Assessment of Corrective Measures TVA Colbert Fossil Plant, Tuscumbia, Alabama

July 15, 2019

Prepared for:

Tennessee Valley Authority
Chattanooga, Tennessee

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This document entitled Assessment of Corrective Measures TVA Colbert Fossil Plant, Tuscumbia, Alabama was prepared by Stantec Consulting Services Inc. ("Stantec") for the account of Tennessee Valley Authority (TVA; the "Client").

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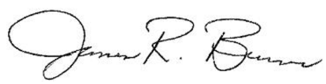
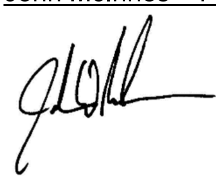


Approved by: John McInnes – Principal Geologist



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Abbreviations

ACM	Assessment of Corrective Measures
ADEM	Alabama Department of Environmental Management
CCR	Coal combustion residuals
CFR	Title 40, Code of Federal Regulations
COF	Colbert Fossil Plant
COI	Constituent of interest
CSM	Conceptual site model
CY	Cubic yards
EIS	Environmental Impact Statement
EIST	Enhanced In-Situ Treatment
GWPS	Groundwater Protection Standard(s)
HSU	Hydro-stratigraphic unit
MNA	Monitored Natural Attenuation
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
PRB	Permeable reactive barriers
ROD	Record of Decision
SSL	Statistically Significant Level
SSLs	Statistically Significant Levels
TVA	Tennessee Valley Authority
U.S. EPA	United States Environmental Protection Agency

Executive Summary

On April 17, 2015, the United States Environmental Protection Agency (U.S. EPA) published a rule that sets forth national criteria for the management of coal combustion residuals (CCR) produced by electric utilities. The requirements can be found in Title 40, Code of Federal Regulations (40 CFR) Part 257. The rule includes requirements for monitoring groundwater and assessing corrective measures if constituents listed in Appendix IV of the rule are detected in groundwater samples collected from downgradient monitoring wells at statistically significant levels (SSLs) greater than established groundwater protection standards (GWPS).

In January 2019, the Tennessee Valley Authority (TVA) completed an evaluation of whether there were SSLs over GWPS established under 40 CFR § 257.95(h) for one or more Appendix IV constituents in accordance with 40 CFR § 257.95(g) at the Ash Disposal Area 4 (also known as Ash Pond 4) at the Colbert Fossil Plant (COF). During Assessment Monitoring, two SSLs, one for arsenic and one for cobalt, were identified at wells COF-105 and COF-102, respectively. As of the date of this report, TVA has not completed a demonstration that a source other than the CCR unit associated with wells COF-105 and COF-102 at COF caused the SSLs, as allowed under 40 CFR § 257.95(g)(3)(ii).

In accordance with 40 CFR § 257.96(a), TVA prepared this 2019 Assessment of Corrective Measures (ACM) Report for the Ash Disposal Area 4 CCR Unit, at COF. This ACM Report provides an assessment of the effectiveness of potential corrective measures by addressing the criteria provided in 40 CFR § 257.96(c). Ash Disposal Area 4 is monitored by a CCR Rule groundwater monitoring well network of one upgradient well and four downgradient wells.

Three primary strategies have been evaluated to address groundwater exhibiting concentrations of arsenic and cobalt above the GWPS. These strategies include Monitored Natural Attenuation (MNA), Hydraulic Containment and Treatment, and Enhanced In-Situ Treatment (EIST).

Following preparation of this ACM Report, the remedy selection process will begin to select a remedy that meets the requirements of 40 CFR § 257.97(b) and § 257.97(c). TVA is preparing this ACM report to comply with 40 CFR § 257.96.

At least 30 days prior to when the final remedy is selected, a public meeting will be held with interested and affected parties to discuss the results of the corrective measures assessment in accordance with 40 CFR § 257.96(e). Semi-annual reports will be prepared pursuant to 40 CFR § 257.97(a) to document progress toward remedy selection and design. TVA will continue to review new data as it becomes available and implement changes to the groundwater monitoring and corrective action program as necessary to maintain compliance with 40 CFR § 257.90 through § 257.98.

1.0 INTRODUCTION

This Assessment of Corrective Measures (ACM) Report has been prepared to meet the requirements in the United States Environmental Protection Agency (U.S. EPA) Coal Combustion Residuals (CCR) Rule, 40 CFR § 257.96. During assessment monitoring when at least one constituent listed in Appendix IV of the CCR Rule is detected at a statistically significantly level (SSL) above a site-specific groundwater protection standard (GWPS) established pursuant to 40 CFR § 257.95(h), and the owner/operator has been unable to demonstrate that a source other than the CCR unit or an error caused the SSL, the owner/operator must initiate an ACM. At the Tennessee Valley Authority (TVA) Colbert Fossil Plant (COF) Ash Disposal Area 4 (also known as Ash Pond 4) (hereinafter CCR Unit), groundwater assessment monitoring detected an SSL above GWPS of arsenic at monitoring well COF-105 and an SSL for cobalt at COF-102. TVA initiated an ACM on April 15, 2019. This report documents the completion of the required ACM and discusses potential corrective measures as required under the CCR Rule. For purposes of this report, any SSL of Appendix IV constituents over GWPS will be defined as a constituent of interest (COI).

1.1 OVERVIEW OF CCR RULE REQUIREMENTS FOR ACM IN 40 CFR § 257.96

Section 257.96(a) of the CCR Rule requires that, within 90 days of determining an SSL exceeds a GWPS of an Appendix IV constituent, the owner/operator must initiate an ACM to prevent further releases, to remediate any releases, and to restore the affected area to original conditions. The ACM report must be completed within 90 days of initiating the ACM unless the owner/operator demonstrates that an extension of no longer than 60 days is needed due to site-specific conditions or circumstances. A qualified professional engineer must certify the accuracy of the extension demonstration. The certified demonstration must be included in the annual groundwater monitoring and corrective action report required by 40 CFR § 257.90(e). TVA did not seek an extension for completing the ACM.

The CCR Rule requires that the ACM report under 40 CFR § 257.96(a) must include an analysis of the effectiveness of potential corrective measures in meeting the requirements and objectives of the remedy. More specifically, 40 CFR § 257.96(c) provides that:

The assessment under paragraph (a) of this section must include an analysis of the effectiveness of potential corrective measures in meeting all of the requirements and objectives of the remedy as described under 40 CFR § 257.97 addressing at least the following:

(1) The performance, reliability, ease of implementation, and potential impacts of appropriate potential remedies, including; safety impacts, cross-media impacts, and control of exposure to any residual contamination;

(2) The time required to begin and complete the remedy; and

(3) The institutional requirements such as state and local permit requirements or other environmental or public health requirements that may substantially affect implementation of the remedy(s).

Potential corrective measures to be considered for the CCR Unit are generally discussed in Section 4.0, **Appendix A**, and **Appendix B** of this report.

1.2 OVERVIEW OF CCR RULE REQUIREMENTS FOR REMEDY SELECTION IN 40 CFR § 257.97

Once the ACM report is complete, the process for selecting a remedy will commence. The owner/operator must select a remedy that, at a minimum, meets the requirements of 40 CFR § 257.97(b) and must consider the evaluation factors set forth in 40 CFR § 257.97(c). In addition, at least 30 days prior to the selection of the remedy, the owner/operator must discuss the results of the corrective measures assessment in a public meeting required by 40 CFR § 257.96(e). The owner/operator must also provide a schedule for implementing the selected remedy that takes into account the factors set forth in 40 CFR § 257.97(d).

After the ACM report is completed and before the remedy is selected, 40 CFR § 257.97(a) requires semi-annual reports to be prepared describing the progress in selecting and designing the remedy. The CCR Rule contemplates that more investigation and consideration may be needed to evaluate and design the remedy before making the final selection. Once a final remedy is chosen, a final report describing the remedy and how it meets the standards set forth in 40 CFR § 257.97(b) will be prepared.

As part of an agreement with the Alabama Department of Environmental Management (ADEM), TVA is required to submit a separate ACM report to ADEM to address groundwater in the vicinity of Ash Stack 5 as well as Ash Disposal Area 4 (also known as Ash Pond 4). Consequently, the potential corrective measures evaluated and potentially selected under each ACM may overlap or supplement each other, as appropriate, and the schedules for implementation may vary. Despite differences, both ACMs focus on assessing and evaluating corrective measures at COF that are protective of human health and the environment.

2.0 BACKGROUND

COF is located in Tuscumbia, Colbert County, Alabama. The facility lies on the south bank of the Tennessee River approximately 12 miles west of the center of the City of Tuscumbia. COF ceased coal burning operations on March 23, 2016, and Ash Disposal Area 4 was closed in-place with closure being deemed complete on March 6, 2018. **Figure 2-1** shows an overview map of COF, including its facilities, background and downgradient CCR monitoring wells, and Ash Disposal Area 4 (CCR Unit). When coal burning operations were active, the plant formerly managed CCR in Ash Disposal Area 4.

2.1 CCR UNIT DESCRIPTION

Ash Disposal Area 4 is the CCR unit at COF that is subject to the CCR Rule. The CCR Unit was capped and closed in-place in accordance with a closure plan developed in October 2016 in accordance with 40 CFR § 257.102(b). Closure was deemed to be complete on March 6, 2018 (AECOM, 2018). Ash Disposal Area 4 was built in 1972 and formerly received sluiced bottom ash and minor amounts of fly ash. The estimated maximum inventory of CCR over the active life of Ash Disposal Area 4 is approximately 2.6 million cubic yards (CY) (AECOM, 2016).

2.2 OVERVIEW OF OCTOBER 2016 CLOSURE PLAN

TVA began its evaluation of closure options under U.S.EPA CCR Rule by developing a programmatic *Ash Impoundment Closure Environmental Impact Statement* (EIS) to address potential environmental risks associated with CCR impoundments. The EIS is divided into two parts – Part 1 is the programmatic analysis that is generally applicable to TVA CCR impoundments and Part 2 includes an analysis of 10 site-specific ash impoundment closures, including the Ash Disposal Area 4 at COF. On August 27, 2015, TVA published a Notice of Intent (NOI) in the Federal Register that an EIS would be developed to assess risks associated with closure alternatives for existing CCR impoundments. TVA issued news releases on its website and to public media outlets and accepted public comments for 34 days until September 30, 2015.

