SANBORN HEAD

Building Trust. Engineering Success.

ASSESSMENT OF CORRECTIVE MEASURES

AEP MOUNTAINEER PLANT

BOTTOM ASH PONDS

New Haven, West Virginia

Prepared for American Electric Power
File No. 4345.01
June 24, 2019

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

This document is the Assessment of Corrective Measures (ACM) Report for groundwater impacts associated with the Bottom Ash Pond (BAP) complex, a coal combustion residuals[1] unit at the American Electric Power (AEP) Mountaineer Power Plant in Letart, West Virginia (the Site) near the Town of New Haven. On behalf of AEP, Sanborn, Head & Associates, Inc. (Sanborn Head) has prepared this report according to the requirements set forth by the U.S. Environmental Protection Agency (USEPA) in the Coal Combustion Residuals (CCR[2]) Rule under Subtitle D of the Resource Conservation and Recovery Act (RCRA) which regulates the disposal of CCR from electric utilities and independent power producers. The CCR Rule establishes minimum criteria for CCR landfills, CCR surface impoundments, and all lateral expansions of CCR units including location restrictions, liner design criteria, structural integrity requirements, operating criteria, groundwater monitoring and corrective action requirements, closure and post-closure care requirements, and recordkeeping, notification, and internet posting requirements. [3]

Groundwater concentrations of lithium (a listed constituent in Appendix IV of the CCR Rule) at the Mountaineer Power Plant have been detected at statistically significant levels (SSLs) exceeding the groundwater protection standard (GWPS), as discussed in the 2019 report, *Statistical Analysis Summary, Bottom Ash Pond*.[4] In accordance with the CCR Rule, corrective measures must be assessed.

1.1 Document Purpose

The purpose of this Assessment of Corrective Measures Report is to identify, develop, and evaluate potential corrective measures that could be implemented at the Mountaineer Power Plant to prevent further releases and to remediate CCR impacts.

1.2 Review of Data Sources

Sanborn Head utilized a compilation of data sources to facilitate the analysis of Site conditions. These sources are discussed in the following sections.

***Ash Pond System-CCR Groundwater Monitoring Well Network Evaluation, Mountaineer Plant*, prepared by Arcadis U.S., Inc., on behalf of AEP, dated October 27, 2016**

Sanborn Head reviewed the Ash Pond System-CCR Groundwater Monitoring Well Network Evaluation completed by Arcadis in January 2016. As part of this evaluation, Arcadis

---

1 The EPA CCR Rule defines coal combustion residuals as material that is generated from the combustion of coal, including solid fuels classified as anthracite, bituminous, subbituminous, and lignite, for the purpose of generating steam for the purpose of powering a generator to produce electricity or electricity and other thermal energy by electric utilities and independent power producers. CCR includes fly ash, bottom ash, boiler slag, and flue gas desulfurization materials.

2 Title 40 of the Code of Federal Regulations (CFR) Parts 257 and 261 (40 CFR 257 and 261) dated April 17, 2015.

3 Ibid.

4 *Statistical Analysis Summary, Bottom Ash Pond, Mountaineer Plant, New Haven, West Virginia* prepared by Geosyntec dated January 8, 2019.

conducted a groundwater flow modeling study to improve the understanding of the effect of the Site production wells on flow patterns in the vicinity of the BAPs. The predicted flow patterns were considered in the selection of new monitoring well locations.

***Little Broad Run Landfill – CCR Groundwater Monitoring Well Network Evaluation, Mountaineer Plant*, prepared by Arcadis, on behalf of AEP, dated October 18, 2016**

Sanborn Head reviewed the Little Broad Run Landfill report prepared by Arcadis in October 2016. The report provides comprehensive background information pertaining to the configuration, construction, and operational history of the landfill.

***Annual Groundwater Monitoring Report, APC Power Company, Mountaineer Plant, Bottom Ash Pond CCR Management Unit*, prepared by AEP Service Corporation dated January 2019**

Sanborn Head reviewed the 2019 Annual Groundwater Monitoring Report completed by AEP Service Corporation in January 2019. Information on the Site and groundwater conditions provided in this report includes a location plan for existing groundwater monitoring wells, static water elevation data, evaluation of groundwater velocities and flow directions, and potentiometric maps. The report also provides the following information:

- Assessment of 2016 and 2017 groundwater data to establish background values for Appendix III and Appendix IV parameters;
- Statistical evaluation of groundwater quality data based on the background sampling events and the October 2017 detection monitoring event;
- Groundwater quality data from the assessment monitoring events in May and September 2018.

***Statistical Analysis Summary, Bottom Ash Pond, Mountaineer Plant*, prepared by Geosyntec, on behalf of AEP, dated January 8, 2019**

Sanborn Head reviewed the Statistical Analysis Summary completed by Geosyntec in January 2019. Geosyntec performed a statistical evaluation of data from the assessment monitoring events in May and September 2018 and utilized these results to establish Groundwater Protection Standards (GWPSs) for Appendix IV parameters. In this analysis, SSLs were identified for lithium.

2.0 SITE BACKGROUND

The Mountaineer Power Plant is an electric power generating facility identified with the address of 1347 Graham Station Road, Letart, West Virginia, 25253. The Site is located on approximately 1,925 acres along the western bank of the Ohio River approximately two (2) miles east of the City of New Haven in Mason County, West Virginia (latitude 38°58'47.38"N, longitude 81°55'50.60"W). The location of the Site property is depicted in Figure 1.

2.1 Site Description and History

The Site is owned and operated by Appalachian Power Company, a wholly-owned subsidiary of AEP. The Mountaineer Power Plant burns approximately 9,000 tons of coal and provides approximately 1,300 megawatts of power for consumption on a daily basis.

The Ohio River is located east of the Site. The area on the southeastern border of the Site is occupied by the retired AEP Phillip Sporn Plant which ceased operations in 2015. West Virginia Route 62 (Graham Station Road) runs through the Site, and Little Broad Run is near the western border. The Town of New Haven lies to the northwest of the Site.

Two currently inactive underground coal mines lie on the western side of the Site.[5] Broad Run Mine (RDT-500476A) and the Phillip Sporn Mine (RDT-324045A) formerly extracted coal from the Redstone Seam of the Monongahela Formation.

As shown on Figure 2, the Site includes the following significant features:

- The Mountaineer Power Plant;
- The Bottom Ash Pond (BAP) Complex (West Virginia ID No. 05307).
- Five (5) groundwater pumping wells to provide water for plant operations; and
- A coal storage area.

In addition, the Little Broad Run Landfill (Application No. WV 0077038) is located approximately 1.5 miles west of the Site, and accepts CCR from the Mountaineer power plant.

Significant aspects of several of these features are discussed in the following sections.

2.1.1 Bottom Ash Pond Complex

The BAP Complex is comprised of the following components: East BAP, West BAP, East Wastewater Pond, West Wastewater Pond, Reclaim Pond, and Clearwater Pond. Of the BAP complex features mentioned herein, only the West and East BAPs are considered part of the regulated CCR impoundment.

The BAP Complex is located in the southern portion of the AEP Mountaineer Plant, approximately 0.5 mile southwest of the Ohio River. The retired AEP Phillip Sporn Plant separates the BAP Complex from the Ohio River. The BAPs are bordered by West Virginia Route 62 (Graham Station Road) to the northeast, a fly ash conveyor to the northwest and western sides of the BAP, Little Broad Run to the southwest, and wastewater ponds to the southeast. Refer to Figure 2 for a site plan.

The West and East BAPs, with a combined normal pool surface area of 28 acres, are constructed of earthen embankments approximately 35 ft tall, and lined with 3 feet of clay derived from offsite borrow areas[6]. The BAPs receive influent through above- and below-

[5] "Underground and Surface Coal Mines." West Virginia Geological and Economic Survey. April 19, 2019. http://www.wvgs.wvnet.edu/GIS/CBMP/all_mining.html

[6] *Ash Pond System-CCR Groundwater Monitoring Well Network Evaluation, Mountaineer Plant*, prepared by Arcadis U.S., Inc., on behalf of AEP, dated October 27, 2016.

ground piping from coal pile run-off, fly ash silo and turbine room sumps, pyrite and bottom ash transport, stormwater, and the facility's bioreactor, as well as direct precipitation[7]. Reportedly, the West BAP receives more influent than the East BAP. Impounded water generally flows from northwest to southeast through the BAPs, and then from the BAP (West/East) to the Wastewater Ponds (West/East), next to either the Reclaim Pond or Clearwater Pond, and eventually to the Ohio River[8]. In addition to BAP effluent, the wastewater ponds receive influent from the water treatment sump and cooling tower blowdown.

As described in the Groundwater Monitoring Well Network Evaluation (GMWNE) [9], the BAP groundwater monitoring network consists of four upgradient (MW-1601A, MW-1602, MW-1603, and MW-1608) and eight downgradient (MW-1604S/D, MW-1605S/D, MW-1606S/D, and MW-1607S/D) monitoring wells sampled for water quality. An additional eleven monitoring wells/wells/piezometers are used for hydraulic monitoring only. Refer to Figure 2 for monitoring well locations.

2.1.2 Groundwater Pumping Wells

Five (5) groundwater pumping wells are currently active at the Site. Two wells (West 1 and East 1) provide cooling and process water for the Site. West 1 and East 1 have pumping capacities of approximately 930-950 gallons per minute (gpm) and 550-575 gpm, respectively. Well 4 supplies water for the wastewater system, and Wells 5 and 6 supply water for the emergency fire suppression system. Wells 4, 5 and 6 are pumped at lower flow rates than West 1 and East 1, and are operated on an intermittent, "as needed" basis. There are no groundwater wells supplying water for human consumption at the Site.

2.1.3 Little Broad Run Landfill[10]

The Little Broad Run (LBR) Landfill, located approximately 1.5 miles west of the Site, is bordered by undeveloped, wooded land in an isolated area. The landfill occupies approximately 660 total acres, of which 325 acres are permitted for ash disposal. The LBR Landfill began operation in 1978 and accepted both bottom ash and fly ash from the Mountaineer and Sporn power plants. Since the Sporn Plant closure on June 1, 2015, the Mountaineer Plant is the primary contributor of CCR byproducts, but the landfill occasionally receives materials from other AEP locations including Clinch River, VA; Glyn Lyn, VA; and Kanawha River, WV.

The LBR has 9 permitted valley-fill Areas and 5 vertical expansion Phases that are permitted for construction over the valley-fill landfill area. As of 2015, Areas 1 through 7 were filled and temporarily closed with two feet of soil cover to their permitted final grades or were transitioned into vertical expansion filling operations; Areas 8 and 9 have not been

---

7 History of Construction CFR 257.73(c)(1) Bottom Ash Complex Mountaineer Plant, prepared by American Electric Power Service Corporation on behalf of Appalachian Power Company, dated October 2016.

8 Ibid.

9 Ash Pond System-CCR Groundwater Monitoring Well Network Evaluation, Mountaineer Plant, prepared by Arcadis U.S., Inc., on behalf of AEP, dated October 27, 2016.

10 *Little Broad Run Landfill – CCR Groundwater Monitoring Well Network Evaluation*, Mountaineer Plant prepared by Arcadis dated October 18, 2016.

constructed. The first phase of the vertical expansion was subdivided into three sub-phases (1A, 1B, and 1C). Current filling operations are primarily in Phase 1B.

2.2 CCR Regulatory Status

Two Mountaineer Plant ash storage sites are included in the CCR monitoring program, including the bottom ash ponds and the LBR landfill, and both storage sites are in active use. Mountaineer Plant has switched to dry fly ash handling, and fly ash is now stored in the lined LBR landfill operated by AEP. Bottom ash from the plant is stored in the bottom ash ponds. The CCR Rule requires groundwater monitoring and establishes criteria for existing and new CCR landfills and surface impoundments. In accordance with the CCR Rule, detection monitoring for the Mountaineer Site was conducted in 2017 and 2018. At this time, Mountaineer's LBR Landfill is in a detection monitoring status and does not require an assessment of corrective measures to be performed.[11] Any further reference to the LBR Landfill in this document in the following sections relates only to the potential for the landfill to act as a potential disposal location for CCR that is in the BAPs.

The following is a summary of the steps that have resulted in the need for this assessment of corrective measures to be performed for the Mountaineer Plant BAPs.

Statistical analysis of the groundwater quality data showed statistically significant increases (SSIs) in the following Appendix III parameters: boron, calcium, chloride, fluoride, sulfate, and TDS. In April 2018, an alternative source demonstration was undertaken, and it concluded that an alternative source for the Appendix III parameter SSIs could not be identified at the time. An assessment monitoring program for Appendix IV parameters was initiated in April 2018, and sampling for Appendix III and IV parameters was conducted in May and September 2018. A Groundwater Protection Standard (GWPS) was established for each Appendix IV parameter in accordance with 40 CFR 257.95(h). Statistical analysis of the monitoring data yielded confidence intervals for each Appendix IV parameter at each compliance well. An SSL was indicated if the Lower Confidence Limit (LCL) of a parameter exceeded the GWPS. Through this analysis, SSLs were identified for lithium as LCLs for lithium exceeded the GWPS of 0.040 mg/L at MW-1605D (0.0653 mg/L), MW-1605S (0.0594 mg/L), MW-1606D (0.111 mg/L), MW-1606S (0.102 mg/L), MW-1607D (0.0718 mg/L), and MW-1607S (0.0918 mg/L).

2.3 Conceptual Site Model (CSM)

The CSM presented in this ACM Report was developed by Sanborn Head to document the current understanding of the relationship of the BAP to the regional and Site geology and hydrogeology, and to provide guidance for future investigation, data collection and evaluation, and the assessment of corrective measures.

[11] *Annual Groundwater Monitoring Report, Appalachian Power Company Mountaineer Plant, Landfill CCR Management Unit*, prepared by American Electric Power Service Corporation, dated January, 2019

2.3.1 Physiographic Setting

The Site lies within the Ohio River alluvial floodplain and the Upper Ohio-Shade watershed. The elevation of the Ohio River to the east of the Site is regulated by the upstream Racine Lock (Letart, WV) and the downstream Robert C. Byrd Lock (Gallipolis Ferry, WV). The normal pool stage under non-flood conditions is an elevation of approximately 542 ft amsl near to the Site. The Site topography is relatively flat with a typical elevation of around 590 ft amsl, with steeper inclines to the west due to the slope of the valley and to the east where the river bank slopes down to the river.

2.3.2 Site Geology

Previous investigations as summarized in *Ash Pond System-CCR Groundwater Monitoring Well Network Evaluation* (Arcadis, 2016) have provided information to characterize the geology of the Site. The general stratigraphic units were identified as unconsolidated valley-fill alluvial deposits (silt, clay, sand and gravel), and bedrock. In addition, fill material, comprised reworked soils (i.e., silt, clay and sand) and mine spoil, is found in areas of the Site that have been excavated and reworked during construction activities, and covers a relatively limited area. A generalized cross-section depicting the Site geology is shown in Figure 3.

The unconsolidated valley-fill alluvial deposits consist of the following two units:

- Alternating horizons of clay and clayey silt, with thickness ranging from about 0 to 30 feet below ground surface (ft bgs); and

- Sand, generally medium to coarse grained, with some gravel horizons, that generally coarsens with depth. The sand unit varies in thickness across the Site and is typically has thickness in the range of 40 to 60 ft.

Bedrock beneath the Site is described as a fine to medium grained, moderately hard, competent sandstone. Depth to bedrock typically ranges from approximately 60 to 90 ft bgs across the Site.

2.3.3 Site Hydrogeology

The Ohio River flows north-northwest along the northeastern Site boundary, but regionally flows south and west. The alluvial sand and gravel associated with the Ohio River valley was the only aquifer encountered at the Site, with a saturated thickness of about 20 to 45 ft. The aquifer is primarily recharged by local precipitation and inflow from the Ohio River during high river stages. Depth to groundwater at the Site ranges is around 40 to 50 ft bgs.

Groundwater flow is influenced by Site pumping wells and by the stage of the Ohio River. During regular operating conditions, wells East 1 and West 1 are actively pumping and have capacities of approximately 550 and 950 gallons per minute (gpm), respectively although the wells are typically operated at lower flow rates. Groundwater elevations measured on February 4, 2019 (shown on Figure 5), under these pumping conditions resulted in a cone of depression that extends at least 800 feet from the wells and in which the overall groundwater flow direction is toward the wells. Outside of this area, groundwater flow is generally east towards the Ohio River.

A groundwater flow modeling study was conducted by Arcadis in 2016[12] to improve the understanding of the effect of facility well pumping on the flow patterns in the vicinity of the BAP complex. This study included the following factors:

- Pumping rates of 400 gpm each for East 1 and West 1;
- Pumping rates of 19 gpm each for Well 5 and Well 6;
- Normal operating levels for the Mountaineer pond elevations (BAPs, wastewater ponds, reclaim pond, and clearwater pond);
- Inactive and dry Sporn ponds due to plant closure;
- Ohio River water level for December (groundwater flow toward river)

The results of the model show good agreement with measured groundwater elevations and inferred flow directions observed at the Site under typical pumping conditions. Both suggest a pattern of groundwater flow diverging away from the BAP complex ponds, with flow being directed toward the Ohio River and the cone of depression surrounding the East 1 and West 1 wells.

Vertical groundwater flow at the Site is expected to be downward in the vicinity of the BAP complex, which is a source of groundwater recharge under current conditions, as well as near to the plant supply wells which are screened in the deeper part of the granular overburden. Groundwater that is not captured by the plant supply wells is expected to flow generally eastward toward the Ohio River, where the vertical gradient is anticipated to be upward as the groundwater discharges to surface water.

