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MEMORANDUM

To: Nate Benforado, Southern Environmental Law Center
From: Anthony Brown, **aquilogic**, Inc.
Steve Ross, **aquilogic**, Inc.

Subject: Review of Groundwater Conditions
Coal Ash Waste Ponds at the Chesterfield Power Station
Project No.: 019-08

Aquilogic, Inc. (**aquilogic**) has been retained by Southern Environmental Law Center (SELC) to provide expert consultation and analysis in connection with the coal ash ponds located at the Dominion Chesterfield Power Station in Chesterfield County, Virginia (the Site) (**Figure 1**). The Chesterfield Power Station is located at 500 Coxendale Road, Chester, Chesterfield County, Virginia. The scope of this phase of work was to evaluate groundwater and contaminant conditions at the Site, and how a closure plan following a cap-in-place approach would affect those conditions. As part of the evaluation we addressed the following questions:

1. Is groundwater within the ash ponds at the Site in direct hydrologic connection with surface waters, including the Tidal James River Old Channel (Old Channel)?
2. Is groundwater at the Site in contact with coal combustion residuals (CCR) or coal ash waste placed in the Upper and Lower Ash Ponds?
3. Is the coal ash waste in the Lower and Upper Ash Ponds contaminating groundwater?
4. Does coal ash waste pollution in groundwater discharge to surface water, including the Old Channel?
5. Is surface water at the Site in direct contact with coal ash waste?
6. Will capping of the ash ponds prevent the continued contamination of groundwater at the ash ponds?
7. Will capping of the ash ponds prevent the discharge of contaminated groundwater to the surface water, including the Old Channel?

SUMMARY OF EVALUATION

1. **Is groundwater within the ash ponds at the Site in direct hydrologic connection with surface waters, including the Tidal James River Old Channel?**

Yes. Groundwater is present in the Lower and Upper Ash Ponds at higher elevations than the surrounding area. The groundwater potentiometric surface (i.e., groundwater table) within the ash ponds is present at between 0.36 and 12.49 feet above mean sea level (MSL) in April 2017 (AECOM, 2017, Technical Memorandum 6, Figure TM6-8). Based upon linear interpolation of tide heights between two NOAA harmonic stations located upstream (NOAA 8636941) and downstream (NOAA 8638481) of the Site, the elevations of the river and other surface waters adjacent to the ash ponds vary from a high (mean higher high water) of approximately 1.53 feet above MSL to a low (mean lower low water) of 1.60 feet below MSL. Groundwater will flow from higher total head to lower total head; thus, from the ash ponds to the adjacent surface waters.

Consultants for Dominion have identified a radial groundwater flow pattern within each of the ash ponds (AECOM, 2017 Technical Memorandum 6 pg. 4-7). As a result of the radial groundwater flow direction within the ash ponds, groundwater from each ash pond will flow towards adjacent surface water bodies, including the Old Channel.

The earthen berms that surround the ponds are not barriers to groundwater flow. They may slightly inhibit groundwater flow allowing groundwater to "mound up" slightly within the bermed area. However, groundwater within the ash ponds will flow through and beneath the berms and discharge to the adjacent surface waters.

The groundwater potentiometric surface (i.e., the water table) generally mimics area topography with groundwater movement from topographically high areas to topographically low areas. The area north of the Lower Ash Pond at the Power Plant coal loading area and baseball field is at a higher ground elevation than the Lower Ash Pond itself. Groundwater is likely flowing in a southward direction from beneath the baseball field area to beneath the Lower Ash Pond.

Therefore, given the above, groundwater within the ash ponds at the Site is in direct hydrologic connection with the surrounding surface waters.

2. **Is groundwater at the Site in contact with CCR or coal ash waste placed in the Upper and Lower Ash Ponds?**

Yes. Consultants to Dominion state that 3,600,000 and 11,300,000 cubic yards of coal ash waste remains in the Lower and Upper Ash Ponds, respectively, as of July 10, 2017 (AECOM, 2017, pg. 8-1). According to consultants to Dominion, the base of the Upper Ash Pond is approximately 2.5 feet above MSL (Golder, 2016, pg. 2). The potentiometric groundwater surface in the Upper Ash Pond is up to 7.76 feet above MSL (AECOM, 2017, Technical Memorandum 6, Figure TM6-8). Thus, groundwater within the Upper Ash Pond is in contact with the lower 5 feet of coal ash waste. The Upper Ash Pond is not lined; therefore, some portion of direct precipitation and any sluice water will infiltrate into, and percolate down through, the coal ash waste. This percolating water will recharge groundwater within the Upper Ash Pond.

The base of the Lower Ash Pond is 0 feet MSL (Geosyntec, 2016 Appendix A, Drawing 2). The potentiometric groundwater surface in the Lower Ash Pond is up to 12.49 feet above MSL (AECOM, 2017, Technical Memorandum 6, Figure TM6-8). Thus groundwater within the Lower Ash Pond is in contact with more than 12 feet of coal ash waste.

Therefore, given the above, groundwater at the Site is in contact with CCR or coal ash waste placed in the Lower and Upper Ash Ponds.

3. Is the coal ash waste in the Lower and Upper Ash Ponds contaminating groundwater?

Yes. Based on groundwater data, constituents in the coal ash waste are dissolving into groundwater within and flowing through the ash ponds that thence flows out of the ash ponds into the adjacent surface waters. In addition, constituents in the coal ash waste above the groundwater table dissolve into percolating water that recharges and further contaminates groundwater. The constituents in coal ash waste detected in groundwater above background levels are referred to herein as contaminants of concern (COCs). There are a number of contaminants detected at levels above background and in excess of maximum contaminant levels, including boron (a key COC for the Site), radium 226/228, and other metals such as arsenic, cobalt, molybdenum and nickel. Therefore, coal ash waste in the ash ponds is contaminating groundwater.

4. Does coal ash waste pollution in groundwater discharge to surface water, including the Old Channel?

Yes. Groundwater contaminated with constituents from the coal ash waste in the ash ponds (see **Question 3**) flows with groundwater (see **Question 1**) and discharges to adjacent surface water, including the Old Channel. This discharge likely occurs via seeps in the ash pond perimeter embankments, seeps on the stream banks, and as bed-seepage through stream bed sediments. Ponded surface water in Lower Ash Pond abuts against the southern perimeter embankment and is likely discharging through embankment seepage to the adjacent surface waters. The discharge of groundwater to surface is established not only by the existing groundwater quality information and groundwater versus surface water elevations, but also by sampling of surface waste adjacent to the Dutch Gap Conservation area. Therefore, coal ash waste pollution in groundwater does discharge to surface water.

5. Is surface water at the Site in direct contact with coal ash waste?

Yes. Ponded surface water is present in the Lower Ash Pond. This ponded water is likely formed by water accumulation from the sluicing activities that transports the coal ash waste from the plant process area and direct precipitation. This ponded surface water is in direct contact with coal ash waste and is in direct hydrologic communication with underlying and adjacent groundwater (see **Question 1**). Therefore, surface water at the Lower Ash Pond is in direct contact with coal ash waste.

Dominion has yet to investigate whether coal ash waste is present in river bed sediments in the Old Channel, James River, or marshes and ponds within the Dutch Gap Conservation Area. Therefore, coal ash waste may also be in direct contact with surface waters in these areas.

Of particular note, the ash ponds are located directly within an active river system. Over time, the James River has changed course. The River has created a series of former meander bends that are connected to, but now offset from, the main James River channel. Low-lying riparian marshes and ponds occupy the area between the former meander bends and the current James River channel. The Dutch Gap Conservation Area encompasses one of these former meander bends and associated marshes/ponds. More importantly, the ash ponds are also present in this area; that is, within an active hydrologic system.

Natural rivers will change their course over time, as evident at the James River. The existing channel will likely be maintained during regular flow events. However, there is the potential that, at some point in the future, the James River may seek to reestablish its course through the Dutch Gap Conservation Area during a major flow event (e.g., major flood associated with high rainfall and a high tidal surge). Even if the course is not reestablished, there would likely be severe erosion during such an event. This could have a catastrophic impact on the ash ponds, from either erosion of the embankments and direct discharge of some coal ash waste into the James River to complete erosion of the coal ash waste and flow downstream in the river.

For example, on June 23, 1972 during Hurricane Agnes, flow in the James River at Richmond peaked at 313,000 cubic feet per second (cfs), ten times higher than regular annual storm flows (NOAA, 2017). The James River rose over 28 feet or almost 17 feet above flood stage (NOAA, 2017). Such an event would completely submerge the Lower Ash Pond and most of the Upper Ash Pond and cause severe erosion and discharge of coal ash waste into the James River. Therefore, there is a risk of a catastrophic failure at the ash ponds should they be left in-place in such an active hydrologic system.

