SETTLEMENT/WATER ISSUES RELATED TO PLACEMENT OF ADDITIONAL MATERIAL ON THE EXISTING TAILINGS IMPOUNDMENT

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GALLUP, NM

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EXECUTIVE SUMMARY

This report provides a preliminary evaluation of potential settlement issues associated with the placement of soils removed during the Northeast Church Rock Mine Site Removal Action directly on parts or all of the existing tailings impoundments at the adjacent Northeast Church Rock Mill Site. Specifically, the question was raised whether there is a possibility that significant water could be 'squeezed' from the existing fine grained tailings due to additional surcharge loading on the tailings impoundment. The original fine tailings were placed in a near saturated state and were covered about two decades ago.

Findings from this cursory evaluation conclude that water will not be 'squeezed' from the existing fine grained tailings due to the proposed surcharge loads. The evaluation is based on available data from existing documentation of the tailings closure, estimated values, and values from the literature.

1.0 INTRODUCTION

The Northeast Church Rock (NECR) Mine Site was an underground Uranium mine active from 1968 to 1982, when it went to stand-by status. The primary ore mined was coffinite. Mine reclamation is warranted as a result of these mining operations.

An Engineering Evaluation/Cost Analysis (EE/CA) was prepared by the United States Environmental Protection Agency (EPA), Region 9 to evaluate Non-Time- Critical Removal Action (NTCRA or "Removal Action") alternatives for soil and sediment (mine wastes) at NECR. The site is located about 16 miles northeast of Gallup in McKinley County, New Mexico. The site is a semi-arid climate averaging about 12-inches of precipitation per year at an elevation of about 7000-ft above sea level. The vegetation is generally categorized as a pinyon-juniper landscape with shrubs and native grasses. The near surface soil and alluvium on site are predominantly a clay loam.

The primary elements of the Preferred Alternative from the EECA include:

- Excavation and transport of all mine waste soil with radium above 2.24 pCi/g (10-4), except in the ponds, where it would be excavated to a maximum depth of 10 feet. · Consolidation of the mine wastes with a cap and liner in an existing disposal cell on the adjacent UNC mill site, or construction of a new cell at the UNC mill facility currently under license by the U.S. Nuclear Regulatory Commission (NRC);
- Principal threat mine wastes to be taken to an off-site licensed controlled disposal facility, such as at Grandview, ID, or an alternative appropriate facility. For waste with total Uranium concentrations exceeding 500 mg/kg, it may be viable to reprocess the waste at the White Mesa Mill in Utah or a similar mill;
- Site restoration with erosion and storm water controls, regrading and revegetation for future grazing; and

- Long-term maintenance for capped repository, which would occupy an estimated 30 acres and would become part of DOE's legacy management program in perpetuity.

United Nuclear is evaluating the possibility of placing soils removed during the Removal Action on one or more of the existing tailings impoundments rather than creating a new repository on-site. This evaluation examines the possibility of settlement of the existing buried tailings and the subsequent potential 'squeezing' of additional water from these fine grained tailings.

2.0 SETTLEMENT

The following profile was used to evaluate settlement in the fine grained tailings layer (figure 1). The assumed worst case profile was evaluated whereby the fine grained tailings were approximately 15-ft thick while the coarse tailings were only 7-ft thick. The 7-ft thick coarse tailings is the minimum thickness for this layer and thus offered the lowest pressure on the fine-grained tailings and thus the minimum amount of primary consolidation from the original closure.

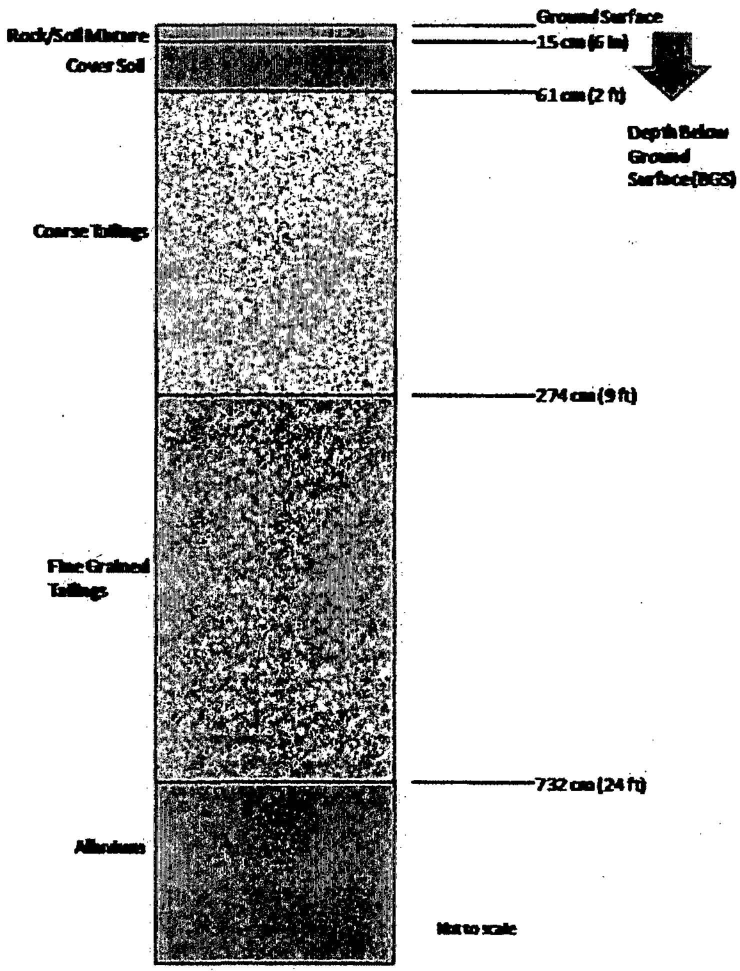

FIGURE 1
PROFILE OF EXISTING TAILINGS IMPOUNDMENT

Terzaghi's theory of consolidation was utilized to calculate the primary settlement in the fine grained tailings from this original profile. The following assumptions were utilized:

