TVA Watts Bar Fossil Plant – Spring City, Tennessee

Ash Pond Closure Plan

Tennessee Valley Authority
1101 Market St.
Chattanooga, TN 37402-2801

October 8, 2013

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Appendices

Section 1

Introduction

As required by National Pollutant Discharge Elimination System (NPDES) permit TN0005461, Tennessee Valley Authority (TVA) is submitting this Ash Pond Closure Plan (herein, "Closure Plan") for the Watts Bar Fossil Plant (WBF) Ash Area, located in Spring City, TN along the Tennessee River. The Closure Plan is being submitted to the Tennessee Department of Environment and Conservation (TDEC) Division of Water Resources (DWR) with additional copies provided for review. This plan provides the conceptual design for ash area closure at the WBF facility in addition to the planned monitoring and maintenance activities for the facility during the post-closure period. The 90% design plan drawings will be submitted to TDEC upon completion in November.

1.1 Background

WBF is located in Spring City, TN and was originally constructed between 1940 and 1945. The site consisted of a main powerhouse building, a coal stockpile and various processing ponds, including ash processing and an ash stilling pond.

In 1982, WBF ceased power production operations and TVA terminated the air permits for the plant in 1997. In 2007, a closure plan was submitted to TDEC and a dome-shaped soil cap was constructed for the Slag Processing Area and Chemical Pond Area. The construction was completed in 2009 under Permit TNR190741. However, the vegetation covers did not adequately establish on the closure areas and the Borrow Area was not stabilized.

In 2012, TVA deconstructed the main powerhouse and the disturbed footprint was backfilled, covered and seeded. During the same year, TVA also initiated the evaluation of the containment dike for the ash pond, as per the recommendations of the Coal Combustion Residue Impoundment Round 11 - Dam Assessment Report for the WBF facility (Revised April 2013 - http://www.epa.gov/wastes/nonhaz/industrial/special/fossil/surveys2/tva_wattsbar_final.pdf).

The first step in the process was to lower the elevation of the containment dike for the pond in order to reduce the total amount of available storage at the site. It should be noted that there were no stability issues with the existing dike. This project to reduce the storage capacity provided by the dike and construction of a new spillway for the pond is currently underway and scheduled for completion in the spring of 2014. The next step will be closure of the Ash/Stilling Pond Area, which includes removal of the ash from the pond and complete closure of the ash area.

This closure plan will specifically address the proposed closure of the Ash/Stilling Pond Area. Closure of the remaining areas of the site will be completed separately.

1.2 Existing Conditions

The Ash Pond Area consists of the "wet" Ash Pond and the dry ash storage area. Refer to Sheet 1 in Appendix A for a site overview of the area.

The following subsections contain a description of the existing pond, along with ongoing and planned improvements.

1.2.1 Ash/Stilling Pond

The Ash/Stilling Pond Area covers approximately 14.3 acres. The upland drainage area to the pond is approximately 180 acres. The area was previously used as an ash pond but now serves as a storm water discharge area. The area was constructed in 1974 by adding a series of culverts (six 24-inch diameter RCP drainage pipes) under the road between the Slag Processing Area and Ash/Stilling Pond and a perimeter dike built with earth fill. In 1977, a splitter dike was constructed within the pond. Due to the deposition of ash over time, two separate sub-areas have formed; a "wet" ash area and a dry ash area. The "wet" ash area contains approximately 85,000 cubic yards (CY) of ash. The dry ash area is located between the existing roadway and the wet ash area. The dry ash area has formed over time as the coarser particles settled in an area directly downstream of the discharge culvert. Three riser-barrel (morning glory) outlet structures are located in the southeastern corner of the Ash/Stilling Pond Area that discharges through NPDES Permitted Outfall 002. The existing riser barrels are constructed out of corrugated metal.

1.2.2 Stability Analysis

In April of 2012, a stability analysis of the ash pond area was performed (refer to Appendix E). The analysis considered seepage, static slope stability, and seismic slope stability. As documented in the report, the slope stability analyses indicated acceptable factors of safety under static and seismic loading conditions for all sections.

1.2.3 On-Going Site Improvements

Currently, TVA is constructing improvements to the wet pond area. A new concrete box spillway is being constructed to replace the existing, deteriorated riser-barrel spillway system. In addition, the containment dike is being lowered to reduce the total storage capacity of the pond. Once the new spillway system is complete, the existing spillway barrels will be grouted and abandoned in place. The existing riser pipes will be removed. A portion of the existing pond will remain in place as a stormwater control device for the entire site and upstream drainage area (180 acres). Also, drainage around the existing dry ash area will be diverted to a new stormwater channel to convey water properly through the site to the new stormwater pond. This will all be completed before construction of the Ash Pond Closure project addressed in this plan.

1.3 Regulatory Framework for Closure

NPDES Permit TN0005461 Part III (B) requires an ash pond closure plan be submitted for TDEC approval. The purpose of the Closure Plan is to propose closure actions which will be implemented after approval from TDEC.

1.4 Facility Contact Information

The following is the contact for activities at TVA's Watts Bar Fossil Plant.

Owner:	Tennessee Valley Authority (TVA)
Contact:	Sr. Manager of Water and Waste Compliance

Section 2

Closure Sequence and Schedule

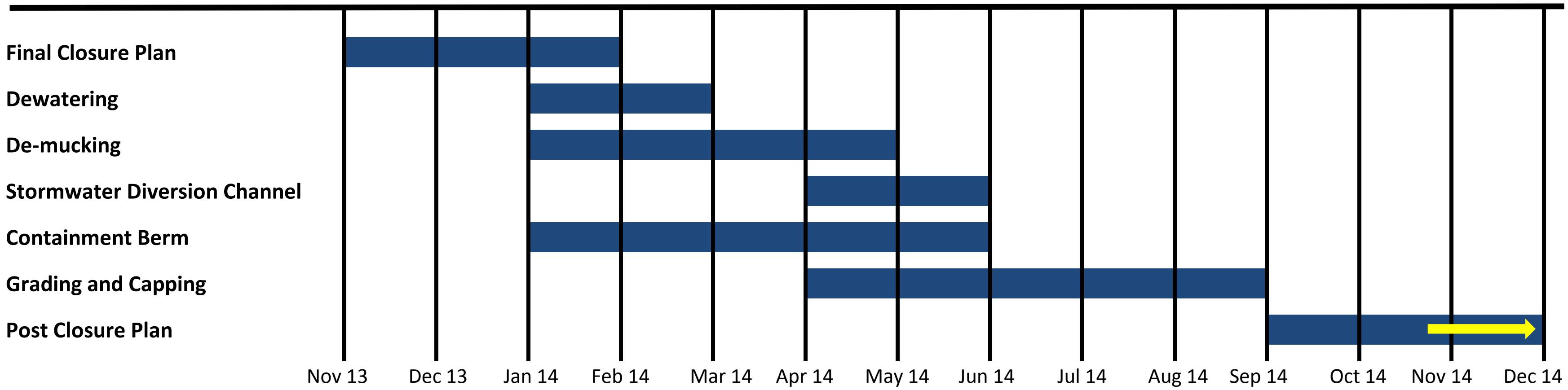
There are various phases proposed for the Ash Pond Closure project. Phase 1 is the conceptual design; Phase 2 is the detailed design; and Phase 3 is the implementation phase of the project, where construction occurs. TVA has completed the conceptual design phase and is currently working through the detailed design phase. The plans included in this document are near 90% at the time of this submittal. The 90% design plans will be completed by November 2013. TVA will submit the 90% plans to TDEC upon completion and will note any significant changes.

As noted, the site is currently under construction to lower the containment dike and to build a new spillway for the stormwater pond. As such, the Ash Pond has been dewatered. Upon completion of the current project and approval of this closure plan, the following sequence of activities is anticipated:

1. De-mucking and continued dewatering of the wet ash pond.
2. Stacking of the dewatered ash in the existing dry ash area.
3. Construction of a closure cap on the dry ash area.
4. Final conversion of the wet ash pond to a stormwater detention pond.

The figure on the following page provides a full schedule of the project milestones and duration.

Watts Bar Fossil - Ash Pond Closure Schedule



Watts Bar Fossil
Ash Pond Closure Plan
Revised: Oct 2013

Section 3

Site Considerations

Site considerations for closure are presented in this section.

3.1 Closure Strategy and Footprint

Water discharge from the work area during construction will be monitored at Outfall 002, in accordance with the NPDES permit. The recommended project approach is to establish a stormwater management system and cap for the Ash Area. Conceptual drawings of the closure area are provided in Appendix A. The closure is only for the Ash Area north of the Ash/Stilling Pond Area. Ash Area closure will occur in phases and the final cover system will be installed when the final grades are achieved.

The closure area for consideration in this Closure Plan consists of approximately 5.5 acres. The proposed closure plan provides a minimum 2% design grade on the closure cap to properly manage storm water, prevent ponding of water on the final cover and allow ease in mowing vegetation on the final cover. Side slopes of the closure cell will have a minimum slope of 4:1. A minimum 1% grade is provided along the length of the perimeter diversion dikes and ditches. Construction of a perimeter dike between the wet ash and dry ash areas will be required to enhance overall stability of the cap area. A permanent vegetative cover will be established. The design of all these features is detailed in the plans for construction.

3.2 Stormwater Management System

A stormwater management system will be established and installed as part of the closure. The existing stormwater conveyance channel around the dry ash area will be re-routed to the western edge of the dry ash area to enhance future settling time in the final stormwater pond. This ditch will be lined with the same material as the ash closure area to eliminate any contact between natural stormwater and subgrade material which may contain ash. Perimeter diversion dikes and ditches will be constructed at the base of the cap to direct runoff from the closure area to the stormwater pond or the re-routed conveyance channel as appropriate. The proposed stormwater management system is shown on the drawings in Appendix A.

All disturbed areas associated with the Ash Pond Closure project will be graded to allow positive drainage to the final stormwater pond. Additional erosion controls will be addressed with appropriate structural and non-structural sediment and erosion control practices as prescribed in the most recent edition of the Tennessee Erosion and Sediment Control Handbook. The existing Storm Water Pollution Prevention Plan (SWPPP) associated with Permit TNR190741 will be updated to incorporate address the potential impacts of this project.

Section 4

Engineering and Design

A summary of the engineering considerations and design is provided in this section.

4.1 Dewatering Activities

Dewatering of the wet ash storage pond and the dry ash area will be an essential component of the closure process. To facilitate the current spillway project and lowering of the containment dike, the water in the existing wet ash pond has been drained using a series of pumps. This operation was performed using a series of control measures to complete dewatering without exceeding allowable Total Suspended Solids (TSS) concentrations in accordance with the NPDES permit. Dewatering using this method will continue throughout the Ash Pond Closure phase.

In addition to dewatering of the pond, small drainage channels have been excavated within the dry ash area to facilitate additional dewatering of the dry ash materials. Drainage from the dry ash area is directed to the pond for additional settling before being discharged from the site.

4.2 De-Mucking and Stacking During Operations

The de-mucking process involves removal of the ash in the pond following the dewatering process described above. The wet ash material removed will be stacked for drying before the closure cell can be constructed. Removal of CCPs will be deemed complete by visual observation with materials predominately gray in color classified as CCPs. Materials predominately red or brown in color shall be classified native soils and may remain. No visible CCP equates to 10 percent or less of CCP material observed in a grid area. After CCPs are removed and native soils are observed it is anticipated that the Stilling Pond footprint will not require a cap.

Limited area is available for stacking during the de-mucking process. The current plan is to perform all de-mucking and stacking operations within the footprint of the dewatered pond and the existing dry ash area. Due to the limited footprint, there may be instances during the stacking process where ash may be stacked temporarily to an elevation above the existing containment dike for operational purposes and to enhance dewatering.

4.3 Dike Construction

The existing ash pond containment dike will remain in its present location. However, a 325-foot section of the containment dike will be lowered during the current project, as shown on Sheet 3 of Appendix A. The 325-foot section of the containment dike will be lowered approximately 10-feet to reduce the total storage capacity of the stormwater pond. This current project will satisfy conditions stated by EPA in its evaluation of this ash containment facility regarding long-term safety and stability.

4.4 Closure Cover System Design

A geosynthetic final cover system is being proposed to cap the Ash Area. Use of a geosynthetic cap will provide acceptable performance of the cover system while minimizing the quantity of soil cover to be imported.

The geosynthetic final cover is proposed to consist of the following materials and thicknesses, as listed in order of construction (bottom to top):

- 40-mil LLDPE geomembrane;
- Geocomposite drainage layer; and,
- 24-inches of cover soil, the top 6-inches for the support of vegetative cover.

The cap would be graded to provide positive drainage of surface water and seeded to establish a vegetative cover for erosion control. The conceptual final cover design is provided in the drawings in Appendix A. In general, closure activities, including grading, cover system installation, and establishing vegetative cover, will be completed in the shortest practicable time after fill areas within the closure footprint have achieved final grade.

As soon as practical after final grading, a protective vegetative cover of acceptable grasses will be established over disturbed areas of the site. This will include seeding, mulching, and any necessary fertilization at a minimum, and may include additional activities such as sodding of steeper slopes and drainage ways, if necessary. Temporary erosion control blankets may be used, if necessary, to provide seedbed protection and prevent wash-out of seed and fertilizer during vegetation establishment.

The closure will be scheduled to facilitate at least one month in the growing season to establish a grass cover, or alternatively, the entire cover will be re-seeded at the start of the next growing season, after confirming that the grades of the cover and the condition of the cover soil are in accordance with the Closure Plan.

4.5 Grading and Surface Water Management

A conceptual grading plan for surface water management has been developed to allow drainage off the final cover. The maximum final grade of the cover will be designed to:

- Minimizes precipitation run-on from adjacent areas;
- Minimizes erosion (e.g., no steep slopes);
- Optimizes drainage of precipitation falling on closured area (e.g., prevent pooling); and
- Provides a surface drainage system which is consistent with the surrounding area and in no way significantly adversely affects proper drainage from these areas.

In general, cover slopes will be graded at a minimum of 2% which will drain towards perimeter diversion dikes and ditches sloped at a minimum of 1%. Stormwater runoff will be conveyed to the proposed stormwater pond and will discharge to Lake Chickamauga through NPDES Outfall 002, which will be re-located in conjunction with the new spillway.

4.6 Erosion and Sediment Control

As a result of previous on-going closure activities at the site, an existing SWPPP for the site is in place under Permit TNR190741. For this project, the SWPPP will be updated to include all new work activities as well as associated erosion and sediment controls. All controls will be designed in accordance with the TDEC Erosion and Sediment Control Manual.

As part of the Phase 2 construction-level design documents, a plan will be developed to manage Total Suspended Solids (TSS) at Outfall 002 during construction. Controls may include, but are not limited to, diversion of flows, the addition of coagulants, and the use of turbidity curtains.

4.7 Construction Quality Assurance

A Construction Quality Assurance Plan (CQA Plan) will be developed for the ash area closure. Construction inspections will be conducted to document the closure construction and Quality Assurance/Quality Control (QA/QC) testing. Sections of the CQA Plan will include:

- Purpose, Scope, and Project Description
- Limitations of the Plan
- Responsibility and Authority
- QA/QC Program Activities
- Specific Product Submittals and Material Testing Requirements
- Surveying Requirements
- Project Documentation

4.8 Groundwater Monitoring Network

A network of groundwater wells will be used to conduct groundwater monitoring in the vicinity of the Ash Area. The network will consist of one upgradient or background well and two hydraulically downgradient wells, in accordance with the requirements for landfills under the TDEC Division of Solid Waste Management (DSWM) regulations. The upgradient well will be used to establish baseline groundwater quality measurements. The parameters proposed for semi-annual monitoring are the inorganic parameters in Appendix I of the TDEC DSWM regulations. These parameters are routinely used to detect CCP impact to groundwater resulting from the closed area.

The WBF Groundwater Monitoring Plan in Appendix B summarizes the proposed monitoring network for the ash pond closure.

Section 5

Closure Requirements

The following sections summarize requirements for closure and on-going observations.

5.1 Closure Certification

Upon completion of approved closure construction activities, a closure report will be prepared by an independent professional engineer registered in the State of Tennessee to document the completed construction activities. The closure report will be submitted to TDEC for review.

5.2 Groundwater Monitoring Plan

Groundwater sampling will be conducted semi-annually during closure and post closure. After two years, an appropriate number of samples (8) will have been collected to support TVA's statistical analysis method. Prior to that, any exceedances of MCLs will be reported to TDEC.

The CCP boundary will be monitored by a well network of one up-gradient/background well and two down-gradient wells. The up-gradient well is located to be representative of background water quality unaffected by a CCP unit. Down-gradient wells shall be hydraulically down-gradient, and be constructed in such a manner as to detect CCP-related impacts. Wells will be screened in the soil overburden aquifer immediately underlying the site, as the primary receptor of potential migrating CCP-borne constituents in groundwater.

Recommended placement of monitoring wells was based on potentiometric contouring developed from water levels in existing wells, adjacent river level data, hydrogeologic information and/or database information. The proposed plan provided in Appendix B represents a monitoring system for WBF during closure and post-closure that meets the requirements for Class II landfills.

Groundwater will be analyzed for the 17 inorganic constituents identified in Appendix I of TDEC Rule 0400-11-01-.04. Organic compounds identified in Appendix I are not typically constituents of CCPs. Groundwater monitoring data will be reported to TDEC within 60 days after the last day of sampling.

The Ash Pond Closure Groundwater Monitoring Plan summarizes field procedures and groundwater sampling protocols, analysis, and record keeping requirements generally associated with TDEC Class II landfill groundwater monitoring requirements. The plan is included in Appendix B.

5.3 Quarterly Reporting

As required by Part III (B) of NPDES Permit TN0005461, quarterly updates on progress toward closure will be submitted with the Discharge Monitoring Reports for March, June, September, and December after the Closure Plan has been approved by the state. Quarterly reporting will address the estimated future date for complete closure and elimination of ash pond discharges as well as updated information on planning, design, and construction milestones for each upcoming quarter. The quarterly updates will address closure of the areas identified in this Closure Plan. An example reporting form is provided in Appendix C.

5.4 Financial Assurance

As an agency and instrumentality of the United States created by the TVA Act of 1933, 16 U.S.C. § 831-831dd (2006), TVA is not required to provide financial assurance.

Section 6

Post-Closure Plan

TVA will implement a post-closure plan that will involve inspection and monitoring activities. Regularly scheduled inspection shall be performed to verify that the closure plan procedures have been effectively implemented.

6.1 Post-Closure Care Period

The post-closure care period will continue for 30 years after date of final completion of closure of the ash pond and dry ash area unless a shorter period is approved by TDEC. Post closure can be reduced or extended beyond 30 years as groundwater monitoring data prove appropriate.

6.2 Post-Closure Care Activities

During the post-closure care period, the following activities may be performed:

A. Maintain the approved final contours and drainage systems of the site such that precipitation run-on is minimized, erosion of the cover/cap is minimized, precipitation on the fill is controlled and directed off the closure area, and unintended ponding is eliminated.

B. Ensure that a healthy vegetative cover is established and maintained on the site.

C. Maintain the drainage facilities and other erosion/sediment controls (if present) in a functional state until the vegetative cover is established sufficiently to render such maintenance unnecessary. Removal or cessation of maintenance must be approved by TDEC.

D. Maintain and monitor the ground water monitoring system in accordance with the Ground Water Monitoring Plan approved by TDEC. The monitoring system and sampling and analysis program approved as part of this Closure Plan shall be continued during the post-closure period, unless the Closure Plan is modified to establish a different system or program.

E. A post-closure completion report prepared by an independent registered professional engineer licensed in the State of Tennessee shall be submitted to TDEC for review and approval following the post-closure care period.

An inspection form for post-closure care and monitoring activities is included in Appendix D.

Appendix A

Ash Pond Closure Drawings

XX | C | SHEET 0

ISSUED FOR APPROVAL

ASH POND CLOSURE PLAN
WATTS BAR FOSSIL PLANT

SPRING CITY, RHEA COUNTY, TENNESSEE

PREPARED FOR

TENNESSEE VALLEY AUTHORITY

PREPARED BY

CDM Smith

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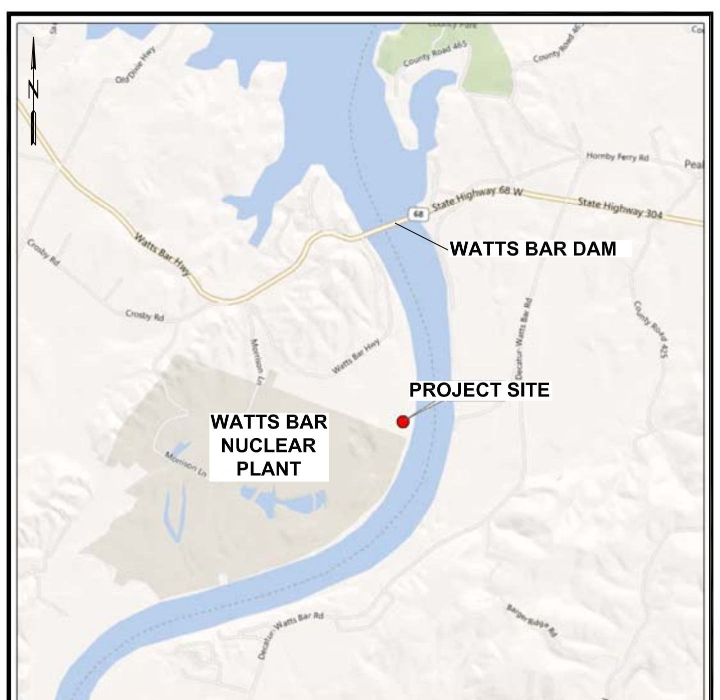
INDEX OF SHEETS



VICINITY MAP
NOT TO SCALE

ISSUED FOR APPROVAL - NOT FOR CONSTRUCTION

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DISCIPLINE INTERFACE
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SCALE: NONE EXCEPT AS NOTED

CONTRACT NO.
CDM SMITH

ASH POND CLOSURE PLAN
CLOSURE PLAN
COVER SHEET

DESIGNED BY:	DRAWN BY:	CHECKED BY:	SUPERVISED BY:	REVIEWED BY:	APPROVED BY:	ISSUED BY:
K. YANG	M. KOSKI	D.NEAMTU	S.WHITESIDE	J.MULLINS	M.TURNBOW	J.KAMMEYER

WATTS BAR FOSSIL PLANT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R 2012 | DATE 7/3/13 | 14 | C | SHEET 0 | R

CDM SMITH
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PLOT FACTOR:XX
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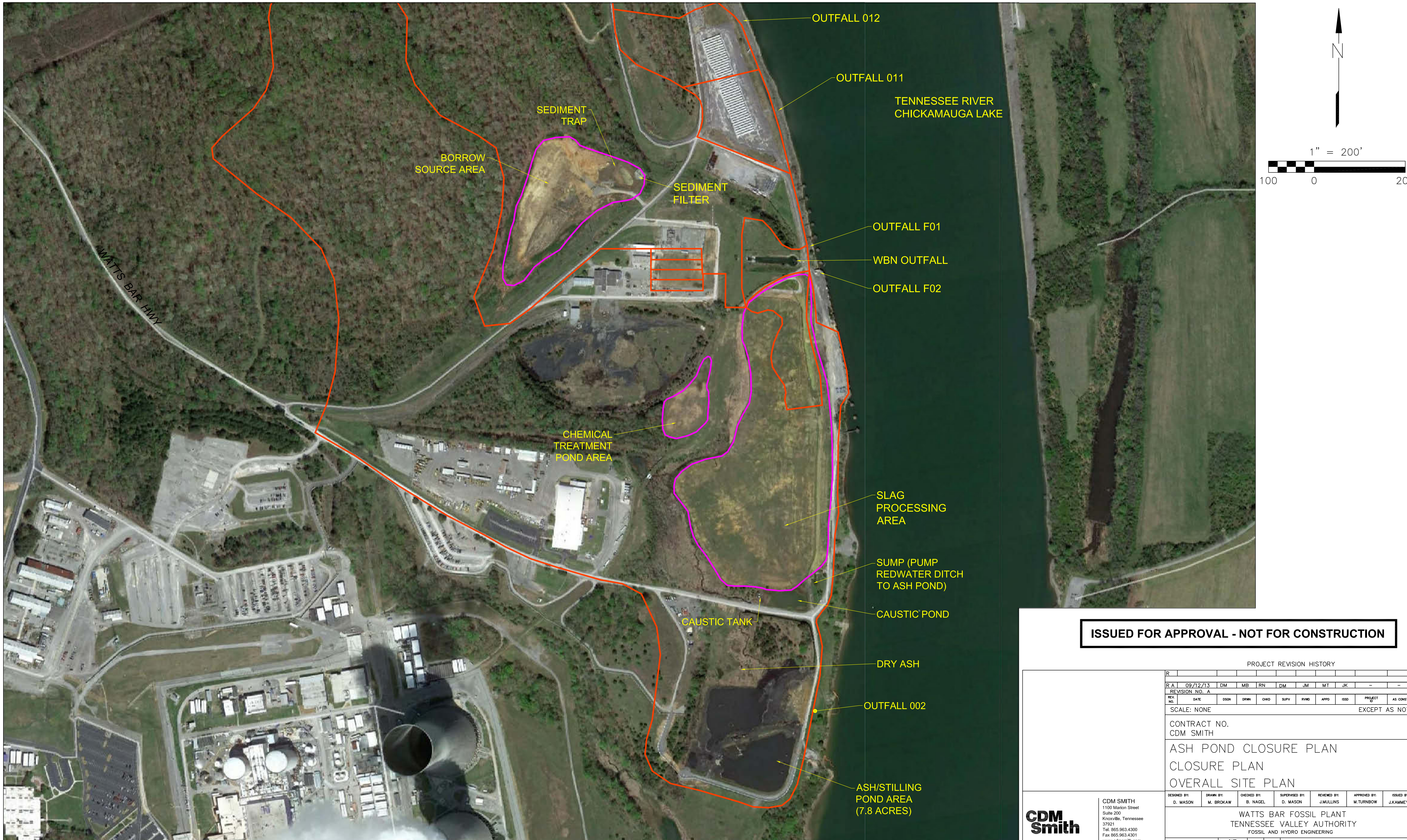

ISSUED FOR APPROVAL - NOT FOR CONSTRUCTION

PROJECT REVISION HISTORY

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REVISION NO. A

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SCALE: NONE EXCEPT AS NOTED

CONTRACT NO.
CDM SMITH

ASH POND CLOSURE PLAN
CLOSURE PLAN
OVERALL SITE PLAN

DESIGNED BY:	DRAWN BY:	CHECKED BY:	SUPERVISED BY:	REVIEWED BY:	APPROVED BY:	ISSUED BY:
D. MASON	M. BROKAW	B. NAGEL	D. MASON	J.MULLINS	M.TURNBOW	J.KAMMEYER

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WATTS BAR FOSSIL PLANT
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AUTOCAD R2012	DATE 09/12/2013	14	C	SHEET 1	R A

CDM SMITH	A
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PLOT FACTOR:XX
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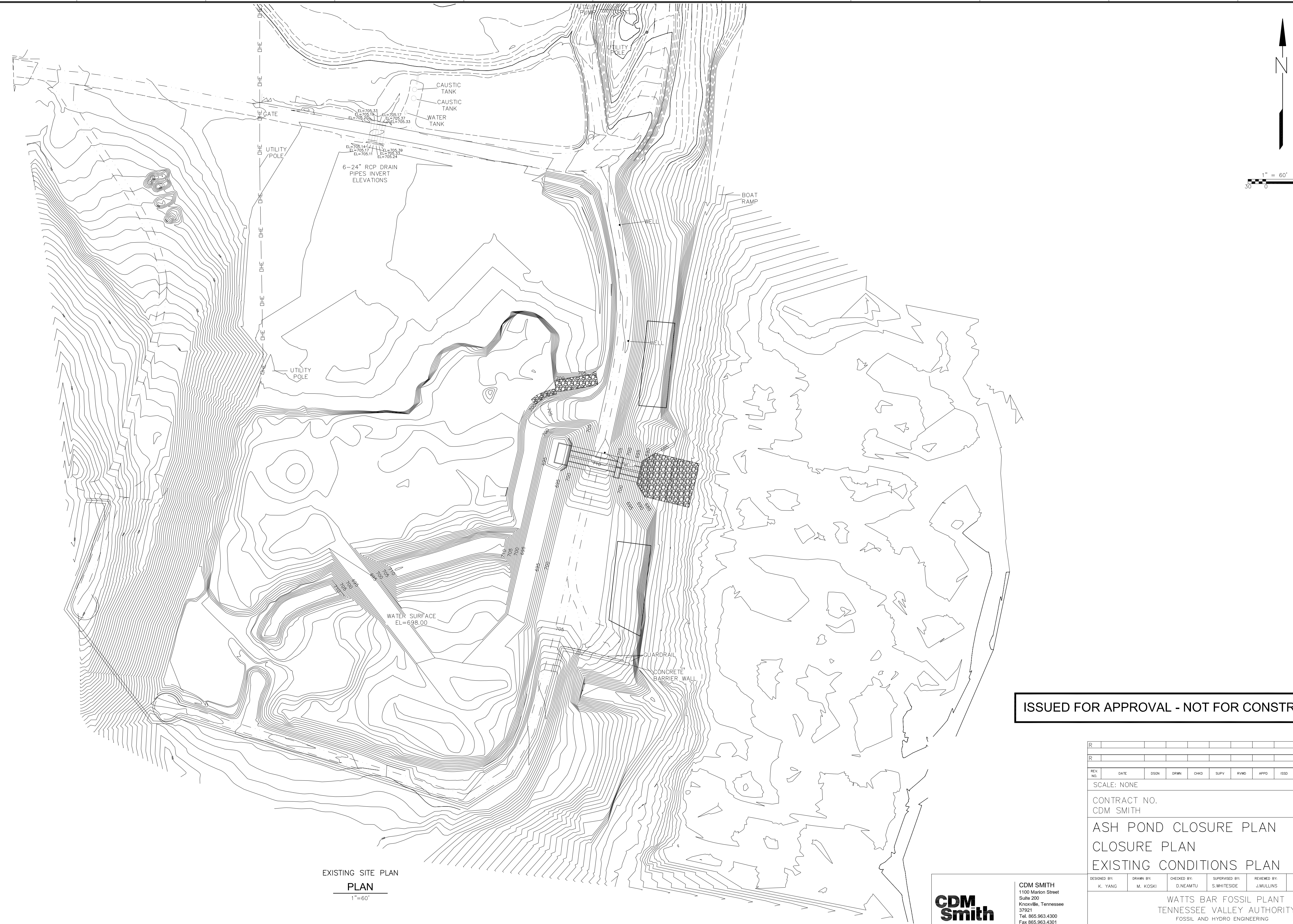

EXISTING SITE PLAN

PLAN

1"=60'

ISSUED FOR APPROVAL - NOT FOR CONSTRUCTION

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DISCIPLINE INTERFACE

SCALE: NONE EXCEPT AS NOTED

CONTRACT NO.
CDM SMITH

ASH POND CLOSURE PLAN
CLOSURE PLAN
EXISTING CONDITIONS PLAN

DESIGNED BY:	DRAWN BY:	CHECKED BY:	SUPERVISED BY:	REVIEWED BY:	APPROVED BY:	ISSUED BY:
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CDM SMITH
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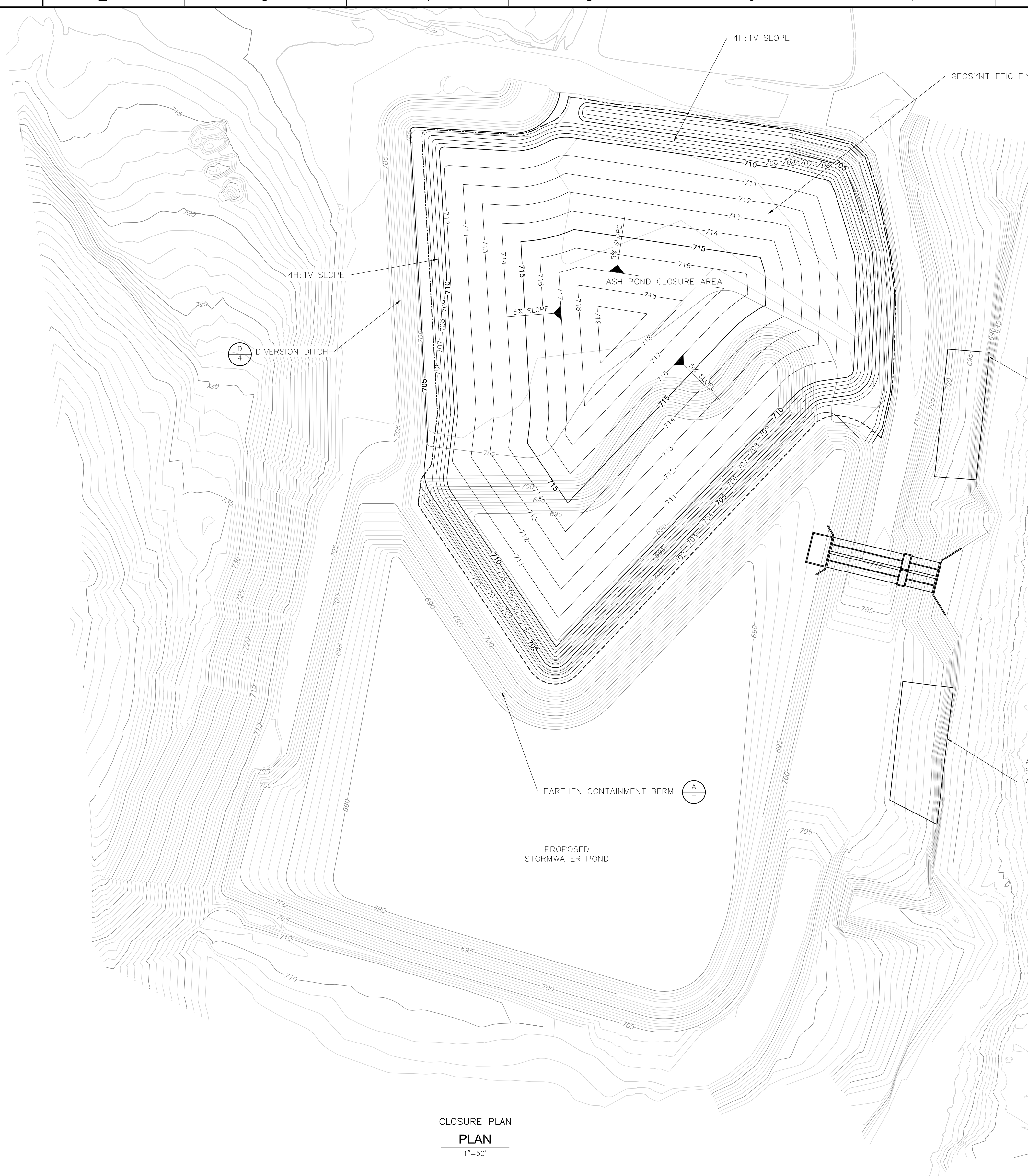
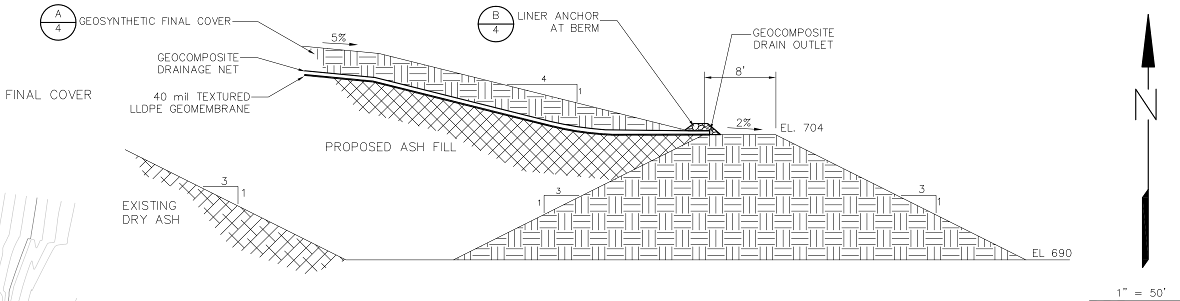


CLOSURE PLAN

PLAN

1"=50'



EARTHEN CONTAINMENT BERM WITH ASH

DETAIL A
NTS

LEGEND:

GEOCOMPOSITE DRAIN OUTLET AT EARTHEN CONTAINMENT BERM (SEE NOTE 2)

GEOCOMPOSITE DRAIN OUTLET AT DIVERSION DITCH (SEE NOTE 3)

GEOCOMPOSITE DRAIN OUTLET AT DRAINAGE DITCH (SEE NOTE 4)

NOTES:

1. PROPOSED GRADES SHOWN REPRESENT TOP OF ASH.
2. ANCHOR GEOMEMBRANE AND DAYLIGHT GEOCOMPOSITE DRAINAGE NET PER DETAIL B ON SHEET 4.
3. JOIN GEOMEMBRANE TO DIVERSION DITCH AND DAYLIGHT GEOCOMPOSITE DRAINAGE NET PER DETAIL D ON SHEET 4.
4. ANCHOR GEOMEMBRANE AND DAYLIGHT GEOCOMPOSITE DRAINAGE NET PER DETAIL C ON SHEET 4.

ISSUED FOR APPROVAL - NOT FOR CONSTRUCTION

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SCALE: AS SHOWN EXCEPT AS NOTED

CONTRACT NO.
CDM SMITH

ASH POND CLOSURE PLAN
CLOSURE PLAN
PROPOSED ASH POND CLOSURE PLAN

DESIGNED BY:	DRAWN BY:	CHECKED BY:	SUPERVISED BY:	REVIEWED BY:	APPROVED BY:	ISSUED BY:
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FOSSIL AND HYDRO ENGINEERING

AUTOCAD R2012 | DATE 7/3/13 | 14 | C | SHEET 3 | R

CDM SMITH
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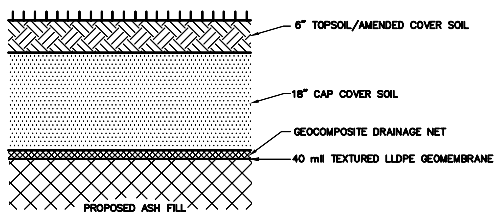
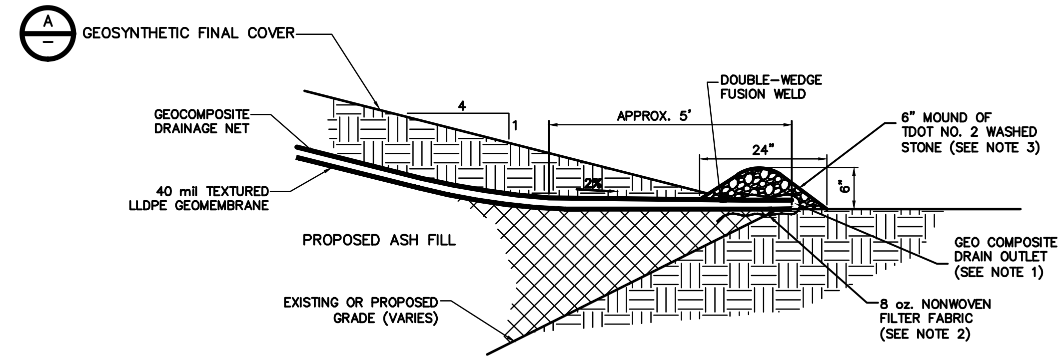


NOTES:

1. CLEAR AND GRUB TREES AND STRIP VEGETATION FROM DRY ASH AREA. DETERMINE EXISTING INTERMEDIATE COVER MATERIAL THICKNESS.
2. REMOVE EXISTING INTERMEDIATE COVER MATERIAL IN AREAS GREATER THAN 12 INCHES.
3. REPAIR EROSION DAMAGE USING REMOVED INTERMEDIATE COVER MATERIAL AND VERIFY MINIMUM 12" INTERMEDIATE COVER MATERIAL LAYER THICKNESS. IMPORT OFF-SITE INTERMEDIATE COVER MATERIAL IF NECESSARY.
4. FOLLOWING THICKNESS VERIFICATION AND PLACEMENT OF PROPOSED ASH FILL, PLACE FINAL COVER GEOSYNTHETICS.

