Dwyer Engineering, LLC

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Cynthia Wetmore
Technical Support, Superfund
U.S. EPA, Mail Code SFD-8-2
75 Hawthorne St.
San Francisco, CA 94105

Dear Ms. Wetmore:

This letter presents the proposed approach to analyze the potential that consolidation of the existing Church Rock Mill tailings impoundment due to construction of the NECR mine waste repository on top of the impoundment may induce seepage from the tailings. It evaluates both the repository surcharges associated with conceptual design layouts, as well as the maximum allowable repository surcharge that does not induce seepage from the tailings. Evaluating the maximum allowable surcharge will allow us to consider alternative repository layouts during the design process.

Previous analyses performed by Dwyer Engineering (Dwyer Engineering, 2011, 2013) indicated that construction of the repository on the existing tailings impoundment would not induce seepage from the tailings. Because only limited site data were available, these analyses relied on multiple assumptions. In response to Agency comments, MWH conducted an extensive field testing and drilling program to obtain further information on the geotechnical properties of the impoundment materials. Drilling and sampling were conducted in late 2013, with laboratory testing completed in the first half of 2014. These new data will be used as a basis for performing the updated analysis.

This memorandum presents the following:

(1) a summary of laboratory test results for tailings impoundment samples, and

(2) a description of the proposed consolidation analyses, including impoundment profiles and input parameters to be used in the analyses.

Following agency input on the approach proposed herein, an updated consolidation analysis will be completed and a report will be provided including a detailed description of the analyses performed, results of the analyses, potential implications for repository design, and information required to address pertinent agency comments provided on the previous Dwyer Engineering (2011, 2013) reports.

Field Program Results

MWH completed 32 cone penetration test (CPT) soundings and 8 geotechnical borings (paired with CPT holes) within the existing tailings impoundment, focusing on the areas

underlying the proposed repository alternatives. The field investigation was conducted to further evaluate the thickness, geotechnical, and hydraulic properties of cover soil, fill material, and coarse and fine tailings. The geotechnical and hydraulic properties of the underlying natural materials were also evaluated. MWH measured in-situ properties and collected samples of cover soil, fill soil, tailings, alluvium, sandstone, and shale at multiple locations within the existing impoundment. The data and material properties are discussed below. The CPT and drilling locations are shown on Figure 1. The investigation produced significant amounts of data on the geometry, thickness, and extent of the tailings layers, as well as actual geotechnical properties, which were not available for the previous analyses performed by Dwyer Engineering. MWH is in the process of developing a report summarizing the results of the investigation, which will be submitted to the agencies with the Pre-Design Studies (PDS) Report.

Proposed Modeling Approach

Utilizing the data obtained through the field investigation and the conceptual repository layouts, additional evaluations will be performed to assess the potential for induced seepage from the existing tailings resulting from the proposed placement of mine spoils on the impoundment. These evaluations will use thicknesses of tailings measured during the field program and material properties measured in the laboratory, to provide more robust results than could be obtained prior to the pre-design field studies. The proposed evaluations will be performed for multiple locations within the footprints of the proposed repository alternatives. To be most conservative, each location will use the maximum mine spoil thickness as previously proposed in the three conceptual repository alternatives. In addition, the maximum allowable spoils thickness (surcharge) that does not induce seepage from the tailings will be evaluated. Input parameters will be values obtained from the field investigation and subsequent laboratory testing for each respective profile evaluated.

The previous evaluations performed (Dwyer, 2011, 2013) to estimate consolidation due to placement of mine spoils on the existing impoundment and the associated potential to induce seepage from the tailings required a number of assumptions and were time-dependent. That is, the current moisture status of the subsurface soils was not known and modeling was required to estimate the current moisture status of the tailings based on historical records and estimated moisture contents at the time the tailings were deposited. Because unsaturated flow for the 21 years from time of placement to the current date was estimated from the modeling, and because the individual soil storage capacity along with upper boundary (climate and vegetation) and lower boundary (underlying materials) conditions were all sensitive parameters, the final results were compared to field capacity for the fine tailings after consolation.

Conversely, the additional evaluation described below does not require unsaturated flow modeling, instead utilizing the actual data acquired during the 2013 field investigation. Consequently, time is not an assumed variable in the proposed modeling approach described herein. The approach described below will enable evaluation of the various soil profiles for the degree of saturation before and after consolidation due to the placement of mine spoils on the existing impoundment. If the tailings are found to be unsaturated after consolidation due to mine spoil placement, water will not be forced from the tailings as a result of consolidation. That is, if the material is found to be unsaturated (less than 100% saturation) the material volume has available pore space (voids filled with air) which can be

filled by water as the profile consolidates, up to the point where the material reaches full saturation. Beyond full saturation, additional consolidation stress would tend to induce seepage from the tailings. Laboratory test results will be used to more accurately calculate the changes to the degree of saturation for the tailings layers resulting from consolidation, and consider whether refined design parameters can be developed to maintain less than 100% saturation after construction of the repository.

