Alabama Power

Susan B. Comensky
Vice President
Environmental Affairs

600 North 18th Street
Post Office Box 2641
12N-0830
Birmingham, Alabama 35291

Tel 205.257.0298
Fax 205.257.4349
scomensk@southernco.com

July 11, 2019

Mr. Eric L. Sanderson, P. E., Chief
Solid Waste Branch
Alabama Department of Environmental Management
1400 Coliseum Boulevard
Montgomery, Alabama 36110-2400

Re: Assessment of Corrective Measures for the Plant Greene County Ash Pond

Dear Mr. Sanderson:

Alabama Power Company is the owner and operator of the Plant Greene County Ash Pond, located at Forkland, Alabama. Pursuant to 40 CFR § 257.96, rule 335-13-15-.06(7) of the regulations of the Alabama Department of Environmental Management (ADEM), and Paragraph C of ADEM Administrative Order No. 18-097-GW, please find enclosed an Assessment of Corrective Measures (ACM) for the Plant Greene County Ash Pond.

The ACM is the first step in developing a long-term corrective action plan to address exceedances of groundwater protection standards (GWPS) identified at the site. As part of the ACM, potential groundwater corrective measures were identified and evaluated based on the criteria outlined in § 257.96(c) and r. 335-13-15-.06(7)(c). The closure plan for the Plant Greene County Ash Pond, as reflected in the permit application package filed at ADEM in December 2018, was also considered because source control activities are integral to the long-term corrective action plan and will influence corrective measures performance at the site.

As proposed in the December permit application and the updated package to be submitted on July 15, 2019, Alabama Power plans to close the Plant Greene County Ash Pond by dewatering, excavating, consolidating, and capping the ash with an impermeable composite cover system to prevent infiltration. In addition, Alabama Power will use other advanced engineering technologies beyond the minimum requirements of the CCR rule to accelerate water removal, provide additional redundancy in the dike, seal off horizontal access with a barrier wall, and seal off vertical access with an impermeable cap.

Dewatering will consist of removing the free liquids from the pond, which will reduce the volume of water available to potentially migrate from the ash pond during closure and minimize the hydraulic head within the pond, thereby reducing pressure to cause any migration from the pond. As part of ash consolidation, the closure plan proposes to excavate ash and move it to an area of higher elevation create a buffer of up to 400 yards from the river. Construction will require the movement of approximately 6 million cubic yards of ash within the unit (out of a total volume of some 11 million cubic yards of material). The process will reduce the footprint of the area covered by ash by approximately 268 acres, or more than half. The area of consolidation will be protected by the existing perimeter berms as well as an advanced engineering feature of an additional dike around the contained ash, providing redundant flood protection. Ongoing groundwater monitoring will provide important information that will ensure the remediation goals of the long-term corrective action plan are being met.

Alabama Power will take advantage of a geological feature that is specific to Plant Greene County. Below the entire area of consolidation is a natural low permeability feature known as the Demopolis and Mooresville chalk. According to available data, these chalk layers likely extend to 300 to 400 feet beneath the site. This feature will work with enhanced engineering technologies that are built into the closure plan to provide robust source control. Additionally, we have designed a subsurface barrier wall around the consolidated footprint that extends downward from the interior of the inner dike and ties into the chalk. It has the effect of locking the subsurface of the containment area in place.

To meet the requirements of Part C of the Administrative Order, and after a thorough consideration of available corrective measures, Alabama Power is proposing a remedial system that consists of combined source control and monitored natural attenuation at the site. The dewatering and enhanced closure design of the Plant Greene County Ash Pond are expected to reduce the source contribution to groundwater such that the attenuation may be all that is needed to achieve the GWPS in a reasonable timeframe. However, using an adaptive site management process, site conditions will be monitored and necessary adjustments will be made, leading to continuous improvements in the corrective measures performance. The closure configuration includes space between the capped area and the outer dike, should Alabama Power identify a need for further action in that area.

Thank you for your consideration. Please feel free to contact me if Alabama Power can provide additional information or answer any questions.

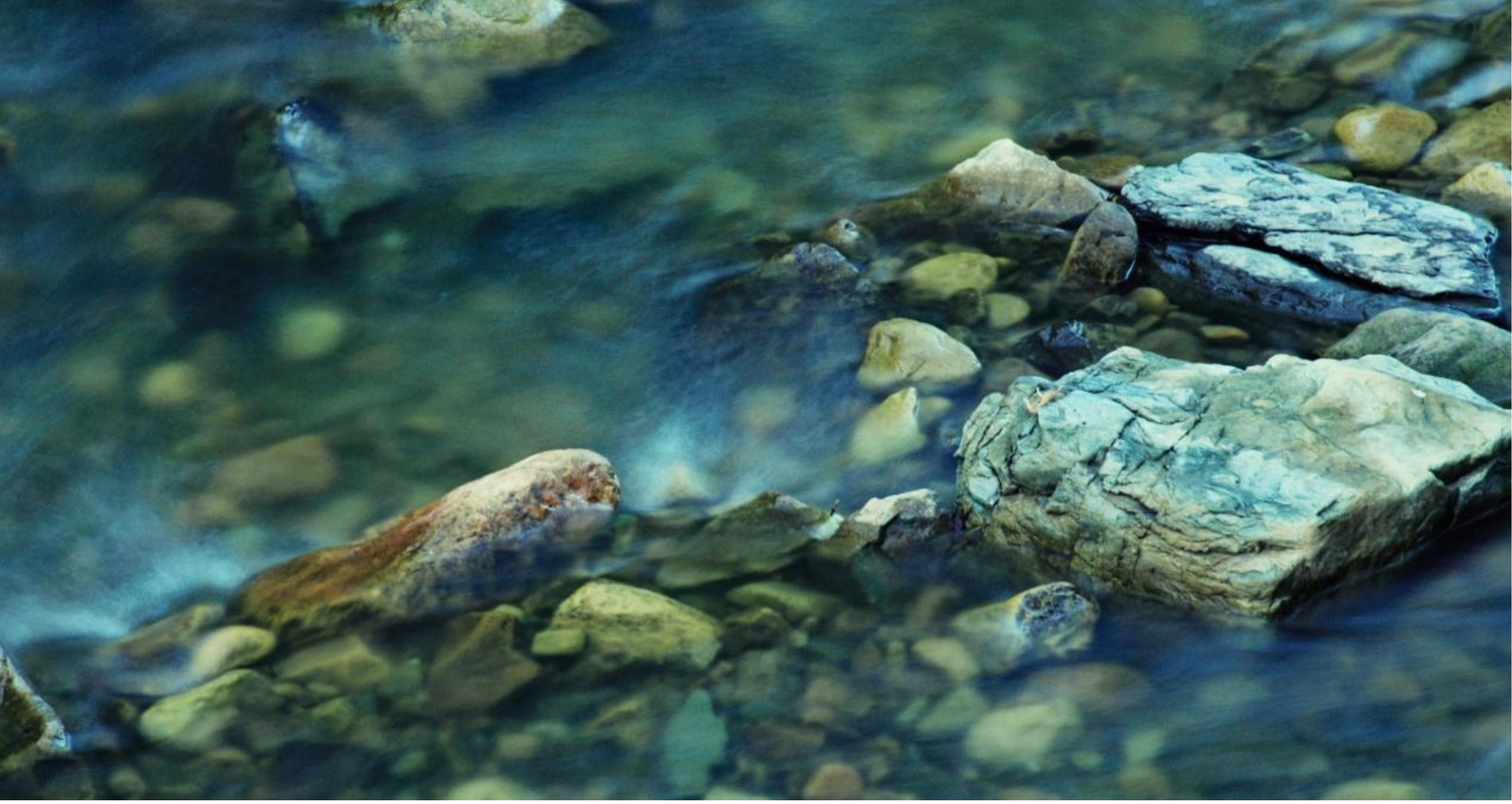
Sincerely,

Susan B. Comensky

Susan B. Comensky

Enclosures

cc w/enc.: Heather Jones
Scott Story



June 2019
Greene County

Assessment of Corrective Measures
Greene County Ash Pond

Prepared for Alabama Power Company

June 2019
Greene County

Assessment of Corrective Measures
Greene County Ash Pond

Prepared for
Alabama Power Company
1313 6th Avenue North
Birmingham, AL 35203

Prepared by
Anchor QEA, LLC
One Perimeter Park South, Suite 100N
Birmingham, AL 35243

Project Number: 171114-02.01
https://anchorqea-my.sharepoint.com/personal/aaccardi_anchorqea_com/Documents/PRIVILEGED & CONFIDENTIAL_ACMs/Greene/Text/Assessment of Corrective Measures_Greene County_6-12-19.docx

TABLE OF CONTENTS

TABLES

FIGURES

ABBREVIATIONS

ACM	Assessment of Corrective Measures
ADEM	Alabama Department of Environmental Management
Admin. Code	Administrative Code
CCR	coal combustion residuals
CCR rule	80 Federal Register 21302 (April 17, 2015); "Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities"
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act, or Superfund
CFR	Code of Federal Regulations
cm/sec	centimeters per second
CMS	Corrective Measures Study
CSM	conceptual site model
EPRI	Electric Power Research Institute
FeS_2	pyrite
GWPS	groundwater protection standard
MNA	monitored natural attenuation
MSL	mean sea level
PRB	permeable reactive barrier
RCRA	Resource Conservation and Recovery Act
RCRA FIRST Toolbox	*Resource Conservation and Recovery Act Facilities Investigation Remedy Selection Track: A Toolbox for Corrective Action*
Site	Greene County Ash Pond
SSI	statistically significant increase
SSL	statistically significant level
USEPA	U.S. Environmental Protection Agency

1 Introduction

This Assessment of Corrective Measures (ACM) has been prepared pursuant to the U.S. Environmental Protection Agency (USEPA) coal combustion residuals (CCR) rule (40 Code of Federal Regulations [CFR] Part 257 Subpart D), Alabama Department of Environmental Management's (ADEM's) Administrative Code (Admin. Code) r. 335-13-15, and an Administrative Order issued by ADEM (AO 18-097-GW) to evaluate potential groundwater corrective measures for the occurrence of arsenic, cobalt, and lithium in groundwater at statistically significant levels (SSLs) at the Greene County Ash Pond (Site).

Specifically, this ACM is prepared pursuant to 40 CFR 257.96, ADEM Admin. Code r. 335-13-15-.06(7), and Part C of the Administrative Order. Pursuant to the requirements of Part C of the Administrative Order, this ACM also "include(s) the remedy proposed to the Department for approval."

This ACM was initiated within 90 days of identifying the SSLs on January 13, 2019; a 60-day extension until June 12, 2019, for completion of the ACM was documented on April 12, 2019.

This ACM is the first step in developing a long-term corrective action plan to address exceedances of groundwater protection standards (GWPS) identified at the Site. Based on the results of the ACM, further evaluation will be performed, site-specific studies completed, and a final long-term corrective action plan developed and implemented pursuant to 40 CFR 257.97–98 and ADEM Admin. Code r. 335-13-15-.06(8) and (9).

In addition to the corrective measures discussed in this ACM, APC will close the Ash Pond by excavation and consolidation of the unit's CCR material into a smaller area located within the current footprint of the Ash Pond. A final cover system will be installed that is designed to minimize infiltration and erosion. A summary of the Closure Plan was published to APC's CCR compliance webpage in November 2016.

Completing a final long-term corrective action frequently takes several years. Therefore, corrective measures presented herein can be applied as warranted based on site conditions during closures and while implementing a long-term corrective action strategy to meet remedial objectives at the Site.

1.1 Purpose and Approach

The purpose of this ACM is to begin the process of selecting corrective measure(s). This process may be composed of multiple components to analyze the effectiveness of corrective measures and to address the potential prior migration of CCR constituents to groundwater at the Site.