6. **Will capping of the ash ponds prevent the continued contamination of groundwater at the ash ponds?**

No. Under a "Cap-in-Place" scenario, groundwater will likely continue to flow through the Lower Ash Pond from the north (up-gradient), and constituents in the coal ash waste will continue to dissolve into the flowing groundwater**.** In addition, some infiltration (albeit reduced by the capping of the ash ponds) from precipitation will continue to percolate through the cap into the coal ash waste and recharge groundwater, and constituents in the coal ash waste above groundwater will dissolve into this percolating water, as detailed in **Question 3**. The continued dissolution of coal ash waste constituents into groundwater and percolating water will result in concentrations of COCs in groundwater beneath and down-gradient of the ash ponds above background levels. Therefore, capping in place will not prevent the continued contamination of groundwater at the ash ponds.

As noted, groundwater is in direct contact with coal ash waste at the ash ponds. This condition will persist even after implementation of the proposal cap-in-place closure plan. According to the Electric Power Research Institute (EPRI), a utility industry trade group, "*Caps are not effective when CCP (*coal combustion product*) is filled below the water table, because groundwater flowing through the CCP will generate leachate even in the absence of vertical infiltration through the CCP*" (EPRI, 2006, pg. 3-6).

7. **Will capping of the ash ponds prevent the discharge of contaminated groundwater to the surface water, including the Old Channel?**

No. As to the Lower Ash Pond, groundwater to the north of the Lower Ash Pond will likely continue to flow into and through the ash pond and thence discharge to adjacent surface water (see **Question 1**).

Likewise, contaminated groundwater from the Upper Ash Pond will continue to discharge to surface water even with a theoretical "perfect"cap. Currently, groundwater levels at the Upper Ash Pond are within the coal ash waste (see **Question 2**). It is anticipated that capping would reduce infiltration and recharge, resulting in lower groundwater levels within the Upper Ash Pond. But even if the groundwater levels are lowered by the cap, groundwater from the Upper Ash Pond will continue to discharge due to tidal effects. Water levels in the James River fluctuate about three feet in response to tides. Given the direct hydrologic connection between groundwater in the ash ponds and the surrounding surface waters, groundwater levels in the ash ponds will respond to tides, but the response will be muted and delayed. That is, the fluctuation will be far less than three feet and will be delayed when compared to the surface water level changes. Even assuming groundwater levels in the ash ponds approximate those in the James River, on average, at low tide, groundwater levels would be at least three feet higher than the water in the adjacent surface waters. At that time, contaminated groundwater will discharge to the surface water in response to the difference in hydraulic head. At high tide, surface water levels would be higher than groundwater levels within the ash ponds, and water would flow back into the ash ponds, but not the same water that flowed out at low tide (which has flowed downstream). The water flowing into the ash pond would mix with contaminated groundwater and some of this mixed-contaminated groundwater would flow out at the next low tide. Thus, for about 12 hours per day, contaminated groundwater would flow into the adjacent surface waters, and for 12 hours surface water would flow into the ash ponds. This effect is referred to as tidal pulsing. Thus, even after implementation of a theoretically "perfect" cap-in-place closure plan, some contaminated groundwater will continue to discharge to the adjacent surface waters.

If the cap does not extend across the perimeter embankments, then infiltration of precipitation and subsequent groundwater recharge at the embankments would continue. This would result in groundwater levels within the Upper Ash Pond permanently above the surrounding surface waters. Thus, the discharge of contaminated groundwater from within the Upper Ash Pond to the adjacent surface waters would continue, albeit less than the pre-cap condition.

Therefore, given the above, capping of the ash ponds will not prevent the discharge of contaminated groundwater to the surface water, including the Old Channel.

SITE DESCRIPTION

The Site consists of a coal-fired electricity-generating facility (power plant) located in Chesterfield County, Virginia, approximately 20 miles south of Richmond (**Figure 1**). The Site is situated on approximately 844 acres along the southern bank of the James River (AECOM, 2017, Technical Memorandum pg. 4-1). The County of Chesterfield Proctors Creek Wastewater Treatment plant is located west of the Site, and isolated industrial facilities further to the west and southwest. Marshes and ponds of the Dutch Gap Conservation Area are located to the south and southwest, Henricus Historical Park and residential lots to the east, and agricultural land to the north. In the Site vicinity, the community of Chester is located to the west and south, industry is located along the James River to the north, farming activities are located north of the James River, and the community of Rivers Bend is located to the east beyond the Dutch Gap Conservation Area. Much of the site vicinity is covered in wooded areas, marshes, ponds, and tracts of residential lots.

The topographic surface at the facility is level and falls within the James River floodplain. Ground surface elevations range from approximately 10 to 30 feet above MSL with the exception of the Upper Ash Pond, which rises to 80 feet above MSL (AECOM, 2017, pg. 8-4).

ASH POND INFORMATION

The Chesterfield Power Station, the largest fossil-fueled power station in Virginia, has been in operation since at least 1944 and was converted to dry ash handling in October 2017 (AECOM, 2017, pg. 8-4). The original two power generating units were supplemented by additional units in 1952 (Unit 3), 1960 (Unit 4), 1964 (Unit 5), 1969 (Unit 6), 1990 (Unit 7), and 1992 (Unit 8). The six currently active units have a generation capacity of 1,640 megawatts (MW). Units 3 through 6 burn up to 8,400 tons of coal per day to generate electricity; while units 7 and 8 are combined cycle units burning natural gas and distillate oil.

The ash ponds at the Site are located within the Dutch Gap Conservation Area between a former river meander (Old Channel) and the current course of the James River. The Lower Ash Pond is surrounded by the Power Plant coal-loading area and baseball field to the north, cooling channel to the west, the Old Channel to the southwest, a large pond to the south, the Upper Ash Pond to the southeast, and a marsh area to the east. The Old Channel of the James River runs directly beneath the Lower Ash Pond. The Upper Ash Pond is surrounded by a marsh to the north, marshes and ponds to the east, south and west, and Lower Ash Pond to the northwest. Thus, aside from north of the Lower Ash Pond, the ash ponds are surrounded by surface waters in ponds, marshes, or surface water channels on all sides.

There are two ash ponds located at the Site: Lower Ash Pond and Upper Ash Pond (**Figure 2**). According to Consultants to Dominion "*The Lower Ash Pond was constructed in 1964, and the Upper Ash Pond was constructed in 1983. Both ponds served as CCR* [coal combustion residuals] *settling ponds for the facility's wastewater treatment system. Available site records indicate that these settling ponds consist of unlined storage units that have received only CCR and associated coal combustion process waste for disposal. Settled CCR in the Lower Ash Pond has been excavated, dewatered, and transferred to the Upper Ash Pond for permanent storage. An earthen dike with a minimum crest width of 20 feet borders the ponds. The Lower Ash Pond encompasses approximately 101 acres, and the Upper Ash Pond encompasses approximately 112 acres*" (AECOM, 2017, Technical Memorandum 6 pg. 4-1).

The disposition of coal ash waste generated between 1944 and 1964 could not be identified in the reports prepared by consultants to Dominion that were reviewed by **aquilogic**. It is highly possible that later power generating units were constructed in areas used for the disposal of coal ash waste prior to 1964. Historical aerial photographs and topographic maps, along with power plant operational records, would need to be reviewed to identify the exact location of coal ash waste placed at the Site prior to 1964.

Additional information for the process at the ash ponds include "*As a by-product of coal combustion, the Station generates fly ash and bottom ash, which is transported hydraulically (sluiced) to the Lower Ash Pond. Fly ash slurry is initially deposited into a settling channel from* *which CCR (coal combustion residual) is dipped, stacked, and allowed to dewater. Water is decanted from the Lower Ash Pond through an outfall structure located in the southeast corner of the impoundment.* (Geosyntec, 2017, pg. 1).

According to Consultants to Dominion "*The Upper Ash Pond was constructed within earthen perimeter embankments with a crest elevation of approximately 42 feet above mean sea level (AMSL). Available design information for the Upper Ash Pond indicates that the base of the impoundment is located at an approximate elevation of 2.5 feet AMSL*" (Golder, 2016, pg. 2). The Lower and Upper Ash Ponds are reported to contain 3,600,000 and 11,300,000 cubic yards of coal ash waste, respectively, as of July 10, 2017 (AECOM, 2017, pg. 8-1).

SITE SURFACE WATER HYDROLOGY

The Site is in the Chesapeake Bay watershed. The Chesapeake Bay watershed consists of 65,000 square miles and includes more than 150 rivers and streams (USDA, 2017). Adjacent to the Site, the Old Channel of the James River flows through the Dutch Gap Conservation Area, south of the ash ponds (**Figure** 2). The Old Channel continues flowing eastward and joins with the main channel of the James River. From the Site, the James River flows approximately 60 miles east to its mouth, which opens into the Chesapeake Bay. Tidal charts indicate that the James River fluctuates an average of 3 feet between regular high and low tides adjacent to the Site (USGS, 2018). Based upon linear interpolation of tide heights between two NOAA harmonic stations located upstream (NOAA 8636941) and downstream (NOAA 8638481) of the Site, the elevations of the river and other surface waters adjacent to the ash ponds vary from a high (mean higher high water) of approximately 1.53 feet above MSL to a low (mean lower low water) of 1.60 feet below MSL.

