Kingston Ash Recovery Project
Non-Time-Critical Removal Action
Embayment/Dredge Cell
Engineering Evaluation/Cost Analysis (EE/CA)

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List of Acronyms

ARAR	Applicable or Relevant and Appropriate Requirement
AWQC	Ambient Water Quality Criterion
BERA	Baseline Ecological Risk Assessment
BTEX	benzene, toluene, ethylbenzene and total xylenes
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CCC	Criterion Continuous Concentration
cm	centimeter
COC	Constituent of Concern
COI	Constituent of Interest
COPC	Constituent of Potential Concern
COPEC	Constituent of Potential Ecological Concern
CRM	Clinch River Mile
CSF	Cancer Slope Factor
cy	cubic yard
DOE	Department of Defense
DOT	U.S. Department of Transportation
EE/CA	Engineering Evaluation/Cost Analysis
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ERA	Ecological Risk Assessment
ERM	Emory River Mile
ESV	Ecological Screening Value
ºF	degrees Fahrenheit
FR	Federal Register
ft	foot
ft^2	square foot
GAF	gastrointestinal absorption factor
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
IEUBK	Integrated Exposure Uptake Biokinetic Model for Lead in Children
ILCR	Incremental Lifetime Cancer Risk
IRIS	Integrated Risk Information System
KIF	Kingston Fossil Plant
lin ft	lineal foot
LOAEL	lowest-observed-adverse-effect levels
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MCL	Maximum Contaminant Level
msl	mean sea level
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NOAEL	no-observed-adverse-effect level
NPDES	National Pollutant Discharge Elimination System
O&M	operation and maintenance
OSHA	Occupational Safety and Health Act
OSWER	Office of Solid Waste and Emergency Response
PAH	polynuclear aromatic hydrocarbon
PbB	predict blood lead level
pCi/g	picocuries per gram

PPE	personal protective equipment
PPRTV	Provisional Peer Reviewed Toxicity Value
psf	pounds per square foot
QAPP	Quality Assurance Project Plan
RDI	recommended dietary intake
RfD	reference dose
RfC	reference air concentration
RAO	removal action objective
sec	second
SF	slope factor
SLERA	Screening-Level Ecological Risk Assessment
SMDP	Scientific Management Decision Point
STSC	Superfund Technical Support Center
TCLP	Toxicity Characteristic Leaching Procedure
TDEC	Tennessee Department of Environment and Conservation
TSS	total suspended solids
TVA	Tennessee Valley Authority
UCL_{95}	95 percent upper confidence limit on the arithmetic mean

EXECUTIVE SUMMARY

This Engineering Evaluation/Cost Analysis (EE/CA) evaluates alternatives for restoration of the Swan Pond Embayment area impacted by the spilled fly ash at the Tennessee Valley Authority (TVA) Kingston Fossil Plant (KIF) release site in Roane County, Tennessee. This EE/CA also addresses stabilization and closure of the former Dredge Cell.

On Monday, December 22, 2008, a coal fly ash spill occurred at TVA's KIF, allowing a large amount of fly ash to escape from the Dredge Cell into the Swan Pond Embayment and the adjoining Emory River. On January 12, 2009, the Tennessee Department of Environment and Conservation (TDEC) issued a Commissioner's Order, Case No. OGC09-0001, requiring action be taken to respond to the emergency under Tennessee Code Annotated §69-3-109(b)(1), the Water Quality Control Act. On May 11, 2009, an Administrative Order and Agreement on Consent was signed between the U.S. Environmental Protection Agency (EPA) and TVA providing the regulatory framework for the restoration. The restoration work is being conducted under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and more specifically, under the removal program. A significant portion of the restoration efforts are currently underway as a time-critical removal action for removal of ash from the Emory River. The Work Plan for performing non-time-critical removal actions at the Site recommended that two EE/CAs be prepared, one for the embayment/Dredge Cell area and the other for residual ash in the river. This EE/CA addresses the embayment/Dredge Cell area. The EE/CA for the river system will be prepared at a later date, following further sampling and analysis of biotic and abiotic media, which will be used to assess potential human health and ecological risks for the river system.

The purpose of this EE/CA is to describe the objectives of the removal action in the embayment and Dredge Cell areas, describe and evaluate available alternatives for restoration of the environment impacted by the spilled fly ash, and identify the recommended action. This EE/CA has been prepared in accordance with EPA's *Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA.*

Site Conditions. Failure of the Dredge Cell dike released about 5.4 million cubic yards (cy) of coal ash. Approximately 2.4 million cy of that ash filled the Swan Pond Embayment, and the remaining 3.0 million cy entered the Emory River. Most of the ash in the river is being removed under the time-critical removal action. The ash is composed of fine silica particles similar to sand. Trace amounts of metals and radionuclides occur naturally in the coal and remain in the ash after coal combustion.

Soils in the area consist of residual or alluvial deposits overlying low water-producing bedrock. Alluvial soils lie beneath the ash disposal areas in the old floodplain of the Emory River, and are up to 65-ft deep. Groundwater moves from upland areas to the stream valleys, ultimately discharging to the Emory River. This discharge area is characterized by upward gradients toward the river, which minimizes the likelihood that ash-related contaminants could move toward upland wells or springs.

Wetlands present within the spill footprint were filled entirely by ash, thus eliminating these areas. Open water areas within the embayment and Emory River have also been filled with ash. The ash occurring above water level has been temporarily seeded with grass to minimize erosion.

Nature and Extent of Contamination. More than 50 samples of the ash have been collected and analyzed for metals; 11 samples have been analyzed for organic chemicals, mercury, and radionuclides. Metals, primarily arsenic, have been the focus of this monitoring. Arsenic is present in the ash at an average concentration of 65 milligrams per kilogram (mg/kg), which is above EPA's residential Regional Screening Level of 0.39 mg/kg.

Surface water samples have been collected from recently constructed clean water ditches and settling basins within the embayment area. More than 48 samples have been collected and analyzed by TVA since the clean water ditches were completed as of the initial writing of this EE/CA. The average arsenic concentration is 0.0341 milligrams per liter (mg/L), which is greater than TDEC's Ambient Water Quality Criteria (AWQC) of 0.010 mg/L. Maximum concentrations of antimony and selenium have also exceeded water quality criteria.

Groundwater monitoring has been conducted since 2005 from four monitoring wells associated with the Dredge Cell; two of these wells were destroyed during the ash spill, although one was replaced. Three wells have also recently been installed around the Ash Processing Area. Arsenic levels have been historically low (less than 0.014 mg/L); in recent sampling arsenic was detected at 0.0297 mg/L in one well. Arsenic levels have therefore exceeded the drinking water maximum contaminant level of 0.010 mg/L.

Human Health Risk Assessment. A human health risk assessment was completed to develop quantitative and qualitative estimates of potential cancer risks and non-cancer hazards for human receptors exposed to environmental media impacted by ash in Swan Pond Embayment and the Dredge Cell. Risks to both current (near-term) and potential future receptors were evaluated.

Cancer risk estimates for current exposure scenarios did not exceed the target risk range for any receptor. The highest calculated risk, 5E-05 for an adolescent trespasser, is within the target risk range. An adolescent trespasser may be exposed to ash through incidental ingestion, inhalation, dermal contact, and external. The cancer risk is driven by ingestion of arsenic and external exposure to gamma radiation from K-40, Ra-226, Ra-228, and Th-228. Noncancer hazard estimates for current exposure scenarios do not exceed the noncancer hazard threshold of 1 for any receptor. Therefore, the occurrence of adverse noncancer effects is unlikely for current receptors.

Cancer risk estimates for future exposure scenarios exceeded the target risk range for a future onsite resident (adult and child), indoor or outdoor worker, and groundskeeper. The highest cancer risk (2E-03) was calculated for an onsite resident adult living directly on the exposed ash. The cancer risk estimates are driven by ingestion of arsenic and external exposure to gamma radiation from K-40, Ra-226, Ra-228, and Th-228. There is considerable uncertainty in these estimates in that levels of radioactivity in the ash for K-40, Ra-226, Ra-228, and Th-228 are similar to those of typical regional soils. The estimates may therefore overestimate risks above normal regional background levels.

Noncancer hazard estimates for future exposure scenarios exceeded the noncancer hazard threshold of 1 for an onsite resident (child). The highest hazard index (8) was calculated for a child resident living and playing directly on the exposed ash. The primary contributors to this hazard are ingestion of arsenic, cobalt, thallium, aluminum, iron, vanadium, and chromium in ash; and (for future residents living onsite) ingestion of arsenic in groundwater. Results of lead modeling for an onsite child resident and an onsite worker indicate that potential exposures to lead in ash do not result in unacceptable blood lead levels to either receptor.

Ecological Risk Assessment. A Screening-Level Ecological Risk Assessment (SLERA) was conducted to evaluate potential risks to terrestrial and aquatic ecological receptors exposed to detected constituents in ash and surface water in the embayment and Dredge Cell. The screening involved comparing the maximum detected concentration of each analyte in each medium to ecological screening values (ESV). ESVs are constituent concentrations below which there is negligible risk to receptors exposed to them. The ratio of the maximum concentration to ESV is called the hazard quotient (HQ). Results of the SLERA indicate that several constituents may be of potential concern to ecological receptors:

- Ash as Soil: 16 inorganic constituents in ash as soil were selected as contaminants of potential ecological concern (COPECs) because their maximum concentrations exceeded an HQ of 1.

- Ash as Sediment: 17 inorganic constituents in ash as sediment were selected as COPECs, either because maximum concentrations exceeded an HQ of 1, an ESV was not available, or the constituents are typically present in fly ash.

- Surface Water: 11 inorganic constituents in surface water were selected as COPECs, either because maximum concentrations exceeded an HQ of 1, an ESV was not available, or the constituents are typically present in fly ash.

The SLERA indicates a potential for adverse ecological effects for terrestrial and aquatic receptors in the embayment/Dredge Cell area. Alternative remedies being considered for the site entail the complete removal of ash from the embayment and capping of the Dredge Cell with clean soil, which will eliminate the potential exposure pathways for ecological receptors. Therefore, a Baseline Ecological Risk Assessment is not warranted and no additional data are needed to support the selection of a removal action to protect ecological receptors in the Dredge Cell and Swan Pond Embayment.

Removal Action Objectives. Results of the screening-level human health and ecological risk assessments indicate potential risk to human and ecological receptors due to exposure to naturally occurring metals and radionuclides in the ash. A removal action is needed to mitigate the threat or potential threat to the public or the environment. The following are the specific removal action objectives (RAOs):

- Minimize direct contact between ash material in the embayment and water flowing through the embayment area into Watts Bar Reservoir;
- Minimize migration of ash and its constituents from the embayment or Dredge Cell into affected waters due to erosion;
- Minimize direct contact exposure by human or ecological receptors to ash on the ground;
- Restore the embayment to pre-spill conditions;
- Close the former Dredge Cell in accordance with Tennessee Solid Waste Rule 1200-1-7; and
- Dispose of waste streams from the removal action.

Development of Alternatives. Presumptive remedies are preferred technologies or response actions for sites with similar characteristics that have been identified by EPA to streamline remedy selection and accelerate site cleanup. For low-level threat waste found at metals-in-soil sites, the presumptive remedy is containment, although excavation with disposal and other institutional controls have also been used. Due to similarities between soil and ash and due to the presence of metals, containment and/or excavation with disposal are preferred technologies for this site.

A limited number of alternatives has been developed. These alternatives are intended to represent a range of possibilities for restoration of the embayment and Dredge Cell areas, with distinctly different advantages and disadvantages, so that tradeoffs between them can be clearly defined and evaluated. The following alternatives have been developed:

- Alternative 1: Excavate Embayment and Dispose Offsite (2.8 million cy); Grade and Close Dredge Cell. The actions under this alternative are designed to avoid returning any spilled ash back into the Dredge Cell but to close the remainder of the Dredge Cell in place. Alternative 1 would remove the ash and other materials in the embayment and dispose of this material offsite. A dike would be installed to keep ash in the cell from entering the embayment in the future and the Dredge Cell would

be graded for drainage. The height of the closed cell would be approximately 790 ft above mean sea level (msl). The embayment would be restored to an aquatic and riparian environment.

- Alternative 2: Excavate Embayment and Portions of Dredge Cell and Dispose Offsite (6.8 million cy); Grade and Close Remainder of Dredge Cell. The actions under this alternative are designed to minimize long-term reliance on a dike containment system by removing much of the ash from the Dredge Cell above the surrounding ground level. Alternative 2 would remove the ash and other materials in the embayment, plus enough ash from the Dredge Cell to limit long-term reliance on a dike between the cell and the embayment, yet would leave enough ash to provide buttressing for the remaining dikes. The removed material would be disposed offsite. The Dredge Cell would be graded to a gradual slope, with a maximum height of the closed cell of approximately 780 ft msl at its highest point, although most of the Dredge Cell would be below elevation 765 ft msl. The embayment would be restored to an aquatic and riparian environment.

- Alternative 3: Excavate Embayment and Dispose Onsite; Close the Dredge Cell. The actions under this alternative are designed to minimize any further offsite hauling of ash. Alternative 3 would use onsite disposal locations for the ash removed from the embayment. For evaluation purposes, this alternative uses the Dredge Cell as a disposal facility for the 2.5 million cy of ash from the embayment. No material would be taken offsite. The ash and other material in the embayment would be removed and placed in compacted lifts in the Dredge Cell. A dike would be installed to keep ash in the cell from entering the embayment in the future and the Dredge Cell would be graded for drainage. The height of the closed cell would be approximately 805 ft msl. A subalternative was developed for Alternative 3 that would place material from the embayment into the Ash Pond prior to closure, which would lower the height of the closed cell to 390 ft msl. The embayment would be restored to an aquatic and riparian environment.

- Several options were considered, but not retained as alternatives, as explained in the EE/CA Work Plan. Those options included leaving all materials within the embayment and either covering them in-place or placing a liner beneath them; excavating all ash from the embayment and replacing with clean fill dirt; and excavating all ash from both the embayment and the entire Dredge Cell.

Evaluation of Alternatives. The relative performance of each alternative has been evaluated with respect to its effectiveness, implementability, and cost. The purpose of this comparative analysis is to highlight the advantages and disadvantages of each alternative relative to one another so that key tradeoffs that would affect the remedy selection can be identified.

Effectiveness. Each alternative would fully meet RAOs. The ash within the embayment would be removed to the maximum extent practicable, so as to restore the natural resources and area waters. The Dredge Cell would be closed. As a result, the terms of both the TDEC Commissioner's Order and the EPA Administrative Order would be met.

Each alternative would be protective of both human health and the environment. Removal of the ash from the embayment would eliminate direct contact with water flowing through the area and eliminate future migration of ash into the river due to erosion. Closure of the former Dredge Cell, which would include a clay cover over the ash, would also eliminate future migration of ash due to erosion and eliminate direct contact with ash on the ground by either human or ecological receptors. Existing TVA access controls would prevent future use of the closed Dredge Cell area for unauthorized purposes.

Each alternative would comply with applicable or relevant and appropriate requirements, including landfill closure, restoration of waters of the state and associated floodplain and wetland areas,

management of waste materials, dust control, and erosion and sediment control. Information satisfying the requirements of a Jurisdictional Assessment is provided in Appendix D.

Each of the alternatives would be effective over the long-term, although in differing ways. Removing the ash from the embayment and closure of the Dredge Cell would be permanent actions that would effectively restore the waters of the state; eliminate direct contact, erosion, and migration of ash to the river; and properly contain or dispose of the remaining ash materials.

Differing levels of foundation treatment would be implemented under each alternative so that the perimeter dike containment system would be effective and stable over the long-term. Analysis of dike stability under static loading conditions resulted in safety factors greater than 1.5 for each alternative, which are indicative of stable conditions. The conceptual dike configuration and foundation design for each of the alternatives address the four contributing factors cited by AECOM in their root cause analysis of the former dike failure:

1. Fill Geometry. The former failed dike was constructed using small dikes stacked progressively up slope on top of nearly 80 ft of sluiced ash and a sensitive silt ("slimes") layer. Total height of the dikes that surrounded the former Dredge Cell prior to its failure was elevation 820 ft msl. Under Alternatives 1 and 3, Dike C would be constructed using a single compacted soil dike placed on a crushed rock working platform. The perimeter dikes would be highest under Alternative 3a and least under Alternative 2. Under Alternative 3a, the perimeter dikes would be constructed to a height of 787 ft msl. Under Alternatives 1 and 3b, the dikes would be built to a height of 765 ft msl. Under Alternative 2, the top of ash around three sides of the Dredge Cell would be constructed even with the surrounding ground surface (735 ft msl along Dike C and 765 ft msl along the Ball Field and Swan Pond Road), and to a height of 780 ft msl at Dike D. Each of these dike configurations is much lower than the former Dredge Cell prior to its failure.

2. Fill Rates. The elevation of the ash in the former Dredge Cell prior to failure was increasing at a rate of about 6 ft/year, more rapidly compared to earlier years, which added load to the wet ash beneath the dikes. In particular, the filling resulted in loose, wet ash saturated throughout its depth, which led to high porewater pressures at depth and low strength in the sluiced ash materials. Under each of the three alternatives, the conceptual cell fill would be constructed by dry stacking using dewatered ash, compacted in thin lifts. Results of the test embankment have shown that such construction methods would not result in excess porewater pressures in the foundation ash materials under a rate of filling equivalent to 5 ft/month.

3. Soft Foundation Soils. Creep deformations within the submerged loose slimes was occurring under the load of loose wet ash in the former Dredge Cell, which caused a reduction in the strength of the slimes and led to deep-seated failure of the dike. Under each of the three alternatives, the conceptual dike would be reinforced with soil/cement columns that would not rely on the strength of the soft foundation soil layer for stability, but would instead transfer the load substantially to the soil/cement columns.

4. Loose Wet Ash. The original sluiced ash was deposited under water, resulting in a high void ratio (very loose ash) that did not consolidate or densify under the surcharge weight of ash placed above it. As a result, the loose wet ash had a low undrained shear strength with a very sensitive structure. Under each of the three alternatives, the conceptual dike would be constructed using dewatered ash, compacted in thin lifts. Results of the test embankment study have shown that the undrained shear strength of the compacted dry ash is greater than loose wet ash. The compacted dry ash would therefore be much stronger than the loose wet ash in the former Dredge Cell.

The conceptual foundation design under each alternative includes a treatment zone consisting of soil/cement columns arranged in a grid pattern for optimum mitigation of potential liquefaction following an earthquake. Alternative 3 provides the most robust foundation treatment, because its perimeter dikes are much higher. Alternative 2 would provide the least amount of foundation treatment. Resulting safety factors greater than 1.1 were calculated for each alternative, which are suitable under short-term seismic loading conditions. There is uncertainty under Alternative 2 as to whether the perimeter gentle slopes, particularly along Dike C, would be stable under short-term seismic loading conditions without foundation treatment. Additional foundation treatment could be implemented as a contingency measure.

Different disposal options would be implemented under each alternative. Alternative 3 would not transport any ash generated during the non-time-critical removal action offsite for disposal. The material from the embayment would be placed within the Dredge Cell, resulting in a total of 13.6 million cy of material beneath the clay cover. A subalternative was evaluated for Alternative 3 that would place material from the embayment within the Ash Pond, rather than the Dredge Cell, and close both areas at the same time. Alternative 1 would transport approximately 2.8 million cy of material offsite for disposal; approximately 10.8 million cy of material would remain in the Dredge Cell. Alternative 2 would transport the greatest volume (approximately 6.8 million cy) of material offsite for disposal; approximately 6.8 million cy would remain in the Dredge Cell.

Under Alternatives 1 and 2, the offsite disposal facility would be an existing, permitted solid waste landfill. The landfill would operate under the restrictions of its specific permit, including waste acceptance criteria, groundwater protection systems, leachate collection and treatment systems, interim and final cover, and other terms of the operating permit. EPA must be notified of the specific landfill prior to shipment of any ash. Offsite disposal under Alternatives 1 and 2 would therefore be effective in reducing onsite volumes and managing the ash in a permitted manner.

Each of the alternatives would be effective over the short term (during construction); RAOs would be achieved once construction is complete. Short-term impacts could occur during the excavation and processing of the ash. Engineering measures would be implemented to protect remediation workers and the community, including dust control measures, health and safety measures, and erosion and sediment control measures. Under Alternatives 1 and 2, transportation control measures would also be implemented to protect the community and minimize spills.

Inherent short-term risks would be associated with shipment of ash over public roadways or railways. Short-term risks of railroad incidents or rail-vehicle intersection accidents would be proportionate to the number of trip-miles. Alternative 2 would pose the greatest impact; offsite transport of more than 6.8 million cy of ash would result in nearly 300,000 trip-miles by rail alone and could result in risks estimated at 3 rail accidents, 2 rail injuries, and 0.9 rail fatalities. Alternative 1 would pose less impact; offsite transport of 2.8 million cy of ash would result in nearly 125,000 trip-miles by rail alone and could result in risks estimated at 1 rail accident, 2 rail injuries, and 0.9 rail fatalities. Alternative 3 would eliminate offsite transportation impacts, since no material would be shipped offsite.

Subalternatives were evaluated for Alternatives 1 and 2 that would transport a portion of the material (760,000 cy) offsite by truck. Such truck transport would pose short-term risks of traffic accidents as a result of over 1.7 million trip-miles by truck over public roadways, primarily interstate highways. Short-term risk calculations suggest an estimated 2 truck accidents, 0.8 truck injuries, and 0.04 truck fatalities could occur under those subalternatives.

Implementability. The alternatives would be implementable using conventional technologies and would achieve RAOs at the completion of construction. Alternative 2 would take the longest to complete, nearly 4.1 years due to material handling constraints on offsite shipments. Alternative 3a would take nearly 4.0

years to complete, due to installation of a robust perimeter dike foundation treatment system and difficult ash compaction. Alternative 1 would take the least time to complete, approximately 2.8 years.

Closure of the Ash Pond under these alternatives would occur at a later date and would take another 10 months to complete. Subalternative 3b would place material from the embayment within the Ash Pond and close both the Dredge Cell and Ash Pond at the same time, requiring a total of 4.1 years to complete.

Excavation and dewatering would be most difficult under Alternative 2, due to the large volume of material shipped offsite (6.8 million cy). Alternative 1 would be somewhat less difficult, due to lesser volumes (2.8 million cy offsite and 1.8 million cy from regrading onsite). Alternative 3 would involve the least amount of material handling (2.5 million cy from the embayment and Dike 2, plus 1.1 million cy from regrading), all of which would be onsite since there would be no offsite shipment. However, dewatering and compaction of ash in lifts to strict engineering requirements would be difficult and slow to implement under Alternative 3.

Transportation of the ash would be complicated by the large volume of material and limited disposal options. Alternative 2 would involve the greatest volume (6.8 million cy) and take the longest time to complete offsite shipments, estimated at 45 months for rail transport alone. Alternative 1 would also involve a large volume (2.8 million cy), and long time to complete offsite shipments, estimated at 19 months for rail transport alone. Alternative 3 would involve no offsite shipment of ash, and therefore would avoid transportation impacts.

There is greater uncertainty in implementing Alternative 2 as to whether sufficient capacity is available at the disposal facilities to handle the 6.8 million cy of material generated during the non-time-critical removal action. Although volumes are less under Alternative 1 (2.8 million cy), offsite disposal capacity is still uncertain. Alternative 3 would not rely on any offsite disposal capacity.

Specialty contractors with deep soil mixing expertise would be required for implementation of the foundation treatment for the perimeter dike containment structure around both the Dredge Cell and Ash Pond. Alternative 3a would install the most robust foundation treatment zone, involving 22,600 linear feet (lin ft) of dike perimeter, 1,241,000 square feet (ft^2) of grid area, and 654,000 cy of soil/cement. There is uncertainty in implementing Alternative 3a as to whether sufficient capacity would be available among the experienced specialty contractors to handle this large production volume. Alternatives 1 and 3b would involve similar levels of foundation treatment. Alternative 1 would involve 17,200 lin ft of dike, 650,000 ft^2 of grid area, and 298,000 cy of soil/cement. Alternative 3b would involve 16,600 lin ft of dike, 581,000 ft^2 grid area, and 259,500 cy of soil/cement. Alternative 2 would involve much less foundation treatment, 12,800 lf of dike, 306,000 ft^2 grid area, and 154,500 cy of soil/cement.

Regrading of the Dredge Cell to provide final contour grades would be complicated under each alternative due to the difficult compaction properties and high erodibility of the ash. The ash is highly sensitive to moisture variations, requiring careful quality control to achieve optimum moisture for compaction. Instrumentation (piezometers, settlement plates, and inclinometers) would be needed to monitor the construction of the fill. Erosion control measures would be used during ash fill placement to prevent excessive erosion. Alternative 3 would involve the greatest amount of filling plus regrading (3.6 to 3.8 million cy) and a higher level of instrumentation for dike monitoring and quality control. Alternative 1 would involve considerably less volume (1.8 million cy) and moderate level of instrumentation. Alternative 2 would involve minimal regrading, since most of the material would be removed, and smaller level of instrumentation.

The implementability of the embayment restoration would be similar under all three alternatives, requiring specialty subcontractors experienced in wetland restoration. Approximately 28 acres of mixed

forested, scrub-shrub, and emergent wetlands would be contoured and replanted with native plant species. Several years would be required to establish a self-sustaining habitat.

Long-term operation and maintenance (O&M) activities would be similar under each of the three alternatives, and would include routine inspection and maintenance of the perimeter dikes and cover containment systems. Long-term monitoring of groundwater would be required to evaluate future impact of groundwater migration to the river system; this monitoring is to be addressed under the EE/CA for the river system. Long-term institutional controls, including site access control and land use restrictions would be readily implemented as part of ongoing KIF operations.

Cost. Capital costs are highest for Alternative 2 ($719.3 to $741.1 million) due to the high cost of transport and disposal of the much larger volume of material. Capital costs are lowest for Alternative 3 ($268.2 to 315.5 million) because no material is disposed offsite. Capital costs of Alternative 1 are in between ($439.6 to $455.3 million). All costs are reported in 2009 dollars.

Subalternatives were developed for Alternatives 1 and 2 to compare the costs of transporting approximately 760,000 cy of ash from the north embayment area by truck instead of rail. Although hauling by truck is less costly than by rail, the unit costs of disposal in Alabama (transported by rail) can be higher due to the lesser volume of material, which offsets some of that savings.

A subalternative was developed for Alternative 3 that would compare the costs of closing the Ash Pond at the same time as the Dredge Cell instead of closing it at a later date. Closing the two areas at the same time would result in a cost savings, primarily due to reducing the foundation treatment needed for perimeter dike containment, eliminating imported fill material to close the Ash Pond, and schedule efficiencies in integrating Ash Pond closure with Dredge Cell closure.

Ongoing O&M costs are the same for all alternatives, since the O&M activities are the same. O&M costs are estimated at $686,000/year (2009 dollars).

1. INTRODUCTION

This Engineering Evaluation/Cost Analysis (EE/CA) evaluates alternatives for restoration of the Swan Pond Embayment area impacted by the spilled fly ash at the Tennessee Valley Authority (TVA) Kingston Fossil Plant (KIF) release site in Roane County, Tennessee (Figure 1). The EE/CA also addresses stabilization and closure of the former Dredge Cell.

On Monday, December 22, 2008, just before 1 a.m., a coal fly ash spill occurred at TVA's KIF, allowing a large amount of fly ash to escape from the Dredge Cell into the Swan Pond Embayment and adjoining Emory River. Shortly after the ash spill, on January 12, 2009, the Tennessee Department of Environment and Conservation (TDEC) issued a Commissioner's Order, Case No. OGC09-0001, requiring action be taken as necessary to respond to the emergency under Tennessee Code Annotated §69-3-109(b)(1), the Water Quality Control Act. The TDEC Order required a plan addressing both the short-term and long-term management of coal ash at the Kingston Plant, including remediation and stabilization of the failed ash waste cells, proper management of the recovered ash, and a revised closure plan for the ash disposal facility.

On May 11, 2009, an Administrative Order and Agreement on Consent was signed between the U.S. Environmental Protection Agency (EPA) and TVA providing the regulatory framework for the restoration efforts. The restoration work is being conducted under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and more specifically, under the removal program. A significant portion of the restoration efforts are currently underway and being conducted as a time-critical removal action. In accordance with Section IX.30 of the Administrative Order, a Work Plan for performing one or more EE/CAs for non-time-critical removal actions at the Site was prepared. That Work Plan (Jacobs 2009) recommended that two EE/CAs be prepared, one for the embayment/Dredge Cell area and the other for residual ash in the river. This EE/CA addresses the embayment/Dredge Cell area. The EE/CA for the river system will be prepared at a later date, following further sampling and analysis of biotic and abiotic media, which will be used to assess potential human health and ecological risks for the river system.

The purpose of this EE/CA is to describe the objectives of the removal action in the embayment and Dredge Cell areas, describe and evaluate available alternatives for restoration of spilled fly ash, and identify the recommended action. This EE/CA has been prepared in accordance with EPA's *Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA* (EPA 1993). The EE/CA is organized as follows:

- Section 1, Introduction, summarizes available data used to characterize the site and surrounding areas, and evaluates potential human health and ecological risks.

- Section 2, Removal Action Objectives, identifies the scope, goals, and objectives of the non-time-critical removal action and summarizes applicable or relevant and appropriate requirements (ARARs).

- Section 3, Removal Action Alternatives, identifies applicable technologies and develops alternatives for restoration of the embayment and Dredge Cell areas.

- Section 4, Analysis of Alternatives, presents an individual analysis of the alternatives based on effectiveness, implementability, and cost, followed by a comparative analysis to identify trade-offs between alternatives.

- Section 5, Recommended Removal Action Alternative, identifies the removal action alternative that best satisfies the evaluation criteria.

– Figures are located at the end of the document, attached.

1.1 SITE DESCRIPTION

1.1.1 Site Location and History

The KIF is located just off Swan Pond Road at the confluence of the Emory and Clinch Rivers on Watts Bar Reservoir in Roane County, near Kingston, Tennessee (Figures 1 and 2). Plant construction began in 1951 and was completed in 1955. KIF is one of TVA's larger fossil plants and generates 10 billion kilowatt-hours of electricity a year, enough to supply the needs of about 670,000 homes in the Tennessee Valley. KIF has nine coal-fired generating units, consuming some 14,000 tons of coal a day. The winter net dependable generating capacity is 1,456 megawatts.