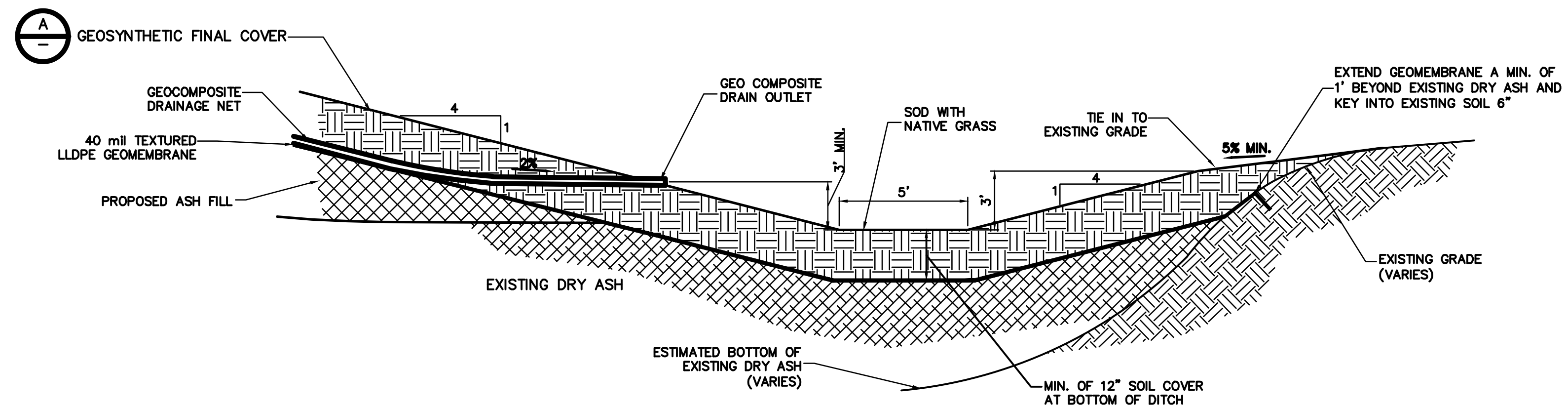
GEOSYNTHETIC FINAL COVER
DETAIL A –
NTS



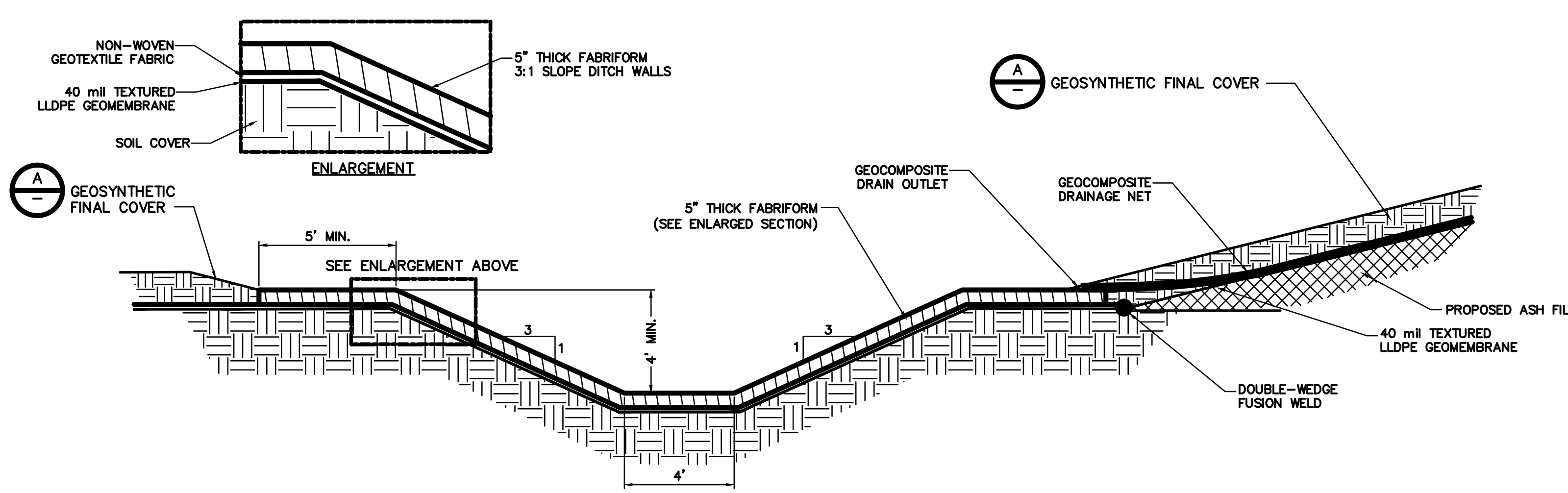
NOTES:

1. INSTALL GEOMEMBRANE AND DRAINAGE NET AND EXTEND A MINIMUM OF 1' PAST EDGE OF STACKED ASH TO PROVIDE A DRAINAGE OUTLET.
2. WRAP 3' STRIPS OF FILTER FABRIC AROUND THE END OF THE GEOMEMBRANE AND DRAIN OUTLET. CONTRACTOR SHALL HEAT AND TACK THE TOP OF THE FILTER FABRIC TO THE GEOCOMPOSITE DRAINAGE NET, OR DOUBLE-WEDGE FUSION WELD AS REQUIRED BY THE ENGINEER.
3. MOUND TDOT NO. 2 WASHED STONE ATOP GEOCOMPOSITE DRAINAGE NET AND FILTER FABRIC. MOUND SHALL BE APPROXIMATELY 6" HIGH, BUT NO GREATER THAN 12". WIDTH SHALL BE NO LESS THAN 24" AND SHALL COVER FILTER FABRIC ENTIRELY.
4. PLACE CAP COVER SOIL AND GRADE TO EDGE OF STONE.

LINER ANCHOR AT BERM
DETAIL B –
NTS



LINER ANCHOR AT DRAINAGE DITCH
DETAIL C –
NTS



DIVERSION DITCH
DETAIL D –
NTS

ISSUED FOR APPROVAL - NOT FOR CONSTRUCTION

REV. NO.	DATE	DSGN	DRWN	CHKD	SUPV	RVWD	APPD	ISSD	PROJECT ID	AS CONST	REV CD
R									–	–	–
R									–	–	–

DISCIPLINE INTERFACE

SCALE: NONE EXCEPT AS NOTED

CONTRACT NO.
CDM SMITH

ASH AREA CLOSURE PROJECT
CLOSURE PLAN
FINAL COVER AND CLOSURE DETAILS

DESIGNED BY:	DRAWN BY:	CHECKED BY:	SUPERVISED BY:	REVIEWED BY:	APPROVED BY:	ISSUED BY:
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WATTS BAR FOSSIL PLANT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

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AUTOCAD R2012	DATE 3/22/13	14	C	SHEET 4	R

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TASK COMPLETED BY: REV NO.

PLOT FACTOR:XX
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

Appendix B

Groundwater Monitoring Plan

TVA Watts Bar Fossil Plant – Spring City, Tennessee

Ash Pond Closure

Groundwater Monitoring Plan

Tennessee Valley Authority
1101 Market St.
Chattanooga, TN 37402-2801

October 8, 2013

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Section 1

Introduction

This Ash Pond Closure Groundwater Monitoring Plan for the TVA Watts Bar Fossil Plant (WBF) provides the field procedures and groundwater sampling protocols, analysis, and record keeping requirements associated with the ash pond closure.

To date, monitoring wells have not been installed to monitor the WBF ash pond. Recommended placement of monitoring wells in this Plan is based on potentiometric contouring developed from water levels in existing piezometers at the site, adjacent river level data, hydrogeologic information and/or other database information. The well locations are placed to target at the lesser of 150 meters from the Coal Combustion facilities or at the property boundary. The boundary will be monitored by a well network of one upgradient/background well and two downgradient wells. The upgradient well is located to be representative of background water quality unaffected by a CCP unit. Downgradient wells shall be hydraulically downgradient, and be constructed in such as manner as to detect CCP-related impacts. Wells will be screened in the soil overburden aquifer immediately underlying the site, as the primary receptor of potential migrating CCP-borne constituents in groundwater. TVA believes the proposed well locations will provide an adequate monitoring system for the WBF Ash/Settling Pond during closure and post-closure. A site map of the area is provided in **Figure 1-1**. The proposed well locations are provided in Figure 2-1.

1.1 Summary of Site Geology and Hydrogeology

The project area lies within the Tennessee Valley and Ridge Physiographic Province. This province is characterized by a series of elongated low ridges with intervening valleys that trend in the northeast-southwest direction. The geology of the Valley and Ridge consists primarily of sedimentary bedrock dominated by late Cambrian and early Ordovician material. These materials include limestone, sandstone, dolomite, and shale.

A previous subsurface exploration program consisted of ten (13) test borings (B-1, B-2, B-3, B-103, B-104, B-104A, B-105, B-106, B-107, B-108, B-109, B-110, and B-111) and three (3) hand augers (HA-1, HA-2, and HA-3). Test boring depths ranged from 28 to 58.5 feet below existing ground surface (ft-bgs) and hand auger depths ranged from 13 to 16 ft-bgs. Test boring locations B-3, B-103, B-107, and B-110 were converted to groundwater observation piezometers upon completion. The boring and hand-auger locations are shown on **Figure 1-2.**

Subsurface soil conditions were interpreted based on the subsurface explorations performed as part of this program, as well as CDM Smith's understanding of the local geology. Test borings drilled through the containment berm at the site generally encountered fill underlain by alluvial soil underlain by bedrock. Test borings drilled through the splitter dike and in the Dry Ash area at the site generally encountered CCP materials underlain by alluvial soil underlain by bedrock. A description of each unit is provided in sections 1.1.1 to 1.1.4.

1.1.1 Fly Ash/Bottom Ash (CCP Materials)

Fly Ash was encountered in the hand augers (HA-1, HA-2, and HA-3) and borings (B-109, B-110, and B-111) located in the Dry Ash Area, north of the Ash/Stilling Pond. The fly ash material was generally wet, very loose to loose, and fine-grained. Bottom ash was encountered in the borings performed through the splitter dike (B-104 and B- 104A). The bottom ash material was generally wet, medium dense to dense, and medium- to coarse-grained.

1.1.2 Fill

Fill consisting of clay and silt was encountered in B-103, B-105, B-107, and B-108. The fill material was generally moist, varying in stiffness and was encountered at depths up to 23 ft-bgs.

1.1.3 Alluvial Soil

The fill was underlain by alluvial soils consisting of sand and silt with varying amounts of clay. The stratum typically consisted of soft/loose to stiff/medium dense, gray or brown, sandy silt with varying amounts clay. Typically gravel-sized rounded river stone with varying amounts of sand were encountered within 1 to 5 feet of auger refusal.

1.1.4 Interbedded Limestone and Shale

The alluvial soil was underlain by bedrock consisting of interbedded limestone and shale. The limestone was typically hard, moderately to highly weathered, and extremely thin to thin bedding with very poor rock quality designation. The shale was extremely weathered with very little recovery during coring. The top of bedrock was encountered at the boring locations between EL. 664.4 and EL. 669.2.

1.1.5 Groundwater Conditions

Groundwater levels were measured in the groundwater observation wells installed as part of CDM Smith's geotechnical investigations and are summarized in **Table 1-1**. In general, groundwater elevation readings in the containment berm east of the Ash/Stilling Pond typically ranged from approximately EL. 683 to EL. 684. The groundwater elevation in the Dry Ash Area northwest of the Ash/Stilling Pond was approximately EL. 700, as measured in the observation well installed in this area. Based on the measured groundwater elevations in this area, the water table occurs in the alluvial soil.

Groundwater elevations collected on June 20, 2012 from the wells installed during investigations were used to determine generalized groundwater flow direction for the area, as shown on **Figure 1-2**. The groundwater elevations in the Ash Pond Area indicate that groundwater flow is generally from west to east toward Chickamauga Lake, with eventual discharge to Chickamauga Lake.

Table 1-1
Groundwater Elevation Summary
TVA Watts Bar Fossil Plant
Ash Pond Closure Area

Boring Location	Ground Surface Elevation (1)	Groundwater Level Readings		Date
		feet below ground surface	Elevation (ft)	
B-1	699	12.1	686.9	11/16/2011
		9.3	689.7	1/11/2012
B-2	711	27.4	683.6	1/10/2012
B-3	701	15.7	685.3	11/16/2011
		19.0	682.0	1/10/2012
		18.1	682.9	1/11/2012
		17.4	683.6	6/15/2012
		17.5	683.5	6/20/2012
		17.6	683.4	3/29/2013
B-103	711	27.2	683.8	6/13/2012
		27.3	683.7	6/14/2012
		27.5	683.5	6/15/2012
		27.7	683.3	6/20/2012
B-107	710	27.8	682.2	6/14/2012
		26.2	683.8	6/15/2012
		26.4	683.6	6/20/2012
B-110	707	7.2	699.8	6/20/2012
		4.6	702.4	3/29/2013

Note: Ground surface elevation is approximate. Estimated from hand-held GPS unit.

CDM Smith

Figure No. 1-1
TVA- WATTS BAR FOSSIL PLANT
OVERALL SITE PLAN

MAY 2013

CDM Smith

Figure No. 1-2
GENERAL GROUNDWATER FLOW DIRECTION MAP
TVA- WATTS BAR FOSSIL PLANT
ASH POND AREA
AUG 2007

Section 2

Proposed Groundwater Monitoring System

The proposed monitoring well network for the Ash Pond Area closure will consist of three wells; one new background well and two new downgradient wells. The following nomenclature and well siting rationale will be used for the proposed monitoring wells and surface water location to be installed for the Ash Pond closure area:

MW-1
Monitoring well MW-1 will serve as the background well for the site. It will be installed approximately 300 feet west of the Ash Pond closure area.

MW-2
Monitoring well MW-2 will serve as a compliance well to monitor the uppermost stormwater flow from the southern portion of the closure area. The well will be installed approximately 250-feet from the closure area between the closure area and Chickamauga Lake.

MW-3
Monitoring well MW-3 will serve as a compliance well to monitor the uppermost stormwater flow from the central portion of the closure area, approximately 500 feet north of WBFMW-2. The well will be installed approximately 250-feet from the closure area between the closure area and Chickamauga Lake.

MW-2 and MW-3 will be located hydraulically downgradient of the Ash Pond area, and all will be screened in saturated soil overburden. The monitoring wells will be installed using current industry and regulatory protocols to prevent introducing contaminants during the drilling and installation process. These procedures include, in part: decontamination of the drilling equipment and tools before and after each well by washing with hot, potable water delivered under high pressure; using a new well screen and riser that have been cleaned and sealed in plastic at the factory; and placing washed filter pack sand that is approved by the National Science Foundation (NSF). Other steps employed during the installations will include the workers donning clean, rubber gloves during the handling of downhole equipment and well materials, and using potable water for grouting purposes. Lastly, all fieldwork will be performed and documented under the direct supervision of a qualified hydrogeologist or engineer.

2.1 Monitoring Well Design and Construction

The monitoring well network presented herein has been designed to effectively provide detection monitoring of the uppermost aquifer at the Ash Pond closure area.

2.1.1 Well Network Design

The basis for the well network design is as follows:

- The upgradient well shall be positioned to be representative of the background water flowing under the facility,
- The downgradient wells should be positioned approximately 250 feet away from the CCP waste facility, if feasible,

- All wells shall be screened in similar stratum that would be the most active for contaminant transport.

All of the wells will be screened in the alluvial overburden, above the bedrock. This zone represents the uppermost aquifer at the site, and would likely be the first strata to yield signs of any CCP-borne impact from the ash pond.

2.1.2 Well Selection/Placement Rationale

The wells will be located in the same geologic units so that upgradient and downgradient groundwater quality data can be compared. Based on previous investigations in the closure area, groundwater typically occurs above the bedrock in the alluvium in both the upgradient and downgradient areas of the site.

The background well will be positioned to be free from the influence of any waste disposal facility. The new downgradient wells will provide spatial coverage to detect any impacts on the groundwater quality from the Ash/Settling Pond closure area. Their proposed locations are distributed along the outer boundary of the facility, and screened vertically in the alluvial overburden where migration of contaminants away from the facility would be expected to be detected.

2.1.3 Proposed Monitoring Well Details

A site plan showing the proposed monitoring well locations is provided in **Figure 2-1.** Well construction diagrams and logs will be provided following construction. Anticipated construction details of the proposed monitoring well network for the Ash/Settling Pond closure area are provided in **Table 2-1**.

The well borings will be drilled using 4¼-inch inside diameter hollow-stem augers (nominal 8-inch diameter borehole) through the soil overburden. Standard penetration tests (SPTs) will be performed at five-foot depth intervals through the soil overburden to assist the project engineer in characterizing the subsurface soil materials.

Upon completion of drilling, two-inch diameter Schedule 40 PVC well screen (0.010-inch slots) and riser will be installed in the boreholes. The screen and riser will be flush-joint, threaded PVC pipe. A two-inch diameter Schedule 40 PVC bottom well plug measuring approximately six inches in length will be threaded onto the bottom of the screen. The PVC riser will extend approximately three feet above the ground surface and capped with a locking well expansion plug. Annular backfill will consist of a sand filter pack (20/40 mesh) extending from the bottom of the borehole to an elevation corresponding to approximately two to three feet above the well screen. A minimum two-foot thick bentonite seal will be placed on top of the sand filter pack. Following sufficient hydration of the bentonite seal, the remaining annular backfill, consisting of cement-bentonite grout (5% bentonite by weight), will be tremmied in-place from the top of the seal to the ground surface.

Subsequent wellhead construction will consist of an above-grade, eight-inch square steel locking protective cover set in a five-foot square by approximate four-inch thick concrete surface seal. Lastly, four-inch diameter steel protective barriers filled with concrete will be installed at each corner of the concrete surface seal. A typical monitoring well construction diagram is provided on **Figure 2-2**.

After completing the installation activities, each well will be developed by a combination of bailing and pumping. The bailer will be lowered and raised within the screened interval to create a surging action to dislodge particles within the well and sand filter pack. The bailer will then be removed from the well and emptied. This process will be repeated several times until the turbidity of the water within the well had stabilized. Lastly, a submersible pump will be used to further develop the well until negligible turbidity is achieved.

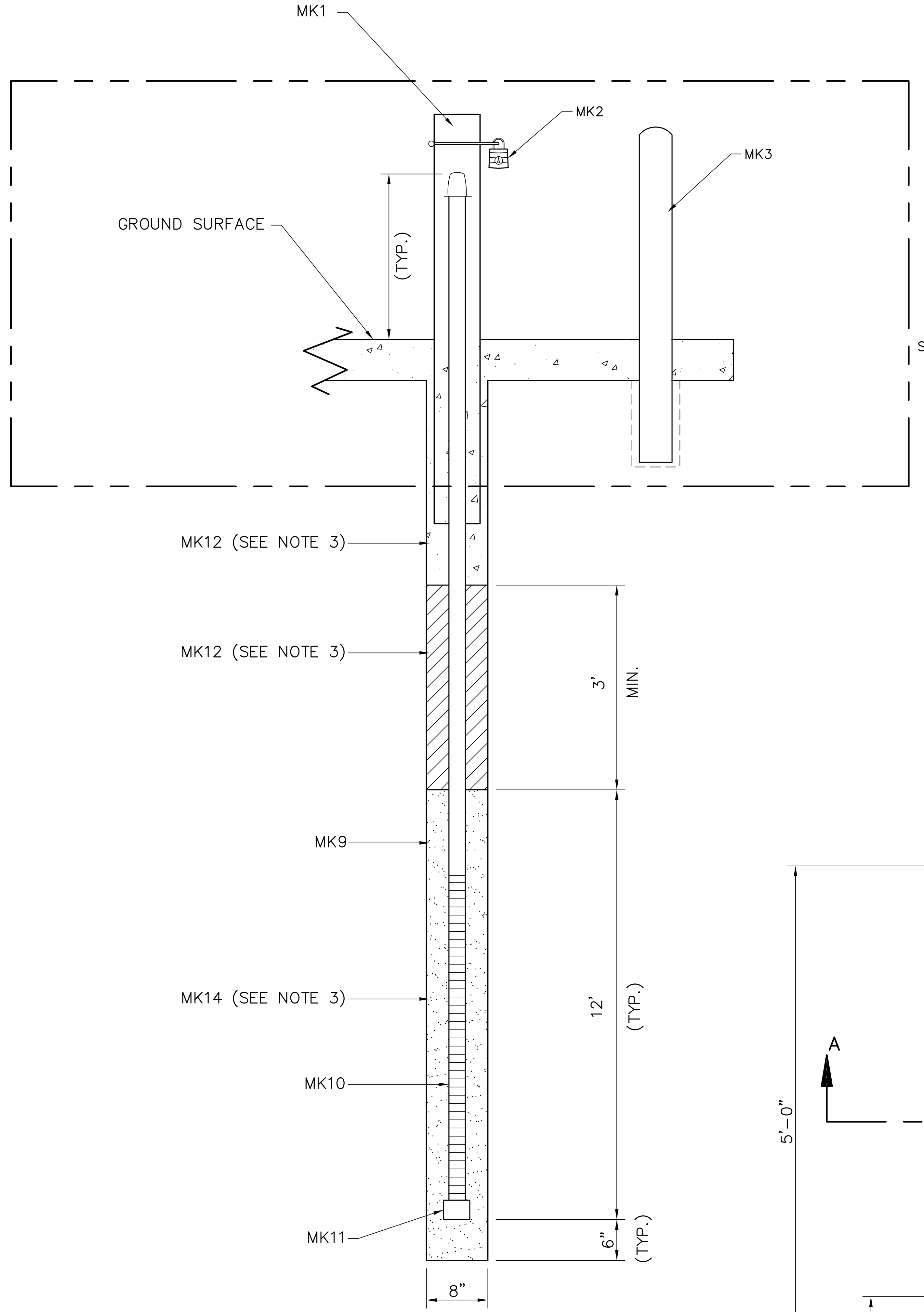
Table 2-1
Proposed Groundwater Monitoring System Details
TVA Watts Bar Fossil Plant
Ash Pond Closure Area

Proposed Monitoring Well I.D.	Ground Elevation* (feet AMSL)	Borehole Depth (feet)	Screened Interval (feet bgs)	Sand Pack (feet bgs)	Bentonite Seal (feet bgs)	Well Borehole Diameter (inches)	Well Casing Diameter (inches)	Rationale
MW-1	710+/-	40 (1)(2)	25 - 40(2)	TBD	TBD	8	2	Proposed upgradient background well installed in alluvium. West of Ash Pond Area.
MW-2	690+/-	25 (1)(2)	10 - 25(2)	TBD	TBD	8	2	Shallow compliance well installed in alluvium to monitor flow from the southern portion of the closure area. The well will be installed approximately 250-feet from the closure area between the closure area and Chickamauga Lake.
MW-3	690+/-	25 (1)(2)	10 - 25(2)	TBD	TBD	8	2	Compliance well installed in alluvium to monitor flow from the closure area, approximately 500 feet north of MW-2. The well will be installed approximately 250-feet from the closure area between the closure area and Chickamauga Lake.

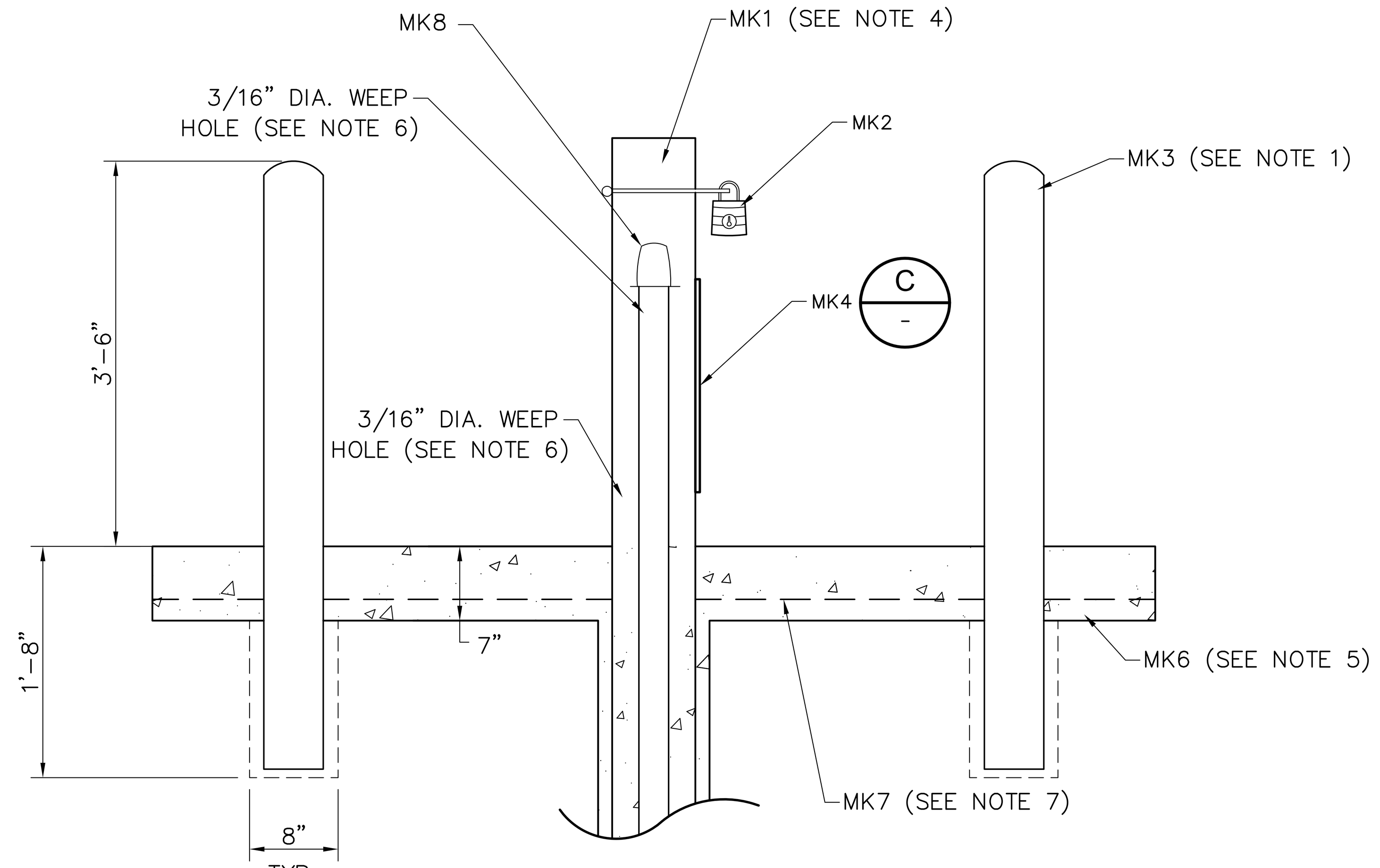
Notes:
(1) Wells will be installed using hollow stem augers.
(2) The borehole and screen interval depths are estimated. Actual depths will depend on subsurface conditions.
AMSL- Above Mean Sea Level
TOC - Top of Casing
NA - Not Applicable

CDM Smith

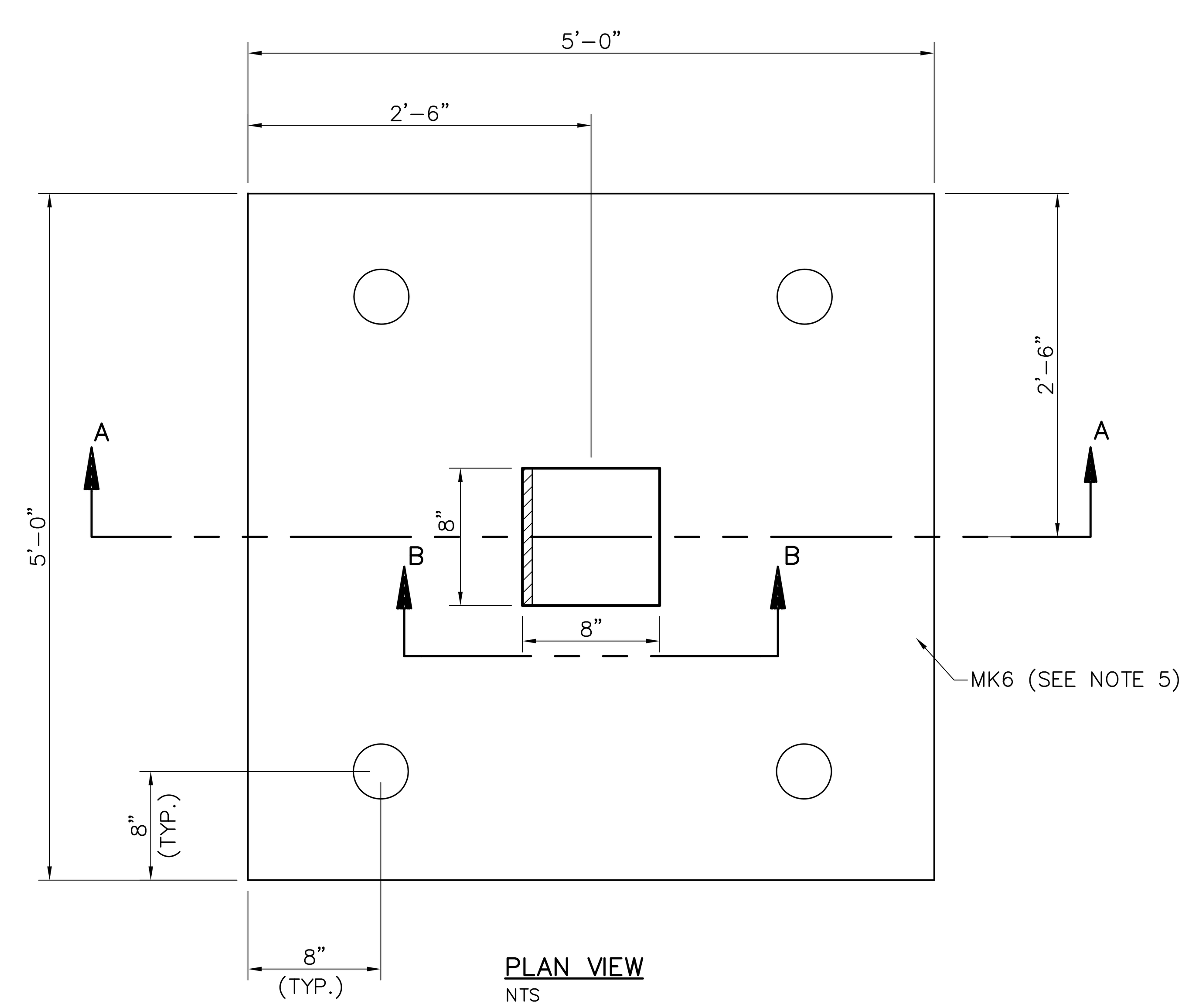
Figure No. 2-1
PROPOSED GROUNDWATER MONITORING NETWORK
TVA- WATTS BAR FOSSIL PLANT
ASH POND AREA
AUG 2007



MONITORING WELL
DETAIL A
NTS



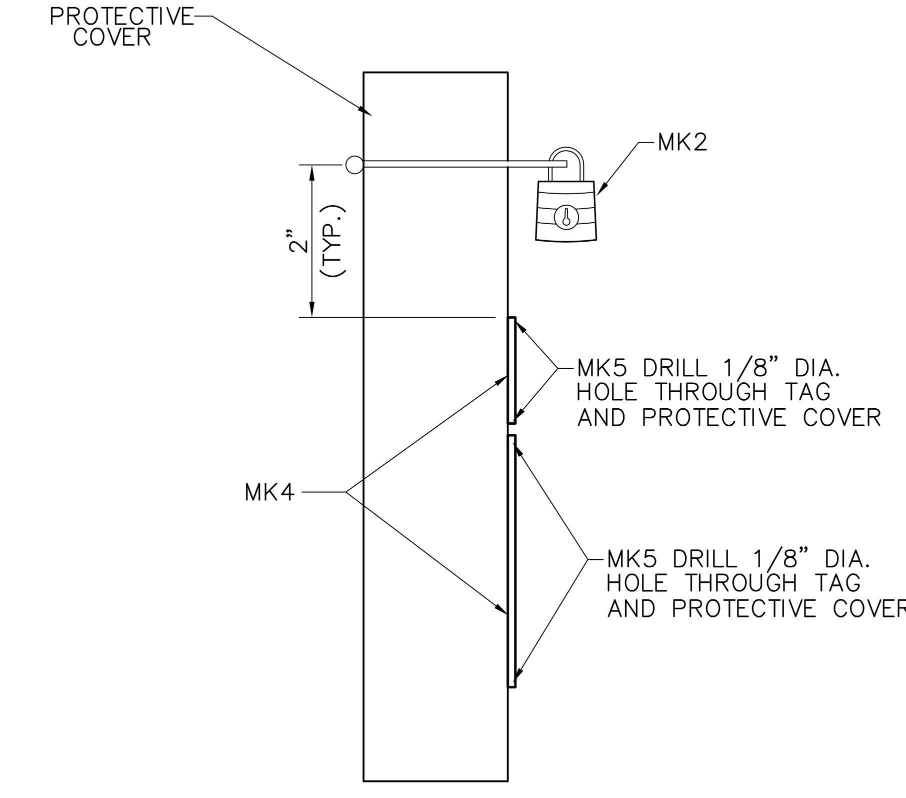
ENLARGED SECTION (A-A)
DETAIL B
NTS



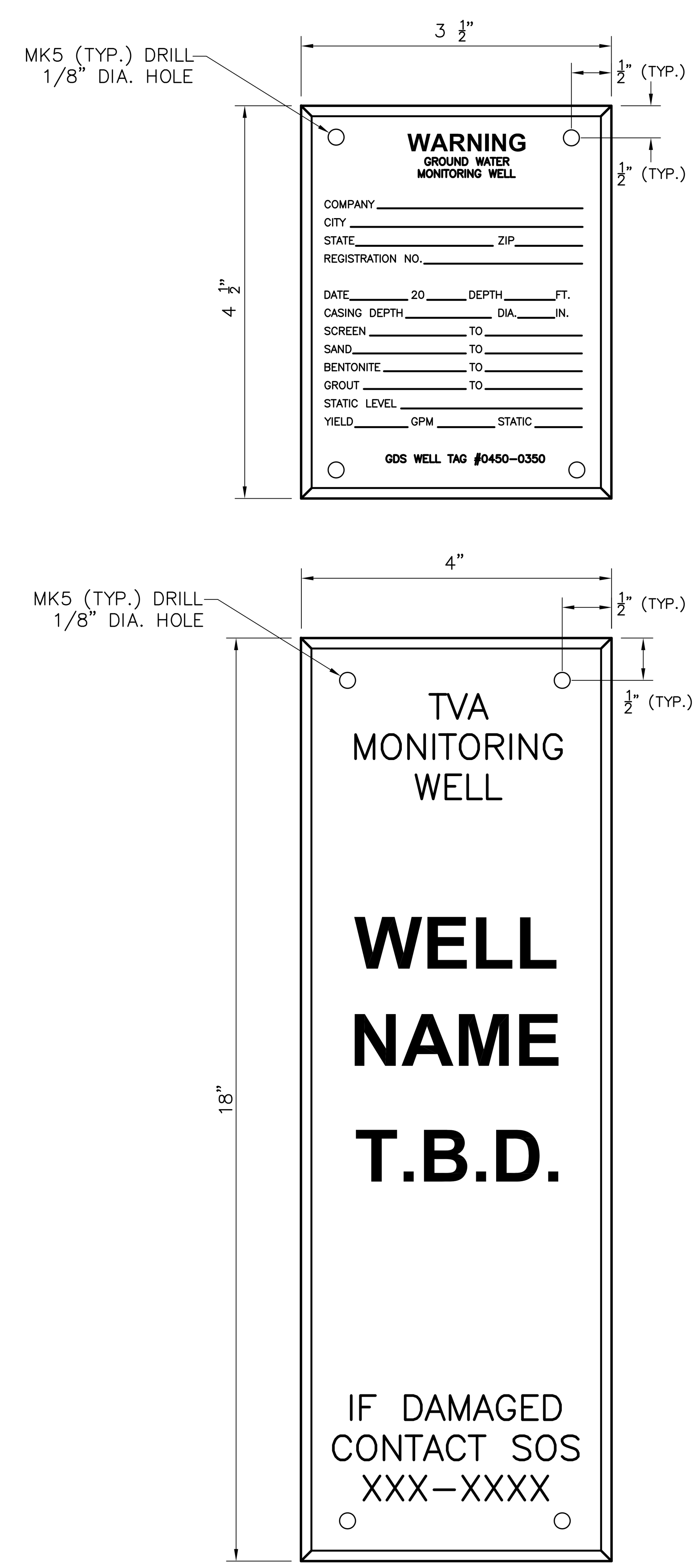
PLAN VIEW
NTS

WELLHEAD NOTES:

1. PROTECTIVE BOLLARDS TO BE FILLED WITH 3000 PSI CONCRETE, AND CONE–TAPER THE TOP.
2. DRILL 3/16" DIA. VENT HOLE 2" BELOW TOP OF THE PVC RISER.
3. NEW PROTECTIVE COVERS DO NOT REQUIRE PAINTING.
4. POSITION PROTECTIVE COVER WITH HINGE AT THE SAME ELEVATION AS TOP OF PVC RISER. FILL INSIDE OF PROTECTIVE COVER WITH CEMENT GROUT TO SAME LEVEL AS CONCRETE PAD.
5. SLOPE CONCRETE UPWARD TO PROTECTIVE COVER TO PREVENT PONDING WATER.
6. DRILL 3/16" DIA. WEEP HOLE AT TOP OF GROUT INSIDE PROTECTIVE COVER.
7. PLACE WIRE MESH 2" MINIMUM FROM ALL CONCRETE EDGES.



WELL I.D. MOUNTING (B-B)
DETAIL C
NTS



WELL I.D. TAGS (MK4)
DETAIL D
NTS

MARK NUMBERS AND MATERIAL LIST

MARK NO.	QUANTITY PER WELL	DESCRIPTION
1	1 EACH	GLOBAL SQUARE STEEL PROCOVER, GALVANIZED GDS SQ–PC 8"X8"X5" PROVIDED BY GLOBAL DRILLING SUPPLY, OR EQUIVALENT
2	1 EACH	BRASS MASTER LOCK, KEYED 0896
3	4 EACH	4" DIA. STEEL PIPE BOLLARD–PAINTED YELLOW, GDS GUARD PIPE 4"X5", PROVIDED BY GLOBAL DRILLING SUPPLY OR EQUIVALENT
4	1 EACH	WELL I.D. TAGS
5	8 EACH	DOME HEAD ALUMINUM RIVET #PASD403E, PROVIDED BY HANSON RIVET & SUPPLY CO. OR EQUIVALENT
6	AS REQ.	CONCRETE 3000 PSI
7	AS REQ.	3/16"X4"X4" WELDED WIRE. OVERLAPPED 4" AT JOINTS
8	1 EACH	2" SCH. 40 PVC SLIP CAP
9	AS REQ.	2" SCH. 40 PVC RISER. JSF 2"X10"–R "FLUSH THREAD", PROVIDED BY GLOBAL DRILLING SUPPLY OR EQUIVALENT
10	1 EACH	2" DIA. SCH. 40 PVC WELL SCREEN. JSF 2"X10'–010 "FLUSH THREAD" PROVIDED BY GLOBAL DRILLING SUPPLY OR EQUIVALENT
11	1 EACH	2" DIA. SCH. 40 PVC BOTTOM CAP. 2" FEM CAP "FLUSH THREAD" PROVIDED BY GLOBAL DRILLING SUPPLY OR EQUIVALENT
12	AS REQ.	GROUT–PORTLAND TYPE I OR II CEMENT WITH 5% BENTONITE BY WT.
13	AS REQ.	BENTONITE SEAL–PDS TR 30/38 COATED PELLET PROVIDED BY GLOBAL DRILLING SUPPLY OR EQUIVALENT. PARTIALLY PRE–HYDRATE PRIOR
14	AS REQ.	FILTER SAND– GLOBAL NO. 7 (20X40MESH) PROVIDED BY GLOBAL DRILLING SUPPLY OR EQUIVALENT

MONITORING WELL NOTES:

1. BORING TO BE ADVANCED WITH HOLLOW STEM AUGERS THROUGH OVERBURDEN TO TARGET DEPTHS.
2. TARGET TIP ELEVATIONS TO BE DETERMINED FROM PRE–INSTALLATION EXPLORATORY BORINGS.
3. ANNULAR BACKFILL MATERIAL (SAND, BENTONITE, AND GROUT) TO BE TREMMIE–PLACED WITH SOUNDING MEASUREMENTS DURING AND AFTER CONSTRUCTION.

