arsenic rose from generally being below the detection level of 0.005 mg/L between 1985 and 1990, to consistently measuring over the federal MCL of 0.01 mg/L from 2000 to 2009. In Well MP-13B, arsenic levels rose to nearly 0.02 mg/L in 1986, shortly after CCW disposal began, but then dropped below detection levels from 1993 to 1999. Then, in 2000, the arsenic concentration began rising again and peaked at over 0.02 mg/L in 2008 (See Figure 1). Similarly, arsenic in Well MP-22, was consistently below detection limits before 1998 and then rose to between 0.03 and 0.04 mg/L in 2008 (See Figure 2). Well MP-22 also had the highest boron levels on-site at over 1.8 mg/L. When asked for the actual laboratory results of groundwater monitoring at the site, staff at the North Dakota Department of Health could only provide rounded values from sampling events furnished by Basin Electric Power Cooperative in trend graphs, examples of which are provided in Figures 1 and 2 below.

Figure 1. Arsenic and selenium at MP-13B.

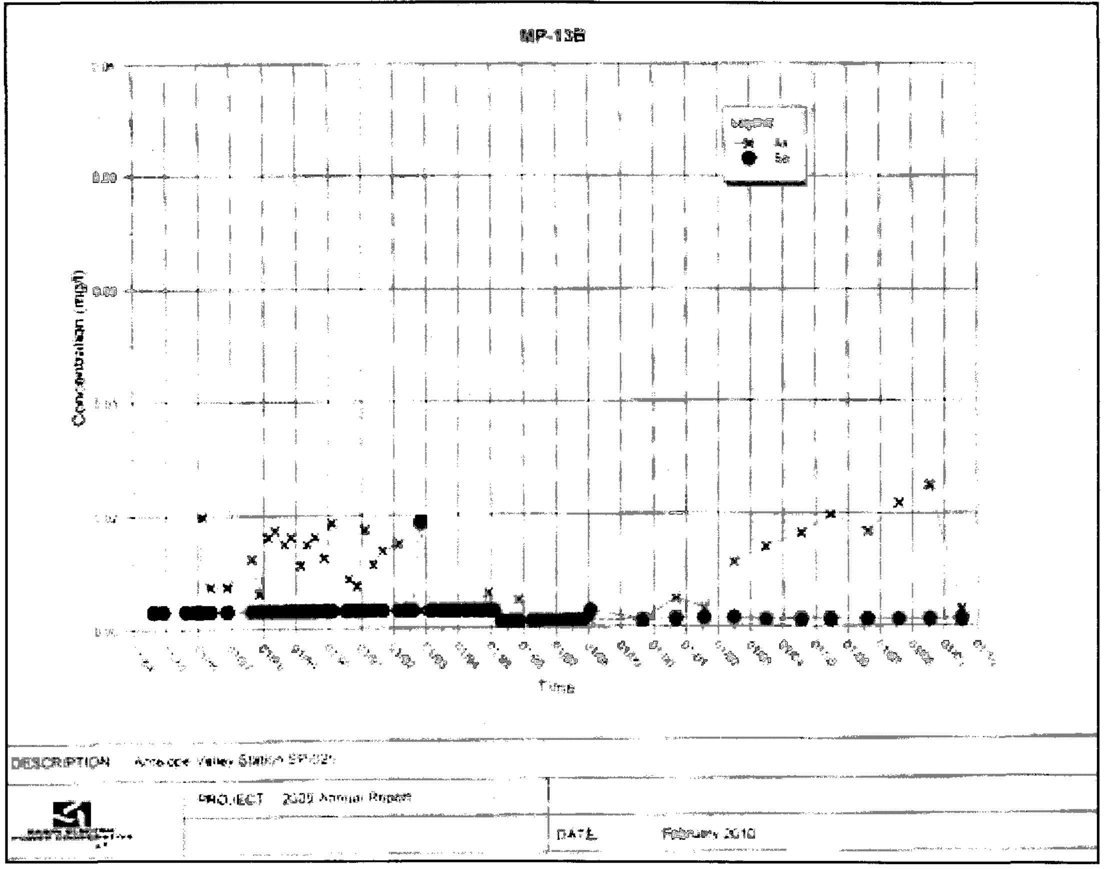
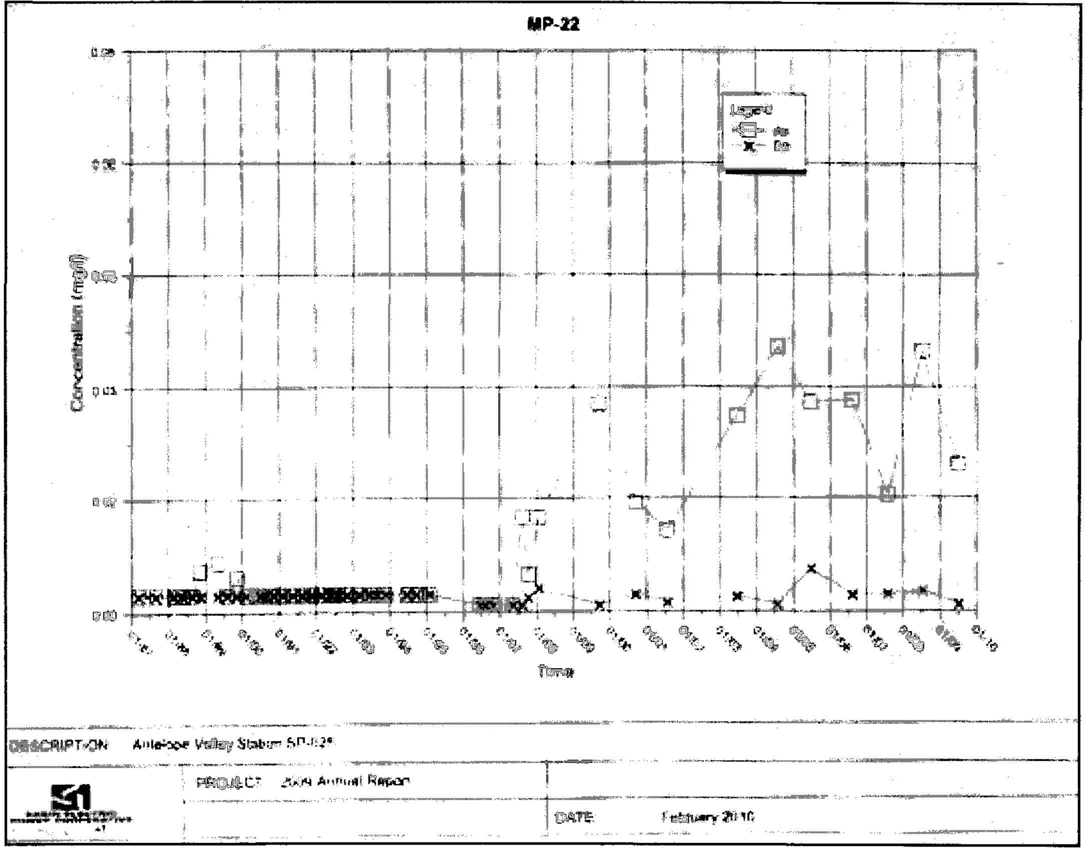


Figure 2. Arsenic and selenium at MP-22.



Arsenic

According to North Dakota State Water Commission, no private drinking water wells exist within a two-mile radius of the Antelope Valley Station. However, the area surrounding the station is primarily agricultural, and there are privately-owned wells that are all used for irrigation. There are two public water supplies located within a five-mile radius of the plant. The first public well is approximately 2.2 miles northeast of the station, and it serves as both an irrigation and drinking water source for roughly four farms in the area. The second public well is located 4.4 miles southeast of the site, serving a collection of farm houses. Data can be found on North Dakota State Water Commission's Groundwater Data Query on a county-by-county basis.

Arsenic levels were first measured in on-site groundwater above the federal MCL in 1986.

None

Fly ash, bottom ash, flue gas desulfurization wastes (FGD), and inert construction wastes

The CCW disposal unit is a closed landfill (Solid Waste Permit #SP-02) lined with clay. The CCW landfill was constructed on property that contains a reclaimed coal mine.

The CCW disposal site has been inactive since 1998 and was previously in operation since at least 1984. It will be in the post-closure monitoring phase through 2015. The Antelope Valley Station also maintains an active coal ash landfill and two ponds used for settling solids out of coal ash sluice water that were not examined in this report.

The major geological feature in the area is the Beulah Trench, a former glacial diversion channel. An aquifer of regional significance, the Antelope Valley Aquifer, is located throughout the length of the Beulah Trench. The trench and aquifer runs adjacent to the site to the west and north of the CCW landfill, and directly below the power plant itself. The Beulah-Zap bed, a lignite formation that is used as a source of groundwater for drinking and livestock, runs beneath the landfill site. The bed slopes down to the west toward the Beulah Trench. Groundwater flow generally follows the bed from the site to the Beulah Trench (BEPC, 1981). Well MP-22 is drilled into the aquifer flowing directly beneath the landfill, the Beulah-Zap bed. The Beulah-Zap bed slopes down into the Beulah Trench, which is the formation that MP-12A and MP-13B are drilled into. Well 22 is screened in the Beulah-Zap Bed while wells 12A and 13B are screened in the Beulah Trench sediments (BEPC, 2009).

Groundwater quality at the site is influenced by reclaimed coal mines. The increasing arsenic trends in the three wells indicate that the arsenic is linked to the coal ash disposal. The correlation in MP-22 of the highest arsenic and boron levels at the site also indicate that coal ash is the source of increasing arsenic levels.

BEPC. 2009. Basin Electric Power Cooperative, 2009 Annual Report for Solid Waste Permit SP-025.

BEPC. 1981. Basin Electric Power Cooperative (BEPC), Antelope Valley Station Solid Waste Disposal, Permit Application for Permit #SP-025.

Entity/Company – Location

Basin Electric Power Cooperative - Leland Olds Station
3901 Hwy. 200A
Stanton, ND 58571
Mercer County
Latitude: 47.280028 Longitude: -101.315817

Determination

Demonstrated damage to on-site groundwater

Probable Cause(s)

Leaching of coal combustion waste (CCW) contaminants from CCW ponds into groundwater

Summary

The Basin Electric Power Cooperative's Leland Olds Station has three active coal ash disposal ponds (Pond 1, Pond 2, and Pond 3) and two decommissioned coal ash ponds that have been closed and capped (Pond 4 and 5). None of the coal ash ponds are lined with synthetic materials, but clay liners have been used under all of the ponds (Holzwarth, 2009). Groundwater monitoring data indicates the decommissioned ash ponds contaminated underlying groundwater with arsenic, lead, boron and selenium. In downgradient monitoring wells, arsenic was measured at 0.0789 mg/L, 7.9 times the federal Maximum Contaminant Level (MCL), in 2009, and lead was measured at 0.0716 mg/L (4.8 times the MCL) in 2006. Boron and selenium have also been found at elevated levels in Leland Olds Station's on-site groundwater monitoring wells.

Leland Olds Station disposes of CCW in on-site ponds east of the power plant pursuant to permit SP-038. Pond 1 was first commissioned in 1966, Pond 2 and 3 in 1975, and Pond 4 in 1985. Pond 5 was designated as a special waste disposal site also containing fly ash. Up until 1990, both fly ash and bottom ash were disposed of in the on-site ponds. Pond 4 and Pond 5 were reclaimed between 1992 and 1996. In the process, fly ash was moved from Ponds 1 and 2 into Ponds 4 and 5. Both Ponds 4 and 5 were decommissioned and capped in 1996. Since 1992, all bottom ash is now sluiced to the active ash ponds (1, 2, and 3), and fly ash disposal was moved off-site to the mine spoils of the Glenharold Mine under permit SP-143. The oldest groundwater monitoring data available for review was found in trend graphs of sampling dating to 1991. From 1982 to 1996, Leland Olds Station sampled 11 groundwater monitoring wells, three surface water locations, and CCW leachate from Pond 2 on a quarterly basis. As of 1997, the frequency of sampling was reduced to once per year (BEPC, 2004).

- **Arsenic** exceedances were found in three monitoring wells in 2009: 22-ADB (0.0269 mg/L) about 150 feet downgradient from Pond 5, 22-ABC (highest exceedance at 0.0789 mg/L) about 100 feet downgradient from Pond 2, 3, and 4, and 22-DAA3 (0.0259 mg/L) about 150 feet downgradient from Pond 5. Well 22-ABC has an increasing trend of arsenic concentration between 1982 and 2009. While the plant acknowledges arsenic being present in well 22-ABC, they do not explicitly admit that it is the result of CCW contamination; however, the data indicates that CCW is the source of the arsenic.
- **Boron** exceedances above an unspecified state groundwater standard occurred in five downgradient monitoring wells in 2009: 22-ABC, 22-ABC2, 22-ABC3, 22-BAC1, and 22-BAC2. The highest exceedance was observed in well 22-ABC3 at 2.1 mg/L (BEPC, 2009). Wells ABC, ABC2, and ABC3 all reside in the same area as well 22-ABC. Wells 22-BAC1 and 2 are downgradient from Pond 1.
- **Lead** was measured in 2006 in well 22-DCC at 0.0716 mg/L, 4.7 times higher than the MCL (BEPC, 2009). This well's location was not delineated on a map.
- **Selenium** was detected in 2004 in all downgradient wells, but not above the MCL of 0.05 mg/L. The highest level of selenium, 0.0244 mg/L was in well 22-DCC. In 2009, selenium was detected again in well 22-DCC and two other downgradient monitoring wells, 22-ABC2 and 22-ABC3 (BEPC, 2009).

SMCL exceedances were also commonplace throughout most groundwater monitoring wells. Increasing trends in sulfates and total dissolved solids are evident in downgradient wells 22-ADB and 22-DAA3 where arsenic concentrations exceeded the MCL in 2009. Well 22-DAA3 also had the highest iron concentrations reaching up to 25.3 mg/L (more than 84 times the SMCL) in 2009 (BEPC, 2009).

No data was available in the files reviewed for the sole "upgradient" well, 22-CDB located adjacent to Pond 4.

Arsenic, boron, iron, lead, selenium, sulfates, and total dissolved solids

Three municipal drinking water wells lie within 5 miles of Leland Olds Station. In addition, individuals who catch and consume the fish or extract irrigation water from the Missouri River could potentially be at risk, as selenium and lead are bioaccumulative in both aquatic organisms and vegetation, including farm produce. Data was obtained from North Dakota's Well and Groundwater Database, which arranges all known and state-registered water wells by county and well use. Data records may be missing or incomplete.

[illegible] and Date Damage Occurred / Identified

An exceedance of the arsenic MCL was first measured in monitoring well 22-ABC in 1985.

Regulatory Action

No state enforcement actions have been taken.

Waste Types

Bottom ash, fly ash (including economizer ash, air heater ash, and hopper ash), water treatment wastes, coal slack from runoff pond, boiler blowdown, washdown wastes from conveyor system, and coal slack (a fine gradient waste material from bituminous coal) from a runoff pond

[illegible]

Leland Olds Station holds two permits (SP-038 and SP-143) with the North Dakota Department of Health – Division of Waste Management. SP-038 applies to the CCW disposal on-site to the east of the plant in Ponds 1, 2 and 3. These ponds were designed to receive 2.7 million cubic yards of CCW, with a total permit area of 364.6 acres. Basin Electric Power Cooperative told EPA in 2009 that its coal ash ponds were "not lined with engineered clay or synthetic materials" and that "documentation regarding the design and construction" of the ponds was "unavailable" due to the age of the ponds (Holzwarth, 2009). Permit SP-143 is for off-site disposal of fly ash in the mine spoils of the Glenharold Mine.

[illegible]

Active and inactive. Ponds 1, 2, and 3 are active, while Ponds 4 and 5 are inactive (fly ash is no longer disposed of in Pond 4 and 5. The ponds were capped with two feet of clay cover and two feet of top cover material in 1996.

[illegible]

The Leland Olds Station is located on lower terraces of the Missouri River, on its flood plain. The Missouri River flows in a southeasterly direction and is within 250 feet of Pond 3 and decommissioned Pond 5. These terraces consist of mostly silts and clays, which make up the Missouri River alluvium. The Missouri Aquifer underlies the terraces and flood plains of the Missouri River Valley in the area of the Leland Olds Station pond complex. According to the plant's potentiometric maps, the groundwater exhibits both a northeasterly flow from the plant to the Missouri River, as well as flow going southeast from the CCW disposal site towards the Missouri River. The rate of movement is estimated at 0.9 feet per year (Torgerson, 2010).

Underneath the coal ash ponds, the uppermost clay layer ranges between 0 to 26 feet, with an average of 8 feet in thickness, and it is generally dry. Underneath the clay is a layer composed of silt and sand that contains the groundwater of the Missouri River Aquifer with thickness varying between 2 to 25 feet and averaging 8 to 9 feet thick (BEPC, 2004). In the area of the plant, the Missouri Aquifer is two miles wide (BIE Inc, 1991).

The water within the Missouri Aquifer contains moderate amounts of dissolved mineral constituents, mostly sodium and bicarbonate. In 1973, background total dissolved solids concentrations ranged between 585 to 1660 mg/L. Alderin Creek, an intermittent stream that drains the disposal sites, discharges into the Missouri River and recharges the Missouri Aquifer. The impact of the disposal sites on the creek could not be assessed as water quality data for the creek were not available.

Basin Electric Power Cooperative (BEPC). 2009. Leland Olds Station: Annual Reports for Solid Waste Permits #SP-038 and #SP-143. Bismark, ND.

BEPC. 2004. Leland Olds Station: Annual Report for Solid Waste Permit #SP-038. Bismark, ND.

Braun Intertec Environmental, Inc (BIE Inc.). 1991. A Report to Basin Electric Power Cooperative: Work Plan for Hydrogeologic and Geotechnical Studies. Stanton, North Dakota. Report Number CFEX-91-032L.

Holzwarth. 2009. Letter from Robert Holzwarth, VP Plant Operations, Basin Electric Cooperative to Richard Kinch, EPA, from Basin Electric Power Cooperative, Re: Request for Information Under Section 104(e) of CERCLA (Mar. 25, 2009), *available at* http://www.epa.gov/waste/nonhaz/industrial/special/fossil/surveys/basin-leland.pdf.

Tillotson. 2010. E-mail correspondence from Steve, J. Tillotson, Assistant Director, Division of Waste Management, North Dakota Department of Health. (June 30, 2010).

Torgerson. 2010. Phone conversation and e-mail correspondence with Brad J. Torgerson, Environmental Scientist, Division of Waste Management, North Dakota Department of Health (July 20, 2010).

Entity/Company – Location

Nebraska Public Power District - Sheldon Station Coal Ash Pit #3
4500 West Pella Road
Hallam, NE 68368
Lancaster County
Latitude: 40.552055   Longitude: -96.783233

Determination

Demonstrated damage to groundwater moving off-site (at property boundary)

Probable Cause(s)

Leaching of coal combustion waste (CCW) contaminants into groundwater

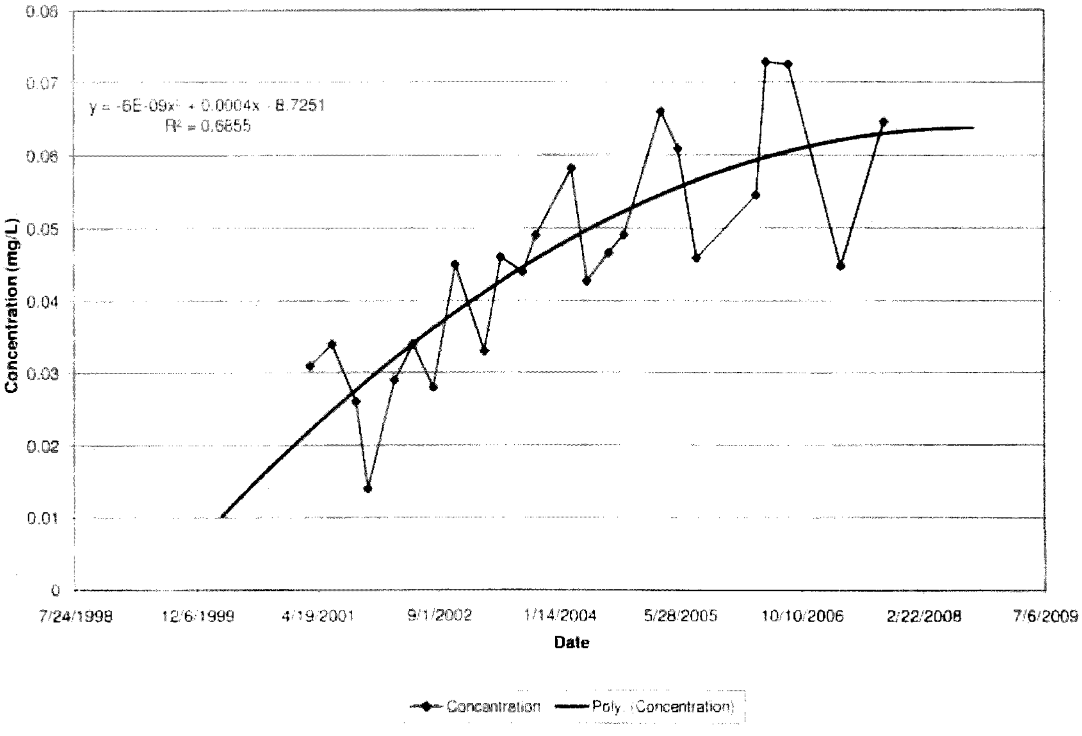
Summary

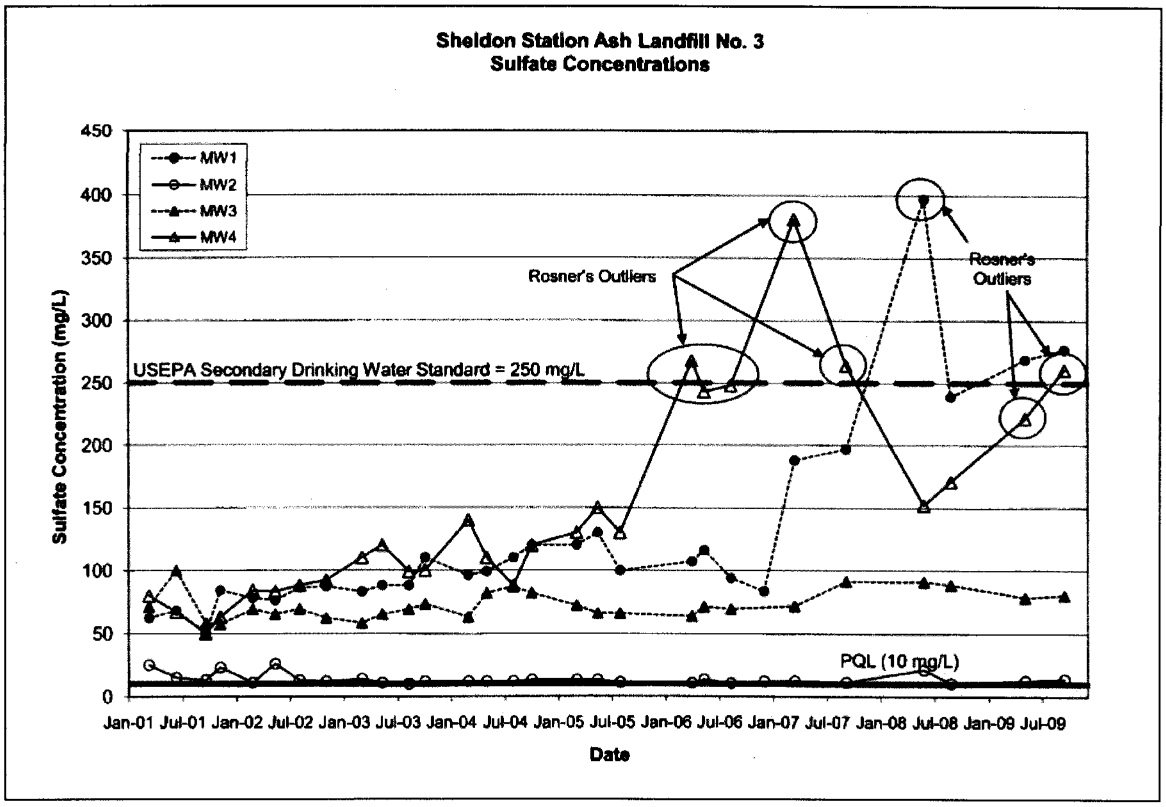
Shallow groundwater downgradient of a closed, clay-lined coal ash landfill at the Sheldon Station in Southeast Nebraska has become contaminated with selenium federal Maximum Contaminant Levels (MCLs) and sulfate exceeding federal Secondary Maximum Contaminant Levels (SMCLs). From 2002 onward, the two downgradient monitoring wells for Ash Pit #3 have detected steadily rising levels of selenium (up to 0.073 mg/L) and sulfate (over 350 mg/L). The full extent of the contamination is unknown because these are the only two downgradient wells for the coal ash landfill. In response to the evidence of contamination, the Nebraska Department of Environmental Quality (NDEQ) has extended the post closure ground water monitoring period by 5 years and requested that additional ground water monitoring wells be installed.

Both downgradient monitoring wells have shown increases over time of typical CCW contaminants, such as selenium in MW-3 and sulfates in MW-4 (NPPD, 2009a). In MW-3, selenium concentrations have followed a steadily increasing trend from 2002 to 2009 (See Figure 1). Selenium concentrations in MW-3 have increased from concentrations as low as 0.014 mg/L in 2001 to as high as 0.0728 mg/L in 2006 exceeding the MCL of 0.050 mg/L. Sulfate levels in MW-4 have steadily increased over time, rising from 50 mg/L in 2001 to a high of 381 mg/L in 2007, surpassing the Secondary MCL (SMCL) of 250 mg/L (See Figure 2). Water quality in "upgradient" well MW-1 also appears to be heavily influenced with both chloride and sulfate levels showing steadily increasing patterns in the wells. The Nebraska Public Power District (NPPD) blames this increase on cooling water discharge to a wetlands area upgradient of the well (NPPD, 2009b). However, the closeness of MW-1 to the edge of the landfill where elevated groundwater levels as are result of mounding are likely, means that localized flow of groundwater toward the well from the landfill is a more likely source of the chloride and sulfate. Selenium concentrations in groundwater in the area typically do not exceed 0.01 mg/L, and sulfate levels do not typically exceed 100 mg/L (NDEQ, 2009). Despite the increases of selenium and sulfate in MW-3 and MW-4 located at the northern property line approximately 400 feet beyond the CCW landfill, no off-site monitoring has been conducted to date.

NPPD has argued that the selenium levels detected in MW3 must be from naturally occurring sources since the selenium levels detected in laboratory coal ash leachate tests were an order of magnitude lower than those found in MW3. However, samples from wells drilled in the saturated ash in the CCW landfill found selenium levels ranging from 0.113 to 0.19 mg/L (NPPD, 1999). The pore water wells (wells screened within the CCW itself rather than the underlying aquifer) also had the highest sulfate results of any of the test wells sampled in 1999. These pore water results verify that the coal ash is the probable source of the rising selenium and sulfate in downgradient wells, MW-3 and MW-4.

Figure 1:
Concentration of Selenium in Well AP-3 MW-3





Selenium and sulfate

One irrigation well is located downgradient of the CCW landfill within one mile of the Sheldon Station Ash Pit #3 (NPPD, 1999). Nebraska's GW Well Data Retrieval site also indicated one downgradient irrigation well.

Selenium levels in MW-3 first exceeded the federal MCL of 0.05 mg/L in 2004. Sulfate levels in MW-4 first exceeded the federal SMCL of 250 mg/L in 2006.

In 2009, the Nebraska Department of Environmental Quality (NDEQ) extended the post closure groundwater monitoring period by 5 years due to evidence of contamination (NDEQ, 2009) and requested that additional groundwater monitoring wells be installed to determine the extent and rate of contamination in the plume moving north. NPPD has agreed to install two additional groundwater monitoring wells (NPPD, 2009b).

Fly ash and bottom ash

Ash Pit #3 is a clay-lined landfill with a total capacity of 350,000 cubic yards.

Inactive. In 1999, NPPD stopped placing CCW in Coal Ash Pit #3 after 9 years of disposal at the site (NPPD, 1999). The coal ash pit is currently in the post-closure groundwater monitoring phase. In addition to Coal Ash Pit #3 the plant maintains an active ash landfill, Coal Ash Pit #4. Monitoring data for Coal Ash Pit #4 was not reviewed for this report.

Coal Ash Pit #3 sits in glacial drift hills in the Salt Creek drainage basin which flows to the Platte River. The upper 100 to 150 feet of the glacial till sediments are designated as a glacial till aquifer and are comprised of a mixture of sand, silt, and clay. Perched water has been encountered on the plant property at depths of 8 to 24 below ground surface in the till. The upper portions of the glacial till aquifer are directly beneath the base of the landfill (NPPD, 1999) with the distance from the base of the ash to the ground water table being less than 25 ft. throughout most of the landfill area. The regional aquifer ranges from 100 to 150 feet below the ground surface at the site comprising deeper depths of the glacial till aquifer.

The Nebraska Public Power District's (NPPD) Sheldon Station is located in southeast Nebraska and has a capacity of 229 MW.

Nebraska Department of Environmental Quality (NDEQ). 2009. Review of Ash Pit #3 Post-Closure Groundwater Monitoring Report.

Nebraska Public Power District (NPPD). 2009a. Third Quarter 2009 Ground Water Monitoring Results.

NPPD. 2009b. Request to Terminate Post Closure Monitoring.

NPPD. 1999. Hydrogeological Characterization and Appendices.

Entity/Company – Location

AES - Cayuga Coal Ash Disposal Landfill
228 Cayuga Drive
Lansing, NY 14882
Tompkins County
Latitude: 42.601778 Longitude: 76.634639

Determination

Demonstrated damage to groundwater on-site and a former private residential well (now owned by AES)

Probable Cause(s)

Contaminated leachate and runoff from a coal combustion waste (CCW) landfill discharged directly from a pond into Cayuga Lake and contaminated groundwater from a partially unlined CCW landfill.

Summary

Groundwater monitoring data shows that the partially-lined coal ash landfill at the Cayuga Plant has contaminated underlying groundwater with selenium up to 1.5 times the federal Maximum Contaminant Level (MCL) and 7.6 times the New York State Groundwater Standard (NYGWS); cadmium up to 8 times the MCL; and arsenic at up to 10 times the MCL and NYGWS. Manganese, aluminum, sulfate, and total dissolved solids also exceed federal Secondary MCLs (SMCLs) at the majority of AES Cayuga's downgradient wells, and also at some of the wells labeled "upgradient." Data from AES also shows that discharges to Cayuga Lake from the CCW leachate pond, which collects leachate from the CCW landfill grossly exceed federal water quality criteria for selenium (up to 55 times higher than the chronic toxicity standard for aquatic life), arsenic (up to 4,778 times higher than the standard for protection of human health from surface water ingestion and fish consumption), and cadmium (up to 26 times higher than the acute toxicity standard for aquatic life). Yet the State Pollutant Discharge Elimination System (SPDES) permit that regulates this discharge has no limits for many of these parameters, nor is the New York Department of Environmental Protection monitoring surface water in Cayuga Lake near this discharge. AES Cayuga purchased a former residential well, located downgradient, southwest of the landfill, and evidence of CCW metals can be seen in this well.

Test of Proof

The Cayuga Ash Disposal Landfill consists of two sections, a pre-1984 section (Phase I), which is now closed, and the active section (Phase II), which is currently receiving CCW. Phase I is unlined, but a series of pipes were installed below the Phase I landfill to collect CCW leachate. Phase II has a composite liner of soil and a synthetic liner with leachate collection and leak detection systems.

CCW Leachate Collection System

AES Cayuga collects CCW leachate and surface water runoff from the CCW landfill in a pond, and once the pond fills to capacity, AES drains the pond directly into Cayuga Lake. For example, AES's CCW leachate pond discharged over 3.8 million gallons into Cayuga Lake in March 2008, and its "batch discharges" of CCW leachate and landfill runoff totaled over 19 million gallons in 2008 (AMEC, 2009). The CCW Leachate Pond discharge via Outfall 013 is monitored according to SPDES permit NY-000-1333. Samples of CCW Leachate show that the CCW Leachate, prior to discharge from the CCW leachate pond contains levels of aluminum, arsenic, boron, cadmium, manganese, selenium, sulfate, and TDS that exceed federal and/or State groundwater standards. However, in the chart below, concentrations of these constituents are compared to EPA National Recommended Water Quality Criteria, since CCW leachate is discharged to Cayuga Lake.

For brevity, only selenium, cadmium, arsenic, and boron concentrations are provided from CCW Leachate Quarterly Monitoring Reports below for 2007 to 2008. The CCW leachate samples taken at AES Cayuga routinely exceeded federal and/or State standards over a longer period of time, and for more pollutants than summarized here.

AES Cayuga – CCW Leachate Collection System

Year	# Exceedances	EPA Health Standards & Water Quality Criteria (mg/L)	Quarter / Well / Maximum	Value (mg/L)
2008	14	Selenium Chronic (0.005)	May 2008, MAPXUDXX05:	**0.273**
2007	12	Selenium Chronic (0.005)	May 2007, MAPXUDXX05:	**0.231**
2008	8	Cadmium Acute (0,002)	Nov. 2008, MAPXUDXX01:	**0.0357**
2007	9	Cadmium Acute (0,002)	Nov. 2007, MAPXUDXX01:	**0.0520**
2008	10	Arsenic Human Health (0.000018)	Aug. 2008, MAPXUDXX04:	**0.049**
2007	11	Arsenic Human Health (0.000018)	Nov. 2007, MAPXUDXX04:	**0.086**
2008	14	Boron Lifetime Health Advisory Level (6)	Nov. 2008, MAPXUDXX05:	**67.4**
2007	15	Boron Lifetime Health Advisory Level (6)	Aug. 2007, MAPXUDXX04:	**75.1**

NOTE: MAPXUDXX01 collects CCW leachate from the original 1977 ash disposal site and 1978 expansion; MAPXUDXX02 collects CCW leachate from the 1979 and 1982 expansions; MAPXUDXX04 collects CCW leachate from the 1990 expansion; and MAPXUDXX05 collects CCW leachate from the 1984 and 1986 expansions.

Groundwater Suppression System

The groundwater suppression system at AES Cayuga's CCW landfill is comprised of a series of pipes installed underneath several portions of the landfill prior to CCW disposal. Samples from this water system are taken from an area where the pipes enter a manhole. This water also drains to the CCW leachate pond before it drains to Cayuga Lake. As noted above, the discharge via Outfall 013 is monitored according to SPDES permit NY-000-1333. According to AES' monitoring reports, water sampled prior to discharge from the groundwater suppression system often contains levels of aluminum, arsenic, boron, cadmium, manganese, sulfate, total dissolved solids, and selenium above federal and/or State groundwater standards (AMEC 2008, 2009). In the table below, EPA National Recommended Water Quality Criteria are compared to pollutant concentrations in the groundwater suppression system as this water is discharged to Cayuga Lake via the CCW leachate pond (Gruppe, 2010).

For brevity, only exceedances of selected pollutants from Groundwater Suppression System Quarterly Reports over a two-year period are summarized below. A greater number of pollutants over a greater period of time have been present in the groundwater suppression water exceeding federal and/or State water protection standards.

AES Cayuga – Coal Ash Disposal Site Groundwater Suppression System

Year	# Exceedances	EPA Health Standards & Water Quality Criteria (mg/L)	Quarter / Well / Maximum Value (mg/L)
2008	7	Selenium Chronic (0.005)	Aug. 2008, MAGXGDXX06: **0.088**
2007	9	Selenium Chronic (0.005)	Aug. 2007, MAGXGDXX07: **0.122**
2008	4	Cadmium Acute (0.002)	Aug. 2008, MAGXGDXX04: **0.017**
2007	4	Cadmium Acute (0.002)	Nov. 2007, MAGXGDXX04: **0.024**
2008	15	Arsenic Human Health (0.000018)	Feb. 2008, MAGXGDXX06: **0.024**
2007	15	Arsenic Human Health (0.000018)	Feb. 2007, MAGXGDXX07: **0.019**
2008	10	Boron Lifetime Health Advisory Level (6)	Aug. 2008, MAGXGDXX09: **9.3**
2007	14	Boron Lifetime Health Advisory Level (6)	Aug. 2007, MAGXGDXX09: **14.3**

NOTE: MAGXGDXX04 drains the area beneath the 1979 landfill extension; MAGXGDXX06 drains the area west of the 1979 extension, along the main haul road; MAGXGDXX07 drains the area beneath the 1984 extension and northern edge of the 1982 extension; MAGXGDXX09 drains the area beneath the 1986 extension.

Groundwater Monitoring Wells

AES Cayuga maintains a network of 35 groundwater monitoring wells at various depths and locations around its CCW landfill. Despite the general groundwater flow towards Cayuga Lake, there are several wells labeled "upgradient" that appear to be influenced by the CCW landfill. Available information suggests that at least five wells designated as upgradient have been contaminated by arsenic and, to a lesser extent, selenium, from the CCW landfill. The lines of evidence supporting this conclusion include:

- The land use upgradient from the landfill is agricultural and unlikely to be contributing arsenic to the monitoring wells. An assessment by USGS of naturally occurring and anthropogenic arsenic in groundwater did not identify any locations in state of New York with naturally high background levels or areas with arsenic in groundwater associated with the use, production, or disposal of arsenical pesticides (Welch et al. 2000).
- Localized groundwater flow in a direction upgradient from the normal flow direction is common in the vicinity of CCW landfills as a result of groundwater mounding within the disposal area. The higher groundwater elevation in the landfill allows contaminants to flow into wells that would normally be upgradient and thus can be contaminated by waste leachate despite their designation as upgradient (see, for example, the Iowa Neal North site in this report).
- The location of these "upgradient" monitoring wells are either adjacent to, or within 150 feet of, the edge of the landfill (most are within 50 feet of the landfill) and likely influenced by groundwater flow direction reversals related to mounding. NY State Regulators have questioned whether some wells, such as MAGUXX-7712, are truly "upgradient" from the landfill (AMEC 2008).
- A review of site maps for the landfill indicates that there are no monitoring wells or piezometers within the landfill that might reflect mounding, so potentiometric maps drawn from existing monitoring wells, which are used to define the direction of groundwater flow, may not be accurate.

In addition to downgradient monitoring wells, the table below shows that five "upgradient" wells have levels of contaminants that exceed federal and/or State groundwater standards for the same contaminants, particularly selenium and arsenic, that are elevated in the CCW leachate and in the water from the groundwater suppression system. Although not included on this chart for the sake of brevity, manganese, aluminum, sulfate, and total dissolved solids also exceed federal SMCLs at the majority of AES Cayuga's downgradient wells, and also at some of the wells labeled "upgradient."

AES Cayuga – Groundwater Monitoring Wells

Sample Date	Parameter / Standard (mg/L)	"Upgradient" Wells (mg/L)	Downgradient Wells (mg/L)
Feb. 2008	Arsenic (0.01)	MAGUXX-8303: 0.0113 MAGUD-8714: 0.0103	MAGDXX-8105: 0.0121 MAGDXX-8106: 0.0102
May 2008	Arsenic (0.01)	MAGUD-8714: 0.0128	MAGDI-8707: 0.0115 MAGDD-9114: 0.0171
Aug. 2008	Arsenic (0.01)	MAGUD-9001: 0.101	MAGDD-8702: 0.0108 MAGDD-8705: 0.0147 MAGDXX-8213: 0.0112
Feb. 2007	Arsenic (0.01)	MAGUXX-7712: 0.010 MAGUXX-8303: 0.012 MAGUD-9001: 0.013 MAGUD-8714: 0.033	MAGDXX-7721: 0.016 MAGDXX-8105: 0.018 MAGDXX-8106: 0.015 MAGDXX-8302: 0.013 MAGDD-8702: 0.012 MAGDI-8703: 0.013 MAGDSH-8707: 0.011 MAGCD-9111: 0.010 MAGDI-8715: 0.010 MAGDI-8705: 0.017
May 2007	Arsenic (0.01)	ND	MAGDXX-7731: 0.010 MAGDSH-8707: 0.013 MAGDD-9114: 0.014
Aug. 2007	Arsenic (0.01)	ND	MAGDI-8716: 0.015
Nov. 2007	Arsenic (0.01)	MAGUD-8714: 0.023	MAGDXX-7721: 0.019 MAGDXX-7731: 0.011 MAGDD-9114: 0.013 MAGDI-8715: 0.010
Feb. 2008	Selenium (0.05) NY Standard (0.01)	ND	MAGDXX-8106: 0.036 MAGDA-8305: 0.0105
May 2008	Selenium (0.05) NY Standard (0.01)	MAGUXX-7712: 0.01 MAGUXX-8303: 0.013 MAGUXX-8304: 0.01 MAGUD-9001: 0.01 MAGUSH-9001: 0.01 MAGUD-8714: 0.01	All downgradient wells in May 2008 were measured at or above the State selenium standard. Notable exceedances include: MAGDXX-8106: 0.076 MAGDXX-8305:0.032 MAGDD-8703: 0.022
Aug. 2008	Selenium (0.05) NY Standard (0.01)	ND	MAGDXX-8106: 0.058
Nov. 2008	Selenium (0.05) NY Standard (0.01)	MAGUD-9001: 0.006 MAGUSH-9001: 0.005	MAGDXX-8106: 0.058 MAGDA-8305: 0.05 MAGDD-8715: 0.013
Feb. 2007	Selenium (0.05) NY Standard (0.01)	MAGUXX-7712: 0.01	MAGDXX-8106: 0.053 MAGDSH-8703: 0.011
May 2007	Selenium (0.05) NY Standard (0.01)	ND	MAGDXX-8106: 0.055 MAGDXX-8301: 0.013 MAGDA-8305: 0.024 MAGDXX-8213: 0.011

Sample Date	Parameter / Standard (mg/L)	"Upgradient" Wells (mg/L)	Downgradient Wells (mg/L)
Aug. 2007	Selenium (0.05) NY Standard (0.01)	ND	MAGDXX-8106: 0.066 MAGDA-8305: 0.021
Nov. 2007	Selenium (0.05) NY Standard (0.01)	ND	MAGDXX-8106: 0.059 MAGDD-8705: 0.010 MADSH-8703: 0.012 MAGDI-8715: 0.01

Constituents Involved

Arsenic, boron, cadmium, selenium, lead, total dissolved solids, aluminum, manganese, sulfate

At Risk Population

There are homes and farms near the AES Ash Disposal Facility, several within 0.03 – 0.1 miles from the coal ash landfill property boundary to the east of AES Cayuga's "upgradient" wells (that contain elevated levels of arsenic and selenium). Many of the homes near the AES site draw water from wells, and nearby homes have drinking water wells drilled 60-125 feet deep.

There are also homes downgradient of the coal ash landfill, south of the AES Cayuga plant, along the banks of Cayuga Lake. Some of these homes may share the drinking water line that AES Cayuga brought in for its Plant employees, and some may draw drinking water from wells. Cayuga Lake is directly downgradient from the CCW landfill. Groundwater flows from under the CCW landfill and leachate pond toward the lake, and the contents of AES's CCW leachate collection pond discharge directly into the lake without treatment. No surface water sampling data from Cayuga Lake is available. As one of the famed "Finger Lakes," Cayuga Lake is a major destination for fishing and other water-related recreation.

