June 2021

Semi-Annual Remedy Selection and Design Progress Report Plant Gadsden

Prepared for Alabama Power Company

June 2021

Semi-Annual Remedy Selection and Design Progress Report Plant Gadsden

James C. Redwine

James C. Redwine
Senior Reviewer
Date: 6/11/2021

Kristi Mitchell
Originator
Date: 6/11/2021

Prepared for
Alabama Power Company
600 18th Street North
Birmingham, Alabama 35203

Prepared by
Anchor QEA, LLC
600 Vestavia Parkway, Suite 121
Vestavia Hills, Alabama 35216

Project Number: 201114-03.02

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

ABBREVIATIONS

ACM	Assessment of Corrective Measures
ADEM	Alabama Department of Environmental Management
Alabama Power	Alabama Power Company
CCR	coal combustion residuals
CEC	cation exchange capacity
CFR	Code of Federal Regulations
COI	constituents of interest
CSM	conceptual site model
EGL	Environmental Geochemistry Laboratory
EPA	U.S. Environmental Protection Agency
GWPS	groundwater protection standards
mg/kg	milligram per kilogram
mg/L	milligram per liter
MNA	monitored natural attenuation
SEM	scanning electron microscopy
Site	Ash Pond at Plant Gadsden
SSE	selective sequential extraction
XRD	X-ray diffraction
XRF	X-ray fluorescence

1 Introduction

In accordance with the U.S. Environmental Protection Agency's (EPA's) coal combustion residuals (CCR) Rule 40 Code of Federal Regulations (CFR) § 257.97(a), the Alabama Department of Environmental Management's (ADEM's) Admin. Code r. 335-13-15-.06(8)(a), and Part C of Administrative Order No. 19-104-GW, this *Semi-Annual Remedy Selection and Design Progress Report* has been prepared for the Ash Pond at Plant Gadsden (Site). Specifically, this report has been prepared to describe the progress made in evaluating the selected remedy and alternative remedies and designing a remedy plan in the first semi-annual period of 2021.

In July 2020, Alabama Power Company (Alabama Power) completed an Assessment of Corrective Measures (ACM; Anchor QEA 2020a) to address the occurrence of arsenic and lithium in groundwater at statistically significant levels. In the ACM, the following remedies were considered feasible for corrective measures for groundwater:

- Monitored natural attenuation (MNA)
- Hydraulic containment (pump and treat)
- Permeable reactive barrier (PRB) walls
- Vertical barrier walls as components of other corrective measures
- Geochemical manipulation via injections (i.e., enhanced natural attenuation)
- Permeation grouting
- In situ solidification/stabilization

As required by the Administrative Order, MNA was proposed as the main groundwater corrective action remedy for the Site. Source control has already been implemented—specifically, dewatering, grading, and capping of the ash (source) and related activities.

The EPA defines MNA as 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 time frame that is reasonable compared to that offered by other more active methods" (EPA 1999, 2015). An MNA demonstration consists of the following steps or tiers (EPA 2015):

1. Demonstrate that the area of impacts (plume) is stable or shrinking.
2. Determine the mechanisms and rates of attenuation.
3. Determine that 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 as expected.

In the previous reporting period, assessment work was started to evaluate and demonstrate MNA and geochemical manipulation as corrective measures at the Site. As shown in Table 1, some MNA investigations (completed or are in progress) were designed to primarily support Tiers 1 (area of impacts stable or shrinking); 2a (mechanisms of attenuation); and, to some extent, 3b (stability of attenuation) for an MNA demonstration. Groundwater samples and solids (precipitates) were collected from select wells, and groundwater sampling results will be used to perform geochemical modeling, which predicts attenuating species under Site geochemical conditions. Well solids analysis will be used to determine attenuating phases for the constituents of interest (COI; arsenic and lithium) at the Site. Solids analysis also provides insight into the stability of the attenuating mechanisms.

