floodplains may be larger than what the maps currently show.

An increased flood risk and larger floodplains mean a greater risk that flooding will inundate coal ash impoundments located near waterways. Even if flood waters do not overtop the berms around an impoundment, flooding can erode and damage the berms, which are made of soil and coal ash, contributing to the risk of a spill.

At many of Indiana's coal ash impoundments the utilities have proposed 'closure-in-place' which means leaving the coal ash in the floodplain and building a cap over it. However, the proposed caps would consist of a sheet of impermeable synthetic material, often referred to as 'geomembrane', covered by 3 feet of soil and planted with vegetation, so they would also be vulnerable to erosion by flood waters. Therefore, coal ash disposal is safer on high ground away from bodies of water.

Disposing of coal ash in the floodplain is also risky because Indiana rivers are susceptible to significant shifts in their courses over time. In 2013 the US Geological Survey published a report on channel migration rates for 38 of the largest streams in Indiana[75] that shows that rivers in west-central and east-central Indiana have had significant channel migration in recent years, particularly the lower Wabash River and lower White River which had among the highest migration rates. The lower Wabash and lower White River are home to coal ash disposal units at six major power plants. Where coal ash is disposed of adjacent to rivers, channel migration could erode into the ash over time causing release of the ash into the river. Figure 10 illustrates channel migration. It is from the cover of the USGS report, and shows migration of the White River near Centerton, IN. The blue arrows point to utility poles.

Figure 9. Coal ash disposal sites and their relationship to the floodplain[76]

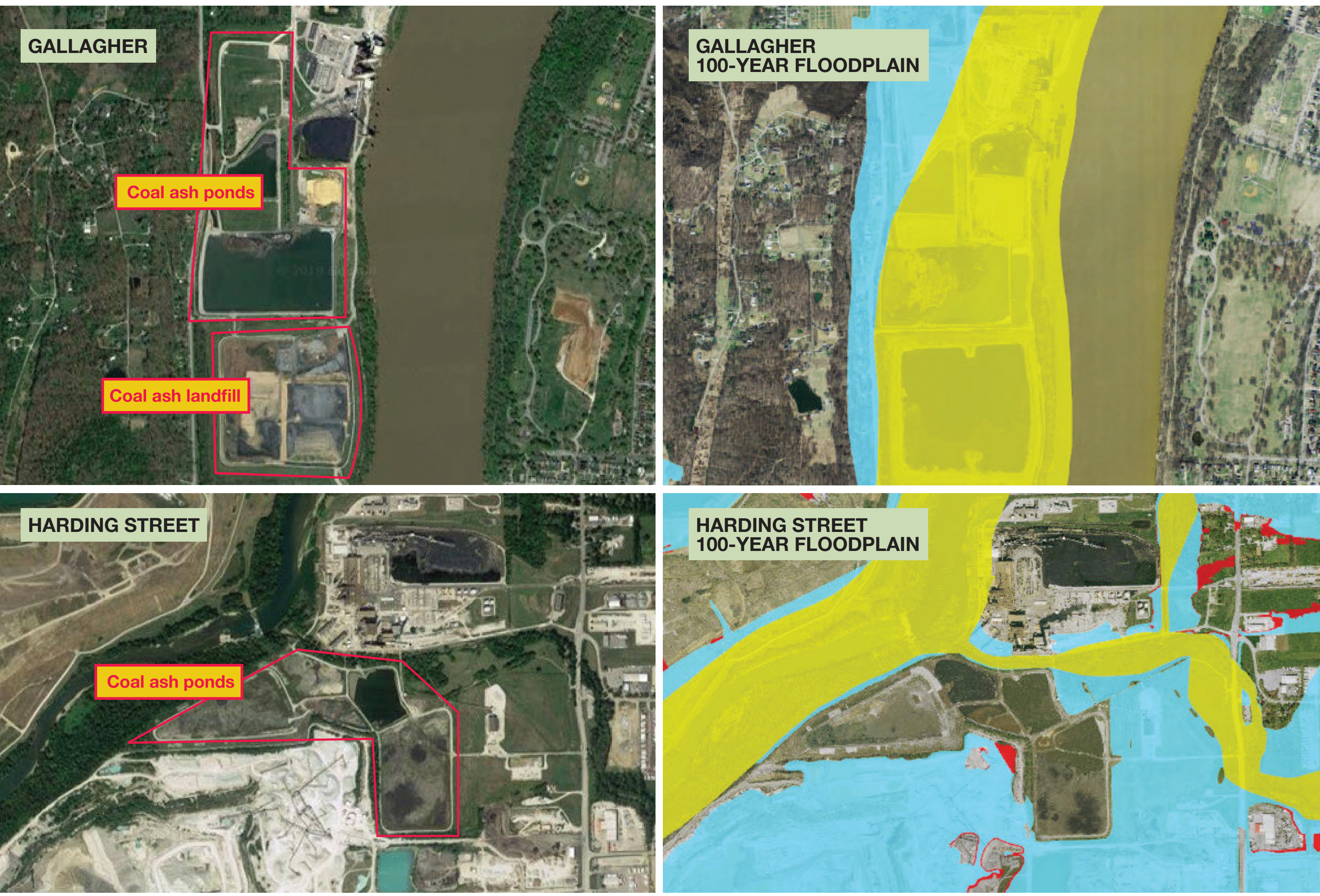


Figure 10. Example of channel migration of an Indiana river.