1. Terzaghi's 1-D consolidation theory is valid for this case;
2. The fine grained tailings behave as a saturated clay;
3. Soil parameters from various 'as-built' reports from the tailings closure and assumed values where soil parameters in prior reports were not found.

$$S_c = C_c * [H_o/(1 + e_o)] * \log [(\sigma + \Delta\sigma)/\sigma]$$ primary consolidation

$$S_c = C_a * H_o * \log [t_2/t_1]$$ secondary consolidation

Refer to Appendix A for more details of calculations. A summary of the calculations include:

- Primary consolidation in fine grained tailings layer is 2-ft. The time-dependent secondary consolidation in the same layer is 1.1 ft. The total settlement to date in the fine grained tailings layer is approximately 3.1-ft.
- It is undetermined whether the best scenario would include placing all of the soil removed from the interim action (about 900,000 CY) on the south, central, or north cell; or spreading it over all three cells. Consequently an analysis was performed to evaluate all 4 scenarios. The original void ratio in the fine grained tailings layer was assumed to be 1.38 based on the applicable references. Assuming the total soil removed from the interim action were placed on the south, central, or north cell; or spreading it over all three cells; the new void ratio (e) and porosity (n) for this fine grained tailings layer as a result of the total settlement discussed above is:
    - Scenario 1 – Interim soil placed on South Cell: e = 0.72; n = 0.42;
    - Scenario 2 – Interim soil placed on Central Cell: e = 0.78; n = 0.44;
    - Scenario 3 – Interim soil placed on North Cell: e = 0.76; n = 0.43;
    - Scenario 4 – Interim soil placed on Total of all Cells = 0.82; n = 0.45.

The maximum water content a soil can hold after all downward drainage resulting from gravitational forces is referred to as its field capacity. Field capacity is often arbitrarily reported as the water content at 330-cm of matric potential head (Jury *et al.* 1991). Below field capacity, the hydraulic conductivity is assumed to be so low that gravity drainage becomes negligible and the soil moisture is held in place by suction or matric potential. Consequently, a soil's field capacity is deemed to bound the soil layer moisture content or have excess pore water pressure to yield significant moisture from the proposed 'squeezing' water out of the fine grained soil layer scenarios discussed above.

3.0 MODELING

The profile (figure 1) was modeled to evaluate the condition of the fine grained tailings layer after the primary and secondary settlement occurred (3.1-ft), but prior to placement of additional soil from the interim action was placed on a tailings cell. The profile was modeled to evaluate the unsaturated flow over the 19 years from the assumed end of the primary consolidation until the current date. The initial condition of the fine grained soil was assumed to be at field capacity following the primary consolidation. This is a conservative assumption because during primary consolidation, the excess pore water is squeezed from the soil pore spaces. Thus the wettest condition it can be in following primary consolidation is the moisture content associated with the field capacity of the soil. It is conservative because it is likely the soil is drier than the moisture content associated with the field capacity. The resulting condition of the fine grained tailings layer could then be compared to the field capacity of the calculated moisture characteristic curves for each scenario evaluated after the 19 year period. If the condition of the fine grained tailings layer had a soil suction greater than its respective field capacity, then it is determined that any water remaining in the layer is within the water storage capacity of that layer and thus no water will be squeezed out. If the suction is less than the field capacity, then excess water can be squeezed out.

Software [UNSAT H (Fayer 2000)] utilized for the analysis of the unsaturated analysis is based on the Richard's Equation (ITRC 2003). The Richards Equation is as follows:

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z}\left[K(\psi)\left(\frac{\partial \psi}{\partial z} + 1\right)\right] - \Lambda(z,t)$$

Where:

K is the hydraulic conductivity,

ψ is the pressure head,

z is the elevation above a vertical datum,

θ is the water content,

t is time, and

$\Lambda(z,t)$ = a sink term for root water uptake.

The cover profile modeled utilized an upper boundary condition composed of site-specific average climate data for a period of 19 years.

3.1 OVERVIEW OF UNSAT-H

UNSAT-H is a one-dimensional, finite-difference computer program developed at the Pacific Northwest National Laboratory by Fayer and Jones (1990). UNSAT-H simulates water flow through soils by solving Richards' Equation and simulates heat flow by solving Fourier's heat conduction equation.

