APPENDIX B –
CORRECTIVE MEASURES
ASSESSMENT

Appendix B - Corrective Measures Assessment Technical Memorandum

TDEC Commissioner's Order
Environmental Investigation Plan
Allen Fossil Plant
Memphis, Tennessee

October 30, 2025

Prepared for:

Tennessee Valley Authority
Chattanooga, Tennessee

Prepared by:

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Lexington, Kentucky

REVISION LOG

Revision	Description	Date
0	DRAFT Submittal to TDEC	August 9, 2024
1	Addresses November 15, 2024 TDEC Review Comments and Issued for TDEC	February 13, 2025
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Sign-Off Sheet

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Abbreviations

ALF Plant	Allen Fossil Plant
CARA	Corrective Action Risk Assessment
CBR	Closure by removal
CCR	Coal Combustion Residuals
DoR	Division of Remediation
DSWM	Tennessee Divisions of Waste Management
EADA	East Ash Disposal Area
EAR	Environmental Assessment Report
EI	Environmental Investigation
EIST	Enhanced *In Situ* Treatment
GWPS	Groundwater protection standards
IRA	Interim Removal Action
MNA	Monitored Natural Attenuation
NPDES	National Pollutant Discharge Elimination System
POTW	Publicly-owned treatment works
ROD	Record of Decision
Stantec	Stantec Consulting Services Inc.
TDEC	Tennessee Department of Environment and Conservation
TDEC Order	Commissioner’s Order No. OGC15-0177
TM	Technical Memorandum
TVA	Tennessee Valley Authority
USEPA	United States Environmental Protection Agency
WADA	West Ash Disposal Area

1.0 INTRODUCTION AND OBJECTIVES

Stantec Consulting Services Inc. (Stantec), on behalf of the Tennessee Valley Authority (TVA), has prepared this Corrective Measures Assessment Technical Memorandum (TM) to summarize the assessment of potential corrective measures for the former West Ash Disposal Area (WADA) coal combustion residuals (CCR) unit at TVA's Allen Fossil Plant (ALF Plant) located in Memphis, Tennessee.

The overall objective of the corrective measures assessment is to identify corrective actions at the former WADA or within adjacent environmental media in support of fulfilling the requirements of the Tennessee Department of Environment and Conservation (TDEC) issued Commissioner's Order No. OGC15-0177 (TDEC Order) to TVA (TDEC 2015). The TDEC Order sets forth a "process for the investigation, assessment, and remediation of unacceptable risks" at TVA's coal ash disposal sites in Tennessee. The Corrective Action/Risk Assessment (CARA) Plan has been prepared pursuant to the TDEC Order process to evaluate whether unacceptable risks related to former management of CCR material exist at the former WADA, specify the actions TVA plans to take at the former WADA and the basis of those actions, and incorporate operational changes planned or in progress by TVA.

This TM documents the assessment of corrective measures using the process described in Chapter 6 of the CARA Plan. The specific objectives of the corrective measures assessment are summarized as follows:

- Summarize the environmental investigation (EI) and risk-based findings that require corrective action and identification of corrective measures
- Identify potentially applicable corrective measure technologies that may meet the standards specified by the TDEC Division of Solid Waste Management (DSWM), which would also fulfill the requirements of the TDEC Order (e.g., attain groundwater protection standards [GWPS])
- Assemble applicable corrective measure technologies into corrective measure alternatives based on site-specific technology evaluations
- Evaluate the corrective measure alternatives using factors specified in TDEC regulations, supplemented with additional factors specified by TVA
- Identify a corrective action for the former WADA where corrective action is required.

2.0 BACKGROUND

The following presents brief descriptions of the ALF Plant CCR units and provides summaries of key findings from the ALF Plant Environmental Assessment Report (EAR; TVA 2024) and risk-based evaluation. Further information is provided in the CARA Plan main document.

2.1 CCR UNITS

There are two CCR units at the ALF Plant:

- Former WADA
- East Ash Disposal Area (EADA)

The former WADA is approximately 39.5 acres and located west of the former power plant. The USACE levee forms the south dike of the former WADA. The former WADA does not appear to have been subdivided during its construction or periods of operation for the purpose of CCR management, as documented in the Remedial Action Completion Report (Stantec 2024a). The WADA ceased receiving CCR material in 1992 and is therefore exempt from the 2015 CCR Rule, although it continued to be a National Pollutant Discharge Elimination System (NPDES) regulated unit. In late 2021, TVA began removing CCR material from the WADA and finished CCR material removal in November 2023. The majority of the former WADA currently consists of grassland (herbaceous) vegetation and lacks standing surface water conditions. The turf grass was placed following CCR material removal, backfilling, and grading, which was completed by the fall of 2023.

