SEEPAGE ANALYSIS

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COMPUTATION COVER SHEET

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SEEPAGE ANALYSIS

PURPOSE

The purpose of this calculation package is to present the results of seepage analyses performed for the proposed Gypsum Disposal Facility at the Kingston Fossil Plant (KIF) located in Roane County, Tennessee. This gypsum disposal facility will be owned, constructed, and operated by Tennessee Valley Authority (TVA). The analyses were performed to: (i) evaluate the effectiveness of the internal drainage system for the gypsum stack; (ii) estimate flow quantities through the internal drainage system; and (iii) estimate water levels within the disposal facility at different time periods throughout the life and post-closure period of the facility.

DESCRIPTION OF THE PROPOSED INTERNAL DRAINAGE SYSTEM FOR THE GYPSUM DISPOSAL FACILITY

The purpose of the internal drainage system for the proposed gypsum disposal facility is to facilitate drainage of water and reduce pore-water pressures within the gypsum stack. The internal drainage system consists of a central drainage corridor and perimeter drainage trenches. The central drainage corridor is located in Phase I and II and consists of a series of high density polyethylene (HDPE) perforated pipes encased in highly-permeable, geotextile-wrapped gravel surround. Water collected by the central drainage corridor is conveyed to an underdrain lift station, located outside the waste footprint and pumped into the proposed stormwater pond. A layout of the proposed central corridor for Phase I and II and location of the underdrain lift station is shown on Drawings 10W427-5 and 10W427-9. During gypsum disposal operations and as gypsum perimeter dikes are constructed, perimeter drainage trenches will be constructed at consistent vertical spacing within the constructed gypsum dike. The purpose of these perimeter drains is to minimize pore pressure build up along the inside of the outer slopes of the facility. The perimeter drainage trench will consist of a perforated pipe encased in highly-permeable, geotextile-wrapped gravel. Water collected by the perimeter trenches will be directed towards equally spaced outlet pipes which in turn convey collected water to the final cover drainage bench and/or perimeter channel. This water will then flow by gravity to the stormwater pond for subsequent disposal at the KIF discharge channel. Details of the perimeter drainage trenches are shown on Drawing 10W427-18.

METHOD OF ANALYSIS

Seepage analyses for the proposed disposal facility were performed using a two-dimensional finite element program SEEP/W V4.24. The program was used to model the movement of water and pore-pressure distribution within the gypsum stack under steady-state and transient conditions. The program was used also to estimate flow quantities through the proposed internal drainage system. Information required for the analyses includes:

- the geometry of the gypsum stack at the cross section location;

- the geometry of the internal drainage system (i.e., central drainage corridor and perimeter drainage trenches);
- the hydraulic properties of for gypsum; and
- boundary conditions and initial conditions (in case of transient analysis).

ANALYSIS CROSS-SECTION

The analysis of seepage flow within the gypsum disposal facility is considered a three-dimensional problem due to the limited lateral extent of the central drainage corridor and the discrete locations of the perimeter drainage trenches. Because of the limitation of SEEP/W in analyzing three-dimensional seepage flows, analysis can be approximated by analyzing seepage flow at several cross sections oriented perpendicular to the central drainage corridor. Flow through the central drainage corridor can then be computed by summing the contribution of flow quantities estimated from the selected cross-sections.

To reduce computational effort and time, analysis presented as part of this calculation package were performed for one cross section that contribute the maximum flow to the central drainage corridor (i.e., cross section with maximum width). Assuming the quantity of flow towards the central drainage corridor to be the same along the entire drainage corridor, the resulting estimate of flow volume through the central drainage corridor will be conservative. Location of analysis cross section with respect to final cover grades at the end of wet stack operations is shown in Figure 1. Cross section geometry and stratigraphy are shown in Figure 2. Details description of cross section stratigraphy is presented in the following section.

CROSS SECTION STRATIGRAPHY AND MATERIAL PARAMETERS

Material contained within the gypsum disposal facility consists mainly of coarse grained gypsum and fine grained gypsum. A brief description of the genesis of the gypsum anticipated to be encountered within the disposal facility is presented as follows:

- *Coarse Gypsum*: Coarse grained gypsum is a by-product of the rim-ditch operations of sluiced material placement. Coarser grained gypsum settles out in or near the rim ditch and is scooped out and compacted to form the perimeter dikes.

- *Fine Gypsum*: Fine grained gypsum is also a by-product of the rim-ditch method of sluiced material placement, however the finer grained material travels further from the discharge point and tends to be located towards the center of the gypsum pond than the coarser material.

