June 2021

Semi-Annual Remedy Selection and Design Progress Report
Plant Barry

Prepared for Alabama Power Company

June 2021

Semi-Annual Remedy Selection and Design Progress Report Plant Barry

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: 201114-01.02

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
Kd	partition coefficient
MNA	monitored natural attenuation
SEM	scanning electron microscopy
Site	Ash Pond at Plant Barry
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. 18-094-GW, this *Semi-Annual Remedy Selection and Design Progress Report* has been prepared for the Ash Pond at Plant Barry (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 June 2019, Alabama Power Company (Alabama Power) completed an Assessment of Corrective Measures (ACM; Anchor QEA 2019) to address the occurrence of arsenic and cobalt 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 walls
- Vertical barrier walls
- Geochemical manipulation via injections (i.e., enhanced natural attenuation)

As required by the Administrative Order, MNA was proposed as the main groundwater corrective action remedy for the Site. Source control measures consisting of consolidation, dewatering, and capping of the ash (source) were already planned as part of pond closure. A selection of closure design drawings is included in Appendix A.

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 completed to evaluate and demonstrate MNA and geochemical manipulation as corrective measures at the Site. As shown in Table 1, the MNA investigations during the previous reporting period primarily supported 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 were used to perform geochemical modeling, which predicted attenuating species under Site geochemical conditions. Well solids were analyzed to determine attenuating phases for the constituents of interest (COI; arsenic and cobalt) at the Site. Solids analysis also provides insight into the stability of the attenuating mechanisms.

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; area 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	Satisfied
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	Satisfied (inferred from identified attenuation mechanisms) Batch tests 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)	Satisfied

Investigations during the current reporting period were 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 batch uptake (uptake isotherm) laboratory experiments to determine capacity, rates, and stability of MNA. Soil and groundwater characterization and batch uptake 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*.

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, laboratory analysis of groundwater and precipitates (attenuating solids) was conducted to support MNA and geochemical manipulation. The major rationale for these investigations includes the following:

- Identifying attenuating mechanisms
- Gaining an understanding of the stability of the attenuating mechanisms
- Identifying potential geochemical manipulation approaches for COI based on Site geochemical conditions and attenuation processes already occurring naturally

To support these investigations, the following field and laboratory investigations were performed in previous reporting periods:

- 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)
- Performed geochemical modeling using the U.S. Geological Survey computer program PHREEQC with the WATEQ4F thermodynamic database
- Collected precipitate (solid) samples from the bottom of monitoring wells
- Analyzed precipitate samples by X-ray fluorescence (XRF) and X-ray diffraction (XRD)
- Directly observed attenuating mineral phases by scanning electron microscopy (SEM)
- Determined association of COI with attenuating phases, determined relative strength of attenuation, and provided a sense of permanence by selective sequential extraction (SSE)
- Assessed ion exchange as an attenuation mechanism by cation exchange capacity (CEC)
- Analyzed the laboratory data described above to develop a geochemical CSM and to evaluate MNA and geochemical manipulation

Results from existing groundwater data analysis, geochemical modeling, and well solids analyses provide multiple lines of evidence for attenuation mechanisms for arsenic and cobalt, as summarized in Table 2. The attenuating mechanisms identified include sorption-coprecipitation on iron oxides, cation exchange on clays, coprecipitation in carbonate minerals, and incorporation of arsenic in barium arsenate. Supporting data for Table 2 and the geochemical CSM are provided in previous progress reports (Anchor QEA 2020a, 2020b).

Table 2
Geochemical Evidence for Attenuation Mechanisms for Arsenic and Cobalt

Mechanism	Geochemical Modeling	XRF	XRD	SSE	CEC
Sorption on iron oxides (arsenic and cobalt)	X	X	X	X	
Cation exchange on clays (cobalt)			X	X	X
Coprecipitation in iron oxides and/or carbonates (arsenic and cobalt)	X	X	X	X	
Precipitation in barium arsenate (arsenic)	X			X	

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 2019), completing a final long-term corrective action plan is often a multi-year process.

During the current reporting period, soil (aquifer) and groundwater samples were collected and analyzed to conduct batch uptake (uptake isotherm) laboratory experiments to determine capacity, rates, and stability of MNA. Flow-through column tests may also be used to determine capacity, rates, and stability and are often more efficient for multiple COI. However, due to the relatively low concentrations of arsenic and cobalt in groundwater at the Site, breakthrough in columns may take a long time. Therefore, batch studies were selected.

