GEOTECH INVESTIGATION

General

A preliminary stability analysis was performed for the proposed Options 1, 2, or 3 gypsum or gypsum-fly ash stacks at TVA's Kingston Fossil (Power) Plant near Knoxville, Tennessee. The preliminary stability analysis was performed for the following purposes:

- To examine if construction of the stacks to the proposed heights and configurations are likely to be stable, especially during a design seismic event, as required by the Tennessee Division of Solid Waste Management (TDSWM) (see Reference 9).
- To help identify specific factors that will affect stack stability and to determine whether these factors can be mitigated by engineering solutions.
- To help select the most appropriate option(s) for a detailed investigation and design if the project is to be implemented.

Two alternate sites within the plant property, namely the Peninsula site and the existing ash disposal site, were considered for the stack. Options 1A and 1B are at the Peninsula site and 2A, 2B, 3A and 3B are at the ash site. The stack height, configuration, etc. and the topographical features are shown on the drawings (Reference 1).

A preliminary pseudostatic global slope stability analysis was performed using the computer program PCSTABL5M. This computer program was developed at Purdue University and uses the STED preprocessor. For the stability analysis we selected two critical sections of the proposed maximum heights of the stack (Options 1A and 2B), one at each of the two sites.

The analysis was performed using subsurface profiles and properties of subsurface materials interpreted from the available subsurface and geological data for the two sites (References 2, 5, 6, and 7). Limited data regarding the properties of FGD sludge or sedimented gypsum was also made available from TVA records (References 3,4 and 8).

It should be noted that the plant is located in a probable high-seismic zone of the eastern continental United States (USGS maximum horizontal acceleration, a_{max}, of approximately 0.22g). Therefore, for locating a new solid waste facility at this plant, a detailed static and seismic stability evaluation is required for obtaining a construction permit. The evaluation should be performed using appropriate subsurface data for the selected site and data for the gypsum to be deposited or placed in the selected manner.

Critical Sections and Subsurface Profiles

Following a review of all options and considering the existing subsurface and topographical conditions, two sections, one each at Options 1A and 2B, were determined to be critical for the preliminary analysis. The locations of these critical sections are shown on Figures 1 and 2. The subsurface profiles at the two locations were developed from the subsurface data pertinent to the locations and are shown on Figures 3 and 4. The subsurface profiles are also shown on the results of the stability evaluation (STED printouts attached).

The profile at the Peninsula site (Option 1A) was based on data from Reference 2 and that at the ash site (Option 2B) was based on data from References 5, 6 and 7. The profiles were simplified for the computer evaluation. The combination of foundation condition and the stack height/configuration at these locations appear to be the most critical for the two sites.

For the stability evaluation, the dry stack was assumed to consist of two primary layers: The top layer consisting of gypsum deposited in the final approximately 3-year period, and the lower layer consisting of earlier deposits.

The wet-stack was assumed to consist of a 150 feet wide (horizontally) exterior shell of stronger material (perimeter dike and compacted deposits below the dikes) and an interior portion of wet placed material represented by three gypsum layers. The top interior layer consists of gypsum deposited for the final approximately two years. The middle layer consists of gypsum deposited during the next three earlier years, and the bottom layer consists of gypsum deposited at least five years before the closure. This layering allows accounting for consolidation and strength-gain with time in the analytical models.

Subsoil, Fly Ash and Gypsum Properties

The subsoil properties used in the stability analysis for the Peninsula site (Option 1A) were interpreted based on the standard penetration test (SPT) and laboratory test data provided in Reference 2. The subsoil and ash properties for the ash site (Option 2B) were obtained from the data presented in References 5, 6, and 7 that included the SPT results and laboratory triaxial shear testing of samples. Judgment was required to determine appropriateness of data presented in these references due to the time elapsed since it was procured.

A significant variation in the scrubber-sludge (gypsum) data was noticed during a review of References 3, 4 and 8. It is known that gypsum crystallizes in the presence of water and hardens as time passes; that is, it attains greater cohesion with time. However, the magnitude of these effects, especially on its strength under variable confinement and moisture conditions that can be anticipated when it will be stacked as high as 220 feet, is difficult to assess as the literature in that regard is scarce or non-existent. Therefore, due to lack of consistent or reliable data for gypsum, the design properties used in the analysis are the best guesses and may need to be verified in the future.

The material properties used in the analysis are shown on the attached Figures 3 and 4 and on the attached STED model printouts. It should be noted that the properties used for the static and seismic conditions are not different, primarily because the stack and foundation materials under the sustained weight of the proposed high stacks built over a

Conclusions and Recommendations

General

The results of the two-dimensional stability analysis shown on Tables 1 and 2 provide factors of safety ranging from 0.79 to 1.95. In general, the results show that for a given condition, a factor of safety during the design seismic event (0.15g) of 1.0 can be obtained when a static factor of safety of about 1.6 to 1.8 is achieved for the same condition. It is clear that if the three-dimensional effect is considered, it is feasible to engineer the stack design to attain a factor of safety against global slope failure during seismic conditions greater than 1.0. The engineering measures include adequate stack-drainage to lower the phreatic surface sufficiently within the stack and foundation improvement to stiffen soft foundation soil adequately as indicated from this stability evaluation.