Following this initial NOI, TVA developed a Draft EIS and posted it to the TVA website on December 30, 2015. An NOI was published in the Federal Register on January 8, 2016, and press releases were issued to public media outlets announcing availability of the EIS. The formal public comment period was initially intended to last 45 days but was extended through March 9, 2016 in response to requests for additional public and agency review time.

During the public comment period, TVA organized ten open house meetings in local communities, posted informational videos and other content on the TVA website, and issued information to state and local officials and advisory boards. Public comment was encouraged throughout the process in verbal discussions at open house meetings, written submittals on public response cards, or electronic messages through a portal on the TVA website.

The Final EIS was posted on June 10, 2016 through July 9, 2016, and the Final Record of Decision (ROD) was published on July 28, 2016. As a result of the EIS process, the decision was made to close the CCR Unit in place. A plan for closing the CCR Unit was developed in October 2016 in accordance with 40 CFR § 257.102(b). The Ash Disposal Area 4 at COF was closed in-place in accordance with the closure plan, and closure was deemed to be complete on March 6, 2018 (AECOM, 2018).

2.3 CONCEPTUAL SITE MODEL SUMMARY

The geologic and hydrogeologic conceptual site model (CSM) is one of the primary tools that can be used to support decisions on corrective measures.

2.3.1 Geology and Hydrogeology

The following sections provide a summary of the geologic and hydrogeologic CSM. The subsurface geology at COF is characterized by three hydro-stratigraphic units (HSUs). An HSU is defined as "a body of rock distinguished and characterized by its porosity and permeability" (Seaber, 1988). The HSUs relevant to this report are the Alluvial aquifer, the Residuum water-bearing unit (Residuum), and the Tuscumbia-Fort Payne Bedrock aquifer (Bedrock aquifer). A geologic cross-section of Ash Disposal Area 4 is depicted in **Figure 2-2**.

2.3.1.1 Alluvial Aquifer

The Alluvial aquifer is considered the uppermost aquifer in the area around Ash Disposal Area 4. It is composed of Pleistocene-age alluvium deposits that overlie bedrock. The Alluvial aquifer has a limited areal extent, and at COF, it is located adjacent to Cane Creek. Alluvium is a general term for clay, silt, sand, gravel or similar unconsolidated detrital material, deposited during comparatively recent geologic time by a stream or other body of running water, as a sorted or semi-sorted sediment. The alluvium near Ash Disposal Area 4 that was deposited in the incised paleochannel of Cane Creek has been observed to be as much as 45 to 50 feet thick.

A chert-rich clay residuum derived from the weathering of underlying limestone bedrock overlies the Tuscumbia Limestone. The thickness of the residuum at COF is highly variable, ranging from zero thickness (where bedrock is exposed at the surface) to 60 to 70 feet thick. The residuum unit does not yield a significant quantity of groundwater and is not used as a source of drinking water or for other general purposes.

2.3.1.2 Tuscumbia-Fort Payne Bedrock Aquifer

The Tuscumbia Fort-Payne Bedrock aquifer at COF is composed of the Tuscumbia Limestone and Fort Payne Chert. These units are light to medium gray, fine to medium-grained fossiliferous, cherty limestone and the contact between the two units is often undistinguishable. The Tuscumbia limestone contains two types of fractures: (1) horizontal fractures that occur along bedding planes, and (2) a conjugate set of high angle fractures that trend approximately N50°E and N50°W. Dissolution of the Tuscumbia limestone has resulted in the development of karst that is characterized by high secondary porosity. The dissolution features are generally oriented in the same directions as the fracture networks. Dissolution along these features results in a well-developed system of interconnected secondary porosity features (dissolution features). Wells that penetrate enlarged joint/fracture sets and bedding planes yield large quantities of water, and typically respond quickly to recharge events (i.e., rain). Wells that do not intersect with these features have lower yields and slower recharge response times.

2.3.2 Groundwater Flow Direction

The predominant groundwater flow direction at the CCR Unit in the Alluvial Aquifer is to the north/northeast, towards Cane Creek. **Figure 2-3** presents a groundwater flow direction map that was developed based on groundwater elevation data retrieved on April 22, 2019.

Recharge of the Alluvial aquifer and Residuum throughout the area occurs via direct infiltration of rainfall. The Residuum has very low hydraulic conductivity and therefore serves as an aquitard which prevents vertical migration to the Alluvial aquifer. Conversely, the Alluvial aquifer has relatively high conductivity and is in close proximity to Cane Creek, which is a gaining stream.

As is shown in **Figure 2-3**, groundwater flow direction in the Alluvial aquifer at the CCR Unit is towards Cane Creek; given the CCR Unit monitoring well network is generally located west-southwest of Cane Creek, flow direction is to the east-northeast.

2.3.3 Potential Receptor Review

Although private groundwater wells have been identified in the area of COF, the area is served by municipal water supply. Water use surveys conducted in 1993 and 2003 indicated that private wells near COF were used generally as backup water supplies and/or for purposes other than drinking water, such as lawn/garden irrigation and car washing. Depths of private wells identified by the 2003 survey range from 136 to 265 feet, suggesting that the wells were completed in the Tuscumbia-Fort Payne aquifer. No industrial or commercial groundwater production wells were identified within five miles of COF.

Groundwater monitoring wells have been installed around the perimeter of the COF facility as part of additional environmental investigations recently conducted. Data from these wells indicate that COIs are not migrating off site to adjacent properties.

3.0 GROUNDWATER ASSESSMENT MONITORING PROGRAM

Groundwater assessment monitoring has been conducted at COF in accordance with 40 CFR § 257.95.

3.1 GROUNDWATER MONITORING NETWORK

In compliance with 40 CFR § 257.91, one background well (CA5) was established upgradient and four monitoring wells (COF-102, COF-104, COF-105, and COF-106) were installed downgradient of the CCR unit. The locations of these monitoring wells are presented on **Figure 2-1**.

3.2 GROUNDWATER ASSESSMENT

Groundwater assessment monitoring was conducted during 2018. The following Appendix IV constituents were detected at an SSL above a GWPS:

- An SSL for arsenic was identified at monitoring well COF-105;
  - The maximum concentration of arsenic detected in 2018 was 0.052 milligrams per liter (mg/L); and
  - The GWPS for arsenic is 0.010 mg/L.
- An SSL for cobalt was identified at monitoring well COF-102;
  - The maximum concentration of cobalt detected in 2018 was 0.039 mg/l; and
  - The GWPS for cobalt is 0.006 mg/L.

3.3 GROUNDWATER CHARACTERIZATION

Groundwater data obtained from monitoring wells proximal to COF-105 and COF-102 were used as the basis to initially characterize the horizontal and vertical extents of Appendix IV SSLs in groundwater. Data from both CCR and non-CCR monitoring wells (shown on **Figure 3-1**) were considered in this initial characterization of the nature and extent of the release as required by 40 CFR § 257.95(g)(1).

The horizontal extent of arsenic concentrations above the GWPS observed at monitoring well COF-105 are initially defined by monitoring wells COF-102 to the south, and COF-104 to the north. The vertical extent of arsenic was evaluated through analysis of samples from monitoring wells COF-112BR, CA30B and CA13. These wells are screened in the underlying Tuscumbia limestone bedrock aquifer and do not exhibit arsenic concentrations above the GWPS. The extent of arsenic impacts is provided in **Figure 3-1**.

The horizontal extent of cobalt concentrations above the GWPS observed at monitoring well COF-102 are defined by monitoring wells CA5 to the south and COF-105 to the north. The vertical extent of cobalt was evaluated through analysis of samples from monitoring wells COF-115BR and CA30B. These wells are screened in the underlying Tuscumbia limestone bedrock aquifer and do not exhibit cobalt concentrations above the GWPS. The extent of cobalt impacts is provided in **Figure 3-1**.

Supplemental groundwater characterization (including installation and monitoring of multiple wells in the vicinity of the CCR unit is being conducted to further refine the characterization of the nature and extent of Appendix IV constituents exhibiting an SSL above GWPS. The investigation activities are being conducted as part of work plans overseen by ADEM. The results of these investigations will be considered during the remedy selection process for the CCR Unit. Additional supplemental characterization may include the following:

- Refining the extent of arsenic above GWPS northwest of COF-105 along the perimeter of the CCR Unit;
- Refining the characterization of the extent of cobalt above GWPS west of COF-102 along the perimeter of the CCR Unit;
- Evaluating the groundwater flow and transport proximal to Cane Creek; and
- Sampling of any new wells installed for purposes of evaluating and designing a remedy.

3.4 SUMMARY OF ALTERNATE SOURCE DEMONSTRATION

At this time, an alternate source demonstration has not been completed at COF for the arsenic and cobalt SSLs at wells COF-105 and COF-102, respectively.

4.0 ASSESSMENT OF CORRECTIVE MEASURES

Section 257.96(a) of the CCR Rule requires that, within 90 days of determining an SSL exceeding a GWPS of an Appendix IV constituent, the owner/operator must initiate an ACM to prevent further releases, to remediate any releases, and to restore the affected area to original conditions.

Groundwater assessment monitoring conducted for the CCR Unit indicates that arsenic was present at an SSL above the GWPS as defined in 40 CFR § 257.95(h) at monitoring well COF-105 and cobalt was present at an SSL above the GWPS at monitoring well COF-102. As discussed in Section 3.3, additional groundwater characterization will be conducted during the remedy selection process.

This section of the report provides an ACM to address groundwater exhibiting arsenic and cobalt above the GWPS.

4.1 ANALYSIS OF CORRECTIVE MEASURES

The objective of the ACM is defined in 40 CFR § 257.96(a) and consists of preventing further releases, remediating any releases, and restoring the affected area to original conditions.

An assessment of corrective measures to address Appendix IV SSLs has been initiated in accordance with 40 CFR § 257.96(a), and an analysis of potential corrective measures is being conducted in accordance with 40 CFR § 257.96(c).