PRELIMINARY- NOT FOR CONSTRUCTION

PROJECT REVISION HISTORY

REV. NO.	DATE	DSGN	DRWN	CHKD	SUPV	RVWD	APPD	ISSD	PROJECT ID	AS CONST	REV CD
R											
R A	08/26/13	MC	MB	RN	MC	JM	MT	JK	–	–	–

REVISION NO. A

DISCIPLINE INTERFACE 1 2 3 4

SCALE: NONE EXCEPT AS NOTED

FIGURE 2–2

TYPICAL MONITORING WELL CONSTRUCTION DETAILS WATER QUALITY MONITORING PLAN

DESIGNED BY:	DRAWN BY:	CHECKED BY:	SUPERVISED BY:	REVIEWED BY:	APPROVED BY:	ISSUED BY:
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WATTS BAR FOSSIL PLANT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R2012 | DATE 08/26/2013 | 14 | C | R A

CDM SMITH | A
TASK COMPLETED BY: | REV NO.

PLOT FACTOR:XX
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

Section 3

Groundwater Sampling and Analysis Procedures

The following section briefly summarizes the primary components of the groundwater sampling and analysis plan. These components are described in detail in the following paragraphs; though generally follow the protocols for well purging and groundwater sample collection procedures presented in the U.S. Environmental Protection Agency (USEPA) publication SW-611, Procedures Manual for Ground-Water Monitoring at Solid Waste Disposal Facilities (USEPA, 1980). The document contains protocol for groundwater level measurements, groundwater sample collection, preservation, shipment, record-keeping, chain of custody, quality assurance and quality control, and copies of groundwater quality data field worksheets; and other pertinent forms.

3.1 Groundwater Level Measurements

The depth to water surface from the top of each reference point (e.g., top of well casing) will be measured in each well to the nearest 0.01 foot with an electronic water level indicator before pumping or bailing begins. The groundwater level measurements will be taken for all wells prior to purging and sampling of any well. The total depth of the well will be measured using a weighted tape. The volume of water present in the well prior to sampling will be calculated and recorded along with other well measurements and observations on the Groundwater Data Field Worksheet (TVA Form 30066A) in **Appendix A**. The water level indicator will be cleaned after each measurement by rinsing with distilled water and wiping dry as it is wound on the reel.

3.2 Groundwater Purging and Sampling

A sheet of plastic will be spread on the ground prior to well purging to minimize the potential for contamination caused by contact of the equipment with the ground surface. Wells will be purged prior to sampling to ensure that representative groundwater is obtained from the uppermost aquifer. Either the low-flow minimal drawdown or volume-averaging purging methods will be performed. Low-flow sampling will be performed in general accordance with USEPA published protocols (USEPA 1996A and 1996B) or the American Society for Testing and Materials standard practice (ASTM, 2002). Volume-averaging purging will be performed by removing a minimum of three columns of water from a well using a variable-speed submersible pump or bailer.

For low-flow sampling, field parameters will be continuously monitored while purging using a calibrated, in-line, multi-parameter, flow-through cell. Sample collection will begin after stabilization of the field parameters. Parameter stability will be defined as three successive readings taken at 3- to 5-minute intervals that are within ±0.1 for pH, ±3% for conductivity, ±10% for turbidity (or less than 10 NTU), and ±3% °C for groundwater temperature. For the volume averaging purging method, field parameters will be measured periodically during purging in an open sample container using a calibrated multi-parameter water quality meter, but purging will be considered complete upon the removal of three columns of water from the well.

Time, purge rate, and groundwater level will be periodically recorded throughout the purging operation. Well purge water will be handled in accordance with applicable investigation derived waste (IDW) protocols and regulations.

If a low yielding well is purged dry, a sample will be collected using a new disposable Teflon bailer or pump as soon as sufficient water is present in the well to obtain the necessary sample volume.

Samples will be collected directly from the pump discharge line (or disposable bailer) in new certified sample containers containing appropriate preservatives (where applicable). Clean nitrile (or equivalent) gloves will be worn when handling sample containers and the sampling equipment. When filling sample bottles, care will be taken to minimize sample aeration and overfilling. Sample bottles will be filled one at a time and capped before filling the next bottle. Samples will be placed on ice immediately after collection.

All sample containers will be labeled with permanent sample identifications (ID). This sample ID number will be unique for each sample collected and will be cross-referenced on all field sheets and on the sample chain of custody (COC) form. An example COC is provided in Appendix A.

Any problem observed that might affect the quality of these procedures will be identified and recorded on the field data sheet, along with the action(s) taken to resolve it. Problems that might affect quality include clogged sampling tubes, highly turbid samples, defective material or equipment, failure to comply with quality procedures, or atmospheric/ambient conditions.

3.3 Field Instruments and Equipment

Field equipment will be calibrated according to the manufacturer's specification. Calibration results will be recorded in the project field logbook. Field equipment will also receive routine maintenance checks in order to minimize equipment breakdown. Maintenance checks will generally coincide with the calibration procedures. Any equipment found to be operating improperly will be taken out of use, and a note stating the time and date of this action will be made in the field log book.

In the instance that a piece of field equipment malfunctions, it will be repaired, replaced, or recalibrated, as necessary. This will be performed according to the instrument manufacturer's operation and maintenance manual. Once completed, the time and date of its return to service will also be recorded. Experienced personnel will perform all field equipment preventive maintenance. The preventive maintenance requirements and procedures for laboratory analytical equipment will be specified in the laboratory quality assurance (QA) manuals.

3.4 Sampling Equipment and Decontamination Procedures

To minimize the potential for cross contamination, non-dedicated sampling equipment (i.e., submersible pumps, water-level indicator, and other non-disposable sampling equipment) will be decontaminated prior to use and following the sampling of each well. Pumps will not be removed between purging and sampling operations. The pump and tubing (including support cable and electrical wires that are in contact with the well) will be decontaminated by first flushing/rinsing with either (a) deionized (DI) water or potable tap water if no organic contaminants are present in the groundwater, or (b) a non-phosphate detergent solution (e.g., Liqui-Nox®), if organic contamination is suspected. Equipment will then undergo final flushing/rinsing with DI water to remove initial rinsate.

3.5 Data Quality Objectives

Data Quality Objectives (DQOs) are qualitative and quantitative statements that specify the quality of the data required to support decisions made using the analytical data. DQOs are determined by the intended use of the analytical data. Therefore, DQOs must be specific for each site and project activity.

This groundwater monitoring plan provides the information necessary to develop and implement field sampling, COC forms, laboratory analysis, and chemical data reporting procedures that will provide adequate coverage and analytical data. The minimum data documentation requirements for the groundwater monitoring activities are outlined as follows.

3.5.1 Sampling Quality Control Data and Information

The following information shall be recorded and maintained:

- Sender's COC forms;
- Date and time each sample was taken;
- Map or diagram indicating sample locations;
- Any notable observations (color, clarity, texture, reaction with preservatives, etc.);
- Trip Blank (if Volatile Organic Compounds (VOCs) or Semi-Volatile Organic Compounds (SVOCs) are sampled);
- Equipment Blank (Rinsate Blank);
- Identity of field duplicates (a minimum of one duplicate for every 20 or fewer samples).

3.5.2 Laboratory Quality Assurance/Quality Control (QA/QC) Data

The following information shall be recorded and maintained:

- Lab -completed COC forms;
- Date and time of receipt at the laboratory;
- Condition of samples upon receipt at the laboratory;
- Sample identification number or designation;
- Sample preparation, extraction, cleanup, or digestion method(s) and date(s);
- Analytical method (name, number, and source) and date of analysis; and
- Final analytical results
- Case narrative (Includes deviations from standard analytical or preparatory procedure(s); quality control problems encountered—whether stemming from system, instrumentation, analyst error, or sample matrix; corrective measures taken; if corrective measures as called for in the method were not taken; results of corrective measures taken; etc.).

3.6 Field Quality Control Samples

Field QC samples will routinely include one set of equipment blanks and one pair of duplicate samples collected from a single monitoring well. If VOC or SVOC sampling is performed, one trip blank will also be collected. QC samples will be identified on the sample container label and on the COC documentation.

3.6.1 Trip Blanks

A trip blank will be prepared in the laboratory and accompany sample containers at all times. It will be logged on the COC and handled in the same manner as other samples, except that it will remain unopened. Typically, trip blanks are only used when groundwater samples are collected for VOCs.

Based on the selected analytical parameters, trip blanks are not anticipated to be necessary. However, if trip blanks are necessary, there will be one analyzed per sampling event.

3.6.2 Equipment Rinsate Blanks

An equipment rinsate blank is prepared in the field using deionized/distilled water provided by the laboratory. The lab-provided water is poured over/through sampling equipment that has been previously decontaminated. The rinsate is then collected into the appropriate sample bottles and analyzed for the same parameters as the primary groundwater samples. The purpose of this blank is to confirm that field conditions and/or the equipment are not introducing contaminants to the samples. Equipment rinsate blanks will be collected at a rate of 1/week/matrix or 1/20 samples/matrix, whichever is less, with a minimum of one rinsate blank every sampling event.

3.6.3 Field Duplicate Samples

A field duplicate sample will be collected simultaneously with a primary field sample using the same sample collection methodology. The results will provide some indication of the homogeneity of the sample medium and the precision of the field sampling and laboratory sample analysis. Accurate field notes will be used to match each duplicate to its corresponding investigatory sample. Field duplicate samples will be transported to the laboratory along with other samples. Field duplicates will be collected at a rate of 1/10/matrix, whichever is less, with a minimum of one duplicate blank every sampling event.

3.7 Chain-of-Custody Control

The groundwater monitoring program is designed to confirm the integrity of samples from time of collection to time of laboratory data reporting. This includes the ability to trace the possession and handling of samples from the time of collection through analysis and final disposition. All environmental samples will be handled under strict COC procedures, beginning in the field. The designated Field Team Leader will be the field sample custodian and will be responsible for verifying that the procedures are followed. Sample custody for field activities will include the use of COC forms, sample labels, custody seals, and field logbooks.

When the COC is initiated at the laboratory, the laboratory personnel responsible for shipping sampling containers will have initiated and signed the COC form and sealed the shipping container with a COC seal. The field staff will acknowledge receipt and container integrity by signing the COC form, noting any discrepancies. If custody of the samples (and sample containers) are exchanged during field sampling, such transfer must be documented on the COC form. When samples are sent to the analytical laboratory, the shipping method and tracking number will be recorded on the COC prior to shipping and in the field logbook, and the Field Team Leader will retain a copy of the completed COC. An example COC form is included in Appendix A.

3.8 Laboratory Analyses

The unfiltered groundwater samples will be analyzed for the 17 inorganic constituents listed in Appendix I of Rule 0400-11-01-.04 (**Table 3-1**). With the exception of mercury, and fluoride, the inorganics will be analyzed by EPA Method 6010/6020. Mercury will be analyzed by EPA Method 7470/7471, and Fluoride by EPA method 300 as shown in Table 3-1. Any deviation from these analytical methods will be documented in the narrative of groundwater monitoring reports.

Analysis of required constituents will be performed in accordance with USEPA SW-846 methods. Laboratory reporting limits will be the lowest practical quantitation limits that can be reliably achieved within specified limits of precision and accuracy with a target of at least four times below MCLs in Appendix III of Rule 0400-11-01-.04 or other Groundwater Protection Standards (GWPS) approved by TDEC.

The laboratory will maintain detailed records of analytical procedures for a minimum of five years, in order to support the validity of the analytical work. Each laboratory data report will verify that the approved analytical method was performed and that QA/QC checks were within the established protocol limits. The verification must be provided by the laboratory project manager, laboratory manager, or QA officer. Any QA problems encountered during sample analysis will be clearly described in the laboratory report.

3.9 Recordkeeping

A project field logbook(s) will be maintained by TVA or their representative. The logbook and field data sheets addendum to the logbook will be used to record pertinent data and observations for each sampling event. Between sampling events the logbook will be maintained by the project lead in a secure location (e.g., office project file). A sample field data sheet, form TVA 30066A, is included in Appendix A.

TVA will maintain records of groundwater monitoring data including monitoring reports, laboratory analytical reports, and groundwater elevation data. TVA will retain other relevant and appropriate project information in project files including field notes, correspondence, and reference information. These records will be maintained throughout the post-closure care period.

Table 3-1
Appendix I Inorganic Constituents and Analytical Methods
for Detection Monitoring
TVA Watts Bar Fossil Plant
Ash Pond Closure Area

PARAMETER	UNITS	ANALYTICAL METHOD
Antimony	ug/l	SW-846 6010/EPA 200
Arsenic	ug/l	SW-846 6010/EPA 200
Barium	ug/l	SW-846 6010/EPA 200
Beryllium	ug/l	SW-846 6010/EPA 200
Cadmium	ug/l	SW-846 6010/EPA 200
Chromium	ug/l	SW-846 6010/EPA 200
Cobalt	ug/l	SW-846 6010/EPA 200
Copper	ug/l	SW-846 6010/EPA 200
Fluoride	ug/l	EPA 300
Lead	ug/l	SW-846 6010/EPA 200
Mercury	ug/l	SW-846 7470/EPA 200
Nickel	ug/l	SW-846 6010/EPA 200
Selenium	ug/l	SW-846 6010/EPA 200
Silver	ug/l	SW-846 6010/EPA 200
Thallium	ug/l	SW-846 6010/EPA 200
Vanadium	ug/l	SW-846 6010/EPA 200
Zinc	ug/l	SW-846 6010/EPA 200

Section 4
Groundwater Monitoring Program

The following section describes the Groundwater Monitoring Program that is proposed for the Watts Bar Fossil Plant Ash Pond Area which in lieu of any specific regulations for ash pond closures, follows the TDEC Solid Waste regulations established in Rule 0400-11-01-.04. The proposed Detection Monitoring Program for the Area will be implemented upon closure, and TDEC's approval of this plan. The Area will be closed in accordance with the schedule provided in the Closure Plan.

4.1 Detection Monitoring Program

The ash pond area at WBF does not have an existing groundwater monitoring network. Because no historical sampling has occurred, data is needed to establish a statistical baseline and initial background concentrations in the wells. In order to establish baseline data levels, 8 samples shall be collected and analyzed from each of the newly installed wells within the first two years following installation. During the sampling events, groundwater samples from the monitoring wells will be analyzed for the inorganic constituents listed in **Table 3-1**.

None of the volatile organic compounds listed in Appendix I of TDEC Solid Waste Regulations are expected to be present in coal combustion products. Therefore only the inorganic parameters are proposed for the Detection Monitoring Program. The analytical methods used to analyze all samples will be the appropriate methods from EPA Publication SW-846, and are listed in **Table 3-1**.

The laboratory reporting limits (PQL or PQL equivalent such as EQL, RL, LOQ, etc.) will be the lowest practical quantitation limits that can be reliably achieved within specified limits of precision and accuracy, with a target of at least four times below all established ground water protection standards in Appendix I of Rule 0400-11-01-.04, or other ground water protection standards approved by TDEC. There are SW-846 methods (e.g., 6010B) that have a few analytes (e.g. antimony, cadmium, and thallium) with practical quantitation limits (laboratory reporting limits) that are greater than groundwater protection standard(s). In those few cases, another SW-846 method (e.g., 6020) will be used with the laboratory reporting limits being the lowest PQL that can be reliably achieved within specified limits of precision and accuracy.

Groundwater monitoring will be conducted semi-annually after closure for long-term monitoring, unless statistical or MCL exceedance triggers additional action by TDEC. While sampling, the Field Data Sheet (TVA Form 30066A) will be used to document that all samples will be unfiltered.

4.1.1 Reporting

TVA will submit to TDEC the groundwater sampling and analysis results, statistical determinations, and associated recordings of the groundwater surface elevations within 60 days of the last day of sampling, unless otherwise directed by TDEC. The groundwater monitoring reports will provide the following:

- A description of the sampling procedures performed (including field measurements of pH, conductivity, temperature, turbidity, etc.; and calculations/measurements of purge volumes), the date(s) and time(s) of field activities (including field instrument calibration and decontamination), and the weather conditions at the site when the activities were performed.

- The mean sea level (MSL) elevation of the top of the casing for each monitoring well, the location and the groundwater surface elevations for each monitoring point, and the groundwater flow direction and gradient.
- A description of the results of the inspections of all monitoring wells pad, aboveground casing, locking cap, and lock.
- A scaled map of the facility showing the locations of all monitoring points and the MSL potentiometric surface determined from water level measurements collected during the event, the property boundaries, and closed fill areas.
- A list of the monitoring parameters and the methods used to analyze the samples.
- Copies of the COC forms and the laboratory report sheets.
- Tables summarizing the most recent analytical data for each monitoring point compared to background groundwater quality concentrations and groundwater protection standards.
- The statistical method described in Section 4.1.2 will be used in evaluating monitoring data.
- The results of the statistical evaluation to determine whether or not there has been a statistically significant increase above background values for all naturally occurring parameters/constituents monitored.
- A conclusion section that summarizes the results of the groundwater sampling event, notes anything unusual, and provides the appropriate sampling/analyses determinations (based on the appropriate groundwater monitoring program) and the approximate start date for the next planned sampling event. The conclusion shall also summarize all naturally occurring constituents that are statistically significant above background values, all detected constituents that do not naturally occur, and all constituents that exceed the groundwater protection standards established.
- Certification by a person representing TVA as described in Rule 0400-11-01-.04.

4.1.2 Statistical Data Evaluation

An interwell statistical analysis, consistent with the requirements of Rule 0400-11-01-.04 will be the methodology applied to future monitoring data to assure timely detection of statistical exceedances at the compliance monitoring boundary. Normality testing will be used to evaluate the data at a 0.01 or 0.05 significance level, in accordance with Rule 0400-11-01-.04 (7) (a) 4. (vi). Generally, only 25% of the data are either normally or log-normally distributed, while 75% are non-normal. The high percentage of non-normally distributed data is generally due to a high percentage of measurements below analytical reporting limits.

In general the NPI method assumes that the distribution of baseline and future compliance sampling data are identical in the absence of contamination from a facility. An upper prediction limit (UPL) for each constituent is determined based on the maximum concentration detected during the baseline sampling period. A baseline data set will be compiled by collecting 8 semi-annual samples from the upgradient and downgradient wells.

4.1.2.1 Statistical Methods

When the statistical characteristics of monitoring data match the distribution described above, that indicates that the prediction interval methods adapted by Gibbons (1990 and 1994) would likely be applicable to the groundwater detection monitoring program. Either parametric or nonparametric prediction interval methods would be applied depending on normality of individual constituent data. In general, one-sided upper prediction limits (UPLs) derived from n baseline measurements from each well and having a (1-α) probability of including at least one of two future measurements at the well would be computed for each constituent using the methods of Gibbons (1994, pp. 8-76), where α is the Type 1 (false-positive) error level. Future sample measurements from each well will be compared to baseline UPLs developed from a minimum of eight baseline monitoring events for each well. If a new measurement exceeds a UPL, one verification resample would be collected from each monitoring well having a statistical exception. The resample would be analyzed only for the exceeded constituent(s). Should the resample result exceed the UPL, the exception would be deemed statistically significant; otherwise, the original UPL exception would be considered insignificant.

A site-wide Type 1 error rate as discussed above in Section 4.1.2 would be maintained in application of the parametric prediction interval method. The corresponding individual sample constituent error rates for comparisons would be computed and reported based on the number of compliance locations, constituents, and verification resamples using the methodology presented in ASTM D6312-98 (ASTM, 2005). For nonparametric prediction interval testing, the confidence level is based only on the number of sample data in the baseline dataset and the number of resamples. Constituent UPLs would be continually updated as new sample measurements are added to the pool of data.

Statistical analysis of monitoring data will be performed using MANAGES (version 3.0) data management and evaluation software (Electric Power Research Institute [EPRI], 2006), or similar data management and software programs. The statistical analysis includes characterization of the data, assumption testing, and specific statistical comparisons to test hypotheses, which involve testing for trends and seasonality, and interpretation of results. All methods used will be in accordance with the following USEPA guidance and ASTM standards:

- Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities – Unified Guidance Office of Resource Conservation and Recovery Program Implementation and Information Division USEPA, EPA 530-R-09-007, March 2009.

- ASTM D7048 Standard Guide for Applying Statistical Methods for Assessment and Corrective Action Environmental Monitoring Programs.

- ASTM D6312 Standard Guide for Developing Appropriate Statistical Approaches for Groundwater Detection Monitoring Programs.

Monitoring well data will also be compared to the TDEC MCLs listed in Appendix III of Rule 0400- 11-01-.04. If the MCL is exceeded during a subsequent sampling event, the well will be resampled to conduct confirmation sampling. If all the resample measurements exceed the MCL, the original exceedance will be confirmed. If the resample results are below the MCL, the original exceedance is considered insignificant.

4.2 Assessment Monitoring Program

If groundwater detection monitoring results indicate either a SSI above background for any naturally occurring constituent or a confirmed detection of any required monitoring parameter that does not occur naturally, TDEC DSWM will be notified within 14 days of this finding.

4.3 Post Closure Monitoring

Groundwater monitoring will be conducted semi-annually following the Ash Pond closure for long-term monitoring purposes, unless exceedances trigger additional from TDEC.

4.4 Monitoring Well Abandonment

Well abandonment is conducted to prevent the well from becoming a conduit for water or contaminants to migrate from the ground surface to the aquifer or between aquifers. Well abandonment will be performed by a Tennessee licensed driller in a manner consistent with TDEC Rules and ASTM standards. The preferred method of abandonment is to completely remove the wells outer casing (sometimes known as surface casing), the riser pipe, and the well screen from the borehole; however, certain situations may warrant grouting the well or a portion of the casing in place (e.g., if removing a well that is grouted into rock would potentially create a greater migratory pathway to the aquifer, then the well will be properly sealed in place).

Wells that have been constructed with an outer casing will be filled from the bottom of the well, up to the bottom of the outer casing using the positive displacement method ("tremie method"). A Type-1 Portland cement (ASTM C-150 or equivalent) mixed with potable water and 3-5% bentonite will be used as the plugging material. The cement mixture will be allowed to cure, and the tremie method may be performed in lifts or stages depending on boring depth. The wells outer casing will then be removed by either overdrilling or excavation and winch line extraction. The borehole will then be sealed to a depth of approximately 2 feet below the ground surface with the cement mixture using the tremie method. In situations where removal of the outer casing is impractical or not feasible, the casing will be cut approximately 2 feet below ground surface and the entire length of pipe will be sealed with the cement mixture using the tremie method. After the cement mixture has hardened, the boring will be topped off with material that matches the surrounding ground surface (e.g., soil and seeded, asphalt, stone, etc.).

Piezometers installed at the site for the geotechnical investigation will be properly abandoned prior to beginning closure activities. If the integrity of a permanent monitoring well is compromised (or is suspected of being compromised) prior to the completion of the Post Closure Monitoring period, TDEC DSWM will be promptly notified and the well will be properly abandoned in a manner consistent with the methods referenced above. A replacement well will be installed if required by TDEC DSWM. At the completion of the Post Closure Monitoring period, all monitoring wells associated with the landfill monitoring network will be properly abandoned.

Section 5
References

ASTM, 2002. Standard Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations. American Society for Testing and Materials. D6771-02. 2002.

ASTM, 2005. Standard Guide for Developing Appropriate Statistical Approaches for Ground-Water Detection Monitoring. Designation D6312–98. West Conshohocken, Pennsylvania: American Society for Testing and Materials. 2005.

ASTM, 2010. Standard Guide for Applying Statistical Methods for Assessment and Corrective Action Environmental Monitoring Programs. D7048-10. 2010.

CDM Smith. 2012. Technical Memo. Geotechnical Design Memorandum Watts Bar Fossil Plant Coal Combustion Products Closure Project Phase 2 - Ash/Stilling Pond Breaching Project. August.

Tennessee Department of Environment and Conservation (TDEC), Division of Geology.

EPRI (Electrical Power Research Institute), 2006. MANAGES 3.0, Groundwater Data Management and Evaluation Software, Version 3.0.

Gibbons R. D., 1990. A general statistical procedure for groundwater detection monitoring at waste disposal facilities. Groundwater. 282 pp. 235-243.

Gibbons R. D., 1994. Statistical Methods for Groundwater Monitoring. J. Wiley Sons Inc. New York New York.

TDEC-DSWM. Ground Water Monitoring Guidance for Solid Waste Landfill Units.

USEPA, 1980. Procedures Manual for Ground Water Monitoring at Solid Waste Disposal Facilities.

U.S. Environmental Protection Agency, Report EPA/530/SW-611; 68-01-3210; PB84-174820, 266 p.
USEPA, 1996A. Ground Water Issue, Low-Flow (Minimal Drawdown Sampling Procedures). Document Number 540/S-95/504. Office of Research and Development, Office of Solid Waste and Emergency Response. April, 1996.

USEPA, 1996B. Low Stress (Low-Flow) Purging and Sampling Procedure for the Collection of Ground Water Samples from Monitoring Wells. Revision 2. USEPA Region I. July, 1996.

USEPA, 2009. Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities. Unified Guidance, EPA 530/R-09-007. Office of Resource Conservation and Recovery. March 2009.

Appendix A

Sample Monitoring Forms

Preliminary Groundwater Data Field Worksheet

Sheet ____________ **of** ____________

Project/Site	Well Number 84068	Purge Date	Year	Month	Day

Depth to Water (m) 4195	Bottom of Well (m) 4194	Well Diameter (mm) 4188	Survey Leader	Field Crew
☐ Depth of Screen	☐ Open Bore Hole			
(m) 4191	To	(m) 4190	Sample Label	☐ Unfiltered ☐ Filtered ☐ Both Filter Type and Size:

[Bottom of Well - Depth to Water] x Volume Factor =	Well Volume	Target Purge Volume	Actual Purge Volume
[( )m - ( )m] x ( )L/m =	(L)	(L)	(L) 4186

Purge Pump: ☐ Bladder ☐ Centrifugal ☐ Peristaltic ☐ Dedicated **Other (list):** ____________

Sample Pump: ☐ Bladder ☐ Centrifugal ☐ Peristaltic ☐ Dedicated **Other (list):** ____________

Notes and WQ Observations	Time ET CT	Pump Rate (L/min)	Depth to Water (m)	Pump Depth (m)	Temp °C	pH (s.u.)	DO (mg/L)	COND (umhos/cm)	(+/-) ORP (mV)	Turbidity (NTU)
Begin Purge →										

Remarks: ____________

Reviewed By: ____________ Survey Leader ____________ Date ____________ Project Leader ____________ Date

Sample Collector:			
Sample Date			Time
Year	Month	Day	ET CT
Pump Duration:			min 72004

"999" = 2 days

Sample Readings

	4193	4192	10	400	300	94	90	
Analysis Time ET CT	Pump Rate (L/min)	Pump Depth (m)	Temp °C EPA 170.1	pH (s.u.) EPA 150.1	DO (mg/L) EPA 360.1	COND (umhos/cm) EPA 120.1	(+/-) ORP (mv) SM 2580B	Turbidity (NTU) EPA 180.1

Additional Sample Data

Analyst:					
Date Analyzed	415	431	436	437	
Year Month Day	Phenol Alkalinity mg/L (EPA 310.1)	Total Alk. mg/L (EPA 310.1)	Mineral Acidity mg/L (EPA 305.1)	CO_2 Acidity mg/L (EPA 305.1)	
Turbidity 1350 ☐ Clear ☐ Slightly Turbid ☐ Turbid ☐ Highly Turbid	Time:	Time:	Time:	Time:	
	Initial:	Initial:	Initial:	Initial:	
Color:	Bottles Required ☐ BOD ☐ COD ☐ TOC ☐ TIC	☐ Ferrous ☐ Metals ☐ Dis. Metals	☐ Mineral ☐ Dis. Mineral ☐ Nutrient	☐ Phenol ☐ Filt TIC ☐ TSS/TDS	Others (list):
Odor:					

Well Diameter (mm)		Vol. Factor (L/m)
12.7	(0.5 in)	0.127
51	(2 in)	2.027
76	(3 in)	4.560
102	(4 in)	8.107
127	(5 in)	12.668
153	(6 in)	18.228

>>> Select a Laboratory <<<

#N/A
#N/A
#N/A
#N/A

TestAmerica — THE LEADER IN ENVIRONMENTAL TESTING

Chain of Custody Record

TestAmerica Laboratories, Inc.

Client Contact	Project Manager:	Site Contact:	Date:	COC No:
Your Company Name here	Tel/Fax:	Lab Contact:	Carrier:	_______ of ______ COCs
Address	**Analysis Turnaround Time**			Job No.
City/State/Zip	Calendar (C) or Work Days (W) __________			
(xxx) xxx-xxxx P hone	TAT if different from Below _________			
(xxx) xxx-xxxx F AX	☐ 2 weeks			SDG No.
Project Name:	☐ 1 week			
Site:	☐ 2 days			
P O #	☐ 1 day			Sampler:

Sample Identification	Sample Date	Sample Time	Sample Type	Matrix	# of Cont.	Filtered Sample																		Sample Specific Notes:

Preservation Used: 1= Ice, 2= HCl; 3= H2SO4; 4=HNO3; 5=NaOH; 6= Other ____________

Possible Hazard Identification

☐ *Non-Hazard* ☐ *Flammable* ☐ *Skin Irritant* *Poison B* ☐ *Unknown* ☐

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)

☐ *Return To Client* ☐ *Disposal By Lab* ☐ *Archive For* __________ *Months*

Special Instructions/QC Requirements & Comments:

Relinquished by:	Company:	Date/Time:	Received by:	Company:	Date/Time:
Relinquished by:	Company:	Date/Time:	Received by:	Company:	Date/Time:
Relinquished by:	Company:	Date/Time:	Received by:	Company:	Date/Time:

Appendix C

Quarterly Report Form

TVA Watts Bar Fossil Plant
Ash Pond Closure Plan
Quarterly Reporting

TVA

Closure Area:	
Quarter:	
Start Date:	
End Date:	

Description:	

Completed this Quarter:	

Projected next Quarter:	

List of Revised Attachments:	

Appendix D

Post-Closure Monitoring Checklist

Post-Closure Inspection and Maintenance Report Form - Quarterly Inspection

Location/Feature Inspected	Date of Inspection	Time of Inspection	Inspection After Significant Rainfall	Observed Maintenance Deficiency (see list below)	Condition (see below)	Corrective Action Required/Other Remarks	Date Repair Completed

Condition Code: G = Good; **M** = Marginal (needs maintenance within 7-days); **P** = Poor (needs immediate maintenance); **C** = Needs to be cleaned
O = Other (Explain in Corrective Action Section)

INSPECTION CHECKLIST			
GROUND SUBSIDENCE	**SLOPE STABILITY**	**MONITORING WELLS**	**OUTFALLS/HYDRAULIC STRUCTURES**
1. Evidence of cracking	9. Rotational/block failure	15. Well identification not visible	22. Erosion observed
2. Evidence of depression	10. Maintenance sloughing	16. Well cap unlocked or insecure	23. Sedimentation observed
3. Evidence of sinkhole	11. Evidence of seeps	17. Ponded water in well vicinity	24. Inlet/outlet obstruction
4. Evidence of ponding	**CHANNELS/LININGS**	18. Subsidence in well vicinity	**GENERAL/OTHER SITE FEATURES**
FINAL COVER	12. Erosion observed	19. Erosion in well vicinity	25. Evidence of unauthorized entry
5. Animal burrows observed	13. Sedimentation observed	20. Collision damage	26. Damage/missing facility signage
6. Stressed vegetation observed	14. Lining deterioration/displacement	21. Well casing degradation	27. Other deficiency observed
7. Undesired vegetation present			
8. Excavation in final cover			

PRECIPITATION DATA		
Date	Rain Data	
	Intensity	Amt

	Name	Title	Signature
Inspector Information:			

Appendix E

Stability Analysis (April 2012)

CDM Smith
5400 Glenwood Ave, Suite 300
Raleigh, North Carolina 27612
tel: 919 325-3500
fax: 919 781-5730

April 30, 2012

Mr. James D. Mullins, P.E.
Senior Program Manager
Tennessee Valley Authority
CCP Engineering
1101 Market Street, LP 5E-C
Chattanooga, TN 37402

Subject: Report – Revision No. 1
Existing Conditions Stability Analyses
Ash Pond Area at Watts Bar Fossil Plant

Dear Mr. Mullins:

The purpose of this letter report is to present the results of the existing conditions stability analyses performed by CDM Smith for the Ash/Stilling Pond area at the Watts Bar Fossil (WBF) plant near Spring City, Tennessee. These analyses were performed to support the U.S. Environmental Protection Agency's assessment of the Tennessee Valley Authority's (TVA) Coal Combustion Products (CCP) disposal facilities.

Project Background

The WBF plant is directly downstream of the Watts Bar Dam and Lock and abuts the west bank of the Tennessee River. Currently, the WBF plant is not operational and decommissioning is underway. The WBF plant was a coal-fired power plant built by TVA between 1940 and 1945. The plant was operated in two stages, from end of construction to 1957 and from 1970 to 1982. During the plant operation, ash and boiler slag generated by the plant were stockpiled and stored on-site.

In 2010, TVA contracted with CDM Smith to perform Phase I preliminary design services to support final closure of the WBF plant as part of the WBF Plant Coal Combustion Products Closure Project. The final closure encompasses multiple areas which include disposal facilities, impoundments, and stormwater ponds permitted in accordance with multiple regulations. The project includes closure of five (5) main areas: (i) the Borrow Source Area, (ii), Slag Processing Area (iii), Chemical Pond Area, (iv) Ash/Stilling Pond Area, and (v) Riverbank Area, as shown on **Figure 1**.

As part of this work, TVA requested that CDM Smith provide an existing condition evaluation for the stability of the Ash/Stilling Pond Area. This evaluation considered stability of the Ash/Stilling

Pond Area under static and seismic loading conditions based upon available data, as described herein.

Available Information

During the preliminary design phase for the closure, CDM Smith reviewed the following available information provided by TVA:

- MACTEC geotechnical report at Borrow Area
- QA/QC reports for closure construction at Chemical Pond and Slag Disposal Area during 2006 to 2009.
- TVA Disposal Facility Assessment, Phase I Plant Summary, Watts Bar Fossil Plant (WBF), by Stantec, 2009.
- Final Report – Development of Hazard Deaggregation Inputs for Use in Risk Analysis of Fossil Plants, by AMEC GeoMatrix, March 2010.
- Watts Bar Fossil Plant, Annual Inspection Report for Ash/Waste Disposal Areas, from 1967 through 2008.
- Watts Bar Fossil Plant, Slag Disposal Area Closure Plan, Project Planning Document, approved by TVA in January 2007.
- Fly Ash, Bottom Ash, and Scrubber Gypsum Study, by Law Engineering, November 1995.
- TVA Coal Combustion Products Management Program, Master Programmatic Document (Revision 1.0), December 7, 2009.

In addition, CDM Smith performed the following site-specific investigations to supplement the available data:

- Site walk and surficial soil sampling in the Borrow Area and Slag Disposal Area in August 2011.
- Bulk sampling and laboratory testing of underwater ash samples from the Ash/Stilling Pond Area in August 2011.

- Site survey of the Slag Disposal Area and Ash/Stilling Pond Area in December of 2011. Survey was performed by TVA at the request of CDM Smith.

- Subsurface exploration program along west bank of Tennessee River consisting of three geotechnical borings and installation of two groundwater observation wells.

The subsurface exploration program was completed in January 2012 and boring logs and water level readings from the wells are currently available and included as **Attachment A**. Laboratory testing results for disturbed and undisturbed samples collected in these borings are also contained in Attachment A.

Existing Conditions Evaluation

The existing conditions stability analyses for the Ash/Stilling Pond Area were performed at two critical cross-sections, as shown on **Figure 2**. The two critical cross-sections were selected at locations exhibiting the steepest exterior embankment slopes and riverbank slopes. The locations of the geotechnical borings completed in January 2012 are also shown on this figure. Cross-section A-A' extends through the Wet Ash Pond Area and Cross-Section B-B' extends through the Dry Ash Area, as shown on **Figures 3A** and **3B**, respectively. The cross-sections were developed based upon available topographic survey, design plans for the ponds, and the subsurface conditions encountered in the test borings. Currently there are no bathymetric survey data available for the river bank slope below normal water level. For this evaluation, the river bank slope was assumed to follow the same natural slope above water level and extend to the top of the bedrock at the river bed.

Selection of Design Parameters

The engineering design properties of the ash and soil layers for the seepage and stability analysis of the cross-sections are summarized in **Tables 1a and 1b**. The basis for selection of the design properties is also listed in the tables. In general, ash properties were estimated based upon available data from similar TVA facilities and soil properties were estimated based upon the subsurface investigation data, empirical correlations, and experience in similar geologic conditions.

Table 1a: Parameters used in SEEP/W Seepage Analyses

Layer	**Material**	k_h		k_h / k_v	**Basis of Parameter Selection**
		ft/day	cm/sec		
	Ash Material	0.45	1.6E-04	20	Based on comparison between laboratory testing data for existing ash material and TVA's CCP material database
1	Fill	0.0028	1.0E-06	10	From Peck[1]; typical value for mixture of sand, clay, and silt.
2A	Medium Stiff to Stiff Clay	0.0014	5.0E-07	15	From Peck; typical value for low-permeability soil.
2B	Soft Clay and Silt	0.0014	5.0E-07	15	From Peck; typical value for low-permeability soil.
3	Sand	2.83	1.0E-03	4	From Peck; typical value for sand.
4	Weathered Rock and Gravel	28.35	1.0E-02	4	From Peck; typical value for sand and gravel mixtures.
5	Interbedded Shale and Limestone Bedrock	0.0006	2.0E-07	1	From Domenico[2]; page 39; high-end value for Shale bedrock.

Reference:

1. Ralph B. Peck, 'Foundation Engineering', 2nd edition, 1974; page 43.

2. Patrick A. Domenico, 'Physical and Chemical Hydrogeology', 2nd edition, 1997.

CDM Smith

Table 1b: Strength Parameters used in SLOPE/W Stability Analyses

Layer	Material	Unit Weight, pcf	Friction Angle, degrees	Undrained Shear Strength, psf	Basis of Parameter Selection[1]
	Ash Material (wet)	70	20	-	Comparison between laboratory testing data for existing ash material and TVA's CCP material database
	Ash Material (dry)	85	25	-	
1	Fill	120/115[2]	32	-	Selected based on lower 1/3 N-values[3] from B-2 and B-3
2A	Medium Stiff to Stiff Clay	110/105[2]	29	1300	Selected based upon lower 1/3 pocket penetrometer readings[4] from B-2 and B-3 and laboratory shear strength testing on U-1 from B-2.
2B	Soft Clay and Silt	110	28	500	Selected based upon N-values and pocket penetrometer readings[4] from B-2 and B-3
3	Sand	120	30	-	Selected based on Lower 1/3 N-values[3] from B-2 and B-3
4	Weathered Rock and Gravel	125	40	-	Based upon experience in similar geologic conditions
5	Bedrock	Impenetrable			Assumed

Notes:

1. Correlation of N-value and friction angle from Ralph B. Peck, 'Foundation Engineering', 2nd edition, 1974; page 310.
2. Values listed are saturated/moist unit weights.
3. Lower 1/3 value is defined as the value where at least 2/3 of all the readings are greater or equal. N-value is defined as the sum of the blows to drive the 2nd and 3rd 6-inch-increments of each split spoon sample.
4. Pocket penetrometer readings were performed on split spoon samples and Shelby tube sample during drilling.

Laboratory strength data was not available at the time of the issue of the original report. However, laboratory results for an undisturbed Shelby Tube sample (U-1) taken in the medium to stiff clay layer (Layer 2A) in boring B-2 are now available. Based upon the laboratory results and the insitu data from borings B-2 and B-3 (pocket penetrometer), the undrained shear strength for this layer has been revised to 1300 psf. The undrained shear strength data for Layer 2A and Layer 2B are shown on **Figure 4**.

For stability analyses under seismic conditions, peak ground acceleration for the WBF plant site was selected based upon a review of the *"Final Report - Development of Hazard Deaggregation Inputs for Use in Risk Analysis of Fossil Plants"*, by AMEC GeoMatrix, dated March 28, 2010 and the USGS 2008 Hazards Map available at http://earthquake.usgs.gov. **Table 2** summarizes the data from the three TVA plants closest to WBF and the USGS Hazard Map values for the WBF. Based upon these data, the peak ground acceleration for WBF was interpolated to be 0.042g for a 500-year return period and a 0.116g for a 2500-year return period. Ground motion corresponding to a 2500-year return period is consistent with seismic stability guidance provided by the TVA Master Programmatic Document (Revision 1.0). A peak ground acceleration of 0.116g was used in the stability analyses under seismic conditions.