PERMITTED DISCHARGES

Coal ash can also affect rivers and lakes through permitted discharges. Permits are required under the federal Clean Water Act for any discharge of pollutants into waters of the United States[77]. Indiana's utilities have had permits for discharging a variety of different types of wastewater including the excess water from coal ash impoundments. Since impoundment water has been in contact with coal ash, it contains heavy metals leached from the ash. When that water is discharged into a water body, those heavy metals are released into the receiving river or lake.

Because of new limits on coal ash wastewater in 2015[78], many utilities turned to dry ash handling to reduce their need for discharge permits.

For those still using discharge permits, coal ash wastewater discharges can be millions of gallons per day and carry hundreds or even thousands of pounds of pollutants into waterways. For example, reports from Petersburg that are required under its discharge permit show that they are discharging between 56 and 139 million gallons of ash handling wastewater per month into the White River[79]. For many of these power plant discharges that include excess coal ash impoundment water, the permits do not limit the concentrations of metals being discharged, but only require these amounts to be reported.[80]

SEEPAGE OF CONTAMINATED GROUNDWATER

Along with spills and permitted discharges, there is a third mechanism by which coal ash impacts waterways and that is through seepage of contaminated groundwater. Groundwater is usually flowing underground, rather than sitting still. Water soaks into the ground from rain or snow melt until it meets the water table, which is the point where the ground is saturated with water. It then flows from areas where the water table is higher toward areas where it is lower. At the majority of Indiana's coal ash sites the ultimate destination of the groundwater is the nearby waterbody, either Lake Michigan or one of the rivers.

Figure 11 Groundwater flow at Cayuga ash ponds[81]

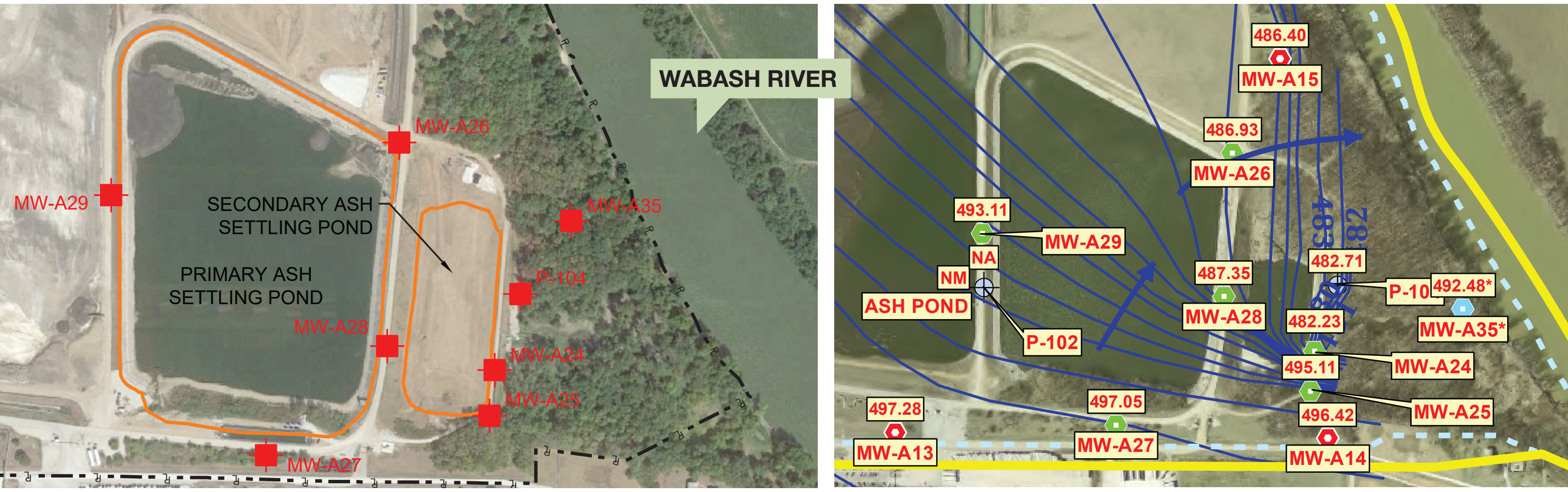


Figure 11 gives an example of groundwater seepage into the Wabash River. The left image is a satellite photo of two coal ash impoundments at the Cayuga Generating Station called Primary Ash Settling Pond and Secondary Ash Settling Pond[82]. Red squares mark the locations of groundwater monitoring wells, which are labeled with letters and numbers, like "MW-A29" to the left of the ponds. The right image shows the same ponds with the groundwater elevations in feet above sea level marked in red numbers next to each well. For example, on the left side of the image well MW-A29 has a groundwater elevation of 493.11 feet above sea level. The right image also has blue lines along which the groundwater is estimated to be at the same level. The groundwater elevation is generally lower on the right side of the image, closer to the Wabash River. The blue arrows indicate the estimated path of groundwater flow from the ash ponds to the Wabash River.

Except for the Tanners Creek site, the groundwater at all of Indiana's coal ash disposal sites is moving toward the adjacent water body. Table 5 lists the disposal sites and the water body that is receiving groundwater from that site.