Although the plant supply wells are generally operated continuously, an opportunity to observe groundwater flow under non-pumping conditions was provided in March 2019 when pumps at the facility were shut down for maintenance. Two sets of groundwater elevation measurements were collected during this time. The first set of measurements was recorded on March 1 after the pumps had been shut down since sometime prior to February 27. The resulting contours indicate that shallow horizontal groundwater flow is generally west to southwest. During this time, the Ohio River elevation ranged from approximately 560 ft amsl on February 25 to 547 ft amsl on March 1, although typical elevation near the Site is approximately 542 feet amsl. While non-pumping conditions will provide an understanding of groundwater flow under static conditions, the elevated stage of the Ohio River during this timeframe was observed to potentially cause temporary reversal of "normal" groundwater flow direction adjacent to the river, resulting in flow out of the Ohio River and into the groundwater of the sand and gravel for a short duration. This effect is defined as riverbank storage: when the river level rises during a flood, water will flow from the river into the riverbank; the flood water that is stored in the riverbank (as groundwater) will then flow back into the river over a period following recession of the high river levels. The volume of water entering the river bank from the river and the duration of this effect is dependent on the permeability of the riverbank soils. A second set of water level

[12] *Ash Pond System-CCR Groundwater Monitoring Well Network Evaluation, Mountaineer Plant*, prepared by Arcadis U.S., Inc., on behalf of AEP, dated October 27, 2016.

measurements was collected on March 7, 2019 once flooding in the Ohio River had subsided to a more typical Ohio River stage of 541.48 amsl. The resulting groundwater contours indicate that groundwater flow in the sand and gravel is generally northeast toward the Ohio River under static, non-pumping conditions (noting that there may be some residual transient influence of pumping in the area located between the pumping wells and the Ohio River).

Sanborn Head further assessed the onsite groundwater flow including flow direction and groundwater travel time under both non-pumping and pumping conditions for groundwater originating from the edge of the BAPs. This assessment was performed using a particle tracking method that is implemented in the ArcGIS software package. The particle tracking tool requires groundwater contours, saturated thickness, and hydraulic conductivity values in order to calculate the direction and travel time of groundwater from a specified starting point. Groundwater contours used for the calculation are described in Figure 4 and 5. Saturated thickness of the sand and gravel was calculated using the groundwater elevation contours and an estimated depth to bedrock. The depth to bedrock and the hydraulic conductivity data was applied using information presented in the groundwater flow modeling study conducted by Arcadis in 2016[13].

Groundwater conditions while pumps were not in operation (i.e. for measurements recorded on March 7, 2019), are illustrated in Figure 4. As depicted in the figure, groundwater generally flows northeast from the BAPs toward the Main Plant Area and onward toward the Ohio River. The ArcGIS particle tracking method indicates particle travel from the north and northeast sides of the BAPs is initially north at travel times ranging from <5 to 5-20 years with groundwater flow turning toward the northeast beginning in the southwest portion of the Main Plant Area with travel times ranging from <5 to 20-40 years, slowing as the path progresses. Inferred groundwater travel from the southeast side of the BAPs is northeast at a rate of 5-20 years with more downgradient flow near the Main Plant Area turning more toward the north with travel times ranging from 5-20 to 40-60 years, slowing as the path progresses.

Groundwater flow conditions under the more typical pumping conditions (i.e., measurements recorded on February 4, 2019) are illustrated in Figure 5. As depicted in the figure, groundwater generally flows north from the BAPs toward the vicinity of Well 5 in the southwest portion of the Main Plant Area. A cone of depression is present beneath the main plant area resulting from pumping of the plant supply wells (East 1 and West 1). The ArcGIS particle tracking method indicates particle travel from the north and northeast sides of the BAPs is generally toward Well 5 with a travel time of <5 years, and groundwater flow from the southeast side of the BAPs is toward the area slightly east of Well 5 at travel times ranging from <5 to >15 years, slowing as the path progresses.

[13] *Ash Pond System-CCR Groundwater Monitoring Well Network Evaluation, Mountaineer Plant*, prepared by Arcadis U.S., Inc., on behalf of AEP, dated October 27, 2016.

2.3.4 Population and Land Use

The CSM enables a qualitative assessment of the risk to human and ecological receptors from CCR impacts in groundwater at the Mountaineer Power Plant. Lithium was the only Appendix IV parameter for which an SSL was determined. The BAPs appear to be one potential source of lithium in groundwater, and this point of origin was considered in the evaluation of migration pathways to receptors.

Land use downgradient of the BAPs includes the AEP energy production facility to the northeast, the former Sporn Plant bottom ash ponds to the east and northeast, and the former Sporn Plant to the southeast. Downgradient flow ends at the plant supply wells (under pumping conditions) or the Ohio River (under static, non-pumping conditions). Discharge to the river is not expected to cause appreciable increase in the lithium concentration of the river or impacts to ecological or human receptors due to the substantial dilution from the high volumetric flow of the river, of approximately 50,000 CFS under long term average flow conditions.

Five non-potable production wells exist onsite that are used for process water, fire water supply, and the plant's wastewater system.[14] Under current conditions, the extracted water is used for Site operations and then discharged in accordance with the Site's National Pollutant Discharge Elimination System (NPDES) permit. Prior to discharge, the extracted water is delivered to the Site's wastewater treatment plant for removal of solids and then to a bioreactor for treatment of metals. From the bioreactor, the water moves to the clearwater pond in the BAP complex for settling and then from clearwater pond to the Ohio River outfall where it is monitored for NPDES compliance.

A well inventory performed by Arcadis (2016) identified one USGS well within a 0.5-mile buffer of the BAP complex with the apparent purpose of groundwater monitoring.[15] Two public water supply wells for the town of New Haven (New Haven 3 and New Haven 4) are located over 6,000 feet to the northwest of the BAPs as shown on Figure 2. Figures 4 and 5 illustrate that under both non-pumping and pumping conditions, these wells are upgradient from the BAPs and contamination from the BAPs would not travel towards or reach them. Further, the BAPs are outside of the local Source Water Protection Area (reference SWPA report). Therefore, groundwater transport of lithium emanating from the BAPs is not likely to affect water extracted for drinking water purposes in the area.

2.3.5 Lithium Distribution and Transport in Groundwater

Detection monitoring events that identified SSIs occurred on October 30, 2017 and January 22, 2018. Statistical analysis to determine SSIs was conducted using groundwater data collected from eight wells along the downgradient perimeter of the BAPs (MW-1604D, MW-1604S, MW-1605D, MW-1605S, MW-1606D, MW-1606S, MW-1607D, and MW-1607S). This process identified SSIs for boron, calcium, chloride, fluoride, sulfate, and TDS, and all locations showed an SSI for at least one parameter.

[14] Ibid.

[15] *Little Broad Run Landfill-CCR Groundwater Monitoring Well Network Evaluation*, prepared by Arcadis U.S., Inc., on behalf of AEP, dated October 18, 2016.

Assessment monitoring was conducted on May 9, 2018 and September 9, 2018. Lithium concentrations at the wells where multi-parameter SSIs were identified ranged from 0.016 to 0.118 mg/L. Exceedances of the established GWPS for lithium (0.04 mg/L) occurred at seven of the eight wells (concentrations at MW-1604D were below the GWPS).

Background, detection, and assessment monitoring provided data for lithium concentrations in groundwater between 2016 and 2018. This information was used to infer the distribution of lithium in overburden groundwater across the Site. MW-1608 can be considered an indicator of background levels as it lies side-gradient to and approximately 0.8 miles northwest of the BAPs. Lithium concentrations at MW-1608 ranged from non-detect (reporting limit of 0.0002 mg/L) to 0.016 mg/L. MW-1601A, MW-1602, and MW-1603 are upgradient to and on the southern and western side of the BAPs. Lithium concentrations at these locations ranged from non-detect (reporting limit of 0.0002 mg/L) to 0.022 mg/L. MW-1604D, MW-1604S, MW-1605D, MW-1605S, MW-1606D, MW-1606S, MW-1607D, and MW-1607S are immediately downgradient from the BAPs. Lithium concentrations at these locations ranged from 0.016 mg/L to 0.132 mg/L. As supported by these data, and as previously described in work by others[(e.g. 16,17)], concentrations of lithium in groundwater are elevated in downgradient monitoring wells compared to upgradient monitoring wells.

The geochemistry and environmental fate and transport of lithium is summarized in *Chemical Constituents in Coal Combustion Products: Lithium.* (EPRI, Palo Alto, CA: 2018. 3002012311), and pertinent information from this guidance document relative to the ACM is provided below. In addition, a literature review was performed to collect published soil/water partition coefficient (K_d) values for lithium. The K_d is a factor that is applied to the groundwater seepage velocity rate, to account for the retardation (i.e., slowing down) of a dissolved contaminant due to partitioning (i.e., by adsorption to solid particles) of the contaminant between solid and dissolved phases. K_d is defined as the ratio of: the contaminant concentration sorbed per unit mass of solid, to the dissolved concentration of the contaminant remaining in solution at equilibrium, or

K_d = Contaminant Concentration in Soil / Contaminant Concentration Dissolved in Groundwater.

The literature-derived K_d values are used to calculate retardation factors for lithium as part of the ACM. K_d values vary based on factors such as: method of analysis; soil composition (e.g. grain size, mineralogy, organic matter content, initial COC concentration); water composition (e.g. initial COC concentration, pH); and solid/liquid ratio. Therefore, the literature search was limited to references that provide overview of multiple studies to gain an understanding of the degree of variability, as well as studies based on conditions generally similar to those encountered at the site (e.g. granular soils and near neutral groundwater pH). A summary of the literature review is provided in Exhibit 1.

16 Ash Pond System-CCR Groundwater Monitoring Well Network Evaluation, Mountaineer Plant, prepared by Arcadis U.S., Inc., on behalf of AEP, dated October 27, 2016.

17 Statistical Analysis Summary Bottom Ash Pond, Mountaineer Plant, prepared by Geosyntec Consultants on behalf of AEP, dated January 15, 2018.

Exhibit 1 – Summary of Literature Review - Partition Coefficient Values

Analyte	Soil/Water Partition Coefficient (mL/g)	Reference	Notes
Lithium	0.0	(a) USDOE 1989	pH 5 to 9, sandy soils
	0.2		pH 5 to 9, loamy soils
	0.8		pH 5 to 9, clayey soils

Notes:
1. References:
(a) Chemical Data Bases for the Multimedia Environmental Pollutant Assessment System (MEPAS): Version 1, prepared by Strenge, D.L. and Peterson, S.R. (Pacific Northwest National Laboratory operated by Battelle) on behalf of the U.S. Department of Energy, dated December 1989.

2. Soil/water partition coefficients (K_d) are presented in units of milliliters per gram (mL/g).

Lithium is generally weakly or not taken up by soils (low K_d), and its leaching is expected to decrease as pH increases. These relatively low K_d values are consistent with the generally relatively weak cation exchange strength of lithium relative to the other monovalent cations (e.g., Na^+, K^+, Rb^+) and divalent cations (e.g., Mg^{2+}, Ca^{2+}, Co^{2+})[18] (Rose et al, 1979). Lithium is thought to substitute for major elements such as sodium or potassium in silicate minerals such as clays and feldspars. Lithium may therefore be weakly attenuated in the shallow silty clay soils beneath the BAPs, but would be expected to be relatively mobile in the groundwater present in the deeper sand and gravel under existing Site conditions. This information, along with the observation of generally elevated lithium concentrations (relative to the GWPS of 40 µg/l) in groundwater in the downgradient wells, suggest that lithium is relatively mobile under site conditions.

3.0 IDENTIFICATION AND DEVELOPMENT OF CORRECTIVE MEASURE ALTERNATIVES

This section of the report identifies remedial technologies that are applicable to the groundwater conditions at the Site and evaluates the merits of using each technology for development of corrective measure alternatives to achieve the corrective action objectives discussed in this section. Selection of remedial technologies and development of corrective measure alternatives for the Site was performed with the understanding that AEP will include source control in conjunction with groundwater remedial technologies.

3.1 Establishment of Corrective Action Objectives

Based on the CSM described above, and in accordance with the CCR Rule, the following remedial objectives were developed for the Site:

- Control the CCR source material to limit the potential for release of lithium into groundwater;

[18] Rose, A.W., Hawkes, H.E. and Webb, J.S. (1979) Geochemistry in Mineral Exploration. 2nd Edition, Academic Press, London, 658.

- Prevent potential human exposure to groundwater impacted by lithium, including potential downgradient receptors at concentrations exceeding USEPA Maximum Contaminant Levels (MCLs) and GWPSs; and

- Restore groundwater quality within the aquifer consistent with MCLs/GWPS.

3.2 Screening and Evaluation of Remedial Technologies

Sanborn Head performed an initial screening and evaluation of multiple remedial technologies as summarized in Table 1. The evaluation for the Site included a range of general response actions, including: no further action, institutional controls, monitored natural attenuation, in-situ treatment, ex-situ treatment and discharge, containment, and source control. The remedial technologies were evaluated based on their risk reduction and protectiveness, potential effectiveness in the treatment of lithium contamination in groundwater based on available literature, and implementability with respect to site conditions. As summarized in Table 1, the following technologies were retained for development of corrective measures alternatives:

- Institutional Controls;

- Passive In-Situ Treatment by Monitored Natural Attenuation;

- Active In-situ Treatment by Permeable Reactive Barrier;

- Groundwater Plume Containment by Hydraulic Containment System; and

- Source Control (bottom ash will either be removed by excavation or the bottom ash ponds will be capped in-place).

3.3 Development of Corrective Measures Alternatives

The primary corrective measure for each alternative includes source control. In addition to implementation of the source control measures, each alternative includes a different groundwater remediation approach that has the potential to meet the corrective action objectives of preventing potential human exposure to groundwater impacted by lithium and restoring groundwater quality within the aquifer consistent with MCLs/GWPS. The three remedial alternatives developed for detailed evaluation include:

- Alternative #1: Source Removal and Disposal with Monitored Natural Attenuation

- Alternative #2: Source Removal and Disposal with Groundwater Plume Containment by Hydraulic Containment System

- Alternative #3: Source Removal and Disposal and In-Situ Treatment by Permeable Reactive Barrier

In addition to source removal, each alternative includes institutional controls to restrict use of the groundwater as drinking water until the corrective action objectives are met. Each alternative is discussed and evaluated in detail in the following section.

4.0 DETAILED EVALUATION OF CORRECTIVE MEASURE ALTERNATIVES

As discussed in Section 3.0, three remedial alternatives have been developed that have the potential to be implemented at the Site to prevent further releases of lithium and to remediate existing lithium impacts to groundwater. Each of these alternatives includes removal of the CCR source material thereby significantly reducing or eliminating additional contaminant mass flux to groundwater. Sanborn Head performed an evaluation of each alternative based on the criteria in 40 CFR 257.96 and 257.97 including:

- Overall Protection of Human Health and the Environment
- Ability to Comply with Groundwater Protection Standard
- Source Control and Reduction of Contaminated Material
- Long-Term Effectiveness
- Short-Term Effectiveness
- Implementability
- Long-Term Management Requirements
- Community Acceptance
- State Acceptance
- Time Required to Meet Remedial Objectives

The following three subsections include an evaluation of the above criteria for each of the three alternatives.

4.1 Alternative 1 – Source Removal and Disposal with Monitored Natural Attenuation

This alternative includes monitored natural attenuation (MNA) of the dissolved phase plume following removal and disposal of CCR source material from the BAPs. MNA would be facilitated by the removal of CCR source material that would reduce or eliminate the contaminant mass flux into the groundwater from the BAPs. The conceptual approach for this alternative is presented on Figure 6. The alternative involves routine periodic monitoring of the existing groundwater monitoring network for a list of analytes similar to the current CCR monitoring program[19]. MNA relies on naturally occurring subsurface processes that act to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in groundwater. These processes include oxidation/reduction, precipitation, sorption, dispersion and dilution.

4.1.1 Overall Protection of Human Health and the Environment

The combination of CCR source material removal and MNA would significantly reduce or eliminate CCR contaminant leaching to groundwater and allow for dissolved concentrations in groundwater to attenuate over time. During the attenuation process, institutional controls would protect local residents and other potentially affected people by limiting exposure to impacted groundwater. In addition, this Alternative is protective of the New Haven public

[19] Ash Pond System-CCR Groundwater Monitoring Well Network Evaluation, Mountaineer Plant, prepared by Arcadis U.S., Inc., on behalf of AEP, dated October 27, 2016.

water supply wells located along the northwest property boundary, based on a groundwater modeling simulation showing no migration of contaminant to the wells.

This alternative is anticipated to maintain current groundwater chemistry conditions (e.g., pH), therefore, selecting this remedial alternative would not likely result in unintended changes to concentrations of other metals that may be present.

Excavation and removal of the CCR material could create the potential for worker exposure to contaminated material and potential off-site fugitive dust emissions; however, the impact is anticipated to be short-term and could be managed with engineering controls.

4.1.2 Ability to Comply with Groundwater Protection Standard

This alternative provides the Site the ability to comply with the GWPS over time through source removal and natural attenuation.

4.1.3 Source Control and Reduction of Contaminated Material

Ceasing discharge of bottom ash and sluice water into the BAPs and excavating and removing existing CCR material in the BAP with disposal in the Site's lined landfill would adequately control the source. The concentration of dissolved lithium in groundwater and in unsaturated overburden materials beneath the current BAPs would reduce naturally over time through advective transport, dispersion, dilution, and sorption.