The only characteristic of interest for the calculation of seepage flow and pore-water pressure distribution within the gypsum disposal facility is the hydraulic conductivity. Gypsum is currently not generated from the TVA Kingston Fossil Plant. Therefore, information on the hydraulic conductivity of gypsum was obtained from laboratory tests performed on similar gypsum material generated from other

TVA fossil plants (MACTEC, 1995; MACTEC, 2004). Hydraulic conductivity test results performed on representative gypsum material obtained from other TVA fossil plants are presented in Appendix A. According to these test results, the hydraulic conductivity of gypsum ranges from 1.5 x 10^{-4} cm/sec to 6.65 x 10^{-4} cm/sec. The average hydraulic conductivity of the coarse gypsum was calculated to be approximately 5 x 10^{-4} cm/sec. It is worth noting that the permeability tests performed on representative gypsum samples under a confining pressure ranging between 7 to 14 psi. To account for higher confining pressures anticipated within the gypsum stack, the hydraulic conductivity of fine gypsum was assumed to be 1 x 10^{-5} cm/sec.

The horizontal hydraulic conductivity (K_h) of the gypsum material is anticipated to be greater than the vertical hydraulic conductivity (K_v) due to the layered nature of the sedimented gypsum. Field measurements of water levels and hydraulic conductivity measurements within existing TVA disposal facilities indicated that the ratio of horizontal and vertical hydraulic conductivity (K_h/K_v) ranges between 2 to 4. For the purpose of this analysis, a K_h/K_v of 2 was considered. A summary of hydraulic conductivity used in the analysis are presented in Table1.

Table 1. Summary of Hydraulic Conductivity Used in the Seepage Analyses

Material	Hydraulic Conductivity (K, cm/sec)	K_h/K_v
Fine Gypsum	1 x 10^{-5}	2
Coarse Gypsum	5 x 10^{-4}	2

ANALYSIS CASES

Seepage analyses were preformed for the selected cross section considering three analysis cases. Description of these analysis cases is presented below:

Case I – Considering No Central Drainage Corridor (Steady State Condition): This case was analyzed to evaluate the effectiveness of the perimeter drainage trenches in reducing seepage pressures along the inside face of the facility outbound slope and estimate the maximum seepage flow towards the perimeter drainage trench.

Case II – Considering No Central drainage Corridor (Transient Condition): This case was analyzed to provide a base for comparison in demonstrating the effectiveness of the proposed central drainage corridor in facilitating water drainage and reducing water levels in the gypsum stack. Water levels within the wet gypsum stack was estimated at different time periods.

Case III - Considering a Central Drainage Corridor (Transient condition): This case was analyzed to evaluate water levels within the facility at different time intervals and the corresponding seepage flow into the proposed central drainage corridor.

FINITE ELEMENT MESH AND BOUNDARY CONDITIONS

Figure 3 presents the finite element mesh used for the analyses. Figure 4 presents boundary conditions for analysis cases I through III. For transient analyses (i.e., Case II and III), initial boundary condition assumes the initial water level to be at the top of the wet stack at an elevation approximately 928 ft above msl. Stated differently, it is assumed that flow towards the internal drainage system will commence when the wet stack reaches the end of wet disposal operations. This is considered to be a very conservative approach since the drainage through the central corridor will occur during the earlier stages of wet disposal resulting in water levels within the stack being lower than the assumed starting elevation. For analysis case III, the width of the central drainage corridor is considered 150 ft.

RESULTS AND CONCLUSIONS

Graphical output of the seepage analysis for Case I (i.e., steady state conditions – considering no central drainage corridor) is presented in Figures 5. Based on analysis results, the seepage flow towards perimeter drainage trenches drains is estimated to range from 7.76 x 10^{-6} to 5.51.0 x 10^{-5} ft^3/sec/ft, which is equivalent to approximately 5 to 35 gallons/day/ft.

Graphical output for the seepage analysis for Cases II and III are presented in Figures 6 and 7, respectively. Based on the results of modeling, it is noted that water levels within the stack will be reduced considerably quicker using the central drainage corridor (i.e., Case III) when compared to the case without a central drainage (Case II). The rate of reduction is estimated to be approximately twice that of the case with no internal drainage. This is considered beneficial in terms of: (i) reducing the head on the geologic buffer layer; and (ii) the factor of safety for slope stability will be improved as water levels are reduced in the stack.

Finally, it is worth noting that for the analyses presented herein, the following assumptions were made:

(i) the hydraulic conductivity of the gypsum are representative of gypsum material to be disposed of in the proposed facility; and

(ii) outlet pipes of the perimeter drainage trenches and central drainage corridor discharge will be inspected and maintained periodically to ensure that there is no clogging.

REFERENCES

MACTEC "Use of Coal Combustion By-Products as Engineered Fills," prepared by Law Engineering (currently MACTEC), November 1995.

MACTEC "Laboratory Testing Results – Samples from Gypsum Pond at Cumberland Fossil Plant," prepared for Parsons E&C on behalf of TVA, 13May, 2004.