The CCR rule (40 CFR 257 Subpart D), ADEM Admin. Code (r. 335-13-15), and ADEM AO 18-097-GW provide requirements for an ACM. In addition, the subsequent 2016 USEPA report entitled *Resource Conservation and Recovery Act Facilities Investigation Remedy Selection Track: A Toolbox for Corrective Action* (RCRA FIRST Toolbox; USEPA 2016) provides general guidance for conducting a Corrective Measures Study (CMS) at Resource Conservation and Recovery Act (RCRA) facilities. Because a CMS is equivalent to an ACM, ACM will be used in this report for consistency with the CCR rule terminology. The RCRA FIRST Toolbox (USEPA 2016) describes three approaches for assessing the need for, or performing, an ACM at RCRA facilities:

1. **No ACM:** "This is a likely outcome when interim measures are suitable for the final remedy, when post-closure will include provisions for corrective action, or when the only additional requirements are institutional controls" (USEPA 2016). Examples where an ACM is not likely to be needed include the following:
    a. Low risk facilities
    b. Excavation/removal remedies
    c. Presumptive remedies/proven effective remedies in similar cases
2. **Limited ACM:** In some cases, the final remedy may be obvious, but additional field work, bench-scale testing, or pilot testing may be required to support the final decision. The RCRA FIRST Toolbox includes a path for additional study without requiring a full ACM.
3. **Full ACM:** USEPA recommends that a full ACM be used only when more than one viable alternative exists to meet site cleanup and other criteria. USEPA discourages creating alternatives (such as No Action) for comparison purposes only.

According to the RCRA FIRST Toolbox (USEPA 2016), a full ACM is not required in every case, and determining the appropriate level of study is the first step in an ACM. Because three Appendix IV constituents (arsenic, cobalt, and lithium) were identified at the Site and several technologies are available for addressing the constituents, a full and thorough ACM was performed for the Site.

Per USEPA (2016) guidance, corrective measures that were clearly not viable were not evaluated. Initial steps in the ACM included analyzing existing Site information and developing a conceptual site model (CSM). Closure and source control plans were also considered since those activities are integral to the long-term strategy and will influence groundwater corrective measures performance. Potential groundwater correction measures were then identified and evaluated against the applicable criteria.

Frequently-used technologies that are unlikely to perform satisfactorily or reliably at the Site, or that are technically impractical to implement were not thoroughly evaluated as part of this ACM. A brief explanation is provided for each remedy not thoroughly evaluated. Though several technologies and combinations of these technologies appear viable for the Site, further evaluation of the technologies is needed to identify a remedy (or remedies) that may be implemented as part of a long-term corrective action plan.

1.2 Remedy Evaluation Criteria

Once potential remedies were identified, they were evaluated using the criteria outlined in 40 CFR 257.96 and ADEM Admin. Code r. 335-13-15-.06(7), which state that the ACM should include an analysis of the effectiveness of potential corrective measures that considers the following:

- Performance
- Reliability
- Ease of implementation
- Potential impacts of the remedy (including safety, cross-media, and exposure)
- The time required to begin and complete the remedy
- Any institutional requirements (e.g., permitting or environmental and public health requirements) that could affect implementation of the remedy

These evaluation criteria, discussed in more detail in the following sections, were considered for each potential remedy.

1.2.1 Performance

Factors taken into consideration when determining the performance of a remedy include the degree to which the remedy removes released Appendix IV constituents from the environment and the ability of the remedy to achieve GWPS at compliance boundaries.

1.2.2 Reliability

Reliability includes the type and degree of long-term management (e.g., monitoring, operations, and maintenance) of a remedy, the reliability of the engineering and institutional controls to maintain the effectiveness of the remedy, potential need for replacement, or any other operational reliability issues that may arise for the remedy that will limit its use or effectiveness in meeting the corrective action objectives.

1.2.3 Ease of Implementation

Ease of implementation includes the degree of difficulty associated with installing or constructing a remedy due to Site conditions, including the need to obtain necessary approvals and/or permits from other agencies, the availability of necessary equipment and/or specialists to implement the remedy, and the available capacity and location of treatment, storage, or disposal services, if needed.

1.2.4 Potential Impacts of the Remedy

Potential impacts of a remedy include the short-term risks that might be posed to the community or the environment during implementation of the remedy (e.g., due to excavation, transportation, disposal, or containment of CCR material), potential for exposure of humans and environmental receptors to remaining CCR material following implementation of the remedy, and cross-media impacts due to the remedy.

1.2.5 Time Required to Begin and Complete the Remedy

The time required to begin and complete a remedy considers the amount of time needed to completely design and implement (i.e., begin) the remedy as well as the time it will take the implemented remedy to achieve applicable GWPS at compliance points.

1.2.6 Institutional, Environmental, or Public Health Requirements

Institutional requirements can vary from site to site and technology to technology. Any state, local, or site-specific requirements (e.g., permits), or other environmental or public health requirements, that could substantially affect construction or implementation of the remedy are considered.

2 Site Background and Characteristics

2.1 Location

The Site is located in southeastern Greene County, Alabama. The physical address is 801 Steam Plant Road, Forkland, Alabama 36740. The Greene County plant lies in portions of Sections 21 and 28, Township 19 North, Range 3 East. Data are based on visual inspection of U.S. Geological Survey topographic quadrangle maps and GIS maps (USGS 2018).

The Ash Pond is located south of the main plant along the Black Warrior River to the south and the barge canal to the east. Figure 1 depicts the location of the Site with respect to the surrounding area. The Ash Pond went into service in 1964 and is approximately 477 acres in size.

2.2 Site History

The Site is an electricity generating facility that included coal-fired and gas-fired units. The Ash Pond received and stores CCR produced during the coal-fired electricity generating process prior to the cessation of coal burning in March 2016. As of April 15, 2019, the Ash Pond ceased receipt of all CCR and non-CCR wastestreams. Per ADEM Admin. Code r. 335-13-15-.09, Alabama Power Company submitted a closure plan for the Ash Pond to ADEM for review and approval, as part of the permitting package.

The Ash Pond was originally constructed between 1960 and 1965. The Ash Pond is formed by a continuous dike referenced as the east, south, north, and west dikes. The crest elevations of the dikes are as follows: the east dike ranges from 102.6 to 113.6 feet above mean sea level (MSL), the south dike ranges from 95.5 to 103 feet MSL, the west dike ranges from 95.5 to 103.2 feet MSL, and the north dike ranges from 103.3 to 113.6 feet MSL. The maximum height of the embankment is 25 feet. The current dike elevations were reached on the east and west by raising the top elevations by as much as 3 feet between 1994 and 2005. The crest width ranges between 30 feet and 50 feet along all four dikes.

2.3 Hydrogeological Conceptual Site Model and Groundwater Flow

The major components of the hydrogeological CSM include the following (Southern Company Services 2018a):

- Geologic Unit 1 (Figure 2)—Predominantly low permeability clays; with a general thickness between 5 and 15 feet; vertical hydraulic conductivities ranging from 8.0×10^{-8} centimeters per second (cm/sec) to 7.8×10^{-6} cm/sec with an average of 1.7×10^{-6} cm/sec; Unit 1 provides upper confining to semi-confining conditions between CCR and the uppermost aquifer

- Uppermost Aquifer (Geologic Unit 2)—Fine- to medium-grained sand with clay lenses in upper sections and fine gravel towards the base, generally located 5 to 15 feet beneath the top of the dike; 10 to 30 feet in thickness; horizontal hydraulic conductivities ranging from 1.68×10^{-3} cm/sec to 8.29×10^{-2} cm/sec with an average of 1.83×10^{-2} cm/sec
- Geologic Unit 3—low permeability chalk and marl; with a general thickness of 250 feet; vertical hydraulic conductivities ranging from 1.4×10^{-8} cm/sec to 5.0×10^{-8} cm/sec; Unit 3 provides lower confining conditions for the uppermost aquifer
- Groundwater Flow Characteristics:
  - Vertical groundwater flow in upper strata is likely retarded by low permeability clays of Unit 1.
  - Sources of recharge are largely from the infiltration of precipitation and estimated to be 5 to 6 inches per year.
  - Groundwater flow reflects the topography at the Site and flows radially from higher elevations north towards the Black Warrior River and barge canal.
  - Horizontal hydraulic conductivity values in the uppermost aquifer averaged 1.83×10^{-2} cm/sec as determined from slug testing.
  - Clean, fine to medium sands at the Site generally provide horizontal hydraulic conductivity values between 8.8×10^{-3} and 1.20×10^{-2} cm/sec.
  - Horizontal hydraulic values are typically highest to the south in zones where gravel are present (order of magnitude ranging from 5.0×10^{-2} to 8.0×10^{-2} cm/sec) and lowest in more clayey intervals (order of magnitude of 1.5×10^{-3} cm/sec).
  - Groundwater flow velocity is generally between 1 and 3 feet per day.

Historical potentiometric data from the Site indicates that groundwater flow directions have been consistent at the Site during the monitoring period. Groundwater flow at the Site reflects the natural topography where gravity is the dominant force driving flow. Groundwater flows from higher topographic elevations near the northernmost edge of the Ash Pond towards the north, east, and south-southeast. A topographic high southwest of the pond provides a localized mound where groundwater elevations are higher than neighboring monitoring wells.

Groundwater elevations fluctuate in response to rainfall. Seasonal variations of 1.7 to 10 feet are typical at the Site. These fluctuations are consistent in response in monitoring wells across the Site but vary in magnitude. Groundwater flow direction is consistent despite seasonal fluctuations. Groundwater elevation data indicate that water levels tend to be higher in the spring and early summer and lower during the fall and winter seasons. A typical potentiometric surface map is presented in Figure 3. Table 1 provides a summary of historical groundwater elevation data for the Site.

2.4 Delineation of Appendix IV Constituents

The groundwater monitoring network is composed of 29 monitoring wells and 4 piezometers installed around the Ash Pond (Figure 3 and Table 2): 7 upgradient and 22 downgradient. Monitoring well locations GC-AP-MW-23, GC-AP-MW-24, and GC-AP-MW-26 through GC-AP-MW-30 serve as upgradient locations for the Ash Pond, as determined by water level monitoring and potentiometric surface maps constructed for the Site. Upgradient wells are screened within the same uppermost aquifer as downgradient locations and are representative of background groundwater quality at the Site. Monitoring well locations GC-AP-MW-1 through GC-AP-MW-18, GC-AP-MW-21, GC-AP-MW-25, and GC-AP-MW-31 through GC-AP-MW-33 are utilized as downgradient locations for the Ash Pond, as determined by water level monitoring and potentiometric surface maps constructed for the Site.

Background sampling occurred between February 2016 and June 2017. Compliance detection sampling began following completion of background sampling, with sampling occurring in August 2017. Statistically significant increases (SSIs) of Appendix III constituents were noted during the September 2017 compliance detection sampling event, as described in the *2017 Annual Groundwater Monitoring and Corrective Action Report* (Southern Company Services 2018b). The Appendix III SSIs triggered assessment sampling for Appendix IV constituents, with sampling events occurring in January, June, and November 2018. Appendix IV GWPS values are shown in Table 3.

The June and November 2018 sampling events noted Appendix IV constituents arsenic, lithium and cobalt at SSLs above GWPS. SSLs above the GWPS for arsenic (0.01 mg/L), lithium (0.04 mg/L), and cobalt (0.006 mg/L) from the June and November 2018 sampling events are summarized as follows:

- Arsenic was reported at SSLs above the GWPS at the following monitoring wells for both June and November 2018 sampling events: GC-AP-MW-1, GC-AP-MW-5, GC-AP-MW-10, GC-AP-MW-14, GC-AP-MW-16, GC-AP-MW-17, and GC-AP-MW-18.
- Lithium was reported at SSLs above the GWPS at the following monitoring wells for both June and November 2018 sampling events: GC-AP-MW-15 and GC-AP-MW-17.
- Cobalt was reported at SSLs above the GWPS at monitoring wells GC-AP-MW-1 and GC-AP-MW-11 during the November 2018 sampling event. Cobalt was not reported at SSLs above the GWPS during the June 2018 sampling event.

To delineate groundwater impacts, additional monitoring wells consisting of 11 horizontal delineation wells were installed at locations downgradient of monitoring wells where Appendix IV SSIs were observed. Additionally, an existing on-site piezometer was utilized as a

12th horizontal delineation well. Vertical delineation wells were not required at the Site as the uppermost aquifer is confined at its base by 250 feet of low permeability chalk (10^{-8} cm/s) and the thickness of the aquifer is thin (10 to 30 feet). Horizontal delineation wells were installed in the Unit 2 sands at depths between 20 and 40 feet below ground surface.