The James River is an active stream and has changed its course in the vicinity of the Site on numerous occasions. This is evident in current aerial imagery where former river meanders exist on either side of the current river course. The Dutch Gap Conservation Area occupies an area between a former river meander and the current course of the James River. Low-lying, riparian marshes and ponds are present between the meander and the James River, and the coal ash ponds at the Site are located within this active hydrologic area. A similar meander and marsh/pond area is also located on the north side of the James River opposite the Site.

Flows in the James River vary seasonally and in response to less frequent storm events (e.g., Hurricanes). In general, peak annual storm flows in the James River are between 30,000 and 50,000 cfs (Richmond station, NOAA, 2017); however, larger flows occur every few years during major storm events and even larger flows during less frequent catastrophic storm events. Since 1934, peak daily flows have exceeded 100,000 cfs with a flood stage above 18 feet on 25 occasions (water levels of 12 feet are considered in flood). Peak daily flows have exceeded 200,000 cfs with a flood stage above 24 feet on only three occasions (August 21, 1969, June 23, 1972, and November 7, 1985). The highest storm event occurred on June 23, 1972 during Hurricane Agnes with a flow of 313,000 cfs and a flood stage of 28.62 feet. With a flood stage of 24 feet, all of the Lower Ash Pond and much of the Upper Ash Pond would be submerged under flood waters.

Ponded water is present at the Lower Ash Pond. This water drains through a decant pipe near the southwest corner of the ash pond and discharges directly into the Old Channel. This water has been in contact with coal ash waste in the Lower Ash Pond and likely contains high concentrations of COCs. It does not appear that this water is treated prior to being discharged to the Old Channel.

HYDRO-STRATIGRAPHY

The movement of groundwater depends in part on the hydro-stratigraphy beneath the Site. Four hydrogeologic units, or groundwater zones, are present beneath the Site: Columbia Aquifer, Aquia Aquifer, Potomac Aquifer, and basement bedrock aquifer (Golder, 2016, pgs 4 and 5). These hydrogeological units are described as follows:

- The Columbia Aquifer lies directly beneath the coal ash waste at the ash ponds. The Columbia Aquifer is composed of Quaternary and Tertiary sediments. This unconfined or water table aquifer consists of undifferentiated Quaternary alluvium associated with the James River and is described as sand and gravel that locally has a clayey matrix. The alluvium deposits are interbedded with silts and clays of fluvial and marine origin. The Columbia Aquifer varies in thickness from 0 to 30 feet beneath the Site. Hydraulic conductivity of the sediments range over approximately four (4) orders of magnitude, with a geometric average of 9.06×10^{-4} cm/s. The average estimated horizontal rate of groundwater flow in the Columbia Aquifer beneath the Site is approximately 131 feet per year (Golder, 2016, pg. 8).
- Directly underlying the Columbia Aquifer is the semi-confined Aquia Aquifer. A discontinuous clayey silt separates the Columbia and Aquia Aquifers (Golder, 2016, pg. 5). The Aquia Aquifer is composed of discontinuous dense fine to medium silty sand with clay lenses. Hydraulic conductivity of the aquifer varies from 1.0×10^{-4} to 1.0×10^{-3} cm/s.
- Underlying the Aquia Aquifer is the Potomac Aquifer. These two aquifers are separated by a hard silty-clay that underlies all of the Site except the south central area. The confining unit has an estimated hydraulic conductivity of 1.0×10^{-8} cm/sec. The confined Potomac Aquifer is characterized by silty sands to gravel with hydraulic conductivities varying from 1.0×10^{-6} to 1.0×10^{-2} cm/sec and varies in thickness from 0 to 160 feet. In general, the Potomac Aquifer hydraulic conductivity increases with depth (coarsening downward). A hard silty-clay is present at the bottom of the Potomac Formation. The hard silty clay is estimated to have a hydraulic conductivity of 1.0×10^{-8} cm/sec.

- The Potomac Aquifer overlies the fractured bedrock aquifer associated with the Petersburg Granite. The fractured bedrock aquifer consists of dense saprolite and fractured igneous granitic rock.

At the ash ponds, coal ash waste has been placed immediately above sediments of the Columbia Aquifer. With ongoing recharge, groundwater elevations have risen, and groundwater is present within the coal ash waste in the ash ponds. At the Upper Ash Pond, coal ash waste is present at about 2.5 to 80 feet above MSL, and groundwater is present at 0.36 to 7.76 feet above MSL (Golder, 2016 pg. 2 and AECOM, 2017, Technical Memorandum 6, Figures TM6-7 and TM6-8). Thus, the lower 5 feet of the coal ash waste at the Upper Ash Pond is saturated with groundwater. The base of the Lower Ash Pond is 0 feet MSL (Geosyntec, 2016 Appendix A, Drawing 2). The potentiometric groundwater surface in the Lower Ash Pond is up to 12.49 feet above MSL (AECOM, 2017, Technical Memorandum 6, Figure TM6-8). Thus, the lower 12 feet of the coal ash waste at the Lower Ash Pond is saturated with groundwater.

GROUNDWATER FLOW AND DISCHARGE TO SURFACE WATER

According to consultants to Dominion "*The uppermost sediments at the station are alluvial materials associated with the present day James River. Ground surface topography in the area of the station is typically level, with some slightly sloping grades adjacent to the banks of the James River, and groundwater in the uppermost aquifer generally flows radially from beneath the Lower and Upper Ash Ponds*" (AECOM, 2017 Technical Memorandum 6 pg. 4-7).

The accumulation of coal ash waste at the ash ponds and recharge from precipitation and sluiced water results in higher groundwater elevations beneath the center of each pond than the surrounding surface waters (AECOM 2017, Technical Memorandum 6, Figure TM6-8). Groundwater elevations within the Lower Ash Pond range from 1.39 to 12.49 feet above MSL. Groundwater elevations within the Upper Ash Pond range from 0.36 to 7.76 feet above MSL. The elevation of adjacent surface water bodies ranges from 1.60 feet below MSL to 1.53 feet above MSL, between low and high tide. Groundwater flows from areas of high groundwater head (elevation for an unconfined, water table aquifer) to areas of lower head. Thus, at the ash ponds, groundwater in the Columbia Aquifer and coal ash waste flows radially out from the center to the adjacent surface waters, including the James River and Old Channel.

The earthen berms that surround the ponds are not barriers to groundwater flow. They may slightly inhibit groundwater flow allowing groundwater to "mound up" slightly within the bermed area. However, groundwater within the ash ponds will flow through and beneath the berms and discharge to the adjacent surface waters.

As described by consultants to Dominion "*In the immediate area of the Facility, the Columbia aquifer is bounded by groundwater discharge sinks associated with the tidal James River to the* *west, south, and east, with a similar groundwater sink (discharge) area located immediately north of the Facility in the abandoned James River channel*" (Golder 2016, pg 7). Thus, as described by consultants to Dominion, groundwater is flowing from the Upper and Lower Ash Ponds toward the James River and Old Channel and discharging to these surface water bodies.

The groundwater surface generally mimics area topography with groundwater movement from topographically high areas to topographically low areas. The area north of the Lower Ash Pond at the Power Plant coal loading area and baseball field is at a higher ground elevation than the Lower Ash Pond itself. According to Dominion's consultant "*In the immediate vicinity of the Facility, the groundwater elevation ranges from sea level along the banks of the James River up to approximately 15 feet AMSL where the Facility abuts the Lower Ash Pond*" (Golder, 2016, pg. 7). Groundwater is likely flowing in a southward direction from beneath the baseball field area to beneath the Lower Ash Pond.

It should be noted that the Upper Ash Pond appears to have been constructed with a toe drain system. According to Dominion's consultant "*In addition to the natural recharge and discharge cycles associated with precipitation infiltration and vertical recharge to stratigraphically lower water-bearing units and gradient controlling discharges to the James River, the water table surface in the Columbia Aquifer beneath the Facility is influenced by a perimeter toe drain that was installed around the outside of the Upper Ash Pond [UAP] berm when it was constructed in the 1980's. The approximate location of the perimeter toe drain is shown on Drawing 2. The toe drain was installed as an engineering control during construction of the UAP to remove collected water from the impoundment berm to maintain and protect the berm's structural integrity. The toe drain is largely constructed in Layer 1 with sections that extend through Layer 2 into Layer 3. Based on review of the design drawings for the toe drain, approximate invert elevations for the toe drain are indicated on Drawing 2 every 500 feet (approximate). These invert elevations, where they are lower than the inferred groundwater surface, indicate that the toe drain will influence the water table elevation when it is being pumped. The toe drain is currently in operation and is expected to remain in operation during the post closure period of the Upper Ash Pond*" (Golder, 2016, pg 7). A portion of the groundwater migrating from the Upper Ash Pond will be captured by the toe drain. From the material reviewed, it is not known what happens to the water removed by the toe drain system.