The analysis will consist of the following steps:

1. Calculate the repository surcharge using the measured unit weight of the mine soils and cover materials as well as the proposed maximum thickness of the repository at the profile location.

2. Use the laboratory data to calculate current saturation values of the existing tailings.

$$e_0 = \left(\frac{SG * \rho_w}{\rho_b}\right) - 1$$

Where: $e_0 = initial\ soil\ void\ ratio$
$SG = soil\ specific\ gravity$
$\rho_w = density\ of\ water$
$\rho_b = bulk\ density\ of\ soil$

$$S_0 = \frac{w * SG}{e_0}$$

Where: $S_0 = soil\ initial\ degree\ of\ saturation$
$w = soil\ water\ content\ by\ mass$

3. Calculate consolidation of the tailings using the results of the consolidation tests performed on the impoundment materials and the surcharge load calculated in Step 1.

$$s = \frac{C_c}{1 + e_0} * t_0 * log\left[\frac{\sigma + \Delta\sigma}{\sigma}\right]$$

Where: $C_c = consolidation\ index$
$t_0 = inital\ soil\ layer\ thickness$
$\sigma = inital\ stress\ from\ overlying\ materials$
$\Delta\sigma$
$= change\ in\ stress\ due\ to\ placement\ of\ mine\ spoils\ and\ cover$
$t_f = t_0 - s$
$s = settlement\ due\ to\ surcharge$

$$e_f = e_0 - \left[s - \frac{1 + e_0}{t_0}\right]$$

Where: $e_f = final\ void\ ratio\ after\ consolidation$

4. Calculate the changes to the degree of saturation resulting from the surcharge loads.

$$S_f = \frac{w * SG}{e_f}$$

Where: $S_f = final\ degree\ of\ saturation\ for\ individual\ layers$

5. Calculate the consolidation and degree of saturation for multiple layers within profiles being evaluated. This is done due to the heterogeneities of the materials identified during the field investigation. The multiple layers of the fine tailings will then be combined by weighting the computed degree of saturation for each individual layer by the thickness of that respective layer to determine an overall degree of saturation for the fine tailings for the entire profile. This final degree of saturation will determine whether each individual profile has the potential to yield water due to placement of mine spoils on the existing impoundment (i.e. final degree of saturation above 100%).

$$S_{total} = \frac{\sum(S_{fi} * t_{fi})}{\sum t_{fi}}$$

Where:

$S_{total} = composite\ degree\ of\ saturation\ for\ fine\ tailings\ in\ profile$

$S_{fi} = final\ degree\ of\ saturation\ for\ each\ soil\ layer$

$t_{fi} = final\ thickness\ of\ each\ soil\ layer\ after\ consolidation$

6. Lastly, determine, for each individual profile, the maximum allowable repository thickness at which the degree of saturation will be less than 100% (the maximum thickness at which seepage would not occur). This information will facilitate consideration and development of design layouts and thicknesses that will not induce seepage.

Proposed Profiles and Material Properties

MWH and Dwyer Engineering developed profiles to model the tailings' response to repository construction. Profiles within the tailings impoundment were selected to represent typical areas as well as areas with the thickest tailings profile within the footprints of the proposed repository alternatives. The profiles to be evaluated include those associated with Borrow Pit 1 (Boreholes B8 and B11 and CPT18 which had the thickest tailings measurements); Borrow Pit 2 (Borehole B11); the North Cell (Boreholes B2, B23 and CPT 4); and the Central Cell (Borehole B15). Additionally, the modeling profiles and geotechnical properties proposed for use in the analyses were developed considering the following information:

- Critical areas where thick layers of fine tailings exist in conjunction with significant proposed repository fill thicknesses.

- The thickness of the individual layers in each area based on the tabulated values from the respective CPT and/or borings, which are representative of conditions in each area.

- Water content and density values based on laboratory test results from a representative group of samples from each unit within each area (Borrow Pit 1, Borrow Pit 2, Central Cell, or North Cell).

- Consolidation test results for coarse and fine-grained tailings in each respective area.

- Measured heterogeneities in geotechnical properties across the vertical extent of the layer in the given location (laboratory data is included on Table 2).

- Alluvium was encountered directly underlying the tailings in all borings and CPTs conducted for the PDS.

