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July 17, 2009

Mr. Ralph E. Rodgers
Tennessee Valley Authority
400 West Summit Hill Drive
Knoxville, Tennessee 37902-1401

Re: AECOM Response to Mr. Barry Thacker June 26, 2009 Draft White Paper, Kingston Dredge Cell Failure, Kingston Fossil Plant, Harriman, TN
AECOM Project No. 60095742

Dear Mr. Rodgers:

As requested by the Tennessee Department of Environment and Conservation (TDEC) on July 8, 2009, we have reviewed Mr. Barry Thacker's draft white paper and attached figures showing seepage and effective stress analyses (ESA) stability computations for the dredge cell. AECOM's ten volume RCA report was posted to the TVA web site on June 25, 2009. Mr. Thacker's draft white paper is dated June 26, 2009. During the course of our work, Mr. Thacker did not contact AECOM to access the site or discuss analysis methods.

AECOM's Understanding of Thacker's Failure Mode

The draft white paper agrees with the general location of the initial failure presented in the RCA report prepared by AECOM, i.e., at the northwest corner of the dredge cells. However, a mechanism for the initial failure is proposed that is different from the one presented in the AECOM report.

In summary, the failure mechanism presented in the Thacker white paper is based on the development of high pore pressures in the ash beneath the second and third dike construction phases that constitute perimeter Dike C. The high pore pressures would originate from the pore pressures beneath the saturated ash being placed behind the upstream dikes built south of the 200-foot setback area. The connection of these high pore pressures to the ash behind Dike C would be due to a postulated high horizontal permeability of the ash. This would be the case if there were continuous high permeability layers within the ash. In Thacker's analysis, this is assumed and is represented as a ratio of horizontal to vertical permeability (K_h/K_v) of the sluiced ash of 100. Even though analyses were also presented for ratios of 10 and 1, the failure mechanism presented in the white paper is based on the results obtained with the ratio of 100. With the ratio of 100, the pore pressures computed beneath the second stage of Dike C are so high that for all practical purposes the second stage dike is almost fully supported by the pore pressures, i.e., the effective stresses in the ash are very small and the second stage dike is almost floating on water. Under these circumstances, the failure mechanism proposed in the white paper is computationally understandable in that the second stage dike would fail and release the ash behind.

Thus, the key question is whether or not the sluiced ash below elevation (El.) 768 feet had the high horizontal to vertical permeability (K_h/K_v) ratio of 100 assumed in the Mr. Thacker's white paper. This high ratio assumes that there are layers of relatively clean bottom ash and sand sized flyash with little amounts of silt in the sluiced ash below El. 760 feet in area north of Cell 2 and behind Dike C. From the standpoint of creating the high pore pressures under Dike C the permeability of most interest is the ash that was stored behind the initial Dike C. The ash in question, was part of a flow slide failure, and was not available for inspection, sampling and testing for the RCA studies. We have pre-failure information concerning its composition and stratification from previous explorations (Singleton 1994 Borings SS-3, SS-6, US-7, and MACTEC 2005 Boring B-4) under and north of Dredge Cell 2. Moreover, we know that the ash in question was deposited hydraulically with the discharge point being at the southern end of the initial 1954 dredge cell, while the original riser spillway to remove the excess water was located at the northwest end on Dike C over 5,000 feet away from the plant discharge pipe. Thus the ash that was deposited against the north section of Dike C should be consistently fine-grained, since any coarse material would have settled near the discharge point. Figure 1 is attached showing a plan view of the dredge cell and two cross-sections including the pre-failure subsurface conditions from the pre-failure explorations.

Based on design drawings and examination of aerial photographs (included in the RCA report) there would be no bottom ash dikes or divider structures north of Cell 1 or west of the Phase 1 Cell except for perimeter Dikes B and C. Recall sluiced ash was deposited into a pool ranging from El. 735 to 742 feet from 1954 to 1958. Between 1958 and 1977 the main ash pond was maintained at approximately El. 746 feet until 1977 when Dikes B and C were raised to El. 765 feet, where from then on the ash collection pond was maintained at El. 760 feet. There was no evidence of bottom ash placed below El. 760 under Cell 2 or under the setback area along Dike C. See Figure 1 for a cross-section sluiced ash conditions under the dredge cells.

The postulated pore pressure development using a permeability ratio of 100 would have been gradual as the dredge cells were being filled as illustrated in Figure 9 of the white paper. High pore pressures would have developed at the surface of Dike C and likely caused serious piping problems at the "hinge" between the initial and the second phase Dike C well before the December 2008 failure. No such problems were reported on the north, east and south sides of the dredge cell structure prior to the failure.

For Cell 2, Stage D2 construction began on October 16, 2008 and was last loaded with sluiced ash on December 18, 2008. The first time seepage water was noted discharging from the heel drains of Upstream Dikes A and B was on December 9, 2008. In other words, it took nearly two months for the wetted front of the saturating Cell 2 to permeate the heel drains of Cell 2 Upstream Dikes A and B. Therefore, it is unlikely that in two months Dike C became saturated or over-pressurized.

Typically at this plant, an active dredge cell is hydraulically filled in five to six months, and then allowed to lay dormant until the adjacent cell has been filled in with sluiced ash and filling was reportedly four days per week for 10 hours per day. With the exception for four (4) hours per week when operators pump ash and water into the inactive cells to reduce dusting. Each dredge cell vertical expansion is in 5-foot increments, in a back and forth manner. Note Cell 1 operated from March 31, 2008 through October 12, 2008.

Measured versus Assumed Sluiced Ash Hydraulic Conductivities

For this response, we have reviewed our hydraulic conductivity data for unfailed sluiced ash in the Dredge Cell site as presented in our RCA report. As a review we have made measurements in unfailed sluiced ash using triaxial permeability tests on undisturbed horizontally and vertically oriented ash samples from Cell 1 and used piezocone dissipation tests to estimate horizontal conductivity of the sluiced ash.

The following hydraulic conductivity test summary is presented in the Table 1.

Table 1: Hydraulic Conductivity Summary for Kingston Studies

Material	K_h, cm/sec	K_v, cm/sec	Test Data Population	Test Type
Unfailed Sluiced Ash Above El. 790	6.3E-05 AM 1.3E-05 GM	5.3E-05 AM 1.3E-05 GM	19 horizontal tests and 19 vertical tests	Triaxial Permeability Testing on Tubes
Unfailed Sluiced Ash below El. 765	1.2E-05 AM 3.8E-05 GM	NA	21 tests, from CPTu probes 09-110, 302, 303, 304, 600, 601 & 604 in unfailed ash	CPTu Piezocone Dissipation Tests (Based on T50)
Flyash Slimes	2.4E-07	1.2E-07	One test	CPTu 09-104-C1
Thacker Sluiced Ash	**3.8E-03**	**3.8E-05**	**See Note 1**	**Assumed Values**
Sluiced Flyash Law Eng.	N/A	3.4 to 8.3 E-05	Dredge Cell 1 and 3	1995 ASTM D5084
Sluiced Flyash MACTEC	1.4E-05 1.67E06	5.1E-06 3.6E-06	Boring B-1 Boring B-2	2004 ASTM 6391
Parsons E&C and Geosyntec Agreed Upon Sluiced Ash	3.7E-05	1.9E-05	SEEP/W Seepage Calibration	2004 and 2007 Field Testing in Wells

Notes: AM – Arithmetic Mean, GM – Geometric Mean, NA - Not Applicable
Note 1 – Not stated in Thacker's White Paper

A quick examination of the table above shows that there is no physical measurement data of unfailed sluiced flyash justifying Mr. Thacker's assumed K_h of 3.8E-03 cm/sec. Furthermore, there is little evidence based on testing old and recent flyash at the site that the K_h/K_v ratio exceeds 2. The use of a K_h/K_v ratio in the flyash below El. 765 feet of 10, 25, 50 or 100 is not justifiable based on site-specific testing in unfailed flyash from under the Dredge Cell at the Kingston site.

We have estimated the K_h/K_v ratio for sluiced ash to be 2 or less. We have no evidence of a K_h/K_v ratio as high as 100, which Mr. Thacker has assumed for the Kingston site based on his knowledge of coal refuse ponds. (It should be noted that coal refuse is not the same material as sluiced flyash.) Based on a review of Mr. Thacker's previous work shown on his website, he uses the same K_h/K_v ratio of 100 from his re-evaluations of Buffalo Creek Dam No. 3, Big Branch and for Kingston sluiced ash, as if it were universal constant for all sluiced materials. Mr. Thacker's does not address why his K_h/K_v ratio does not match AECOM field and laboratory measurements on unfailed sluiced ash, or the work of Law Engineering, MACTEC, Parsons and Geosyntec at the Kingston site.