Ash, a by-product of a coal-fired power plant, is stored in unlined containment areas, including a former Dredge Cell (Figure 3). Failure of the Dredge Cell dike released about 5.4 million cubic yards (cy) of coal ash. At the time of the slide, the area contained about 16.2 million cy of ash and associated dikes. The dike failure caused about 60 acres of ash in the 127-acre containment area to be displaced. The released ash covered about 300 acres. Fly ash filled the Swan Pond Embayment on the north side of the KIF property adjacent to the failed Dredge Cell. A temporary dike (Dike 2) was constructed in the eastern portion of the Swan Pond Embayment to contain the fly ash to the west of the dike until a response action plan could be developed, approved by the regulators, and implemented. Fly ash also entered the channel and overbank areas of the riverine section of the Emory River. TVA is recovering the material outside of the Swan Pond Embayment (east of Dike 2) by use of mechanical excavators and dredging operations under a time-critical removal action.

The fly ash that was released to the Emory River originates from the coal burned in boilers for power production at KIF. The coal, in its natural state, contains various inorganics that can be retained with the ash after burning. The ash itself is primarily composed of fine silica particles similar to sand. Trace amounts of arsenic, chromium, copper, lead, mercury, nickel, selenium, thallium, vanadium, zinc, and other metals which occur naturally in the coal remain in the ash after coal combustion. Naturally occurring radionuclides, such as isotopes of potassium, radium, uranium, and thorium, may also remain in the ash after coal combustion. These metals and radionuclides are typically bound to the ash.

1.1.2 Demographics

Roane County had a total population of 53,399 in 2007. The county is primarily rural, with about 60 percent of the population living outside of incorporated cities and towns. The nearest cities include Kingston (population 5,524) approximately 2 miles southeast of the KIF, Harriman (population 6,668) 3 miles northwest, and Rockwood (population 5,559) 10 miles southwest.

Per the EPA Administrative Order, the "site" is defined as those areas of the KIF where waste material has been deposited, stored, disposed of, or placed or has migrated or otherwise come to be located. Most of the 300 acres directly affected by the release was TVA property, although 40 non-TVA owned properties, constituting a total of 8 acres, were affected. TVA has since purchased most of the affected properties and others in the area that may be affected by response actions.

1.1.3 Climate

Climate in the region surrounding Kingston, Tennessee is warm during summer when average daily temperatures tend to be in the 70's and cold during winter when temperatures tend to be in the 30's. The warmest month of the year is July with an average maximum temperature of 87 ºF, while the coldest

month of the year is January with an average minimum temperature of 25 ºF. Temperature variations between night and day tend to be moderate during summer with a difference that can reach 23 ºF, and moderate during winter with an average difference of 22 ºF.

The annual average precipitation at Kingston is 53.23 inches. Rainfall is fairly evenly distributed throughout the year. The wettest months of the year occur between November and April, with highest average monthly precipitation in March of 5.70 inches. The driest months of the year occur in August through October (NWS 2006).

1.1.4 Topography

KIF and the area affected by the ash release lie within the Valley and Ridge physiographic province, a region characterized by narrow, subparallel ridges and valleys trending northeast-southwest. Physiographic boundaries of the site are Pine Ridge to the west of the site, Swan Pond Creek drainage to the north, and the Emory River/Watts Bar Reservoir to the east and south. Topography varies from elevations of 1,000 to 1,100 ft mean sea level (msl) on the tops of the ridges to 737 ft msl at Watts Bar Reservoir. Early maps of the area indicate the ash storage area was formerly a seasonal backwater or flood plain of the Emory River. The backwater was likely subject to periodic flooding; the Emory River floodplain elevations before construction of the KIF varied between approximately 725 and 735 ft msl (based on a 1924 topographic survey). Bottom elevation of the pre-slide embayment area varies between 735 and 737 ft msl. After the slide, ash and intermixed soil filled much of the embayment to depths of more than 20 ft; current top of ash elevations vary between 750 and 760 ft msl, although piles of ash up to elevation 790 ft msl are present. Within the former Dredge Cell, top of ash elevations vary between 740 and 820 ft msl.

1.1.5 Surface Water Hydrology

The KIF is on the Emory River, 2.6 river miles above the confluence of the Clinch and Tennessee Rivers. The Emory River drains a watershed area of approximately 865 mi^2 with average flow rates between 700 and 1,300 cubic ft per second. The affected reach of Watts Bar Reservoir transitions from the upstream riverine (riverlike) reaches of the Emory River to the more lacustrine (lakelike) conditions found in the impounded portions of the backwaters of Watts Bar Reservoir. The reservoir pool extends upstream to above Harriman (Emory River Mile [ERM] 11). Swan Pond Embayment is a backwater slough of Watts Bar Reservoir created in the floodplain of Swan Pond Creek as the reservoir filled. Overbank areas in the Swan Pond Embayment are very shallow. In accordance with the TVA Watts Bar Operating Guide, normal summer pool within Watts Bar Reservoir is maintained between 740 and 741 ft msl; normal winter pool is maintained between 735 and 737 ft msl.

The area most affected by the ash release extends from ERM 1.5 to 3.5. Prior to the failure of the dredge cells, the 100-year flood elevations for this reach of the Emory River varied from elevation 747.6 ft msl at ERM 1.5 to elevation 749.4 ft msl at ERM 3.5. At the Swan Pond Embayment, located at ERM 2.2, the 100-year flood elevation would be approximately 748 ft msl. The 100-year flood post-slide elevations would be about 5 ft higher than preslide elevations immediately upstream of Weir 1 and about 8 ft higher than preslide elevations along Emory River Road and Lakeshore Drive.

The Emory, Clinch, and Tennessee Rivers are waters of the state. “Waters of the State” are defined by T.C.A. §69-3-103(33) and are classified by the Tennessee Water Quality Control Board for suitable uses. The three rivers have been classified for the following uses: domestic water supply, industrial water supply, fish and aquatic life, recreation, irrigation, livestock watering and wildlife, and navigation. The Tennessee River is the source of drinking water for the city of Kingston, Tennessee. The downstream Watts Bar Reservoir is used by several municipalities as a source of drinking water.

1.1.6 Geology

The controlling structural feature of the region is a series of northeast-striking thrust faults which have forced older rocks from the southeast over younger units. Bedrock units of the Rome Formation, the Lower Conasauga Group, and the Knox Group occur beneath the affected area in northeast-trending bands (Figure 4). These units generally dip to the southeast at angles averaging 45 to 50 degrees.

Alluvial and/or residual deposits generally cover bedrock, and form a blanket separating ash deposits from underlying bedrock. Alluvium is generally limited to the natural (pre-reservoir) floodplains of the Emory River and its tributaries. The alluvium consists of a thin (<6-inch) layer of sensitive silt ("slimes"), which overlies a layer of medium to very stiff silt and clay, which in turn transitions to a very loose to medium dense sand and silt. Thickness of the alluvial deposits beneath the ash disposal areas at the plant site ranges up to 65 ft, but thickness is unknown in areas offsite. Residuum (clayey soil derived from the weathering of the underlying bedrock) is expected to cover the remaining upland areas within the region, but data regarding its thickness offsite is currently unavailable.

Bedrock beneath most of the ash-affected area is represented by the Lower Conasauga Group and Rome formation. The Lower Conasauga Group primarily consists of shale with interbedded siltstone, limestone, and conglomerate, and is locally of low water-producing capacity. The Rome formation consists of interbedded shale, sandstone, and siltstone, and is a poor water producer. The primary water-bearing units of the region are the limestone and dolomite members of the Knox Group and the Maynardville formation (Upper Conasauga). The Knox Group includes several relatively pure, thick-bedded limestone and dolomite members susceptible to karst development, as evidenced by the sinkholes shown on Figure 4. The only ash-affected areas overlying the Knox Group include the stream bank margins along Swan Pond Embayment.

1.1.7 Hydrogeology

Groundwater within the region is derived from infiltration of precipitation through the soil overburden. Direct recharge to bedrock aquifers by storm runoff through sinkholes may also occur in areas underlain by karst bedrock. Shallow groundwater movement is generally from upland areas to adjacent stream valleys with groundwater ultimately discharging to streams and springs (Figure 5). The occurrence of numerous springs along the Emory River and within the Swan Pond Embayment indicates the site lies within a regional groundwater discharge area. Limited stream recharge of shallow groundwater could occur during periods of rapid rise in reservoir elevation causing temporary reversal of groundwater hydraulic gradients. It is likely that shallow groundwater originating on the Dredge Cell site discharges directly to the Emory River.

In a groundwater discharge setting, deeper wells should have higher hydraulic head (higher groundwater elevation) than shallow wells. To assess the likelihood of upward groundwater gradients, the correlation coefficient of well depth versus groundwater elevation was calculated for the wells in both the dredge and gypsum cells (located east of the main KIF plant area). Results showed correlation coefficients of 0.84 and 0.62 for the Dredge Cell and gypsum cell, respectively. Similarly, depth data obtained from eight geotechnical borings installed in the Ash Pond to the top of rock showed a correlation coefficient of 0.82. These correlations support the expectation of discharge conditions and upward gradients.

Preliminary review of available water supply data indicates that the water-supply wells and springs in the site locality are situated upgradient of ash-affected land bordering streams. Consequently, any ash-related constituents entering shallow groundwater beneath affected areas would be transported a short distance to local streams without encountering wells or springs. There are no water-supply wells downgradient of the ash, between the ash and the reservoir.

1.1.8 Ecology

Aquatic ecosystems existed in the Swan Pond Embayment prior to the ash release, but were virtually eliminated by the release. Approximately 300 dead fish were found stranded along the banks of the embayment in a debris-line presumably formed during the initial surge of ash. Bottom-dwelling animals (mussels, insects, crayfish, etc.) in areas where large amounts of ash were deposited were likely unable to escape the spill and would have physically been covered by deposits (TVA 2009b).

TVA has systematically monitored the ecological conditions of its reservoirs since 1990 as part of the Vital Signs Monitoring Program. The fish assemblage within the Clinch River in Watts Bar Reservoir has consistently rated good, except for lower scores in 2007, a likely result of widespread drought conditions that continued into 2008. Watts Bar Reservoir rated at or above the valleywide average in the quality of its sport fishery (TVA 2009b).

The mussel fauna in the Emory River near KIF has been substantially altered by the impoundment of Watts Bar Reservoir and upstream impacts including mining and urbanization. Six mussel species (giant floater, fragile papershell, pistolgrip, pimpleback, wartyback, and threehorn wartyback) and a common aquatic snail (hornsnail) were found in a recent survey of this area. All of these species, except pistolgrip, are generally tolerant of reservoir conditions.

Wetland areas also existed in the Swan Pond Embayment prior to the ash release. These wetlands were typically associated with shoreline margins, in floodplains of tributary streams, small islands, and at the heads of reservoir coves. Additional small areas with wetland vegetation occurred in ditches along the roadsides or railroad lines. These wetlands included a mix of forested, shrub, and/or herbaceous vegetation depending on the land use. National Wetland Inventory maps show narrow fringe wetlands along the shorelines, three small island wetlands, and a small forested island wetland above the mouth of the Emory River. Between the mouth of Swan Pond Embayment and Swan Pond Circle Road, there were narrow fringe wetlands and two small forested, island wetlands. Above Swan Pond Circle Road, there were narrow fringe wetlands along the shoreline, and wetlands in narrow patches along the margins of the southernmost ash cells. The ash slide eliminated the wetlands (including three small island wetlands) in the spill area. The ash spill also affected wetlands in the Ash Pond area; some of these wetlands were heavily used by waterfowl and shorebirds.

Terrestrial plant and animal communities in the Ash Pond area have been greatly altered by KIF operations. The dominant plant communities consist of a variety of wetland species in and on the fringe of the lower settling ponds and at the outer base of the dikes. The collapsed dredge cells contained very little vegetation. The dikes were mostly vegetated with a mixture of common, weedy native and nonnative grasses and herbs. A band of riparian trees and shrubs, including sycamore, willow, boxelder, and alder occurred along much of the outer edge adjacent to the reservoir. Similar riparian vegetation occurred along other parts of the shoreline of Swan Pond Embayment and on the islands in the embayment. Other affected areas of the reservoir shoreline were landscaped, suburban lawns or oak-hickory forest.

The Ash Ponds have been heavily used by shorebirds, waterfowl, amphibians, and reptiles, primarily concentrated in the lower settling ponds, which remain relatively intact. The lower settling ponds, Swan Pond Embayment, and the adjacent Emory River were heavily used by Canada geese, wood ducks, great blue and green herons, great egrets, belted kingfishers, and double-crested cormorants. A variety of songbirds, semiaquatic mammals, turtles, and water snakes were also abundant in the riparian vegetation along the shoreline. Ospreys are common in the area, often nesting on natural and man-made structures on and around the KIF properties. Heron colonies also occur near the KIF; the closest is approximately 0.3 mile upstream and in direct line of sight of the affected area. A second colony including great blue herons

and double-crested cormorants occurs just downstream of the junction of the Emory and Clinch Rivers. The areas filled with spilled ash are no longer suitable for most of these species.

1.2 PREVIOUS REMOVAL ACTIONS

Immediately following the ash spill, an Incident Command Center was established and emergency measures were implemented to ensure safety of people in the area, contain and evaluate the damage, and plan for recovery of the ash. Several routine monitoring programs were put in place to monitor river water, drinking water, and air quality. Road, railroads, and utilities were repaired and replaced. Dikes and weirs, both on land and in the water, were constructed to control the ash movement. Dust control activities were implemented and are ongoing. Storm water management systems, such as clean water diversion ditches and ash water collection and settling basins, were constructed.

On August 4, 2009, an Action Memorandum was approved for removing ash from the Emory River east of Dike 2 under a time-critical removal action (TVA 2009a). The decision was made to remove ash from the river using hydraulic or mechanical dredging and from dry land areas behind Dike 2 using land-based equipment and then process, transport, and dispose of the ash recovered. The purpose of removing the ash from the river was to limit the potential for future ash migration and to prevent upstream flooding in the event of a large rainfall. This time-critical removal action is ongoing, and is anticipated to be complete by May 2010.

As part of the time-critical removal action, dredged material (which is only about 10 to 15% solids initially) is being pumped into a Rim Ditch where solids settle out of the solution. The water continues flowing through the Sluice Ditch into the Ash Pond and then into the Stilling Pond where further settlement occurs (Figure 3). Settled ash is removed from the ditches through mechanical excavation and windrowed to dry to between 70 and 80% solids in an ash processing area. The ash is then moved to a storage area which is sufficiently large to allow short-term staging of the ash awaiting transportation and disposal. Ash recovered through mechanical dredging or land-based equipment is transported in trucks to one of several ash storage areas. Processed ash is being loaded into railcars, and is being transported to the Perry County Associates (Arrowood) Landfill in Alabama, for disposal. Cenospheres and entrained river debris are also being removed from downstream coves and disposed of with the processed ash.

1.3 NATURE AND EXTENT OF CONTAMINATION

1.3.1 Ash

TVA, TDEC, and EPA performed soil and ash sampling in the former Dredge Cell, in the embayment, and at several private residences following the release. The objectives of the soil and ash sampling were to characterize the chemical nature of the ash, determine if the released ash resulted in residual impacts to native soil, and evaluate the potential threat of the released ash to human health and the environment. In addition, characterization of recovered ash was done to assess disposal options and to guide potential remediation activities.

TVA Sampling. TVA collected eight ash samples from private residential properties adjacent to the KIF site on December 27, 28, and 29, 2008 and January 2, 2009. These samples (locations PR-1 through PR-4 and PR-7 through PR-10) were analyzed for total metals and Toxicity Characteristic Leaching Procedure (TCLP) metals. On December 31, 2008, TVA collected five surface ash samples from ash remaining in the former Dredge Cell and 23 subsurface ash samples from one Geoprobe® vertical profile within the Dredge Cell. These ash samples (locations S-1 through S-5 and the Geoprobe® location) were analyzed for benzene, toluene, ethylbenzene, and total xylenes (BTEX) by EPA SW-846 Method 8260; total metals by EPA SW-846 Method 6010B; mercury by EPA SW-846 Method 7471; and TCLP metals by EPA SW-

846 Methods 1311 and 6010B. A total of 19 five-point composite ash samples were collected on January 6 and 12, 2009, from the released ash in Swan Pond Embayment. These samples (locations AFA-1 through AFA-19) were analyzed for total metals by EPA SW-846 Method 6010B.

The locations of the December 2008 and January 2009 ash samples are depicted on Figure 6. Data for ash samples collected in December and January were rejected because of method compliance and reporting issues identified during the rigorous data validation process. Sample media were returned to TVA and sent to multiple contract laboratories for reanalysis of metals. Samples were not reanalyzed for mercury because sample holding time had been exceeded. Three of the ash samples (PR-9, AFA-16, and AFA-18) were not returned for re-analysis, therefore, data are unavailable for these samples.

Eleven supplemental ash samples (EECA-1 through EECA-11) were collected in September 2009 from the Dredge Cell and embayment area and analyzed for polynuclear aromatic hydrocarbons (PAHs), mercury, and radioisotopes. The locations of the September 2009 ash samples are also depicted on Figure 6.

Table 1-1 presents the range of concentrations of metals and radioisotopes found in TVA ash sampling. The following analytes are considered constituents of interest (COI) related to fly ash: arsenic, chromium, copper, lead, mercury, nickel, selenium, thallium, vanadium, zinc, and the naturally occurring radionuclides, specifically isotopes of uranium and thorium, their short-lived daughter products, and potassium-40.

Arsenic is one of the naturally-occurring trace elements that is concentrated in the ash through the coal combustion process at KIF. Arsenic is a known human carcinogen routinely detected in ash samples at concentrations that may be a concern for human exposures. As such, arsenic may be considered to represent the constituents within the ash. Arsenic concentrations in ash samples collected by TVA ranged from 2.78 to 166 milligrams per kilogram (mg/kg) (at a sampling interval from 44 to 46 ft below ground surface), with an average of 65 mg/kg. Concentrations of arsenic exceed EPA's residential Regional Screening Level of 0.39 mg/kg. However, arsenic is widely distributed in the natural environment. As described in Appendix A, maximum arsenic levels for soils typical of the Roane County region range from 6.4 to 655 mg/kg. Levels in the ash are therefore similar to those of typical regional soils. It should be noted that ash is not natural soil, and therefore direct comparisons to "background" concentrations cannot be made. These comparisons are only meant to provide a framework for recognizing differences or similarities between the ash constituents and those found in typical regional soils.

Other naturally-occurring trace elements in ash show results greater than would be expected in typical regional soils. Barium, beryllium, boron, selenium, and vanadium were detected in more than 80% of the ash samples and at maximum concentrations that are greater than maximum levels for soils typical of the Roane County region. Similarly, essential dietary nutrients such as potassium and sodium were also detected at maximum concentrations greater than those for typical regional soils.

PAHs are not anticipated to be present in the ash due to the conditions under which the coal is combusted (e.g., high temperature, oxygen rich environment). TVA conducted confirmatory analytical sampling for PAHs in September 2009; as anticipated, PAHs were not detected, except for 2-methylnaphthalene in a single ash sample. That sample was collected from an area of the ash that has had substantial regrading and movement of ash by heavy equipment. Therefore, the presence of 2-methylnaphthalene is likely attributable to deposition from equipment exhaust. The 2-methylnaphthalene detection was slightly greater than the reporting limit; re-extraction/reanalysis did not confirm the presence of 2-methylnaphthalene above the reporting limit.

Table 1-1. Summary Statistics for TVA, TDEC, and EPA Ash Data

Analyte	Unit	Summary Statistics for TVA Ash Data				Summary Statistics for TDEC Ash Data				Summary Statistics for EPA Ash Data			
		Min. Detected Result	Max. Detected Result	Average Detected Result	Frequency of Detect	Min. Detected Result	Max. Detected Result	Average Detected Result	Frequency of Detect	Min. Detected Result	Max. Detected Result	Average Detected Result	Frequency of Detect
Aluminum	mg/kg	8,710	45,200	25,193	52/52	1,000	22,000	14,200	11/11	10,500	28,900	17,543	7/7
Antimony	mg/kg	ND	ND	ND	0/52	2.4	2.4	2.4	1/12	0.916	1.63	1.21	7/7
Arsenic	mg/kg	2.78	166	65	52/52	26	100	73	12/12	44.8	81.3	61.1	7/7
Barium	mg/kg	69.7	1,410	710	52/52	180	1,100	358	12/12	188	864	395	7/7
Beryllium	mg/kg	1.66	9.6	5.8	47/52	1.5	7.9	3.2	12/12	0.122	6.25	1.59	7/7
Boron	mg/kg	14.8	212	99	48/52	NA	NA	NA	NA	NA	NA	NA	NA
Cadmium	mg/kg	ND	ND	ND	0/52	0.2	0.2	0.2	2/12	0.577	1.23	0.86	7/7
Calcium	mg/kg	1,460	30,900	12,081	52/52	2,000	27,000	5,325	12/12	2,190	19,500	8,156	7/7
Chromium	mg/kg	9.64	66	42	52/52	16	43	25	12/12	18.2	41.3	28.2	7/7
Cobalt	mg/kg	13.1	29.7	20.8	42/52	6.7	29	13	12/12	7.91	18.7	12.1	7/7
Copper	mg/kg	8.49	102	64	52/52	25	76	47	12/12	29.9	69.4	47.8	7/7
Iron	mg/kg	9,840	39,700	19,814	52/52	10,000	15,000	12,417	12/12	9,590	19,300	13,699	7/7
Lead	mg/kg	10.7	46	27	52/52	9.8	29	19	12/12	15.3	56.9	25.6	7/7
Lithium	mg/kg	NA	NA	NA	NA	16	36	25	10/10	NA	NA	NA	NA
Magnesium	mg/kg	662	6,230	2,875	52/52	730	6,400	1,616	12/12	713	4,300	1,946	7/7
Manganese	mg/kg	45.6	698	139	52/52	56	260	99	12/12	45.7	447	138	7/7
Mercury	mg/kg	0.136	0.209	0.17	4/12	NA	NA	NA	0/11	0.0563	0.116	0.087	7/7
Molybdenum	mg/kg	ND	ND	ND	0/52	1.6	5.3	3.3	7/10	NA	NA	NA	NA
Nickel	mg/kg	7.37	64.4	38.6	52/52	13	37	23	12/12	17.1	32.3	24.1	7/7
Potassium	mg/kg	642	7,040	3,581	52/52	NA	NA	NA	NA	1,340	3,280	2,340	7/7
Selenium	mg/kg	2.64	17.8	6.7	45/52	2.2	2.2	2.2	1/12	3.13	7.15	5.88	7/7
Silica	mg/kg	NA	NA	NA	NA	NA	NA	NA	NA	40.1	1,060	527	6/6
Silver	mg/kg	ND	ND	ND	0/52	ND	ND	ND	0/12	NA	NA	NA	NA
Sodium	mg/kg	283	1,790	843	46/52	NA	NA	NA	NA	147	725	344	7/7
Strontium	mg/kg	NA	NA	NA	NA	130	260	202	10/10	NA	NA	NA	NA
Thallium	mg/kg	2.65	3.8	3.1	4/52	1.8	1.8	1.8	1/12	4.36	4.36	4.36	1/7
Uranium	mg/kg	NA	NA	NA	NA	2.3	4	3.1	10/10	NA	NA	NA	NA
Vanadium	mg/kg	15.6	163	104	52/52	42	150	77	12/12	44.6	121	73	7/7
Zinc	mg/kg	23.5	94.7	57.4	52/52	25	67	40	12/12	24.3	55.6	39.7	7/7

Table 1-1. Summary Statistics for TVA, TDEC, and EPA Ash Data
(continued)

Analyte	Unit	Summary Statistics for TVA Ash Data				Summary Statistics for TDEC Ash Data				Summary Statistics for EPA Ash Data			
		Min. Detected Result	Max. Detected Result	Average Detected Result	Frequency of Detect	Min. Detected Result	Max. Detected Result	Average Detected Result	Frequency of Detect	Min. Detected Result	Max. Detected Result	Average Detected Result	Frequency of Detect
Gross Alpha	pCi/g	NA	NA	NA	NA	4.6	25	8.99	12/12	NA	NA	NA	NA
Gross Beta	pCi/g	NA	NA	NA	NA	1.88	10	4.76	12/12	NA	NA	NA	NA
Actinium-228	pCi/g	3.63	5.28	4.24	11/11	2.47	3.76	3.06	12/12	NA	NA	NA	NA
Bismuth-212	pCi/g	NA	NA	NA	NA	1.73	3.08	2.24	12/12	NA	NA	NA	NA
Bismuth-214	pCi/g	4.51	6.62	5.56	11/11	2.89	5.96	3.99	12/12	NA	NA	NA	NA
Lead-212	pCi/g	3.7	4.98	4.38	11/11	2.368	3.84	2.99	12/12	NA	NA	NA	NA
Lead-214	pCi/g	4.85	7.1	5.83	11/11	3.37	6.52	4.43	12/12	NA	NA	NA	NA
Potassium-40	pCi/g	20.8	32.4	27.2	11/11	14.62	25.76	18.85	12/12	NA	NA	NA	NA
Radium-226	pCi/g	4.6	8.79	5.85	11/11	NA	NA	NA	NA	NA	NA	NA	NA
Radium-228	pCi/g	3.63	5.28	4.24	11/11	NA	NA	NA	NA	NA	NA	NA	NA
Thallium-208	pCi/g	3.11	4.43	3.4	10/11	0.836	1.24	1.01	12/12	NA	NA	NA	NA
Thorium-228	pCi/g	0.41	1.46	0.779	11/11	NA	NA	NA	NA	NA	NA	NA	NA
Thorium-230	pCi/g	0.941	3.99	2.21	11/11	NA	NA	NA	NA	NA	NA	NA	NA
Thorium-232	pCi/g	0.321	1.82	1.0	11/11	NA	NA	NA	NA	NA	NA	NA	NA
Thorium-234	pCi/g	5.97	11.3	7.49	10/11	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-234	pCi/g	0.816	2.51	1.78	11/11	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-235	pCi/g	0.0401	0.182	0.118	11/11	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-238	pCi/g	0.865	2.33	1.76	11/11	NA	NA	NA	NA	NA	NA	NA	NA

Notes:
NA = not analyzed
ND = not detected
Results are reported on a dry-weight basis.

Ash is known to contain naturally-occurring "primordial" radionuclides, specifically isotopes of uranium, thorium, and potassium-40, and their short-lived daughter products. Initial analysis of the ash included only gamma spectroscopy which identified potassium-40, radium-226, and several of the gamma-emitting short-lived daughter products of uranium and thorium. This is consistent with results from analysis conducted by TDEC. In order to accurately characterize the activity of the uranium, thorium, and radium isotopes, which cannot be characterized using gamma spectroscopy, additional ash samples were collected by TVA and analyzed by both alpha spectroscopy and gamma spectroscopy. Results are listed in Table 1-1. As described in Appendix A, levels of radioactivity in the ash are similar to those of typical regional soils. An exception is that levels of radium-226 generally exceed the range typical of regional soils; levels of radium-226 in regional soils are typically in the range of 0.5 to 2 picocuries per gram (pCi/g), whereas those in ash range between 4.5 and 9 pCi/g.

Ash samples collected from residential properties had results similar to those from the released ash in the embayment, and the ash remaining in the former Dredge Cell; the ash is a relatively well-mixed, homogenous material with no discernable difference in its constituent concentrations across the site.

The extent of fly ash in the Swan Pond Embayment addressed in this EE/CA covers approximately 76 acres of land beyond the original boundary of the Dredge Cell, west of Dike 2. The estimated volume of this ash is approximately 2.4 million cy. Approximately 10.8 million cy of ash and associated containment dikes remain in the approximately 127-acre footprint of the former Dredge Cell.

Additional ash samples were collected for TCLP waste characterization from the Ash Processing area between February and August 2009. EPA defines a material as a hazardous waste if it exhibits one of four characteristics: ignitability, corrosivity, reactivity, and toxicity (U.S. Code of Federal Regulations [CFR], Title 40, Part 261, Subpart C). Toxicity is defined by EPA through the TCLP laboratory procedure, which simulates the leaching of contaminated liquids from the waste. The TCLP helps identify wastes likely to leach concentrations of contaminants that may be harmful to human health or the environment. A total of 68 samples have been tested for TCLP metals by TVA of the ash for waste characterization purposes (Table 1-2).

Table 1-2. Summary Statistics of TCLP Results for Ash Waste Characterization

Analyte	Units	Minimum Detected Result	Maximum Detected Result	Frequency of Detect	TCLP Limit
Arsenic	mg/L	0.0106	0.16	7/68	5
Barium	mg/L	0.0964	3.63	68/68	100
Cadmium	mg/L	0.013	0.152	8/68	1
Chromium	mg/L	0.0067	0.069	12/68	5
Copper	mg/L	0.149	0.149	1/68	N/A
Lead	mg/L	0.00531	0.066	5/68	5
Mercury	mg/L	ND	ND	0/68	0.2
Nickel	mg/L	ND	ND	0/68	N/A
Selenium	mg/L	0.0103	0.141	9/68	1
Silver	mg/L	ND	ND	0/68	5
Zinc	mg/L	ND	ND	0/68	N/A

Notes:
N/A = not applicable (although this analyte was reported, there is no TCLP limit for this analyte).
ND = not detected
mg/L = milligram/liter

Of the 8 RCRA-listed metals with defined TCLP limits, only 6 metals have detected. In each case, the maximum detected concentration in the TCLP leachate was substantially less than its corresponding TCLP limit. Therefore, the concentrations of the TCLP metals, including arsenic, found in samples from the KIF release site have been consistently below the threshold values that would categorize the ash as hazardous waste material under 40 CFR Part 261. Therefore, the ash does not show any characteristic of a defined hazardous waste.

TDEC Sampling. TDEC collected 12 ash samples on January 6 and 7, 2009. Two of the ash samples were collected from the Dredge Cell and the remaining samples were collected from surrounding residential properties. The samples were analyzed for total metals, TCLP metals, BTEX, radionuclides (gross alpha and gross beta), and PAHs. TDEC has reviewed the data and has posted relevant information on their website. As reported on their website, the ash does contain metals and radioactive materials. Table 1-1 presents the range of concentrations of metals detected in ash samples collected by TDEC. After review of the metal analyses, the only metal identified by TDEC at concentrations that may present a potential health hazard is arsenic. The TDEC ash samples contained arsenic ranging from 26 to 100 mg/kg (with an average of 73 mg/kg), which agrees with the range found in TVA sampling. TDEC did not detect any volatile organic compounds (which include BTEX) or PAHs in the ash samples.