AES purchased one residential well downgradient of its CCW landfill, well MAGDWS-XXO1. This former private well has levels of arsenic close to federal MCLs, for example, the federal MCL is 0.010 mg/L and the residential well tested at .0097 mg/L in May 2008. The former residential well also routinely exceeds federal and/or State groundwater standards for iron (3.79 mg/L); lead (0.027 mg/L), manganese (0.103 mg/L), total dissolved solids (687 mg/L), and zinc (11.9 mg/L). For example, in May 2008, the former residential well was at the New York State limit for selenium of 10 µg/L.

Incident and Date Damage Occurred / Identified

Documentation of damage has occurred since the 2000s

Regulatory Action

On February 2, 2009, the Cayuga facility received a Notice of Violation from the New York State Department of Conservation that the facility had exceeded the permitted volume limit of the coal ash that can be disposed of in the landfill (AES 2009). As of February 26, 2010, discussions between the State and AES Cayuga were ongoing (AES 2009, Gruppe 2010).

Despite the facts of the acquisition of a nearby residential well, the contamination of monitoring wells with metals above federal MCLs as well as some state standards, and the discharges from the CCW leachate pond that are concentrated with metals, there is no evidence that the State has undertaken testing of nearby residential wells or has sampled Cayuga Lake for impacts from the CCW leachate pond. It has taken no enforcement action over water pollution at this site or required AES Cayuga to take corrective actions, limit its discharge to Cayuga Lake, or determine the full impacts of its CCW disposal on the nearby community, lake or groundwater quality.

CCW (including fly ash, FGD byproducts, pyrites and other wastes) from AES Cayuga Plant and fly ash from a Cornell University heating plant

Unlined CCW leachate pond that discharges directly to Cayuga Lake; 50-acre CCW landfill that is partially lined

Active

May 2008 water levels in shallow and deep wells in the vicinity of the landfill show up to a 4.6 foot downward hydraulic gradient that facilitates downward migration of contaminants from the landfill to the bedrock aquifer (AMEC Geomatrix, 2009). The CCW landfill sits up on a plateau, near several farms and homes, above the Cayuga Plant and Cayuga Lake. A March 2009 Annual Solid Waste Operating Report for AES Cayuga describes the hydrogeologic conditions of the CCW landfill site:

> The Site is situated on the down-slope portion of a ridge which is bordered on the west by a deep, glacially gouged valley occupied by Cayuga Lake. The ridge is relatively broad and slopes gently to within approximately one mile of Cayuga Lake, at which point the slope steepens dramatically to the lake edge. The natural topography at the Site ranges from 830 feet amsl to 680 feet amsl. The geology at the Site consists of a thick sequence of shale and siltstone bedrock with thin limestone interbeds from Middle to Late Devonian age overlain by a veneer of unconsolidated glacially-derived sediments. The unconsolidated sediments consist of gravel, sand, silt and clay derived from till. Groundwater flows occurs in both overburden and bedrock. Bedrock groundwater movement is controlled by horizontal fractures along bedding place partings, and vertical fractures characterizing the regional bedrock fracture set. The dominant groundwater flow direction in bedrock and glacial overburden is to the west-southwest toward Cayuga Lake. (AMEC 2009, emphasis added).

The AES Cayuga power plant (306 MW) has two coal-fired generating units that were built in 1955. The plant is located on the eastern shore of Cayuga Lake, about 15 miles northwest of Ithaca, New York. In 2008, the Cayuga Plant disposed of 108,330 tons of fly ash, industrial waste, and flue gas desulfurization (FGD) byproducts at its 50-acre landfill located just uphill from the Plant. In addition to its own CCW, AES Cayuga disposes of limited quantities of fly ash from the heating plant at Cornell University.

AES Cayuga. 2009. Annual Report (10-K) (Feb. 26, 2010), *available at*: http://www.aes.com.

AES Cayuga. 2007. AES Cayuga, SPDES Permit Application and Response to Request for Information (Mar. 23, 2007).

AMEC Geomatrix. 2009. AMEC Geomatrix, Inc., Year 2008 Annual Solid Waste Operating Report – AES Cayuga (prepared for AES Cayuga) (Mar. 2009).

AMEC Geomatrix. 2008. AMEC Geomatrix, Inc., Year 2007 Annual Solid Waste Operating Report – AES Cayuga (prepared for AES Cayuga) (Feb. 2008).

Gruppe 2010. Phone conversation with Jim Gruppe of NY DEP regarding groundwater at AES Cayuga site (June 14, 2010).

NYSDEC. 2010. New York State Department of Environmental Conservation (NYSDEC), AES Cayuga SPDES Permit NY 0001333 (effective date: Jan. 1, 2010).

Entity Company – Location

American Electric Power - Cardinal Fly Ash Reservoir (FAR) 1 and 2,
306 County Road 7 East
Brilliant, OH 43913
Jefferson County
Latitude: 40.2462 Longitude: -80.6526

Determination

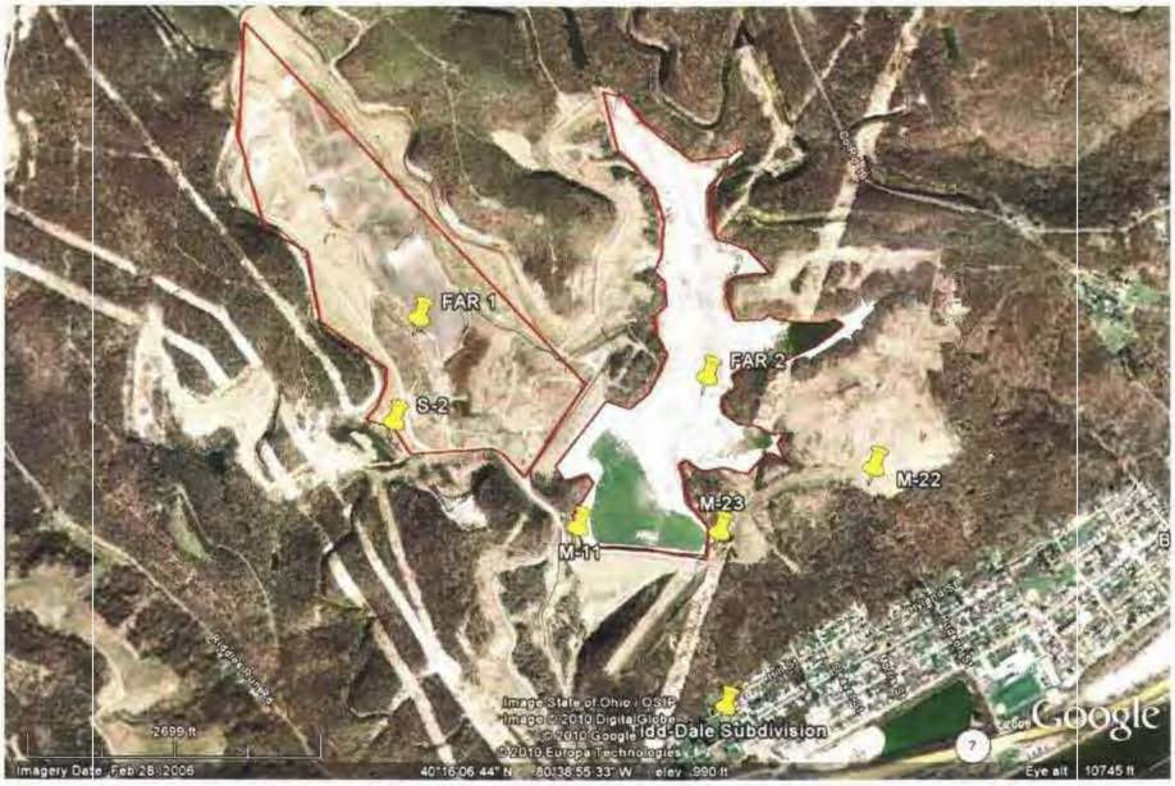
Demonstrated damage to groundwater moving off-site (discharging into Riddles Run and Blockhouse Hollow)

Probable Cause(s)

Migration of contaminants from unlined coal combustion waste (CCW) ponds into groundwater

Summary

A CCW landfill and unlined CCW ponds at the American Electric Power (AEP) Cardinal Plant have contaminated underlying groundwater with heavy metals and boron. The AEP site consists of three disposal areas: a closed unlined coal ash pond (called Fly Ash Reservoir or FAR 1); an active unlined coal ash pond (FAR 2); and a flue gas desulfurization landfill constructed on top of the closed ash pond (FAR 1). Statistical analysis of groundwater monitoring at the site indicates that "fly ash related constituents" have entered the groundwater surrounding the two ash impoundments (OH EPA, 2004). Arsenic up to 0.1 mg/L has been detected in monitoring wells, 10 times the EPA Maximum Contaminant Level (MCL). Molybdenum up to 0.43 mg/L, 10 times the EPA Lifetime Health Advisory Level of 0.04 mg/L, has been detected in downgradient wells. Boron levels, up to 5.57 mg/L, also exceed the EPA Child Health Advisory Level in several wells. Four groundwater monitoring wells have been placed under "assessment monitoring" by the Ohio Environmental Protection Agency (OH EPA) due to evidence of CCW contamination (AEP, 2009; OH EPA, 2010).



[illegible]

AEP's 2004 Ground Water Assessment Report submitted to OH EPA confirmed the presence of coal ash related constituents in the groundwater surrounding the ponds (impoundments), called "Fly Ash Reservoirs" or "FAR 1" and "2" at this site. FAR 1 and 2 are in direct contact with the Shallow and Morgantown Sandstone Aquifer (OH EPA, 2006). Changes in groundwater levels over time indicate that the coal ash water in these impoundments has become a major source of recharge for the Morgantown Sandstone Aquifer (AEP, 2007). AEP itself admits that the continued inundation of the aquifer by water from FAR 2 will at least in the short-term have "a significant influence on groundwater quality from ash pond recharge" (AEP, 2007). Samples from wells drilled into the ash in FAR 1 show that the water in the ash impoundments contains high levels of arsenic (up to 0.466 mg/L), boron (up to 12 mg/L), and molybdenum (up to 1.47 mg/L).

Statistically significant increases were confirmed for a number of constituents in groundwater leaving the impoundments including arsenic (OH EPA, 2004). Arsenic levels in several wells exceed the EPA MCL and were found at concentrations as high as 0.1 mg/L. The well showing the highest arsenic levels (S-2) is designated "upgradient" by the plant's contractors, but this well consistently has thigh levels of boron (1.71-5.57 mg/L) and molybdenum (up to 0.024 mg/L versus non-detected concentrations in most upgradient wells). Both parameters are designated ash indicators for the site in the shallow aquifer (AEP, 2009). OH EPA has determined that mounding has occurred in groundwater around the site based on steadily rising head levels in wells around FAR 1 (OH EPA, 2010), which allows groundwater from the disposal area to flow to well S-2, which may have been upgradient before disposal began, but now is contaminated . Other downgradient wells have shown levels of boron (up to 4.55 mg/L) and molybdenum (up to 0.43 mg/L) above EPA Health Advisory Levels.

OH EPA has required no off-site monitoring around the AEP Cardinal Plant despite the fact that the contaminated Morgantown Aquifer is the source for a number of seeps and springs along the sides of Blockhouse Hollow downstream of the dam of FAR 2 and along Riddles Run (AEP, 2009). Despite these seeps downgradient of the ash impoundments, individual sampling of the seeps has not been conducted (OH EPA 2010). Sampling of one spring near the CCW disposal areas is scheduled to begin later this year (AEP, 2009). However, seeps have also begun to appear in the dam of FAR 2 (OH EPA, 2010), which is ranked as a "high hazard" surface impoundment (USEPA, 2009). Any theoretical discharge from the ash impoundments to these seeps is included in the discharge permit for outfall 019 of Cardinal's NPDES permit (OH EPA, 2010), which discharges into Blockhouse Hollow. Monitoring of this outfall has found high levels of arsenic (up to 0.204 mg/L) and molybdenum (up to 0.284 mg/L) in the discharge although there are no limits for either metal in the NPDES permit. The creek receiving this discharge in Blockhouse Hollow runs directly beside the Tidd-Dale Subdivision but has yet to be sampled (OH EPA, 2010).

[illegible]

Arsenic, boron, and molybdenum

[illegible]

The Tidd-Dale Subdivision, which is approximately 2000 feet from the FAR 2 dam, relies on private drinking water wells. According to the latest potentiometric map of the AEP Cardinal Plant, which indicates the direction of groundwater flow, the Tidd-Dale Subdivision is in the direct path of groundwater flow from FAR 2. At least nine private wells are located in the subdivision. OH EPA has not required any sampling of these wells. (OH EPA, 2010).

Data from Ohio Department of Natural Resources' (DNR) Groundwater Mapping Query yielded a total of 16 private wells within a two mile radius of the AEP Cardinal site. In addition, there are a total of 5 public drinking water sources within a five mile radius of the site, one of which is located east of the Tidd-Dale Subdivision, less than two miles from the FAR 2 dam. Across state lines in West Virginia, well logs were not comprehensive and had no geospatial data attributed to the well log. Although drinking water well data are often organized at the county level within the Department of Health in West Virginia, there were limited data records for Brooke County. According the West Virginia Department of Environmental Protection (WDEP), private wells are the only source of drinking water in rural Brooke County.

Incident and Date Damage Occurred / Identified

AEP reported statistically significant increases of CCW constituents in groundwater monitoring wells to OH EPA as early 1999 and 2000, with exceedances of MCLs and Health Advisory Levels first detected in 1993.

Regulatory Action

Due to the groundwater contamination reported by AEP, OH EPA placed four wells under "assessment monitoring" (AEP, 2009; OH EPA, 2010). Assessment monitoring is required whenever a groundwater monitoring well shows two consecutive statistical increases in contaminant levels. Under assessment monitoring, AEP is required to determine the extent and rate of groundwater contamination. AEP must then develop a plan of action to address the contamination. AEP's 2002 Ground Water Monitoring Assessment Report asserted that the groundwater contamination was due to previous mining and other sources of pollution. However, evidence of groundwater contamination was sufficient for OH EPA to request an expansion of the monitoring program in 2004 to determine the full extent of possible contamination (OH EPA, 2004). In 2009, AEP submitted a second Assessment Monitoring Report to OH EPA based on the results of the expanded groundwater monitoring program, which included wells downgradient of FAR 2. In addition, AEP is scheduled to install four new wells on the southern edge of FAR 2 in 2010 as part of the second "assessment monitoring" plan and will begin monitoring a seep downstream of the dam to determine the possible flow of CCW contaminants.

Waste Stream

Fly ash, bottom ash, and flue gas desulfurization (FGD) wastes

Type(s) of Waste Management Unit

FAR (Fly Ash Reservoirs) 1 and 2 are unlined coal ash impoundments. A landfill with a synthetic liner was constructed on top of FAR 1 for FGD wastes.

[illegible]

FAR 1 has been inactive since 2000, when all disposal of sluiced ash was switched to FAR 2. The FGD landfill (built on top of FAR 1) and FAR 2 are still active.

[illegible]

The AEP facility and CCW disposal sites sit on the edge of bluffs overlooking the Ohio River. An area known as Block House Hollow, which is made up of two stream valleys, was dammed to make the CCW ponds, FAR 1 and 2. Hydrogeological reports conducted at the site identify three aquifers underlying AEP Cardinal's property: the Shallow Aquifer; the Morgantown Sandstone Aquifer: and the Cow Run Sandstone Aquifer (listed in order of increasing depth). Water from the impoundments comes into direct contact with outcroppings of the Shallow Aquifer and Morgantown Sandstone in the former stream valleys (AEP, 2009). The Shallow Aquifer and Morgantown Sandstone are separated by a layer of shale. The Morgantown and Cow Run Sandstone aquifers are separated by a layer of shale, limestone lenses, and siltstone.

The original direction of flow for the Shallow Aquifer and Morgantown Sandstone generally followed the shape of the topography with the aquifers sloping down along the bluffs and into the stream valleys. However, water from FAR 1 and 2 has inundated the Shallow and Morgantown Sandstone Aquifers and significantly altered groundwater flow patterns around the disposal area (AEP, 2007). Head levels in one groundwater monitoring well rose by 80 feet over a 12-year period. The original direction of flow around FAR 1 was to the south-southwest, but this direction has shifted, as evidenced by changes in head levels and concentrations of ash indicator parameters in groundwater monitoring wells. The new direction of groundwater flow has been difficult to determine due to influence from both FAR 1 and 2 (OH EPA, 2006). Concentrations of ash indicators in wells downgradient of FAR 2 indicate flow south toward the FAR 2 dam and to the south-southeast. Seeps have appeared around the FAR 2 dam as the water level in FAR 2 has increased (OH EPA, 2010).

[illegible]

A sad commentary on how lax USEPA has been in investigating potential damage cases, is that both the FGD landfill (called Cardinal PFBC monofill) and FAR 2 (called Cardinal Fly Ash Reservoir II Impoundment) were rejected as damage cases in its damage case assessment report because "The data do not show any exceedances of primary or secondary MCLs" (USEPA, 2007) .

[illegible]

AEP. 2009. American Electric Power, Cardinal Waste Management Units Groundwater Monitoring Program.

AEP. 2007. American Electric Power, Fly Ash Reservoir 1 Groundwater Monitoring Assessment Report.

OH EPA. 2010. Ohio Environmental Protection Agency, Phone conversation with Jane Jacobs, Geohydrologist, OH EPA (June 9, 2010).

OH EPA. 2006. Ohio Environmental Protection Agency, Review of October the 27, 2005 PTI Application (Apr. 10, 2006).

OH EPA. 2004. Ohio Environmental Protection Agency, Review of the July 12, 2004 Ground Water Quality Assessment Report (Dec. 28, 2004).

USEPA. 2009. Fact Sheet: Coal Combustion Residues (CCR) – Surface Impoundments with High Hazard Potential Ratings. EPA530-F-09-006 (updated Aug. 2009), *available at* http://www.epa.gov/osw/nonhaz/industrial/special/fossil/ccrs-fs/index.htm.

USEPA. 2007. U.S. Environmental Protection Agency (USEPA), Coal Combustion Waste Damage Case Assessments, Office of Solid Waste (July 9, 2007).

Entity/Company – Location

American Electric Power d/b/a Ohio Power Company – General James M. Gavin Power Plant
7397 State Rte. 7 North
Cheshire, OH 45620
Gallia County
Latitude: 38.9367 Longitude: -82.1158

Determination

Demonstrated damage to groundwater off-site (in monitoring well beyond the southern property line and surface water & aquatic life in Stingy Run and Kyger Creek).

Probable Cause(s)

Leaking of coal combustion waste (CCW) contaminants from the CCW landfill site into groundwater.

Summary

Groundwater monitoring demonstrates that American Electric Power's (AEP) Gavin CCW landfill and decommissioned fly ash pond have contaminated underlying groundwater with pollutants above federal Maximum Contaminant Levels (MCLs). For example, groundwater contains arsenic up to 0.057 mg/L (5.7 times the federal MCL); barium up to 13,800 mg/L (6.9 times the MCL); cadmium up to 0.007 mg/L (1.4 times the MCL); and lead up to 0.051 mg/L (3.4 times the MCL). In addition, CCW disposal at the Gavin Plant caused widespread major exceedances of the MCL for alpha activity as high as 1,497 pCi/L (99.8 times higher than the MCL) and molybdenum concentrations as high as 0.409 mg/L (more than 10 times the federal Lifetime Health Advisory Level). The contamination appears to be spreading as the number of contaminated groundwater wells has increased over time and includes a monitoring well south of the property line in the direction of contaminant flow. NPDES permit violations for the landfill and a closed fly ash/bottom ash pond have also occurred for copper, boron, and sulfate, and acute toxicity to aquatic life has been observed.

The Gavin CCW landfill is approximately 255 acres, covers three distinct valleys, and is located 1.25 miles northwest of the Gavin Plant at River Mile 258 on the Ohio River (AEP, 1998). Initially, the valleys were designated as landfill Phase A, Phase B, and Phase C. Landfill Phase A (80 acres) was constructed in 1994, Phase B (50 acres) in 1996, and Phase C (111 acres) in 1998. Each of the three valleys was filled to a total elevation of about 720 feet, and AEP merged the three phases into one CCW landfill area. Phase A was still undergoing the final cover process as of 2009 and Phase B's final cap was installed in 2003 (AEP, 2005). Phases D and E will be placed on top of the three initial phases until the landfill reaches its final elevation of 900 feet. Phases A, B, and C are full, and current disposal operations are in Phases D and E (AEP, 2009). Three small lined ponds collect leachate from the CCW landfill and are located to the south, east, and northeast of the landfill.

One foot of clay and a 30-mil geosynthetic liner was used in the CCW landfills, however the levels of contamination in groundwater monitoring wells indicates it is ineffective. Fly ash is mixed with the FGD sludge and is then sent by conveyor to the Gavin CCW landfill.

EPA ranked a fly ash pond and a bottom ash pond at Gavin as "high hazard" surface impoundments (USEPA, 2009). The "decommissioned" fly ash pond is located approximately 1500 feet to the northwest of the landfill site and covers 300 acres. It is no longer receiving ash, although AEP is still in the process of deciding how to close the ash pond (OEPA, 2008). Tests run by AEP have determined that the effluent from the fly ash pond has been toxic to aquatic life.

Groundwater

In 2000, rapid loading of CCW in Phase A resulted in a rise in groundwater levels at the toe of the disposal area. The loading appears to have increased pore pressures in the foundation soils as the waste materials consolidated forcing groundwater out. Such increase in pore pressure may result in slope stability problems for the landfill. In response, the plant disposed ash in both Phase B and C, while avoiding filling near the toe of Phase C due to the same concerns associated with slope stability.

Exceedances of MCLs have been observed in on-site groundwater monitoring wells downgradient of landfill Phases A and C in addition to wells upgradient of the landfill. The highest alpha activity (1497 pCi/L) was observed in 2007 in Well 9801 downgradient from Phase C of the landfill monitoring the uppermost Shales/Cow Run Sandstone aquifer. In the same well in 2008, cadmium was measured at 0.007 mg/L (1.4 times the MCL) and lead at 0.051 mg/L (3.4 times the MCL) (AEP, 2009).

The characterization of Wells 94126 and 94128 as "upgradient" wells is questionable. The highest barium concentration measured at the site was at Well 94126 at 13.8 mg/L (6.9 times the MCL), and barium levels have been increasing at this well for a long time. High alpha activity has been measured at the well (137 pCi/L in 1994, 9.1 times the MCL). However the water level of Well 94126 was almost 30 feet lower than the water elevation of the center of the landfill (AEP, 2009). The higher water level in the landfill compared to this well within 200 feet of the landfill suggests contaminants would flow from the landfill to the well. In addition, Wells 94126 and 94128 are nested in the same location in a valley at a surface elevation that is 150–200 feet downhill from the 300 acre decommissioned ash pond, which still contains large areas of open water. Well 94128 is screened in the shallow Morgantown Sandstone aquifer directly underneath unconsolidated alluvium and Well 94126 is screened below the Morgantown Sandstone in the uppermost portion of Cow Run Sandstone aquifer.

Molybdenum was observed in five on-site monitoring wells with its highest levels in Well 94128 at 0.409 mg/L, more than 10 times the federal Life-time Health Advisory, in 2008. Four downgradient wells have also measured high molybdenum. These include concentrations of up to 0.207 mg/L in 2003 and 0.237 mg/L in 2006 in Well 93101 in the Cow Run aquifer, which exceed the Health Advisory by more than 5 times and 0.1 mg/L in 2007 in Well 94140 exceeding the Health Advisory by 2.5 times. Well 94140 is approximately 700 feet south of the landfill and beyond the landfill property line.

Monitoring between 1994 and 2008 revealed arsenic exceedances in seven wells. The highest arsenic measured was 0.057 mg/L in 1996 in Well 94128. The second highest was 0.053 mg/L in 1998 in Well 94128.

Statistical increases for several contaminants have also been observed. Since 1998, sulfate increases have been observed in Well 94140 downgradient from Phase A of the landfill (AEP, 1998; 2009b). Barium concentrations have also increased since the beginning of Well 94126's monitoring history with 3.4 mg/L measured in 1994, an average of 7.9 mg/L measured between 1994 and 2009, and a maximum of 13.8 mg/L measured in 2003 in this well (AEP, 2009b).

There is also evidence of contaminants migrating from the landfill site. In 1994, seven downgradient and two upgradient wells showed alpha contamination ranging from15 to137 pCi/L. By 2009, 15 of 31 wells had shown consistent alpha activity exceedances between 1994 and 2009 (AEP, 2009b). In addition to molybdenum above the federal Health Advisory, manganese was found at 0.089 mg/L, nearly twice the SMCL (0.050 mg/L), TDS at 1,500 mg/L, three times the SMCL (500 mg/L) and chloride at 450 mg/L, exceeding the SMCL (250 mg/L), at Well 94140 south of the property line in 1996-1998 (AEP, 2009e).

2) Surface Water:

NPDES permit violations also exist for the Gavin CCW landfill site. In April 2009, an exceedance of the daily maximum concentration for boron was reported from Outfall 007 with a measured discharge of 8.860 mg/L compared to a permit limit of 8.551 mg/L. This outfall discharges from landfill Phase A. In July 2009, two exceedances of the daily maximum concentration for boron were also reported at Outfall 007 with measured discharges of 9.470 mg/L and 8.900 mg/L.

The Gavin Plant also conducts effluent toxicity monitoring by measuring acute toxicity units (TUa) and lethal concentrations (LC50) for its outfalls discharging into Kyger Creek and the Ohio River, pursuant to Part 1(C)(2)(D) of the plant's NPDES permit (AEP, 2005). A toxicity unit (TU) is a unit of measure for effluent toxicity. Toxicity units increase as the toxicity of the effluent increases (i.e., a TU of 4.00 is twice as toxic as a TU of 2.00). Acute toxicity units (TUa) describe the toxicity resulting from an exposure that occurs only once. Lethal concentration (LC50) is a calculated percentage of effluent at which 50 percent of test organisms die in a 24-hour test period. Measurements of these toxicity characteristics are taken from the outfall, the mixing zone, and upstream.

Outfall 001 discharges from the decommissioned fly ash pond into Stingy Run which flows into Kyger Creek, a tributary to the Ohio River. The allowable effluent toxicity (AET) for Outfall 001 from the decommissioned ash pond is 0.3 TUa, and it applies to both the effluent at the discharge and in the mixing zone (OEPA, 2008b).

In March 2008, Outfall 001 had test results that were acutely toxic to the *Ceriodaphnia dubia* (*C. dubia*), an aquatic insect, but not toxic to fathead minnow. The TUa values for samples taken from Outfall 001's effluent and the mixing zone were 3.3 and 1.9 respectively (11 and 6.3 times the AET limit). Water samples were taken from upstream (in Kyger Creek upstream of its confluence with Stingy Run), at the outfall and in the mixing zone. Mortality to C. *dubia* was significant in the samples taken from the outfall at 85%, and mixing zone at 70%. Upstream Kyger Creek water was not acutely toxic (less than 25% mortality) to C. *dubia* (AEP, 2008b). Total effluent concentrations of aluminum, nickel, and zinc were 3.26 mg/L, 0.070 mg/L and 0.158 mg/L, respectively (AEP, 2009). In comparison to the EPA National Recommended Water Quality Standards, the aluminum concentration was 4.3 times higher than the criteria maximum concentration (CMC) for acute exposure, nickel was 1.3 times higher than the criterion continuous concentration (CCC) for chronic exposure, and zinc was 1.3 times higher than CMC for acute exposure (the nickel and zinc criterion assume a water hardness of 100 mg/L, EPA WQS).

In June 2008, Outfall 001 effluent was found to be acutely toxic to C. *dubia*. Fifty percent of the test population died (LC50 value) when exposed to water containing 43.8% ash effluent, resulting in a TUa of 2.3 (7.67 times the AET limit). At full-strength effluent, 100% mortality was observed in the outfall sample and 50% mortality was observed in the mixing zone sample, while upstream water from Kyger Creek was not toxic to C.*dubia*. An effluent nickel concentration of 0.065 mg/L, 1.2 times higher than the CCC for chronic exposure, and a zinc concentration of 0.13 mg/L, 1.1 times higher than the CMC for acute exposure, are suspected of causing the toxicity by AEP (AEP, 2008).

Discharge from Outfall 008 flows from the landfill's leachate collection ponds into Kyger Creek, and the subsequent receiving stream is the Ohio River. The AET for Outfall 008 is 1.0 TUa (OEPA, 2008). Tests were conducted in August 2008 at Outfall 008. Results showed 100% mortality in full-strength effluent samples for both C. *dubia* and fathead minnow. Fifty percent mortality was observed in the mixing zone sample to C. *dubia* and 15% mortality to fathead minnow. The calculated TUa values were 3.4 for full strength effluent and 2.8 in the mixing zone (3.4 and 2.8 times the AET limit).

At Outfall 008, 50% of the C. *dubia* also died when exposed to water containing 29.7% effluent, and 50% of fathead minnows died when exposed to water containing 35.3% effluent (LC50 concentrations). AEP claims that toxicity came from low pH (6.60, which is in the acceptable EPA range) and high TDS (3910 mg/L) levels (AEP, 2009).

Alpha activity, arsenic, barium, cadmium, lead, molybdenum, sulfate, and total dissolved solids in groundwater; aluminum, copper, nickel, and zinc in surface water discharges

Sixty-three wells used for public or private drinking water were found within a 1.5 mile radius of the fly ash pond. Neither AEP nor the Ohio Department of Natural Resources describe whether the wells are used for municipal or private water supplies. In addition to concerns about groundwater in the area being used as drinking water, human exposure to contaminants may occur if fish caught in Stingy Run, Kyger Creek, or the Ohio River downstream from the landfill site are consumed.

Incident and Data Damage Sources – Timeline

1994: First exceedances of alpha activity and barium are identified
1995: First exceedances of arsenic and lead are identified
1997: First exceedance of molybdenum is identified
2008: First exceedance of cadmium of identified.
2009: Ponding and erosion was located in the Phase D area of the landfill (GCGHD, 2009).

Regulatory Action

OH EPA has not taken enforcement action to stop contamination at the Gavin CCW landfill and, instead, has ordered AEP to conduct "assessment monitoring" at four groundwater monitoring wells, a few more than once. These have included Well 9801 in 2005 and 2009, Well 9803 in 2004 and 2009, Well 94140 in 1997, 2000, and 2008 and Well 9806 in 2005 (AEP, 2009). Under the requirements of OAC 3745-30-08 (AEP, 2009), "assessment monitoring" is required whenever a well shows two consecutive statistical increases in contaminant levels. Under assessment monitoring, AEP is required to determine the extent and rate of contamination. The facility must then develop a plan of action from this information to address the contamination. However, AEP claims that its assessment monitoring has produced false statistical positives, suggesting that no increases above background levels of waste-derived contaminants have occurred at any monitoring well downgradient of the CCW landfill. This claim enabled AEP to return to a less stringent groundwater monitoring program for the site per OAC 3745-30-08(D)(13).

The OH EPA's response to the boron NPDES exceedances in 2009 was to notify AEP that the allowable daily maximum concentration of boron would be increased in 2009 and thus such boron concentrations would no longer exceed the permit limit (OEPA, 2008).

Fly ash, bottom ash, filter cake, lime, flue gas desulfurization (FGD) waste

A CCW landfill and a fly ash and bottom ash pond (AEP, 2009d). Both ponds are lined (AEP, 2002).

Active and inactive units: *Active* units are Phases D, E, and F of the landfill and the bottom ash pond (receives a variable rate of bottom ash and some is removed periodically for beneficial reuse); *Inactive* units are Phases A, B, C of the landfill and the fly ash pond.

AEP has not provided a clear description of the hydrogeologic conditions at Gavin's CCW landfill. AEP claims that, "the hydrogeology of the disposal site is characterized by a multi-level perched water table bedrock aquifer system" (AEP, 2002). However, the Morgantown Sandstone and Cow Run Sandstone aquifers identified in the permit are regional aquifers that extend over a wide area, reaching out at least to Brilliant, Ohio approximately 120 miles northeast of the Gavin site (AEP, 2007). In descending order, the Connellsville Sandstone forms the first perched water table underlying the landfill and is restricted to the intervening ridges within the landfill's footprint. A natural geologic barrier composed of the Clarksburg Redbeds and low permeable residual clay plus geologic barrier soils separates the Connellsville Sandstone from the lower Morgantown and Cow Run Sandstone aquifers. As such, the Connellsville Sandstone unit is designated a significant zone of saturation above the uppermost aquifer system. The Morgantown Sandstone lies beneath the alluvial clayey silts in a valley that is identified as being "within Pond 3," and which is downgradient of the landfill and to the northeast of Phase C of the landfill. The Morgantown Sandstone overlies the Cow Run Sandstone (AEP, 2002).

The Cow Run Sandstone has been designated as the uppermost aquifer that is most monitored because it is continuous beneath the entire site, even though in reality it is lower than the other relevant aquifers on-site (AEP, 2002). The Morgantown Sandstone is also identified as part of the uppermost aquifer system. Both of these sandstone members also include zones of sandy shale strata. The alluvium is located above these sandstones and composed of "predominantly silty clay" (AEP, 2002). The alluvium is screened by monitoring Well 9803 towards the base in "a brown clayey sand and gravel" (AEP, 2002). Potentiometric data indicates a downward flow from the alluvium into the underlying bedrock (AEP, 2002).

According to AEP, groundwater flow changes depending on which valley of the landfill it flows through (AEP, 2002). One direction of groundwater is in a northeasterly direction through and under Phases C and D of the landfill. Another direction of groundwater flow is curving southeast at first, but then reorienting to a western direction under and through landfill Phases B and E. A third direction of groundwater flow is toward the south through Phase A. No information on the rate of groundwater flow is currently available. Phase A discharges into leachate Pond 1 to the south. Leachate from Phases B and E flows into Pond 2 to the east of the landfill. Phase C and D's leachate flows into Pond 3 to the northeast of the landfill (AEP, 2009). Notable impacts were not observed in groundwater around these ponds in the data examined in this report.

Additional Narrative

Effluent Limits Fail to Protect Kyger Creek and its Tributaries

Usually, the effluent limits for a discharge to a low-flow stream are lower than those for a larger river because the latter has much greater water volume that dilutes the discharge, allowing for a greater concentration of the pollutant in the discharge before any water quality criteria is violated in the receiving water. However, the water quality criteria for Kyger Creek and its tributaries are much less stringent than that of the Ohio River.

For example, the Ohio River's state water quality standards for lead is set at 150 µg/L as a "Maximum for Aquatic Life" and 310 µg/L for the "Inside Mixing Zone Maximum" set by the OH EPA. A mixing zone is a discreet volume of water in the receiving water in which the more stringent chronic water quality standards typically do not apply. In comparison to the Ohio River, OH EPA has set water quality criteria for Kyger Creek that allow a maximum lead level in Kyger Creek for aquatic life protection of 710 µg/L and lead levels as high as 1400 µg/L in mixing zones in the creek. Similarly, the allowable limits for cadmium, nickel, selenium, silver, beryllium, chromium, di-n-butyl phthalate, and zinc are all much higher for Kyger Creek than the Ohio River. In other words, the water quality standards set for Kyger Creek allow for substantial surface water pollution to occur from the Gavin site.

[illegible]

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Entity/Company – Location

Hyman Budoff / Merle & Charles Kittinger – Industrial Excess Landfill (IEL) Superfund Site
12464 Cleveland Avenue
Uniontown, OH 44685
Stark County
Latitude: 40.968689 Longitude: -81.405153

Determination

Demonstrated damage to off-site groundwater, including damage to many domestic drinking water wells

Probable Cause(s)

Coal combustion waste (CCW) is the likely source of metals contamination at levels above MCLs in numerous wells. CCW may also contribute to measured levels of alpha and beta radioactivity in more than a dozen wells.

Summary

The Industrial Excess Landfill (IEL), designated by the U.S. Environmental Protection Agency (USEPA) as a Superfund Site in 1984, received an estimated 1 million tons of coal ash from industrial boilers in the Akron/Canton area in the 1960s. In the 1970s, IEL received 1 million tons of industrial organic liquids and other wastes. Although the landfill contains a mixture of industrial wastes, only coal ash contains the toxic heavy metals found in on-site and off-site groundwater wells.

Locations of MW14 (within landfill) and off-site monitoring wells are approximate.

IEL is located in a former sand and gravel pit with residential areas to the north, west and south where hundreds of people depended upon private wells for drinking water. Widespread, significant exceedances of maximum contaminant levels (MCLs) for drinking water and other health-based standards for metals were found in monitoring well clusters located in or close to residential areas. Metals where drinking water standards have been exceeded (maximum exceedances in parentheses) include: antimony (52 times the federal standard), arsenic (13 times the federal standard), beryllium (30 times the federal standard), cadmium (53 times the federal standard), chromium (17 times the federal standard), lead (47 times USEPA's action level), thallium (6.5 times the federal standard), and nickel (12.4 times USEPA's former MCL). Radionuclides probably associated with the coal ash (radon), and anthropogenic radioisotopes where coal ash-colloids probably facilitated off-site transport (plutonium and technetium-99) have also migrated into the residential areas to the north, west, and south.

In 1987, USEPA, in response to the groundwater contamination, required 100 homes west of the site to be provided with free hook-ups to public water. Contamination by coal ash contaminants, however, was also detected to the north and south of the landfill. Thus, while the Agency has determined that the Superfund remedy is "complete," harm to residents who live in the vicinity of the site continues. Many residents in these areas cannot afford the $5,000 hookup fee and continue to use private wells. The neighborhoods southwest, west, and northeast of the landfill have had high incidences of cancer since at least the early 1990s.

The Industrial Excess Landfill (IEL), located in Lake Township southeast of Uniontown, Ohio, covers about 30 acres and averages 45 feet in height. Prior to 1959, the property was mined for sand and gravel. From 1959 until the mid-1960s, materials approved by the Ohio Department of Health for inclusion in the landfill included coal fly ash, masonry rubble, paper, scrap lumber, and other non-toxic materials (Jackson et al. 1989). In the mid-1960s, coal fly ash was the primary waste placed at the landfill. The northwest and northcentral portions of IEL were lined with fly ash (ATDSR, 1998). Approximately one-third of the IEL landfill is filled with coal ash from industrial boilers in the Akron/Canton area (Weatherington-Rice and Aller, 2005). This represents an estimated 450-acre feet of coal ash totaling approximately 1 million tons. Starting in the late 1960s and through the 1970s, about 1 million gallons of industrial liquid wastes were dumped onto the ground and into an evaporation lagoon constructed on-site. In addition to industrial wastes, the landfill also accepted waste from hospitals, septic tank cleaning firms, and the general public. In response to increasing complaints by nearby residents, the Stark County Board of Health ordered IEL to stop dumping chemical wastes in 1972, but other waste disposal continued until the landfill ceased operations in 1980, and was covered with soil consisting of highly permeable sand and gravel (USEPA, 2009). The landfill was listed on the USEPA's National Priorities List (NPL) as a Superfund site in 1986, and USEPA claims that remedial action was completed in 2005 (see Regulatory Action section).

USEPA's remedial actions at the IEL landfill have focused almost exclusively on contamination by volatile organic chemicals (VOCs), and no mention is made in documents posted on USEPA Region 5's website that CCW was a significant source of groundwater contamination by metals at the site (USEPA Region 5, 2010). The evidence, however, supports the conclusion that coal ash at the IEL site is either exclusively or the predominant source of the extensive metals contamination documented at the site:

- All the metals found to exceed MCLs in off-site wells (antimony, arsenic, beryllium, cadmium, chromium, lead, nickel, and thallium) are present in Ohio coals. For example, concentrations of thallium, an extremely uncommon element for manufacturing, have been measured in coal ash with maximum concentrations ranging from 28 ppm (Stark County) to 150 ppm (Tuscarawas County), both likely sources of coal that was burned to create the ash. Lead, frequently detected above federal standards in off-site wells, commonly ranges from 40 to 210 ppm in Stark County coal ash. Uranium has been measured as high as 63 ppm in Stark County coal ash and 320 ppm in Tuscarawas County coal ash, and thorium up to 22 ppm in Stark County and 60 ppm in Tuscarawas County coal ashes (Botoman and Stith, 1986).

- The high pH in many wells also indicates that the coal ash at the site is the dominant influence on the inorganic contaminants. The natural geochemistry of the area, low-lime glacial tills and sand and gravels of Late Wisconsinan and Illinoian age, and mostly acidic sandstones, shales, coal, and underclay, creates a low pH.
- Common metals found to be soluble in high pH settings include arsenic, cadmium, chromium, and lead, all coal ash metals that have been found in high concentrations off-site (Roadcap et al., 2005).

The alkaline conditions created by water percolating through the ash, and the fine-grained nature of the ash itself, creates conditions favorable for facilitated transport of colloidal precipitates and sorbed metals on colloidal-sized particles of ash, which are able to migrate through the permeable sand and gravel aquifer in which coal ash has been directly placed (Roadcap et al. 2005).

In 1987, the first systematic sampling of groundwater within and adjacent to the IEL landfill was undertaken (Jackson et al. (1989)). These first samples were split between consultants for USEPA, the industrial users of the site and the University of Akron's Center for Environmental Studies. Samples were collected from seven nested wells placed at the outer margins of the landfill, and five nested wells outside the landfill boundaries (well nests are wells in the same location that are placed a different depths to sample different aquifers). Most well nests included shallow (S), medium (M or I) and deep (D) wells, with a total of 27 wells sampled. MCLs were exceeded for one or more metals in three downgradient well nests on the south margin of the landfill (MW1S&M, MW3M&D and MW7S,M&D—groundwater in these wells is moving off-site), in three downgradient well nests off-site (MW6S, MW10S,M&D, and one downgradient well nest 900 feet east (MW8M&D) to the south of the landfill. Specific results of the sampling included:

- **Antinomy** exceeded the MCL of 0.006 mg/L in nine wells. Concentrations in four on-site wells (1S, 1M, 3M and 3D) ranged from 0.075 to 0.098 mg/L. Downgradient off-site well concentrations of antimony at 8M and 8D, located about 900 feet west of the landfill, ranged from 0.024 to 0.038 mg/L, 4.0 to 6.3 times the MCL.
- **Arsenic** exceeded the MCL of 0.01 mg/L in eight on-site wells (1S,&M, 3M&D and 7D&S), and one off-site well 8M (0.06 mg/L), the most distant well from the landfill. Concentrations ranged from 0.06 to 0.54 mg/L, up to 54 times the MCL.
- **Chromium** exceeded the MCL of 0.10 mg/L in one downgradient off-site well (6S), with a measured value of 0.18 mg/L.
- **Lead** exceeded the USEPA Action Level (AL) of 0.015 mg/L in four wells, three of them downgradient off-site wells (10S, 10M, and 10D). Concentrations ranged from 0.18 to 0.24 mg/L, 12 to 16 times the AL.