Thacker's Request for Piezometer and Well Data

Mr. Thacker requested a summary of piezometers, "old dewatering wells" and "dewatering well overflowing redwater" located along Dike C. AECOM identified four active monitoring wells located along the north side of the failed dredge cell. There were no piezometers or old dewatering wells in the TVA records. Figure 1 shows the active pre-failure well locations and Figure 2 provides water level readings from 2007 through 2008.

We did find reference to two 1976 wells installed by Singleton described in a 1991 TVA report. The wells are labeled as J4A and J4B. They are located at the northwest corner of Dike C as shown on attached Figure 1. We understand the 4-inch observation wells show water levels ranging from El. 739.4 to 743.22 feet at J4A from November 1, 1989 to June 5, 1990 and from El. 734.77 to 743.42 feet at J4B, for the same time frame. We know the ash collection pond is static at El. 760 to 761 feet and the Watts Bar Reservoir fluctuates between El. 735 and 742 feet. These retired wells were lost after the December 22, 2008 failure.

We understand TVA installed monitoring Well Nos. KIF-4A and KIF-4B circa 1988. TVA has also labeled these wells as KSW-4A and KSW-4B. KIF-4A (KSW-4A) was not read after 1998. (For purposes of further discussion in this paragraph AECOM will define these wells as 4A and 4B.) These wells were monitored as geo-chemical monitoring wells. Well 4B is at approximate ground surface El. 753.0 feet, with a top of casing at El. 756.8 feet, with a screen interval from El. 716.2 down to El. 714.7 feet. The water level in Well 4B was at El. 741.3 on December 1, 2008. The TVA reported Watt Bar Reservoir was at 736.7 feet on December 1, 2008. This well data indicates relatively low uplift under the Dike C in the native alluvium. Abandoned Wells 4A and active well 4B were lost after the December 22, 2008. The only active ground water quality wells outside the Dredge Cell area monitored by TVA in 2008 were Well 4B (NW corner of Dike C), 6A (East Settling Pond along Dike C), Well 16A (at Swan Pond Road at west corner of Cell 1 and 2), and Well 13B (at the end of ash sluiced ash flume, at location next to the northeast corner of former "Ball Field").

AECOM has reviewed well construction logs for monitoring wells installed by MACTEC in September 2005; namely MW-13, MW-14 and MW-15, located on the north slope of Cell 2. Table 2 below states the observed readings in wells under the north end of Cell 2.

Table 2: MACTEC 2005 Observation Well Data

Cell 2 Well Number	Ground Surface El. (feet)	Screen El. Range (feet)	Depth of Well (feet)	Water El. in Well 9/14/05	Water El. in Well 9/19/08	Water El. in Well 11/19/08
MW-13	804	764. 2 to 759.2	45	773.35	772.63	780.99
MW-14	784	744.2 to 739.2	45	766.10	769.09	775.18
MW-15	771	746.2 to 741.2	30	764.14	767.16	772.02

We cannot find any unusual uplift conditions based on the September 2005 readings when Cell 1 was actively being filled. The September 2005 readings match the September 2008, when Cell 1 was actively being filled. The November 2008 readings were made one month after filling began in Cell 2.

Since AECOM does not have all of the details of Mr. Thacker's SEEP/W seepage analysis, AECOM ran supplemental SEEP/W computations for the northwest section of Cell 2 using K_h/K_v ratios of 1, 2, 10 and 100 for the sluiced ash. We ran two geometric models of the north side of Cell 2:

1. The first model using the boundary conditions shown in Appendix B of Volume IV (see Figures 3 through 6) and;
2. A second model using Cell 2 pond having a south boundary located at an average radius of 500 feet to ensure there was sufficient water maintain a phreatic surface at the El. 816 pool level when K_h/K_v ratios are higher than 10 (see Figures (7 through 10) .

Results of our analysis shows the K_h/K_v ratio of 1 and 2 seem to be a good match for both SEEP/W boundary conditions for Well MW-15 located at the toe of Cell 2, Dike A. The K_h/K_v ratio of 10 over predicts the water level in wells MW-15. The K_h/K_v ratio 100 shows model instability due to unsaturated ash from El. 816 feet down to El. 790 feet. We know from interviews with TVA personnel that more that 25% of the Cell 2 pool was present on Sunday, December 21, 2008, three days after sluicing stopped for the weekend. Results of these computer runs are attached. The AECOM analyses show the well locations on the analysis cross-section, with the screen zone highlighted.

As summary of AECOM's two models and Thacker's model results for MW-15 are shown in Table 3 below.

Table 3: Predicted versus Measured Water Head in Well MW-15

K_h/K_v Ratio in Sluiced Ash	MW-15 Predicted head AECOM RCA 6/25/09 Model	MW-15 AECOM Predicted head Supplemental Model	Thacker 6/26/09 Model	MW-15 Measurement on 11/19/08
1	771.5	772.0	770	772
2	772.5	773.5	NA	772
10	775.3	777.5	773	772
100	775.5	783.0	778	772

AECOM used measured K_h values, while Thacker used values published by Parsons and Geosyntec. See Table 1 above for K_h values. NA – Not analyzed

It is clear from this analyses that the actual versus the predicted water heads are closer to a K_h/K_v ratio of 1 to 2, rather than 100. We understand water levels will increase in the dike as the ash pond saturates with time as the water front advances into the rolled flyash dikes. We consider monitoring well MW-15 will attain a steady state seepage flow regime as the collection zone is deep into the original ash. Examination of Figure 2 shows that well levels from 2007 through 2008 do not show substantial fluctuations during or after active operations at Cell 2. In fact, actual water level readings in well MW-15 match AECOM SEEP/W runs using a K_h/K_v ratio of 1 to 2, and were not close to the Thacker suggested K_h/K_v of 10 or 100 ratio.

Mr. Thacker's comment about the word "piezometer" labeled on one of AECOM relic survey plan refers to a location showing the 2009 set of permanent multi-level pneumatic piezometers installed in AECOM Boring No. 09-102, located approximately 10 feet north of the toe of Dike A for Cell 2 in the setback area.

Current Engineering Practice: Effective Stress versus Total Stress Analyses

We acknowledge and certainly subscribe to the U.S. Army Corps of Engineers' (USACE) Slope Stability Manual EM 1110-2-1902, Table 2-1 for the analysis and design of slopes which is applicable to dams, embankments and their foundations. However, the Corps' engineering manual is silent on post-failure root cause failure analyses (RCA) of slopes, embankments or impoundments that fail during actual vertical development. Since the Kingston dredge cells failed suddenly when they were well below their final design grade, the USACE Table 2-1 would

suggest this design condition to be a "During Construction and End-of-Construction," condition. This contradicts Mr. Thacker's recommendation to use Steady-State Seepage Conditions with drained shear strengths related to effective stresses for a completed structure operating at normal pool elevation.

In the USACE Slope Stability Manual EM1110-2-1902, Section 2-3 they make two statements of interest:

1. As a rough guide, soils with hydraulic conductivity (k) greater than 1E-04 centimeters per second (cm/sec) will be fully drained, and soils with k less than 1E-07 cm/sec will be undrained during construction.
2. Most importantly they add in the same section that when appreciable but incomplete drainage is expected, stability should be analyzed for drained and undrained strengths and the less stable case should be used for design.

Construction filling rates for the dredge cells being filled over older sluiced ash are slower than for normal construction rates (Stage D2 Cell 2 filling was about 1-foot per month). Thus, we believe the ash would have behaved in a drained manner during normal cell filling even though its K_h is lower than the 1E-04 cm/sec given in the USACE manual for drained behavior.