At Cayuga, the groundwater flow into the Wabash River is visible at multiple seepage points along the river bank and the seepage is measurable. From April 2016 to February 2017, the total flow from 19 seepage points varied between 387.6 and 2142 gallons per minute, which is between 670,000 and 3,080,000 gallons per day, into the river or the canal leading to the river[83]. The concentrations of coal ash contaminants in the seeps include boron as high as 5.5 mg/L, sulfate 292 mg/L, and molybdenum 0.24 mg/L, all clear indicators of coal ash impact.

Table 5. Indiana coal ash sites and the waterbody receiving groundwater from that site

Coal ash disposal site	Water body receiving groundwater
Bailly	Toward Indiana Dunes National Park and from there to Lake Michigan
Brown	Ohio River
Cayuga	Wabash River
Clifty Creek	Ohio River
Culley	Ohio River
Eagle Valley	White River
Gallagher	Ohio River
Gibson	Wabash River
Harding Street	Toward the adjacent quarry which pumps water out to the White River[84]
Merom	Toward Turtle Creek Reservoir which releases groundwater into the Wabash River
Michigan City	Lake Michigan
Petersburg	White River
Ratts	White River
Rockport	Ohio River
Schahfer	Kankakee River
Tanner's Creek	Ohio River (for a portion of the site)
Wabash River	Wabash River
Whitewater Valley	Whitewater River

Groundwater flow has also been measured at the Michigan City Generating Station. While the individual seepage points and volumes were not identified and measured as they were at Cayuga, the Closure Application includes a calculation that the groundwater under the ash ponds is moving toward Lake Michigan at 230 feet per year[85]. This means that, on average, any particular portion of groundwater will move 230 feet during a year, indicating a continuous flow of the groundwater into the Lake. The authors are not aware of measurements of the quantity of groundwater seepage at any other coal ash sites in Indiana.

The movement of the groundwater at coal ash sites is movement of contaminated groundwater at most sites, so it is carrying coal ash contaminants into the rivers or Lake Michigan.

The impact of coal ash contaminated groundwater flowing into Indiana's rivers and Lake Michigan has not been adequately studied. It could be getting into the food chain or affecting the health of aquatic species. The seepage has gone on for decades, so it could be creating areas of contaminated sediments in the river or lake beds. Such sediment contamination has been documented at the Dominion Chesapeake Energy Center in Virginia where coal ash contaminated groundwater seeping into the adjacent river contaminated river-bottom sediment with arsenic up to 8.2 mg/Kg and the porewater[86] in the sediment with arsenic up to 0.452 mg/L[87]. Similarly, seepage of coal ash groundwater at the Michigan City Generating Station raised the pore water arsenic in Lake Michigan sediments as high as 0.018 mg/L and in Trail Creek, which flows into Lake Michigan, as high as 0.03 mg/L[88]. Organisms living in and feeding from the sediments form the base of many aquatic food chains. Some coal ash contaminants are known to be passed along the food chain or even to accumulate to higher concentrations in higher order predators, such as fish, which may be consumed by humans.

Mercury is likely to be present in coal ash contaminated groundwater at levels that could lead to mercury accumulation in fish. While mercury was detected only rarely in the groundwater samples at Indiana's coal ash sites, it may be there at concentrations below the limits of detection. An EPA study of leaching from coal ash showed mercury concentrations from nondetectable at <0.01 ug/L up to 0.66 ug/L (or 660 ng/L)[89]. The Electric Power Research Institute (EPRI) measured mercury concentrations in leachates collected from 29 coal ash disposal sites. The EPRI study found 0.25 to 61 ng/L of mercury in ash leachate samples with a median of 3.8 ng/L and 0.82 to 79 ng/L in flue gas desulfurization (FGD) leachate samples with a median of 8.3 ng/L. EPRI reported that none of the samples were below their detection limit[90]. Given these data from EPA and EPRI, we expect mercury to be present in the groundwater at Indiana's coal ash sites.

Mercury would be detected at Indiana's coal ash sites, if sensitive enough analytical methods were used. Most of Indiana's coal ash groundwater monitoring reports listed limits of detection for mercury of 0.0002 mg/L, which is the same as 0.2 micrograms per liter (ug/L) or 200 nanograms per liter(ng/L).

Concentrations lower than 200 ng/L are relevant. The Indiana surface water quality standard for aquatic life for mercury is 12 ng/L[91]. The human health water quality criterion for mercury from the Ohio River Valley Water Sanitation Commission (ORSANCO) is also 12 ng/L[92]. According to the EPRI study, coal ash contaminated groundwater frequently has more than 12 ng/L of mercury. Coal ash contaminated groundwater in Indiana is seeping into rivers and Lake Michigan and may have mercury exceeding the water quality standards.

The water quality standards for mercury are set at very low concentrations because once mercury is released into aquatic environments, it undergoes bioaccumulation and biomagnification. It is first converted by microbes into methylmercury which then accumulates up the food chain[93] in a process known as biomagnification. Through biomagnification, fish at the top of the food chain can have methylmercury levels in their muscle more than one million times higher than it is in the water. The primary source of mercury exposure for humans is through the consumption of fish. Both fresh water and ocean dwelling fish can accumulate methylmercury[94].

Methylmercury is toxic to the nervous system. The adult lethal dose in humans is as little as 200 milligrams[95]. At the quantities that a person could be exposed to by frequently eating certain fish, studies have shown measurable decreases in dexterity, peripheral vision, visual sensitivity, and coordination in adults[96]. Children exposed to methylmercury from fish during their mothers' pregnancies have lower scores on motor, verbal and attention tests at ages 7 and 14 years[97,98].