UNSAT-H separates precipitation falling on an earthen cover into infiltration and overland flow. The quantity of water that infiltrates depends on the infiltration capacity of the soil profile immediately prior to rainfall (e.g., total available porosity). Thus, the fraction of precipitation shed as overland flow depends on the saturated and unsaturated hydraulic conductivities of the soil included in the final cover. If the rate of precipitation exceeds the soil's infiltration capacity, the excess water is shed as surface runoff. UNSAT-H does not consider absorption and interception of water by the plant canopy or the effect of slope and slope-length when computing surface runoff since it is a 1-dimensional model.

Water that has infiltrated a soil profile during an UNSAT-H simulation moves upward or downward as a consequence of gravity and matric potential. Evaporation from the cover surface is computed using Fick's law. Water removal by transpiration of plants is treated as a sink term in Richards' equation. Potential evapotranspiration (PET) is computed from the daily wind speed, relative humidity, net solar radiation, and daily minimum and maximum air temperatures using a modified form of Penman's equation given by Doorenbos and Pruitt (1977). Soil water storage is computed by integrating the water content profile. Flux from the lower boundary is via percolation. UNSAT-H, being a one-dimensional program, does not compute lateral drainage .

3.2 INPUT PARAMETERS

A set of input parameters were developed for simulations using UNSAT-H for the soil profile. These parameters were developed based on field and laboratory measurements, values from the literature, and assumed values.

3.2.1 MODEL GEOMETRY

The model geometry is that shown in Figure 1.

3.2.2 BOUNDARY CONDITIONS

Weather data available through the United States Department of Commerce, National Climate Data Center was evaluated (http://cdo.ncdc.noaa.gov/pls/plclimprod/poemain.accessrouter?datasetabbv=SOD&countryabbv=&georegionabbv=). An average climate year (1949) consisting of an annual precipitation of 11.7 inches (29.7 cm) of precipitation was utilized for 19 consecutive years. The PET during this period was calculated via New Mexico State University's Potential and Actual Crop Evapotranspiration Wizard. This software package available on the internet at http://weather.nmsu.edu/pet/JS_pet.htm was utilized to calculate daily PET values based on the daily weather data. The maximum and minimum daily temperatures, daily precipitation value, site latitude, and a site specific calibration coefficient of 0.16 were input parameters used to calculate PET (Samani and Pessarkli, 1986). The Samani method used to calculate PET correlates very well with the Penman method utilized within UNSAT H (Samani and Pessarkli, 1986).

The flow of water across the surface and lower boundary of the cover profile of interest is determined by boundary condition specifications. For infiltration events, the upper boundary was set to a maximum hourly flux (representative of local conditions). For these runs it was conservatively set to 0.4 inches (1 cm) per hour that produced minimal runoff while maximizing infiltration. The UNSAT-H program partitions PET into potential evaporation (E_p) and potential transpiration (T_p). Potential evaporation is estimated or derived from daily weather parameters (Fayer 2000). Potential transpiration is calculated using a function (Equation 1) that is based on the value of the assigned leaf area index (LAI) and an equation developed by Ritchie and Burnett (1971) as follows:

$$T_p = PET\,[a + b(LAI)^c] \quad \text{where } d \le LAI \le e \qquad \textbf{Equation 1}$$

where:

a,b,c,d, and e are fitting parameters;

a = 0.0, b = 0.52, and c = 0.5, d = 0.1, and e = 2.7 (Fayer 2000)

The UNSAT-H program then partitioned the daily PET values into E_p and T_p. T_p was calculated using a function developed by Equation 1 above.

The lower boundary condition used was set as a unit gradient. This boundary condition was placed deep in the soil profile modeled; well beneath the fine grained tailings layer and any transient moisture activity to ensure it had no significant impact on the predicted outcome.

3.2.3 VEGETATION DATA

The input parameters representing vegetation include the LAI, rooting depth and density, root growth rate, the suction head values that corresponds to the soil's field capacity, wilting point, and water content above which plants do not transpire because of anaerobic conditions. The onset and termination of the growing season for the site are defined in terms of Julian days. A percent bare area is also defined in the UNSAT H model and is often based on visual observation of undisturbed areas near the evaporation ponds. The maximum rooting depth should be based on expected vegetation characteristics. The root length density (RLD) in UNSAT H is assumed to follow an exponential function such as that defined in Equation 2:

$$RLD = a \exp(-bz) + c \qquad \textbf{Equation 2}$$

where:

a,b, and c are fitting parameters

z = depth below surface

The parameters used for the RLD functions in Equation 2 were: a = 0.315, b=0.0073, and c = 0.076 (Fayer 2000). The time required for maximum rooting depth establishment was set at full depth beginning on day 1. The rooting depth was conservatively set at 2-feet (60 cm) based on field observations. This is very conservative given roots from native shrubs and grasses can easily reach depths much greater than this.

An average LAI of 1.8 was used (Dwyer 2003). The onset and termination of the growing season for the site were Julian days 75 and 299, respectively. The LAI was transitioned from 0 to 1.8 starting with Julian day 75 to 135. Day 135 through 250, the full LAI equal to 1.8 was utilized. The LAI was then transitioned down from 1.8 to 0 from Julian day 250 to 299. This was conservative since it is realistic that plants can transpire year round at this site. An average percent bare area of 75% was used in the UNSAT H model based on visual observation of native vegetation in the surrounding area. This is conservative given many areas have higher plant densities than the assumed 25% coverage and an effective ET Cover should produce vegetation as good as or better than the surrounding areas due to seeding operations and lack of a shallow caliche layer that limits the storage capacity. Furthermore, the assumed percent bare area of 75% essentially reduces the maximum LAI to 0.45 (25% of 1.8).