Since the active Kingston cells were constructed over a thin layer of relatively impermeable flyash slimes (K_h = 2.4E-07 cm/sec), and complete Dredge Cell 2 failure occurred during Stage D2 filling, below final design grade, we interpret the Corps manual to suggest the analyst choose shear strengths in the slimes using their stated criteria for "low-permeability soils - use undrained strengths related to total stresses," and "For saturated soils use Φ=0. Total stress envelops for Φ>0 are only applicable to partially saturated soils." Furthermore, for "during construction" design condition, the Corps recommends pore water pressures for "Low-permeability soils – Total stresses are used; pore pressures are set to zero in slope stability computations." We prefer to use steady state seepage models when embankments or impoundments reach their steady state final design height and have a normal operating pool or pond that attains steady state seepage. The staged dredge cell construction at Kingston is periodic and not held at a constant elevation or pool level and therefore should not be considered a steady-state seepage or final dam geometry.

Examination of Corps documentation recommends using QRS, or "Q" or "UU" shear strengths for total stress analyses for during construction or end-of-construction or some intermediate construction stage. For the low permeability slimes and native clay we adopted undrained shear strengths (S_u). This methodology is supported by Duncan and Wright (2005) on page 24 of their book titled *Soil Strength and Slope Stability* where they state:

> "*Undrained strength* is the strength of the soil when loaded to failure under undrained conditions. In the field, conditions closely approximating undrained conditions result when loads are applied to a mass of soil faster than the soil can drain."

Dr. Charles Ladd in his paper presented for his 22nd Terzaghi Lecture on *Stability Evaluation during Staged Construction* (ASCE, 1991) concludes that:

> "Conventional effective stress analyses should not be used for staged construction because the computed factor of safety inherently assumes a drained failure that can give highly misleading and unsafe estimates of potential instability."

Dr. Ladd further states in his summary and conclusions that:

> "Section 3 presents a conceptual comparison of ESA and USA factor of safety (Figure 3) and detailed results for three case histories (Table 3 and Figs. 4-11), which show FS(ESA)/FS(USA) ratios of about two. Although the undrained strength analyses (USA) involve simplifying assumptions that tend to err on the safe side, the *writer concludes that conventional effective stress analyses (ESA) based on realistic strength parameters (c' and Φ) and measured pore pressures can give misleading and unsafe estimates of actual factors of safety for staged construction*. This results from the inherent ESA assumption of drained, rather than an undrained failure."

AECOM performed RCA analysis of LTV's steel companies Clark Landfill failure using Effective Stress Analysis (ESA) and Total Stress Analysis (TSA)/Undrained Stress Analysis (USA) methods and was able to predict excess pore water pressures in rapidly loaded, under-consolidated, contractive clays that failed during active filling by deep wedge block sliding under a high steel waste landfill next to Lake Michigan. This deep-seated failure involved the rapid failure of more than 2.0 million cubic yards of waste and clay into the waters of Lake Michigan. The undrained failure of the clay foundation had an A_f factor well above positive 1.0, based on measured positive excess pore water pressures under an adjacent fill that was on the verge of failure.

AECOM did an RCA failure analysis for the State of Illinois using undrained shear strengths for a clay fill dam built over organic silts using USA stability analysis methods. The Drake Lake Dam foundation failure is presented in a paper titled; "Drake Lake Dam – A Case History" published in the ASDSO Proceedings of the Dam Safety 2002 Conference by Butler, Bushell, Walton and Mathur.

Up until the time of failure the sluiced ash and slimes behaved in a partially drained or drained behavior. Therefore, ESA analyses would be valid. However, once the magnitude of loading, rate of loading, or lack of adequate drainage reached a critical condition the undrained contractive behavior of the slimes and sluiced ash controlled and that condition lead to the demise of Dredge Cell 2.

At the Kingston site, the two weakest materials that would control failure were the loose ash and the foundation slimes layer. Both these materials were highly contractive and thus an analysis of stability using ESA with pre-failure pore pressures would greatly overestimate stability.

Therefore, AECOM, with input from Dr. Gonzalo Castro, P.E., NAE and other professional engineers on the TVA OIG and TDEC review groups determined on February 13, 2008 that we could not develop an accurate, excess pore water pressure model for the contractive slimes and loose wet ash because of limited deep pre-failure piezometer and instrumentation data. AECOM modeled the slimes using field vane shear and CK_oUDSS direct simple shear tests to define undrained shear strength (S_u). The analysis then proceeded in stages. First the ash was assumed to behave drained and the slimes undrained, with consideration of strain compatibility. This analysis led to the conclusion that the slimes were overloaded and would creep. The high shear stress creep in the very high water content slimes would transfer load rapidly to the ash, which was then assumed to behave undrained, clearly indicating that a failure would ensue. We believe that this approach realistically represents the actual sequence of events in the initial failure at the NW corner of cell 2.

In addition to the hydraulic conductivity and observation well information, there is also physical evidence that Mr. Thacker's failure mode was unlikely to have occurred:

1. The ash deposited upstream of the north end of Dike C was the finest grained and deposited more than 5,000 feet from the discharge ash sluice pipe from the plant for the first 10 years of operation. The flyash deposition was by deltaic action that progressed from south to north. The 1958 ash ponds were more than 300 acres in size with south end inflow and north end outflow. Sluiced ash was not discharged off Dike C which is contrary to coal refuse, iron, and copper tailing facilities that have multiple discharge locations along upstream dikes. Furthermore, the ash pond had one riser spillway located at the Northwest Corner of Dike C, and it operated from 1958 through 1977 when sluiced ash filled in the majority of the ash pond up to El. 760 feet. Based on inspection photographs and aerial photography there were no divider dikes built over ash covering the north half of Cell 2 until 1996 when Cell 2 Dike A was constructed 200 feet south of Dike C on sluiced ash at El. 768 to 770 feet. Therefore, there is no evidence of mechanically placed ash or coarse grained bottom ash placed north of Cell 2 from El. 770 feet down to El. 730 feet, the top of the natural clay foundation.

2. Pre-failure test borings made by 1994 Singleton (SS series) and the 2005 MACTEC (B-4) show no evidence of bottom ash layers in the sluiced ash under El. 760 feet under Cell 2, under the 200-foot setback area north to the Dike C, or under the third Dike C dike raising (SS-3 and SS-6). Attached Figure 1 includes a cross-section based on pre-failure borings. There is no pre-failure data that shows highly permeable sluiced ash under Cell 2 dike system and the 200-foot wide setback area (Boring US-7 Singleton 1994).

3. AECOM has run piezocone dissipation tests in unfailed sluiced ash below El. 765 feet under Cell 1 and in the ash under the north end of Dike D, next to former the Cell 2. The average of these cone dissipation tests

shows an estimated average horizontal conductivity K_h of 3.8E-05 cm/sec (7.5E-05 ft/min). This is significantly less than the horizontal conductivity of 3.8E-03 cm/sec (7.5E-03 ft/min) assumed by Mr. Thacker. There is no physical or testing evidence that a K_h/K_v ratio of greater than 10, much less 100 exists in the sluiced ash at this site.

4. The AECOM location of the phreatic surface (top equipotential line of u = 0 psf) at Dike C was determined by the seepage flow model using the computer program SEEP/W and inputting our field and laboratory measured hydraulic conductivity data which matches the location of the phreatic surface at water levels noted in the 1994 SS-1, SS-2 and SS-3 boreholes when sluicing was active in Cells 1, 2 and 3. This would represent a time when there was process water and ash was directly behind the lower Dike C, shown on AECOM Figure 1.2.4_5 in the RCA report.

5. There was consequential deep seated foundation failure under Dike C after the north side of Cell 2 slid across the slimes and surcharged Dike C. The Dike C failure relics were nearly intact and some of the displaced Dike C relics showed intact dike and foundation clay material. It is also important to note that the Dike C failure was rapid in that there was very little ash between Dike C and the north hill side that was impacted with a dramatic flood wave up to 47 feet above the pool El. 737 feet at the time of failure.

6. AECOM also has physical failure slide plane evidence from Osterberg tubes and inclinometer data in the slimes and loose ash under and next to Cell 2. This evidence shows that instability was deep, where the distance is greatest to release excess pore water pressure in the metastable ash and contractive, creep-sensitive slimes. We have no practical means to determine the positive A_f factor in predicting the contractive behavior of the sluiced ash and slimes under El. 765 feet, therefore AECOM used undrained strengths in the low-permeability plastic silt sized slimes.

AECOM believes that the sluiced ash will behave in a drained manner under normal cell filling, but the slimes behaved in an undrained manner. The ash would behave undrained if there is a relatively rapid increase in stresses or deformations due to redistribution as the slimes yield and/or creep, i.e., what we refer to as triggering of liquefaction. It is also should be noted, that in design practice one would use the lower of drained and undrained, unless a contractive material is so free draining that we cannot foresee a condition when it will behave undrained. For dilative soils one usually uses drained strengths to avoid reliance on negative pore pressures. As far as the ESA and TSA (USA) obviously there is no difference when one is assuming drained strength.