Since 1990, groundwater sampling has taken place at 27 locations with most locations having monitoring wells screened at three depths. Well sampling from May 1992 to 1993 found extensive exceedances of MCLs in downgradient ***off-site*** monitoring wells (data summarized from Exhibit 41 in BWEC, 1999):

- **Antinomy** exceeded the MCL of 0.006 mg/L in six wells (8S, 18S, 23S, 24S, 25S and 27s) with concentrations ranging from 0.061 to 0.315 mg/L, 10 to 52 times the MCL.
- **Arsenic** exceeded the MCL of 0.01 mg/L in three wells (18S, 23S and 24S) with concentrations ranging from 0.055
- to 0.132 mg/L, 5 to 13 times the MCL.
- **Barium** exceeded the MCL of 2.0 mg/L in three wells (OW-9, 24S and 27S) with concentrations ranging from 2.1 to 2.3 mg/L.
- **Beryllium** exceeded the MCL of 0.004 mg/L in eight wells (8S, 18S, 19S, 21S, 23S, 24S, and 27S), with concentrations ranging from .0052 to 0.121 mg/L, up to 30 times the MCL.
- **Cadmium** exceeded the MCL of 0.005 mg/L in nine wells (1D, 8D, 18S, 12I, 23S, 24S, 25S, 27S and 28D) with concentrations ranging from 0.0054 to 0. 0.265 mg/L, up to 53 times the MCL.
- **Chromium** exceeded the MCL of 0.10 mg/L in eight wells (8S, 18S, 21I, 24S, 24I, 25I, 25S, and 27S) with concentrations ranging from 0.127 to 0.739 mg/L, up to 7 times the MCL.

- **Lead** exceeded the AL of 0.15 mg/L in 26 wells (1D, 6S, 8D, 8S, 10D, 10S, 11D, 11S, 18I, 18S, 19S, 21I, 21S, 23I, 23S, 24S, 24I, 25I, 25S, 26S, 27D, 27I, 27S, 28D, OW8, OW9), with concentrations ranging from 0.0161 to 0.70 mg/L, up to 47 times the AL.
- **Mercury** exceeded the MCL of 0.002 mg/L in two wells (27S and OW11), with concentrations ranging from 0.0024 to 0.0055 mg/L, up to 2.75 times the MCL.
- **Nickel** exceeded the MCL of 0.10 mg/L, which was applicable at the time of sampling, in 13 wells (8S, 10S, 11I, 18S, 21I, 21S, 23S, 24I, 24S, 25I, 25S, 26S, 27S) with concentrations ranging from 0.113 to 1.24 mg/L, up to 12.4 times the MCL. (This MCL was remanded in 1995.)

Geraghty & Miller (1997), consultants for the potentially responsible parties (PRPs) at IEL argued that groundwater sampling since 1990 indicated that natural attenuation of metals at the IEL site was taking place and that no further actions were required to address metals contamination. Ohio EPA (OH EPA) objected to this assertion and released their own report with the following conclusions based on their review of the groundwater data (OH EPA, 1997):

- Several metals such as barium, nickel, cadmium, chromium, and zinc have shown concentration *increases* in groundwater at the site since 1993.
- Metallic contaminants were found at very high concentrations in nearly all of the off-site monitoring wells.
- The claim that metals exceeding MCLs near the landfill were due to natural conditions unrelated to land filling activities were unsubstantiated.
- The statement that statistical evaluation shows metal levels to be similar to background concentrations is unsupported.
- The claims that the metals are in geochemical equilibrium with their surroundings and that they are mobilized as precipitates are also unsupported.
- "Ohio EPA does not accept claims that dismiss the landfill as a source of significant metallic contamination...Nor does OEPA have any reason to believe that future releases of heavy metals will not occur."

Despite the strong evidence for off-site contamination of groundwater by metals, Sharp and Associates (2003), consultants for the PRPs at the IEL site, evaluated the 50+ monitoring wells at the IEL site in 2000, and recommended that 34 wells be abandoned. The basis for recommending that 18 of these wells be abandoned was that sampling indicated that they had been "clean" for ten or more years. Furthermore, the report claimed that 17 of the wells where monitoring was continuing were also clean.

A review of this report and available groundwater monitoring data by Weatherington-Rice and Aller (2005), consultants for Concerned Citizens of Lake Township (CCLT), found that MCLs for one or more metals had been exceeded since 1997 in most of the wells claimed to be clean. Furthermore, the consultants for CCLT found that the PRP consultants excluded pH as a parameter when evaluating whether a well was clean. Elevated pH indicates that groundwater has been affected by coal ash. If one considers wells where pH greater than 8.0, which is above natural groundwater conditions, has been measured, only 4 of the 35 wells claimed to be "clean" can be considered clean in terms of having no exceedances of MCLs or elevated pH since 1997.

Weatherington-Rice and Aller (2005) analyzed groundwater sampling data from 1997 to 2001 and identified 35 wells where MCLs had been exceeded for one or more metals. These 35 wells include five wells placed within the landfill, 15 wells that are located at the margin of the landfill with contaminants moving off-site, and 16 wells at ten off-site locations. The distance of off-site monitoring wells from the margin of the landfill ranges from several hundred feet to more than 1,600 feet. Six of the off-site wells with MCL exceedances have been abandoned. As has already been discussed, the list of toxic metals where concentrations have exceeded MCLs is typical of metals associated with coal ash: including antimony, arsenic, cadmium, chromium, lead, selenium, and thallium.

Nineteen of the wells where MCLs have been exceeded since 1997 have been abandoned with the approval of the USEPA. Yet, for example, exceedances of MCLs at well MW12I, located about 1000 feet north of the project site, have been measured for cadmium, chromium, lead, selenium, and thallium. This is one of the most distant monitoring wells from the landfill, and the large number of metals with MCL exceedances suggests a preferential pathway for flow of contaminants to the north in the sand and gravels deposits in the north-trending bedrock valley east of the landfill.

A recent search of the database developed by Bennett & Williams Environmental Consultants for groundwater sampling data collected from 1991 to 2000 focused on identifying MCL exceedances for coal-ash related metals in off-site monitoring wells (all of which are located in or close to residential areas). The results of this search documents extensive off-site contamination (Weatherington-Rice, Zwierschke, and Aller, 2010):

- All 11 off-site monitoring well clusters (S, I & D combined for purposes of this summary) had MCL exceedances for at least two and as many as eight toxic metals: MW6 (As, Pb), MW8 (Cd,Pb), MW10 (As, Cd, Pb, Ni), MW12 (As, Cd, Pb, Ni, Tl), MW18 (Sb, As, Be, Cd, Cr, Pb, Ni, Tl), MW23 (As, Be, Cd, Pb, Ni), MW24 (Sb, As, Be, Cd, Cr, Pb, Ni), MW25 (Be, Cd, Cr, Pb, Ni), MW26 (Cd, Pb, Ni), MW27 (Sb, As, Be, Cd, Cr, Pb, Ni, Tl), and MW28 (Cd, Pb, Ni).
- MCL for antimony (0.006 mg/L) was exceeded in three well clusters: MW18 (0.099 mg/L), MW24 (0.161 mg/L), and MW27 (0.133 mg/L). The maximum value of 0.161 is 27 times the MCL.
- MCL for arsenic (0.01 mg/L) was exceeded in seven well clusters: MW6 (0.0135 to 0.0144 mg/L, MW10 (0.052 mg/L), MW12 (0.0124 to 0.0133 mg/L), MW18 (0.025 to 0.099 mg/L), MW23 (0.014 to 0.0279 mg/L), MW24 (0.0103 to 0.132 mg/L), and MW27 (0.0116 to 0.0797 mg/L).
- MCL for beryllium (0.002 mg/L) was exceeded in five well clusters: MW18 (0.0513 mg/L), MW23 (0.0052 to 0.0091 mg/L), MW24 (0.0054 to 0.0957 mg/L), MW25 (0.024 mg/L), and MW27 (0.0058 to 0.0121 mg/L).
- MCL for cadmium (0.005 mg/L) was exceeded in 10 well clusters: MW8 (0.0054 to 0.0115), MW10 (0.013 to 0.016), MW12 (0.0103 to 0.045 mg/L), MW18 (0.0053 mg/L), MW23 (0.0118 mg/L), MW24 (0.008 mg/L), MW25 (0.0051 to 0.0087 mg/L), MW26 (0.0083 mg/L), MW27(0.0074 to 0.014 mg/L), and MW28 (0.0095 to 0.265mg/L). The maximum value of 0.265 mg/L is 53 times the MCL.MCL for chromium (0.1 mg/L) was exceeded in four well clusters: MW18 (0.093 to 0.278 mg/L) , MW24 (0.168 to 0.214 mg/L) , MW25 (0.160 to 0.561 mg/L) , and MW27 (0.115 to 1.680 mg/L). The maximum value of 1.68 mg/L is 17 times the MCL.
- MCL for lead (0.015 mg/L) was exceeded in all 12 well clusters: MW6 (0.032 to 0.0665 mg/L), MW8 (0.017 to 0.0803 mg/L), MW10 (0.0175 to 0.107 mg/L), MW12 (0.032 to 0.0982 mg/L), MW18 (0.0206 to .0279 mg/L), MW23 (0.0198 to 0.0834 mg/L), MW24 (0.0174 to 0.659 mg/L), MW25 (0.0154 to 0.104 mg/L), MW26 (0.0226 mg/L), MW27 (0.060 to 0.453 mg/L), and MW28 (0.025 mg/L).
- The former MCL for nickel (0.1 mg/L) was exceeded in 10 well clusters: MW10 (0.120 to 0.193 mg/L), MW12 (0.139 to 0.921 mg/L), MW18 (0.142 to 2.2 mg/L), MW23 0.105 to 0.175 (mg/L), MW24 (0.211 to 1.240 mg/L), MW25 (0.150 to 0.698 mg/L), MW26 (0.123 to 1.550 mg/L), MW27 (0.219 to 0.735 mg/L), and MW28 (0.115 to 0.336 mg/L). The maximum value of 2.2 mg/L is 22 times the former MCL, but would not be considered an exceedances since it was sampled in 1997 after the the MCL was remanded.
- MCL for thallium (0.002 mg/L) was exceeded in four well clusters: MW12 (0.0129 mg/L), MW18 (0.0105 to 0.0125 mg/L), MW27 (0.0025 mg/L). The maximum value of 0.0129 is 6.5 times the MCL.

The focus of the recent groundwater database search was on off-site monitoring wells, but on-site MW14 was also included for comparison. This well had exceedances or arsenic, beryllium, cadmium, chromium, lead, nickel and thallium as follows: arsenic (0.0202 to 0.139 mg/L), beryllium (0.005 mg/L), cadmium (0.007 to 0.0152 mg/L), chromium (0.104 to 0.16 mg/L), lead (0.146 to 0.268 mg/L), nickel (0.160 to 0.254 mg/L) and thallium (0.0102 mg/L).

Furthermore, a variety of technically questionable sampling procedures appear to have led to measured contaminant levels that may well be *lower* than actual concentrations. These include:

- Samples collected starting in 1998 used low-flow sampling procedures in a way that collected stagnant water in the wells rather than representative groundwater samples, as indicated by lack of stabilization of field parameters (Lake Township, 2001; Weatherington-Rice and Aller, 2005). One of USEPA's own geologists noted inadequate purging in the November 2000 sampling event (USEPA, 2001). Sampling stagnant water from a well can underestimate metals and radionuclides that sink to the bottom of the casing.
- Failure to resolve issues related to high pH readings in ten well nests may mask the potential for mobilization of metals in groundwater (Weatherington-Rice and Aller, 2005).
- Failure to preserve IEL samples for metals in the field with acid and blanket filtering of samples in the laboratory without also testing unfiltered samples has probably led to underestimation of metals and radionuclides.
- Sample detection limits for several samples collected in 1992 and 1993 were above the MCL (BWEC, 1999).
- Field filtering of all samples for radionuclides in 1992-1993 created a low bias for those sampling rounds.

The weight of evidence that on-site and off-site groundwater has been, and continues to be, contaminated by CCW is very strong. Large quantities of coal ash have been placed at the site. The toxic metals found in high levels in the groundwater, are typical of those found at other CCW disposal sites where groundwater contamination has occurred and are present in high concentrations in locally mined Ohio coals, which are the likely source of the ash. No other sources of significant metals contamination have been identified as having been disposed at the site. The permeable sand and gravel aquifers in the area allow contamination to move quickly off-site. Despite evidence of ongoing migration of toxic metals in groundwater flowing through residential areas near IEL, in 2004 19 wells where MCLs had been exceeded, eight located in or adjacent to residential areas, were decommissioned with USEPA's approval. The rest of the monitoring wells have not been tested for metals since 2004 (Borello, 2010). Ongoing off-site contamination by radionuclides, at least partly attributable to the CCW, is also occurring (see Additional Narrative).

Antimony, arsenic, barium, beryllium, cadmium, chromium, lead, mercury, selenium, and thallium; high pH; and various radioisotopes. No information is available for boron and molybdenum, signature CCW metals, because they have never been included in list of metals analyzed for at IEL.

Exceedances of MCLs for antimony, arsenic, chromium, and lead were discovered in nine wells when the first systematic groundwater sampling occurred in May 1987. Exceedances of metals and radionuclides have continued to be measured in on-site and off-site wells through 2001, the most recent sampling data available.

Records in the Stark County Health Department indicate that significant complaints about the site began in 1971. In 1983, local residents voiced concerns about pollution from the site to township officials, the Stark County Commissioners, the Stark County Health Department, the Ohio EPA and other governmental units (Jackson et al. 1989). In October, 1984 the site was proposed for inclusion in the National Priority List (NPL) of hazardous waste sites for cleanup under the Superfund program, and in June 1986 it was listed as Final on the NPL (USEPA, 2010). Residential well sampling performed in 1987 showed that private wells were being impacted by groundwater contaminated by volatile organic contaminants (VOCs) and USEPA installed air strippers in the affected residences. That same year, USEPA signed a Record of Decision (ROD) requiring installation of an alternate water supply in an area containing 100 homes downgradient of the site to the west. In July 1989 USEPA signed a second ROD selecting actions to clean up the site, which included covering the entire site with a multi-layer cap, expanding the landfill gas extraction and treatment system, extracting and treating contaminated groundwater; and pumping groundwater to maintain the water table at a level that is below that of the wastes in the landfill.

However USEPA used the results of monitoring data collected in March 1997 and September 1998 to justify removing the pump-and-treat remediation system (USEPA, 2009). Then in September 2002, a final remedy was selected that eliminated the original ROD action of covering the entire site with a multi-layer cap, and implemented Monitored Natural Attenuation (MNA). For reasons that are unclear, USEPA also allowed the existing gas extraction and treatment system at the landfill to be shut down in 2005 (Borello, 2010). This is the system that ATDSR (1989) considered to be inadequate to protect the health of nearby residents. Other than ongoing monitoring, remedial activities were completed in May 2005 (USEPA, 2010).

There has been no sampling for metals at IEL since August, 2004 (OEPA, 2010). The EPA has not responded to requests from U.S. Senator Sherrod Brown from Ohio to document the basis for its decision to eliminate the provision the 1989 ROD to expand the landfill gas extraction and treatment system or the justification for shutting down the existing system around 2005 (Borello, 2010). In 2004, USEPA authorized the decommissioning of 33 monitoring wells, which further hampers the ability to evaluate the Monitored Natural Attenuation (MNA) at the site. Major controversy has surrounded USEPA's actions and interpretations of data on the contaminants that are present and the seriousness of remaining contamination at IEL site (see, OEPA, 1997, CCLT website listed in the Sources section, Weatherington-Rice and Aller, 2005, and discussion of evidence for contamination by anthropogenic radioisotopes in Additional Narrative, below).

One million tons of coal ash from industrial boilers, masonry rubble, paper, scrap lumber, and other materials deemed to be non-toxic were placed in the landfill up to the mid-1960s. From the late 1960s to late 1970s the landfill received industrial organic chemical liquid wastes, waste from hospitals, septic tank cleaning firms, and the general public.

Landfill without liners or cap in an abandoned sand and gravel quarry; lagoon for industrial organic chemical liquid wastes.

Inactive. Landfill ceased operation in 1980, and remedial action measures were deemed "completed" in 2005.

The IEL landfill is in a complex hydrogeologic setting with 50 to 140 feet of unconsolidated glacial kame moraine sand and gravel deposits on top of basal glacial till, overlying sand and gravel deposits. A SW-NE bedrock sandstone ridge beneath the landfill is flanked by two parallel valleys filled with sand and gravel outwash. A basal till approximately 5 to 10 feet thick lies on top of the sand and gravel outwash in the area of the landfill. The sand and gravel mined at the landfill was from kame moraine deposits up to about 60 feet thick overlying the basal till. Three aquifers are present in the area of the landfill: (1) a perched water table in the kame moraine deposits; (2) an intermediate aquifer in the sand and gravel below the basal till; and (3) a deep aquifer in the sandstone. Mounding of the water table in the area of the landfill (elevated groundwater levels within the landfill) results in groundwater flow in all directions from the landfill. The general direction of groundwater flow in the middle aquifer is to the west and south. The apparent direction of groundwater flow in the sandstone unit is to the south. The sand and gravel aquifers are highly permeable (groundwater flow as high as 6 feet/day), allowing contaminants from the IEL site to quickly move off-site once they enter the groundwater system. As noted earlier, although the general direction of groundwater flow is to the west and south, the large number of metals with MCL exceedances in MW12I suggests there is also a highly permeable preferential pathway for flow of contaminants to the north in the sand and gravel deposits in the north-trending bedrock valley east of the landfill. In this area, pumping of residential wells has probably drawn contaminants to the north, across the normal westward groundwater gradient. Unfortunately, MW121 was decommissioned in 2004 (Summarized from Jackson et al., 1989)

At Risk Population

The locations of private wells, shown on the aerial map below, were obtained from the Ohio Department of Natural Resources' Well Query Database in 2010. This database allows the user to download locations of wells that are registered with the state at the county level. According to this database, there are 3,912 registered private wells within a two-mile radius of the IEL site. No public well data was available from Ohio DNR.

A well map compiled by Weatherington-Rice and Aller (2005) identifies about 90 private wells within 1,500 feet of the IEL site where some groundwater sampling data are available. In the late 1980s, an estimated 2,500 to 3,000 people lived within a one-mile radius of the IEL site (ATDSR, 1989). According to the 1990 Census, 27,121 people live within a three-mile radius of the site, including children below the age of nine years (USEPA, 2009). A narrow corridor of 100 homes west of IEL received free hook-ups to public water to replace wells that were contaminated. Residents northwest and southwest, who may have had contaminated wells, were required to pay a $5,000 hook-up fee, which not all homeowners could afford. It is possible that 30% the residents near IEL still use private wells. At least two of the four private wells where technetium-99 as found in 2005 were used for drinking water at the time of sampling (Borello, 2010).

Mounding of groundwater in the disposal area may cause localized flow in other directions.

Residents in the vicinity of the IEL site relied exclusively on private wells until USEPA required installation of an alternative water supply in 1989, about 15 years after residents began to be potentially exposed to contaminants from the initial disposal of fly ash in the highly permeable upper sand and gravel aquifer. The human health impact of this exposure and subsequent failures by USEPA to take adequate remedial actions at the IEL site have been tragic:

- By the early 1990s, Elaine Panitz, on the faculty at Princeton University, expressed concern to ATDSR about the incidence of cancer in the vicinity of IEL, including three cases of rare cancer (Panitz, 1992).
- The Lake Township Board of Trustees compiled information collected by Darlene Lansing, R.N., and from testimony by residents given at public hearings to develop a list, by cancer types, of cancer cases and the streets on which they occurred. Three areas show a high incidence of cancer west, southwest, and northeast of the IEL site (Lake Township, 1999 Exhibits L and M).
- Monitoring well 26I, which was decommissioned in 2004, is located in a neighborhood where cancers have been reported over the years in nearly every home (Borello, 2010)

[illegible]

The question as to whether radioactive wastes were placed in the IEL site has been the subject of considerable controversy.

Monitoring wells at the IEL site have been sampled for gross alpha and beta radioactivity in 2000 and 2001 by consultants for the PRPs. Review of these sampling results by Weatherington-Rice and Aller (2005) found the following:

- Alpha radioactivity exceeded 5 pCi/L in eight wells (12D, 6.82; 14S, 15.2 to 16.9; 14I, 6.08; 16I, 13.8; 17S, 10.9 to 25.9; 23S, 7.5 to 13.0; 26I, 7.2 to 9.5) and was detected in two additional wells (20D, 26S). When gross alpha concentrations exceed 5 pCi/L, testing for radium 226 and 228 should be performed to determine if the radium 226/228 MCL of 5 pCi/L has been exceeded. One well (14S) exceeded the MCL of 15 pCi/Lfor gross alpha radiation. Three of the wells where alpha radioactivity exceeded the MCL's for pCi/L were off-site. Earlier testing of four residential wells near the site for alpha radiation from 1991 to 1993 exceeded 5 pCi/L at RW42 (14), RW42 (11), RW64 (9.7) and RW72 (6.1) (Weatherington-Rice, Zwierschke and Aller, 2010).
- MCL for beta radioactivity (>50 pCi/L), which ATDSR (1989) has suggested is coming from the coal ash at the IEL site, was exceeded in two wells (14S, 60.7 to 70.6; 17S, 64.6 to 66.7) and was detected in 19 other wells (1D, 12D, 14I, 15S, 16I, 17D, 18I, 18S, 19S, 20D, 20I, 20S, 21I, 21S, 22I, 23D, 23I, 23S, and 26I). Seven of the wells where beta radioactivity was detected were off-site wells.
- Earlier sampling of residential wells found total beta radioactivity of 280 pCi/L in one residential well (RW42) on March 20, 1991 (Weatherington-Rice, Zwierschke, and Aller, 2010).

During a sampling event in November 2000, Radium-226 was detected in off-site well 23S and total Radium in on-site well 17S at concentrations above the MCL (Lake Township, 2001).

In July and October 2005, consultants for CCLT performed groundwater sampling for radioisotopes from two irrigation wells and four domestic wells north, northwest, west, and southwest of the IEL site, at depths ranging from 35 to about 100 feet. Samples were analyzed for uranium, plutonium, technetium, and radium. Results for uranium and plutonium were in accordance with naturally occurring radioactivity in undisturbed environments and radium 226+228 was measured at a maximum of 1.9 pCi/L. Technetium-99, an anthropogenic isotope, was detected in all samples at levels ranging from 2.7 to 6.9 pCi/L (Ketterer and Baskaran, 2006a). In another report, experts in environmental radiochemistry and isotope geochemistry, Ketterer and Baskaran (2006b), reviewed prior information related to radioactivity at the IEL site, with specific focus on evidence for anthropogenic radioactivity resulting from disposal of wastes at the site, as distinct from "naturally" occurring sources (which include radioisotopes from fallout from nuclear testing) and radioactivity associated with coal ash. The results of this review can be summarized as follows:

- Tritium in IEL vicinity samples exceed the anticipated concentrations of tritium in precipitation and surface waters by approximately one order of magnitude, though well below EPA's MCL of 20,000 pCi/L.
- A May 2001 sample from 14S detected Technetium-99 at a level of 16.49 pCi/L. Technetium-99 is a fission product, and its presence is usually associated with recycled uranium. It is also a decay product of Technetium-99m, a metastable isomer used as a radioactive tracer in medical tests. As noted above, sampling in 2005 found Technetium-99 in all off-site domestic and irrigation wells that were sampled. Technetium is a beta-emitter.
- Detectable plutonium in an on-site borehole soil sample at 92 feet, and levels of plutonium in groundwater samples from four wells (1D and 1I at the southwest corner of the landfill and off-site wells 23S and 26I) that are 100 to 100,000 times higher than values reported for natural water systems are "impossible to reconcile" with plutonium levels that would be expected from fallout from weapons testing.
- Evidence for non-naturally occurring uranium at IEL is inconclusive. However, USEPA has failed to adequately conduct appropriate analysis (namely, mass spectrometry) that could readily and definitively examine the uranium isotope compositions.
- The presence of high levels of gross alpha and gross beta radioactivity in some wells (data summarized above) suggest improper accounting for all alpha- or beta-emitting isotopes and/or generally unreliable radiochemical data.

The federal government has dismissed claims that radioactive contamination from plutonium is a concern at the site, and EPA's Science Advisory Board reviewed data from the site in 1994 and concluded that it was highly unlikely that radioactive contamination is, or was present at IEL. According to USEPA, since 1994 a "small fraction of samples [have] yielded possible detections at extremely low concentrations" (DOJ/USEPA, 2001).

Although USEPA continues to refuse to acknowledge the presence of radioactive wastes at the IEL site, the evidence for their presence summarized above is strong. The earlier discussion noted that ATSDR has suggested that elevated beta radiation detected in monitoring well samples at IEL are the result of fly ash disposal at the landfill (ATSDR, 1998). Also, as discussed earlier, coals mined in the vicinity of the IEL site are known to have elevated concentrations of uranium and thorium in their ash. Available information does not allow assessment of how much of the elevated radiation levels that have been found in groundwater come from coal ash and how much from other anthropogenic sources. Evidence supporting the conclusion that coal ash at that the IEL site is contributing to off-site elevated radiation in groundwater includes:

- The Radium-226, detected in off-site well 23S above the MCL, is a decay product of Uranium-238, which could well come from uranium in the coal ash at the IEL site. Radium-226 in turn decays to Radon-222, a gas. One study has shown that a coal ash landfill at Wright Patterson Air Force Base in Ohio produced concentrations of radon that have been calculated to exceed indoor radon concentrations in a hypothetical structure built on the landfill (Kryusiak, 1995).
- The Ohio Department of Health has identified IEL as a confirmed radiologically contaminated site with uranium and radon, both coal ash constituents (Ohio Department of Health, 1994).
- Off-site migration of soil-gas, VOCs and gaseous radioisotopes such as Radon-222 (an ash- associated contaminant) remain a concern at the IEL site. The initial Public Health Assessment for IEL found that the existing soil-gas collection and venting system may have been allowing significant concentrations of soil-gas to migrate off-site (ATDSR, 1989).

Colloidal-facilitated transport of inorganic contaminants is a well-established mechanism for movement of contaminants in aquifers (Huling, 1989). It has already been noted that alkaline conditions and the fine-grained nature of the coal ash itself created favorable conditions for colloidal-facilitated transport of metals at IEL. Colloids also have the potential to transport radionuclides (McCarthy and Zachara, 1989), and enhanced mobility of plutonium in the saturated zone has been observed in association with various silicate minerals at the Nevada Test Site (Kerting et al., 1999). It is likely that coal-ash colloids assisted in the transport of the plutonium found in off-site wells 23S and 26I (the latter well is now decommissioned), and the technetium-99 that was found in the six off-site wells that were sampled in 2005.

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Entity/Company – Location

American Electric Power (AEP) d/b/a Ohio Power Company – Muskingum River Plant
County Lane Rd. 32
Beverly, OH 45715
Washington County
Latitude: 39.5868 Longitude: -81.6827

Determination

Demonstrated damage to groundwater moving off-site (to southern property line)

Probable Cause(s)

Leaching of coal combustion waste (CCW) contaminants into groundwater from the upper fly ash reservoir

Summary

Monitoring at AEP's Muskingum River Plant shows exceedances of federal Maximum Contaminant Levels (MCLs) for alpha particles in the shallow aquifer that is the source of water for private wells in the area, with a maximum level of 128 pCi/L (8.5 times the MCL) found in a well about 350 feet downgradient from the upper fly ash pond. Seepage from the fly ash reservoir dam, which flows into the Muskingum River, has arsenic concentrations of 0.031 mg/L (3.1 times the MCL), boron concentrations of 2.46 mg/L (approaching EPAs Child Health Advisory standard), and mercury concentrations of 0.00671 mg/L (3.3 times the MCL and 4.8 times the EPA Water Quality Criteria for acute toxicity to aquatic life in freshwater). Elevated groundwater levels in the vicinity of the fly ash ponds (mounding) causes groundwater to flow in all directions, so CCW contaminants are moving beyond the disposal site into shallow groundwater to the southeast and southwest toward private wells.

[illegible]

AEP's on-site groundwater monitoring data collected between 2005 and 2008 documented the following exceedances of MCLs and secondary MCLs (SMCLs) in shallow and deep groundwater downgradient of the upper fly ash reservoir.

In the shallow aquifer, two monitoring wells (M-9612 and OB-2) south of the disposal site showed primary MCL exceedances of alpha particles, with the highest exceedance at 128 pCi/L (8.5 times the MCL) in well M-9612, located roughly 350 feet downgradient from the upper fly ash pond (AEP uses the term "reservoir") in the shallow aquifer. Well M-9612 also exhibits upward trends in concentrations for calcium, magnesium, and sulfate. Well OB-2 is located approximately 200 feet south of the ash pond and has upward trends in concentrations for barium and total dissolved solids (TDS).

Data that directly measured concentrations of ash constituents in seepage from the fly ash reservoir dam were available from Outfall 002 which discharges to the Muskingum River. The ash pond effluent including this seepage is channeled from the fly ash pond dam through a pipeline to Outfall 002 north of the ash pond on the Muskingum River (AEP, 2007). The data on the seepage suggests that the leachate from the pond has arsenic concentrations of 0.031 mg/L (3.1 times the MCL), sulfate concentrations of 377 mg/L (exceeds SMCL of 250 mg/L), boron concentrations of 2.46 mg/L (close to the federal Child Health Advisory of 3.0 mg/L and 3.3 times USEPA's surface water guideline of 0.75 mg/L for long term irrigation for sensitive crops), and mercury concentrations of 0.00671 mg/L (3.3 time the MCL and 4.8 times the EPA Water Quality Criteria for acute toxicity to aquatic life in freshwater of 0.0014 mg/L) (OH EPA, 2007). The similarity of these concentrations to those of the deep Pomeroy Aquifer downgradient of the fly ash pond suggests that contaminants from the shallow aquifer have seeped into the deeper Pomeroy Aquifer. In fact, AEP agrees that such vertical seepage occurs (AEP, 2004). Further confirmation of vertical seepage is that six monitoring wells in the deep aquifer showed barium exceedances with an upward trend with the highest exceedance found in well M-9611 (75.6 mg/L, more than 37 times the MCL) near shallow well OB-2 that also has an upward trend in barium.

On-site groundwater monitoring data showed ranges of exceedances of the SMCL for iron (0.3 – 26 mg/L, 1 to 86 times the SMCL) where exceedances were found in all monitoring wells, and sulfate (250 – 462 mg/L, 1 to 1.8 times the SMCL) in 4 monitoring wells, 3 of which were found in the shallow aquifer downgradient of the reservoir (AEP, 2008). TDS exceeded the SMCL of 500 mg/L in multiple downgradient monitoring wells in the shallow aquifer with a maximum of 902 mg/L.

The downgradient conductivity in the shallow aquifer ranges from 1,290 to 1,760 µmhos/cm in Well M-9617 and from 874 to 1,174 µmhos/cm in well OB-2 (AEP, 2008). Studies of inland fresh waters indicate that streams supporting good mixed fisheries have a conductivity range between 150 and 500 µmhos/cm. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macroinvertebrates. Industrial waters can range as high as 10,000 µmhos/cm (EPA 2006). The discharge limit for the Ohio River, into which the Muskingum flows, is 800 µmhos/cm (KYWater.org, 2003).

Alpha activity, arsenic, barium, conductivity, iron, and sulfate

At Risk Population

Mounding of groundwater in the disposal area may cause localized flow in other directions.

The Muskingum Plant has 70 private drinking water wells within a two-mile radius of the fly ash disposal facility. No public drinking water intakes were found within a five-mile radius of the site. Data was obtained from Ohio's Department of Natural Resources Well Log Database. A 10 mile by 10 mile square was first constructed with the ash disposal facility at the epicenter. Well data was obtained for this area and then consolidated to private wells within a two-mile radius of the facility (70).

The Muskingum River is presently designated for the following uses: Warmwater Habitat, Agricultural Water Supply, Industrial Water Supply, and Primary Contact Recreation (OPC, 2007). Inside a 1.5-mile radius of the ash pond, 48 drinking water wells were found, with at least two wells as close as 0.25 miles from the ash pond (ODNR, 2010). However, information on water use was unavailable. Well owners generally reported that the quality of the groundwater seemed good, although complaints of hardness, yellow staining (high iron), and smell (probably sulfides) were received in a few interviews by the plant (AEP, 2004). Although the utility has occasionally interviewed well owners about the quality of their water, there is no evidence that AEP or the state are sampling off-site wells.

Incident and Date Damage Occurred – [illegible]

The earliest MCL exceedances were monitored in 2005.

A 2004 Regulatory Order by Ohio Environmental Protection Agency (OH EPA) mandated AEP to implement a groundwater monitoring plan that included installation of fifteen groundwater monitoring wells, four groundwater elevation monitoring wells, and 5 piezometers at the Upper Fly Ash Reservoir as part of a plan to increase the height of the Reservoir's dam (AEP, 2005). The groundwater monitoring data in this report is the result of this regulatory action.

Fly ash and bottom ash from the Muskingum River Plant

Upper Fly Ash Reservoir (pond)

Active

The Ohio Power Company Muskingum River Plant's primary outfalls discharge into the Muskingum River at River Mile (RM) 29. In addition to Outfall 002 discharging into the Muskingum River, the upper fly ash reservoir, located one-half mile south of the plant has one outfall for emergency overflow discharging to Millstone Creek, and another outfall for emergency overflow emptying into an unnamed tributary of Millstone Creek (OPC, 2007). Millstone Creek runs into the Muskingum River (OPC, 2007).

The bedrock aquifer beneath the upper fly ash reservoir is comprised of an upper significant zone of saturation overlying a bedrock sandstone aquifer. The significant zone of saturation is comprised of the Gilboy Sandstone to the base of the Benwood Limestone and is predominantly fractured bedrock. This aquifer, referred to as the Shallow aquifer, is monitored by eight wells of which one is upgradient. The Meigs Creek clay shale serves as a continuous geologic barrier that overlies the Pomeroy/Pittsburg sandstone bedrock aquifer. This aquifer, referred to as the Pomeroy Aquifer, is a brackish aquifer with total dissolved solids (TDS) values ranging from 11,000 to 29,000 ppm and is monitored by seven wells. (OPC, 2008).

Seepage from the fly ash pond is expected to form a groundwater mound and exhibit a dominant and divergent radial flow through the fractures within the bedrock (AEP, 2004). Preferential flow continues to occur along the abutments and toward the valleys of the unnamed tributary or Millstone Creek where it is currently diverted into a collection basin. No information is available on water quality at the collection basin because AEP believes it is already monitoring that water quality at Outfall 002 (AEP, 2004), and OH EPA apparently accepts this view. The direction of groundwater flow would be expected to follow a path along the bedrock aquifer underneath the pond to the southeast, as well as toward the Muskingum River (AEP, 2004). To the southwest, seepage from the shallow aquifer has been investigated, though impact is assumed to be minimal due to the fine-silty composition of the soil. In addition, vertical seepage occurs from the shallow aquifer into the deeper Pomeroy aquifer (AEP, 2004).

Boron, a key constituent for identifying contamination from CCW, is not analyzed in either on-site or off-site groundwater monitoring wells, although it is monitored in the seepage from the dam at Outfall 002.

While the fly ash reservoir's emergency overflow Outfalls (007 and 008) discharge into the Millstone Creek and its unnamed tributary, none of the maps of the site delineate where these streams are located. While these outfalls' sporadic discharges are monitored, no monitoring data was available for the streams.

AEP claims that Pleistocene unit permeability, or the potential for contaminants to leak from ash ponds into aquifers, is characterized as low to very low for the soil at the bottom of the pond and dam foundation soils (7.82×10^{-2} cm/sec) (AEP, 2004). However, several experts recommend that permeability should be no less than 1×10^{-7}cm/sec (Albrecht and Cartwright, 1989). In other words, the soil beneath the unlined pond is in the range of being 800,000 times more permeable than what is recommended for ash ponds.

[illegible]

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Entity/Company – Location

American Electric Power d/b/a Public Service Company of Oklahoma – Northeastern Station Ash Landfill
7300 East Hwy. 88
Oologah, OK 74053
Rogers County
Latitude: 36.431667 Longitude: -95.700833

Determination

Demonstrated damage to groundwater moving off-site (to the Verdigris River at the southern boundary)

Probable Cause

Leaching of coal combustion waste (CCW) contaminants from CCW landfill to groundwater

Summary

Recent monitoring has revealed that groundwater under the Northeastern Station's unlined coal ash landfill is heavily contaminated with plumes of metals spreading in at least three directions. Average concentrations of selenium have been measured at 8–10 times the federal Maximum Contaminant Level (MCL) in two wells, periodic exceedances in three other wells, and a maximum selenium concentration of 1.85 mg/L (37 times the federal MCL and 185 times the Oklahoma MCL). Average arsenic concentrations have exceeded the MCL in four wells and are more than 6 times the federal MCL in one well. Average chromium concentrations exceed the MCL in one well and periodic concentrations of chromium exceed the MCL in two other wells with a maximum concentration more than twice the MCL. Lead has exceeded the federal and state MCLs in at least seven wells and measured more than 13 times the MCL (Federal Action Level) in one well. Vanadium has been found at 9 times state health-based standards in one well and exceeded those standards in several other wells. Barium has been found at 4 times the federal MCL in one well. Thallium has exceeded the MCL in two wells. The Oklahoma Department of Environmental Quality (ODEQ) ordered an investigation and corrective action to address the contaminant plume, moving rapidly off-site to the south near the Veridigris River. The plume exceeds the arsenic MCL by more than 3 times some 900 feet from the landfill.

Level of Proof

The Northeastern Station has been dumping CCW in an on-site landfill since 1978, but groundwater monitoring at the landfill did not begin until March 2008. The initial installation of four monitoring wells at that time assumed groundwater flow direction southeast toward the Verdigris River and MW1 on the northern side of the fill was identified as "upgradient." Installation of additional wells indicates that shallow groundwater is flowing in all directions from the landfill, and the deeper groundwater is flowing to the north-northwest. The present monitoring network samples shallow and deep wells at each location (see satellite photo for location of wells). There are no monitoring wells in the system that can be considered background. Eight quarters of sampling in 2008 and 2009 produced the following results. Note that not all wells were sampled each quarter, and thus their average concentrations do not represent 8 samples, which ODEQ requires for statistical analysis:

- **Arsenic.** Average values in four wells exceed the MCL: MW2S (0.035 mg/L), MW2D (0.062 mg/L, maximum 0.073 mg/L), MW8S (0.034 mg/L, maximum 0.094 mg/L), and MW8D (0.013 mg/L, maximum 0.014 mg/L) ranging from 1.3 to 6.2 times the MCL for drinking water. The maximum concentration, found at MW8S, was 0.094 mg/L, 9.4 times the MCL. The exceedances in both the shallow and deep wells at MW8 are significant because these are the most distant wells from the landfill, about 900 feet away. Periodic exceedances of the MCL for arsenic have occurred in five other wells (MW1S, MW1D, MW3S, MW6D, and MW7D).
- **Chromium.** Average chromium concentrations in MW2S (0.12 mg/L) exceed the MCL for chromium (0.1 mg/L). MW8S averages 0.083 mg/L with possible upward trend. The maximum concentration of 0.225 mg/L in MW8S is more than twice the MCL. Periodic exceedances of MCL for chromium have occurred in MW2D and MW7D.
- **Selenium.** Average values in two wells exceed the MCL: concentrations in MW2S (0.485 mg/L) and MW2D (0.447 mg/L) are more than 40 times the Oklahoma MCL for selenium of 0.01 mg/L, and nearly 10 times higher than the federal MCL of 0.05 mg/L. A maximum concentration of 1.85 mg/L is 185 times the state MCL and 37 times the federal MCL for selenium. Periodic exceedances of the MCL have occurred in three other wells (MW1S, MW1D, and MW3S).
- **Vanadium.** There are no Oklahoma or federal MCLs for vanadium, but average values in two wells exceed health-based groundwater standards in Florida and Minnesota (0.049 and 0.05 mg/L respectively): MW2S (0.379 mg/L), MW2D (0. 287 mg/L, maximum of 0.465 mg/L), with the average ranging from 5.7 to 7.6 times these health standards. The average concentration at MW8S (0.051) is just above the FL/MN standards. Periodic exceedances of the FL/MN standards for vanadium have occurred in 4 other wells (MW1D, MW3S, MW6D, MW7D).
- **Sulfate.** Seven wells have average sulfate concentrations that exceed the federal Secondary MCL (SMCL) (500 mg/L): MW1S (550 mg/L), MW1D (798 mg/L), MW2S (590 mg/L), MW2D (633 mg/L), MW3S (553 mg/L), MW7D (1004 mg/L, with a strong upward trend), and MW8D (505 mg/L).
- **pH.** Three wells show high pH, with averages exceeding the SMCL (>8.5): MW1S (9.4), MW2S (11.6), and MW2D (11.0). MW8D exceeded the SMCL for pH in two of four samples with an average value within the upper range of acceptable (8.475). Between June and September 2009, pH in MW7S jumped from 6.9 to 10.4 and has remained above 10.0, clearly indicating a geochemical impact from ash leachate.

In addition, high concentrations of other toxic metals have been measured. Barium has been measured at MW7D (maximum value of 8.69 mg/L) 4.3 times the federal MCL and 8.6 times the state MCL of 1.0 mg/L. Periodic exceedances of EPA's Action Level for lead (0.015 mg/L) have been found at MW1D (max. value of 0.025 mg/L), MW2S (max.value of 0.018 mg/L), MW2D (max. value of 0.017 mg/L) and MW3S (max. value of 0.043 mg/L). Samples have exceeded Oklahoma's higher MCL for lead of 0.05 mg/L at three wells: MW6D (max. value of 0.053 mg/L), MW7D (max.value of 0.208 mg/L), and MW8S (max. value of 0.140 mg/L). The MCL of 0.002 mg/L for thallium has been exceeded once at MW1S and MW2S (0.003 mg/L in both wells).

In just two years of groundwater monitoring, the exceedances of MCLs have been widespread at this coal ash landfill. Of the 16 wells installed in the monitoring network, two (MW4S and MW6S) have either been dry or had too little water to yield a useful groundwater sample. Of the remaining 14 wells, samples from only one, MW5D on the west site of the landfill, have not exceeded MCLs for at least one parameter. The most severely contaminated wells are MW2S & D, on the southernmost tip of the landfill, near the Verdigris River. These wells both have average concentrations of arsenic, selenium, and vanadium exceeding MCLs and sulfate and pH exceeding the SMCLs, and the shallow well has an average concentration of chromium exceeding the MCL.

Despite evidence clearly documenting radial flow outward in all directions from the landfill, ODEQ continues to designate MW1S and MW1D on the northern perimeter of the fill as upgradient monitoring wells. The high pH (average 9.4) and sulfate (average 550 mg/L) and periodic exceedances of MCLs for arsenic, selenium and thallium in MW1S make it clear that water in this well has been contaminated by the coal ash in the landfill. The same is true for MW1D where average sulfate is very high (798 mg/L), and MCLs are periodically exceeded for arsenic, lead and vanadium.