Soil samples were collected from locations included in Table 3 from March 16 to 22, 2021. Groundwater samples were collected from BY-AP-MW-8, BY-AP-MW-10, BY-AP-MW-15, and BY-AP-MW-15V from May 12 to 19, 2021. Soil and groundwater sampling locations are shown in Figure 1. Note that delineation wells are not compared to groundwater protection standards (GWPS) and are therefore not included as statistically significant levels in Figure 1.

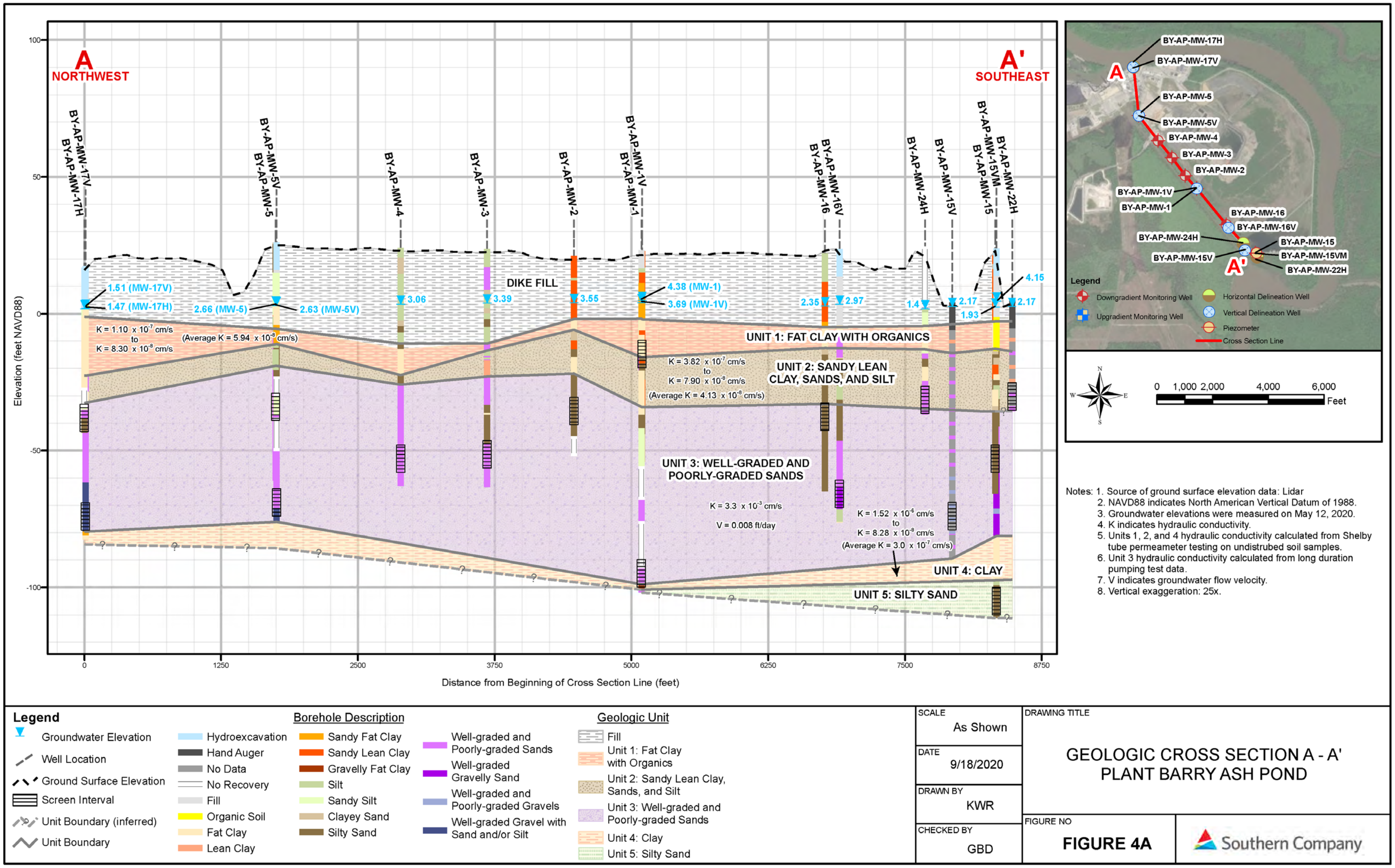
Table 3
Soil (Aquifer Solids) Sampling Locations