This RCA stability and failure mode analyses at Kingston should not be considered a condemnation of all ESA analyses. The four failure modes at Kingston are specific to the Harriman, Tennessee site. Failure modes at other sites will be different based on the rate of loading, water levels, dike containment geometry, seepage controls, and type of foundation materials. The Kingston RCA analysis ended using an USA model in the slimes to represent an undrained shear strength model of a low permeability, creep sensitive, strain softening plastic silt flyash, and a drained model for the ash, up till the point of triggering when we used the peak undrained shear strength ratio of 0.3 for the wet, loose contractive ash to demonstrate static liquefaction. This decision to use a USA analysis was the result of discussions between other RCA geotechnical reviewers, Dr. Castro and AECOM. Mr. Thacker admits that little piezometric information was available prior to failure. Furthermore, we would have difficulty predicting excess pore water pressures without extensive performance pre-failure monitoring of instrumentation in the contractive slimes and sluiced ash, if conditions became undrained.

Summary

The fate of this impoundment was known on December 22, 2008. The foundation of Cell 2 was on the verge of failure for weeks prior to the date of failure due to the lack of drainage in the slimes and loose wet ash under Cell 2.

Mr. Thacker's unsolicited analysis in February 2009 predicted shallow failure along the west side of the site and then another failure mode in June 2009 when he modeled instability on the northwest side of Dike C assuming drained behavior of the sluiced ash and the presence of an undocumented layer of bottom ash under Cell 2, the north setback area, and under Dike C. His independent analysis is silent on the fact that the plastic slimes have

low permeability, were contractive and did not behave in a drained manner during staged, undrained loading during Cell 2 Stage D2 filling.

Thacker and AECOM agree with the fact that Cell 2 failed to the north, but Mr. Thacker relies upon drained strength parameters (Φ=31.5 degrees and zero cohesion) and assumed high horizontal hydraulic conductivities that create buoyancy under Dike C. Mr. Thacker's hypothesis relies on manipulating hydraulic conductivity data in the ash to show 33 feet of excess head under Dike C, an earth fill structure located more than 200 feet from the active dredge Cell 2. Since we have visual evidence of the slide plane at the base of the flyash and no evidence of bottom ash along the north side of Cell 2 below El. 760 feet in borings prior to failure, AECOM respectfully does not agree with Mr. Thacker's drained analysis using assumed and unrealistically high horizontal hydraulic conductivities in the wet ash and rolled fly ash dikes. Thacker's analysis also ignores the presence of the slimes and liquefiable ash. Mr. Thacker's drained ESA analysis approach is flawed since it does not address the actual undrained failure modes in the slimes and loose wet ash and does not match actual slide plane locations.

AECOM completed the RCA report in June 25, 2009 and TVA posted the AECOM report on their internet website on June 25, 2009. It is interesting to note that Mr. Thacker completed his white paper evaluation within 24 hours of the RCA report being made public. It took AECOM five months to review TVA records, conduct explorations, perform testing and analyses to issue the ten volume RCA report.

Thank you for the opportunity to address statements made in the Mr. Thacker's white paper. Please contact us if you have any questions.

Very truly yours,

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

William Butler, P.E.
Senior Geotechnical Engineer

References
Attachments

Cc: John Kammeyer – TVA
Dr. Gonzalo Castro

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References

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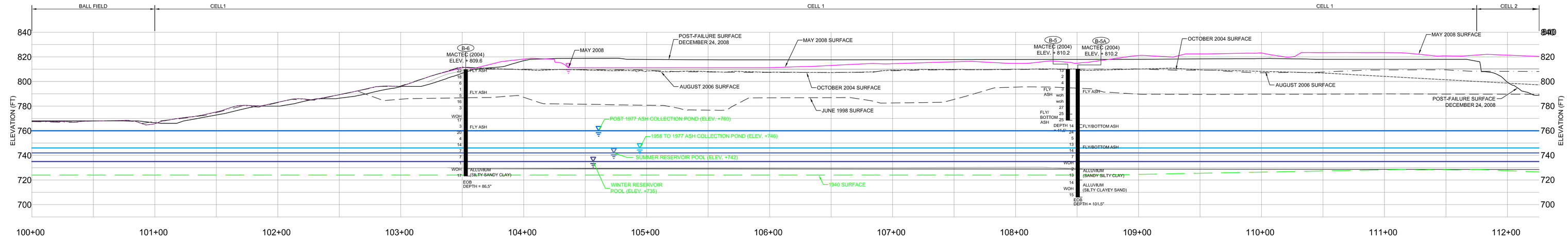
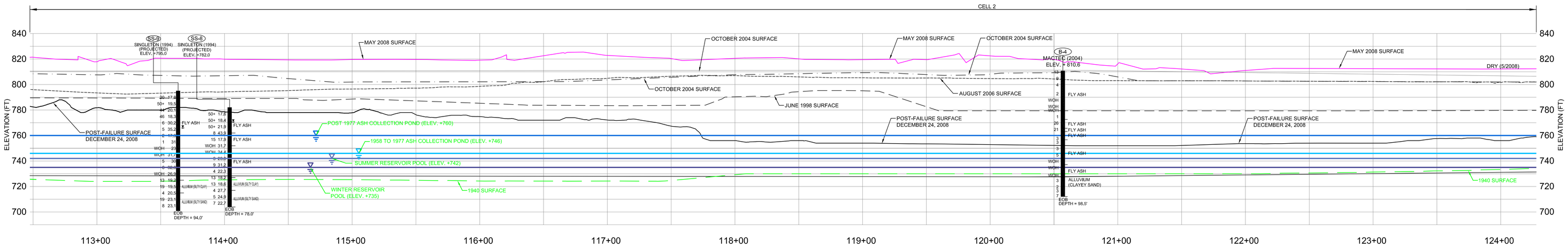
Attachments

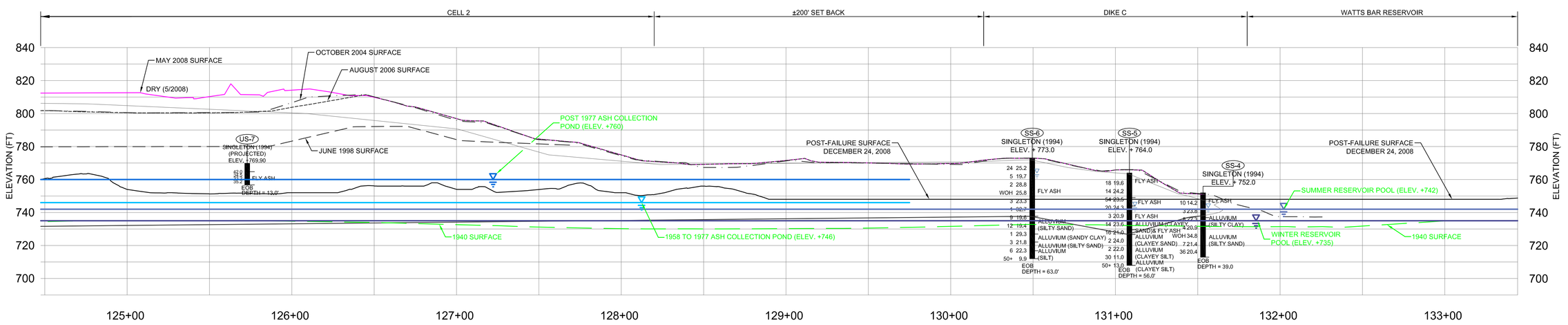
Figure 1	Plan View and Cross-Sections A-A' and B-B'
Figure 2	Historic Well Reading from North Slope of Cell 1 and Dike C
Figures 3	AECOM RCA Analysis Kh/Kv = 1
Figures 4	AECOM RCA Analysis Kh/Kv = 2
Figures 5	AECOM RCA Analysis Kh/Kv = 10
Figures 6	AECOM RCA Analysis Kh/kv = 100
Figures 7	AECOM Extend Section Analysis Kh/Kv = 1
Figures 8	AECOM Extend Section Analysis Kh/Kv = 2
Figures 9	AECOM Extend Section Analysis Kh/Kv = 10
Figures 10	AECOM Extend Section Analysis Kh/Kv = 100