The EADA, which is approximately 80 acres, is located east of the former coal yard and former power plant. In accordance with the Record of Decision (ROD) issued by TDEC DoR, closure by removal (CBR) was selected for the EADA. As of July 2024, approximately 590,000 cubic yards of CCR material have been removed from the EADA and disposed at a permitted landfill. CBR is expected to be complete by 2029. In addition to CBR, an Interim Response Action (IRA) was selected in the ROD and began operation in early 2023 to address groundwater quality at the EADA while closure is underway. This IRA focuses on extraction and treatment of shallow groundwater with elevated concentrations of arsenic. Extracted groundwater is treated at an onsite groundwater treatment system located near the EADA.

2.2 SUMMARY OF INVESTIGATION AND RISK-BASED FINDINGS REQUIRING CORRECTIVE ACTION

Environmental media identified for corrective action in this CARA Plan are based on the findings in the EAR, which focused on the groundwater conditions near the former WADA. The EAR findings were based on comparison of groundwater sample analytical results for CCR constituents to TDEC-approved screening levels. The EAR also concluded that historical operations at the ALF Plant do not appear to have impacted the ecological habitat in the vicinity of the ALF Plant, and the former WADA is not expected to routinely support unique or rare wildlife species. In addition, an evaluation of potential receptors and exposure pathways (CARA Plan Chapter 4) concluded that there are no unacceptable risks to human health based on current conditions and recent groundwater data at the former WADA. Therefore, corrective action is only required for groundwater in order to attain GWPS consistent with regulatory requirements at the wells presented below:

Summary of Findings That Require Corrective Action in the CARA Plan		
CCR Unit	**Groundwater Constituent(s)**	**Monitoring Well(s)**
Former WADA	Molybdenum	ALF-207B, ALF-207A, ALF-208, and ALF-208B
	Arsenic(1)	ALF-208 and ALF-219B
1) As of May 2024, the arsenic concentration at well ALF 220B had been consistently above the GWPS, but there were not enough sample results to identify arsenic above the GWPS at a statistically significant level. The statistical evaluation of arsenic data at ALF 220B will be completed after a sufficient number of sampling results are available. If that future evaluation indicates arsenic is present at a statistically significant level above the GWPS, then ALF 220B would be included for corrective action to address arsenic in a future revision of this CARA Plan.		

The GWPS established for the CARA Plan are based on regulatory standards (see CARA Plan Chapter 6.1) and are presented in Table 1, which includes GWPS for molybdenum and arsenic.

The findings above requiring the assessment of corrective measures and identification of corrective actions in this CARA Plan, are based on groundwater data presented in the EAR. Historical arsenic concentrations were below the GWPS at well ALF-208 but were identified as being statistically above the GWPS in the EAR. This identification in the EAR was based on only two samples collected during CCR material removal activities in 2023 that exhibited higher arsenic concentrations. The most recent data from well ALF-208 collected in 2024 appear more consistent with the historical, pre-CCR material removal data. These data suggest that the two 2023 sample results may be excursions related to the in-progress closure activities and may not be statistically representative of the aquifer conditions. Further evaluation of the sampling results from well ALF-208 will be performed as additional data become available (as with all wells being monitored at the former WADA), and the statistical analysis will be updated in a future revision of this CARA Plan.

TVA is continuing to monitor groundwater at the former WADA, and these data will further inform the type, extent or need of groundwater corrective action. For context, the statistical evaluation in the EAR asked the question, “Do the available data show that a statistically significant concentration of a given CCR constituent is above a GWPS?” As additional groundwater data are collected during the CARA Plan finalization and detailed design processes, an additional question becomes important: “Do current groundwater monitoring data confirm that there continue to be statistically significant constituent concentrations above GWPS, and are those concentrations increasing, stable, or decreasing?” This question gets to the issue of changing groundwater conditions, and of whether implementation of an active, passive, or no corrective measure is ultimately needed.

3.0 ASSEMBLY OF CORRECTIVE MEASURE ALTERNATIVES

Three primary corrective measure strategies have been identified as potentially applicable to address groundwater exhibiting statistically significant concentrations above the GWPS at the former WADA:

- Hydraulic Control (also often called hydraulic containment) and Treatment
- Monitored Natural Attenuation (MNA)
- Enhanced *In Situ* Treatment (EIST).

Descriptions of these approaches for groundwater corrective measures are provided in Attachment A.