EPA Sampling. On December 27, 2008, EPA's contractor collected two 10-point composite samples from the ash pile onsite and three grab samples of ash that had been deposited along the roadway. Samples collected on December 27, 2008, were analyzed for target analyte list metals, BTEX, silica, and TCLP metals. Table 1-1 presents the range of concentrations of metals detected in ash samples collected by EPA. Similar to TVA and TDEC sampling results, EPA testing showed arsenic to be present in the ash at levels ranging from 44.8 to 81.3 mg/kg (with an average of 61.1 mg/kg). EPA testing of the ash found no gasoline products and showed that the ash would not qualify as hazardous waste based on TCLP analysis.

1.3.2 Surface Water

Surface water sampling is being conducted in the Swan Pond Embayment to evaluate the quality and flow of the water entering the Emory River from the Swan Pond Embayment following the spill. Samples are taken routinely from two stations: the discharge from the settling basins (SETTB) and the clean water ditch just downstream of the settling basin discharge (CWDITCH) (Figure 7). The sampling was initially performed upgradient of Dike 2 prior to treatment (during construction of the interim drainage system); those initial data are not used in this EE/CA because the results are not indicative of current water quality conditions discharging from the area. Sampling of surface water in the clean water ditch and settling basin began on July 7, 2009. After 2 weeks of daily sample collection, sampling was reduced to two times a week and after a storm event of more than 0.5-inch rainfall in 24 hours.

Table 1-3 summarizes the concentrations of inorganic constituents detected in surface water samples collected from the Swan Pond Embayment clean water ditch and the settling basins through the time of initial writing of this report (9/3/09). Concentrations of each metal analyte are compared to its corresponding water quality criteria for those analytes where criteria are available, per TDEC Water Quality Criteria, Rule 1200-4-3.03(1)(j), (3)(g), and 4(j).

Antimony, arsenic, and selenium have exceeded at least one water quality criterion in at least one sample. The maximum antimony concentration (0.009 milligrams per liter [mg/L]) nominally exceeds its maximum contaminant level (MCL) for Domestic Water Supply and Ambient Water Quality Criterion (AWQC) for Recreational Use (Water and Organisms). However, the mean (average) antimony concentration is well below the Criterion for Continuous Concentration (CCC), so that antimony is not a constituent of concern on a continuous basis. Arsenic concentrations in surface water samples range from 0.0123 to 0.0792 mg/L, all of which exceed its MCL and AWQC, suggesting that arsenic is present in

Table 1-3. Summary Statistics for TVA Surface Water Data from Swan Pond Embayment

Analyte	Unit	Minimum Detected Result	Maximum Detected Result	Mean	Frequency of Detect	Domestic Water Supply MCL	Fish & Aquatic Life (Max.)* CMC	Fish & Aquatic Life (Ave.)* CCC	Recreation Water & Organisms AWQC	Location for Maximum Detection
Aluminum, Total	mg/L	0.256	2.09	0.682	48/48	--	--	--	--	SETTB
Antimony, Total	mg/L	0.00202	**0.009**	0.00305	32/48	0.006	--	--	0.0056	SETTB
Arsenic, Total	mg/L	**0.0123**	**0.0792**	**0.0341**	48/48	0.01	0.34	0.15	0.01	SETTB
Barium, Total	mg/L	0.0793	0.22	0.118	48/48	2	--	--	--	SETTB
Beryllium, Total	mg/L	<0.002	<0.002	<0.002	0/48	0.004	--	--	--	
Boron, Total	mg/L	0.154	1.93	0.649	48/48	--	--	--	--	SETTB
Cadmium, Total	mg/L	<0.001	<0.001	<0.001	0/48	0.005	0.003	0.0003	--	
Calcium, Total	mg/L	31.9	80.7	45.3	48/48	--	--	--	--	SETTB
Chromium, Total	mg/L	0.00204	0.0032	0.00115	5/48	0.1	0.75	0.097	--	SETTB
Cobalt, Total	mg/L	<0.002	<0.002	<0.002	0/48	--	--	--	--	
Copper, Total	mg/L	<0.005	<0.005	<0.005	0/48	--	0.018	0.012	--	
Iron, Total	mg/L	0.0775	3.1	0.355	48/48	--	--	--	--	CWDITCH
Lead, Total	mg/L	0.00207	0.00238	0.0011	4/48	0.005	0.09	0.0036	--	CWDITCH
Magnesium, Total	mg/L	9.44	15.1	12.7	48/48	--	--	--	--	CWDITCH
Manganese, Total	mg/L	0.017	1.18	0.0887	48/48	--	--	--	--	CWDITCH
Mercury, Total	mg/L	<0.0002	<0.0002	<0.0002	0/48	0.002	0.0014	0.00077	0.00005	
Molybdenum, Total	mg/L	0.00948	0.161	0.0567	48/48	--	--	--	--	SETTB
Nickel, Total	mg/L	<0.005	<0.005	<0.005	0/48	--	0.62	0.069	0.61	
Potassium, Total	mg/L	1.74	6.65	3.34	48/48	--	--	--	--	SETTB
Selenium, Total	mg/L	0.00254	**0.0359**	**0.00913**	46/48	--	0.02	0.005	--	SETTB
Silver, Total	mg/L	<0.002	<0.002	<0.002	0/48	--	0.006	--	--	
Sodium, Total	mg/L	1.37	3.67	2.19	48/48	--	--	--	--	SETTB
Thallium, Total	mg/L	<0.002	<0.002	<0.002	0/48	--	--	--	0.00024	
Vanadium, Total	mg/L	0.00668	0.0722	0.027	48/48	--	--	--	--	SETTB
Zinc, Total	mg/L	<0.05	<0.05	<0.05	0/48	--	0.15	0.16	--	
Alkalinity	mg/L	103	114	108.5	2/2	--	--	--	--	CWDITCH
Hardness (As CaCO3)	mg/L	135	143	139	2/2	--	--	--	--	CWDITCH
pH	pH	7.8	7.9	7.88	4/4	6.0 - 9.0	6.0 - 9.0	6.0 - 9.0	6.0 - 9.0	SETTB
Total Dissolved Solids	mg/L	176	196	186	2/2	500	--	--	--	SETTB
Total Suspended Solids	mg/L	4.1	64.8	15.7	48/48	--	--	--	--	CWDITCH

Notes:
Samples collected following construction of ditches and basins (7/7/09) through initial writing of this report (9/13/09).
The MEAN is calculated using the RL/2 as the value for samples that did not have a detectable concentration. All values are total (unfiltered) results.
* values for cadmium, chromium, copper, lead, nickel, silver, and zinc adjusted for average hardness of 139 mg/L per TDEC Rule 1200-4-3.03(3)(g).
Bold font indicates value exceeds reference criterion.
AWQC = Ambient Water Quality Criteria; TDEC Rule 1200-4-3.03(4)(j)
CCC = Criterion Continuous Concentration; TDEC Rule 1200-4-3.03(3)(g)
CMC = Criterion Maximum Concentration; TDEC Rule 1200-4-3.03(3)(g)
MCL = Maximum Contaminant Level; TDEC Rule 1200-4-3.03(1)(j)
For additional definitions, see the Acronyms List.

surface water within the embayment above levels of concern for recreation use. For selenium, both the maximum (0.0359 mg/L) and mean (0.00913 mg/L) concentrations exceed corresponding Criterion for Maximum Concentration (CMC) and CCC for Fish and Aquatic Life (0.02 mg/L and 0.005 mg/L, respectively). Therefore, selenium in surface water within the embayment may be of continuing concern for fish and wildlife. It should be noted that the maximum concentrations of antimony, arsenic, and selenium have been reported for samples from the settling basin discharge, prior to mixing with the clean water ditch.

1.3.3 Groundwater

Compliance monitoring of the Dredge Cell and Ash Pond area is being conducted in accordance with its operating permit No. IDL 73-0094 (TDEC 2006). As a permitted industrial waste landfill, the Dredge Cell is subject to TDEC Rule 1200-01-07 for Solid Waste Processing and Disposal. These standards set methods, the suite of analysis, and frequencies of sampling for monitoring of groundwater. Historically, unfiltered groundwater samples have been collected semiannually from at least four monitoring wells associated with the Dredge Cell, and analyzed for the 17 inorganic constituents listed in Appendix I of the TDEC Rule 1200-1-7-.04. Well KIF-22 has historically been sampled only for general water chemistry (e.g., field parameters, nitrogen compounds, and organic carbon) and water levels. Groundwater samples were not analyzed for radionuclides. Two of these monitoring wells (4B and 16A) were destroyed in the ash spill incident; in addition, a new well (6AR) was recently installed to replace well 6A, which was damaged by equipment. The three remaining wells (6AR, 13B, and 22) are being sampled semi-annually. Three new wells (AD-1, AD-2, and AD-3) were also installed in the Ash Dewatering area, and are planned to be sampled monthly. As a result, groundwater monitoring of the Dredge Cell and the Ash Dewatering area is currently accomplished through a network of six wells (Figure 7).

Groundwater data from the June 10-11, 2009, sampling event are summarized in Table 1-4. Concentrations of each metal analyte are compared to its corresponding MCL for those analytes where MCLs are available, per TDEC Water Quality Criteria for Domestic Water Supplies, Rule 1200-4-3.03(1)(j). Results show that only one analyte exceeded its MCL in one well. Arsenic was detected at 0.0297 mg/L in well AD2, which exceeds its MCL of 0.010 mg/L. No other metal was detected above its MCL in any well.

Arsenic trends cannot be established for well AD-1, AD-2, or AD-3, since they have just recently been installed. Arsenic trends cannot be established for well KIF-22, since that well has not historically been sampled for arsenic. Arsenic trends can be seen in other wells for the past 10 years, as shown in Table 1-5. The maximum concentration of arsenic (0.0297 mg/L) has been reported in the recent sampling of well AD-2, as described above. Total arsenic concentrations in well 6A have occasionally exceeded the current MCL in the past 10 years, but have remained less than 0.014 mg/L; fluctuations are over a relatively narrow range and do not indicate either an increasing nor a decreasing trend. Arsenic concentrations in other wells have not exceeded the MCL.

Historically, silver has been occasionally detected in one well (6A) at concentrations that exceed its MCL of 0.10 mg/L. However, in 2006 TDEC granted a site-specific standard of 0.18 mg/L for silver in recognition of the fact that silver is present in natural soil and groundwater sources, but is absent in ash.

Because there is no man-made liner beneath the Dredge Cell or Ash Pond and because groundwater discharges only a short distance to Watts Bar Reservoir, the flux of constituents in groundwater could conceivably impact the river system. A sampling and analysis plan is being developed for further geohydrological assessment of the site to determine the potential long-term impact that groundwater may have on surface water in the reservoir. This hydrological assessment is being conducted as part of the EE/CA for the river system. Results of surface water sampling to date have not shown exceedances of surface water quality criteria in the river, even though groundwater seepage from the Ash Pond and Dredge Cells has been occurring for 50 years. Results of TVA sampling in the river are available online at

Table 1-4. Summary of TVA Groundwater Data

	Well Number	13B	22	6A	AD1	AD2	AD3	Reference
	Sample Date	06/11/2009	06/10/2009	06/11/2009	06/11/2009	06/11/2009	06/11/2009	MCL
Analyte	**Unit**							
Aluminum	mg/L	<0.1	<0.1	<1	1.17	<0.1	<0.1	
Antimony	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.006
Arsenic	mg/L	0.00326	<0.002	0.00646	<0.002	**0.0297**	0.00205	0.01
Barium	mg/L	0.485	0.0246	<0.1	0.101	0.0437	0.0396	2
Beryllium	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.004
Boron	mg/L	0.144	0.666	0.711	0.116	0.429	0.587	
Cadmium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.005
Calcium	mg/L	21.5	32.4	252	8.85	27.9	261	
Chloride	mg/L	3.43	11.8	6.12	1.56	17.6	7.73	
Chromium	mg/L	<0.002	<0.002	<0.02	0.0029	<0.002	<0.002	0.1
Cobalt	mg/L	<0.002	<0.002	<0.002	<0.002	0.00372	0.00326	
Copper	mg/L	<0.005	<0.005	<0.05	<0.005	<0.005	<0.005	1.3
Fluoride	mg/L	0.148	<0.1	<0.1	0.233	<0.1	0.14	4
Iron	mg/L	0.107	0.129	1050	0.92	1.04	0.331	
Lead	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.005
Magnesium	mg/L	2.85	9.31	94.7	2.16	4.02	35.1	
Manganese	mg/L	0.095	2.37	179	0.176	0.534	7.82	
Mercury	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.002
Molybdenum	mg/L	<0.005	<0.005	<0.05	<0.005	<0.005	<0.005	
Nickel	mg/L	<0.005	<0.005	<0.05	<0.005	<0.005	<0.005	
Potassium	mg/L	3.73	2.68	<10	2.84	3.29	3.81	
Selenium	mg/L	<0.002	<0.002	<0.02	<0.002	<0.002	<0.002	0.05
Silver	mg/L	<0.002	<0.002	<0.02	<0.002	<0.002	<0.002	
Sodium	mg/L	93.9	8.45	20.6	94.3	12.7	18.1	
Strontium	mg/L	0.451	0.478	0.681	0.201	0.274	0.55	
Sulfate	mg/L	45.8	79.5	3500	28.7	71	574	
Thallium	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.002
Vanadium	mg/L	<0.004	<0.004	<0.04	0.00522	<0.004	<0.004	
Zinc	mg/L	<0.05	<0.05	<0.5	<0.05	<0.05	<0.05	
Ammonia, as N	mg/L	<0.1	0.915	0.448	<0.1	<0.1	<0.1	
Nitrate-nitrite nitrogen	mg/L	<0.1	<0.1	<50	<0.1	<0.1	<0.1	1
Total Inorganic Carbon	mg/L	46.1	20.2	101	42.6	14.8	80.3	
Total Kjeldahl Nitrogen	mg/L	<0.1	1	9.92	<0.1	<0.1	<0.1	
Total Suspended Solids	mg/L	<1.33	<1.33	131	5.2	<1.33	<1.33	
Total Dissolved Solids	mg/L	300	205	5280	259	171	1110	

Notes:
MCL = Maximum Contaminant Level; lead value from TDEC Rule 1200-4-3.03(1) General Water Quality Criteria for Domestic Water Supply
Bold font indicates value exceeds reference criterion.
All values are total (unfiltered) results.

Table 1-5. Arsenic Concentration Trends in Groundwater

Well Number		KIF-13B	KIF-16A	KIF-22	KIF-4B	KIF-6A	KIF-AD1	KIF-AD2	KIF-AD3
Well Depth		71-81 ft	52-62 ft	14-49 ft	19-24 ft	50-55 ft	21-31 ft	14-24 ft	9-14 ft
Sample Date	**Unit**								
12/06-07/1999	mg/L	<0.001	<0.001	NA	<0.001	<0.001	NA	NA	NA
12/14/2000	mg/L	<0.001	<0.001	NA	0.002	0.003	NA	NA	NA
06/28/2001	mg/L	<0.001	<0.001	NA	<0.001	<0.001	NA	NA	NA
12/31/2001	mg/L	<0.001	<0.001	NA	0.0042	**0.011**	NA	NA	NA
06/28/2002	mg/L	0.002	<0.001	NA	<0.001	0.008	NA	NA	NA
01/08/2003	mg/L	<0.001	0.006	NA	0.004	0.006	NA	NA	NA
06/16-17/2003	mg/L	<0.001	<0.001	NA	<0.001	<0.001	NA	NA	NA
09/02/2003	mg/L	0.0002	0.0009	NA	0.0012	**0.0115**	NA	NA	NA
12/29/2003	mg/L	<0.001	0.0006	NA	0.0004	0.005	NA	NA	NA
03/10/2004	mg/L	<0.001	0.0005	NA	0.002	0.0057	NA	NA	NA
06/07/2004	mg/L	0.001	0.002	NA	0.004	**0.011**	NA	NA	NA
09/14-16/2004	mg/L	0.002	0.002	NA	0.001	**0.013**	NA	NA	NA
12/08/2004	mg/L	<0.001	<0.001	NA	0.005	**0.014**	NA	NA	NA
03/15-17/2005	mg/L	<0.001	0.001	NA	0.003	0.006	NA	NA	NA
05/31-6/01/2005	mg/L	<0.001	0.001	NA	0.001	0.004	NA	NA	NA
12/13/2005	mg/L	<0.001	0.001	NA	<0.001	0.005	NA	NA	NA
06/06/2006	mg/L	<0.001	<0.001	NA	<0.001	0.003	NA	NA	NA
12/12-15/2006	mg/L	<0.001	0.001	NA	0.001	0.004	NA	NA	NA
06/05/2007	mg/L	0.0013	0.0011	NA	0.0016	0.0064	NA	NA	NA
12/03-04/2007	mg/L	<0.001	<0.001	NA	0.0018	<0.005	NA	NA	NA
06/02/2008	mg/L	0.0011	0.0014	NA	0.0017	0.0063	NA	NA	NA
12/01-02/2008	mg/L	0.0011	0.0014	NA	<0.001	**0.011**	NA	NA	NA
02/11/2009	mg/L	NA	NA	NA	NA	<0.005	NA	NA	NA
06/10-11/2009	mg/L	0.00326	NA	<0.002	NA	0.00646	<0.002	**0.0297**	0.00205
07/23/2009	mg/L	NA	NA	NA	NA	NA	NA	**0.0142**	NA

Notes:
Bold font indicates value exceeds reference criterion for arsenic (0.010 mg/L).
All values are total (unfiltered) results.
NA = not analyzed on this date.

www.tva.gov/kingston; results of independent TDEC sampling are also available online at http://www.state.tn.us/environment/kingston.

1.4 HUMAN HEALTH RISK EVALUATION

A human health risk assessment was completed to develop quantitative and qualitative estimates of potential cancer risks and non-cancer hazards for human receptors exposed to environmental media impacted by ash west of Dike 2. Risks to both current (or near-term) and potential future receptors were evaluated. The risk analysis was based on analytical data collected from ash, surface water, and groundwater sampling. The risk assessment was conducted in accordance with EPA *Risk Assessment Guidance for Superfund* protocols; methods and details of the human health risk evaluation are presented in Appendix A.

1.4.1 Data Evaluation

Data from samples collected by TVA were used in the quantitative risk assessment. Data collected by TDEC and EPA were used to provide a qualitative evaluation of the representativeness of the TVA data. Analytical data were reviewed to ensure that data of acceptable quality and quantity are used in the risk assessment. Uncertainty was evaluated by reviewing such aspects as the sources of the data, consistency in data collection methods and handling, analytical methods and detection limits, data quality indicators (precision, accuracy, representativeness, comparability, and completeness), and data qualifiers.

Constituents of potential concern (COPCs) are chemicals that are potentially site-related and whose data are of sufficient quality for use in the quantitative risk assessment. These chemicals may contribute significantly to human or ecological risk and are carried through the risk assessment process. Trace metals and radionuclides are commonly found in fly ash as byproducts of coal combustion. Ten metals (arsenic, chromium, copper, lead, mercury, nickel, selenium, thallium, vanadium, and zinc) and naturally occurring radionuclides (potassium, radium, thorium, and uranium) are considered COIs and were carried forward in the human health risk assessment. Background screening was not used to eliminate COPCs, rather background is used in the uncertainty analysis to place the risk estimates in context with local or regional concentrations.

Exposure point concentrations were determined and chemical intakes calculated for the various exposure pathways identified for the site. Because potential receptors were assumed to move randomly across the site spending equivalent amounts of time in each location, contact with a contaminated medium over time is best represented by the average concentration of the detected analytes. Because of the uncertainty associated with estimating the true average concentration at a site, the representative concentration used is the 95% upper confidence limit (UCL_{95}) on the arithmetic mean (EPA 2002). The UCL_{95} is defined as a value that, when calculated repeatedly for randomly drawn subsets of site data, equals or exceeds the true mean 95% of the time. When limited data are available or when the data are extremely variable, the UCL_{95} can be greater than the highest detected concentration. Therefore, the exposure point concentration represents the UCL_{95} or the maximum detected concentration whichever is smaller.

COPCs were identified by evaluating site-related constituents and COIs against risk-based concentration screening levels. Chemical data were compared to the most recent version of the EPA regional residential risk-based screening levels (EPA 2009) for soil or tap water as appropriate for the matrix. A target cancer risk level of 1.0E-06 was used as a screening level for carcinogens; a target hazard index (HI) of 0.1 was used as a screening level for non-carcinogens. No constituents were eliminated as COPCs based on this screen. Essential nutrients (i.e., calcium, chloride, iodine, magnesium, phosphorus, potassium, and sodium) are an integral part of the human food supply and are often added to foods as supplements. Essential nutrients were eliminated as COPCs because maximum detected concentrations were less than recommended dietary intake values.

1.4.2 Exposure Assessment

For the human health risk assessment, potential receptors are distinguished as onsite and offsite. Onsite receptors are those who reside, work, or play on the ash, whereas, offsite receptors are those whose activities occur in areas where ash is not present but where ash may migrate through air dispersion or tracking.

For exposure to ash as soil, potential current receptors evaluated included an offsite resident exposed to ash through inhalation of fugitive dust dispersed in the air from the ash; an offsite indoor worker exposed through incidental ingestion, inhalation, and external radiation in dust or from material tracked indoors; an offsite outdoor worker exposed to ash through incidental ingestion, inhalation, dermal contact, and external radiation from material deposited by wind or tracked by human or vehicle traffic; and an onsite adolescent trespasser exposed through incidental ingestion, inhalation, dermal contact, and external radiation. Potential future receptors included an onsite future resident; an onsite indoor worker; an onsite outdoor worker; a groundskeeper; and a recreator. These potential future receptors were evaluated for exposure to ash through incidental ingestion, inhalation, dermal contact, and external radiation.

For exposure to surface water, potential current receptors evaluated are an adolescent trespasser as a recreator exposed to ash-related constituents in surface water while wading in the ditches in the Swan Pond Embayment area.

For exposure to groundwater, potential future receptors evaluated are an onsite resident exposed to groundwater through ingestion, inhalation of water vapor, and dermal contact; and an indoor worker exposed to groundwater used as a potable water supply.

Detailed equations used to quantify exposures are provided in Appendix A.

1.4.3 Toxicity Assessment

Toxicity is defined as the ability of a chemical to induce adverse effects in biological systems. The toxicity assessment weighs available evidence regarding the potential for a chemical to cause adverse effects in exposed individuals (hazard identification), and provides an estimate of the relationship between exposure to the chemical and the likelihood of adverse effects (dose-response assessment).

The human health risk assessment used EPA-derived toxicity values. There are two types of toxicity values: cancer slope factors for evaluating carcinogenic effects and reference doses for evaluating noncarcinogenic effects. Slope factors and reference doses used in the risk assessment were obtained from the latest version of the region screening levels tables which follows EPA's three-tiered hierarchy (EPA 2003). Details of the evaluation of carcinogenicity, noncarcinogenic effects, dermal toxicity, and target organ toxicity are presented in Appendix A.

1.4.4 Risk Characterization

Risk characterization integrates the results of the exposure and toxicity assessments to estimate potential cancer risks and noncancer hazards. Carcinogenic risk is expressed in terms of the probability that an individual will contract cancer over a lifetime of exposure and is referred to as incremental lifetime cancer risk (ILCR). The ILCR is the potential increased probability that an individual may develop cancer due to exposure to site-related constituents. Chemical-specific and radionuclide-specific risks are then summed to determine the total cancer risk associated with each exposure route. Risks for each exposure route are then summed to estimate a total risk for an individual receptor exposed through more than one route. The calculated cancer risk estimates are compared to the target risk range specified in the NCP of 1E-06 to

1E-04, or 1 in 1 million to 1 in 10,000 exposed persons developing cancer. ILCRs below 1E-06 are considered acceptable. ILCRs above 1E-04 are considered unacceptable.

Noncarcinogenic hazards are expressed in terms of hazard quotients (HQs) and hazard indexes (HIs). An HQ is calculated for each chemical for each exposure route by dividing the exposure dose by the chemical-specific reference dose. An HI is calculated for each exposure route by summing the HQs. HIs for each exposure route and media are summed to derive a total HI for each scenario. An HI greater than 1 has been defined as the level of concern for potential adverse non-carcinogenic health effects (EPA 1989).

Constituents of Concern (COCs) are COPCs that significantly contribute to a pathway in a exposure scenario for a receptor that either (a) exceeds a 1E-04 cumulative site cancer risk; or (b) exceeds a noncarcinogenic HI of 1. Chemicals are not considered to be significant contributors to risk and, therefore, are not COCs if their individual ILCR contribution is less than 1E-06 and their individual noncarcinogenic HQ is less than 0.1.

Detailed calculations of cancer risk and noncancer hazard estimates are presented in Appendix A. Table 1-6 summarizes the risk characterization results.

Table 1-6. Risk Characterization Results

Receptor	Incremental Lifetime Cancer Risk	Noncarcinogenic Hazard Index
Current Exposures		
Offsite resident (adult)	3E-08	0.009
Offsite resident (child)	3E-08	0.009
Offsite indoor worker	7E-06	0.2
Offsite outdoor worker	2E-05	0.4
Onsite trespasser (adolescent)	5E-05	0.4
Future Exposures		
Onsite resident (adult)	2E-03	1
Onsite resident (child)	6E-04	8
Onsite indoor worker	3E-04	0.4
Onsite outdoor worker	6E-04	0.5
Onsite groundskeeper	4E-04	0.9
Onsite recreator (adult)	2E-06	0.01
Onsite recreator (adolescent)	1E-06	0.03

1.4.4.1 Current Exposure Scenarios

Cancer risk estimates for current exposure scenarios did not exceed the target risk range for any receptor. The highest calculated risk was 5E-05 for an adolescent trespasser. This risk is driven by ingestion of arsenic and external exposure to gamma radiation from K-40, Ra-226, Ra-228, and Th-228.

Noncancer hazard estimates for current exposure scenarios did not exceed the HI threshold of 1 for any receptor. Hazard estimates ranged from 0.009 for the offsite adult and child resident to 0.4 for the offsite outdoor worker and onsite adolescent trespasser. Therefore, the occurrence of adverse noncancer effects is unlikely.

1.4.4.2 Future Exposure Scenarios

Cancer risk estimates for future exposure scenarios exceeded the target risk range for a future onsite resident (adult and child), indoor or outdoor worker, and groundskeeper. The highest cancer risk (2E-03)

was calculated for an onsite resident adult living directly on the exposed ash. The cancer risk estimates are driven by ingestion of arsenic and external exposure to gamma radiation from K-40, Ra-226, Ra-228, and Th-228. There is uncertainty in these estimates in that levels of arsenic and radioactivity in the ash are generally similar to those of typical regional soils. An exception is that levels of radium-226 in ash generally exceed the range typical of regional soils. The estimates may therefore overestimate risks above normal regional background levels.

Noncancer hazard estimates for future exposure scenarios exceeded the HI threshold of 1 for an onsite resident (child). The hazard estimate for the onsite resident (adult) is equal to the noncancer hazard threshold. The highest HI (8) was calculated for a child resident living and playing directly on the exposed ash. The primary contributors to the HI are ingestion of arsenic, cobalt, thallium, aluminum, iron, vanadium, and chromium in ash and, ingestion of arsenic in groundwater. Results of lead modeling for an onsite child resident and an onsite worker indicate that potential exposures to lead in ash do not result in unacceptable blood lead levels to either receptor.

The hazard estimates for a recreator (adult or adolescent) and indoor worker are less than the noncancer hazard threshold. The primary contributors to the HI are ingestion of arsenic and thallium in ash and arsenic in groundwater. Individually, these constituents have HIs less than 1.0. Therefore, the occurrence of adverse noncancer effects is unlikely for these future receptors.

1.5 SCREENING-LEVEL ECOLOGICAL RISK EVALUATION

A Screening-Level Ecological Risk Assessment (SLERA) was conducted to evaluate potential risks to terrestrial and aquatic ecological receptors exposed to detected constituents in ash and surface water west of Dike 2. The ash is primarily considered a potential risk to terrestrial ecological receptors; however, this assessment also assesses potential risks to aquatic and sediment-associated biota. To be conservative, the SLERA evaluates potential exposures to ash in this area as if it were soil (ash as soil) as well as if it were sediment (ash as sediment). The SLERA also evaluates potential current and near-term aquatic exposures to constituents in surface water, based on surface water samples from the clean water ditch and settling basins. The SLERA has been conducted in accordance with EPA *Ecological Risk Assessment Guidance for Superfund*; methods and details of the SLERA are presented in Appendix B.

1.5.1 Step 1: Screening-Level Problem Formulation and Ecological Effects Characterization

The screening-level problem formulation serves to define the reasons for the SLERA and to define the methods for analyzing/characterizing risks. The goal is a conservative evaluation of the likelihood for adverse effects (and the ecological significance of predicted adverse effects) to wildlife that may be exposed to site-related constituents. Problem formulation produces three outputs: (1) assessment endpoints that adequately reflect management goals and the ecosystem the goals are meant to protect, (2) a conceptual site model that describes the relationships between stressors and the assessment endpoints, and (3) a plan for analyzing the potential risks to the assessment endpoints. Details of the problem formulation are presented in Appendix B.

Prior to the ash spill, dominant plant communities west of Dike 2 included a variety of wetland species along the outer bases of the dikes that are typically associated with shoreline margins, floodplains, small islands, and reservoir coves. The Dredge Cell failure released ash into the Swan Pond Embayment, completely covering the aquatic habitat in this portion of Watts Bar Reservoir and eliminating wetlands in the spill area.

For the SLERA, potentially affected receptors include terrestrial and aquatic organisms that may be exposed to metals or radiological constituents within the ash. Terrestrial animals may be exposed through

ingestion, inhalation, dermal contact, or food chain; soil invertebrates through ingestion, inhalation, or dermal contact; and terrestrial plants through direct contact, leaf absorption or root uptake. Aquatic animals may be exposed through dermal or gill absorption, ingestion, or food chain; benthic invertebrates through ingestion, inhalation, or dermal contact; and aquatic plants through direct contact, leaf absorption or root uptake. The measurement endpoints for assessing potential effects on these organisms are the constituent screening toxicity values, which are constituent concentrations below which there is negligible risk to receptors. For soil, the EPA ecological soil screening levels and ecological screening values (ESVs) are used; for sediment, the EPA sediment ESVs; and for surface water, the AWQC and EPA surface water ESVs are used. These values are presented in Appendix B.

1.5.2 Step 2: Screening-Level Exposure Estimate and Risk Calculation

The exposure concentrations used in the SLERA are the maximum detected concentrations for ash as surface soil, ash as sediment, and surface water. To estimate risk, HQs were calculated for each medium. An HQ is the unitless ratio of a constituent concentration to its corresponding screening ecotoxicity value that is considered protective of wildlife. HQs equal to or less than 1 indicate that adverse impacts to wildlife are unlikely; HQs exceeding 1 indicate that further assessment may be necessary to evaluate the potential for adverse impacts to wildlife. Therefore, the constituents with HQs greater than 1 are identified as constituents of potential ecological concern (COPECs). In addition, the COIs commonly associated with fly ash are carried forward as COPECs regardless of the SLERA HQ screening results. To be conservative, any constituent that lacks a screening value will also be carried forward as a COPEC. The results of the SLERA risk calculations are presented in Appendix B and summarized below:

- Ash as soil: 16 inorganics were detected with maximum concentrations above their corresponding ESVs (i.e., an HQ greater than 1). Four constituents were identified as essential nutrients that do not pose risk to ecological receptors.