COAL ASH PLACED IN MINES

Minefilling, the disposal of coal ash in surface coal mines, is another form of coal ash management that poses risks to groundwater and surface water. In 2018, according to the latest data available, 15.4 million tons of coal ash were used in mining applications in the U.S.[99] In Indiana, this practice has been underway since the late 1980's although its utilization has declined substantially since then.[100]

In 1988, the Indiana General Assembly passed a law to exempt coal ash disposal at surface coal mines from regulation under the state's solid waste rules, which are administered by IDEM.[101] After several unsuccessful efforts by the Indiana DNR to adopt rules for this practice, DNR instead adopted policy guidance to govern coal ash disposal in surface mines under the authority of the U.S. Surface Mine Control and Reclamation Act (SMCRA). The DNR implements this law in Indiana.[102]

As a result, coal mining companies and electric utilities actively sought DNR approval to dump coal ash in surface mines as an added option to disposal in surface impoundments and landfills. Of the 16 approved permits as of 2005, disposal occurred at 9 permitted sites which since declined to just a few sites. From 1989 to 2005, over seven million tons of ash material was deposited in nine surface mines in Indiana.

Coal ash disposal in surface mines poses similar risks to groundwater as do unlined impoundments and landfills. When excavation of a surface mine encounters the water table, which is common, the excavated mine pit has to be dewatered during mining. Once mining ceases, the groundwater will recharge the mine pit and saturate any coal ash placed there. After the groundwater inflow stabilizes, any contaminants leached from coal ash can migrate over time through the groundwater system and pose a risk to any wells in the area surrounding the coal mine. A study at one Indiana mine, the Universal Ash Site owned by Duke Energy predecessor Cinergy, compared contaminant concentrations found in monitoring wells to expected concentrations from laboratory leachate tests. The study found that actual boron concentrations were higher than the levels predicted by the tests and exceeded the EPA's health advisory level by a factor of 27. Moreover, actual concentrations of several other metals exceeded drinking water or other standards, including for arsenic, lead, and molybdenum.[103]

In response to the concerns about the environmental impact of minefilling, in 2006 the National Research Council, part of the National Academy of Sciences, issued a report on this topic. The Council recommended that "...enforceable federal standards be established for the disposal of CCRs in minefills."[104] As a result, in 2007 the U.S. Office of Surface Mining Reclamation and Enforcement proposed the first-ever federal regulation for minefilling.[105] The OSMRE never finalized its minefill rule.[106] This has left minefilling oversight to the states.

The 2015 federal CCR Rule does not regulate minefills and exempted actions that meet the definition of "beneficial use" of coal ash from its provisions.[107] EPA is currently considering rule amendments that would revise the definition of beneficial use,[108] which may affect minefill practices. Electric utilities and coal mining companies argue that coal ash disposal in surface mines is a "beneficial use" since it may stabilize coal mine pits and help to reduce the acidity of waters affected by mine runoff. The State of Indiana agrees, and has adopted a nonrule policy document for "Beneficial Utilization of Coal Combustion Waste at Surface Coal Mines."[109]

At least one Indiana power plant is still utilizing minefilling for its coal ash. IPL's Petersburg Generating Station in Pike County sends some of the coal ash it produces to a nearby surface mine.[110]

Protecting Water Resources from Coal Ash

GROUNDWATER CLEANUP METHODS

After groundwater has been contaminated, there are several methods for cleaning up the contamination, but cleanup is expensive, difficult, and takes years or even decades to accomplish. Groundwater cleanup methods generally fall into three categories: 1) bringing the water to the surface and putting it through a purification process, so-called 'pump and treat'; 2) placing materials in the ground that change the form of the contaminants or immobilize them, also referred to as 'in situ technologies'; and 3) waiting for natural processes to dilute or breakdown the contaminants, which is referred to as Monitored Natural Attenuation[111, 112].

The cleanup method appropriate for a given site depends on many factors including the nature of the contaminants, the depth and lateral extent of the contaminant plume, the characteristics of the local soil, and the dimensions and porosity of the involved aquifer. The design of the cleanup system will also depend on how clean the groundwater needs to be when the cleanup is done. The CCR Rule requires sites with groundwater contaminated by coal ash to select a groundwater remedy that will

(1) Be protective of human health and the environment
(2) Attain the groundwater protection standard as specified pursuant to § 257.95(h)[113]

The groundwater protection standard for each contaminant is either the Maximum Contaminant Level (MCL) allowed in drinking water under the US Safe Drinking Water Act or levels specified in the CCR Rule for contaminants that do not have an MCL. If a contaminant is present in the background samples of the local groundwater at levels that are higher than the MCL or specified level, then the background level becomes the groundwater protection standard for that contaminant. For example, if the local geology causes high levels of arsenic in groundwater, that would be detected in background samples and set as the 'groundwater protection standard', and the utility would not be held responsible for cleaning up arsenic that was there naturally.

When groundwater cannot be cleaned up or it is deemed too expensive to clean it up, steps can be taken to try to hold it in place and prevent movement of the contamination. The most common form of containment is a subsurface barrier called a slurry wall[114].