3.2.4 SOIL PROPERTIES RELATED TO VEGETATION

Suction head values corresponding to the wilting point, field capacity, and a head value corresponding to the water content above which plants do not transpire because of anaerobic conditions were defined. Matric potential or suction heads are generally written as positive numbers, but in reality are negative values. Consequently, the higher the value, the greater the soil suction. The maximum water content a soil can hold after all downward drainage resulting from gravitational forces is referred to as its field capacity. Field capacity is arbitrarily reported as the water content at about 10.8 ft (330-cm) of matric potential head (Jury et al. 1991). Below field capacity, the hydraulic conductivity is assumed to be so low that gravity drainage becomes negligible and the soil moisture is held in place by suction or matric potential.

Not all of the water stored in the soil can be removed via transpiration. Vegetation is generally assumed to reduce the soil moisture content to the permanent wilting point, which is typically defined as the water content at 656.2 ft (20,000 cm) of matric potential head for native grasses. This 656.2 ft (20,000 cm) value was conservatively used although some shrubs present in the area could remove water from the soil to a suction of 3280.8 ft (100,000 cm) (Hillel 1998). Evaporation from the soil surface can further reduce the soil moisture below the wilting point toward the residual saturation, which is the water content at an infinite matric potential. The head corresponding to the water content below which plant transpiration starts to decrease was defined as 32.2 ft (1000 cm) (Fayer 2000). The head value corresponding to the water content above which plants do not transpire because of anaerobic conditions was defined at 4-in (10 cm) based on the assumed moisture characteristic curves for the utilized soil hydraulic properties.

3.2.5 SOIL PROPERTIES

Soil hydraulic properties were based on grain size distributions of soil samples summarized in AMEC (2008) for alluvium material and "as-built" reports for tailings material. This data was then used to classify the soil according to the United States Department of Agriculture (USDA) soil classification system (Table 1 and Figure 2). Data from the RETC model was then utilized for the classified soils to determine their unsaturated and saturated hydraulic properties. The RETC Model was developed by the US Salinity Laboratory for quantifying the hydraulic functions of unsaturated soils