Borrow Pit 1 appears to be the most critical profile to be analyzed based on the thickness of tailings and potential thickness of mine spoils to be placed over that area. The profiles that will be analyzed, given the approach and considerations listed above, are presented in Table 1. The field and laboratory data obtained from the impoundment investigation (Table 2) provides an appropriate data set for development of material properties representative of each material type in each profile.

Table 1 –Profiles for Consolidation Calculations

Layer Thickness		Profile to be Evaluated and Source of Input Data (field investigation and identified location)							
		Borrow Pit 1			Borrow Pit 2	North Cell			Central Cell
		B10	B8	CPT 18	B11	B2	B23	CPT 4	B15
New Material	**Mine Spoils + Cover**[1]	25-ft	22-ft	24-ft	24-ft	15-ft	18-ft	11-ft	8-ft
Existing Material	**Fill + Cover**	7-ft	7-ft	12-ft	42.5-ft	12-ft	13-ft	15-ft	6-ft
	Coarse-grained tailings	12-ft	19-ft	0	0	0	0	0	24ft
	Fine-grained tailings	25-ft	18-ft	28-ft	11.5-ft	2.5-ft	3-ft	4.5-ft	0-ft

1. As noted in step 6 above, each profile will be analyzed to determine the maximum allowable repository thickness at which the degree of saturation will be less than 100% (and hence seepage would not occur). The depth of mine spoils and cover to be placed was rounded up to the nearest foot.

Geochemical Properties of the Tailings

The milling processes used at the Church Rock Mill introduced a significant amount of sulfate into the tailings. Gypsum was noted as the primary by-product of the milling process in the 1981 Mill License Renewal Application (D'Appolonia, 1981). The concentration of gypsum in the tailings varies with grain size, with the greatest amount of gypsum present in the fine-grained tailings. The paragraphs below describe the processes that lead to gypsum formation and the influence of that gypsum on the geotechnical properties of the tailings.

Calcium-bearing minerals naturally occur in the sedimentary rock and ore body at the site. The ore milling process dissolved many of the calcium-bearing minerals, resulting in free calcium ions available in the mill circuit. Sulfate was added during the milling process in the form of sulfuric acid (H_2SO_4) to aid in the dissolution of uranium. Gypsum ($CaSO_4 \bullet 2H_2O$)

may precipitate in systems when excess Ca^{2+} and SO_4^{2-} are present in aqueous solutions. As a result of the milling processes, free calcium and sulfate ions in the tailings solution precipitated in the form of gypsum after the tailings and solution were deposited in the impoundment.

The presence of gypsum is known to affect certain geotechnical laboratory test results, specifically particle-size distribution and water content. Per ASTM 2216-10, soil water content is determined by heating a sample of soil to 110°C and measuring the mass of water removed by evaporation. When a sample containing gypsum is heated to 110°C, the gypsum loses its molecular water and becomes bassenite ($CaSO_4 \bullet 0.5H_20$) and anhydrite ($CaSO_4$). Since molecular water accounts for about 20% of the mass in gypsum, this loss of molecular water manifests itself as elevated soil water content when samples containing gypsum are dried at 110°C. For this reason, ASTM 2216-10 (ASTM, 2010) suggests heating soil samples containing gypsum at a lower oven temperature of 60°C to determine the soil water content. The use of this lower oven temperature allows the soil (pore) moisture to evaporate without removing the molecular water from the system.

Geotechnical Laboratory Test Results

MWH realized the potential for the presence of gypsum in the tailings samples after the start of the geotechnical laboratory testing program. Due to the timing, a significant portion of the laboratory testing had already been completed. However, to properly account for the presence of gypsum in the tailings samples, the laboratory testing program was revised to obtain the water content for remaining specimens using both drying temperatures. The remaining specimens, which included 15 tailings samples, were initially dried at 60°C and weighed to calculate water content. The oven temperature was then increased to 110°C, and the same specimens were weighed a second time to calculate the water content corresponding to the 110°C oven temperature. This information provided a comparison set of data for the water contents measured at the two oven temperatures. The relationship between the water contents measured at 60°C and those measured at 110°C was then used to develop a correlation between the two values and to adjust the initial test results in samples that were heated to 110°C only. Water contents measured at 60°C, were generally about 0.5% to 3.0% lower than water contents measured at 110°C. The results of geotechnical laboratory testing on tailings impoundment samples are included in Table 2. Table 2 presents a series of water contents measured for both oven temperatures as well as water content, specific gravity, and dry density results adjusted to reflect a 60°C water content.