- Ash as sediment: 5 inorganics were detected with maximum concentrations above their corresponding ESVs, 10 constituents did not have an ESV available, and 2 inorganics were identified as COIs. Four constituents were identified as essential nutrients that do not pose risk to ecological receptors.

- Surface water: 5 inorganics were detected with maximum concentrations above their corresponding ESVs, 4 constituents did not have an ESV available, 2 inorganics were identified as COIs. Four constituents were identified as essential nutrients that do not pose risk to ecological receptors.

1.5.3 Reporting Conclusions

The results of the SLERA are expressed in terms of the following conclusions or recommended actions.

For the terrestrial habitat west of Dike 2, 16 inorganic constituents in ash as soil were selected as COPECs because their maximum concentrations exceeded an HQ of 1. Based on the available evidence, the possibility of adverse ecological risks for ecological receptors potentially exposed to ash as soil west of Dike 2 cannot be excluded.

For the aquatic habitat west of Dike 2, 17 inorganic constituents in ash as sediment were selected as COPECs and 11 inorganic constituents in surface water were selected as COPECs because maximum concentrations exceeded an HQ of 1, an ESV was not available, or constituents were identified as COIs in fly ash. Based on the available evidence, the possibility of adverse ecological risks for ecological receptors potentially exposed to COPECs in ash as sediment and surface water cannot be excluded.

EPA's Ecological Risk Assessment (ERA) guidance includes clearly-identified points for stakeholder communication and decision-making, referred to as scientific management decision points (SMDP). Generally, the following types of decisions are considered at the SMDPs:

- Whether no further action is appropriate based on concerns for wildlife,
- Whether further ERA is warranted, or
- Whether remedial actions can be implemented to reduce or prevent risks to wildlife.

The SLERA, as one such SMDP, indicates a potential for adverse ecological effects for terrestrial and aquatic receptors in the areas west of Dike 2. The remedial action alternatives for the Dredge Cell and Embayment entail the complete removal of ash from the embayment and capping of the Dredge Cell with clean soil. Given that the remedies for this area of the site will eliminate the potential exposure pathways for ecological receptors, a Baseline Ecological Risk Assessment is not warranted and no additional data are needed to support the selection of a remedial action to protect ecological receptors in the Dredge Cell and Swan Pond Embayment.

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2. REMOVAL ACTION OBJECTIVES

This section identifies the scope, goals, and objectives for the non-time-critical removal action.

2.1 SCOPE AND PURPOSE

The scope of the removal action is to fulfill mid-term strategic objectives for the site, as defined in the Administrative Order (EPA 2009a) for the embayment area west of Dike 2 and for the former Dredge Cell. These objectives include removal of any remaining coal ash from embayments and tributaries west of Dike 2 to the maximum extent practicable, removal of coal ash from impacted upland areas and surface soils to the maximum extent practicable, and proper disposal of all coal ash material recovered during these efforts.

The scope of the non-time-critical removal action decision for the embayment/Dredge Cell includes removal of any residual coal ash released into the embayment area west of Dike 2 from the failure of the Dredge Cell, and closure of the failed Dredge Cell itself. Not only will the final condition of these geographic areas be decided, but disposal locations of the removed material will be part of the decision. Ultimately, the decision for the embayment/Dredge Cell will center around the following questions:

- In what condition should the embayment area be left?
- Should excavated material be disposed onsite or offsite?
- In what condition should the Dredge Cell be left, including any remaining dike system to contain ash?

The timing of the decision on the embayment and Dredge Cell is important. The time-critical action is scheduled to be completed in spring 2010. Significant construction and transportation activities will have been underway for over a year to accomplish this goal. The remaining ash in the embayment will have been contained by constructing drainage features to separate clean water runoff from the ash. Although the clean water ditches have been designed for a 25-year recurrence interval, some of the drainage features in the embayment (sediment basins) have been sized for a storm event having only a 2-year recurrence interval; a delay in the decision would increase the risk of future ash releases during greater storm events. A decision on these questions and associated removal action scope is needed by spring 2010 to allow continuation of removal activities.

The removal action is to remove the ash and restore the embayment to pre-spill conditions. This EE/CA provides information to satisfy the requirements for a Jurisdictional Assessment, including maps of the site prior to the spill and following the non-time-critical removal action, areas/species/habitat impacted, revegetation with selected species, habitat created, microtopography, and similar elements for the area west of Dike 2. The information supporting the Jurisdictional Assessment is provided in Appendix D.

The removal action does not address removal of residual ash from the area east of Dike 2, the Emory, Clinch, or Tennessee Rivers, or restoration of other waters impacted by the coal ash release. Those areas will be addressed in a separate EE/CA to be prepared following completion of data gathering activities currently underway and in accordance with the Jurisdictional Assessment required in the Administrative Order. A sampling and analysis plan is being prepared to collect data for risk assessment purposes. That process will continue throughout implementation of the non-time-critical removal action described in this EE/CA. The weight-of-evidence risk evaluation and risk management decisions for the river system will also include the restored Swan Pond Embayment and flux of constituents in groundwater from the closed Dredge Cell.

2.2 GOALS AND OBJECTIVES

Results of the screening level human health and ecological risk assessments indicate potential risk to human and ecological receptors due to exposure naturally occurring metals and radionuclides in the ash. A removal action is needed to mitigate the threat or potential threat to the public or the environment. The following are the specific removal action objectives (RAOs):

- Minimize direct contact between ash material in the embayment and water flowing through the embayment area into Watts Bar Reservoir;
- Minimize migration of ash and its constituents from the embayment or Dredge Cell into affected waters due to erosion;
- Minimize direct contact exposure by human or ecological receptors to ash on the ground;
- Restore the embayment to pre-spill conditions;
- Close the former Dredge Cell in accordance with Tennessee Solid Waste Rule 1200-1-7; and
- Dispose of waste streams from the removal action in accordance with ARARs.

2.3 IDENTIFICATION OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

CERCLA Section 121 specifies that actions for cleanup of hazardous substances must comply with requirements or standards under federal or more stringent state environmental laws that are applicable or relevant and appropriate to the hazardous substances or particular circumstances at a site. Onsite removal actions conducted under CERCLA are required to attain these ARARs to the extent practicable, considering the exigencies of the situation. This action is being conducted as a non-time-critical removal action. A list of ARARs is provided in Appendix C.

The terms defined below are used.

- Applicable requirements are "those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site" (40 CFR 300.5).

- Relevant and appropriate requirements are "those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting law that, while not applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site" (40 CFR 300.5).

- In the absence of federal or state-promulgated regulations, there are many criteria, advisories, guidance values, and proposed standards that are not legally binding but can serve as useful guidance for setting protective cleanup levels. These are not potential ARARs but are "to-be-considered" guidance [40 CFR 300.400(g)(13)].

CERCLA onsite response actions must comply with only the substantive requirements of a regulation to obtain federal, state, or local permits [CERCLA Sect. 121(e)]. To ensure that CERCLA response actions proceed as rapidly as possible, EPA has reaffirmed this position in the final National Oil and Hazardous Substances Pollution Contingency Plan (NCP) [Title 55, Federal Register (FR), Part 8756, March 8, 1990]. Substantive requirements pertain directly to the actions or conditions at a site, while

administrative requirements facilitate their implementation. ARARs are typically divided into three groups: (1) chemical-specific; (2) location-specific; and (3) action-specific.

- Chemical-specific requirements set health or risk-based concentration limits or discharge limitations in various environmental media for specific hazardous substances, pollutants, or contaminants (55 FR 8741, March 8, 1990). These requirements generally set protective cleanup levels for the contaminants of concern in the designated media or otherwise indicate a safe level of discharge that may be incorporated when considering a specific remedial activity. The anticipated chemical-specific ARARs identified include drinking water standards and the applicable surface water quality standards for the stream's designated use.

- Location-specific requirements establish restrictions on permissible concentrations of hazardous substances or establish requirements for how activities will be conducted because they are in special locations (wetlands, floodplains). Those location-specific requirements for this action are associated primarily with wetlands and floodplains.

- Action-specific ARARs include operation, performance, and design requirements or limitations based on the waste types, media, and response actions.

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3. REMOVAL ACTION ALTERNATIVES

3.1 TECHNOLOGY IDENTIFICATION

This section identifies the applicable technologies based on site-specific conditions and contaminants. The EE/CA technology identification process is focused only on those technologies that have proven to be effective at similar sites. Technologies were identified from multiple sources, including *Presumptive Remedy for Metals-in-Soil Sites* (EPA 1999), *Contaminated Site Cleanup Information* (EPA 2009b), *Assessment and Remediation of Contaminated Sediments, Remediation Guidance Document* (EPA 1994), and *Metals in Soils 1998 Technology Status Report* (ITRC 1998).

Presumptive remedies are preferred technologies or response actions for sites with similar characteristics that have been identified by EPA to streamline remedy selection and accelerate site cleanup. For low-level threat waste found at metals-in-soil sites, the presumptive remedy is containment, although excavation with disposal and other institutional controls have also been used (EPA 1999). Low-level threat wastes include contaminated source material of low to moderate toxicity that are relatively immobile. The coal fly ash source material is considered a low-level threat waste because of its low toxicity (excess cancer risk is near the acceptable risk range), and low mobility (metals are typically bound to the ash). Due to similarities between soil and ash and due to the presence of metals, containment and/or excavation with disposal are preferred technologies (EPA 1999).

CERCLA expresses a preference for treatment over containment or land disposal to address the principal threat at a site. Innovative technologies should be used when they clearly offer superior treatment performance and implementability, lesser impacts, or lower costs than demonstrated technologies. Removal actions cannot conform entirely to these requirements because of site-related time constraints, so that only the most qualified and proven technologies should be considered (EPA1993). Containment, excavation, and disposal are proven technologies.

Table 3-1 presents results of the technology screening for fly ash source material, including an effectiveness, implementability, and cost evaluation. Containment, excavation, and disposal are retained for use in developing alternatives. Phytoremediation may be considered as a potential "polishing step" for treatment of metals in residual soil at the site following containment or excavation/disposal, but is an innovative technology with considerable uncertainty in its effectiveness. Other technologies are not considered cost-effective nor implementable at the site.

Containment would significantly reduce the risk of exposure to the public or environment through engineered barriers that would minimize migration of contaminants and the likelihood of direct exposure. Long-term protection can be ensured through continued maintenance. While containment would reduce contaminant release rates, it is not considered treatment. Containment systems are commercially available, demonstrated technologies that use standard construction equipment and labor and readily-available materials. Costs are generally less expensive than most forms of treatment.

Several types of containment systems could be used. Natural soil materials are appropriate in minimizing direct contact; clay caps are appropriate for both minimizing direct contact and reducing infiltration; and multilayer caps (combining geosynthetic and clay layers into the cap) are most effective in minimizing infiltration. At the KIF release site, natural clay materials are relatively abundant and available nearby although permeability of the compacted clay is unknown. Because contaminants are typically bound to the ash, and because shallow groundwater discharges to local streams without encountering wells or springs, the reduction of infiltration offered by clay caps is appropriate at the site. Therefore, a clay cap option is carried forward in this EE/CA as a representative type of containment system for use in developing alternatives. Other low-permeability caps, such as a composite clay liner system, may also be used.

Table 3-1. Identification and Screening of Technologies

Technology	Effectiveness	Implementability	Cost	Retained for Evaluation
Institutional Controls Deed restrictions, fences, signs	Not effective as stand-alone technology; not effective for ecological receptors.	Readily implemented onsite; not implementable offsite.	Low	Yes
Containment Soil, clay, membrane cap/cover	Effective for direct contact; effective for infiltration depending on cover type.	Readily implemented, proven.	Low	Yes
Excavation / Disposal Dredge, excavate, haul, dispose onsite or offsite	Effective for removing contaminants from site; offsite protectiveness depends on proper disposal.	Readily implemented, proven. Offsite disposal availability depends on quantities and nature of waste material, transportation availability.	Medium – High; Costly with large volumes	Yes
Phytoremediation Plant uptake of constituents	Innovative; potentially effective for removing contaminants from soil or near-shore sediment, but with higher uncertainty.	Not proven, demonstration pilot test likely needed. Implementable depending on plant stock availability.	Medium	No
Separation Screen/sieve large soil fractions	Not effective since material is relatively homogenous; removal of large fraction would not change volume/mass.	Readily implementable, requires greater material handling and dust control.	Medium	No
Electrokinetic Separation Mobilize ions under electric current to toward electrodes	Innovative; potentially effective for higher levels of inorganic contamination.	Not proven, demonstration pilot test likely needed. Requires specialty equipment/vendor with lower availability.	High; high energy demand for low mass of contaminant	No
Soil Washing/Soil Flushing Wash/flush constituents out of soil	Innovative; not effective for homogenous material with low contaminant mass; removal of large fraction would not change volume/mass.	Not proven, demonstration pilot test likely needed. Requires specialty equipment/vendor with lower availability.	High; high energy demand and water treatment	No
Chemical Reduction / Oxidation Change ionic state of constituents to make less mobile or toxic	Innovative; potentially effective for reducing mobility of target ions; long-term uncertainty in geochemical conditions.	Not proven, demonstration pilot test needed. Requires material processing to ensure contact of reagent with target constituent.	Medium – High; Costly with large volumes	No
Chemical Extraction / Recovery Leach constituents out of soil using acid or other chemical	Innovative; not cost-effective for material with low contaminant mass.	Not proven; requires extensive wastewater treatment and metal recovery processes.	High	No
Immobilization / Stabilization Mix chemical with soil to make constituents less mobile	Effective for metals/radionuclides in soil, cost-effective for fly ash material with low contaminant mass. Results of TCLP tests show fly ash has low leachability (below regulatory limits).	Readily implementable, requires greater material handling and dust control; adds extensive volume/mass of stabilization agent (cement, polymer) requiring disposal.	Medium – High	No
Vitrification Turn soil into glass-like mass using high temperature furnaces	Innovative; not cost-effective for material with low contaminant mass.	Not proven, requires extensive material handling, energy consumption, and safety precautions; requires specialty equipment and/or vendor with limited availability.	Very High	No

Excavation would achieve protectiveness of the public and environment by removing and properly disposing of the ash material. Long-term protection would be ensured at the site by permanently removing the material. While excavation would reduce the volume of material onsite, it is not considered treatment and the ash material would remain essentially unchanged. Excavation systems are easily implementable, using standard construction equipment and labor that is already being used at the site. Costs of excavation are reasonable for small to medium volumes of contaminated material, but may become very high for large volumes.

Several types of excavation systems could be used. Hydraulic dredging is appropriate in excavating ash from deeper water conditions; mechanical dredging is appropriate in removing debris or ash below water; and mechanical excavators (backhoes) are appropriate in land-based trenching in softer subgrades; and scrapers are appropriate in land-based trenching in firmer subgrades. Within the embayment area, both hydraulic dredging and mechanical excavators may be most cost effective, and are carried forward in this EE/CA as representative types of excavation systems for use in developing alternatives. Other excavation techniques would be used as appropriate depending on actual conditions encountered during excavation.

Disposal would achieve protectiveness by transporting materials from the site, and subsequently placing them in an acceptable waste management facility. The degree of protectiveness and reduction in mobility of contaminants is dependent on the specific waste management practices at the disposal facility. Because the ash material is not a listed nor characteristic hazardous waste, disposal may occur within a permitted solid waste landfill. Special measures may be required to protect workers and residents during transport. Costs of disposal, as with excavation, are typically higher for large volumes and are also higher for long transportation distances.

Onsite disposal within areas of historical ash disposal, including the former Dredge Cell, may be appropriate if stable conditions can be ensured. A test embankment is currently being constructed within the Dredge Cell to evaluate onsite disposal. Offsite disposal facilities could include appropriate commercial, permitted landfills, such as the Perry County Associates (Arrowhead) Landfill in Alabama or Chestnut Ridge Landfill in Anderson County, Tennessee. Transportation could occur by rail to Alabama or truck hauling to Anderson County. Because each of these types of disposal are appropriate for consideration at the KIF release site, they are both retained for use in developing alternatives, and evaluated further in this EE/CA.

3.2 DEVELOPMENT OF ALTERNATIVES

In this section, technologies retained from Section 3.1 are combined (as applicable) to form alternatives to meet the RAOs. A limited number of alternatives is developed. These alternatives are intended to represent a range of possibilities for restoration of the embayment and Dredge Cell areas, with distinctly different advantages and disadvantages, so that tradeoffs between them can be clearly defined and evaluated.

The following alternatives have been developed; detailed descriptions are presented in Sections 3.2.1 through 3.2.3:

- **Alternative 1:** Excavate Embayment and Dispose Offsite (2.8 million cy); Grade and Close Dredge Cell. Alternative 1 would remove the ash in the embayment (2.4 million cy), the ash from the test embankment within the Dredge Cell (0.3 million cy), and material from Dike 2 and the settling basins (0.1 million cy) and dispose of this material offsite. A dike would be installed to keep ash in the cell from entering the embayment in the future and the Dredge Cell would be graded for drainage. The height of the closed cell would be approximately 790 ft msl. The embayment would be restored to an aquatic and riparian environment.

- **Alternative 2:** Excavate Embayment and Portions of Dredge Cell and Dispose Offsite (6.5 million cy); Grade and Close Remainder of Dredge Cell. Alternative 2 would remove the ash in the embayment (2.4 million cy), the test embankment (0.3 million cy), Dike 2 and the settling basins (0.1 million cy), plus enough ash from the Dredge Cell (3.7 million cy) to limit long-term reliance on a dike between the cell and the embayment, yet would leave enough ash to provide buttressing for the remaining dikes. The removed material would be disposed offsite. The Dredge Cell would be graded to a gradual slope, with a maximum height of the closed cell of approximately 780 ft msl at its highest point, although most of the Dredge Cell would be below elevation 765 ft msl. The embayment would be restored to an aquatic and riparian environment.

- **Alternative 3:** Excavate Embayment and Dispose Onsite; Close the Dredge Cell. Alternative 3 would use onsite disposal locations for the ash removed from the embayment. For evaluation purposes, this alternative uses the Dredge Cell as the disposal facility. No material would be taken offsite. The ash in the embayment (2.4 million cy) and material from Dike 2 and the settling basins (0.1 million cy) would be removed and stacked in the Dredge Cell. Material placed in the cell for the test embankment would remain in the cell. A dike would be installed to keep ash in the cell from entering the embayment in the future and the Dredge Cell would be graded for drainage. The height of the closed cell would be approximately 805 ft msl. A subalternative was developed for this alternative that would place material from the embayment into the Ash Pond prior to closure, which would lower the height of the Dredge Cell to 390 ft msl. The embayment would be restored to an aquatic and riparian environment.

In developing the alternatives, several options were considered, but not retained for further consideration. These options include the following:

- Leaving all materials within the embayment and covering them in-place was considered. This would minimize any further hauling of recovered ash from the site to reduce impacts to public safety. The former embayment could be restored to alternative use, such as potential future recreational use as a ball field. However, this option would clearly violate the terms of both the TDEC Commissioner's Order and the EPA Administrative Order. The TDEC Commissioner's Order requires that the Corrective Action Plan for the site include "restoration of all natural resources damaged as a result of the coal ash release". The EPA Administrative Order requires that the site objectives are to "remove coal ash from the embayments and tributaries west of Dike 2, to the maximum extent practicable, … [and] restore area waters impacted by the coal ash release." Because this option would not remove all ash to the maximum extent practicable nor restore all natural resources or area waters, it was not developed further.

- Excavating all ash from the embayment, placing a liner on the native ground surface, and replacing the ash back into the embayment was considered. This would minimize hauling of recovered ash from the site and minimize ash placement back in the Dredge Cell. This option would not restore all natural resources and area waters impacted by the coal ash release. It would involve double-handling of large volumes of ash, and require a large interim storage area for the excavated ash. This alternative would violate substantive requirements of ARARs (TDEC environmental codified Regulations Chapter 1200-1-7, Solid Waste Processing and Disposal) in that waste materials would be placed within waters of the state, within the 100-year floodplain. Placement of a liner at the bottom of the embayment would be technically impractical because it would be below lake level and because there are numerous springs that feed the embayment from the surrounding hillsides. Effectiveness of a liner would be limited because ash would remain below water level. For these reasons, this option was not developed further.

- Excavating all ash from the embayment, then filling the embayment back up with clean fill dirt was also considered. Doing so would allow the embayment area to be used for recreation, such as a ball field or community park. Whereas this option would remove ash to the maximum extent practicable, it would not restore all natural resources and area waters impacted by the coal ash release. The option would also double the volume of material hauled away from and back to the site over public roads or railways. This alternative would violate potential ARARs in that fill materials would be placed within waters of the state, within the 100-year floodplain. For these reasons, this option was not developed further.

- Excavating all ash from the embayment and disposing of the ash in an onsite lined landfill was also considered. Doing so could provide further protection against leachate migration to groundwater or ultimately to the river system. An engineered disposal facility would be designed to meet or exceed current state regulations for coal ash disposal and best management practices, including site characterization, multi-layer composite lining system, leachate collection system, and groundwater monitoring program. Tennessee has recently enacted a new coal disposal law (TDEC r68-211-106), which requires new coal ash disposal facilities to have a liner to prevent leaching, in addition to a final cap before closure. EPA is currently proposing federal regulations that could require similar requirements for new coal ash disposal facilities. However, the construction of a new onsite landfill would significantly increase both the time to achieve closure and the cost of closure for the recovered ash, while having little effect on minimizing potential future environmental releases. Siting of a new landfill on TVA property outside of the CERCLA action areas would require lengthy site characterization and permitting, a process that typically requires several years to complete, and would therefore substantially delay removal of ash from the embayment. While TVA has acquired property as a result of the ash spill, a new landfill would require development of a contiguous site greater than 50 acres in size in which to dispose of the recovered ash. The cost to develop and close a new landfill would be greater than closure of just the Dredge Cell and Ash Pond, since ash would still remain in the failed Dredge Cell and Ash Pond areas that would require perimeter dike containment reinforcement, capping, and groundwater monitoring, similar to alternatives that have been fully developed. More importantly, disposing of the recovered ash in a separate new landfill would not be effective in reducing the potential contaminant flux from the closed site to the river system, since the ash remaining in the failed Dredge Cell and Ash Pond occurs below the water table and would continue as a source of contaminant transport whether the recovered ash is placed above it or not. Instead, a new landfill would further increase the risk (however small) of potential future environmental releases by opening up a whole new land area to permanent waste management land use, with corresponding chance of future leaching, erosion, or other hypothetical modes of failure. The additional perceived protection against leachate migration that a new lined landfill might afford would be relatively insignificant, since groundwater at the site has not been shown to be significantly impacted. Groundwater quality has only slightly exceeded drinking water standards for one constituent (arsenic) after more than 50 years of the ash being in contact with groundwater. For these reasons, this option was not developed further.

- Excavating all ash from both the embayment and the entire Dredge Cell area, and disposing of all the material offsite was also considered. Doing so would virtually eliminate the threat of future release of residual ash from the site. However, this would dramatically increase the volumes of materials transported offsite, with associated impacts on residents. Over 10 million cy of ash would require transportation and disposal. Implementability would be difficult, as the shear volumes of material would overwhelm existing landfill capacity. Costs of excavation, transportation, and disposal would be twice as high as any other alternative, while the added degree of protectiveness is limited. For these reasons, this option was not developed further.

3.2.1 Alternative 1: Excavate Embayment and Dispose Offsite; Grade and Close Dredge Cell

The actions under this alternative are designed to avoid returning any spilled ash back into the Dredge Cell but to close the remainder of the Dredge Cell in place. The major components for this alternative are listed in Table 3-2 and the end-state of the alternative is illustrated on Figure 8. A conceptual schedule for construction sequencing is shown on Figure 9. Two subalternatives (1a and 1b) were developed to evaluate offsite transportation and disposal options. Alternative 1a would transport material offsite by rail only; Alternative 1b would transport material offsite using a combination of rail and truck.

Table 3-2. Summary of Actions for Alternative 1, Excavate Embayment and Dispose Offsite; Grade and Close Dredge Cell

Action	Summary
Infrastructure	Construct or install areas for drying ash and equipment for transporting ash across Swan Pond Circle Road.
Remove Dredge Cell test embankment	Remove approximately 300,000 cy of ash used in a geotechnical test in the Dredge Cell. This material was generated by activities to remove ash east of Dike 2 as part of the time-critical removal action.
Excavate the Swan Pond Embayment	Remove spilled ash outside the limits of the Dredge Cell that remain after the time-critical removal action with land-based equipment.
Dredge the Swan Pond Embayment	Remove spilled ash in the waterways that is too wet to remove with land-based equipment with hydraulic dredges.
Remove clean water ditches	Remove the rock-covered banks of the clean water ditches that are covering ash and move the material to the Ball Field for disposition.
Remove Dike 2 and Settling Basins	Remove the rock and ash associated with the containment dike and the dirty water settling basins and move the material to the Ball Field for disposition.
Transport the ash offsite	Move the ash to the Ball Field area for final processing and loading. Two subalternatives, 1a and 1b, have been developed. Alternative 1a would transport the ash by rail to Alabama. Alternative 1b would transport ash from the northern part of the embayment by truck to the Chestnut Ridge Landfill in Tennessee.
Restore embayment	Introduce aquatic plants into the remediated area to facilitate recovery.
Install perimeter containment	Construct a working platform. Install a perimeter containment system and deep soil stabilization system on all sides of the Dredge Cell and Ash Pond.
Grade Dredge Cell and Ash Pond	Regrade the ash in the Dredge Cell and fill Ash Pond to design elevations that will allow drainage. Install a drainage system.
Cover Dredge Cell and Ash Pond	Cover the regraded cell as well as the perimeter dike and vegetate.
Monitoring	Install and monitor groundwater wells around the closed Dredge Cell and Ash Pond.
Institutional Controls	Prevent future use of the Dredge Cell through institutional controls.

Infrastructure. Initial activities would provide the support system needed to implement this alternative. First, there is the potential, depending on the weather and time of year, that additional areas for processing ash would be needed. These areas would be developed on non-impacted TVA land, immediately adjacent to the north embayment. Approximately 8 to10 acres would be developed. The initial processing area would be used to support excavation efforts in the north embayment. The area would be lined with 2 ft of rock and drainageways would be developed to allow water to drain from the ash to a settling pond where clean water would be discharged to the clean water system.

For Alternative 1a (rail transport for offsite disposal), a mechanism would be needed to transport ash from the north portion of the embayment across Swan Pond Circle Road (a public road) to the areas south of the road, where existing rail loading facilities are located. For purposes of this EE/CA, a conveyor system is assumed; however, during the design phase of any of the alternatives, other means of transport may be developed. The conveyor would move ash from the processing area east along the edge of the north embayment area, across the road and then along the clean water ditch on the south side of the road to an

offload section in the northwest corner of the central portion of the Swan Pond Embayment. A loading hopper and roughly 1,500 ft of a covered conveyor is assumed to be used.

For Alternative 1b (truck transport of a portion of the ash for offsite disposal), the ash would be removed from the north embayment directly offsite by dump trucks and no transport mechanism across the road would be needed.

Remove Dredge Cell test embankment. In FY 2009 and 2010, ash was brought into a constructed cell pad in the Dredge Cell to conduct an embankment test. The objectives of the test were to evaluate the stability of the underlying ash as new ash is stacked on top as well as to evaluate the stability of the stacked ash. The area has been instrumented with piezometers, settlement plates, and inclinometers. At the time of the initial drafts of this EE/CA, roughly 75,000 to 100,000 cy of compacted ash is in place. It is assumed that up to 300,000 cy of ash will be stacked and present in the Dredge Cell when the test is complete. There was a commitment made between TVA and TDEC that since the ash used in the test was generated as part of the time-critical removal action, it would be removed under all alternatives except an alternative that brought ash back into the Dredge Cell (Alternative 3).

The ash would be loaded into articulating trucks (roughly 22 cy per truck) and taken to the Ball Field for disposal. Most of the 300,000 cy is anticipated to be sufficiently dry to go directly into load piles for disposal.

Excavate the Swan Pond Embayment. Up to 2.4 million cy of ash, rock, and clayey soil are present in the north and central portions of the Swan Pond Embayment. Much of this ash is retrievable by mechanical means. For the purposes of this discussion, roughly 80% (1.9 million cy) is assumed to be retrievable with excavators, dozers, and trucks. The ash would be piled and when dry enough, removed from the area by conveyor or truck. For Alternative 1a, the ash would be loaded into articulating off-road dump trucks (after conveyance from the north embayment) and moved to the Ball Field for further drying (if needed) and loading into rail cars. For Alternative 1b, the excavated ash from the north portion of the embayment would be moved by dump truck for offsite disposal and the excavated ash in Swan Pond Embayment would be moved by articulating truck to the Ball Field for offsite disposal by rail.

In all cases, the wetter ash would be processed before placing in trucks by piling or spreading out and disking and rolling. The processing may occur near the point of generation or may occur in the Ball Field. In general, a moisture content between 20 and 30% is desired prior to disposal. Ash can be moved onsite through off-road trucks or with scrapers and pans. Trees that are retrieved either within the ash or that are removed will be chipped and either used onsite to stabilize the surface of the ash to support trucks or sent offsite for disposal. Up to 50 truckloads of timber are included. Periodically, disturbed ash may be sprayed with a component like Flexterra® to control dust for the short-term.

Dredge the Swan Pond Embayment. Ash in the waterways that is too wet to remove with traditional land-based equipment would be dredged from the embayment. It is assumed that 20% of the material is dredged (approximately 500,000 cy). A small 10-inch dredge would be used to remove most of the material although larger dredges may be useful in some areas. The dredged material would be piped to the existing rim ditch (with a booster pump) and discharged to the ditch. It is anticipated that up to 90% of the solids would settle out of solution through the Rim Ditch and Sluice Trench. The remaining water would then discharge to the Stilling Pond prior to discharge through an National Pollutant Discharge Elimination System (NPDES) discharge. During dredging, ash from the KIF plant operation would also discharge to the Sluice Trench until such time as the plant has been converted to dry ash processing methods. Ash would be recovered from the Rim Ditch/Sluice Trench with a combination of excavators and clamshells. The ash would be processed on the Ball Field to allow it to dry sufficiently to be loaded onto rail cars.