4.1.4 Long-Term Effectiveness

The effectiveness of this remedy relies on completion of source removal in the BAP complex and ceasing discharge of additional CCR material to the BAPs, which will effectively eliminate future input of lithium to groundwater. Once the contamination source is removed, it is expected that natural attenuation will reduce lithium concentrations over time. Monitored natural attenuation has been effectively used as a passive remedy for groundwater remediation at numerous sites throughout the U.S. and is a proven and widely accepted approach; reliability and permanence are considered probable.

This alternative relies on a strong understanding and characterization of subsurface conditions. With the removal and disposal of the CCR source material, the mass of lithium available for leaching will be limited, and hence lithium leaching is expected to decrease with time assuming current groundwater pH and redox conditions are maintained. Our review of historical data sources, and additional Site characterization and data analysis conducted including plume stability analysis and groundwater modeling confirm our understanding that the subsurface conditions at the Site are sufficiently stable to employ this approach.

4.1.5 Short-Term Effectiveness

Removing and disposing of the source material from the BAPs will have a positive effect in the short term by significantly decreasing, and potentially eliminating mass flux of additional contaminant to groundwater. Groundwater monitoring will provide verification of effectiveness and is expected to indicate decreasing concentrations of lithium in groundwater within several years of completion of source removal activities. However, the short-term effectiveness of achieving the GWPSs at locations hydrogeologically downgradient from the BAPs (e.g., near the Mountaineer Plant) may be influenced by contaminant contribution to groundwater from other potential sources near the BAP complex (e.g., the Sporn Plant former ash ponds).

4.1.6 Implementability

Removal of CCR material from the BAPs is implementable using standard earthwork construction equipment with disposal of the excavated material in the Little Broad Run Landfill. MNA could be readily implemented using the existing groundwater monitoring network for a list of analytes similar to the current CCR monitoring program. MNA does not require direct energy inputs and would not remove water from the aquifer.

Prior to implementation of the excavation and removal phase, an engineered design plan should be developed that considers the geotechnical requirements for BAP stability, dewatering requirements, wastewater management/treatment processes, and construction sequencing.

4.1.7 Long-Term Management Requirements

Groundwater monitoring to evaluate the progress of attenuation, distinguish contaminant contribution to groundwater from other potential sources near the BAP complex (e.g., the Sporn Plant former ash ponds), and ensure that GWPSs are met are the only long-term management requirements for this option. Groundwater monitoring is anticipated to occur on a semi-annual basis until the GWPSs are met.

4.1.8 Community Acceptance

Currently, no concerns relating to local permitting or approval processes have been identified. Community acceptance will be assessed during public meetings.

4.1.9 State Acceptance

State acceptance of this alternative requires a Solid Waste Landfill Permit and a Construction Stormwater General Permit. As the area disturbed during source removal would exceed three (3) acres, as part of the construction stormwater general permitting process a Construction Site Registration Application must be submitted at least forty-five (45) days prior to site disturbance. Also, the proximity of Little Broadrun Stream would necessitate the establishment of a fifty (50) foot natural vegetative buffer in addition to other erosion control BMPs. AEP already possesses Solid Waste Landfill Permit WV077038 which may need to be modified under this alternative.

4.1.10 Time Required to Meet Remedial Objectives

Because lithium will not degrade in the subsurface, MNA will reduce lithium concentrations in groundwater over time through natural attenuation processes such as advective transport, dilution, dispersion, and sorption. Based on attenuation modeling and predicted conditions at the Site following source removal, the time for this Alternative to reach GWPSs for the contaminant of concern is estimated to be approximately 10 years or longer depending on actual conditions. The actual timeframe to reach GWPSs may be influenced by contaminant contribution to groundwater from other potential sources near the BAP complex (e.g., the Sporn Plant former ash ponds).

4.2 Alternative 2 – Source Removal and Disposal with Groundwater Plume Containment by Hydraulic Containment System

This alternative proposes operating up to five of the groundwater pumping wells that are currently active at the Site to provide hydraulic control of the groundwater plume following removal of the CCR source material in the BAP and disposal of that material in the Site's lined landfill. As groundwater is pumped from the extraction well network, a hydraulic gradient is created that draws the contaminated groundwater towards the extraction wells and limits or prevents the contaminated water from migrating off site. The conceptual approach for this alternative is presented on Figure 7. The two primary wells proposed for the hydraulic containment system (HCS) include West 1 and East 1, which provide cooling and process water for the Site. West 1 and East 1 have pumping capacities of approximately 930-950 gallons per minute (gpm) and 550-575 gpm, respectively. Wells 4, 5 and 6 would be pumped at lower flow rates than West 1 and East 1, and would be operated on an intermittent basis to supplement the HCS as needed to maintain hydraulic capture of contaminated groundwater at the Site.

Similar to current conditions, the extracted water would be used for Site operations and then delivered to the Site's wastewater treatment plant prior to discharge at the Ohio River outfall where it would be monitored in accordance with the Site's National Pollutant Discharge Elimination System (NPDES) permit.

Within the source area, natural attenuation processes such as advective transport, sorption, dispersion, and dilution would act on the existing groundwater and unsaturated overburden materials to gradually reduce the residual contaminant mass in the area until compliance with GWPSs was achieved.

4.2.1 Overall Protection of Human Health and the Environment

The combination of CCR removal and hydraulic containment would remove contaminant mass from the ground and minimize further leaching to groundwater. This method would also significantly reduce and potentially eliminate off-site migration of lithium, and allow for dissolved concentrations of contaminant to attenuate. During the attenuation process, institutional controls would protect local residents and other potentially affected people by limiting exposure to impacted groundwater. In addition, this Alternative is protective of the New Haven public water supply wells located along the northwest property boundary, based on a groundwater modeling simulation showing no migration of contaminant to the wells.

This alternative is anticipated to maintain current groundwater chemistry conditions (e.g., pH) and would not likely result in unintended changes to concentrations of other metals that may be present.

Excavation and removal of the CCR material could create the potential for worker exposure to contaminated material and potential off-site fugitive dust emissions; however, the impact is anticipated to be short-term and could be managed with engineering controls.

The utilization of extracted water for Site operations could create the potential for worker exposure, although the likelihood of contact is minimal due to the essentially non-volatile nature of lithium and enclosed process equipment. Final discharge to the Ohio River would not present a concern to human health and the environment as the discharge would meet regulatory standards.

4.2.2 Ability to Comply with Groundwater Protection Standard

This alternative provides the Site the ability to comply with the GWPS over time through source removal, containment and extraction of contaminated groundwater, and natural attenuation.

4.2.3 Source Control and Reduction of Contaminated Material

Ceasing discharge of bottom ash and sluice water into the BAPs and excavating and removing existing CCR material in the BAP with disposal at the Site's lined landfill would adequately control the source of contamination. Reduction of contaminated groundwater would be achieved through contaminant mass removal via the HCS and through natural attenuation involving, dispersion, dilution, and sorption over time.

4.2.4 Long-Term Effectiveness

The effectiveness of this remedy relies on two integrated measures. First, the completion of source removal in the BAP complex will effectively eliminate future mass flux of lithium from the BAPs to groundwater. Second, the containment and extraction of contaminated groundwater will significantly reduce and potentially eliminate off-site migration of lithium and remove contaminant mass from groundwater. While mass removal rates of groundwater extraction are typically low, the reliability and permanence of this approach is considered probable.

This alternative relies on a strong understanding and characterization of subsurface conditions. With the removal and disposal of the CCR source material, the mass of lithium available for leaching will be limited, and hence lithium leaching is expected to decrease with time assuming current groundwater pH and redox conditions are maintained. Our review of historical data sources, and additional Site characterization and data analysis conducted including plume stability analysis and groundwater modeling confirm our understanding that the subsurface conditions at the Site are sufficiently stable to employ this approach.

4.2.5 Short-Term Effectiveness

Removing and disposing of the source material from the BAPs will have a positive effect in the short term by significantly decreasing, and potentially eliminating mass flux of additional contaminant to groundwater. Operating the HCS will also have a positive effect in the short term by significantly decreasing, and potentially eliminating off-site migration of lithium. Groundwater monitoring will provide verification of effectiveness and is expected to indicate decreasing concentrations of lithium in groundwater within the BAP complex within several years, and the containment of contaminated groundwater while the HCS is operated. Also, monitoring of extracted and treated groundwater will provide a method to assess contaminant mass removal to evaluate the effectiveness of the approach.

The short-term effectiveness of achieving the GWPSs at locations hydrogeologically downgradient from the BAPs (e.g., near the Mountaineer Plant) may be influenced by contaminant contribution to groundwater from other potential sources near the BAP complex (e.g., the Sporn Plant former ash ponds); however, HCS is anticipated to effectively contain contaminated groundwater at and downgradient from the BAP complex in the short term.

4.2.6 Implementability

Removal of CCR material from the BAPs is implementable using standard earthwork construction equipment with disposal of the excavated material in the Little Broad Run Landfill. Prior to implementation of the excavation and removal phase, an engineered design plan should be developed that considers the geotechnical requirements for BAP stability, dewatering requirements, wastewater management/treatment processes, and construction sequencing.

Hydraulic containment is readily implementable using existing facility groundwater extraction wells and treatment processes. Monitoring can be performed prior to discharge for a list of analytes similar to the current CCR monitoring program and discharge monitoring under the Site's NPDES permit.

In the case that the Mountaineer Power Plant ceases operations before the corrective action objectives are met, a groundwater extraction and treatment system may need to be implemented. In addition, if the existing facility treatment processes do not meet the contaminant removal requirements, additional ex-situ treatment may need to be applied.

4.2.7 Long-Term Management Requirements

Long-term management requirements for this alternative include operation and maintenance of the HCS and the Site's wastewater treatment systems. Groundwater and discharge water quality monitoring would be required to evaluate the effectiveness of the HCS and the progress of attenuation to ensure that GWPSs are met. In addition, groundwater monitoring to distinguish contaminant contribution to groundwater from other potential sources near the BAP complex (e.g., the Sporn Plant former ash ponds) is included to evaluate the effectiveness of this alternative at meeting the GWPSs.

4.2.8 Community Acceptance

Currently, no concerns relating to local permitting or approval processes have been identified based on the Alternative's similarity to current operations. Community acceptance will be assessed during public meetings.

4.2.9 State Acceptance

Similar to Alternative 1, state acceptance of this alternative requires a Solid Waste Landfill Permit and a Construction Stormwater General Permit. As the area disturbed during source removal would exceed three (3) acres, as part of the construction stormwater general permitting process a Construction Site Registration Application must be submitted at least forty-five (45) days prior to site disturbance. Also, the proximity of Little Broadrun Stream would necessitate the establishment of a fifty (50) foot natural vegetative buffer in addition to other erosion control BMPs. AEP already possesses Solid Waste Landfill Permit WV077038, which may need to be modified under this alternative.

Alternative 2 additionally requires an Individual Industrial Facilities NPDES Permit to discharge extracted water to the Ohio River. AEP already possesses Individual Industrial Facilities NPDES Permit WV0048500 for discharge of extracted groundwater to the Ohio River. The current NPDES permit expired in 2013, and although AEP has submitted a permit renewal application and provided supplemental information in 2018, a renewed permit has not been issued to AEP yet.

Based on communications with the West Virginia Department of Environmental Protection (WVDEP), in the case that a new or modified groundwater extraction and treatment system needs to be implemented (e.g., if the Mountaineer Power Plant ceases operations before the corrective action objectives are met) the NDPES permit may need to be modified. In addition, if the existing facility treatment processes do not meet the contaminant removal requirements and additional ex-situ treatment is required, a modification to the NDPES permit may be required.

4.2.10 Time Required to Meet Remedial Objectives

Because lithium has not been demonstrated to readily degrade in the subsurface, natural attenuation will reduce lithium concentrations over time through natural attenuation processes such as dilution, dispersion, and sorption. The operation of the HCS has the potential to accelerate the attenuation process through additional flushing of groundwater through areas with residual contamination. Based on attenuation modeling and predicted conditions at the Site following source removal and operation of the HCS, the time to reach GWPSs for lithium within the existing BAP complex is estimated to be approximately 5 years.

Achievement of GWPSs in the areas downgradient of the existing BAP complex would be accelerated relative to Alternative 1 by operation of the HCS. The time to reach GWPSs for lithium downgradient of the existing BAP complex is estimated to be approximately 5 years or longer depending on actual conditions. The actual timeframe to reach GWPSs may be influenced by contaminant contribution to groundwater from other potential sources near the BAP complex (e.g., the Sporn Plant former ash ponds).

4.3 Alternative 3 – Source Removal and Disposal and In-Situ Treatment by Permeable Reactive Barrier

This alternative includes installation of an on-site permeable reactive barrier (PRB) located hydrogeologically downgradient from the BAPs along the northwestern and northeastern edges, as shown on Figure 8. The proposed PRB would include an engineered reactive amendment/media that is intended to remove lithium from groundwater by precipitation and/or sorption to the media to reduce the concentration of lithium in groundwater downgradient of the PRB. The PRB would transect the aquifer and be keyed into the underlying low-permeability layer (sandstone bedrock) to provide contact with the plume across the vertical extent of the permeable saturated zone, as shown on Figure 9. This alternative would decrease concentrations downgradient from the PRB as contaminant mass would be removed from the groundwater as it passes through the media.

4.3.1 Overall Protection of Human Health and the Environment

The combination of CCR removal and in-situ treatment is a two-stage approach. First, source removal would remove contaminant mass from the ground and minimize further leaching to groundwater. Eliminating the contaminant source would allow for dissolved concentrations of contaminant to attenuate through sorption, dispersion, and dilution. Second, installation of a PRB would potentially eliminate off-site migration of lithium and allow for downgradient attenuation. During the attenuation process, institutional controls would protect local residents and other potentially affected people by limiting exposure to impacted groundwater. In addition, this Alternative is protective of the New Haven public water supply wells located along the northwest property boundary, based on a groundwater modeling simulation showing no migration of contaminant to the wells.

Excavation and removal of the CCR material could create the potential for worker exposure to contaminated material and potential off-site fugitive dust emissions; however, the impact is anticipated to be short-term and could be managed with engineering controls.

Installation of a PRB could involve the disruption of surface and deep soils which could create the potential for worker exposure to contaminated material and off-site fugitive dust emissions. After installation, PRB treatment is not expected to pose further environmental or human health risks as operation is in the subsurface region; however, if media replacement is required, disruption of surface and deep soils could create the potential for worker exposure and off-site fugitive dust emissions during the replacement work.

While PRB treatment is expected to capture lithium and therefore limit off-site and downgradient migration, permanent immobilization is uncertain. Mobilization of previously captured contaminant could create future exposure concerns.

4.3.2 Ability to Comply with Groundwater Protection Standard

This alternative provides the Site the ability to comply with the GWPS over time through source removal, immobilization of lithium, and natural attenuation.

4.3.3 Source Control and Reduction of Contaminated Material

Ceasing discharge of bottom ash and sluice water into the BAPs and excavating and removing existing CCR material with disposal at the Site's lined landfill would adequately control the source of contamination. Reduction of contamination in groundwater would be achieved by immobilizing lithium using a PRB and through natural attenuation involving advective transport, dispersion, dilution, and sorption over time.

4.3.4 Long-Term Effectiveness

The effectiveness of this remedy relies on two integrated measures. First, the completion of source removal in the BAP complex will significantly reduce or eliminate future mass flux of contaminant to groundwater. Once the contamination source is removed, it is expected that natural attenuation will reduce lithium groundwater concentrations in areas upgradient of the PRB over time.

Second, the immobilization of lithium in groundwater passing through the PRB will likely eliminate off-site migration of lithium and facilitate attenuation in downgradient groundwater. However, the long-term effectiveness of the PRB approach is uncertain due to long-term in-situ sorption rates and behavior. Further, because lithium is simply immobilized, but not destroyed or removed from the subsurface region, there is the potential that changes in subsurface geochemical conditions could cause sorbed lithium to return to solution and mobilize in the future. Additionally, the media could run out of reactive capacity and no longer be effective at immobilizing additional mass of lithium; in this case replacing the media, or installing additional media may be needed to achieve the corrective action objectives.

This alternative relies on a strong understanding and characterization of subsurface conditions. With the removal and disposal of the CCR source material, the mass of lithium available for leaching will be limited, and hence lithium leaching is expected to decrease with time assuming current groundwater pH and redox conditions are maintained. Our review of historical data sources, and additional Site characterization and data analysis conducted including plume stability analysis and groundwater modeling confirm our understanding that the subsurface conditions at the Site are sufficiently stable to employ this approach.

4.3.5 Short-Term Effectiveness

Removing and disposing of the source material from the BAPs will have a positive effect in the short term by significantly decreasing, and potentially eliminating mass flux of additional contaminant to groundwater. Installation of a PRB will also have a positive effect in the short term by significantly decreasing, and potentially eliminating off-site migration of lithium.

Groundwater monitoring will provide verification of effectiveness and is expected to indicate decreasing concentrations of lithium in groundwater within the BAP complex within several years, and the immediate containment of contaminated groundwater emanating from the BAPs. Monitoring will also help gauge the ongoing effectiveness and required management of the PRB, as return of contamination in downgradient groundwater could indicate that the PRB media is spent and requires renewal (e.g., installation of additional reactive media).