The hydrometer test results, specifically for specimens containing fine-grained tailings, have also likely been affected by gypsum. Gypsum influences results of particle-size analysis in two ways: gypsum is a flocculant for clay minerals and gypsum has a lower density than soil, both of which can skew the fine-grained particle distributions during measurement using the hydrometer method (Arnett, 2009). The particle-size distribution tests were conducted using the standard amount of sodium hexametaphosphate as a deflocculant. Because additional deflocculant was not added to account for the presence of gypsum, the hydrometer results presented in Table 2 may not be representative of the actual particle sizes. The presence of gypsum in the test solution would reduce the effectiveness of the deflocculant resulting in a higher measured percentage of larger (silt-size) particles.

Historic research (McCormack, 1926) quantified the effects of overburden pressure on the dehydration of gypsum, and concluded that pressure alone does not result in dehydration of gypsum, because the water in gypsum is bound molecularly. Pressure can accelerate the dehydration process of gypsum, but only when the system has already reached the temperature required for dehydration (greater than 100°C). Therefore the molecular water in the tailings in the form of gypsum cannot be squeezed from the tailings due to construction of the proposed repository. Although higher water contents were measured in the tailings samples using an oven temperature of 110°C, only the soil water measured at an oven temperature of 60°C are applicable for use in the consolidation analyses. As a result, the material properties used for the consolidation calculations will be based on the 110°C water contents, with the exception of the fine-grained tailings, where the 60°C water contents and specific gravity values will be used as they are more appropriate for use, given the presence of gypsum.

Next Steps

Following receipt of agency input on the approach presented in this memo, the profiles and geotechnical information presented herein will be used to evaluate consolidation and the potential for induced seepage due to construction of the proposed repository, and to consider development of design parameters to maintain a degree of saturation less 100%. Results of the evaluation will be provided as an addendum to the PDS Report. In addition to the results of the consolidation analyses, the PDS report will include results of the PDS investigations at the Northeast Church Rock Mine Site and Church Rock Mill Site.

Attachments:

Figure 1 Tailings Impoundment Thickness, Field Sampling Locations and Repository Layouts

Table 2 Church Rock Mill Site Impoundment - Summary of Geotechnical Laboratory Data

References:

D'Appolonia. 1981. *State of New Mexico Environmental Improvement Division, Uranium Mill License renewal Application-Environmental Report License No. NM-UNC-ML, UNC Mining and Milling Church Rock Operations Division of United Nuclear Corporation. Vol.1, Text and Tables.* December.

Dwyer, Stephen F. 2013. Addendum: *Evaluation of Consolidation and Water Storage Capacity Related to the Placement of Mine Material on the Existing UNC Mill Site Tailings Impoundment Report.* May 1.

Dwyer, Stephen F. 2011. Addendum: *Evaluation of Consolidation and Water Storage Capacity Related to the Placement of Mine Material on the Existing UNC Mill Site Tailings Impoundment Report.* May.

Arnet, M.P., 2009. *Particle Size Distribution of Gypseous Samples*. Texas A&M University. May.

ASTM Standard D2216. 2010. *Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass*. ASTM International, West Conshokocken, PA, 2010, DOI: 10.1520/D2216-10, www.astm.org.

McCormack, J.T., 1926. *Experiments on the Dehydration of Gypsum*. The Journal of Geology, Vol. 34, No. 5 (Jul. – Aug., 1926), pp. 429-433.