Investigations were also designed to support Tiers 2b (rates of attenuation), 3a (aquifer capacity for attenuation), and 3b (stability of attenuation) for an MNA demonstration. Soil (aquifer) and groundwater samples from multiple locations were collected and analyzed to conduct column study laboratory experiments to determine capacity, rates, and stability of MNA. Soil and groundwater characterization and column study experiments are currently in progress.

Any data obtained during on-site investigations or to evaluate corrective action alternatives will be included in the subsequent *Semi-Annual Groundwater Monitoring and Corrective Action Reports*.

Table 1
Monitored Natural Attenuation Demonstration

Tier	Approach	Status of MNA Demonstration
Tier 1: Area of Impacts Stable or Shrinking	Concentration vs. time and/or distance graphs, statistics, isoconcentrations in plan and/or section view, Ricker Method (part of ongoing monitoring)	In progress; areas of impacts expected to decrease post-closure
Tier 2a: Determine Mechanisms of Attenuation	Analysis of well solids: XRF, XRD, SEM, CEC, SSE; complete analysis of groundwater (major cations and anions); geochemical modeling	In progress
Tier 2b: Determine Rates of Attenuation	Derived from concentration vs. time graphs, batch and/or column tests, geochemical modeling	In progress
Tier 3a: Determine System (Aquifer) Capacity for Attenuation	Batch and/or column tests, geochemical modeling	In progress
Tier 3b: Determine Stability of the Attenuating Mechanisms (Solids) and COI	SSE on tested materials from batch and column tests, geochemical modeling, inference from mechanisms	In progress
Tier 4a: Design a Performance Monitoring Program	Additional wells, repeat well solids and/or complete groundwater analysis, triggers	In progress
Tier 4b: Identify Alternative Remedies Should MNA Not Perform as Expected	Completed as part of the ACM; some technologies may need further testing and/or development (bench and pilot)	In progress

2 Summary of Work Completed

Assessment work has been completed and laboratory work has been performed to support MNA and in situ geochemical manipulation as discussed in the ACM. MNA and geochemical manipulation are both geochemically based, such that site-specific geochemical data and analyses can be applied to both technologies.

2.1 Synopsis of Work Completed During Previous Reporting Periods

During previous reporting periods, the following field and laboratory investigations were performed (Anchor QEA 2020b):

- Evaluated groundwater analytical data (primarily graphing) to look for evidence of natural attenuation occurring in space and time.
- Collected groundwater samples from background and impacted wells and performed a complete chemical analysis on the samples to enable groundwater geochemical modeling and the development of a geochemical conceptual site model (CSM).
- Collected attenuating solid (precipitate) samples from the bottom of monitoring wells.
- Analyzed precipitate samples by X-ray fluorescence (XRF) to determine bulk chemistry and evaluate associations among elements (e.g., arsenic with iron).

2.2 Synopsis of Work Completed During Current Reporting Period

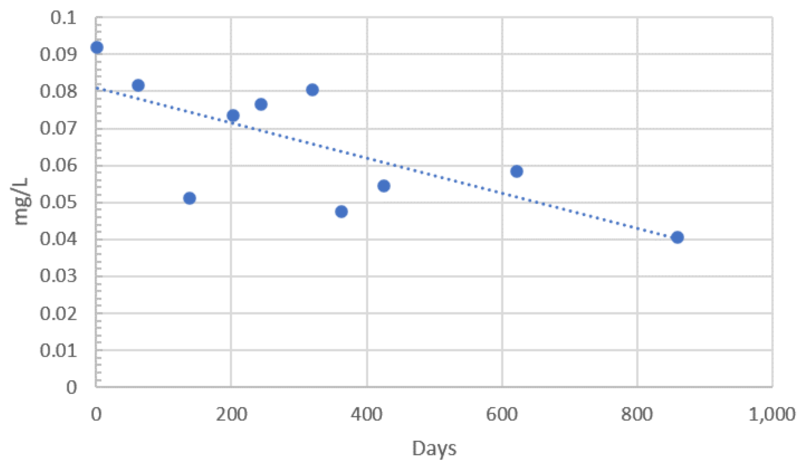
Site investigations and preliminary design work have continued at the Site to support remedy selection and design. As discussed in the ACM (Anchor QEA 2020a), completing a final long-term corrective action plan is often a multi-year process.