CROSS SECTION A-A'
SCALE : 1" = 30'

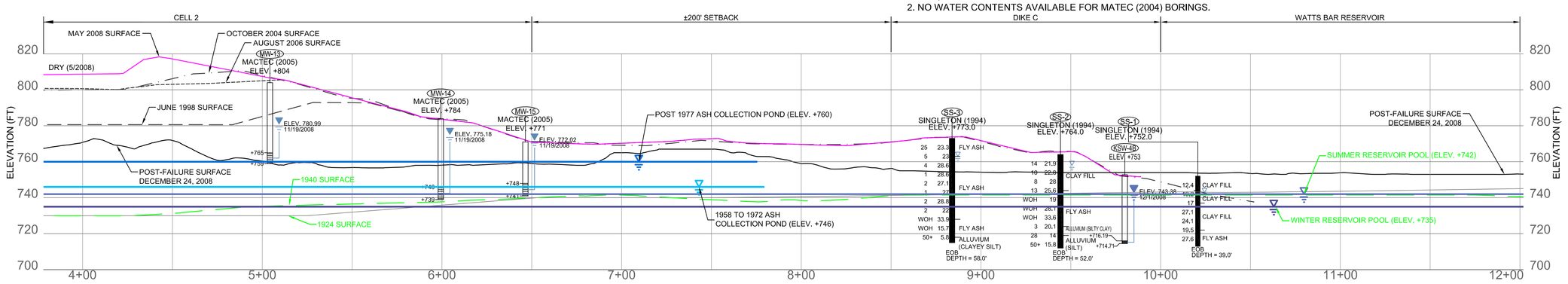


CROSS SECTION A-A'
SCALE : 1" = 30'



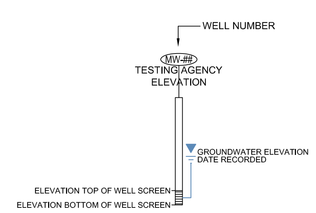
CROSS SECTION A-A'
SCALE : 1" = 30'

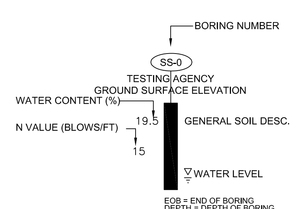
NOTES:
1. SS-4, SS-5 AND SS-6 BORINGS LOCATIONS ARE APPROXIMATE.
2. NO WATER CONTENTS AVAILABLE FOR MATEC (2004) BORINGS.



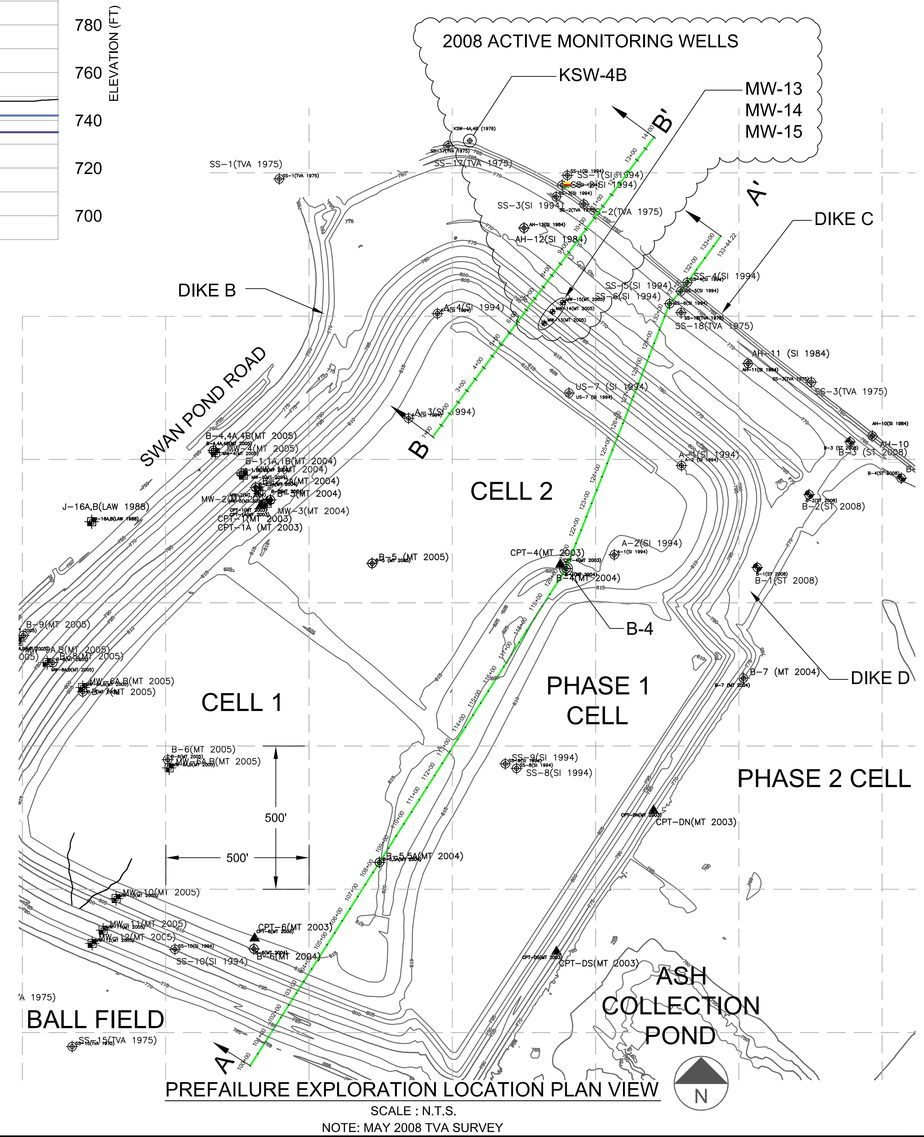
CROSS SECTION B-B'
SCALE : 1" = 30'

NOTE:
BORING AND WELL LOCATIONS ARE APPROXIMATE





NOTE:
BORING AND WELL LOCATIONS ARE APPROXIMATE



PREFAILURE EXPLORATION LOCATION PLAN VIEW
SCALE : N.T.S.
NOTE: MAY 2008 TVA SURVEY

AECOM

847.279.2500

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ROOT CAUSE ANALYSIS
TVA KINGSTON DREDGE CELL FAILURE
ON DECEMBER 22, 2008
KINGSTON FOSSIL PLANT
HARRIMAN, TENNESSEE

PREFAILURE CROSS SECTIONS A-A' & B-B'

TVA- KINGSTON
COAL ASH POND RCA
KINGSTON, TENNESSEE

Issued

Rev	Date	Description

Designed:	RCR	07/15/2009
Drawn:	DJD	7/15/2009
Checked:	LWB	07/15/2009
Approved:	WHM	07/15/2009

PROJECT NUMBER
60095742

SHEET REFERENCE NUMBER
FIG-1

SHEET 01 OF 01

X:\PROJECTS\60095742*.dwg\CROSS-SECTION-A-B-working-2.dwg; 7/16/2009 4:31:20 PM; DEARMAN, DANIEL; STS.stb