Two other well nests (multiple wells at the same location that are screened at levels to sample groundwater from different aquifers) at the Northeastern landfill also show evidence of significant contamination. Wells MW8S & D are located about 900 feet northwest of the landfill, and yet average concentrations of arsenic in both the shallow and the deep well exceed the MCL. In MW8S the average concentration of vanadium is high, and the average concentration of chromium is near the MCL with a possible upward trend. Well nest MW7S & D is located north of the landfill, and recent sampling at MW7S has shown a rapid increase in pH (from less than 7.0 in the first three quarters to more than 10.0 in the last two quarters of the two year period) and MW7D has the highest sulfate average of any well (1004 mg/L) with a significant upward trend. Concentrations of arsenic, barium, chromium, lead, and vanadium exceeding the MCL and other state standards for vanadium have also been measured at one or both of these wells.

In summary, contaminated groundwater from the Northeastern CCW landfill is moving off-site in all directions in both the surface and deeper groundwater systems. The most significant contaminant plume is moving to the south toward the Verdigris River, but significant levels of contamination have moved at least 900 feet to the northwest from the landfill, and a significant increase in contamination has also appeared in the well nest due north. Some degree of contamination is also moving southeast of the landfill toward the Verdigris River in the vicinity of MW3S where arsenic has been above MCL in the last three quarters and elevated concentrations of chromium, selenium, and average sulfate above the U.S. Environmental Protection Agency's Health Advisory Levels have been measured in recent sampling.

Arsenic, barium, chromium, lead, selenium, vanadium, thallium, sulfate, and high pH

According to the Oklahoma Department of Natural Resources (ODNR), there are six private wells used for drinking water in the town of Oologah. Three public drinking water wells exist within a five-mile radius of the Northeastern Plant. ODNR has been working to place all records into a GIS layer that can be plotted and related to other relevant data, so current well data from Oklahoma DNR may be incomplete. In addition, any of the nearby businesses, including the Power Plant itself, could conceivably be affected by contaminated groundwater. The community of Oologah is within two miles north and northwest of the landfill, and the Stilling Basin Public Use Area is located on the Verdigris River immediately one quarter mile upstream of the CCW landfill.

Mounding of groundwater in the disposal area may cause localized flow in other directions.

[illegible]

First round of groundwater sampling in March 2008 found arsenic above the MCL in two of four wells, and selenium above the MCL in one well.

[illegible]

On September 26, 2007, ODEQ sent a letter to American Electric Power (AEP) requiring the establishment of a groundwater monitoring program at Northeastern Station's fly ash landfill. AEP submitted an initial Hydrogeologic Investigation Drilling Plan to ODEQ in November 2007 (Terracon, 2007). After the first round of sampling in four wells, ODEQ noted MCL exceedances for arsenic and selenium, and high pH, alkalinity, sodium and, sulfate. In 2008, AEP submitted a drilling plan for 12 additional monitoring wells, which ODEQ eventually approved. After the second round of sampling in July 2008, ODEQ noted that in addition to arsenic and selenium, the MCL for chromium was exceeded in one well. ODEQ sent a letter to AEP on September 28, 2009 in response to the Groundwater Report for the Second Quarter of 2009, which noted that the data fell short of the required eight rounds for statistical analysis but concluded:

> [F]rom the data collected to date it is reasonable to suspect that a release from the landfill is impacting groundwater quality in the vicinity of MW-2S and MW-2D. There is additional concern that due to the relatively high flow rate of groundwater through the limestone surface (940.43 feet per year) and close proximity of the wells to the Verdigris River (approximately 75 feet) that the plume might have reached the river.

ODEQ has required further investigation and possible remedial action for the contaminant plume moving south from the landfill. However, ODEQ does not yet appear to have identified the northwestward moving, and emerging northward-moving contaminant plumes as a concern. Despite evidence to the contrary, ODEQ continues to designate MW1S and MW1D as "upgradient" monitoring wells. The high pH (average 9.4) and sulfate (average 550 mg/L) and periodic exceedances of MCLs for arsenic, selenium and thallium indicate clearly that water in these wells has been contaminated by the coal ash in the landfill. The same is true for the contamination recognized by ODEQ at MW2D, where average sulfate is very high (798 mg/L) and MCLs are periodically exceeded for arsenic, lead, and vanadium.

Coal fly ash and bottom ash

The 65-acre unlined fly ash landfill southeast of the power station has been in use since coal-fired Units 3 & 4 started operating in 1978. The fly ash landfill operates under Oklahoma State Department of Health landfill permit FA3566010 issued on July 20, 1978 (Terracon, 2009).

A 69-acre bottom ash pond with an approximate capacity of 700 acre-ft is located northwest of the landfill. Actual storage capacity is unknown due to the quarry dug during construction of the plant. The capacity of the pond is based on the memories of long-time employees regarding personal soundings of depths, and drawing scaling. The volume currently stored is variable, with ash routinely removed for beneficial use (AEP, 2009). The bottom ash pond does not appear to be subject to groundwater monitoring (discussed in more detail below).

Both the fly ash landfill and bottom ash impoundment are active. Increased volume of CCW from Installation of new pollution control devices has resulted in a proposed vertical expansion of the landfill (Terracon, 2009).

Hydrogeologic Conditions

In the vicinity of the ash landfill there are three lithologic units. From shallow to deeper depth, they are: (1) an unconsolidated gravelly clay unit ranging in thickness from almost thirty feet to being absent; (2) Lower Pawnee Limestone member of the Pennsylvanian-age Oologah Formation with a thickness ranging from 5 to 43 feet; and (3) Labette Shale member of the Oologah Formation that lies at depth ranging from around 33 to 43 feet below ground surface. Although the landfill is located adjacent to the Verdigris River, no Quaternary alluvial deposits of sand, gravel and clay associated with the river have reportedly been encountered within the landfill or power plant property. The monitoring well network involves nested wells screened in the limestone (designated S for "shallow") and the lower shale unit (designated D for "deep"). During the hydrogeologic investigations, perched groundwater in the unconsolidated materials was occasionally present, but appeared to be discontinuous across the site. The initial installation of four monitoring wells assumed groundwater flow direction southeast toward the Verdigris River, and MW1 was identified as "upgradient." When additional monitoring wells were installed in late 2008, MW1S appeared to be on a groundwater divide with flow going to the northwest toward MW8S and southeast toward the landfill. In June 2009, the water elevation in piezometers set in the landfill indicated flow from the landfill toward MW1S, and the presence of contaminants in both MW1S and MW8S downgradient from MW1S confirm that this should not be designated as an upgradient well. Since the deeper monitoring wells were installed in late 2008, MW1D has been downgradient from the landfill in all the potentiometric maps in all subsequent quarterly groundwater reports, yet ODEQ continues to identify MW1D as an upgradient well in its review of the data.

It should be noted that MW8S&D northwest of the landfill, which show evidence of significant contamination, may be affected by migration of metals from the bottom ash pond that lies to the northwest of the landfill. Hydrogeologic investigations at the Northeastern Plant seem to have focused exclusively on the vicinity of the landfill, and no site characterization or groundwater monitoring has specifically addressed the possibility of contamination from the bottom ash pond. Nevertheless, the topography of the site suggests that the landfill is the likely source of contamination in this well (summarized from Terracon, 2008).

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AEP. 2008-2009. Quarterly Groundwater Reports Fourth Quarter, Northeastern Power Station Ash Landfill, Oolalgah, Oklahoma for Samples Collected March-08, July-08, October-08, November-08, March-09, June-09, September-09, and December-09.

Terracon. 2007. Hydrogeologic Investigation Drilling Plan Revision 0. Northeastern Station – Units 3 & 4 Fly Ash Landfill, Oologah, Oklahoma. Prepared for American Electric Power (Nov. 28, 2007).

Terracon. 2009. Hydrogeologic Investigation Report Public Service Company of Oklahoma Northeastern Stations 3& 4 Fly Ash Landfill, Oologah, Oklahoma. Prepared for Public Service Company of Oklahoma (July 16, 2009).

Entity/Company - Location

Portland General Electric Company (PGE) - Boardman Plant
73334 Tower Road
Boardman, OR 97818
Morrow County
Latitude: 45.693611 Longitude: -119.805833

Determination

Demonstrated damage to groundwater moving off-site (at western property boundary)

Probable Cause(s)

Leaching of coal combustion waste (CCW) contaminants from the CCW disposal area and numerous disposal units

Summary

Groundwater contamination underneath a 40-acre CCW disposal area, seven wastewater ponds, and a 1,500-acre Reservoir at the Boardman Plant has been contaminated in excess of Oregon groundwater standards, EPA Maximum Contaminant Levels (MCLs) and Secondary MCLS (SMCLs) since 1981. Selenium concentrations have reached 0.019 mg/L (1.9 times the Oregon Numerical Groundwater Quality Reference Level) in two wells; and vanadium concentrations have risen to 0.126 mg/L in three wells (2.5 times the Oregon Reference Level) in recent groundwater monitoring. Total Dissolved Solids (TDS) concentrations have also exceeded federal and Oregon standards in three wells. A nearby farming operation has been using large volumes of water from the Carty reservoir since 2001, despite the Boardman Plant's disposal of bottom ash drain water and other liquid industrial wastes into this reservoir.

[illegible] of Proof

The Boardman Plant has a 40-acre coal ash disposal area, a 1,500-acre closed-loop reservoir, and six industrial wastewater ponds. Only two of the six wastewater ponds are lined. The water monitoring program for the Boardman Plant includes just six groundwater wells and three surface water sampling points from the reservoir (sampling makeup water, at the plant intake, and at a withdrawal for agricultural irrigation). Only one groundwater well, Well 130, monitors the wastewater ponds, and it is usually too dry to sample it. Arsenic has been found in Well 008 at levels between 1 and 2 times the MCL in groundwater on the other side of Carty Reservoir as well as occasionally at similar levels in wells at the coal ash disposal area while arsenic has been consistently below the MCL in the reservoir water. However this report focuses on impacts more clearly seen in the groundwater monitored by Wells 052, 053, 120 and 122 around the 40-acre coal ash disposal area. Two of them, Wells 052 and 053, are located 750 and 1,500 feet from the disposal area, respectively, and a third one, Well 122, is too dry to sample, leaving only Well 120 in close proximity to the coal ash.

Portland General Electric Company (PGE), the owner of Boardman Plant, has argued that seepage from the Carty Reservoir has created widespread, perched aquifer conditions, and that this seepage is responsible for shallow groundwater in coal ash disposal area wells located approximately 2,000 feet (0.4-mile) away from the reservoir. PGE has also argued that Reservoir seepage has higher quality than naturally occurring groundwater (PGE, 2005). If these assertions were true, then the quality of groundwater in these wells would be similar to that of the reservoir. However, a comparison of 2009 data from groundwater wells at the coal ash disposal area with data from the Reservoir from 1981-1987 suggests that groundwater in the coal ash disposal area has been contaminated by CCW and is not similar to Reservoir water. The data shows that typical CCW indicator parameters are present at the following levels in on-site groundwater, particularly around the 40-acre coal ash disposal area:

- **Selenium** – has exceeded the Oregon Numerical Groundwater Quality Reference Level (0.01 mg/L) in coal ash disposal area Wells 053 and 120. Samples collected from Well 120, the nearest well to the coal ash disposal area, exceeded the State standard in 1987, the first year a sample was collected, and 13 additional times since 1987. The maximum selenium concentration reported for Well 120 was 0.019 mg/L in 1989. The State standard has been exceeded twice in Well 053, the first time in 1982 at 0.016 mg/L, the maximum concentration measured. A comparison with Reservoir water is not possible as the Reservoir is not analyzed for selenium.
- **Vanadium** – has exhibited increasing trends in all wells on-site with the highest concentrations measured in wells monitoring the coal ash disposal area. Reservoir water samples are not analyzed for vanadium. Although there is no federal or State MCL for vanadium, Oregon Groundwater Quality Protection Rule 340-040-0001 requires that all current and scientifically valid information be available to determine acceptable pollutant concentrations. Florida (Florida, 2010) has a groundwater standard of 0.049 mg/L for vanadium and Minnesota (Minnesota, 2010) has a groundwater standard of 0.050 mg/L. Increased trends beyond these standards were found in the following wells:
    - Coal ash Disposal Area Wells – increased vanadium trends began in 1991 in wells closest to the coal ash disposal area, Wells 052 and 120, and in 1998 in Well 053 located further away. Concentrations in Well 052 have exceeded 0.050 mg/L every year since 1991 (19 times), and the maximum concentration measured was 0.075 mg/L in 2002. Concentrations in Well 120 began exceeding 0.050 mg/L in 1991 and have exceeded it every year since. The maximum concentration reported for Well 120 was 0.089 mg/L in 2006. Vanadium concentrations in Well 053 also exceeded 0.050 mg/L in 1991 and have exceeded it every year since 1998. Well 053 had the highest reported concentration, 0.126 mg/L in 2006.
- **Alkalinity** – had remained constant and relatively flat at the Reservoir (121 mg/L average, 135 mg/L maximum), yet dramatically increased in Well 053 (coal ash disposal area well) during the same period (290 mg/L average, 360 mg/L maximum, increasing trend).

- **Chloride** – has remained relatively constant and flat in the Reservoir water (18 mg/L average, 31 mg/L maximum) while chloride concentrations in the coal ash disposal area well closest to the coal ash, Well 120, have been much higher (135 mg/L average, 197 mg/L maximum).
- **Sulfate** – has remained relatively constant and flat at the Reservoir (33 mg/L average, 47 mg/L maximum), while sulfate concentrations in two coal ash disposal area wells have been much higher and had increasing trends (Well 052: 164 mg/L average, 209 mg/L maximum; Well 120: 157 mg/L average, 240 mg/L maximum). In 2008, PGE concluded that there were "significant" increases in sulfate in Wells 052 and 120 but that the increase was related to unspecified "sampling and analysis problems" rather than CCW disposal or Plant operations.
- **TDS** – has remained relatively constant and flat at the Reservoir (213 mg/L average, 261 mg/L maximum) but been much higher at Well 052 (647 mg/L average, 734 mg/L maximum) and Well 053 (639 mg/L average, 952 mg/L maximum) and highest closest to the coal ash disposal area at Well 120 (846 mg/L average, 1,073 mg/L maximum). TDS concentrations have exceeded the federal SMCL (500 mg/L) as well as the Oregon Numerical Groundwater Quality Guidance Level in each of the three wells at the coal ash disposal area for every annual sampling event for more than two decades (Well 052, 25 years; Well 053, 29 years; and Well 120, 23 years).

Groundwater data suggest a correlation between higher concentrations of vanadium and higher bicarbonate alkalinity concentrations. As the alkalinity of the groundwater has generally increased, the vanadium concentrations have increased.

Seepage from the Carty Reservoir results in 2,000 acre-feet (651 million gallons) of recharge annually to the underlying groundwater (PGE, 2005). Shortly after Carty Reservoir was filled, Six Mile Creek, a previously dry canyon stream bed, began to flow (Richardson, 2010) – indicating that the Creek flow was due to Reservoir leakage into the stream bed and that water quality in the Creek would be substantially similar to water in the Reservoir. PGE has not reported an annual seepage volume from any industrial wastewater pond or the coal ash disposal area.

Selenium, vanadium, total dissolved solids, chloride, sulfate, and alkalinity

Groundwater in the vicinity of the Boardman Plant is used extensively for commercial irrigation and water supply. A review of well logs within 5 miles of the Boardman Plant found 14 wells for commercial irrigation, 19 wells for private water supply, and 18 wells for livestock watering (OWRD, 2010). Eleven of the water supply wells were for the PGE plant, and one of those wells was an "industrial" well, indicating that local groundwater may be used as a drinking water source at the Plant. Of the 10 drinking water wells, the average completion depth was only 103 feet deep – indicating that the shallow groundwater is used for drinking water.

In 2001, the Carty Reservoir began an annual "blow down" to remove poor quality water by providing it to Threemile Canyon Farms, an organic, commercial farming operation just west of the plant, for irrigation (PGE, 2010). Recently, approximately 465 million gallons were withdrawn from Carty Reservoir during three months in 2009 (PGE, 2010). PGE does not test this irrigation water for selenium or vanadium despite the exceedances of standards in groundwater at the Boardman Plant.

The largest number of irrigation and livestock well owners are located just west of the Boardman Plant, near R.D. Offutt, a large concentrated animal feedlot operation (CAFO) that is co-located with Threemile Canyon Farms operations (Richardson, 2010). A review of well logs for the R.D. Offutt wells indicates they are drawing shallow groundwater for commercial purposes – with five of 13 wells nearest the plant being completed less than 80 feet below ground surface. Of those wells, four were less than 30 feet deep.

Incident and Date Damage Occurred / Identified

Exceedances of groundwater standards were first documented in 1981.

Regulatory Actions

The Site Certificate Agreement that set the environmental monitoring and discharge conditions for this Plant is based upon a 1975 version of Oregon Administrative Rules Chapter 345, Division 26, "Construction and Operation Rules for Thermal Power Plants". The Certificate Agreement is handled by the Oregon Department of Energy (ODOE). PGE has gone to ODOE in 2003 and 2004 to reduce both the number of parameters sampled, and water monitoring requirements (ODOE, 2010). Water discharges are regulated under Water Pollution Control Facilities Permit (No. 100189) based on criteria established in 1975 (PGE, 2005). According to The Oregon Department of Environmental Quality (ODEQ) no assessment of the contamination long evident at this site has been required because no such requirement was included in the Site Certificate 35 years ago when the Certificate was first approved (Nadler, June 2010).

Oregon Groundwater Quality Protection Rules OAR 340-040 require that a monitoring system "be capable of determining rate and direction of groundwater movement", and that both upgradient and downgradient groundwater quality be determined. Neither a potentiometric surface diagram nor a determination of groundwater flow rate was found in this file review. Further, PGE has not established upgradient and downgradient wells for any disposal unit. In fact, the monitoring system at the Carty Reservoir includes only one well; the evaporation pond to the north includes only one well; and the industrial waste ponds, including those located between the reservoir and the plant, include no wells. In short, the groundwater monitoring and sampling program does not comply with current Oregon rules, which also would have required a Preliminary Assessment Plan within 30 days of a "significant increase" in groundwater parameters if immediate re-sampling did not indicate invalid results. However, these groundwater protection rules were not in effect in 1975, when the certificate was first issued and thus do not apply to this site (Nadler, June 2010).

[illegible]

Fly ash, bottom ash, and economizer ash (PGE, 2010) (economizer ash is similar to bottom ash in particle size (Nadler, July 2010))

[illegible]

CCW disposal areas include a 40-acre coal ash disposal area, a 1,500-acre, closed loop Reservoir, and six other industrial wastewater ponds. Carty Reservoir is over 3 miles long and was created to supply cooling water, boiler make-up water, and fire water to the plant. Bottom ash transport water, boiler blowdown, and cooling water discharge into Carty Reservoir (Nadler, June and July 2010). The Reservoir is also used for disposal of liquid wastes (PGE, 2005). Much of the raw water for the Reservoir comes from nearby Threemile Canyon Farms, an adjacent organic, commercial farming operation (potatoes and dairy cows) which gets the water from the Columbia River.

According to aerial photography and the most recent annual groundwater report (PGE, 2010), at least six industrial wastewater ponds and three sewage lagoons exist on the Plant property – in addition to the Carty Reservoir. Four ponds located south of the Boardman Plant and between it and Carty Reservoir are used to settle bottom ash from transport water prior to discharge into Carty Reservoir (Nadler, July 2010). Two other ponds north of the Plant are used to evaporate water softening treatment wastewater and laboratory wastes (Nadler, July 2010). Three other ponds located just northwest of the Plant and the coal pile, identified by PGE as being "industrial wastewater ponds," are instead domestic sewage lagoons (Nadler, July 2010). Low volume wastes such as turbine cleaning water are transported off-site for disposal (Nadler, July 2010).

The two evaporation ponds north of the Plant were unlined until 2007 (PGE, 2010). These ponds receive wastewater discharges that are too high in TDS for discharge to the Carty Reservoir (PGE, 2005). PGE monitors for only flow, pH, TDS, and ammonia-nitrogen and none of the metals that are prevalent in on-site wells. Approximately 3 million gallons of wastewater was discharged to the ponds in just three months in 2007, prior to the liner being constructed under them (PGE, 2008), and millions of gallons were likely discharged on an annual basis for at least 26 years prior to the liner installation. Only one well, Well 130, monitors groundwater under these ponds, and PGE maintains that Well 130 has never had sufficient water to sample since it was installed in 1980 (PGE, 2010). The fact that there has not been perching of groundwater on the Pomona Basalt zone as has happened beneath the ash landfill, suggests that there is a prefential pathway for rapid downward migration of the wastewater to the deeper Columbia River Basalt aquifer.

The 40-acre coal ash disposal area (PGE, 2010) is separated from the Carty Reservoir by man-made dikes (PGE, 2005). Excess water in the coal ash disposal process evaporates within the disposal area (PGE, 2005). Approximately 93 percent of the coal ash generated in 2009 was sold for beneficial re-use (PGE, 2010) in the concrete industry (Nadler, 2010). The bottom of the coal ash disposal area is 8 feet above the highest reservoir elevation and is lined (thickness not given) with coal ash that was hydrated and compacted to a 1×10^{-7} centimeters per second permeability (PGE, 2005). However the presence of CCW-related contaminants in the monitoring wells around the disposal area indicates that the liner is not functioning as a significant barrier for downward migration of contaminants from the landfill.

Active

A shallow, perched aquifer occurs beneath the plant area atop the Pomona Basalt formation "due to surface water of the Carty Reservoir" (PGE, 2005). The five monitoring wells at the plant's coal ash disposal area and near the reservoir are screened in this perched Pomona Basalt zone. Well 130, located at the industrial waste evaporation ponds to the north, is screened in the shallow Elephant Basalt formation above the Pomona Basalt and PGE reports that it is too dry to sample.

The main groundwater aquifer occurs 350 feet below the plant in the Columbia River Basalt formation (PGE, 2005). The deepest well at the Boardman Plant is 108 feet deep), and the average depth of wells that produce water is 81 feet (PGE, 2005). Thus the deeper Columbia River Basalt regional aquifer is not monitored for any effect from the plant operations.

Dramatic changes in groundwater elevations in Well 052 and Well 120 suggest that increased groundwater infiltration has resulted from the coal ash disposal area. Well 052, located 250 yards to the northeast of the coal ash disposal area and almost 700 yards feet from the Carty Reservoir, was initially too dry (less than 1-foot of static water level) to sample when it was installed in 1980 but by 1985, the water level had risen almost 19 feet. From 1986 to 1996, the water level continued to rise to a current stabilized 40-foot water column (PGE, 2010). Groundwater in Well 120, 25 yards south of the coal ash disposal area and almost 700 yards from the Carty Reservoir, was not found until 1987, seven years after the well was first installed. Groundwater elevations then rose by 9 feet in Well 120 and have remained constant since 1997.

Florida. 2010. Florida Department of Environmental Protection, Groundwater and Surface Water Clean-up Target Levels, *available at* http://www.health.state.mn.us/divs/eh/risk/guidance/gw/table.html.

Minnesota. 2010. Minnesota Department of Health Groundwater Values Table, Health Risk Limit values, *available at* http://www.health.state.mn.us/divs/eh/risk/guidance/gw/table.html.

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PGE. 2008. Annual Water Quality Monitoring Report for 2007 to Carl Nadler, Department of Environmental Quality, from Arya Behbehani-Divers, Manager, Environmental Services (Feb. 25, 2010).

PGE. 2005. Letter to Carl Nadler, Oregon Department of Environmental Quality, from Steven Anderson, Environmental Specialist (Feb. 15, 2005).

Entity/Company – Location

FirstEnergy – Bruce Mansfield Power Plant's Little Blue Run Surface Impoundment
P.O. Box 128
Greene Township, Beaver County, PA and Grant District, Hancock County, WV
Latitude: 40.626375 Longitude: -80.514947

Determination

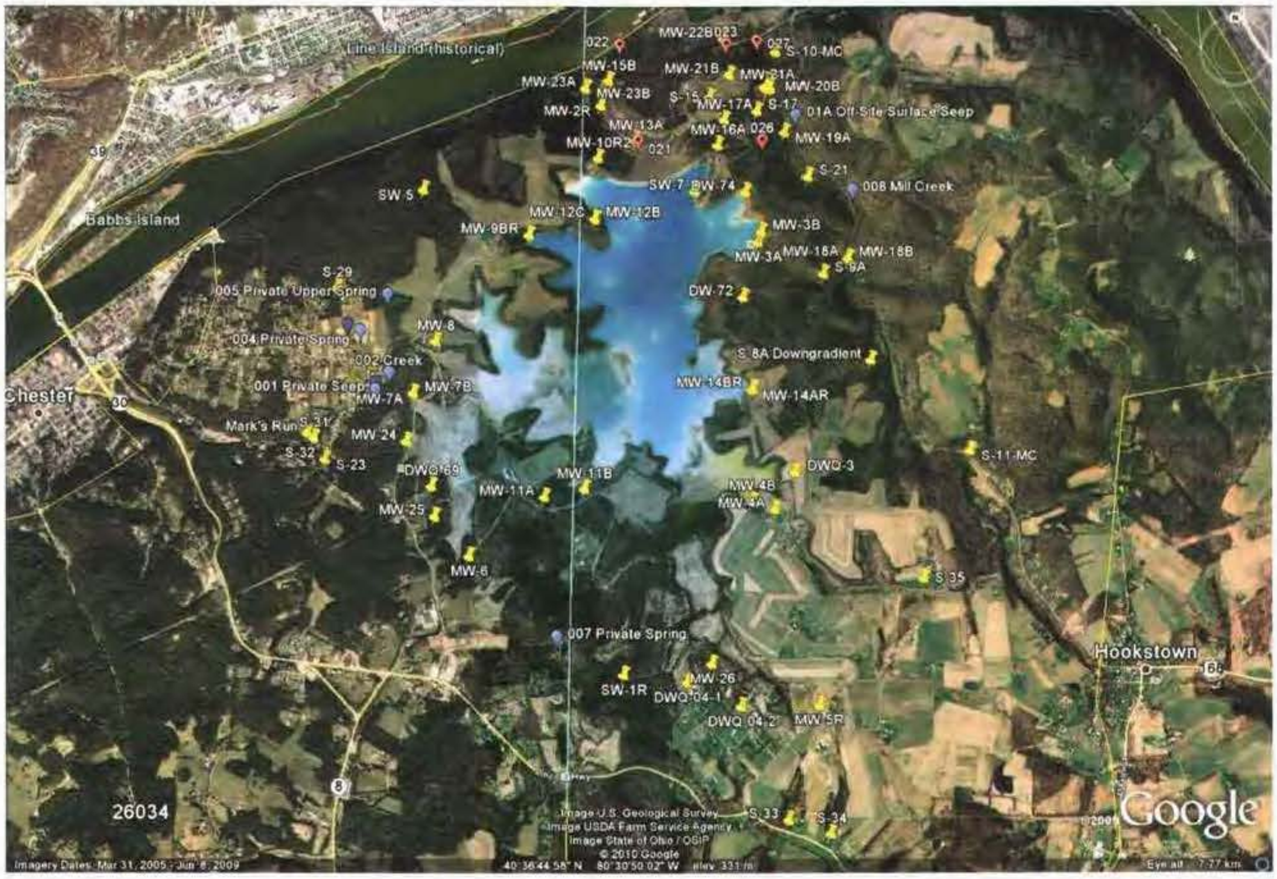
Demonstrated damage to off-site groundwater and off-site surface water (in domestic wells and in Marks Run and other surface waters)

Probable Cause(s)

Leaching, seepage, and discharge of coal combustion waste (CCW) contaminants from Little Blue impoundment into groundwater and surface waters. The additional head pressure created by the expansion of the CCW impoundment in 2006 may also be forcing contaminated water further away from the impoundment.

Summary

Discharges to groundwater and surface water from the 1,300-acre "Little Blue" surface impoundment have exceeded MCLs for arsenic and other parameters in multiple off-site residential drinking wells (prompting several property buyouts by FirstEnergy), exceeded Pennsylvania Water Quality Criteria (PA WQC), including the Criteria Continuous Concentration (CCC) and Criteria Maximum Concentration (CMC), in Mark's Run and other off-site surface water sources, and pervasively exceeded federal Maximum Contaminant Levels (MCLs) at many on-site groundwater monitoring wells.



*For this site, "Off-site" means property that is currently beyond the property boundary or was originally beyond the property boundary but has since been bought out by FirstEnergy or Penn Power. This determination was made using the best available data. "On-site moving off-site" means the well is on-site but more than 150 feet from the closest part of the impoundment.

For example:

- Arsenic has been measured in at least two off-site residential drinking wells above the MCL of 0.01 mg/L, including a reading of 0.0146 mg/L in one family's well in 2008, and a reading of 0.021 mg/L at another family's well. MCLs for cadmium, barium, fluoride, lead, and turbidity were also exceeded in off-site residential drinking wells, as were Secondary MCLs (SMCLs) for aluminum, chloride, iron, manganese, pH, sulfate, and total dissolved solids (TDS).
- In off-site surface water, arsenic has exceeded the PA WQC of 0.01 mg/L at least eight times at three locations between 2003 and 2010, with concentrations trending upwards, including a reading of 0.028 mg/L (2.8 times the criteria) in 2010. Thallium, cadmium, hexavalent chromium, lead, antimony, selenium, and boron also exceeded PA WQC in off-site surface water, as did many pollutants with secondary WQC.
- In on-site groundwater that flows off-site, *arsenic exceeded the 0.010 mg/L MCL at least 24 times in 14 wells in 2006, 2009, and 2010*, including concentrations of 0.030, 0.033, and 0.036 mg/L in three different wells. Fluoride, lead, and turbidity MCLs were also exceeded, as well as SMCLs for several other pollutants. On-site groundwater monitoring wells also had exceedances of SMCLs for chloride, iron, manganese sulfate, and turbidity.
- On-site surface waters that flow off-site were contaminated with arsenic at 0.013 mg/L, 1.3 times the WQC of 0.01 mg/L, antimony at 0.012 mg/L, more than double the CCC of 0.0046 mg/L. Selenium was also double the PA WQC at on-site surface water monitoring point SW-3. In addition, aluminum exceeded secondary standards in on-site surface water that flows off-site.

FirstEnergy's Little Blue Run ("Little Blue") surface impoundment, the largest impoundment east of the Mississippi River, is an unlined CCW disposal area with a permitted area of *1,694.6 acres* that contains flue gas desulfurization (FGD) sludge and fly ash. This CCW surface impoundment has potential environmental and public health impacts in three states, as the impoundment spans Pennsylvania and West Virginia, and its earthen dam retaining wall is immediately across the Ohio River from Ohio. Coal ash slurry from the Bruce Mansfield Power Plant is transported via a seven and a half mile pipe to Little Blue. Data gathered from private residential well testing results, discharge monitoring reports, Notice of Violations (NOVs), inspection reports, and correspondence files revealed the following evidence of CCW contamination:.

Off-site groundwater – off-site groundwater contamination has been pervasive, including drinking water wells 0.5 mile away or further from the Little Blue impoundment. See Chart 1. These exceedances appear to have increased since the expansion of the impoundment in 2006. Evidence of contaminated off-site drinking water includes arsenic readings in excess of the MCL (0.01 mg/L) in at least eight off-site groundwater wells. Two of these wells were residential drinking water wells, with one well containing arsenic at 0.021 mg/L (more than twice the MCL), and another family's well containing arsenic concentrations that increased from 0.013 to 0.0146 mg/L between 2008 and 2009. MCLs were also exceeded in off-site groundwater wells for cadmium, barium, fluoride, lead, and turbidity. In addition, many SMCLs were exceeded in off-site groundwater. As a result, FirstEnergy has monitored drinking water wells at several nearby homes, and subsequently purchased those homes due to well contamination.

Off-site surface water – off-site surface water contamination includes exceedances of both continuous/chronic (CCC) and maximum/acute (CMC) limits set forth in Pennsylvania Water Quality Criteria (WQC). These exceedances occurred both at FirstEnergy's off-site monitoring points in streams and creeks, including Mark's Run and Little Blue Run, and at seeps located at private residences. *See* Chart 1 (for brevity, several pollutants in off-site surface water that exceeded MCLs but did not have an associated WQC were not charted). Many criteria have exceeded WQC only after the expansion of the impoundment in 2006. For example, arsenic levels have steadily increased, only exceeding WQC at one point in Pennsylvania, S-17 (a surface water seep about 1,490 feet from the closest part of Little Blue) in 2003, with a reading of 0.016 mg/L. Between 2008 and 2010, arsenic was found in two additional surface water points, including exceedances at S-31 (a monitoring point in Mark's Run, in a residential neighborhood in West Virginia) and at SW-5 (a spring over 2,000 feet from Little Blue), with arsenic concentrations of 0.024 and 0.028 mg/L. Other off-site surface water exceedances included an exceedance of the CMC for hexavalent chromium, a lead reading of 0.15 mg/L, far exceeding the CCC of 0.01094 mg/L, at an off-site unpermitted seep, and pervasive boron contamination at at least seven wells. Cadmium, thallium, selenium, and boron also exceeded WQC in off-site creeks, springs, and seeps.

These off-site surface water exceedances occurred in at least 17 downgradient surface water sources, including: SW-5, a surface water source (type marked "other" and likely a seep) in Pennsylvania; S-9a (a spring in Pennsylvania); S-10-MC (a stream in Pennsylvania); S-16-MC (a stream in Pennsylvania); S-17 (a spring in Pennsylvania); S-28 (a spring in West Virginia); S-30 (a spring in West Virginia); S-31 (a spring in West Virginia); S-32 (a spring in West Virginia); S-34 (a spring in West Virginia); S-35 (a spring in West Virginia); LR-1 (a spring in West Virginia); LR-2 (a spring in West Virginia); Mark's Run (a stream in West Virginia); a seep at a private residence in West Virginia; and two springs at two private residences in Pennsylvania.

Chart 1. OFF-SITE CONTAMINATION FROM LITTLE BLUE

CONTAMINANT	MEDIUM	STANDARD	SAMPLING DATES	#EXCEED -ANCES	# WELLS	HIGHEST EXCEEDANCE
Arsenic (mg/L)	Groundwater – drinking wells	MCL: 0.01	1993, 2008–2009	5	2	**0.021**
Arsenic (mg/L)	Groundwater	MCL: 0.01	2006–2009	8	6	**0.025**
Barium (mg/L)	Groundwater – drinking wells and tap water	MCL: 2	1993–2005	3	3	**5.98**
Cadmium (mg/L)	Groundwater – drinking well	MCL: 0.005	1996	1	1	**0.85 (total) 0.5 (dissolved)**
Fluoride (mg/L)	Groundwater – drinking well	MCL: 2	2008–2009	3	1	**2.3**
Lead (mg/L)	Groundwater – drinking wells and tap water	Federal Action Level: 0.005	1993–2009	5	5	**1.8 (total) 0.3 (dissolved)**
Turbidity (NTU)	Groundwater – drinking wells	PA MCL: 1	2004-2006	2	2	**40**
Turbidity (NTU)	Groundwater	PA MCL: 1	1993–2009	46	21	**220**
Aluminum (mg/L)	Groundwater – drinking wells	SMCL: 0.2	2009	1	1	**0.711**
Chloride (mg/L)	Groundwater	SMCL: 250	2004–2010	7	7	**1,900**

CONTAMINANT	MEDIUM	STANDARD	SAMPLING DATES	#EXCEED-ANCES	# WELLS	HIGHEST EXCEEDANCE
	– drinking wells					
Chloride (mg/L)	Groundwater	SMCL: 250	2008	5	5	**3,520**
Iron (mg/L)	Groundwater – drinking wells and tap water	SMCL: 0.3	1993–2010	21	10	**29**
Iron (mg/L)	Groundwater	SMCL: 0.3	2008	5	5	**36**
Manganese (mg/L)	Groundwater – drinking wells	SMCL: 0.005	1993–2009	31	19	**2.399**
Manganese (mg/L)	Groundwater	SMCL: 0.005	2008	8	8	**3.27**
pH (standard units)	Groundwater – drinking wells	SMCL: 6.5–8.5	1997–2009	10	2	**8.7**
Sulfate (mg/L)	Groundwater – drinking wells	SMCL: 250	2010	3	1	**910**
Sulfate (mg/L)	Groundwater	SMCL: 250	2007–2009	6	4	**1,710**
TDS (mg/L)	Groundwater – drinking wells	SMCL: 500	1992–2010	15	7	**2,900**
TDS (mg/L)	Groundwater	SMCL: 500	2008	10	10	**7,310**
Antimony (mg/L)	Surface Water	PA Health Criteria: 0.0056	2003	4	1	**0.010**
Arsenic (mg/L)	Surface Water	PA CCC: 0.010	2003-2010	8	3	**0.028**
Boron (mg/L)	Surface Water	PA CCC: 1.6	2008–2010	23	7	**15.200**
Cadmium (mg/L)	Surface Water	PA CCC: 0.00064	2010	1	1	**0.00074**
Hexavalent Chromium (mg/L)	Surface Water	PA CCC: 0.010 PA CMC: 0.016	2003 (average of 3 analyses)	1	1	**0.028**
Lead (mg/L)	Surface Water	PA CCC: 0.01094	2010	2	2	**0.150**
Selenium (mg/L)	Surface Water	PA CCC: 0.0046	1989–2003	2	2	**0.150**
Thallium (mg/L)	Surface Water	PA CCC: 0.00024	2009	1	1	**0.00046**
pH (standard units)	Surface Water	Secondary PA WQC: 6.5–8.5	2007–2010	2	2	**5.5**
Total Suspended Solids (mg/L)	Surface Water	Permit Limit: 60	1989	1	1	**194**

On-site groundwater moving off-site – on-site groundwater contamination includes extensive arsenic contamination, with at least 24 MCL exceedances in at least 14 different wells that were more than 150 feet away from the closest part of Little Blue. All of these samples were taken between 2006 and 2010, after FirstEnergy's expansion of Little Blue. See Chart 2. Fluoride and turbidity MCLs were exceeded 27 and 41 times, respectively. In 1996, lead exceeded the Federal Action Level of 0.015 mg/L with readings of 2.69 mg/L (538 times the MCL) and 1.41 mg/L (282 times the MCL). There were also numerous violations of SMCLs for turbidity, chloride, iron, manganese, and sulfate, and pH was cited for showing an increasing trend at one well in 2003.

On-site surface water moving off-site – on-site surface water contamination moving off-site includes exceedances of PA WQC for arsenic, antimony, hexavalent chromium, selenium, thallium, and boron, with the boron exceedances occurring at least 15 times at 9 downgradient monitoring points: Outfall 001 (discharge to Hayden Run Creek); Outfall 021 (discharge to a stream, Little Blue Run, that discharges to the Ohio River); Outfall 023 (collected seeps/springs to Mill Creek); Outfall 025 (collected seeps/springs to Mill Creek); Outfall 026 (collected seeps/springs to Mill Creek); SW-3 (a seep in Pennsylvania just below the earthen dam); SW-4 (a seep in Pennsylvania just below the earthen dam); S-15 (a spring in Pennsylvania about 1,300 feet from the impoundment); and S-18 (a spring in Pennsylvania). See Chart 2.

Chart 2. ON-SITE CONTAMINATION MOVING OFF-SITE

CONTAMINANT	MEDIUM	STANDARD	SAMPLING DATES	#EXCEED -ANCES	# WELLS	HIGHEST EXCEEDANCE
Arsenic (mg/L)	Groundwater	MCL: 0.01	2006–2010	24	14	**0.036**
Fluoride (mg/L)	Groundwater	PA MCL: 2	1994–2006	27	1	**6.4**
Lead (mg/L)	Groundwater	MCL: 0.015	1996	2	2	**2.69**
Turbidity (NTU)	Groundwater	PA MCL: 1	1993–2008	41	18	**8,800**
Chloride (mg/L)	Groundwater	SMCL: 250	1998–2009	18	15	**5,190**
Iron (mg/L)	Groundwater	SMCL: 0.3	2007–2008	8	8	**6.41**
Manganese (mg/L)	Groundwater	SMCL: 0.05	2007–2008	12	10	**3.77**
Sulfate (mg/L)	Groundwater	SMCL: 250	2007–2009	11	10	**1,980**
Antimony (mg/L)	Surface Water	PA Health Criteria: 0.0056	1998	1	1	**0.012**
Arsenic (mg/L)	Surface Water	PA CCC: 0.010	2008	1	1	**0.013**
Boron (mg/L)	Surface Water	PA CCC: 1.6	1993–2010	15	6	**11.8**
Hexavalent Chromium (mg/L)	Surface Water	PA CCC: 0.01 PA CMC: 0.016	1993, 1998	2	2	**0.02**
Selenium (mg/L)	Surface Water	PA CCC: 0.0046	1993, 2004	2	2	**0.0939**
Thallium (mg/L)	Surface Water	PA CCC: 0.00024	1998	4	3	**0.005**
Aluminum (mg/L)	Surface Water	Secondary PA CCC: 0.75	1993	1	1	**1**

On-site groundwater – despite the fact that most of the on-site monitoring points and wells are "moving off-site" (meaning they are more than 150 feet from the boundary of the impoundment), on-site groundwater also had exceedances of MCLs, including multiple turbidity MCL exceedances and a manganese SMCL exceedances. *See* Chart 3 (for brevity, no SMCL exceedances were included on this chart, although there were many).

On-site surface water – on-site surface water showed an exceedance of the CCC for selenium at SW-3 (a seep in Pennsylvania just below the earthen dam)(exceedances of nonpriority pollutants under PA WQC, such as aluminum, boron, and barium, were not tracked at on-site points). *See* Chart 3.

Chart 3. ON-SITE CONTAMINATION

CONTAMINANT	MEDIUM	STANDARD	SAMPLING DATES	#EXCEEDANCES	# WELLS	HIGHEST EXCEEDANCE
Turbidity (NTU)	Groundwater	PA MCL: 1	1993–2008	6	3	**26**
Manganese (mg/L)	Groundwater	SMCL: 0.05	2008	1	1	**2.37**
Selenium (mg/L)	Surface Water	PA CCC: 0.0046	2004	2	1	**0.0929**

In addition, a monitoring well that appears to be monitoring surface water of the impoundment itself (SW-7) measured exceedances of the PA CCC for arsenic (0.010 mg/L) twice in 2009–2010, with readings of 0.023 and 0.025 mg/L, and it also measured at least six exceedances of the boron PA CCC (1.6 mg/L), with a high reading of 15.7 mg/L. Outfall 507 measured an exceedance of the hexavalent chromium PA CCC (0.016 mg/L), with a reading of 0.026 mg/L in 1998. In addition, thallium measured 0.015 mg/L in 1998 at Outfall 507, exceeding the PA CCC (0.013 mg/L) and the Health Criteria (0.00024 mg/L).

Constituents Involved

Aluminum, antimony, arsenic, barium, boron, cadmium, calcium, chloride, chromium (hexavalent), fluoride, iron, lead, manganese, pH, selenium, sodium, sulfate, total dissolved solids, total suspended solids, thallium, turbidity

At-Risk Population

At least 22 private wells have already been contaminated with CCW pollutants above the primary or secondary MCLs, including the township building's well. FirstEnergy has already purchased several of these contaminated properties and/or supplied the residents thereof with an alternate drinking water supply. Because Greene Township has no public water supplies, every single resident—2,705 people, according to 2000 census data—is drinking private well water. In addition, there are many affected citizens in West Virginia, although comprehensive well data was unavailable for this region. Water degradation may also be migrating across the Ohio River into Ohio, but the community there is on public water.