Indiana's coal ash sites have been assessing groundwater cleanup options, but as of this writing none has selected the cleanup method it will use. Before a utility may select a specific cleanup remedy, it must hold a public meeting to allow the affected community and others to comment on the potential cleanup remedies.[115]

To reduce or eliminate the need for groundwater cleanup at leaking impoundments, the environmentally preferred solution is complete excavation of the coal ash and moving it to a lined, modern landfill outside of the floodplain.

DISPOSAL METHODS THAT PREVENT WATER CONTAMINATION

Preventing water contamination is less difficult and less expensive than trying to clean it up. With coal ash, the key to preventing water contamination is keeping the ash from coming in contact with water. As described above, coal ash can contact water when water is used to sluice coal ash into an impoundment, when rain or snow melt soak into an ash disposal site, when flood water inundates a disposal site, or when there is a structural break in the disposal site which spills ash into a waterway.

There is one other way coal ash can be in contact with water that is less obvious - groundwater infiltration. If coal ash is disposed of below the ground surface without a liner, then any time the water table is high enough, groundwater will infiltrate into the ash. At 9 Indiana sites the deepest portions of the ash are below the water table continuously, so the ash is always saturated. Prior to initiating closure, portions of the ash at Bailly, Brown, Eagle Valley, Cayuga, Gallagher, Gibson, Wabash, Tanners Creek and Culley were sitting in the groundwater because the bottom of the ash was below the water table[116]. Most of Indiana's coal ash disposal sites have relatively shallow water tables, so ash may only have to be 10 or 20 feet deep to be below the water table.

The depth of the water table is not constant. The water table rises and falls depending on weather conditions and water levels in adjacent bodies of water. Most of Indiana's coal ash sites are adjacent to bodies of water that communicate with the groundwater, so the water table rises and falls depending on the height of the water in the adjacent water body. For example, measurements of the water table near Ash Pond B at the Wabash River

Generating Station were 447 - 450 feet above sea level during dry conditions but reached 470 feet when the Wabash River was high[117]. The bottom of the coal ash in Wabash River's Ash Pond B is at 450 feet[118] and there is no liner under the ash, so when the river is high, groundwater is infiltrating the ash.

By taking into account all the ways water can get into coal ash, it is possible to design the optimal method of disposal for protecting water resources. The disposal site would be located on high ground, well out of the floodplain, with an impermeable liner under the ash and leachate collection system to protect the groundwater and an impermeable cover over it to prevent rain and snow melt from getting to the ash. Well engineered landfills that meet the requirements of the CCR Rule have all of these features[119].

COAL ASH CLOSURE IN INDIANA

As Indiana's utilities close their coal ash impoundments, they are making decisions about the final disposal of the ash in those impoundments. To date, 11 closure plans have been filed with IDEM for coal ash sites in Indiana. The majority propose leaving the coal ash in place and building an impermeable cap over it. This will prevent rain and snow melt from running down into the ash, but will not prevent groundwater infiltration or the effects of flooding. All of these closure plans will leave water resources at risk, except Noblesville.

At Noblesville, Duke Energy is consolidating coal ash that was left in large piles and coal ash that was used as fill. Once consolidated, they are capping the coal ash in place[120]. Since the disposal site is not in the floodplain and the bottom of the ash is well above the water table, this closure method should keep the coal ash dry and protect the local water resources.

NIPSCO's Michigan City site has the only closure plan in Indiana to date that proposes removal of the ash from unlined impoundments in the floodplain and disposal at a lined landfill on high ground. Unfortunately, the plan is somewhat marred by the fact that much of the coal ash at Michigan City is not in the ash ponds. Coal ash was used extensively as fill material on NIPSCO's Michigan City property from the 1930's to the 1970's, and there are no plans, yet, to excavate the fill ash[121].

Table 6. Proposed closure of Indiana coal ash impoundments.

Site	Closure Plan[122]	Floodplain	Ash in Groundwater before closure
Bailly	Excavation	no	yes
Brown	Excavation	no	yes
Cayuga	Cap in place	yes	yes
Clifty Creek	Cap in place	yes	no
Culley	Cap in place	yes	yes
Eagle Valley	Cap in place	yes	yes
Harding Street	Cap in place	yes	likely during high water
Gallagher	Cap in place	yes	yes
Gibson	Cap in place	yes	yes
Michigan City	Excavation	yes	no[123]
Noblesville	Cap in place	no	no[124]
Tanner's Creek	Cap in place	yes	yes
Wabash River	Cap in place	yes	yes

There are preliminary plans for excavation at two other Indiana coal ash sites, Bailly and A.B. Brown, but full closure plans have not been filed with IDEM, as of this writing. NIPSCO has posted brief 'conceptual closure plans' for excavation of Primary Settling Pond 1[125], Primary 2[126] , Secondary Settling Pond #1[127] , and Boiler Slag Pond[128] at Bailly.

Vectren has petitioned the Indiana Utility Regulatory Commission regarding recovering costs associated with excavating its coal ash ponds at the A.B. Brown power plant, selling as much of the ash as possible for reuse and placing the remaining 1.25 million tons in its on-site landfill[129]. The Vectren testimony in the case included a description of how groundwater would continue entering the ash if it were capped in place. Vectren calculated that excavation and landfilling would be less expensive than capping in place. If they proposed capping the ash in place, IDEM might not permit it given the ongoing contact with groundwater. They also argued that cap-in-place would continue the groundwater contamination and that could lead to a requirement to excavate the ash in the future. Altogether Vectren argued that cap-in-place would have put them at risk for higher total costs. At Brown, the company's economic reasoning led to a plan that will better protect the water resources.