The short-term effectiveness of achieving the GWPSs at locations hydrogeologically downgradient from the BAPs (e.g., near the Mountaineer Plant) may be influenced by contaminant contribution to groundwater from other potential sources near the BAP complex (e.g., the Sporn Plant former ash ponds); however, installation of a PRB as described in Alternative 3 is anticipated to effectively contain contaminated groundwater emanating from the BAPs in the short term.

4.3.6 Implementability

Removal of CCR material from the BAPs is implementable using standard earthwork construction equipment with disposal of the excavated material in the Little Broad Run Landfill. Prior to implementation of the excavation and removal phase, an engineered design plan should be developed that considers the geotechnical requirements for BAP stability, dewatering requirements, wastewater management/treatment processes, and construction sequencing/coordination with installation of the PRB.

Two approaches to implementation of the PRB are possible. The first option involves installation of the PRB as a bio-polymer slurry trench filled with reactive media that is keyed into the lower permeability sandstone and shale materials at depths up to approximately 80-90 feet below grade. This installation could be accomplished using a modified backhoe with an extended boom or a clamshell-type excavator along with use of a biodegradable polymer liquid that could be pumped into the trench during excavation to provide stability to the excavated trench walls. However, installation to depths of up to 90 feet below grade and 50 feet below the water table could result in a high risk of construction difficulties. The presence of flowing or running sands, as observed during previous drilling operations at the Site, in the subsurface could eliminate this method of construction or necessitate use of a non-continuous permeable trench (e.g., alternating reactive "panels" and low permeability elements to improve trench stability during excavation) as it would be very difficult to keep the trench from collapsing during construction. This method would also require a working platform wide enough to accommodate removal of spoils from excavation, and the area between the downgradient edge of the existing BAPs and the Site property boundary is limited.

The second installation option for the PRB would depend on the properties of the selected amendment/media (e.g., particle size). The PRB could potentially be installed as a network of injection borings; however, if the particle size of the amendment/media is large relative to the available pore size of subsurface soils in the PRB alignment, it may not effectively distribute in the subsurface and may not allow sufficient mass into the subsurface to contain the plume for a significant time period before the media is expended. In addition, uniform radial distribution of reactive material from each injection point is difficult to achieve, which could require substantial over-injection of reagent to prevent gaps in the barrier, as gaps would reduce the performance of the PRB by allowing contaminated groundwater to pass through untreated. The injection radius of influence and injection rates for the selected amendment/media would need to be evaluated in a pilot test prior to implementation.

4.3.7 Long-Term Management Requirements

Long-term management requirements for this alternative include groundwater monitoring to evaluate the effectiveness of the PRB, distinguish contaminant contribution to groundwater from other potential sources near the BAP complex (e.g., the Sporn Plant former ash ponds), and the progress of attenuation to ensure that GWPSs are met. Monitoring will help gauge the ongoing effectiveness and required management of the PRB, as return of contamination in downgradient groundwater could indicate that the PRB media is spent and requires renewal (e.g., installation of additional reactive media). Other than monitoring, the routine operational requirements of the PRB wall are limited, unless supplemental renewal of PRB media is required. If renewal is required, an effort similar to the initial installation of the PRB would be required although only expended portions of the wall would require renewal (e.g., if the reactive media is installed in panels, renewal could be achieved by replacing individual expended panel sections only).

4.3.8 Community Acceptance

Currently, no concerns relating to local permitting or approval processes have been identified. Community acceptance will be assessed during public meetings.

4.3.9 State Acceptance

Similar to Alternatives 1 and 2, state acceptance of this alternative requires a Solid Waste Landfill Permit and a Construction Stormwater General Permit. As the area disturbed during source removal would exceed three (3) acres, as part of the construction stormwater general permitting process a Construction Site Registration Application must be submitted at least forty-five (45) days prior to site disturbance. Also, the proximity of Little Broadrun Stream would necessitate the establishment of a fifty (50) foot natural vegetative buffer in addition to other erosion control BMPs. AEP already possesses Solid Waste Landfill Permit WV077038, which may need to be modified under this alternative.

Alternative 3 would additionally require a Rule Authorization Letter (RAL) approving installation of the PRB, as the construction methods (either slurry trench or injection well) would require the injection of a fluid into the subsurface. Based on correspondence with the WVDEP, obtaining an RAL would allow the installation of the PRBs described in Alternative 3 without obtaining an Underground Injection Control (UIC) permit.

4.3.10 Time Required to Meet Remedial Objectives

Because the contaminant of concern has not been demonstrated to readily degrade in the subsurface, natural attenuation will reduce lithium concentrations over time through natural attenuation processes such as dilution, dispersion, and sorption. Based on attenuation modeling and predicted conditions at the Site following source removal, the time to reach GWPSs for lithium within the existing BAP complex is estimated to be approximately 8 years.

Achievement of GWPSs in the areas downgradient of the PRB would be accelerated relative to Alternative 1 by the significant reduction or elimination of off-site migration of contaminant. The time to reach GWPSs for lithium downgradient of the PRB is estimated to be approximately 8 years or longer depending on actual conditions. The actual timeframe to reach GWPSs may be influenced by contaminant contribution to groundwater from other potential sources near the BAP complex (e.g., the Sporn Plant former ash ponds).

5.0 SUMMARY

A comparative summary of remedial alternatives for the BAPs is presented in the Risk-Based Technical Options (RBTO) Matrix included in Table 2. The RBTO Matrix lists the three options (i.e., alternatives) evaluated for the BAPs, the risks associated with each option, the benefits of each option, and the key assumptions.

In accordance with the CCR Rule, at least 30 days prior to selecting a corrective measure alternative, AEP will organize a public meeting to solicit input from interested and affected parties. Based on the results of this ACM report, and in consideration of any public comments received, AEP will select a corrective measure alternative that will achieve the corrective action objectives described in this report.

6.0 REFERENCES

- *History of Construction CFR 257.73(c)(1) Bottom Ash Complex Mountaineer Plant*, prepared by American Electric Power Service Corporation on behalf of Appalachian Power Company, dated October 2016.
- *Annual Groundwater Monitoring Report, Appalachian Power Company Mountaineer Plant, Landfill CCR Management Unit*, prepared by American Electric Power Service Corporation, dated January 2019
- *Little Broad Run Landfill – CCR Groundwater Monitoring Well Network Evaluation*, Mountaineer Plant prepared by Arcadis, on behalf of AEP, dated October 18, 2016.
- *Ash Pond System-CCR Groundwater Monitoring Well Network Evaluation*, Mountaineer Plant, prepared by Arcadis, on behalf of AEP, dated October 27, 2016.
- *Statistical Analysis Summary Bottom Ash Pond*, Mountaineer Plant, prepared by Geosyntec Consultants, on behalf of AEP, dated January 15, 2018.
- *Statistical Analysis Summary, Bottom Ash Pond, Mountaineer Plant, New Haven, West Virginia* prepared by Geosyntec Consultants, on behalf of AEP, dated January 8, 2019.
- EPRI, 2015a. *Monitored Natural Attenuation for Inorganic Constituents in Coal Combustion Residuals*. EPRI, Palo Alto, CA: 2015. 3002006285.
- *Corrective Action Technology Profile: Groundwater Extraction and Treatment at Coal Combustion Residual Facilities*. EPRI, Palo Alto, CA: 2017. 3002010945.
- *Chemical Constituents in Coal Combustion Products: Lithium.* EPRI, Palo Alto, CA: 2018. 3002012311.
- *Corrective Action Technology Profile: Permeable Reactive Barriers for Groundwater Treatment at Coal Combustion Product Landfills and Impoundments.* EPRI, Palo Alto, CA: 2018. 3002012315.
- *Geochemistry in Mineral Exploration*. 2nd Edition. Rose, A.W., Hawkes, H.E. and Webb, J.S., 1979. Academic Press, London, pp658.

TABLES

TABLE 1
Screening and Evaluation of Remedial Technologies
Bottom Ash Pond ACM
American Electric Power Mountaineer Power Plant
New Haven, West Virginia

General Response Action	Remedial Technology	Process Option	Description	Risk Reduction/Protectiveness	Effectiveness	Implementability	Initial Screening
No Further Action	Not considered a treatment remedy	N/A	No additional monitoring.	Provides no additional risk reduction or protectiveness.	Natural attenuation of contaminants (dissolved metals) in groundwater by adsorption, dilution and dispersion is assumed to occur but not verified.	Easily implemented.	Eliminated. Monitoring of Natural Attenuation (MNA) considered more protective.
Institutional Controls	Not considered a treatment remedy	N/A	This option involves implementation of institutional controls such as activity and use restrictions to limit the potential for unintended access to the waste materials or contaminated groundwater.	May reduce potential exposure of receptors by restricting access and future land use. Provides some level of protection over No Further Action.	Does not reduce certain contaminant migration pathways offsite such as leaching to groundwater, fugitive dust, surface runoff, etc. Does not permanently address contamination problem, therefore long-term effectiveness is uncertain.	Easily implemented. Typically used in conjunction with engineering controls when the remedy results in long-term waste management on site.	**Retained for development of remedial alternatives.**
Passive In-Situ Treatment	Attenuation	Monitoring of Natural Attenuation (MNA)	This option involves routine periodic monitoring of the existing groundwater monitoring network. MNA relies on naturally occurring subsurface processes that act to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in groundwater. These processes include oxidation/reduction, precipitation, sorption, dispersion, and dilution. MNA typically requires long-term monitoring to verify performance.	Unlike some contaminants, metals are incapable of breaking down to simpler, less toxic compounds. Attenuation would rely primarily on changes of mobility or dilution through isolation from source areas. Maintaining current conditions is also unlikely to change the concentrations of other metals present i.e., unlike other options that may change the groundwater chemistry there are not likely to be any unintended changes because of selecting this remedial technology.	Performance data is limited with respect to sites with metals contamination. Effectiveness is site-specific and exact processes that are occurring may be uncertain. Metals are generally considered recalcitrant to degradation in natural systems. If the contamination source is removed, the mass of lithium available for leaching is limited and lithium leaching is expected to decrease with time assuming current groundwater pH and redox conditions are maintained.	Monitoring is readily implemented using the existing groundwater monitoring network.	**Retained for development of remedial alternatives.**
Active In-Situ Treatment	Physical/Chemical Sorption/ Precipitation	Permeable Reactive Barrier	This technology involves installation of an engineered subsurface treatment zone across the flow path of the dissolved contaminant plume. As groundwater passes through the zone, it is treated in-situ by reactive media that is intended to remove contaminants by destruction, precipitation, or sorption to the media and reduce their concentrations in groundwater. The barrier can be used in conjunction with impermeable wall sections (funnels) to force groundwater to flow through the permeable sections (gates).	Removes contaminants from groundwater but not likely to destroy metals. Would potentially eliminate migration off-site and allow for downgradient groundwater to attenuate thereby reducing concentrations; however, because the metals are not destroyed but only immobilized, there is concern that over time they will again become mobile.	Potentially effective method for in-situ adsorption and/or precipitation. Long-term effectiveness is questionable due to uncertain in-situ adsorption rates and behavior. Reagents and media for treatment of lithium have not been tested in a CCP setting. A groundwataer treatability study performed by Anchor QEA, LLC indicated that the amendment Carus MMO II (a granular powder composed of iron, manganese, aluminum, oxides, and calcium carbonate) is effective at removing lithium from groundwater in a laboratory setting. Installation of adsorptive media is unlikely to cause desorption of metals, but may not attenuate all metals or may attenuate metals to varying degrees. Furthermore, because the metals are not destroyed but only immobilized, there is concern that over time they will again become mobile.	Implementable as a vertical barrier keyed into the lower permeability sandstone and shale materials at depths up to approximately 80-90 feet below grade. The PRB could be installed with a modified backhoe with extended boom; however, installation to depths of up to 90 feet below grade and 50 feet below the water table could result in high risk of construction difficulties. Installation would also require a working platform wide enough to accommodate removal of spoils from excavation. Depending on the properities of the seletected media (e.g., particle size), the PRB could also potentially be installed as a network of injection borings similar to the In-Situ Injection option. The injection radius of influence should be evaluated in a pilot test prior to implementation.	**Retained for development of remedial alternatives.**

TABLE 1
Screening and Evaluation of Remedial Technologies
Bottom Ash Pond ACM
American Electric Power Mountaineer Power Plant
New Haven, West Virginia

General Response Action	Remedial Technology	Process Option	Description	Risk Reduction/Protectiveness	Effectiveness	Implementability	Initial Screening
Active In-Situ Treatment	Physical/Chemical Sorption/ Precipitation	In-Situ Stabilization	This technology involves injection of a chemical into the dissolved contaminant plume. The chemical is intended to raise or lower pH, modify redox conditions, and/or provide adsorptive capacity, and thereby enhance the adsorption and/or precipitation of metals and reduce their concentrations in groundwater. The treatment zone can be used in conjunction with impermeable wall sections (funnels) to force groundwater to flow through the permeable sections (gates).	Removes contaminants from groundwater but not likely to destroy metals. Would potentially eliminate migration off-site and allow for downgradient groundwater to attenuate thereby reducing concentrations; however, the variable, and sometimes opposite, leaching behavior of metals in response to an increase or decrease in pH, suggests that the injected reagent option may cause concentrations of some other metals to increase unintentionally. If groundwater composition changes, the tendency of metals to leach or attenuate may change in response. Furthermore, because the metals are not destroyed but only immobilized, there is concern that over time they will again become mobile.	Changing redox conditions may influence concentrations of other metals apart from the lithium. The variable, and sometimes opposite, leaching behavior of metals in response to an increase or decrease in pH, suggests that the injected reagent option may cause concentrations of some other metals to increase unintentionally. If groundwater composition changes, the tendency of metals to leach or attenuate may change in response. Changing redox conditions is anticipated to have similarly variable effects on different site metals based on differences in metals behavior. Furthermore, because the metals are not destroyed but only immobilized, there is concern that over time they will again become mobile.	Implementable as a network of injection borings installed in a single line of injection wells, multiple treatment lines, or a grid pattern. Can be designed to have a continuous treatment zone by overlapping multiple rows of injection points based on the anticipated ROI; however, uniform radial distribution of reactive material from each injection point is not likely to be achieved, which could reduce the performance of the treatment zone or require higher injection volumes. Pilot testing should be completed prior to design of the full-scale system to evaluate hydraulic fracturing and particulate distribution throughout the targeted treatment ROI.	Eliminated. Implementation could result in mobilzation of other potential contaminants.
Ex-Situ Treatment	Reverse Osmosis	Porous Membrane	Removal of dissolved lithium from extracted groundwater by using pressure to force an aqueous solution through a porous membrane.	Removal of metals from extracted groundwater would eliminate off-site migration of metals, remove metal mass from dissolved phase for off-site disposal (sludge), and would allow for off-site groundwater to attenuate.	Effective in removing most cationic and anionic solutes, but lithium-specific treatment data are limited. Supported liquid membrane (SLM) is considered an efficient technology for selective separation and concentration of different chemical species; however, lithium-specific membrane technologies are still in the experimental phase of development.	Not readily implemented. Still in the experimental phase of development.	Eliminated. Technology not proven for lithium.
	Precipitation and Co-precipitation	Chemical Precipitation and Coagulation/ Flocculation	Adjustment of extracted groundwater to an optimal pH range by addition of acids or bases, and depending on the solution, addition of precipitating agents. Compounds may precipitate out of solution depending on pH, temperature, and/or other physicochemical parameters or they may co-precipitate by adhereing to less soluble compounds.	Removal of metals from extracted groundwater would eliminate off-site migration of metals, remove metal mass from dissolved phase for off-site disposal (sludge), and would allow for off-site groundwater to attenuate.	Precipitation and co-precipitation have been utilized as part of lithium recovery from high concentration brines, seawater, and geothermal waters, but data on lithium-specific precipitation and coprecipitation treatment performance for groundwater remediation are limited. The kinetics are dependent on concentrations of dissolved solids (including lithium), pH, temperature, and the choice of precipitation agents, therefore, site-specific bench- and pilot-scale testing is performed to assess potential effectiveness.	Utilized for removal of dissolved metals from solutions in a variety of applications, including environmental remediation, industrial waste treatment, and mining. Water conditioning is often needed to help remove precipitates from process water. The handling of solids generated will need to be considered based on site-specific water quality.	Eliminated. Technology not proven for lithium.
	Ion Exchange	Resins	Ion exchange is the reversible exchange of ions between a solid-phase (resin) and a liquid-phase (extracted groundwater). The ions are electrostatically bound to the solid-phase resin and removed from the extracted groundwater. Resins may require regeneration with an acid or alkaline solution depending on the application.	Removal of metals from extracted groundwater would eliminate off-site migration of metals, remove metal mass from dissolved phase for off-site disposal (sludge), and would allow for off-site groundwater to attenuate.	High removal efficiency and high treatment capacity may be possible with ion exchange, however, multiple resin beds may be required to treat the various constituents. Other anions and cations may need to be removed so that the resin can effectively target the specified constituent. Previous efforts have demonstrated that some ion exchange resins have an affinity for lithium.	Readily implementable, however there are currently no lithium-selective resins currently on the market. Bench-scale testing should be completed prior to design of the full-scale system. Need to consider resin regeneration requirements and management of associated wastewater stream.	Eliminated. Technology not proven for lithium.