Soil Sample ID	Adjacent Monitoring Well(s)	Soil Sample ID	Adjacent Monitoring Well(s)
1A	BY-AP-MW-7, BY-AP-MW-7V, BY-AP-MW-23H	4A	BY-AP-MW-12, BY-AP-MW-12V, BY-AP-MW-20H
1B		4B	
1C		4C	
2A	BY-AP-MW-8, BY-AP-MW-8V, BY-AP-MW-18H	5A	BY-AP-MW-15, BY-AP-MW-15V, BY-AP-MW-24H
2B		5B	
3A	BY-AP-MW-10, BY-AP-MW-10V, BY-AP-MW-19H	5C	
3B		6	BY-AP-MW-3

Figure 1
Soil and Groundwater Sampling Locations

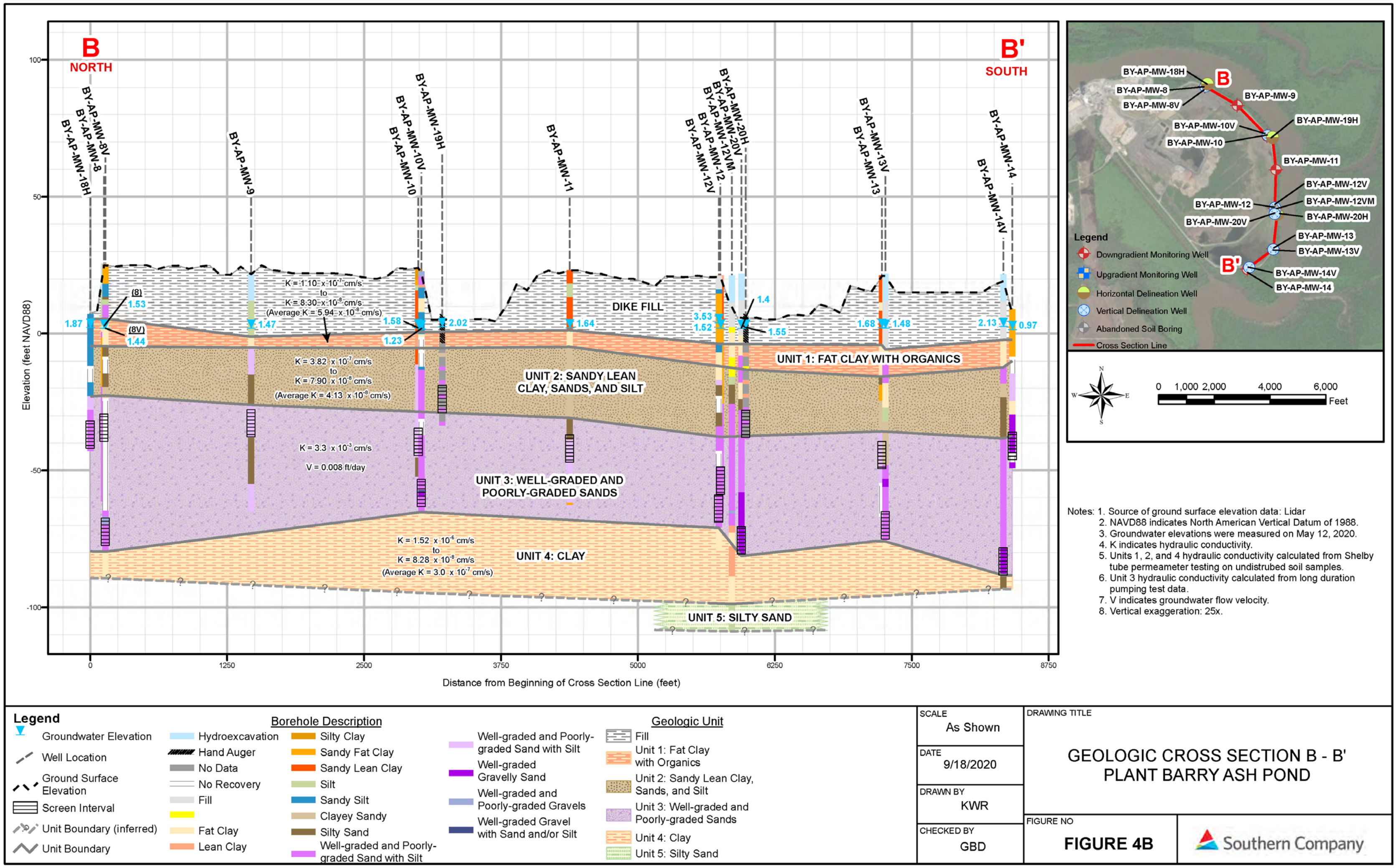
Soil samples were collected using sonic drilling technology at six locations (14 borings) at the Site: one location upgradient and five locations along potential groundwater flow paths (downgradient) from the CCR unit. Two composite soil samples were collected per boring: one from Unit 2 (sandy lean clay, sands, and silt) and one from Unit 3 (well-graded to poorly graded sands). Geologic cross sections are show in Figures 2 and 3. Photographs of representative soil samples are shown in Figure 4. 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 batch uptake experiments.