Incident and Date Damage Occurred / Identified

The Pennsylvania Department of Environmental Protection (PADEP) has long documented the contamination flowing from the Little Blue surface impoundment. From at least 1989 to the present day, FirstEnergy (and previously, Penn Power) has been exceeding permit limits and both State and federal drinking water and surface water standards due to the irresponsible disposal of CCW in the Little Blue impoundment.

Admitted Damage

On February 16, 2010, PADEP sent a letter to FirstEnergy regarding high arsenic levels at 10 groundwater and surface water monitoring points, stating, "According to the data, *elevated levels of Arsenic* were detected in Monitoring Wells MW-13A, MW-15B, MW-16C, MW-17A, MW-20B, MW-23B, SW-5, SW-7, S-17, and S-31" (PADEP, 2010) (emphasis added). In a response letter dated February 24, 2010, FirstEnergy acknowledged the arsenic levels and further stated: "As you will recall, the DEP prepared a similar letter dated December 20, 2007 regarding detectable concentrations of arsenic reported in four monitoring points during the third quarter 2007 sampling event" (FirstEnergy, 2010). FirstEnergy's environmental consultants re-tested arsenic levels to determine whether interference had been causing arsenic spikes, but found that the re-tested "results were comparable."

In 2009, USEPA and FirstEnergy ranked Little Blue as a "High" hazard dam on the National Inventory of Dams, meaning that a failure of the dam "will probably cause loss of human life." (USEPA, 2009).

In 2009, an Annual Operations report prepared by environmental consultants for FirstEnergy states:

Sharp increases in sulfate, chloride, sodium, and specific conductance at MW-6 indicate early signs of supernatant impacts. This well is located along Lewis Road on the southwestern side of the impoundment, and has served as a background well. Due to the placement of CCB in this portion of the impoundment, this well is now located within several feet of the impoundment. Shallow impacted groundwater may be migrating along the soil-bedrock interface or through weathered bedrock in the vicinity of this well and may be short circuiting to deeper zones. Because this well is one of the original monitoring wells installed at the Site (1974), it does not meet current standards for well construction and will be replaced with a new well to prevent the migration of impacted water to deeper zones.

(CEC, 2009). The same 2009 report states that on the ridge east of the impoundment, "Monitoring wells MW-3A and MW-14AR continues[sic] to show increasing concentrations of sulfate, chloride, and sodium indicating possible early signs of supernatant impact." FirstEnergy's consultants go on to state:

On the western side of the impoundment, early signs of supernatant impacts may be evident along Johnsonville Road. At MW-7A and MW-7B, sulfate, chloride, calcium and specific conductance all showed distinct increasing trends in 2008, indicating possible supernatant impacts. . . . Similarly, increasing sulfate concentrations and analysis of the Piper diagrams at wells MW-24 and DW69 indicate possible supernatant impacts. Spring S-30 continues to display increases in sulfate, chloride, sodium, calcium, magnesium and specific conductance, further suggesting signs of supernatant impacts. In addition, newly identified springs in Lawrenceville at locations down gradient of springs S-30 and S-31 appear to display impacts from the impoundment.

The 2007 Annual Report prepared by FirstEnergy's environmental consultants labels each of the following as a "supernatant impacted well": MW-1; MW-2R; MW-3B; MW-9BR; MW-12B; MW-12C; MW-13A; MW-13B; MW-15B; MW-16A; MW-17A; MW-17B; MW-22B; MW-23A: MW-24; SW-3; SW-4; SW-5; S-9A; S-15; and S-17 (CEC, 2007).

In 2003, FirstEnergy's environmental consultants sent a letter to PADEP expressly labeling Monitoring Wells 3B, 13A, and 13B "*Supernatant-Affected Wells*" (CEC, 2003).

In the 1996 Consent Order and Agreement, Penn Power (the owner of Little Blue prior to FirstEnergy) and PADEP admit that "Existing groundwater monitoring data indicate slight groundwater impact from Little Blue Run supernatant. . . relative to background. All quantifiable impacts are of secondary maximum contaminant level ("SMCL") or indicator parameters, including Sodium, Calcium, Chloride, and Sulfate" (PADEP, 1996).

In 1994, FirstEnergy was required to provide a water supply to a private residence, and a PADEP letter to Penn Power admits that the impoundment contaminated and made unusable a private well (PADEP, 1994a):

This result indicates a *continuing upward trend* in levels of sodium, chloride and sulfate which has persisted since 1991. . . .This trend represents a *measurable increase in the concentration of these contaminants and therefore is defined as groundwater degradation.* Since the groundwater gradient is probably from the impoundment supernatant at elevation of 1050' toward the [XXXX] well water elevation at approximately 985', *it is very probable that the impoundment is responsible for this adverse effect on the water supply.*

This letter is notice from the Department that *the operator, Pennsylvania Power Company, is responsible for adversely affecting the water supply of Mr. [XXXX].*"

A 1994 letter from PADEP to the environmental consulting firm states, "*[t]his impoundment is affecting groundwater over a large area with multiple aquifers.*" (PADEP, 1994b) (emphasis added).

As early as 1989, PADEP admitted that chloride measured at 3,530 mg/L (more than 14 times the SMCL of 250) in groundwater is "abnormally high," that calcium levels were "elevated" in three groundwater wells, that both "*can be traced to leaching of surface water through the waste*" at the impoundment, and that "elevated" levels of calcium "*can be associated with the waste disposed at Little Blue.*" (PADEP, 1989b) (emphasis added).

Other Incidents

In 2009, dry conditions on the surface of the impoundment covered nearby residents' homes in a layer of coal ash fugitive dust, prompting an NOV (PADEP, 2009).

In 2007, a PADEP site inspector "noted a white discharge from spring S-2 on the hillside east of the dam face. Photos were taken of the discharge. There was a rotten egg odor in the vicinity of the open channel next to the main access road" (PADEP, 2007).

Twenty gallons of lime slurry discharged into the Ohio River from the Little Blue impoundment in June 1994, although the constituents in the discharge are unknown (Penn Power, 1994a).

In January 1994, 800 gallons of scrubber sludge discharged to the Ohio River from the impoundment, although the constituents in the discharge are unknown. There was also a seepage into Mill Creek in March 1994, the size and constituents of which are unknown (Penn Power, 1994b).

A thick layer of coal ash dust was released from the surface of the Little Blue impoundment as fugitive dust from January 30 to February 4, 1993, and PADEP issued a Notice of Violation for violations of Sections 6.1(a), 6.1(b), and 8 of the Air Pollution Control Act, and Sections 123.1 and 123.2 of 25 Pa. Code §§ 123.1(a) and 123.2 (PADEP, 1993).

A 1991 inspection report noted a milky-white discharge from the distilling pond and from NPDES Outfall 001, and marked "non-compliance" with regard to "Operation in accordance with approved plans" and for "Leachate treatment facilities being operated properly." (PADEP, 1991a). The pH was measured from 8.7 to 9.4. *Id.* A Notice of Violation issued cited violations of sections 302(b)(3), 610(2), and 610(4) of the Pennsylvania Solid Waste Management Act and sections 301 and 307(c) of the Clean Streams Law (CLS) (PADEP, 1991c). The NOV (PADEP, 1991) stated that a:

[W]ater discharge coming from Little Blue Run development area fly ash disposal landfill was discolored and the bottom of the distilling basin was covered with a white sediment. Water samples were taken at the NPDES Permit No. PA0027260, Outfall 001 discharge point. The analysis from these samples showed total suspended solids at 194 mg/l (maximum limit 60 mg/l) and pH 10.5 (maximum limit pH 9), both over the NPDES permit discharge limits and in violation of the above mentioned sections of the PSWMA and the CSL.

On August 30, 1991, 100 gallons of CCW slurry from Little Blue spilled into the sewer (PADEP, 1991b).

An unpermitted discharge violation was reported by Penn Power to PADEP in July 1991 (PADEP, 1991d).

A 1989 Consent Assessment of Civil Penalty stated "[L]eakage at the closed valves of the supernatant/river return pumps resulted in a discharge to Outfall 001. Water samples taken at Outfall 001 discharge point showed suspended solids of 194 mg/l and a pH of 10.5, both which exceed the NPDES permit limits of 60 mg/l for suspended solids and 9 pH." PADEP assessed a $4,000 penalty for this discharge into Mill Creek, but Penn Power paid only $2,500 with a Consent Agreement from PADEP (Penn Power, 1989).

PADEP's regulatory actions have not been aimed at a comprehensive solution to address the ongoing contamination and seepage from Little Blue; rather, PADEP's actions have been aimed at patching small seeps throughout the years. Selected PADEP actions for the Little Blue impoundment include:

February 16, 2010: PADEP sent a letter to FirstEnergy requesting re-sampling of ten groundwater and surface water monitoring points with high arsenic levels and stating, "According to the data, elevated levels of Arsenic were detected in Monitoring Wells MW-13A, MW-15B, MW-16C, MW-17A, MW-20B, MW-23B, SW-5, SW-7, S-17, and S-31" (PADEP, 2010).

March 12, 2009: PADEP issued an NOV for a dusting event that covered many residents' properties with a layer of coal ash on March 4, 2009 (PADEP, 2009).

October 21, 2008: PADEP sent FirstEnergy a letter stating: "The Department's results indicate that sodium and chloride levels are elevated indicating that the surface water point has been impacted by leachate from the impoundment," and required FirstEnergy to select one of three remediation options (PADEP, 2008). As of mid-2010, it is still not clear what remediation option, if any, FirstEnergy has undertaken at Little Blue.

Sept. 19, 2003: PADEP inspection report cites FirstEnergy because "fly ash sludge" was "disposed outside the permit area" in violation of Pennsylvania law; an NOV was issued on September 23, 2003 (PADEP, 2003).

June 21, 1994: Settlement with PADEP for groundwater contamination; *penalty amount N/A* (PADEP, 1994a).

Jan. 30–Feb. 4, 1993: PADEP issued an NOV for fugitive dust violations, *no penalty paid* (PADEP, 1993).

Sept. 3, 1991: PADEP issued an NOV for discoloration of discharge; *no penalty paid* (PADEP, 1991c).

July 31, 1989: PADEP issued an NOV for suspended solids and pH exceedances, *$2,500 penalty paid* (Penn Power, 1996).

FirstEnergy was required to post a $22,219,252 bond for financial assurance in 2006. (PADEP, 2006 (2)).

It is important to note that, through a Memorandum of Understanding entered into in 2006 (when the impoundment was expanded) by PADEP and the West Virginia DEP, PADEP is the lead permitting and enforcement agency for Little Blue, including those parts of Little Blue that lie in West Virginia (WVDEP, 2006).

In addition, PADEP allowed First Energy to obtain a solid waste permit without "mandatory trigger abatement levels" for boron. "Trigger levels" were also removed and replaced with only monitoring requirements for arsenic, cadmium, chromium, copper, lead, magnesium, mercury, selenium, silver, zinc, ammonia-nitrogen, bicarbonate, calcium, chemical oxygen demand, chloride, iron, manganese, pH, potassium, sodium, specific conductance, sulfate, TDS, alkalinity, total organic carbon, and turbidity by the PADEP. *Compare* (PADEP, 1997b *with* PADEP, 1997c). This was supposedly done "because the conditions of the site do not reflect the need for abatement." (PADEP, 1997a).

Flue gas desulfurization sludge, fly ash

Active. FirstEnergy disposes of about *1–3 million gallons of coal ash a day* into Little Blue.

Type(s) of Waste Management Unit

"High" hazard 900–1,300-acre coal ash surface impoundment without a liner. The liner requirement was waived upon promulgation of PA coal ash regulations in 1992, and again with the expansion of the impoundment in 2006, for which FirstEnergy secured a "demonstration" permit. The CCW in Little Blue is kept from spilling into the Ohio River by a 400 foot high earthen dam, the largest of its type in the eastern United States.

Hydrogeologic Conditions

Groundwater monitoring at the Little Blue impoundment identified eight aquifers:

- Shallow Bedrock: Middle Glenshaw Aquifer; Lower Glenshaw Aquifer; Freeport Aquifer; Worthington Aquifer;
- Intermediate Bedrock: Kittanning Aquifer; Clarion Aquifer;
- Deep Bedrock: Homewood Aquifer; and
- Surficial/Unconsolidated: The Regolith and Alluvium Aquifer

(Penn Power, 1997b, *see also* PADEP, 1996). "Groundwater flow patterns at Little Blue Run are a complex, three-dimensional field because of the high relief and complex stratigraphy of the area." *Id.* The company admitted, "These units are not highly permeable, but are more permeable than other units in the stratigraphic series" (Penn Power, 1997b).

The company also stated, "the facility could potentially affect water supplies in the Mill Creek Valley to the east, the Lawrenceville area to the west, and Coffey Road to the south" (Penn Power, 1997b).

The depth in the Glenshaw Aquifer, the "top most saturated statigraphic unit across the site," ranged from 944.7 to 1093.47 ft MSL (Penn Power, 1997c). There are also several small mines below the impoundment in the Lower Kittaning and Freeport seams, which were backfilled with soil or fly ash cement during the impoundment's construction. (Penn Power, 1997b).

Also of note is that Penn Power identified and admitted discharging to three surface water receptors in the vicinity of Little Blue, and stated that groundwater from the impoundment "discharges to springs, which enter Mill Creek, Little Blue Run, and the Ohio River" (Penn Power, 1997c). The impoundment discharges to Mill Creek about 100 yards before the confluence of Mill Creek and the Ohio River. *Id.*

Berea Sandstone lies 600 feet below the base of the impoundment (Rose, 2004).

[illegible]

As of 1996, the 2,460 megawatt Bruce Mansfield plant could generate as much as four million gallons of coal ash a day, all of which is pumped through a seven mile pipeline into the Little Blue surface impoundment (PADEP, 1996). "Constructed between 1973 and 1977, Little Blue Run comprises approximately 1,300 acres in a steep-walled valley." *Id.* "A 9 million cubic yard earth and rockfill dam, the largest embankment dam of its type in the Eastern United States, serves as the enclosure for the waste disposal facility." *Id.* The impoundment spans two states and its waste permit authorizes a dump area of *1,694.9 acres*. (PADEP, 2006a).

The site was expanded in 2006, and, including the buffer areas owned by FirstEnergy, currently occupies over 18% of the landmass of Greene Township (not to mention the many acres in West Virginia). In order to expand the 1,300-acre impoundment, FirstEnergy secured a "demonstration" permit to determine whether specific uses of coal ash solids and geo-tube technology could stabilize the waste site and extend the life of the unit so as to avoid having to expand into greenfield sites. Despite this statement and despite its already increased size, a new 200- to 1,200-acre expansion (the "Little Blue East" site) is being proposed adjacent to the current impoundment (Bauder, 2010c).

Little Blue has a Clean Water Act National Pollutant Discharge Elimination System (NPDES) and Pennsylvania Clean Streams Law permit, Permit No. PA0027481, and a Solid Waste Permit, No. 300558. However, PADEP has granted this site a waiver of the Pennsylvania residual waste regulations that require liners, leachate collection systems, and siting restrictions (PADEP, 1996). The impoundment was thereby also exempted from the requirement to retrofit for a 25-year 24-hour flood (*Id.*),

Bottom ash has also been spread on roads for "dust suppression" since at least 1987 (Penn Power, 1997a; PADEP, 1987).

As part of its expansion efforts, FirstEnergy is currently asking residents living near Little Blue to sign wavers authorizing FirstEnergy to be excused from setbacks in Pennsylvania regulations (Bauder, 2010a).

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PADEP. 1994b. Letter from D.K. Hartner, Hydrogeologist, PADEP, to Robert Johns, Penn Power, Re: Groundwater Assessment, Little Blue Run Development Area (May 26, 1994).

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Entity/Company – Location

Allegheny Energy Supply Company – Hatfield's Ferry Power Station
2907 East Royfurman Highway
Masontown, PA 15461
Greene County
Latitude: 39.853611 Longitude: -79.946389

Determination

Demonstrated damage to groundwater moving off-site and to off-site surface water and aquatic life (in Little Whitely Creek and tributaries)

Probable Cause(s)

Leaching from the coal combustion waste (CCW) landfill to groundwater and discharges of CCW leachate into streams

Summary

An unlined CCW landfill located off-property from the Hatfield's Ferry Power Plant has contaminated groundwater, polluted surface water, and damaged aquatic ecosystems since at least 2001. Federal groundwater Maximum Contaminant Levels (MCLs) standards for arsenic, aluminum, boron, chromium, manganese, molybdenum, sulfate, and total dissolved solids (TDS) have been exceeded since at least 2001. Concentrations of groundwater contaminants mirror those in CCW leachate samples from the landfill collected at the same time. The horizontal extent of contamination has not yet been defined.

For example, since at least 2005, arsenic has repeatedly exceeded the MCL in three wells hundreds of yards south and east of the landfill, with total concentrations as much as 342 times the MCL and dissolved concentrations more than 11 times the MCL. Allegheny Energy's wetland treatment system for CCW leachate is ineffective at treating several parameters indicative of CCW leachate – notably aluminum, boron, manganese, molybdenum, sulfate, thallium, and TDS – resulting violations of permit limits and continued harmful discharges to the receiving stream in violation of Pennsylvania Water Quality Criteria (WQC) for boron. In addition, a stream habitat and macroinvertebrate survey of four streams emanating from the landfill property shows that two streams closest to the CCW landfill are impaired by CCW leachate from the landfill.

Surface Water

The Hatfield's Ferry CCW landfill was permitted as a 40-acre unlined disposal site in May, 1984. From 1984 until 2001, CCW leachate and shallow groundwater that contacted CCW was directed, without any treatment, to an earthen impoundment, and then discharged into an unnamed tributary of Little Whiteley Creek. The Pennsylvania Department of Environmental Protection (PADEP) determined that the CCW leachate discharges were the causes of exceedances of the effluent limitations in the NPDES permit for the landfill (Allegheny, 2006b). Allegheny Energy began operating a passive wetland treatment system for CCW leachate in Spring 2001. The wetland treatment system was designed to remove or reduce concentrations of iron, aluminum, manganese, and total suspended solids and to control pH (Allegheny, 2006b) – but was not specifically designed to treat other problematic constituents in CCW leachate. The PADEP issued a Consent Order and Agreement in March 2008 (PADEP, 2008) because of continued violations of aluminum, manganese, and thallium NPDES effluent limits from November 2003 to August 2007 associated with the wetland treatment system (Allegheny, 2008). Maximum concentrations during that period, compared to the NPDES permit limits, are:

- **Aluminum** – a 3.459 mg/L concentration versus a daily maximum permit limit of 1.2 mg/L permit limit; a 0.962 mg/L monthly average concentration versus a 0.6 mg/L permit limit for monthly average (April 2007).
- **Manganese** – a 2.623 mg/L concentration versus a daily maximum limit of 2.4 mg/L (Feb. 2004); a 1.45 mg/L monthly average concentration versus a 1.2 mg/L limit for monthly average (January 2004).
- **Thallium** – a 0.0062 mg/L concentration versus a daily maximum limit of 0.0042 mg/L; a 0.0028 mg/L monthly average concentration versus a 0.0021 mg/L limit for monthly average (August 2005).

The PADEP in-stream Human Health Water Quality Criteria for thallium is 0.00024 mg/L, which is an order of magnitude less than the 0.0021 mg/L monthly average and 0.0042 mg/L daily maximum concentrations allowed in the NPDES permit. The wetland treatment system discharge is likely a large percentage of the total flow volume of the unnamed tributary of Little Whiteley Creek, with little dilution afforded in its receiving waters. This raises concern that the concentrations violating the permit limits from 2003 to 2007, if not the permit limits themselves, might allow for thallium to be discharged in concentrations causing regular exceedances of the human health criterion for thallium (0.00024 mg/L) in the unnamed tributary.

Although the 2008 Consent Order addressed NPDES permit exceedances for thallium, the CCW landfill permit does not require that thallium be analyzed in groundwater, in CCW leachate, or at surface water monitoring points. Thallium testing (weekly) is only required for NPDES monitoring associated with the discharge from the wetland treatment system.

Monitoring results for the discharges from CCW leachate collection sumps to the treatment system and surface water monitoring stations were reviewed for April / May 2002 data (Allegheny, 2002), one year after the treatment system was installed, and for April / May 2006 (Allegheny, 2006a). The results show that discharges to the unnamed tributary of Little Whiteley Creek from the wetland treatment system are still indicative of inadequately treated CCW leachate.

Background concentrations of CCW parameters in Little Whiteley Creek approximately 200 feet upstream from its confluence with the unnamed tributary that originates at the landfill (LW-1U), the unnamed tributary prior to reaching Little Whiteley Creek (UT-1D), and the combined flow downstream in Little Whiteley Creek (LW-2D), were compared in the chart below The results showed concentrations exceeding the PA WQC chronic concentration (Criteria Continuous Concentration, or CCC) for boron (1.6 mg/L) in the receiving stream (the unnamed tributary) by 2.6 to 5.3 times which became worse in 2006 and 2008 despite treatment of the leachate in the wetland system. In addition, all three years of boron measurements in this stream also exceeded the U.S. Environmental Protection Agency's (USEPA) Child Health Advisory for boron (3 mg/L), with the 2006 and 2008 concentrations more than twice as high as this Advisory and also exceeding the Life-time Advisory for boron of 6 mg/L).

There were also high and increasing concentrations of molybdenum, sulfate, and TDS (for which there are no PA WQC) in this receiving stream, and there were elevated concentrations of all of these pollutants, including boron, in Little Whitely Creek downstream of the confluence with the unnamed tributary. Finally there were increasing concentrations of calcium and magnesium which are highly soluble parameters frequently found in coal ashes. Note in the table below:

* LW-1U is upstream Little Whiteley Creek (reference sample).

* UT-1D is the unnamed tributary from the landfill.

* LW-2D is downstream from the unnamed landfill tributary's confluence with Little Whiteley Creek.

Parameter	**April / May 2002 (mg/L)**			**April / May 2006 (mg/L)**			**May 2008 (mg/L)**		
	LW-1U Upstream	UT-1D from landfill	LW-2D Down-stream	LW-1U Upstream	UT-1D from landfill	LW-2D Down-stream	LW-1U Upstream	UT-1D from landfill	LW-2D Down-stream
Boron	0.04	**4.24**	0.142	0.082	**7.171**	0.381	0.130	**8.428**	0.523
Calcium	36	229	42.2	46.5	334	61	64	347	78
Magnesium	9.8	87.2	12.54	13.57	133	20.87	18	149	26
Manganese	0.251	0.355	0.288	0.103	0.275	0.117	0.114	0.150	0.287
Molybdenum	N.D.	**0.097**	N.D	0.0055	**0.486**	0.016	0.0095	**0.49**	0.0047
Sulfate	53.3	860	78	85.6	1,137	157	92	1,256	180
TDS	216	1,397	216	238	2,179	339	311	2,537	410
Alkalinity (as $CaCO_3$)	72.2	197	80.4	84	241	103	114	221	122

While there is no numeric water quality criteria for molybdenum in Pennsylvania surface waters, the concentrations in the unnamed tributary from the landfill readily exceed USEPA's Health Advisory for ingestion of molybdenum in drinking water. All three years of molybdenum measurements exceed both the Child 10-day (0.080 mg/L) and Lifetime Health Advisory (0.040 mg/L) limits, with the 2006 and 2008 concentrations exceeding the Child Health Advisory by 6 times and the Lifetime Health Advisory by more than 12 times.

In addition, there are four perennial streams that emanate from shallow groundwater around the CCW landfill and flow off-site into larger streams that have a protected use for aquatic life (GAI, 2006). A 2006 habitat and stream survey shows that CCW leachate from Phases 1 and 2 of the landfill have degraded the two streams closest to the landfill. Of the four streams, the stream sections with the healthiest benthic macroinvertibrate community structure were the downstream portions of the unnamed tributary to the southwest (discharges to Little

Whitely Creek north of the unnamed tributary that the landfill flows into) and the unnamed tributary to the southeast (discharges to the Monongahela River) – both being the farthest from the landfill. The entire unnamed tributary stream section that receives treated (and historically untreated) leachate from the landfill is impaired, containing only organisms that are tolerant to pollution and having a concreted bottom from an unknown chemical compound. The unnamed tributary nearest Phase 2 of the landfill and along the landfill haul road was also severely impaired, having only organisms that are tolerant to pollution. GAI Consultants, Inc. concluded that both unnamed tributaries nearest the CCW landfill are indicative of polluted water or disturbed habitat.

Surface water and stream assessment results show that discharges from the landfill violate PADEP regulations setting general water criteria for protecting surface waters. Those criteria do not allow "*point or non-point source discharges in concentrations or amounts sufficient to be inimical or harmful to the water uses to be protected or to human, animal, plant, or aquatic life*" or for a substance to "*to settle or form deposits.*"

In addition, Allegheny Energy monitors discharges from each CCW leachate collection sump annually as a condition of its landfill permit. The data show what parameters and concentrations were likely discharged continually into the unnamed tributary from the beginning of the landfill's operation in 1984 to 2001, before the wetland treatment system was installed. When the leachate sump data are compared to the upstream Little Whiteley Creek upstream reference sample (LW-1U, see table above), the concentrations are substantially higher for every parameter at the sumps, as follows. For reference, if PA WQC were compared to the leachate sump water (to which PA WQC would not apply), concentrations of boron would be exceeding the CCC by at least a factor of 10 in every single reading in the table below.

Parameter	April / May 2002 CCW Leachate Sump Results (mg/L)		April / May 2006 CCW Leachate Sump Results (mg/L)		May 2009 CCW Leachate Sump Results (mg/L)	
	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2
Boron	16.74	18.37	16.91	18.61	16.75	16.29
Calcium	539	549	471	498	539	528
Magnesium	275	218	327	100	214.6	213
Manganese	13.12	5.13	11.59	2.97	5.10	4.92
Molybdenum	0.428	1.013	0.039	4.50	1.267	1.295
Sulfate	2,275	2,260	2,328	2,230	2,236	2,272
TDS	3,843	3,724	3,938	3,931	3,596	3,591
Alkalinity (as $CaCO_3$)	349	289	355	195	254	258

Allegheny Energy conducts groundwater monitoring on a semi-annual basis; however, it only samples metals once per year. With the exception of molybdenum, the groundwater results are generally similar to the CCW leachate sump data and samples of the tributary downstream from the leachate treatment wetland discharge – indicating that the groundwater has been substantially affected by CCW leachate. A summary of CCW parameter results for the April / May 2006 and the May 2009 groundwater monitoring event for shallow mine spoil aquifer and rind aquifer wells downgradient of CCW at Phases 1 and 2 is as follows:

Parameter	MW-202B (mg/L)		MW-203B (mg/L)		MW-204B (mg/L)		MW-206A (mg/L)		MW-207A (mg/L)		Standard (mg/L)
	2006	2009	2006	2009	2006	2009	2006	2009	2006	2009	
Boron	**13.73**	**12.69**	1.433	**2.594**	**11.76**	**14.570**	**12.09**	**13.25**	**13.25**	**13.88**	1.6
Calcium	599.2	571	327	368	593	633	552	539	534	514	-
Magnesium	288	287	78	91	273	321	447	363	564	559	-
Manganese	**0.586**	**1.12**	**1.33**	**0.792**	<0.005	<0.005	**2.45**	**1.50**	**0.774**	**1.39**	0.05
Molybdenum	0.016	<0.001	0.002	<0.001	0.0015	<0.001	<0.001	0.002	0.003	0.001	0.04
Sulfate	**1,877**	**1,973**	**579**	**842**	**1,871**	**2,275**	125	**2,253**	**2,996**	**2,899**	250
TDS	**3,629**	**3,491**	**1,448**	**1,703**	**3,543**	**3,895**	**4,327**	**3,837**	**4,925**	**4,634**	500
Alkalinity (as $CaCO_3$)	442	446	410	368	476	477	479	465	523	503	-

Note: standards for boron and molybdenum are USEPA Lifetime Health Advisory concentrations

Concentrations of boron exceeded the U. S. Environmental Protection Agency's (USEPA) Health Advisory; manganese exceeded the SMCL in four of five shallow wells in two aquifers; and sulfate and TDS exceeded the SMCLs in all five of the wells. Groundwater results for five Benwood Limestone aquifer wells for the same years (the deepest aquifer on-site, MW-201C, MW-202C, MW-203C, MW-5C, and MW-208C) were not tabulated above but they contained no boron concentration greater than 0.268 mg/L; no sulfate concentration greater than 171 mg/L; and the highest TDS concentration was 1,766 mg/L – all three parameters at average concentrations substantially less than those in the overlying rind and shallow mine spoil aquifers.

Allegheny Energy has concluded that shallow groundwater flow directions mimic the ground surface. The only wells installed in the mine spoil aquifer, MW-206A and MW-207A, are located just south of the Phase 1 and 2 disposal areas but north of Phase 3 and the former Hartley mine ash disposal area, and are used as "upgradient" wells for the landfill monitoring program. Although Allegheny Energy has concluded, according to their hydrogeologic characterization, that groundwater in the mine spoil aquifer flows south-to-north and intermixes with the rind aquifer to the north (wells MW-202B, MW-203B, and MW-204B) (Allegheny, 2006b), wells MW-206A and MW-207A are actually situated downgradient of Phase 3 of the landfill and at least in part, downgradient from Phases 1 and 2 of the landfill. Allegheny Energy, also the generator of the coal ash placed in the Hartley mine on the south side of the CCW landfill, stated in an August 20, 1997 revision to an application to modify the permit for the landfill, that the elevated concentrations of boron in MW-206A and MW-207A were "due to the fact that fly ash has been co-disposed with mine spoil in the upgradient area, in addition to the permitted disposal area" (CATF, 2007).

Molybdenum, a classic coal ash indicator metal, has been found in on-site wells near the CCW landfill and downgradient from the former Hartley mine coal ash disposal site – in addition to being in surface waters leaving the permitted landfill and in leachate. The concentration of molybdenum in MW-1, located downgradient of the mine disposal site, was 0.190 mg/L in September 1998 and 0.0115 mg/L in MW-207A in August 1997 (CATF, 2007).

Given that the groundwater at MW-206A and MW-207A has been contaminated with ash constituents, there is no unaffected upgradient background well with which to compare downgradient landfill well results. MW-206A and MW-207A are situated where groundwater flows radially to the west, north, and east from the crest of the landfill property (Allegheny, 2006b), in addition to being downgradient from a portion of the strip mine where ash was placed. Neither the easterly nor westerly groundwater flow component is completely monitored.

As a condition of the Phase 3 landfill expansion, six additional rind aquifer monitoring wells were installed downgradient of a new lined leachate storage impoundment northeast of Phases 1 and 2, near the landfill haul road, and south of Phase 3 near the former Hartley Mine coal ash disposal area. None of the new wells were located east or west of Phase 3 in the indicated direction of groundwater flow that mimics the ground surface, according to Allegheny. A summary of the data collected in December 2009 for the new wells shows that the highest contamination in the new wells is downgradient of Phases 1 and 2 of the landfill and the new lined leachate collection sump for Phase 3 (Allegheny, 2010b), as follows:

	New Groundwater Monitoring Wells (December 2009)						
Parameter	MW-212A	MW-213A	MW-215A	MW-216A	MW-217A	MW-218A	Standard
Aluminum	**1.23**	**7.13**	0.082	**0.282**	**1.7**	**79.3**	0.2
Arsenic	0.002	**0.184**	<0.002	<0.002	**0.040**	**1.68**	0.01
Boron	3.031	**6.12**	**12.66**	**7.38**	**22.02**	**31.7**	6
Calcium	71	233	412	325	664	879	-
Chromium	0.006	0.007	<0.002	<0.002	**0.104**	illegible	0.1
Magnesium	28	14	300	91	1.66	18.8	-
Manganese	**0.183**	**0.55**	**2.5**	**29**	0.018	**0.548**	0.05
Molybdenum	<0.001	**0.174**	0.002	0.002	**0.46**	**1.31**	0.04
Sulfate	**769**	**323**	**1,999**	**1,136**	**1,480**	**1,512**	250
TDS	**1,712**	**702**	**3,424**	**1,816**	**2,380**	**2,412**	500
Alkalinity (as $CaCO_3$)	545	210	371	80	<5	<5	-

Samples collected from well MW-213A, downgradient of coal ash in the Hartley Mine and more than a thousand yards south of Phases 1 and 2 of the landfill and from MW-217A, and MW-218A, more than 500 yards east of waste placement areas in the landfill, show that arsenic concentrations well above the MCL have been measured beyond the site in downgradient groundwater since at least 2005 (Allegheny, 2010a). Total arsenic concentrations exceeded the MCL in 19 of 19 sampling events from 2005 to 2010 for these three wells; dissolved arsenic concentrations in MW-213A exceeded the MCL 17 of 19 events; and dissolved arsenic in MW-217A and MW-218A exceeded the MCL 19 of 19 events. The range of arsenic concentrations in these wells from September 15, 2005 to the March 3, 2010 sampling event is as follows:

Parameter	MW-213A (mg/L)	MW-217A (mg/L)	MW-218A (mg/L)	Standard (mg/L)
Total Arsenic	**0.089 – 0.537**	**0.036 – 0.8396**	**0.077 – 3.419**	0.010
Dissolved Arsenic	0.008 – **0.0428**	**0.0131 – 0.0353**	**0.0276 – 0.1136**	0.010

The concentrations of CCW parameters in MW-217A and MW-218A and their locations show an easterly groundwater flow direction beyond the landfill – a flow direction that was not monitored until 2005. This easterly flow is still not monitored for the newest phase of the landfill (Phase 3). Further, there are no wells downgradient from MW-217A and MW-218A defining the horizontal extent of the contamination towards the Monongahela River from Phases 1 and 2.

Constituents Involved

Aluminum, arsenic, boron, chromium, iron, manganese, molybdenum, thallium, total dissolved solids, and sulfate

At-Risk Populations

There are 7 private drinking water wells and one public drinking water well within a two-mile radius of the Hatfield's Ferry CCW disposal areas. Well log locations were obtained from Pennsylvania's Groundwater

Database (PAGWIS). This data set is updated on a county by county basis once every six months and only includes well records with latitude and longitude coordinates assigned to the well. Because many private wells in Pennsylvania may be registered with a township but not necessarily the Commonwealth, this data is likely incomplete.

Incident and Date Damage Occurred / Identified

Violations of NPDES permit limits were first cited in November 2003, exceedances of the PA WQC for boron have been recorded since at least 2001, and exceedances of MCLs and health advisories in groundwater have been measured from at least as far back as April 2001.

Regulatory Actions

PADEP entered into a Consent Order and Agreement (COA) with Allegheny Energy in March 2008 because of NPDES permit violations (PADEP, 2008). Specifically, from November 2003 to August 2007, Allegheny Energy violated permit effluents limits for aluminum, manganese, and thallium in its discharge to an unnamed tributary of Little Whiteley Creek from its wetland treatment system (Allegheny, 2008). The COA required that Allegheny Energy submit a corrective action plan within 180 days to achieve permit limitations in all affected outfalls. The COA also allows Allegheny Energy two years to implement corrective actions for the wetland discharges once the proposed corrective action is approved or once the Phase 3 landfill expansion is issued, whichever is later.

PADEP received a corrective action plan from Allegheny Energy on September 24, 2008, which stated that the permit exceedances were due to leachate overflows from the sedimentation basin due to force main malfunctions, stormwater containing fly ash during heavy rains, and the inherent "analytical result variance" of the thallium analytical method itself. None of the corrective actions were blamed on the inability of the wetland treatment system to treat CCW. The substance and effectiveness of Allegheny Energy's measures to stop continued violations of NPDES permit limits are still unclear.

Fly ash, bottom ash, pyrites, wastewater treatment sludges, pond sediments, refractory materials, and sandblasting media from the Hatfield's Ferry Power Plant. In addition, flue gas desulfurization (FGD) sludges from the plant have been disposed in the landfill beginning in approximately 2007 (PADEP, 2007).

The Hatfield's Ferry plant began operating in 1969, and PADEP issued the first CCW landfill permit for the site on May 7, 1984 (PADEP, 2007). The landfill permit authorized the disposal of CCW within a 40-acre unlined area designated as Phase 1 and Phase 2. Allegheny Energy also disposed of CCW in the Hartley strip mine, located on adjoining property to the south. (CATF, 2007)

CCW Landfill Phases 1 and 2 were constructed with a leachate collection system to gather water infiltrating through the CCW and an under-drain system to remove groundwater from the coal ash (Allegheny, 2006b). The underdrain system was designed to "collect and segregate springs and seep flow from the former strip mine area from the CCB (coal combustion byproduct) leachate" (Allegheny, 2008). Leachate and shallow groundwater collected from Phases 1 and 2 are discharged into a tributary to Little Whiteley Creek after treatment in the wetland treatment system which consists of one equalization basin, four geosynthetic clay lined wetland cells, five rock drain cells, and a sedimentation pond.

In 1998, the PADEP re-permitted the site, expanding it to 187 acres, allowing additional waste streams to be disposed there, expanding the monitoring system, and authorizing operation of the landfill through March 2008.

The Hatfield's Ferry Plant added FGD units (scrubbers) in 2007, resulting in 1.8 million more tons of CCW being sent annually to the landfill (PADEP, 2007). PADEP approved the Phase 3 expansion on May 4, 2009 with a design that includes a geocomposite liner for the expansion. The footprint of Phase 3 is 110 acres, almost 17 acres of which will overlie unlined portions of Phases 1 and 2.

Active

Four aquifers have been identified at the landfill: a mine spoil aquifer located to the south of Phases 1 and 2; a rind aquifer consisting of weathered bedrock; a deeper Uniontown Sandstone aquifer; and an even deeper Benwood Limestone aquifer (GAI, 2001). Groundwater flow directions within the mine spoil and rind aquifers are generally in the same direction as the ground surface topography – discharging to the west, north, and east along the top of bedrock and along a covered stream valley that discharges to the Monongahela River south of Phases 1 and 2. Groundwater within the Uniontown and Benwood formations generally flows to the northwest towards bedrock outcrop areas and eventually mixes with mine spoil and rind aquifer groundwater. Shallow groundwater flow in the bedrock is due to natural stress fractures in the bedrock and from secondary fractures from strip mining. The groundwater flow rates are reportedly very high, especially near stream valleys and bedrock outcrop areas – with maximum seepage velocities of 149 feet per year for the mine spoil aquifer, 735 feet per year for the rind aquifer, 735 feet per year for the Uniontown Sandstone aquifer, and 137 feet per year for the Benwood Limestone aquifer (Allegheny, 2006b). The landfill site is a recharge area for each underlying aquifer (Allegheny, 2006b).

Four streams around the landfill perimeter originate from shallow groundwater that emanates at springs or wetlands. Those streams are located to the north, northeast, southeast, and southwest – indicating that groundwater flow emanates radially from the landfill that is located on higher ground elevations. All of the streams are perennial streams classified as Warm Water Fisheries (WWF) under PADEP regulations and have a protected use for aquatic life (GAI, 2006).

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Entity Company - Location

Otter Tail Power - Big Stone Power Plant
48450 144th Street
Big Stone City, SD 57216
Grant County
Latitude: 45.305833 Longitude: -96.490278

Determination

Demonstrated damage to groundwater moving off-site (at northern and eastern property boundaries and south toward the Whetstone River)

Probable Cause(s)

Leaching of coal combustion waste (CCW) contaminants from CCW disposal units, ponds, and impoundments

Summary

The Big Stone Power Plant's CCW landfill, bottom ash pond, and seven other waste disposal ponds have contaminated groundwater in excess of groundwater quality standards in 21 of 25 wells monitoring two separate aquifers. Exceedances have been measured in downgradient groundwater for arsenic at more than 13 times the federal MCL at 0.1322 mg/L, boron up to 34 times the federal Lifetime Health Advisory Level at 204 mg/L, lead up to 7 times the federal Action Level at 0.1086 mg/L, strontium up to 1.5 times the federal Lifetime Health Advisory at 6.03 mg/L, chloride up to 13 times the federal Secondary MCL (SMCL) at 3,330 mg/L, and sulfate up to 112 times the state standard and 224 times the federal SMCL at 56,000 mg/L.

Groundwater data from the cooling water pond and the evaporation pond demonstrate contamination at the property lines. South Dakota Department of Environment and Natural Resources Solid Waste officials insist that contamination is coming from the concentration of water softener brine wastes, but the unprecedented concentrations of sulfate, boron and strontium in the groundwater at this site that are specifically designated as ash monitoring parameters by the waste permit, indicates CCW is playing a major part in this pollution.

Furthermore, groundwater contour maps indicate that pollution is moving off-site yet no off-site monitoring or sampling of surface waters has occurred despite state records indicating more than 100 private and public wells are within five miles of the site. In addition groundwater from the site discharges into nearby surface waters (Whetsone River and Big Stone Lake) that have multiple designated uses.

[illegible]

Annual groundwater monitoring reports provided by the South Dakota Department of Environment and Natural Resources (DENR) Waste Management Program from 2007 through 2009 were reviewed (DENR, 2007; DENR, 2008; DENR, 2009). The groundwater monitoring program consists of 25 wells, 17 of which are screened at shallow depths and 8 of which are screened at intermediate depths. Many wells are nested together to provide an indication of vertical contaminant transport. The wells are situated at CCW disposal units east of Big Stone Power Plant. Not all CCW ponds and impoundments at Big Stone have a permit, and not all CCW disposal units are monitored. None of the groundwater monitoring wells examined in this report could be considered "upgradient" of CCW waste disposal units or CCW ponds.

In general, Big Stone's groundwater monitoring wells are sampled quarterly; however, not all wells are sampled in every event, and the list of parameters varies for four different groups of wells (H-Series, BC-Series, S-Series, and Well-Series wells). The H-Series wells monitor water flowing in the center of the site underneath and between the cooling pond, the ash landfill and pond and evaporation and holding ponds. The BC and S series wells monitor water in the southwestern part of the site downgradient of the brine ponds and cooling water pond and possibly a separate bottom ash pond and lime sludge ponds located further to the west which are otherwise entirely unmonitored. And Well-Series wells monitor water in the southeastern part of the site downgradient of the holding water pond. Only dissolved and no total analyses for metals was done for samples from wells at the ash pond and landfill, which may account for why these wells were the only wells at Big Stone that did not show exceedances of MCLs for arsenic or lead. Both dissolved and total metal exceedances were reported from other wells in 2007 and 2008 before analysis of total concentrations for trace metals was eliminated from all monitoring in 2009.

A review of Big Stone's groundwater monitoring data reveals the following elevated concentrations and exceedances of South Dakota Groundwater Quality Standards (Chapter 74:54:01), used by South Dakota Department of Environment and Natural Resources (DENR), and federal MCLs in on-site groundwater downgradient of CCW disposal areas:

- **Arsenic** concentrations exceeded both the DENR standard and federal MCL (0.01 mg/L) in 11 wells in both the shallow and intermediate aquifers, with the highest measurement exceeding the standard by more than 13 times. The highest arsenic concentrations were reported in the brine pond wells, and the wells with the highest concentrations (S-2, BC-2, BC-3, and BC-4) of arsenic generally corresponded to those with the highest concentrations of boron, lead, sulfate, and chloride. The MCL for arsenic was exceeded for both dissolved and total metals results.
- **Boron** concentrations – exceeded the EPA Lifetime Health Advisory Level (6 mg/L) (EPA, Boron) in 8 wells in the shallow aquifer. The highest concentrations, up to 34 times the Health Advisory level, were reported in wells near the brine ponds, the cooling water pond, and the ash pond. The wells

with the highest concentrations of boron generally corresponded to those with high arsenic, lead, sulfate, and chloride levels.