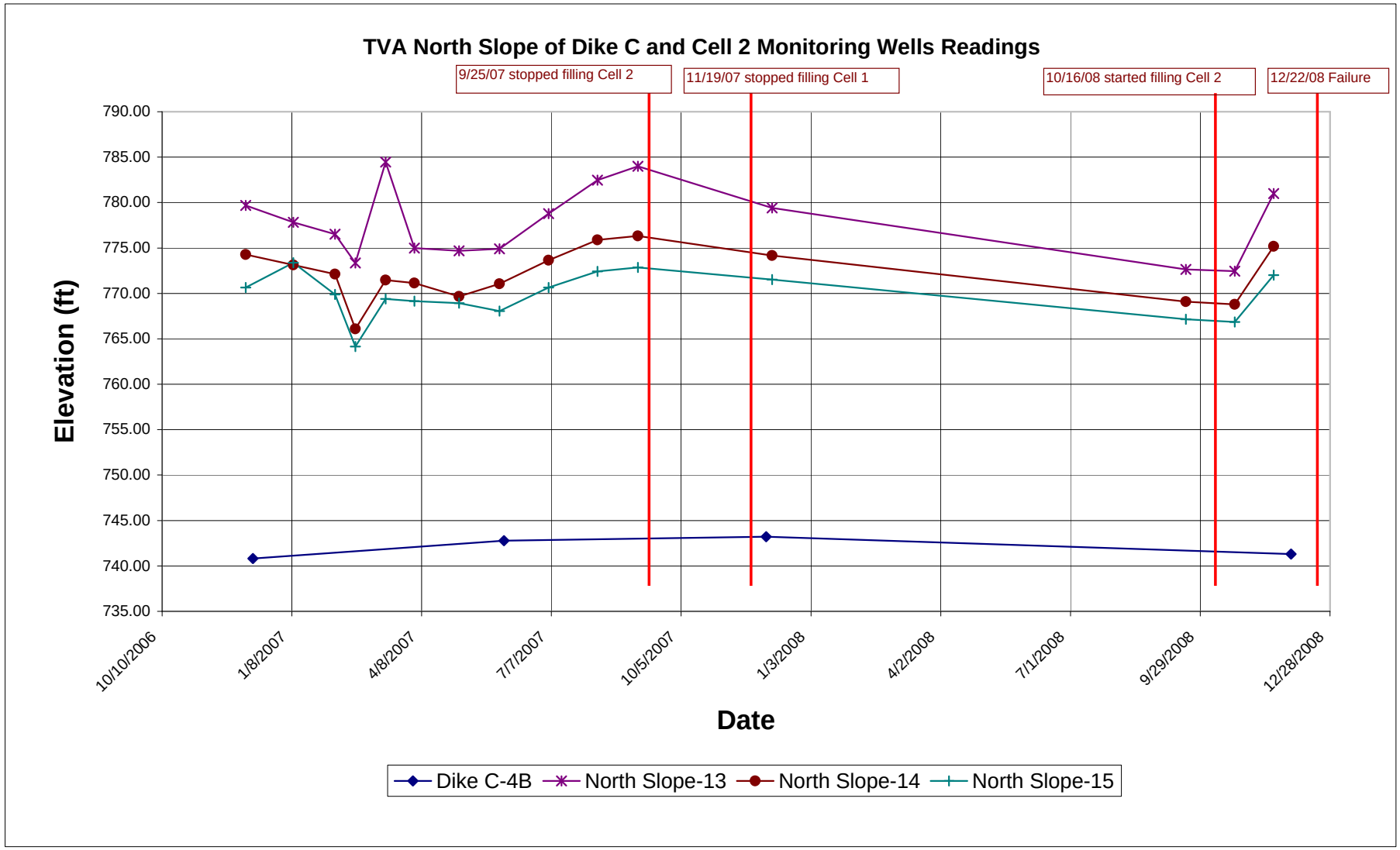


Figure 2 - Historic Well Reading from North Slope of Cell 1 and Dike C

Title: TVA - Kingston RCA
Comments: Seepage Analysis for Cell 2 Northwest Cross Section
Method: Steady-State

AECOM Parameters RCA
Kh/Kv = 1

Name: Alluvium - Silty Sands and Silts
Model: Saturated Only
K-Sat: 2.99e-007 ft/sec
K-Ratio: 0.5

Name: Alluvium - Clays and Silts
Model: Saturated Only
K-Sat: 4.92e-008 ft/sec
K-Ratio: 1

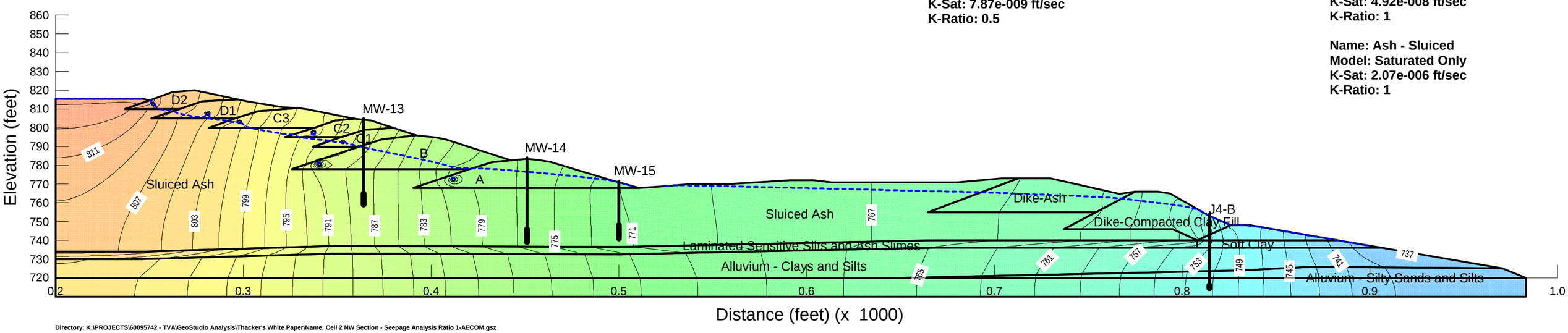
Name: Laminated Sensitive Silts and Ash Slimes
Model: Saturated Only
K-Sat: 7.87e-009 ft/sec
K-Ratio: 0.5

Name: Dike - Ash
Model: Saturated Only
K-Sat: 4.6e-007 ft/sec
K-Ratio: 0.5

Name: Dike - Compacted Clay Fill
Model: Saturated Only
K-Sat: 1.64e-007 ft/sec
K-Ratio: 0.5

Name: Soft Clay
Model: Saturated Only
K-Sat: 4.92e-008 ft/sec
K-Ratio: 1

Name: Ash - Sluiced
Model: Saturated Only
K-Sat: 2.07e-006 ft/sec
K-Ratio: 1



Directory: K:\PROJECTS\60095742 - TVA\GeoStudio Analysis\Thacker's White Paper\Name: Cell 2 NW Section - Seepage Analysis Ratio 1-AECOM.gsz

Figure 3

Title: TVA - Kingston RCA
Comments: Seepage Analysis for Cell 2 Northwest Cross Section
Method: Steady-State

AECOM Parameters RCA
Kh/Kv = 2

Name: Alluvium - Silty Sands and Silts
Model: Saturated Only
K-Sat: 2.99e-007 ft/sec
K-Ratio: 0.5

Name: Alluvium - Clays and Silts
Model: Saturated Only
K-Sat: 4.92e-008 ft/sec
K-Ratio: 1

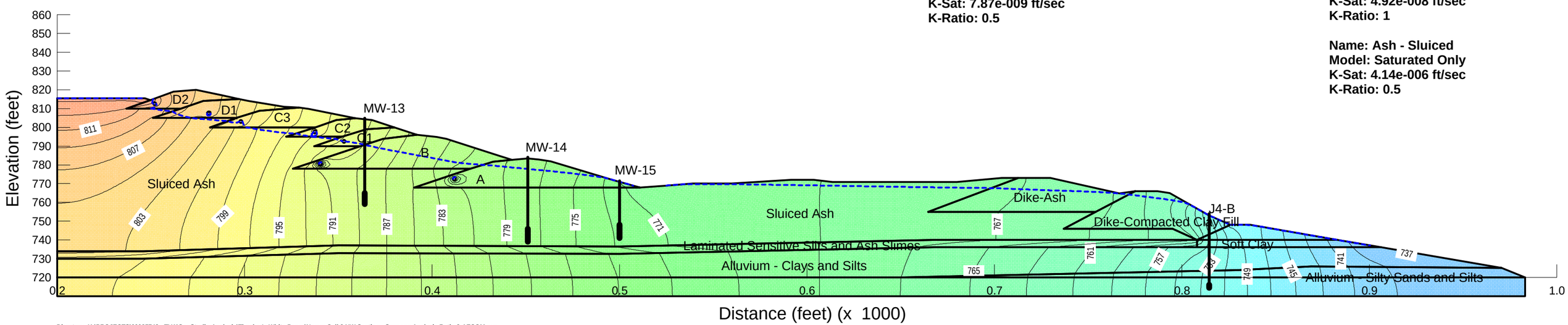
Name: Laminated Sensitive Silts and Ash Slimes
Model: Saturated Only
K-Sat: 7.87e-009 ft/sec
K-Ratio: 0.5

Name: Dike - Ash
Model: Saturated Only
K-Sat: 4.6e-007 ft/sec
K-Ratio: 0.5

Name: Dike - Compacted Clay Fill
Model: Saturated Only
K-Sat: 1.64e-007 ft/sec
K-Ratio: 0.5