Figure 2
Geologic Cross Section A-A’



Source: SCS 2020

Figure 3
Geologic Cross Section B-B′



Source: SCS 2020

Figure 4
Representative Soil Samples

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 batch uptake experiments.

Characterization of the soil samples is ongoing and will consist of the following analyses: grain size, XRF, XRD, SEM, CEC, and SSE. Results from these analyses will be used to select discrete samples for batch uptake experiments. Concentrations of COI in groundwater will be measured prior to beginning the batch uptake experiments.

Batch uptake (uptake isotherm) laboratory experiments will be performed to determine the attenuating capacity of the aquifer. Groundwater will be reacted with variable amounts of aquifer solids (soil) to determine the partitioning and mass of COI that can be taken up per unit mass of aquifer solids over a range of liquid-to-solid ratios to determine the COI attenuation capacity of aquifer solids. The attenuation capacity will then be scaled up to the total volume of the aquifer (within a defined area) to determine the aquifer capacity for COI attenuation.

The batch uptake experiments will be performed according to ASTM International Standard C1733-20 (Standard Test Method for Distribution Coefficient of Inorganic Species by Batch Method) or a modified C1733-20 method. This is a commonly used method for determining Kd (partition coefficient); however, the objective will be to determine the actual mass taken up (sorbed and/or precipitated) by the soils, not the soil-water distribution ratio (Kd).

Concentrations of COI in groundwater will be measured prior to beginning the experiments. Soil and groundwater will be mixed over a range of liquid-to-solid ratios (preferred) or, alternatively, by spiking the samples to increase COI loading. Samples will be agitated, typically for 24 hours, and then centrifuged. COI in the liquid portion will be measured to determine the mass taken up by the soil. Representative solid samples will be retained for SSE. The SSE will provide information on the mechanism(s) and stability of COI uptake during the batch test experiments and presumably in the aquifer.

Based on the results of the batch uptake tests, 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 batch test results will be used to constrain key model parameters including concentration(s) of sorbing phases. Because the CCR unit is closing, no additional COI mass will be added to the aquifer system, which can be simulated through time.

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 2019) was updated based on a more detailed analysis of site-specific conditions (Appendix B).

After more detailed evaluation in the context of site-specific conditions, the following technologies are recommended for additional evaluation: MNA and geochemical manipulation via injection (enhanced MNA). Hydraulic containment (pump-and-treat) and permeable reactive barrier walls (including associated conventional barrier 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 cobalt 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 cobalt 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 is not recommended for the following reasons:

- Inefficiency due to groundwater not requiring treatment being drawn to the pumping wells
- High operation and maintenance requirements
- Long time required to achieve GWPS, likely beyond the post-closure period of 30 years
- 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).

Permeable reactive barrier walls, and associated impermeable barrier walls, are not recommended for further evaluation because: 1) difficulty of construction to the bottom of the Unit 3 aquifer (greater than about 90 feet); 2) periodic replacement of the reactive media for a permeable reactive barrier wall, as the media becomes spent or clogged; and 3) inability to address impacted groundwater down-gradient of the wall installation.