Work performed during the current reporting period includes:

- Assessment of MNA Tier 1 (area of impacts, stable or shrinking), including plotting of COI versus time
- Collection of groundwater and soil samples for column experiments
- Analysis of bulk chemistry by XRF
- Precipitate and soil characterization by grain size analysis, X-ray diffraction (XRD), scanning electron microscopy (SEM), cation exchange capacity (CEC), and selective sequential extraction (SSE), all in progress
- Column studies and subsequent SSE to inform rates of attenuation, capacity of the aquifer for the COI, and stability of the attenuating mechanisms (in progress)

Based on the May 2020 *Groundwater Investigation Report* (SCS 2020), impacts appear stable or diminishing and are limited to the areas around GSD-AP-MW-2 and GSD-AP-MW-4. The decreasing trend for lithium in GSD-AP-MW-2 over time support this conclusion (Figure 1). Though indications of natural attenuation are present at the Site, natural attenuation is expected to increase with time following pond capping and closure, which occurred in 2018.

Figure 1
Concentration vs. Time in GSD-AP-MW-2: Lithium



During the current reporting period, soil (aquifer) and groundwater samples were collected and analyzed to conduct column study laboratory experiments to determine capacity, rates, and stability of MNA. Soil samples were collected on March 3, 2021, from the GSD-AP-MW-2VB boring during an additional vertical delineation well installation. Groundwater samples were collected from GSD-AP-MW-2, GSD-AP-MW-4, GSD-AP-MW-4V, and GSD-AP-PZ-1 on March 24, 2021. Soil and groundwater sampling locations are shown in Figure 2. Note that delineation wells are not compared to groundwater protection standards (GWPS) and are therefore not included as statistically significant levels in Figure 2.

Figure 2
Soil and Groundwater Sampling Locations

Soil samples were collected using sonic drilling technology. Composite soil samples were collected from 11.5 to 13 feet, 13 to 14.5 feet, 14.5 to 16 feet, 16 to 17.5 feet, 17.5 to 19 feet, 19 to 20.5 feet, and 20.5 to 21 feet below ground surface from the GSD-AP-MW-2VB boring. Photographs of representative soil samples are shown in Figure 3. Samples were selected in the field, packaged to preserve field redox conditions (airtight containers packed in Mylar bags with oxygen-scavenging packets), and shipped on ice to Anchor QEA's Environmental Geochemistry Laboratory (EGL) in Portland, Oregon, for column study experiments.