To discern the nature of source, pore water samples from three locations within the Ash Pond were collected and analyzed for Appendix III and IV constituents. Analytical results from the three pore water samples indicate that cobalt is not present and or remains sorbed to solid material and is not readily leached. Therefore, an alternate source demonstration is being considered for cobalt GWPS exceedances at the Site.

2.5 Pond Closure – Source Control

A hybrid closure will be utilized for the Plant Greene County Ash Pond. The current 477-acre footprint will be reduced to an approximately 221-acre closed area by dewatering, excavating, and consolidating ash. The consolidated footprint will be enclosed by a new interior dike along the eastern, southern, and western boundaries. Additionally, a barrier wall keyed into the low-permeability Demopolis Chalk will be installed along with the new interior dike system. This hydraulic barrier will be connected to geomembrane of the final cover system. These actions will effectively control the source of CCR constituents to groundwater by removing free liquid from the ash, reducing the area of ash, and preventing further infiltration through the ash. The current closure plan estimates that dewatering, excavation, consolidation, and capping will be completed in 2027.

As part of closure, the Ash Pond will be dewatered sufficiently to remove the free liquids. Removing free liquids will reduce the volume of water available to migrate from the Ash Pond during closure and minimize hydraulic head within the pond, thereby reducing pressure to cause migration from the Ash Pond.

The final cover will be constructed to control, minimize or eliminate, to the maximum extent feasible, post closure infiltration of liquids into the waste and potential releases of CCR from the unit. This will be prevented by providing sufficient grades and slopes to: 1) preclude the probability of future impoundment of water, slurry, or sediment; 2) ensure slope and cover system stability; 3) minimize the need for further maintenance; and, 4) be completed in the shortest amount of time consistent with recognized and generally accepted good engineering practices.

The final cover system will be designed to minimize infiltration and erosion. The final cover system, at a minimum, will be designed to meet or exceed the requirements of r. 335-13-15-

.07(3)(d)3.(ii) (alternative cover system). Current design for the cover system is the synthetic ClosureTurf® cover system that utilizes a 50-mil LLDPE geomembrane overlain by an engineered synthetic turf. The synthetic turf will contain a minimum ½ inch sand infill. The permeability of the final cover system will be less than the permeability of the natural subsoils beneath the surface impoundment. Final design will ensure the disruption of the integrity of the final cover system is minimized through a design that accommodates settlement and subsidence, in addition to providing an upper component for protection from wind or water erosion.

The hydraulic barrier wall is part of an integrated interstitial water immobilization system along with the new and existing dike systems and final cover system. The purpose of the hydraulic barrier wall is two-fold: 1) to eliminate or greatly reduce the ability of any residual CCR pore water to migrate away from the consolidated footprint; and 2) prevent lateral flow or recharge to the consolidated ash from the local aquifer system. The barrier wall vertically keyed into the low-permeability chalk (~10^{-8} cm/sec) will provide a low permeability barrier in both a lateral and vertical sense and thus restrict impacts to the aquifer system.

3 Groundwater Corrective Measures Alternatives

3.1 Objectives of the Corrective Measures

Following 40 CFR 257.97(b) and ADEM Admin. Code r. 335-13-15-.06(8)(b), the following summarizes the criteria that must be met by the remedy:

- Protect human health and the environment.
- Attain applicable groundwater protection standards.
- Control the source of the release so as to reduce or eliminate, to the maximum extent feasible, further releases of Appendix IV constituents to the environment.
- Remove from the environment as much of the material released from the CCR unit as is feasible, considering factors such as avoiding inappropriate disturbances of sensitive ecosystems.
- Comply with any relevant standards (i.e., all applicable RCRA requirements) for management of wastes generated by the remedial actions.

All corrective measures selected for evaluation for potential use at the Site are anticipated to satisfy the above performance criteria to varying degrees of effectiveness.

3.2 Potential Groundwater Corrective Measures

The following presents a summary of potential groundwater corrective measures evaluated as part of this ACM. Based on Site-specific information and knowledge of corrective alternatives, the following remedies—or combination of remedies—are being considered using the evaluation criteria specified in 40 CFR 257.96(c) and ADEM Admin. Code r. 335-13-15-.06(7)(c):

- Monitored natural attenuation (MNA)
- Hydraulic containment (pump-and-treat)
- Permeable reactive barriers (PRBs)
- Subsurface barrier walls
- Geochemical manipulation (via in situ injection)

Two frequently considered remedies, 1) phytoremediation and 2) in situ grouting, were not considered viable at the Site. Conventional phytoremediation for inorganic constituents may be effective for impacts at or near the ground surface. Appendix IV SSLs occur in groundwater at depths below 10 to 20 feet and conventional phytoremediation would not be effective at those depths. The TreeWell phytoremediation technology may be effective to depths of 50 feet (under proper conditions), but trees do not bioaccumulate arsenic, cobalt, and lithium and would not transpire a sufficient amount of water to achieve hydraulic containment in the hydrogeologic conditions at the Site.

In situ grouting was not considered because the grain size is likely too fine and the low permeability zones in the Unit 2 Sand will impede the horizontal distribution of the grout, thus rendering it impractical.

3.2.1 Monitored Natural Attenuation

MNA has been a component of corrective action at RCRA and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) sites since the 1990s. MNA describes a range of physical and biological processes in the environment that reduce the concentration, toxicity, or mobility of constituents in groundwater. For inorganic constituents, the mechanisms of natural attenuation include biostabilization, sorption, dispersion, and precipitation (USEPA 1999; 2007a; 2007b). MNA as a remedial alternative is dependent on a good understanding of localized hydrogeologic conditions and may require considerable information and monitoring over an extended period of time. MNA is not an approach that will lead to rapid closure of a site and is frequently used in combination with other remedies at a site.

Where site conditions are conducive to MNA, it has the potential to provide a more sustainable, lower cost alternative to aggressive remediation technologies such as pump-and-treat. The Electric Power Research Institute (EPRI) has prepared a document describing implementation of MNA for 24 inorganic constituents, which include most Appendix III and IV constituents (EPRI 2015a).

USEPA defines MNA as follows (USEPA 1999, 2015):

> The reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remediation objectives within a timeframe that is reasonable compared to that offered by other more active methods. The "natural remediation processes" that are at work in such a remediation approach include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater.

When properly implemented, MNA removes constituents from groundwater and immobilize them onto aquifer solids. Decisions to utilize MNA as a remedy or remedy component should be thoroughly supported by site-specific data and analysis (USEPA 1999, 2015).

According to USEPA (2015) guidance, a four-phase approach should be used to establish whether MNA can be successfully implemented at a given site. The phases (also referred to as "steps" or "tiers") include (USEPA 1999, 2007a):

1. Demonstrate that the extent of groundwater impacts is stable.
2. Determine the mechanisms and rates of attenuation.
3. Determine if the capacity of the aquifer is sufficient to attenuate the mass of constituents in groundwater and that the immobilized constituents are stable and will not remobilize.
4. Design a performance monitoring program based on the mechanisms of attenuation and establish contingency remedies (tailored to site-specific conditions) should MNA not perform adequately.

Based on MNA case histories for inorganic constituents, MNA timeframes range from a few years to decades (EPRI 2015a). Because pond closure activities (consolidation and capping) at the Site are projected to take approximately 8 years, the timeframe for MNA is compatible with the closure period.

Attenuation mechanisms can be placed in two broad categories, physical and chemical. Physical mechanisms include dilution, dispersion, flushing, and related processes. All constituents are subject to physical attenuation mechanisms, so physical processes should be considered in MNA evaluations. In its most recent guidance, USEPA (2015) discourages using dilution and dispersion as primary MNA mechanisms, as these mechanisms disperse contaminant mass rather than immobilize it. Further, USEPA (2015) advises that dilution and dispersion may be appropriate as a polishing step (e.g., at the boundaries of a plume, when source control is complete, an active remedy is being used at the Site, and appropriate land use and groundwater controls are in place).

Common chemical mechanisms of attenuation for constituents include adsorption to, or coprecipitation with, oxides and hydrous oxides (oxyhydroxides) of iron and manganese; coprecipitation with, and adsorption to, iron sulfides such as pyrite (FeS_2); and precipitation as carbonates, sulfides, sulfates, and/or phosphates (USEPA 2007b).

Arsenic, cobalt, and lithium are subject to physical attenuation mechanisms, and arsenic, cobalt, and possibly lithium may also be chemically attenuated (e.g., by sorption to naturally occurring oxyhydroxides of iron and other metals, and by coprecipitating with common minerals such as iron sulfides). Therefore, MNA is a potentially viable corrective measure for groundwater at the Site.

3.2.2 Hydraulic Containment (Pump and Treat)

Hydraulic containment utilizes pumping wells (and sometimes injection wells, trenches, galleries, and/or trees) to contain and prevent the expansion of impacted groundwater. Effective hydraulic containment uses pumping wells or other subsurface hydraulic mechanisms to create a horizontal and vertical capture zone or a hydraulic barrier. Hydraulic containment is one of the most mature corrective action technologies, and it is described in *Pump-and-Treat Ground-Water Remediation: A Guide for Decision Makers and Practitioners* (USEPA 1996) and *Groundwater Contamination, Optimal Capture and Containment* (Gorelick et al. 1993). After pumping, the water may be reused in beneficial applications or treated, discharged, or reinjected.

Based on the Unit 2 Sand hydraulic characteristics, hydraulic containment could be implemented within the Unit 2 Sand. Because arsenic, cobalt, and probably lithium are treatable by commonly used technologies, pump-and-treat is a potentially viable corrective measure for groundwater at the Site.

3.2.3 Permeable Reactive Barrier Walls

A PRB wall is the emplacement of chemically reactive materials in the subsurface to intercept impacted groundwater, provide a flow path through the reactive media, and capture or transform the constituents in groundwater to achieve target groundwater standards downgradient of the PRB (Powell et al. 1998). EPRI (2006) provides an overview of PRBs and possible PRB reactive media for constituents from CCR.

The PRB is an in situ technology that allows impacted water to flow through the media and provides a barrier to constituents rather than to groundwater flow. PRBs can be used to treat groundwater impacted with metals and metalloids, chlorinated volatile organic compounds, petroleum hydrocarbons, and radionuclides. The main processes by which a PRB is used to remediate groundwater are transformation and immobilization. Transformation, or conversion, involves transforming a constituent to a less toxic form such as reduction of chromium (VI) to chromium (III). Immobilization is of the most interest with respect to inorganic constituents such as those at CCR sites. Immobilization of constituents takes place through precipitation from the dissolved state or through sorption to reactive media in the PRB (Powell et al. 2002; EPRI 2006).

There are two design configurations for PRB walls (ITRC 2005; EPRI 2006):

- Continuous PRBs are ones in which the reactive media extend across the entire path of the plume. These should have minimal impact on groundwater flow and do not necessarily have to be tied to a low hydraulic conductivity unit, although that would be dependent on the depth of impacts and would safeguard against constituents flowing under the PRB if permeability of the reactive media was reduced.
- Funnel-and-gate systems incorporate barrier walls to control and direct flow to the reactive gate. The funnels can be constructed of sheetpiles, bentonite, or other barrier wall material. Similar to barrier walls used for containment, funnels must be tied into a confining bed or low hydraulic conductivity unit to avoid having impacted water flow under the wall. Funnels can also be placed in zones of greatest contaminant mass flux through the aquifer, to maximize efficiency of treatment. The use of a funnel can cause a significant increase in groundwater flow velocity, which must be considered in designing the reactive portion of the wall for residence time. The funnel must be designed to extend beyond the extent of the plume to avoid end-around flow.