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 (enhanced MNA)), and possibly other corrective action technologies:

- Complete laboratory work to determine MNA capacity, rates, and stability
- 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
- Continue to determine how corrective actions could be integrated with pond closure, such as dewatering and associated water treatment systems

Though substantial evidence for natural attenuation exists for the Site (Section 2), natural attenuation is expected to increase as source control measures are implemented (i.e., dewatering, consolidation, and capping). MNA will almost certainly be one component, if not the only component, of corrective action. MNA could be implemented immediately upon pond closure, or prior to pond closure, provided the changing, dynamic conditions of the groundwater system are taken into account.

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

- Prepare a Remedy Selection Report by October 31, 2021
- Develop a Corrective Action Groundwater Monitoring Program by January 29, 2022

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). The adaptive site management approach and adaptive triggers will be discussed in the Corrective Action Groundwater Monitoring Program description.

4 References

Anchor QEA (Anchor QEA, LLC), 2019. *Assessment of Corrective Measures.* Plant Barry Ash Pond. Prepared for Alabama Power Company. June 2019.

Anchor QEA, 2020a. *Semi-Annual Remedy Selection and Design Progress Report.* Plant Barry Ash Pond. Prepared for Alabama Power Company. June 2020.

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

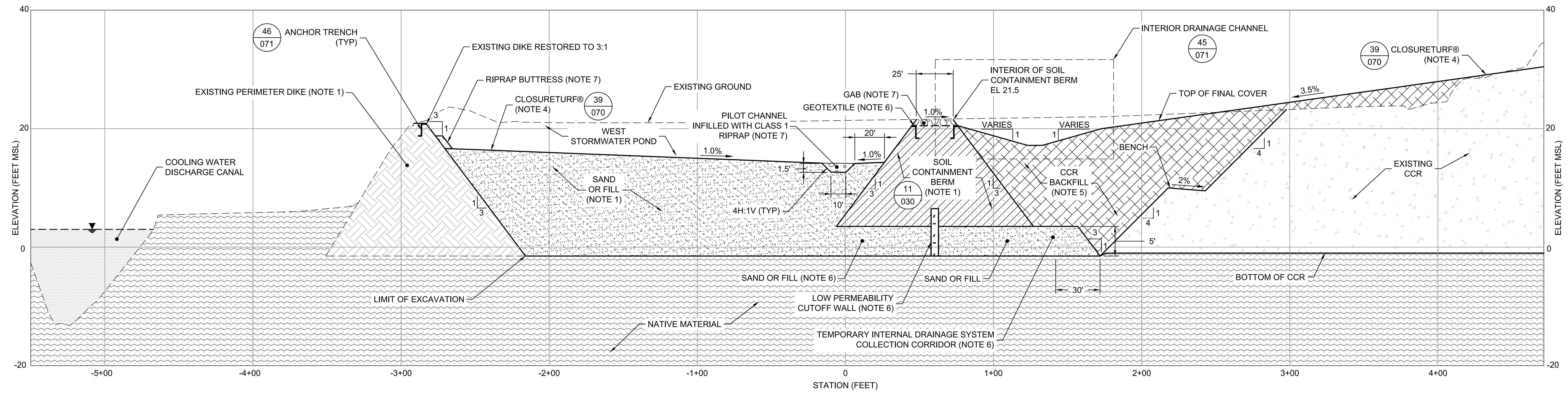
EPA (U.S. Environmental Protection Agency), 1999. *Use of Monitored Natural Attenuation of Superfund, RCRA Corrective Action, and Underground Storage Tank Sites.* Office of Solid Waste and Emergency Response. EPA/OSWER No. 9200.4-17P. April 1999.

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.