According to consultant to Dominion "*There are no surveyed drinking water wells downgradient from the Chesterfield Power Station (i.e., between the power generation plant, the Lower Ash Pond, the Upper Ash Pond, the thermal channel, or the James River; URS, 2012), and no drinking water supply wells are located on the Chesterfield Power Station property*" AECOM, 2017, Technical Memorandum 6, pg. 4-2).

GROUNDWATER AND SURFACE WATER CONTAMINATION

Groundwater Contamination

As discussed earlier, both unlined ash ponds served as settling ponds for coal ash waste from the facility's "wastewater treatment system". Coal ash waste settled in the Lower Ash Pond has been excavated, dewatered, and transferred to the Upper Ash Pond for permanent storage. Constituents in coal ash waste dissolve into water involved in the transport (i.e., sluicing) of the coal ash waste from the power plant to the Lower Ash Pond. This contaminated transport water recharges groundwater in the Lower Ash Pond. Precipitation falling on the Lower Ash Pond also percolates through coal ash waste and recharges groundwater. Constituents in the coal ash waste dissolve into the percolating water and further contaminate groundwater. Coal ash waste is also likely located below the groundwater table within Lower Ash Pond. Constituents in the coal ash waste dissolve into the contaminated groundwater flowing within the Lower Ash Pond, adding to the levels of contamination.

When coal ash waste is transferred to the Upper Ash Pond it continues to serve as a source of contamination to groundwater. Precipitation that falls on the surface at the Upper Ash Pond will infiltrate into the subsurface. This infiltrating water percolates through the coal ash waste and recharges groundwater. Constituents in the coal ash waste above the groundwater table dissolve into percolating water that recharges and contaminates groundwater within Upper Ash Pond. In addition, constituents in the coal ash waste dissolve into groundwater flowing through the Upper Ash Pond and contaminate the groundwater.

Constituents of coal ash waste, such as boron, dissolve into the sluice water, percolating recharge water, and groundwater itself. Historical groundwater contaminant concentrations from sampling events in 2016 and 2017 are provided by consultants to Dominion (AECOM, 2017, Technical Memorandum 6, Tables TM6-14 to TM6-17). The following paragraphs summarize this data.

To assess groundwater impact from the ash ponds, a comparison to background conditions needs to be completed. Consultants to Dominion have identified the following monitoring wells as representative of background concentrations for each of the identified aquifers (AECOM, 2017, Technical Memorandum 6, pg. 4-4):

- Columbia Aquifer - monitoring wells MW-29U and MW-35S
- Potomac Aquifer - monitoring wells MW-29U, MW-30U, MW-35D, and MW-35S
- Fractured Bedrock Aquifer - monitoring wells MW-31D and MW-35B

Consultants to Dominion have proposed preliminary background values (PBV) for the various coal ash waste constituents dissolved in groundwater (AECOM, 2017, Technical Memorandum 6

Tables 6-14- TM6-17). We have compared the constituent levels detected in groundwater samples to these PBVs. If we have proposed a different PBV, our rationale is provided.

Down-gradient of the Ash Ponds in the Columbia Aquifer

Lower Ash Pond

The following select constituent concentrations were detected in groundwater samples in July 2017 from monitoring wells MW-22, MW-27, MW-34, MW-B40A, MW-B50, and MW-28, screened down-gradient of the Lower Ash Pond in the Columbia Aquifer:

COC	Units	PBV or MCL	MW-22	MW-27	MW-34	MW-B40A	MW-B50	MW-28
Boron	mg/L	*<0.05*	**0.52**	**0.383**	**1.22**	**1.81**	**0.333**	**0.116**
Arsenic	mg/L	0.010	<0.0010	<0.0010	**0.0171**	0.0072	0.0046	**0.177**
Calcium	mg/L	63.9	29.4	20.5	**85.1**	47.9	**79**	36.1
Chloride	mg/L	46	26.9	24.7	**86.4**	**133**	46.3	18.2
Cobalt	mg/L	0.0086	0.0032	**0.0124**	0.0039	0.00016J	0.0019	0.00011J
Nickel	mg/L	0.0076	0.0072	**0.0124**	<0.0050	<0.0050	<0.0050	<0.0050
Sulfate	mg/L	10.86	**17.7**	**27**	<1.0	0.66J	**64.4**	**29.7**
TDS	mg/L	450	202	183	305	419	377	168

Notes:
<: not detected at or above the noted reporting limit
mg/L: milligrams per liter
0.010 mg/L is the MCL for arsenic
Bold: above PBV or MCL
NE: not established
<0.05: different PBV than proposed
MCL: maximum contaminant level

The above monitoring wells were selected as they are located on all sides of the Lower Ash Pond. An arsenic PBV was not established by consultants to Dominion as the arsenic concentration in groundwater sampled from background monitoring well MW-29U was 0.0178 mg/L, higher than the concentrations detected in many other monitoring wells. Consultants to Dominion proposed a PBV for boron of 0.1 mg/L. However, no concentrations above 0.05 mg/L were detected in the background monitoring wells in July 2017. Thus, a concentration of <0.05 mg/L is a more appropriate PBV for boron, and this has been used for comparison purposes.

Boron was detected in groundwater samples from all monitoring wells listed above surrounding the Lower Ash Pond at concentrations above the PBV proposed by consultants to Dominion and the more appropriate PBV selected by **aquilogic**. Thus, boron is a key COC associated with coal ash waste at the Site. Arsenic, calcium, chloride, and sulfate were detected at concentrations above the proposed PBV in groundwater samples from more than one monitoring well listed previously. It should be noted that additional monitoring wells other than those listed previously are present around the perimeter of the Lower Ash Basin. These monitoring wells contain COC such as arsenic (MW-23, MW-25, , and MW-32) and radium 226/228 (MW-23 and MW-28).

Upper Ash Pond

The following select constituent concentrations were detected in groundwater samples in July 2017 from monitoring wells MW-1, MW-3, MW-8R, MW-11 and MW-16, screened down-gradient of the Upper Ash Pond within the Columbia Aquifer:

COC	Units	PBV or MCL	MW-1	MW-3	MW-8R	MW-11	MW-16	MW-17S
Boron	mg/L	*<0.05*	**2.76**	**1.88**	**1.49**	**1.44**	**2.77**	**2.03**
Arsenic	mg/L	0.010	<0.0010	<0.0010	**0.0162**	0.00097	<0.0010	**0.0312**
Calcium	mg/L	63.9	**83.2**	**195**	**126**	13	**379**	**401**
Chloride	mg/L	46	19.5	7.8	10.6	15.5	**219**	17.7
Cobalt	mg/L	0.0086	0.0012	**0.0125**	0.0073	0.00079	**0.0221J**	**0.0278J+**
Nickel	mg/L	0.0076	0.0049J	<0.0050	<0.0050	<0.00050	0.0047J	0.0072
Sulfate	mg/L	10.86	**72.3**	**269**	**209**	**139**	**605**	**201**
TDS	mg/L	450	**464**	**784**	**734**	**609**	**1560**	**787**

Notes:
<: not detected at or above the noted reporting limit
mg/L: milligrams per liter
0.010 mg/L is the MCL for arsenic
J: Result is less than the reporting limit, but greater or equal to the method detection limit.
J+: estimated result biased high
NE: not established
<0.05: different PBV than proposed
MCL: maximum contaminant level
Bold = above PBV or MCL

The above monitoring wells were selected as they are located on all sides of the Upper Ash Pond.

Boron was detected in groundwater samples from these monitoring wells surrounding the Upper Ash Pond at concentrations above the PBV proposed by Consultants to Dominion and the more appropriate PBV selected by **aquilogic**. This confirms that boron is a key COC associated with coal ash waste at the Site. Arsenic, calcium, cobalt, sulfate and TDS were detected at concentrations above their respective proposed PBVs in groundwater samples from more than one monitoring well. It should be noted that additional monitoring wells other than those listed previously are present around the perimeter of the Upper Ash Basin. These monitoring wells contain COC such as arsenic (MW-8R, MW-12, and MW-13), cobalt (MW-12, MW-13, MW-20, and MW-22) and radium 226/228 (MW-1 and MW-2). Thus, significant contamination of groundwater in the Columbia Aquifer by arsenic, boron, calcium, cobalt, radium 226/228, sulfate and TDS, associated with coal ash waste is present beneath the Site.