- **Lead** concentrations – exceeded both the DENR standard and federal MCL (0.015 mg/L) for total lead in 4 wells in the shallow aquifer. The highest concentrations, up to 7.2 times above the MCL, were reported in wells near the brine ponds and the southeastern corner of the cooling water pond area.
- **Sulfate** concentrations – exceeded the DENR standard (500 mg/L) as well as the federal SMCL (250 mg/L) in 19 wells in both the shallow and intermediate aquifers. High sulfate concentrations were reported in wells near the brine ponds, the ash pond, the evaporation pond, the cooling water pond, and the holding pond. However, concentrations ranging from 24,300 to 56,000 mg/L (the latter being 112 times the DENR standard and 224 times the SMCL) in the brine pond wells were more than an order of magnitude higher than sulfate in other wells - attesting to an extreme level of degradation in shallow groundwater around the brine ponds.
- **Chloride** concentrations – exceeded the DENR standard and federal SMCL (250 mg/L) in 7 wells in the shallow aquifer. The highest concentrations, up to 13 times this standard, were reported in the shallow groundwater in the brine pond area.
- **Strontium** concentrations – exceeded the EPA Lifetime Health Advisory level of 4 mg/L in two shallow aquifer wells located near the brine ponds where the highest concentrations of other constituents were reported.
- **Total Dissolved Solids** – exceeded the DENR standard (1,000 mg/L) as well as the federal SMCL (500 mg/L) in wells downgradient of the ash pond, the ash landfill, and the holding pond area wells – the only samples where TDS was analyzed (2007 only). Although TDS was not measured near the brine ponds, TDS levels should be higher in wells near the brine pond wells that have had very high sulfate and chloride concentrations.

A tabulated summary of the highest reported concentrations for each well above the DENR standard for the 3 reporting years is as follows (DENR, 2007; DENR, 2008; DENR, 2009):

Well Name Aquifer	2007 Result (highest > std.)	2008 Result (highest > std.)	2009 Result (highest > std.)
H2-OX Shallow aquifer	3,200 mg/L sulfate	2,530 mg/L sulfate	2,790 mg/L sulfate
H3-OX Shallow aquifer	10.5 mg/L boron 2,040 mg/L sulfate	10.9 mg/L boron 1,950 mg/L sulfate	14 mg/L boron 2,540 mg/L sulfate
H3-I Intermediate aquifer	900 mg/L sulfate	854 mg/L sulfate	925 mg/L sulfate
H4-I Shallow aquifer	1,140 mg/L sulfate	1,120 mg/L sulfate	1,510 mg/L sulfate
H4-OX Shallow aquifer	1,550 mg/L sulfate	1,330 mg/L sulfate	1,770 mg/L sulfate
S-1 Shallow aquifer	0.0382 mg/L arsenic 25.4 mg/L boron 2,800 mg/L chloride 39,000 mg/L sulfate	0.0334 mg/L arsenic 22.8 mg/L boron 2,580 mg/L chloride 47,100 mg/L sulfate	23.9 mg/L boron 2,940 mg/L chloride 34,500 mg/L sulfate
S-2 Shallow aquifer	0.0499 mg/L arsenic 42.2 mg/L boron 3,020 mg/L chloride 47,000 mg/L sulfate	0.0466 mg/L arsenic 52.3 mg/L boron 2,960 mg/L chloride 54,200 mg/L sulfate	0.0210 mg/L arsenic 50.7 mg/L boron 3,330 mg/L chloride 52,300 mg/L sulfate
S-3 Intermediate aquifer	0.0222 mg/L arsenic 733 mg/L sulfate	0.0201 mg/L arsenic 807 mg/L sulfate	0.022 mg/L arsenic 510 mg/L chloride 951 mg/L sulfate
S-4	0.0113 mg/L arsenic		

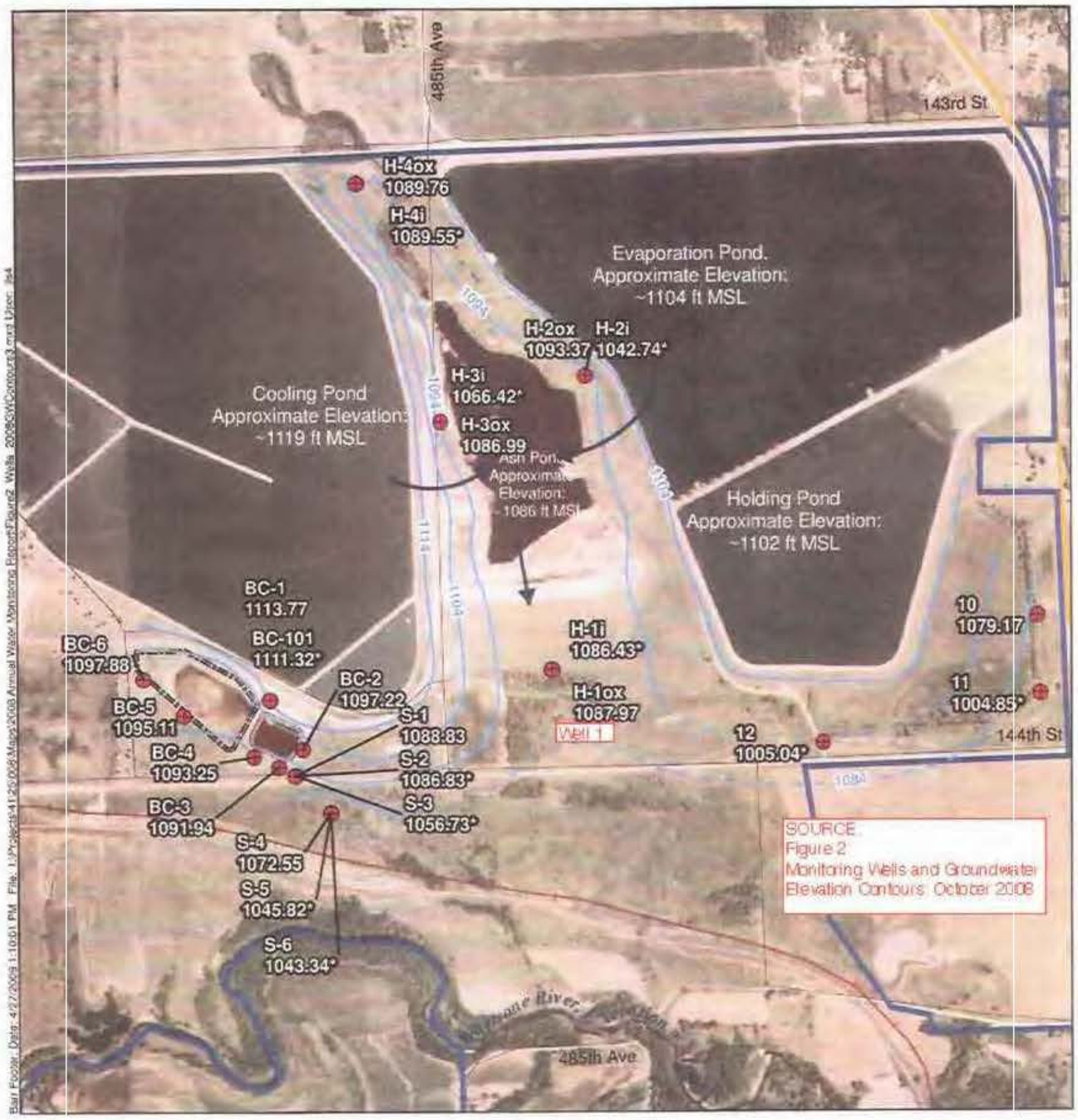
Well Name Aquifer	2007 Result (highest > std.)	2008 Result (highest > std.)	2009 Result (highest > std.)
Shallow aquifer	298 mg/L chloride 1,520 mg/L sulfate	301 mg/L chloride 1,600 mg/L sulfate	334 mg/L chloride 2,050 mg/L sulfate
S-5 Intermediate aquifer	No samples collected	899 mg/L sulfate	1,040 mg/L sulfate
BC-1 Shallow aquifer	0.0352 mg/L arsenic 7.41 mg/L boron 0.0189 mg/L lead 2,250 mg/L sulfate	0.0204 mg/L arsenic 8.52 mg/L boron 0.0417 mg/L lead 1,250 mg/L sulfate	4.21 mg/L boron 1,430 mg/L sulfate
BC-101 Shallow aquifer	0.1322 mg/L arsenic 0.1086 mg/L lead 1,250 mg/L sulfate	0.0395 mg/L arsenic 0.0290 mg/L lead 1,150 mg/L sulfate	1,330 mg/L sulfate
BC-2 Shallow aquifer	0.0378 mg/L arsenic 172 mg/L boron 2,400 mg/L chloride 51,900 mg/L sulfate 5.69 mg/L strontium	0.0342 mg/L arsenic 84.50 mg/L boron 2,260 mg/L chloride 45,600 mg/L sulfate 4.94 mg/L strontium	69.4 mg/L boron 1,900 mg/L chloride 29,600 mg/L sulfate 4.2 mg/L strontium
BC-3 Shallow aquifer	0.0296 mg/L arsenic 65.1 mg/L boron 2,200 mg/L chloride 30,000 mg/L sulfate	0.0298 mg/L arsenic 46.1 mg/L boron 2,050 mg/L chloride 25,300 mg/L sulfate	36.3 mg/L boron 2,100 mg/L chloride 24,800 mg/L sulfate
BC-4 Shallow aquifer	0.0524 mg/L arsenic 204 mg/L boron 2,190 mg/L chloride 56,000 mg/L sulfate 6.03 mg/L strontium	0.0543 mg/L arsenic 194 mg/L boron 1,970 mg/L chloride 54,400 mg/L sulfate 5.56 mg/L strontium	126 mg/L boron 690 mg/L chloride 24,300 mg/L sulfate
BC-5 Shallow aquifer	0.0364 mg/L arsenic 28.6 mg/L boron 0.0429 mg/L lead 649 mg/L chloride 8,800 mg/L sulfate	0.0374 mg/L arsenic 14.1 mg/L boron 0.0296 mg/L lead 495 mg/L chloride 7,450 mg/L sulfate	15.4 mg/L boron 390 mg/L chloride 6,060 mg/L sulfate
BC-6 Shallow aquifer	0.0463 mg/L arsenic 0.0321 mg/L lead 1,850 mg/L sulfate	0.0318 mg/L arsenic 0.0349 mg/L lead 1,640 mg/L sulfate	1,800 mg/L sulfate
Well 1 Unknown aquifer	1,550 mg/L TDS 868 mg/L sulfate		
Well 10	620 mg/L TDS	No metals analyses	No metals analyses
Well 11 Intermediate aquifer	1,380 mg/L TDS 650 mg/L sulfate	636 mg/L sulfate No metals analyses	640 mg/L sulfate No metals analyses
Well 12 Intermediate aquifer	1,220 mg/L TDS 577 mg/L sulfate	571 mg/L sulfate No metals analyses	Only one sample No metals analyses

Although the groundwater monitoring system includes 25 wells, a review of the location and depths of the wells with parameter concentrations greater than DENR standards and the October 2008 potentiometric surface diagram (see reproduction below from Figure 2 *Monitoring Wells and Groundwater Elevation Contours: October 2008*, Otter Tail Power) suggests that the groundwater monitoring system at Big Stone is inadequate to define the nature and extent of contamination, based on the following deficiencies:

- There are no downgradient wells in the shallow or intermediate aquifers placed between the newest brine pond and the Whetstone River, located approximately 1,000 feet away from the new pond. The river is likely a shallow groundwater discharge point and is also the property line to the south. Groundwater monitoring results indicate substantial groundwater exceedances at this area.
- Wells S-4, S-5, and S-6 are only partially downgradient (mostly sidegradient) from the old brine pond area it monitors. No wells exist downgradient from the two brine ponds towards Whetstone

River, as wells S-4, S-5, and S-6 are not hydraulically downgradient of wells with the highest concentrations of pollutants (such as Wells S-1, S-2, BC-2, BC-3, and BC-4). As a result, the lateral extent of contamination has not yet been fully defined.

- Two wells (H1-I, H1-OX) that are downgradient of the ash pond and the ash landfill are located almost 900 feet from the ash disposal units, too far away to reliably distinguish impacts to water quality from these units. They are also located side-by-side and apparently monitor the same aquifer, functioning effectively as just one monitoring point. The position of the wells so far away from the disposal units allows for dilution from the considerable mounding effects of the adjacent cooling water and evaporation ponds and does not account for horizontal variability of the groundwater.
- Twenty-five feet of shallow aquifer groundwater mounding occurs from the cooling pond, and 10 feet of mounding occurs from the evaporation pond - indicating substantial leakage through the bottom of each pond. The cooling water pond is located along the northern property line with no wells along that side. The evaporation pond is located along the northern and eastern property lines, with no wells along those property lines. Although there may be off-site contamination, groundwater is not being monitored along much of the perimeter of this site.
- Water-filled natural depressions indicative of farm ponds are present north of the property lines near the cooling water pond and the evaporation pond. Given the amount of mounding of shallow groundwater present, the possibility exists that these ponds receive shallow groundwater from the cooling water and evaporation ponds.
- No wells exist between contaminated Wells 11 and 12 to monitor the intermediate aquifer south of the holding pond in the southeastern corner of the site at the property line. The lateral extent of contamination in the intermediate and shallow aquifers has not been fully defined in this area even though multiple private wells and at least one public well appear to be within a mile of the boundary at this corner of the site.
- Twenty feet of groundwater mounding occurs in the shallow aquifer south and southeast of the holding pond, indicating that the pond is leaking.



SOURCE:
Figure 2
Monitoring Wells and Groundwater Elevation Contours October 2008

Constituents Involved

Arsenic, boron, lead, strontium, chlorides, sulfate, and TDS

At Risk Populations

Groundwater is the only source of public water supply in South Dakota, with no known surface water supply intake in the entire state (Wendte, July 2010).

The same aquifer that is contaminated by Big Stone's CCW disposal units appears to be used by multiple wells in relatively close proximity. The DENR has record of 119 wells within a five-mile radius of the power plant, and 19 are private drinking water wells within a two mile radius of the site (Wendte, July 2010). A quick review of those records identified wells for such uses as domestic home wells, commercial farm wells, geothermal wells, and even municipal public water supplies. In fact, the southeastern corner of the plant property is less than a mile from the heart of Big Stone City, which owns at least one municipal water supply well. Furthermore. numerous private domestic wells also exist within Big Stone City. Those wells are shallow – generally less than 100 feet deep. According to the DENR, Big Stone City is now supplied potable drinking water from the town of Ortonville, Minnesota, an adjacent community (Wendte, July 2010). DENR is in the process of digitizing paper well records; in the interim, well data may be incomplete.

In addition to the proximity to drinking water wells, the CCW disposal areas are near Big Stone Lake and the Whetstone River, both of which have multiple protected uses. In fact, the most contaminated wells at Big Stone Power Plant are located less than 1,000 feet from the Whetstone River. Big Stone Lake is located approximately 1,000 feet east of the power plant property. Currently, Big Stone Lake and the Whetstone River have DENR-designated uses for warm water permanent fish life propagation, limited contact recreation, fish and wildlife propagation, and irrigation (Wendte, July 2010). Big Stone Lake is also designated as immersion recreational water.

Incident and Date Damage Occurred / Identified

Data in this report identifies damage between 2007 and 2009.

Regulatory Actions

DENR required Big Stone to conduct assessment measures due to a release from the brine ponds (Wendte and Kropp, 2010). The assessment included installing additional wells around the pond(s) and a nest of three wells, S-4, S-5, and S-6, south towards the Whetstone River. These wells were installed in August 1990 (Wendte, July 2010). However, after the wells were installed, rather than conducting enhanced monitoring to determine the source and extent of contamination, the facility continued to monitor the groundwater under the normal detection-monitoring program. Thus significant contamination exists 20 years after the limited assessment was performed. Yet no new off-site (beyond the Big Stone property line) wells have ever been installed, no existing off-site wells have been sampled, and no surface water samples have been collected to-date (Wendte and Kropp, 2010).

Waste Stream

Fly ash, bottom ash, settled lime water softener sludges, and process wastewater discharges to ponds

Type(s) of Waste Management Unit

Units included in the plant solid waste permit are: an ash landfill and pond with no liner that contain fly ash and bottom ash, two brine ponds that are composite lined with an under drain collection system, two unlined lime sludge water softener ponds, and an inert construction/demolition debris landfill (Wendte and Kropp, 2010). Fly ash collected by plant air pollution control devices is hauled in dry form to the ash landfill for disposal (Wendte, July 2010). An ash pond located between the cooling water pond and the evaporation pond is used to settle solids associated with stormwater runoff from the ash landfill (Wendte, June 2010).

Although the lime sludge water softener ponds are permitted under solid waste rules, there is no groundwater monitoring system associated with them.

The brine ponds are used to settle solids generated during raw water softening to make the water more suitable for use in on-site boilers (Wendte and Kropp, 2010). Although the two brine ponds are lined, they are constructed over the original 12-acre brine pond that was never lined (Wendte, June 2010). Shallow groundwater beneath the brine ponds (the area of the most severely contaminated groundwater) is collected in an under drain system, and that water is disposed of in the cooling water pond (Wendte, July 2010). As the concentrations of parameters in the cooling water pond increase, the water becomes unacceptable for plant use (Wendte, July 2010). As a result, water from the cooling water pond is pumped to the evaporation pond, where it is allowed to evaporate and to percolate to the groundwater. Fresh water from Big Stone Lake is then added to the cooling water pond to be used in the boilers (Wendte, July 2010). Evaporation pond water is also pumped to the holding pond. Water from the holding pond is treated, and water with undesirable constituents unsuitable for plant use is discharged into the brine ponds – the area with the worst groundwater contamination. The treated holding pond water is used in plant boilers (Wendte and Kropp, 2010). Without a permitted surface discharge, aside from evaporation the only exit for water from this closed loop system that concentrates wastes and impurities in the waters is into the shallow groundwater at the site along with all leachate from the unlined ash pond and landfill

In addition, a bottom ash settling pond (undetermined if a liner is present) located near the power plant and west of the disposal units assessed in this report is used to settle slurried ash, and that ash is either transported off-site for reuse or is disposed of in the ash landfill (Wendte, July 2010). The pond is periodically dredged (no frequency given) for disposal into the landfill. Since the ash pond is not considered to be a "disposal" unit, the DENR Waste Management Program does not regulate the pond (Wendte and Kropp, 2010).

The DENR was unaware if the evaporation pond or the cooling water pond has a liner (Wendte, July 2010), despite the ponds receiving plant process wastewaters. Those ponds and the holding water pond are not included in the solid waste permit, nor do they have a surface water or groundwater discharge permit. Each pond is nearly 1-mile wide.

[illegible]

Active

Two water-bearing zones are being monitored, with the most shallow zone being approximately 16 feet below ground surface (average static water level) and the intermediate/ deep zone being 58 feet deep (average static water levels) (Big Stone, 2008). According to DENR staff familiar with the solid waste permitting program for this plant, no "aquifer" as defined by South Dakota groundwater regulations exists beneath the plant (Wendte and Kropp, 2010). The monitoring system includes numerous well nests where wells that are situated side-by-side monitor different and sometimes the same water-bearing zones. Those that monitor different zones have vastly different static water levels for the same monitoring event.

A review of an October 2008 potentiometric surface diagram, which shows the direction of groundwater flow (higher elevation to lower elevation), indicates a steep groundwater gradient in the area of the highest parameter contamination – almost 6 percent in the brine pond area and 3 percent in the holding pond area – due to substantial mounding of the shallow groundwater; i.e localized elevation of groundwater (Otter Tail Power, 2008). No flow rates or seepage velocities were found during the file review.

Although the South Dakota Groundwater Quality Standards state that any subsurface water in a saturated zone that has an ambient TDSconcentration of less than 10,000 mg/L is classified as being "groundwater" and having a beneficial use of drinking water, suitable for human consumption, results from 2007 indicated that the TDS concentrations downgradient of waste disposal units were approximately 1,300 mg/L (DENR, 2007). Therefore, the water meets the DENR definition of useable groundwater (DENR, 2007). This acceptable water quality contradicts the DENR's claim that the groundwater beneath the power plant is not an aquifer.

Chapter 74:54:02:02, "Groundwater Discharge Permits, Applicant for Groundwater Discharge Plan," requires facilities that discharge wastes or pollutants that "may move directly or indirectly into groundwater" to apply for a groundwater discharge permit. The DENR Groundwater Program stated that the Big Stone plant does not have a groundwater discharge permit of any type for any pond (Walsh, 2010) – despite the fact that, at a minimum, the ash pond, the cooling water pond, and the evaporation pond are designed without a liner. If groundwater analyses demonstrate that monitoring results do not comply with the groundwater protection standards, a groundwater discharge permit is required (Walsh, 2010). Groundwater analyses submitted to the Waste Management Program demonstrate that multiple exceedances of South Dakota groundwater protection standards have long been occurring in seepage to groundwater from the ponds – yet the ponds are operating without groundwater discharge permits. There is no surface water discharge from either the cooling water or evaporation pond (Bruscher, 2010), which means that contaminants in these ponds enter the groundwater system via downward and lateral seepage.

The DENR Waste Management Program allows groundwater results for metals to be presented as dissolved (field-filtered) metals, instead of the traditionally EPA-accepted total (unfiltered) results. The South Dakota DENR contends that total metals results overstate pollutant concentrations because of naturally occurring glacial till materials that are present in suspended form (Wendte and Kropp, 2010). An alternative groundwater monitoring parameter list has been developed for the Big Stone plant to include constituents that are indicative of coal combustion wastes, such as boron, sulfate, and strontium (Wendte and Kropp, 2010) – the very constituents that are in very high concentrations in the groundwater at the plant. Groundwater data for the Big Stone plant is primarily reported as dissolved metals; however, some 2007 and 2008 data is reported in both total and dissolved forms. In 2009, only the dissolved fractions of metals were reported in groundwater monitoring results .

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Wendte. July 2010. Email correspondence from Jim Wendte, Natural Resources Engineer Director, Waste Management Program, South Dakota Department of Environment and Natural Resources (July 15, 2010).

Wendte and Kropp. 2010. Telephone conversation with Jim Wendte, Natural Resources Engineer Director and Steve Kropp, Natural Resources Engineering Specialist, Waste Management Program, South Dakota Department of Environment and Natural Resources (June 23, 2010).

Entity/Company – Location

Tennessee Valley Authority - Cumberland Steam Plant
815 Cumberland City Road
Cumberland City, Stewart County, TN 37050
Latitude: 36.3812 Longitude: -87.6515

Determination

Demonstrated damage to on-site groundwater

Probable Cause(s)

Leaching of coal combustion waste (CCW) contaminants from disposal areas into groundwater

Summary

Groundwater downgradient of a gypsum storage area and ash ponds at the Tennessee Valley Authority (TVA) Cumberland Fossil Plant is contaminated with arsenic concentrations up to 2.2 times the federal Maximum Contaminant Level (MCL), selenium concentrations up to 3 times the MCL, and boron up to 12.7 times the federal Health Advisory Level. Concentrations of aluminum, chloride, iron, manganese, sulfate, and total dissolved solids (TDS) also routinely exceeded federal Secondary MCLs (SMCLs) in wells downgradient of the CCW disposal sites. The stark contrast between these concentrations and those at upgradient monitoring points, which are often below detection limits, clearly suggests that CCW leachate is contaminating groundwater. The construction of two CCW storage-disposal areas on top of earlier ash ponds and on top of a former creek channel have created conditions conducive to groundwater contamination. The current Ash Pond and Gypsum Storage Area at the Cumberland Fossil Plant are also both on EPA's list of "High Hazard" surface impoundments.

Test of Proof

At Cumberland Fossil Plant, TVA collects groundwater samples from downgradient monitoring wells 93-1 through 93-4 (including replacement well 93-2R) and from upgradient sampling stations at Rye Spring and Wells Creek.

As the chart below demonstrates, upgradient water samples of boron, arsenic, and selenium have been often Below Detection Limit (BDL), while downgradient groundwater water samples are well above MCLs and Health Advisory Levels, indicating groundwater contamination from CCW leachate leaking from the unlined ponds.

TVA Cumberland Fossil Plant - Dry Ash and Gypsum Disposal Areas

Sample Date	Parameter / Standard (mg/L)	Upgradient Samples (mg/L)	Downgradient Well Exceedances (mg/L)
10/7/2009	Boron (3.0))(Health Advisory Level for Children)	Rye Spring: BDL Wells Creek: BDL	Well 93-2: **38** Well 93-2R: **15** Well 93-3: **6.2** Well 93-4: **4.0**
7/22/2009	Boron (3.0)	Rye Spring: 2.2 Wells Creek: BDL	Well 93-2: **35** Well 93-2R: **14** Well 93-3: **5.5**
1/21/2009	Boron (3.0)	Rye Spring: 0.26 Wells Creek: BDL	Well 93-2: **38** Well 93-2R: **15** Well 93-3: **5.9**
7/16/2008	Boron (3.0)	Rye Spring: BDL Wells Creek: BDL	Well 93-2: **38** Well 93-2R: **14** Well 93-3: **5.4**
1/23/2008	Boron (3.0)	Rye Spring: BDL Wells Creek: BDL	Well 93-2: **35** Well 93-2R: **10** Well 93-3: **5.1**
10/7/2009	Arsenic (0.010)	Rye Spring: BDL Wells Creek: BDL	Well 93-2: **0.014**
7/22/2009	Arsenic (0.01)	Rye Spring: 0.0019 Wells Creek: 0.0026	Well 93-1: **0.014** Well 93-2: **0.022** Well 93-2R: **0.020** Well 93-4: **0.010**
4/14/2009	Arsenic (0.01)	Rye Spring: BDL Wells Creek: BDL	Well 93-2: **0.010**
1/21/2009	Arsenic (0.01)	Rye Spring: BDL Wells Creek: BDL	Well 93-1: **0.013**
7/16/2008	Arsenic (0.01)	Rye Spring: .0062 Wells Creek: BDL	Well 93-1: **0.017** Well 93-2: **0.021** Well 93-2R: **0.016**
1/23/2008	Arsenic (0.01)	Rye Spring: BDL Wells Creek: BDL	Well 93-1: **0.014** Well 93-2: **0.013**
10/7/2009	Selenium (0.05)	Rye Spring: 0.0013 Wells Creek: BDL	Well 93-2: **0.091**
7/22/2009	Selenium (0.05)	Rye Spring: BDL Wells Creek: BDL	Well 93-2: **0.15**
4/14/2009	Selenium (0.05)	Rye Spring: 0.0013 Wells Creek: BDL	Well 93-2: **0.12**
1/21/2009	Selenium (0.05)	Rye Spring: BDL Wells Creek: BDL	Well 93-2: **0.07**

TVA Cumberland Fossil Plant - Dry Ash and Gypsum Disposal Areas			
Sample Date	**Parameter / Standard (mg/L)**	**Upgradient Samples (mg/L)**	**Downgradient Well Exceedances (mg/L)**
7/16/2008	Selenium (0.05)	Rye Spring: 0.0013 Wells Creek: BDL	Well 93-2: **0.06**
1/23/2008	Selenium (0.05)	Rye Spring: 0.0016 Wells Creek: 0.0011	Well 93-2: **0.098**

In addition, upgradient water samples of aluminum, chloride, iron, manganese, sulfate, and TDS are often BDL, while downgradient groundwater water samples are well above SMCLs, indicating groundwater contamination from CCW leachate. For example, in an October 2009 TVA groundwater monitoring report, upgradient levels of TDS were 200 mg/L and 400 mg/L, yet *all* downgradient wells were over the SMCL of 500 mg/L, with levels as high as 6,600 mg/L at Well 93-2. Similarly, in October 2009, upgradient sulfate levels were 5.9 mg/L and 50 mg/L, yet the majority of downgradient wells were over the SMCL of 250 mg/L, with levels as high as 2,000 mg/L at Well 93-2. Similar trends are evident for aluminum, iron, and manganese, where maximum aluminum concentrations have reached as high as 2.5mg/L in July 2009 (aluminum SMCL is 0.05 – 0.2 mg/L); maximum iron concentrations reached 10 mg/L in July 2008 (iron SMCL is 0.3 mg/L); and maximum manganese levels reached 18 mg/L in several tests (manganese SMCL is 0.05 mg/L).

Constituents Involved

Aluminum, arsenic, boron, chloride, iron, manganese, selenium, sulfate, and total dissolved solids

At Risk Population

There are 440 households within a 3-mile radius of the TVA Cumberland Fossil Plant, and the "high hazard" ranking for Cumberland Fossil Plant's surface impoundments indicates that persons living nearby are likely to be seriously harmed by any failure of Cumberland's storage facilities. The area surrounding TVA Cumberland is rural, and the overwhelming majority of drinking water sources in Stewart County are drawn from groundwater according to the U.S. EPA's Safe Drinking Water Information System. Those that are not drawing from groundwater take water from the Cumberland River. Private and public well locational data was unavailable for all TVA sites. It is unclear whether well records are housed with TDEC or TVA. Employees of TDEC insisted this data was closely held for "security reasons" and could not be accessed by the public; however, TVA may disclose well records that they maintained. When TVA was contacted, they claimed to have no well records and referred back to TDEC. This back and forth referral occurred multiple times over the course of a month and yielded no results. It is unclear whether records do or do not exist.

Incident and Date Damage Initially Identified

Documentation of damage has occurred since the 2000s

Waste Profile

The dry ash that is not marketed to the concrete industry is hauled to an on-site dry stack disposal area (Dry Ash Stack). In addition, approximately 135,000 tons per year of bottom ash is wet-sluiced to the Active Ash Pond. Dewatered bottom ash is reclaimed from the Active Ash Pond and stacked within the Dry Ash Stack. Approximately 1,100,000 tons of gypsum is produced each year, and gypsum that is not marketed to the wallboard industry is wet-sluiced to the Gypsum Storage Area (gypsum pond).

Type(s) of Waste Management Unit

Dry storage built over wet surface impoundments, and wet surface impoundments built over a former creek bed. It is unclear whether any of TVA's ash storage facilities (old or new) were lined to prevent CCW leachate from entering groundwater. In view of the fact that the fly ash pond was constructed in 1969 and that Tennessee regulations do not require installation of liners for CCW ponds, it is highly unlikely that 50-acre ash pond at the TVA Cumberland Fossil Plant is lined.

Active or Inactive Waste Management Unit

Active

Hydrogeologic Conditions

The 2009 Stantec Engineering Evaluation of Cumberland Fossil Plant notes that, "Because the plant is situated along the banks of Wells Creek and the Cumberland River, a mantle of alluvial soils primarily consisting of silty lean clays overlay bedrock across portions of the site." (Stantec, 2009). In addition, TVA states in its October 2009 Groundwater Monitoring Report:

> Southwestward flow of groundwater beneath the disposal area is indicated by the potentiometric contours with an average horizontal hydraulic gradient of approximately 0.0072. Because potentiometric level data are spatially limited, the estimated groundwater gradient is probably not representative of overall gradients in the disposal site vicinity. The bottom ash pond and the rim-ditch stacking operation in the gypsum disposal area likely produce radial groundwater flow away from these impoundments which cannot be adequately defined with the existing well network. . . The dry ash and gypsum disposal areas are underlain (in descending order) by some 40 feet of fly ash and bottom ash deposits, approximately 15 to 20 feet of residual and/or alluvial soils, and by limestone bedrock. The older ash deposits, which represent the shallowest water-bearing unit, exhibit a mean hydraulic conductivity of approximately 2.5x10-5 cm/s (or 0.022 m/d) and a porosity of 0.48. Using these data and the current groundwater gradient given above, the local groundwater seepage velocity through the ash deposits is estimated from Darcy's Law to be approximately 3.3x10-4 m/d.

[illegible]

The Cumberland Fossil Plant has two coal-fired generating units. Construction began in 1968 and was completed in 1973. The plant consumes approximately 20,000 tons of coal per day. The Cumberland Fossil Plant has three CCW areas on-site: (1) a gypsum storage area (approximately 170 acres) that was built on top of the plant's original ash pond in 1996; (2) an ash pond (approximately 50 acres), which was constructed in 1969 and required the relocation of Wells Creek. As a result, portions of the ash pond and dry ash stack were constructed over the original location of Wells Creek; and (3) a dry ash stack (approximately 110 acres) that is continually being constructed, and the stack's maximum height is approximately 35 feet. The stack is being constructed over sluiced bottom and fly ash, and it is unknown how much sluiced ash is beneath the stack.

[illegible]

Stantec. 2009. Stantec Engineering Report, TVA Disposal Facility Assessment, Phase 1 Plant Summary, Cumberland Fossil Plant (CUF) (June 24, 2009), *available at* http://www.tva.gov/power/stantec/tn/rpt_006_appndx_d_cuf_171468118.pdf.

TVA. 2008–2009. Quarterly Groundwater Assessment Monitoring Reports, Cumberland Fossil Plant Dry Ash and Gypsum Disposal Areas (prepared by J. Mark Boggs, P.G.).

U.S. EPA. 2009. U.S. Environmental Protection Agency, Fact Sheet: Coal Combustion Residues (CCR) - Surface Impoundments with High Hazard Potential Ratings, EPA530-F-09-006 (updated Aug. 2009), *available at* http://www.epa.gov/osw/nonhaz/industrial/special/fossil/ccrs-fs/national.pdf.

Entity/Company – Location

Tennessee Valley Authority - Gallatin Fossil Plant
1499 Steam Plant Road
Gallatin, Sumner County, TN 37066
Latitude: 36.315 Longitude: -86.408

Determination

Demonstrated damage to on-site groundwater moving off-site (into the adjacent Cumberland River).

Probable Cause(s)

Leaching of coal combustion waste (CCW) contaminants from CCW disposal areas into groundwater

Summary

An unlined, closed CCW impoundment at the Tennessee Valley Authority (TVA) Gallatin Fossil Plant is contaminating groundwater with beryllium 4 to 6 times the federal Maximum Contaminant Level (MCL), cadmium exceeding the MCL, nickel exceeding the Tennessee MCL by up to 2.5 times, and boron consistently exceeding federal Health Advisory Levels. In addition, aluminum, iron, manganese, sulfate and total dissolved solids (TDS) also routinely exceed federal Secondary MCLs (SMCLs) at downgradient wells. Two newer active CCW ponds at Gallatin are not monitored. Like the closed impoundment, these ponds are also unlined.

Test of Proof

At Gallatin Fossil Plant, TVA collects groundwater samples from upgradient wells GAF-21 and GAF-22 (new as of October 2009), and from downgradient compliance wells GAF-19R and GAF-20 around the closed CCW impoundment.

As the chart below demonstrates, upgradient water samples of boron are Below Detection Limit (BDL), while downgradient groundwater water samples are well above the Health Advisory Levels, indicating groundwater contamination from CCW leachate. Similarly, cadmium, nickel, and beryllium are consistently higher in downgradient wells than upgradient wells, and all the values listed below in downgradient wells are above the MCLs and/or State Groundwater standards.

TVA Gallatin Fossil Plant – Closed Ash Disposal Area (TVA, 2008–2009)

Sample Date	Parameter / Standard (mg/L)	Upgradient Well (mg/L)	Downgradient Well Exceedances (mg/L)
10/14/2009	Boron (3.0))(Health Advisory Level for Children)	GAF-21: BDL GAF-22: BDL	**GAF-19R: 3.9** **GAF-20: 5.6**
7/14/2009	Boron (3.0)	GAF-21: BDL	**GAF-19R: 3.9** **GAF-20: 5.4**
2/5/2009	Boron (3.0)	GAF-21: BDL	**GAF-19R: 4.1** **GAF-20: 5.5**
8/12/2008	Boron (3.0)	GAF-21: BDL	**GAF-19R: 4.5** **GAF-20: 5.5**
2/19/2008	Boron (3.0)	GAF-21: BDL	**GAF-19R: 3.6** **GAF-20: 5.6**
10/14/2009	Cadmium (0.005)	GAF-21: 0.0049 GAF-22: BDL	**GAF-19R: 0.005**
7/14/2009	Cadmium (0.005)	GAF-21: 0.0058	**GAF-19R: 0.0052**
4/1/2009	Cadmium (0.005)	GAF-21: 0.0014	**GAF-19R: 0.0064**
8/12/2008	Cadmium (0.005)	GAF-21: BDL	**GAF-19R: 0.0057**
2/19/2008	Cadmium (0.005)	GAF-21: 0.0010	**GAF-19R: 0.005**
10/14/2009	Nickel (TN Standard: 0.1)	GAF-21: 0.069 GAF-22: 0.039	**GAF-19R: 0.20**
7/14/2009	Nickel (0.1)	GAF-21: 0.11	**GAF-19R: 0.25**
4/1/2009	Nickel (0.1)	GAF-21: 0.030	**GAF-19R: 0.23**
2/5/2009	Nickel (0.1)	GAF-21: 0.013	**GAF-19R: 0.19**
8/12/2008	Nickel (0.1)	GAF-21: 0.016	**GAF-19R: 0.22**
2/19/2008	Nickel (0.1)	GAF-21: 0.020	**GAF-19R: 0.16**
10/14/2009	Beryllium (0.004)	GAF-21:BDL GAF-22: BDL	**GAF-19R: 0.016**
7/14/2009	Beryllium (0.004)	GAF-21: 0.0028	**GAF-19R: 0.019**
4/1/2009	Beryllium (0.004)	GAF-21: BDL	**GAF-19R: 0.023**
2/5/2009	Beryllium (0.004)	GAF-21: BDL	**GAF-19R: 0.019**
8/12/2008	Beryllium (0.004)	GAF-21: BDL	**GAF-19R: 0.019**
2/19/2008	Beryllium (0.004)	GAF-21: BDL	**GAF-19R: 0.017**

In addition, data from downgradient groundwater wells reveal that SMCLs, such as sulfate, manganese, iron, and TDS are well above both SMCLs and upgradient values, indicating groundwater contamination from CCW leachate. For example, in an October 2009 TVA groundwater monitoring report, upgradient levels of TDS were 320 mg/L in Well 22, yet downgradient wells were over the SMCL of 500 mg/L, with levels as high as 6,500 mg/L at Well 19R). Also in October 2009, the upgradient sulfate level was 32 mg/L at Well 22, yet downgradient wells were over the SMCL of 250 mg/L, with levels as high as 4,700 mg/L at Well 19R. Similar trends are evident for aluminum, iron, and manganese, where maximum aluminum (SMCL of 0.05–0.2 mg/L) concentrations reached 130 mg/L, maximum iron (SMCL of 0.3 mg/L) concentrations reached 930 mg/L, and maximum manganese (SMCL of 0.05 mg/L) levels often reach 22 mg/L.

Aluminum, boron, beryllium, cadmium, iron, manganese, nickel, sulfate, and total dissolved solids

Many public drinking water sources for communities near the TVA Gallatin Plant use treated water directly from the Cumberland River. For example, the Gallatin Water Department, which serves approximately 38,000 people and supplies water to other companies, such as Castalian Springs in Bethpage, TN, is located just over one mile downstream of the TVA Gallatin Steam Plant's Ash Ponds. It is unclear whether well records and locations are housed with TDEC or TVA. During data retrieval process, employees of TDEC insisted this data was closely held for "security reasons" and could not be accessed by the public; however, TVA may disclose well records that they maintained. When TVA was contacted, they claimed to have no well records and referred back to TDEC. This back and forth referral occurred multiple times over the course of a month and yielded no results. It is unclear whether records do or do not exist.

Documentation of damage has occurred since the 2000s

Bottom ash and fly ash from the TVA Gallatin Fossil Plant

Aside from the closed ash disposal area, which is approximately 73 acres and is unlined, the Gallatin Fossil Plant has a bottom ash pond of approximately 269 acres and a fly ash pond of approximately 157 acres, both of which are also unlined. .

Active and inactive; the closed pond is inactive, but the bottom ash pond and fly ash pond at Gallatin are both active.

The Stantec Engineering Evaluation of Gallatin Fossil Plant notes that, "the geologic mapping depicts alluvial deposits consisting of clay, silt and very fine sand across large portions of the site" (Stantec, 2009). The Stantec report also notes that "the USGS topographic mapping depicts several enclosed drainage basins indicative of karst activity within the vicinity of the plant" (Stantec, 2009). In addition, TVA states in its October 2009 Groundwater Monitoring Report:

> Hydrogeologic data for compliance monitoring wells indicate that shallow groundwater movement beneath the Abandoned Ash Disposal Area occurs in Quaternary age alluvial deposits. Wells range from approximately 49 to 52 feet in depth and all are completed in alluvial deposits. The average horizontal hydraulic gradient (Jh) in the disposal site vicinity is approximately 0.0192, based on the October 14 water level measurements in wells GAF-19R through GAF-21. The direction of the horizontal gradient is southwesterly toward the Cumberland River. The highest measured hydraulic conductivity in the vicinity of the disposal area is 2.2E-7 cm/s. This measurement represents an estimate of vertical hydraulic conductivity (Kv) since it was determined from laboratory testing of an undisturbed soil core. The horizontal component of hydraulic conductivity (Kh) is conservatively estimated to be about ten times Kv or approximately 2.2E-6 cm/s (6.2E-3 ft/d). Aneffective soil porosity (θ) of 0.2 is assumed in estimating the horizontal seepage velocity (v) through the soil zone. Applying Darcy's Law (i.e., $v = Kh*Jh/\theta$), an average horizontal seepage velocity between the disposal site and the river of approximately 0.22 ft/yr is conservatively estimated.

Construction of theGallatin Fossil Plant began in 1953 and was completed in 1959. Gallatin consumes approximately 12,350 tons of coal per day, and is located on the north bank of the Cumberland River, about 30 miles northeast of Nashville, TN. The Gallatin Fossil Plant has three CCW areas on-site: (1) a bottom ash pond (approximately 248 acres); (2) a fly ash pond (approximately 167 acres); and (3) a closed ash disposal area (approximately 73 acres).

The closed coal ash disposal area was the first ash disposal area, and dates back to Gallatin's construction in the late 1950s. TVA sluiced wet ash to this disposal area until 1970 and then abandoned the site. In 1985, new slides began to develop around the dike, and in 1986 the entire perimeter dike was reconstructed and flattened. The Tennessee Department of Environment and Conservation approved a closure plan for the closed ash impoundment in 1997.

Recently, in July 2010, TVA announced it would install 13 new piezometers to detect potential seepage from its active ash ponds into the Cumberland River (Potter, 2010).

Potter. 2010. Daniel Potter, Nashville Public Radio, *New Monitors to Dectect Seepage at TVA Gallatin Plant's Ash Pond*, (July 21, 2010).