Table 2: Summary of Available Seismic Hazards Results (AMEC Report and USGS)

Plant	Latitude	Longitude	Return Period (years)	Probability of Exceedance	PGA, (g)	
					AMEC Report	USGS
Bull Run	36.00	-84.15	2500	2% in 50 years	0.131	0.155
			500	10% in 50 years	0.043	0.044
Kingston	35.90	-84.51	2500	2% in 50 years	0.115	0.134
			500	10% in 50 years	0.041	0.041
Watts Bar	35.61	-84.78	2500	2% in 50 years	***0.116***	0.135
			500	10% in 50 years	***0.042***	0.042
Widows Creek	34.90	-85.75	2500	2% in 50 years	0.1	0.115
			500	10% in 50 years	0.038	0.038

Bolded values were interpolated from tabulated data.

Seepage Analyses and Results
The phreatic surface for each stability analysis was developed from seepage analyses performed with the SEEP/W 2007 software package by GEO-SLOPE International, Ltd. This computer program uses the inputted geometry, soil, rock, and ash properties, and boundary conditions (surface water and groundwater conditions) to develop a steady-state seepage profile. For our analyses, the model was calibrated using the field data gathered during the recent geotechnical investigation by CDM Smith including:

- Water levels observed in the Ash/Stilling Pond
- Groundwater levels measured in the observation wells
- River level elevation data available at "http://www.tva.gov/lakes/wbh_o.htm" for the dates/times.

Once the model was calibrated, the steady-state phreatic surface was developed for normal pool conditions in the Ash/Stilling Pond (EL. 705).

Static Slope Stability Analyses and Results
Analyses for overall (global) stability under static conditions were performed using the SLOPE/W 2007 modeling software package from GEO-SLOPE. This computer program uses the inputted slope geometry, soil, rock, and ash properties, and phreatic surface and calculates the factors of safety against deep-seated circular failures. Phreatic surfaces generated by SEEP/W were imported to SLOPE/W for the static and seismic slope stability analyses. The Spencer method was selected for the slope stability analyses. The minimum acceptable static factor of safety against overall slope failure is 1.5 for normal pool conditions.

Effective stress strength parameters were used for all materials in static analyses. The stability analyses are included in **Attachment B** and the minimum factors of safety for deep-seated circular failure surfaces are presented in **Table 3**. Failure surfaces less than 5 feet deep are considered to be sloughing/surficial failures. The stability analyses did exhibit some lower factors of safety for sloughing/surficial failures along the river bank, but these failure surfaces did not extend into the pond berm such that the global stability of the ash pond would be impacted. Results presented herein considered the deep-seated failures that extend into the ash pond areas only. All factors of safety for static conditions equal or exceed the minimum required.

Table 3: Results of Slope Stability Analyses – Static Conditions

Run #	Modeling Scenario	Calculated Factor of Safety	
		Inboard Slope	Outboard Slope
A-1	Static Slope Stability at Wet Pond	1.9	1.8
B-1	Static Slope Stability at Dry Ash Area	2.4	1.5

Seismic Slope Stability Analyses and Results

The stability analyses under seismic loading conditions were performed using a pseudostatic method, where the added inertial load from an earthquake is represented by a horizontal pseudostatic coefficient. Based upon the Standard Penetration Test N-values and fines content of the subsurface soils, the soils at the site are not considered to be susceptible to liquefaction. The analyses assumed no liquefaction of the subsurface soils and undrained shear strength parameters were used for the natural clay soils (Layer 2A and Layer 2B). The peak ground acceleration was estimated as 0.116g. Tolerable deformations were assumed for cases where the pseudostatic factor of safety is greater than 1.0. Normal pool conditions were assumed (El. 705).

The stability analyses are included in Attachment B and the minimum factors of safety for deep-seated circular surfaces are presented in **Table 4**. All factors of safety for seismic (pseudostatic) conditions equal or exceed the minimum required.

Table 4: Results of Slope Stability Analyses – Seismic Conditions

Run #	Modeling Scenario	Calculated Factor of Safety	
		Inboard Slope	Outboard Slope
A-2	Seismic Conditions at Wet Pond	1.4	1.1
B-2	Seismic Conditions at Dry Ash Pond	1.3	1.0

Conclusions

The slope stability analyses indicate acceptable factors of safety under static and seismic loading conditions for all sections. The seismic slope stability analyses presented in this letter use a pseudostatic approach to represent existing conditions. For seismic assessment of the closure design, TVA will employ a comprehensive risk-based approach, with design and mitigation decisions based upon the probability and consequences of failure. This approach is outlined in the document *"Seismic Risk Assessment, Closed CCP Storage Facilities, Tennessee Valley Authority"* dated March, 2010 and included as **Attachment C**.

Limitations

This letter report has been prepared for specific application to the subject project in accordance with generally accepted geotechnical engineering practices. No other warranty, express or implied, is made. In the event that any changes occur, the conclusions and recommendations presented in this memorandum should not be considered valid, unless changes are reviewed and conclusions of this memorandum are modified or verified in writing.

STEPHEN L. WHITESIDE
REGISTERED ENGINEER
AGRICULTURE
COMMERCE
No. 108556
STATE OF TENNESSEE

Stephen L. Whiteside
4/30/12

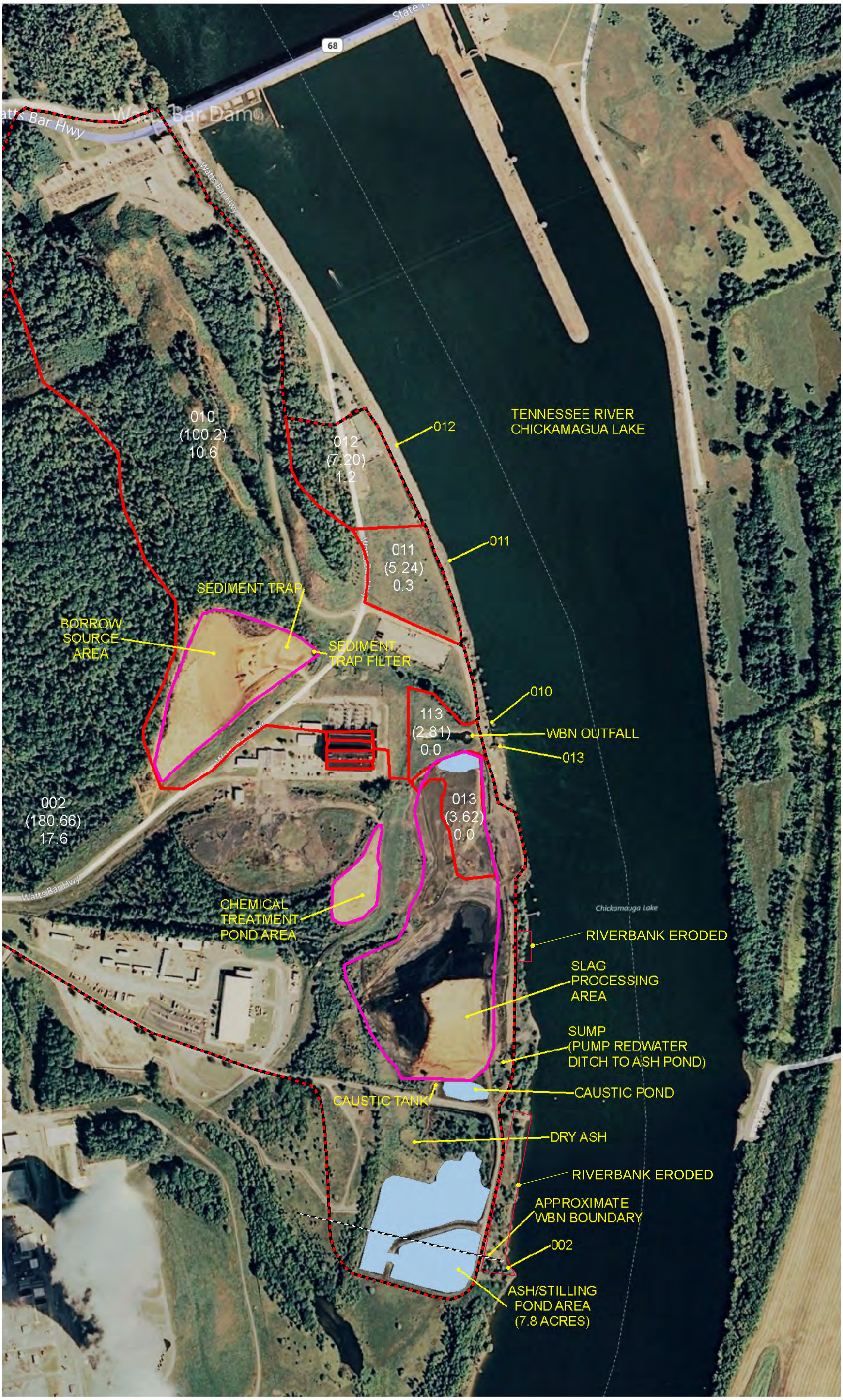
Very truly yours,

Stephen L. Whiteside

Stephen L. Whiteside, P.E.
Vice President
CDM Smith Inc.

cc: Michael Bachand, CDM Smith
Jintao Wen, CDM Smith
Danielle Neamtu, CDM Smith

FIGURES



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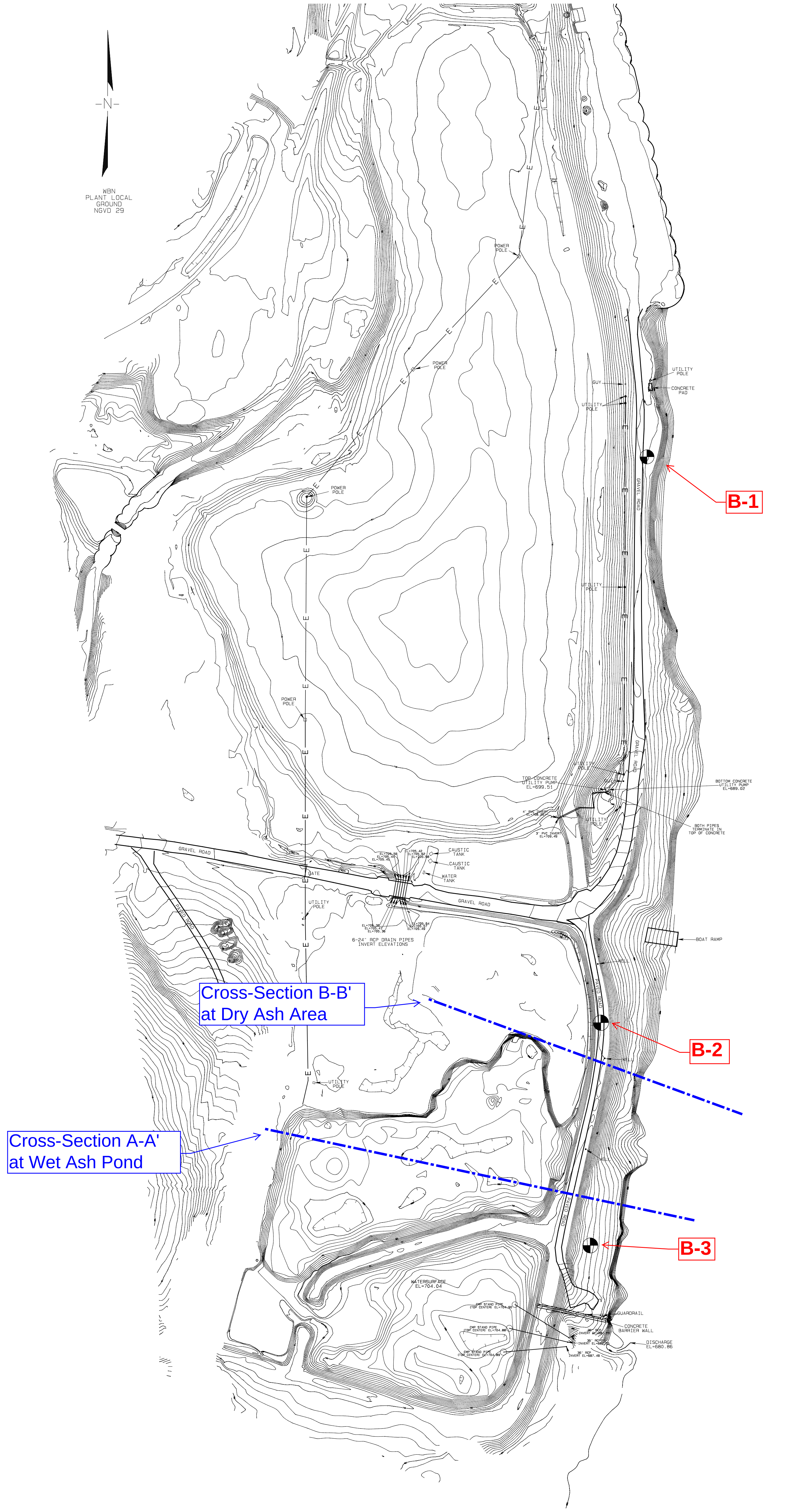
Watts Bar Fossil Plant
Tennessee Valley Authority
Coal Combustion Products Closure Project

Locations of Closure Areas

Figure 1



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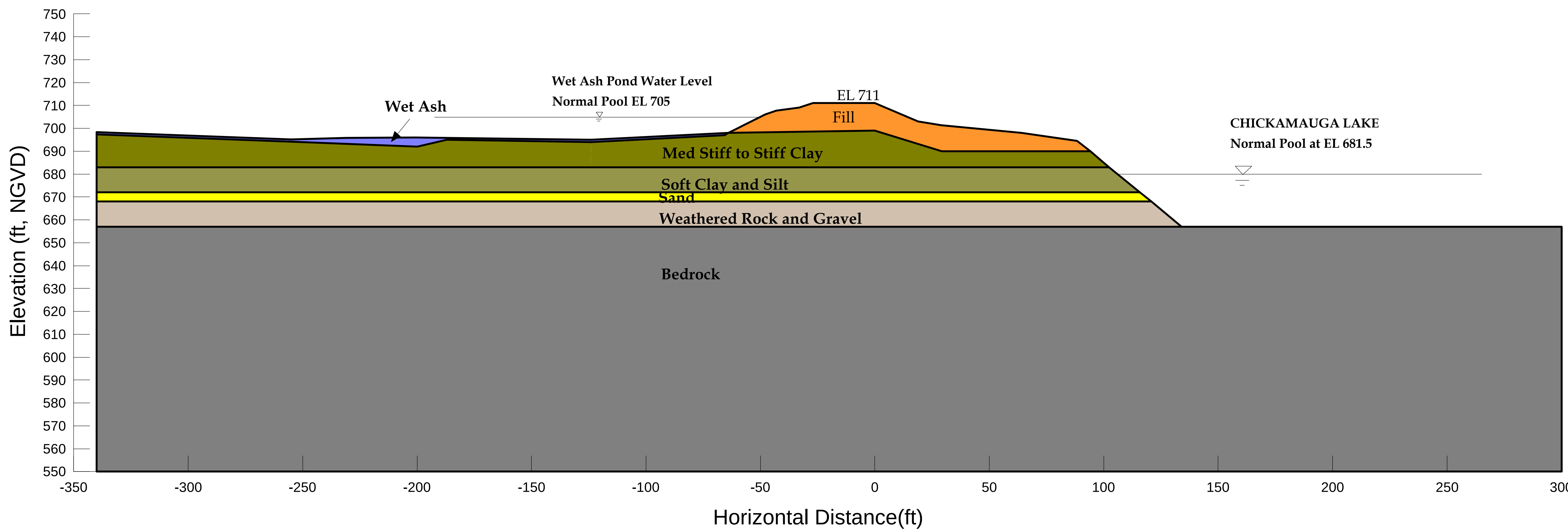
Tennessee Valley Authority
Coal Combustion Products Closure Project

Borings and Cross-Section Locations

Figure 2

TVA Watts Bar Fossil Plant, Spring City, TN
Seepage and Slope Stability Analyses
Cross-Section A-A' at Wet Ash Pond Area



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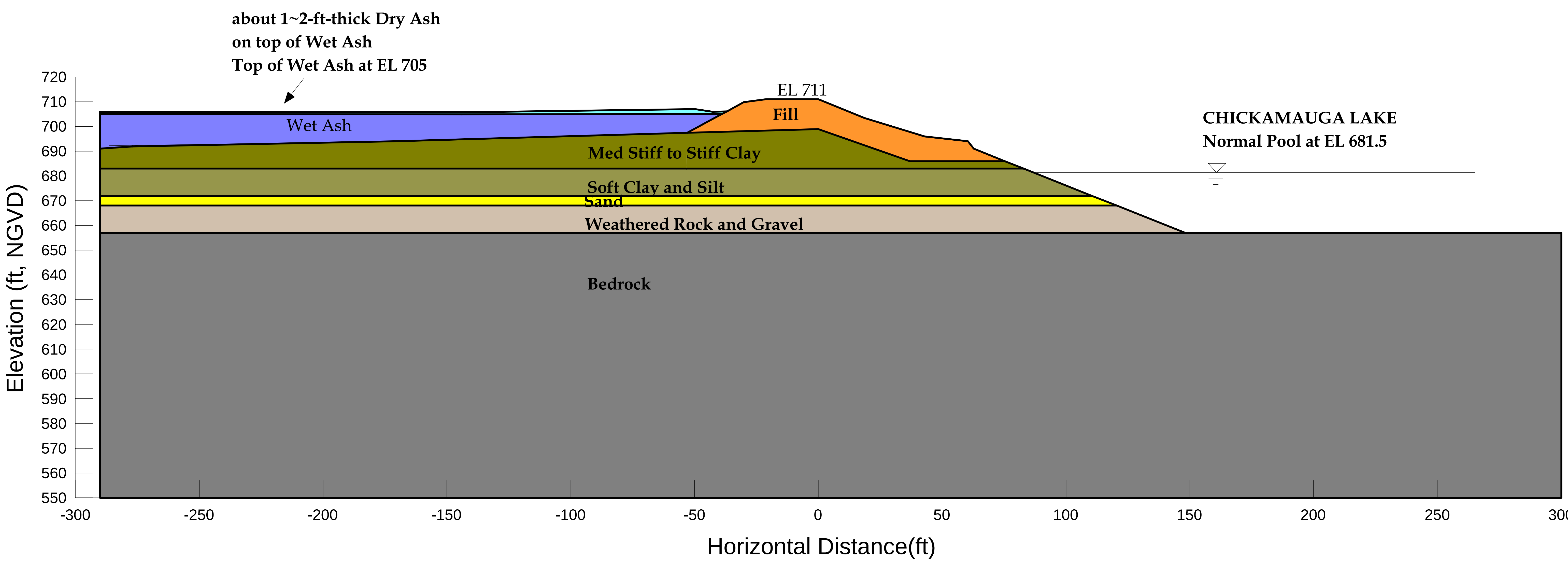
Watts Bar Fossil Plant
Tennessee Valley Authority
Coal Combustion Products Closure Project

Cross-Section A-A' at Wet Ash Pond Area

Figure 3A

TVA Watts Bar Fossil Plant, Spring City, TN
Seepage and Slope Stability Analyses
Cross-Section B-B' at Dry Ash Area



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Cross-Section B-B' at Dry Ash Area

Figure 3B

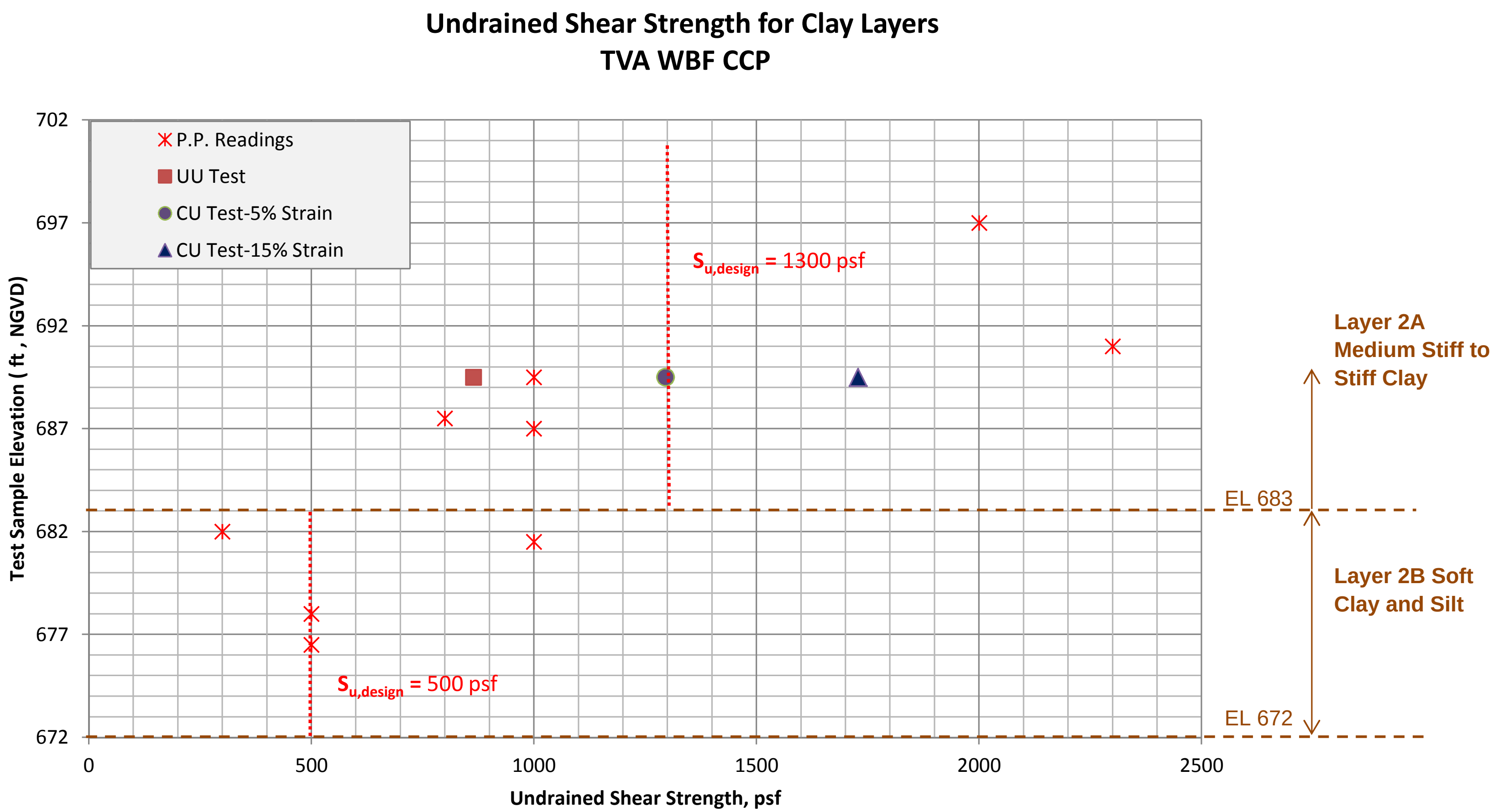

Figure 4. Undrained Shear Strength for Natural Clays

ATTACHMENT A

CDM Smith

BOREHOLE LOG
B-1

Client: TVA
Project Name: TVA Watts Bar Fossil Plant
Project Location: Spring City, TN
Project Number: 83529

Drilling Contractor: Total Depth Drilling
Surface Elevation (ft.): 699
Drilling Method/Rig: 3.25" HSA/CME-55
Total Depth (ft.): 44.6
Drillers: Tim Hall
Depth to Initial Water Level (ft-bgs): 9.3
Drilling Date: Start: 11-16-11 **End:** 11-17-11
Abandonment Method: Converted to observation well
Borehole Coordinates:
Field Screening Instrument:
N 466,232.90 E 2,331,561.10
Logged By: M. Howe

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
			699.0 / 0				GW	2-inches GRAVEL.
SS	S-1	12/11			10, 40		FILL	Moist to wet, dense to very dense, tan-brown and gray, GRAVEL and SILT. **-FILL-**
SS	S-2	24/22			12, 17, 27, 22			Moist, dense, dark brown and yellow-brown, fine to coarse SAND, little silt, gravel, trace clay.
SS	S-3	24/18		0.25	13, 19, 21, 11			Moist, hard, orange-brown to blue-gray and tan, SILT, some sand.
SS	S-4	24/20	694.0 / 5	1.0	3, 8, 5, 6			Moist, stiff, tan to blue-gray mottling, CLAY, trace silt, sand, and wood fragments.
SS	S-5	24/16		0.75	2, 3, 2, 2			Moist, medium stiff, tan to blue-gray, CLAY, trace silt, sand, and gravel.
SS	S-6	24/18	689.0 / 10	0.5	3, 3, 4, 6			Moist, medium stiff, medium brown to tan-brown, SILT, some sand, trace gravel.
SS	S-7	24/18	684.0		2, 2, 2, 2		SC/SM	Wet, very loose to loose, fine SAND, some clay, little silt. **- ALLUVIAL SOIL -**

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
HSA - Hollow Stem Auger
SSA - Solid Stem Auger
HA - Hand Auger
AR - Air Rotary
DTR - Dual Tube Rotary
FR - Foam Rotary
MR - Mud Rotary
RC - Reverse Circulation
CT - Cable Tool
JET - Jetting
D - Driving
DTC - Drill Through Casing

SAMPLING TYPES:
AS - Auger/Grab Sample
CS - California Sampler
BX - 1.5" Rock Core
NX - 2.1" Rock Core
GP - Geoprobe
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
OTHER:
AGS - Above Ground Surface

REMARKS

Hammer weight = 140 pounds, drop height = 30 inches
Split spoon = 2 inches OD, 24 inches long

Borehole coordinates are approximate based upon handheld GPS and elevations are estimated by overlaying coordinates with the survey.

Reviewed by: Danielle Neamtu **Date:** 4-25-12

CDM Smith

BOREHOLE LOG
B-1

Client: TVA

Project Location: Spring City, TN

Project Name: TVA Watts Bar Fossil Plant

Project Number: 83529

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
			684.0 15				SC/SM	
SS	S-8	24/24	679.0 20	0.75	2 3 4 5		CL	Moist to wet, medium stiff, red-brown to tan-brown, CLAY, little to some sand.
SS	S-9	24/24	674.0 25	0.5	2 4 4 5			Moist to wet, medium stiff to stiff, orange-brown to gray-tan, CLAY, some silt, trace to little sand.
SS	S-10	24/24	669.0 30		1 2 3 7		SM/SC	Wet, loose, gray to tan, fine SAND, little silt, clay.
SS	S-11	15/10			11 67 100/3"		SC/SM	Moist to wet, very dense, gray, fine to coarse SAND, little clay, silt, trace gravel. **-WEATHERED ROCK-** Auger refusal at 33.0 feet below ground surface.
NQ	C-1	63/6	664.0 35		2:45 1:45 2:15 8:30 3:15		GW	Split-spoon refusal at 34.3 feet below ground surface. **RUN 1: 34.3 to 39.6 feet-bgs** REC = 9.5%, RQD = 0% Moderately hard, highly weathered, green and brown to gray, aphanitic, INTERBEDDED SHALE, LIMESTONE, and RIVER ROCK; extremely thin bedding, low angle jointing, very close spacing, rough, discolored, open, quartz vugs.

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BOREHOLE LOG
B-1

Client: TVA
Project Name: TVA Watts Bar Fossil Plant
Project Location: Spring City, TN
Project Number: 83529

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
					3:00		GW	
NQ	C-2	60/7.5	659.0 40		8:15 5:00 4:15 6:45 3:30		SHALE/LS	**RUN 2: 39.6 to 44.6 feet-bgs** REC = 12.5%, RQD = 0% Moderately hard to hard, highly weathered, gray, aphanitic, INTERBEDDED SHALE and LIMESTONE; very thin to extremely thin bedding, low angle jointing, very close to close spacing, rough, discolored, open, calcite veins.
			654.0 45 649.0 50 644.0 55 639.0 60					Boring terminated at 44.6 feet below ground surface.

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BOREHOLE LOG
B-2

Client: TVA
Project Name: TVA Watts Bar Fossil Plant
Project Location: Spring City, TN
Project Number: 83529

Drilling Contractor: Total Depth Drilling
Surface Elevation (ft.): 711
Drilling Method/Rig: 3.25" HSA/CME-55
Total Depth (ft.): 46.1
Drillers: Allan Fowler
Depth to Initial Water Level (ft-bgs): 27.4
Drilling Date: Start: 1-10-12 **End:** 1-10-12
Abandonment Method: Grouted to ground surface
Borehole Coordinates:
Field Screening Instrument:
N 465,036.40 E 2,331,471.00
Logged By: M. Howe

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
			711.0 0				ASPHALT	3-inches ASPHALT PAVEMENT.
							GW	8-inches GRAVEL BASE.
SS	1	24/23		3.0	5 6 8 9		FILL	Moist, stiff, orange brown, CLAY, **-FILL-**
SS	2	24/24	706.0 5	>4.5	3 6 10 14			Moist, very stiff, orange brown, CLAY, some silt, trace gravel. Moist, very stiff, dark brown, CLAY, some silt, trace gravel.
SS	3	24/24		>4.5	5 8 11 12			Moist, very stiff, dark brown with gray mottling, CLAY, some silt.
SS	4	24/24		4.0	5 8 10 11			Moist, very stiff, dark brown with light brown and gray mottling, CLAY, some silt.
SS	5	24/24	701.0 10	4.5	4 6 7 9			Moist, stiff, dark brown with gray and light brown mottling, CLAY, some silt.
SS	6	24/14	696.0	2.0	3 6 7		CH	Moist, stiff, orange to yellow brown, CLAY, little sand (in lenses). **- ALLUVIAL SOIL -**

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
HSA - Hollow Stem Auger
SSA - Solid Stem Auger
HA - Hand Auger
AR - Air Rotary
DTR - Dual Tube Rotary
FR - Foam Rotary
MR - Mud Rotary
RC - Reverse Circulation
CT - Cable Tool
JET - Jetting
D - Driving
DTC - Drill Through Casing

SAMPLING TYPES:
AS - Auger/Grab Sample
CS - California Sampler
BX - 1.5" Rock Core
NX - 2.1" Rock Core
GP - Geoprobe
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
OTHER:
AGS - Above Ground Surface

REMARKS

Hammer weight = 140 pounds, drop height = 30 inches
Split spoon = 2 inches OD, 24 inches long

Borehole coordinates are approximate based upon handheld GPS and elevations are estimated by overlaying coordinates with the survey.

Reviewed by: Danielle Neamtu **Date:** 4-25-12

CDM Smith

BOREHOLE LOG
B-2

Client: TVA
Project Location: Spring City, TN
Project Name: TVA Watts Bar Fossil Plant
Project Number: 83529

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
			696.0 15		8		CH	
SS	7	24/24	691.0 20	2.3	3 3 5 5		CL	Moist, medium stiff to stiff, medium brown to tan, CLAY, trace to little sand.
ST	1	24/24		1.0				Shelby tube sample collected from 20.5 to 22.5 feet below ground surface. Moist to wet, medium brown, CLAY, little silt, trace sand.
SS	8	24/19		0.8	2 3 3 3			Moist, medium stiff, medium brown, CLAY, trace to little silt.
			686.0 25					
SS	9	24/24	681.0 30	1.0	1 2 3 3			Moist to wet, medium stiff, medium brown, CLAY, little silt, trace sand.
SS	10	24/24	676.0 35	0.5	1 2 2 2			Wet, soft to medium stiff, medium brown, CLAY, some silt, little sand.
					1			Wet, loose, medium brown, fine to medium SAND, trace silt.

BOREHOLE LOG
B-2

Client: TVA
Project Location: Spring City, TN
Project Name: TVA Watts Bar Fossil Plant
Project Number: 83529

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
SS	11	24/24	671.0 / 40		2 4 6		SP-SM	Wet, medium dense, medium brown, fine to medium SAND, trace silt.
SS	12	23/23	666.0 / 45		1 11 13 100/5"			
							SW/GW	Wet, very dense, gray, fine to coarse SAND and GRAVEL, trace silt. **-WEATHERED ROCK-**
SS	13	1/1			100/1"			Auger refusal at 46.0 feet below ground surface. Split-spoon refusal at 46.1 feet below ground surface.
			661.0 / 50					
			656.0 / 55					
			651.0 / 60					

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BOREHOLE LOG
B-3

Client: TVA
Project Name: TVA Watts Bar Fossil Plant
Project Location: Spring City, TN
Project Number: 83529

Drilling Contractor: Total Depth Drilling
Surface Elevation (ft.): 701
Drilling Method/Rig: 3.25" HSA/CME-55
Total Depth (ft.): 54.8
Drillers: Tim Hall
Depth to Initial Water Level (ft-bgs): 18.1
Drilling Date: Start: 11-15-11 **End:** 11-16-11
Abandonment Method: Converted to observation well
Borehole Coordinates:
Field Screening Instrument:
N 464,593.80 E 2,331,431.10
Logged By: M. Howe

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. / Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
			701.0 / 0		2		TOPSOIL	2-inches TOPSOIL.
SS	S-1	24/18		3.5	4, 5, 6		FILL	Moist, stiff, medium brown to dark brown, CLAY, trace sand, **-FILL-**
SS	S-2	24/24		1.0	4, 7, 12, 9			Moist, very stiff, medium brown to dark brown with orange, CLAY, trace sand.
SS	S-3	24/20	696.0 / 5	2.0	4, 6, 6, 5			Moist, stiff, medium brown with orange, SILT, some sand.
SS	S-4	24/22		1.0	6, 5, 7, 5			Moist, medium dense, medium brown to orange-brown, fine SAND, little silt.
SS	S-5	24/19		1.0	4, 4, 7, 5			Moist, stiff, medium brown to orange-brown, CLAY, little sand. Moist, medium dense, medium brown to orange-brown, fine SAND, some silt, clay.
			691.0 / 10					
SS	S-6	24/22		1.0	3, 4, 5, 5		CL	Moist to wet, stiff, medium brown, CLAY, little silt. **- ALLUVIAL SOIL -**
			686.0					

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
HSA - Hollow Stem Auger
SSA - Solid Stem Auger
HA - Hand Auger
AR - Air Rotary
DTR - Dual Tube Rotary
FR - Foam Rotary
MR - Mud Rotary
RC - Reverse Circulation
CT - Cable Tool
JET - Jetting
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BX - 1.5" Rock Core
NX - 2.1" Rock Core
GP - Geoprobe
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
OTHER:
AGS - Above Ground Surface

REMARKS

Hammer weight = 140 pounds, drop height = 30 inches
Split spoon = 2 inches OD, 24 inches long

Borehole coordinates are approximate based upon handheld GPS and elevations are estimated by overlaying coordinates with the survey.

Reviewed by: Danielle Neamtu **Date:** 4-25-12

CDM Smith

BOREHOLE LOG
B-3

Client: TVA
Project Location: Spring City, TN
Project Name: TVA Watts Bar Fossil Plant
Project Number: 83529

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
			686.0 15				CL	
SS	S-7	24/10		0.3	1 1 1 2		CL-ML	Wet, very soft to soft, medium brown to tan-brown, SILT and CLAY, little sand.
			681.0 20					
SS	S-8	24/24		0.5	2 1 2 2		CL	Wet, soft, medium brown to tan-brown, CLAY, some silt, trace sand.
			676.0 25					
SS	S-9	24/24			2 1 2 3		SP-SM	Wet, very loose, medium brown to gray-brown, fine SAND, little silt.
			671.0 30					
SS	S-10	24/15			2 8 11 12			Wet, medium dense, tan to gray, fine to coarse SAND, some gravel, trace silt.
			666.0 35					
SS	S-11	8/8			48 100/2"		SM/SC	Wet, very dense, gray, fine to coarse SAND, little silt, clay, trace gravel. **-WEATHERED ROCK-**

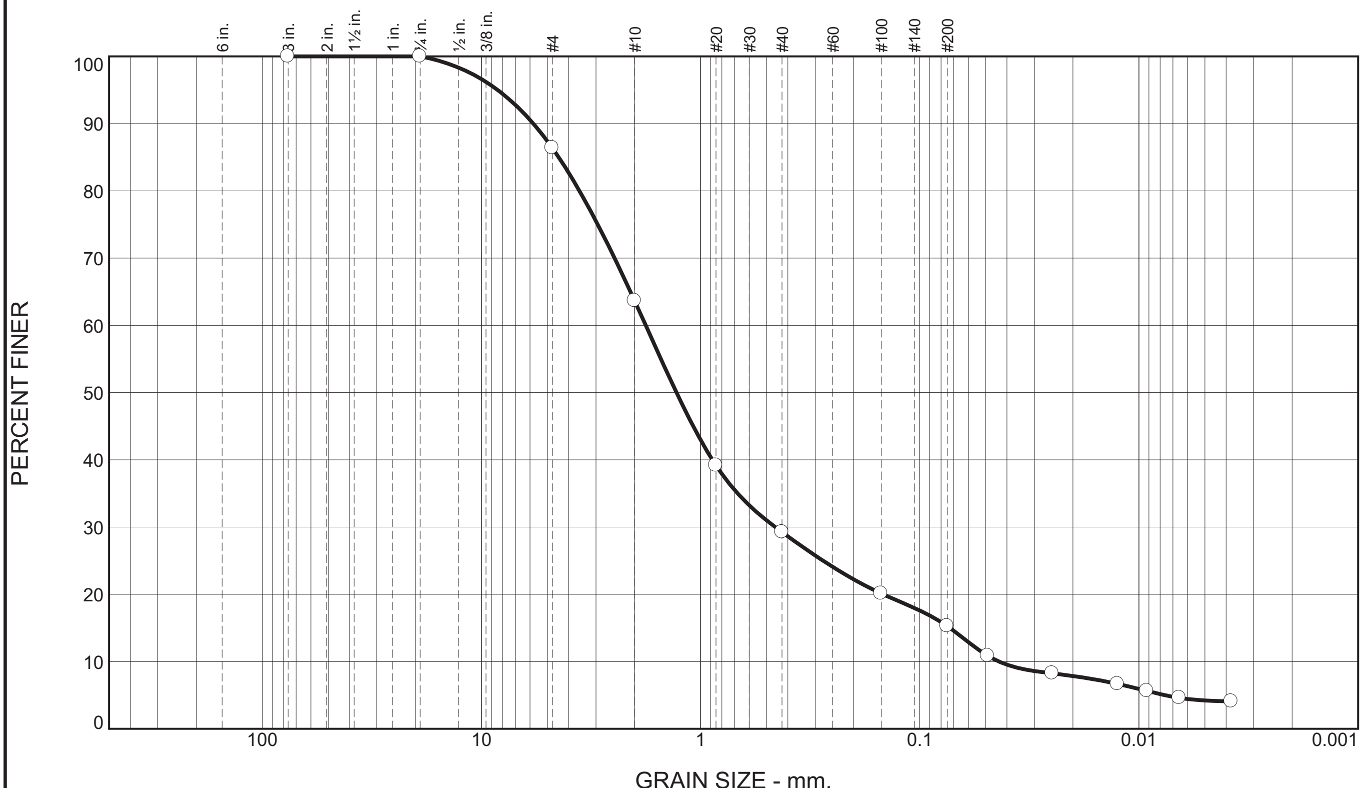
CDM Smith

BOREHOLE LOG
B-3

Client: TVA
Project Location: Spring City, TN
Project Name: TVA Watts Bar Fossil Plant
Project Number: 83529

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
			661.0 / 40				SM/SC	Split-spoon refusal at 38.7 feet below ground surface. Auger refusal at 40.4 feet below ground surface.
NQ	C-1	52.8/6			7:30, 6:00, 6:00, 5:15, 2:00		GW	**RUN 1: 40.4 to 44.8 feet-bgs** REC = 9%, RQD = 0% Moderately hard to hard, highly weathered, brown and orange to gray, aphanitic, interbedded SHALE, LIMESTONE, and RIVER ROCK; extremely thin bedding, low angle jointing, very close spacing, rough, discolored, open, calcite veins.
NQ	C-2	60/14	656.0 / 45		4:30, 7:00, 6:00, 7:15, 8:15		SHALE/LS	**RUN 2: 44.8 to 49.8 feet-bgs** REC = 23%, RQD = 0% Moderately hard to hard, highly weathered,gray, aphanitic, interbedded LIMESTONE and SHALE; very thin bedding, low angle jointing, very close spacing, rough, discolored, open, calcite veins.
NQ	C-3	60/9.5	651.0 / 50		9:45, 16:15, 7:30, 8:15, 6:45		SHALE/LS	**RUN 3: 49.8 to 54.8 feet-bgs** REC = 16%, RQD = 0% Moderately hard, highly weathered,gray, aphanitic, interbedded LIMESTONE and SHALE; extremely thin to very thin bedding, low angle jointing, very close spacing, rough, discolored, open.
			646.0 / 55					Boring terminated at 54.8 feet below ground surface.
			641.0 / 60					