Remove Clean Water Ditches. A series of clean water ditches were installed during the time-critical removal action to bypass upgradient surface water around the ash. Nearly 5,900 lin ft of ditches, 4-ft deep and 16 to 20 ft across were constructed through the north and central portions of the Swan Pond Embayment. At least one side of the ditch is made of ash and is lined and covered in rock. This portion of the ditch, including the overlying rock, would need to be removed so as to remove the underlying ash. The volume of material removed is included as part of the larger volume presented in the excavation component of the alternative. However, this component is discussed separately because it would occur near the end of the project to ensure the upstream water continues to bypass the ash until no ash remains.

Remove Dike 2 and Settling Basins. Dike 2 is a temporary rock dike comprised of shot rock, riprap, and smaller-sized rock saturated with ash. The dike is approximately 1,400-ft long with an average height of 12 ft and average width of 30 ft at the top. The dike is sloped at 2:1 on both sides although the slopes can vary from 3:1 to 1.5:1. It is estimated that there are approximately 90,000 tons of rock in the dike. The dike has served as a barrier to prevent ash from moving into the Emory River from the embayment and to serve as a haul road. The dike was founded across foundation silts and sands following removal of displaced ash. The exception is a 500-ft segment located along the northern portion of the dike where complete removal of displaced ash materials was reportedly not performed.

Immediately adjacent to Dike 2 are several settling basins that serve as a treatment system for water that migrates over ash. Roughly 5 acres are used for the basins with 20-ft wide shot rock tops, 2:1 slopes, and 10 ft in depth. At the time of closure, it is assumed that the basins will be 50% full of ash, roughly 38,000 cy. The settling basins are estimated to be built of 40,000 tons of shot rock.

Both the dike and the settling basins must remain in service until the last of the ash is removed west of Dike 2. At that time, the ash-saturated shot rock would be removed and transported to the Ball Field for disposal. Although not figured into the cost estimate, efforts may be taken to wash some of the larger shot rock of ash to avoid having to dispose of the clean rock offsite. If there are opportunities for using some of the clean rock for onsite drainage and erosion control, these opportunities will be explored.

Transport Ash Offsite. Two subalternatives were developed; one using rail to transport the removed ash to an offsite landfill, and one using a combination of trucks and rail to transport ash to separate offsite landfills. For ash leaving the site by rail, the infrastructure set up under the time-critical removal action to move ash to Alabama would remain and be used. That infrastructure includes the railyard and the two rail spurs along the edges of the Ball Field. It is assumed that the rail cars would be lined with a 10-mil liner, loaded with up to 100 tons of ash per rail car, and shipped offsite in 85- to 110-car trains. During wet times of the year when the generated ash cannot be dried sufficiently to 25% or less moisture content, an absorbent would be added to the rail cars, either in the form of a blanket or bulk polymer absorbent.

For Alternative 1a, the ash would be transported by rail only. Approximately 2.4 million cy of ash would be generated from the embayment and 300,000 cy of ash from the test embankment, along with an additional 130,000 cy of rock from Dike 2 and the settling basins. To transport this volume of material, nearly 430 85-car trains (or nearly 330 110-car trains) would be needed. The schedule assumes a combination of 85- and 110-car trains would be used, resulting in a total of 380 trains carrying an average of nearly 7,500 cy per train. Roughly 467 calendar days would be needed to remove the material (assuming 80% production of one train a day, 7 days a week). However, offsite shipments would be restricted by the rate at which the ash can be excavated and hauled to the Ball Field for loading onto railcars; as a result, total duration of offsite shipments is estimated at nearly 19 months.

For Alternative 1b, the ash would be transported by trucks to supplement transport by rail. Use of trucks in the north portion of the embayment would eliminate the need to transport the drier excavated ash across Swan Pond Circle Road. No conveyor system would be needed. Wetter material dredged from the

bottom of the embayment would be conveyed through a pipe beneath the road to the rim ditch, then dipped out of the rim ditch and placed on the Ball Field for dewatering prior to shipment to Alabama by rail. Although most of the material (2.04 million cy) would be removed from the site by rail to Alabama, roughly 760,000 cy of drier material from the north embayment would be removed by truck. For ash leaving the site by truck, loading stations would be set up the northern embayment area with scaffolds for use in lining and/or covering trucks with tarps. Either a liner would be used or a tight tarp with absorbent socks would be placed in the trucks. The trucks would be loaded with an excavator or a front-end loader. Several loading stations may operate at once.

To transport 760,000 cy of ash assuming 22 cy of ash per truck, 40 trucks operating three turns a day (120 truck loads per day), roughly 14 months, or just over a year, would be required (assuming 80% production, operating 6 days a week). This truck shipping would occur in parallel with train shipments. The trucks would take the ash to an approved landfill, such as the Chestnut Ridge Landfill, located north of Knoxville in Anderson County, Tennessee. This landfill has been approved by the EPA to accept CERCLA waste. The landfill is a Class 1 Subtitle D landfill with up to 5.0 million cy of capacity for ash. The Chestnut Ridge Landfill would be accessed by I-40 E to I-640 E/I-75 N to exit 117, State Highway 170, and right on Fleenor Mill Road. This route is approximately 50 miles in length one way and most of this is interstate highway. Rail transport of the remaining 2.04 million cy of material would require roughly 13 months.

For the selected disposal site(s), TVA would submit an EPA identification number as well as the necessary contact information to acquire a CERCLA offsite disposal clearance. Proper notifications would be made to the appropriate personnel at EPA before removal of ash from KIF property.

Restore Embayment. Following the removal of ash from the areas west of Dike 2, the embayment ecosystem would be restored to pre-spill conditions as best determined from analysis of existing data, site observations, reference site data, and best professional judgment. Appendix D presents a conceptual restoration plan for the embayment, including descriptions and maps of the site before the spill and following the non-time-critical removal action; the areas, species, and habitat that have been impacted; and concepts for revegetation with selected species, habitat created, and topography.

This alternative would attempt to simulate the pre-spill topography of the embayment shoreline and surrounding areas. It is recognized as part of this conceptual restoration design that areas of native soil may have been lost as a result of the ash spill or ash removal operation, which may have implications on the final restoration design. For the purposes of this EE/CA, it is assumed that pre-spill terrestrial environments will be able to be restored to an elevation that supports native plant communities. This may require previous riparian forest communities being restored to a wetland emergent community. However, it is possible that enough volume of native soil could have been lost in some areas such that the final elevation of native soils is too low to support planting of native plant communities. This situation could result in the restoration of a greater areal extent of open water habitat than the pre-spill condition.

Development of an excavation and final grading plan would incorporate the following actions:

- Excavating to remove visible ash to the maximum extent practicable. Along the banks of the embayment and surrounding historic floodplain, excavation and dredging would attempt to preserve as much of the native soil profile as possible.

- Achieving suitable elevations within the floodplain necessary to support the restoration of a complex mosaic of forested, scrub-shrub, and emergent wetland plant communities. This includes the restoration of floodplain microtopography and wetland hydrology (i.e., constructed vernal pools) that historically provided important off-channel, seasonal, aquatic habitat for amphibians, birds, and other

semi-aquatic species. A conceptual cross-section of the restored embayment with reference to different native plant communities is included as Figure 10.

- Restoring the island that was historically located on the northern perimeter of the central embayment. The island was likely an aquatic habitat feature important to fish and other aquatic species. Restoration would include filling and/or regrading to establish pre-spill topography.

- Characterizing the bottom sediments exposed by excavation/dredging or filling/regrading for organic content and moisture retention capacities to determine if soil amendments would be necessary to support the restoration of native plant communities. Hydric soils were identified in the wetland ecosystems surrounding the embayment. Given that the embayment appears subject to high sediment deposition, the bottom substrate of the embayment is expected to reestablish naturally.

The final planting design would restore a complex mosaic of native wetland and upland plant communities to areas previously dominated by forest and scrub-shrub habitat. Species composition and densities of restored plant communities would be based upon previously collected data within the embayment area, as well as data collected from surrounding reference communities in a similar geomorphic position. A preliminary list of native species that could be incorporated into the final planting design is included in Appendix D.

Restoration of a complex mosaic of forest, scrub-shrub, and emergent wetland plant communities along the embayment shorelines would encourage natural repopulation of native faunal groups. The conceptual restoration plan would not attempt to repopulate with benthic invertebrate cultures, fish stocking, or resettlement of faunal groups. A summary of the approach specific to the different faunal groups is provided below:

- Fish populations historically used the embayment areas as off-channel habitat necessary for foraging, resting, cover, and potentially spawning. This alternative would restore the shoreline complexity and riparian cover important to fish to provide shade and organic inputs. In addition, this alternative would restore the island along the northern perimeter of the embayment that likely provided aquatic structural complexity important to fish, benthic macroinvertebrates, and larger semi-aquatic fauna.

- Semi-aquatic mammals, turtles, water snakes, and a variety of amphibians including frogs and salamanders likely used the lacustrine fringe emergent wetlands as well as the floodplain forest and scrub-shrub plant communities. This alternative would restore the shoreline complexity to provide horizontal and vertical structure important to a suite of semi-aquatic and terrestrial fauna.

- A wide diversity of bird species used the embayment ecosystem for foraging, nesting, resting, etc. This alternative would restore a mosaic of native plant communities with horizontal and vertical structure to attract a suite of native bird species that historically utilized the area. Artificial snags would be constructed with onsite coarse wood to provide additional roosting habitat proximal to open water habitat. The mudflats surrounding the embayments during low water levels would be restored to provide habitat for the piping plover, which is the only federally-listed endangered species known to occur as a casual migrant in the area affected by the ash spill.

Install Perimeter Containment. Site-specific geotechnical explorations conducted within the Dredge Cell associated with AECOM's root cause analysis (AECOM 2009) and Stantec's site characterization studies (Appendix E) have typically encountered saturated ash materials and native foundation clays, silts, and sands underlain by bedrock. Preliminary results from a liquefaction potential analysis indicate that the foundation ash and native silt/sand layers may liquefy under design earthquake loads. For this reason, this alternative would construct a foundation treatment zone consisting of a grid of soil/cement columns

installed using deep soil mixing techniques beneath the perimeter dikes. In the United States, this technique was first developed in the 1950s as intrusion grout mixed-in-place piles. Significant refinement has been made since its full-scale applications became feasible in the 1970s. Although the initial intent of deep soil mixing was relatively large-area soil treatment for soft ground stabilization, its applications have been expanded to include hydraulic cutoff and excavation support walls, slope stabilization, liquefaction mitigation, and environmental remediation.

Major factors that influence the engineering properties of a foundation treatment zone include soil type, amount of cement or other admixtures used, water/cement ratio, degree of soil/cement mixing, curing environment, and age. For liquefaction mitigation, research indicates that with similar ground treatment ratios, a grid pattern is most effective, followed by a wall type, and then a column type. Therefore, a grid pattern is assumed for this conceptual design. Selected foundation zones would be treated by mechanically mixing in-situ soil materials with a cement grout slurry using a hollow-stem paddle mixer. The drilling equipment would be configured using three 3-ft diameter augers with overlapping paddles to create a net 7-ft wide soil/cement column. Successive columns would be installed to create a contiguous subsurface "wall" of soil/cement. These walls would then be configured into the required grid pattern.

An earthen berm would be built along the Dike C corridor prior to stabilizing the underlying foundation material. Compactible earthen fill would be placed in maximum 8-inch-thick loose lifts. The material would be compacted to a minimum of 95% of standard Proctor maximum dry density. Quality control samples would be taken to confirm appropriate moisture content for optimum compaction. Outslope armoring of the new Dike C would be constructed of riprap.

A rock buttress would be constructed of shot rock or equivalent material on the outslope area of Dike D to flatten the slope to 4:1 (horizontal:vertical). A non-woven geotextile filter fabric would be placed along existing surfaces before placing the shot rock. A perimeter ditch would be constructed around the entire perimeter of the Dredge Cell to divert surface drainage away from the site and to control runoff from the site. The ditch would be lined with 1 ft of fine-grained soil, covered with 1 ft of topsoil, and protected with a synthetic turf reinforcement mat to establish a vegetative (grass) cover.

The conceptual perimeter dike containment system, including the foundation materials and foundation treatment zone outlined above, were incorporated into a preliminary stability model. This model was intended to represent generalized site conditions for the sole purpose of assessing stability improvements along various perimeter alignments.

It is anticipated that the post-earthquake condition with predominantly liquefied foundation conditions will control the dike design; therefore, only a preliminary post-earthquake slope stability assessment was performed for this EE/CA. More detailed seismic analysis and static stability calculations are being conducted under other concurrent studies. Residual and dynamic undrained shear strengths were assigned to various foundation and constructed layers to represent liquefied and non-liquefied conditions, respectively. Published correlations were used to estimate residual strengths for liquefied foundation layers and were based on in-situ penetration resistance (established from both standard and cone penetration tests). For foundation (or other constructed) layers that are not anticipated to liquefy, static undrained shear strengths were reduced by 20 percent to account for potential excess porewater pressures that may be generated during the design earthquake.

Slope stability calculations were performed using SLOPE/W (GEO-SLOPE International Ltd.). The Spencer method was used to compute the factor of safety for modeled failure surfaces. An optimization process was then conducted to obtain the critical failure surface. Initial calculations were performed to assess the minimum strength required to achieve a target factor of safety of 1.1. This was accomplished in a trial-and-error fashion by adjusting material properties within defined treatment zones. The required

undrained shear strength can be achieved using a minimum of 20% soil replacement ratio (treated soil as a percent of total soil volume); to be conservative, a 25% soil replacement ratio has been used in estimating costs in this EE/CA.

The results of the slope stability calculations show that embankment outslopes constructed to grades of 5% or less would result in factors of safety greater than the defined target of 1.1 without foundation treatment. However, steeper slopes modeled (i.e., 4:1) would result in factors of safety less than 0.5 without foundation treatment. This evidence along with the recognized uncertainties with estimating material properties, particularly residual strengths, suggest that some degree of perimeter improvements should be assumed to be needed along embankment outslopes. The results of this analysis can be found in Appendix E. For Alternative 1 it is assumed that half the length of the dike alignment along Swan Pond Road and along the Ball Field would require foundation treatment. The conceptual foundation treatment zones are as follows:

- Dike C corridor: 130-ft wide foundation treatment zone beneath proposed earthen berm, about 40-ft deep; riprap armoring along the upstream face (outslope).

- Dike D corridor: 35-ft wide foundation treatment zone at the dike toe, 60-ft deep. rock buttress on a 4:1 slope on the upstream face (outslope).

- Ball Field corridor: 35-ft wide foundation treatment zone for 50% of corridor, about 60-ft deep.

- Swan Pond Road corridor: 35-ft wide foundation treatment zone for 50% of the corridor length, about 60-ft deep.

- Ash Pond corridor (at a later date): Along the northern Dike C, a 25-ft wide foundation treatment zone, about 60-ft deep at the dike crest, and another 25-ft wide treatment zone, 50-ft deep at the dike toe. Along the eastern divider dike, a 15-ft wide foundation treatment zone, 60-ft deep at the dike crest, and another 15-ft wide zone, 50 ft deep at the dike toe. Along the southern Dike C, one 25-ft wide foundation treatment zone, 30-ft deep at the dike crest.

Figure 11 shows the conceptual design of the perimeter dike containment system.

Grade Dredge Cell and Ash Pond. Conceptual constructed site conditions for Alternative 1 consist of graded slopes to facilitate drainage within the Dredge Cell and Ash Pond. Approximately 127 acres are contained within the old Dredge Cell foot print; approximately 120 acres are within the Ash Pond footprint (including the Lateral Expansion Area). The cell would be regraded with 5% outslopes and a maximum 2% crest slope to a peak elevation of 790 ft. It is estimated that over 1.6 million cy of ash would be moved around within the cell to establish these final grades; some imported fill (up to 250,000 cy) may be required for grading of the Ash Pond. The final regrading would occur once the test embankment ash has been removed. The regrading would occur over time but would be coordinated with the construction of the working platform within the Dredge Cell and for the new perimeter dike containment system. Closure of the Ash Pond would occur at a later date.

Cover Dredge Cell and Ash Pond. Once the Dredge Cell has been graded and the dike containment system has been installed, a soil cover would be placed. The cover would control erosion, control dust generation, promote runoff and evapotranspiration, limit infiltration, and provide a surface for vegetative growth. Prior to placement of the cover material, any vegetation that may have been established for temporary dust control would be removed. The surface would be scarified to promote lift bonding. Approximately 2 ft of clay and 1 ft of topsoil would be placed over the entire area and contoured. Once the cover reaches final grade, it would be seeded and mulched with an approved permanent seed mixture

and mulch material. Seeded areas would be maintained through irrigation appropriate for weather conditions until vegetation is established. The cover may require periodic repairs of erosion features or of areas that did not sustain vegetation.

The Ash Pond would be closed at a later date: closure could also include covering with 2 ft of clay and 1 ft of topsoil, seeding, and mulching.

Monitoring. Because ash would remain in the Dredge Cell, the groundwater underneath the cell and surface water flowing from the cell would be monitored quarterly for some period of time until the results indicate stable conditions. Once stable conditions are confirmed for four quarters, the monitoring would be reduced to semi-annually. It is assumed that up to four new monitoring wells would be installed and monitored for metals and radionuclides. Because this is a CERCLA site, these monitoring results would be documented in a five-year effectiveness review report. A detailed monitoring plan would be developed as part of the selected removal action.

The containment system as well as the drainage systems would be periodically inspected. The details of the inspection process would be developed as part of the final design. However, for the purpose of this EE/CA, it is assumed that monthly inspections occur.

Institutional Controls. The Dredge Cell would be maintained as a disposal location for the foreseeable future. Under state solid waste regulations, access to the cell would be controlled for only maintenance or monitoring.

3.2.2 Alternative 2: Excavate Embayment and Portions of Dredge Cell and Dispose Offsite; Grade and Close Remainder of Dredge Cell

The actions under this alternative are designed to minimize long-term reliance on a dike containment system. Because ash exists underneath the former Dredge Cell to elevation 725 ft msl, some type of perimeter dike containment system would be required. However, this alternative removes much of the ash from the Dredge Cell above the surrounding ground level (approximately elevation 765 ft msl) so as to lessen the dependence on the containment system. Many of the components are the same as for Alternative 1. As with Alternative 1, two subalternatives (2a and 2b) were developed to evaluate offsite transportation and disposal options. The major components for this alternative are listed in Table 3-3 and the end-state of the alternative is illustrated on Figure 12. A conceptual schedule for construction sequencing is shown on Figure 13.

Infrastructure. Some initial activities would be necessary to provide the support system needed to implement this alternative. These are the same as those developed for Alternative 1; an ash processing area and a conveyor system.

For Alternative 2a (rail transport for offsite disposal), the conveyor would move ash from the processing area west along the edge of the north embayment, across the road and then along the clean water ditch on the south side of the road to an offload section in the northwest corner of Swan Pond Embayment. A loading hopper and roughly 1,500 ft of a covered conveyor is assumed to be used.

For Alternative 2b (truck transport of a portion of the ash for offsite disposal), the ash would be removed from the north embayment directly offsite by dump trucks and no transport mechanism across the road would be needed.

Table 3-3. Summary of Actions for Alternative 2, Excavate Embayment and Portions of Dredge Cell and Dispose Offsite; Grade and Close Remainder of Dredge Cell

Action	Summary
Infrastructure	Construct or install areas for drying ash and equipment for transporting ash across Swan Pond Circle Road.
Remove Dredge Cell test embankment and ash from Dredge Cell, recontour	Remove approximately 300,000 cy of ash used in a geotechnical test in the Dredge Cell. Remove an additional 3.6 million cy of ash from the Dredge Cell. Recontour ash to provide drainage.
Excavate the Swan Pond Embayment	Remove spilled ash outside the limits of the Dredge Cell that remain after the time-critical removal action with land-based equipment.
Dredge the Swan Pond Embayment	Remove spilled ash in the waterways that is too wet to remove with traditional land-based equipment with hydraulic dredges.
Remove clean water ditches	Remove the rock-covered banks of the clean water ditches that are covering ash and move the material to the Ball Field for disposition.
Remove Dike 2 and Settling Basins	Remove rock and ash associated with the containment dike and the dirty water settling basins. Move to the Ball Field for disposition.
Transport the ash offsite	Move the ash to the Ball Field area for final processing and loading. Two subalternatives, 2a and 2b, have been developed. Alternative 2a would transport the ash by rail to Alabama. Alternative 2b would transport a significant amount of ash by truck to the Chestnut Ridge Landfill in Tennessee.
Restore embayment	Introduce aquatic plants into the remediated area to facilitate recovery.
Install perimeter containment	Construct a working platform. Install a perimeter containment system and deep soil stabilization system on one side of the Dredge Cell (Dike D) and Ash Pond.
Grade Dredge Cell and Ash Pond	Fill Ash Pond to design elevation that will allow drainage. Install a drainage system.
Cover Dredge Cell and Ash Pond	Cover the regraded cell as well as the perimeter dike and vegetate.
Monitoring	Install and monitor groundwater wells around the closed Dredge Cell and Ash Pond.
Institutional Controls	Prevent future use of the Dredge Cell through institutional controls.

Remove Dredge Cell test embankment and ash in Dredge Cell, recontour. To meet the final contour requirements, it is assumed that up to 4.0 million cy of ash would be removed, plus the 300,000 cy of ash in the test embankment. The final site conditions for Alternative 2 would include graded slopes to facilitate drainage within the Dredge Cell with a central ditch. The Dredge Cell would be regraded with one to 3% slopes from the existing Dike D crest elevation (maximum elevation of 780 ft msl) and the Swan Pond Road corridor (elevation 765 ft msl) to a central ditch. The central ditch would be constructed with a 1% slope from the Ball Field corridor (maximum elevation 770 ft msl) to the Swan Pond Embayment area (elevation 736 ft msl following ash removal).

Dry ash from the Dredge Cell would be stockpiled and loaded into articulating trucks and taken to the Ball Field for processing. The production rate assumes 22 cy per truck, with 40 trucks operating over a 10-hour shift, and 240 total round trips per day, for a production rate of 5,280 cy/ day. Wetter ash would be processed to dry it to a moisture content between 20 and 30%. Processing would consist of piling to allow drainage, spreading out and disking ("windrowing") to evaporate water, or any combination. Processing would either be conducted in areas of the Dredge Cell not yet excavated or in the Ball Field area, depending on how much ash has been stockpiled in the Ball Field waiting for loading into rail cars.

Excavate the Swan Pond Embayment. Up to 2.4 million cy of ash, rock, and clayey soil are present in the north and central portions of the Swan Pond Embayment, which would be removed in Alternative 2 in a manner similar to Alternative 1. Around 1.9 million cy would be removed by excavation equipment. The ash would be piled and when dry enough, removed from the area by conveyor or truck. For Alternative 2a, the ash would be conveyed and/or loaded into articulating off-road dump trucks and moved to the Ball Field for further drying (if needed) and loading into rail cars. For Alternative 2b, the excavated ash from the north portion of the embayment would be moved by dump truck directly offsite

for disposal and the excavated ash in central portion of the embayment would be moved by articulating truck to the Ball Field for offsite disposal by rail.

Dredge the Swan Pond Embayment. Ash in the waterways that is too wet to remove with traditional land-based equipment (assumed 0.5 million cy) would be dredged from the embayment, similar to Alternative 1.

Remove Clean Water Ditches. A series of clean water ditches were installed during the time-critical removal action to bypass upgradient surface water around the ash. These ditches would be removed under Alternative 2, as with Alternative 1.

Remove Dike 2 and Settling Basins. As with Alternative 1, Alternative 2 includes removing Dike 2 and the settling basins.

Transport Ash Offsite. The offsite disposal options are the same as those discussed in Alternative 1. For Alternative 2a, approximately 2.4 million cy of ash would be generated from the embayment, 300,000 cy from the test embankment, another 4.0 million cy from the Dredge Cell, along with an additional 130,000 cy of rock from Dike 2 and the settling basins. To transport this volume of material using a combination of 85- and 110-car trains would require a total of approximately 870 trains carrying an average of nearly 7,500 cy per train. Roughly 1,270 calendar days would be needed to remove the material (assuming 80% production of one train a day, 7 days a week). However, offsite shipments would be restricted by the rate at which the ash can be excavated and hauled to the Ball Field for loading onto railcars; as a result, total duration of offsite shipments is estimated at nearly 45 months.

For Alternative 2b, the truck volume (760,000 cy) would remain the same as Alternative 1b, but the rest of the ash generated (roughly 6.04 million cy) would be disposed by rail. Approximately 14 months would be required for truck transport; roughly 39 months, would be required for rail transport.

Restore Embayment. The approach for restoring the aquatic and riparian environment within the Swan Pond Embayment is the same in Alternative 2 as in Alternative 1.

Install Perimeter Containment. Dike D and the dikes surrounding the Ash Pond would require foundation treatment under Alternative 2. Perimeter containment around the Ash Pond would be the same as that described for Alternative 1, and would be installed at a later date. Because the ash would be removed to the surrounding grade in other areas (including the Dike C, Ball Field, and Swan Pond Road corridors) reducing the height of ash, no foundation treatment would be required in those areas. For Dike D, a 35-ft wide foundation treatment zone would be installed at the dike toe, about 60 ft deep. A 4:1 rock buttress would also be constructed on the outslope area at the base of the dike to flatten the slope. The improvements would be as described in Alternative 1.

Grade Dredge Cell and Ash Pond. The surface of the ash would be graded and fill placed within the Ash Pond to facilitate drainage. The Ash Pond would be closed at a later date.

Cover Dredge Cell and Ash Pond. Once the Dredge Cell has been graded, a soil cover would be placed, as in Alternative 1. Prior to placement of the cover material, any vegetation that may have been established for temporary dust control would be removed. The surface would be scarified to promote lift bonding. Approximately 2 ft of clay and 1 ft of topsoil would be placed over the entire area and contoured. Once the cover reaches final grade, it would be seeded and mulched with an approved permanent seed mixture and mulch material. Seeded areas would be maintained through irrigation appropriate for weather conditions until vegetation is established. The cover may require periodic repairs of erosion features or of areas that did not sustain vegetation.

Monitoring. Because ash would remain in the Dredge Cell, the groundwater underneath the cell and surface water flowing from the cell would be monitored quarterly for some period of time until the results indicate stable conditions. Once stable conditions are confirmed for 4 quarters, the monitoring would be reduced to semi-annually. It is assumed that up to 4 new monitoring wells would be installed and monitored for metals and radionuclides. Because this site is a CERCLA site, these monitoring results would be documented in a five-year effectiveness review report. A detailed monitoring plan would be developed as part of the selected removal action.

The containment system as well as the drainage systems would be periodically inspected. The details of the inspection process will be developed as part of the final design. However, for the purpose of this EE/CA, it is assumed that monthly inspections occur.

Institutional Controls. The Dredge Cell would be maintained as a disposal location for the foreseeable future. Under state solid waste regulations, access to the cell would be controlled for only maintenance or monitoring.

3.2.3 Alternative 3: Excavate Embayment and Dispose Onsite; Close the Dredge Cell

The actions under this alternative are designed to minimize any further offsite hauling of ash. Alternative 3 is very similar to Alternative 1 except that the ash removed from the embayment would be disposed onsite in locations where ash has historically been disposed. For evaluation purposes, this alternative uses the Dredge Cell as a disposal facility. There would be no further offsite shipment of ash. The major components for this alternative are listed in Table 3-4. Two subalternatives (3a and 3b) were developed to evaluate onsite disposal options. Alternative 3a would place material from the embayment into the Dredge Cell and close the Ash Pond at a later date. The end state of Alternative 3a is illustrated on Figure 14, and a conceptual schedule for construction sequencing for Alternative 3a is shown on Figure 15. Alternative 3b would place that material into the Ash Pond and close both areas at the same time. The end state of Alternative 3b is illustrated on Figure 16 and a conceptual schedule for construction sequencing is shown on Figure 17.

Infrastructure. As with Alternatives 1a and 2a, an ash processing area for the north embayment and a conveyor system to move the ash across Swan Pond Circle Road would be constructed.

Excavate the Swan Pond Embayment. This component is the same for all action alternatives. For the purposes of this discussion, roughly 80% (roughly 1.9 million cy) is assumed to be retrievable with excavators, dozers, and trucks. The ash would be piled and when dry enough, removed from the area by conveyor or truck. The ash would be transported to the Ball Field for dewatering, if needed.

In all cases, the wetter ash would be processed before placing on conveyors by piling or spreading out and disking and rolling. The processing would occur either near the point of generation, during compaction, or in the Ball Field processing area. In general, a moisture content between 20 and 25% is desired prior to stacking. Ash would be moved onsite through off-road trucks or with scrapers and pans. Trees that are retrieved either within the ash or that are removed would be chipped and either used onsite to stabilize the surface of the ash to support trucks or sent offsite for disposal. Up to 50 truckloads of timber are included. Periodically, disturbed ash may be sprayed with a component like Flexterra® to control dust for the short term.

Table 3-4. Summary of Actions for Alternative 3, Excavate Embayment and Dispose Onsite; Close the Dredge Cell and Ash Pond

Action	Summary
Infrastructure	Construct or install areas for drying ash and equipment for transporting ash across Swan Pond Circle Road.
Excavate the Swan Pond Embayment	Remove spilled ash outside the limits of the Dredge Cell that remain after the time-critical removal action with land-based equipment.
Dredge the Swan Pond Embayment	Remove spilled ash in the waterways that is too wet to remove with traditional land-based equipment with hydraulic dredges.
Remove clean water ditches	Remove the rock-covered banks of the clean water ditches that are covering ash and move the material to the Ball Field for disposition.
Remove Dike 2 and Settling Basins	Remove rock and ash associated with the containment dike and the dirty water settling basins. Move to the Ball Field for disposition.
Restore embayment	Introduce aquatic plants into the remediated area to facilitate recovery.
Install perimeter containment	Construct a working platform. Install a perimeter containment system and deep soil stabilization system on all sides of the Dredge Cell and Ash Pond.
Stack Ash	Construct a working platform. Move the ash to the Dredge Cell (3a) or Ash Pond (3b) and stack/compact the material in lifts.
Grade Dredge Cell and Ash Pond	Regrade the ash in the Dredge Cell and Ash Pond to design elevations that will allow drainage. Install drainage system.
Cover Dredge Cell and Ash Pond	Cover the regraded Dredge Cell and Ash Pond as well as the perimeter dike and vegetate.
Monitoring	Install and monitor groundwater wells around the closed Dredge Cell and Ash Pond.
Institutional Controls	Prevent future use of the Dredge Cell through institutional controls.