Groundwater residence time through the gate needs to be sufficient to allow capture of the constituents as groundwater moves through the reactive media. Site characterization is especially important with PRBs to allow proper design where groundwater flows naturally through the reactive media. An understanding of the following site and constituent characteristics is crucial to the success of the system (Powell et al. 1998; EPRI 2006):

- The permeability of the reactive zone, which must be kept greater than or equal to the aquifer to avoid diverting flow away from the PRB
- An understanding of the groundwater impact area boundaries and flow paths
  - The reactive media and funnel system, if used, must be properly designed and placed such that the groundwater will not bypass or be diverted around or under the system.
  - Excessive depth and fractured rock are difficult for placement of media.
- The geochemistry of the constituents and how they will interact with the reactive media
- Determination of how quickly groundwater will move through the reactive media to calculate residence time of the impacted groundwater
- The ability of the reactive media to remove constituents from groundwater yet remain reactive for an extended period

Major considerations in selecting reactive media for PRBs include the following (Gavaskar et al. 1998; EPRI 2006):

- Reactivity: The media should have adequate reactivity to immobilize a constituent within the residence time of the design.
- Hydraulic performance: The media should facilitate adequate flow through the PRB, which usually means it has a greater particle size than the surrounding aquifer media. Alternatively, gravel may be placed upgradient of PRBs to direct flow through them.
- Stability: The media should remain reactive for an amount of time that makes its use economically viable compared to other technologies.
- Environmentally compatible by-products: The media should not release by-products that are not environmentally acceptable in the aquifer environment. For example, media should not produce excess alkalinity (or acidity) such that pH is raised (or lowered) to unacceptable levels.
- Availability and price: The media should be easy to obtain in large quantities at a price that makes the PRB economically feasible.

Inorganic constituents have been shown to be amenable to remediation using PRB technology when using the appropriate reactive media. These include arsenic, chromium, sulfate, selenium, nickel, lead, uranium, technetium, iron, manganese, copper, cobalt, cadmium, zinc, molybdenum, nitrate, and phosphate (McGregor et al. 2002; EPRI 2006; EPRI 2015a; Dugan 2017).

A PRB can be installed through trenching, or soil excavation, in a similar manner as a slurry wall. A biopolymer slurry is used to stabilize the trench walls during excavation. The biopolymer is usually guar gum-based to allow microbial breakdown of residual slurry after placement of the reactive media. The reactive media is placed through the slurry by tremie. The depths are limited to about 90 feet, or the depth a trench can be kept open (ITRC 2005).

Due to the hydraulic characteristics of the Unit 2 sand, the presence of a laterally extensive lower confining bed (Unit 3 chalk and marl), and the availability of reactive media for inorganic constituents, the PRB wall is a potentially viable corrective measure for groundwater at the Site.

3.2.4 Vertical Barrier Walls

Vertical barrier walls are used to stop the flow of groundwater and any constituents that groundwater contains. Though effective, vertical barrier walls may serve as groundwater dams, so hydraulic containment to address mounding of groundwater behind barrier walls or flow of groundwater around the ends of barrier walls should be considered.

Bentonite slurry walls have been used for decades to control the flow of groundwater in both environmental applications as well as general foundation construction. Soil-bentonite walls are constructed by excavating a narrow vertical trench and injecting bentonite slurry to support the trench walls. The bentonite slurry used to support the trench walls is generally a mixture of pulverized bentonite and water. Water from the slurry bleeds into the trench wall, leaving behind a mat of particles known as filter cake, which along with the hydrostatic force of the slurry, holds the trench open. Once the trench reaches final grade, the trench is backfilled with a mixture of soil from the excavation, slurry, and soil from other sources, as necessary, to achieve the desired properties of strength and hydraulic conductivity. The backfill is generally placed with a tremie, clamshell, and/or a bulldozer, displacing the trench support slurry. The filter cake remains in place and, along with the gradation of the backfill used in the wall, is a function of the hydraulic conductivity of the final wall. Installation of soil-bentonite barrier walls can require significant amounts of space for mixing backfill (Bliss 2014). At CCR facilities, berms may be constructed to provide the working space for barrier wall emplacement.

Cement-bentonite barrier walls are similar to soil-bentonite walls except that the stabilizing fluid used during excavation is a cement-bentonite water mix. The slurry remains in place to form the wall, so a separate operation to mix the backfill and displace the slurry is not necessary. Since the excavated material is not used in the backfill mix, significant amounts of spoil are generated with this type of barrier wall. Also, due to the method of excavation with the slurry, there can be a significant amount of slurry waste (up to 40% of the total trench/panel volume) during excavation (EPRI 2015b).

A barrier wall keyed into the low permeability Demopolis Chalk (Unit 3) will be installed as part of pond closure. Barrier walls could also be used to improve the subsurface hydraulic (flow) conditions for PRB walls and pump-and-treat. For example, barrier walls could form the impermeable portions of a funnel-and-gate PRB wall to direct groundwater to the treatment gates containing reactive media and could be used in a similar way to direct groundwater toward pumping wells in a pump-and-treat system. Because they could be part of PRB or hydraulic containment (pump-and-treat) systems, barriers walls are potentially viable corrective measures at the Site.

3.2.5 Geochemical Manipulation

Geochemical manipulation via subsurface injections is an emerging remediation technology for inorganic constituents in groundwater. Geochemical manipulation for inorganic constituents may be applied in three modes: redox manipulation; adsorption to iron or other metal oxyhydroxides under oxidizing groundwater conditions; and adsorption to, or coprecipitation with, iron or other metal sulfides under reducing conditions (sequestration in sulfides).

Redox manipulation has been applied to metals such as chromium since the 1990s, where reducing compounds are injected to chemically reduce chromium (VI) to the more benign chromium (III) (USEPA 2000; Ludwig et al. 2007). Geochemical processes such as adsorption and coprecipitation are applicable to arsenic, cobalt, and lithium. In adsorption under oxidizing conditions, an iron source (such as ferrous sulfate) is injected into the subsurface and oxidizes to iron oxyhydroxides (ferrihydrite) to which contaminants adsorb (Pugh et al. 2012; Redwine et al. 2004). Due to the generally mildly reducing conditions at the Site, sequestration in sulfides is potentially the most viable of the geochemical manipulation technologies.

In the sequestration-in-sulfides technology, soluble sources of organic carbon, ferrous iron, and sulfate are injected into the subsurface to optimize conditions for sulfate-reducing bacteria growth (Saunders 1998). Sulfate-reducing bacteria produce sulfide minerals as a by-product of their metabolism, and constituents are removed from groundwater and immobilized by the sulfide minerals. Trace constituents substitute for other elements in the sulfide mineral structure and are adsorbed to sulfide mineral surfaces. In recent successful applications for arsenic, treatment solution consisting of molasses, ferrous sulfate heptahydrate, and small amounts of commercial fertilizer dissolved in unchlorinated water were injected to significantly decrease arsenic concentrations in groundwater.

The following metals may be removed from groundwater by sulfide mineral formation: antimony, arsenic, cadmium, cobalt, copper, mercury, lead, molybdenum, nickel, selenium, thallium, and zinc, in addition to some rarer elements (Abraitis et al. 2004; EPRI 2015b). The most common sulfide minerals include the iron sulfide family (FeS, FeS_2), though many other sulfide minerals are documented.

Because of the generally mildly reducing groundwater conditions at the Site, and effectiveness for arsenic and cobalt, sequestration in sulfide minerals is a potentially viable option for corrective action at the Site. Because the technology has not yet been demonstrated for large areas, its optimum application may be treatment of isolated areas (e.g., in the vicinity of a few impacted wells).

3.3 Potential Remedy Evaluation

3.3.1 Introduction

The following remedies are considered potentially feasible for corrective measures for groundwater at the Site:

- Monitored natural attenuation
- Hydraulic containment (pump and treat)
- Funnel-and-gate PRB wall
- Vertical barrier walls as components of other corrective measures
- Geochemical manipulation (injections), particularly sequestration in sulfide minerals

Although these technologies are potentially feasible remedies, further data collection and evaluation are required to (1) verify the feasibility of each, and (2) provide sufficient information to design a corrective action system that meets the criteria specified in 40 CFR 257.97(b) and ADEM Admin. Code r. 335-13-15-.06(8)(b). Table 6 provides a summary of these technologies compared to the evaluation criteria discussed in Section 1 as applied to Site conditions. Table 7 discusses advantages and disadvantages of each technology that should be considered.

3.3.2 MNA

MNA is compatible with the other groundwater corrective actions that are potentially viable for the Site. At a minimum, MNA can serve as a polishing step (USEPA 2015), which may be all that is needed at the Site due to source control and the small reduction in constituent concentrations required to meet GWPS.

The performance of MNA requires further investigation, especially related to the identification of attenuating mechanisms, capacity of Unit 2 for attenuation, and time to achieve GWPS. Because Unit 2 is a sandy aquifer, the capacity for attenuation may not be as high as in an aquifer that contains more fines (silt and clay) or organic material. Dewatering, consolidation, and capping of the Ash Pond and the planned barrier wall will likely reduce the source contribution to groundwater such that the attenuation capacity of Unit 2 may be sufficient to achieve GWPS in a reasonable timeframe.

Implementation of MNA at the Site will be relatively easy. Most of the wells for MNA are already in place, though a few additional wells may need to be installed to monitor progress in critical areas. Solid (e.g., aquifer) samples will need to be collected to identify attenuating mechanisms and to test capacity, permanence, and help determine the time required to achieve GWPS.

Reliability of MNA will be relatively high, and potential impacts of the remedy will be negligible because MNA is non-intrusive and requires almost no operation and maintenance.

Implementation of MNA would require some geochemical studies and possibly the installation of some new wells. Because MNA does not require design and construction of infrastructure other than new monitoring wells, it can be initiated within 6 months to a year. At least 1 year of groundwater monitoring data is recommended before implementation of MNA is considered complete. The additional data would be needed for statistical analysis and to determine if additional monitoring wells need to be installed. Therefore, complete implementation of MNA would take about 18 to 24 months.

Time for MNA to achieve GWPS is currently unknown and would require additional studies. Published and unpublished case histories for arsenic, and by inference cobalt and lithium, suggest that MNA would take 2 decades or more to achieve groundwater protection standards. However, the timeframe at the Site may be less because of the source control measures (dewatering, consolidation, and capping).

3.3.3 Hydraulic Containment (Pump-and-Treat)

Hydraulic containment via pump-and-treat has been used for groundwater corrective action for decades. When the pump-and-treat system is online, the performance is considered high: arsenic and cobalt are readily treated, and if the system subsurface hydraulics are designed properly, the area of impact will stabilize or shrink. Because these systems require substantial operation and maintenance, the reliability is considered not as high as some other technologies. Pumps, piping, and the water treatment system must be maintained and will be offline occasionally for various reasons.

Similarly, hydraulic containment is not as easy to implement as some other technologies (e.g., MNA or geochemical manipulation), due to design, and installation of wells, pumps, and piping. An on-site water treatment plant would be required to accommodate both the quantity, and constituents in the pumped groundwater. Since the quantity of water requiring treatment cannot be ascertained without further study, the design parameters of the treatment system would also need to be verified through additional investigations.

Hydraulic containment could be designed and installed within 1 to 2 years. Time to achieve GWPS could take more than a decade due to the slow desorption kinetics of arsenic, cobalt, and lithium from the Unit 2 aquifer, though both the planned source control and MNA should accelerate this process.

Regulatory requirements and institutional controls may be greater for hydraulic containment than some of the other technologies. For example, permits may be required for the withdrawal and re-injection (if used) of water, and the chemistry of the effluent after treatment would need to be compatible with the National Pollutant Discharge Elimination System permit.

Aggressive technologies such as hydraulic containment (pump-and-treat) may offer few or no advantages over MNA. For example, pump-and-treat for arsenic, cobalt, and lithium and other inorganic constituents may reach a point of diminishing returns relatively quickly (few months to a few years), as the concentration decreases and the subsequent reduction in concentration changes very little through time (EPRI 2018). The diminishing rate of concentration reduction is likely due to the slow desorption kinetics of constituents from aquifer solids (Bethke and Brady 2000; USEPA 2000). Due to the slow desorption kinetics, pump-and-treat may take a decade or more to achieve GWPS, such that it offers no time advantage over MNA (EPRI 2018).