4.2 CCR UNIT CLOSURE STATUS

The objectives of corrective measures under 40 CFR § 257.96(a) are to “prevent further releases [from the CCR Unit], to remediate any releases, and to restore affected areas to original conditions.” Ultimately, in accordance with 40 CFR § 257.97(b)(3), the selected corrective measure must at a minimum “[c]ontrol the source(s) of releases so as to reduce or eliminate, to the maximum extent feasible, further releases of constituents of Appendix IV to this part into the environment.” The Preamble (80 Fed. Reg. 21302, 21406) to the CCR Rule discusses that source control measures may include modifying operational procedures. As COF ceased generating electricity in 2016, TVA closed and capped the CCR Unit at COF. Ground surface of the CCR Unit has been restored with a vegetative cover.

The Ash Disposal Area 4 CCR Unit was closed in-place in accordance with 40 CFR § 257.102(d). Capping of the CCR Unit significantly inhibits storm water infiltration and reduces the potential for further migration of COIs. The completed closure and capping of the CCR Unit serves as source control measures as required under 40 CFR § 257.97(b)(2). Continued assessment monitoring to be conducted during the remedy selection process will track changes in groundwater conditions as a result of closure. It may take time before the effects of closure are reflected in the monitoring data. This data will also be considered in the selection of a remedy in accordance with 40 CFR § 257.97.

Since closure of the Ash Disposal Area 4 CCR Unit serves as a source control measure, the remedial technologies considered in the following sections are focused on addressing the area of groundwater exhibiting arsenic and cobalt at concentrations above the GWPS. Furthermore, the process for selecting a remedy includes continued evaluation of groundwater monitoring data collected after closure of the CCR unit was deemed complete in March 2018. These data findings will inform decision making related to timing, scope, and necessity of both potential interim actions, if necessary, and the selection of a groundwater remedy. Initial groundwater monitoring data collected after closure of Ash Disposal Area 4 exhibits a visibly decreasing trend for cobalt in COF-102. This initial trend suggests that closure is supporting improved groundwater conditions for cobalt.

Groundwater monitoring continues under assessment monitoring until selection of a remedy. After selection of the remedy, a Corrective Action Groundwater Monitoring Program in accordance with 40 CFR 257.98(a)(1) will be established and continue until GWPS are achieved as defined in 40 CFR § 257.98(c)(2).

4.3 POTENTIAL REMEDIAL TECHNOLOGIES

This ACM provides an evaluation of potential remedial technologies to address SSLs observed at monitoring wells COF-105 and COF-102. As discussed, in Section 4.2, the CCR Unit was closed in-place in March 2018 in accordance with 40 CFR § 257.102(d). In addition to this source control measure, three primary strategies have been evaluated to address groundwater exhibiting concentrations above the GWPS including the following:

- Monitored Natural Attenuation (MNA);
- Hydraulic Containment and Treatment; and
- Enhanced In-Situ Treatment (EIST).

Appendix A provides a detailed summary of each of these corrective measures.

The hydraulic containment and treatment and the EIST corrective measures both require treatment of groundwater (either in-situ or ex-situ). **Table 1** presents a summary of technologies evaluated to treat arsenic and cobalt in groundwater.

4.4 EFFECTIVENESS OF PROPOSED CORRECTIVE MEASURES

The effectiveness of each corrective measure discussed in Section 4.3 was analyzed in accordance with 40 CFR § 257.96(c). The following qualitative approach was used to compare the effectiveness of the proposed corrective measures:

- *Performance, Reliability, and Ease of Implementation* – These criteria were scored as High, Medium or Low. A High ranking indicates a corrective measure performs comparatively well in that evaluation category;

- *Potential Impacts of Potential Remedies to Safety, Cross Media Impacts, and Exposure to residual COIs* – These criteria were scored as Low Risk, Medium Risk, or High Risk. A Low Risk ranking indicates a corrective measure performs comparatively well in that evaluation category;
- *The Time Required to Begin and Completed the Remedy*: An estimate of the time frame required to begin and complete the remedy is discussed in **Appendix B**; and
- *Institutional Requirements:* State and local permit requirements and other public health requirements that may substantially affect implementation of the remedy are also discussed in **Appendix B**.

The results of the qualitative evaluation of corrective measures completed for the CCR Unit are presented in **Appendix B** and **Table B-1**.

5.0 SELECTION OF GROUNDWATER REMEDY

A remedy to address SSLs in groundwater will be selected in accordance with 40 CFR § 257.97. This section of the report summarizes additional information that is expected to be obtained and reviewed prior to selection of a remedy.

5.1 DATA REQUIREMENTS FOR DESIGN OF GROUNDWATER REMEDY

The groundwater remedy selection process will include the collection of supplemental data to fill data gaps and characterize changes in groundwater conditions following closure of the unit (i.e., source control). In addition, groundwater modeling, as appropriate, will be conducted to further evaluate the applicability of groundwater containment and treatment alternatives. The following discussion provides an overview of additional data collection and analysis to be conducted to support remedy selection.

The extent of arsenic and cobalt above GWPS has been initially characterized in accordance with 40 CFR § 257.95(g)(1) and will be further refined as additional data is obtained. The results will assist in the selection of a groundwater remedy in accordance with 40 CFR § 257.97(b) and 40 CFR § 257.97(c).

Groundwater assessment monitoring will continue in accordance with 40 CFR § 257.96(b) until the remedy is selected and the corrective action groundwater monitoring program is initiated under 40 CFR § 257.98(a)(1). Continued assessment monitoring will generate data to evaluate the effect of the closure of Ash Disposal Area 4 on groundwater concentrations and trends. These data will inform evaluation of the effectiveness of closure in controlling the source and preventing further releases. The scope and necessity of additional groundwater remedies and potential interim actions will be determined based upon analysis of data collected as part of the groundwater assessment monitoring program.

Groundwater modeling, as appropriate, will be conducted to support the basis of design for any potential remedy that involves groundwater containment and treatment. A groundwater model will be developed to define basis of design requirements for potential groundwater remedies. The basis of design parameters defined through groundwater modeling, as appropriate, can include:

- Groundwater flow velocities and flow direction;
- Groundwater extraction rates for containment remedies;
- Groundwater mounding potential resultant from installation of EIST;
- Changes in groundwater flow directions resulting from EIST installation;
- Lengths of EIST to contain release; and
- Estimated time frame to reduce concentrations of COIs to levels necessary to achieve GWPS.

Groundwater modeling can also be useful for estimating the time frame for restoring groundwater to concentration levels less than the GWPS.

As shown in **Table 1**, treatment technologies that are effective for arsenic and cobalt can include:

- Advanced Filtration;
- Chemical Precipitation;
- Co-Precipitation;
- Redox Manipulation – Oxidation/Reduction Treatment;
- Absorption (Chemical Fixation); and
- Ion Exchange.

5.2 SEMI-ANNUAL REPORTING, PUBLIC MEETING, REMEDY SELECTION, AND FINAL REPORT

Following completion of this ACM, the owner/operator must select a remedy as soon as feasible to comply with 40 CFR § 257.97(a). Progress toward the selection and design of the remedy will be documented in semi-annual reports in accordance with 40 CFR § 257.97(a).

At least 30-days prior to selecting a remedy, a public meeting to discuss the results of the corrective measures assessment will be conducted as required by 40 CFR § 257.96(e).

A final report will be generated after the remedy is selected. This final report will describe the remedy and how it meets the standards specified in 40 CFR § 257.97(b) and 257.97(c).

Recordkeeping requirements specified in 40 CFR § 257.105(h), notification requirements specified in 40 CFR § 257.106(h), and internet requirements specified in 257.107(h) will be complied with as required by 40 CFR § 257.96(f).

6.0 REFERENCES

AECOM. (2016). *History of Construction for Coal Combustion Residuals (CCR) Existing Surface Impoundment – Ash Disposal Area 4 Colbert Fossil Plant, Colbert County, Alabama.* December 9.

AECOM. (2018). *Notification of Closure Completion Ash Disposal Area 4 EPA Final CCR Rule TVA Colbert Fossil Plant Tuscumbia, Alabama.* March 27.

Seaber, Paul R. (1988). Hydrostratigraphic Units.