These potential corrective measure technologies were further evaluated, and then retained technologies were assembled into potential corrective measures for groundwater at the former WADA.

3.1 FURTHER EVALUATION OF POTENTIAL CORRECTIVE MEASURE TECHNOLOGIES

Hydraulic control and treatment, MNA, and EIST were evaluated to assess each of these technologies' potential applicability as corrective measures to address statistically significant concentrations of molybdenum and arsenic above GWPS in groundwater wells at the former WADA. Based on this further evaluation, EIST was not retained for further consideration as a groundwater corrective measure as described below. In the future, as the implemented corrective action progresses and conditions change, some of these corrective measure technologies may be applicable for further study and considered for targeted implementation as part of the groundwater corrective action. The future integration of additional corrective measures or modifications of the implemented corrective action would be completed in conjunction with an adaptive management process (see CARA Plan Chapter 7.2.2) in coordination with and approval by TDEC and in accordance with applicable regulations.

3.1.1 Hydraulic Control and Treatment

Hydraulic control relies on groundwater extraction to control movement of groundwater. Groundwater extraction and treatment is used worldwide as a reliable, proven technology for hydraulic control, and is implementable and sustainable. A calibrated numerical groundwater flow model was previously developed for the ALF Plant as documented in the *Groundwater Flow and Solute Transport Modeling Report* (TVA 2020) and further discussed in the Groundwater Extraction TM (CARA Plan Appendix D). The results of the modeling showed that groundwater extraction would provide hydraulic control in the uppermost aquifer at an implementable total flow rate until GWPS are achieved and maintained.

Though the natural groundwater flow direction varies seasonally depending on the stage level of McKellar Lake, the net gradient and flow direction in the uppermost aquifer at the former WADA are to the north toward the lake (CARA Plan Chapter 2.2.5). The groundwater extraction system would be installed within the uppermost aquifer immediately upgradient of monitoring well clusters ALF-207 and ALF-208 along the downgradient (northern) former WADA boundary (i.e., between the downgradient monitoring wells and the downgradient former WADA boundary). The normal flow of groundwater in the uppermost aquifer would be intercepted by the extraction system, preventing it from moving downgradient of the former WADA. Given the close proximity of the groundwater extraction system to the downgradient monitoring wells, it is anticipated that GWPS would be attained at these monitoring wells within just a few years following groundwater extraction implementation. After GWPS are attained at these former WADA monitoring wells, the groundwater extraction system would continue to operate, capturing groundwater and preventing it from moving downgradient of the former WADA. Over time, the physical and geochemical processes that occur during the natural flow of groundwater through foundation soils, coupled with the source control provided by the CCR material removal already completed as part of the closure actions (CARA Plan, Chapter 5), will reduce the concentrations of targeted constituents in the upgradient uppermost aquifer (including arsenic at well ALF-219B) such that concentrations at the monitoring wells will not rise above GWPS when the groundwater extraction system is turned off. Attaining and maintaining this condition is the ultimate objective of the groundwater corrective action.

The time required to achieve this groundwater corrective action objective is uncertain due to a variety of factors. These factors include the initial magnitude of concentrations above the GWPS, the manner in which physical and geochemical processes act on different CCR constituents, and the seasonably variable rate and direction of groundwater flow within the uppermost aquifer. However, routine groundwater monitoring at other TVA Plant CCR units has shown that implemented source control measures started to have a beneficial effect on groundwater quality within a 5- to 10-year timeframe. Given the complete removal of CCR material from the former WADA, it is anticipated that beneficial effects on groundwater quality may be observed sooner. Also, the groundwater corrective action objective might be achieved at some locations sooner than others, and portions of the extraction system in such locations could be turned off sooner as part of the routine monitoring, operation, and maintenance of the corrective action.

Extracted groundwater would be pumped through a conveyance pipeline and treated at the existing onsite groundwater treatment system currently operating as part of the IRA (see CARA Plan Appendix D). The actual groundwater extraction locations and rates, the water treatment (if needed) and discharge approach, and associated details would be developed in the final design process following CARA Plan approval.

Based upon these further evaluations of hydraulic control and treatment technologies, groundwater extraction and treatment was retained as a corrective measure alternative to address statistically significant concentrations of molybdenum and arsenic above GWPS in groundwater at the former WADA.