3.3.4 Permeable Reactive Barrier Walls

PRB walls may be installed with continuous reactive media or with impermeable sections punctuated by reactive treatment gates (funnel-and-gate configuration). The funnel-and-gate configuration directs flow through the reactive gates, thereby improving treatment efficiency. Because of the large area to be treated, and increased efficiency of the system, the funnel-and-gate configuration is envisioned for the Site.

When working effectively in suitable conditions, PRB walls can reduce constituents to GWPS downgradient of the walls. However, because of site-specific uncertainties associated with the reactive media and subsurface hydraulics, performance is considered medium to high. Similarly, because the reactive media is expended and may clog through time, and will need to be replaced at some point, reliability is considered to be medium. Further technology-specific evaluation is required to more definitively determine the feasibility of implementing a PRB at the Site.

Due to the required depth of the PRB at the Site, implementation should not be difficult. Alteration of subsurface hydraulics (flow) may be a potential impact of this remedy. Because of required laboratory treatability studies on the reactive media, and construction of the wall, time to implement the remedy is estimated to be 2 to 4 years. Time to achieve GWPS is estimated to be at least a decade or more, though a groundwater model could help to better define this period.

3.3.5 Vertical Barrier Walls

A barrier wall keyed into the low permeability Demopolis Chalk (Unit 3) will be installed as part of pond closure. The vertical barrier walls could be used to enhance the subsurface hydraulics for other treatments, for example, as impermeable sections between pumping zones, or impermeable sections between reactive gates in a funnel-and-gate PRB wall.

Subsurface vertical barrier walls are a widely used and accepted technology, with relatively high performance and reliability. Implementation should not be difficult, as barrier walls are routinely constructed to the depths required at the Site. Potential impacts of the remedy include alteration of subsurface hydraulics (flow).

Time to implement the remedy (construct the wall) could be 1 to 2 years, and time to achieve groundwater protection standards would be the same length of time as the companion technology (i.e., hydraulic containment or PRBs).

3.3.6 Geochemical Manipulation

Geochemical manipulation via injection is an emerging technology for inorganic constituents. The permanence of geochemical manipulation has not yet been demonstrated, due to its short history of application; therefore, performance is not considered high at the present time. Similarly, reliability is considered medium or moderate because Site geochemical conditions should not change beyond the tolerance of the treatment. The most effective use of this technology at the Site is probably for smaller isolated areas, where performance can be readily monitored and re-treatment applied if needed.

Geochemical manipulation is relatively easy to moderate to implement, particularly in small areas. The main infrastructure required are injection wells, though the treatment solution may be injected through direct-push drill rigs. Even though infrastructure requirements are minimal, some laboratory and/or field pilot test work will need to be done, and a state underground injection control permit may be required, so geochemical manipulation is estimated to require a few years to implement. Because the longevity of this technology has not yet been demonstrated and multiple injections may be required, up to a decade or more may be needed to achieve GWPS.

4 Remedy Selection Process

Pursuant to 40 CFR 257.97 and ADEM Admin. Code r. 335-13-15-.06(8), after completing this ACM, the Site must select a remedy as soon as feasible. In contrast, Part C of the Administrative Order states that this ACM must include the remedy proposed to the Department for approval.

To meet the requirement of Part C, the Site remedy is proposed to consist of:

1. Source control by consolidating the CCR material and capping it with a low-permeability cover system to prevent infiltration
2. Source and groundwater control by installing a vertical barrier wall around the perimeter of the consolidated Ash Pond footprint as part of closure
3. Monitored natural attenuation and with routine evaluation of system performance to assure that remediation goals are being met
4. Adaptive site management and remediation system enhancement or modification to assure that remediation performance goals are met

40 CFR 257.97(b) and ADEM Admin. Code r. 335-13-15-.06(8)(b), specify the following criteria that must be met by the remedy:

- Protect human health and the environment.
- Attain applicable groundwater protection standards.
- Control the source of the release so as to reduce or eliminate, to the maximum extent feasible, further releases of Appendix IV constituents to the environment.
- Remove from the environment as much of the material released from the CCR unit as is feasible, considering factors such as avoiding inappropriate disturbances of sensitive ecosystems.
- Comply with any relevant standards (i.e., all applicable RCRA requirements) for management of wastes generated by the remedial actions.

Combined closure/source control, groundwater control, and MNA are anticipated to meet the requirements of 40 CFR 257.97(b) and ADEM Admin. Code r. 335-13-15-.06(8)(b). In an adaptive site management process, system performance is monitored and one or more technologies identified in this ACM used to supplement the remedy as soon as feasible if the system is not performing as intended or corrective action goals not met.

Using adaptive site management, a remedial approach will be implemented, conditions monitored, and results interpreted. The framework for future decision-making is as follows. Based on monitoring data adjustments will be made to the corrective measures as necessary, leading to continuous improvements in Site knowledge and corrective measures performance.

Specifically, potential changes in Site conditions associated with pond closure may require periodic changes to the corrective measure system. Moreover, Site conditions may require the implementation of more than one corrective measure technology to meet remediation goals over the life of the project. To account for potentially changing conditions at the Site, an adaptive site management process will be implemented using 1 or more of the technologies described in this ACM.

At the Site, Appendix IV SSLs have been identified and pond closure is underway but not complete. As soon as practical, MNA will be implemented to address the SSLs based on the current Site conditions. Using an adaptive site management approach, a remediation approach will be used whereby (1) the corrective measures system will be implemented to address current conditions, (2) the performance of the system will be monitored and evaluated semi-annually, (3) the site conceptual model updated as more data is collected, and (4) adjustment and augmentation made to the corrective action system to assure that performance criteria are met.

4.1 Additional Data Needs

Additional data and analysis will be required to perform a thorough site-specific evaluation and supplement the design of groundwater corrective actions for the Site. The following provides a summary of typical additional data needed to evaluate and select a remedy system.

- Geochemical studies of groundwater and aquifer media and geochemical modeling as needed
- Subsurface hydraulic calculations or models
- Laboratory treatability studies on groundwater, aquifer media, reactive media, and potential treatment solutions for injection
- Field pilot studies based on results of laboratory treatability studies

4.2 Schedule

Table 8 provides a generalized conceptual schedule for evaluating additional information and selecting a remedy to potentially supplement the proposed corrective action.

5 References

Abraitis, P.K., R.A.D. Patrick, and D.J. Vaughan, 2004. "Variations in the Compositional, Textural and Electrical Properties of Natural Pyrite: A Review." *International Journal of Mineral Processing* 47:41-59.

Bethke, C.M., and P.V. Brady, 2000. "How the K_d Approach Undermines Ground Water Cleanup." *Groundwater* 38(3):435-443.

Bliss, M., 2014. *Chapter 16: "Cutoff Walls." Design Standard No. 13 Embankment Dams. DS-13(16)-14: Phase 4 Final.* Prepared for the U.S. Department of the Interior, Bureau of Reclamation. July 2014.

Dugan, P.J., 2017. *What's Really in the Water? New Treatment Options for Coal Combustion Residuals (CCRs) and Mining-Influenced Water*. Paper presented at the 34th Annual Pittsburgh Coal Conference 2017 (Pittsburgh, Pennsylvania); September 2017.

EPRI (Electric Power Research Institute), 2006. *Groundwater Remediation of Inorganic Constituents at Coal Combustion Product Management Sites: Overview of Technologies, Focusing on Permeable Reactive Barriers*. EPRI, Palo Alto, California: 2006. 1012584.

EPRI, 2015a. *Monitored Natural Attenuation for Inorganic Constituents in Coal Combustion Residuals.* EPRI, Palo Alto, California: December 2015. 3002006285.

EPRI, 2015b. *Corrective Action for Closed and Closing Ash Ponds*. Final Report. EPRI, Palo Alto, California: December 2015. 3002006292.

EPRI, 2018. *Groundwater Remediation Planning, Applications, Limitations, Cost Model.* EPRI, Palo Alto, California: 2018. 3002012313.

Gavaskar, A., B. Sass, N. Gupta, J. Hicks, S. Yoon, T. Fox, and J. Sminchak, 1998. *Performance Evaluation of a Pilot-Scale Permeable Reactive Barrier at Former Naval Air Station Moffett Field, Mountain View, California.* Prepared for the Naval Facilities Engineering Service Center, Port Hueneme, California.

Gorelick, S.M, R.A. Freeze, D. Donohue, and J.F. Keely, 1993. *Groundwater Contamination Optimal Capture and Containment.* Boca Raton, Florida: Lewis Publishers.

ITRC (Interstate Technology and Regulatory Council), 2005. *Permeable Reactive Barriers: Lessons Learned/New Directions*. Interstate Technology and Regulatory Council, Permeable Reactive Barriers Team, PRB-4, Washington, D.C.

Ludwig, R.D., C. Su, T.R. Lee, R.T. Wilkin, S.D. Acree, R.R. Ross, and A. Keeley, 2007. "In Situ Chemical Reduction of Cr(VI) in Groundwater Using a Combination of Ferrous Sulfate and Sodium Dithionate: A Field Investigation." *Environmental Science and Technology* 15(42):7726.

McGregor, R.G., S. Hansler, D.W. Blowes, and E. Laratta, 2002. "The Use of a PRB to Treat Groundwater Impacted by Coal-Combustion By-Products." In *Proceedings, Third International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, Calif*. Paper 2A-02. Columbus, Ohio: Battelle Press.

Powell, R.M., R.W. Puls, D. Blowes, J. Vogan, R.W. Gillham, P.D. Powell, D. Schultz, R. Landis, and T. Sivavec, 1998. *Permeable Reactive Barrier Technologies for Contaminant Remediation*. EPA/600/R-98/125.

Powell, R.M., P.D. Powell (Powell & Associates Science Services), and R.W. Puls (Subsurface Protection and Remediation Division National Risk Management Research Laboratory), 2002. *Economic Analysis of the Implementation of Permeable Reactive Barriers for Remediation of Contaminated Ground*. EPA/600/R-02/034. June 2002.

Pugh, J.D., D.W. Morris, and J.C. Redwine, 2012. U.S. Patent 8,157,476: In situ Systems and Methods for the Immobilization of Contaminants. Original Assignee: Southern Company Services, Inc. April 2012.

Redwine, J.C., J.R. Howell, R.J. Donahoe, and L. Yang, 2004. "In situ Chemical Fixation of Arsenic in Soil: Laboratory and Field Results." In: *Proceedings, Air and Waste Management Association 97th Annual Conference and Exhibition, Indianapolis, Indiana*.

Saunders, J.A., 1998. In-situ Bioremediation of Metal-Contaminated Groundwater, U.S. Patent No. 5,833,855.

Southern Company Services, 2017. *Closure Plan for Existing CCR Surface Impoundment. Plant Greene County Ash Pond*. October 2017.

Southern Company Services, 2018a. *Facility Plan for Groundwater Investigation, Plant Greene County Ash Pond*. October 2018.

Southern Company Services, 2018b. *2017 Annual Groundwater Monitoring and Corrective Action Report*. Plant Greene County Ash Pond. January 31, 2018.

USEPA (U.S. Environmental Protection Agency), 1996. *Pump-and-Treat Groundwater Remediation: A Guide for Decision Makers and Practitioners*. EPA 625/R-95/005, July 1996.

USEPA, 1999. *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites.* EPA/OSWER No. 9200.4-17P, Office of Solid Waste and Emergency Response, Washington D.C.

USEPA, 2000. *In Situ Treatment of Soil and Groundwater Contaminated with Chromium*. Technical Resource Guide. EPA-625/R-00/005. October 2000.

USEPA, 2007a. *Monitored Natural Attenuation of Inorganic Contaminants in Ground Water. Volume 1– Technical Basis for Assessment*. EPA/600/R-07/139. October 2007.

USEPA, 2007b. *Monitored Natural Attenuation of Inorganic Contaminants in Ground Water. Volume 2. Assessment for Non-Radionuclides Including Arsenic, Cadmium, Chromium, Copper, Lead, Nickel, Nitrate, Perchlorate, and Selenium*. EPA/600/R-07/140. October 2007.