Sincerely,

Stephen F. Dwyer
Dwyer Engineering LLC

cc:
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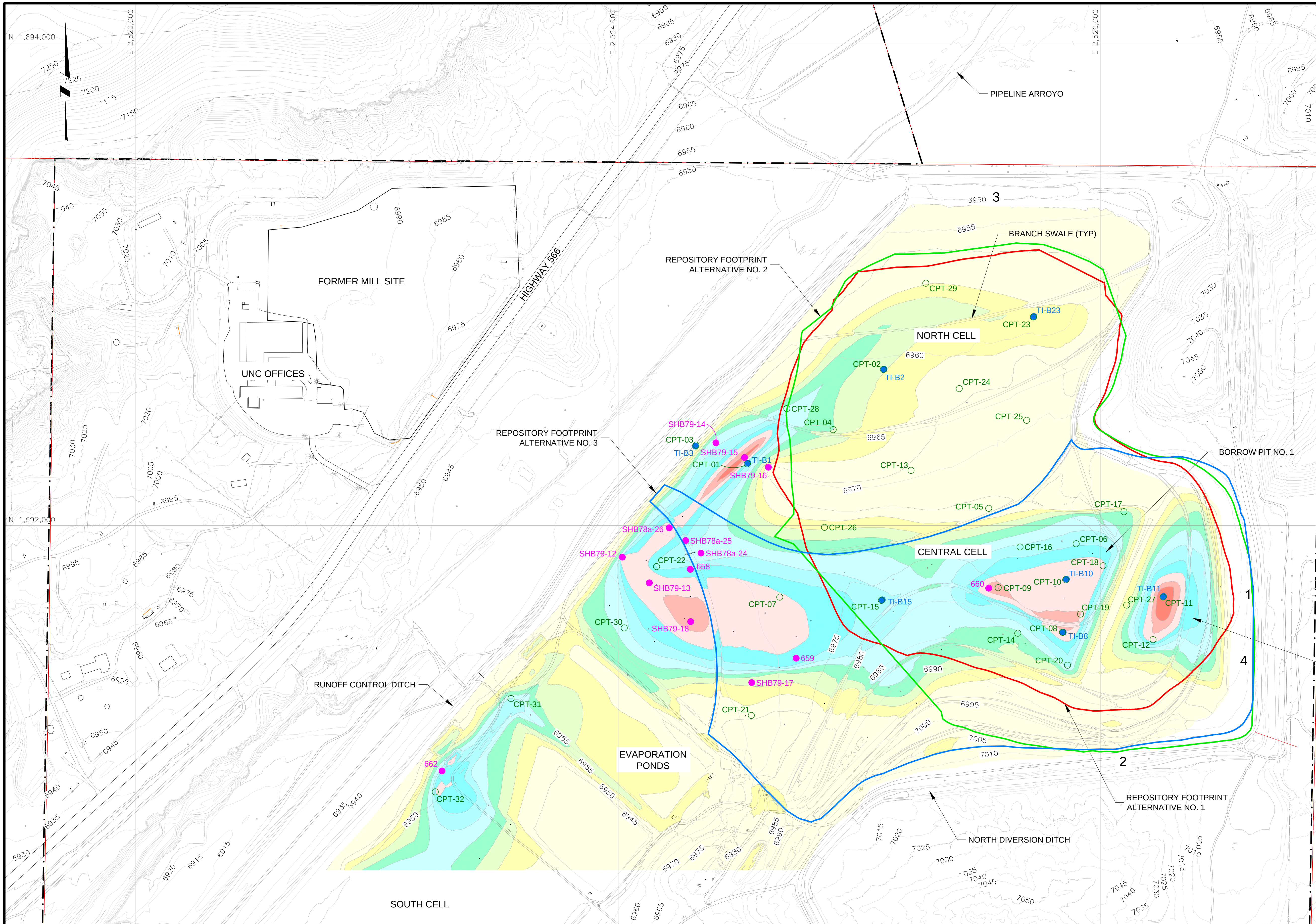
Janet Brooks, EPA Region 6
Yolande Norman, NRC
Deborah Steckley, DOE Office of Legacy Management
Randy McAlister, GE
Lance Hauer, GE
Jason Cumbers, MWH



LEGEND:

5605	EXISTING GROUND SURFACE ELEVATION, FEET
	EXISTING ROAD
	EXISTING DRAINAGE
	FENCE
	SECTION LINE
	MILLSITE PROPERTY BOUNDARY
SHBXX–XX	HISTORIC GEOTECHNICAL BORINGS WITH TAILINGS INFORMATION BY SERGENT, HAUSKINS AND BECKWITH (1978–1979)
6XX	HISTORIC BORINGS WITH TAILINGS INFORMATION UNC (1986)
TI–BXX	AUGER BOREHOLE SAMPLING LOCATION (MWH, 2013)
CPT–XX	CPT LOCATION (MWH, 2013)
	PHYSICAL STRUCTURE

IMPOUNDMENT THICKNESS (EXISTING GROUND SUFACE TO BOTTOM OF TAILINGS)

0'	–	10'	
10'	–	15'	
15'	–	20'	
20'	–	25'	
25'	–	30'	
30'	–	35'	
35'	–	40'	
40'	–	45'	
45'	–	50'	
50'	–	55'	

L:\Design-Drafting\Clients-Q-Z\UNC\10503682 CHURCH ROCK\013-Sheet Set\2014-06-13 CONSOLIDATION MEMO\10503682 PDS04

ISSUE/REV	DESCRIPTION	TECH	ENG	DATE
0	CONSOLIDATION ANALYSIS APPROACH	DM	JC	06–13

DISCLAIMER:
THIS DRAWING WAS DEVELOPED THROUGH THE APPLICATION OF PROFESSIONAL ENGINEERING SKILL AND PROPRIETARY METHODOLOGIES, PROCESSES AND KNOW HOW OF MWH AS AUTHOR ALL PURSUANT TO THE TERMS OF A CONTRACTUAL SCOPE OF WORK GOVERNING ITS PREPARATION. THIS DRAWING MAY NOT BE USED OR MODIFIED OTHER THAN IN STRICT ACCORDANCE WITH THE TERMS OF THE GOVERNING CONTRACT AND SCOPE OF WORK OR OTHERWISE ABSENT THE INVOLVEMENT AND CONSENT OF THE AUTHOR. ANY ALTERATION OR ADAPTATION OF THIS DRAWING SHALL BE CONSISTENT WITH THE AUTHOR'S CONTRACTUAL AND PROPRIETARY RIGHTS AND BE AT USER'S SOLE RISK AND WITHOUT ANY LIABILITY OR LEGAL RESPONSIBILITY OF MWH.