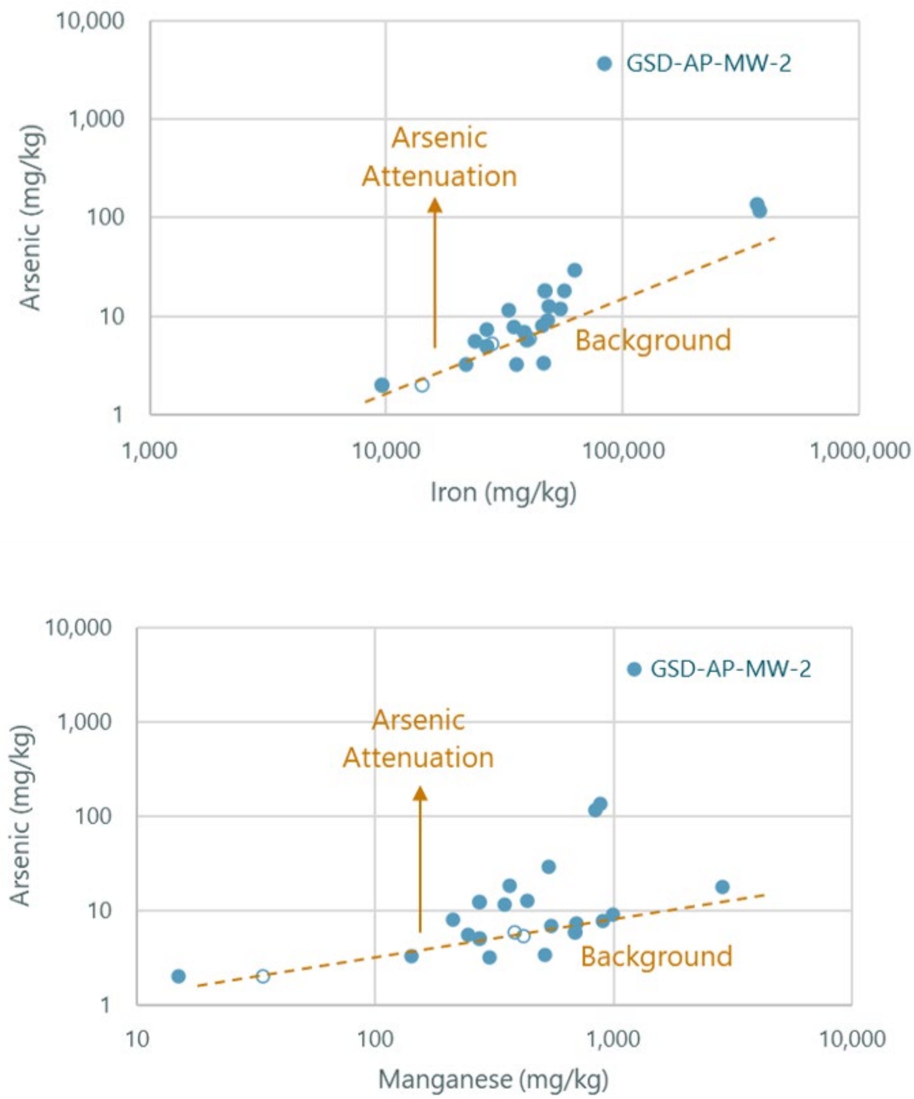
Figure 3
Representative Soil Samples from GSD-AP-MW-2VB

Groundwater was collected in a manner to preserve oxidation-reduction conditions of samples. Prior to groundwater sample collection, the well was purged until the following field parameters were stabilized: turbidity, oxidation-reduction potential, dissolved oxygen, specific conductance, temperature, and pH. Groundwater samples were collected by pumping from the well directly into a collapsible Cubitainer, which was filled completely and capped with zero headspace. Groundwater was field-filtered with a standard in-line 0.45-micron capsule filter. The filled container was packed and sealed inside a large Mylar bag containing oxygen-absorbent packets and shipped on ice to Anchor QEA's EGL for column study experiments.

Characterization of the soil samples includes grain size analysis, XRF, XRD, SEM, CEC, and SSE. Bulk chemistry by XRF is complete, though the other analyses are still in progress.

Preliminary analysis of bulk chemistry data from well precipitates (solids) shows a relationship between arsenic and iron, and arsenic and manganese (Figure 4), indicating that iron and manganese compounds (probably oxides) are attenuating arsenic. The open circles in Figure 4 represent data from background wells; a regression line through these data defines the background relationship between arsenic and iron, and arsenic and manganese. Points above the background line indicate arsenic enrichment and attenuation, which is clearly shown in Figure 4.

Figure 4
Bulk Chemistry by XRF: Arsenic



Column studies are being performed using Site soil and groundwater samples to inform rates and stability of attenuation, and the capacity of the aquifer matrix (part of Tier 3) to attenuate arsenic and lithium. Concentrations of COI in groundwater were measured prior to beginning the column study experiments.