While the closure plans are for impoundments that have been in recent use, they do not address out-of-service ash impoundments from prior decades. For example, at Gallagher the present-day landfill was built on top of a former coal ash pond containing more than 3,000,000 cubic yards of ash up to 32 feet deep[130]. The bottom 5 to 14 feet of that former ash pond is below the water table, so the ash at that depth is saturated with groundwater[131]. Similarly, at Clifty Creek the landfill was built in 1988 on top of the ash impoundment that had collected the prior 33 years of coal ash[132]. The former ash impoundment is not addressed in the Clifty Creek closure plan[133].

There are at least three other sites where old, out of service ponds are contaminating groundwater but are not subject to clean up plans. These include a former pond under the on-site Tanners Creek coal ash landfill,[134] the original ash pond at Duke's Cayuga Generating Station,[135] and an old pond at NIPSCO's Michigan City power plant.[136] Combined, historic coal ash impoundments considered "legacy" ponds under the CCR rule or other out-of-service ponds represent about 10% of Indiana's total number of coal ash ponds.

WATER-PROTECTIVE ASH DISPOSAL IN OTHER STATES

In a number of states, significant steps are being taken to protect water resources. Coal ash is being removed from unlined impoundments in the floodplain and taken to dry, lined landfills on high ground. It is being removed from sites where it is contaminating groundwater. In Tennessee, excavation of 12 million cubic yards of ash was required at the Gallatin coal plant on the Cumberland River because the unlined impoundments were found to be in violation of the Clean Water Act[137]. All unlined impoundments in North Carolina are now required to excavate the ash to lined landfills as the result of litigation, state agency determinations, and state legislation[138,139,140]. The most recent determination by the North Carolina Department of Environmental Quality requires excavation of more than 76 million tons of ash from unlined impoundments at six facilities[141]. Santee Cooper, one of South Carolina's largest electric utilities, is excavating or planning to excavate all of its unlined coal ash ponds, a total of more than 12 million tons. They are sending the ash for recycling for the cement/drywall industry or water-protective disposal[142]. In Florida coal ash excavation is underway at the former Scholz power plant to stop contaminated seepage into the Apalachicola River[143].

The Tennessee Valley Authority, which has many decades of heavy investment in coal-fired electricity, recently determined that excavation is the preferred option for the coal ash at the Allen plant in Memphis because it would mean lower environmental impact and improvements in local economic development[144]. The excavation will remove 3.5 million cubic yards of coal ash from unlined impoundments that were threatening local drinking water supplies[145].

A number of these excavations involve massive amounts of coal ash, but despite that hurdle, they are getting done. Table 7 lists some examples of coal ash impoundments undergoing excavation and those that have already been completed.

At the Grainger coal plant site, arsenic concentrations have declined 90% from what they were before excavation. At the Wateree coal plant site, arsenic is down 80% because of coal ash excavation[146].

These examples clearly demonstrate that disposing of coal ash in a manner that protects water resources is achievable. They are removing coal ash from unlined impoundments in the floodplain and from leaking impoundments that are contaminating groundwater and rivers and recycling it or placing it in dry, lined landfills.

Table 7. Coal ash impoundments in other states undergoing excavation

Site	State	Quantity of ash (tons)[147]	Cleanup method	Timeline
Dominion Energy[148]	Virginia	30,000,000	excavation	in process
Dominion Energy Wateree Station[149]	South Carolina	3,500,000	excavation	completed Dec 2019
Santee Cooper, all sites[150]	South Carolina	12,000,000	excavation	in process
Duke Dan River[151]	North Carolina	3,990,000	excavation	completed May 2019
Duke Riverbend[152]	North Carolina	5,350,000	excavation	completed March 2019
Duke Cliffside[153]	North Carolina	460,000	excavation	completed March 2017
Duke Cliffside[154]	North Carolina	7,590,000	excavation	by 2029
TVA Gallatin[155]	Tennessee	14,400,000	excavation	in process
TVA Allen[156]	Tennessee	4,200,000	excavation	in process
Santee Cooper Grainger[157]	South Carolina	1,749,623	excavation	completed May 2020
Georgia Power - 19 ash ponds[158]	Georgia		excavation	ongoing

Not only is water-protective coal ash disposal being achieved, but some utilities are doing it without an impact to ratepayers. Santee Cooper and SCE&G in South Carolina have said that their excavations won't affect electricity rates[159]. TVA worked the cost of its Gallatin coal ash cleanup into its current financial plan to avoid creating 'any sort of pressure on rate increases,' according to CEO Jeff Lyash[160,161]. By contrast, Alabama Power has announced a 3% increase in rates when they are not excavating their ash, but just capping it in place[162].

Some states have passed laws regulating coal ash disposal beyond the requirements of the federal CCR Rule. Preceding the adoption of the federal Rule, North Carolina passed a law in 2014 following the Dan River coal ash spill that prohibits coal ash disposal in impoundments and requires the ash in most existing impoundments be moved to lined disposal. The North Carolina law also required testing private wells near coal ash disposal sites and providing an alternate water source for any that were contaminated[163]. In March of 2019, Virginia enacted a new law requiring removal of coal ash from unlined ponds adjacent to major waterways, which means excavation of more than 27 million cubic yards[164, 165]. Puerto Rico passed a law requiring removal of a massive coal ash pile created by energy company AES and prohibiting future unencapsulated collections of coal ash[166]. Michigan passed a law in 2018 creating a state permitting program for coal ash disposal that requires closure of impoundments within six months if they are found to be contaminating groundwater[167]. Illinois passed a law in 2019 requiring utilities to analyze disposal options when closing coal ash impoundments and engage the public in the decision[168].