Stantec. 2009. Stantec Engineering Report, TVA Disposal Facility Assessment, Phase 1 Plant Summary, Gallatin Fossil Plant (GAF) (June 24, 2009), *available at* http://www.tva.gov/power/stantec/tn/rpt_007_appndx_e_gaf_171468118.pdf.

Tennessee Valley Authority (TVA). 2009. Letter from Anda Ray, TVA, to the U.S. Environmental Protection Agency (Mar. 25, 2009), *Aavailable at:* http://www.epa.gov/osw/nonhaz/industrial/special/fossil/surveys/tva-fossil.pdf

TVA. 2008-2009. Quarterly Groundwater Assessment Monitoring Reports, Gallatin Fossil Plant Abandoned Ash Disposal Area (prepared by J. Mark Boggs, P.G.)

USEPA. 2010. United States Environmental Protection Agency (USEPA), Safe Drinking Water Information System (SDWIS) Report for the Gallatin Water Department (last updated July 14, 2010), *available at* http://www.epa.gov/enviro/html/sdwis/index.html.

Entity/Company – Location

Tennessee Valley Authority - Johnsonville Fossil Plant
535 Steam Plant Road
New Johnsonville, TN 37134
Humphreys County
Latitude: 36.035 Longitude: –87.984

Determination

Demonstrated damage to on-site groundwater discharging to surface water (Tennessee River).

Probable Cause(s)

Leaching of coal combustion waste (CCW) contaminants from CCW landfills and ponds to underlying groundwater that discharges to the Tennessee River

Summary

The Johnsonville Fossil Plant's active CCW disposal area sits on an unlined island in the middle of the Tennessee River. Data obtained from the Tennessee Valley Authority (TVA) show that groundwater on the island contains high levels of arsenic, aluminum, boron, cadmium, chromium, iron, lead, manganese, molybdenum, sulfate, and total dissolved solids (TDS) far above federal Maximum Contaminant Levels (MCLs), Secondary MCLs (SMCLs), and federal health advisory levels. For example, groundwater monitoring wells show arsenic concentrations as high as 0.52 mg/L (52 times the MCL); boron as high as 48 mg/L (8 times the lifetime health advisory level); cadmium at 0.260 mg/L (52 times the MCL); and lead at 0.39 mg/L (26 times the MCL). Even though TVA still uses the island as its "Active Ash Disposal Area," the State allowed TVA to stop monitoring the island and an abandoned, unlined "Area A" where levels of CCW metals were the highest. The State has not required TVA to monitor off-site groundwater or surface water to protect against further contamination.

Test of Proof

TVA's groundwater monitoring data reveal that levels of arsenic, aluminum, boron, cadmium, chromium, iron, lead, manganese, molybdenum, sulfate, and TDS have substantially exceeded federal MCLs, SMCLs, and federal health advisory levels at Johnsonville's "Active Ash Disposal Area," located on an island in the middle of the Tennessee River. Similarly, groundwater monitoring reports at the Dredged Ash Disposal Area. Abandoned Coal Ash Disposal Area "Area A," and South Rail Loop Ash Disposal Area show levels of sulfate, TDS, aluminum, iron, and manganese exceeding MCLs. In addition, boron levels exceed federal health advisory levels in groundwater monitoring wells at the South Rail Loop Ash Disposal Area. At present, TVA only monitors groundwater at two of its four ash disposal sites at the Johsonville Plant – the South Rail Loop Ash Disposal Area, and the Dredged Ash Disposal Area.

Active Ash Disposal Island

The "Active Ash Disposal Area" is an 87-acre unlined CCW disposal site that includes a landfill and ponds and is situated on an island in the middle of the Tennessee River. TVA began monitoring groundwater on the island in the early 1990s, then stopped monitoring, perhaps due to the extreme exceedances of both federal and state standards. No wells on the island can be considered upgradient, and pollutants, such as arsenic, exceed federal standards at every single well on the island. For brevity, only select pollutants and wells are included in this report, and since TVA stopped monitoring, only select years are available.

TVA's groundwater monitoring data from 1986, 1988, and 1991 - 1994 on the island is summarized below and shows that results for arsenic, boron, lead, molybdenum, and cadmium were far higher than federal MCLs and Lifetime Health Advisory Levels.

- **Arsenic** exceeded the MCL (0.010 mg/L) 17 times, with levels as high as 0.52 mg/L (52 times the MCL in well SS16), and 0.065 mg/L (over 6 times the MCL in well SS13).
- **Boron** exceeded federal health advisory levels 14 times, with levels as high as 16 mg/L (over 2 times the federal lifetime health advisory level in well SS13); and 8.4 mg/L (1.4 times the federal lifetime health advisory level in well SS16).
- **Cadmium** exceeded the MCL (0.005 mg/L) 8 times, with levels as high as 0.260 (52 times the MCL in well SS16), and 0.086 mg/l (over 17 times the MCL in well SS13).
- **Lead** exceeded the MCL (0.015 mg/L) 13 times, with levels as high as 0.120 mg/L (8 times the MCL in well SS13), and 0.100 mg/L (over 6 times the MCL in well SS16).
- **Molybdenum** exceeded the federal lifetime health advisory level (0.040 mg/L) 10 times, with levels as high as 1.2 mg/L (30 times the federal lifetime health advisory level in well SS16), and 0.510 mg/L (over 12 times the federal lifetime health advisory level in well SS16).

In addition, TVA data shows that wells on the island also exceeded federal standards for additional pollutants, including aluminum, chromium, iron, manganese, sulfate, and TDS. For example, chromium reached 0,16 mg/L (over the MCL of 0.1 mg/L); aluminum reached 470 mg/L (over *9,400 times* the SMCL of 0.05 mg/L); iron reached 200 mg/L (*over 660 times* the SMCL of 0.3 mg/L); manganese reached 16 mg/L (320 *times* the SMCL of 0.05 mg/L); sulfate reached 1,500 mg/L (*6 times* the SMCL of 250 mg/L); and total dissolved solids reached 2,000 mg/L (*4 times* the SMCL of 500 mg/L).

North Abandoned Ash Disposal Area ("Area A")

The unlined North Abandoned Ash Disposal Area ("Area A") is approximately 45 acres, and was the original CCW disposal pond for the plant. It located north of the plant, was built in the early 1950s, and is currently closed. TVA operated six groundwater monitoring wells near Area A. However, like the Active Ash Disposal Area, TVA ceased monitoring groundwater in this area. For brevity, only select pollutants and wells are included in this report, and since TVA stopped monitoring, only select years are available. TVA's groundwater monitoring data from 1991 - 1994 on the island is summarized below and shows that results for arsenic, boron, lead, molybdenum, and cadmium were far higher than federal MCLs and Lifetime Health Advisory Levels.

- Arsenic exceeded the MCL (0.010 mg/L) over 75 times, with levels as high as 0.57 mg/L (57 times the MCL in well C6), and 0.39 mg/L (39 times the MCL in well C1)
- Boron exceeded federal lifetime health advisory level (6 mg/L) over 60 times, with levels as high as 48 mg/L (8 times the federal lifetime health advisory level in well C1), and 40 mg/L (over 6 times the federal lifetime health advisory level in Well C1).
- Lead exceeded the MCL (0.015 mg/L) over 30 times, with levels as high as 0.39 mg/L (26 times the MCL in well C6) and 0.25 mg/L (over 16 times the MCL in well C6).
- Molybdenum exceeded the federal lifetime health advisory level (0.040 mg/L) over 50 times, with levels as high as 0.42 mg/L (over 10 times the federal lifetime health advisory level in well C5), and 0.35 mg/L (over 8 times the federal lifetime health advisory level in well C2).
- Cadmium exceeded the MCL (0.005 mg/L) over 20 times, with levels as high as 0.24 mg/L (48 times the MCL in well C5), and 0.037 mg/L (over 7 times the MCL in well C1).

In addition, groundwater in Area A exceeded standards for other pollutants, including aluminum, chromium, iron, manganese, sulfate, and total dissolved solids. For example chromium reached 0.62 mg/L (over *6 times* the MCL of 0.1 mg/L); aluminum reached 1,100 mg/L (*over twenty thousand times* the SMCL of 0.05 mg/L); iron reached 830 mg/L (*over 2,700 times* the SMCL of 0.3 mg/L); manganese reached 10 mg/L (*200 times* the SMCL of 0.05mg/L); sulfate reached 2000 mg/L (*8 times* the SMCL of 250 mg/L); and TDS reached 3300 mg/L (*over 6 times* the SMCL of 500 mg/L).

South Rail Loop Ash Disposal Area

The South Railroad Loop Ash Disposal Area is a 95-acre, closed CCW landfill. There are four monitoring wells at the South Rail Loop Disposal Area, one upgradient (Well B-9), and three downgradient wells (B5, B6, and B8). TVA's data from downgradient wells documents substantial degradation of groundwater in quarterly reports during 2008–2009 at this site as summarized below:

- Aluminum exceeded the most protective SMCL (0.05 mg/L) 9 times in downgradient groundwater wells, with levels as high as 2.0 mg/L (*40 times* the most protective SMCL in well B5).
- Manganese exceeded the SMCL (0.05 mg/L) 12 times in downgradient groundwater wells, with levels as high as 2.7 mg/L (*54 times* the SMCL in well B8).
- Sulfate exceeded the SMCL (250 mg/L) 6 times in downgradient groundwater wells, with levels as high as 1200 mg/L (*4.8 times* the SMCL in well B8).
- Iron exceeded the SMCL (0.3 mg/L) 10 times in downgradient groundwater wells, with levels as high as 2.7 mg/L (*9 times* the SMCL in well B6).
- TDS exceeded the SMCL (500 mg/L) 6 times in downgradient groundwater wells, with levels as high as 1700 mg/L (*3.4 times* the SMCL in well B8).
- Boron exceeded the federal lifetime health advisory level (6 mg/L) 5 times in downgradient groundwater wells, with levels as high as 10 mg/L (*1.6 times* the Lifetime Health Advisory Level in well B8).

TVA states that groundwater at the South Rail Loop Ash Disposal Area "generally flows westward across the disposal site" to the Tennessee River, and "[g]roundwater passing beneath the site ultimately discharges to the Tennessee River" (TVA 2008, 2007 and 2006).

Dredged Ash Disposal Area

The Dredged Ash Disposal Area is a 35-acre closed, unlined CCW Dredge Pond, east of the Gas Turbines Area that has a "buffer of 3 feet of soil with a permeability of 1×10^{-6} cm/sec" (TVA 1992). There are four monitoring wells at the Dredged Ash Disposal Area, one upgradient (Well B13), and three downgradient wells (B10, B11, and B12). TVA data collected in 2008-2009 documents contamination of groundwater as follows:

- Aluminum exceeded the most protective SMCL (0.05 mg/L) 9 times in downgradient groundwater wells, with levels as high as 14 mg/L (*280 times* the most protective SMCL in well B10).
- Manganese exceeded the SMCL (0.05 mg/L) 9 times in downgradient groundwater wells, with levels as high as 2.2 mg/L (*44 times* the SMCL in well B12).
- Iron exceeded the SMCL (0.3 mg/L) 10 times in downgradient groundwater wells, with levels as high as 14 mg/L (*46 times* the SMCL in well B10).
- Chloride exceeded the SMCL (250 mg/L) 7 times in downgradient groundwater wells, with levels as high as 920 (*3.6 times* the SMCL in well B12).
- Total Dissolved Solids exceeded the SMCL (500 mg/L) 7 times in downgradient groundwater wells, with levels as high as 1,800 (*3.6 times* the SMCL in well B12).

TVA states that groundwater at the Dredged Ash Disposal Area "generally flows southwestward across the disposal site" to the Tennessee River, and [g]roundwater passing beneath the site ultimately discharges to the Tennessee River" (TVA 2008, 2007 and 2006).

Surface Water Monitoring – Tennessee River

- Several of the CCW pollutants that are present at high levels in groundwater underneath the Dredge Ash Disposal Area and South Rail Loop Ash Disposal Area are also present at levels in Tennessee River/Kentucky Lake at levels that exceed Water Quality Criteria ("WQC") as measured at Johnsonville Fossil Plant's water intake point. Manganese concentrations in the Tennessee River were measured at 0.079 mg/L; above the EPA WQC for Human Health of: 0.05 mg/L
- Iron concentrations in the Tennessee River were measured at 0.395 mg/L, above the EPA WQC for Human Health of: 0.300 mg/L.
- Aluminum concentrations in the Tennessee River were measured at 1.04 mg/L, above EPA WQC for Freshwater Aquatic Life: 0.087 mg/L (chronic) and 0.75 mg/L (acute).

Despite evidence of surface water quality impacts from Johnsonville Fossil Plant CCW disposal, the State has not required TVA Johnsonville Fossil Plant to limit its discharge of CCW pollutants, monitor CCW disposal areas more frequently, or take any corrective action to reduce or prevent contamination.

Aluminum, arsenic, boron, cadmium, chromium, chloride, total dissolved solids, iron, lead, manganese, molybdenum, sulfate

The Johnsonville Fossil Plant is located near several municipal water intake pipes along the Tennessee River, including the New Johnsonville Municipal Water Intake at River Mile 100.6, and the City of Camden Water Intake at River Mile 100.3. The Ash Ponds and Disposal Areas at Johnsonville discharge through Outfalls and seepage points between River Miles 99 and 101. The Tennessee River and Kentucky Lake are major recreational areas, and several boat launches, wildlife, and recreational areas are nearby.

Although there are over 1,000 households within a 3-mile radius of the TVA Johnsonville Fossil Plant (EPA, 2010) many of whom could be using groundwater as a source of drinking water in residential drinking water wells, the Tennessee Department of Environment and Conservation (TDEC) would not respond to requests for data regarding wells in the vicinity.

Documentation of damage has occurred since 1986

CCW (Fly ash and bottom ash) from TVA Johnsonville Fossil Plant (TVA, 2009).

TVA has four ash disposal areas at the Johnsonville Fossil Plant, including an unlined island in the Tennessee River, called "Active Ash Disposal Areas 2 & 3," a dredged ash disposal area that was a pond, a disposal area in the South Railroad Loop that was a landfill, and an abandoned unlined coal ash pond that was covered and closed, north of the Plant (Area A) (Stantec 2009).

Active and inactive; the island disposal site in the Tennessee River (Ash Disposal Areas 2 & 3) is active; the other three CCW ponds and landfills are inactive and closed.

The Stantec Engineering Evaluation of Johnsonville Fossil Plant describes the site:

> The Johnsonville Fossil Plant is located in west-central Tennessee along the eastern bank of the Tennessee River, just south (upstream) of the confluence of the river and Trace Creek. As such, much of the site is underlain by alluvium and terrace deposits varying in thickness from less than 20 feet along the tributary stream banks up to more than 100 feet within the floodplain of the Tennessee River. The underlying bedrock consists of the Lower Mississippian age Fort Payne Formation and Devonian age Chattanooga Shale and Camden Formations, in general order of descending lithology. The Fort Payne Formation varies from a sandy, cherty limestone in the upper portions of the unit to an interbedded shale and cherty limestone lower in the stratigraphic column. The Chattanooga Shale is a fissile, carbonaceous shale thought to act as an aquitard preventing the downward migration of groundwater, etc. into the underlying Camden formation, the principal aquifer in the region. The Camden formation consists of thin beds of cherty limestone interbedded with softer clay layers. Previous drilling at the site, discussed in reports and other documentation provided by TVA, suggests the presence of several small faults and a larger fault in the bedrock underlying the plant, as inferred from borehole data in the Camden Formation.

In addition, TVA has studied groundwater at Johnsonville and reports that "Local groundwater movement at the plant site is generally from east to west toward the Tennessee River. Groundwater recharge occurs by local infiltration of precipitation at ground surface and laterally from upland areas east of the site. Groundwater passing beneath the site ultimately discharges to the Tennessee River." TVA also stated that groundwater at the Dredged Ash Disposal Area "generally flows southwestward across the disposal site," and groundwater at the South Rail Loop Ash Disposal Area "generally flows westward across the disposal site" toward the Tennessee River, and "[g]roundwater passing beneath the site ultimately discharges to the Tennessee River" (TVA 2008, 2007 and 2006).

Additional Narrative

The Johnsonville Fossil Plant has ten coal-fired generating units, and burns approximately 9,600 tons of coal per day. Johnsonville Fossil Plant is the oldest coal plant in Tennessee. Plant construction began in 1949 and was completed in 1952. The Johnsonville Fossil Plant is located on the banks of the Tennessee River at Kentucky Lake.

Sources

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Tennessee Valley Authority (TVA). 2009. Letter from Anda Ray, TVA, to the U.S. Environmental Protection Agency (Mar. 25, 2009). *Available at:* http://www.epa.gov/osw/nonhaz/industrial/special/fossil/surveys/tva-fossil.pdf

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USEPA. 2010. Enforcement & Compliance History Online (ECHO), TVA Johnsonville Fossil Plant, Demographic Profile of Surrounding Area (3 Miles) available at http://www.epa-echo.gov/cgi-bin/get1cReport.cgi?tool=echo&IDNumber=110000370535 (last visited August 23, 2010).

U.S. Fish and Wildlife Service. 2010. Biological Opinion of Johnsonville Fossil Plant Construction (Feb. 1, 2010).

Entity/Company -Location

Lower Colorado River Authority - Fayette Power Project (Sam Seymour)
6549 Power Plant Road
La Grange, TX 78945-3739
Fayette County
Latitude: 29.915669 Longitude: -96.751510

Determination

Demonstrated damage to groundwater moving off-site (to the southeast and southwest and discharging to Cedar and Baylor Creeks)

Probable Cause

Leaching of coal combustion waste (CCW) contaminants from waste units into underlying groundwater

Summary

Groundwater sampling at LCRA's Fayette Power Project (FPP) has found levels of selenium, cobalt, and molybdenum exceeding Texas Protective Contamination Levels (PCLs) and federal Maximum Contaminant Levels (MCLs). Selenium levels have reached more than 4 times the PCL and MCL in a well that is probably impacted by the coal ash pond at the site. Cobalt levels have reached more than three times the PCL, and molybdenum has exceeded the federal Lifetime Health Advisory Level by nearly four times and exceeded the PCL in water downgradient of ash disposal areas. Aluminum, chloride, manganese, sulfate, and total dissolved solids (TDS) exceed federal Secondary MCLs (SMCL). The Texas Commission on Environmental Quality (TCEQ) has notified two neighboring landowners that their wells may be contaminated with molybdenum from this site.

Note: The locations of the monitoring wells are approximate.

Groundwater monitoring at FPP in 2009 revealed elevated levels of aluminum, arsenic, chloride, cobalt, manganese, molybdenum, selenium, sulfate, and TDS. The 2009 Annual Groundwater Monitoring Report submitted by LCRA show concentrations of other heavy metals that exceed Texas PCLs and/or federal MCLs:

- **Cobalt** exceeded the residential and commercial PCLs of 0.0073mg/L and 0.022 mg/L respectively at CBL-138 – a monitoring well about 750 feet downgradient from the CCW landfill – during both samples in 2009. [Note: the wells monitoring the CCW landfill are tested semi-annually while most other monitoring wells at FPP are tested quarterly.] In 2009, the maximum cobalt concentration detected in CBL-138 was 0.0303 mg/L or more than 4 times the residential PCL.
- **Molybdenum** exceeded the residential PCL of 0.122 mg/L at AP-406, a monitoring well downgradient of the coal ash pond, four times during 2009. A review of historical molybdenum results for AP-406, a well downgradient from the ash pond, indicates an increasing trend since monitoring began in 2004. July 2009 was the first time molybdenum concentrations exceeded the PCL. The maximum concentration measured at AP-406 was 0.154 mg/L (nearly four times the federal Lifetime Health Advisory Level of 0.04 mg/L). TCEQ has notified two neighboring landowners of possible molybdenum groundwater contamination.
- **Selenium** exceeded the MCL and commercial and residential PCL of 0.05 mg/L at AP-407 (discussed further below) and RP-67 – a well immediately east of the reclaim pond where waste waters and FGD sludge from the scrubber on Unit 3 of the power plant are sent. There is a steep hydraulic gradient between the reclaim pond (elevation around 400 feet) and RP-67 (groundwater elevations around 322 feet), which is missed by the potentiometric surface map used to show generalized groundwater flow directions. Selenium was previously detected in RP-67, but MCL/PCL exceedances have only occurred since July 2008. The maximum concentration detected in RP-67 was 0.0746 mg/L. Molybdenum concentrations exceeded the PCL also in RP-67 during two groundwater tests conducted in 2009, but exceeded the Federal Health Advisory Level by more than twice during all four groundwater tests in 2009.

LCRA annual groundwater monitoring reports submitted to TCEQ show rising concentrations of selenium in AP-407, the groundwater monitoring well just west of the coal ash pond, but considered upgradient. In the four monitoring tests conducted in 2003, the selenium concentration in AP-407 averaged 0.129 mg/L – more than 2.5 times the federal MCL and the Protective Contamination Level (PCL) set forth in the Texas Risk Reduction Program (TRRP). Selenium concentrations were notably higher in the four samples collected in 2009 which averaged 0.203 mg/L (more than four times the MCL and PCL). The maximum selenium concentration at AP-407 was 0.212 mg/L in 2009.

In a 2005 wastewater permit renewal, TCEQ required LCRA to submit a "Groundwater Selenium Assessment Work Plan" to identify the source of selenium contamination in groundwater. The Work Plan that was submitted (Fayette Power Project, 2005), reported results of additional testing of groundwater in the vicinity of the coal pile to the west of AP-207, which is the only other logical possible source for the selenium. This testing ruled out the coal pile as a source, and additional investigations are underway. The ash pond remains the likely source of the selenium. The actual elevation of groundwater in AP-407 (around 353 feet in 2009) is very close to the elevation of the water in the ash pond (around 350 feet), so relatively minor fluctuations in either the groundwater in the well (downward) and the ash pond (upward) could cause flow from the pond towards AP-407.

Federal SMCLs, which are used in Texas as relevant groundwater standards, were exceeded in downgradient wells for all waste management units at FPP:

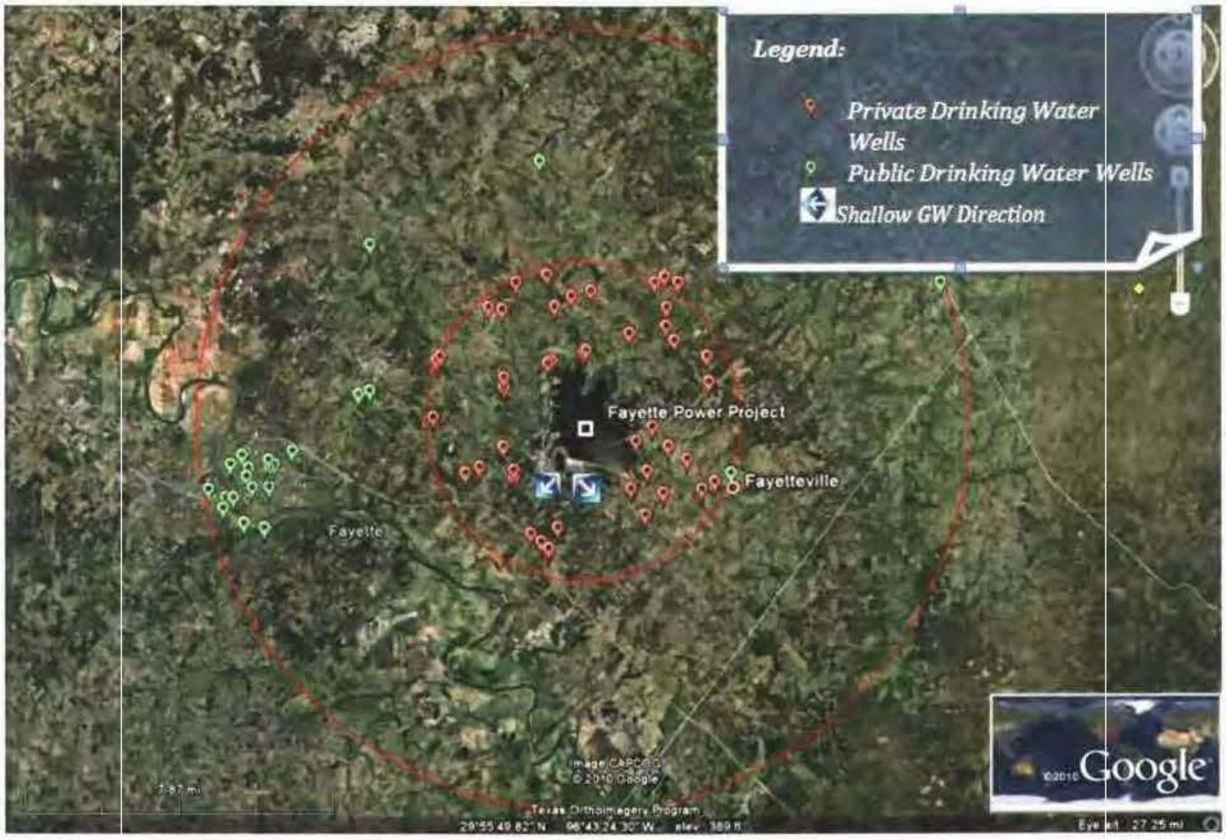
- **Aluminum** was detected at 0.361 mg/L and 0.284 mg/L (more than 7 times the SMCL of 0.05 mg/L) at wells downgradient from the CCW landfill.

- **Chloride** was detected at levels exceeding the SMCL at monitoring wells downgradient from the ash pond, class II landfill and CCW landfill. It was also detected at RP-67, a monitoring well hydraulically downgradient from the reclaim pond. Chloride levels were detected in all four quarters in these wells at levels roughly two to seven times the SMCL of 250 mg/L. Chloride levels at CBL-120 and CBL-138, the two monitoring wells downgradient from the CCW landfill, were significantly higher than other monitoring wells at FPP. Each well showed a chloride concentration over 1,400 mg/L (5.6 times the SMCL) in both samples collected in 2009.
- **Manganese** levels were continually found to exceed the SMCL of 0.05 mg/L at downgradient wells from the ash pond, CCW landfill and well affected by the reclaim pond. AP-6, a monitoring well down-gradient from the ash pond, showed levels of manganese at 0.651 – 1.01 mg/L (up to 20 times higher than the SMCL) during four sampling events in 2009.
- **Sulfate** concentrations exceeded the SMCL of 250 mg/L at wells downgradient from all waste management units during all quarters in 2009. Well AP-6, downgradient from the ash pond, had the highest concentrations between 820 – 1,380 mg/L (up to 5.5 times the SMCL).
- **TDS** exceeded the SMCL of 500 mg/L during all four quarters and at all monitoring wells during 2009. The highest exceedance occurred at CBL-138, a well down-gradient from the CCW landfill where TDS levels ranged from 4,120 – 4430 mg/L (8 to 9 times the SMCL).

Constituents Involved

Aluminum, arsenic, chloride, cobalt, manganese, molybdenum, selenium, sulfate, total dissolved solids

At-Risk Population



FPP is located on Lake Fayette (a power plant cooling reservoir), which is a popular recreational lake for fishing and boating in central Texas. Oak Thicket Park, located on the lake, offers camp sites, cabins, hiking and biking trails, picnic facilities, a playground, and swimming.

Recently, TCEQ sent out a letter warning private well owners near FPP that their wells may be contaminated with molybdenum. It is not clear whether TCEQ contacted other property owners in the area, such as farmers or nearby wineries.

There are 42 private wells within a two-mile radius and 23 public wells within a five-mile radius of FPP. Drinking water well data was obtained from the Texas Water Development Board, and some data may be missing or incomplete.

[illegible]

Since at least 2005, TCEQ has known of groundwater contamination at FPP. In 2009, groundwater monitoring at FPP revealed elevated levels of aluminum, arsenic, chloride, cobalt, manganese, molybdenum, selenium, sulfate, and total dissolved solids.

[illegible]

In 2005, TCEQ required LCRA to submit a "Groundwater Selenium Assessment Work Plan" to identify the source of selenium contamination in groundwater at FPP. TCEQ has also sent letters to neighboring landowners to inform them of possible molybdenum contamination in their drinking water wells. TCEQ has not fined or otherwise penalized LCRA for contaminating the groundwater and has not required any corrective action beyond the Selenium Assessment Plan to address contamination. TCEQ has also not required off-site sampling or conducted its own sampling of off-site surface water, groundwater, or domestic wells to determine the extent of potential contamination off-site.

[illegible]

Fly ash, bottom ash, boiler slag, FGD waste, construction wastes, other non-CCW wastes (Texas Commission on Environmental Quality, 2009)

[illegible]

FPP has four active Waste Management Units:

1. Coal Ash Pond (contains coal ash from Units 1 & 2, wastewater treatment sludge, boiler slag, and boiler cleaning wastes. The coal ash pond began operation in 1979, and has a storage capacity of 3.7 million cubic yards; in 2009, the pond contained 3.4 million cubic yards of waste);
2. Reclaim Pond (contains wastewater treatment sludge, fly ash from Unit 3, waste wet scrubber sludge, and waste metal cleaning solution);
3. Coal Ash Landfill; and
4. Class II Sanitary Landfill.

LCRA has submitted preliminary plans to close the coal ash pond at FPP. It is not known when this will be completed.

[illegible]

According to LCRA's Phase I Investigation Reports submitted to TCEQ, "FPP is situated on a ridge between Cedar Creek located to the east, Baylor Creek to the west, and Cedar Creek Reservoir to the north. The site is underlain by three shallow groundwater bearing units (GWBUs) of the Oakville Formation. The shallowest GWBU is the Upper Sand, which is found only in the north and west portions of the site where surface elevations are highest. The second and thirds GWBUs are the Middle Sand and Lower Sand, respectively.

Both of these units are laterally continuous throughout the site and dip to the southeast. The GWBUS are each separated from one another by thick, laterally-continuous clay or clayey strata which appear to possess good confining characteristics. Groundwater recharge to the transmissive units is from direct surface water infiltration in outcrop areas and/or from the Cedar Creek Reservoir adjacent to the north.

Groundwater flow generally follows topography, resulting in variable flow to the southeast and southwest. Groundwater discharges into Cedar Creek, Baylor Creek and its tributaries, as well as flowing into the geologic units that regionally dip to the southeast" (Fayette Power Project, 2009).

Arsenic exceeded the MCL and commercial and residential Texas PCLs of 0.01 mg/L at C2L-412 – a monitoring well downgradient of the Class II landfill. In 2009, the maximum concentration of arsenic detected at C2L-412 was more than twice the MCL and PCL at 0.023 mg/L. The MCL and PCL were exceeded during all four groundwater samplings in 2009. C2L-412 monitors a higher aquifer that is not present in the coal combustion waste (CCW) disposal areas. The source of the arsenic contamination is unclear.

Although LCRA has disposed of ash baghouse filters in this landfill, LCRA reportedly does not dump CCW into this landfill. It is unclear if this landfill is still in operation or not. LCRA began dumping in the Class II landfill in 1979. Since then, LCRA has reported dumping waste concrete, brick and wood, waste resin beads, blast media, insulation, empty RCRA containers, cleaning rags, paint waste, metal plating waste, fluorescent lamps, office wastes, and other non-CCW wastes.

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Texas Commission on Environmental Quality. 2009. Compliance Evaluation Investigation Report at Fayette Power Project (March 10, 2009).

Entity/Company – Location

American Electric Power d/b/a Appalachian Power – Clinch River Plant
Rte. 664 & Rte. 665
Cleveland, VA 24225
Russell County
Latitude: 36.932778 Longitude: -82.198611

Determination

Demonstrated off-site ecological damage to aquatic ecosystems (fish, snails, mussels, and aquatic macroinvertebrates in the Clinch River)

Probable Cause(s)

Initial damage to aquatic ecosystems caused by failure of an ash pond dike. Ongoing stress has occurred from effluent discharges from the Clinch River Power Plant and ash disposal areas.

Summary

In June 1967, an environmental disaster occurred on the Clinch River when a section of coal ash pond dike at the Clinch River Power Plant collapsed releasing a caustic slug of ash slurry that equaled 40% of the daily flow of the Clinch River. The pH of the release was as high as 12.7. Approximately 162,000 fish were killed in a 106 km (65.9 mile) stretch of the Clinch River in Virginia, and an additional 55,000 fish were killed in a 39 km (24.2 mile) stretch of the River in Tennessee. Benthic macroinvertebrates were completely eliminated for a distance of 5 to 6 km (3.1 to 3.7 miles) below the spill site, and drastically reduced in number for 124 km (77 Miles) below the site. Snails and mussels were eliminated for 18 km (11.2 miles) below the power plant.

Imagery ©2010 DigitalGlobe, GeoEye, Commonwealth o

The Clinch River watershed has an assemblage of freshwater mussel species that is among the most diverse in the world. Unfortunately, forty years after the spill, aquatic ecosystems downstream of the Clinch River Plant remain degraded especially with respect to mussel populations. Much of the present impairment is being caused by high concentrations of copper and aluminum in effluent from the power plant. There is evidence however that high concentrations of aluminum in ash pond effluent also contribute to the present biotic impairment.

The 300-mile long Clinch River, a major tributary of the Upper Tennessee River system, contains an assemblage of freshwater mussel fauna (unioniods) that is among the most diverse in the world. Sampling performed at selected sites within the Clinch River between 1979 and 1994 found a total of 39 mussel species, six of which were endangered and 14 of which were endemic to the Cumberland Plateau (Ahlstedt and Tuberville, 1997). In the watershed at least four fish and 18 freshwater mussel (Unionoidea) species are listed as either federally endangered, threatened, or of special concern (USEPA, 1997).

In 1967, a 15 to 25 meter (50 to 80-foot) section of a dike surrounding Ash Pond 1A/1B failed. In less than an hour, 400 acre-feet of ash slurry poured into Dump's Creek which joins the Clinch River only 0.8 km (one-half mile) downstream. This caustic slug equaled 40% of the daily flow of the Clinch River at the time and blocked the normal flow for several minutes. It also raised the water level several meters and forced some of the waste approximately 0.8 km (one-half mile) upstream (Crossman et al. 1973).

The ash from the coal burned at the Clinch River plant had a high free lime (CaO) content, which reacted with water in the settling pond to form $Ca(OH)_2$, a highly alkaline material. During the release, elevated pH as high as 12.7 (TVA, 1967), was the source of toxicity. The slug of fly ash killed approximately 162,000 fish in a 106 km (65.9 mile) stretch of the Clinch River in Virginia, and an additional 55,000 fish in a 39 km (24.2 mile) stretch of the river in Tennessee. Benthic macroinvertebrates were completely eliminated for a distance of 5 to 6 km (3.1 to 3.7 miles) below the spill site, and drastically reduced in number for 124 km (77 Miles) below the site. Snails and mussels were eliminated for 18 km (11.2 miles) below the power plant (Crossman et al. 1973).

Two years later, the benthic macroinvertebrate communities that were completely eliminated below the power plant had recovered in terms of taxon richness relative to the upstream stations. However, the right bank of the river directly below the plant received continuing effluent discharges and communities there were still impaired (Crossman et. al. 1973).

In contrast to benthic macroinvertebrates, in general the mollusk communities were not as successful in recolonizing the impacted area, having significantly reduced numbers up to 30 km (18.6 miles) downstream of the power plant. Additionally samples from the area affected by the spill had fewer species of insect fauna that are sensitive to pollution than samples from unpolluted reaches of the stream, although it was not possible to discriminate between remnant effects of the spills (there was also a more limited acidic spill in 1970) and chronic stress due to the day-to-day operation of the power plant (Crossman et al. 1974).

An intensive survey of mollusk fauna almost twenty years after the spill found that they were non-existent within the stream section influenced by the Clinch River Plant effluent (Stansbery, et al. 1986). More recent surveys found that native mussels remained absent from the area of influence of discharges from the plant (0.5 to 0.6 km, 1,640 to 1,970 feet, downstream), though recent surveys suggest downstream distributions of native species are closer to the CRP discharge than has been reported previously (Hull, 2002).

In addition to the acutely toxic spill discussed above, high concentrations of metals, most notably copper, in the effluent discharges from the power plant have been associated with biological impairment. Effluent concentrations for copper exceeded water quality criteria from 1985 to 1989 (Cherry et al. 1996). The average concentration was 0.436 mg/L, 33 times the acute WQC (0.013 mg/L), and 48 times the chronic WQC (0.009 mg/L). Various studies linked these exceedances to depression of enzymatic activity in transplanted clams (Farris et al. 1988; Belanger et al. 1990) and shifts from pollution-sensitive aquatic insect species to more pollution tolerant species (Clements et al. 1988; Van Hassel and Gaulke, 1986). Replacement of cooling tower piping was completed in 1987 and wastewater treatment modifications were made in 1993 to reduce effluent metals concentrations. Sampling conducted for further ecological studies from January 2000 to October 2002, measured average concentrations of copper at 0.014 mg/L, slightly above applicable WQC at the time. During the same time period, aluminum averaged 0.843 mg/l, almost ten times the chronic WQC of .087 mg/L. (Hull, 2002). These effluent discharges are process waters from the power plant, not discharges from the bottom ash pond northeast of the plant although high aluminum concentrations have continued to occur in the discharge from Ash Pond Area 1 discussed below.

Following the reductions in effluent copper, most benthic macroinvertebrate community parameters (e.g., richness and diversity) recovered at affected sites from levels that were typically 70% of reference levels to levels that ranged from 80% to more than 100% of reference levels. However, bivalves remained impaired downstream, with transplanted mollusks at effluent-affected sites having a typical survivorship of 40% and growth 20% that of reference sties. Concentrations of aluminum which continued to be measured at almost ten times the water quality criteria for chronic exposure have been identified as a likely candidate for continuing impairment of aquatic ecosystems downstream from the Clinch River plant (Hull, 2002).

Crossman et al. (1974) noted the difficulty in discriminating between the effects of the 1967 and 1970 spills and chronic stress due to effluent discharges of process water from the Clinch River Plant. Ecological studies from 2000 to 2002 addressed this question by including study sites adjacent to the Ash Pond Area 1 northeast of the plant and the fly ash landfill west of the plant. Hull (2002) found that the most severe biotic impairment was caused by effluent discharges at the plant itself, which extended to a distance of about 0.6 km (1,970 feet) downstream. Impairment of bivalves was observed but was less evident below the ash landfill and low-volume leachate from Ash Pond Area 1. Hull (2002) also sampled water quality in Ash Pond Area 1 to quantify settling efficiency of metals (Al, Cu, Fe, Zn) from the point of influent to the point of discharge from the second settling pond. Near the point of discharge aluminum was 1.2 mg/L, 1.6 times the WQC for acute exposure (0.75 mg/L) and 14 times higher than the WQC for chronic exposure (0.087 mg/L). Throughout the ponds the pH averaged about 10, well above the SMCL maximum of 8.5.

pH and aluminum

The authors are not aware of any attempt to document human exposure to the pollution events at this power plant. Virginia public well data is closely held and Virginia DEQ would not release the location of any nearby drinking water wells or information attributed with public wells. Private well data is organized at the county level with comprehensiveness and data quality varying greatly from county to county. Russell County has no well records that are electronic or able to be mapped. Well drillers in this county are not required to report a Latitude/Longitude for a well location, just the address of the property drilled.

June, 1967 (ash pond dike failure). In 1970, a less extensive acid spill took place. As of 2002 high concentrations of aluminum in effluent from Ash Pond Area 1 continued to stress aquatic ecosystems.

None reported related to the ash spill. High concentrations of power plant effluent metals in the late 1980s were addressed by operational changes.

Fly ash and bottom ash

Bottom Ash Pond Areas 1 and 2 were commissioned in 1964. Pond Area 1 has a surface area of 45 acres. A fly ash landfill also exists at the site.

Ash Pond Area 1(from which the spill took place) is active. Bottom Ash Pond 2 was taken out of service in 1998. The fly ash landfill is active. (Appalachian Power, 2009)

Ash ponds are placed on alluvial sediments of the Clinch River and Middle Fork of Clinch River (also called Dump's Creek), and the ash landfill is also placed on alluvial sediments of the Clinch River.

This damage case has an odd history. EPA identified it as one of only two "documented" cases of CCW disposal sites causing significant harm to the environment in its 1988 Report to Congress (USEPA, 1988). It was also identified as a proven damage case for purpose of the 1993 Regulatory determination, but was then rejected as a damage case for purposes of the 1999 Report to Congress because there was no co-management of other wastes with the CCW. The fact that this site was not included as a damage case in the 1999 Report to Congress led it to be rejected as a damage case in EPA's CCW Damage Case Assessment Report (USEPA 2007). If this strange logic (that CCW waste disposal sites have to include other non-coal wastes to be classified as a damage case), had been applied to all damage cases in EPA's 2007 assessment, most would have been rejected. Given the extensive data regarding ecological damage from CCW disposal at the Clinch River Plant, EPA should include this site in its list of CCW damage cases.

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Entity/Company – Location

American Electric Power d/b/a Appalachian Power Company - Glen Lyn Plant
100 Apoco Rd.
Glen Lyn, VA 24093
Giles County
Latitude: 37.371389 Longitude: -80.862222

Determination

Demonstrated off-site damage to surface water and aquatic ecosystems (aquatic macroinvertebrates and bacteria in a receiving stream)

Probable Cause(s)

Discharge of coal combustion waste (CCW) pond effluent to surface stream

Summary

A number of scientific studies in the late 1970s and 1980s documented adverse biological impacts of effluent discharges from the fly ash pond at the Glen Lyn Power Plant in Virginia on a mountain stream before it reaches its confluence with the New River at Glen Lyn. Effluent from the fly ash holding pond, released from the late 1970s to the middle of 1980, caused exceedances of Virginia Water Quality Standards in the River that were more than 30 times the acute Water Quality Criteria (WQC) for cadmium and more than four times the acute WQC for selenium and significantly reduced the taxon (a group of one or more organisms that taxonomists judge to be a unit) richness and diversity of benthic macroinvertebrates in receiving waters.

The high pH of the stream (9.5) was acutely toxic to sensitive aquatic mayfly species, and the structure and metabolic functioning of heterotrophic bacteria was significantly reduced in the stream. After ash pond discharges into the river stopped during the summer of 1980, the benthic macroinvertebrate community showed signs of ecological recovery within ten months. Another study found bioconcentration factors for Duckweed (*Lemna perpusilla*) growing in the coal ash impoundment ranged from 580 for copper to 10,000 for cadmium and nickel, making these metals a potential biological problem to other organisms if the Duckweed was flushed from the pond under high flow conditions.

[illegible]

The impact on aquatic organisms of the discharge of effluent from a fly ash holding pond at the Glen Lyn Plant (also called a "secondary retaining basin") into a "receiving mountain stream," west of the coal ash pond and flowing north into the New River, was the subject of several scientific studies in the late 1970s and until discharges stopped in the summer of 1980. The Glen Lyn Plant is located south of the pond that was studied, at the confluence of the East and New Rivers. When ash pond effluent discharges into the stream peaked in early 1980 the taxon richness and diversity of benthic macroinvertebrates in the stream was significantly reduced (Specht et al. 1984). Mayflies were greatly reduced in numbers in the ash influenced stream and a population shift occurred whereby more pollution-resistant coleopterans flourished. The toxic impacts of the fly ash effluent were due to high total suspended solids (TSS = 102 mg/L), a rise in pH to 9.5, and elevation of trace elements in the stream above Virginia Water Quality Criteria (WQC) as follows (WQC values below assume hardness of 100 mg/L CaCO3):

- **Cadmium** concentrations (0.09 mg/l) were 30 times VA acute WQC of 0.0030 mg/L and 82 times chronic WQC of 0.0011 mg/L;
- **Chromium** concentrations (0.07 mg/l) were close to the VA chronic WQC of 0.074 mg/L: and
  Selenium concentrations (0.085 mg/l) more than 4 times VA acute WQC of 0.02 mg/L and 17 times VA chronic WQC of 0.005 mg/L.