TABLE 1
Screening and Evaluation of Remedial Technologies
Bottom Ash Pond ACM
American Electric Power Mountaineer Power Plant
New Haven, West Virginia

General Response Action	Remedial Technology	Process Option	Description	Risk Reduction/Protectiveness	Effectiveness	Implementability	Initial Screening
Containment	Stabilization / Solidification	Chemical reagent	A chemical reagent is physically mixed into the Bottom Ash Pond (BAP) to solidify the waste material and lower its hydraulic conductivity to limit the volume of water that can move through it and chemically binds constituents to the solid matrix.	Would significantly reduce leaching to groundwater. Creating a low permeability barrier may change pH, redox conditions and temperature near the BAP, which could affect groundwater metal concentrations.	Potentially effective method of source control. Does not directly address existing plume; however, it may be effective at reducing contaminant concentrations in combination with MNA.	Requires a stable work platform to support construction equipment and may require removal and management of water contained in the BAP. Can be safety risks involved with working on the wet bottom ash material until it has solidified.	Eliminated. Removal and Disposal option considered more effective and implementable.
	Lined Landfill	Geomembrane liner with leachate collection system	Bottom ash material is excavated from the BAP, stockpiled on site, and then placed in a new on-site landfill with a liner and leachate collection system built in the footprint of the former BAP.	Provides a barrier between the waste material and the underlying soil and groundwater. Adding an impermeable liner may change pH, redox conditions and temperature under the BAP, which could affect groundwater metal concentrations.	Effective method of source control. Does not directly address existing plume; however it may be effective at reducing contaminant concentrations in combination with MNA.	Can be significant safety or monetary/scope risks involved working on wet bottom ash during dewatering and excavation required for liner installation. Requires area for storing waste material during liner installation and double handling of waste.	Eliminated. Removal and Disposal option considered more implementable.
	Barrier Cap System	Geomembrane or compacted soil	A barrier cap system designed to minimize vertical infiltration of rainwater into the BAP. The barrier can consist of compacted soil, geomembrane, or both.	Adding an impermeable cap may change pH, redox conditions and temperature under the BAP, which could affect groundwater metal concentrations, or changing stormwater management may locally influence groundwater flow conditions, and could result in negative impacts to mobility.	Potentially effective method of source control at unlined facilities when groundwater does not intersect the BAP. Even if there is intersecting groundwater, a cap can reduce the mass flux of constituents released to groundwater. Does not directly address existing plume; however it may be effective at reducing contaminant concentrations in combination with MNA.	Implementable as a geomembrane or compacted soil barrier. Need to consider geotechnical requirements for BAP stability, dewatering requirements and treatment processes, and construction sequencing if being implemented with additional technologies (e.g., PRB).	Eliminated. Removal and Disposal option considered more effective and implementable.
	Barrier Wall	Sheet Pile Wall	A subsurface vertical wall constructed by driving vertical sheets of steel into the ground and joining the sheets together using sealants such as grout or cement. The wall is used to contain or divert the lateral flow of groundwater. Vertical barriers are used in combination with groundwater extraction for hydraulic control.	Installation of a vertical barrier coupled with hydraulic control using groundwater extraction would limit off-site migration of contaminants and remove dissolved phase contaminants from impacted groundwater for off-site disposal. Off-site groundwater concentrations would then naturally attenuate once migration from the source has been eliminated.	Potentially effective method for hydraulically facilitating containment/removal with groundwater extraction or a PRB. Not effective by itself in limiting migration of contaminants. Concern for seal between metal sheets and concern for achieving total depth due to refusal at shallower depths might result in partially penetrating barrier allowing for continued migration unless groundwater extraction is significantly modified to address.	Implementable as a vertical barrier to depths of 50 to 80 ft bgs. However, challenges with sealing sheets and driving to these depths could result in the barrier being only partially penetrating and allowing for continued migration at depth or requiring additional pumping to achieve hydraulic control. Does not require removal of spoils.	Eliminated. Hydraulic containment system considered more effective and implementable.
		Slurry Wall	A subsurface vertical wall constructed by filling a vertically excavated trench with a slurry to prevent collapse of the trench walls. The wall, which is often keyed into a low permeability natural base such as clay or competent bedrock, is backfilled with a low permeability material (e.g., soil-bentonite) to form a subsurface vertical barrier which is used to contain or divert lateral groundwater flow. Vertical barriers are used in combination with groundwater extraction for hydraulic control.	Same as sheet pile wall above.	Potentially effective method for hydraulically facilitating containment/removal with groundwater extraction or a PRB. Not effective by itself in limiting migration of contaminants and long-term effectiveness questionable.	Implementable as a vertical barrier keyed into the lower permeability sandstone material at depths up to approximately 50 to 80 feet. Potentially applicable with installation by a modified excavator with extended boom to depths of up to approximately 80 to 90 feet, or deeper with crane-mounted clamshell excavator. Requires a working platform wide enough to accommodate removal spoils from excavation. Removal of material could affect stability of BAP embankment.	Eliminated. Hydraulic containment system considered more effective and implementable.

TABLE 1
Screening and Evaluation of Remedial Technologies
Bottom Ash Pond ACM
American Electric Power Mountaineer Power Plant
New Haven, West Virginia

General Response Action	Remedial Technology	Process Option	Description	Risk Reduction/Protectiveness	Effectiveness	Implementability	Initial Screening
Containment	Barrier Wall	Grout Curtain Wall	A subsurface vertical wall constructed by injecting a grout mixture into soil pores under pressure to form a cementious mass. The wall is used to contain or divert the lateral flow of groundwater. Vertical barriers are used in combination with groundwater extraction for hydraulic control.	Same as sheet pile wall above.	Potentially effective method for hydraulically facilitating containment/removal via groundwater extraction or a PRB. Not effective by itself in limiting migration of contaminants. Concern of ability to uniformly distribute grout material in subsurface due to potential heterogeneities in the formation. Uneven distribution could result in flow paths where contaminants could bypass the barrier.	Potentially applicable to depths of up to approximately 80 to 90 feet. Concern for evenly distributed grout in subsurface could result in a barrier with flow paths still able to migrate downgradient of barrier.	Eliminated. Hydraulic containment system considered more effective and implementable.
	Hydraulic Containment System	Groundwater Extraction	Groundwater is pumped from one or more extraction wells located near the source area creating a hydraulic gradient that prevents contaminated groundwater from migrating off site. Extracted water is treated ex-situ to remove contaminants as needed to support discharge.	Groundwater extraction would eliminate off-site migration of metals, remove contaminant mass from the ground, and would allow for off-site groundwater to attenuate.	Effective at controlling migration of groundwater; however, the mass removal rates are typically very slow and limited by pore-water exchange and the relative amount of sorbed mass.	Readily implementable using existing facility groundwater extraction wells.	**Retained for development of remedial alternatives.**
Removal and Disposal	Excavate and Remove	Disposal in Lined Landfill	Bottom ash material is excavated from the BAP and transported to a lined landfill for disposal.	Would eliminate leaching from source materials to groundwater and allow for dissolved concentrations in groundwater to attenuate over time.	Effective method for source removal. Mass of contaminants (dissolved metals) in the groundwater is reduced naturally over time by, dispersion, dilution, and sorption.	Readily implementable using the facility's existing lined landfill for disposal of excavated material. Need to consider geotechnical requirements for BAP stability, dewatering requirements and treatment processes, and construction sequencing if being implemented with additional technologies (e.g., PRB).	**Retained for development of remedial alternatives.**

References:

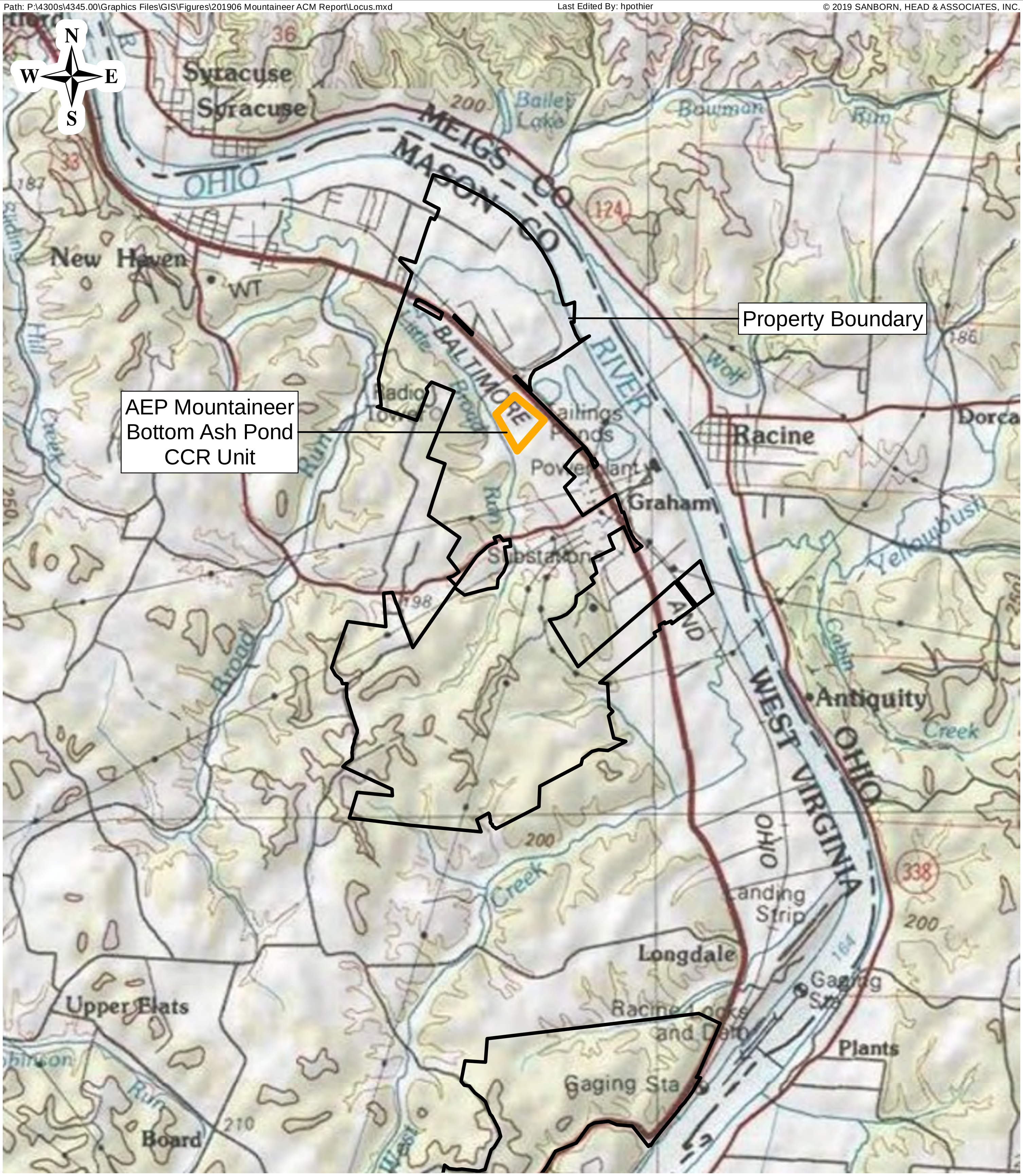
1. Chemical Constituents in Coal Combustion Products: Lithium, prepared by Electric Power Research Institute, dated April 2018.
2. Corrective Action Technology Profile, Groundwater Extraction and Treatment at Coal Combustion Residual Facilities, prepared by Electric Power Research Institute, dated September 2017.
3. Cost and Application Considerations for Remediation Technologies at Coal Combustion Residual Landfills and Impoundments, prepared by Electric Power Research Institute, dated March 2018.

TABLE 2
Risk-Based Technical Options Matrix
Bottom Ash Pond ACM
American Electric Power Mountaineer Power Plant
New Haven, West Virginia

Option	Description	Risks	Key Assumptions	Benefits
Source Removal and Disposal with Monitored Natural Attenuation	Removal and disposal of ash from the bottom ash ponds with the mass of contaminants (dissolved metals) in the groundwater reducing naturally over time by dispersion, dilution, and sorption.	Natural attenuation will take longer to address off-site contamination and may be incapable of reducing targeted contaminant concentrations below GWPS or background concentrations.	This option assumes that the contaminant source is controlled, and no additional sources are contributing to the groundwater contamination.	Monitoring of natural attenuation is a low-cost, highly implementable option, particularly if paired with elimination or isolation of source materials.
Source Removal and Disposal with Groundwater Containment by Hydraulic Containment System	Removal and disposal of ash from the bottom ash ponds. The mass of contaminants (dissolved metals) in the groundwater is contained on site by a hydraulic gradient induced by groundwater extraction from existing pumping wells. The mass of contaminants in on-site and off-site groundwater is reduced over time through active extraction and naturally by dispersion, dilution, and sorption. Extracted groundwater is treated and discharged to surface water in accordance with a NPDES permit.	Maintainability of this option is dependent on the facility continuing to operate until the corrective action objectives are met. If the existing extraction wells do not provide adequate hydraulic containment or if the facility cannot accept and effectively treat all the extracted groundwater, then a separate groundwater extraction and treatment system may need to be implemented to achieve the corrective action objectives.	This option assumes that the existing extraction wells can effectively induce a hydraulic gradient that will keep groundwater contaminants from migrating off site; the facility's process water system can accept and effectively treat the extracted groundwater; and the facility remains in service during the lifetime of the remediation project.	Use of extracted groundwater could off-set the use of other make-up water sources and save the cost of treating the extracted groundwater.
Source Removal and Disposal and In-Situ Treatment by Permeable Reactive Barrier	Removal and disposal of ash from the bottom ash ponds. The mass of contaminants (dissolved metals) in the groundwater is treated in-situ via installation of an engineered, subsurface treatment zone across the flow path of a dissolved contaminant plume. The mass of dissolved contaminants in groundwater is reduced over time through sorption of the contaminants to the reactive media. The mass of contaminants downgradient from the PRB is reduced over time naturally by dispersion, dilution, and sorption.	Implementability of the permeable reactive barrier (PRB) is dependent on assessment of geotechnical information which is currently unavailable. Unsuitable subgrade material for the PRB could increase cost. Until an in-situ pilot test is performed, the effectiveness of a PRB for removal of lithium is uncertain. Additionally, because the metals are immobilized but not destroyed, changes in subsurface conditions could cause sorbed contaminants to mobilize in the future.	This option assumes that the PRB can be installed as a slurry trench or as a network of injection wells; that there is a commercially available amendment/media that can effectively treat lithium in-situ; and that the amendment/media would not need to be replaced or supplemented with additional injections to meet the corrective action objectives.	Once installed, the PRB does not need to be operated or maintained. The only long-term management requirement for this option is groundwater monitoring to evaluate the effectiveness of the PRB.

FIGURES

Path: P:\4300s\4345.00\Graphics Files\GIS\Figures\201906 Mountaineer ACM Report\Locus.mxd Last Edited By: hpothier



Drawn By: H. Pothier
Designed By: A. Ashton
Reviewed By: C. Crocetti
Project No: 4345.01
Date: June 2019

Miles
0.5 0.25 0 0.5 1

SANBORN | HEAD

Figure 1

Locus Plan

Mountaineer Bottom Ash Pond -
Assessment of Corrective Measures

American Electric Power
AEP Mountaineer Generating Plant
New Haven, West Virginia

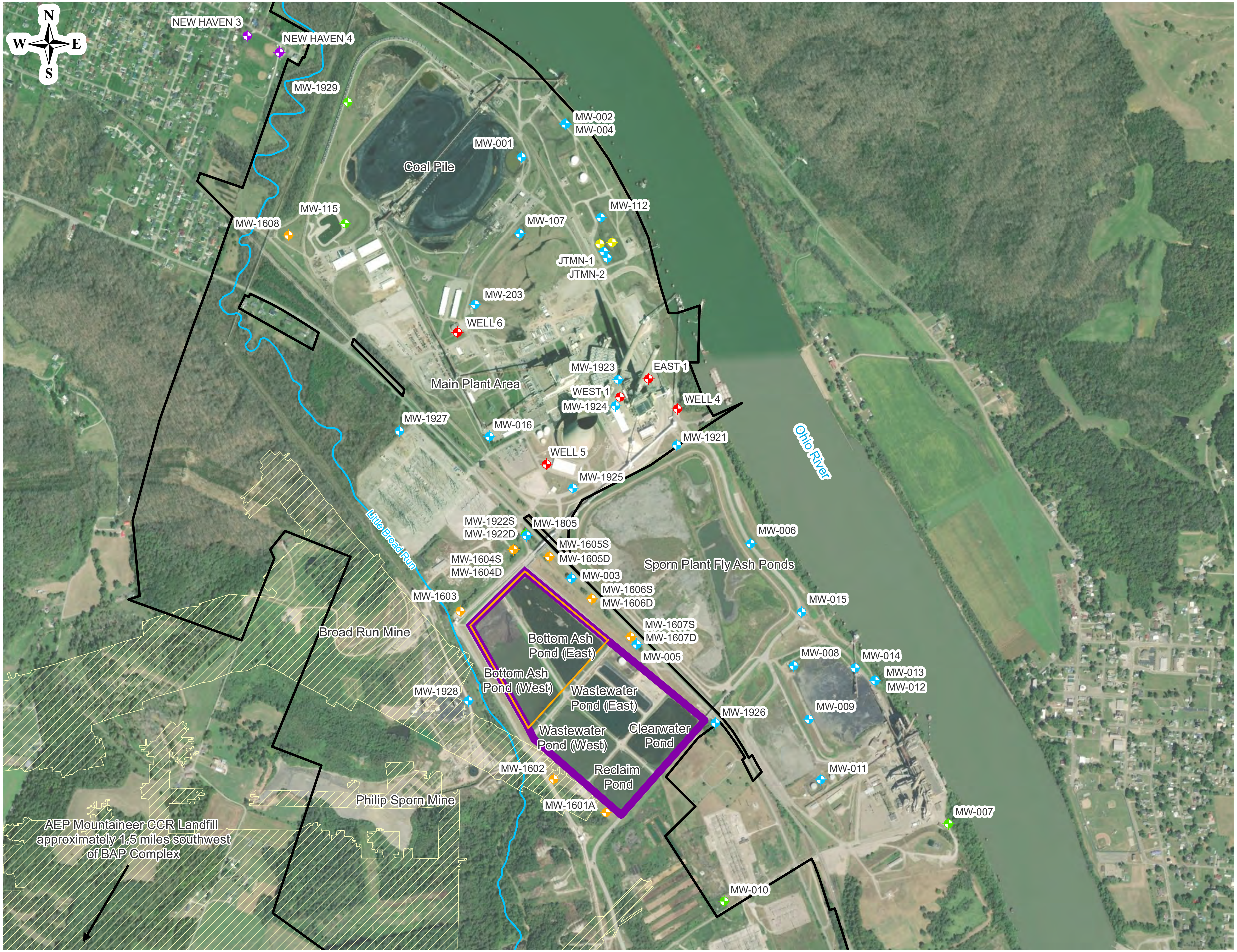


Figure 2

Site Plan and Monitoring Well Locations

Mountaineer Bottom Ash Pond - Assessment of Corrective Measures

American Electric Power
AEP Mountaineer Generating Plant
New Haven, West Virginia

Drawn By:	H. Pothier
Designed By:	A. Ashton
Reviewed By:	C. Crocetti
Project No:	4345.01
Date:	June 2019

Figure Narrative

This site plan depicts the general area in and around American Electric Power's (AEP) Mountaineer Generating Plant in Letart near the Town of New Haven, West Virginia. The location of key site features pertinent to this report including the power plant, bottom ash pond complex, and site pumping (water supply) wells are shown. Shallow groundwater monitoring wells i.e., screened in the overburden sand and gravel are shown for reference.