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	13.6	22.8	34.4	13.9	11.1	4.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3	100.0		
3/4	100.0		
#4	86.4		
#10	63.6		
#20	39.1		
#40	29.2		
#100	20.1		
#200	15.3		

* (no specification provided)

Material Description

Silty Sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 5.8002 D_{85}= 4.4393 D_{60}= 1.7795
D_{50}= 1.2880 D_{30}= 0.4565 D_{15}= 0.0730
D_{10}= 0.0435 C_u= 40.87 C_c= 2.69

Classification

USCS= SM AASHTO=

Remarks

As received moisture content=6.9%
Soil classification and description based on Visual Manual Procedure ASTM D2488

Source of Sample: B-1 **Depth:** 1-3
Sample Number: S-2

Date: 11/16/2011

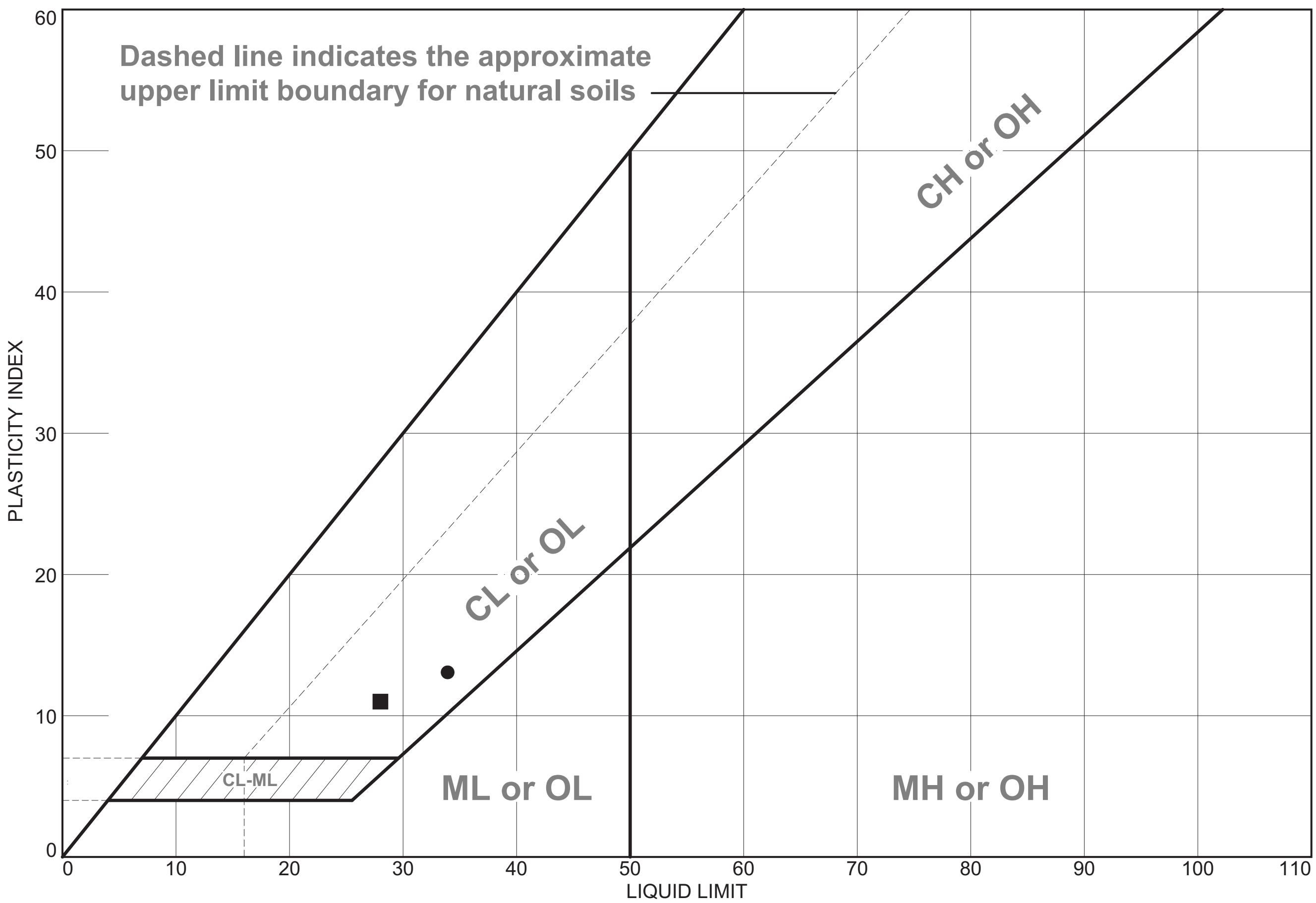
CDM Smith

Cambridge, Massachusetts

Client: TVA
Project: Watts Bar Fossil Plant CCP Closure
Project No: 95618-83529 **Figure**

Tested By: NE **Checked By:** MR

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Lean clay	34	21	13			CL
■	Lean clay	28	17	11			CL

Project No. 95618-83529 **Client:** TVA

Project: Watts Bar Fossil Plant CCP Closure

●**Source of Sample:** B-1 **Depth:** 5-7 **Sample Number:** S-4

■**Source of Sample:** B-1 **Depth:** 23-25 **Sample Number:** S-9

Remarks:

●As received moisture content=16.2%

■As received moisture content=23.0%

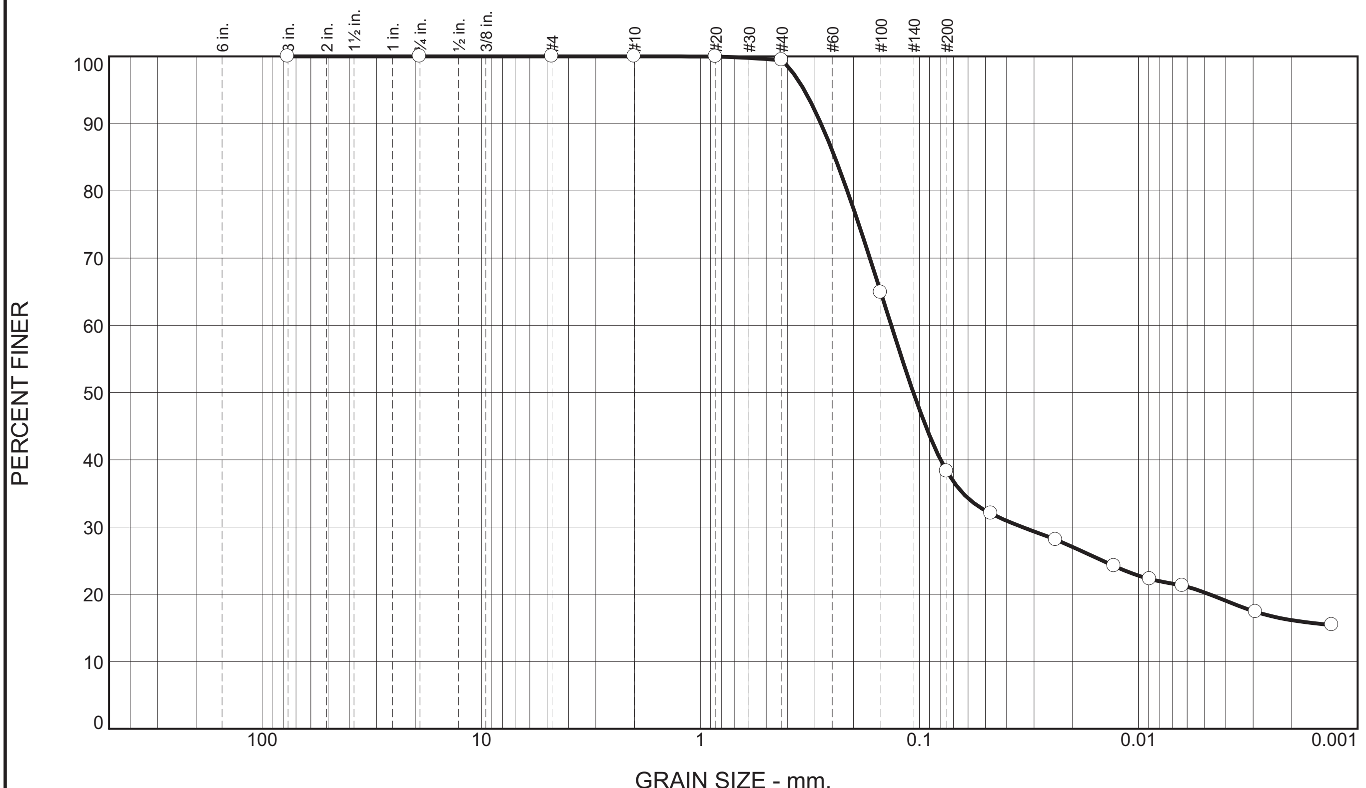
CDM Smith

Cambridge, Massachusetts

Figure

Tested By: NE **Checked By:** MR

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	0.6	61.1	18.0	20.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3	100.0		
3/4	100.0		
#4	100.0		
#10	100.0		
#20	100.0		
#40	99.4		
#100	64.9		
#200	38.3		

* (no specification provided)

Material Description

Clayey sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.2815 D_{85}= 0.2433 D_{60}= 0.1345
D_{50}= 0.1066 D_{30}= 0.0339 D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SC AASHTO=

Remarks

As received moisture content=20.2%
Soil classification and description based on Visual Manual Procedure ASTM D2488

Source of Sample: B-1 **Depth:** 13-15
Sample Number: S-7

Date: 11/16/2011

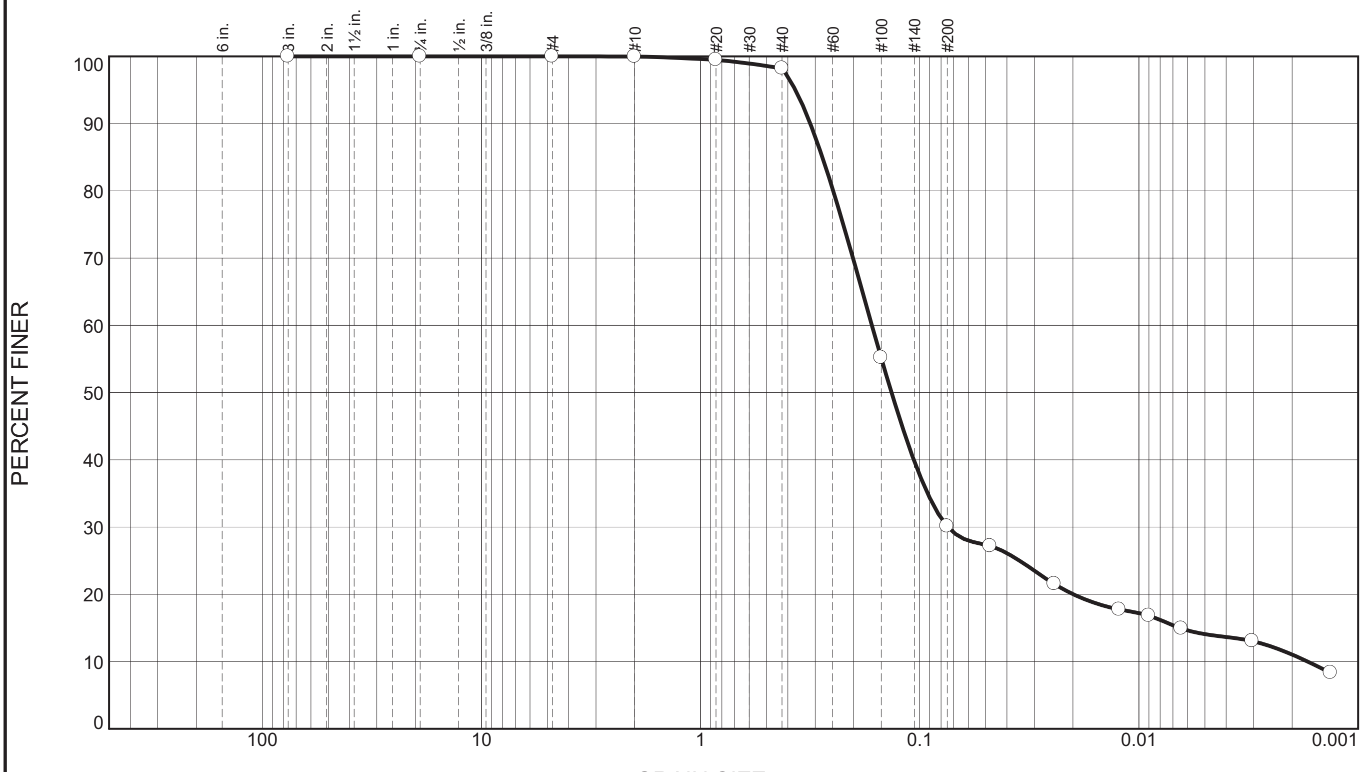
CDM Smith

Cambridge, Massachusetts

Client: TVA
Project: Watts Bar Fossil Plant CCP Closure
Project No: 95618-83529 **Figure**

Tested By: NE **Checked By:** MR

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	1.8	68.1	16.0	14.1

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3	100.0		
3/4	100.0		
#4	100.0		
#10	100.0		
#20	99.5		
#40	98.2		
#100	55.2		
#200	30.1		

* (no specification provided)

Material Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.3160 D_{85}= 0.2782 D_{60}= 0.1653
D_{50}= 0.1346 D_{30}= 0.0744 D_{15}= 0.0065
D_{10}= 0.0017 C_u= 97.09 C_c= 19.66

Classification

USCS= SM AASHTO=

Remarks

As received moisture content=34.5%
Soil classification and description based on Visual Manual Procedure ASTM D2488

Source of Sample: B-1 **Depth:** 28-30
Sample Number: S-10

Date: 11/16/2012

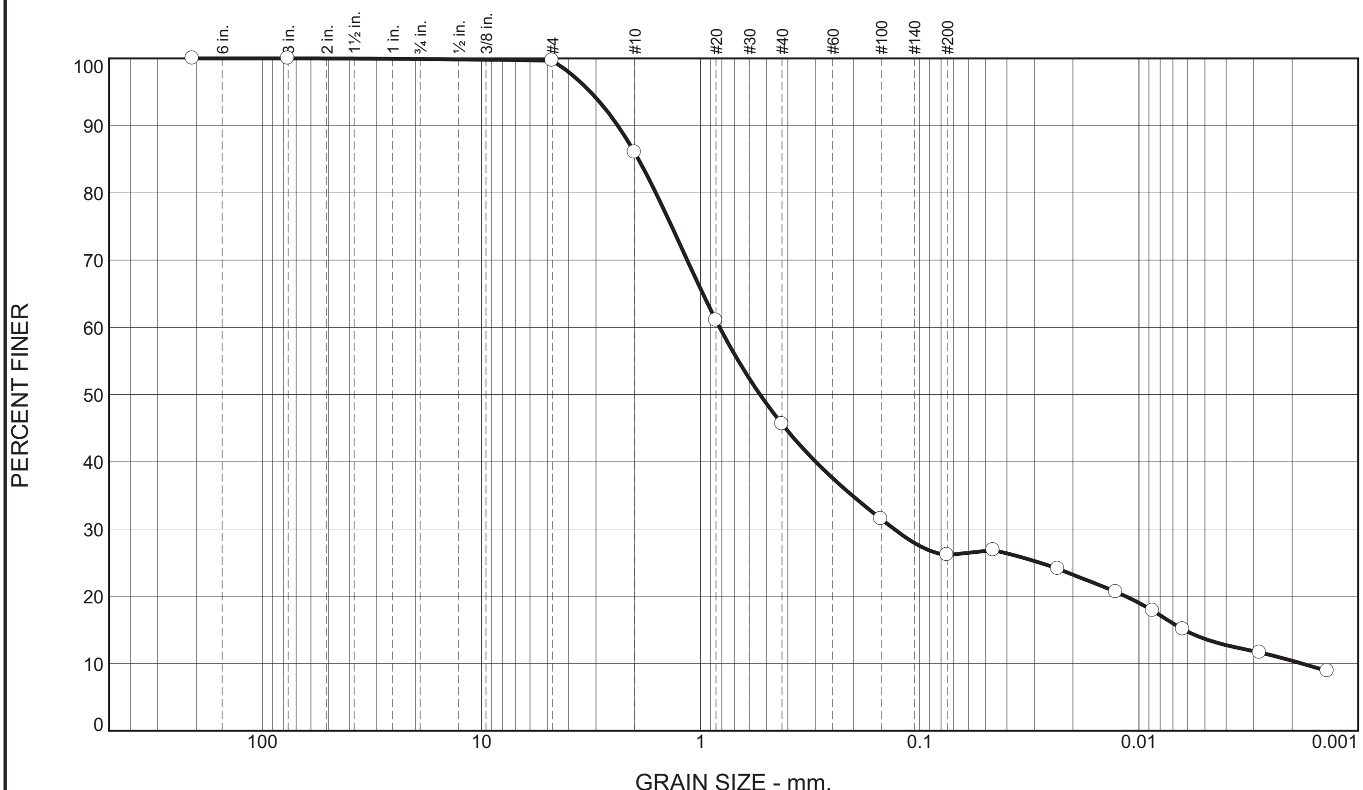
CDM Smith

Cambridge, Massachusetts

Client: TVA
Project: Watts Bar Fossil Plant CCP Closure
Project No: 95618-83529 **Figure**

Tested By: NE **Checked By:** MR

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.1	0.2	13.7	40.4	19.5	12.4	13.7

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
8.19	100.0		
3	100.0		
#4	99.7		
#10	86.0		
#20	61.0		
#40	45.6		
#100	31.5		
#200	26.1		

* (no specification provided)

Material Description

Silty sand
Note: Portion of sample soft, weathered rock easily broken into smaller fractions during sample preparation.

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 2.3878 D_{85}= 1.9212 D_{60}= 0.8189
D_{50}= 0.5357 D_{30}= 0.1310 D_{15}= 0.0062
D_{10}= 0.0018 C_u= 453.07 C_c= 11.59

Classification

USCS= SM AASHTO=

Remarks

As received moisture content=7.4%
Soil classification and description based on Visual Manual Procedure ASTM D2488

Source of Sample: B-1 **Depth:** 33-34.5
Sample Number: S-11

Date: 11/16/2011

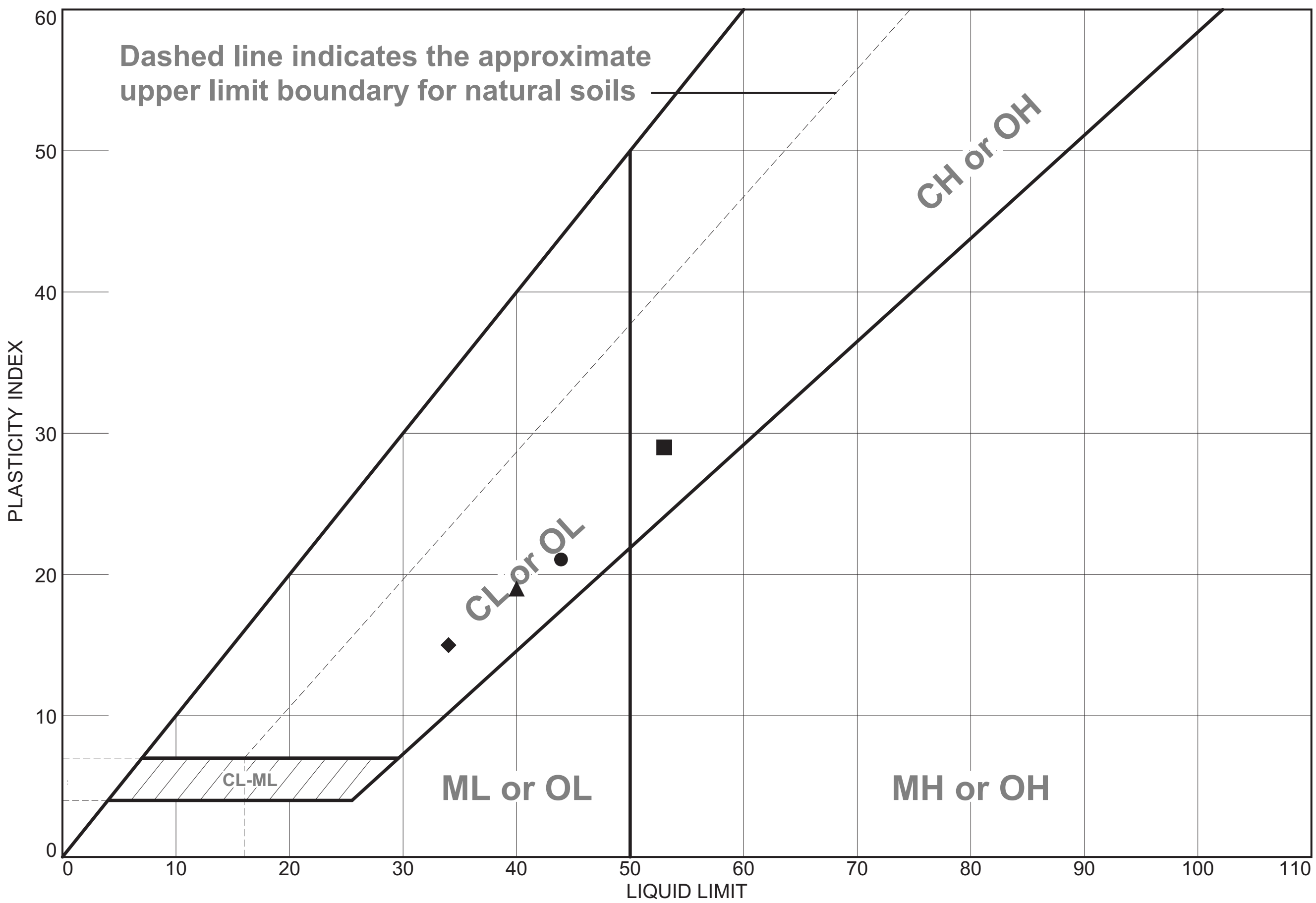
CDM Smith

Cambridge, Massachusetts

Client: TVA
Project: Watts Bar Fossil Plant CCP Closure
Project No: 95618-83529 **Figure**

Tested By: NE **Checked By:** MR

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Lean clay	44	23	21			CL
■	Fat clay	53	24	29			CH
▲	Lean clay	40	21	19			CL
◆	Lean clay	34	19	15			CL

Project No. 95618-83529 **Client:** TVA

Project: Watts Bar Fossil Plant CCP Closure

●**Source of Sample:** B-2 **Depth:** 5-7 **Sample Number:** S-3
■**Source of Sample:** B-2 **Depth:** 13.5-15.5 **Sample Number:** S-6
▲**Source of Sample:** B-2 **Depth:** 28.5-30.5 **Sample Number:** S-9
◆**Source of Sample:** B-2 **Depth:** 20.5-22.5 **Sample Number:** U-1

Remarks:
●As received moisture content=21.7%
■As received moisture content=20.6%
▲As received moisture content=27.8%
◆As received moisture content=14.6%

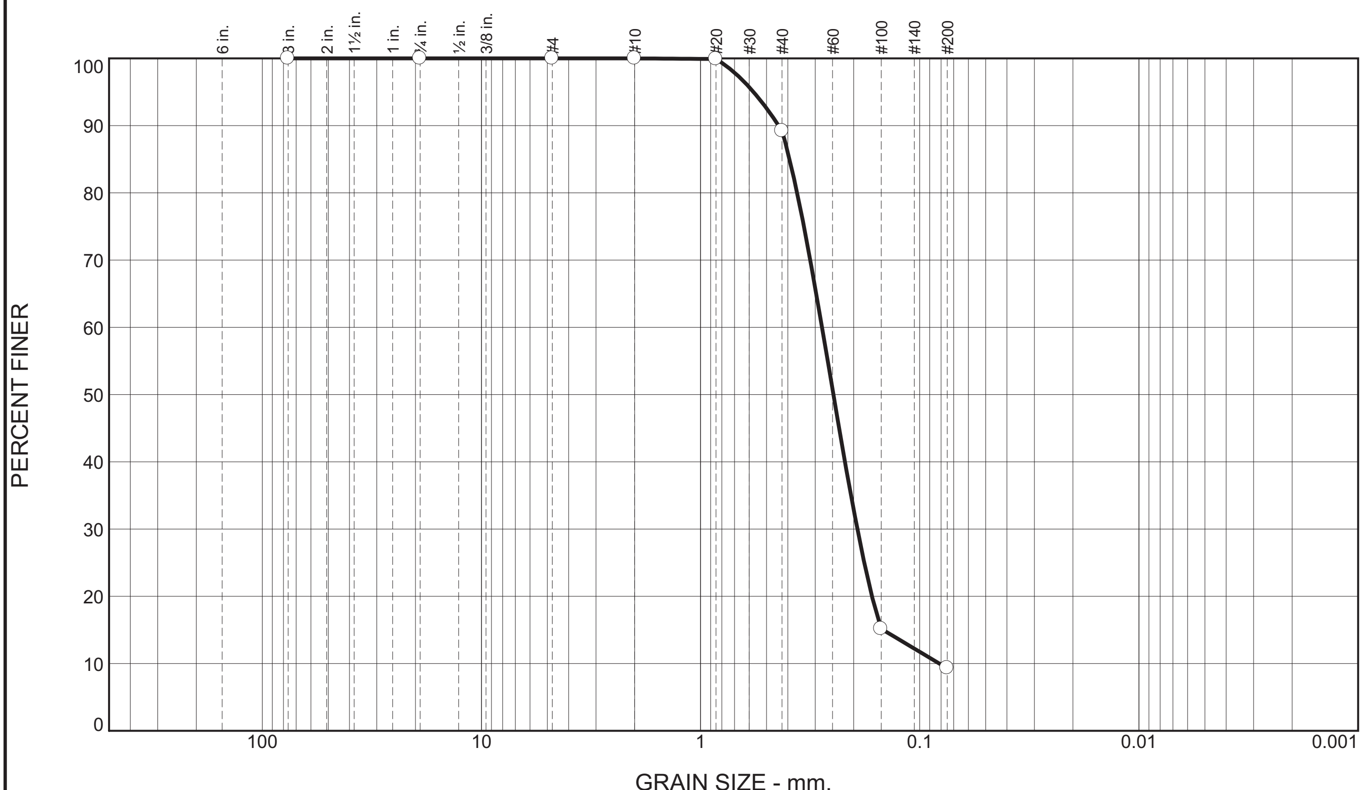
CDM Smith

Cambridge, Massachusetts

Figure

Tested By: NE **Checked By:** MR

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	10.8	79.9	9.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3	100.0		
3/4	100.0		
#4	100.0		
#10	100.0		
#20	99.9		
#40	89.2		
#100	15.2		
#200	9.3		

* (no specification provided)

Material Description

Poorly graded sand with silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.4406 D_{85}= 0.3927 D_{60}= 0.2792
D_{50}= 0.2477 D_{30}= 0.1926 D_{15}= 0.1470
D_{10}= 0.0814 C_u= 3.43 C_c= 1.63

Classification

USCS= SP-SM AASHTO=

Remarks

As received moisture content=27.6%
Soil classification and description based on Visual Manual Procedure ASTM D 2488

Source of Sample: B-2 **Depth:** 38.5-40.5
Sample Number: S-11
Date: 1/10/2012

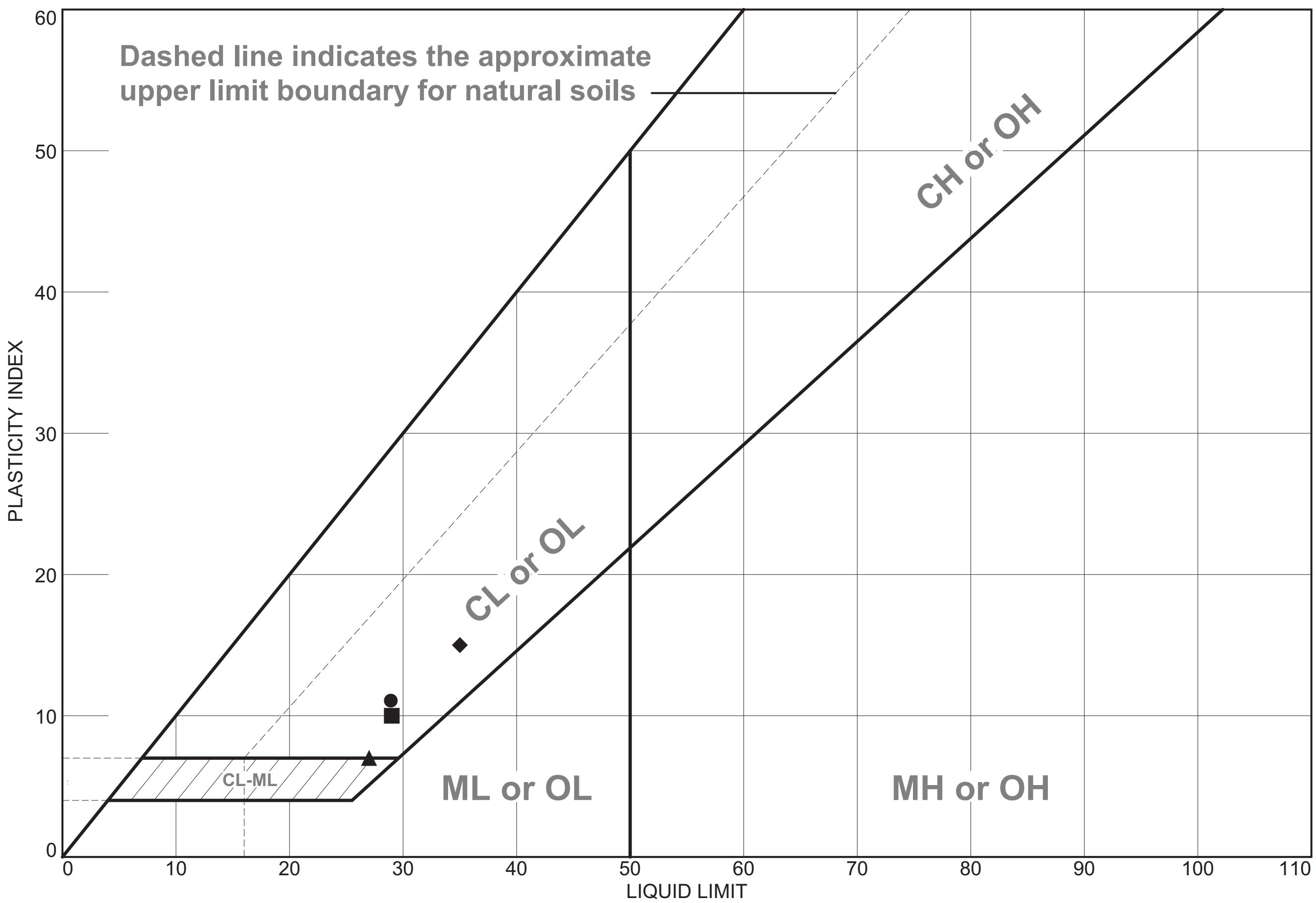
CDM Smith

Cambridge, Massachusetts

Client: TVA
Project: Watts Bar Fossil Plant CCP Closure
Project No: 95618-83529 **Figure**

Tested By: NE **Checked By:** MR

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Lean clay	29	18	11			CL
■	Lean clay	29	19	10			CL
▲	Lean clay-low plasticity silt	27	20	7			CL-ML
◆	Lean clay	35	20	15			CL

Project No. 95618-83529 **Client:** TVA

Project: Watts Bar Fossil Plant CCP Closure

●**Source of Sample:** B-3 **Depth:** 2-4 **Sample Number:** S-2
■**Source of Sample:** B-3 **Depth:** 13-15 **Sample Number:** S-6
▲**Source of Sample:** B-3 **Depth:** 18-20 **Sample Number:** S-7
◆**Source of Sample:** B-3 **Depth:** 23-25 **Sample Number:** S-8

Remarks:
●As received moisture content=14.5%
■As received moisture content=21.3%
▲As received moisture content=28.1%
◆As received moisture content=31.9%

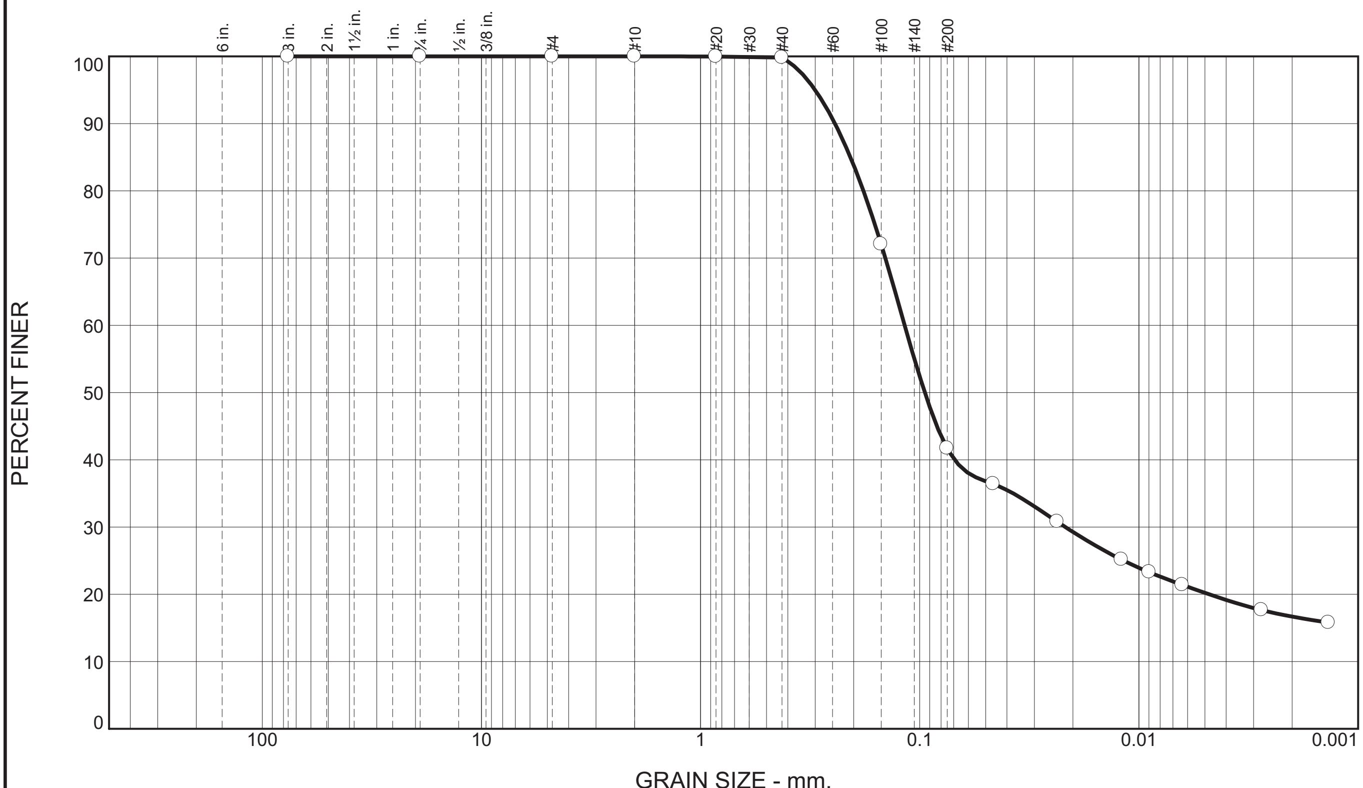
CDM Smith

Cambridge, Massachusetts

Figure

Tested By: NE **Checked By:** MR

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	0.2	58.1	21.5	20.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3	100.0		
3/4	100.0		
#4	100.0		
#10	100.0		
#20	100.0		
#40	99.8		
#100	72.1		
#200	41.7		

* (no specification provided)

Material Description

Clayey sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.2437 D_{85}= 0.2072 D_{60}= 0.1172
D_{50}= 0.0948 D_{30}= 0.0217 D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SC AASHTO=

Remarks

As received moisture content=14.5%
Soil classification and description based on Visual Manual Procedure ASTM D 2488

Source of Sample: B-3 **Depth:** 8-10
Sample Number: S-5

Date: 11/15/2011

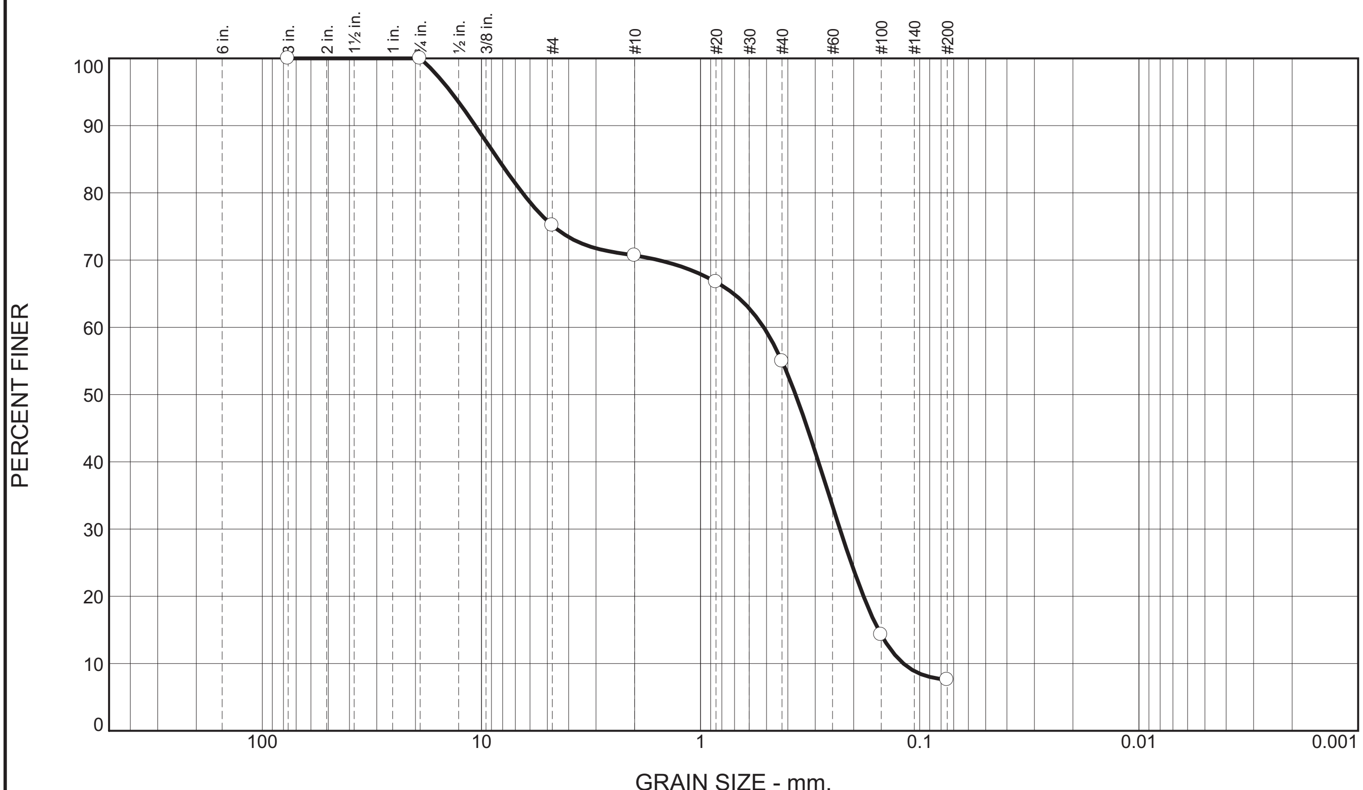
CDM Smith

Cambridge, Massachusetts

Client: TVA
Project: Watts Bar Fossil Plant CCP Closure
Project No: 95618-83529 **Figure**

Tested By: NE **Checked By:** MR

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	24.8	4.5	15.8	47.3	7.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3	100.0		
3/4	100.0		
#4	75.2		
#10	70.7		
#20	66.7		
#40	54.9		
#100	14.3		
#200	7.6		

* (no specification provided)

Material Description

Poorly graded sand with silt and gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 10.6723 D_{85}= 8.3878 D_{60}= 0.5154
D_{50}= 0.3688 D_{30}= 0.2314 D_{15}= 0.1542
D_{10}= 0.1187 C_u= 4.34 C_c= 0.88

Classification

USCS= SP-SM AASHTO=

Remarks

As received moisture content=22.0%
Soil classification and description based on Visual Manual Procedure ASTM D 2488