3.1.2 Monitored Natural Attenuation

MNA relies on the natural geochemical system to attenuate concentrations of target constituents by adsorption onto unconsolidated materials or by other geochemical or physical processes. Because the CCR material has already been removed from the former WADA, source control (complete source removal) has been achieved in this area. Because CCR removal from the former WADA was only recently completed, a robust dataset of post-CCR material removal groundwater quality is not yet available, and the groundwater data collected to date primarily reflect conditions prior to removal of the CCR material. However, using the available groundwater monitoring data, an initial evaluation following the four-tiered approach specified in the USEPA MNA guidance (USEPA 2015) indicates that MNA could be an effective corrective measure technology for groundwater at the former WADA (CARA Plan Appendix C). Overall, molybdenum and arsenic concentrations in groundwater at the former WADA overall appear stable to decreasing following the completion of CCR material removal as part of the closure actions, with concentrations at shallow well ALF-208 exhibiting sharp decreases. This evaluation suggests that the USEPA Tier-I criteria are satisfied in that the area of groundwater exhibiting arsenic and molybdenum concentrations above GWPS is not expanding or migrating (i.e., stable and limited to known wells), and well ALF-208 has exhibited decreases in both arsenic and molybdenum concentrations. Upgradient intermediate well ALF-219B has also exhibited decreasing arsenic concentrations since the conclusion of CCR material removal activities. However, additional post-CCR material removal groundwater monitoring and geochemical data are needed to further substantiate these apparent trends and the Tier-1 evaluation results, and to support further Tier-2 and Tier-3 evaluations.

TVA will continue routine quarterly groundwater monitoring and plans to collect additional geochemical data during the CARA Plan finalization and detailed corrective action design processes to support a complete four-tiered analysis of MNA at the former WADA, consistent with the USEPA MNA guidance. For these reasons, MNA was retained as a primary groundwater corrective measure alternative to address statistically significant concentrations of molybdenum and arsenic above GWPS in groundwater at the former WADA.

3.1.3 Enhanced In Situ Treatment

EIST relies on the corrective measure to change geochemical conditions within the aquifer to facilitate attenuation of the target constituents. For the former WADA groundwater, the target constituents are molybdenum and arsenic. At this time, treatability studies have not been performed to directly evaluate how various potential reagents might affect the geochemistry and concentrations of molybdenum and arsenic in the former WADA groundwater. Therefore, uncertainty remains as to whether an *in situ* treatment would result in a reduction in the concentration of the target constituents without potentially affecting the concentrations of other constituents. For this reason, EIST was not retained for further consideration as a primary groundwater corrective measure alternative for the former WADA at this time.

3.2 GROUNDWATER CORRECTIVE MEASURE ALTERNATIVES

Based on the further evaluation of potential corrective measure technologies presented above, hydraulic control using groundwater extraction and treatment, and MNA were retained for further consideration as primary groundwater corrective measure alternatives to address molybdenum and arsenic in groundwater at the former WADA.

3.2.1 Hydraulic Control and Treatment

Groundwater flow modeling and other evaluations were performed to support the evaluation of hydraulic control using groundwater extraction and treatment as a corrective action for groundwater at the former WADA as described in Section 3.1.3 above (also see CARA Plan Appendix D). Design drawings further describing this corrective action approach are provided in CARA Plan Appendix E. Based on the evaluations performed, it is estimated that GWPS would be attained at the downgradient former WADA monitoring wells within just a few years of implementation and that subsequent operation would continue to capture groundwater, preventing it from moving downgradient of the former WADA until groundwater extraction is no longer needed to maintain GWPS at the downgradient wells. Over time, the physical and geochemical processes that occur during the natural flow of groundwater through foundation soils, coupled with the source control, will reduce the concentrations of targeted constituents in the upgradient uppermost aquifer (including arsenic at well ALF-219B) such that concentrations at the former WADA monitoring wells will not rise above GWPS when the groundwater extraction system is turned off.

Groundwater would be extracted from the uppermost aquifer along the downgradient boundary of the former WADA as described above. A variety of groundwater pumps and controllers are available that can provide a suitable range of flow rates, are compatible with the groundwater geochemical conditions, and are not reactive with the metals in the groundwater. There are also options available for compatible conveyance piping, instrumentation, and other equipment. Extracted groundwater would be pumped through a conveyance pipeline to the existing onsite treatment system that is currently used to treat groundwater extracted from the EADA as part of the IRA. If required, modification of the existing treatment system to accommodate extracted groundwater from the former WADA would be evaluated during detailed corrective action design. Treated water would be discharged to the sanitary sewer system (i.e., to the local publicly-owned treatment works, or POTW) under the existing permit which may require revision. The actual groundwater extraction locations and rates, the water treatment (if needed) and discharge approach, and associated details would be developed in the final design process following the CARA Plan approval.