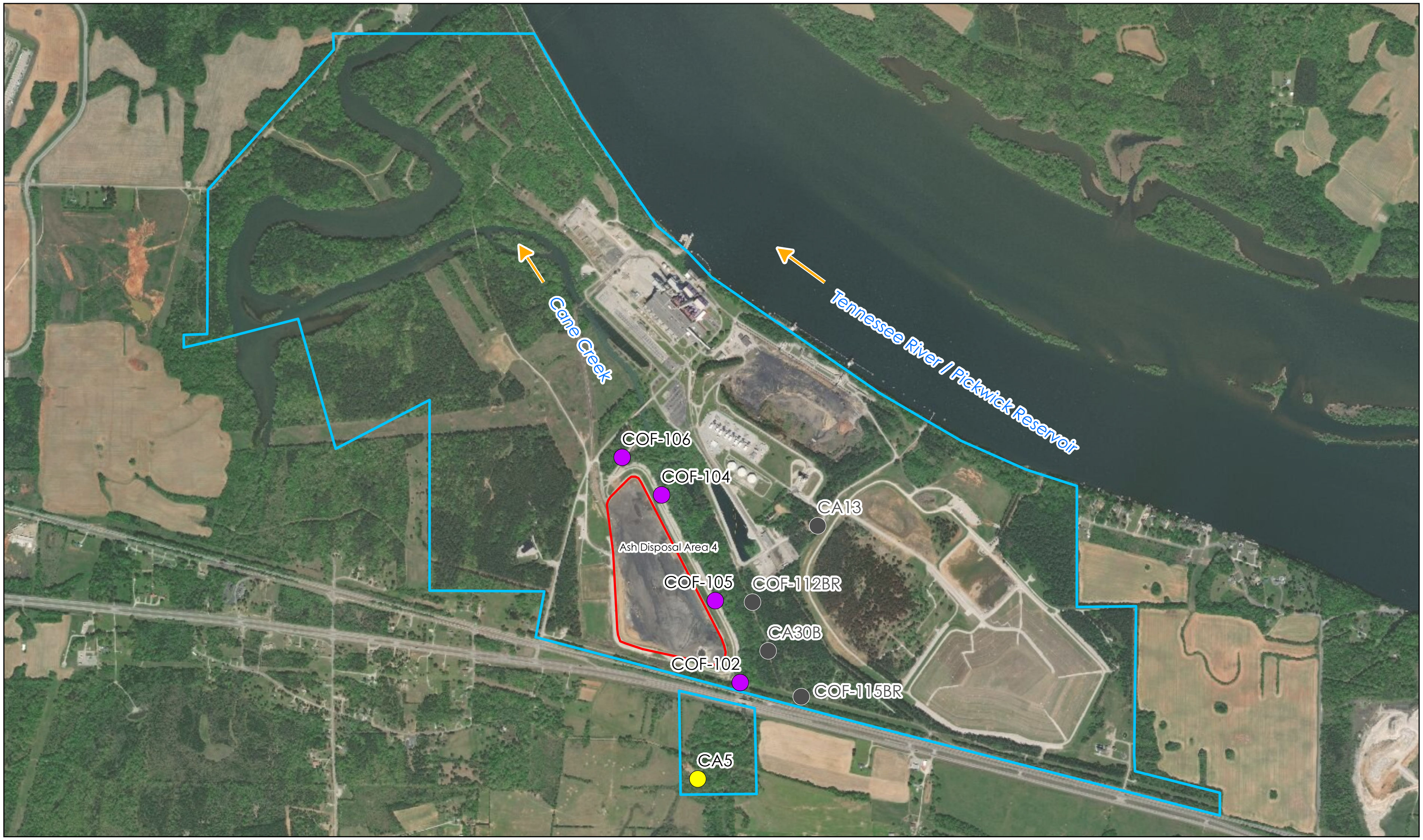
TABLES

TABLE 1.
WATER TREATMENT TECHNOLOGIES FOR CONSTITUENTS TENNESSEE VALLEY AUTHORITY - COLBERT FOSSIL PLANT CCR UNIT

Water Treatment Technology	COI*	
	Arsenic	Cobalt
Advanced Filtration	X	X
Chemical Precipitation	X	X
Co-precipitation	X	X
Redox Manipulation	X	X
Absorption (Chemical Fixation)	X	X
Ion Exchange	X	X

*Constituent of Interest

Figures



Legend
- Background Well
- Downgradient Well
- Investigation Well
- CCR Unit Subject to CCR Rule
- TVA Property Boundary

N

0 1,000 2,000 Feet
(At original document size of 8.5x11)
1:24,000

Notes
1. Coordinate System: NAD 1983 StatePlane Alabama West FIPS 0102 Feet
2. Background: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Project Location
City of Tuscumbia
Colbert County,
Alabama

Prepared by LMB on 2019-07-15
Technical Review by EP on 2019-07-15
Independent Review by JB on 2019-07-15

Client/Project
Tennessee Valley Authority
Colbert Fossil Plant
CCR Rule

182603471

Figure No.
Figure 2-1

Title
CCR Unit with Background and Downgradient Wells

TVA

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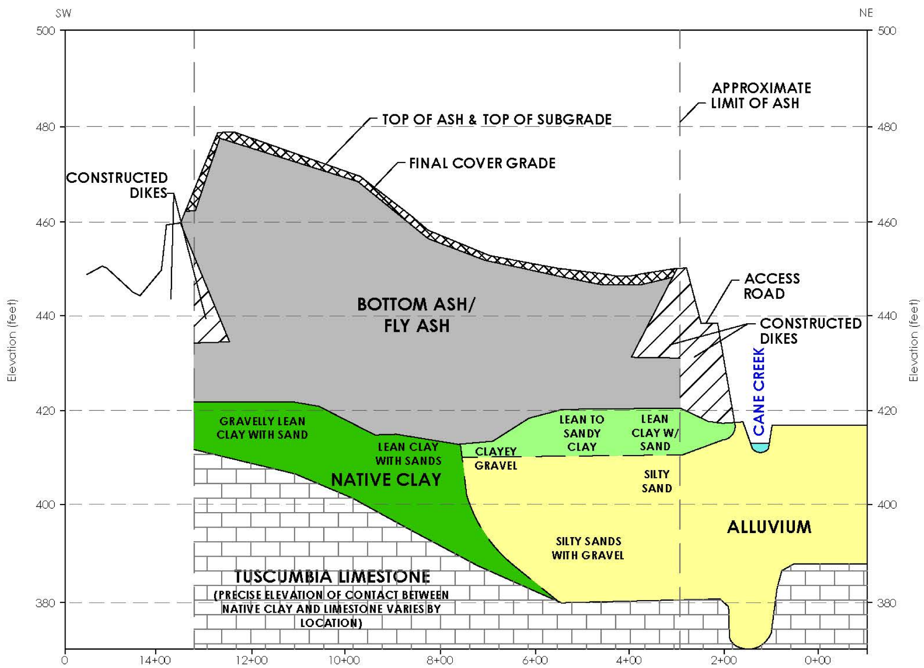

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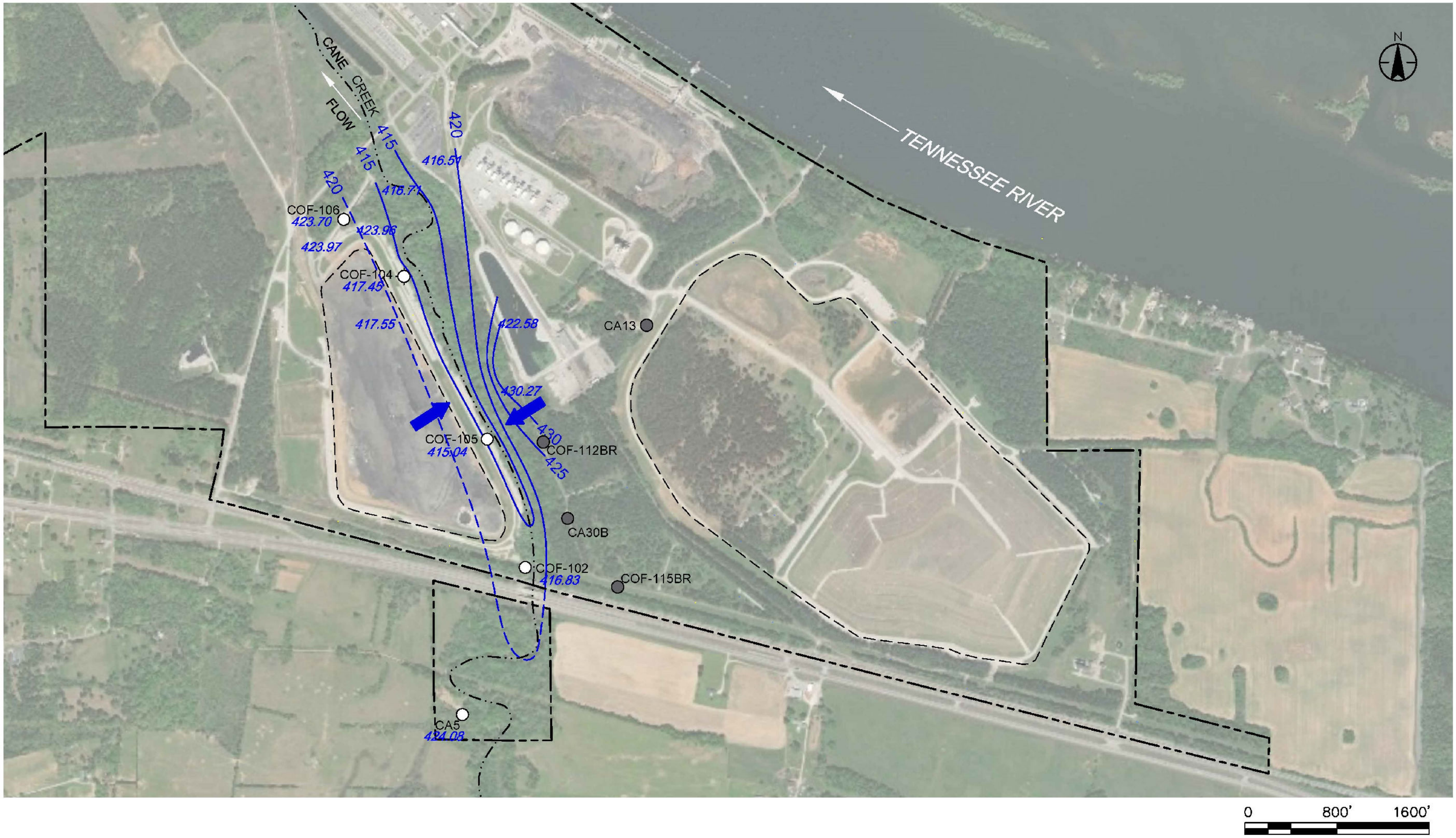
Independent Review by JB on 2019-07-15

Client/Project
182603471
Tennessee Valley Authority
Colbert Fossil Plant
CCR Rule

Figure No.
Figure 2-2

Title
Geological Cross-Section COF Ash Disposal Area 4

TVA



LEGEND

- INVESTIGATION WELL
- CCR Monitoring WELL
- GROUNDWATER ELEVATION CONTOUR (FT NGVD 29)
- APPROXIMATE GROUNDWATER FLOW DIRECTION
- 417.17 GROUNDWATER ELEVATION (FT NGVD 29)