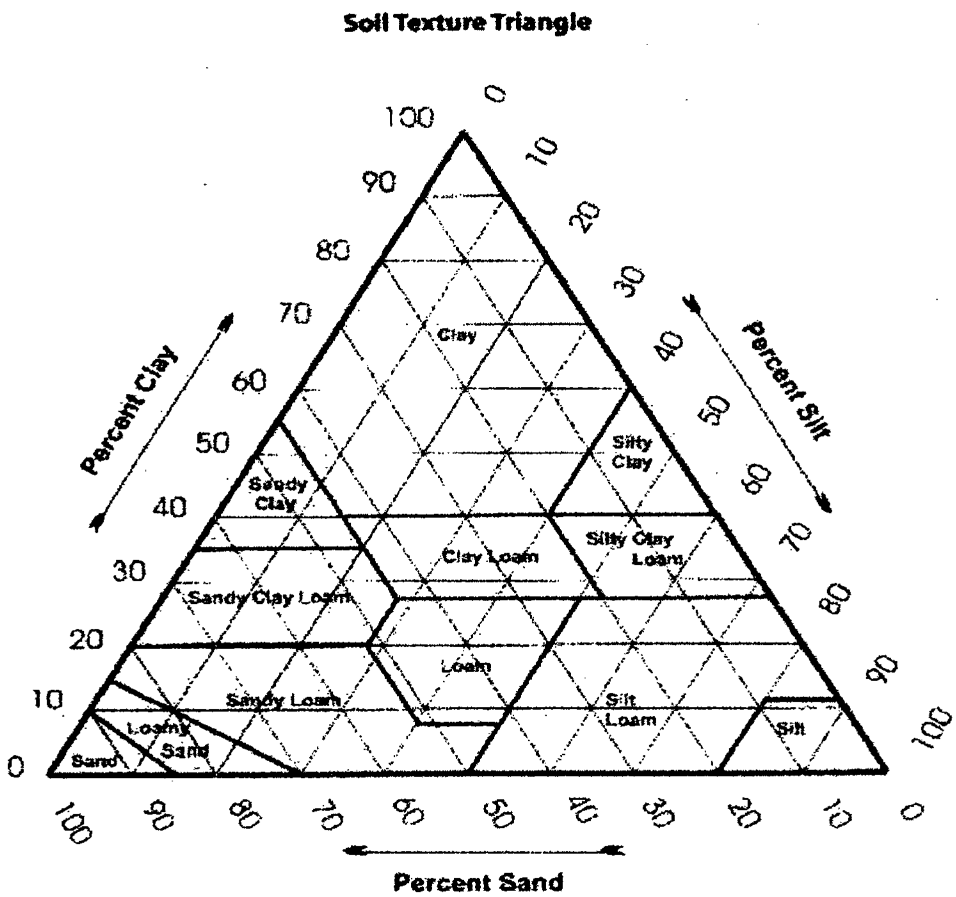

Figure 2. USDA Soil Classification

Sand: Soil particles between 0.05 and 2.0 mm in size

Silt: Soil particles between 0.002 mm and 0.05 mm

Clay: Soil particles smaller than 0.002 mm (2 microns) in size

The Mualem (van Genuchten et al 1991) conductivity function was used to describe the unsaturated hydraulic conductivity of the soils. The van Genuchten 'm' parameter for this function is assumed to be'1-1/n'; 'n' being one of the established van Genuchten parameters (van Genuchten et al 1991). The initial suction value for soil layers other than the fine grained tailings layer modeled were set at a value of 10,000 cm. The initial suction value for the fine grained soil was set at its field capacity or 330 cm. This value for the fine grained tailings layer was utilized because it is assumed that following the primary consolidation of this layer, the soil suction of this soil layer would be no less than this value. During primary consolidation a soil's excess pore water is squeezed out yielding a layer that is at least as dry as its moisture content related to field capacity or drier.

The following are the soil properties utilized in the modeling performed.

Table 1
SOIL HYDRAULIC PROPERTIES

Soil	Depth BGS[1]	K_{sat} (cm/hr)	Van Genuchten Parameters				Reference
			θ_s	θ_r	α (1/cm)	n	
Rock/Soil Surface Layer	0 to 6-in	3.64	0.43	0.06	0.1057	1.36	Dwyer 2003
Cover Soil	6-in to 2-ft	0.23	0.39	0.075	0.039	1.194	RETC Model for Clay Loam
Coarse Tailings	2-ft to 9-ft	4.42	0.44	0.065	0.075	1.89	RETC Model for Sandy Loam with modified θ_s per reported porosity
Fine Tailings	9-ft to 24-ft	0.2	0.47	0.068	0.008	1.09	RETC Model for Clay with modified θ_s per reported porosity
Alluvium	24-ft to 54-ft	0.23	0.39	0.075	0.039	1.194	RETC Model for Clay Loam

[1] BGS = below ground surface

3.3 MODELING RESULTS

The modified soil properties based on the primary and secondary settlement were modeled with the results summarized in figure 2. The water storage capacity of the various soil layers is bounded by the suction associated with field capacity (330 cm) and the wilting point (15,000 cm). Initial suction values at the end of the primary settlement are shown as are the final suction values at the completion of the 19 year period where secondary settlement was ongoing. The final suction values are those assumed to present if soils excavated during the Removal Action were placed directly on the tailings cells.

It can be seen from the final suction values in Figure 2 that the soils in the fine grained layer have dried significantly resulting in elevated suction values. Because the suction values are significantly higher than the soil's field capacity, this analysis indicates that additional surcharge loads from the placement of Interim Action soil on the tailings would not result in residual water being 'squeezed' out of this layer.