DRAWING REFERENCE(S):
- EXISTING SURFACE TOPOGRAPHY GENERATED FROM AERIAL PHOTOGRAPHS DATED NOV 2013 BY COOPER AERIAL SURVEYS CO.
- THE GROUND SURFACE ELEVATIONS SHOWN ON THE BORING LOGS IN THE SHB (1978 AND 1979) REPORTS WERE ADJUSTED BY MINUS 5 FEET VERTICAL, BASED ON A COMPARISON BETWEEN THE 2013 TOPOGRAPHY AND THE TOPOGRAPHY SHOWN IN THE OCTOBER 1978 REPORT PREPARED BY SHB.
- BORROW PIT CONFIGURATIONS BASED ON TOPOGRAPHY INCLUDED WITH UNC (1993) AND OPERATIONAL AERIAL PHOTOS.

PROJECTION: STATE PLANE COORDINATES
ZONE: NEW MEXICO WEST
DATUM: NAD 83
UNITS: NAD 83

DESIGNED BY	J CUMBERS	05–14
DRAWN BY	D MIRANDA	05–14
CHECKED BY	C STRACHAN	05–14
APPROVED BY	E DORNFEST	05–14
PROJECT MANAGER	T LEESON	05–14
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

PROJECT LOCATION: CHURCH ROCK MILL SITE

PROJECT: CONSOLIDATION ANALYSIS APPROACH

TITLE: TAILINGS IMPOUNDMENT THICKNESS (COVER AND TAILINGS) ISOPACH MAP

MWH

FIGURE 1

FILE NAME: 10503682 PDS04

Table 2. Summary of Geotechnical Laboratory Test Results - Mill Site Impoundment

Area	Boring	Sample Type (9)	Sample Depth Interval (ft.)		Material Description (1)	USCS (1)	Water content (by mass) 110C	Water content (by mass) 60C	SWCC - Saturated water content (by mass) (Note 2)	SWCC - Specimen dry density (pcf) (Note 2)	Dry density (pcf), 110C	Dry density (pcf), 60C	Specific gravity, 110C	Specific gravity, 60C	Atterberg limits (%)			USCS % gravel (size)	USCS % sand (size)	% Passing No. 200 sieve	% Silt (size)	USDA % clay (size <0.002 mm)	Flexible wall permeability (cm/sec) (3)	Permeability confining stress (psi)	Consolidation (Cc) (7)	Collapse potential (%) (inundation load (psf))	Triaxial (12) (peak friction angle (ϕ) (degrees), cohesion (psf), where applicable)
															LL	PL	PI										
CENTRAL CELL	TI-B1	CA	16	16.5	Lean Clay with Sand (Fill)	CL	16.2				104.7				33	13	20	0.3	27.2	72.5	42.9	29.6					
	TI-B1	CA	20.5	21	Coarse Tailings		6.1	5.7																			
	TI-B1	CA	21	21.5	Coarse Tailings		7.5		21.9 / 19.8	96.5 / 99.6	105.5							0.0	90.7	9.3	5.5	3.8	3.7E-04	18	0.024		
	TI-B1	ST	27	27.5	Coarse Tailings	SP	4.0				97.6		2.67		NP	-	-	0.0	92.7	7.3	5.2	2.1	2.9E-03	14			34.9
	TI-B1	CA	30	30.5	Coarse Tailings		13.9	13.5																			
	TI-B1	CA	30.5	31	Coarse Tailings		14.6		29.6 / 33.8	84.2 / 83.6	91.6												3.0E-07	25	0.092		
	TI-B1	CA (top)	31	31.5	Coarse Tailings		0.8	0.4																			
	TI-B1	CA (bottom)	31	31.5	Fine Tailings	CL	-	41.6				76.5	2.68	*2.69*	44	17	27	0.0	30.9	69.1	54.6	14.5					33.3
	TI-B1	CC-AC	32	33	Coarse/Fine Tailings	CL	29.3	*27.8*							33	16	17	0.0	46.7	53.3	37.4	15.9					
	TI-B1	CA	36	36.5	Clayey Sand		21.0	19.9	36.3 / 33.2	85.2 / 88.0	97.3		2.73					0.0	62.5	37.5	32.8	4.7	1.7E-06	32	0.059		
	TI-B1	CA	41	41.5	Lean Clay with Sand	CL	26.7				98.6				31	15	16	0.0	18.2	81.8	54.7	27.1	1.2E-07	35			
	TI-B1	ST	45	46	Clayey Sand		22	21.2			106.0														0.058		34.4
	TI-B10	ST (top)	10	11	Coarse Tailings		9.7	9.1			110	110.5	2.63	2.65													
	TI-B10	ST (bottom)	10	11	Coarse Tailings		9.0		20.7 / 21.5	102.6 / 101.2	96.8							0.2	71.9	27.9	16.6	11.3	4.3E-04	34	0.094		
	TI-B10	CC-AC (Note 4) (top)	12.5	14	Coarse Tailings		6.7	6.3					2.61	2.64													
	TI-B10	CC-AC (Note 4) (bot)	12.5	14	Coarse Tailings		7.5		31.3 / 31.4	85.0 / 85.0	99.1							0.7	71.5	27.8	18.9	8.9	6.7E-05	36			
	TI-B10	CA	15	15.5	Coarse Tailings		9.3				103.0																
	TI-B10	CA	16	16.5	Coarse Tailings	SM	6.5				100.0		2.65		NP	-	-	2.4	82.3	15.3	10.2	5.1					