Notes

1. Locations of the monitoring wells and other site features were provided by Geosyntec Consultants.

2. Aerial Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Legend

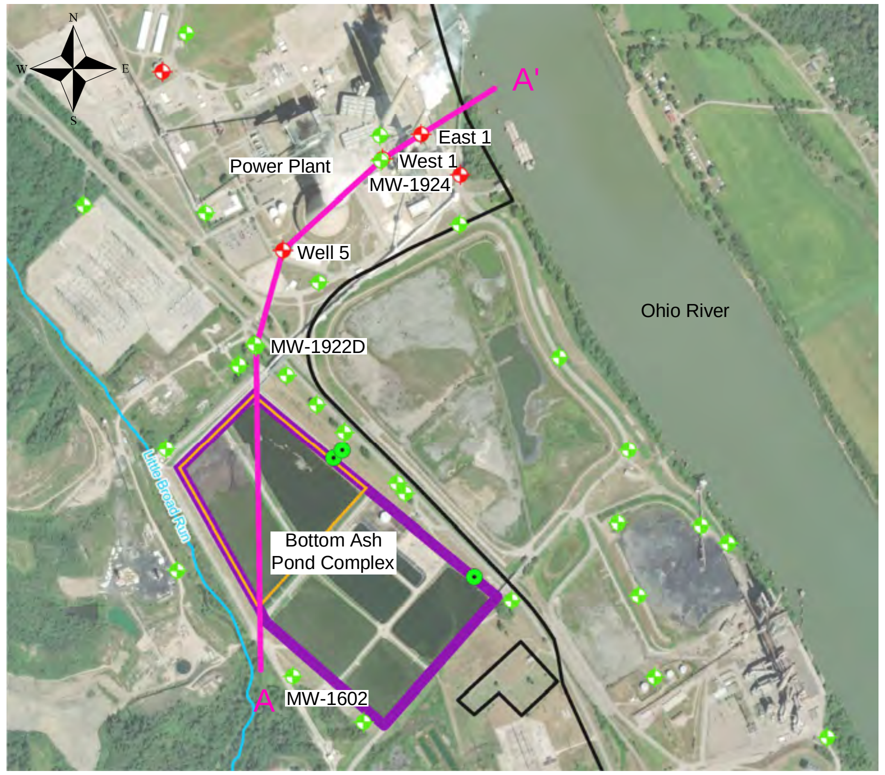
- AEP Supply Well (non-potable)
- Former AEP Supply Well (potable)
- Public Supply Well
- CCR Monitoring Well Network
- Other Monitoring Well (used for water level measurements)
- Other Monitoring Well (not used for water level measurements)
- Approximate area of underground mine
- CCR Unit
- Mountaineer Bottom Ash Complex (BAC)
- Property Boundary

500 250 0 500 1,000
Feet

SANBORN HEAD

Last Edited By: hpothier

Path: P:\4300s\4345.00\Graphics Files\GIS\Figures\201906 Mountaineer ACM Report\Site_Plan.mxd



Plan View

Not to scale

Notes

1. Stratigraphic information is conceptual and was interpreted from site boring/monitoring well logs provided by AEP.

2. Bottom Ash Pond Complex construction information was compiled from the History of Construction Bottom Ash Pond Complex Report available on AEP's CCR website.

3. Ground elevations were interpreted from digital elevation measurement data obtained from the West Virginia GIS website (http://mapwv.gov/gis.html). Bottom ash pond elevations are based on information in the History of Construction Report.

4. Groundwater elevations are conceptual and based on measurements obtained during site water supply well pumping conditions. Groundwater elevations will vary from those shown due to changing conditions including precipitation, and groundwater pumping.

Legend

West 1 — Well designation

Ground surface

Geologic contact

Water table

Well screen

Bottom of boring

Flow direction

Figure 3

Cross Section A-A'

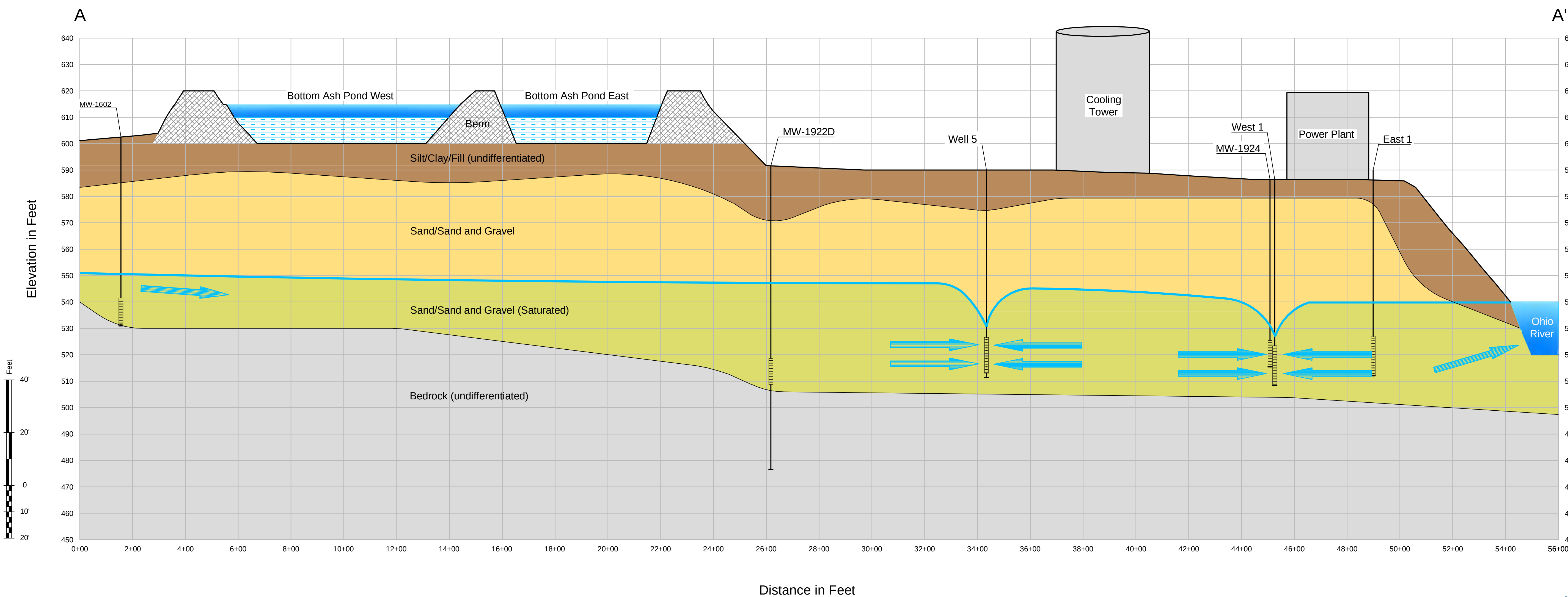
Mountaineer Bottom Ash Pond - Assessment of Corrective Measures

American Electric Power
AEP Mountaineer Generating Plant
New Haven, West Virginia

Drawn By: E. Wright
Designed By: A. Ashton
Reviewed By: C. Crocetti
Project No: 4345.01
Date: June 2019

Figure Narrative

This figure depicts conceptual hydrostratigraphy and the relative position of key site features in the vicinity of the Bottom Ash Pond Complex at the American Electric Power (AEP) Mountaineer Generating Plant. Refer to the inset plan on this figure (or Figure 2) for the locations of the explorations and features shown on this cross-section. The information presented herein is generalized and based on widely spaced explorations, actual conditions should be expected to vary from those shown.



Horizontal Scale

200' 100' 0 200' 400' Feet

SANBORN | HEAD

Figure 4

Groundwater Flow under Non-Pumping Conditions

Mountaineer Bottom Ash Pond - Assessment of Corrective Measures

American Electric Power
AEP Mountaineer Generating Plant
New Haven, West Virginia

Drawn By: H. Pothier
Designed By: A. Ashton
Reviewed By: C. Crocetti
Project No: 4345.01
Date: June 2019

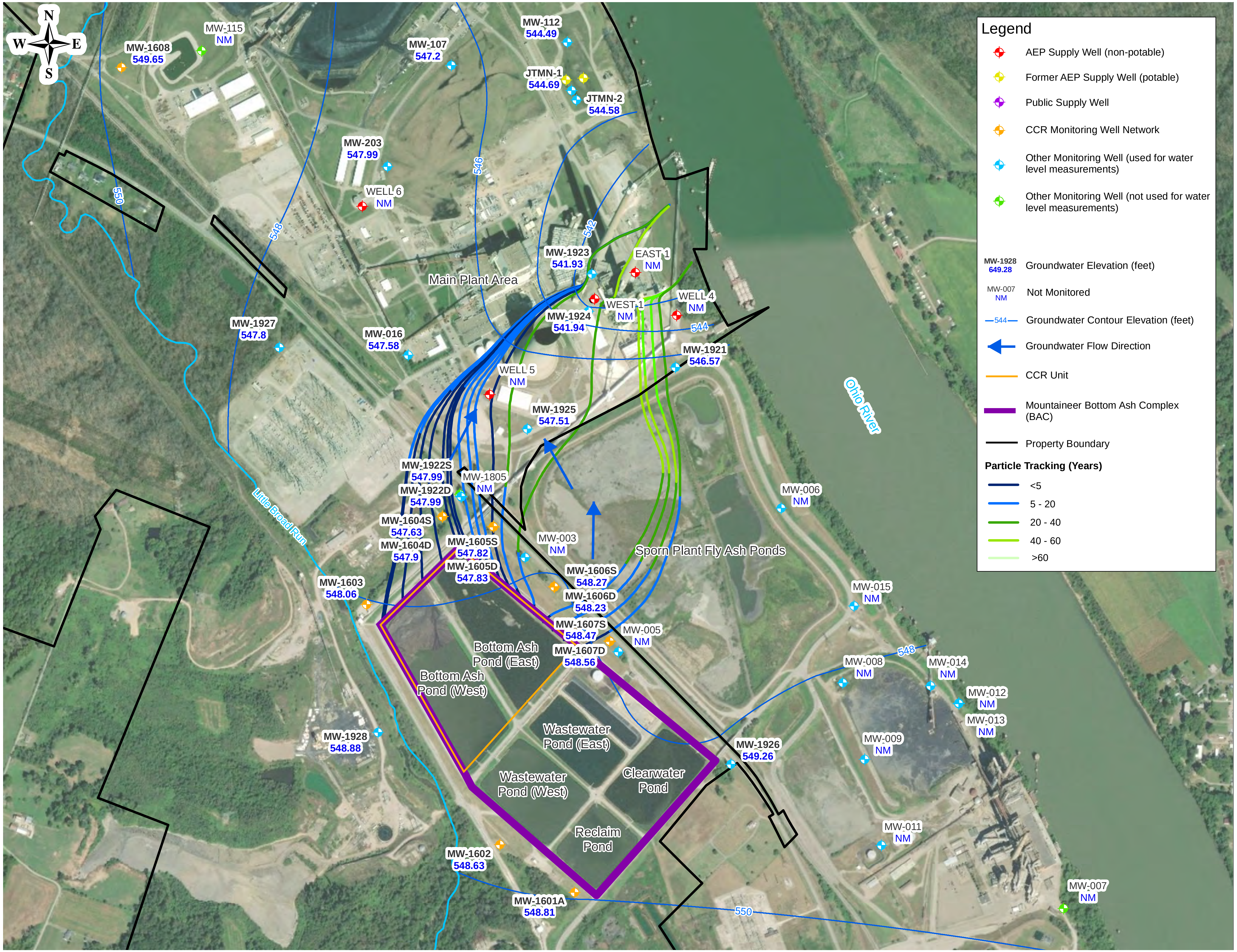


Figure Narrative

This figure shows the site groundwater elevation contour map for overburden sand and gravel deposits based on static (non-pumping) conditions. The groundwater elevation contours were drawn by Geosyntec and provided as an electronic GIS shapefile to Sanborn Head via email on May 8, 2019. The groundwater elevation contours are based on the groundwater levels measured in the site monitoring wells by Geosyntec on March 7, 2019, and provided to Sanborn Head as an electronic GIS file via email on May 8, 2019. Note that groundwater elevations may vary due to seasonal or other changes in precipitation, recharge, temperature, and other factors. The groundwater elevation contours are based on interpolation between widely-spaced data points, and developed by Geosyntec to illustrate general trends in groundwater elevations and flow. Note that other interpretations are possible, and actual conditions may vary from those depicted in the figure. Sanborn Head has relied upon the groundwater elevation data provided by Geosyntec, and has not conducted an independent evaluation of the reliability of these data. The contours and groundwater elevations have been used by Sanborn Head without modification and applied for planning level assessment of corrective measures; they are not considered suitable for remedial design purposes. The figure also depicts the approximate forward rate and direction of groundwater flow from the bottom ash ponds based on an ArcGIS particle tracking method that was performed by Sanborn Head. The color symbology of the particle tracks indicates travel time along the flow path.