INDIANA STANDS IN STARK CONTRAST

Compared to Virginia, South Carolina, North Carolina, Georgia, Tennessee, Michigan, Illinois, and Puerto Rico, Indiana's approach to coal ash stands in stark contrast. Indiana has 13 sites with unlined coal ash impoundments in the floodplain of major rivers or Lake Michigan, all of which have contaminated the underlying groundwater. To date, only one of those sites has filed a plan to excavate the ash and recycle it or take it to a lined landfill on high ground. For the millions of cubic yards of ash at the other sites, the utilities are planning to leave the ash in place and build a cap over it. This will allow continued groundwater infiltration into the ash, continued groundwater contamination, and continued risk during flood events.

Of 9 Indiana coal ash sites with the ash sitting directly in the groundwater, IDEM has only required 1 to remove the ash from groundwater; 2 have stated their intention to excavate the ash; and 6 have plans to cap the ash in place that IDEM is still reviewing and requiring changes.

Most utilities in Indiana have strenuously resisted excavating coal ash. For Duke Energy, with 4 leaking, floodplain disposal sites in Indiana, this is particularly ironic given the many millions of tons it is excavating in the Carolinas. Duke even brags on its website that "Nearly 28 million tons of ash have been excavated since basin closure began in recent years, with more than 5 million tons moved in 2019 alone."[169], while refusing to even consider excavation at its Indiana sites.

By contrast, tens of millions of tons of coal ash are being removed from leaking impoundments in the floodplains of rivers in the Carolinas, Virginia, Georgia, and Tennessee stopping the groundwater contamination and protecting the rivers.

Recommendations for Protecting Indiana's Water Resources from Coal Ash

1. **Stop contaminating groundwater and remove coal ash from the floodplain.** Any coal ash that continues to be produced should either be used in encapsulated beneficial uses, like cement or asphalt, or disposed of in well-engineered, lined landfills on high ground (out of the floodplain). For the many coal ash impoundments that are currently impacting groundwater in Indiana, they should be closed in a manner that permanently prevents water from contacting the ash. That means impoundments that are in the floodplain or that have ash close to or in the groundwater need to be excavated and the ash taken to a lined landfill on high ground.

2. **Stop using coal ash as fill material.** Use of coal ash as structural fill in construction projects, or highways, allows coal ash to continue to come into contact with water.

3. **Clean up the contaminated groundwater**. Most of Indiana's utilities are in the process of selecting a remedy for their coal ash contaminated groundwater, as required by the federal rule.

4. **The Indiana Utility Regulatory Commission should compel utilities to fully disclose the financial risks of keeping coal ash in place** in the event of a catastrophe, or when cleanup of contamination is required.

5. **Stop burning coal.** The ultimate solution to the problem of coal ash is to move away from using coal. Coal fueled much of our economy during the twentieth century, but it is time to move on. New coal plants are more expensive than utility-scale renewables plus utility-scale storage[170] and coal causes environmental harm when it is mined, when it is burned, and when the coal ash is disposed of. The shift away from coal is already taking place and appears to be accelerating. Between 2010 and 2019, 546 coal-fired power generating units in the U.S. were retired[171]. In Indiana, 90% of electricity came from coal in 2010, but only 59% in 2019[172]. In 2018, one of Indiana's major utilities, NIPSCO, announced plans to phase out the use of all fossil fuels, and move to producing electricity entirely from renewable sources[173]. Production of electricity using wind and solar is growing rapidly. In April 2019, for the first time in the U.S., more electricity was generated using renewable sources than using coal[174].

Appendix A. Percent of downgradient groundwater samples exceeding the health-based limit

	Bailly	Brown	Cayuga	Clifty Creek	Culley	Eagle Valley	Gallagher	Gibson	Harding Street	Michigan City	Petersburg	Rockport	Schahfer	Wabash River	Whitewater Valley
Antimony			11		3	6			8						
Arsenic	11.9	8			22	42	15	27	54	94		58	10	5	
Boron		54	22	52	80		66	38	58	17	71		32	36	59
Cobalt			11		25		22	8			7		7		
Lead					7			5							
Lithium	7.1	17	67	100	38	41	15	18	71	6.5	14		2	4	85
Molybdenum	9.5	17	17	75	47	59	47	23	58	2	50		3	15	59
Radium					3.3		1.2	1.5						1.3	
Selenium	7.1									8					
Sulfate		62	22		43		23	29		3	79		37	16	85
Thalium	20									33					

Appendix B. Groundwater monitoring reports included in the groundwater analysis in this paper.