	TI-B10	ST	21.5	22.5	Coarse/Fine Tailings	CL	28.1	*26.7*			91.9	*92.9*			43	19	24	0.0	43.0	57.0	51.4	5.6			0.111		
	TI-B10	CA	25.75	26	Fine Tailings		43.7	41.0																			
	TI-B10	CA	26	26.5	Fine Tailings	CH	60.4	*57.4*			63.1	*64.3*	2.71	*2.80*	74	27	47	0.0	10.0	90.0	82.6	7.4					
	TI-B10	ST	30.3	30.7	Fine Tailings	CH	47.7	*45.3*			72.2	*73.4*	2.71	*2.78*	57	22	35	0.0	24.3	75.7	68.4	7.3					
	TI-B10	ST	32	32.5	Coarse Tailings	SM	15.4				100.1		2.67		NP	-	-	0.0	83.1	16.9	12.6	4.3					
	TI-B10	CA	35	35.5	Fine Tailings		50.2	*47.7*			71.3	*72.5*															
	TI-B10	CA	35.5	36	Fine Tailings		54.2	51.4																			
	TI-B10	CA	36	36.5	Coarse/Fine Tailings	SC/CL	33.9	*32.2*			86.7	*87.8*	2.68	*2.72*	36	16	20	0.0	50.6	49.4	31.1	18.3					
	TI-B10	ST (top)	40	41	Fine Tailings		47.3	45.7			70.5	73.7	2.54	2.56													
	TI-B10	ST (bottom)	40	41	Fine Tailings	CH	49.7	*47.2*	47.7 / 55.7	75.3 / 67.9	73.3	*74.5*			61	21	40	0.0	20.7	79.3	46.5	32.9	2.9E-08	58	0.315		
	TI-B10	CA	46	46.5	Silty Sand		9.9				95.4		2.74					0.0	65.8	34.2	23.4	10.8					
	TI-B10	ST	55	56	Silty Sand		14.1		25.7 / 24.8	98.0 / 99.9	100.8												2.4E-05	72	0.139		
	TI-B10	CA	66	66.5	Silty Sand / Sandy Silt	SC/ML	13.8				94.5				NP	-	-	0.0	50.1	49.9	33.4	16.5					
	TI-B10	CA	71	71.5	Silty Sand		18.1				100.8																
	TI-B10	CA	91	91.5	Clayey Sand		18.6				105.6		2.66														
	TI-B10	CC	106.9	107.3	Sandstone		14.2				109.1												1.4E-07	115			
	TI-B11	CA	6	6.5	Silty Clay (Fill)		8.6				93.5																
	TI-B11	ST	15	16	Clayey Sand (Fill)		8.2		16.0 / 16.3	117.7 / 116.6	110.4		2.67					3.9	57.6	38.5	24.6	13.9	2.5E-05	38	0.085		
	TI-B11	CA	21	21.5	Sandy Clay (Fill)		12.3				107.6																
	TI-B11	ST	30.5	31.5	Sandy Clay (Fill)	CL	13.7				112.4				30	13	17	7.1	41.3	51.6	33.9	17.7	9.0E-07	51	0.059		
	TI-B11	CA	45.5	46	Fine Tailings		117.2	88.7																			
	TI-B11	ST	51.5	52.5	Fine Tailings	CH	63.0	*59.9*			62.5	*63.7*	2.75	*2.84*	91	30	61	0.0	2.7	97.3	90	7.3	3.1E-08	67	0.482		
	TI-B11	ST	56	57	Silty Sand	SM	16.2		31.0 / 30.8	90.6 / 92.8	77.9		2.64		NP	-	-	0.0	60.4	39.6	31.9	7.7	5.6E-04	72	0.129		
	TI-B11	CA	61	61.5	Sandy Clay		16.0				95.4							0.0	38.7	61.3	44.1	17.2					
	TI-B11	CA	66	66.5	Silty Sand		14.2				96.2																
	TI-B11	CA	81	81.5	Clayey Sand with Gravel		11.0				107.6		2.76					12.9	65.6	21.5	9.9	11.6					
	TI-B11	CA	100	100.2	Sandstone		21.1				103.9												1.3E-05	112			
	TI-B8	CA (Note 5)	25	25.5	Coarse Tailings		9.0	8.4			103.7	104.2	2.72	2.72													
	TI-B8	CA (Note 5)	25.5	26	Coarse Tailings		6.2		25.7	94.6	99.6							0.0	87.9	12.7	7.9	4.8	3.6E-04	46			
	TI-B8	CA (Note 5)	26	26.5	Coarse Tailings	SM	16.8		27.0	94.8	91.7				NP	-	-	0.0	76.0	24.0	19.0	5.0					
	TI-B8	ST	30	31	Fine Tailings	CH	65.1	*61.8*			61.5	*62.7*			74	25	49	0.0	9.2	90.8	81.2	9.6			0.426		
	TI-B8	ST	31	31.5	Fine Tailings		44.3	41.4																			
	TI-B8	ST (top)	35	36	Coarse Tailings		14.3	13.6			90.9	91.4	2.66	2.67													
	TI-B8	ST (bottom)	35	36	Coarse Tailings		16.5		31.2 / 39.3	89.3 / 82.3	89.6		2.67										1.6E-05	43			
	TI-B8	ST (top)	41	42	Fine Tailings		41.8	*39.7*			79.2	*80.4*	2.60	2.63													
	TI-B8	ST (bottom)	41	42	Coarse/Fine Tailings	SC/CL	35.6	34.3	33.1 / 31.6	88.7 / 90.7	82.8	83.6			35	16	19	0.0	51.2	48.8	40.7	8.1	1.3E-07	53	0.262		
	TI-B8	CC-AC (Note 6) (top)	43.5	44.5	Coarse/Fine Tailings		31.2	29.3			91.0	92.3															
	TI-B8	CC-AC (Note 6) (bot)	43.5	44.5	Fine Tailings		45.6	*43.3*	47.9 / 49.0	74.4 / 73.6	73.6	*74.8*						0.0	14.5	85.5	74.7	10.8	3.0E-08	61			