3.2.2 Monitored Natural Attenuation

As described previously, MNA relies on the natural geochemical system to attenuate concentrations of target constituents by adsorption onto unconsolidated materials or by other geochemical or physical mechanisms. An initial evaluation following the four-tiered approach specified in the USEPA MNA guidance (USEPA 2015) was performed using the available data. The results of this initial evaluation indicate that the area of groundwater with molybdenum or arsenic concentrations above GWPS is likely stable or decreasing, and that MNA could be an effective corrective measure technology for groundwater at the former WADA. However, because the CCR material removal at the former WADA were only recently completed, the post-CCR material removal groundwater dataset is limited and insufficiently to support a complete MNA evaluation, and the groundwater data collected to date primarily reflect conditions prior to removal of the CCR material. Additional post-CCR material removal groundwater monitoring and geochemical data are needed to support a complete MNA evaluation using USEPA's four-tiered approach to confirm that MNA is expected to provide stable, long-term molybdenum and arsenic concentrations below the GWPS in groundwater at the former WADA. TVA will continue routine quarterly groundwater monitoring and plans to collect additional geochemical data during the CARA Plan finalization and detailed corrective action design processes to support a complete MNA evaluation.

4.0 IDENTIFIED CORRECTIVE ACTION

As noted above, this CARA Plan is based on groundwater data that primarily reflects conditions prior to the recent removal of CCR material from the former WADA. Since the removal of CCR material, changes in concentrations of CCR constituents in groundwater at the former WADA have occurred, and it is likely that groundwater quality will improve over time due to natural processes. An initial evaluation indicates that MNA could be an effective corrective action for groundwater, but there are currently insufficient post-removal groundwater data to support a complete MNA evaluation; therefore, TVA has identified groundwater extraction and treatment as a potential corrective action at this time. Although this identified corrective action has been further developed within this CARA Plan, TVA will continue to perform routine groundwater monitoring, and plans to collect additional geochemical data prior to preparing detailed designs for groundwater extraction and treatment. If future data and evaluations confirm that MNA will be effective, then TVA will coordinate with and obtain approval from TDEC to implement MNA as the corrective action. Otherwise, implementation of the identified corrective action of groundwater extraction and treatment will continue in accordance with the schedule provided in this CARA Plan.

The groundwater extraction system would be installed along the northern, downgradient boundary of the former WADA, immediately upgradient of the ALF-207 and ALF-208 well clusters such that the normal flow of groundwater is intercepted by the extraction system, preventing it from moving downgradient of the former WADA (Exhibit 1). Extracted groundwater would be pumped through a conveyance pipeline to the existing onsite treatment system that is currently used to treat groundwater extracted from the EADA as part of the IRA. If required, modification of the existing treatment system to accommodate extracted groundwater from the former WADA would be evaluated during detailed corrective action design. Treated water would be discharged to the sanitary sewer system (i.e., to the local POTW) under the existing permit which may require revision.

Groundwater monitoring will continue until the CARA Plan is approved and detailed corrective action design is completed, after which the corrective action would be implemented (CARA Plan Chapter 8.3). During implementation, performance of the corrective action will be monitored to assess if the desired results are being achieved or if modifications are needed. Table 6-2 in the CARA Plan explains how the corrective action requirements contained in TDEC DSWM regulations were considered and will be addressed by the identified corrective action, which also fulfills the requirements in the TDEC Order. An overall schedule for implementation and completion of the corrective action is also provided in Chapter 8 of the CARA Plan.

4.1 COMPLETION OF CORRECTIVE ACTION

For former WADA groundwater, the corrective action will be considered complete when the GWPS have been achieved for the constituents shown in Table 1-1, concentrations of those constituents have not exceeded the GWPS for three consecutive years, and the actions required to complete the corrective measures are satisfied.

Pursuant to TDEC DSWM 0400-11-01-.04(7)(a)9(iv), TVA will manage solid waste associated with the corrective action in a manner that is protective of human health and the environment and complies with applicable waste disposal requirements.

Pursuant to TDEC DSWM (7(0400-11-01-.04(7)(a)9(vi), once a corrective action has been completed, TVA will submit to TDEC within 14 days a certification that the corrective action has been completed.

5.0 REFERENCES

Stantec Consulting Services Inc. (Stantec). (2020). *Feasibility Study: East Ash Disposal Area*. Prepared for Tennessee Valley Authority. August 26, 2020.

Stantec. (2024a). *West Ash Disposal Area (WADA) Closure Report*. Prepared for Tennessee Valley Authority. June 2024.