Additional discussions of the results of the two-dimensional stability analysis for the two sites are provided below. Additional general conclusions are as follows:

- Flattening the stack slope from 3H:1V to 4H:1V improves stability somewhat, but apparently is not required if adequate bench width is provided with 3H:1V slopes.
- Low-friction cohesive foundation soil (such as at the Peninsula site) is apparently less favorable for the proposed stack heights than a low-cohesion frictional soil (such as at the Ash site).
- Control of the water table within the stack itself is critical at both sites. Final design of a dry or wet stack system should include drainage design based on the anticipated hydraulic properties of the stack materials. Ground water control measures within the pile will be much more elaborate and expensive for wet stacking than with dry stacking.

Specifically for Peninsula Site

Based on Reference 2 data, an approximately 20-foot thick soft soil layer (soil layer 4 in the STED model) may exist approximately 20 feet below existing ground surface. This layer, if large in extent may have a significant effect on the overall stack stability. Future investigation should verify the extent, in-situ strength and deformation characteristics of this soil as well as those of the overlying stiffer soil. The top of rock contours should also be closely verified, along with the presence of solution cavities. Measures such as gravel columns along with a stone blanket below the impervious liner may be required to stiffen the soft soil if its extent is large and significant to the stack stability.

The design of a dry stack system to the configurations shown on the drawings should be feasible from a global stability standpoint.

References:

1. Options 1A, 1B, 2A, and 2B sketches (SK PR0637 series drawings), including other corresponding sketches showing details of the options.
2. MACTECH report titles, "Report of Geotechnical Exploration for Proposed Scrubber Stack Disposal Area", dated March 26, 2003, along with revised page and top of rock contour plans provided by MACTECH.
3. Data on sludge and sludge-ash mixtures provided by Dan Smith (ATTACHMENT A, Pages 3-26 through 3-30).
4. Law Engineering's "FINAL REPORT – Fly Ash, Bottom Ash and Scrubber Gypsum Study" – to TVA dated November 7, 1995, along with transmittal letter dated November 10, 1995.
5. Singleton Laboratories' report titled "KINGSTON FOSSIL PLANT – DREDGE CELLS CLOSURE SOILS INVESTIGATION", dated September 29, 1994.
6. U.S. Government reports titled, "KINGSTON STEAM PLANT – DIKE C, SOILS INVESTIGATION, EN DES SOIL SCHEDULE 82.3", dated June 22, 1984, and January 10, 1985.
7. Reports on ASH DISPOSAL AREA DIKE RAISING - SOIL INVESTIGATION:
   - A. Evaluation, by O.H. Raine, dated 11/12/75.
   - B. Investigation data report by Gene Farmer, dated November 3, 1975.
   - C. RFP for investigation, by W.W. Engle, dated June 26, 1974.
8. Ardaman & Associates, Inc., "Interim Report on Evaluation of the FGD Gypsum-Flyash Waste Wet-Stacking Disposal facility, Widows Creek Steam Plant, Stevenson, Alabama", dated April 22, 1991.
9. Tennessee Division of Solid waste management, Technical Guidance Document – Earthquake Evaluation Guidance Policy

Appendix

Tables, Figures, STED Models and Attachment A

Table 1 – Summary of Stability Analysis Models – Peninsula Site

Model Description	Water Table	Top of Stack (feet, NGVD)	Stacking Method	Slopes	Horizontal Earthquake Coefficient	Factor of Safety
1A - Soft Foundation Soils	2/3 Stack +880'	950	Dry	3H:1V with 15' benches	0	0.97
1A - Stiff Foundation Soils	2/3 Stack +880'	950	Dry	3H:1V with 15' benches	0	1.21
1A - Very Stiff Foundation Soils	2/3 Stack +880'	950	Dry	3H:1V with 15' benches	0	1.40
1A - Very Stiff Foundation Soils	2/3 Stack +880'	950	Dry	3H:1V with 15' benches	0.15g	0.83
1A - Very Stiff Foundation Soils	Lowered to +795'	950	Dry	3H:1V with 15' benches	0.15g	1.00
1A - Stiff Foundation Soils	2/3 Stack +860'	910	Dry	4H:1V with 15' benches	0.15g	0.82
1A - Very Stiff Foundation Soils	2/3 Stack +860'	910	Dry	4H:1V with 15' benches	0.15g	1.05
1A - Stiff Foundation Soils	Lowered to +800'	910	Dry	4H:1V with 15' benches	0.15g	1.01
1A - Very Stiff Foundation Soils	+905' at High Point	950	Wet	3H:1V with 15' benches	0	1.36
1A - Very Stiff Foundation Soils	+905' at High Point	950	Wet	3H:1V with 15' benches	0.15g	0.79
1A - Very Stiff Foundation Soils	+905' at High Point	950	Wet	3H:1V with 15' benches	0.11g	0.90

Table 2 – Summary of Stability Analysis Models – Existing Ash Disposal Site

Water Table	Top of Stack (feet, NGVD)	Stacking Method	Slopes	Horizontal Earthquake Coefficient	Factor of Safety
2/3 Stack +900’	980	Dry	3H:1V with 10’ benches	0	1.95
2/3 Stack +900’	980	Dry	3H:1V with 10’ benches	0.15g	1.22
2/3 Stack +900’	980	Dry	3H:1V with 10’ benches	0.22g	1.02
+980’	980	Wet	3H:1V with 10’ benches	0	1.90
+980’	980	Wet	3H:1V with 10’ benches	0.15g	1.17
+980’	980	Wet	3H:1V with 10’ benches	0.22g	0.96