Site groundwater containing arsenic and lithium is run through the columns, and the COI concentrations are measured in the elutriate (i.e., until breakthrough occurs). SSE will be performed on tested soil from the columns to provide information on the mechanisms of attenuation and to assess their stability.

Based on the results of column studies, groundwater modeling will be performed to assess the rates and capacity of the aquifer for attenuation using a 1D or 2D reactive transport model (PHREEQC, PHAST, or PHT3D). The column test results will be used to constrain key model parameters, including concentration(s) of sorbing phases.

In addition to the laboratory studies, corrective actions in the context of site-specific conditions were compared to the evaluation criteria in the CCR Rule, with emphasis on deficiencies that could eliminate a corrective action from further consideration. The corrective action evaluation table from the ACM (Anchor QEA 2020a) was updated based on a more detailed analysis of site-specific conditions (Appendix A).

After more detailed evaluation in the context of site-specific conditions, the following technologies are recommended for additional evaluation: MNA, hydraulic containment (tree wells), geochemical manipulation via injection (enhanced MNA), and in situ solidification/stabilization. Hydraulic containment (pump-and-treat), permeation grouting, and PRB walls are not recommended for additional evaluation.

Geochemical manipulation, specifically injection treatments, is retained for the following reasons:

- Proven effectiveness for arsenic in field applications, and effective for lithium in laboratory treatability studies on CCR-impacted groundwater
- Suitable for spot (isolated area) treatment, or creation of a linear treatment zone perpendicular to groundwater flow
- Compatible with, and can enhance, natural attenuation processes

Typical steps in a geochemical manipulation treatment include the following:

- Laboratory treatability studies to determine the optimum reagents, concentration, and dose
- Design, including spacing and depth of injection points, injection rates, travel time, and radius of influence; design considerations are largely based on site hydrogeological characteristics and injection logistics
- Additional fine-scale delineation of the impacted area in the field
- Implementation of a field pilot test and remedial effectiveness monitoring

Arsenic has been successfully treated in field applications under a broad range of site geochemical conditions, including adsorption to iron oxyhydroxides under oxidizing conditions (with and without pH adjustment) and sequestration in and on iron sulfide minerals created by injection. Both technologies are ferrous-sulfate-based, though sequestration in sulfide minerals includes the addition of a carbon source (e.g., molasses) as the sulfide process is mediated by naturally occurring iron-reducing bacteria. Mixed metal oxides containing iron, manganese, and magnesium have been successful for arsenic and lithium treatment in laboratory studies.

Especially for spot treatment, the area of impacts is typically better defined (delineated) prior to injection. The delineation may include collection of numerous groundwater samples through direct-push technology on a grid. Groundwater samples are screened with field test kits, with a subset of samples sent to an analytical laboratory for confirmation analyses.

Hydraulic containment (pump-and-treat) is not recommended for the following reasons:

- Inefficiency due to infrastructure, pumping, and subsequent water treatment focused on two relatively small discrete locations; specifically, infrastructure requirements would be relatively large as compared to the amount of groundwater extracted and treated
- Relatively high operation and maintenance requirements
- Low sustainability (excessive use of resources)

Hydraulic containment (pump-and-treat) will likely not offer any time advantage to achieving GWPS over MNA or enhanced MNA due to the slow release of COI from the aquifer media. In fact, MNA and enhanced MNA may achieve GWPS sooner than pump-and-treat. Natural attenuation is occurring at the Site, and pump-and-treat would operate against (essentially try to reverse) the natural processes already occurring. Geochemical manipulation, on the other hand, would be designed to enhance natural attenuation. Due to the many pumping wells required to achieve hydraulic containment, ongoing water treatment, and long duration required (decades), hydraulic containment (pump-and-treat) would require many resources (electricity, water treatment chemicals, etc.) without offering any advantages over MNA or geochemical manipulation (enhanced MNA).