Name: Soft Clay
Model: Saturated Only
K-Sat: 4.92e-008 ft/sec
K-Ratio: 1

Name: Ash - Sluiced
Model: Saturated Only
K-Sat: 4.14e-006 ft/sec
K-Ratio: 0.5



Directory: K:\PROJECTS\60095742 - TVA\GeoStudio Analysis\Thacker's White Paper\Name: Cell 2 NW Section - Seepage Analysis Ratio 2-AECOM.gsz

Figure 4

Title: TVA - Kingston RCA
Comments: Seepage Analysis for Cell 2 Northwest Cross Section
Method: Steady-State

AECOM Parameters RCA
Kh/Kv = 10

Name: Alluvium - Silty Sands and Silts
Model: Saturated Only
K-Sat: 2.99e-007 ft/sec
K-Ratio: 0.5

Name: Alluvium - Clays and Silts
Model: Saturated Only
K-Sat: 4.92e-008 ft/sec
K-Ratio: 1

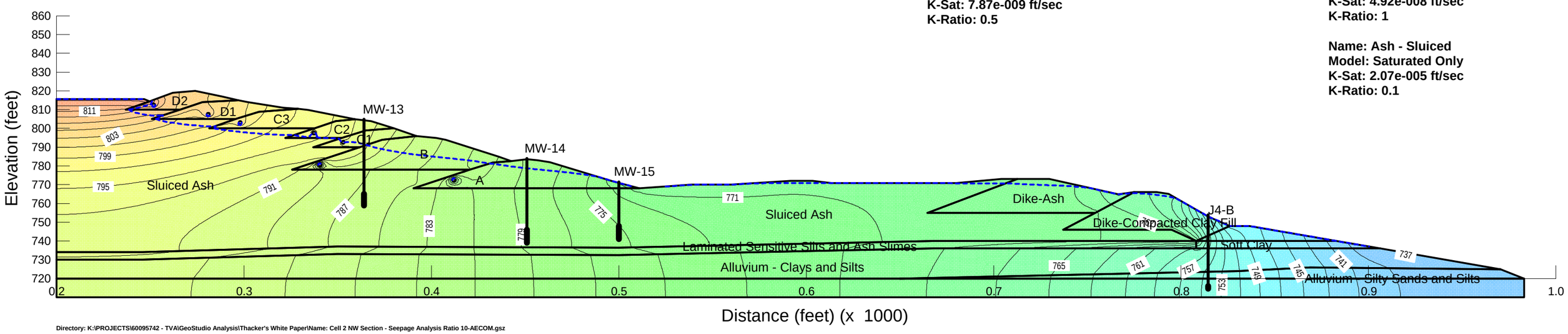
Name: Laminated Sensitive Silts and Ash Slimes
Model: Saturated Only
K-Sat: 7.87e-009 ft/sec
K-Ratio: 0.5

Name: Dike - Ash
Model: Saturated Only
K-Sat: 4.6e-007 ft/sec
K-Ratio: 0.5

Name: Dike - Compacted Clay Fill
Model: Saturated Only
K-Sat: 1.64e-007 ft/sec
K-Ratio: 0.5

Name: Soft Clay
Model: Saturated Only
K-Sat: 4.92e-008 ft/sec
K-Ratio: 1

Name: Ash - Sluiced
Model: Saturated Only
K-Sat: 2.07e-005 ft/sec
K-Ratio: 0.1



Directory: K:\PROJECTS\60095742 - TVA\GeoStudio Analysis\Thacker's White Paper\Name: Cell 2 NW Section - Seepage Analysis Ratio 10-AECOM.gsz

Figure 5

Title: TVA - Kingston RCA
Comments: Seepage Analysis for Cell 2 Northwest Cross Section
Method: Steady-State

AECOM Parameters RCA
Kh/Kv = 100

Name: Alluvium - Silty Sands and Silts
Model: Saturated Only
K-Sat: 2.99e-007 ft/sec
K-Ratio: 0.5

Name: Alluvium - Clays and Silts
Model: Saturated Only
K-Sat: 4.92e-008 ft/sec
K-Ratio: 1

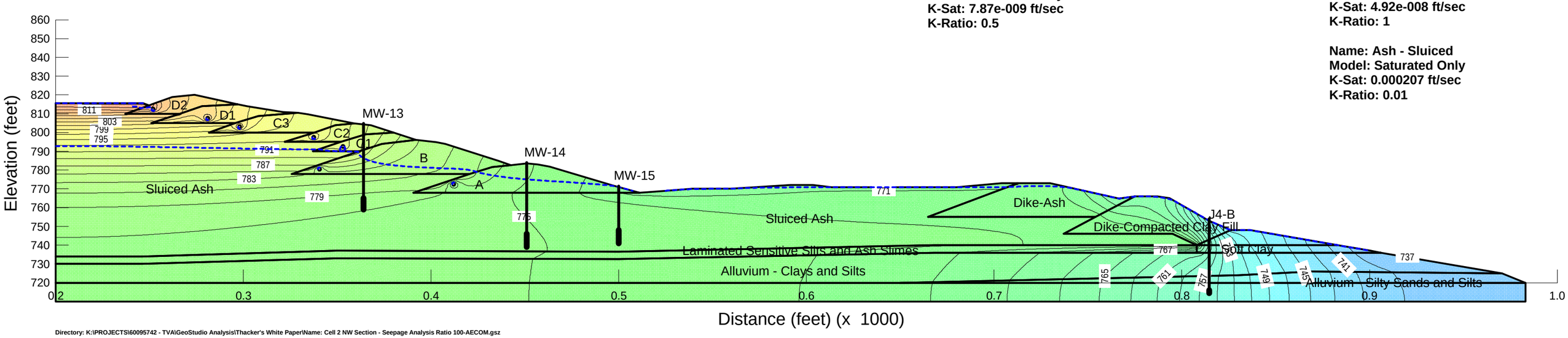
Name: Laminated Sensitive Silts and Ash Slimes
Model: Saturated Only
K-Sat: 7.87e-009 ft/sec
K-Ratio: 0.5

Name: Dike - Ash
Model: Saturated Only
K-Sat: 4.6e-007 ft/sec
K-Ratio: 0.5

Name: Dike - Compacted Clay Fill
Model: Saturated Only
K-Sat: 1.64e-007 ft/sec
K-Ratio: 0.5

Name: Soft Clay
Model: Saturated Only
K-Sat: 4.92e-008 ft/sec
K-Ratio: 1

Name: Ash - Sluiced
Model: Saturated Only
K-Sat: 0.000207 ft/sec
K-Ratio: 0.01



Directory: K:\PROJECTS\60095742 - TVA\GeoStudio Analysis\Thacker's White Paper\Name: Cell 2 NW Section - Seepage Analysis Ratio 100-AECOM.gsz

Figure 6

Title: TVA - Kingston RCA
Comments: Seepage Analysis for Cell 2 Northwest Cross Section
Method: Steady-State

AECOM Parameters RCA Analysis
Extended Section
Kh/Kv = 1

Name: Alluvium - Silty Sands and Silts
Model: Saturated Only
K-Sat: 2.99e-007 ft/sec
K-Ratio: 0.5

Name: Alluvium - Clays and Silts
Model: Saturated Only
K-Sat: 4.92e-008 ft/sec
K-Ratio: 1

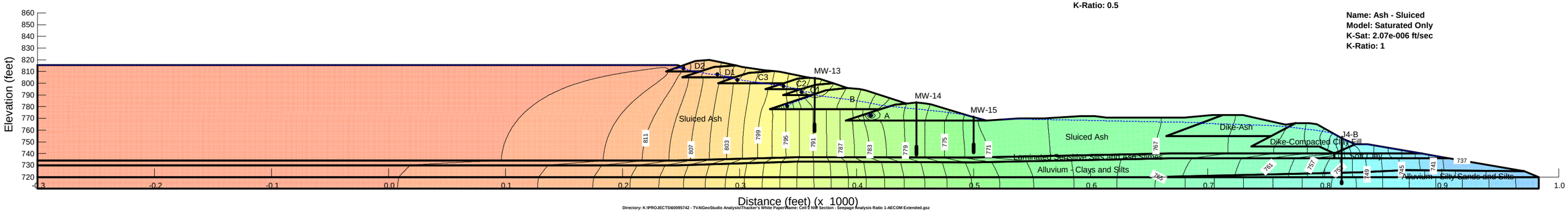
Name: Laminated Sensitive Silts and Ash Slimes
Model: Saturated Only
K-Sat: 7.87e-009 ft/sec
K-Ratio: 0.5