Source of Sample: B-3 **Depth:** 33-35
Sample Number: S-10

Date: 11/15/2011

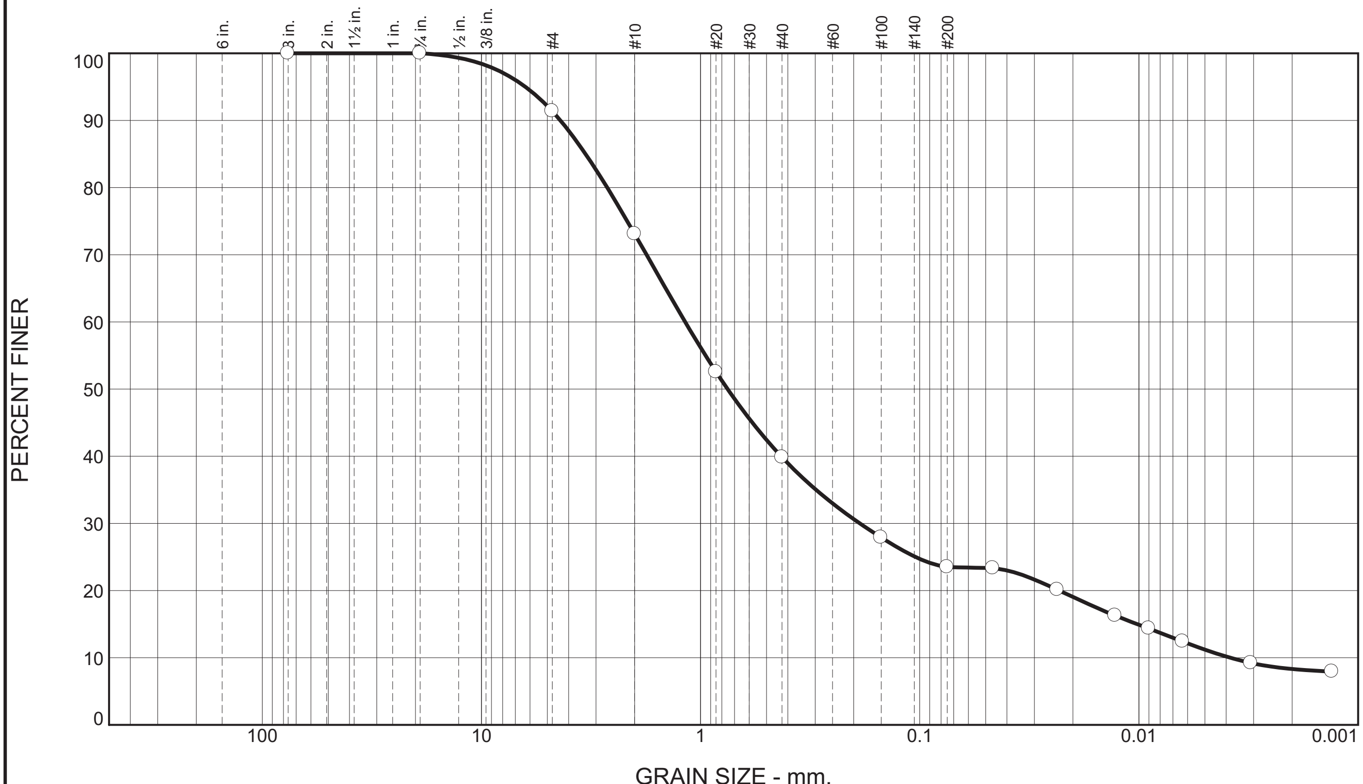
CDM Smith

Cambridge, Massachusetts

Client: TVA
Project: Watts Bar Fossil Plant CCP Closure
Project No: 95618-83529 **Figure**

Tested By: NE **Checked By:** MR

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	8.6	18.3	33.3	16.3	12.3	11.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3	100.0		
3/4	100.0		
#4	91.4		
#10	73.1		
#20	52.5		
#40	39.8		
#100	27.9		
#200	23.5		

* (no specification provided)

Material Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 4.3626 D_{85}= 3.3491 D_{60}= 1.1759
D_{50}= 0.7530 D_{30}= 0.1876 D_{15}= 0.0102
D_{10}= 0.0038 C_u= 306.42 C_c= 7.80

Classification

USCS= SM AASHTO=

Remarks

As received moisture content=11.6%
Soil classification and description based on Visual Manual Procedure ASTM D2488

Source of Sample: B-3 **Depth:** 38-38.7
Sample Number: S-11

Date: 11/15/2011

CDM Smith

Cambridge, Massachusetts

Client: TVA
Project: Watts Bar Fossil Plant CCP Closure
Project No: 95618-83529 **Figure**

Tested By: NE **Checked By:** MR

Geotechnical Engineering Laboratory

ISOTROPICALLY CONSOLIDATED UNDRAINED TRIAXIAL TEST SUMMARY - ASTM D4767

Client:	TVA	**Test Date:**	3/14/2012	**LL :**	34
Project:	Watts Bar	**Exploration No:**	B-2	**PL :**	19
Location:	Spring City, TN	**Sample No:**	U-1 Specimen 1	**PI :**	15
Project No:	95618-83529	**Depth (ft):**	21	**USCS:**	CL

Initial

Moisture Content (%):	20.7%
Dry Unit Weight (pcf):	105.9
Diameter (in):	1.407
Height (in):	3.125
Void Ratio (-):	0.59
Saturation (%):	94.7%
Moisture Content (Trim.%):	19.9%
Cross Sectional Area (in^2):	1.555

Final

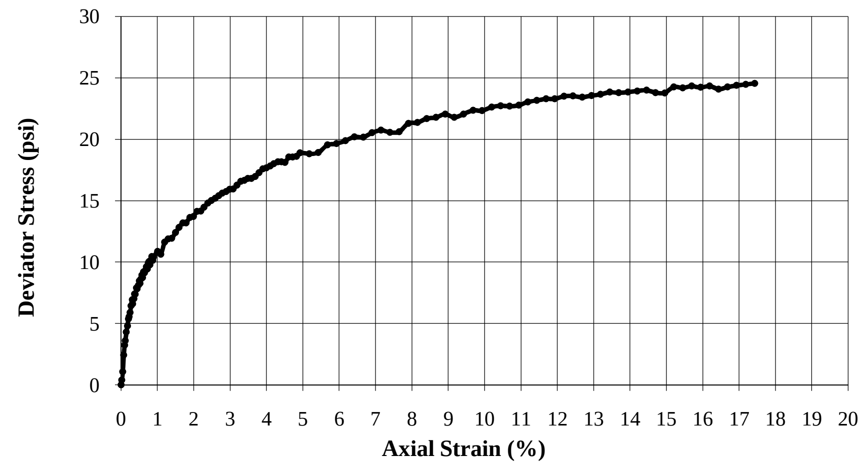
Moisture Content (%):	23.2%
Dry Unit Weight (pcf):	103.3
Height (in):	2.564
Void Ratio (-):	0.63
Saturation (%):	99.4%
Cross Sectional Area (in^2):	1.926

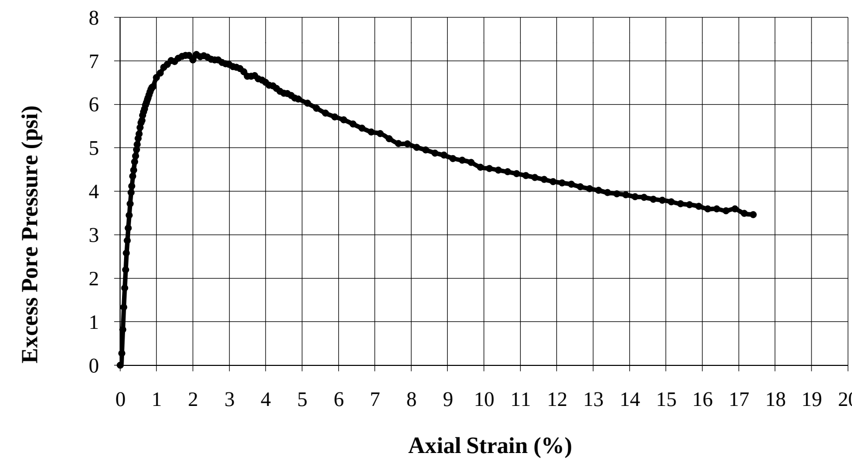
End of Consolidation Data

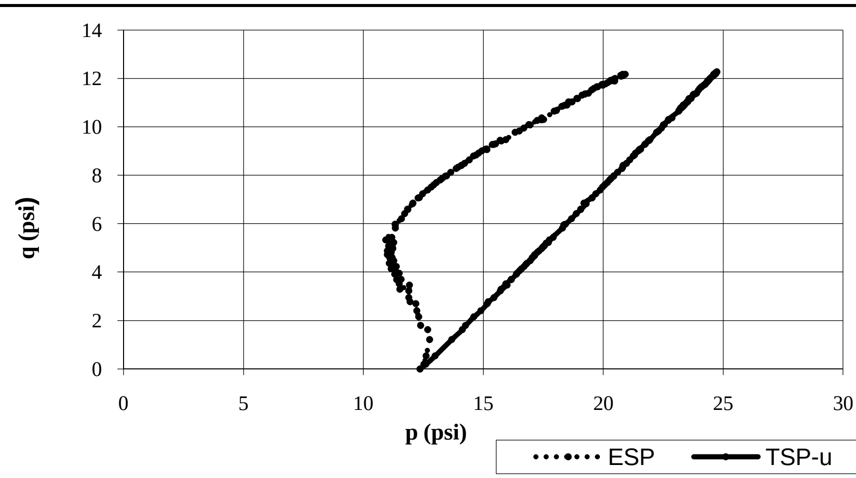
A_c Evaluated using Method	B
Sample Saturated using Method	B
Moisture Content (%):	23.2%
Dry Unit Weight (pcf):	103.3
Height (in):	3.125
Void Ratio (-):	0.63
Saturation (%):	99.4%
Cross Sectional Area (in^2):	1.590
Pore Pressure Parameter B (-):	0.97
Final Back Pressure (psi):	80
Consolidation Pressure (psi):	12.21

Shear Data

Shear Strain Rate (%/hr):	1%
Max. Deviator Stress (psi):	24.56
Strain at Failure (%):	15.00
Minor Eff. Pr. Stress (psi):	8.88
Major Eff. Pr. Stress (psi):	33.44
Undrained Strength Ratio (-):	1.01







Notes:

1. Value of Specific Gravity Gs is assumed
2. Failure criterion: max. deviator stress at strain ≤ 15%

Remarks:

Geotechnical Engineering Laboratory

ISOTROPICALLY CONSOLIDATED UNDRAINED TRIAXIAL TEST SUMMARY - ASTM D4767

Client:	TVA	**Test Date:**	3/14/2012	**LL :**	34
Project:	Watts Bar	**Exploration No:**	B-2	**PL :**	19
Location:	Spring City, TN	**Sample No:**	U-1 Specimen 2	**PI :**	15
Project No:	95618-83529	**Depth (ft):**	21	**USCS:**	CL

Initial

Moisture Content (%):	19.3%
Dry Unit Weight (pcf):	104.4
Diameter (in):	1.385
Height (in):	3.220
Void Ratio (-):	0.61
Saturation (%):	84.8%
Moisture Content (Trim.%):	20.6%
Cross Sectional Area (in^2):	1.507

Final

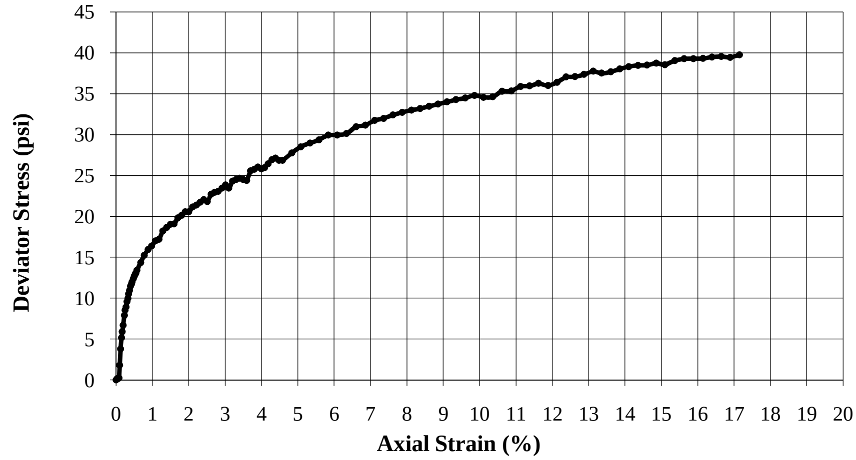
Moisture Content (%):	22.8%
Dry Unit Weight (pcf):	104.0
Height (in):	2.651
Void Ratio (-):	0.62
Saturation (%):	99.4%
Cross Sectional Area (in^2):	1.820

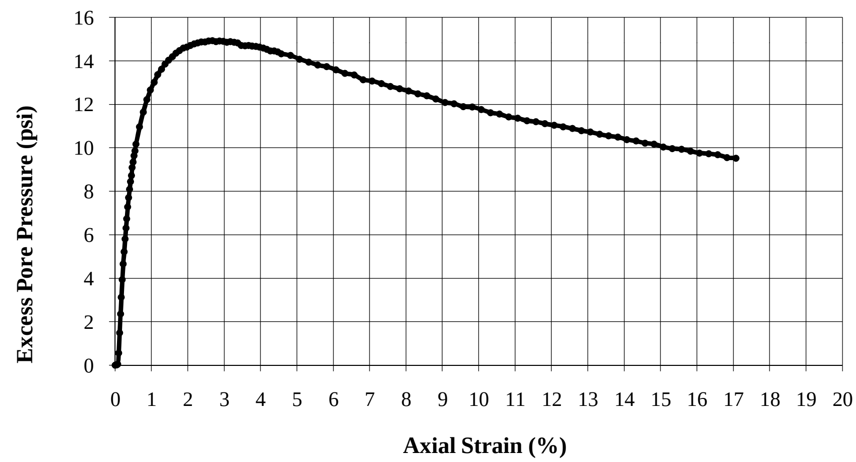
End of Consolidation Data

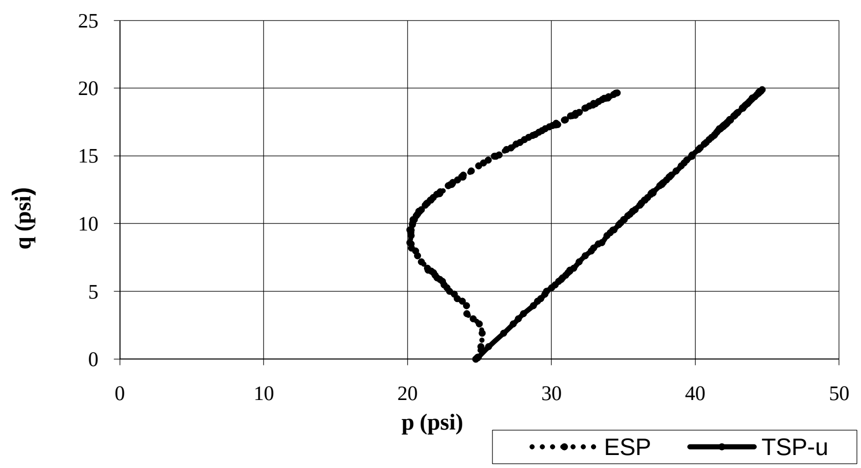
A_c Evaluated using Method	B
Sample Saturated using Method	B
Moisture Content (%):	22.8%
Dry Unit Weight (pcf):	104.0
Height (in):	3.219
Void Ratio (-):	0.62
Saturation (%):	99.4%
Cross Sectional Area (in^2):	1.508
Pore Pressure Parameter B (-):	0.97
Final Back Pressure (psi):	85
Consolidation Pressure (psi):	24.34

Shear Data

Shear Strain Rate (%/hr):	1%
Max. Deviator Stress (psi):	39.77
Strain at Failure (%):	15.00
Minor Eff. Pr. Stress (psi):	15.25
Major Eff. Pr. Stress (psi):	55.02
Undrained Strength Ratio (-):	0.82







Notes:

1. Value of Specific Gravity Gs is assumed
2. Failure criterion: max. deviator stress at strain ≤ 15%

Remarks:

Geotechnical Engineering Laboratory

ISOTROPICALLY CONSOLIDATED UNDRAINED TRIAXIAL TEST SUMMARY - ASTM D4767

Client:	TVA	**Test Date:**	3/14/2012	**LL :**	34
Project:	Watts Bar	**Exploration No:**	B2	**PL :**	19
Location:	Spring City, TN	**Sample No:**	U-1 Specimen 3	**PI :**	15
Project No:	95618-83529	**Depth (ft):**	21	**USCS:**	CL

Initial

Moisture Content (%):	20.8%
Dry Unit Weight (pcf):	104.5
Diameter (in):	1.411
Height (in):	3.085
Void Ratio (-):	0.61
Saturation (%):	91.7%
Moisture Content (Trim.%):	20.2%
Cross Sectional Area (in^2):	1.564

Final

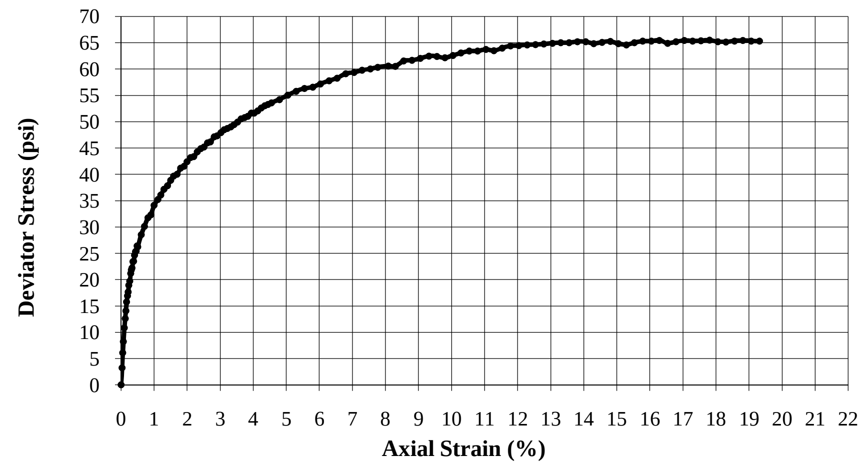
Moisture Content (%):	21.1%
Dry Unit Weight (pcf):	107.1
Height (in):	2.480
Void Ratio (-):	0.57
Saturation (%):	99.4%
Cross Sectional Area (in^2):	1.853

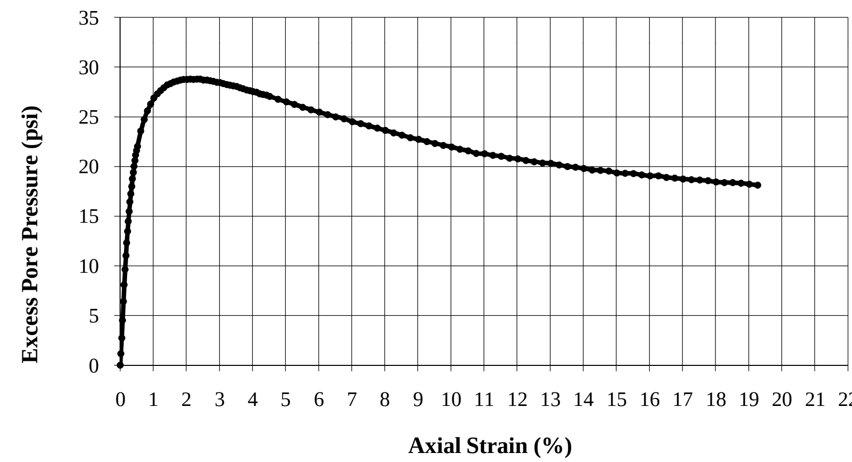
End of Consolidation Data

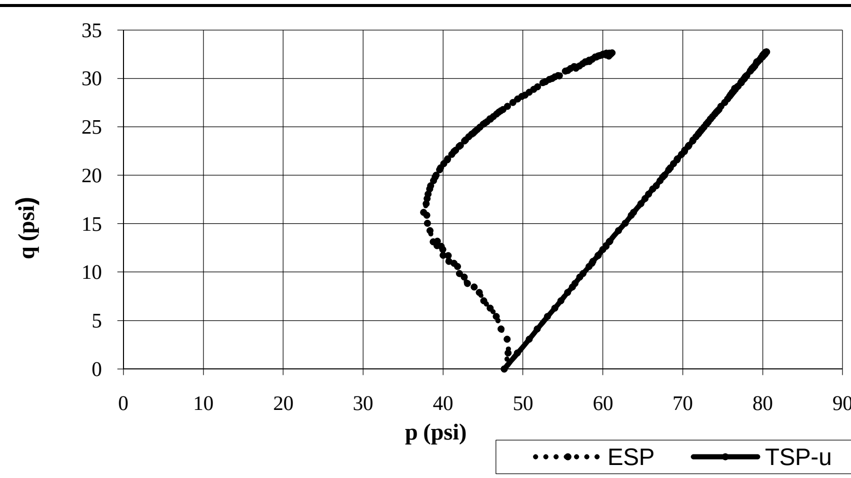
A_c Evaluated using Method	B
Sample Saturated using Method	B
Moisture Content (%):	21.1%
Dry Unit Weight (pcf):	107.1
Height (in):	3.084
Void Ratio (-):	0.57
Saturation (%):	99.4%
Cross Sectional Area (in^2):	1.523
Pore Pressure Parameter B (-):	0.97
Final Back Pressure (psi):	107
Consolidation Pressure (psi):	48.22

Shear Data

Shear Strain Rate (%/hr):	1%
Max. Deviator Stress (psi):	65.49
Strain at Failure (%):	15.00
Minor Eff. Pr. Stress (psi):	29.14
Major Eff. Pr. Stress (psi):	94.62
Undrained Strength Ratio (-):	0.68







Notes:

1. Value of Specific Gravity Gs is assumed
2. Failure criterion: max. deviator stress at strain ≤ 15%

Remarks:

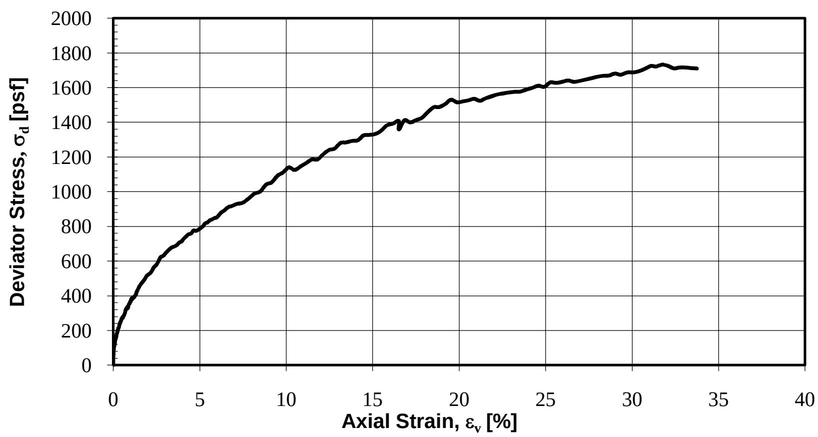
CDM Smith

Geotechnical Engineering Laboratory

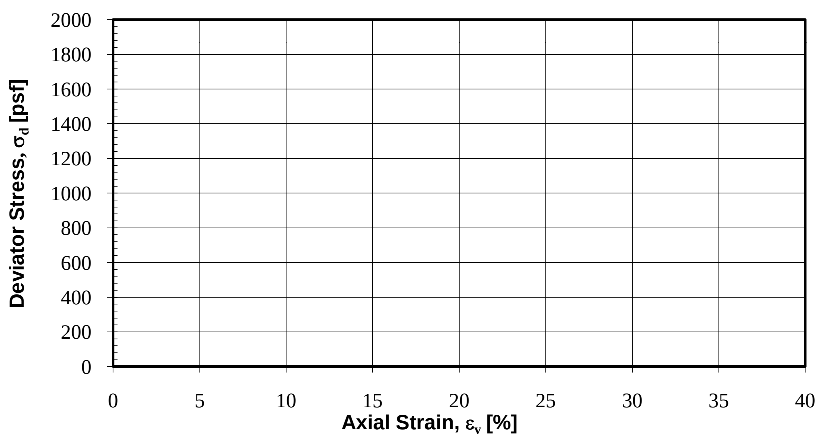
UNCONSOLIDATED-UNDRAINED TRIAXIAL TEST SUMMARY - ASTM D2850

Client:	TVA	**Test Date:**	3/14/2012	**LL :**	34
Project:	Watts Bar	**Exploration No:**	B-2	**PL :**	19
Location:		**Sample No:**	U-1	**PI :**	15
Project No:	95618-83529	**Depth (ft):**	21.5	**USCS:**	CL

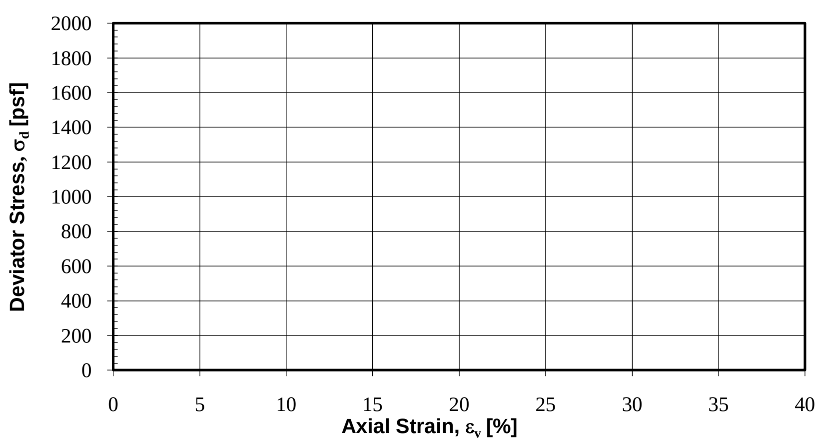
Specimen 1	**Initial**	**Final**
Moisture Content (%):	21.1%	22.0%
Dry Unit Weight (pcf):	126.5	-
Diameter (in):	1.390	-
Height (in):	2.750	-
Void Ratio (-):	0.61	0.61
Saturation (%):	93.3%	97.4%
Specific Gravity (-)(1):	2.70	
Moisture Content (Trim.%):	20.2%	
Strain Rate (%/min):	0.7	
Confining Pressure (psi):	7	
Strain at Failure (%):	15.00	
Compressive Strength (psf)(2)	12.0	



Specimen	**Initial**	**Final**
Moisture Content (%):		
Dry Unit Weight (pcf):		
Diameter (in):		
Height (in):		
Void Ratio (-):		
Saturation (%):		
Specific Gravity (-)(1):		
Moisture Content (Trim.%):		
Strain Rate (%/min):		
Confining Pressure (psi):		
Strain at Failure (%):		
Compressive Strength (psi)(2)		



Specimen	**Initial**	**Final**
Moisture Content (%):		
Dry Unit Weight (pcf):		
Diameter (in):		
Height (in):		
Void Ratio (-):		
Saturation (%):		
Specific Gravity (-)(1):		
Moisture Content (Trim.%):		
Strain Rate (%/min):		
Confining Pressure (psi):		
Strain at Failure (%):		
Compressive Strength (psi)(2)		



Notes:

1. Value of specific gravity is assumed
2. Failure criterion: maximum deviator stress at strain less than or equal to 15%

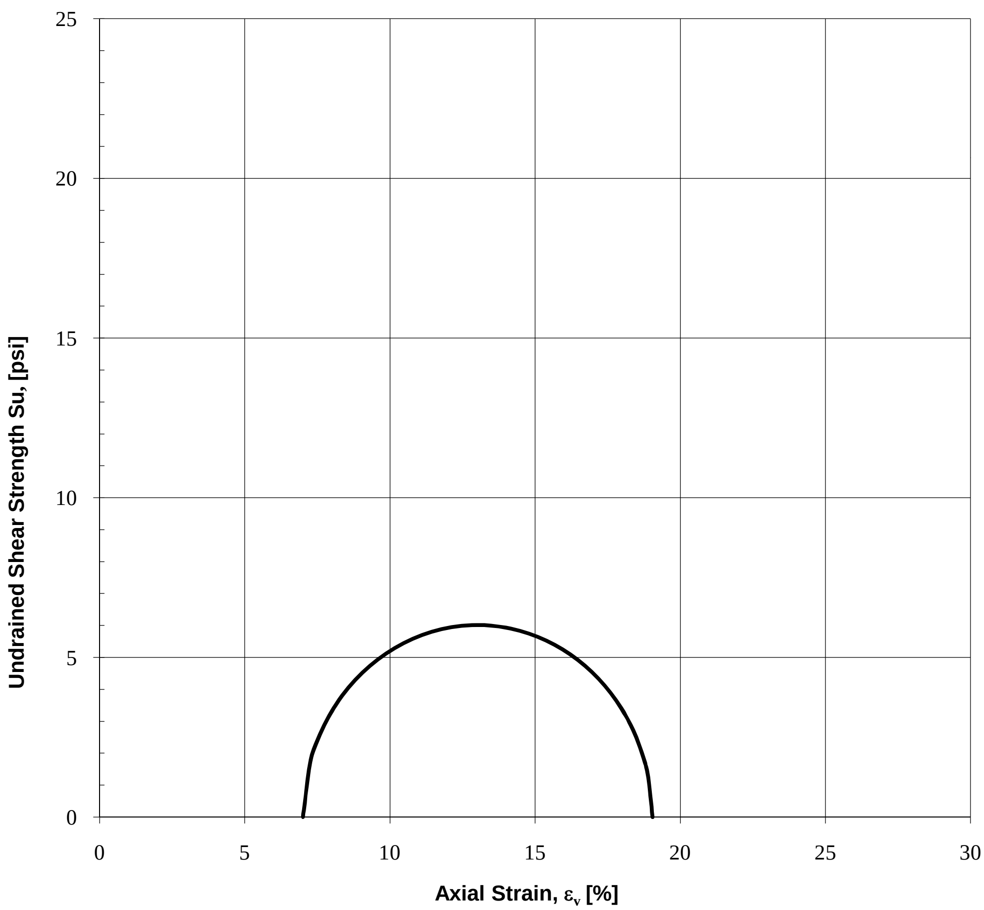
Test Remarks:

Geotechnical Engineering Laboratory

UNCONSOLIDATED-UNDRAINED TEST - MOHR CIRCLES

Client:	TVA	**Test Date:**	3/14/2012	**LL :**	34
Project:	Watts Bar	**Exploration No:**	B-2	**PL :**	19
Location:	0	**Sample No:**	U-1	**PI :**	15
Project No:	95618-83529	**Depth (ft):**	21.5	**USCS:**	CL

	Specimen 1	Specimen 2	Specimen 3
Confining Pressure (psi)	7	0	0
Undrained Shear Strength Su (psi)	6.02	0.00	0.00
Strain at Failure (%)	15.00	0.00	0.00
Initial Moisture Content (%)	21.1%	0.0%	0.0%
Initial Saturation (%)	93.3%	0.0%	0.0%
Average Su (psi)			



Notes:

Test Remarks:

CDM Smith

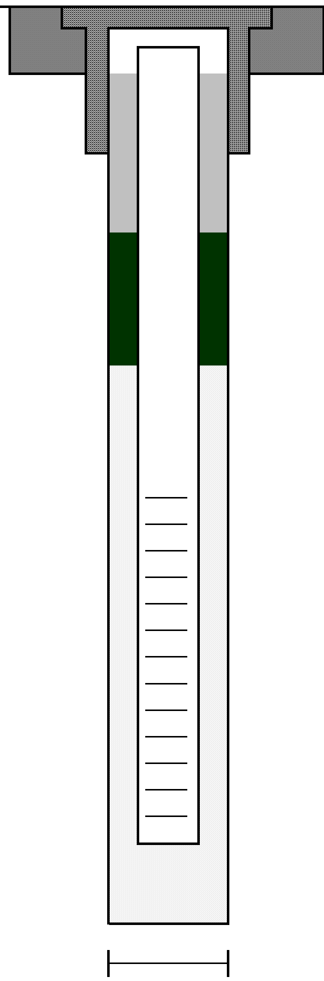
5400 Glenwood Ave
Suite 300
Raleigh, NC 27612
(919) 787-5620

Monitoring Well Installation Log

Client:	TVA	Contractor:	Total Depth Drilling	Boring/Well No.:	B-1/MW-1
Project Name:	Watts Bar Fossil Plant	Driller:	Tim Hall	Date Installed:	11/17/11 - 01/11/12
Project Location:	Watts Bar (Rhea Co.), TN	Ground EL:	699.0 ft	Logged By:	MRH
Project Number:	83529	Riser EL:		Page:	1 of 1

GROUND SURFACE

ROADWAY BOX



SURFACE SEAL: (Thickness & Type)	1 ft - Portland Cement
BACKFILL MATERIAL: (Type)	Soil sloughed into hole
TOP OF SEAL:	16 ft
SEAL CONSTRUCTION: (Thickness & Type)	7 ft - Bentonite
TOP OF SANDPACK:	23 ft
RISER CONSTRUCTION: (Type, Diameter Material)	Schedule 40 PVC, 2 - Inch
TOP OF SCREEN:	25 ft
SANDPACK TYPE:	Filter Sand - DSI Well Gravel Pack
SCREEN MATERIAL: (Type, Slot, Diameter Material)	Schedule 40 PVC, 0.10, 2-Inch
BOTTOM OF SCREEN:	35 ft
BOTTOM OF BOREHOLE:	44.6 ft
BOREHOLE DIAMETER:	0.75 ft - soil/0.24 ft - rock

NOTE: All depths are in feet below ground surface, unless noted otherwise.

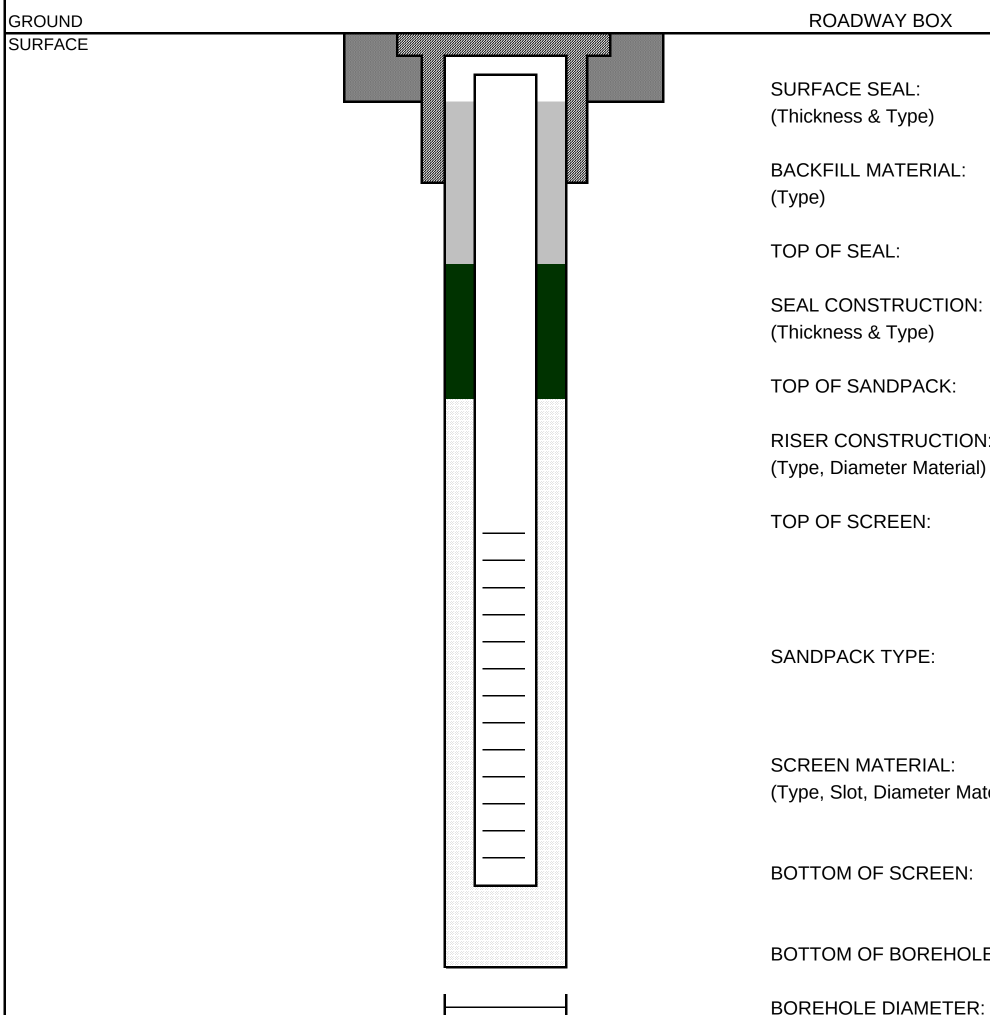
Remarks:

Updated On: 04/09/01

CDM Smith
5400 Glenwood Ave
Suite 300
Raleigh, NC 27612
(919) 787-5620

Monitoring Well Installation Log

Client:	TVA	Contractor:	Total Depth Drilling	Boring/Well No.:	B-3/MW-3
Project Name:	Watts Bar Fossil Plant	Driller:	Tim Hall	Date Installed:	11/16/2011
Project Location:	Watts Bar (Rhea Co.), TN	Ground EL:	701.0 ft	Logged By:	MRH
Project Number:	83529	Riser EL:		Page:	1 of 1



SURFACE SEAL: (Thickness & Type)	3 ft - Portland Cement
BACKFILL MATERIAL: (Type)	Filter Sand (DSI gravel pack)
TOP OF SEAL:	24 ft
SEAL CONSTRUCTION: (Thickness & Type)	4 ft - Bentonite
TOP OF SANDPACK:	28 ft
RISER CONSTRUCTION: (Type, Diameter Material)	Schedule 40 PVC, 2-Inch
TOP OF SCREEN:	30 ft
SANDPACK TYPE:	:Filter Sand - DSI Well Gravel Pack
SCREEN MATERIAL: (Type, Slot, Diameter Material)	Schedule 40 PVC, 0.10, 2-Inch
BOTTOM OF SCREEN:	40 ft
BOTTOM OF BOREHOLE:	54.8 ft
BOREHOLE DIAMETER:	0.75 ft - soil/0.24 ft - rock

NOTE: All depths are in feet below ground surface, unless noted otherwise.

Remarks:

Updated On: 04/09/01

Summary of Groundwater Level Readings

TVA WBF CCP Closure

Spring City, TN

Location	Ground Surface Elevation	Groundwater Level Readings		Date	Time (24 hr)
		in feet below ground surface	Elevation, ft		
B-1	699	12.1	686.9	11/16/2011	17:15
		13.1	685.9	11/16/2011	17:40
		9.32	689.7	1/11/2012	10:40
B-2	711	37.1	673.9	1/10/2012	13:05
		27.4	683.6	1/10/2012	14:50
B-3	701	31.15	669.9	11/15/2011	10:20
		15.70	685.3	11/16/2011	11:00
		19.00	682.0	1/10/2012	15:10
		18.11	682.9	1/11/2012	11:10

Note: Elevations & locations based on estimated distance to existing features.