Permeation grouting can be performed in alluvial sands and gravels if the fines (silt and clay) content is not high enough to inhibit the mobility of the grout in the pore spaces. Based on a review of grain size analyses performed in 2019, and consistent with visual observation (left photograph in Figure 3), many soil samples contain fines greater than about 20%, which would impede the flow of grout. Some sand and gravel zones may be amenable to permeation grouting but probably not the entire saturated thickness of the surficial aquifer in the areas of impacts. Permeation grouting is therefore not recommended for further evaluation.

PRB walls are not recommended for the following reasons:

- Geometry of the areas of impact – Impacts occur in two discrete, isolated areas. PRB walls are more effective for linear installations perpendicular to groundwater flow across plumes.
- Some potentiometric data suggest that the flow direction may be changing from southeast to northwest in the area of impacts due to pond closure; if so, the only available location for the PRB wall would be upgradient of the impacts.
- Periodic replacement of the PRB media as it becomes spent, and/or due to clogging

3 Planned Activities and Anticipated Schedule

The following conceptual-level feasibility study activities are planned for the next reporting period (July to October 2021) to evaluate MNA, geochemical manipulation, and possibly other corrective action technologies:

- Complete geochemical modeling, XRD, SSE, SEM, and CEC work on well solids (precipitates) and aquifer solids (soil)
- Integrate the XRD, SEM, SSE, CEC, and geochemical modeling results into a geochemical CSM; perform additional geochemical modeling if needed
- Continue to compare site-specific corrective actions to the evaluation criteria in the CCR Rule, with emphasis on deficiencies that could eliminate a corrective action from further consideration

The longer-term schedule for developing a groundwater corrective action system at the Site is as follows:

- Finish laboratory work to determine MNA capacity, rates, and stability (second and third quarters 2021)
- Prepare a Remedy Selection Report, including an MNA Demonstration (September 2021)
- Develop a Corrective Action Groundwater Monitoring Program (December 2021)

During the next reporting period, other potential remedies identified in the ACM will continue to be evaluated with respect to technical feasibility, ability to attain target standards, and ease of implementation.

During the next reporting period, groundwater monitoring will continue, a final remedy plan will be developed, and the Remedy Selection Report will be prepared describing the remedy plan and how it demonstrably meets the requirements of 40 CFR § 257.97(a) and ADEM Administrative Code r. 335-13-15-.06(8)(a). Details regarding adaptive management triggers and criteria will be included in the Corrective Action Groundwater Monitoring Program.

4 References

Anchor QEA (Anchor QEA, LLC), 2020a. *Assessment of Corrective Measures.* Plant Gadsden Ash Pond. Prepared for Alabama Power Company. July 2020.

Anchor QEA, 2020b. *Semi-Annual Remedy Selection and Design Progress Report.* Plant Gadsden. Prepared for Alabama Power Company. December 2020.

EPA (U.S. Environmental Protection Agency), 1999. *Use of Monitored Natural Attenuation of Superfund, RCRA Corrective Action, and Underground Storage Tank Sites.* Office of Solid Waste and Emergency Response. EPA/OSWER No. 9200.4-17P. April 1999.

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

EPRI (Electric Power Research Institute), 2015. *Corrective Action for Closed and Closing Ash Ponds*. Final Report. 3002006292. December 2015.

SCS (Southern Company Services, Inc.), 2020. *Groundwater Investigation Report.* Plant Gadsden Ash Pond. Prepared for Alabama Power Company. May 22, 2020.