Project Location
City of Tuscumbia
Colbert County,
Alabama

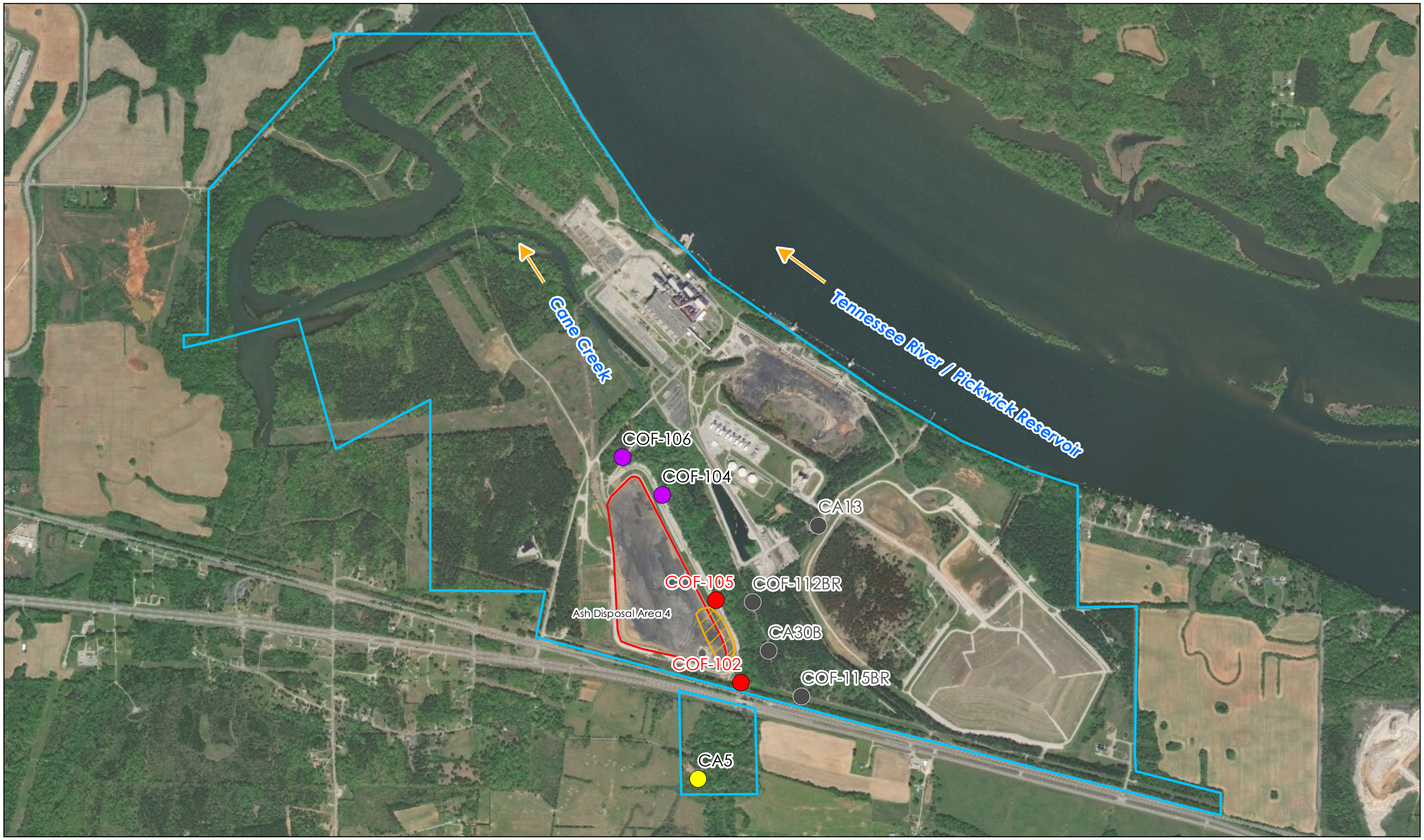
Prepared by LMB on 2019-07-11
Technical Review by EP on 2019-07-11
Independent Review by JB on 2019-07-11

Client/Project
182603471
Tennessee Valley Authority
Colbert Fossil Plant
CCR Rule

Figure No.
Figure 2-3

Title
COF Ash Disposal Area 4

U:\TVA-ACM\COF\gis\mxd\TVA_ACM_COF_Figure2-3.mxd Revised: 2019-07-11 By: LBlackman



Legend

- GWPS Exceedance Well
- Background Well
- Downgradient Well
- Investigation Well
- CCR Unit Subject to CCR Rule
- TVA Property Boundary
- Potential Treatment Zones (Arsenic & Cobalt)

N

0 1,000 2,000 Feet

(At original document size of 8.5x11)
1:24,000

Notes

1. Coordinate System: NAD 1983 StatePlane Alabama West FIPS 0102 Feet
2. Background: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Project Location
City of Tuscumbia
Colbert County,
Alabama

Prepared by LMB on 2019-07-11
Technical Review by EP on 2019-07-11
Independent Review by JB on 2019-07-11

Client/Project
Tennessee Valley Authority
Colbert Fossil Plant
CCR Rule

182603471

Figure No.
Figure 3-1

Title
Monitoring Wells and Limits of COI Impacts

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APPENDIX A

Potential Remedies

1.0 GROUNDWATER CORRECTIVE MEASURES STRATEGIES

Three strategies to address impacted groundwater have been developed to assess corrective measures. Each strategy is detailed in this appendix. For purposes of this report, any SSL detections of Appendix IV constituents over GWPS will be defined as a constituent of interest (COI).

1.1 MONITORED NATURAL ATTENUATION

Monitored Natural Attenuation (MNA) is a remedial strategy that involves establishing a program to monitor the physical, chemical, or biological processes that currently exist at a site. These processes can often work to reduce the toxicity, concentration, and mobility of site COIs in a time frame that is acceptable and that at times can be comparable to other technologies. MNA is increasingly employed at sites where COI concentrations are near threshold levels, do not have an immediate pathway to sensitive receptors, and are not resultant from an on-going source.

MNA implementation would consist of establishing a monitoring and assessment program to determine if the COI concentrations present in the groundwater were being reduced as a result of closure of the CCR Unit. Existing and potentially new monitoring wells at the facility would be used to characterize reduction in COI concentrations over time.

At wells COF-102 and COF-105 of the CCR Unit, there is a statistically significant level (SSL) above the groundwater protection standard (GWPS) for cobalt and arsenic, respectively. Closure of the CCR Unit occurred in 2018. The following conditions at COF make MNA a viable strategy:

- Limited impacts to groundwater: Currently, an SSL above GWPS established under 40 CFR § 257.95(h) for arsenic and cobalt is observed along an isolated portion of the CCR Unit. There are no drinking water supply wells on site, including between the CCR Unit and the adjacent surface water. Recent groundwater data indicates that there is no off-site migration of arsenic and cobalt to adjacent properties; and
- Naturally-occurring reactions in native soils: Arsenic and cobalt are susceptible to a variety of filtering and oxidation/reduction (redox) reactions that can separate or precipitate dissolved concentrations to remove them from aqueous solution. Arsenic and cobalt can be present in multiple valance states and their chemical reactivity is affected by groundwater pH, redox potential, the presence of iron and sulfur, and other subsurface variations. The effectiveness of geochemical processes can be evaluated by collecting native soil and groundwater samples and conducting bench-scale testing to evaluate the effectiveness of MNA.

Continued monitoring, in accordance with the Groundwater Monitoring Program, would be necessary to validate that COI concentrations continue to decrease at an acceptable rate.

Reliance on existing systems rather than active treatment may require institutional controls to restrict access to impacted zones. MNA relies upon naturally occurring processes to reduce impact levels and, by itself, does not provide a means to affect change in the subsurface environment. This strategy can be effective, especially when used in combination with unit closure and source control.

1.2 HYDRAULIC CONTAINMENT AND GROUNDWATER TREATMENT

Hydraulic containment is a technology that has been employed for decades to control impacted groundwater. Containment is typically achieved through the use of low-permeability barriers, high-permeability collection galleries, submersible pumps, or a combination of these features. The applicability and orientation of a hydraulic containment system is largely based on site-specific conditions including aquifer dimensions and conductivity, presence of confining layers, depth, gradient, characteristics of the COIs, and presence of receiving water bodies or wells.

Hydraulic containment systems can be very effective at controlling the migration of constituents in groundwater, particularly when there are sensitive systems nearby or a continuing source of contamination.

Hydraulic containment systems include physical barriers and pumping systems as summarized below:

- Physical Barriers:
    - Slurry Walls: Soil/bentonite slurries placed inside a 3-foot wide trench keyed into an impermeable soil layer (clay) serves as a physical barrier that prohibits the movement of groundwater and contains COI migration.
    - Sheet Pile Walls: Steel panels driven through the soil column to key into an impermeable zone serves as a physical barrier that prohibits movement of groundwater and contains COI migration.
    - Soil/Bentonite Walls: Dry soil/bentonite mixtures placed inside a 3-foot wide trench keyed into an impermeable soil layer (clay) serves as a physical barrier that prohibits the movement of groundwater and contains COI migration.
- Pumping Systems:
    - Vertical Wells: The use of vertical wells is a proven technology that can be used in unconsolidated soils and bedrock. The number of wells, spacing between wells and well depths are a function of aquifer characteristics.
    - Horizontal Wells: The use of horizontal wells potentially allows for the installation of more well screen along a zone of COI impacts, in comparison with vertical wells, thus improving the overall efficiency of the extraction system. The use of horizontal wells is not recommended for aquifers where there is large differential between high and low groundwater elevations as it may be difficult to pinpoint the COI recovery zone. Deep horizontal wells may not be as practical as vertical wells due to Site-specific conditions.
    - Trenching Systems: Trenches function in a manner similar to horizontal wells but are installed with conventional excavation techniques. The use of trenches is cost-effective when COIs are present at shallow depths and high groundwater flow rates.

- Phytoremediation: This technique is feasible when COIs are present at concentrations less than those levels that are toxic to plant life. Trees with deep root zones can extract groundwater containing COIs above GWPS and assimilate the COIs within their cell structure. This removes the COI from the groundwater and can result in obtaining the GWPS in an accelerated time frame. For closed in-place CCR Units, it is important to promote vertical growth of the tree root structure as opposed to lateral growth. Lateral growth of the plant roots can damage the liner system covering the CCR. Damages to the liner system would allow rainwater to come into contact with the CCR which could extend the time required to achieve GWPS.

The basis of design for a hydraulic containment system is typically generated by developing a detailed hydrogeologic CSM and a numerical groundwater model. The CSM serves as the basis for developing a numerical groundwater flow and solute transport model that is calibrated and verified against actual site conditions. The calibrated groundwater model is then used to evaluate a variety of approaches (e.g., vertical wells, horizontal wells, physical barriers) and to estimate the groundwater extraction rates necessary to contain the target zone. Understanding extraction rate requirements is important for developing an effective means of treating extracted groundwater.

Extracted groundwater often requires treatment to remove or reduce the concentration of the COIs prior to discharge to a receiving water body, publicly owned treatment works, land application, or re-injection through a well system.