ATTACHMENT B

Client: TVA
Project: WBF CCP CLOSURE

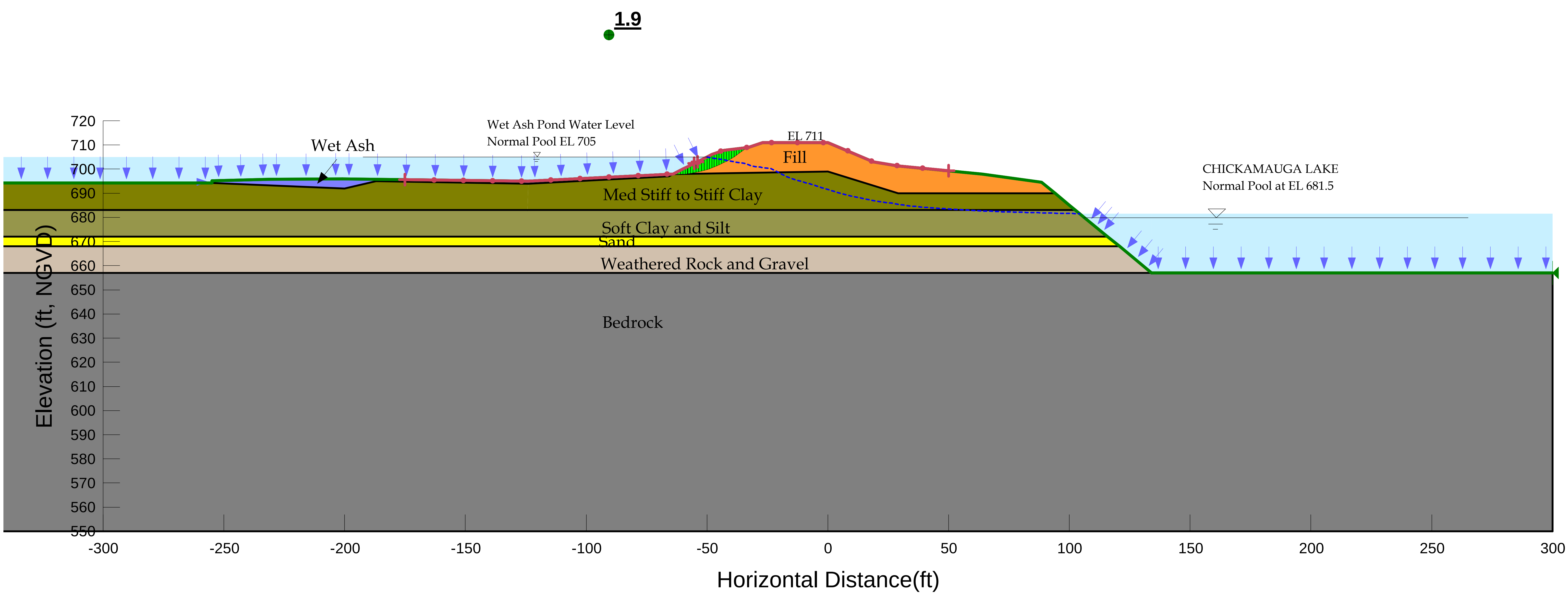
Computed By: Wen, Jintao
Date & Time: 1/20/2012 10:03:52 AM

TVA Watts Bar Fossil Plant, Spring City, TN
Seepage and Slope Stability Analyses
Cross-Section A-A' at Wet Ash Pond Area

Case Number: A-1
Location: Section A-A'

Model Scenario:
Existing Conditon at Wet Ash Pond Area
Static Analysis

Layer 1: Fill 120 pcf 115 pcf 0 psf 32 °
Layer 2A: Med Stiff to Stiff Clay 110 pcf 105 pcf 0 psf 29 °
Layer 2B: Soft Clay and Silt 110 pcf 0 psf 28 °
Layer 3: Sand 120 pcf 0 psf 30 °
Layer 4: Weathered Rock and Gravel 125 pcf 0 psf 40 °
Wet Ash 70 pcf 0 psf 20 °
Layer 5: Bedrock



Client: TVA
Project: WBF CCP CLOSURE

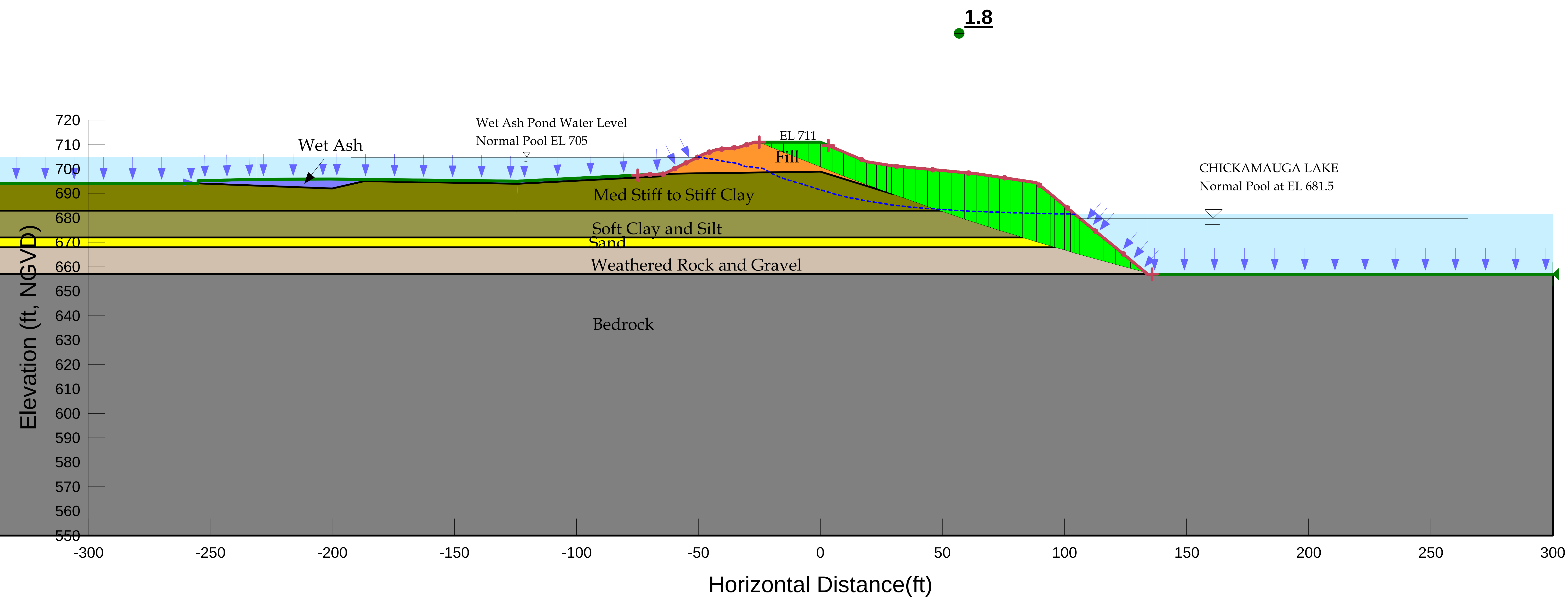
Computed By: Wen, Jintao
Date & Time: 1/20/2012 10:03:52 AM

TVA Watts Bar Fossil Plant, Spring City, TN
Seepage and Slope Stability Analyses
Cross-Section A-A' at Wet Ash Pond Area

Case Number: A-1
Location: Section A-A'

Model Scenario:
Existing Conditon at Wet Ash Pond Area
Static Analysis

Layer 1: Fill 120 pcf 115 pcf 0 psf 32 °
Layer 2A: Med Stiff to Stiff Clay 110 pcf 105 pcf 0 psf 29 °
Layer 2B: Soft Clay and Silt 110 pcf 0 psf 28 °
Layer 3: Sand 120 pcf 0 psf 30 °
Layer 4: Weathered Rock and Gravel 125 pcf 0 psf 40 °
Wet Ash 70 pcf 0 psf 20 °
Layer 5: Bedrock



Client: TVA
Project: WBF CCP CLOSURE

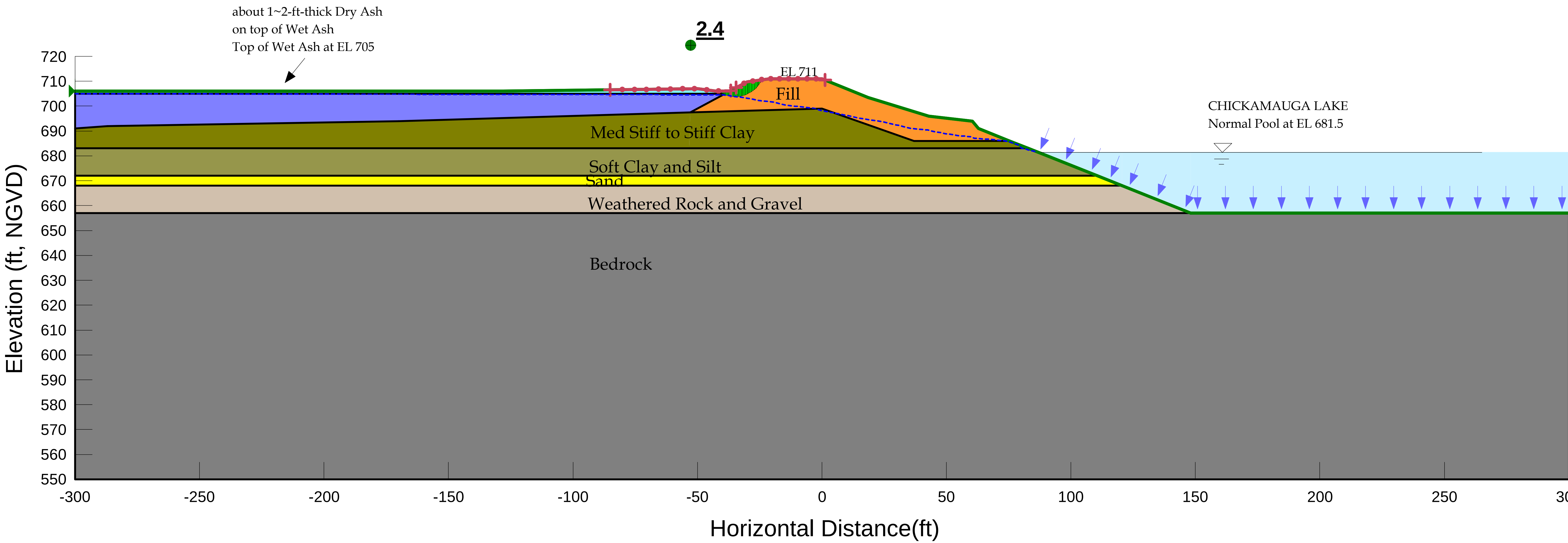
Computed By: Wen, Jintao
Date & Time: 1/20/2012 9:58:09 AM

TVA Watts Bar Fossil Plant, Spring City, TN
Seepage and Slope Stability Analyses
Cross-Section B-B' at Dry Ash Area

Case Number: B-1
Location: Section B-B'

Model Scenario:
Existing Conditon at Dry Ash Area.
Static Analsyes

Layer 1: Fill 120 pcf 115 pcf 0 psf 32 °
Dry Ash 85 pcf 0 psf 25 °
Layer 2A: Med Stiff to Stiff Clay 110 pcf 105 pcf 0 psf 29 °
Layer 2B: Soft Clay and Silt 110 pcf 0 psf 28 °
Layer 3: Sand 120 pcf 0 psf 30 °
Layer 4: Weathered Rock and Gravel 125 pcf 0 psf 40 °
Wet Ash 70 pcf 0 psf 20 °
Layer 5: Bedrock



Client: TVA
Project: WBF CCP CLOSURE

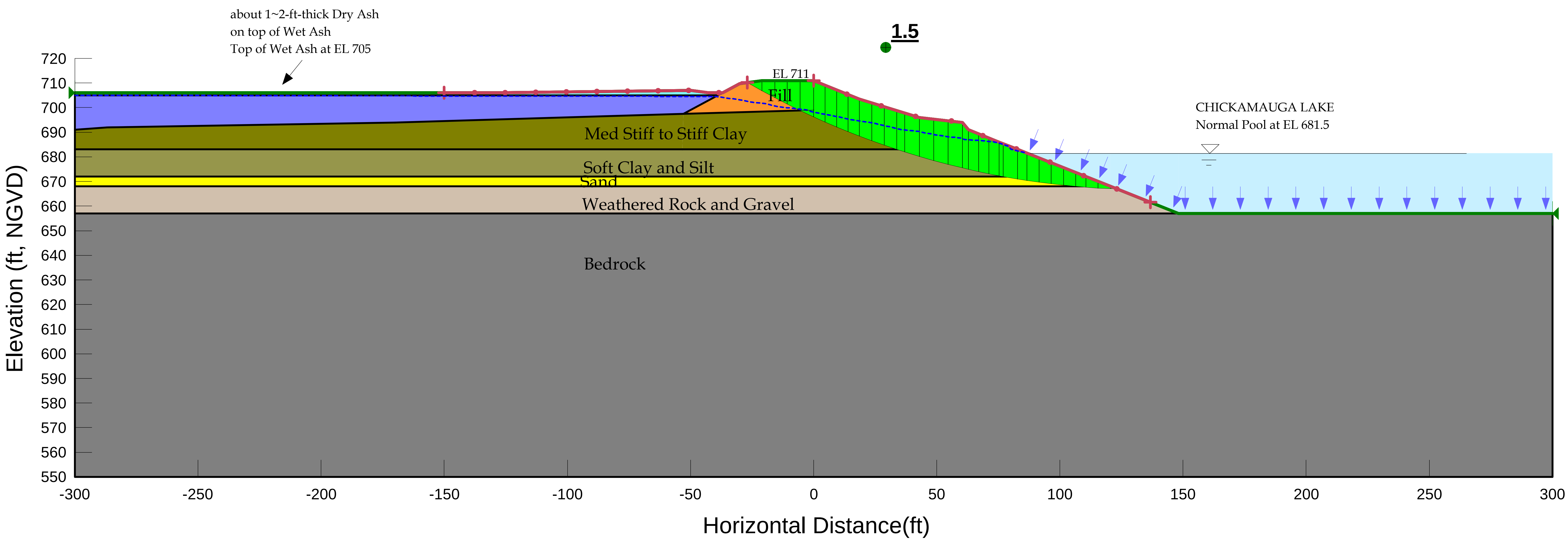
Computed By: Wen, Jintao
Date & Time: 1/20/2012 10:02:17 AM

TVA Watts Bar Fossil Plant, Spring City, TN
Seepage and Slope Stability Analyses
Cross-Section B-B' at Dry Ash Area

Case Number: B-1
Location: Section B-B'

Model Scenario:
Existing Conditon at Dry Ash Area.
Static Analsyes

Layer 1: Fill 120 pcf 115 pcf 0 psf 32 °
Dry Ash 85 pcf 0 psf 25 °
Layer 2A: Med Stiff to Stiff Clay 110 pcf 105 pcf 0 psf 29 °
Layer 2B: Soft Clay and Silt 110 pcf 0 psf 28 °
Layer 3: Sand 120 pcf 0 psf 30 °
Layer 4: Weathered Rock and Gravel 125 pcf 0 psf 40 °
Wet Ash 70 pcf 0 psf 20 °
Layer 5: Bedrock



Client: TVA
Project: WBF CCP CLOSURE

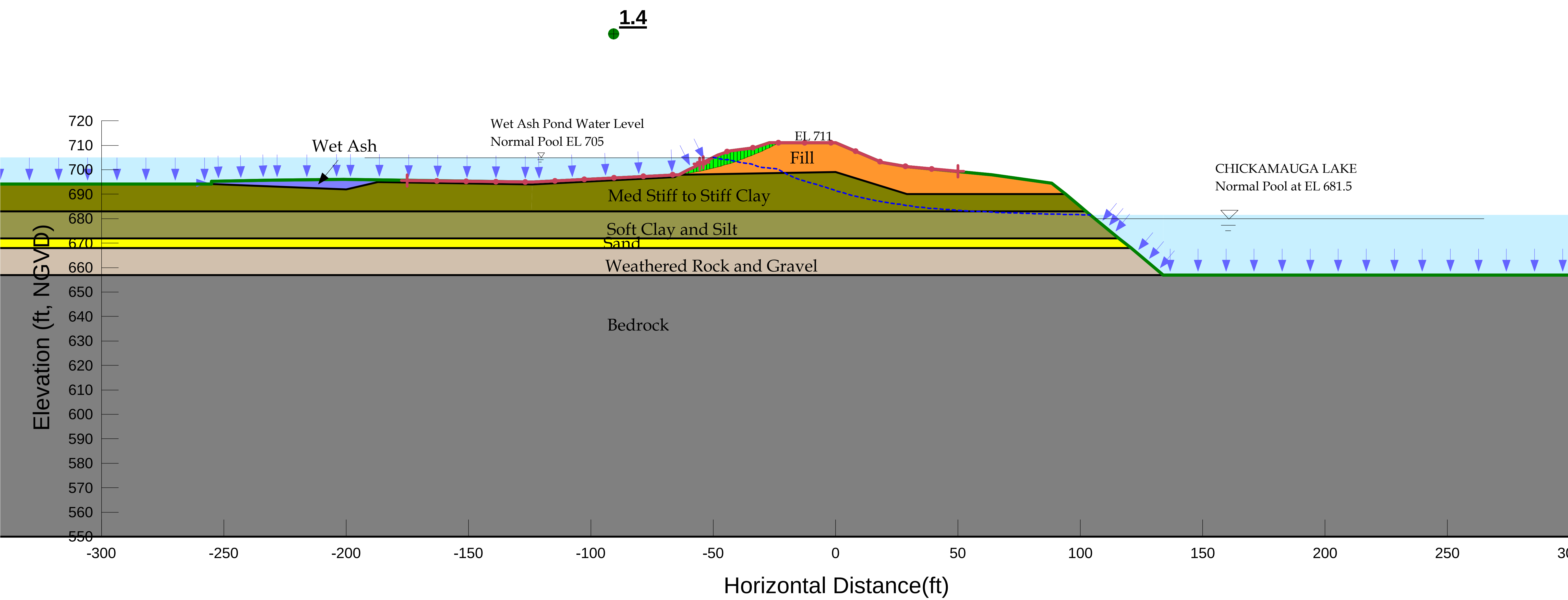
Computed By: Wen, Jintao
Date & Time: 4/25/2012 3:08:18 PM

TVA Watts Bar Fossil Plant, Spring City, TN
Seepage and Slope Stability Analyses
Cross-Section A-A' at Wet Ash Pond Area

Case Number: A-2
Location: Section A-A'

Model Scenario:
Existing Conditon at Wet Ash Pond
Seismic Analysis PHA=0.116g

Layer 1: Fill 120 pcf 115 pcf 0 psf 32 °
Layer 2A: Med Stiff to Stiff Clay 110 pcf 105 pcf 1300 psf 0 °
Layer 2B: Soft Clay and Silt 110 pcf 500 psf 0 °
Layer 3: Sand 120 pcf 0 psf 30 °
Layer 4: Weathered Rock and Gravel 125 pcf 0 psf 40 °
Wet Ash 70 pcf 0 psf 20 °
Layer 5: Bedrock



Client: TVA
Project: WBF CCP CLOSURE

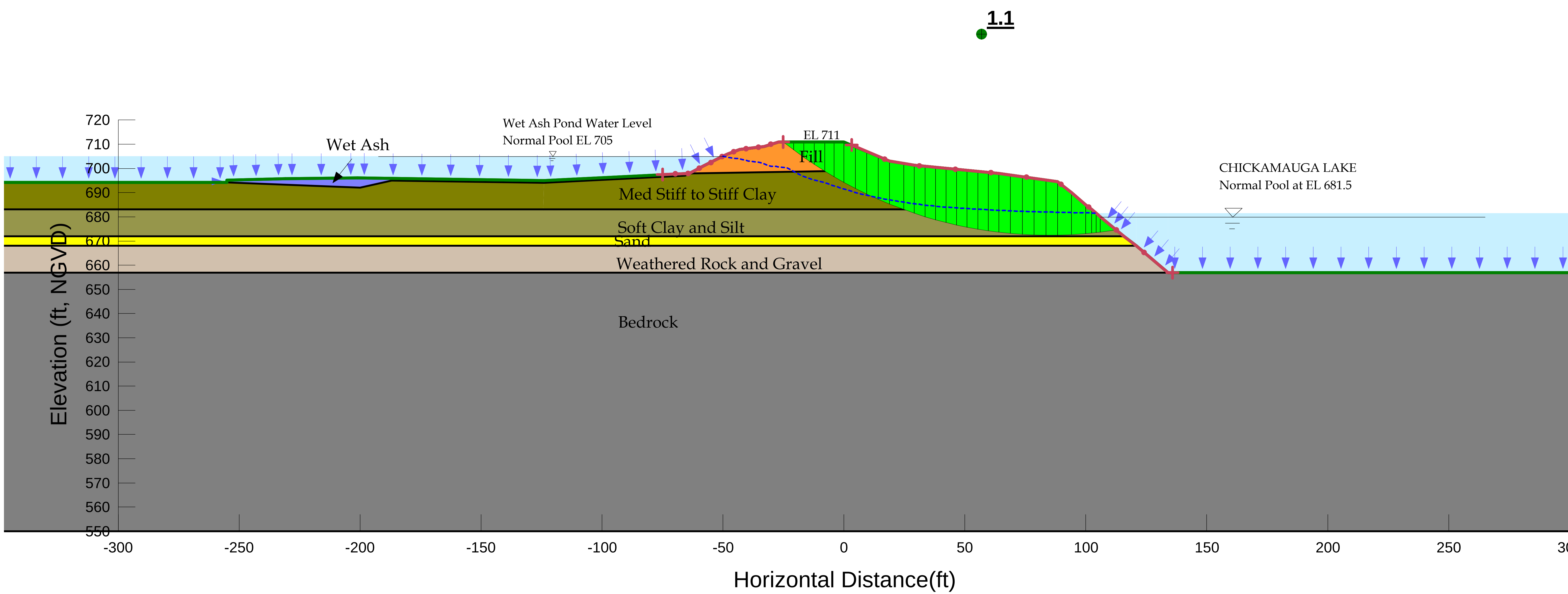
Computed By: Wen, Jintao
Date & Time: 4/25/2012 3:08:18 PM

TVA Watts Bar Fossil Plant, Spring City, TN
Seepage and Slope Stability Analyses
Cross-Section A-A' at Wet Ash Pond Area

Case Number: A-2
Location: Section A-A'

Model Scenario:
Existing Conditon at Wet Ash Pond
Seismic Analysis PHA=0.116g

Layer 1: Fill 120 pcf 115 pcf 0 psf 32 °
Layer 2A: Med Stiff to Stiff Clay 110 pcf 105 pcf 1300 psf 0 °
Layer 2B: Soft Clay and Silt 110 pcf 500 psf 0 °
Layer 3: Sand 120 pcf 0 psf 30 °
Layer 4: Weathered Rock and Gravel 125 pcf 0 psf 40 °
Wet Ash 70 pcf 0 psf 20 °
Layer 5: Bedrock



Client: TVA
Project: WBF CCP CLOSURE

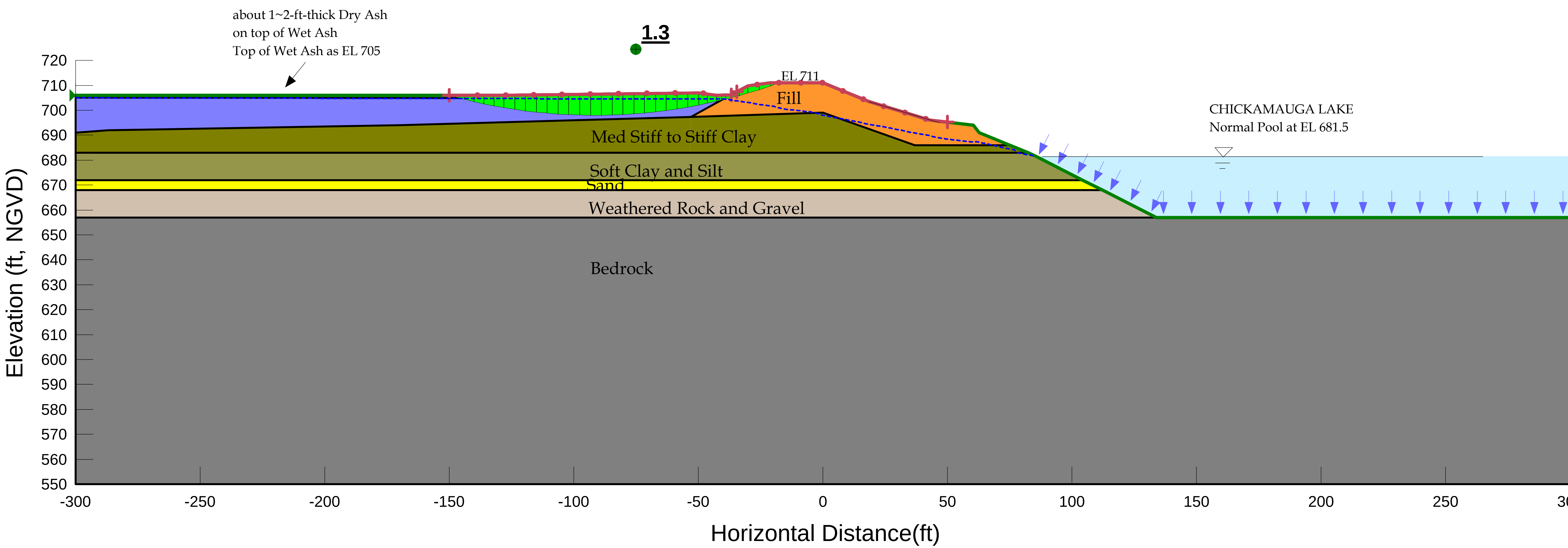
Computed By: Wen, Jintao
Date & Time: 4/25/2012 3:05:46 PM

TVA Watts Bar Fossil Plant, Spring City, TN
Seepage and Slope Stability Analyses
Cross-Section B-B' at Dry Ash Area

Case Number: B-2
Location: Section B-B'

Model Scenario:
Existing Conditon at Dry Ash Area.
Seismic Analsyes, PHA=0.116g

Layer 1: Fill 120 pcf 115 pcf 0 psf 32 °
Dry Ash 85 pcf 0 psf 25 °
Layer 2A: Med Stiff to Stiff Clay 110 pcf 105 pcf 1300 psf 0 °
Layer 2B: Soft Clay and Silt 110 pcf 500 psf 0 °
Layer 3: Sand 120 pcf 0 psf 30 °
Layer 4: Weathered Rock and Gravel 125 pcf 0 psf 40 °
Wet Ash 70 pcf 0 psf 20 °
Layer 5: Bedrock



Client: TVA
Project: WBF CCP CLOSURE

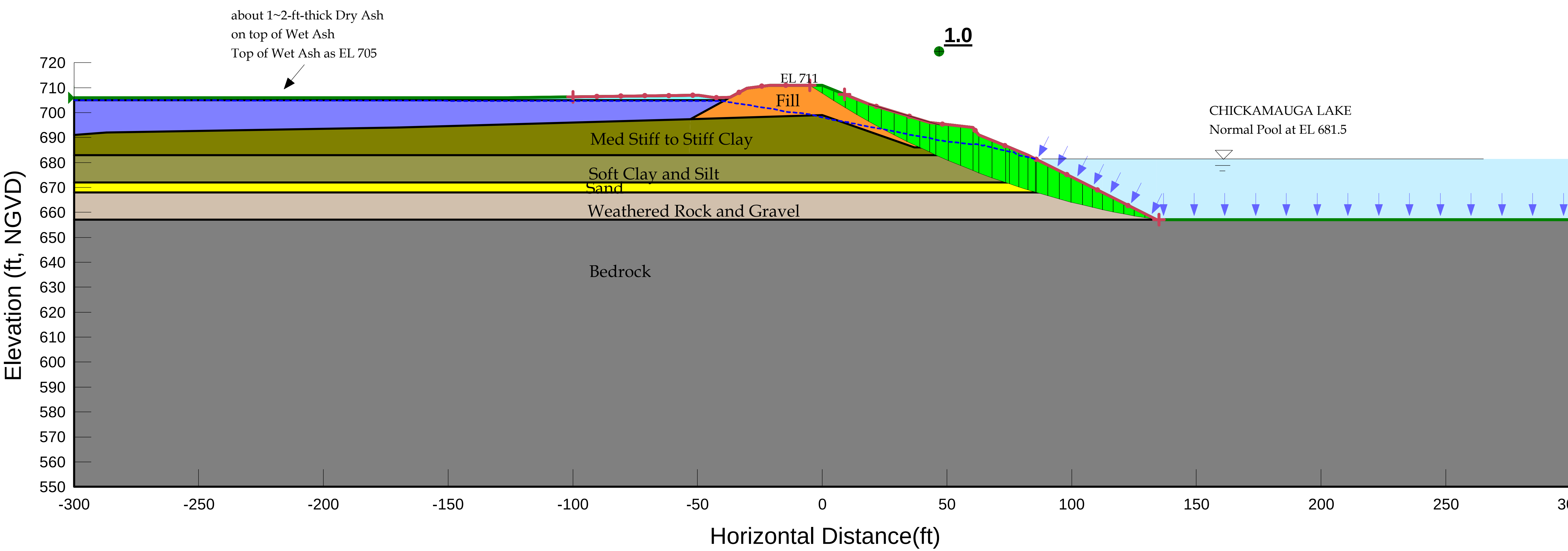
Computed By: Wen, Jintao
Date & Time: 4/25/2012 3:05:46 PM

TVA Watts Bar Fossil Plant, Spring City, TN
Seepage and Slope Stability Analyses
Cross-Section B-B' at Dry Ash Area

Case Number: B-2
Location: Section B-B'

Model Scenario:
Existing Conditon at Dry Ash Area.
Seismic Analsyes, PHA=0.116g

Layer 1: Fill 120 pcf 115 pcf 0 psf 32 °
Dry Ash 85 pcf 0 psf 25 °
Layer 2A: Med Stiff to Stiff Clay 110 pcf 105 pcf 1300 psf 0 °
Layer 2B: Soft Clay and Silt 110 pcf 500 psf 0 °
Layer 3: Sand 120 pcf 0 psf 30 °
Layer 4: Weathered Rock and Gravel 125 pcf 0 psf 40 °
Wet Ash 70 pcf 0 psf 20 °
Layer 5: Bedrock



Client: TVA
Project: WBF CCP CLOSURE

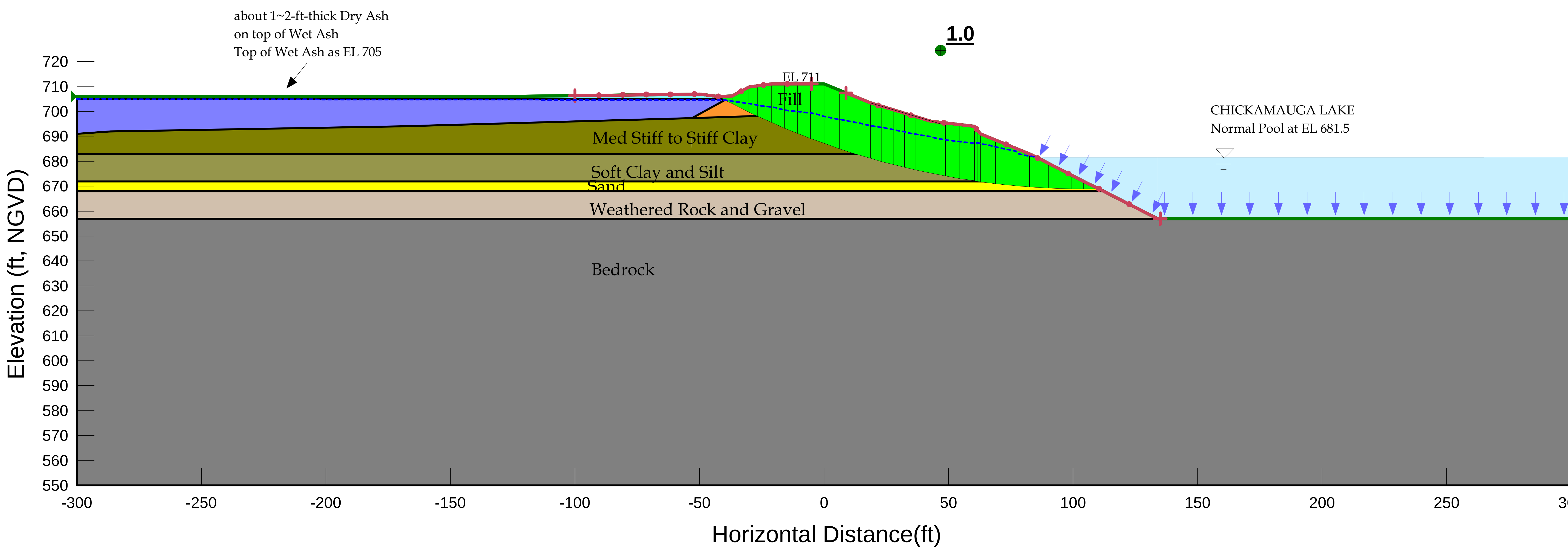
Computed By: Wen, Jintao
Date & Time: 4/20/2012 10:49:51 AM

TVA Watts Bar Fossil Plant, Spring City, TN
Seepage and Slope Stability Analyses
Cross-Section B-B' at Dry Ash Area

Case Number: B-2
Location: Section B-B'

Model Scenario:
Existing Conditon at Dry Ash Area.
Seismic Analsyes, PHA=0.09g

Layer 1: Fill 120 pcf 115 pcf 0 psf 32 °
Dry Ash 85 pcf 0 psf 25 °
Layer 2A: Med Stiff to Stiff Clay 110 pcf 105 pcf 1000 psf 0 °
Layer 2B: Soft Clay and Silt 110 pcf 500 psf 0 °
Layer 3: Sand 120 pcf 0 psf 30 °
Layer 4: Weathered Rock and Gravel 125 pcf 0 psf 40 °
Wet Ash 70 pcf 0 psf 20 °
Layer 5: Bedrock



ATTACHMENT C

Seismic Risk Assessment
Closed CCP Storage Facilities
Tennessee Valley Authority Fossil Plants

Prepared by:

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Stantec Consulting Services, Inc.

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Stantec Consulting Services, Inc.

Reviewed and Approved by:

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TVA-CCP Interim Engineering Manager
Tennessee Valley Authority

William H. Walton, P.E.
Vice President, Senior Principal Engineer
AECOM

Thomas L. Cooling, P.E.
Vice President, Geotechnical Services
URS Corporation

Gonzalo Castro
Independent Consultant

Seismic Risk Assessment
Closed CCP Storage Facilities
Tennessee Valley Authority Fossil Plants

This document outlines proposed engineering analyses to estimate seismic failure risks at wet storage facilities for coal combustion products, following closure, at various TVA fossil power plants. The specific details outlined in this document are subject to future discussion and modification by the project team.

OVERVIEW

Tennessee Valley Authority (TVA) operates storage facilities for coal combustion products (CCPs) at eleven fossil power generating stations. As TVA transitions to dry systems for handling these materials, 18 to 25 wet storage facilities (CCP ponds, impoundments, dredge cells, etc.) will be closed (drained and capped). The CCP storage facilities are currently operated in accordance with state and federal regulations, but previously issued permits have not required evaluations for seismic performance. Moreover, the existing permits do not require seismic qualification for the storage facilities in their closed configurations.

TVA recognizes there is a potential for strong earthquakes to occur within the region, and there is a tangible risk for seismic failure at each closed CCP facility. These risks, including both the likelihood of failure and the consequences, must be understood to effectively manage TVA's portfolio of byproduct storage sites. This white paper summarizes the methodology that will be used to estimate these risks at the CCP storage facilities following closure.

Seismicity in the TVA service area is attributed to the New Madrid fault and smaller, less concentrated crustal faults. These two earthquake scenarios generate significantly different seismic hazards at each locality and will be considered independently within the risk assessment. At each closed byproduct facility, potential seismic failure modes will be evaluated in sequence. Instability due to soil liquefaction, slope instability due to inertial loading, and other potential failure mechanisms will be addressed. Seismic performance will be evaluated for differing earthquake return periods until a limiting (lowest return period) event that would cause failure is obtained. The probability of seismic failure will then correspond to the probability of this limiting earthquake event. The assessment of risk will also include estimates of potential consequences, as well as costs to mitigate the risks, that reflects the unique setting of the individual storage facilities after closure.

Following the same general methodology, seismic risks will be estimated in two phases. The near-term "Portfolio Seismic Assessment" will provide a rough estimate of seismic risks. The likely performance of each facility will be evaluated using simplified analyses, empirical methods, and the judgment of experienced engineers. The results will establish a ranking of the relative risks across the closure portfolio and also provide a preliminary picture of overall seismic risk. For the subsequent "Facility Seismic Assessments", seismic performance will be judged on the basis of site-specific data and detailed engineering analyses, which will be completed during the closure design process for individual facilities.

SEISMIC RISKS

This white paper provides an overview of the engineering methods proposed by Stantec for estimating seismic risks at TVA's closed byproduct storage sites. For each facility, four specific questions must be answered quantitatively:

(1) What is the approximate probability that a strong earthquake will occur?

Several seismic source zones could produce earthquakes large enough to impact these TVA sites. Very large magnitude earthquakes have occurred within the New Madrid seismic zone, which is located along the western boundaries of Tennessee and Kentucky. Because of their observed large magnitude and frequency of occurrence, New Madrid events contribute substantially to the seismic risks at all TVA sites. Ground motions from a New Madrid earthquake would attenuate with distance toward the east, such that local area sources also contribute significantly to site-specific seismic hazards.

Seismicity across the Tennessee Valley was previously characterized by AMEC/Geomatrix (2004), in a probabilistic study that focused on TVA dam sites. The same seismogenic model can be applied in evaluating earthquakes that would impact other TVA sites. Accordingly, probabilistic seismic hazards obtained from the 2004 AMEC/Geomatrix model will be used in the seismic risk assessment of the closed CCP storage facilities.

(2) Will a given earthquake cause failure in the closed facility?

Many of the TVA byproduct storage facilities are underlain by a substantial thickness of loose, saturated, alluvial soils (silts and sands). Some facilities will have layers of ash or other uncemented CCPs that remain saturated following closure. These materials, especially sluiced fly ash, are prone to liquefaction in a strong earthquake, as cyclic motions cause a build up of pore water pressure and a consequent loss of effective stress and shearing resistance. Extensive liquefaction in a foundation or CCP deposit under a storage facility would be expected, in most cases, to result in lateral spreading and massive slope movements (failure). Even without liquefaction, large slope deformations or failures may be triggered by lateral inertial loads during an earthquake. Liquefaction and dynamic loading of slopes are the most likely failure mechanisms, but other seismic failure modes, which may be unique to a particular closed storage facility, must also be evaluated.

(3) What are the potential consequences of a failure?

In addition to understanding the probability of failure, a risk assessment should consider the potential consequences. A failure is likely to have economic costs associated with clean-up and restoration of the site. Depending on the local site conditions, failure of a closed CCP facility may or may not cause significant impacts on the environment, waterways, transportation routes, buried or overhead utilities, or other infrastructure. Substantial economic costs would result if power generation is interrupted. Failure consequences may also include the potential loss of human life at some sites.

In this proposed seismic risk assessment, the definition of "failure" will be constrained to mean the displacement of stored materials to a distance beyond the permitted boundary of the facility. While smaller deformations in a closed storage facility could cause economic damages, the resulting consequences for TVA should be manageable. Hence, this risk assessment will focus on potential "failures" where stored materials could move past the permitted boundary.

(4) What are the approximate costs to mitigate the risks of a seismic failure?

With an understanding of the probability and consequences of failure, the potential risks can be quantified and understood, possibly leading to decisions to mitigate seismic risks in the closure of certain facilities. Mitigation measures might include ground improvement to reduce liquefaction potential (stone columns, deep soil mixing, jet grouting, or other appropriate technology), stabilization of slopes by flattening or buttressing, enhanced drainage features, or some other engineered solution. The potential cost of these risk mitigation strategies are needed to make appropriate management decisions.

PORTFOLIO AND FACILITY ASSESSMENTS

Seismic evaluations will be completed for each of the CCP storage facilities that TVA has slated for closure; a tentative list is given in Table 1. The assessment of seismic risks will be accomplished in two phases:

A. Portfolio Seismic Assessment

In this first phase, the seismic risk assessment will be carried out using general site information, simplified analyses, empirical methods, and the judgment of experienced engineers. A team of four to five engineers will complete this evaluation for the entire portfolio, with assistance from the engineering teams currently working on each facility. After the probabilistic seismic hazards are defined, this phase of the work can be completed in a relatively short timeframe.

Given the level of effort and the simplified engineering analyses to be employed, the seismic risk estimates from the Phase A assessment will be approximate. Rather than attempting to compute precise risk numbers, Phase A will focus on capturing the relative risks between the different closed facilities. The key to successfully meeting this objective will be the consistent application of the assessment process across the portfolio.

This effort will result in a ranked list of sites that can be used to illustrate where seismic risks are greatest within the portfolio. The results will also provide some insight for understanding and communicating the magnitude of potential risks associated with seismic loading of the closed CCP facilities.

As a secondary objective, the Phase A assessment team will also consider the potential for failure of the active storage facilities, due to an earthquake occurring prior to closure. The seismic risks associated with the operating facility will not be estimated, but the Phase A assessment process provides an opportunity to identify potential failure mechanisms that should be addressed in the short term. This information may suggest the need to re-prioritize the closure schedule. Prior to closure, many of the wet CCP storage facilities retain large pools of water and are thus more susceptible to uncontrolled releases in an earthquake. TVA has already made the decision to close these wet storage facilities to manage these risks, so the effort in Phase A will focus on identifying sites that may have unusually high seismic risks and deserve more study or higher priority in the closure program.

B. Facility Seismic Assessment

In this subsequent phase of work, more detailed engineering analyses will be carried out using site-specific geometry, subsurface conditions, material parameters, and results from static slope stability analyses. Simplified, state-of-the-practice methods of engineering analysis will be used; more complex analytical methods will be generally impractical for this risk assessment.

This phase of the work will be accomplished for individual facilities as part of the closure design, after the completion of other engineering analyses. The risks will be quantified by the design team, with assistance from the portfolio seismic assessment team. Significant, detailed effort will be required to assess each closed facility.