Appendix A
Plant Gadsden Groundwater Corrective Action Evaluation Summary

Table A-1
Plant Gadsden Groundwater Corrective Action Evaluation Summary

Technology	Evaluation Criteria							Correction Action Feasibility
	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	Medium due to the sand and gravel in the surficial soils	Relatively high due to little O&M and other potential repair needs	Relatively easy due to minimal infrastructure (e.g., monitoring wells) needed to implement remedy	None	18-24 months	Estimated > 10 years	None identified	**Feasible**
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	Pumped water will need to be treated	12-24 months	Estimated > 10 years[1]	Needs to be compatible with Site NPDES permit; would potentially need to permit withdrawals from the impacted aquifer	**Not recommended**. Inefficiency due to infrastructure, pumping, and subsequent water treatment focused on two relatively small areas; relatively high O&M requirements; and low sustainability (excessive use of resources). Pump-and-treat systems require relatively high O&M due to well, pump, and piping maintenance and the water treatment system. Poor sustainability; continual use of energy and chemicals over a long period of time (EPRI 2015) with no time advantage to reach GWPS over MNA.
Hydraulic Containment (tree wells)	Medium; the trees will not transpire (pump) during winter	Medium; the trees will not transpire (pump) during winter	Relatively easy	None	6-9 months	Estimated > 10 years[1]	None identified	**Feasible**
Permeable Reactive Barriers	Medium to high; reduces constituents to compliance levels downgradient of reactive barrier	Medium; reactive media will need to be replaced periodically	Medium due to trenching	May alter groundwater flow hydraulics beneath and adjacent to the Site, could be evaluated with groundwater model	12-24 months	Estimated > 10 years	None identified	**Not recommended** due to the geometry of the impacts (discrete isolated areas); potentially changing groundwater flow direction such that the PRB wall would be constructed upgradient of the impacts; and periodic replacement of the reactive media as it becomes spent or clogged.
Barrier Walls (in conjunction with PRBs)	Relatively high; many successful case histories over decades	Relatively high due to minimal need for O&M or replacement	Medium due to trenching or other emplacement methods	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. > 10 years for PRB walls and hydraulic containment	None identified	**Not recommended** due to being contingent on companion technology; see PRB discussion above.

Technology	Evaluation Criteria							Correction Action Feasibility
	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	
Geochemical Manipulation (in situ injection, spot treatment, enhanced MNA)	Medium	Medium; site geochemical conditions need to be maintained to prevent rebound	Relatively easy due to minimal infrastructure (e.g., injection wells or direct push)	Constituents may be mobilized initially upon injection before ultimate immobilization	12-24 months	Estimated 5 to 10 years (for small, localized areas)	State Underground Injection Control permit may be required	**Feasible**
Permeation Grouting	Medium; grout may not be able to penetrate sufficient pore spaces in the areas of impact; grain size at this site may be too fine	Medium	Medium	Will alter groundwater flow hydraulics beneath and adjacent to the Site	12-24 months	Estimated 1 to 5 years after implementation	None identified	**Not Recommended** due to areas of silt and clay in the surficial aquifer, which would impede the flow of grout into pore spaces.
In Situ Solidification/Stabilization	High; many successful case histories over decades	High; little O&M after initial implementation	Medium; requires subsurface work with heavy equipment	Initial increase in COI concentrations due to subsurface disruption; concentrations expected to decrease in a relatively short time period	12-24 months	Estimated 1 to 5 years after implementation	None identified	**Feasible**

Notes:
1. Time frames shown are estimated based on case histories of hydraulic containment of arsenic-impacted sites. Detailed estimate of time requires further investigation.
COI: constituents of interest
GWPS: groundwater protection standards
MNA: monitored natural attenuation
NPDES: National Pollutant Discharge Elimination System
O&M: operation and maintenance
PRB: permeable reactive barrier

References:
Electric Power Research Institute (EPRI), 2015. *Corrective Action for Closed and Closing Ash Ponds*. 3002006292. December 2015..
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.
Southern Company, 2020. *2020 Annual Groundwater Monitoring and Corrective Action Report*. Alabama Power Company, Plant Barry Ash Pond, January 31, 2020.