Name: Dike - Ash
Model: Saturated Only
K-Sat: 4.6e-007 ft/sec
K-Ratio: 0.5

Name: Dike - Compacted Clay Fill
Model: Saturated Only
K-Sat: 1.64e-007 ft/sec
K-Ratio: 0.5

Name: Soft Clay
Model: Saturated Only
K-Sat: 4.92e-008 ft/sec
K-Ratio: 1

Name: Ash - Sluiced
Model: Saturated Only
K-Sat: 2.07e-006 ft/sec
K-Ratio: 1



Directory: K:\PROJECTS\60095742 - TVA\GeoStudio Analysis\Thacker's White Paper\Name: Cell 2 NW Section - Seepage Analysis Ratio 1-AECOM Extended.gsz

Figure 7

Title: TVA - Kingston RCA
Comments: Seepage Analysis for Cell 2 Northwest Cross Section
Method: Steady-State

AECOM Parameters RCA Analysis
Extended Section
Kh/Kv = 2

Name: Alluvium - Silty Sands and Silts
Model: Saturated Only
K-Sat: 2.99e-007 ft/sec
K-Ratio: 0.5

Name: Alluvium - Clays and Silts
Model: Saturated Only
K-Sat: 4.92e-008 ft/sec
K-Ratio: 1

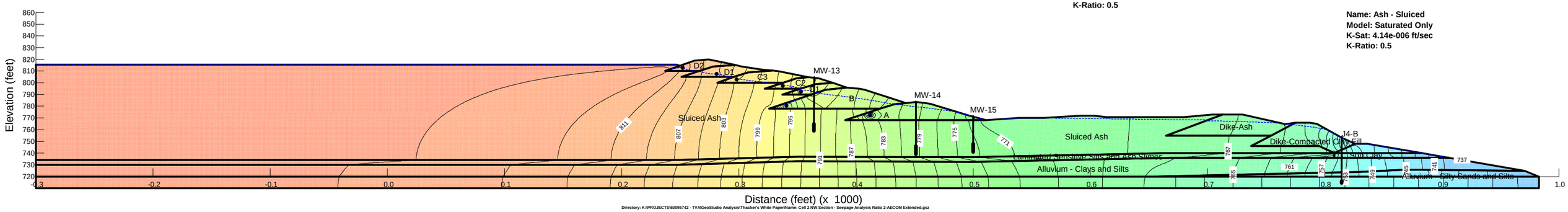
Name: Laminated Sensitive Silts and Ash Slimes
Model: Saturated Only
K-Sat: 7.87e-009 ft/sec
K-Ratio: 0.5

Name: Dike - Ash
Model: Saturated Only
K-Sat: 4.6e-007 ft/sec
K-Ratio: 0.5

Name: Dike - Compacted Clay Fill
Model: Saturated Only
K-Sat: 1.64e-007 ft/sec
K-Ratio: 0.5

Name: Soft Clay
Model: Saturated Only
K-Sat: 4.92e-008 ft/sec
K-Ratio: 1

Name: Ash - Sluiced
Model: Saturated Only
K-Sat: 4.14e-006 ft/sec
K-Ratio: 0.5



Directory: K:\PROJECTS\60095742 - TVA\GeoStudio Analysis\Thacker's White Paper\Name: Cell 2 NW Section - Seepage Analysis Ratio 2-AECOM Extended.gsz

Figure 8

Title: TVA - Kingston RCA
Comments: Seepage Analysis for Cell 2 Northwest Cross Section
Method: Steady-State

AECOM Parameters RCA Analysis
Extended Section
Kh/Kv = 10

Name: Alluvium - Silty Sands and Silts
Model: Saturated Only
K-Sat: 2.99e-007 ft/sec
K-Ratio: 0.5

Name: Alluvium - Clays and Silts
Model: Saturated Only
K-Sat: 4.92e-008 ft/sec
K-Ratio: 1

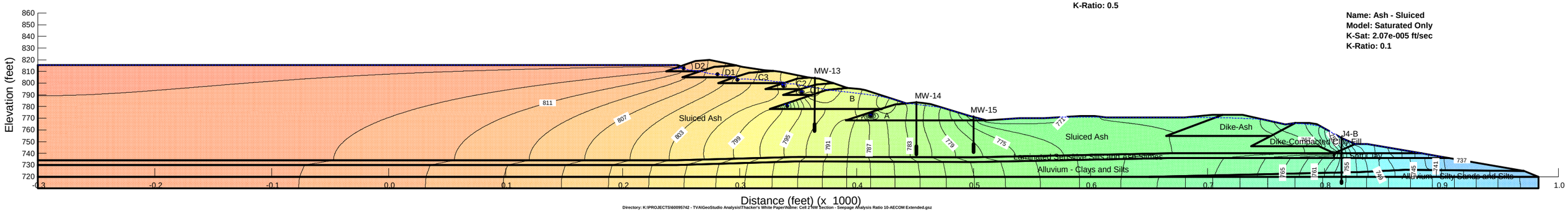
Name: Laminated Sensitive Silts and Ash Slimes
Model: Saturated Only
K-Sat: 7.87e-009 ft/sec
K-Ratio: 0.5

Name: Dike - Ash
Model: Saturated Only
K-Sat: 4.6e-007 ft/sec
K-Ratio: 0.5

Name: Dike - Compacted Clay Fill
Model: Saturated Only
K-Sat: 1.64e-007 ft/sec
K-Ratio: 0.5

Name: Soft Clay
Model: Saturated Only
K-Sat: 4.92e-008 ft/sec
K-Ratio: 1

Name: Ash - Sluiced
Model: Saturated Only
K-Sat: 2.07e-005 ft/sec
K-Ratio: 0.1



Directory: K:\PROJECTS\60095742 - TVA\GeoStudio Analysis\Thacker's White Paper\Name: Cell 2 NW Section - Seepage Analysis Ratio 10-AECOM Extended.gsz

Figure 9

Title: TVA - Kingston RCA
Comments: Seepage Analysis for Cell 2 Northwest Cross Section
Method: Steady-State

AECOM Parameters RCA Analysis
Extended Section
Kh/Kv = 100

Name: Alluvium - Silty Sands and Silts
Model: Saturated Only
K-Sat: 2.99e-007 ft/sec
K-Ratio: 0.5

Name: Alluvium - Clays and Silts
Model: Saturated Only
K-Sat: 4.92e-008 ft/sec
K-Ratio: 1

Name: Laminated Sensitive Silts and Ash Slimes
Model: Saturated Only
K-Sat: 7.87e-009 ft/sec
K-Ratio: 0.5

Name: Dike - Ash
Model: Saturated Only
K-Sat: 4.6e-007 ft/sec
K-Ratio: 0.5

Name: Dike - Compacted Clay Fill
Model: Saturated Only
K-Sat: 1.64e-007 ft/sec
K-Ratio: 0.5

Name: Soft Clay
Model: Saturated Only
K-Sat: 4.92e-008 ft/sec
K-Ratio: 1

Name: Ash - Sluiced
Model: Saturated Only
K-Sat: 0.000207 ft/sec
K-Ratio: 0.01

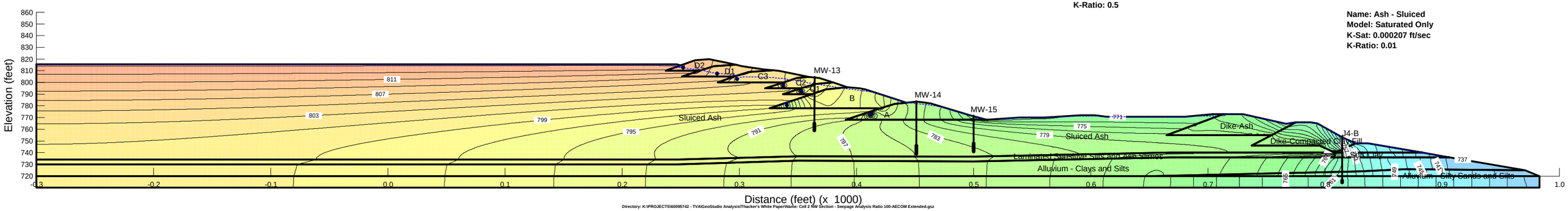


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Figure 10