USEPA, 2015. *Use of Monitored Natural Attenuation for Inorganic Contaminants in Groundwater at Superfund Sites.* U.S. Environmental Protection Agency Office of Solid Waste and Emergency Response Directive 9283.1-36. August 2015.

USEPA, 2016. *Resource Conservation and Recovery Act Facilities Investigation Remedy Selection Track: A Toolbox for Corrective Action*. May 20, 2016.

USGS (U.S. Geological Survey), 2018. Demopolis Quadrangle, 7.5 Minute Series Topographic Map.

Tables

Table 1
Historical Groundwater Elevations Summary

Well ID	Average GW Elevation (feet MSL)	Highest GW Elevation (feet MSL)	Lowest GW Elevation (feet MSL)	GW Elevation Variation (feet)
GC-AP-MW-1	91.38	90.67	92.37	1.70
GC-AP-MW-2	99.94	98.97	100.88	1.91
GC-AP-MW-3	99.55	98.55	100.52	1.97
GC-AP-PZ-4	93.51	91.65	95.26	3.61
GC-AP-MW-5	98.96	96.77	100.96	4.19
GC-AP-MW-6	97.12	94.54	98.78	4.24
GC-AP-MW-7	90.13	86.29	92.51	6.22
GC-AP-MW-8	88.65	84.86	91.16	6.30
GC-AP-MW-9	87.54	83.73	89.88	6.15
GC-AP-MW-10	83.49	82.00	84.69	2.69
GC-AP-MW-11	85.03	83.76	86.58	2.82
GC-AP-MW-12	85.94	84.87	87.65	2.78
GC-AP-MW-13	81.71	80.00	84.35	4.35
GC-AP-MW-14	79.42	76.19	84.38	8.19
GC-AP-MW-15	76.66	73.83	83.64	9.81
GC-AP-MW-16	76.89	74.19	84.14	9.95
GC-AP-MW-17	76.66	73.61	83.48	9.87
GC-AP-MW-18	77.92	75.05	84.8	9.75
GC-AP-PZ-19	77.39	74.69	88.07	13.38
GC-AP-PZ-20	86.69	85.06	89.58	4.52
GC-AP-MW-21	83.03	81.95	84.69	2.74
GC-AP-PZ-22	88.45	88.45	88.45	0
GC-AP-MW-23	91.07	87.12	92.17	5.05
GC-AP-MW-24	87.65	85.58	101.15	15.57
GC-AP-MW-25	84.91	82.79	86.38	3.59
GC-AP-MW-26	79.63	76.77	84.98	8.21
GC-AP-MW-27	77.91	75.34	82.75	7.41
GC-AP-MW-28	79.47	77.11	84.58	7.47
GC-AP-MW-29	84.24	81.62	89.66	8.04
GC-AP-MW-30	94.75	92.11	99.45	7.34
GC-AP-MW-31	97.98	90.22	103.35	13.13
GC-AP-MW-32	90.22	87.15	91.14	3.99
GC-AP-MW-33	84.62	82.64	92.59	9.95

Notes:

Source: Southern Company Services, 2018. *2017 Annual Groundwater Monitoring and Corrective Action Report.* Plant Greene County Ash Pond. January 31, 2018.

GW: groundwater
MSL: mean sea level

Table 2
Groundwater Monitoring Network Details

Well Name	Installation Date	Northing	Easting	Ground Elevation (feet MSL)	Top of Casing Elevation (feet MSL)	Top of Screen Elevation (feet MSL)	Bottom of Screen Elevation (feet MSL)	Purpose
GC-AP-MW-1	08/26/2015	946095.058	1880860.840	104.35	107.69	89.630	79.630	Downgradient
GC-AP-MW-2	08/26/2015	946275.313	1880351.041	103.37	106.05	92.800	82.800	Downgradient
GC-AP-MW-3	05/7/2013	946518.731	1879899.751	103.06	106.37	89.770	79.770	Downgradient
GC-AP-PZ-4	08/26/2015	947156.411	1879158.907	100.70	103.48	86.220	76.220	Piezometer
GC-AP-MW-5	08/25/2015	945868.720	1879098.549	105.61	108.39	91.730	81.730	Downgradient
GC-AP-MW-6	08/25/2015	945091.716	1878587.509	98.51	102.00	82.850	72.850	Downgradient
GC-AP-MW-7	05/7/2013	944928.940	1877364.096	95.23	98.55	76.850	66.850	Downgradient
GC-AP-MW-8	08/24/2015	944228.778	1877306.867	93.81	97.06	76.920	66.920	Downgradient
GC-AP-MW-9	05/8/2013	943193.136	1877287.887	89.90	93.12	71.120	61.120	Downgradient
GC-AP-MW-10	09/2/2015	941883.884	1877251.528	85.42	88.27	72.950	62.950	Downgradient
GC-AP-MW-11	04/23/2013	940847.132	1877472.943	97.74	101.22	73.220	63.220	Upgradient
GC-AP-MW-12	08/24/2015	940132.799	1878416.082	100.18	103.18	76.730	66.730	Upgradient
GC-AP-MW-13	04/24/2013	940377.367	1879757.143	97.18	101.09	82.79	72.790	Downgradient
GC-AP-MW-14	08/24/2015	940941.085	1880988.087	83.17	85.62	73.220	63.220	Downgradient
GC-AP-MW-15	08/27/2015	941183.943	1881893.647	88.94	91.70	61.710	51.710	Downgradient
GC-AP-MW-16	08/21/2015	942161.114	1881839.309	106.10	108.74	70.330	60.330	Downgradient
GC-AP-MW-17	08/27/2015	943039.251	1881842.218	102.27	104.93	66.850	56.850	Downgradient
GC-AP-MW-18	08/21/2015	943761.404	1881853.449	102.14	105.36	67.150	57.150	Downgradient
GC-AP-PZ-19	08/20/2015	944430.495	1881853.918	101.98	104.81	75.740	65.740	Piezometer
GC-AP-MW-21	12/14/2015	940503.250	1877918.180	99.27	102.35	75.250	65.250	Downgradient
GC-AP-MW-22	12/15/2015	947922.724	1882517.278	101.83	104.55	96.830	86.830	Piezometer
GC-AP-MW-23	12/15/2015	947562.080	1882485.060	103.25	106.00	94.220	84.220	Upgradient
GC-AP-MW-24	12/16/2015	947108.604	1882404.441	101.68	104.91	93.180	83.180	Upgradient
GC-AP-MW-25	05/6/2013	945490.181	1889127.695	87.44	90.14	78.210	68.210	Downgradient
GC-AP-MW-26	06/28/2016	944351.106	1890092.898	85.46	88.89	65.990	55.990	Upgradient
GC-AP-MW-27	06/28/2016	942187.048	1889946.802	86.57	88.85	62.170	52.170	Upgradient
GC-AP-MW-28	06/29/2016	944430.936	1889288.393	87.30	89.68	65.780	55.780	Upgradient

Table 2
Groundwater Monitoring Network Details

Well Name	Installation Date	Northing	Easting	Ground Elevation (feet MSL)	Top of Casing Elevation (feet MSL)	Top of Screen Elevation (feet MSL)	Bottom of Screen Elevation (feet MSL)	Purpose
GC-AP-MW-29	06/29/2016	942938.832	1888319.488	90.94	93.68	65.370	55.370	Upgradient
GC-AP-MW-30	06/29/2016	945187.401	1873523.890	102.65	105.41	68.960	58.960	Upgradient
GC-AP-MW-31	07/8/2016	948128.480	1875424.052	106.06	108.70	83.810	73.810	Downgradient
GC-AP-MW-32	07/8/2016	946572.017	1875186.706	106.11	108.94	81.550	71.550	Downgradient
GC-AP-MW-33	07/8/2016	946571.930	1875186.730	102.27	104.93	86.240	76.240	Downgradient

Notes:

1. Northing and easting are in feet relative to the State Plane Alabama West North America Datum of 1983.
2. Elevations are in feet relative to the North American Vertical Datum of 1988 (feet MSL).

Source: Southern Company Services, 2018. *Plant Greene County Ash Pond, 2017 Annual Groundwater Monitoring and Corrective Action Report.*

MSL: mean sea level

Table 3
Greene Ash Pond GWPS

Constituent Name	Units	GWPS	Reference
Antimony	mg/L	0.006	MCL
Arsenic	mg/L	0.01	MCL
Barium	mg/L	2	MCL
Beryllium	mg/L	0.004	MCL
Cadmium	mg/L	0.005	MCL
Chromium	mg/L	0.1	MCL
Cobalt	mg/L	0.006	Rule
Combined Radium 226+228	pCi/L	5	MCL
Fluoride	mg/L	4	MCL
Lead	mg/L	0.015	Rule
Lithium	mg/L	0.04	Rule
Mercury	mg/L	0.002	MCL
Molybdenum	mg/L	0.1	Rule
Selenium	mg/L	0.05	MCL
Thallium	mg/L	0.002	MCL

Notes:

Source: Southern Company Services, 2019. *Plant Greene County Ash Pond, 2019 Annual Groundwater Monitoring and Corrective Action Report.*

Table 4
June 2018 Assessment Sampling Results

Well ID	Purpose	Sample Date	Arsenic^1 (mg/L)	Lithium^2 (mg/L)	Cobalt^3 (mg/L)
GC-AP-MW-1	Downgradient	6/4/2018	0.0195	ND	0.0758
GC-AP-MW-2	Downgradient	6/4/2018	0.0124	ND	0.00866 J
GC-AP-MW-3	Downgradient	6/4/2018	0.00731	ND	0.00380 J
GC-AP-MW-5	Downgradient	6/5/2018	0.454	0.101	0.00481 J
GC-AP-MW-6	Downgradient	6/5/2018	ND	0.0218 J	0.00237 J
GC-AP-MW-7	Downgradient	6/5/2018	ND	ND	ND
GC-AP-MW-8	Downgradient	6/5/2018	ND	0.0286 J	0.00478 J
GC-AP-MW-9	Downgradient	6/5/2018	0.00921	0.0338 J	0.0113
GC-AP-MW-10	Downgradient	6/5/2018	0.0233	0.104	0.0139
GC-AP-MW-11	Downgradient	6/5/2018	0.00637	0.102	0.0360
GC-AP-MW-12	Downgradient	6/6/2018	ND	0.0670	ND
GC-AP-MW-13	Downgradient	6/6/2018	0.00352 J	0.148	ND
GC-AP-MW-14	Downgradient	6/6/2018	0.0372	1.06	0.0240
GC-AP-MW-15	Downgradient	6/5/2018	ND	0.492	0.0148
GC-AP-MW-16	Downgradient	6/5/2018	0.0648	0.490	0.0114
GC-AP-MW-17	Downgradient	6/5/2018	0.382	0.531	0.0456
GC-AP-MW-18	Downgradient	6/5/2018	0.0661	0.353	0.0138
GC-AP-MW-21	Downgradient	6/6/2018	ND	0.0469 J	ND
GC-AP-MW-23	Upgradient	6/6/2018	ND	ND	ND
GC-AP-MW-24	Upgradient	6/5/2018	ND	ND	ND
GC-AP-MW-25	Downgradient	6/6/2018	ND	ND	0.00712 J
GC-AP-MW-26	Upgradient	6/5/2018	ND	ND	0.00223J
GC-AP-MW-27	Upgradient	6/5/2018	ND	ND	ND
GC-AP-MW-28	Upgradient	6/5/2018	ND	ND	ND
GC-AP-MW-29	Upgradient	6/5/2018	ND	ND	0.00317 J
GC-AP-MW-30	Upgradient	6/5/2018	ND	ND	ND
GC-AP-MW-31	Downgradient	6/5/2018	ND	ND	ND
GC-AP-MW-32	Downgradient	6/5/2018	ND	ND	ND
GC-AP-MW-33	Downgradient	6/5/2018	ND	ND	ND

Notes:
1: groundwater protection standard for Arsenic is 0.01 mg/L
2: groundwater protection standard for Lithium is 0.004 mg/L
3: groundwater protection standard for Cobalt is 0.006 mg/L
J: Estimated value; value may not be accurate. Spike recovery or relative percent difference outside of criteria.
mg/L: milligram per liter
ND: non-detect