Compared to Phase A, the risk estimates obtained at this stage will be more reliable and better represent the actual risks for seismic failure. While it will be impossible to know how accurately the risks have been characterized at the completion of Phase B, the objective is to obtain results that are within perhaps ± 30% of the "actual" risk numbers. TVA expects to use the Phase B results to decide if the risks are acceptable, or if the closure design should be modified to mitigate risks for a seismic failure.

The engineering methodology (described below) to be followed in the Phase A and B evaluations will not characterize all of the uncertainties with respect to seismic performance. The uncertainties in the soil parameters and in the liquefaction, stability, and deformation analyses will not be quantified and carried through the risk assessment. Consequently, the estimated risk numbers will be approximate, but the results will be sufficiently accurate to support TVA decisions regarding prioritization for closure or the need for seismic mitigation. At most sites, the risks are expected to be high enough or low enough that further refinement in the risk numbers would not change these decisions. More detailed analysis beyond Phase B would be unjustified in these cases.

This assessment plan does not preclude the possibility that more detailed risk evaluations could be undertaken in subsequent phases of work. The Phase B results might reveal a subset of closed facilities with marginal risks, where a more rigorous and complete calculation of the risks would be needed to support a management decision. Hence, at the conclusion of the Phase B assessments, a "Phase C" evaluation may be needed for select sites and facilities, wherein uncertainties in the soil parameters and performance analyses would be quantified and carried through the risk assessment.

RESULTS AND APPLICATION

The results from the Phase A Portfolio Assessment will be presented in a table, like Table 1. For each facility evaluated, the estimated annual probability of failure due to a seismic event, the expected consequences (economic costs and potential loss of life), and the mitigation costs (design features to reduce risks) will be tabulated. The same parameters, but more accurate numbers, will be reported from the more in-depth Phase B assessments. A qualitative description of the data quality (based on the number of borings, test data on key soil properties, etc.) will also be included, to indicate how well the site conditions were characterized at the time of the Phase A or B assessment.

In both Phase A and B, the evaluation teams will prepare a discussion of significant issues driving the seismic risks at each site. This summary will include knowledge gaps, likely failure mechanisms, unique consequences, suggested approaches for risk mitigation, and other key information. The Phase A evaluation of a facility may point out the need for additional data to support later seismic analyses in Phase B; needed field or laboratory testing could then be accomplished and documented as part of the facility closure design effort.

In the short term, TVA will utilize the Phase A results to better plan budgets and schedules for managing the closure process over the next several years. The Phase A assessment will also be used as an opportunity to identify operating facilities with especially high seismic risks. While these risks will not be quantified for conditions prior to closure, the consideration of potential seismic failure modes may prompt additional study and reconsideration of priorities. Where justified, the priorities for closure may be changed to more quickly address sites with higher seismic risks.

More accurate risk estimates will be obtained from the Phase B assessments, which will be completed as part of the closure design process. Those results will be used, within TVA's existing decision making framework, to judge if seismic mitigation is needed. For context, the criteria in Tables 2 and 3 represent the risk-based framework TVA uses to guide enterprise-level decisions. This framework relies upon broad, qualitative scoring of consequences and risks for the organization. For managing the seismic risks at the closed CCP facilities, complete probabilistic calculations of risk are not needed; approximate estimates of seismic risk will be sufficient to support TVA decisions.

The risks computed in Phase A and B will not be compared to a prescribed threshold or design risk level. Criteria for tolerable seismic risk in these closed CCP storage facilities has not been defined in the existing permits, in TVA policy, or in TVA design guidance.

METHODOLOGY

The same general methodology, outlined in ten steps below and in Figures 1 through 4, will be used to evaluate seismic risk in both the Phase A Portfolio Assessments and the Phase B Facility Assessments. While advanced engineering analyses may be required to demonstrate acceptable seismic performance in a design situation, simplified analyses will be used here, consistent with the goal of estimating the probability of failure.

In Step 1, seismic hazard parameters will be defined for each site; the results will be used as inputs for both the Phase A and Phase B assessments. Then, the evaluation of a particular facility will begin with a review of existing site information (Step 2), followed by engineering analyses for seismic performance. As described in Steps 3 through 7 below, the engineering analyses in Phase B will be more detailed than the simplified estimates in Phase A. The analyses will commence with an initial selection of an earthquake return period and evaluation for seismic performance. Steps 3 through 7 will be repeated until the limiting (lowest) earthquake return period expected to cause failure is obtained. Flowcharts summarizing Steps 1 through 7 in the Phase A and B seismic performance assessments are given in Figures 3 and 4, respectively. The earthquake event with the lowest return period that causes failure will then be used to compute the probability of failure in Step 8. The potential consequences and mitigation costs will be estimated in Steps 9 and 10.

Step 1 – Define Seismic Input Parameters

Seismic hazards at TVA dam sites were quantified in a 2004 study by AMEC/Geomatrix. The New Madrid fault zone and several area source zones contribute to the seismicity of the region, as represented schematically in Figure 1. The New Madrid seismic zone is characterized by a large linear, combined reverse/strike-slip fault. Earthquakes in the area source zones are more diffuse (less concentrated in clusters) and tend to occur in zones of weakness of large crustal extent rather than along narrow, well-defined faults. Earthquakes occurring within the New Madrid Seismic Zone and in area sources outside of it will be considered in developing seismic input parameters for each CCP facility. However, only seismic source zones that contribute significantly to the ground motion hazard at a particular site will be used to develop seismic input parameters.

The national USGS seismic hazard model will not be used in these seismic risk assessments; instead, TVA will ask AMEC/Geomatrix to compute the site-specific seismic hazards for each closed CCP facility. The needed information can be obtained from the existing seismogenic model, but will need to separately consider the hazards associated with the New Madrid events and all other seismic sources (Figure 2), hereafter referred to in this white paper as the “earthquake scenarios”. The following parameters are needed for each earthquake scenario:

- Uniform hazard spectra for frequencies from 0.25 to 100 Hz (100 Hz value is equivalent to peak ground acceleration, PGA) at the top of rock for a range of return periods from 100 to 2,500 years.
- De-aggregation for relevant ground motion frequencies (one or more of the following: 0.5, 1.0, 2.5, 5.0, and 100 Hz) at each return period. The de-aggregation results will be used to select appropriate, representative earthquake parameters (magnitude and distance from the site), from which inputs needed for liquefaction analyses can be developed.

In the Phase A effort, the project team (including seismologists designated by TVA) will meet to consider the earthquake hazard data produced by the AMEC/Geomatrix model for each site. The team will reach consensus on the appropriate parameters (return period, earthquake magnitude, and peak ground acceleration) to be used in evaluating each facility, before proceeding with work on subsequent steps of the analysis. The seismic parameters to be tabulated (Table 4) will then be used in both the Phase A and Phase B assessments.

Ground motion time histories will be needed for the detailed Phase B calculations, and TVA will need to ask AMEC/Geomatrix to provide:

- Representative acceleration time histories (two orthogonal components), representing ground motions at the top of the rock profile for the specified earthquake return periods.

Given the results of the Phase A assessment, the Phase B analyses will focus on a narrower range of possible earthquakes. Hence, acceleration time histories will not be needed for every seismic event listed in Table 4.

Step 2 – Review Site and Facility Information

To meet the requirements for closure of TVA ash storage facilities, the closed condition may involve placement of compacted ash behind a strengthened dike, drainage of pond water to the levels of the surrounding groundwater table, and capping of the area with native soils. The collection of available site information for each facility will be reviewed from a seismic performance perspective. For the Phase B assessment, this information will be augmented with new data that becomes available during the closure design process.

The project information needed for each storage facility includes:

- Planned geometry of the closed storage facility, as needed to meet current design criteria and regulatory requirements.
- Geologic mapping and related information about the site geology.
- Historical records and other information related to site development.
- Boring logs, SPT data, CPT data, shear wave velocities, etc. from field explorations.
- Laboratory data from testing of site materials, including classification, Atterberg limits, moisture content, particle size, specific gravity, unit weight, compaction tests, and other relevant test data.
- Laboratory data on measured strength properties, for both drained and undrained conditions.
- Previously completed slope stability analyses, where available, will be modified for calculations in the risk assessments.

Step 3 - Evaluate Potential for Soil Liquefaction

The potential for soil liquefaction may be the greatest contributor to failure risk at many of the TVA storage sites. Liquefaction will thus be considered first in the assessment of seismic performance at each closed facility (Figures 3 and 4).

The Phase A assessment will utilize empirical charts and back-of-the-envelope calculations to judge if liquefaction would be likely for a given earthquake scenario. For example, Ambraseys (1988) compiled magnitude, epicentral distance, and whether or not liquefaction was observed in past earthquakes, and then suggested a threshold boundary (in terms of magnitude and epicentral distance) where liquefaction might occur in natural soil deposits. Selected, parametric calculations with the simplified procedure outlined by Youd et al (2001) will also be useful in judging what earthquakes would cause liquefaction in the Phase A Portfolio Assessments. These empirical methods may be unconservative for evaluating saturated CCPs, which are often more prone to liquefaction than a sandy soil, but the results will still provide useful guidance in the Phase A assessment.

For the Phase B liquefaction evaluations, detailed engineering analyses will be undertaken to obtain estimates of cyclic loading, soil resistance, and factor of safety as described below. Potentially liquefiable soils include saturated alluvial soils, loose granular fills, and sluiced ash. The detailed analyses will focus on critical cross sections of the closed facilities; liquefaction safety factors will not be computed for all boring locations at a site.

(a) Soil Loading from Earthquake Motions

The magnitude of the cyclic shear stresses induced by an earthquake are represented by the cyclic stress ratio (CSR). The simplified method proposed by Seed and Idriss (1971) will be used to estimate CSR in the Phase A parametric analyses (ground response analyses will not be completed in Phase A).

In Phase B, the CSR at specific locations (borings and depths where in situ penetration resistance are measured) will be computed using one-dimensional, equivalent-linear elastic methods as implemented in the ProSHAKE software. Using an acceleration time history at the top of rock (obtained from the seismic hazards study in Step 1), the computer program will model the upward propagation of the ground motions through a one-dimensional soil profile. For cases where the one-dimensional assumption is inadequate, the calculations can be accomplished using QUAKE, a two-dimensional finite element program that implements the same dynamic modulus reduction curves and damping relationships as used in ProSHAKE.

The cyclic stresses imparted to the soil will be estimated from the earthquake parameters described in Step 1, representing earthquakes on the New Madrid fault and local crustal events.

(b) Soil Resistance from Correlations with Penetration Resistance

The resistance to soil liquefaction, expressed in terms of the cyclic resistance ratio (CRR), will be assessed using the NCEER empirical methodology (Youd et al. 2001). Updates to the procedure from recently published research will be used where warranted. The analyses will be based on the blowcount value (N) measured in the Standard Penetration Test (SPT) or the tip resistance (q_c) measured in the Cone Penetration Test (CPT). In Phase A, typical or representative values will be used in parametric hand calculations; detailed data from site-specific explorations will be analyzed in Phase B.

The NCEER procedure involves a large number of correction factors. Based on the site-specific conditions and soil characteristics, engineering judgment will be used to select appropriate correction factors consistent with the consensus recommendations of the NCEER panel (Youd et al. 2001). To avoid inappropriately inflating the CRR, the NCEER fines content adjustment will not be applied where zero blowcounts (“weight of hammer” or “weight of rod”) are recorded. The magnitude scaling factor (MSF) is used in the empirical liquefaction procedure to normalize the representative earthquake magnitude to a baseline 7.5M earthquake. The earthquake magnitude (M) considered to be most representative of the liquefaction risk will be determined by applying the MSF to the de-aggregation data (from Step 1) for each selected earthquake return period.

Saturated fly ash, where it remains following closure, is likely to be more susceptible to liquefaction than indicated by these empirical methods. Values of CRR determined via the NCEER procedure are related to the observation of liquefaction in natural soils, mostly silty sands. Given the spherical particle shape and uniform, small grain size of fly ash, the NCEER procedure may give CRR values that are too high for saturated fly ash.

Lacking better methods of analysis, the lower-bound, “clean sand” base curve (Youd et al. 2001) will be assumed to apply for fly ash in the Phase A assessment. Within the liquefaction calculations, this will be accomplished for these materials by neglecting the fines content adjustment to the normalized penetration resistance. For Phase B, published and unpublished data from cyclic laboratory testing on similar materials will be sought to augment the indications of liquefaction resistance obtained from in situ penetration tests.

(c) Factor of Safety Against Liquefaction

The factor of safety against liquefaction (FS_{liq}) is defined as the ratio of the liquefaction resistance (CRR) over the earthquake load (CSR). Following TVA design guidance and the precedent set by Seed and Harder (1990), FS_{liq} is interpreted as follows:

- Soil will liquefy where $FS_{liq} \leq 1.1$.
- Expect substantial soil softening where $1.1 < FS_{liq} \leq 1.4$.
- Soil does not liquefy where $FS_{liq} > 1.4$.

Using this criteria for guidance, values of FS_{liq} computed throughout a soil deposit or cross section (at specific CPT-q_c and SPT-N locations) will be reviewed in aggregate. Occasional pockets of liquefied material in isolated locations are unlikely to induce a larger failure, and are typically considered tolerable. Instead, problems associated with soil liquefaction are indicated where continuous zones of significant lateral extent exhibit low values of FS_{liq}. Engineering judgment, including consideration for the likely performance in critical areas, will be used for the overall assessment of each facility. A determination of “extensive” or “insignificant” liquefaction will then lead to the appropriate stability analyses in the next stage of the evaluation, as indicated in Figures 3 and 4.

Step 4 – Characterize Post-Earthquake Soil Strengths

The post-earthquake shearing resistance of each soil and CCP will be estimated, with consideration for the specific characteristics of that material. The full, static shear strength will be assigned to unsaturated soils. Excess pore pressures will not develop in an unsaturated soil during seismic loading, so drained strength parameters can be used. The undrained strengths of saturated soils will be decreased to account for the softening effects of pore pressure buildup during the earthquake. Specifically:

- In saturated clays and soils with $FS_{liq} > 1.4$, 80% of the static undrained strength will be assumed.
- In saturated, low-plasticity, granular soils with $1.1 < FS_{liq} \leq 1.4$, a reduced strength will be assigned, based on the excess pore pressure ratio, r_u (Seed and Harder 1990).

Typical relationships between FS_{liq} and r_u have been published by Marcuson and Hynes (1989).

- In saturated, low-plasticity, granular soils with $FS_{liq} \leq 1.1$, a residual (steady state) strength (S_{us}) will be estimated for the liquefied soil. Values of S_{us} can be obtained from the empirical correlations published by Seed and Harder (1990), Castro (1995), Olson and Stark (2002), Seed et al. (2003), and Idriss and Boulanger (2008).

Subsequent stability and deformation analyses will be accomplished using these reduced strength parameters. No attempt will be made to model the cyclic reduction in soil shear strength during an earthquake. In the deformation analyses, the fully reduced strengths will be assumed at the start of cyclic loading, which will yield conservative estimates of slope displacements.

Step 5 – Analyze Slope Stability

The next step in the performance evaluation (Figures 3 and 4) will consider slope stability, for conditions with or without significant liquefaction. Slope stability will be evaluated using two-dimensional, limit equilibrium, slope stability methods. Reduced soil strengths (from Step 4), conservatively representing the loss of shearing resistance due to cyclic pore pressure generation during the earthquake, will be used in the stability calculations. The analyses will be accomplished using Spencer's method of analysis, as implemented in the SLOPE/W software, considering both circular and translational slip mechanisms.

Input files for static stability calculations, where previously completed for a particular facility, will be updated to represent seismic conditions. These stability analyses may be not available, or the closure geometry may be undefined, for the Phase A assessment of some sites. In those cases, simplified or approximate geometries will be developed for approximate analysis in Phase A. Engineering experience will also be useful in judging likely seismic stability. For example, a complete failure is likely if liquefaction undermines the foundation of the outslope. In the absence of liquefaction, a slope that exhibits adequate safety factors under static conditions is unlikely to fail in an earthquake. Back-of-the-envelope hand calculations can be useful in assessing stability where extensive liquefaction occurs in the saturated materials within or below CCPs retained by a stable perimeter dike. Detailed slope stability calculations, which accurately represent the planned closure geometry, will be used in the Phase B facility assessments.

(a) Slope Stability if Extensive Liquefaction

If extensive liquefaction is indicated, stability will be evaluated for the static conditions immediately following the cessation of the earthquake motions. Residual or steady state strengths will be assigned in zones of liquefied soil, with reduced strengths that account for cyclic softening and pore pressure build up assumed in non-liquefied soil. In both Phase A and B, complete failure (large, unacceptable displacements) will be assumed if the safety factor (FS_{slope}) computed in this step is less than one (Figures 3 and 4).

For slopes where the post-earthquake $FS_{slope} \geq 1$, deformations will be estimated in the Phase B assessment (Step 6 and Figure 4). Slope deformations will not be estimated in the Phase A portfolio assessment, where ground motion time histories will not be available. In Phase A, slopes exhibiting $FS_{slope} \geq 1$ with liquefaction will be assumed stable with tolerable deformations; this condition may exist, for example, where liquefied ash at the base of a closed storage facility is contained within a stable perimeter dike.

Note that pseudostatic stability analyses are not useful for evaluating a factor of safety where extensive liquefaction is expected, because appropriate pseudostatic coefficients can not be defined.

(b) Slope Stability if No Significant Liquefaction

If no significant liquefaction is expected, seismic stability will be analyzed in Phase A using approximate, pseudostatic stability methods (Figure 3). The added inertial loads from the earthquake will be represented with a simple, horizontal pseudostatic coefficient (k_h), which provides an approximate representation of the dynamic loads imposed by an earthquake. The horizontal pseudostatic coefficient will be set to one-tenth of the peak ground acceleration in rock ($k_h = 0.1 \cdot PGA_{rock}$). In Phase A, tolerable deformations (less than about 5 meters) will be assumed if the pseudostatic $FS_{slope} \geq 1$, and failure will be assumed if the pseudostatic $FS_{slope} < 1$.

This approach and criteria are based on the work of Hynes-Griffin and Franklin (1984). They performed Newmark deformation analyses, integrated over 350 ground motion time histories, used an amplification factor of three to represent peak accelerations at the base of an earth embankment, and assumed a displacement of 1 meter would be tolerable for an embankment dam. For a typical CCP facility, assuming no pool is retained following closure, "failure" would imply displacements significantly greater than 1 meter. A tolerable displacement of about 5 meters will be assumed here, for the Phase A risk assessments. From the upper bound curve plotted by Hynes-Griffin and Franklin (1984), a displacement of 5 meters would correspond to a yield acceleration of about 0.03 times the peak acceleration along the slip surface. Then, assuming an amplification factor of 3 for the ground motions at the base of the embankment, this suggests $k_h = 0.1 \cdot PGA_{rock}$ can be used conservatively in the pseudostatic analysis to judge failure, as described above.

Pseudostatic factors of safety will not be computed in the Phase B assessment. Instead, where a liquefaction failure is not predicted, potential slope displacements will be computed as described in Step 6.

Step 6 – Predict Deformations

In the Phase A Portfolio Assessment, closed facilities that are expected to remain stable (pseudostatic $FS_{slope} \geq 1$ with no liquefaction, or post-earthquake $FS_{slope} \geq 1$ with liquefaction) will be assumed to have tolerable displacements. Dynamic slope deformations are difficult to estimate without detailed analysis; the available empirical or approximate methods do not represent the conditions of interest, or the level of effort is not consistent with the goals of the first phase of risk assessments. In addition, earthquake ground motion time histories will not be available for the Phase A analyses.

In the Phase B Facility Assessments, the potential deformation of stable slopes will be evaluated as indicated in Figure 4. Conventional methods of analysis will be implemented to estimate potential slope displacements that accumulate during earthquake shaking; movements are assumed to stop when the earthquake ends, consistent with a post-earthquake safety factor greater than one. The acceleration time histories obtained from the ground response analyses in Step 3a will be used as inputs for computing deformations with one of the following simplified methods:

- Newmark's (1965) method involves double integration of accelerations greater than the yield acceleration (k_y), which will be determined from a succession of pseudostatic slope stability analyses in which k_h is varied. The value of k_h where the pseudostatic FS_{slope} = 1.0 corresponds to the yield acceleration.
- The Makdisi-Seed (1978, 1979) procedure, which better accounts for the dynamic response of embankments. This procedure was developed based on parametric numerical simulations for earthen dams. The procedure is iterative, considers the fundamental periods of the embankment response, and can be completed in steps using published charts. Results from QUAKE can also be used as input in this procedure.

The slope deformations predicted in Phase B will be conservative, because the yield acceleration will be computed based on reduced, post-earthquake soil strengths. In reality, the yield acceleration declines in successive cycles of seismic loading, as pore pressures accumulate and saturated soils become weaker. The analysis outlined in Figure 4 assumes reduced strengths and, where liquefaction is predicted, residual strengths at the start of the earthquake. Detailed numerical simulations can be used to track the progressive softening and liquefaction of soil within an embankment during an earthquake; such analyses are expensive and time consuming. Rigorous analyses of this type will not be justified except in a "Phase C" analysis, or where performance in a given seismic design event must be demonstrated. Note that the logic in Figure 4 might appear to assume a slope will be stable if there is no significant liquefaction; however, the deformation analysis will indicate unlimited deformations and certain failure if $FS_{slope} < 1$ for static, post-earthquake conditions.

Step 7 – Consider Other Potential Failure Modes

For most of the closed facilities, soil liquefaction, slope instability, and slope deformations will be the most likely seismic failure modes. However, depending on the unique configuration of each CCP facility, other potential failure modes may contribute significantly to the seismic risks. For example, the loss of critical drainage structures or retaining walls could lead to a failure condition. Other potential failure modes will be identified and evaluated quantitatively in this step.

As a secondary objective of the Phase A effort, the assessment team will consider the potential for failure of the active storage facilities, due to an earthquake occurring prior to closure. Many of the wet CCP storage facilities retain large pools of water, so this assessment will need to consider additional failure modes such as seepage and embankment cracking. The objective here will be to identify operating facilities that may have unusually high seismic risks, and might deserve more study or higher priority in the closure program.

Step 8 – Estimate Annual Probability of Seismic Failure

As indicated in the flowcharts in Figures 3 and 4, the assessments of seismic performance (in both the Phase A and Phase B efforts) will consider a range of potential earthquakes with differing return periods. The analyses will be repeated until the limiting (lowest) earthquake return period (from the candidate events defined in Step 1) that predicts failure of a particular CCP storage facility is obtained. Interpolation may be used, as appropriate, to narrow the definition of the limiting earthquake.

The return period for each earthquake scenario (Table 4) represents the annual probability of exceedance for the associated ground motion parameter. Hence, for each earthquake scenario, the event with the smallest return period that causes failure represents a limiting case, where all events having longer return periods would also cause failure. The inverse of the limiting return period thus represents the annual probability of seismic failure due to that earthquake scenario.

Step 9 – Estimate Potential Consequences of Failure

The potential consequences of a failure at each closed facility will be estimated in this step. The potential consequences will be unique to each site, but may include any of the following:

- restoration of the site and storage facility,
- clean-up to address environmental impacts,
- off-site disposal of released materials,
- damages and loss of use for transportation routes, including buried or overhead utilities,
- damages to buildings and other infrastructure,
- economic losses from the possible shutdown of power generation, and
- loss of human life (expected to be unlikely at most sites following closure).

Except for the potential loss of life, the failure consequences will be expressed in terms of present day costs. Detailed cost estimates of the potential consequences of failure will not be attempted in the Phase A assessments; instead, the potential magnitude of total consequence costs will be estimated using broad categories (< $100K, < $500K, < $1M, < $5M, < $10M, < $50M, < $100M). Cost estimates that better reflect the local site conditions will be produced by the closure design teams during the Phase B assessments.

Step 10 – Estimate Possible Mitigation Costs

The final step in the process will involve estimating the costs to mitigate seismic risks, perhaps by altering the closure design to withstand stronger earthquakes. Examples of possible mitigation measures include:

- ground improvements to reduce liquefaction potential (stone columns, deep soil mixing, jet grouting, or other appropriate technology),
- altering the geometry of outslopes (setbacks, benches, or flatter slopes) to improve

stability,

- adding buttresses or other supporting structures at the toe of slopes,
- enhanced drainage features, and
- relocation of infrastructure or people away from potential impact zones.

These mitigation approaches generally involve higher construction costs, which can be quantified in terms of present dollars. As with the consequence costs, detailed estimates of mitigation costs will not be attempted in the Phase A assessments. The potential magnitude of mitigation will be estimated in categories (< $100K, < $500K, < $1M, < $5M, < $10M, < $50M, < $100M). Mitigation cost estimates that better reflect the local conditions and facility layout will be developed by the closure design teams during the Phase B assessments.

Table 1. Expected Results from the Phase A and B Seismic Risk Assessments

TVA Facility	Prob. Failure	Econ. Costs	Loss of Life	Mitigat. Costs	Data Quality
ALF East Ash Disposal					
ALF East Stilling Pond					
BRF Dry Fly Ash Disposal					
BRF Fly Ash Pond And Stilling Basin Area 2					
BRF Bottom Ash Disposal Area 1					
BRF Gypsum Disposal Area 2a					
COF Disposal Area 5					
COF Ash Pond 4					
CUF Dry Ash Stack					
CUF Ash Pond					
CUF Gypsum Storage Area					
GAF Fly Ash Pond E					
GAF Bottom Ash Pond A					
GAF Stilling Pond B, C & D					
JSF Dry Fly Ash Stack					
JSF Bottom Ash Disposal Area 2					
JOF Ash Disposal Area 2					
KIF Dike C					
PAF Scrubber Sludge Complex					
PAF Peabody Ash Pond					
PAF Slag Areas 2a & 2b					
SHF Consolidated Waste Dry Stack					
SHF Ash Pond					
WCF Ash Pond Complex					
WCF Gypsum Stack					

Prob Failure = Annual probability of failure due to earthquakes
Econ. Costs = Economic costs resulting from a failure
Loss of Life = Potential loss of life resulting from a failure
Mitigat. Costs = Costs to mitigate seismic risks in closure design
Data Quality = Qualitative indication of how well conditions in the facility are characterized

Table 2. Risk Severity Scoring (Draft) used by TVA

as of 4/22/2009

TVA Risk Event Consequence Rating Scale (Work-In-Progress)						
Strategic Objective	Success Factor	5 Worst Case	4 Severe	3 Major	2 Moderate	1 Minor
Customer	Public Image	International media attention; nearly unanimous public criticism	National media attention; federal, state officials, and customers publicly critical	Regional / local media attention; customers voice concern	Minimal media attention; letters / emails to executive leadership voicing concern	No media attention; sparse criticism
	Rate Impact	Average total retail rate increases by 15%, relative to peers	Average total retail rate increases by 10%-15%, relative to peers	Average total retail rate increases by 5%-10%, relative to peers	Average total retail rate increases by 2%-5%, relative to peers	Average total retail rate increases by 0-2%, relative to peers
People	Safety	Fatalities	Wide spread injuries	Major injuries	Significant injuries	Minor injuries
	Employee Confidence	Widespread departures of key staff with scarce skills or knowledge	Sharp, sustained drop in CHI results; departures of key staff with scarce skills or knowledge	Sharp decline in CHI results	Modest decline in CHI results	No effect on CHI results
Financial	Cash Flow Impact	>$500M	$100M - $500M	$25M - $100M	$5M - $25M	<$5M
	Credit Worthiness	Credit rating downgrade to below investment grade	Credit Rating Downgrade	TVA put on credit watch	TVA put on negative outlook	Credit rating agencies and bondholders express concern
Assets and Operations	LNS (Load not served)*	10% of System Daily Sales (48,000 MWhrs)	1% of System Daily Sales (4,800 MWhrs)	0.1% of System Daily Sales (480 MWhrs)	0.05% of System Daily Sales (240 MWhrs)	140 MWhrs
	CPI (Connection Point Interruptions)	10% of CPs are down simultaneously	5% of CPs are down simultaneously	CPI totaling 10% of current CP count (124 for FY09)	CPI totaling 7.5% of current CP count (93 for FY09)	CPI totaling 5% of current CP count (62 for FY09)
	Duration (in Hours) of Service Interruption	3,000 cumulative hours for CPs	1,000 cumulative hours for CPs	500 cumulative hours for CPs	150 cumulative hours for CPs	50 cumulative hours for CPs
	Delivered Cost of Power	Sustained increase in delivered cost of power >1 year	Increase in delivered cost of power <1 year	Increase in delivered cost of power <1 month	Increase in delivered cost of power <1 week	Delivered cost of power not effected
	Damage to environment; type and magnitude of contamination / discharge	Major coal, nuclear plant accident or dam failure	Significant hazardous waste discharged; nuclear plant accident; dam integrity failure resulting in drawdown of pool elevation	Hazardous materials / waste discharge; clean up / remediation time takes approximately two weeks	Localized environmental damage, no impact to wildlife, clean up / remediation time less than two weeks	Minimal environmental damage, no hazardous discharge; clean up time takes a few days

Table 3. Risk Likelihood Scoring used by TVA

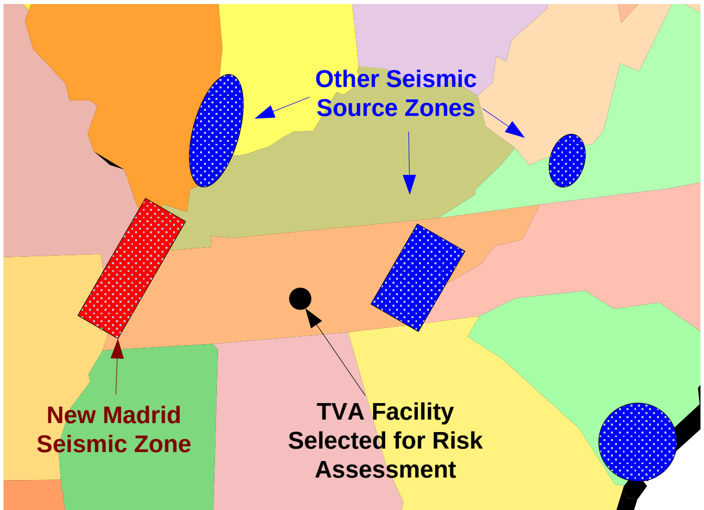
TVA Risk Event Probability Rating Scale		
Score	Rating	Description
5	Virtually Certain	95% probability that the event will occur in the next 3 years /10 years
4	Very Likely	75% probability that the event will occur in the next 3 years/10 years
3	Even Odds	50% probability that the event will occur in the next 3 years/10 years
2	Unlikely	25% probability that the event will occur in the next 3 years/10 years
1	Remote	5% probability that the event will occur in the next 3 years/10 years

- *The 3-year timeframe will be the primary focus for the business unit risk maps*
- *The 10-year risks will be collected by the ERM organization and charted separately for the enterprise*

Table 4. Seismic Hazard Input Data for Probabilistic Assessment of TVA Facilities

Seismic Sources	Return Period (years)	Annual Probability of Exceedance	Peak Ground Acceleration (g)	Earthquake Magnitude
New Madrid Seismic Zone	2,500 1,000 500 250 100	0.0004 0.001 0.002 0.004 0.01	*Values to be determined from the seismic hazard curves*	*Values to be determined from the hazard de-aggregation data**
All Other Seismic Sources	2,500 1,000 500 250 100	0.0004 0.001 0.002 0.004 0.01		

** Representative magnitude corresponding to the maximum contribution to the seismic hazard for liquefaction, as determined from the de-aggregation data weighted by the magnitude scaling factor (maximum PGA / MSF)*



Note: Schematic representation only, locations not accurately depicted, some sources omitted.

Figure 1. Schematic Representation of Seismic Source Model for TVA Facilities

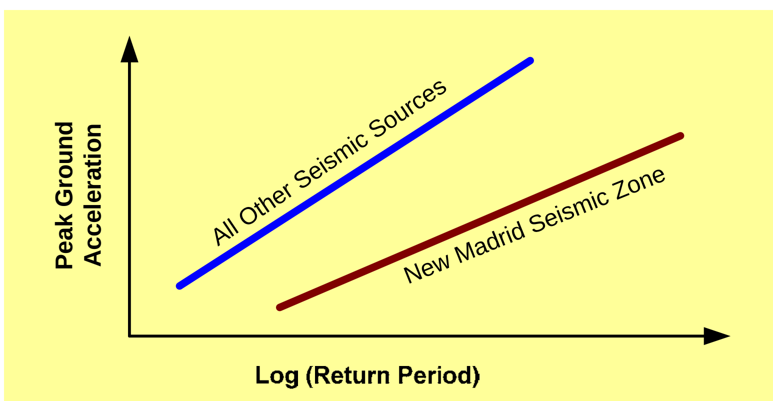


Figure 2. Typical Seismic Hazard Curves for Proposed Probabilistic Assessment of TVA Facilities

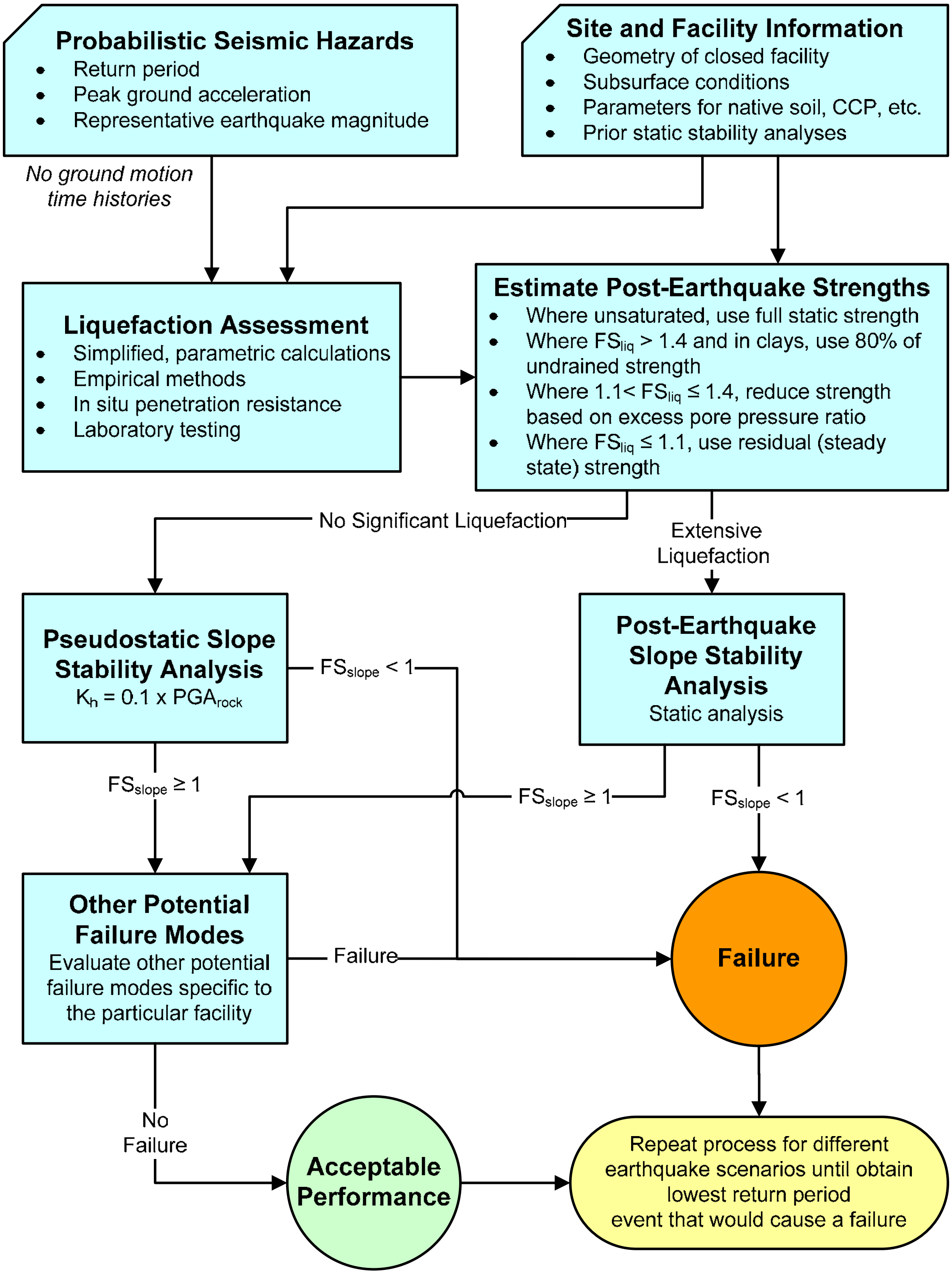


Figure 3. Simplified Flowchart for Assessing Facility Performance During a Probabilistic Seismic Event in Phase A

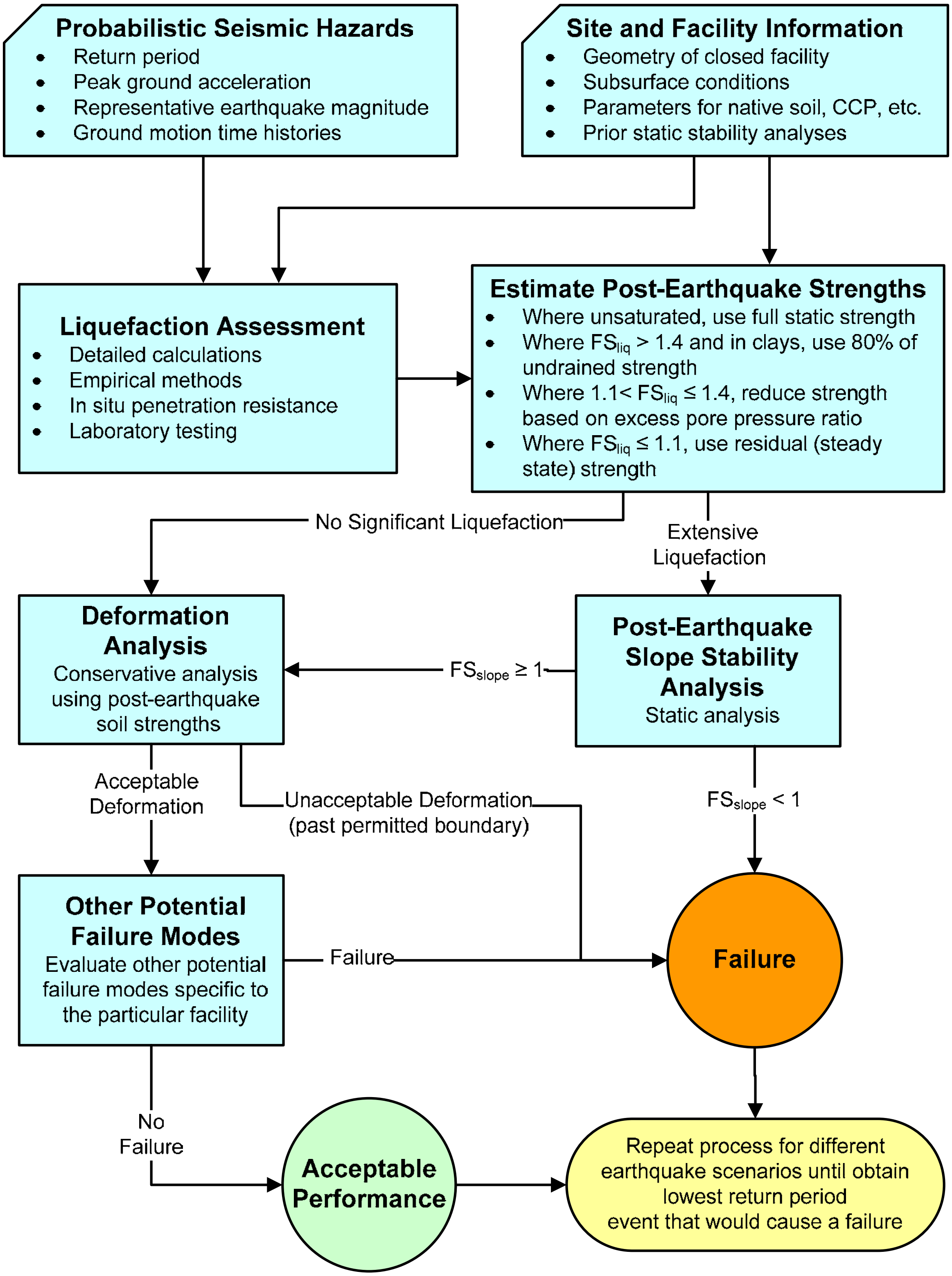


Figure 4. Simplified Flowchart for Assessing Facility Performance During a Probabilistic Seismic Event in Phase B