The impact from the Upper Ash Pond to the Columbia Aquifer is confirmed by Dominion's consultant "*The Upper Ash Pond Columbia Aquifer CCR baseline dataset is provided in Table TM6-15 located at the end of Section 4. These data show that detection monitoring constituents boron, calcium, chloride, fluoride, pH, sulfate, and TDS have been detected in downgradient wells at levels above preliminary background*" (AECON, 2017, Technical Memorandum 6, pg 4-6).

Down-gradient of the Ash Ponds in the Potomac Aquifer

Lower Ash Pond

Consultants to Dominion did not provide information for background or down-gradient monitoring wells screened in the Potomac Aquifer around the Lower Ash Pond (AECOM, 2017, Technical Memorandum 6, Tables TM6-12 and TM6-13).

Upper Ash Pond

The following select constituent concentrations were detected in groundwater samples in July 2017 from monitoring wells MW-3D, MW-4, MW-6D and MW-10, screened within the Potomac Aquifer zone down-gradient of the Upper Ash Pond:

COC	Units	PBV or MCL	MW-3D	MW-4	MW-6D	MW-10
Boron	mg/L	0.15	**1.86**	**1.29**	**1.96**	**0.176**
Arsenic	mg/L	0.010	<0.0010	0.00065J	<0.0010	0.00076J
Calcium	mg/L	63.9	8.33	**138**	45.3	33.3
Chloride	mg/L	46	**50.5**	6.9	9.5	17.8
Cobalt	mg/L	0.0069	0.00019J	**0.135J+**	**0.0230**	**0.0145**
Nickel	mg/L	0.0053	<0.0050	**0.108**	**0.0074**	**0.0089**
Sulfate	mg/L	7.7	**209**	**397**	**658**	**47.7**
TDS	mg/L	450	**714**	**633**	**1280**	**211**

Notes:
<: not detected at or above the noted reporting limit
mg/L: milligrams per liter
equal to the method detection limit.
0.010 mg/L is the MCL for arsenic
Bold = above PBV or MCL
NE: not established
J: Result is less than the reporting limit, but greater or
J+: estimated result biased high
MCL: maximum contaminant level

Boron, sulfate, and TDS were detected in groundwater samples from all monitoring wells surrounding the Upper Ash Pond at concentrations above the PBV proposed by Consultants to Dominion. Cobalt and nickel were detected at concentrations above their respective proposed PBVs in groundwater samples from at least one monitoring well. Thus, significant contamination of groundwater in the Potomac Aquifer by boron, cobalt, nickel, sulfate, and TDS associated with coal ash waste is present beneath the Site.

Down-gradient of the Upper Ash Pond in the Fractured Bedrock Aquifer

Consultants to Dominion have proposed PBVs for the various coal ash waste constituents dissolved in groundwater in the fractured bedrock that are different from those for the Columbia and Potomac Aquifer (AECOM, 2017, Technical Memorandum 6 Tables 6-14- TM6-17). We have compared the constituent levels detected in groundwater samples to these PBVs.

COC	Units	PBV	MW-1DD	MW-6DD	MW-16DD
Boron	mg/L	1.53	0.900	1.51	1.03
Arsenic	mg/L	0.010	<0.0010	<0.0010	0.00079J
Calcium	mg/L	13.41	6.23	7.87	2.43
Chloride	mg/L	314	223	**396**	126
Cobalt	mg/L	0.0034	0.00013J	0.00010J	<0.0010
Nickel	mg/L	0.0145	<0.0050	0.011	<0.0050
Sulfate	mg/L	260	166	126	82.1
TDS	mg/L	787.7	**816**	**1120**	560

Notes:
<: not detected at or above the noted reporting limit
mg/L: milligrams per liter
Bold = above PBV
0.010 mg/L is the MCL for arsenic
NE: not established
J: Result is less than the reporting limit, but greater or equal to the method detection limit.
MCL: maximum contaminant level

TDS were detected at concentrations above their respective proposed PBVs in groundwater samples from at least one monitoring well. However, it does not appear that significant contamination of groundwater in the Fractured Bedrock Aquifer associated with coal ash waste is present beneath the Site.

It should be noted that, at the time of preparing this memorandum, borehole logs and monitoring well construction details for Bedrock Aquifer monitoring wells were not available for review. Once this information is received, an assessment of background boron concentrations in the Fractured Bedrock Aquifer will be completed.

Extent of Contamination

The discussion of the extent of groundwater contamination will focus on boron, as this is the COC considered highly representative of contamination associated with the coal ash waste at the Site. It should be noted that as previously discussed other COC are also present at the Site and include arsenic, calcium, chloride, cobalt, radium 226/228, sulfate and TDS. The distribution of boron in groundwater in the Columbia Aquifer is shown for the Lower and Upper Ash Ponds in **Figures 3 and 4**, respectively. The monitoring well network is located around the perimeter of each of the ash ponds. Boron has been detected above the PBV proposed by consultants to Dominion and the more appropriate PBV selected by **aquilogic** in groundwater samples from most of monitoring wells around the perimeter of the ash ponds. Therefore, the lateral extent of groundwater contamination associated with coal ash waste at the Site is not delineated in Columbia and the Potomac Aquifers.

Transport and Discharge

Boron concentrations above the PBV proposed by consultants to Dominion and the more appropriate PBV selected by **aquilogic** have been detected in groundwater samples from monitoring wells surrounding the Upper and Lower Ash Ponds in the Columbia Aquifer and Potomac Aquifer beneath the Site. Boron concentrations above the PBV proposed by consultants to Dominion and the more appropriate PBV selected by **aquilogic** have been detected in surface water samples from the Dutch Gap Conservation Area (see **Table 1**). Boron is present in coal ash waste, has dissolved into and polluted groundwater flowing through the ash ponds, and discharges with that groundwater to the adjacent surface waters likely via seeps in the perimeter embankments of the ash ponds, river bank-seeps, and bed-seepage through sediments on the bed of the ponds, marshes, cooling channel, and Old Channel.

Surface Water Contamination

Surface water samples have been collected and analyzed by Consultants to Dominion (AECOM, 2017, Technical Memorandum 6, Table TM6-C18 and Figure TM6-9). However, boron concentrations in surface water samples do not appear in the data summary table prepared by Consultants to Dominion. SELC has collected surface water samples on two occasions (July and November/December, 2016). **Table 1** is summary of the analytical results for these samples and the sampling locations are shown in **Figure 5**.

Boron and arsenic were detected in all surface water samples collected by SELC, including at the background location. At the background location, Osborne Landing, boron and arsenic were detected at concentrations of 0.0631 mg/L and 0.00107 mg/L, respectively, with the boron detection containing a J flag analytical identification (**Table 1**). The J flag indicates that the analyte is present at this estimated concentration, but it cannot be confirmed as the concentration is below the laboratory method detection limit (MDL). Boron and arsenic were detected at the other six sampling locations at concentrations much higher than at the background location. The boron concentrations ranged from 0.121J mg/L (Bird House) to 1.99 mg/L (Red Cove) while arsenic ranged from 0.00634 mg/L (Bird House) to 0.0741 mg/L (Red Cove). In general, the highest contaminant concentrations were detected in surface water sample taken at Red Cove.

Surface water samples collected by SELC were also analyzed for boron 11 isotope (i.e, δ^{11} B). Low boron 11 isotopic values (- 9 to + 8 ‰) are likely indicative of coal ash waste impact according to a recently completed peer reviewed scientific paper (Harkness et al., 2016). Three of the four surface water samples collected by SELC contained boron 11 isotope within this isotopic range indicative of coal ash waste impact (i.e., Red Cove, Shipwreck Cove, and Cove Across Triangle **Table 1**).

The surface water contamination detected in these samples results from the dissolution of constituents in coal ash waste present in the Ash Ponds and the discharge of contaminated groundwater to the surface water bodies.

CONTAMINATION SUMMARY

In summary, boron and other constituents in the coal ash waste in the Lower and Upper Ash Ponds above the water table are dissolving into water percolating through the coal ash waste that recharges groundwater. In addition, boron and other constituents in the coal ash waste are also dissolving into groundwater flowing through the coal ash waste. Groundwater then discharges to the surface water bodies, including the Old Channel, via seeps likely through the Ash Pond perimeter embankments, river bank seeps, and as bed-seepage.

CAP-IN-PLACE CLOSURE OPTION

AECOM submitted, on behalf of Dominion, a response to Senate Bill (SB) 1398 to the Virginia Department of Environment Quality (AECOM, 2017). This response document assessed several closure options for the Site including Cap-in-Place. A review of the Cap-in-Place closure option has been completed. Under the closure-in-place option, both ash ponds are proposed to be closed by leaving the coal ash waste in place, removing free liquids, and installing an engineered final cover system (AECOM, 2017, pg. 8-17).