Table 5
November 2018 Assessment Sampling Results

Well ID	Purpose	Sample Date	Arsenic[1] (mg/L)	Lithium[2] (mg/L)	Cobalt[3] (mg/L)
GC-AP-MW-1	Downgradient	11/6/2018	0.0189	ND	0.0898
GC-AP-MW-2	Downgradient	11/6/2018	0.00850	ND	0.0101
GC-AP-MW-3	Downgradient	11/6/2018	0.00685	ND	0.00439 J
GC-AP-MW-5	Downgradient	11/6/2018	0.432	0.116	0.00545
GC-AP-MW-6	Downgradient	11/7/2018	ND	0.0141 J	0.00258 J
GC-AP-MW-7	Downgradient	11/7/2018	ND	ND	0.00277 J
GC-AP-MW-8	Downgradient	11/7/2018	ND	0.0371	0.00651
GC-AP-MW-9	Downgradient	11/7/2018	0.00980	0.0616	0.0145
GC-AP-MW-10	Downgradient	11/7/2018	0.0152	0.110	0.015
GC-AP-MW-11	Downgradient	11/5/2018	0.00195 J	0.0641	0.0171
GC-AP-MW-12	Downgradient	11/5/2018	ND	0.0912	ND
GC-AP-MW-13	Downgradient	11/5/2018	0.00497 J	0.0914	ND
GC-AP-MW-14	Downgradient	11/7/2018	0.0289	0.604	0.0124
GC-AP-MW-15	Downgradient	11/6/2018	ND	0.547	0.0158
GC-AP-MW-16	Downgradient	11/6/2018	0.0701	0.54	0.0141
GC-AP-MW-17	Downgradient	11/6/2018	0.299	0.583	0.0321
GC-AP-MW-18	Downgradient	11/6/2018	0.0509	0.369	0.0158
GC-AP-MW-21	Downgradient	11/5/2018	ND	0.0902	ND
GC-AP-MW-23	Upgradient	11/7/2018	ND	ND	ND
GC-AP-MW-24	Upgradient	11/7/2018	ND	ND	ND
GC-AP-MW-25	Downgradient	11/6/2018	ND	ND	0.00791
GC-AP-MW-26	Upgradient	11/6/2018	ND	ND	0.00202 J
GC-AP-MW-27	Upgradient	11/6/2018	ND	ND	ND
GC-AP-MW-28	Upgradient	11/6/2018	ND	ND	ND
GC-AP-MW-29	Upgradient	11/6/2018	ND	ND	0.00367 J
GC-AP-MW-30	Upgradient	11/6/2018	ND	ND	ND
GC-AP-MW-31	Downgradient	11/6/2018	ND	ND	ND
GC-AP-MW-32	Downgradient	11/5/2018	ND	ND	ND
GC-AP-MW-33	Downgradient	11/6/2018	ND	ND	ND

Notes:
1: groundwater protection standard for Arsenic is 0.01 mg/L
2: groundwater protection standard for Lithium is 0.004 mg/L
3: groundwater protection standard for Cobalt is 0.006 mg/L
J: Estimated value; value may not be accurate. Spike recovery or relative percent difference outside of criteria.
mg/L: milligrams per liter
ND: non-detect

Table 6
Groundwater Corrective Action Evaluation Summary

Technology	Evaluation Criteria						
	Performance	Reliability	Ease or Difficulty of Implementation	Potential Impacts of Remedy	Time to Implement Remedy (Influenced by Regulatory Approval Process)	Time to Achieve Groundwater Protection Standard at the Waste Boundary	Institutional Requirements
Monitored Natural Attenuation[2]	Medium due to sandy aquifer	High due to little operation and maintenance and other potential repair needs	Easy due to minimal infrastructure (e.g., monitoring wells) needed to implement remedy	None	18-24 months	Estimated > 25 years[1]	None identified
Hydraulic Containment (pump-and-treat)	High; reduces constituents to compliance levels when online	Medium to high; system offline at times for maintenance	Moderate due to design and installation of pump-and-treat system	Pumping could impact water supply wells, if present	12-24 months	Estimated > 25 years[1]	Needs to be compatible with Site NPDES permit; would potentially need to permit withdrawals from Unit 3 aquifer
Permeable Reactive Barriers (funnel and gate)	Medium to high; reduces constituents to compliance levels downgradient of reactive barrier	Medium; reactive media will need to be replaced periodically	Easy to moderate due to ability utilize conventional technologies	Will alter groundwater flow hydraulics beneath and adjacent to the Site, could be evaluated with groundwater model	24-48 months	Estimated > 25 years	None identified
Barrier Walls (in conjunction with hydraulic containment or permeable reactive barrier gates)	High	High due to minimal need for O&M or replacement	Easy to moderate due to ability utilize conventional technologies	Will alter groundwater flow hydraulics beneath and adjacent to the Site, could be evaluated with groundwater model	12-24 months	Contingent on companion technology, i.e. > 25 years for PRB walls and hydraulic containment	None identified
Geochemical Manipulation (in situ injection, spot treatment)	Medium	Medium; site geochemical conditions need to be maintained to prevent rebound	Easy to moderate due to minimal infrastructure (e.g., injection wells)	Constituents may be mobilized initially upon injection before ultimate immobilization	12-24 months	Estimated 10 years (for small, localized areas)	State Underground Injection Control permit may be required

Notes:

1. Timeframes shown are estimated based on case histories of monitored natural attenuation and hydraulic containment of arsenic-impacted sites. Detailed estimate of time requires further investigation.
2. Monitored Natural Attenuation is often used in combination with other remedial technologies.

Table 7
Technology Advantages and Disadvantages

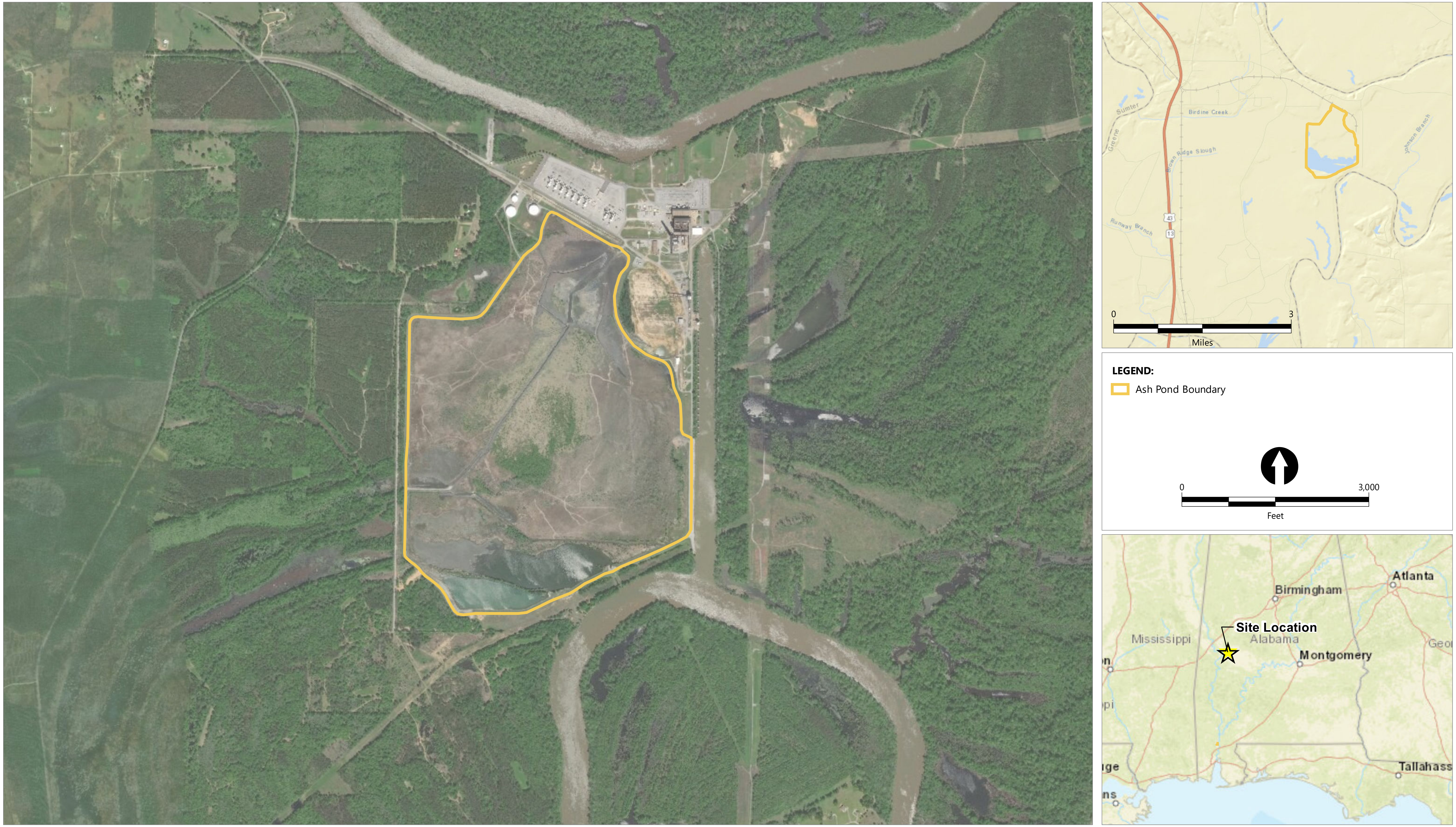
Technology	Advantages (After EPRI 2015)	Disadvantages (After EPRI 2015)
MNA	• Minimal site disruption • Sustainable • Applicable in congested, sensitive or less accessible areas where other technologies may not be feasible	• Other treatment technologies may be required
Hydraulic Containment (pump-and-treat)	• Could potentially utilize existing onsite temporary water treatment plant • Pump-and-treat systems are very effective at hydraulically containing impacted groundwater • Systems can be installed as deep as typical well drilling technology allows • Systems can be modified over time to increase or decrease extraction rates or modify the system to adapt changing site conditions	• More labor, O&M required than other technologies • Constituent levels can rebound if treatment is halted • System may reach a point of diminishing returns where concentrations stabilize above regulatory standards for inorganic constituents
Permeable Reactive Barriers (funnel and gate)	• Low labor, O&M requirements until media needs to be replaced • No need to manage extracted groundwater • Reduced need to dispose treatment by-products until media needs to be replaced	• Requires construction of impermeable barrier wall sections prior to PRB gates • Reactive media will need to be replaced at some point; used media will need to be assessed for hazardous characteristics
Barrier Walls (in conjunction with hydraulic containment or PRB gates)	• Reliable and widely accepted technology	• Mounding, end-around, or under-flow could occur if hydraulics not evaluated properly
Geochemical Manipulation (in situ injection, spot treatment)	• Ability to treat small, localized areas • Minimal site disruption • Applicable in congested, sensitive or less accessible areas where other technologies may not be feasible	• Emerging technology; permanence for inorganic constituents being demonstrated • Not proven for large-scale corrective action

Notes:
EPRI: Electric Power Research Institute
MNA: monitored natural attenuation
O&M: operation and maintenance
PRB: permeable reactive barrier