Treatment of the impacted groundwater can be completed on or off-site using one of the following treatment methodologies:

- pH Adjustment: In cases where low pH is the primary COI, the groundwater can be treated by simple pH adjustment. Increasing the pH of the groundwater is accomplished by the addition of caustic solution (e.g., sodium hydroxide) at a rate that can be determined through bench-scale testing. Similarly, high pH groundwater can be treated through the addition of an acidic solution at a rate that can be determined through bench-scale testing. Other treatment methods discussed below may also require some pH adjustment to facilitate treatment.

- Chemical Precipitation: COIs can be removed from groundwater by raising the pH, using sodium hydroxide, calcium carbonate, or sulfides to convert the soluble COI to an insoluble form that precipitates out from the water stream. Bench-scale testing can be used to determine the addition rates of chemical precipitates and the percent COI removal that can be achieved through this process.

- Adsorption: COIs can be removed from groundwater by passing groundwater through an adsorption media such as bentonite, activated alumina, granular activated carbon, or iron-impregnated silica sands. COIs are adsorbed onto the surface of the media and removed from the groundwater. The adsorption material has a limited service life due to the amount of available treatment surfaces on the media. This adsorption material must be periodically replaced when the available surfaces are consumed with the COI. Bench-scale testing can be used to define the groundwater/media contact time for COI removal and estimate the active life of the adsorption media before it requires replacement.

- Ion Exchange: In this process an ion on the surface of the treatment media is exchanged with the ion that is removed from the impacted groundwater. Ion exchange is a proven technology with different media performing better for different COIs. This technology can be expensive depending on the cost of the ion exchange media. Advances in the beneficial reuse of high calcium content biomaterials has made the use of this technology attractive for some COIs. Bench-scale testing can be performed to determine if ion exchange is a viable technology for consideration. Bench-scale testing can also determine the necessary contact time between the impacted groundwater and ion exchange media, and the service life of the ion exchange media.

Hydraulic containment and groundwater treatment are applicable remedial alternatives due to several conditions at the facility, including:

- Precludes migration to potential receptors: Operation of a hydraulic containment system would demonstrably capture COI-containing groundwater and prevent migration;
- Localized area of impacts: COIs have been detected above GWPS within a limited number of wells around the perimeter of the CCR Unit. The COI impacts are estimated to have a localized extent of impacts and could be managed with a limited number of extraction points; and
- Established treatment technologies: Treatment of COIs in industrial wastewaters is accomplished through multiple proven technologies. Potential treatment alternatives include advanced filtration, chemical precipitation, redox manipulation, adsorption and ion exchange. The most effective alternative(s) would be selected based on the geochemistry of the groundwater and potential bench-scale treatability testing.

A hydrogeologic model would be required to design the hydraulic containment system orientation and bench-scale testing could assist in selecting the preferred treatment technology.

A groundwater monitoring program is typically an integral part of any hydraulic containment system. It is anticipated that after selection of the remedy, a corrective action groundwater monitoring program will be implemented in accordance with 257.98(a)(1). This monitoring program will track changes in COI concentrations and the extent and effectiveness of the containment system.

The time frame to achieve GWPS with a hydraulic containment system is strongly dependent on the site’s hydrogeologic conditions, the degree and extent of COI impact, and the chemical behavior of COIs in the subsurface. These inherent site conditions often function as rate limiting characteristics and should be considered when considering the schedule for achieving GWPS.

1.3 Enhanced In-Situ Treatment (EIST)

In-situ treatment of groundwater using EIST is an established technology for a variety of site conditions and contaminants. This alternative includes measures implemented in-situ to immobilize or reduce the concentration of COIs. In-situ technologies can be deployed in a variety of configurations depending on the extent of COIs and their proximity to potential receptors. Examples of EIST approaches include:

- Infiltration galleries: Regularly spaced injection wells would be installed in the target area to allow for delivery of a reagent to stabilize or transform COIs in-place. An injection gallery allows for repeated treatments as needed to meet remedy goals.
- Direct injection: Regularly spaced injection points can be advanced into the target area to allow for one-time delivery of a reagent to stabilize or transform COIs in-place.
- Permeable reactive barrier: Excavation of a trench perpendicular to groundwater flow direction can be backfilled with a permeable treatment media that allows groundwater to flow through it while reducing concentrations of COIs through chemical, physical, and/or biological processes.

Evaluation of these technologies will require development of a detailed hydrogeologic CSM and a groundwater model. The CSM serves as the basis for developing a numerical groundwater flow and solute transport model that is calibrated and verified against actual site conditions. The hydrogeologic model can then be used to determine the basis of design for deploying an EIST remedy and evaluating contact time and groundwater flow requirements.

Bench-scale testing can be used to evaluate potential reagents to be used in-situ. The bench-scale testing can be designed to develop an understanding of the geochemistry and assess the effectiveness of prospective reagents. Bench-scale testing can also be used to determine the scope and necessity of field-scale pilot testing.

EIST is an applicable remedial alternative based on several conditions at sites, including:

- Localized area of impacts: COIs have been detected above GWPS within a limited number of wells around the perimeter of the CCR Unit. This indicates that in-situ stabilization or an EIST barrier would be limited to only a portion of the perimeter. Additional investigations would be conducted to define the area of treatment or required length of the barrier; and
- Metals treatment technologies: Removal of COIs with multiple treatment technologies has been demonstrated in industrial wastewater applications. Potential treatment alternatives include advanced filtration, co-precipitation, redox manipulation, adsorption, and ion exchange. The most effective alternative(s) would be selected based on the geochemistry of the groundwater and potential bench-scale treatability testing. Bench-scale testing can help to determine the preferred treatment media, groundwater/treatment media contact time, and effectiveness of an EIST barrier application in achieving GWPS.

A groundwater monitoring program is typically an integral part of any EIST system. It is anticipated that after selection of the remedy, a corrective action groundwater monitoring program will be implemented in accordance with 257.98(a)(1). This monitoring program will track changes in COI concentrations and the extent and effectiveness of the EIST system.

Several critical site-specific conditions need to be considered when evaluating the applicability of an EIST barrier, including:

- Site Access: EIST barriers can require access for heavy equipment and a working platform to excavate the trench. Uneven or wooded terrain would complicate site preparation activities and may make installation infeasible.
- Dike Stability: The installation of an EIST could require the use of trenches. The location of the trenches in relationship to the dikes of the CCR Unit requires careful evaluation to make sure that stability of the dike structures is maintained.
- Depth: Installation of EIST barriers can be limited by the design depth and soil types present. Depending on depth and soil characteristics, specialized installation techniques may be required. For example, single-pass trenching machines can install EIST barriers in sandy materials without obstructions but are limited to a maximum depth of approximately 50 feet below ground surface. Slurry trenching techniques can be used to reach deeper impacts, but additional site infrastructure is required to support the installation.
- Geochemistry: The valence state of COIs, pH and redox potential of groundwater, and chemical makeup of the subsurface must be evaluated to determine the applicability of an EIST barrier.

APPENDIX B

ASSESSMENT OF POTENTIAL REMEDIES

1.0 INTRODUCTION

The evaluation of appropriate remedies to meet the requirements of 40 CFR § 257.96(c) is provided in the subsections below and is presented in **Table B-1**. The qualitative assessments in **Table B-1** (low, medium, high) are based on experience, professional judgement, and known Site conditions. This document provides evaluation in compliance with 40 CFR § 257.96(c).

Five remedial alternatives classified under three technology types, hydraulic containment, monitored natural attenuation and enhanced in-situ treatment, will be evaluated as groundwater corrective measures for removal of arsenic and cobalt:

- Hydraulic Containment:
    - Conventional Vertical Well System;
    - Horizontal/ Angular Well System; and
    - Trenching System.
- Monitored Natural Attenuation; and
- Enhanced In-Situ Treatment.

2.0 PERFORMANCE

The performance criteria described in the following section focuses on the specified technology's goal of corrective measures to prevent further releases, remediate any current releases, and restore the affected area to original conditions.

2.1 SOURCE CONTROL TECHNOLOGIES

Source control has been achieved since the CCR Unit has been capped and closed in accordance with the standards under U.S. EPA CCR Rule. Source control technologies are not further evaluated in this report since this assessment of corrective measures focuses on groundwater corrective actions.

2.2 GROUNDWATER CORRECTIVE MEASURES

The groundwater corrective measures evaluated include:

- Monitored Natural Attenuation (MNA);
- Hydraulic Containment; and
- Enhanced In-Situ Treatment.

This section describes these technologies in more detail.

2.2.1 Monitored Natural Attenuation

Additional groundwater assessment monitoring is conducted once source control has been implemented for the CCR Unit. Once the source is controlled, natural groundwater flux should result in reduced concentrations of arsenic and cobalt after a period of time. The groundwater assessment monitoring will determine if the source control measures are reducing or stabilizing arsenic and cobalt concentrations in the groundwater to levels necessary to achieve the GWPS. Trend analyses will be completed to predict the time that it will take for the groundwater to reach GWPS. MNA is a proven technology that has been effectively used at groundwater remediation sites. MNA is considered a **high** performing alternative based on project experience on similar sites and professional judgement.

2.2.2 Hydraulic Containment

If source control technologies do not reduce arsenic and cobalt concentrations to below the GWPS, then additional groundwater remediation corrective measures may be required.

Several site-specific conditions contribute to the effective performance of the hydraulic containment system. These site-specific conditions include:

- Depth to impacted groundwater;
- Length of impacts along the perimeter of the CCR Unit;
- Thickness of Alluvium aquifer impacted;
- Groundwater capture zones within the Alluvium aquifer; and
- Arsenic and cobalt to be removed from the groundwater.

Hydraulic containment systems can be designed based upon data obtained through additional site characterization assessments, groundwater modeling, and bench-scale treatability tests. These additional studies are focused on arsenic and cobalt present at the CCR Unit that exceed GWPS. Data from these studies will help develop a basis of design for the hydraulic containment system which includes:

- Number and depth of the extraction wells in the Alluvium;
- Groundwater extraction rate from the Alluvium;
- Optimum above ground groundwater treatment approach for arsenic and cobalt removal;
- Treated groundwater discharge location; and
- Estimated time frame to achieve GWPS.

Groundwater extraction and treatment is a feasible technology at COF with a **high** or **medium-rated** performance depending on site-specific issues such as groundwater use restrictions.