No details have been provided as to the design of the final engineered cover system. In general, one component of the cover systems includes the installation of a 40 mil High Density Polyethylene (HDPE) geo-membrane liner. The geo-membrane liner is intended to limit the infiltration of water into the ash ponds, and subsequent percolation of water to groundwater. In addition, soil cover will be vegetated to minimize soil erosion in the final cover system.

Caps or liners are rarely, if ever, fully effective in preventing infiltration of precipitation to groundwater. Due to geomembrane defects or installation issues (e.g. liner punctures), the cap/liner itself allows some water to leak across the geomembrane and recharge groundwater. In addition, over time, such caps are vulnerable to degradation and damage from at least the following mechanisms (Environmental Research Foundation, 2003):

- Natural weathering (rain, hail, snow, and wind).
- Sunlight (membrane degradation through the action of ultraviolet radiation resulting in cracking and flaking).
- Vegetation (sending down roots that can penetrate the cap/liner or widen cracks and holes created by other mechanisms).
- Burrowing or soil-dwelling animals (e.g., woodchucks, mice, moles, voles, snakes, insects, and worms) (penetrating a cap/liner, widening cracks and holes created by other mechanisms, and creating voids that result in differential settlement which results in subsidence).

- Subsidence (where uneven settling or cave-in beneath the cap causes a void beneath the cap/liner and can result in tears in geomembrane liners, or result in ponding of water on the surface, which can subject the cap to increased freeze-thaw pressures).
- Human activities of many kinds (most notably the driving of vehicles on the cap that tear the liner or cause other damage).

Thus, over time, these mechanisms can result in higher rates of leakage across the cap, increased percolating water, increased groundwater recharge, and continued groundwater flow toward, and discharge to, the surrounding surface waters.

At the Site, even after installation of the proposed cap, recharge will occur at the perimeter embankments and will sustain the groundwater mound beneath the ash ponds. This will result in continued flow toward, and discharge to, the surrounding water bodies.

The proposed geomembrane cap should reduce, but not eliminate, the percolation of infiltrating water. As a result of continued percolation of water, the contaminants in the coal ash waste above the groundwater surface (in the vadose zone) will continue to dissolve into the percolating water and continue to add contaminant mass to the groundwater. In addition, a groundwater mound will be maintained by three sources of recharge: 1) a limited volume of percolating water that leaks across the cap; 2) the continued unimpeded recharge from percolating water at the perimeter embankments that surround the ash ponds; and 3) up-gradient recharge to the Lower Ash Pond (see **Question 1**). Under such conditions, the groundwater mound should dissipate to some degree but will not flatten to the point where there will be no hydraulic gradient and no groundwater flow. With a groundwater mound below current conditions, the hydraulic gradient will decline and groundwater flow toward, and discharge to, the surrounding surface water bodies should be reduced, but not eliminated. Thus, contaminated groundwater will continue to flow toward, and discharge to, the surrounding surface waters after cap installation.

Even if the hydraulic gradient were reduced to zero, and groundwater flow from ash ponds to the surrounding surface waters eliminated (which will not occur), discharge of groundwater to the surrounding surface water bodies will continue as a result of tidal pulsing. If one assumes reduced groundwater elevations from the proposed cap, the effects of tidal fluctuations on the discharge of groundwater will be more pronounced. Water levels in the James River fluctuate about three feet in response to tides. Given the direct hydrologic connection between groundwater in the ash ponds and the surrounding surface waters, groundwater levels in the ash ponds will respond to tides, but the response will be muted and delayed. That is, the fluctuation will be far less than three feet and will be delayed when compared to the surface water level changes. Even assuming groundwater levels in the ash ponds approximate those in the James River, on average, at low tide, groundwater levels would be at least three feet higher than the water in the adjacent surface waters. At that time, contaminated groundwater will discharge to the surface water in response to the difference in hydraulic head. At high tide, surface water levels would be higher than groundwater levels within the ash ponds, and water would flow back into the ash ponds, but not the same water that flowed out at low tide (which has flowed downstream). The water flowing into the ash pond would mix with contaminated groundwater and some of this mixed-contaminated groundwater would flow out at the next low tide. Thus, for about 12 hours per day, contaminated groundwater would flow into the adjacent surface waters, and for 12 hours surface water would flow into the ash ponds. This effect is referred to as tidal pulsing. The tidal pulsing is not a perfect hydraulic exchange, and there will be a net outflow of contaminated groundwater to surface waters through tidal pulsing.

In summary, even after placement of the proposed Cap-in-Place at the ash ponds, coal ash constituents in the vadose zone will continue to dissolve into percolating water within the ash ponds (resulting from some leakage across the cap/liner) and within the perimeter embankments. These dissolved coal ash constituents will be a continued source of contamination to groundwater. For this closure plan, the coal ash waste will be present and be a long-term source of contamination (i.e., in perpetuity). In addition, with continued percolation of water, the groundwater mound beneath the Site will be maintained, albeit at a level likely lower than the current condition. A radially outward flow of contaminated groundwater will be maintained from the ash ponds, with groundwater flowing toward, and discharging to, the surrounding surface water bodies, including the Old Channel. According to EPRI, "*Caps are not effective when CCP is filled below the water table, because groundwater flowing through the CCP will generate leachate even in the absence of vertical infiltration through the CCP*" (EPRI, 2006, pg. 3-6).

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Table 1: Surface Water Analytical Results

Chesterfield Power Station

Sample ID	Sample Date	Boron (mg/L)	Arsenic (mg/L)	Calcium (mg/L)	Chloride (mg/L)	Cobalt (mg/L)	Nickel (mg/L)	Sulfate (mg/L)	TDS (mg/L)	Zinc (mg/L)	Hexavalent Chromium (mg/L)	δ11 Boron ‰
Osborne Landing (background)	7/6/2016	0.0631 J	0.00107	35.3	12.3	0.000523	0.000169	12.9	106	0.54	<0.0005	NA
Bird House	7/6/2016	0.121 J	0.00634	25.1	16.2	0.0103	0.014	39.3	143	0.0947	<0.0005	NA
Red Cove	7/6/2016	1.99	0.0741	217	41.7	0.024	0.0537	594	1,100	0.0108	<0.0005	NA
Red Cove	12/01/2016	1.44	0.0402	171	26.5	0.0185	0.0158	586	NA	0.0116	0.0011	-1.0
Outfall 005	7/6/2016	0.22	0.0139	17.5	4.14	<0.00027	0.000913 J	14.3	95	0.00698	<0.0005	NA
N. Swamp	11/30/2016	0.458	0.0077	83.8	42.5	0.081	0.0095	1.1	NA	0.0234	0.0046	21.7
Shipwreck Cove	12/01/2016	0.199	0.0069	49.1	30.2	0.0077	0.0139	65.6	NA	0.209	0.00034	-2.6
Cove Across Triangle	12/01/2016	0.377	0.0065	66.7	29.1	0.0141	0.0146	60.4	NA	0.103	0.00045	0.7

Notes:

<: analyte not detected at or above the noted reporting limit

‰: permil

δ11 Boron: boron 11 isotopic

ID: identification

J: estimated value

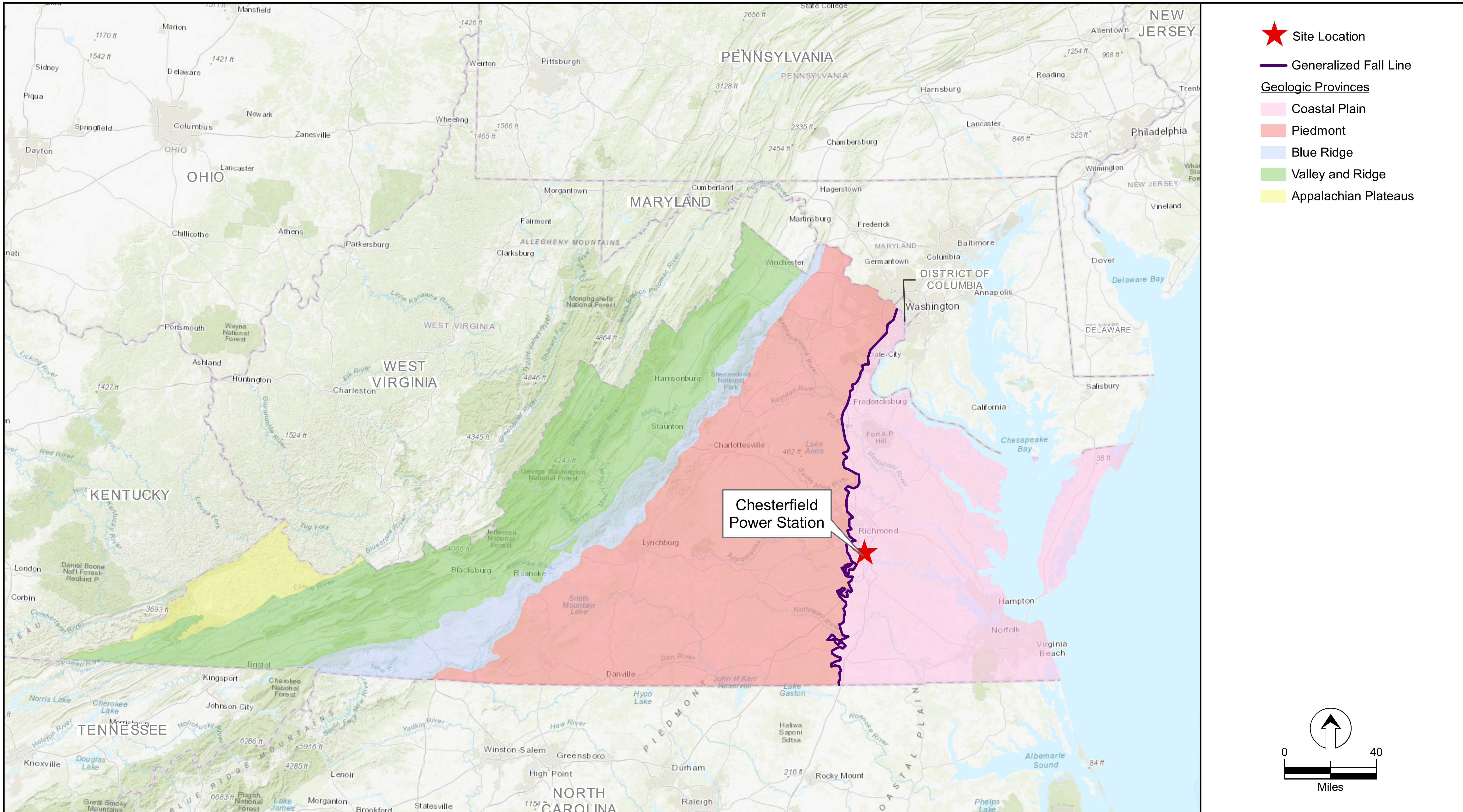
NA: not analyzed

mg/L: milligram per liter

TDS: total dissolved solids

All samples are for total metals.

Sample analytical results and sample locations received from Southern Environmental Law Center (SELC).



aquilogic, Inc.

Chesterfield Power Station
Chester, Virginia

Site Location and State Geologic Provinces

Date: 1/8/2018	Project #: 019-08	Figure 1

Legend

Approximate Ash Pond Boundaries

aquilogic, Inc.

Chesterfield Power Station
Chester, Virginia

Chesterfield Power Station Overview

Date: 1/9/2018	Project #: 019-08	Figure 2

MW-35S	
Date	Boron Concentration (mg/L)
1/12/2017	<0.10
2/23/2017	<0.10
3/16/2017	<0.10
4/7/2017	<0.10
5/3/2017	<0.10
6/6/2017	0.011J+
7/5/2017	<0.0500
8/10/2017	<0.0500

MW-20	
Date	Boron Concentration (mg/L)
10/7/2016	0.71
11/15/2016	0.64
1/12/2017	0.68
2/22/2017	0.71
4/5/2017	0.62
5/17/2017	0.74
6/22/2017	0.74
7/25/2017	0.753

MW-21	
Date	Boron Concentration (mg/L)
10/4/2016	0.47
11/15/2016	0.48
1/12/2017	0.47
2/22/2017	0.38
4/5/2017	0.38
5/17/2017	0.38
6/22/2017	0.495
7/25/2017	0.634

MW-B50	
Date	Boron Concentration (mg/L)
10/12/2016	0.37
11/16/2016	0.35
1/10/2017	0.36
2/22/2017	0.39
4/5/2017	0.38
5/17/2017	0.37
6/22/2017	0.377
7/25/2017	0.333

MW-22	
Date	Boron Concentration (mg/L)
10/4/2016	0.53
11/15/2016	0.51
1/12/2017	0.54
2/22/2017	0.53
4/5/2017	0.51
5/17/2017	0.52
6/22/2017	0.562
7/25/2017	0.52

MW-27	
Date	Boron Concentration (mg/L)
10/4/2016	0.39
11/15/2016	0.39
1/9/2017	0.4
2/22/2017	0.41
4/5/2017	0.42
5/16/2017	0.39
6/22/2017	0.414
7/26/2017	0.383

MW-28	
Date	Boron Concentration (mg/L)
10/12/2016	0.16
11/15/2016	0.13
1/12/2017	0.13
2/22/2017	0.13
4/5/2017	0.12
5/17/2017	0.12
6/22/2017	0.116
7/25/2017	0.116

MW-32	
Date	Boron Concentration (mg/L)
10/3/2016	0.016J
11/16/2016	0.025B
1/12/2017	0.020B
2/23/2017	0.017J
4/6/2017	0.017J
5/17/2017	0.083J
6/22/2017	<0.0500
7/25/2017	<0.0500

MW-26	
Date	Boron Concentration (mg/L)
10/4/2016	0.012J
11/15/2016	0.017B
1/10/2017	0.013J
2/23/2017	0.013J
4/5/2017	0.014J+
5/16/2017	0.0015J
6/22/2017	<0.0500
7/26/2017	<0.0500

MW-23	
Date	Boron Concentration (mg/L)
10/3/2016	0.014J
11/16/2016	0.019B
1/12/2017	0.012B
2/23/2017	0.011J
4/6/2017	0.016J+
5/17/2017	0.013J
6/22/2017	<0.0500
7/26/2017	<0.0500

MW-25	
Date	Boron Concentration (mg/L)
10/12/2016	0.037
11/16/2016	0.0025J
1/10/2017	0.013J
2/23/2017	0.012J
4/5/2017	0.015J
5/17/2017	0.019J
6/22/2017	<0.0500
7/26/2017	<0.0500

MW-29U	
Date	Boron Concentration (mg/L)
10/7/2016	0.040B
11/16/2016	0.018B
1/9/2017	<0.10
2/20/2017	0.0096B
4/3/2017	0.0092J
5/15/2017	0.013J
6/19/2017	<0.0500
7/24/2017	<0.0500

MW-33	
Date	Boron Concentration (mg/L)
10/3/2016	0.081
11/15/2016	0.11
1/12/2017	0.14
2/22/2017	0.13
4/6/2017	0.083J
5/17/2017	0.071J
6/22/2017	0.0638
7/26/2017	0.0508

MW-34	
Date	Boron Concentration (mg/L)
10/12/2016	1.2
11/16/2016	1.2
1/10/2017	1.3
2/23/2017	1.3
4/5/2017	1.3
5/16/2017	1.2
6/22/2017	1.26
7/26/2017	1.22

MW-24	
Date	Boron Concentration (mg/L)
10/7/2016	0.76
11/15/2016	0.7
1/11/2017	0.66
2/22/2017	0.72
4/6/2017	0.69
5/16/2017	0.69
6/21/2017	0.698
7/26/2017	0.677

MW-B40A	
Date	Boron Concentration (mg/L)
10/5/2016	1.7
11/17/2016	1.6
1/12/2017	1.3
2/22/2017	1.4
4/6/2017	1.3
5/16/2017	1.4
6/21/2017	1.73
7/26/2017	1.81

Legend

Lower Ash Pond Monitoring Wells

Approximate Ash Pond Boundaries

Sample Location

WDC-01	
3/2/2017	885

Sample Date

Boron Concentration

Notes:
All locations are approximate.
J = Result is less than the reporting limit but greater or equal to the minimum detection limit
J+ = Estimated result biased high
B = Compound was found in the blank and the sample
mg/L = Milligrams per Liter