Table 8
Schedule

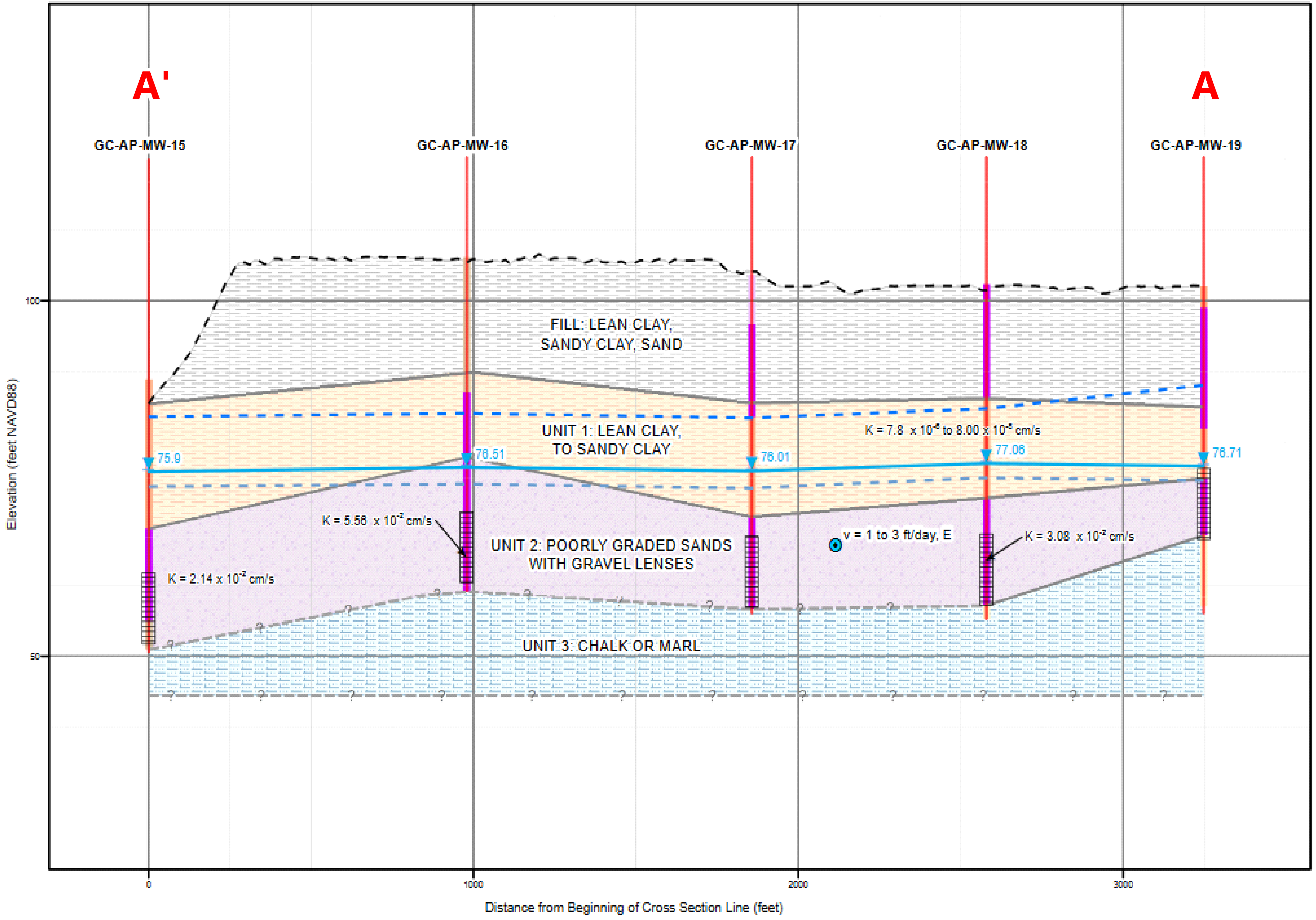
Number	Task	Estimated Completion Date
1	Field Studies and Data Collection	June 2019 – May 2020
2	Groundwater Flow and Geochemical Modeling	June 2019 – May 2020
3	Bench Testing and Pilot Studies	October 2019 – September 2020
4	Preliminary Conceptual Design	October 2020 – March 2021

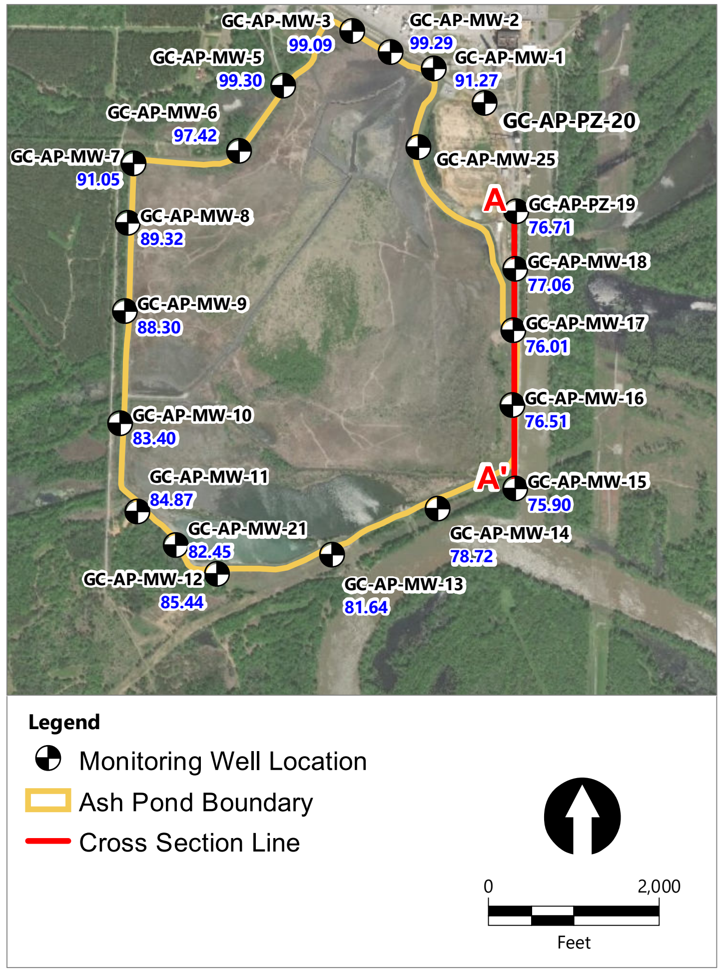
Figures



Publish Date: 2019/05/28, 8:23 AM | User: alesueur
Filepath: \\orcas\gis\Jobs\SouthernCompany_1114\GreeneCounty\Maps\2019_04_ACM\AQ_GreeneCo_Fig01_SiteLocationMap.mxd

Figure 1
Site Location Map
Assessment of Corrective Measures
Alabama Power Company - Greene County





Cross-Section Legend

- ▼ Approximate Groundwater Elevation
- — Approximate Groundwater Elevation
- - - Maximum Groundwater Elevation
- - - Minimum Groundwater Elevation
- ⊙ Represents GW flow directly toward reader
- ▭ Screen Interval
- -·- Ground Surface Elevation
- — Monitoring Well Location
- — Unit Boundary
- ▨ Fat Clay
- ▨ Lean Clay
- ▨ Clayey Sand
- ▨ Well Graded Sand
- ▨ Poorly Graded Sand
- ▨ Fill: Lean Clay, Sandy Clay, Sand
- ▨ Unit 1: Lean Clay to Sandy Clay
- ▨ Unit 2: Poorly Graded Sands with Gravel Lenses
- ▨ Unit 3: Chalk or Marl

NOTES:

1. Source of ground surface elevation data: Lidar
2. NAVD88 indicates North American Vertical Datum of 1988.
3. Approximate groundwater elevation data was collected on June 4, 2018.
4. Maximum and minimum groundwater elevation data were derived from the highest and lowest groundwater elevation values recorded during events spanning February 16, 2016 to June 4, 2018.
5. "v" indicates groundwater flow velocity
6. Cross-section data from *Plant Greene County Ash Pond Facility Plan for Groundwater Investigation*, Southern Company Services, October 2018.

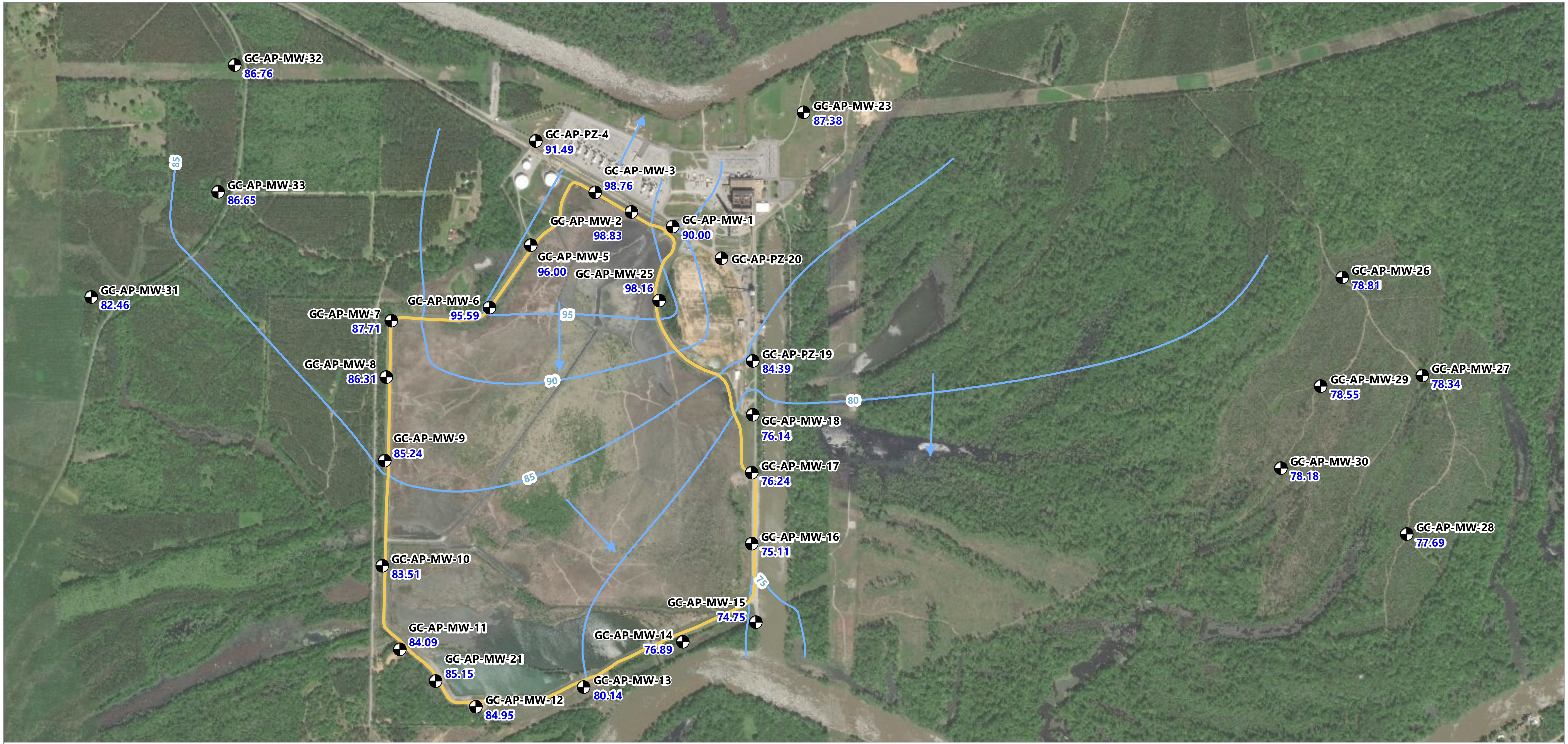
Publish Date: 2019/05/28, 8:24 AM | User: alesueur
Filepath: \\orcas\gis\Jobs\SouthernCompany_1114\GreeneCounty\Maps\2019_04_ACM\AQ_GreeneCo_Fig02_GeologicXsection.mxd

ANCHOR QEA

Figure 2

Geologic Cross-Section

Assessment of Corrective Measures
Alabama Power Company - Greene County



LEGEND:

⊕ Monitoring Well Location

▭ Ash Pond Boundary

→ Approximate Groundwater Flow Direction

— Potentiometric Surface Contour (ft NAVD88)

BY-AP-MW-3 Monitoring Well ID

98.83 Groundwater Elevation

NOTES:

1. Groundwater elevations calculated from depth to water measurements collected in November 2018.

Publish Date: 2019/05/28, 8:25 AM | User: alesueur
Filepath: \\orcas\gis\Jobs\SouthernCompany_1114\GreeneCounty\Maps\2019_04_ACM\AQ_GreeneCo_Fig03_PotentiometricSurface.mxd

ANCHOR QEA

Figure 3

Potentiometric Surface Map

Assessment of Corrective Measures
Alabama Power Company - Greene County