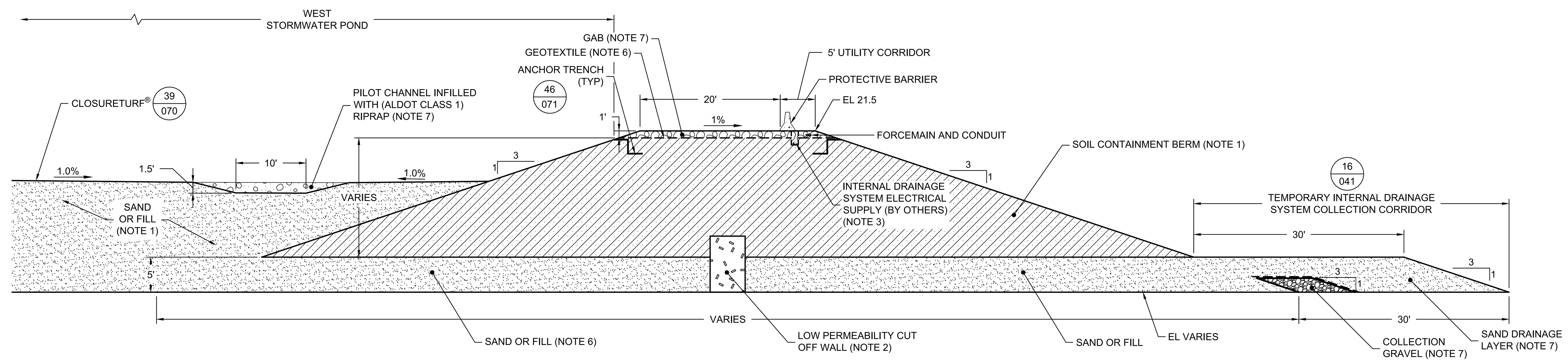
EPRI (Electric Power Research Institute), 2015. *Corrective Action for Closed and Closing Ash Ponds*. Final Report. 3002006292. December 2015.

SCS (Southern Company Services, Inc.), 2020. *Semi-Annual Progress Report and Groundwater Delineation Report.* Plant Barry. Prepared for Alabama Power Company. September 30, 2020.

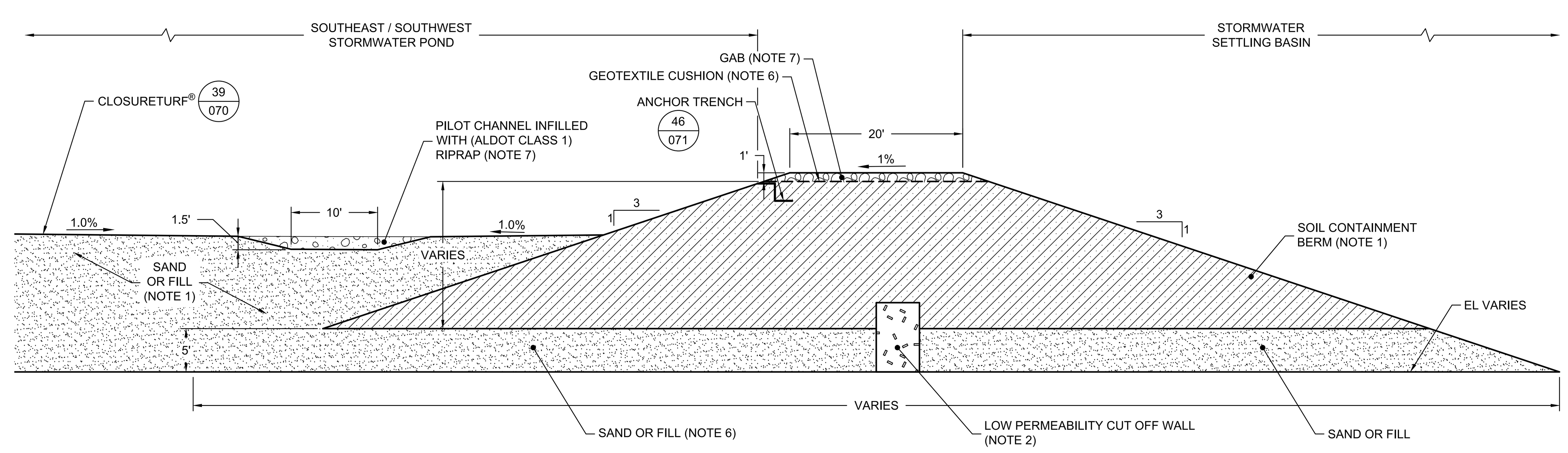
Appendix A
Plant Barry CCR Pond Closure Information



10 / 018 DETAIL
CONTAINMENT SYSTEM
SCALE: 1" = 40' (H); 1" = 10' (V)



11 / 006 DETAIL
SOIL CONTAINMENT BERMS A AND B
SCALE: 1" = 10'



12 / 006 DETAIL
SOIL CONTAINMENT BERM C
SCALE: 1" = 10'

NOTES:

1. FILL MATERIALS FOR THE STORMWATER PONDS AND THE SOIL CONTAINMENT BERM SHALL BE IN ACCORDANCE WITH TECHNICAL SPECIFICATION SECTION 31 23 00.
2. THE METHODS TO PROVIDE HYDRAULIC CONTAINMENT OF THE SOIL CONTAINMENT BERM ARE UNDER CONSIDERATION WITH SCS/APC/TA AND WILL BE OPTIMIZED DURING LATER DESIGN STAGES.
3. APC TO PROVIDE ELECTRICAL SOURCE FOR INTERNAL DRAINAGE SYSTEM ELECTRICAL SUPPLY. CURRENT ALIGNMENT ASSUMES 13.2 KILOVOLT SUPPLY AND DISTRIBUTION TRANSFORMERS AT EACH COLLECTION POINT ARE PROVIDED BY APC.
4. CLOSURETURF SHALL BE IN ACCORDANCE WITH TECHNICAL SPECIFICATION SECTION 31 35 19.
5. EARTHWORK SHALL BE IN ACCORDANCE WITH TECHNICAL SPECIFICATION SECTION 31 23 00.
6. GEOTEXTILE SHALL BE IN ACCORDANCE WITH TECHNICAL SPECIFICATION SECTION 31 05 19.13.
7. AGGREGATE SHALL BE IN ACCORDANCE WITH TECHNICAL SPECIFICATION SECTION 31 05 16.

REV	DATE	DESCRIPTION	DRN	APP
C	12.03.18	DRAFT 90 PERCENT DESIGN DRAWINGS FOR SCS REVIEW	CT	CG
B	08.27.18	DRAFT 60 PERCENT DESIGN DRAWINGS FOR SCS REVIEW	CT	CG
A	04.30.18	DRAFT 30 PERCENT DESIGN DRAWINGS FOR SCS REVIEW	CT	CG

SCB DETAILS

PLANT BARRY CCR POND CLOSURE
MOBILE COUNTY, ALABAMA

SEAL

90 PERCENT DESIGN DRAWING
NOT FOR CONSTRUCTION

Geosyntec consultants
1255 ROBERTS BOULEVARD NW, SUITE 200
KENNESAW, GEORGIA 30144-3694
PHONE: 678.202.9500
WWW.GEOSYNTEC.COM

PROJ. NO.	GW6489	DWG. GW6489.04C029	SHEET 1
SCALE	AS SHOWN	DRAWING 030 OF 99	
DATE	DECEMBER 2018		

Appendix B
Plant Barry Groundwater Corrective Action Evaluation Summary

Table B-1
Plant Barry 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 sandy aquifer	High due to little O&M and other potential repair needs	Easy due to minimal infrastructure (e.g., monitoring wells) needed to implement remedy	None	18-24 months	Estimated > 30 years[1]	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 and due to changing hydraulic and COI loading conditions during pond closure dewatering and consolidation	Pumping could impact water supply wells, if present; hydraulic containment would likely result in pumping of water not requiring treatment	12-24 months	Estimated > 30 years[1]	Needs to be compatible with Site NPDES permit; would potentially need to permit withdrawals from the impacted aquifer and potentially from areas not requiring treatment	**Not recommended** due to inefficiency, high O&M requirements, long time to achieve groundwater protection standards, and low sustainability (excessive use of resources). System would likely reverse the groundwater gradient such that groundwater not requiring treatment may be drawn into the pumping wells and treated. 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.
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	Moderate to moderately difficult due to the depth of the wall; depths for PRBs are limited to about 90 feet, or the depth a trench can be kept open (ITRC 2005); funnels must be tied into a confining bed or low hydraulic conductivity unit to avoid having impacted water flow under the wall (EPRI 2015). The depth to the bottom of the aquifer (i.e., to the clay layer in Unit 4) is greater than 90 feet below existing ground surface in many locations along the Waste Boundary where a PRB has been proposed (Southern Company 2020).	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	**Not recommended** due to difficulty of constructing to the bottom of the impacted aquifer, periodic replacement of the reactive media as it becomes spent or clogged, and inability to address impacted groundwater down-gradient of the wall installation.
Barrier Walls (in conjunction with PRB gates)	High	High due to minimal need for O&M or replacement	Contingent on companion technology, i.e., moderate to moderately difficult; see PRB implementation discussion	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	**Not recommended** due to being contingent on companion technology; see PRB implementation 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	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	**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, DC.
Southern Company, 2020. *2020 Annual Groundwater Monitoring and Corrective Action Report*. Alabama Power Company, Plant Barry Ash Pond, January 31, 2020.