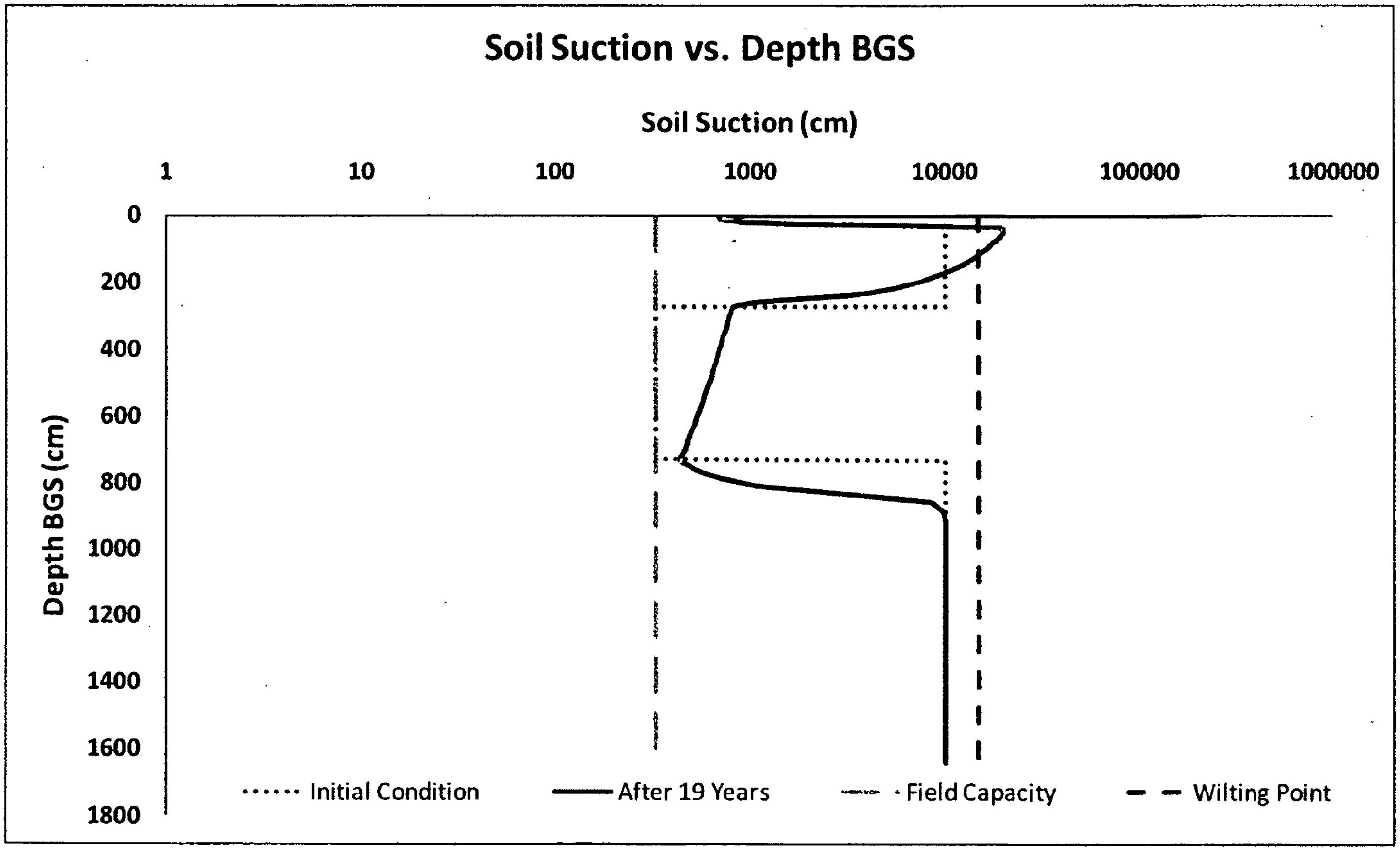

Figure 3
Model Results – Initial and Final Soil Suction Values

4.0 DISCUSSION

The tailings shown in Figure 1 were placed in two layers. The bottom layer was composed of fine grained tailings having a fines content (passing the number 200 sieve) greater than 50%. The top tailings layer was composed of coarse material having greater than 50% sand. These values were reported in the "as-built" reports for the various tailings cells. Excess pore water drains quickly in relatively coarse grained material and thus consolidation also happens quickly. However, in fine grained soils, the primary consolidation is much slower and thus the excess pore water is retained for a much longer period of time. In this case, it was estimated that primary consolidation for the fine grained tailings took several months. Secondary consolidation then took place for a period of 19 years to the date of this evaluation. The profile shown in Figure 1 was analyzed for its potential to allow water to be 'squeezed' from it as a result of the placement of soil excavated during the Removal Action directly on the existing tailings impoundments. Field measured properties were not available for the various soil layers. Consequently, values were conservatively estimated based on measured initial soil values and the approximate period of time the tailings have been in place. Primary consolidation in the fine grained tailings due to the loading as shown in figure 1 was calculated. Additionally, secondary consolidation was estimated based on a time period of 19 years having passed since placement of the tailings. It was estimated that the reduction in void ratio resulting from the primary and secondary consolidation to date is about 35.5%.

The placement of soils from the Removal Action on the tailings would result in a further decrease in the void ratio? as shown in Appendix A. Placement of the soil on the South Cell would further decrease the void ratio? by 19.1%, the Central Cell by 12.36%, the North cell by 14.61%; or if the soil were spread over all Cells, the void ratio would decrease by 7.87%. The further reduction in the fine grained soils layer would not result in water being squeezed out since the modeling showed that the layer has soil suction greater than its field capacity. Thus there is excess storage capacity in the fine grained soils layer that would allow for retaining of moisture under capillary forces (Figure 4).

Referring to Figure 4, the top figure shows a volume of soil at saturation where all the voids are filled with water. This state has excess pore water that can easily be squeezed out by applying a load to it and reducing the volume. This is because the volume of voids is largely comprised of water, with the exception of a small amount of trapped air. However, the middle picture shows that there is significant air in the void spaces with some water. Thus the volume of voids is comprised of air with some water held by capillary forces. Field capacity is an unsaturated state whereby water is retained by capillary forces. So the smaller amount of water in the void spaces is held in the soil at suction values greater than its field capacity. The modeling performed estimated that the present soil suction in the fine grained tailings layer is at a state somewhere between the middle picture in Figure 3 and the bottom picture where all of the voids are filled with air and the only moisture in the soil is referred to as residual water. Residual water cannot be practically removed from a soil, rather it is adsorbed to each respective soil particle at an infinite soil suction.