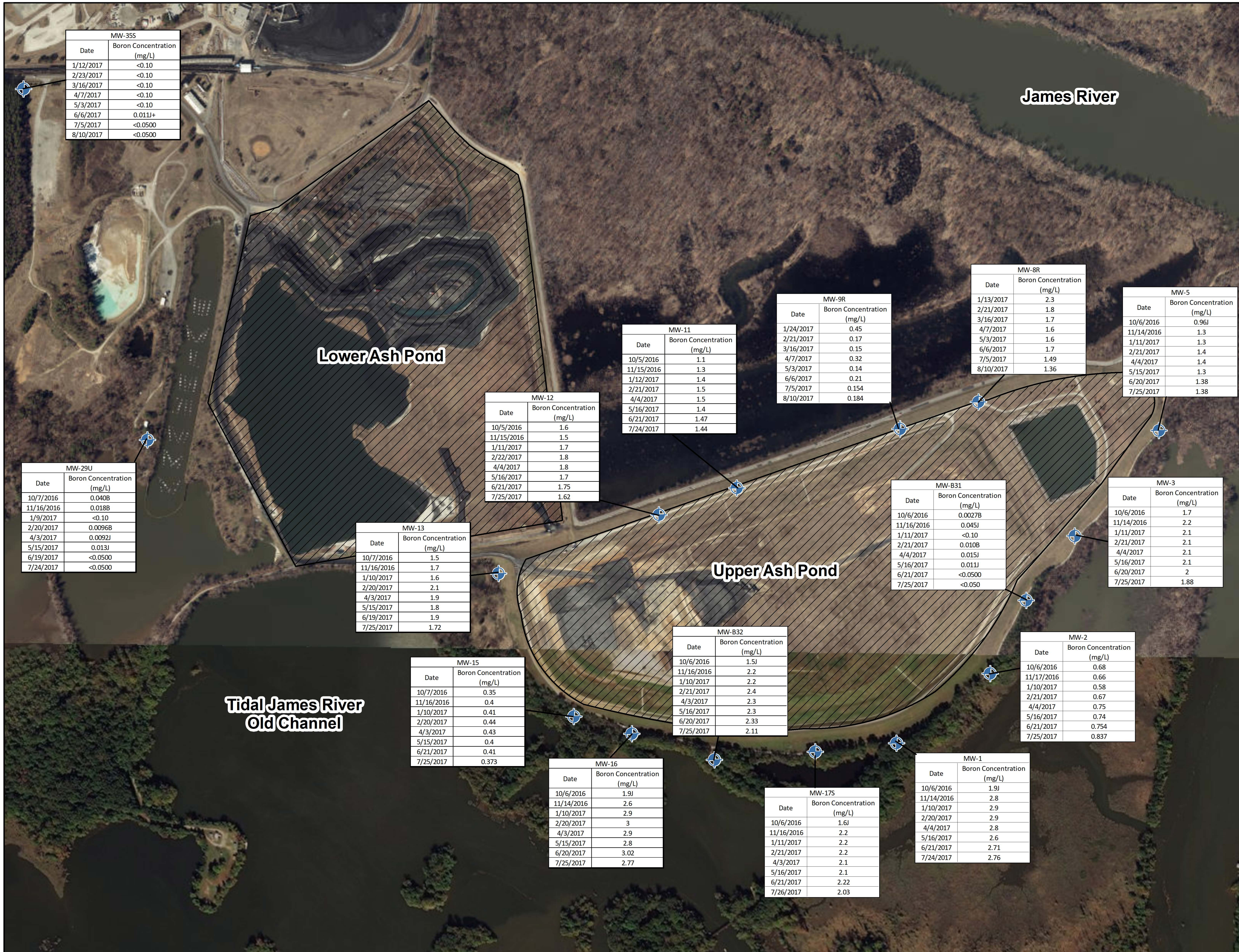
0 500
Feet

aquilogic, Inc.

Chesterfield Power Station
Chester, Virginia

Lower Ash Pond
Boron Concentrations in Groundwater
Columbia Aquifer (Uppermost Aquifer)

Date: 1/9/2018 | Project #: 019-08 | **Figure 3**



MW-35S	
Date	Boron Concentration (mg/L)
1/12/2017	<0.10
2/23/2017	<0.10
3/16/2017	<0.10
4/7/2017	<0.10
5/3/2017	<0.10
6/6/2017	0.011J+
7/5/2017	<0.0500
8/10/2017	<0.0500

MW-29U	
Date	Boron Concentration (mg/L)
10/7/2016	0.040B
11/16/2016	0.018B
1/9/2017	<0.10
2/20/2017	0.0096B
4/3/2017	0.0092J
5/15/2017	0.013J
6/19/2017	<0.0500
7/24/2017	<0.0500

MW-12	
Date	Boron Concentration (mg/L)
10/5/2016	1.6
11/15/2016	1.5
1/11/2017	1.7
2/22/2017	1.8
4/4/2017	1.8
5/16/2017	1.7
6/21/2017	1.75
7/25/2017	1.62

MW-11	
Date	Boron Concentration (mg/L)
10/5/2016	1.1
11/15/2016	1.3
1/12/2017	1.4
2/21/2017	1.5
4/4/2017	1.5
5/16/2017	1.4
6/21/2017	1.47
7/24/2017	1.44

MW-9R	
Date	Boron Concentration (mg/L)
1/24/2017	0.45
2/21/2017	0.17
3/16/2017	0.15
4/7/2017	0.32
5/3/2017	0.14
6/6/2017	0.21
7/5/2017	0.154
8/10/2017	0.184

MW-8R	
Date	Boron Concentration (mg/L)
1/13/2017	2.3
2/21/2017	1.8
3/16/2017	1.7
4/7/2017	1.6
5/3/2017	1.6
6/6/2017	1.7
7/5/2017	1.49
8/10/2017	1.36

MW-5	
Date	Boron Concentration (mg/L)
10/6/2016	0.96J
11/14/2016	1.3
1/11/2017	1.3
2/21/2017	1.4
4/4/2017	1.4
5/15/2017	1.3
6/20/2017	1.38
7/25/2017	1.38

MW-13	
Date	Boron Concentration (mg/L)
10/7/2016	1.5
11/16/2016	1.7
1/10/2017	1.6
2/20/2017	2.1
4/3/2017	1.9
5/15/2017	1.8
6/19/2017	1.9
7/25/2017	1.72

MW-B31	
Date	Boron Concentration (mg/L)
10/6/2016	0.0027B
11/16/2016	0.045J
1/11/2017	<0.10
2/21/2017	0.010B
4/4/2017	0.015J
5/16/2017	0.011J
6/21/2017	<0.0500
7/25/2017	<0.050

MW-3	
Date	Boron Concentration (mg/L)
10/6/2016	1.7
11/14/2016	2.2
1/11/2017	2.1
2/21/2017	2.1
4/4/2017	2.1
5/16/2017	2.1
6/20/2017	2
7/25/2017	1.88

MW-B32	
Date	Boron Concentration (mg/L)
10/6/2016	1.5J
11/16/2016	2.2
1/10/2017	2.2
2/21/2017	2.4
4/3/2017	2.3
5/16/2017	2.3
6/20/2017	2.33
7/25/2017	2.11

MW-2	
Date	Boron Concentration (mg/L)
10/6/2016	0.68
11/17/2016	0.66
1/10/2017	0.58
2/21/2017	0.67
4/4/2017	0.75
5/16/2017	0.74
6/21/2017	0.754
7/25/2017	0.837

MW-15	
Date	Boron Concentration (mg/L)
10/7/2016	0.35
11/16/2016	0.4
1/10/2017	0.41
2/20/2017	0.44
4/3/2017	0.43
5/15/2017	0.4
6/21/2017	0.41
7/25/2017	0.373

MW-16	
Date	Boron Concentration (mg/L)
10/6/2016	1.9J
11/14/2016	2.6
1/10/2017	2.9
2/20/2017	3
4/3/2017	2.9
5/15/2017	2.8
6/20/2017	3.02
7/25/2017	2.77

MW-17S	
Date	Boron Concentration (mg/L)
10/6/2016	1.6J
11/16/2016	2.2
1/11/2017	2.2
2/21/2017	2.2
4/3/2017	2.1
5/16/2017	2.1
6/21/2017	2.22
7/26/2017	2.03

MW-1	
Date	Boron Concentration (mg/L)
10/6/2016	1.9J
11/14/2016	2.8
1/10/2017	2.9
2/20/2017	2.9
4/4/2017	2.8
5/16/2017	2.6
6/21/2017	2.71
7/24/2017	2.76

Legend

Upper Ash Pond Monitoring Wells

Approximate Ash Pond Boundaries

Sample Location

WDC-01	
3/2/2017	885

Sample Date

Boron Concentration

Notes:
All locations are approximate.
J = Result is less than the reporting limit but greater or equal to the minimum detection limit
J+ = Estimated result biased high
B = Compound was found in the blank and the sample
mg/L = Milligrams per Liter

0 750
Feet

aquilogic, Inc.

Chesterfield Power Station
Chester, Virginia

Upper Ash Pond
Boron Concentrations in Groundwater
Columbia Aquifer (Uppermost Aquifer)

Date: 1/9/2018	Project #: 019-08	**Figure 4**

Legend

Sample Location

Trip

- Sampling Trip 1 (7/6/16)
- Sampling Trip 2 (11/30 - 12/1/16)
- Approximate Ash Pond Boundaries

Notes:
All locations are approximate.
Boron Concentrations in Milligrams per Liter (mg/L)
J = Result is less than the reporting limit
but greater or equal to the minimum detection limit
Samples collected by Southern Environmental Law Center

0 750
Feet

aquilogic, Inc.

Chesterfield Power Station
Chester, Virginia

Chesterfield Power Station
Surface Water Boron Concentrations in the Vicinity of the Ash Ponds

Date: 1/10/2018 | Project #: 019-08 | **Figure 5**