Dredge Swan Pond Embayment. Ash in the waterways that is too wet to remove with traditional land-based equipment would be dredged from the embayment. It is assumed that 20% of the material would be dredged (approximately 500,000 cy). A small 10-inch dredge would be used to remove most of the material although larger dredges may be useful in some areas. The dredged material would be piped to the existing rim ditch (with a booster pump) and discharged to the ditch. It is anticipated that up to 90% of the solids would settle out of solution through the Rim Ditch and Sluice Trench. The remaining water would then discharge to the Stilling Pond prior to discharge through an NPDES discharge. During dredging, ash from the plant would also discharge to the Sluice Trench.

Ash would be recovered from the Rim Ditch/Sluice Trench with a combination of excavators and clamshells. The ash would be processed on the Ball Field to allow it to dry sufficiently to be trucked back to the Dredge Cell for stacking.

Remove Clean Water Ditches. The clean water ditches would be removed as in Alternatives 1 and 2.

Remove Dike 2 and Settling Basins. The dike and settling basins would be removed as in Alternatives 1 and 2.

Restore Embayment. The approach for restoring the aquatic and riparian environment within the Swan Pond Embayment would be the same as in Alternatives 1 and 2.

Install Perimeter Containment. Soil stabilization would be implemented as described in Alternative 1 by constructing a foundation treatment zone consisting of a grid of soil/cement columns installed using deep soil mixing techniques. The foundation treatment zones for Alternative 3 would be much more robust due to the higher fill heights, as follows:

- Dike C corridor: 130-ft wide foundation treatment zone beneath proposed earthen berm, about 40-ft deep; riprap armoring along the upstream face (outslope).

- Dike D corridor: Under Alternative 3a, 50-ft wide foundation treatment zone at crest about 80-ft deep and 50-ft wide foundation treatment zone at dike toe, about 60-ft deep; rock buttress on a 4:1 slope on the upstream face (outslope). Under Alternative 3b, there would be no foundation treatment beneath Dike D.

- Ball Field corridor: Under Alternative 3a, 100-ft wide foundation treatment zone about 60-ft deep, under Alternative 3b, 25-ft wide zone about 60-ft deep.

- Swan Pond Road corridor: Under Alternative 3a, 100-ft wide foundation treatment zone, about 60-ft deep, under Alternative 3b, 25-ft wide zone about 60-ft deep.

- Ash Pond corridor: As described for Alternative 1a, along the northern Dike C, a 25-ft wide zone at the dike crest, about 60-ft deep, and another 25-ft wide zone at the dike toe, 50-ft deep. Along the eastern divider dike, a 15-ft wide zone at the dike crest, 60-ft deep, and a 15-ft wide zone at the dike toe, 50-ft deep. Along the southern Dike C, one 25-ft wide zone at the dike crest, 30-ft deep.

An earthen berm would be built along the Dike C corridor prior to stabilizing the underlying material. Compactible earthen fill would be placed in maximum eight-inch loose lifts. The material would be compacted to a minimum of 95% of standard Proctor maximum dry density. Quality control samples would be taken to ensure appropriate moisture content in addition to compaction. Outslope armoring of the new Dike C would be constructed of riprap.

A rock buttress would be constructed of shot rock or equivalent material on the outslope area of Dike D to flatten the slope to 4:1. A non-woven geotextile filter fabric would be placed along existing surfaces before placing the shot rock. The rock would be placed in one foot lifts. A perimeter ditch would be constructed to divert surface drainage away from the site and to control runoff from the site. The ditch would be excavated in existing materials and lined with 1 ft of fine-grained soil, covered with 1 ft of topsoil, and protected with a synthetic turf reinforcement mat to establish a vegetative (grass) cover.

Stack Ash. A working platform would be constructed across the Dredge Cell (Alternative 3a) or Ash Pond (Alternative 3b) before ash is stacked. The working platform would be constructed of biaxial geogrid, no. 57 stone, and no. 10 limestone sand or equivalent. This platform would be similar to the one used to support construction of the perimeter dike containment system. This type of platform was also used in the test embankment within the Dredge Cell.

Dried ash (20 to 25% moisture content) would be placed in relatively thin lifts of 8- to 12-inch thickness, and each lift compacted to a minimum of 90% of standard Proctor maximum dry density. Quality control samples would be taken to confirm appropriate moisture content for optimum compaction. This process would be slow because of the need to dry the ash sufficiently to allow compaction. A production rate of less than 2,800 cy/day was assumed for the 2.5 million cy of wetter ash from the embayment; as a result, a total of 1,100 calendar days (or 3.0 years) would be required for ash stacking. With refinement of the drying process, availability of resources (trucks, excavators), larger active landfill face for compaction, and beneficial weather conditions (particularly in the warmer, dryer summer months), higher production rates of over 5,000 cy/day may be achievable.

Grade Dredge Cell and Ash Pond. Conceptual constructed site conditions for Alternative 3 consist of graded slopes to facilitate drainage within the Dredge Cell. The cell would be regraded with 4:1 outslopes with a maximum 2% crest slope to a peak elevation of 805 ft msl (Alternative 3a). Peak

elevation under Alternative 3b would be lower than Alternative 3a, approximately 790 ft msl. It is assumed that over 0.9 million cy of ash would need to be regraded. The test embankment ash would be regraded also, if any portion extends above final grade. The regrading would occur over time but would be coordinated with the construction of the working platform for the new dike containment system and the ash stacking platform.

Cover Dredge Cell and Ash Pond. Once the Dredge Cell has been graded and the dike containment system has been installed, a soil cover would be placed. Prior to placement of the cover material, any vegetation that may have been established for temporary dust control would be removed. The surface would be scarified to promote lift bonding. Approximately 2 ft of clay and 1 ft of topsoil would be placed over the entire area and contoured. Once the cover reaches final grade, it would be seeded and mulched with an approved permanent seed mixture and mulch material. Seeded areas would be maintained through irrigation appropriate for weather conditions until vegetation is established. The cover may require periodic repairs of erosion features or of areas that did not sustain vegetation.

Monitoring. Because ash would remain in the Dredge Cell, the groundwater underneath the cell and surface water flowing from the cell would be monitored quarterly for some period of time until the results indicate stable conditions. Once stable conditions are confirmed for four quarters, the monitoring would be reduced to semi-annually. It is assumed that up to four new monitoring wells would be installed and monitored for metals and radionuclides. Because this site is a CERCLA site, these monitoring results would be documented in a five-year effectiveness review report. A detailed monitoring plan would be developed as part of the selected removal action.

The containment system as well as the drainage systems would be periodically inspected. The details of the inspection process will be developed as part of the final design. However, for the purpose of this EE/CA, it is assumed that monthly inspections occur.

Institutional Controls. The Dredge Cell would be maintained as a disposal location for the foreseeable future. Under state solid waste regulations, access to the cell would be controlled for only maintenance or monitoring.

3.2.4 Components Common to All Alternatives

The following are activities that will be conducted under each of the alternatives described above.

Environmental Health and Safety. TVA and its contractors will systematically integrate safety into management and work practices so that the implementation of the removal action is accomplished while protecting the public, the worker, and the environment. This will be accomplished through effective integration of safety management into all facets of work planning and execution. Environmental safety and health management is being implemented under current work plans and health and safety plans and includes the following elements:

- Vehicle washing upon leaving the site;
- Personal protective equipment, including steel-toed boots, hard hats, and reflective vests;
- Construction fencing around the CERCLA site;
- Routine air and water monitoring;
- Institutional hygiene monitoring of workers;
- Dust control by watering roadways and work areas or use of Flexterra® polymer treatment; and
- Stormwater pollution prevention and erosion and sediment control.

Dewatering and Water Management. Ash dewatering and water management systems implemented for the ongoing time-critical removal action would be continued, although volumes of hydraulically dredged material would be substantially reduced. Dredged material, which is only about 10 to15% solids initially, would be pumped into the Rim Ditch to allow solids to settle out of the slurry. The water would then flow through a Sluice Ditch into the Ash Pond and then into the Stilling Pond where further settlement would occur. The KIF plant output of fly and bottom ash enters the Sluice Ditch upstream of the discharge of the Rim Ditch. The KIF plant output varies depending on the number of generating units online, but is expected to contribute an average of 50 cy/hour (1,200 cy/day). Although dry ash processes are being evaluated for implementation at KIF, the KIF plant output to the Sluice Ditch is expected to continue until late 2011.

Settled ash would be removed from the ditches through mechanical excavation at a solids content between 35 and 40% solids, then windrowed in an ash processing area to dry to between 77 and 83% solids (20 to 30% moisture content). The ash would then be moved to a storage area for short-term staging of the ash awaiting transportation and disposal. The dried ash would then be loaded into lined rail cars and transported offsite for ultimate disposal. For Alternative 3, the dried ash would be trucked back to the Dredge Cell for disposal.

The objectives of the dredged ash dewatering operation for Alternatives 1 and 2 are to reduce the total water content in the ash so as to meet waste acceptance criteria at the Arrowhead Landfill (i.e., paint filter test) and to facilitate material handling and stability during loading and transport. The target water content would therefore be between 20 and 30% moisture content (77 to 83% solids) to meet these objectives. The objectives of the dewatering operation for Alternative 3 are to reduce the total water content in the ash to allow proper compaction during stacking. The target water content would be lower, between 20 and 25% moisture content (77 to 80% solids), to meet these objectives.

The objectives of the treated water operation are to meet the NPDES permit requirements for effluent from the stilling pond. The NPDES permit limits include an average monthly value of 29.9 mg/L total suspended solids (TSS), and a maximum daily value of 92.0 mg/L TSS. In addition, pH is limited to a minimum of 6.0, and oil and grease limited to an average monthly concentration of 14.4 mg/L and a maximum daily concentration of 19.4 mg/L. Although ammonia nitrogen introduced from nitrogen oxides-control technology at the KIF plant is not expected to cause a measureable increase in ammonia concentration in the river, the permit requires reporting of ammonia nitrogen twice per month. The permit further requires notification to TDEC Division of Water Pollution Control of any activity that would result in the discharge of any toxic substances, generally exceeding 0.10 mg/L (routine basis) or 0.50 mg/L (nonroutine basis). Arsenic and selenium are toxic substances known to be present in fly ash and are therefore specifically monitored.

The NPDES permit further requires that a minimum free water volume in the combined Ash Pond and Stilling Pond be maintained at 102 million gallons. The TVA Operations Plan for waste handling operations within the ponds specifies at least 4 ft below the dike elevation. This freeboard has been selected to contain wave action and rainfall up to a 25-year, 24-hour storm event of 5.5 inches. These requirements will be revisited during final design to allow phased closure of the Ash Pond.

Ball Field Restoration. Following implementation of the non-time-critical removal action being evaluated in this EE/CA, and completion of dredging, dewatering, or offsite ash shipment under the CERCLA action, the Ball Field would be restored by removing any remaining ash down to a gravel and geotextile demarcation layer that had been placed at the beginning of the time-critical removal action. The gravel and geotextile would be removed and disposed with the ash. Topsoil would then be placed over the ground surface, seeded, and mulched to establish a vegetative (grass) cover.

4. ANALYSIS OF ALTERNATIVES

4.1 INDIVIDUAL ANALYSIS OF ALTERNATIVES

This section presents an individual analysis of the alternatives based on effectiveness, implementability, and cost.

Effectiveness. The effectiveness of each technology to meet the RAOs is evaluated in terms of overall protection of human health and the environment, compliance with ARARs, long-term effectiveness and permanence, and short-term effectiveness. Long-term effectiveness considers the magnitude of residual risk, degree of reduction expected in waste toxicity, mobility or volume; the adequacy and reliability of controls; the degree to which treatment is irreversible; and the type and quantity of residuals remaining after treatment. Short-term effectiveness considers protection of workers and the community during the action, environmental impacts, and time until RAOs are achieved.

Implementability. The implementability of each technology addresses the technical and administrative feasibility of implementing an alternative and the availability of materials, equipment, or services required during implementation. This criterion considers the ability to construct and operate the technology within the site and time constraints for the non-time-critical removal action, the time to procure and install necessary equipment and specialists, ability to monitor effectiveness, ease of implementing additional technologies (if necessary), and ability to obtain approval from other agencies.

Cost. The relative cost of each technology is estimated, considering capital cost of material, equipment and installation, as well as the annual operating and maintenance (O&M) costs such as mowing, erosion repair, or dike repair. The capital costs are estimated in 2009 dollars with no adjustment for inflation due to the short time frame associated with the removal action. Costs are considered planning-level estimates, within an accuracy of -30 to +50%.

4.1.1 Alternative 1: Excavate Embayment and Dispose Offsite; Grade and Close Dredge Cell

4.1.1.1 Effectiveness

Alternative 1 would fully meet RAOs. The ash within the embayment would be removed to the maximum extent practicable, so as to restore the natural resources and area waters. The Dredge Cell would be closed. As a result, the terms of both the TDEC Commissioner's Order and the EPA Administrative Order would be met.

Overall Protectiveness. Alternative 1 would be protective of both human health and the environment. Removal of the ash from the embayment would substantially eliminate both direct contact with water flowing through the area and future migration of ash into the river due to erosion. Closure of the former Dredge Cell, which would include a soil and vegetative cover over the ash, would also eliminate future migration of ash due to erosion and eliminate direct contact with ash on the ground by either human or ecological receptors. Existing TVA access controls would prevent future use of the closed Dredge Cell area for unauthorized purposes.

Compliance with ARARs. Alternative 1 would comply with all ARARs, as listed in Appendix C. Closure of the Dredge Cell would be in accordance with Tennessee Solid Waste Rule 1200-1-7, thereby complying with terms of the TDEC Commissioner's Order. The final cover system must be at least 36 inches thick, consisting of a compacted soil layer at least 24 inches thick which has a permeability no greater than 1×10^{-7} centimeter/second (cm/sec), and a second soil layer at least 1-ft thick for the support of vegetative cover. An alternate final cover system may be used provided that it provides equivalent or

superior performance in minimizing infiltration. The final surface must be graded and/or have drainage facilities that minimize erosion of cover material, optimize drainage, and are consistent with drainage in the surrounding area.

Restoration of the embayment would restore waters of the state and the associated floodplain and wetland areas impacted by the ash in compliance with Tennessee rule 1200-4-3 and associated ARARs. Removal of the ash would remove the naturally-occurring metals and radionuclides that could produce toxic effects on the health and safety of humans or animals. Water quality would be restored to meet AWQC in surface water within the embayment. Waters would therefore not contain residual pollutants from the ash that may impair the usefulness of the water as a source of domestic or industrial water supply, recreation, or irrigation, or that may impair the health of fish or aquatic life. Details of the embayment restoration are described in Appendix D. Information satisfying the requirements of a Jurisdictional Assessment, including maps of the site prior to the spill and following the non-time-critical removal action, areas/species/habitat impacted, revegetation with selected species, habitat created, microtopography, and similar elements are provided in Appendix D.

Site preparation, construction, and excavation activities would be conducted in compliance with TDEC 1200-3-8 and TDEC 1200-4-10, including precautions to control fugitive dust emissions, erosion, and sedimentation. Dredged material removed from the embayment would not be placed into an aquatic ecosystem, in compliance with 40 CFR 230.10(a).

Excavated ash would be characterized, managed and disposed in compliance with 40 CFR 262.11 and TDEC 1200-1-11. Ash would be disposed in a permitted solid waste disposal facility in accordance with the applicable state regulations (TDEC 1200-1-7 in Tennessee) under the terms of the facility's permit (i.e., meeting its waste acceptance criteria). Transportation of hazardous materials would comply with all applicable provisions of the Hazardous Materials Transportation Act and U.S. Department of Transportation's (DOT) Hazardous Material Regulations at 49 CFR 171-180.

Alternative 1 would be effective over the long-term. Removing the ash from the embayment and closure of the Dredge Cell would be permanent actions that would effectively restore the waters of the state; eliminate direct contact, erosion, and migration of ash to the river; contain the remaining ash materials; and dispose of the excavated ash at an offsite permitted facility. Long-term effectiveness is further discussed in the following paragraphs.

Effectiveness of restoration. The restoration of a complex mosaic of forested, scrub-shrub, and emergent wetlands would be effective in reestablishing pre-spill topography, plant communities, and habitat for fish, semi-aquatic amphibians, and bird species, as described in Appendix D. The following summarizes the adequacy and reliability of the restoration:

- Excavation and grading would reestablish the pre-spill topography of the embayment shoreline, although loss of native soil in some areas may require previous riparian forest communities being restored to a wetland emergent community or a greater areal extent of open water habitat than the pre-spill condition. Regrading of the embayment shoreline would adequately restore the floodplain microtopography and wetland hydrology present prior to the spill, including restoration of the small island in the central embayment important for fish and other aquatic species. The bottom substrate of the embayment is expected to reestablish naturally, since it is an area of high sediment deposition; organic soil amendments would be added to improve organic content and moisture retention capacities.

- Planting would adequately restore a complex mosaic of native wetland and upland plant communities to areas previously dominated by forest and scrub-shrub habitat. Species composition and densities

would simulate pre-spill conditions based on previous studies, and would adequately restore native biodiversity and habitat along the riparian shoreline. Planting with native species would reliably establish habitat in as short a time as possible. Greater than 75% plant survivability has been shown to be achievable in wetland mitigation projects. Areas of excessive plant loss would be replanted in subsequent seasons to establish a sustainable plant community.

– Natural repopulation of native faunal groups would adequately restore the native biodiversity to pre-spill conditions, once adequate mature habitat has become established. Restoration would adequately reestablish the riparian cover important to fish to provide shade and organic inputs and reestablish the horizontal and vertical structure important to semi-aquatic and terrestrial fauna (amphibians, reptiles, and mammals) and attractive to native bird species. Artificial snags would provide roosting habitat proximal to open water habitat, and restored mudflats would provide casual migrant habitat for the piping plover during low water levels. Native fish and terrestrial fauna are highly mobile in open water and would readily repopulate the embayment area. Substrate for benthic macroinvertebrate habitat would flow into the embayment from streams feeding the embayment and from the reservoir as water levels rise. Benthic hatchlings are highly mobile and would readily repopulate the embayment area.

Contingent actions could be taken to enhance both the terrestrial and aquatic environments, as described in Appendix D. Potential enhancements could include increasing the extent of wetland communities; increasing the number and size of microdepressions or coarse wood structures to mimic treefalls; creating multiple islands as structure for fish, other aquatic species, and birds; constructing weirs with fish ladders to reduce seasonal water level fluctuations, promote emergent wetland vegetation, and increase extent of permanent open water; adding cobbles or boulders along the shoreline to enhance structural complexity for fish and benthic macroinvertebrates; replacing portions of former lawns with native plant communities; increasing the width of the riparian zone and floodplain forests; constructing artificial snags, osprey platforms, or reefs to increase the faunal habitat within the embayment ecosystem.

Effectiveness of cover containment. The 36-inch-thick cover would be effective in eliminating direct contact with ash on the ground by humans or animals, providing sufficient thickness against dust generation or burrowing. The relatively flat surface grades (2 to 5%) and vegetative cover would be effective in eliminating erosion and/or migration of ash to adjacent surface water. Routine inspection and maintenance to repair any erosion features would ensure long-term reliability of the cover. The 24 inch low-permeability clay layer would effectively reduce infiltration of precipitation through the ash. Results of EPA's Hydraulic Evaluation of Landfill Performance modeling indicate reduction in infiltration through the ash from 14.9 inches/year to less than 1.4 inches/year. However, since ash would remain below the water table, the clay layer would not eliminate dissolution or migration of inorganics in groundwater. Existing groundwater monitoring data show negligible impact; the only constituent exceeding drinking water criteria is arsenic, which has been found at low levels (near its MCL).

Preliminary results of the test embankment study being conducted within the former Dredge Cell suggest that foundation settlement beneath the cover would be less than 5.0 inches, most of which would occur during the time that fill is being placed. As a result, surface grades averaging 2 to 5% across the top of the cover and associated drainage systems are expected to be reliable over the long term, with only minor maintenance to repair cover damage due to settlement. The test embankment results further suggest that ash fill placement within the cell is not expected to result in excess porewater pressure buildup beneath the ash, which could otherwise affect fill stability. Maximum loading rates of 5 ft per month not produce excessive pressure nor excessive lateral movements beneath the test fill that could otherwise impact the effectiveness of the cover.

The existing Dredge Cell does not have a gas collection system; no gas collection system would be needed since the ash is relatively inert, nonputrescible inorganic material that would not generate significant quantities of gas. The cell does not have a leachate collection system; no leachate collection system would be needed nor effective, since historically placed ash is present in the cell to depths below groundwater levels and adjacent reservoir levels. The effectiveness of the groundwater protection system, including contaminant flux to the Emory River and Watts Bar reservoir will be evaluated as part of the river system EE/CA.

Effectiveness of dike containment. The perimeter dike containment system would be effective and stable over the long-term. Dike stability under static loading conditions was analyzed using STABL/W, resulting in safety factors greater than 1.5, which are indicative of stable conditions (Appendix E). The conceptual dike configuration and foundation design address the four contributing factors cited by AECOM in their root cause analysis of the former dike failure (AECOM 2009).

1. Fill Geometry. The former failed dike was constructed using small dikes stacked progressively up slope on top of nearly 80 ft of sluiced ash and a sensitive silt ("slimes") layer. Total height of the dikes that surrounded the former Dredge Cell prior to its failure was elevation 820 ft msl. The conceptual dike would be constructed using a single compacted soil dike placed on a crushed rock working platform and 20 ft of ash over silt/clay and sand layers. The ash, silt/clay, and sand layers would be further reinforced with soil-cement columns installed using deep soil mixing methods at a 25% replacement ratio. Maximum height of the dikes would be elevation 780 ft msl along Dike D and elevation 765 ft msl along Dike C, which is 40 to 55 ft lower that the top of the former dikes. The conceptual fill geometry would therefore be stable.

2. Fill Rates. The elevation of the ash in the former Dredge Cell prior to failure was increasing at a rate of about 6 ft/year, more rapidly compared to earlier years, which added load to the wet ash beneath the dikes. In particular, the dredge filling resulted in loose, wet ash saturated throughout its depth, which led to high porewater pressures at depth and low strength in the sluiced ash materials. The conceptual dike would be constructed using dewatered ash, compacted in thin lifts. Results of the test embankment have shown that such construction methods would not result in excess porewater pressures in the foundation ash materials under a rate of filling equivalent to 5 ft/month. The conceptual fill rate and methodology would therefore be safe.

3. Soft Foundation Soils. Creep deformations within the submerged loose slimes was occurring under the load of loose wet ash in the former Dredge Cell, which caused a reduction in the strength of the slimes and led to deep-seated failure of the dike. The conceptual dike would be reinforced with soil/cement columns that would not rely on the strength of the soft foundation soil layer for stability, but would instead transfer the load substantially to the underlying bedrock through the soil/cement columns. The conceptual foundation support would therefore be stable.

4. Loose Wet Ash. The original sluiced ash was deposited under water, resulting in a high void ratio (very loose ash) that did not consolidate or densify under the surcharge weight of ash placed above it. As a result, the loose wet ash had a low undrained shear strength (as low as 100 pounds per square foot [psf]) with a very sensitive structure. The conceptual dike would be constructed using dewatered ash, compacted in thin lifts. Results of the test embankment study have shown that the undrained shear strength of the compacted dry ash increases with depth due to the weight of dry ash above it, and is greater than 500 psf at depth. The conceptual compacted dry ash would therefore be much stronger than the loose wet ash in the former Dredge Cell.

Dike stability was further analyzed under earthquake loading conditions using SLOPE/W simulation software and the Spencer method to compute the factor of safety (Appendix E). This analysis indicates

that the ash and native silt/sand layers may liquefy under design earthquake loads. For this reason, the conceptual foundation design includes a treatment zone consisting of soil/cement columns arranged in a grid pattern up to 130-ft wide for optimum liquefaction mitigation. Resulting safety factors greater than 1.1 were calculated, which is suitable under short-term seismic loading conditions. Therefore, the perimeter dike containment system would be stable under earthquake loads.

Effectiveness of disposal. Alternative 1 would transport approximately 2.8 million cy of recovered ash, clayey soil, and rock offsite for disposal. Approximately 10.8 million cy of ash and associated dikes would remain within the former Dredge Cell. The volume of ash onsite would be reduced and covered to limit migration.

The offsite disposal facility would be an existing, permitted solid waste landfill. The landfill would operate under the restrictions of its specific permit, including waste acceptance criteria, groundwater protection systems, leachate collection and treatment systems, interim and final cover, and other terms of the operating permit. EPA and TDEC must approve the specific landfill prior to shipment of any ash. Offsite disposal would therefore be effective in reducing onsite volumes and managing the ash in a permitted manner.

Effectiveness over the short term. Alternative 1 would also be effective over the short term, during the estimated 2.8 years of construction; RAOs would be achieved once construction is complete. Short-term impacts could occur during the excavation, processing, and transportation of the 2.8 million cy of ash and other material from the embayment and test embankment. Engineering measures would be implemented to protect remediation workers and the community, including the following: (1) dust control measures, such as wetting the ash or spraying with Flexterra®, to minimize generation of fugitive dust; (2) Occupational Safety and Health Act (OSHA) health and safety measures, such as use of personal protective equipment (PPE) and construction safety program, to protect workers; (3) transportation control measures, such as placarding, lining, and shipping in accordance with DOT regulations, to protect the community and minimize spills; and (4) erosion and sediment control measures, such as sediment basins, check dams, temporary seeding, diversion berms, interceptor trenches, silt fences, and erosion protection blankets, to minimize erosion and transport of the ash during construction.

Inherent short-term risks would be associated with shipment of the 2.8 million cy of material over public railways or roadways. Short-term risks of railroad incidents or rail-vehicle intersection accidents would be proportionate to the number of trip-miles. The Perry County Associates, Arrowood Landfill, is located in Perry County, Alabama, approximately 330 miles from the site, and is accessible by rail hauling over Norfolk Southern railways. Assuming a combination of 85- and 110-car trains averaging 7,500 cy capacity, hauling ash to the Arrowood Landfill would involve nearly 125,000 trip-miles over Norfolk Southern railways. For truck hauling under Alternative 1b, short-term risks of traffic accidents would be proportionate to the number of truck trip-miles. The Waste Management, Chestnut Ridge Landfill, is located in Anderson County approximately 50 miles from the site, and is accessible by truck hauling over public roadways. Assuming a 22-cy truck capacity, hauling 760,000 cy of material to the Chestnut Ridge Landfill would involve nearly 7,600 trip-miles over public roadways. Hauling the remaining 2.04 million cy of material by rail would involve 90,000 trip-miles over the railway.

Estimates of the potential number of transportation-related accidents, injuries, and/or fatalities were made based on rate information for rail transport obtained from Argonne National Laboratory (ANL 2009) and for truck transport (DOT 2009). National statistics were used for comparability between the data sources. Rates for accidents, injuries and fatalities were multiplied by the number of rail-car miles and truck-miles, respectively. Due to reporting differences, the number of accidents does not necessarily correlate to the number of injuries or fatalities, since not all accidents result in an injury or fatality, nor are all injuries or fatalities a result of vehicle collisions.

For Alternative 1a, these calculations resulted in an estimate of one rail accident, 0.8 rail injuries, and 0.4 rail fatalities. For Alternative 1b, these calculations resulted in an estimate of 0.4 rail accidents, 0.6 rail injuries, and 0.3 rail fatalities. In addition for Alternative 1b, these calculations resulted in an estimate of 2 truck accidents, 0.8 truck injuries, and 0.04 truck fatalities.

4.1.1.2 Implementability

Alternative 1 would be implementable within 2.8 years following design of the non-time-critical removal action. Closure of the Ash Pond would occur at a later date, and would require another 10 months to complete. Conventional materials, equipment, or services would be available for excavation/dredging, ash hauling, and grading/closure of the Dredge Cell. Similar construction equipment has been used in implementing portions of the ongoing time-critical removal action, demonstrating that the removal action would be implementable and providing valuable lessons learned for design of the non-time-critical removal action. However, significant challenges would be anticipated in implementing the alternative.

Excavation of ash from the embayment would be complicated by high water levels, springs and seeps into the embayment, which would degrade equipment foundation support and aggravate ash dewatering. Low-tire-pressure or amphibious equipment would be used to excavate as much material as possible. When water levels preclude use of land-based equipment, small dredges would be used to complete the ash removal. The shallow depth of water would preclude use of larger dredges. Excavated material from west of Swan Pond Circle Road would need to be carried beneath the roadway using enclosed conveyor systems or bridge structures to avoid interference with public traffic.

Properties of the fine-grained ash would complicate ash dewatering. Experience gained during the time-critical removal action has shown that wetter material at depth or material that becomes wetter as a result of sustained rainfall is difficult to dewater. For optimum material handling and shipping, the moisture content must be reduced from approximately 100% moisture in the embayment to less than 30% moisture in the haul vehicle. Wet ash processing areas would be needed to temporarily disk, blade, or turn the ash in piles or windrows to facilitate drying by evaporation. Use of polymer absorbents may be needed as contingent actions to absorb water that may rise to the top of the truck or rail car bed as a result of vibrations during shipment, and would be disposed with the ash.

Hydraulically dredged ash would require considerably greater processing to dewater the ash, similar to current ash processing. Dredged slurry, containing approximately 15% solids, would need to be pumped nearly a mile to the existing Rim Ditch where gravity settling would occur. Subsequent dewatering by gravity drainage and windrowing would reduce the water content to less than 30% moisture. Alternate processing areas, such as in the Lateral Expansion Area (Cell 4) could be considered; however, the processing area does not readily accommodate equipment traffic or ash drying due to space limitations.

Transportation of the ash would be complicated by the large volume of material and limited disposal options. Under Alternative 1a, transport by rail alone would require a 380 trainloads averaging 7,500 cy per train and hauling daily for 18 months. Rail car loading facilities are available on the Ball Field area of KIF, as they have been installed as part of the time-critical removal action. Under Alternative 1b, transport by truck would require 35,000 truckloads hauling an average of 10 hours/day for 14 months. Transport of the remaining material by rail would require 280 trains for 13 months. Regulatory and/or public opposition to use of a particular disposal facility would complicate implementability of these disposal options. There is therefore some uncertainty as to whether sufficient offsite disposal capacity is available.

Specialty contractors would be required for implementation of the foundation treatment for the perimeter dike containment structures. Deep soil mixing expertise would be required to provide suitable mix

proportions, thoroughness of mixing, and quality control to produce a contiguous soil/cement column to depths of up to 80 ft. Implementation would be further complicated by the large number of columns required. To treat nearly 17,200 lin ft of perimeter dike foundation around both the Dredge Cell and Ash Pond, over an affected area of 650,000 ft^2 and a 25% area replacement ratio, more than 13,000 individual deep auger holes of a nominal 8-ft diameter would have to be drilled, producing more than 298,000 cy of soil/cement.