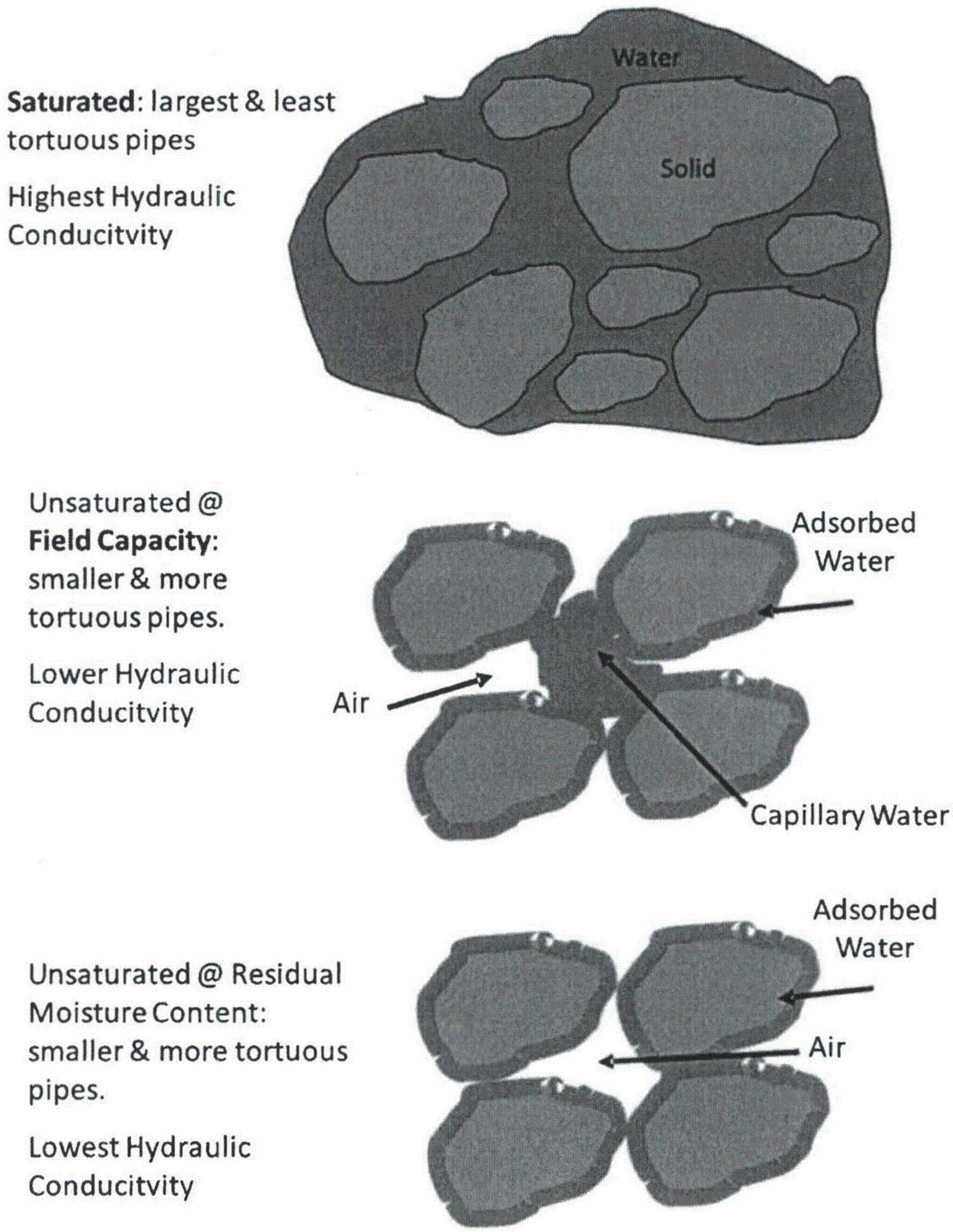

Figure 4
Moisture States of Soil

If the volume of soil and thus its void ratio were reduced further by the addition of soils on top of the tailings impoundment, it does not directly translate into water being squeezed out because the reduced volume of soil will still be capable of retaining all of the water due to capillary forces. This is because the estimated state of the fine grained tailings layer is drier than its field capacity. It can also be seen that the unsaturated condition of the total profile continues to move toward a steady state.

5.0 REFERENCES

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12. South Cell Final Reclamation, As-Built report. April 1996.

13. Central Cell Final Reclamation, As-Built Report. June 1995.

14. North Cell Final Reclamation, As-Built Report. November 1987.

15. Reclamation Plan License No. SUA-1475. June 1987.

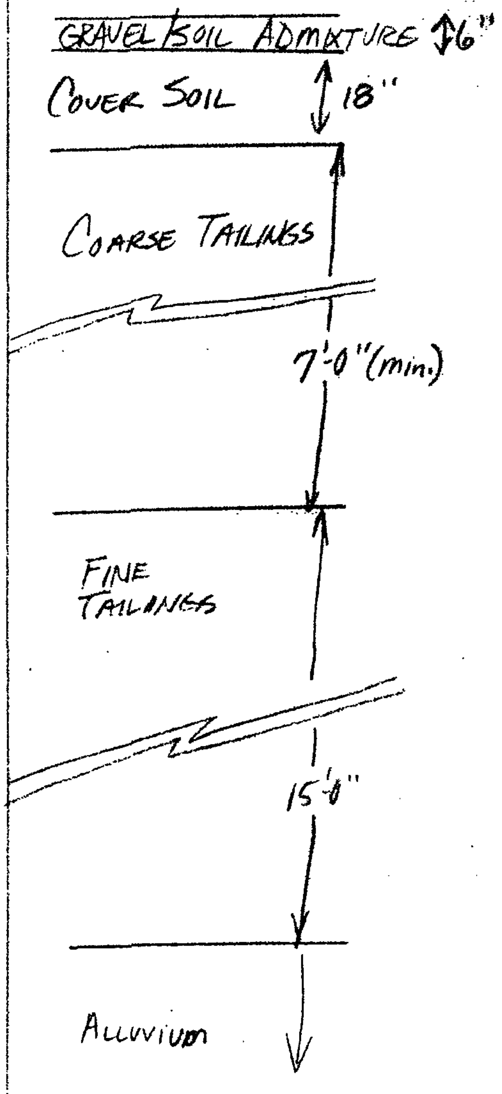
16. Rationale and field Investigation Work Plan to Evaluate Recharge and Potential Cell Sourcing to the Zone 3 Plume Church Rock Site, Gallup, NM. January 2004.