Notes

1. Refer to Figure 2 for additional notes and legend.

350 175 0 350 700 Feet

SANBORN HEAD

Figure 5

Groundwater Flow under Pumping Conditions

Mountaineer Bottom Ash Pond - Assessment of Corrective Measures

American Electric Power
AEP Mountaineer Generating Plant
New Haven, West Virginia

Drawn By: H. Pothier
Designed By: A. Ashton
Reviewed By: C. Crocetti
Project No: 4345.01
Date: June 2019

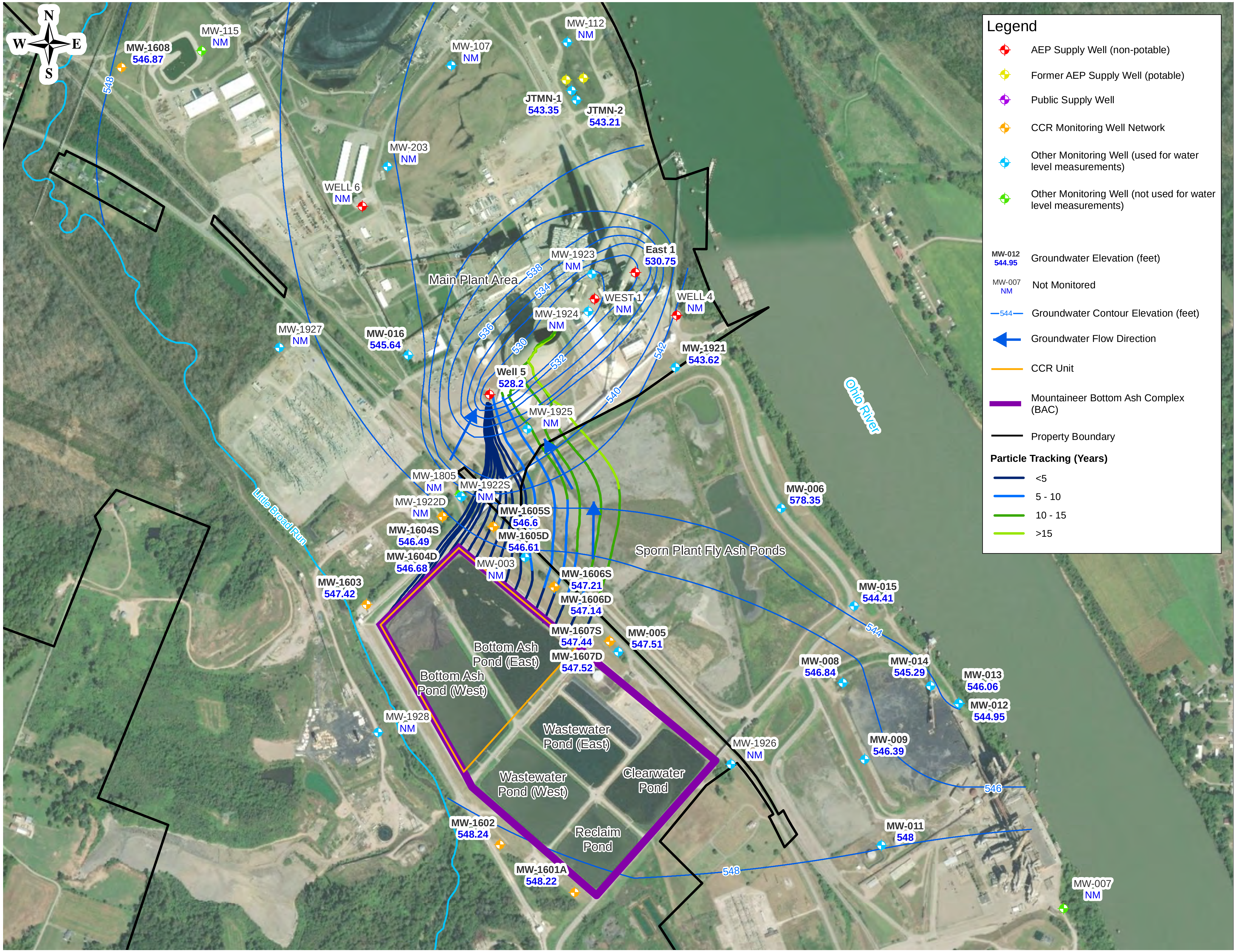


Figure Narrative

This figure shows the site groundwater elevation contour map for overburden sand and gravel deposits based on pumping conditions. The groundwater elevation contours were drawn by Geosyntec and provided as an electronic GIS shapefile to Sanborn Head via email on May 8, 2019. The groundwater elevation contours are based on the groundwater levels measured in the site monitoring wells by Geosyntec on February 4, 2019, and provided to Sanborn Head as an electronic GIS file via email on May 8, 2019. Note that groundwater elevations may vary due to seasonal or other changes in precipitation, recharge, temperature, and other factors. The groundwater elevation contours are based on interpolation between widely-spaced data points, and developed by Geosyntec to illustrate general trends in groundwater elevations and flow. Note that other interpretations are possible, and actual conditions may vary from those depicted in the figure. Sanborn Head has relied upon the groundwater elevation data provided by Geosyntec, and has not conducted an independent evaluation of the reliability of these data. The contours and groundwater elevations have been used by Sanborn Head without modification and applied for planning level assessment of corrective measures; they are not considered suitable for remedial design purposes. The figure also depicts the approximate forward rate and direction of groundwater flow from the bottom ash ponds based on an ArcGIS particle tracking method that was performed by Sanborn Head. The color symbology of the particle tracks indicates travel time along the flow path.

Notes

1. Refer to Figure 2 for additional notes and legend.

350 175 0 350 700 Feet

SANBORN | HEAD

Figure 6

Conceptual Approach for Remedial Alternative 1 (Source Control and Monitored Natural Attenuation)

Mountaineer Bottom Ash Pond - Assessment of Corrective Measures

American Electric Power
AEP Mountaineer Generating Plant
New Haven, West Virginia

Drawn By: E. Wright
Designed By: A. Ashton
Reviewed By: C. Crocetti
Project No: 4345.01
Date: June 2019

Current Condition

Post-Remediation (Short Term)

Post-Remediation (Long Term)

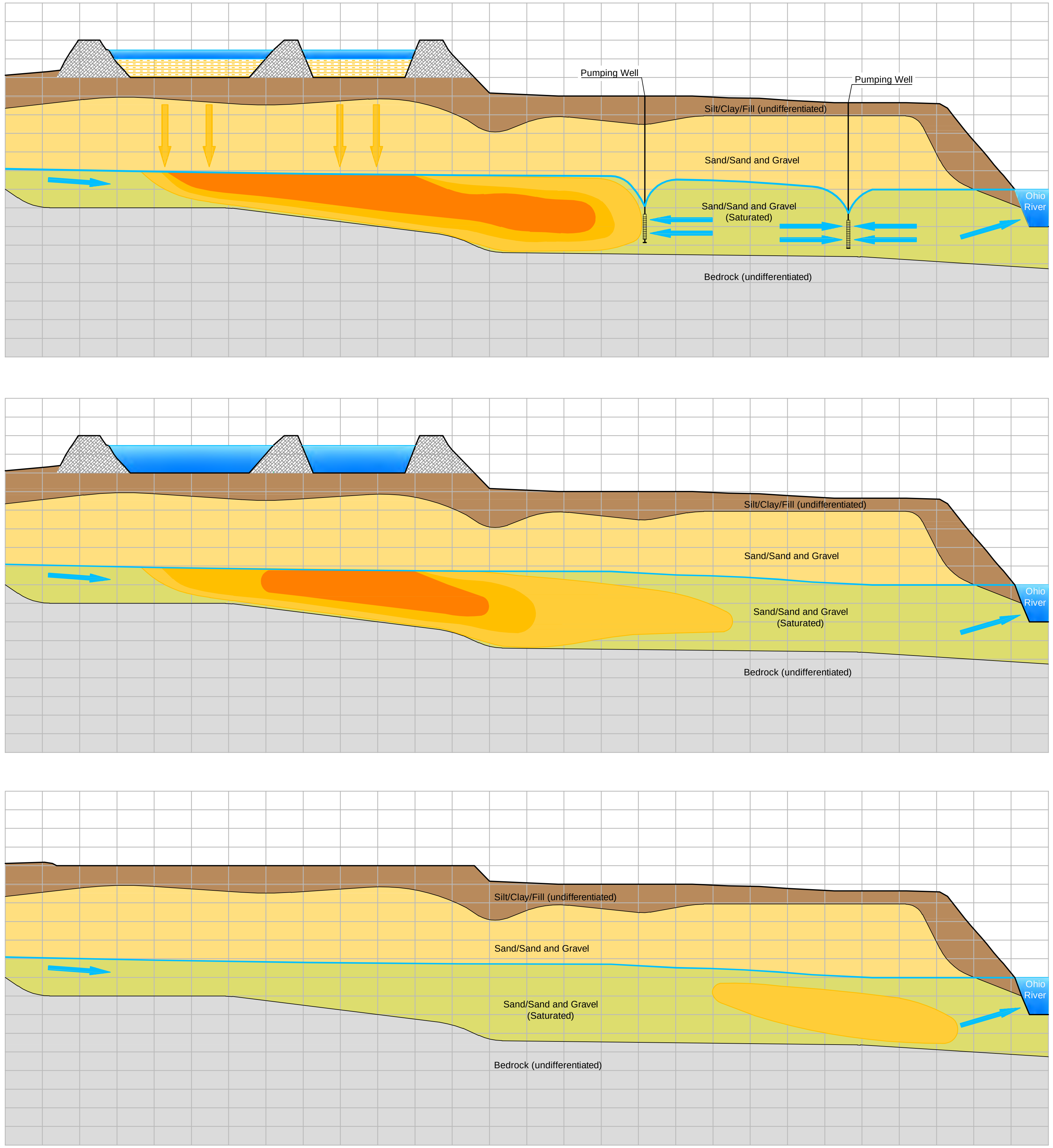


Figure Narrative

This figure shows a hydro-stratigraphical cross-section depicting the conceptual operation of a source control and monitored natural attenuation approach being considered as part of the Assessment of Corrective Measures Alternative 1 (see report text for additional information). The sequence of images portrays potential conditions during current and after initiation of remediation i.e., post-remediation (short-term), and post-remediation (long-term) time frames - see report text for additional information about the remedial alternatives and associated time frames. The conditions shown in this series of figures are conceptual and not intended to represent actual site conditions.

Legend

- Plume concentration high
- Plume concentration medium
- Plume concentration low

Horizontal Scale

325' 162.5' 0 325' 650' Feet

SANBORN HEAD

Figure 7

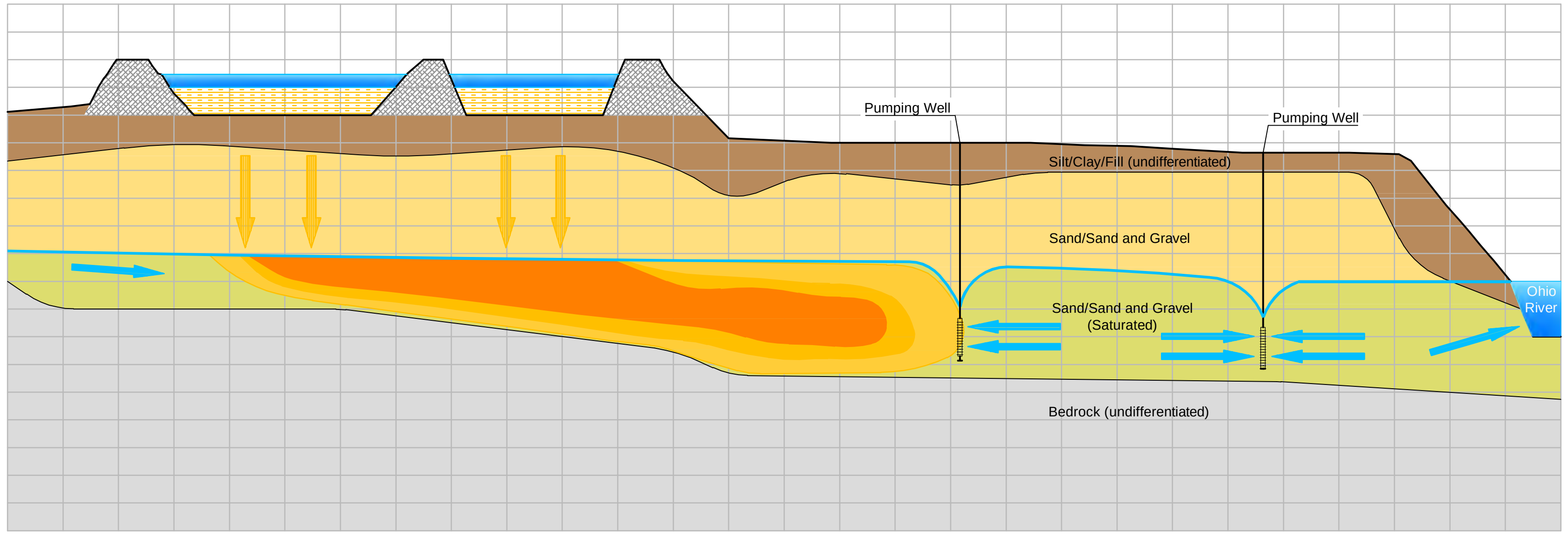
Conceptual Approach for Remedial Alternative 2 (Source Control with Groundwater Extraction and Treatment)

Mountaineer Bottom Ash Pond - Assessment of Corrective Measures

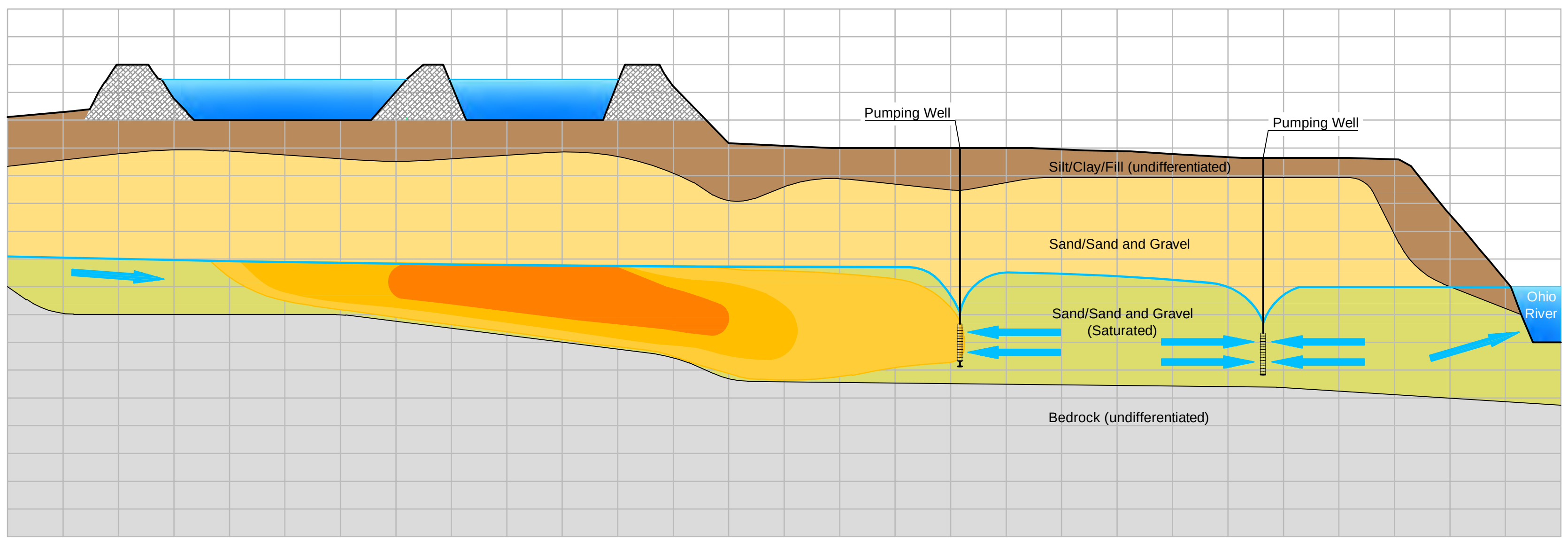
American Electric Power
AEP Mountaineer Generating Plant
New Haven, West Virginia

Drawn By: E. Wright
Designed By: A. Ashton
Reviewed By: C. Crocetti
Project No: 4345.01
Date: June 2019

Current Condition



Post-Remediation (Short Term)



Post-Remediation (Long Term)

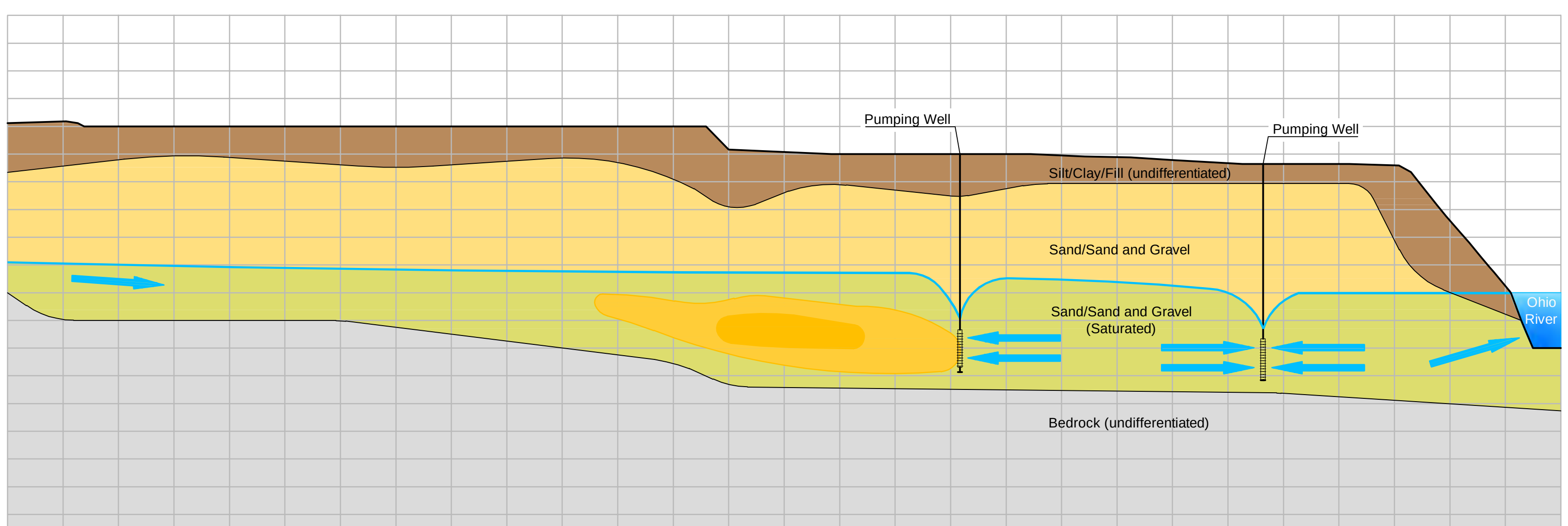


Figure Narrative

This figure shows a hydro-stratigraphical cross-section depicting the conceptual operation of a source control and groundwater extraction and treatment approach being considered as part of the Assessment of Corrective Measures Alternative 2 (see report text for additional information). The sequence of images portrays potential conditions during current and after initiation of remediation i.e., post-remediation (short-term), and post-remediation (long-term) time frames - see report text for additional information about the remedial alternatives and associated time frames. The conditions shown in this series of figures are conceptual and not intended to represent actual site conditions.