Regrading of the Dredge Cell to provide final contour grades would be complicated due to the difficult compaction properties and high erodibility of the ash. Lessons learned during implementation of the test embankment have shown the ash to be highly sensitive to moisture variations, requiring careful quality control to achieve optimum moisture for compaction. Monitoring and surveillance during construction of the perimeter dikes and ash fill compaction would include a network of piezometers, settlement plates, and inclinometers, which have been demonstrated to be effective in monitoring the construction of the test embankment. Erosion control measures such as check dams, temporary seeding, diversion berms, interceptor trenches, and erosion protection blankets would be used during ash fill placement to prevent excessive erosion of the compacted ash prior to construction of the final cover.

Closure of the Ash Pond would occur at a later date, avoiding complications on phasing of construction with ongoing KIF plant discharges or dredge dewatering operations in the Ash Pond.

Restoration of the embayment would require specialty subcontractors experienced in wetland restoration. Sufficient quantities of native plant stocks are available from specialty nurseries. Time to reach sustainable habitat will vary; emergent wetlands would be sustainable in less than 5 years and scrub-shrub wetlands in less than 10 years. Forested wetlands would require decades to reach maturity. Due to their high mobility, natural repopulation of fish and terrestrial fauna would occur immediately as their habitat develops.

Long-term O&M activities would include routine inspection and maintenance of the perimeter dikes and cover containment systems. Once vegetation has been established, cover maintenance would include periodic mowing, repair of erosion control or drainage features, and possible regrading or filling to repair areas of excessive settlement. Long-term monitoring of groundwater would be required; this monitoring is to be further addressed under the EE/CA for the river system. Long-term institutional controls, including site access control and land use restrictions, would be readily implemented as part of ongoing KIF operations.

4.1.1.3 Cost

Capital costs associated with implementing Alternative 1a are estimated at $455.3 million and Alternative 1b at $439.6 million (2009 dollars). Although the cost of hauling by truck is less costly than by rail, the unit costs of disposal in Alabama are higher for Alternative 1b due to the lesser volume of material than for Alternative 1a. Ongoing O&M costs are estimated at $686,000/year (2009 dollars).

4.1.2 Alternative 2: Excavate Embayment and Portions of Dredge Cell and Dispose Offsite; Grade and Close Remainder of Dredge Cell

4.1.2.1 Effectiveness

Alternative 2 would fully meet RAOs. The ash within the embayment would be removed to the maximum extent practicable, so as to restore the natural resources and area waters. The Dredge Cell would be closed. As a result, the terms of both the TDEC Commissioner's Order and the EPA Administrative Order would be met.

Overall protectiveness. Alternative 2 would be protective of both human health and the environment. Removal of the ash from the embayment would substantially eliminate both direct contact with water flowing through the area and future migration of ash into the river due to erosion. Closure of the former Dredge Cell, which would include a soil and vegetative cover over the ash, would also eliminate future migration of ash due to erosion and eliminate direct contact with ash on the ground by either human or ecological receptors. Existing TVA access controls would prevent future use of the closed Dredge Cell area for unauthorized purposes.

Compliance with ARARs. Alternative 2 would comply with all ARARs, as listed in Appendix C. Closure of the Dredge Cell would be in accordance with Tennessee Solid Waste Rule 1200-1-7, thereby complying with terms of the TDEC Commissioner's Order. The final cover system must be at least 36 inches thick, consisting of a compacted soil layer at least 24 inches thick which has a permeability no greater than 1×10^{-7} cm/sec, and a second soil layer at least 1-ft thick for the support of vegetative cover. An alternate final cover system may be used provided that it provides equivalent or superior performance in minimizing infiltration. The final surface must be graded and/or have drainage facilities that minimize erosion of cover material, optimize drainage, and are consistent with drainage in the surrounding area.

Restoration of the embayment would restore waters of the state and the associated floodplain and wetland areas impacted by the ash in compliance with TDEC 1200-4-3 and associated ARARs. Removal of the ash would remove the naturally occurring metals and radionuclides that could produce toxic effects on the health and safety of humans or animals. Water quality would be restored to meet AWQC in surface water within the embayment. Waters would therefore not contain residual pollutants from the ash that may impair the usefulness of the river water as a source of domestic or industrial water supply, recreation, or irrigation, or that may impair the health of fish or aquatic life. Details of the embayment restoration are described in Appendix D. Information satisfying the requirements of a Jurisdictional Assessment, including maps of the site prior to the spill and following the non-time-critical removal action, areas/species/habitat impacted, revegetation with selected species, habitat created, microtopography, and similar elements are provided in Appendix D.

Site preparation, construction, and excavation activities would be conducted in compliance with TDEC 1200-3-8 and TDEC 1200-4-10, including precautions to control fugitive dust emissions, erosion, and sedimentation. Dredged material removed from the embayment would not be placed into an aquatic ecosystem, in compliance with 40 CFR 230.10(a).

Excavated ash would be characterized, managed and disposed in compliance with 40 CFR 262.11 and TDEC 1200-1-11. Ash would be disposed in a permitted solid waste disposal facility in accordance with the applicable state regulations (TDEC 1200-1-7 in Tennessee) under the terms of the facility's permit (i.e., meeting its waste acceptance criteria). Transportation of hazardous materials would comply with all applicable provisions of the Hazardous Materials Transportation Act and DOT's Hazardous Material Regulations at 49 CFR 171-180.

Alternative 2 would be effective over the long-term. Removing the ash from the embayment and closure of Dredge Cell would be permanent actions that would effectively restore the waters of the state; eliminate direct contact, erosion, and migration of ash to the river; contain the remaining ash materials; and dispose of the excavated ash at an offsite permitted facility. Long-term effectiveness is further discussed in the following paragraphs.

Effectiveness of restoration. Because restoration would be the same as for Alternative 1; its effectiveness would also be the same. The restoration of a complex mosaic of forested, scrub-shrub, and emergent wetlands would be effective in reestablishing pre-spill topography, plant communities, and habitat for fish, semi-aquatic amphibians, and bird species, as described in Appendix D.

Effectiveness of cover containment. Because cover containment would be similar to Alternative 1; its effectiveness would also be similar. The 36-inch-thick cover would be effective in eliminating direct contact with ash on the ground by humans or animals, providing sufficient thickness against dust generation or burrowing. The 24-inch low-permeability clay layer would effectively reduce infiltration of precipitation through the ash; however, since ash would remain below the water table, the clay layer would not eliminate dissolution or migration of inorganics in groundwater. Existing groundwater monitoring data show negligible impact; only arsenic has been found at low levels (near its MCL).

Foundation settlement beneath the cover would be less than 3.1 inches, most of which would occur during the time that fill is being placed. As a result, surface grades averaging 1 to 3% across the top of the cover and associated drainage systems are expected to be reliable over the long term, with only minor maintenance to repair cover damage due to settlement. Much of the former Dredge Cell would be excavated (as opposed to being filled) under Alternative 2, which would further reduce expected settlement or buildup of porewater pressure.

Effectiveness of dike containment. The perimeter dike containment system would be effective and stable over the long term. Alternative 2 would minimize long-term reliance on a dike containment system by lowering the height of ash in the Dredge Cell and flattening the surface grades. There would be no dike containment required along the former Dike C corridor, or along the Ball Field or Swan Pond Road corridors. Dike stability under static loading conditions was analyzed using SLOPE/W, resulting in safety factors greater than 1.5, which are indicative of stable conditions (Appendix E). The conceptual dike configuration and foundation design address the four contributing factors cited by AECOM in their root cause analysis of the former dike failure (AECOM 2009):

1. Fill Geometry. The Alternative 2 conceptual fill geometry would eliminate dike containment for all but the existing Dike D corridor. Dike D would be further reinforced with soil-cement columns installed using deep soil mixing methods at a 25% replacement ratio. Maximum height of Dike D would be elevation 780 ft msl, which is 40 ft lower than the top of the former Dredge Cell dike. The top of ash along the other 3 sides of the Dredge Cell would be constructed even with the surrounding ground surface; namely, approximately elevation 765 ft msl along the Ball Field and Swan Pond Road corridors, and elevation 735 ft msl (bottom of embayment) along the former Dike C corridor. The conceptual fill geometry would therefore be stable.

2. Fill Rates. Much of the Dredge Cell in Alternative 2 would be excavated, rather than filled. The conceptual fill rate and methodology would therefore be safe.

3. Soft Foundation Soils. In Alternative 2, the conceptual Dike D would be reinforced with soil-cement columns that would not rely on the strength of the soft foundation soil layer for stability, but would instead transfer the load substantially to the underlying bedrock through the soil-cement columns. The conceptual foundation support would therefore be stable.

4. Loose Wet Ash. Because much of the Dredge Cell in Alternative 2 would be excavated, rather than filled with wet ash. The conceptual grading plan would involve some minor regrading of ash within the Dredge Cell; such fill would be constructed using dewatered ash, compacted in thin lifts. The compacted dry ash would be much stronger than the loose wet ash in the former Dredge Cell.

The conceptual foundation design includes a treatment zone consisting of soil/cement columns arranged in a grid pattern 35-ft wide beneath Dike D and up to 25-ft wide around the Ash Pond for liquefaction mitigation. Resulting safety factors greater than 1.1 were calculated, which is suitable under short-term seismic loading conditions. Therefore, the perimeter dike containment system would be stable under

earthquake loads. There is uncertainty under Alternative 2 as to whether the perimeter gentle slopes, particularly along Dike C, would be stable under short-term seismic loading conditions without foundation treatment. Additional foundation treatment could be implemented as a contingency measure; however, costs of such contingency measures would be correspondingly higher.

Effectiveness of disposal. Alternative 2 would transport approximately 2.4 million cy of recovered ash, 0.3 million cy of ash from the test embankment, plus 4.0 million cy of ash currently within the Dredge Cell, and 0.1 million cy of material from Dike 2 and the settling basins offsite for disposal. Less than 6.8 million cy of ash would remain within the former Dredge Cell. The volume of ash onsite would be reduced and covered to limit migration.

The offsite disposal facility would be an existing, permitted solid waste landfill. The landfill would operate under the restrictions of its specific permit, including waste acceptance criteria, groundwater protection systems, leachate collection and treatment systems, interim and final cover, and other terms of the operating permit. EPA and TDEC must approve the specific landfill prior to shipment of any ash. Offsite disposal would therefore be effective in reducing onsite volumes and managing the ash in a permitted manner.

Effectiveness over the short term. Alternative 2 would be effective over the short term, during the estimated 4.0 years of construction; RAOs would be achieved once construction is complete. Short-term impacts could occur during the excavation, processing, and transportation of the 6.5 million cy of ash from the embayment and Dredge Cell. Engineering measures would be implemented to protect remediation workers and the community, as discussed in Alternative 1, including the following: (1) dust control measures, (2) OSHA health and safety measures, (3) transportation control measures, and (4) erosion and sediment control measures.

Inherent short-term risks would be associated with shipment of the 6.5 million cy of ash over public roadways or railways. Short-term risks of railroad incidents or rail-vehicle intersection accidents would be proportionate to the number of trip-miles. The Perry County Associates, Arrowood Landfill, is located in Perry County, Alabama, approximately 330 miles from the site, and is accessible by rail hauling over Norfolk Southern railways. Assuming a combination of 85- and 110-car trains averaging 7,500 cy capacity, hauling ash to the Arrowood Landfill would involve nearly 290,000 trip-miles over Norfolk Southern railways. For truck hauling under Alternative 2b, short-term risks of traffic accidents would be proportionate to the number of truck trip-miles. Similar to Alternative 1b, hauling 760,000 cy of material to the Chestnut Ridge Landfill would involve nearly 7,600 trip-miles over public roadways. Hauling the remaining 5.74 million cy of material by rail would involve 253,000 trip-miles over the railway.

Estimates of the potential number of accidents, injuries, and/or fatalities were made based on rate information for rail transport (ANL 2009) and for truck transport (DOT 2009). National statistics were used for comparability between the data sources. Rates for accidents, injuries and fatalities were multiplied by the number of rail-car miles and truck-miles, respectively. Due to reporting differences, the number of accidents does not necessarily correlate to the number of injuries or fatalities, since not all accidents result in an injury or fatality, nor are all injuries or fatalities a result of vehicle collisions.

For Alternative 2a, these calculations resulted in an estimate of 3 rail accidents, 2 rail injuries, and 0.9 rail fatalities. For Alternative 2b, these calculations resulted in an estimate of 2 rail accidents, 2 rail injuries, and 0.9 rail fatalities. In addition for Alternative 2b, these calculations resulted in an estimate of 2 truck accidents, 0.8 truck injuries, and 0.04 truck fatalities.

4.1.2.2 Implementability

Alternative 2 would be implementable within 4.1 years following design of the removal action. Closure of the Ash Pond would occur at a later date and would require another 10 months to complete. Conventional materials, equipment, or services would be available for excavation/dredging, ash hauling, and grading/closure of the Dredge Cell. Similar construction equipment has been used in implementing portions of the ongoing time-critical removal action, demonstrating that the removal action would be implementable and providing valuable lessons learned for design of the non-time-critical removal action. However, significant challenges would be anticipated in implementing the alternative.

Difficulties in excavation of ash from the embayment, dewatering of the fine-grained ash, and processing of hydraulically-dredged ash would be similar to those described for Alternative 1; difficulties would be compounded due to the larger quantities of ash that would be handled under Alternative 2. Transportation of the ash would also be complicated by the much larger volume of material and limited disposal options.

Under Alternative 2a, transport by rail alone would require nearly 880 trainloads averaging 7,500 cy per train and hauling daily for 43 months. Rail car loading facilities are available on the Ball Field area of KIF, as they have been installed as part of the time-critical removal action. Under Alternative 2b, transport by truck would require 35,000 truckloads hauling an average of 10 hours/day for 14 months. Transport of the remaining material by rail would require nearly 770 trains for 39 months. Regulatory and/or public opposition to use of a particular disposal facility would complicate implementability of these disposal options. Public opposition may be further aggravated due to the long duration of offsite shipments, especially rail shipments. There is considerable uncertainty in implementing Alternative 2 as to whether sufficient capacity is available at the disposal facilities to handle the 6.5 million cy of material generated during the non-time-critical removal action under Alternative 2, which would be in addition to the disposal of nearly 3.0 million cy of material being generated during the ongoing time-critical removal action.

As with Alternative 1, specialty contractors would be required for implementation of the foundation treatment for the dikes, although fewer columns would be required. To treat nearly 12,800 lin ft of perimeter dike foundation beneath Dike D and around the Ash Pond, over an affected area of 306,000 ft^2 and a 25% area replacement ratio, approximately 6,120 individual deep auger holes of nominal 8-ft diameter would have to be drilled, producing about 154,500 cy of soil/cement.

Regrading of the Dredge Cell to provide final contour grades and erosion control measures would be similar to Alternative 1, since the Dredge Cell footprint would be basically the same size. Because fill heights in Alternative 2 would be much lower, monitoring and surveillance would require a much smaller network of piezometers, settlement plates, and inclinometers.

Closure of the Ash Pond would occur at a later date, avoiding complications in phasing of construction with ongoing KIF plant discharges or dredge dewatering operations in the Ash Pond.

Restoring of the embayment would require specialty subcontractors experienced in wetland restoration. Implementability of the restoration and long-term O&M activities would be similar to that described for Alternative 1.

4.1.2.3 Cost

Capital costs associated with implementing Alternative 2a are estimated at $741.1 million and Alternative 2b at $719.3 million (2009 dollars). The cost of hauling by truck is less costly than by rail, and unlike

Alternative 1, the unit costs of disposal in Alabama are the same for Alternative 2b as for Alternative 2a. Ongoing O&M costs are estimated at $686,000/year (2009 dollars).

4.1.3 Alternative 3: Excavate Embayment and Dispose Onsite; Close the Dredge Cell

4.1.3.1 Effectiveness

Alternative 3 would fully meet RAOs. The ash within the embayment would be removed to the maximum extent practicable, so as to restore the natural resources and area waters. The Dredge Cell would be closed. As a result, the terms of both the TDEC Commissioner's Order and the EPA Administrative Order would be met.

Overall protectiveness. Alternative 3 would be protective of both human health and the environment. Removal of the ash from the embayment would substantially eliminate both direct contact with water flowing through the area and future migration of ash into the river due to erosion. Closure of the former Dredge Cell, which would include a soil and vegetative cover over the ash, would also eliminate future migration of ash due to erosion and eliminate direct contact with ash on the ground by either human or ecological receptors. Existing TVA access controls would prevent future use of the closed Dredge Cell area for unauthorized purposes.

Compliance with ARARs. Alternative 3 would comply with all ARARs, as listed in Appendix C. Closure of the Dredge Cell would be in accordance with Tennessee Solid Waste Rule 1200-1-7, thereby complying with terms of the TDEC Commissioner's Order. The final cover system must be at least 36 inches thick, consisting of a compacted soil layer at least 24 inches thick which has a permeability no greater than 1×10^{-7} cm/sec, and a second soil layer at least 1-ft thick for the support of vegetative cover. An alternate final cover system may be used provided that it provides equivalent or superior performance in minimizing infiltration. The final surface must be graded and/or have drainage facilities that minimize erosion of cover material, optimize drainage, and are consistent with drainage in the surrounding area.

Restoration of the embayment would restore waters of the state and the associated floodplain and wetland areas impacted by the ash in compliance with TDEC 1200-4-3 and associated ARARs. Removal of the ash would remove the naturally occurring metals and radionuclides that could produce toxic effects on the health and safety of humans or animals. Water quality would be restored to meet AWQC in surface water within the embayment. Waters would therefore not contain residual pollutants from the ash that may impair the usefulness of the river water as a source of domestic or industrial water supply, recreation, or irrigation, or that may impair the health of fish or aquatic life. Details of the embayment restoration are described in Appendix D. Information satisfying the requirements of a Jurisdictional Assessment, including maps of the site prior to the spill and following the non-time-critical removal action, areas/species/habitat impacted, revegetation with selected species, habitat created, microtopography, and similar elements are provided in Appendix D.

Site preparation, construction, and excavation activities would be conducted in compliance with TDEC 1200-3-8 and TDEC 1200-4-10, including precautions to control fugitive dust emissions, erosion, and sedimentation. Dredged material removed from the embayment would not be placed into an aquatic ecosystem, in compliance with 40 CFR 230.10(a).

Excavated ash would be characterized, managed and disposed in compliance with 40 CFR 262.11 and TDEC 1200-1-11. Because ash would be disposed onsite, rules pertaining to offsite disposal or transportation of hazardous materials would not be applicable.

Alternative 3 would be effective over the long term. Removing the ash from the embayment and closure of Dredge Cell would be permanent actions that would effectively restore the waters of the state; eliminate direct contact, erosion, and migration of ash to the river; contain the remaining ash materials; and dispose of the excavated ash at an offsite permitted facility. Long-term effectiveness is further discussed in the following paragraphs.

Effectiveness of restoration. Because restoration would be the same as for Alternative 1; its effectiveness would also be the same. The restoration of a complex mosaic of forested, scrub-shrub, and emergent wetlands would be effective in reestablishing pre-spill topography, plant communities, and habitat for fish, semi-aquatic amphibians, and bird species, as described in Appendix D.

Effectiveness of cover containment. Because cover containment would be similar to Alternative 1; its effectiveness would also be similar. The 36-inch-thick cover would be effective in eliminating direct contact with ash on the ground by humans or animals, providing sufficient thickness against dust generation or burrowing. The 24-inch low-permeability clay layer would effectively reduce infiltration of precipitation through the ash; however, since ash would remain below the water table, the clay layer would not eliminate dissolution or migration of inorganics in groundwater. Existing groundwater data show negligible impact; only arsenic has been found at low levels (near its MCL).

Foundation settlement beneath the cover would be less than 8.3 inches under Alternative 3a, most of which would occur during the time that fill is being placed. Because final grades would be lower under Alternative 3b, foundation settlement would also be lower, estimated at less than 5.0 inches. As a result, surface grades averaging 2% across the top of the cover and associated drainage systems are expected to be reliable over the long term, with only minor maintenance to repair cover damage due to settlement. Because final grades would be as much as 15 ft higher under Alternative 3a than other alternatives, potential settlement and buildup of excess porewater pressure would require closer monitoring to verify its effectiveness. The test embankment results further suggest that ash fill placement within the cell is not expected to result in excess porewater pressure buildup beneath the ash, which could otherwise affect fill stability. Maximum loading rates of 5 ft per month not produce excessive pressure nor excessive lateral movements beneath the test fill that could otherwise impact the effectiveness of the cover.

Effectiveness of dike containment. The perimeter dike containment system would be robust, and therefore effective and stable over the long term. Alternative 3 would rely heavily on a perimeter dike containment system having steeper slopes and higher top of dike elevations, therefore a wider treatment zone would need to be constructed, and treatment would be required around the full perimeter length of the Dredge Cell. Dike stability under static loading conditions was analyzed using SLOPE/W, resulting in safety factors greater than 1.5, which are indicative of stable conditions (Appendix E). The conceptual dike configuration and foundation design address the four contributing factors cited by AECOM in their root cause analysis of the former dike failure (AECOM 2009):

1. Fill Geometry. The Alternative 3 conceptual dike would be constructed using a single compacted soil dike placed on a crushed rock working platform and 20 ft of ash over silt/clay and sand layers. The ash, silt/clay, and sand layers would be further reinforced with soil-cement columns installed using deep soil mixing methods at a 25% replacement ratio. Maximum height of the dikes would be elevation 787 ft msl along the perimeter of the Dredge Cell, which is 30 to 35 ft lower that the top of the former dikes. The conceptual fill geometry would therefore be stable.

2. Fill Rates. The conceptual fill in Alternative 3 would be constructed using dewatered ash, compacted in thin lifts. Results of the test embankment have shown that such construction methods would not result in excess porewater pressures in the foundation ash materials under a

rate of filling equivalent to 5 ft/month. The conceptual fill rate and methodology would therefore be safe.

3. Soft Foundation Soils. In Alternative 3, the conceptual dike foundation would be reinforced with soil-cement columns that would not rely on the strength of the soft foundation soil layer for stability, but would instead transfer the load substantially to the underlying bedrock through the soil-cement columns. The conceptual foundation support would therefore be stable.

4. Loose Wet Ash. The conceptual fill would be constructed using dewatered ash, compacted in thin lifts. Results of the test embankment study have shown that the undrained shear strength of the compacted dry ash is greater than 500 psf, which is much greater than loose wet ash. The conceptual compacted dry ash would therefore be much stronger than the loose wet ash in the former Dredge Cell.

Dike stability was further analyzed for Alternative 3 under earthquake loading conditions using SLOPE/W simulation software and the Spencer method to compute the factor of safety (Appendix E). The conceptual foundation design includes a treatment zone consisting of soil/cement columns arranged in a grid pattern up to 130-ft wide for optimum liquefaction mitigation. Resulting safety factors greater than 1.1 were calculated, which is suitable under short-term seismic loading conditions. Therefore, the perimeter dike containment system would be stable under earthquake loads.

Effectiveness of disposal. Alternative 3 would not transport any ash generated during the non-time-critical removal action offsite for disposal. Once the 2.4 million cy of ash recovered from the embayment and 130,000 cy of material from Dike 2 and the settling basins has been placed within the Dredge Cell, approximately 13.4 million cy of ash would remain within the Dredge Cell beneath the clay cover. The ash would be covered to limit migration. Long-term post-closure management of the ash would be conducted by TVA, rather than an offsite commercial disposal facility.

Effectiveness over the short term. Alternative 3 would be effective over the short term, during the estimated 3.8 years of construction; RAOs would be achieved once construction is complete. Minor short-term impacts could occur during the excavation, processing, and hauling of the 2.4 million cy of ash from the embayment to the Dredge Cell. Engineering measures would be implemented to protect remediation workers and the community, as discussed in Alternative 1, including the following: (1) dust control measures, (2) OSHA health and safety measures, and (3) erosion and sediment control measures. Transportation impacts to the community would be greatly diminished, since Alternative 3 would not include shipment of any ash offsite.

4.1.3.2 Implementability

Alternative 3a would be implementable within 3.8 years following design of the removal action. Closure of the Ash Pond would occur at a later date and would require another 10 months to complete. Alternative 3b would close the Ash Pond at the same time as the Dredge Cell and would be implementable within a total of 4.1 years following design of the removal action. Conventional materials, equipment, or services would be available for excavation/dredging, ash hauling, and grading/closure of the Dredge Cell. Similar construction equipment has been used in implementing portions of the ongoing time-critical removal action, demonstrating that the removal action would be implementable and providing valuable lessons learned for design of the non-time-critical removal action. However, significant challenges would be anticipated in implementing the alternative.

Difficulties in excavation of ash from the embayment, dewatering of the fine-grained ash, and processing of hydraulically-dredged ash would be similar to those described for Alternative 1. Experienced gained

during construction of the test embankment during the time-critical removal action has shown that dewatering and compaction of the recovered ash is difficult to implement and may impact production rates. With refinement of the drying process, availability of resources (trucks, excavators), larger active landfill face for compaction, and beneficial weather conditions (particularly in the warmer, dryer months), higher production rates of over 5,000 cy/day for dry stacking of ash may be achievable. This would shorten the time needed to implement this alternative. Implementation could be readily accomplished with minimal impact to the public, since there would be no offsite transportation of the ash, which would limit regulatory and/or public opposition to use of a particular offsite disposal facility.

As with Alternative 1, specialty contractors would be required for implementation of the foundation treatment for the dikes. Under Alternative 3a, much greater numbers of soil/cement columns would be required. To treat nearly 22,600 lin ft of perimeter dike foundation, over an affected area of 1,241,000 ft^2 and a 25% area replacement ratio, nearly 25,000 individual deep auger holes of a nominal 8-ft diameter would have to be drilled, producing about 654,000 cy of soil/cement. There is uncertainty in implementing Alternative 3a as to whether sufficient capacity is available among the experienced specialty contractors to handle this large production volume.

Under Alternative 3b, the treatment zone would be similar to Alternative 1. To treat nearly 16,600 lin ft of perimeter dike foundation, over an area of 581,000 ft^2 and a 25% area replacement ratio, nearly 12,000 individual deep auger holes of a nominal 8-ft diameter would have to be drilled, producing about 259,500 cy of soil/cement.

Regrading of the Dredge Cell to provide final contour grades and erosion control measures would be similar to Alternative 1, since the Dredge Cell footprint would be basically the same size. Because fill heights in Alternative 3a would be higher, monitoring and surveillance would require a much larger network of piezometers, settlement plates, and inclinometers. A working platform would be constructed across the entire Dredge Cell to provide a firm foundation for stacking of ash.

Under Alternative 3a, closure of the Ash Pond would occur at a later date, avoiding complications in phasing of construction with ongoing KIF plant discharges or dredge dewatering operations in the Ash Pond. Under Alternative 3b, closure of the Ash Pond would occur in phases during the same time as closure of the Dredge Cell; pond closure would be carefully coordinated with the dry fly ash conversion project schedule and dredged ash dewatering operations.

Restoring of the embayment would require specialty subcontractors experienced in wetland restoration. Implementability of the restoration and long-term O&M activities would be similar to that described for Alternative 1.

4.1.3.3 Cost

Capital costs associated with implementing Alternative 3a are estimated at $315.5 million and Alternative 3b at $268.2 million (2009 dollars). Closing the Ash Pond at the same time as the Dredge Cell would result in an estimated cost savings due to reducing the foundation treatment needed for perimeter dike containment, eliminating importing fill material to close the Ash Pond, and schedule efficiencies in integrating Ash Pond closure together with Dredge Cell closure.

4.2 COMPARATIVE ANALYSIS OF ALTERNATIVES

This section evaluates the relative performance of each alternative in relation to each of the criteria presented in Section 4.1. The purpose of this comparative analysis is to highlight the advantages and disadvantages of each alternative relative to one another so that key tradeoffs that would affect the

remedy selection can be identified. Table 4-1 summarizes the comparative analysis of alternatives for each of the evaluation factors.

4.2.1 Effectiveness

Each of the three alternatives would fully meet RAOs. The ash within the embayment would be removed to the maximum extent practicable, so as to restore the natural resources and area waters. The Dredge Cell would be closed. As a result, the terms of both the TDEC Commissioner's Order and the EPA Administrative Order would be met.

Overall Protectiveness. Each of the alternatives would be protective of both human health and the environment. Removal of the ash from the embayment would substantially eliminate both direct contact with water flowing through the area and future migration of ash into the river due to erosion. Closure of the former Dredge Cell, which would include a soil and vegetative cover over the ash, would also eliminate future migration of ash due to erosion and eliminate direct contact with ash on the ground by either human or ecological receptors. Existing TVA access controls would prevent future use of the closed Dredge Cell area for unauthorized purposes.

Compliance with ARARs. Each of the alternatives would comply with all ARARs, as listed in Appendix C. Closure of the Dredge Cell would be in accordance with Tennessee Solid Waste Rule 1200-1-7, thereby complying with terms of the TDEC Commissioner's Order. The final cover system must be at least 36 inches thick, consisting of a compacted soil layer at least 24 inches thick which has a permeability no greater than 1×10^{-7} cm/sec, and a second soil layer at least 1-ft thick for the support of vegetative cover. An alternate final cover system may be used provided that it provides equivalent or superior performance in minimizing infiltration. The final surface must be graded and/or have drainage facilities that minimize erosion of cover material, optimize drainage, and are consistent with drainage in the surrounding area.

Restoration of the embayment would restore waters of the state and the associated floodplain and wetland areas impacted by the ash in compliance with TDEC 1200-4-3 and associated ARARs. Removal of the ash would remove the naturally-occurring metals and radionuclides that could produce toxic effects on the health and safety of humans or animals. Water quality would be restored to meet AWQC in surface water within the embayment. Waters would therefore not contain residual pollutants from the ash that may impair the usefulness of the river water as a source of domestic or industrial water supply, recreation, or irrigation, or that may impair the health of fish or aquatic life. Details of the embayment restoration are described in Appendix D. Information satisfying the requirements of a Jurisdictional Assessment, including maps of the site prior to the spill and following the non-time-critical removal action, areas/species/habitat impacted, revegetation with selected species, habitat created, microtopography, and similar elements are provided in Appendix D.

Site preparation, construction, and excavation activities would be conducted in compliance with TDEC 1200-3-8 and TDEC 1200-4-10, including precautions to control fugitive dust emissions, erosion, and sedimentation. Dredged material removed from the embayment would not be placed into an aquatic ecosystem, in compliance with 40 CFR 230.10(a).