APPENDIX A

Profile Evaluated:

Initial Conditions for evaluation

Soil Properties ~ Construction



Cover Soil: γ_d = 110 PCF — Clay Loam

Coarse Tailings:
γ_d = 99 PCF
w = 10.1% (natural)
e = 0.79
n = 0.44
SG = 2.81
S = 36%
Sandy Loam — sand greater than 50%

Fine Tailings:
γ_d = 73 PCF
w = 39%
e = 1.38
n = 0.58
SG = 2.78
S = 80%
Clay

Alluvium: Clay Loam

References for above properties & following analysis:

(1) Evaporation Pond System, As-Built Report March 1989
(2) South Cell Final Reclamation, As-Built Report April 1996
(3) Central Cell Final Reclamation, As-Built Report June 1995
(4) North Cell Final Reclamation, As-Built Report November 1994
(5) Reclamation Plan, License No. SUA-1475 June 1987
(6) Rationale and Field Investigation Work Plan to Evaluate Recharge and Potential Cell Sourcing to the Zone 3 Plume Church Rock Site, Gallup, NM Jan 2004

Calculate Primary Settlement in Fine Tailings Layer:

$$S_c = C_c \left(\frac{H_0}{1+e_0}\right) \log\left[\frac{\sigma + \Delta\sigma}{\sigma}\right]$$

where: C_c = consolidation coefficient
H_0 = height of layer
e_0 = void ratio
σ = original stress
$\Delta\sigma$ = added stress

assume: $C_c = 1.15\,(e_0 - 0.35)$ [Civil Engr. Ref. Manual]

$C_c = 1.15(1.38 - 0.35) = 1.18$

$\sigma = 15'\,(73) = 1095\ PSF$

$\Delta\sigma = 7(99) + 2(110) = 913\ PSF$

$$S = 1.18\left(\frac{15}{1+1.38}\right)\log\left[\frac{1095+913}{1095}\right] \cong 1.96\ ft$$

@ this point ⇒ primary consolidation is complete and moisture content is assumed to be @ field capacity

Secondary Consolidation

$$S_c = C_a\, H \log\left(\frac{t_2}{t_1}\right)$$

assume: $C_a = 0.05\,C_c$ [Ref. Intro. to Geotech. Engr. Holtz & Kovacs]

$C_a = 0.05(1.18) = 0.06$

Primary consolidation reached in 15 weeks per Evap Pond study, conservatively assume 0.5 year.

assume 1990 for completion of primary consolidation

therefore up to today: $S_c = 0.06(15 - 2)\log\left(\frac{19}{0.5}\right)$

$S_c = 1.2\ ft$

∴ $S_{total} \cong$ <u>3.1 ft</u>

Find current void ratio:

$$S = H\left(\frac{\Delta e}{1+e_o}\right) = H\left(\frac{e_o - e_1}{1+e_o}\right)$$

$$3.1 = 15\left(\frac{1.38 - e_1}{1+1.38}\right) \Rightarrow \underline{e_1 = 0.89}$$

$$n = \frac{e}{1+e} = \frac{0.9}{1+0.9} = \underline{0.47}$$

Calculate additional loading on existing tailings, given 900,000 CY of soil from Interim Action is placed on surface (include new 3 ft soil cover).

Areas:

South Cell	~ 19.4 acres	=	845,067 SF
Central Cell	~ 40 acres	=	1,742,407 SF
North Cell	~ 28 acres	=	1,219,685 SF
Total	87.4 acres		3,807,159 SF

Volume = 900,000 CY = 24,300,000 CF, γ_d = 100 PCF (assumed)

$\Delta\sigma$ ~> South Cell ~ 28.8 ft + 3 = 31.8 ft ⇒ 3180 PSF

Central Cell ~ 13.9 ft + 3 = 16.9 ft ⇒ 1690 PSF

North Cell ~ 19.9 ft + 3 = 22.9 ft ⇒ 2290 PSF

Total Site ~ 6.4 ft + 3 = 9.4 ft ⇒ 940 PSF

Calculate Add'l Settlement due to Loading of Interim Action Soil

$$C_c = 1.15\,(0.89 - 0.35) = 0.62$$

$$S_{south\ cell} = 0.62\left(\frac{15-3.1}{1+0.89}\right)\log\left[\frac{(913+1095)+3180}{913+1095}\right] = 1.05\ ft$$

$S_{central\ cell}$ ⇒ 0.68 ft

$S_{north\ cell}$ ⇒ 0.84 ft

S_{total} ⇒ 0.43 ft

Calculate new void ratio in fine grained tailings.

$$e_{south\ cell} = 0.89 - \left[\left(\frac{1.05}{15-3.4}\right)(1+0.89)\right] = 0.72$$

$$n_{south\ cell} = \frac{0.72}{1+0.72} = 0.42$$

$$e_{central\ cell} = 0.78 \quad , \quad n = 0.44$$

$$e_{north\ cell} = 0.76 \quad , \quad n = 0.43$$

$$e_{total} = 0.82 \quad , \quad n = 0.45$$