Stantec. (2024b). *Remedial Investigation & Interim Response Action Groundwater Monitoring Plan, Allen Fossil Plant*. Prepared for Tennessee Valley Authority. March 11, 2024.

Tennessee Department of Environment and Conservation (TDEC). (2015). *Commissioner's Order No. OGC15-0177*. August 6, 2015.

Tennessee Valley Authority (TVA). (2020). *Groundwater Flow and Solute Transport Modeling Report.* Allen Fossil Plant. July 13, 2020.

TVA. (2024). *Environmental Assessment Report*, Revision 2, Allen Fossil Plant. March 22, 2024.

United States Environmental Protection Agency (USEPA). (2015). *Use of Monitored Natural Attenuation for Inorganic Contaminants in Groundwater at Superfund Sites*. 2015.

TABLE

Table 1. Groundwater Protection Standards
Established for the Corrective Action / Risk Assessment Plan

CCR Constituents	**Values**	**Units**
Antimony	6	µg/L
Arsenic	10	µg/L
Barium	2,000	µg/L
Beryllium	4	µg/L
Cadmium	5	µg/L
Chromium (total)	100	µg/L
Cobalt	6	µg/L
Fluoride	4,000	µg/L
Lead	15	µg/L
Lithium	40	µg/L
Mercury	2	µg/L
Molybdenum	100	µg/L
Radium-226 & 228	5	pCi/L
Selenium	50	µg/L
Thallium	2	µg/L

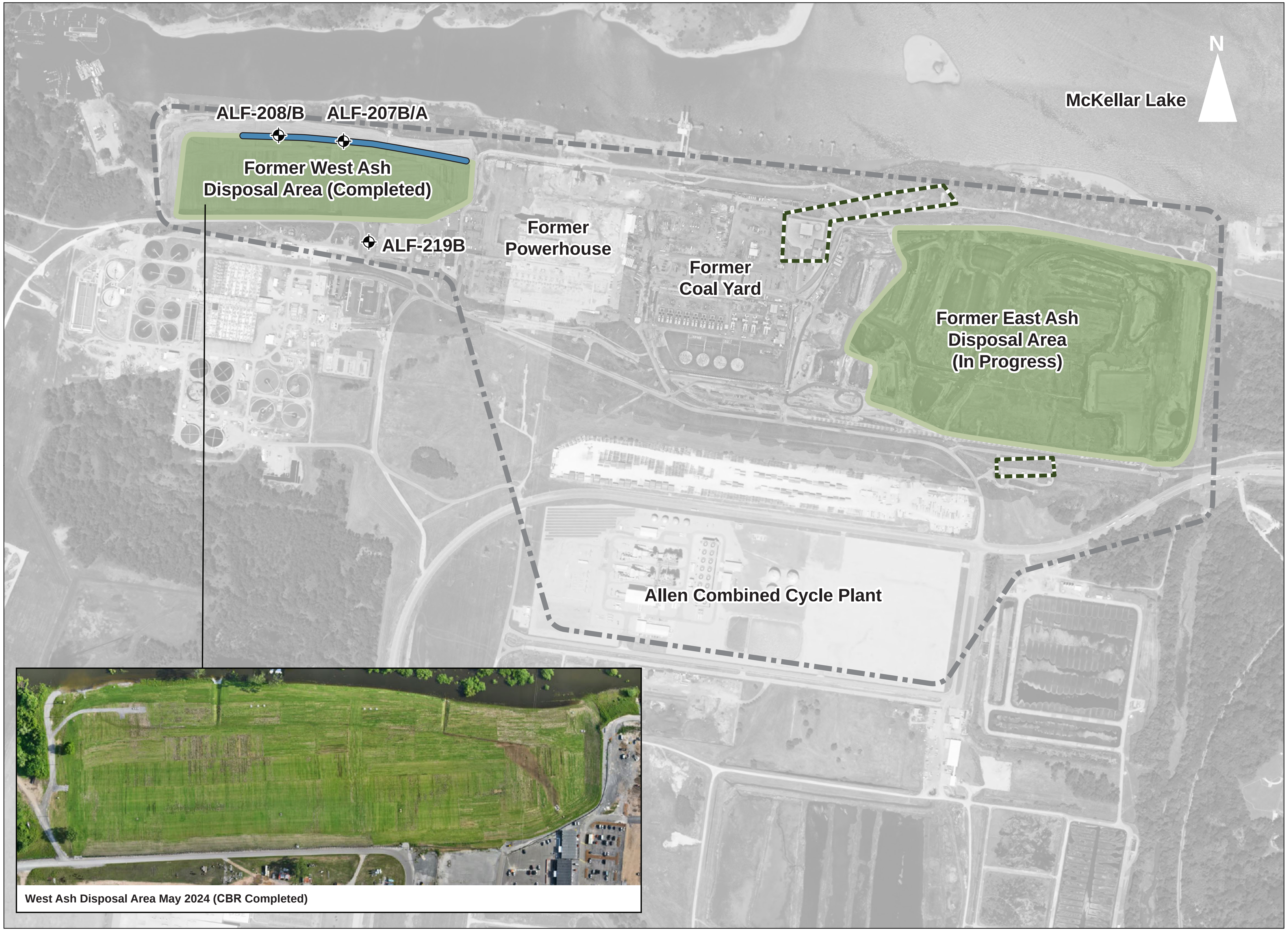
Notes:

Compliance with a GWPS is determined not by comparison to any single sample result, but by comparison to multiple sample results collected over time using statistical methods.

µg/L: micrograms per liter

pCi/L: picoCuries per liter

EXHIBIT



West Ash Disposal Area May 2024 (CBR Completed)

Exhibit No.
1

Title
Identified ALF Plant Former WADA Groundwater Corrective Action

Client/Project
Tennessee Valley Authority
Allen Fossil (ALF) Plant

Project Location
Memphis, Tennessee

175568282
Prepared by KB on 2024-08-01

Legend

ALF Restoration Project (Division of Remediation)

- Closure By Removal (CBR): Removal of CCR Material
- Groundwater Interim Response Action (IRA): Groundwater Extraction & Treatment, Evaluation of Groundwater Conditions
- Routine Site-Wide Groundwater Monitoring

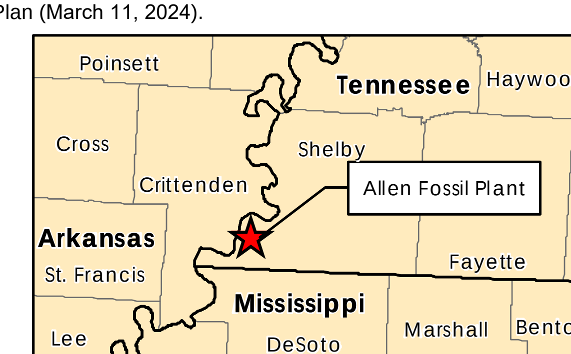
West Ash Disposal Area (WADA) Groundwater CARA PLAN (TDEC Order)

- Monitoring well location(s) with CCR constituent concentration statistically above groundwater protection standard (GWPS)
- WADA Groundwater Extraction and Treatment

If future data and evaluations confirm that monitored natural attenuation (MNA) will be effective, then TVA will coordinate with and obtain approval from TDEC to implement MNA as the corrective action. Otherwise, implementation of the identified corrective action of groundwater extraction and treatment will continue in accordance with the schedule provided in this CARA Plan.

Imagery provided by: NAIP (2023) and TVA (2/29/2024) EADA and WADA

NOTE: See Exhibit 2-4 for WADA monitoring well details. A complete description and depiction of the site-wide groundwater monitoring well network at the ALF Plant is provided in the Groundwater Monitoring Plan (March 11, 2024).



Stantec TVA

ATTACHMENT A

Potential Corrective Measure Strategies

1.0 GROUNDWATER CORRECTIVE MEASURE STRATEGIES

This attachment describes technologies that have been identified as potentially applicable for groundwater corrective action at the Allen Fossil Plant (ALF Plant) CCR units. Three potentially applicable technologies have been identified: hydraulic control and groundwater treatment, enhanced *in situ* treatment (EIST), and monitored natural attenuation (MNA). Each of these technologies is described below. For the purposes of the descriptions below, a constituent of interest (COI) is defined as a CCR constituent in groundwater that requires corrective action.

1.1 HYDRAULIC CONTROL AND GROUNDWATER TREATMENT

Hydraulic control is a reliable, proven technology that has been employed for decades to control impacted groundwater. Control is typically achieved through the use of submersible pumps to extract groundwater from collection galleries, wells or trenches. The applicability and orientation of a hydraulic control system is largely based on site-specific conditions such as aquifer dimensions and hydraulic conductivity, presence of confining layers, depth, gradient, characteristics of the COIs, and presence of receiving water bodies or wells. Hydraulic control systems can be effective at controlling the migration of constituents in groundwater, particularly when there are sensitive systems nearby or a continuing source of contamination. Typical groundwater extraction deployment approaches for hydraulic control are summarized below:

- 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 and the targeted control zone.
- 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 depending on 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 may be cost-effective when COIs are present at shallow depths and with high groundwater flow rates. Groundwater collection galleries function in a manner similar to trenches but usually target a particular location whereas trenches are employed where a long, linear extraction feature is needed.