Golder Associates Inc.(Jan 31, 2020). *2019 Annual Groundwater Monitoring and Corrective Action Report Boiler Slag Pond, NIPSCO LLC Bailly Generating Station.*

Golder Associates Inc.(Jan 31, 2020). *2019 Annual Groundwater Monitoring and Corrective Action Report Primary 1 and Primary 2, NIPSCO LLC Bailly Generating Station.*

Golder Associates Inc.(Jan 31, 2020). *2019 Annual Groundwater Monitoring and Corrective Action Report Secondary 1, NIPSCO LLC Bailly Generating Station.*

Haley & Aldrich, Inc.(Jan 2020). *Annual Groundwater Monitoring and Corrective Action Report, Ash Pond, A.B. Brown Generating Station.*

ATC Group Services, LLC (Dec 30, 2019). *CCR Annual Groundwater Monitoring and Corrective Action Report, Ash Pond System, Cayuga Generating Station.*

Applied Geology and Environmental Science, Inc.(Jan, 2020). *Coal Combustion Residuals Regulation 2019 Groundwater Monitoring and Corrective Action Report, Indiana-Kentucky Electric Corporation, Clifty Creek Station.*

Haley & Aldrich, Inc.(Jan 2020). *Annual Groundwater Monitoring and Corrective Action Report, East Ash Pond, F.B. Culley Generating Station.*

Haley & Aldrich, Inc.(Aug 2019). *2019 Annual Groundwater Monitoring and Corrective Action Report, F.B.Culley Generating Station, West Ash Pond.*

ATC Group Services, LLC (Jan 30, 2020). *2019 CCR Annual Groundwater Monitoring and Corrective Action Report, Indianapolis Power & Light Company, Eagle Valley Generating Station.*

ATC Group Services, LLC (Jan 22, 2020). *CCR Annual Groundwater Monitoring and Corrective Action Report, Ash Pond A, Gallagher Generating Station.*

ATC Group Services, LLC (Jan 24, 2020). *CCR Annual Groundwater Monitoring and Corrective Action Report, Secondary Settling Pond, Gallagher Generating Station.*

ATC Group Services, LLC (Jan 22, 2020). *CCR Annual Groundwater Monitoring and Corrective Action Report, Primary Ash Pond, Gallagher Generating Station.*

ATC Group Services, LLC (Jan 20, 2020). *CCR Annual Groundwater Monitoring and Corrective Action Report, North Ash Basin System, Gibson Generating Station.*

ATC Group Services, LLC (Jan 24, 2020). *CCR Annual Groundwater Monitoring and Corrective Action Report, South Settling Basin System, SW Program ID 26-UP-12, Gibson Generating Station.*

ATC Group Services, LLC (Jan 24, 2020). *CCR Annual Groundwater Monitoring and Corrective Action Report, East Ash Pond Settling Basin, Gibson Generating Station.*

ATC Group Services, LLC (Jan 30, 2020). *2019 CCR Annual Groundwater Monitoring and Corrective Action Report, Indianapolis Power & Light Company, Harding Street Generating Station.*

Golder Associates Inc.(Jan 31, 2020). *2019 Annual Groundwater Monitoring and Corrective Action Report Boiler Slag Pond, NIPSCO LLC Michigan City Generating Station.*

Golder Associates Inc.(Aug 1, 2019). *2018-2019 Annual Groundwater Monitoring and Corrective Action Report, Primary 2, NIPSCO Michigan City Generating Station.*

ATC Group Services, LLC (Jan 30, 2020, revised 9/17/20). *2019 CCR Annual Groundwater Monitoring and Corrective Action Report, Indianapolis Power & Light Company, Petersburg Generating Station, Ash Pond System.*

American Electric Power Service Corporation (Jan 31, 2020). *Annual Groundwater Monitoring Report, Indiana Michigan Power Company, Rockport Plant, Bottom Ash Pond CCR Management Units.*

Golder Associates Inc.(Jan 31, 2020). *2019 Annual Groundwater Monitoring and Corrective Action Report Material Storage Runoff Basin, Metal Cleaning Waste Basin, and Drying Area, NIPSCO LLC R.M. Schahfer Generating Station.*

Golder Associates Inc.(Jan, 2020). *2019 Annual Groundwater Monitoring and Corrective Action Report, Waste Disposal Area, NIPSCO LLC R.M. Schahfer Generating Station.*

ATC Group Services, LLC (Jan 20, 2020). *CCR Annual Groundwater Monitoring and Corrective Action Report, Ash Pond System, Wabash River Generating Station.*

Gai Consultants, Inc.(Aug, 2019). *Annual Groundwater Monitoring and Corrective Action Report, Richmond Power and Light, Whitewater Valley Station Impoundment.*

Endnotes

1 An impoundment is a pit or area surrounded by berms for holding a mixture of coal ash and water. The largest coal ash impoundments cover more than 100 acres and hold coal ash up to 50 feet deep.

2 U.S. Energy Information Administration. *Annual Environmental Information, Schedule 8. Part A. Annual Byproduct Disposition, 2018 Final.* https://www.eia.gov/electricity/data/eia923/

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4 329 IAC 10

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18 Prior to initiating closure, portions of the ash at Bailly, Brown, Eagle Valley, Cayuga, Gallagher, Gibson, Wabash, Tanners Creek and Culley were sitting in the groundwater. See note 115 for references.

19 ATC Group Services, LLC (Jan 2020). *CCR Annual Groundwater Monitoring and Corrective Action Report, North Ash Basin System, Gibson Generating Station*.

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24 U.S. EPA (Nov 2017). *Regional Screening Level Resident Tapwater Table*

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27 American Electric Power. *Assessment Monitoring Program Notice 05-15-2018.*

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