Legend

- Plume concentration high
- Plume concentration medium
- Plume concentration low

Horizontal Scale

325' 162.5' 0 325' 650' Feet

SANBORN HEAD

File: P:\4300s\4345.00\Graphics Files\CAD\Cross Section\CrossSection_Sketches.dwg User: ewright Plot Date: 6-19-19 4:24 PM

Last Edited By: hpothier

Path: P:\4300s\4345.00\Graphics Files\GIS\Figures\201906 Mountaineer ACM Report\Slurry_Wall.mxd

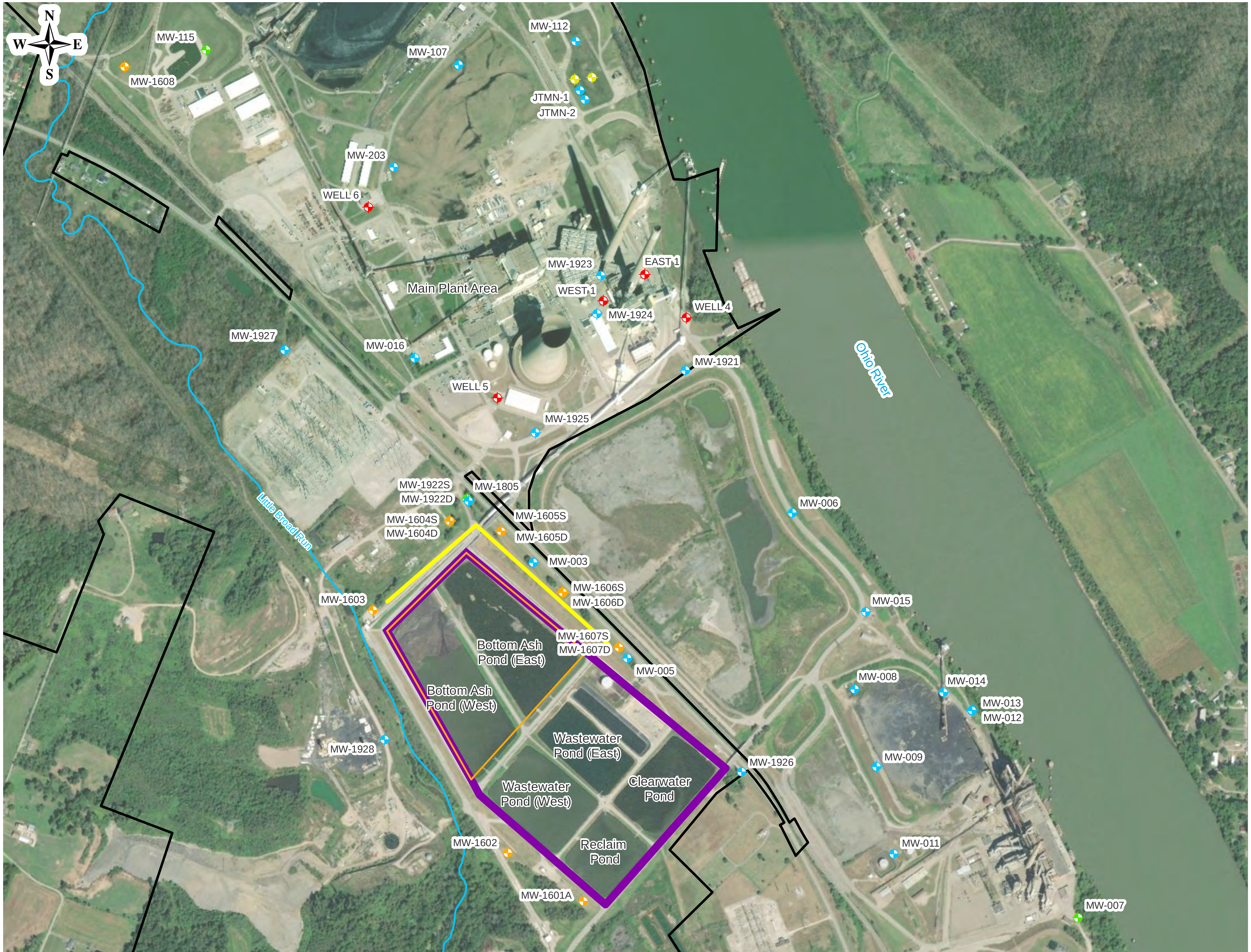


Figure 8

Potential Location of Permeable Reactive Barrier (PRB)

AEP Mountaineer Generating Plant
Bottom Ash Ponds

New Haven, West Virginia

Drawn By:	H. Pothier
Designed By:	A. Ashton
Reviewed By:	C. Crocetti
Project No:	4345.01
Date:	June 2019

Figure Narrative

This figure shows site features, monitoring well locations and potential extent of permeable reactive barrier. The location and dimensions of the permeable reactive barrier are shown for planning purposes only and may change during the design process if this alternative is selected.

Notes

1. Locations of the monitoring wells and other site features were provided by Geosyntec Consultants.

2. Aerial Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

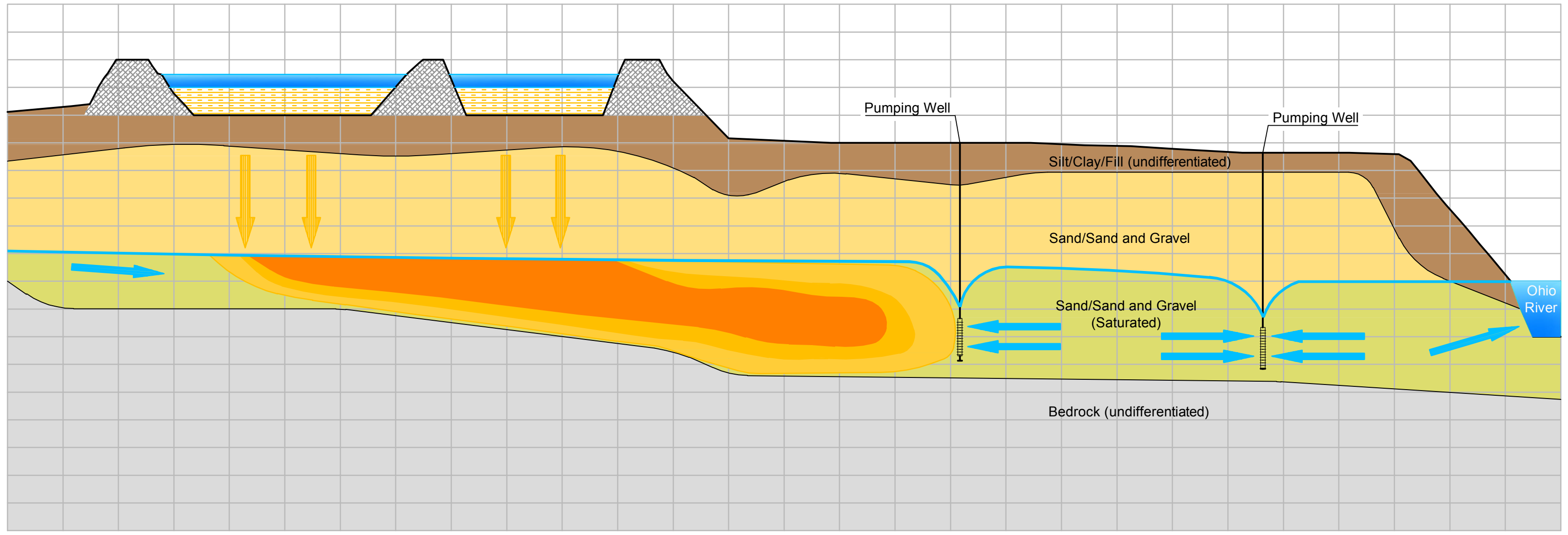
Legend

- AEP Supply Well (non-potable)
- Former AEP Supply Well (potable)
- Public Supply Well
- CCR Monitoring Well Network
- Other Monitoring Well (used for water level measurements)
- Other Monitoring Well (not used for water level measurements)
- Potential PRB Location
- CCR Unit
- Mountaineer Bottom Ash Complex (BAC)
- Property Boundary

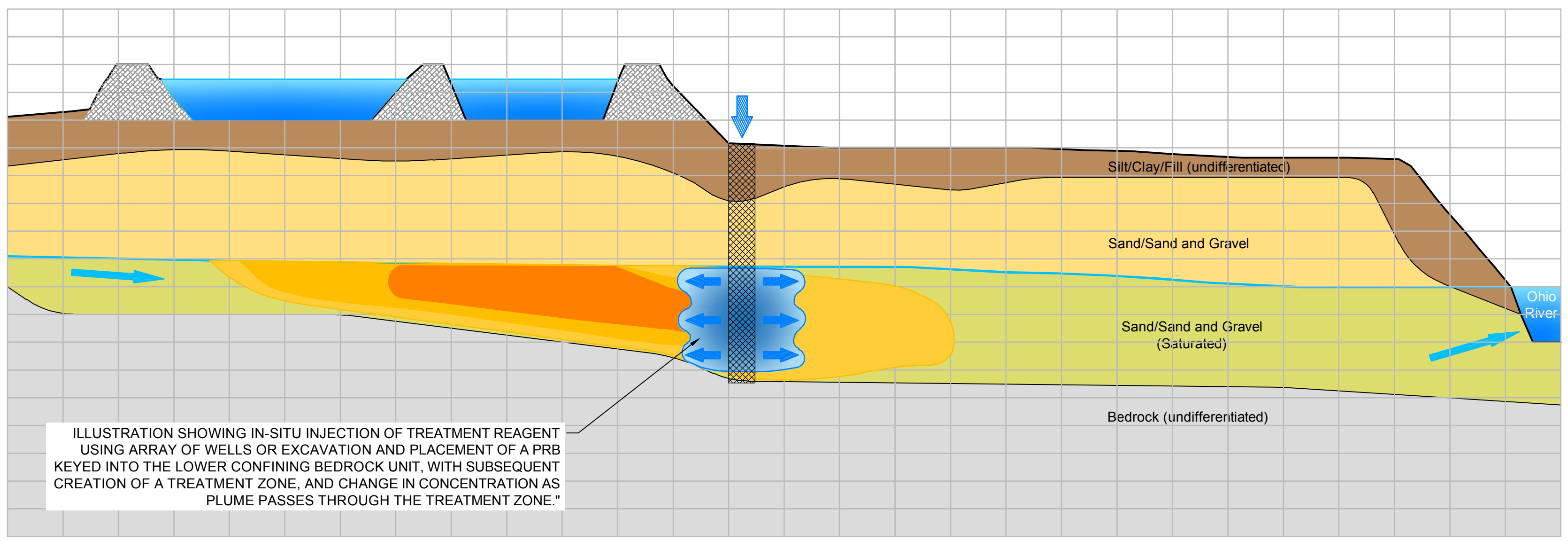
350 175 0 350 700 Feet

SANBORN HEAD

Current Condition



Post-Remediation (Short Term)



Post-Remediation (Long Term)

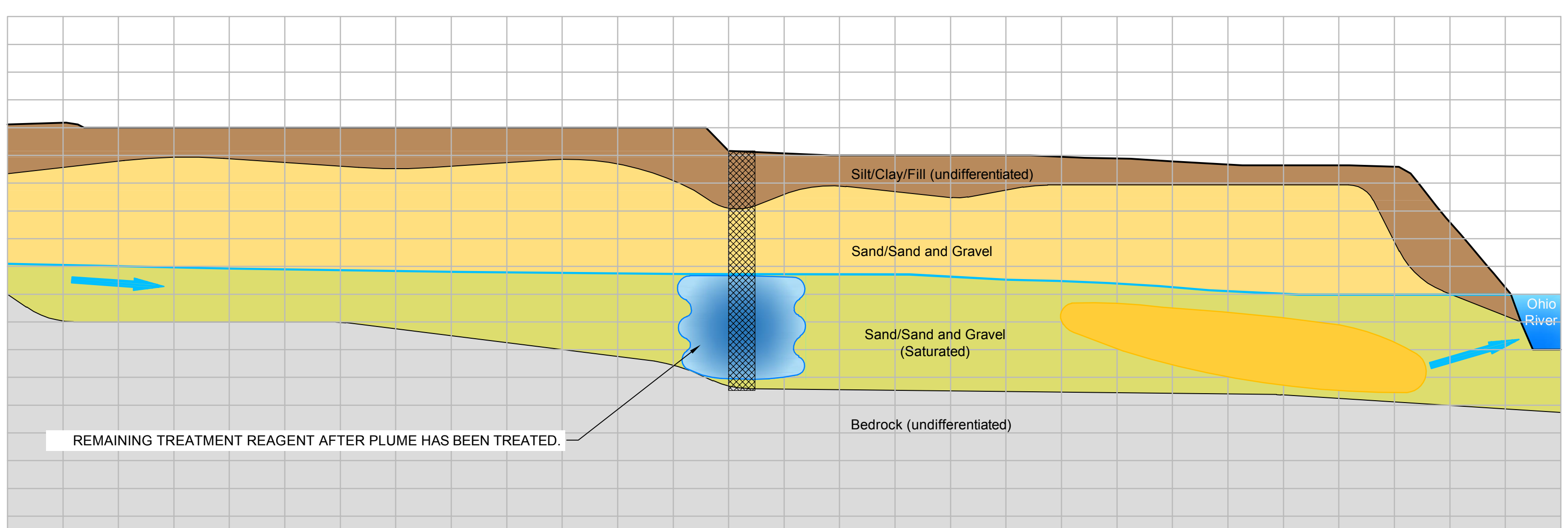


Figure 9

Conceptual Approach for Remedial Alternative 3 (Source Control with Groundwater Treatment by Permeable Reactive Barrier)

Mountaineer Bottom Ash Pond - Assessment of Corrective Measures

American Electric Power
AEP Mountaineer Generating Plant
New Haven, West Virginia

Drawn By: E. Wright
Designed By: A. Ashton
Reviewed By: C. Crocetti
Project No: 4345.01
Date: June 2019

Figure Narrative

This figure shows a hydro-stratigraphical cross-section depicting the conceptual operation of a source control and potential permeable reactive barrier being considered as part of the Assessment of Corrective Measures Alternative 3 (see report text for additional information). The sequence of images portrays potential conditions during current and after initiation of remediation i.e., post-remediation (short-term), and post-remediation (long-term) time frames - see report text for additional information about the remedial alternatives and associated time frames. The conditions shown in this series of figures are conceptual and not intended to represent actual site conditions.

Legend

- Plume concentration high
- Plume concentration medium
- Plume concentration low

Horizontal Scale

325' 162.5' 0 325' 650' Feet

SANBORN HEAD

APPENDIX A

LIMITATIONS

APPENDIX A
LIMITATIONS

1. The conclusions and recommendations described in this report are based in part on the data obtained from a limited number of soil samples from widely spaced subsurface explorations. The nature and extent of variations between these explorations may not become evident until further investigation or remediation is initiated. If variations or other latent conditions then appear evident, it will be necessary to re-evaluate the recommendations of this report.

2. The generalized soil profile described in the text is intended to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized and have been developed by interpretations of widely spaced explorations and samples; actual soil transitions are probably more gradual. For specific information, refer to the exploration logs.

3. Water level measurements have been made in observation wells at times and under conditions stated within the text of the report. Note that fluctuations in the level of the groundwater may occur due to variations in rainfall and other factors not evident at the time measurements were made.

4. Quantitative laboratory analyses were performed by previous investigators as noted within the report. The analyses were performed for specific parameters that were not selected by Sanborn Head. It must be noted that additional compounds not searched for may be present in soil and groundwater at the site. Sanborn Head has relied upon the data provided by the analytical laboratory, and has not conducted an independent evaluation of the reliability of these data. Moreover, it should be noted that variations in the types and concentrations of contaminants and variations in their distribution within the groundwater and soil may occur due to the passage of time, seasonal water table fluctuations, recharge events, and other factors.

5. The conclusions and recommendations contained in this report are based in part upon various types of chemical data as well as historical and hydrogeologic information developed by previous investigators. While Sanborn Head has reviewed that data and information as stated in this report, any of Sanborn Head's interpretations, conclusions, and recommendations that have relied on that information will be contingent on its validity. Should additional chemical data, historical information, or hydrogeologic information become available in the future, such information should be reviewed by Sanborn Head and the interpretations, conclusions and recommendations presented herein should be modified accordingly.

6. This report has been prepared for the exclusive use of American Electric Power (AEP) for specific application for the Assessment of Corrective Measures at AEP's Mountaineer Plant, Letart, West Virginia, in accordance with generally accepted hydrogeologic practices. No other warranty, express or implied, is made.

7. The analyses and recommendations contained in this report are based on the data obtained from the referenced subsurface explorations. The explorations indicate subsurface conditions only at the specific locations and times, and only to the depths penetrated. They do not necessarily reflect strata variations that may exist between such locations. The validity of the recommendations is based in part on assumptions Sanborn Head has made about conditions at the site. Such assumptions may be confirmed only during remediation. If subsurface conditions different from those described become evident, the recommendations in this report must be re-evaluated. It is advised that Sanborn Head be retained to monitor the remediation in order to help confirm that our assumptions and recommendations are valid or to modify them accordingly.

8. In the event that any changes in the nature, design, or location of the facilities are planned, the conclusions and recommendations contained in this report should not be considered valid unless the changes are reviewed and conclusions of this report modified or verified in writing by Sanborn Head. Sanborn Head is not responsible for any claims, damages, or liability associated with interpretation of subsurface data or re-use of the subsurface data or engineering analyses without the express written authorization of Sanborn Head.

\\conserv1\shdata\4300s\4345.01\Source Files\Appendix A.docx