Excavated ash would be characterized, managed and disposed in compliance with 40 CFR 262.11 and TDEC 1200-1-11. Ash would be disposed in a permitted solid waste disposal facility in accordance with the applicable state regulations (TDEC 1200-1-7 in Tennessee) under the terms of the facility's permit (i.e., meeting its waste acceptance criteria). Transportation of hazardous materials would comply with all applicable provisions of the Hazardous Materials Transportation Act and DOT's Hazardous Material Regulations at 49 CFR 171-180.

Table 4-1. Summary of Comparative Analysis of Alternatives

	Alternative 1	Alternative 2	Alternative 3
Effectiveness			
Overall Protectiveness	Protective; ash removed from embayment; former Dredge Cell closed.	Protective; ash removed from embayment; former Dredge Cell closed.	Protective; ash removed from embayment; former Dredge Cell closed.
Compliance with ARARs	Complies with ARARs for landfill closure; restoration of waters of state, floodplains and wetlands; dust emissions & erosion control; and waste handling, transportation and disposal.	Complies with ARARs for landfill closure; restoration of waters of state, floodplains and wetlands; dust emissions & erosion control; and waste handling, transportation and disposal.	Complies with ARARs for landfill closure; restoration of waters of state, floodplains and wetlands; dust emissions & erosion control; and waste handling.
Effectiveness of Restoration	Effective in reestablishing pre-spill topography, plant communities, and habitat.	Effective in reestablishing pre-spill topography, plant communities, and habitat.	Effective in reestablishing pre-spill topography, plant communities, and habitat.
Effectiveness of Cover Containment	Effective in eliminating direct contact, controlling erosion, and reducing infiltration. Total fill height up to 790 ft msl. Cover settlement < 5.0 in. during fill placement. Effective in avoiding excess porepressures or lateral movements.	Effective in eliminating direct contact, controlling erosion, and reducing infiltration. Total fill height up to 780 ft msl, although most below 765 ft msl. Cover settlement < 3.1 in. during fill placement. Effective in avoiding excess porepressures or lateral movements.	Effective in eliminating direct contact, controlling erosion, and reducing infiltration. Total fill height up to 805 ft msl (Alt 3a) or 790 ft msl (Alt 3b). Cover settlement < 8.3 in. (Alt 3a) or <5.0 in. (Alt 3b) during fill placement. Effective in avoiding excess porepressures or lateral movements. Effective in reinforcing the fill using a working platform.
Effectiveness of Dike Containment	Stable under static loading (SF>1.5) and earthquake loading (SF>1.1). Effective in addressing root cause conditions by lowering dike height to ~765 ft msl, placing dewatered ash in thin lifts, & reinforcing the foundation. Effective in mitigating liquefaction by use of soil/cement columns in grid pattern up to 130-ft wide (Dike C); 35-ft wide elsewhere.	Stable under static loading (SF>1.5) and earthquake loading (SF>1.1). Effective in addressing root cause conditions by minimizing reliance on perimeter dikes, placing dewatered ash in thin lifts, & reinforcing the Dike D foundation. Mitigates liquefaction by use of soil/cement columns in grid pattern up to 35-ft wide along Dike D only; uncertain liquefaction potential of gradual slopes (<5% grade).	Stable under static loading (SF>1.5) and earthquake loading (SF>1.1). Effective in addressing root cause conditions by lowering dike height to ~787 ft msl (Alt. 3a) or ~765 ft msl (Alt. 3b), placing dewatered ash in thin lifts, & reinforcing the foundation. Effective in mitigating liquefaction by use of soil/cement columns in grid pattern up to 130-ft wide (Dike C); 100-ft wide elsewhere.
Effectiveness of Disposal	Effective in disposing ~2.8M cy of recovered ash offsite at approved, permitted landfills. Leaves ~10.8 M cy residual ash onsite in closed Dredge Cell; 4.0M cy in closed Ash Pond	Effective in disposing ~6.8M cy of recovered ash plus ash in Dredge Cell offsite at approved, permitted landfills. Leaves ~6.8 M cy residual ash onsite in closed Dredge Cell; 4.0M cy in closed Ash Pond	Effectively eliminates offsite disposal. Effective in disposing all material onsite. Leaves ~13.4M cy residual ash onsite in closed Dredge Cell; 4.0M cy in closed Ash Pond
Short-term Effectiveness	Effective in controlling short-term construction impacts (dust control, health & safety, erosion & sedimentation). Transportation impacts as a result of 125,000 trip-miles by rail (Alt 1a) or combined 1.7M trip-miles truck plus 90,000 trip-miles rail (Alt 1b).	Effective in controlling short-term construction impacts (dust control, health & safety, erosion & sedimentation). Transportation impacts as a result of 300,000 trip-miles by rail (Alt 2a) or combined 1.7Mtrip-miles truck plus 270,000 trip-miles rail (Alt 2b).	Effective in controlling short-term construction impacts (dust control, health & safety, erosion & sedimentation). Effective in eliminating transportation impacts due to offsite shipments.

Table 4-1. Summary of Comparative Analysis of Alternatives (continued)

	Alternative 1	Alternative 2	Alternative 3
Implementability			
Time to Achieve RAOs	Implementable within 2.8 years plus 10 months to close the Ash Pond.	Implementable within 4.1 years plus 10 months to close the Ash Pond.	Implementable within 4.0 years (Alt 3a) plus 10 months to close the Ash Pond. Alt 3b implementable within 4.1 years.
Implementability of Excavation & Dewatering	Complicated by high water levels in embayment, fine-grained properties of ash. Moisture content <30% needed both for shipment (2.8M cy) and for compaction onsite (1.6M cy). Ash dewatering difficult in wet weather; requires wet ash processing areas.	Complicated by high water levels in embayment, fine-grained properties of ash. Moisture content <30% needed for shipment (6.8M cy); minimal compaction onsite. Ash dewatering difficult in wet weather; requires wet ash processing areas.	Complicated by high water levels in embayment, fine-grained properties of ash. Moisture content <30% needed for compaction onsite (3.4M cy). Ash dewatering difficult in wet weather; requires wet ash processing areas.
Implementability of Transportation	Complicated by large volume of material (~2.8M cy) and limited disposal options. Rail transport requires 380 trains hauling for 19 months (1a); or combined 35,000 trucks plus 280 trains hauling for up to 14 months (1b).	Complicated by very large volume of material (~6.8M cy) and limited disposal options. Rail transport requires 910 trains hauling for 45 months (2a); or combined 35,000 trucks & 810 trains hauling for up to 39 months (2b).	Avoids transportation impacts since no waste hauling offsite.
Implementability of Disposal	Complicated by regulatory and/or public opposition. Uncertain capacity to accept 2.8 M cy.	Complicated by regulatory and/or public opposition. Highly uncertain capacity willing to accept 6.8M cy.	Avoids disposal impacts.
Implementability of Foundation Treatment	Requires specialty contractor to treat 17,200 lin ft of dike; 650,000 ft^2 of grid area; 298,000 cy of soil/cement.	Requires specialty contractor to treat 12,800 lin ft of dike; 306,000 ft^2 grid; 154,500 cy of soil/cement.	Alt 3a requires specialty contractors to treat 22,600 lin ft of dike; 1,241,000 ft^2 of grid area; 654,000 cy of soil/cement. Uncertain capacity of contractors with this expertise. Alt 3b to treat 16,600 lin ft of dike; 581,000 ft^2 of grid area; 259,500 cy of soil/cement.
Implementability of Regrading	Regrading of moderate volume (~1.8M cy) complicated by difficult moisture control during compaction and high erodibility of ash. Moderate level of instrumentation needed for dike monitoring and quality control.	Minimal regrading; less affected by moisture control and erodibility. Smaller level of instrumentation needed for dike monitoring and quality control.	Larger volume due to embayment excavation (2.5Mcy) plus regrading (~1.1 to 1.3M cy) complicated by difficult moisture control during compaction and high erodibility of ash. Higher level of instrumentation needed for dike monitoring and quality control.
Implementability of Restoration	Requires specialty contractor to replant ~28 Ac of mixed forested, scrub-shrub, and emergent wetlands. Requires several years to establish self-sustaining habitat.	Requires specialty contractor to replant ~28 Ac of mixed forested, scrub-shrub, and emergent wetlands. Requires several years to establish self-sustaining habitat.	Requires specialty contractor to replant ~28 Ac of mixed forested, scrub-shrub, and emergent wetlands. Requires several years to establish self-sustaining habitat.
Cost			
Capital Cost	$455.3(1a) - $439.6 (1b)	$741.1M (2a) to $719.3M (2b)	$315.5M (3a) to $268.2M (3b)
O&M Cost	$686,000/yr	$686,000/yr	$686,000/yr

Each of the alternatives would be effective over the long term, although in differing ways. Removing the ash from the embayment and closure of Dredge Cell would be permanent actions that would effectively restore the waters of the state; eliminate direct contact, erosion, and migration of ash to the river; contain the remaining ash materials; and dispose of the excavated ash at an offsite permitted facility. Long-term effectiveness is further discussed in the following paragraphs.

Effectiveness of restoration. Each of the alternatives would restore the embayment to pre-spill conditions. The restoration of a complex matrix of forested, scrub-shrub, and emergent wetlands would be effective in reestablishing pre-spill topography, plant communities, and habitat for fish, semi-aquatic amphibians, and bird species, as described in Appendix D. The adequacy and reliability of the restoration would be similar under all three alternatives.

Effectiveness of cover containment. Each of the alternatives would close the Dredge Cell using a 36-inch cover to effectively eliminate direct contact with ash on the ground by humans or animals, and provide sufficient thickness against dust generation or burrowing. The relatively flat surface grades (<5%) and vegetative cover would be effective in eliminating erosion and/or migration of ash to adjacent surface water. The 24-inch low-permeability clay layer would effectively reduce infiltration of precipitation through the ash from 14.9 inches/year to less than 1.4 inches/year. However, since ash would remain below the water table, the clay layer would not eliminate dissolution or migration of inorganics in groundwater. Existing groundwater data show negligible impact; only arsenic has been found at low levels (near its MCL). The effectiveness of the groundwater protection system, including contaminant flux to the Emory River and Watts Bar reservoir will be evaluated as part of the river system EE/CA.

Foundation settlement beneath the cover would depend on total fill height. Alternative 3a would have the largest fill height (up to 805 ft msl) and corresponding cover settlement less than 8.3 inches. Alternatives 1 and 3b would have a total fill height up to 790 ft msl; cover settlement would be less than 5.0 inches, most of which would occur during the time that fill is being placed. Alternative 2 would have a total fill height up to 780 ft msl, although most of the covered area would be below 765 ft msl; cover settlement would be less than 3.1 inches. Surface grades averaging between 1 and 5% across the top of the cover and associated drainage systems are expected to be reliable over the long term under each of the alternatives, with only minor maintenance to repair cover damage due to settlement. Ash fill placement under each alternative is not expected to result in excess porewater pressure buildup beneath the ash, particularly Alternative 2 where much of the former Dredge Cell would be excavated (as opposed to being filled).

Effectiveness of dike containment. Each of the alternatives would implement differing levels of foundation treatment so that the perimeter dike containment system would be effective and stable over the long-term. Analysis of dike stability under static loading conditions resulted in safety factors greater than 1.5, which are indicative of stable conditions for each alternative (Appendix E). The conceptual dike configuration and foundation design for each of the alternatives address the four contributing factors cited by AECOM in their root cause analysis of the former dike failure (AECOM 2009):

1. Fill Geometry. The former failed dike was constructed using small dikes stacked progressively up slope on top of nearly 80 feet of sluiced ash and a sensitive silt ("slimes") layer. Total height of the dikes that surrounded the former Dredge Cell prior to its failure was elevation 820 ft msl. Under Alternatives 1 and 3, Dike C would be constructed using a single compacted soil dike placed on a crushed rock working platform. The perimeter dikes would be highest under Alternative 3 and least under Alternative 2. Under Alternative 3a, the perimeter dikes would be constructed to a height of 787 ft msl. Under Alternatives 1 and 3b, the dikes would be built to a height of 765 ft msl. Under Alternative 2, the top of ash around 3 sides of the Dredge Cell would be constructed even with the surrounding ground surface (735 ft msl along Dike C and 765 ft msl

along the Ball Field and Swan Pond Road), and to a height of 780 ft msl at Dike D. Each of these dike configurations is much lower than the former Dredge Cell prior to its failure. The conceptual fill geometry would therefore be stable under each alternative.

2. Fill Rates. The elevation of the ash in the former Dredge Cell prior to failure was increasing at a rate of about 6 ft/yr, more rapidly compared to earlier years, which added load to the wet ash beneath the dikes. In particular, the Dredge Cell filling resulted in loose, wet ash saturated throughout its depth, which led to high porewater pressures at depth and low strength in the sluiced ash materials. Under each of the three alternatives, the conceptual cell fill would be constructed by dry-stacking using dewatered ash, compacted in thin lifts. Results of the test embankment have shown that such construction methods would not result in excess porewater pressures in the foundation ash materials under a rate of filling equivalent to 5 ft/month. The conceptual fill rate and methodology would therefore be safe under each alternative.

3. Soft Foundation Soils. Creep deformations within the submerged loose slimes was occurring under the load of loose wet ash in the former Dredge Cell, which caused a reduction in the strength of the slimes and led to deep-seated failure of the dike. Under each of the three alternatives, the conceptual dike would be reinforced with soil-cement columns that would not rely on the strength of the soft foundation soil layer for stability, but would instead transfer the load substantially to the underlying bedrock through the soil-cement columns. The conceptual foundation support would therefore be stable under each alternative.

4. Loose Wet Ash. The original sluiced ash was deposited under water, resulting in a high void ratio (very loose ash) that did not consolidate or densify under the surcharge weight of ash placed above it. As a result, the loose wet ash had a low undrained shear strength (as low as 100 psf) with a very sensitive structure. Under each of the three alternatives, the conceptual dike would be constructed using dewatered ash, compacted in thin lifts. Results of the test embankment study have shown that the undrained shear strength of the compacted dry ash is greater than 500 psf. The compacted dry ash would therefore be much stronger under each alternative than the loose wet ash in the former Dredge Cell.

Analysis of dike stability under earthquake loading conditions indicates that the ash and native silt/sand layers may liquefy under design earthquake loads. For this reason, the conceptual foundation design under each alternative includes a treatment zone consisting of soil/cement columns arranged in a grid pattern for optimum liquefaction mitigation. Alternative 3a provides the most robust foundation treatment, because its perimeter dikes are much higher. Under Alternative 3a, the treatment zone would be 130-ft wide along Dike C and 100-ft wide along the other three sides of the Dredge Cell. Under Alternatives 1 and 3b, where dikes are lower, this treatment zone would be 130-ft wide for Dike C and 35-ft wide for the other three sides. Under Alternative 2, no dikes would be built around three sides of the landfill; a 35-ft-wide treatment zone would be built for the existing Dike D. Under Alternatives 1, 2, and 3a, the Ash Pond would be closed at a later date. Foundation treatment around the Ash Pond would be built at that time and would consist of treatment zones up to 50-ft wide. Under Alternative 3b, the Dredge Cell and Ash Pond would be closed at the same time and would consist of foundation treatment zones up to 130-ft wide along Dike C and 25- to 30-ft wide treatment zones along the other three sides.

Resulting safety factors greater than 1.1 were calculated, which is suitable under short-term seismic loading conditions. Therefore, the perimeter dike containment system would be stable under earthquake loads for all three alternatives. There is uncertainty under Alternative 2 as to whether the gentle perimeter slopes, particularly along Dike C, would be stable under short-term seismic loading conditions without foundation treatment. Additional foundation treatment could be implemented as a contingency measure; however, costs of such contingency measures would be correspondingly higher.

Effectiveness of disposal. Alternative 3 would not transport any ash generated during the non-time-critical removal action offsite for disposal. The 2.5 million cy of ash recovered from the embayment and Dike 2 would be placed within the Dredge Cell (Alternative 3a) or Ash Pond (Alternative 3b), resulting in a total of 17.6 million cy of ash beneath the clay cover. Alternative 1 would transport approximately 2.8 million cy of recovered ash, rock, clayey soil, and other material offsite for disposal; approximately 10.8 million cy of ash would remain within the former Dredge Cell and another 4.0 million cy would remain within the former Ash Pond. Alternative 2 would transport the greatest volume (approximately 6.8 million cy) of ash offsite for disposal; approximately 6.8 million cy would remain in the former Dredge Cell and another 4.0 million cy would remain within the former Ash Pond. The ash would be covered under each alternative to limit migration.

Under Alternatives 1 and 2, the offsite disposal facility would be an existing, permitted solid waste landfill. The landfill would operate under the restrictions of its specific permit, including waste acceptance criteria, groundwater protection systems, leachate collection and treatment systems, interim and final cover, and other terms of the operating permit. EPA must be notified of the specific landfill prior to shipment of any ash. Offsite disposal under Alternatives 1 and 2 would therefore be effective in reducing onsite volumes and managing the ash in a permitted manner.

Effectiveness over the short term. Each of the remaining alternatives would be effective over the short term (during construction); RAOs would be achieved once construction is complete. Short-term impacts could occur during the excavation and processing of the ash. Engineering measures would be implemented to protect remediation workers and the community, including the following: (1) dust control measures, such as wetting the ash or spraying with Flexterra®, to minimize generation of fugitive dust; (2) OSHA health and safety measures, such as use of PPE and construction safety program, to protect workers; and (3) erosion and sediment control measures, such as sediment basins, check dams, temporary seeding, diversion berms, interceptor trenches, silt fences, and erosion protection blankets, to minimize erosion and transport of the ash during construction. Under Alternatives 1 and 2, transportation control measures would also be implemented, such as placarding, lining, and shipping in accordance with DOT regulations, to protect the community and minimize spills.

Inherent short-term risks would be associated with shipment of ash over public roadways or railways. Short-term risks of railroad incidents or rail-vehicle intersection accidents would be proportionate to the number of trip-miles. Alternative 2 would pose the greatest impact; offsite transport of more than 6.8 million cy of ash would result in nearly 300,000 trip-miles by rail alone (Alternative 2a) or nearly 1.7 million trip-miles by truck over public roadways plus 270,000 trip-miles by rail (Alternative 2b). Alternative 1 would pose less impact; offsite transport of 2.8 million cy of ash would result in nearly 125,000 trip-miles by rail alone (Alternative 1a) or nearly 1.7 million trip-miles by truck over public roadways plus 90,000 trip-miles by rail (Alternative 1b). Alternative 3 would eliminate offsite transportation impacts, since no material would be shipped offsite.

Estimates of the potential number of accidents, injuries, and/or fatalities were made based on rate information for rail transport (ANL 2009) and for truck transport (DOT 2009). National statistics were used for comparability between the data sources. Rates for accidents, injuries and fatalities were multiplied by the number of rail-car miles and truck-miles, respectively. Due to reporting differences, the number of accidents does not necessarily correlate to the number of injuries or fatalities, since not all accidents result in an injury or fatality, nor are all injuries or fatalities a result of vehicle collisions.

These calculations resulted in the greatest risk of transportation impacts for Alternative 2. For Alternative 2, an estimated 2 to 3 rail accidents, 2 rail injuries, and 0.9 rail fatalities could occur. For Alternative 1, an estimated 0.4 to 1 rail accidents, 0.6 to 0.8 rail injuries, and 0.3 to 0.4 rail fatalities could occur. In addition, for both Alternatives 1b and 2b, an estimated 2 truck accidents, 0.8 truck injuries, and 0.04 truck

fatalities could also occur. There would be no transportation impacts under Alternative 3 associated with offsite transport of ash for disposal.

4.2.2 Implementability

The alternatives would be implementable using conventional technologies and would achieve RAOs at the completion of construction. Alternative 2 would take the longest to complete, nearly 4.1 years due to material handling constraints on offsite shipments. Alternative 3a would take nearly 4.0 years to complete, requiring installation of a robust perimeter dike foundation treatment system. Alternative 1 would take the least time to complete, approximately 2.8 years. Closure of the Ash Pond under these alternatives would occur at a later date and would take another 10 months to complete. Alternative 3b would close the Ash Pond at the same time as the Dredge Cell, requiring a total of 4.1 years to complete.

Excavation of ash from the embayment would be complicated by high water levels, springs and seeps into the embayment, which would degrade equipment foundation support and aggravate ash dewatering. Properties of the fine-grained ash would complicate ash dewatering; material that is wetter at depth or that becomes wetter as a result of sustained rainfall is difficult to dewater. For optimum material handling and shipping, the moisture content must be reduced from approximately 100% moisture in the embayment to less than 30% moisture in the haul vehicle. Wet ash processing areas would be needed to temporarily disk, blade, or turn the ash in piles or windrows to facilitate drying by evaporation. Use of polymer absorbents may be needed as contingent actions to absorb water that may rise to the top of the truck or rail car bed as a result of vibrations during shipment. Excavation and dewatering would be most difficult under Alternative 2, due to the large volume of material shipped offsite (6.8 million cy). Alternative 1 would be somewhat less difficult, due to lesser volumes (2.8 million cy offsite plus 1.8 million cy compacted onsite during regrading). Alternative 3 would involve the least amount of material handling (2.5 million cy from the embayment plus 1.1 to 1.3 million cy from regrading), all of which would be compacted onsite since there would be no offsite shipment. However, ash processing would be slower under Alternative 3 because of the need to dry the ash sufficiently to allow compaction

Transportation of the ash would be complicated by the large volume of material and limited disposal options. Alternative 2 would involve the greatest volume (6.8 million cy) and take the longest time to complete offsite shipments, estimated at 45 months for rail transport alone (Alternative 2a) or up to 39 months for combined truck/rail transport (Alternative 2b). Alternative 1 would also involve a large volume (2.8 million cy), and long time to complete offsite shipments, estimated at 19 months for rail transport alone (Alternative 1a) or up to 14 months for combined truck/rail transport (Alternative 1b). Alternative 3 would involve no offsite shipment of ash, and therefore would avoid transportation impacts.

Regulatory and/or public opposition to use of a particular disposal facility would complicate implementability of offsite disposal options. There is considerable uncertainty in implementing Alternative 2 as to whether sufficient capacity is available at the disposal facilities to handle the 6.8 million cy of material generated during the non-time-critical removal action. Although volumes are less under Alternative 1 (2.8 million cy), disposal capacity is still uncertain. Alternative 3 would involve no offsite disposal, and therefore would avoid the opposition or capacity constraints. Conversely, however, there may be opposition to leaving so much ash on site.

Specialty contractors would be required for implementation of the foundation treatment for the perimeter dike containment structures. Deep soil mixing expertise would be required to provide suitable mix proportions, thoroughness of mixing, and quality control to produce a contiguous soil/cement column to depths of up to 80 ft. Implementation would be further complicated by the large number of columns required. Alternative 3a would install the most robust foundation treatment zone, involving 22,600 lin ft of dike perimeter, 1,241,000 ft^2 of grid area, and 654,000 cy of soil/cement. There is uncertainty in

implementing Alternative 3a as to whether sufficient capacity would be available among the experience specialty contractors to handle this large production volume. Alternative 1 would involve 17,200 lin ft of dike, 650,000 ft^2 of grid area, and 295,000 cy of soil/cement. Alternative 3b would be similar to Alternative 1 involving 16,600 lin ft of dike, 581,000 ft^2 of grid area, and 259,500 cy of soil/cement. Alternative 2 would involve much less foundation treatment, 12,800 lin ft of dike, 306,000 ft^2 grid area, and 154,500 cy of soil/cement.

Regrading and/or filling of the Dredge Cell to provide final contour grades would be complicated under each alternative due to the difficult compaction properties and high erodibility of the ash. The ash is highly sensitive to moisture variations, requiring careful quality control to achieve optimum moisture for compaction. Monitoring and surveillance during construction of the perimeter dikes and ash fill compaction would include a network of piezometers, settlement plates, and inclinometers, which have been demonstrated to be effective in monitoring the construction of the test embankment. Erosion control measures such as check dams, temporary seeding, diversion berms, interceptor trenches, and erosion protection blankets would be used during ash fill placement to prevent excessive erosion of the compacted ash prior to construction of the final cover. Alternative 3 would involve the greatest amount of filling plus regrading (3.6 to 3.8 million cy) and a higher level of instrumentation for dike monitoring and quality control. Alternative 1 would involve considerably less volume (1.8 million cy) and moderate level of instrumentation. Alternative 2 would involve minimal regrading, since most of the material would be removed, and smaller level of instrumentation. To achieve final grades within the Ash Pond under these alternatives would involve about 0.1 million cy of regrading plus the placement of about 0.2 million cy of imported fill.

Under Alternative 3b, closure of the Ash Pond would occur in phases during the same time as closure of the Dredge Cell; pond closure would be carefully coordinated with the dry ash conversion project schedule and dredged ash dewatering operations. Under the remaining alternatives, closure of the Ash Pond would occur at a later date, avoiding the complication of phased construction and integration with dry ash conversion or dredged ash dewatering.

Restoring of the embayment would require specialty subcontractors experienced in wetland restoration. The implementability of the restoration would be similar under all three alternatives. Approximately 28 acres of mixed forested, scrub-shrub, and emergent wetlands would be contoured and replanted with native plant species. Sufficient quantities of native plant stocks are available from specialty nurseries. Time to reach sustainable habitat will vary; emergent wetlands would be sustainable in less than 5 years and scrub-shrub wetlands in less than 10 years. Forested wetlands would require decades to reach maturity. Due to their high mobility, natural repopulation of fish and terrestrial fauna would occur immediately as their habitat develops.

Long-term O&M activities would be similar under each of the three alternatives, and would include routine inspection and maintenance of the perimeter dikes and cover containment systems. Once vegetation has been established, cover maintenance would include periodic mowing, repair of erosion control or drainage features, and possible regrading or filling to repair areas of excessive settlement. Long-term monitoring of groundwater would be required; this monitoring is to be addressed under the EE/CA for the river system. Long-term institutional controls, including site access control and land use restrictions would be readily implemented as part of ongoing KIF operations.

4.2.3 Cost

Capital costs are highest for Alternative 2 ($719.3 to $741.1 million) due to the high cost of transport and disposal of the much larger volume of material. Costs of Alternative 2b are slightly less than 2a because hauling by truck is less costly than by rail. Capital costs are lowest for Alternative 3 ($268.2 to $315.5

million) because no material is disposed offsite. Closing the Ash Pond at the same time as the Dredge Cell would result in an estimated cost savings due to reducing the foundation treatment needed for perimeter dike containment, eliminating imported fill material to close the Ash Pond, and schedule efficiencies in integrating Ash Pond closure together with Dredge Cell closure. Capital costs of Alternative 1 are in between ($439.6 to $455.3 million). Although hauling by truck is less costly than by rail, the unit costs of disposal are higher for Alternative 1b because there would be no quantity discount due to the lesser volume of material than for Alternative 1a. All costs are reported in 2009 dollars.

Ongoing O&M costs are the same for all alternatives, since the O&M activities are the same. O&M costs are estimated at $686,000/year (2009 dollars).

5. RECOMMENDED REMOVAL ACTION ALTERNATIVE

This section identifies the removal action alternative that best satisfies the evaluation criteria based on the comparative analysis described in Section 4.

THIS CHAPTER WILL BE WRITTEN FOLLOWING RECEIPT OF COMMENTS AND INPUTS FROM THE PUBLIC.

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6. REFERENCES

40 CFR Part 300. *National Oil and Hazardous Substances Pollution Contingency Plan (NCP)*.

42 U.S.C. § 7401 et seq., *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986.

AECOM 2009 (June 25). Root Cause Analysis of TVA Kingston Dredge Pond Failure on December 22, 2008, Kingston Fossil Plant, Harriman, Tennessee.

Argonne National Laboratory (ANL) 1999 (April). State-Level Accident Rates of Surface Freight Transportation: A Reexamination. ANL/ESD/TM-150, by C.L. Saricks and M.M. Tompkins, The Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, Argonne, Illinois.

U.S. Department of Transportation (DOT) 2009 (January). Large Truck and Bus Crash Facts 2007, FMCSA-RRA-09-029, Analysis Division, Federal Motor Carrier Safety Administration, available online at: http://www.fmsca.dot.gov.

U.S. Environmental Protection Agency (EPA). 2009a (May 11). *Administrative Order and Agreement on Consent, Docket No. CERCLA-04-2009-3766*, Region 4.

EPA 2009b. *Contaminated Site Cleanup Information* (CLU-in), Technology Innovation Program, available online at: http://www.clu-in.org/remediation/.

EPA 2003. *Human Health Toxicity Values in Superfund Risk Assessments*, OSWER Directive 9285.7-53.

EPA 2002. *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites*, OSWER Directive No. 9285.6-10.

EPA 1999 (September), *Presumptive Remedy for Metals-in-Soil Sites*, EPA 540-F-98-054, OSWER-9355.0-72FS.

EPA 1994. *Assessment and Remediation of Contaminated Sediments (ARCS), Remediation Guidance Document*, EPA 905-B94-003, Great Lakes National Program Office, Chicago, IL. Available online at: http://epa.gov/glnpo/arcs/EPA-905-B94-003/EPA-905-B94-003.html.

EPA 1993 (August). *Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA*, Publication 9360.0-32, Washington, D.C.

EPA 1989. *Risk Assessment Guidance for Superfund, Vol. 1: Human Health Evaluation Manual (Part A)*, EPA/540/1-89/002.

Interstate Technology and Regulatory Cooperation (ITCR) Work Group. 1998 (December). *Metals in Soils 1998 Technology Status Report*.

Jacobs. 2009 (October 15). *Kingston Fly Ash Recovery Project, Non-Time-Critical Removal Action Scope and Work Plan*.

National Weather Service (NWS) 2006 (March 7). *Oak Ridge Climate Normals and Records (1971-2000)*, National Weather Service Forecast Office, Morristown, Tennessee.

Tennessee Department of Environment and Conservation (TDEC) 2009 (January 12), *Commissioner's Order, Case No. OGC09-0001*, Division of Water Pollution Control.

TDEC 2006 (September 12), *Registration Authorizing Solid Waste Disposal Activities in Tennessee, Registration No. IDL 73-0094*, Issued to Tennessee Valley Authority Kingston Fossil Plant.

Tennessee Valley Authority (TVA) 2009a (August 4). *Action Memorandum: Request for Removal Action at the TVA Kingston Fossil Fuel Plant Release Site, Roane County, Tennessee*.

TVA 2009b (February). *Environmental Assessment, Initial Emergency Response Actions for The Kingston Fossil Plant Ash Dike Failure, Roane County, Tennessee*.

TVA 1995 (July). *Closure/Post-Closure Plan, Ash Pond Area, Tennessee Valley Authority Kingston Fossil Plant*.