2.2.3 Enhanced In-Situ Technologies

Several site-specific conditions contribute to the effective performance of the enhanced in-situ technologies (EISTs). These site-specific conditions include:

- Depth to impacted groundwater;
- Length of impacts within the Alluvium along the perimeter of the CCR Unit;
- Groundwater flow rate in the Alluvium; and,
- Arsenic and cobalt to be removed from the groundwater.

EISTs can be designed based upon data obtained through additional site characterization assessments, groundwater fate and transport modeling and potential bench-scale treatability testing. These additional studies are focused on the arsenic and cobalt present at the CCR Unit that exceed GWPS. Data from these studies will help develop a basis of design for the EIST which includes:

- Location and depth of the EIST to intercept arsenic and cobalt present in the Alluvium;
- Optimum EIST media for arsenic and cobalt treatment;
- EIST detention times for effective treatment of arsenic and cobalt;
- Service life for the EIST media;
- Provisions for media replacement; and,
- EIST quantities.

EISTs would generally be considered **high to medium** performing alternatives based upon the shallow depth of groundwater at COF and professional judgement. Bench-scale testing of multiple reagents or modelled site conditions can be evaluated to determine retention times, reaction rates, media selection, quantities and delivery methods for treatment using EIST.

3.0 RELIABILITY

The reliability criterion is based on the degree of certainty that the technology will consistently work toward and attain the specified goal(s) of corrective measures over time.

3.1 GROUNDWATER CORRECTIVE MEASURES

The reliability of the following groundwater corrective measures to treat arsenic and cobalt will be evaluated in this section:

- MNA;
- Hydraulic Containment; and
- EIST.

3.1.1 Monitored Natural Attenuation

MNA is a commonly applied corrective measure that can, under appropriate conditions, reliably reduce arsenic and cobalt concentrations after source control measures are completed. The process of determining the effectiveness and reliability of MNA involves regular monitoring and analysis of groundwater data following closure. This monitoring process and the related data analysis is central to determining whether appropriate conditions exist to support MNA and will serve as the primary means of determining and confirming reliability. MNA may not result in arsenic and cobalt levels in the groundwater returning to levels below the GWPS. In these instances, arsenic and cobalt concentration reduction is achieved through a variety of geochemical and hydrogeologic processes that affect the solubility, sorption, and concentration of the constituents. Therefore, the reliability of MNA is considered to be **high to medium** depending on site conditions.

3.1.2 Hydraulic Containment

Hydraulic containment alternatives are generally considered to be **highly** reliable for containing the arsenic and cobalt contamination and preventing migration. This technology may not be as reliable when considering the reduction of arsenic and cobalt concentrations within the Alluvium. Reduction of arsenic and cobalt concentrations is highly dependent on the success of source control steps, including capping the CCR Unit in 2018, and the ability of arsenic and cobalt to be adsorbed within the soil column. Conventional vertical wells are often installed in a line or series with overlapping radii of influence to effectively capture groundwater within the Alluvium. Modifications can be made during startup and as site conditions change to optimize the system’s performance. If needed, extraction well systems can be expanded with additional wells, after the initial installation. Horizontal well reliability and extraction trench reliability is generally comparable to that of vertical wells, although the application is less common. Site-specific issues could restrict the extraction of groundwater and as a result could lower the reliability of this approach to **medium**.

3.1.3 Enhanced In-Situ Technologies

EIST is a commonly applied corrective measure that can, under appropriate conditions, reliably reduce arsenic and cobalt concentrations after source control measures are completed. The EIST processes can include one or more of the following treatment mechanisms:

- Advanced Filtration;
- Chemical Precipitation; and
- Adsorption.

The process of determining the effectiveness and reliability of EIST involves regular monitoring and analysis of groundwater data following closure. Groundwater monitoring will be conducted to determine the effectiveness of EIST and to determine the time frame required to achieve GWPS. Bench testing allows for the development of a site-specific approach to treat arsenic and cobalt to achieve GWPS.

The reliability of EIST is considered to be **high to medium** based upon arsenic and cobalt being treated and site-specific considerations associated with the Alluvium.

4.0 EASE OF IMPLEMENTATION

This criterion requires evaluation of the alternatives based on the ease of implementation for each of the technologies at the site.

4.1 GROUNDWATER CORRECTIVE MEASURES

The ease of implementation criterion is based on the degree of certainty that the technology can be installed and reduce the concentrations of arsenic and cobalt over time to achieve the GWPS.

4.1.1 Monitored Natural Attenuation

MNA can be readily implemented and existing monitoring wells (potentially supplemented with additional wells) could be used for groundwater monitoring purposes. MNA does not require significant infrastructure and instead relies on natural processes to attenuate arsenic and cobalt concentrations over time. Standard techniques for obtaining and analyzing groundwater data are readily available. Therefore, an MNA corrective measure is evaluated as **highly** implementable.

4.1.2 Hydraulic Containment

Hydraulic containment systems are widely implemented and are a proven technology for treatment of arsenic and cobalt. The ease of implementation varies across the range of available hydraulic containment systems from **medium to high**. Implementation issues associated with each of these techniques is discussed below:

Vertical Wells:

- The number of extraction wells and their spacing distance is dependent upon the horizontal and vertical extent of arsenic and cobalt impacts, the hydrogeologic characteristics of the Alluvium, the groundwater extraction rate and the groundwater capture zone within the Alluvium;
- Specialized drilling equipment may be required to install the wells depending on the depth of arsenic and cobalt impacts; and
- Limited space may be available on the top of the dikes to install the hydraulic containment system.

Horizontal Wells:

- The length of horizontal wells and their installation depth is dependent upon the horizontal and vertical extent of arsenic and cobalt impacts, the hydrogeologic characteristics of the Alluvium, the groundwater extraction rate and the groundwater capture zone within the Alluvium;
- Specialized drilling equipment will be required to install the horizontal wells; and
- It may be difficult to place the horizontal wells at the desired depths due to surface constraints associated with the CCR Unit.

Trenches:

- Specialized drilling equipment will be required to install the trenches;
- Trench stabilization techniques (sheet pile, bio-degradable slurry) are required to prevent collapse of the sidewalls during installation; and
- It may be difficult to place the treatment media at depth in narrow trenches.

The number of wells required for effective capture is based upon the horizontal and vertical extent of the impacted zone and groundwater flow characteristics. Vertical extraction wells could be executed relatively easily with existing site conditions and result in a **high** ease of implementation. Horizonal extraction wells suggest a **medium** ease of implementation due to additional clearances necessary to install wells. Trenching systems suggest a **medium** ease of implementation due to trench stability concerns and potential impacts on sensitive ecosystems.

4.1.3 Enhanced in-situ treatment

EIST for arsenic and cobalt treatment would require additional design, up-front monitoring and shallow wall installation for implementation. This technology is feasible at COF due to the shallow depth of wall installation that is required to treat groundwater. EISTs could be constructed using permeable reactive barriers (PRBs), infiltration galleries or through direct injections. Implementation issues associated with each of these techniques is discussed below:

PRBs:

- Construction of a PRB for arsenic and cobalt treatment may require specialized equipment and construction techniques that could impact the ease of implementation; and
- Following installation, a PRB typically requires minimal maintenance and periodic monitoring.

Infiltration Galleries:

- Injection galleries can be installed with standard drilling equipment;
- Access can be limited, so the location of slopes, existing infrastructure, and other obstructions must be factored into the design; and
- Injection galleries are subject to fouling that can inhibit the injection of reagents particularly if multiple injection events are required.

Direct Injection:

- Direct injection can be accomplished with standard drilling equipment;

- Access can be limited, so the location of slopes, existing infrastructure, and other obstructions must be factored into the design; and
- Multiple direct injection events may be required to achieve the GWPS for arsenic and cobalt.

Once the EIST barriers are installed the remedial alternative is passive and would require only periodic monitoring and maintenance. The overall ease of implementation for an EIST alternative would be **high to medium**.

5.0 POTENTIAL SAFETY IMPACTS

This criterion evaluates the alternatives based on potential safety impacts that may occur as a result from the implementation of the technologies on site to treat arsenic and cobalt in the Alluvium aquifer.

5.1 GROUNDWATER CORRECTIVE MEASURES

Safety impacts that may occur as a result from the implementation of groundwater corrective measures for arsenic and cobalt are discussed in this section.

5.1.1 Monitored Natural Attenuation

MNA safety impacts are minimal due to the inherent passive nature of the system. The primary safety concerns would be associated with the installation of any additional wells should they be required to supplement the existing well network. Additional opportunities for safety impacts would be during groundwater monitoring activities. These impacts are common to any technology that may be deployed, because groundwater monitoring will be required regardless of which remedial technology is implemented. For these reasons, MNA has a **low risk** of safety concerns.

5.1.2 Hydraulic Containment

Groundwater extraction well construction or trenching activities within the Alluvium would require construction activities and consequently pose a **medium risk** of safety impacts. Construction equipment involved in the installation of extraction wells, drilling, electrical work and piping would be a main area for safety impact concern. Operations and maintenance, repair, and replacement activities may also present safety hazards, but are generally lower risk than construction-related safety impacts.

5.1.3 Enhanced In-Situ Technologies

EISTs installed within the Alluvium would require a more detailed construction plan for shallow wall installation and therefore a **medium risk** for safety impacts. Construction equipment would be the main concern because construction projects are inherently more dangerous than other site work due to the presence of heavy machinery. Once installed, EISTs are passive and would result in minimal safety impact potential. EISTs implementation has a **medium risk** for safety concerns.

6.0 POTENTIAL CROSS-MEDIA IMPACTS

This criterion evaluates the alternatives based on potential cross-media impacts that may occur as a result from the implementation of the technologies on site.

6.1 GROUNDWATER CORRECTIVE MEASURES

Potential cross-media impacts that may occur as a result from the implementation of groundwater corrective measures for arsenic and cobalt treatment is discussed in this section.

6.1.1 Monitored Natural Attenuation

Monitored natural attenuation poses minimal risk of cross-media impacts as the systems, when installed, are passive and primarily interact with existing groundwater flow. MNA is considered **low risk** for cross-media impacts.

6.1.2 Hydraulic Containment

Extracted groundwater from the Alluvium is transported from the recovery well to the treatment system using enclosed piping. The main potential for cross-media impacts would occur if the piping failed and untreated extracted groundwater is released to the environment. This risk is mitigated through periodic monitoring of the secondary containment. Hydraulic containment technologies are considered to have a **medium** risk.