The basis of design for a hydraulic control system is typically focused on developing a detailed hydrogeologic CSM and a groundwater flow model. The CSM serves as the basis for developing a numerical groundwater flow model that is calibrated and verified against actual site conditions. The calibrated groundwater flow model is then used to evaluate a variety of approaches (e.g., vertical wells, horizontal wells, trenches) and configurations, and to estimate the groundwater extraction rates necessary to hydraulically control the target zone. Understanding extraction rate requirements is important for developing an effective means of treating extracted groundwater (if treatment is needed).

Extracted groundwater often requires treatment to remove or reduce the concentrations of COIs prior to discharge to a receiving water body, publicly owned treatment works, land application, or re-injection through a well system. Bench-scale testing is often performed to assist in selecting the preferred water treatment technology. Treatment of the extracted groundwater may be completed onsite or offsite using treatment methodologies such as:

- 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 finite 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 may be completed 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.

A groundwater monitoring program is typically an integral part of any hydraulic control system. The monitoring program tracks changes in groundwater levels and COI concentrations to provide feedback on the effectiveness of the hydraulic control system.

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

1.2 ENHANCED IN SITU TREATMENT (EIST)

Enhanced *in situ* treatment of groundwater is an established technology for a variety of site conditions and contaminants. This alternative includes measures implemented *in situ* (i.e., within the aquifer) 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 EIST approaches for CCR constituents is typically dependent upon a detailed hydrogeologic CSM, a groundwater flow model, and a geochemical model. The CSM serves as the basis for developing a numerical groundwater flow model and a geochemical model that are calibrated and verified against actual site conditions. The flow field from the groundwater model serves as an input to the geochemical model along with site-specific geochemical data. The geochemical model is then used to evaluate potential COI attenuation rates and long-term stability for the EIST approach.

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

EIST may be an applicable remedial alternative based on site-specific conditions, such as:

- Localized area of impacts: COIs have been detected above GWPS within a limited number of wells. This indicates that *in situ* treatment would need to be deployed over a limited region. Additional investigations would be conducted to define the targeted treatment area.
- Metals treatment technologies: Removal of COIs with multiple treatment technologies have 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 determine the preferred treatment media, groundwater/treatment media contact time, and effectiveness of an EIST system in achieving GWPS.

A groundwater monitoring program is typically an integral part of any EIST system. The monitoring program tracks changes in COI concentrations providing feedback on the effectiveness of the EIST system.

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

- Site Access: EIST systems can require access for heavy equipment and a working platform to excavate trenches. 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 CCR unit dikes requires careful evaluation to make sure that stability of the dike structures is maintained.
- Depth: Installation of EIST systems 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 systems 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 system.

1.3 MONITORED NATURAL ATTENUATION

Monitored Natural Attenuation (MNA) is a corrective action strategy that involves establishing a program to monitor the physical, chemical, or biological processes that occur naturally at a site. These processes can often work to reduce the toxicity, concentration, or mobility of site COIs in a time frame that is acceptable and can be comparable to other technologies. MNA is increasingly employed at sites where COI concentrations are near threshold levels (e.g., groundwater protection standards [GWPS]), do not have an immediate pathway to sensitive receptors, and are not resultant from an on-going source. These conditions increase the likelihood that natural processes can attenuate COI concentrations in an acceptable time frame.

The basis of a MNA remedy for CCR constituents is typically centered on developing a detailed hydrogeologic conceptual site model (CSM), a groundwater flow model, and a geochemical model. The CSM serves as the basis for developing a numerical groundwater flow model and a geochemical model that are calibrated and verified against actual site conditions. The flow field from the groundwater model serves as an input to the geochemical model along with site-specific geochemical data. The geochemical model is then used to evaluate potential COI attenuation rates and stability of the attenuated COI mass.

MNA implementation would consist of designing a monitoring and assessment program to demonstrate that the COI concentrations present in the groundwater are being reduced by natural processes during and following any closure measures implemented as an outcome of the CARA process. Existing and potentially new monitoring wells at the facility would be used to characterize reduction in COI concentrations over time.

Reliance on natural processes rather than active treatment may require institutional controls to restrict access to affected zones. MNA relies upon naturally occurring processes to reduce COI 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.