The concentrations of some trace metals were excessive in the fly ash influent that entered the holding pond from the electrostatic precipitators (Cairns and Cherry 1983). These concentrations included copper measured at 2.88 mg/l, more than 221 times Virginia's acute WQC for the protection of aquatic life of 0.013 mg/L and zinc at 2.17 mg/l,18 times the VA acute WQC of 0.12 mg/L.

The high pH of the ash-influenced stream (9.5, the upper pH limit for Virginia's WQC standards) was acutely toxic to sensitive mayflies such as *Isonychia bicolor*. The 96-hour acute LC_{50} value for *Isonychia* (the pH at which half of the exposed mayflies died within 96 hours) was reported to be 9.54 (Peters et al. 1985).

After the discharge of the holding pond effluent into the mountain stream was stopped in the summer of 1980, the benthic macroinvertebrate community showed signs of ecological recovery within ten months.

The structural and functional relationships of heterotrophic bacteria (bacteria which use organic compounds as carbon sources) were also evaluated in the ash effluent impacted stream in 1979 (Larrick et al 1981). The mean percent of chromagenic bacterial forms (bacteria that can be studied using color photography) were significantly altered by heavy ash and fly ash effluent. During the time of maximum fly ash effluent release into the stream in 1979, the heterotrophic bacteria structure and function of glucose assimilation were significantly reduced as well. The study was conducted a year before the high total suspended solids (TSS), trace elements, and alkaline pH discharges that caused significant alteration of the benthic macroinvertebrate community had peaked which might have caused further degradation of the heterotrophic bacterial community structure (Specht et al. 1984).

Clark et al. (1981) studied duckweed (*Lemna perpusilla*) inhabiting the secondary retaining basin for bottom ash (also called "heavy" ash) at the Glen Lyn Plant found that the duckweed accumulated heavy and soft metals (cadmium, copper, iron, manganese, zinc, chromium, lead, and nickel) to a much greater extent than levels of these metals found in the water column or basin sediments in laboratory experiments. Calculated bioconcentration factors (BCFs) in duckweed ranged from 580 for copper to 10,000 for cadmium and nickel. The capacity of duckweed to accumulate high concentrations of heavy metals from coal fly ash basins could lead to the displacement of the metals on a seasonal basis making them biologically available to other organisms if the duckweed is flushed from the holding ponds under high flow conditions. The metals can also be released through biological elimination when the duckweed is immersed in the receiving drainage system or released upon mortality and decay of the plant material

Cadmium, copper, chromium, selenium, zinc, pH, and TSS.

The authors are not aware of any attempt to document human exposure to pollution events at this power plant. Virginia public well data is closely held and Virginia DEQ would not release the location of nearby residential or commercial drinking water wells, or information attributed with public wells. Private well data is organized at the county level with comprehensiveness and data quality varying greatly from county to county. Giles County has no well records that are electronic or able to be mapped. Well drillers in this county are not required to report a Latitude/Longitude for well location, just the address of the property drilled.

Identified during scientific studies in the late 1970s and early 1980s

Unknown

Bottom ash and fly ash, but primary studies cited here focused on the fly ash pond effluent impacts

Fly ash and bottom ash surface impoundments

Active. The fly ash pond, commissioned in 1965, is 7.6 acres. The bottom ash pond, commissioned in 1963, is a 5.1-acre multi-pond system where other wastewaters are separately treated in contiguous cells. (Appalachian Power, 2009)

Both ponds are on alluvial sediments of the New and East Rivers.

This ecological damage case was identified in a report prepared for the Hoosier Environmental Council (Cherry et al., 2000), and data from the Cairns and Cherry (1983) are presented in Rowe et al. (2002). The site was not addressed in EPA's 2007 CCW Damage Case Assessment (USEPA, 2007).

Appalachian Power Company. 2009. Glen Lyn Plant, Response to U.S. EPA Coal Combustion Residue Impoundment Survey, *avalable at* http://www.epa.gov/epawaste/nonhaz/industrial/special/fossil/surveys/index.htm.

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Larrick, S. R., J. R. Clark, D. S. Cherry and J. Cairns, Jr. 1981. Structural and Functional Changes of Aquatic Heterotrophic Bacteria to Thermal, Heavy and Fly Ash Effluents. *Water Res.* 15:875-880.
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Virginia Department of Environmental Quality. 2010. Water Quality Standards, *available at* http://www.deq.state.va.us/wqs/.

Entity/Company – Location

Alliant Energy d/b/a Wisconsin Power & Light Company - Columbia Energy Center
W8375 Murray Rd
Pardeeville, WI 53954
Columbia County
Latitude: 43.4864 Longitude: -89.4203

Determination

Demonstrated off-site damage to aquatic ecosystems (aquatic macroinvertebrates in a receiving stream)

Probable Cause(s)

Discharges of toxic coal ash pond effluent to receiving stream

Summary

Ecological studies in the late 1970s identified devastating impacts on aquatic biota in a receiving stream from the discharge of effluent from the coal ash ponds at the Columbia Generating Station in Wisconsin. In 1977, high concentrations of suspended and dissolved solids and potentially toxic heavy metals caused near disappearance of macroinvertebrates 2.2 miles downstream from the effluent discharge point at the ash ponds. Although available data on heavy metal concentrations did not allow calculation of precise exceedances of Water Quality Criteria (WQC), the concentrations of cadmium and copper probably exceeded federal and Wisconsin acute and/or chronic levels for protection of aquatic organisms. Modifications to the treatment of coal and ash slurry effluent at the power plant in 1979 allowed recovery of the macroinvertebrate community, though it was still characterized by a lower total abundance and shift to more pollution-tolerant species.

Note that the upstream site appears to be downstream from the Ash Ponds, but is actually on a stream that enters the affected stream from the east.

Test of Proof

A number of studies conducted by the U.S. Environmental Protection Agency's (USEPA)Environmental Research Laboratory and the University of Wisconsin-Madison's Institute for Environmental Studies from 1974 to 1980 documented detrimental impacts upon the aquatic communities and adverse alterations in population dynamics in a stream receiving effluent discharge from coal ash ponds at the Columbia Electric Generating Station in Columbia County, Wisconsin.

When the Columbia Plant began operations in the mid 1970s, fly ash and bottom ash was slurried into a series of settling basins. Metallic oxides that composed the major reactive portions of the coal ash caused the pH of the slurry water to increase to 10 to 11 standard units and sulfuric acid was added to the effluent to reduce its alkalinity. Following acidification, the coal ash effluent was discharged into a stream that ran south along the east side of Columbia Lake, which received warm water discharged from the Power Plant, before flowing into Rocky Run Creek not far from its confluence with the Wisconsin River. This discharge severely modified stream habitats through precipitation of a chemical floc and increased concentration of suspended and dissolved material including some potentially toxic heavy metals (Andren et al. 1977, Magnuson et al. 1980). Forbes et al (1981) reported that the acidification caused precipitation of elements such as barium, aluminum, and chromium, forming a flocculent which coated the bottom of the ash pit and was carried into the receiving stream. In addition, Forbes et al. (1981) cited increased concentrations of chromium, barium, aluminum, cadmium, and copper downstream of the effluent discharge but information available for review did not include concentration data, so it is not possible to relate these concentrations to applicable water quality criteria. Magnuson et al. (1980) reported the following ranges of concentrations of cadmium and copper in drainage from the ash pond:

- The range of cadmium concentrations of 0.0024 to 0.0029 mg/L, exceeded USEPA's recommended WQC of 0.002 mg/L for acute exposure, and were around 10 times USEPA's WQC of 0.00025 mg/L for chronic exposure. The concentrations may have also exceeded Wisconsin's WQC for chronic exposure in surface waters of 0.00143 to 0.00382 mg/L, depending on hardness. The range of copper concentrations of 0.004 to 0.043 mg/L likely exceeded EPA's WQC criterion of 0.013 mg/L for acute exposure and 0.009 mg/L for chronic exposure (based on 100 mg/L of hardness) and depending on hardness and pH, probably exceeded Wisconsin's acute WQC of 0.00807 to 0.0298 mg/L and chronic WQC of 0.00187 to 0.00572 mg/L, which apply to all surface waters.

Conductivity, elevated in the coal ash effluent by adding sodium bicarbonate to the pulverized coal, provided an easily monitored measure of effluent strength.

Magnuson et al (1981) and Forbes et al. (1981) found that stream habitats receiving effluent concentrations exceeding 1,000 umhos/cm conductivity severely impacted macroinvertebrate populations. In 1977, when conductivity of the ash effluent was at a maximum (2,500 umhos/cm), there was a near disappearance of macroinvertebrates in the receiving stream 2.2 miles downstream from the point of discharge from the ash ponds. The upstream sampling site included 16 taxa and 929 individuals in 1977, while the downstream site 2.2 miles from the ash pond discharge point had four taxa and less than 20 individuals. Webster et al. (1986) conducted a follow-up study of macroinvertebrate abundance and number of taxa in 1980, when process modifications at the plant had reduced the conductivity of effluent to less than 1,000 umhos/cm. That year, the downstream site was similar in taxonomic composition to the 1974 pre-operation community, but had experienced significant shifts in absolute abundance as well as relative abundances of individual taxa. The resulting community was characterized by lower total abundance, and a shift from a community dominated by hdrospyschid caddisflies in 1974–1975 to one dominated by the pollution tolerant isopod, *Asellus racovitzai*, in 1980.

Within three months after the beginning of plant operation, environmental impacts of the ash effluent included elimination or severe reduction of several benthic macroinvertebrate taxa, including a mayfly (*Stenacron* *interpunctatum*), two hydropsychid caddisflies, and a dipteran family (Chironomidae). Two years later, abundance and richness of organisms were further reduced below the effluent discharge. In addition, juvenile scuds (*Gammarus pseudolimnaeus*) were exposed to concentrated ash pit effluent, resulting in 80% mortality. Further studies in the same area that placed crayfish into cages upstream and downstream of the ashpit effluent discharge, found increased concentrations of chromium, selenium, zinc, and iron in crayfish tissues downstream (Forbes et al (1981).

Conductivity (greater than 1,000 umhos/cm up to 2,500 umhos/cm), flocculent (which coated the bottom of the receiving stream), and also cadmium, copper, chromium, barium, aluminum, iron, and zinc

Private and public well data is maintained by WDNR; however, when WDNR was contacted to supply the number and location of private and public wells in a two- and five-mile radius of the Plant, WDNR stated that it did not have locational data attributed to well logs and that there was no way to tell the number of wells in the area. All private and public well logs are in paper form and WDNR does not anticipate mapping wells or putting them in a computerized database.

A decline in total abundance and number of taxa was found four months after effluent discharge began in 1974, with a near disappearance of all macroinvetebrates in 1977. With modifications to the station's operations to reduce flocculants in the ash ponds and conductivity in ash pond discharges, most taxa had recovered in 1980 (Webster et al. 1986).

No regulatory actions reported. The results of the ecological studies led to modification of methods for treating coal to increase the efficiency of the electrostatic precipitators and reduce the harmful effects of the ash pond effluent.

Fly ash and bottom ash

Surface impoundments; currently the Columbia Station has an 8.5-acre Primary Ash Pond with a storage capacity of 115,600 cubic yards that is approximately 50% filled, a 16-acre Secondary Ash Pond with a capacity of 329,700 cubic yards that is about 25% filled and a 1-acre Polishing Pond (Alliant Energy, 2009). All three ponds were commissioned in 1975. Recent information provided by Alliant Energy does not indicate whether the ponds are lined or unlined.

Active

Groundwater data were not reviewed for this site, but the ash ponds are located in alluvial deposits at the confluence of Duck Creek (north of the Ash Ponds) and Wisconsin River (west of the Ash Ponds).

Additional Narrative

Discharges from the ash ponds are covered by Wisconsin Pollutant Discharge Elimination System (WPDES) permits, for which all discharges "including any water quality exceedances" are interpreted as permitted releases (Alliant Energy, 2009).

In March of 2008, the Sierra Club filed a notice of intent to sue Alliant Energy. The notice claimed that the company did not file applications for air permit renewal on a timely basis and in doing so violated the Clean Air Act. In 2009, as a result of pressure from the Sierra Club and others, the federal government revoked its permit to the Columbia Energy Center. The result could mean that Alliant will be forced to install pollution reduction equipment that will generate more coal combustion waste or it could mean shutting down the Columbia Station.

[illegible]

Alliant Energy. 2009. Response to U.S. EPA Information Collection Request on Coal Combustion Residues (CCR) Surface Impoundments (submitted on Behalf of Wisconsin Power and Light) (Mar. 31, 2009). *Available at:* *http://www.epa.gov/osw/nonhaz/industrial/special/fossil/surveys/alliant-ecgs.pdf*

Andren, A., M. Anderson, N. Loux, and R. Talbot. 1977. Aquatic Chemistry. In: *Documentation of Environmental Change Related to the Columbia Electric Generating Station*, Eleventh Semi-Annual Report, Institute for Environmental Studies, University of Wisconsin.

Forbes, A.M., J.J. Magnuson, and D. M. Harrel. 1981. Effects of Habitat Modification from Coal Ash Effluent on Stream Macroinvertebrates. In, *The Warmwater Streams Symposium*, L.A. Krumholtz (editor). Southern Division, American Fisheries Society, pp. 241-249.

Magnuson, J. J., Forbes, A. M., Harrell, D. M. and Schwarzmeier, J. D. 1980. Responses of Stream Invertebrates to an Ashpit Effluent, Wisconsin Power Plant Impact Study. EPA-600/ 3-80-081, U.S. Environmental Protection Agency, Cincinnati, OH.

Webster, K.E., Anne M. Forbes, and John J. Magnuson. 1986. An Evaluation of Environmental Stress Imposed by a Coal Ash Effluent. EPA/600/S3-85/045. U.S. Environmental Protection Agency, Duluth, MN.

Wisconsin Department of Natural Resources (WDNR). 1997. Surface Water Quality Criteria and Secondary Values for Toxic Substances (Chapter NR 105). [Note that this is the version that is posted on both the WDNR and EPA Region 5 websites. In 2000, EPA disapproved the equations used by WI for copper as being less protective than EPA's WQC. These were revised by the

WI Natural Resources Board in 2008 (Wisconsin Natural Resources Board, 2008), and the revised equations accepted by U.S. EPA in 2009), *available at* http://www.epa.gov/waterscience/standards/wqslibrary/wi/ *and recent EPA approval at* http://www.epa.gov/reg5oh2o/wqs5/decisions.htm.

Wisconsin Natural Resources Board. 2008. Adoption of Board Order WQT-35-07, revision of Chapter NR 105 – Surface Water Quality Criteria and Secondary Values for Toxic Substances, *available at* http://dnr.wi.gov/org/nrboard/2008/June/06-08-3A2.pdf.

Entity/Company – Location

Wisconsin Energy (WE Energies (WE)) d/b/a Wisconsin Electric Power Company – Oak Creek Power Plant
Caledonia, Oak Creek South, and Oak Creek North Coal Ash Landfills
4801 E Elm Rd
Oak Creek, WI 53154
Milwaukee County (Oak Creek North and South Landfills)
Racine County (Caledonia Landfill)
Latitude: 40.839028 Longitude: -87.842264

Determination

Demonstrated damage to off-site drinking water wells

Probable Cause(s)

Leaching of contaminants from coal combustion waste (CCW) landfills into groundwater.

Summary

A dozen private drinking water wells within 1,500 feet of the Oak Creek South and Caledonia coal ash landfills (Landfills) at We Energies' Oak Creek Power Plant south of Milwaukee have been found to exceed the Wisconsin Department of Natural Resources (WDNR) NR140 Enforcement Standard (ES) of 0.04 mg/L for molybdenum and preventive action limit (PAL) of 0.19 mg/L for boron. Concentrations have been measured as high as 0.124 mg/L total molybdenum, more than 3 times the ES and USEPA's Lifetime Health Advisory Level.

Map Key: CAL = Caledonia Ash Landfill, OCS = Oak Creek South Ash Landfill, OCN = Oak Creek North Landfill, HLF = Hunts Landfill (Superfund Site), Mo1 = Douglas Avenue private drinking water well cluster, Mo2 = Botting Avenue private drinking water well cluster, Mo3 = Foley Road private drinking water well cluster, Mo4 = County Line Road private drinking water well cluster, ug = upgradient well in Dolomite, w = monitoring wells in dolomite in old ash disposal areas.

Since August 2009, We Energies has been providing bottled water to several dozen residences for drinking and cooking due the presence of high molybdenum in residential drinking water wells near the CCW landfills, but no permanent solution to the contamination has been proposed. WDNR has initiated its own investigation of the problem, but had not taken any regulatory enforcement action as of mid-2010. Although unsafe levels of molybdenum have been present in groundwater since 2002 and WDNR established its ES of 0.04 mg/L for molybdenum in December 2006, We Energies did not inform WDNR or residents that unsafe levels of molybdenum were present in groundwater until August 2009.

Story of Harm

The news media reported serious contamination of private drinking water wells west of the Caledonia Ash Landfill at the Oak Creek Power Plant in late June 2010 (WISN New, 2010; Won, 2010). Although consultants to We Energies have concluded that the molybdenum in the wells is not coming from coal ash in the Caledonia Landfill or other landfills adjacent to the power plant (NRT, 2010), a review of available information strongly supports a conclusion that most, if not all of the molybdenum in the contaminated wells is coming from the coal ash disposal areas. Millions of cubic yards of coal ash have been placed in three large landfills adjacent to the Power Plant, the oldest of which dates back to the mid-1960s. There is also evidence to suggest that wells farther west of the Douglas Avenue and Botting Avenue neighborhoods adjacent to the Caldeonia Landfill, may be affected by CCW dumped farther to the west of the Oak Creek Power Plant landfills. The discussion here focuses on contamination of the dolomite aquifer, which is the source of most, if not all, of the contaminated drinking water wells.

The following evidence provides strong support for a conclusion that the molybdenum in the in the Douglas Avenue and Botting Avenue clusters of contaminated wells is coming from the Oak Creek Power Plant coal ash landfills:

- Sampling of leachate at three different locations in the Caledonia Landfill in 2009 and 2010 found concentration of dissolved molybdenum ranging from 8.8 to 15 mg/L, 220 to 375 times the ES.
- High concentrations of molybdenum have been measured in groundwater monitoring wells northeast of the Oak Creek South Landfill (a dissolved concentration of 0.054 mg/L at W39C—the upper "w" on the satellite photo), and east of the Caledonia Landfill (a dissolved concentration of 0.094 mg/L at MW12D—the lower "w" on the satellite photo). These groundwater monitoring wells are located in coal ash disposal areas that pre-date We Energies permitted CCW landfills.
- The groundwater monitoring wells with molybdenum exceedances were in a highly concentrated area within 1,500 feet of the Oak Creek South and/or Caledonia landfills.
- Maximum boron concentrations in the Douglas Avenue Cluster of residential wells ranged from 0.44 to 0.72 mg/L, up to 3.8 times the Preventive Action Limit (PAL), and the Botting Avenue Cluster of residential wells ranged from 0.37 to 0.52 mg/L, up to 2.7 time the PAL. Boron is a major constituent in fly ash and recent measurements of boron in leachate at the Caledonia Landfill ranged from 3.3 to 41 mg/L, three to 41 times the ES for boron.
- A recently installed groundwater monitoring well (W44—marked "ug" on the satellite photo) in the dolomite aquifer, about 1,500 feet upgradient of the Douglas Avenue and Botting Avenue Clusters, had a maximum concentration of 0.014 mg/L dissolved molybdenum, and relatively low maximum concentration of boron (0.28 mg/L) which does not support the hypothesis there is an upgradient source for the molybdenum.

NRT (2010) presents data on maximum concentrations of molybdenum in private drinking water wells based on sampling from 2007 to 2010. Before September 2009, groundwater samples were analyzed for only dissolved molybdenum, which underestimates the actual exposure to residents using the wells. Starting in September 2009, concentrations of total molybdenum were also tested. The ES established by WDNR for molybdenum applies to total concentrations. Results from private, residential drinking water well sampling is summarized as follows:

- Douglas Avenue Cluster, which also includes a few residential wells on County Line Road where it intersects with Douglas Avenue. These residential drinking water wells are located within 1,000 to 1,500 feet southwest of the Oak Creek South CCW Landfill, which closed in 1992. It is unclear whether this CCW landfill was lined. This cluster of wells is marked as Mo1 on the satellite photo and includes 11 wells (R01 to R09, R25, and R27).

- Botting Avenue Cluster, which also includes a few residential wells on Douglas Avenue. These residential drinking water wells are located within 1,000 to 1,500 feet west of the currently active Caledonia Landfill, which has a liner and leachate collection system. This cluster of wells is marked as Mo2 on the satellite photo and includes 8 wells (R10 to R17).
- About 16 other drinking water wells at distances up to several miles west and one mile south of We Energies CCW landfills have also been sampled at various times.

The analysis of residential drinking water well sampling data by NRT (2010), which only goes back to 2007, focuses on dissolved molybdenum and shows the following:

- In the Douglas Avenue Cluster, 6 of the 10 drinking water wells had maximum molybdenum concentrations higher than the ES of 0.04 mg/L, with the highest measured concentration 0.089 mg/L, more than twice the ES. The well with the highest molybdenum concentrations was only first sampled in 2009. The molybdenum concentrations in the other 4 wells were close to exceeding the standard (80 to 97.5 percent of the standard).
- In the Botting Avenue Cluster 4 of the 7 wells had maximum molybdenum concentrations higher than the ES, with the highest measured concentration 0.046 mg/L. Concentrations in the other 3wells ranged from 0.023 to 0.35 mg/L.
- Molybdenum concentrations were found in wells more than 1500 feet from the CCW Landfills ranged from non-detectable levels to 0.014 mg/L (south of the CCW Landfills) and from 0.016 to 0.032 mg/L (west and southwest of the CCW Landfills).

Residential drinking water has been sampled from wells in the Douglas Avenue and Botting Avenue Clusters since 1989, but only data from 2002 was available for review. These data show that the number of wells with exceedances of the ES is larger than that shown by NRT (2010):

- As early as May 2002, three wells in the Botting Avenue Cluster exceeded the ES for molybdenum with concentrations ranging from 0.045 to 0.049 mg/L. One of these wells (R17) is not identified as contaminated by NRT (2010).
- As early as May 2003, six wells in the Douglas Avenue Cluster exceeded the ES for molybdenum with concentrations ranging from 0.041 to 0.056 mg/L. This includes two wells (R06 and R07) that were not identified as contaminated by NRT (2010). Although the Wisconsin Enforcement Standard applies to concentrations of total molybdenum, rather than dissolved molybdenum, total molybdenum only began to be measured in 2009. When total molybdenum concentrations are considered, one well in the Douglas Avenue Cluster (R25) should be included in the 0.04 mg/L iso-concentration line that maps the extent of the contaminant plume, with 8 of the 10 wells in that Cluster exceeding the ES. Furthermore, the one sampling event for the well in this Cluster with the highest concentration of dissolved molybdenum (R27) showed significantly higher concentration of total molybdenum (.0.124 mg/L, more than 4 times the ES).

Consultants for We Energies (NRT, 2010) have proposed a number of alternative sources for molybdenum in the dolomite aquifer other than the CCW Landfills. Quotes from We Energies' statements are in italics, and an analysis of their statements follows in plain text below:

- *"Naturally-occurring elevated molybdenum concentrations have been found in the Fox River Valley of Wisconsin, where oxidation of sulfide minerals is causing significant water quality issues."* This reference is to an article in Water Well Journal by Riewe et al. (2000). The main focus of the article is arsenic, which has not been identified as an issue in the contaminated wells. Although the article identifies the problem of high arsenic as occurring in dolomite aquifers, an examination of the map showing occurrences of arsenic greater than 0,005 mg/L shows that this is rare occurrence in Racine and Milwaukee Counties, and hence this citation is not applicable to the contaminated well clusters by the CCW landfills.
- *"A 1999 review of wells sampled for Minnesota's Ground Water Monitoring and Assessment Program found that while molybdenum was usually not detected, when detected its concentrations were related to*

concentrations of boron and arsenic, suggesting a geologic source. Similar to the Minnesota findings, the bedrock aquifer near the Oak Creek Power Plant also has elevated (higher than PAL, lower than ES) boron concentrations." As stated earlier, the presence of molybdenum associated with arsenic does not apply here. The consultants correctly point out that boron is also a concern in contaminated wells, and the presence and leachability of boron and molybdenum in fly ash is discussed further below.

- *"A 2008 study of molybdenum occurrence in British drinking water found that relatively high molybdenum concentrations occurred under conditions where there was either oxidation of sulfide minerals or where reducing conditions were prevalent (both naturally-occurring conditions). Pyrite, a sulfide mineral, was observed in the cores taken for W44 (Figure 8), and low iron concentrations in groundwater suggest potential for locally oxidizing conditions near the Oak Creek Power Plant."* This reference is to an unpublished report by the British Geological Survey (Smedley et al., 2008). A review of this report indicates that high concentrations of molybdenum (greater than 0.07 mg/L) are very rare in Britain (three out of 1,398 samples analyzed, or 0.021%), and that maximum concentrations associated with mine drainage water where oxidation of sulfides has occurred are only 0.006 mg/L. The fact that the maximum concentration of molybdenum measured in W44 where the pyrite was observed in the core is 0.016 mg/L suggests that this process might be a minor natural source for molybdenum in groundwater in the area, but can't explain the high concentrations in residential wells near the CCW landfills.

The high concentrations of boron in the leachate from the Caldonia Landfill noted above are consistent with the high concentrations of boron found in Illinois Basin bituminous coals compared to coals from other regions. Zillmer and Fauble (2004) and Wu and Chen (1987) found that very high percentages of boron (58-88%) were leachable from Illinois Basin bituminous coal ashes under alkaline conditions. Boron commonly exceeds WDNR groundwater standards in monitoring wells at CCW disposal sites, especially in sites that were active prior to the late 1980s (Zillmer and Fauble, 2004). In Wisconsin, because boron has such a distinctive association with CCW landfills, the only situation where the State recommends testing for boron in private wells is when they are located within one-quarter of a mile of a CCW landfill (WDNR, 2000).

Furthermore, Ainsworth and Rai (1987) found molybdenum to also be strikingly more concentrated in fly ash from eastern bituminous coal compared to western subbituminous coal and lignite. In addition, Dressen et al. (1977) found that molybdenum is also highly leachable from coal fly ash under alkaline conditions.

Consultants for We Energies (NRT, 2010) have presented the following two main arguments for the case that the molybdenum in the contaminated private drinking water wells is not coming from the CCW landfills:

- Vertical profiles in nested monitoring wells that extend to the bedrock show molybdenum concentrations in the overlying till formation that are lower than in the bedrock, whereas the opposite would be expected if the source was an ash landfill on the power plant property.
- Groundwater flow direction in the dolomite aquifer is toward the northeast, from the residential wells toward the landfills, meaning that molybdenum cannot be migrating west in the dolomite aquifer from the landfills toward the residential wells.

However, the migration of contaminants upgradient from the general flow direction can be explained with one or more of the following principles of contaminant hydrogeology:

- Both the glacial till and dolomite have a low primary porosity, so flow of groundwater associated contaminants is concentrated in the secondary porosity, mainly fractures. Groundwater flow in fractured systems often does not follow the average direction of groundwater flow as measured in water levels in wells.
- Concentrations of molybdenum in monitoring wells that are lower in the till formation than in the underlying dolomite would be expected if the monitoring wells are collecting samples of aquifer groundwater in the till rather than from fractures which would concentrate the downward flow of leachate.

- As noted in the Hydrogeologic Conditions section (below), there is a strong downward gradient of about 40 feet between groundwater levels in the till and the dolomite. This downward gradient would allow rapid downward migration of contaminants along the preferential pathways created by fractures.
- Any pumping of groundwater from a well creates a capture zone that includes water that is downgradient from the well. Collectively the Douglas Avenue and Botting Avenue have created capture zones that extend downgradient to the CCW Landfills. Where fracture flow is present (and the dolomite would not serve as an aquifer if there were not significant secondary porosity and fracture flow occurring), the usual models for estimating capture zones underestimate the distance that downgradient water can be captured, so caution should be used when making theoretical calculations to address this question.

In summary, the available evidence points strongly toward coal ash in the Oak Creek South Landfill and an older coal ash disposal area northeast of that landfill as the primary source of molybdenum in private drinking water wells in the Douglas Avenue Cluster where eight out of ten wells have exceeded the ES. Available evidence suggests that old, pre-permit coal ash disposal areas east of the Caledonia Landfill are the primary source of molybdenum in private drinking water wells in the Botting Avenue Cluster where four of seven wells exceed the ES. Supporting evidence for this conclusion are the high concentrations of molybdenum in the old ash disposal areas (dissolved concentrations of 0.054 and 0.094 mg/L) and very high concentrations of molybdenum in leachate from the Caledonia Landfill (up to 15 mg/L, 375 times the ES).

Molybdenum above WDNR NR140 Enforcement Standards (ES) and boron above WDNR Preventive Action Limits (PALs) in private wells and in monitoring wells for adjacent ash disposal areas. WDNR (2010) also identifies manganese and sulfate above ES and arsenic, boron, fluoride, and mercury above PALs in on-site Caledonia Landfill wells.

Molybdenum concentrations exceeded ES, and boron concentrations were above the PAL in multiple private drinking water wells immediately west of the Caledonia Landfill in May 2002, the earliest date for which data were available to review (WIDNR 2002-2010). Actions to address the problem were not taken until 2009.

When WDNR began regulating CCW landfills in the late 1980s, coal ash disposal had stopped at the Oak Creek North Landfill and was coming to a close at the Oak Creek South Landfill. Permits issued for those landfills focused on establishment of a groundwater monitoring network and placement of two-foot clay caps to reduce infiltration through the unlined landfills. The discussion here focuses on the molybdenum contamination in private drinking water wells southwest of the Oak Creek South Landfill and west of the Caledonia Landfill, which have been monitored since 1989 for a number of general chemistry parameters, including metals by We Energies as part of local agreements with the City of Oak Creek and Village of Caledonia. WDNR did not establish an ES for molybdenum until December 2006, but at least as early as 2002, monitoring data showed concentrations of boron in multiple wells that exceeded the WDNR PAL for boron of 0.19 mg/L. The first notification to residents that the wells were contaminated was a letter dated August 24, 2009 from Wisconsin Energy Corp. (Won, 2010). The monitoring data for the private wells were also not reported to WDNR until August 2009, at which time We Energies was asked to submit an investigation plan, which was submitted on September 4, 2009, and approved on September 29, 2009. We Energies has been providing bottled water to several dozen residents since that time. NRT, a consultant to We Energies, submitted the results of the investigation on March 30, 2010, which concluded that the hypothesis of migration from coal ash sources is "not supported." In June 2010, WDNR assigned staff to investigate the problem. To date WDNR has taken no regulatory enforcement action.

[illegible]

The Caledonia Landfill receives fly ash and bottom ash, flue gas desulfurization by-products (filter cake and off-spec gypsum), and dewatered wastewater treatment plant solids from five power plants operated by WE (Oak Creek, Elm Road, Pleasant Prairie, Valley, and Milwaukee Power). (WI DNR, 2010)

Type of Waste Management Unit

CCW landfill

[illegible]

Active and inactive. One active (Caledonia) and two inactive landfills (Oak Creek North and Oak Creek South) are located east and north of the Oak Creek Plant. The disposal of CCW in unlined sites was an accepted practice in Wisconsin prior to the promulgation of administrative codes and the establishment of procedures for siting and constructing waste disposal facilities 1988 (Zillmer and Fauble, 2004).

- Caledonia (FID#252108450; license #3232) is approximately 45 acres in size and has an approved capacity of 4,050,000 cubic yards. As of May, 2010, approximately 1.75 million cubic yards had been placed in the landfill. Initial approval for the Plan of Operation was received in August 1987. Phase I design and construction specified a 5-foot-thick compacted clay liner (for completed cells 1, 2, 3, 4, 6 and 8). Phase II specifies construction with a 4-foot-thick clay liner and a geomembrane. Phase II also includes a leachate collection system.
- Oak Creek North (FID#241219440; license #0414) started operating in the mid 1960s and closed in the late 1970s or early 1980s. It is not clear whether this landfill was lined.
- Oak Creek South (FID#241219770; license #2357) began receiving ash in 1974 and was closed in 1992 with a two-foot clay cap. Leachate is collected from part of the landfill by gravity drain, which is then pumped to a treatment facility. Clay soil that was excavated in 2005 for the construction of a new power plant was placed on top of this landfill.

Evidence of a liner could not be found for either the Oak Creek North or South Landfills. The Oak Creek Power Plant began operations in the 1950s before permits were required for ash disposal, and other ash disposal areas are located throughout the plant property between the Caledonia and Oak Creek South landfills and Lake Michigan (We Energies, 2002).

[illegible]

Three major hydrogeologic units are present in the CCW Landfill area:

- Massive clay-rich glacial till of the Oak Creek Formation, with generally low hydraulic conductivity. In the vicinity of the Caledonia Landfill the thickness ranged from 150 to 175-feet thick.
- Sand seams of varying continuity within the glacial till, which represent potential pathways for preferential flow of contaminants. In the area of the Caledonia Landfill, these seams appear to be discontinuous. In area of the Oak Creek South Landfill, two continuous sand seams ranging in thickness of 5 to 10 feet (upper) and 10 to 20 feet (lower) are present. There are no geologic boring logs to map potential sand extent to the west.
- Dolomite bedrock below the glacial till serves as the uppermost aquifer in the area. Well logs are not available for most of the residential wells west of the landfills where contamination is evident, but available information indicates that most, if not all are screened in the dolomite bedrock.

Near surface groundwater in the glacial till in the area of the Oak Creek South Landfill flows generally to the northwest and southeast, according a plot of groundwater elevations recorded on November 2009. A plot of water levels in several wells in the till from 1994 to 2009 shows groundwater elevations ranging from 680 to 715 feet. Plots of elevations in the intermediate sand seam in the till in the north area of Oak Creek South Landfill and the dolomite (well nests W37 and W39) range in elevation from around 640 to 655 feet. There is a strong downward gradient in hydraulic head in these well nests (about 40 feet) suggesting that rapid downward migration of contaminants would occur if vertical pathways for flow were available. NRT suggests that drops in water levels in the sand seam and dolomite may have been influenced by dewatering related to construction of new units at the Oak Creek plant in 2005 (NRT 2010). However, similar drops in elevation in the dolomite occurred in the mid-1990s. The very similar elevations and generally parallel fluctuations in the sand seam and the dolomite in the above-mentioned well nests suggest the possibility that the dolomite and sand seam are interconnected hydraulically. (NRT, 2010)

A dozen wells within 1,500 feet of the Caledonia or Oak Creek South Landfills are seriously contaminated by molybdenum and exceed Wisconsin PALs for boron. Although molybdenum levels in these wells have been known to exceed WDRN N140 Enforcement Standards since at least 2002, it was only in August 2009 that residents were informed that their water was unsafe to drink. We Energies has not yet acknowledged that they are responsible for the contamination, but the company has been providing bottled water to residents in more than two dozen homes (WISN News, 2010 and Won, 2010). There is a large neighborhood with around 100 residences located north of the Oak Creek South Landfill and west of the Oak Creek North Landfill. Although most of this area receives public water from Oak Creek, which comes from Lake Michigan, there are a few private wells. Private and public well data is maintained by WDNR. However, when WDNR was asked the number of private and public wells in a 2 and 5 mile radius, it stated it did not have locational data attributed to well logs, or any way to determine the number of wells in the area. WDNR keeps all private and public well logs in paper form and does not anticipate mapping or putting them in a computerized database.

WDNR is in the early stages of its Oak Creek/Caledonia Molybdenum Study. Sampling results in February and March 2010 from 40 private wells by residents in the area using kits provided by the Wisconsin State Laboratory of Hygiene (WSLH, 2010) have identified several more clusters of private wells where the ES for molybdenum and PAL for boron have been exceeded. As discussed earlier, the connection between elevated levels of molybdenum and boron in groundwater with disposal of coal ash in Wisconsin is so strong that the best explanation for the groundwater concentration data for molybdenum and boron, which were available for review at the time of writing, is that one or possibly two additional sources of CCW disposal are located west of the Douglas Avenue and Botting Avenue well clusters. These two additional well clusters are discussed below, but it should be noted that the regional northeast-trending direction of groundwater flow in the dolomite aquifer does not place these clusters upgradient from the Douglas and Botting Avenue well clusters adjacent to the Oak Creek South and Caledonia Landfills discussed earlier.

The Hunts Disposal Landfill, a Superfund site, is located about 1.5 miles west of the Oak Creek South and Caledonia Landfills. At this location municipal and chemical wastes were dumped in an abandoned sand and gravel pit from 1959 until 1974. Molybdenum is not listed as a contaminant of concern for this site (contaminants of concern include arsenic, chromium, and barium.) According to USEPA (2009), "[a]pproximately 40 homes are located within a one-half mile radius of the landfill. A rural community of approximately 150 homes is located west of the site. The community uses local groundwater as a drinking water source. Based on the sampling of the residential wells in the surrounding area, the local water supply is not impacted by the landfill." However, recent sampling of two private wells on County Line Road immediately north and downgradient of the Hunts Disposal Landfill (WSLH, 2010) found concentrations of molybdenum exceeding the ES (both 0.043 mg/L) and boron exceeding the PAL (0.470 to 0.477 mg/L). Neither arsenic nor chromium, contaminants of concern related to the Superfund Site, were detected in either of these wells (barium was not analyzed), but the levels of molybdenum and boron are similar to those in the CCW contaminated Douglas Avenue and Botting Road well clusters. This suggests that the contamination is coming from CCW disposal in the vicinity rather than the other hazardous wastes that were placed in the Hunts Disposal Landfill.

Recent residential well sampling (WSLH, 2010) indicates another cluster of four wells on Foley Road about halfway between the Hunts Landfill and the Caledonia Landfill (marked at Mo3 on the satellite photo) where the ES for molybdenum is exceeded (0.045 to 0.085 mg/L) as well as the PAL for boron (0.399 to 0.574 mg/L). Several considerations suggest that there may be another area of coal ash disposal in this neighborhood:

- The location of the wells is more cross-gradient than downgradient from the Hunts Disposal Landfill.
- Neither arsenic nor chromium, contaminants of concern for the Superfund Site, were detected in any of the Foley Road well samples.
- The four wells where the ES for molybdenum is exceeded are close together, whereas there are eight other private wells on Foley Road with elevated molybdenum, but not above the ES. This suggests a localized source, rather than the Hunts Disposal Landfill.
- There are unvegetated spots in the vicinity of Foley Road and County Line Road in this area that are suggestive of soil disturbance or placement of fill.

Ongoing investigations should provide additional information that will shed light on the molybdenum and boron contamination of groundwater that is present adjacent to the Oak Creek South and Caledonia Landfills, and areas farther to the west. The Oak Creek Power Plant has been operating since the 1950s.

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TABLE 3: COAL COMBUSTION WASTE HEALTH EFFECTS

POLLUTANT	HUMAN HEALTH IMPACTS	ECOLOGICAL IMPACTS
Arsenic	• Inorganic arsenic is a known human carcinogen. • Arsenic is also linked to cardiovascular and dermal effects, encephalopathy, and peripheral neuropathy.	• Arsenic accumulates in freshwater plants and bivalves, where it enters the food supply.
Barium	• Barium can cause gastrointestinal disturbances and muscular weakness. • Ingesting large amounts of barium, dissolved in water, can change heart rhythm, and can cause paralysis and possibly death.	• Barium affects development of germinating bacterial spores and has a variety of effects on microorganisms, including inhibition of cellular processes.
Boron	• Exposure to large amounts of boron (about 30 g of boric acid) over short periods of time can affect the stomach, intestines, liver, kidney, and brain and can eventually lead to death.	• Boron enters the food chain through plant absorption. Exposure to large amounts boron through food or water adversely affects male reproductive organs in animals and can cause birth defects or delayed development.
Chromium	• Chromium VI is a known human carcinogen. • Chromium VI exposure has also caused stomach tumors in humans and animals.	• Chromium can make fish more susceptible to infection and damage/accumulate in various fish tissues and invertebrates such as snails and worms.
Copper	• High levels can cause harmful effects such as irritation of the nose, mouth and eyes, vomiting, diarrhea, stomach cramps, nausea, and even death.	• Copper has adverse reproductive, biochemical, physiological, and behavioral effects on aquatic organisms.
Manganese	• Exposure to high levels of manganese can affect the nervous system. • Very high levels of manganese may impair brain development in children.	• Nervous system and reproductive effects have been observed in animals after high oral doses of manganese.
Mercury	• High mercury levels can permanently damage the brain and other organs. • Mercury can harm developing fetus, causing brain damage, mental retardation, blindness, seizures, and inability to speak.	• Mercury is easily absorbed through organic tissues and membranes. It easily bio-accumulates and can concentrate as it progresses up food chains.
Molybdenum	• Fatigue; Headaches; Joint Pains	• Large amounts can cause fetal deformities in animals.
Nickel	• The International Agency for Research on Cancer (IARC) has determined that some nickel compounds are carcinogenic to humans and that metallic nickel may possibly be carcinogenic to humans.	• Nickel absorption into organisms' organs and bodies can cause growth defects.
Thallium	• Thallium affects the nervous system, lung, heart, liver, and kidney if large amounts are eaten or drunk for short periods of time. • Temporary hair loss, vomiting, and diarrhea can also occur and death may result after exposure to large amounts for short periods. Thallium can be fatal from a dose as low as 1 gram.	• Animal reproductive organs, especially the testes, are damaged after drinking small amounts of thallium contaminated water for 2 months.
Vanadium	• Although impacts from ingestion are unclear, workers who breathed vanadium suffered lung irritation, coughing, wheezing, chest pain, runny nose, and a sore throat.	• Animals that ingested very large doses have died. High levels of vanadium in the water of pregnant animals caused minor birth defects.
Zinc	• Ingesting large doses even for a short time can cause cramps, nausea, and vomiting. • Inhaling large amounts of zinc can cause a short-term disease called metal fume fever.	• High concentrations of zinc in water have been shown to exert adverse reproductive, biochemical, physiological and behavioral effects on a variety of aquatic organisms.

Sources: Agency for Toxic Substances and Disease Registry, ToxFAQs, *available at* http://www.atsdr.cdc.gov/toxfaq.html; World Health Organization International Program on Chemical Safety (IPCS) INCHEM: Environmental Health Criteria, *available at* http://www.inchem.org

Risky Business

Coal Ash Threatens America's Groundwater Resources at 19 More Sites

December 12, 2011

ENVIRONMENTAL INTEGRITY PROJECT

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