6.1.3 Enhanced In-Situ Technologies

There is a potential for the accidental release of diesel fuel during the installation of subsurface barrier walls within the Alluvium. Also, injected treatment reagents would have the potential for being released to the environment. The potential for these types of releases are mitigated through the development of spill prevention control and countermeasure plans. Due to the minimal potential for spills of fuel or treatment reagents during construction activities, EIST is considered a **medium risk**.

7.0 CONTROL OF EXPOSURE TO RESIDUAL CONTAMINATION

This criterion evaluates the alternatives based on exposure to residual contamination to receptors such as humans and the environment that may occur as a result from the implementation of the technologies on site for treatment of arsenic and cobalt.

7.1 GROUNDWATER CORRECTIVE MEASURES

Each groundwater corrective measure discussed in this report has a **low risk** of residual contamination. This is the result of arsenic and cobalt being present in the groundwater at concentrations generally less than a part per million. In addition, the groundwater impacts are present below the ground surface, and when groundwater is brought above the ground surface, it is transported through double walled piping to the treatment system. Therefore, the risk of exposure to residual contamination is low.

8.0 TIME REQUIRED TO BEGIN REMEDY

This criterion evaluates the alternatives based on time required for completion of design, planning, bench-scale testing, permitting, installation and startup of the remedial technologies.

8.1 GROUNDWATER CORRECTIVE ACTION

Closure of the CCR Unit was deemed to be complete in March 2018. Groundwater monitoring is ongoing in accordance with the requirements of 40 CFR § 257.95. The groundwater data obtained since 2018 suggests decreasing or stable trends of COIs at some locations which would suggest that MNA is working at the Site.

Hydraulic containment systems or EISTs would be expected to require between three to five years after selection of a remedy prior to implementation due to the following reasons;

- Design, bench- and pilot-scale testing, reporting and ADEM approval is anticipated to require multiple years;
- State, local, or other environmental permit requirements are anticipated to affect implementation of hydraulic containment or EISTs;
- Closure of the CCR Unit was deemed to be complete in March 2018;
- Groundwater assessment monitoring will determine the need for additional groundwater corrective measures beyond MNA; and
- Obtaining enough groundwater data to evaluate the performance of the CCR Unit closure method requires time.

9.0 TIME REQUIRED TO COMPLETE REMEDY

This criterion evaluates the alternatives based on time required to achieve the necessary goals of the corrective measures and restore groundwater in the affected area to achieve GWPS.

9.1 GROUNDWATER CORRECTIVE MEASURES

Since MNA does not introduce a reagent or barrier, the time to reach the GWPS is currently unknown. The duration is directly dependent on the concentrations of arsenic and cobalt present in the groundwater and the effectiveness of the engineered cap to prevent further releases. It is possible that several decades of monitoring may be required before necessary groundwater conditions are achieved. Fate and transport modeling can be used to predict remediation time frames once enough post-closure monitoring data is obtained.

The time frame to achieve GWPS with hydraulic containment remedies are also subject to concentrations of arsenic and cobalt in the groundwater. Fate and transport modeling can be used to predict remediation time frames once enough post-closure monitoring data is obtained. The alternatives of vertical or horizontal extraction wells would remove arsenic and cobalt mass from the Alluvium, thereby reducing the volume still present in the subsurface. Therefore, the extraction alternatives may restore groundwater in a shorter time frame if source control efforts are effective.

The time frame to achieve GWPS with an EIST system is strongly dependent on the site’s hydrogeologic conditions, the degree and extent of arsenic and cobalt impacts, and the chemical behavior of arsenic and cobalt in the subsurface. These inherent site conditions often function as rate limiting characteristics and should be considered when considering the schedule for achieving GWPS. Groundwater fate and transport modeling can be used to provide an estimated range of time frames to achieve GWPS.

10.0 INSTITUTIONAL REQUIREMENTS: STATE, LOCAL OR OTHER ENVIRONMENTAL PERMIT REQUIREMENTS THAT MAY SUBSTANTIALLY AFFECT IMPLEMENTATION

This criterion evaluates the alternatives based on state, local or other permitting requirements that may substantially affect the implementation of the technologies on site.

10.1 GROUNDWATER CORRECTIVE MEASURES

A groundwater assessment monitoring program will be developed to monitor the effectiveness of the CCR unit closure method and groundwater in-situ treatment or groundwater extraction and treatment technologies, if required. State and local approval may be necessary to execute the construction work plan for additional groundwater corrective measures. The following permits would likely be required:

- Stormwater Permit for Construction Activities – applies for all corrective measures (Hydraulic Containment and EIST) where greater than one acre of land is disturbed as a result of construction activities; and
- Alabama NPDES Permit Modification – modifications to the existing NPDES permit may be required for the hydraulic containment options since an additional source of impacted water is created and may require treatment prior to discharge.

TABLES

TABLE B-1

CORRECTIVE MEASURES QUALITATIVE EVALUATION - 257.96(c) Analysis Criteria

COF CCR Unit

	Groundwater Restoration Action		***Groundwater Restoration Action***		
	Monitored Natural Attenuation	**Enhanced In-Situ Treatment**	**Conventional Vertical Well System**	**Horizontal/ Angular Well System**	**Trenching System**
257.96(c)(1)					
Performance	**High** Soil column will filter particulate that contains arsenic and cobalt/dissolved arsenic and cobalt. Loading will be reduced by source control approaches.	**High** Enhanced in-situ treatment technologies can be evaluated based upon bench-scale testing of impacted groundwater.	**High** Technology is feasible and will be further evaluated in accordance with 257.97, prior to remedy selection.	**High** Technology is feasible and will be further evaluated in accordance with 257.97, prior to remedy selection.	**High** Technology is feasible and will be further evaluated in accordance with 257.97, prior to remedy selection.
Reliability	**High** Soil column will filter particulate that contains arsenic and cobalt/dissolved arsenic and cobalt. Loading will be reduced by source control approaches.	**High** Enhanced in-situ treatment technologies can be evaluated based upon bench-scale testing of impacted groundwater.	**High** Technology is feasible and will be further evaluated in accordance with 257.97, prior to remedy selection.	**High** Technology is feasible and will be further evaluated in accordance with 257.97, prior to remedy selection.	**High** Technology is feasible and will be further evaluated in accordance with 257.97, prior to remedy selection.
Ease of implementation	**High** Corrective Action Groundwater Monitoring will be conducted in accordance with 257.98 (a) (1).	**High** The enhanced in-situ treatment technologies are relatively easy to install in this working environment.	**High** Technology is feasible and will be further evaluated in accordance with 257.97, prior to remedy selection.	**Medium** Technology is feasible and will be further evaluated in accordance with 257.97, prior to remedy selection. Because of additional clearance needed, installation of horizontal wells is more difficult.	**Medium** Technology is feasible and will be further evaluated in accordance with 257.97, prior to remedy selection. Because of trench stability concerns and potential impacts on sensitive ecosystems, installing trenching systems is more difficult.
Potential impacts of appropriate potential remedies: safety impacts	**Low Risk** All work activities are conducted in accordance with a site-specific health and safety plan for safe execution of groundwater monitoring activities.	**Medium Risk** More advanced worker training is required to operate specialized equipment.	**Medium Risk** More advanced worker training is required to operate specialized equipment.	**Medium Risk** More advanced worker training is required to operate specialized equipment.	**Medium Risk** More advanced worker training is required to operate specialized equipment.
Potential impacts of appropriate potential remedies: cross-media impacts	**Low Risk** All work activities occur in-situ.	**Medium Risk** All work activities occur in-situ with some potential to release COC's to the environment through spills.	**Medium Risk** All work activities bring soils and groundwater to ground surface with some potential to release COC's to the environment through spills.	**Medium Risk** All work activities bring soils and groundwater to ground surface with some potential to release COC's to the environment through spills.	**Medium Risk** All work activities bring soils and groundwater to ground surface with some potential to release COC's to the environment through spills.
Potential impacts of appropriate potential remedies: control of exposure to residual COIs	**Low Risk** All work activities occur in-situ/groundwater impacts previously identified.	**Low Risk** All work activities occur in-situ with some potential to release treatment reagents to the environment through spills.	**Low Risk** All work activities bring soils to ground surface with some potential to release COC's to the environment through spills.	**Low Risk** All work activities bring soils to ground surface with some potential to release COC's to the environment through spills.	**Low Risk** All work activities bring soils to ground surface with some potential to release COC's to the environment through spills.
257.96(c)(2)					
Time required to begin remedy	Remedy completed in March 2018	3 to 5 years after a corrective measure is selected	3 to 5 years after a corrective measure is selected	3 to 5 years after a corrective measure is selected	3 to 5 years after a corrective measure is selected
Time required to complete remedy	Varies dependent on groundwater fate transport modeling and concentrations of arsenic and cobalt in groundwater	Varies dependent on groundwater fate transport modeling and concentrations of arsenic and cobalt in groundwater.	Varies dependent on groundwater fate transport modeling and concentrations of arsenic and cobalt in groundwater.	Varies dependent on groundwater fate transport modeling and concentrations of arsenic and cobalt in groundwater.	Varies dependent on groundwater fate transport modeling and concentrations of arsenic and cobalt in groundwater.
257.96(c)(3)					
State, local or other environmental permit requirements that may substantially affect implementation	ADEM input is expected.	ADEM input is expected.	ADEM input is expected. May need to modify NPDES permit.	ADEM input is expected.	ADEM input is expected.
Comments	No timeframe specified to comply with 257.98 (c). Long term groundwater monitoring may be required.	No timeframe specified to comply with 257.98 (c). Corrective Action Groundwater Monitoring terminates if 3 years of data below the GWPS is obtained.	No timeframe specified to comply with 257.98 (c). Corrective Action Groundwater Monitoring terminates if 3 years of data below the GWPS is obtained.	No timeframe specified to comply with 257.98 (c). Corrective Action Groundwater Monitoring terminates if 3 years of data below the GWPS is obtained.	No timeframe specified to comply with 257.98 (c). Corrective Action Groundwater Monitoring terminates if 3 years of data below the GWPS is obtained.