Table 2. Summary of Geotechnical Laboratory Test Results - Mill Site Impoundment

Area	Boring	Sample Type (9)	Sample Depth Interval (ft.)		Material Description (1)	USCS (1)	Water content (by mass) 110C	Water content (by mass) 60C	SWCC - Saturated water content (by mass) (Note 2)	SWCC - Specimen dry density (pcf) (Note 2)	Dry density (pcf), 110C	Dry density (pcf), 60C	Specific gravity, 110C	Specific gravity, 60C	Atterberg limits (%) LL	PL	PI	USCS % gravel (size)	USCS % sand (size)	% Passing No. 200 sieve	% Silt (size)	USDA % clay (size <0.002 mm)	Flexible wall permeability (cm/sec) (3)	Permeability confining stress (psi)	Consolidation (Cc) (7)	Collapse potential (%) (inundation load (psf))	Triaxial (12) (peak friction angle (φ) (degrees), cohesion (psf), where applicable)
CENTRAL CELL	TI-B8	CC-AC (Note 6)	44.5	45	Fine Tailings								2.59	2.60													
	TI-B8	CA	46	46.5	Lean Clay with Sand	CL	21.9				95.2		2.72		30	16	14	0.0	27.9	72.1	55.6	16.5					
	TI-B8	CA	56	56.5	Silty Sand	SM	12.6				97.6		2.70		NP	-	-	0.0	57.0	43.0	30.9	12.1					
	TI-B8	BULK	63.5	64	Shale		X				X												X	-			
	TI-B15	CA	6	6.5	Coarse Tailings		5.4				101.1							0.0	87.5	12.5	9.8	2.7					
	TI-B15	CA	11	11.5	Coarse Tailings		6.8				93.8																
	TI-B15	CC-AC	13.5	14	Coarse Tailings		19.0	18.4					2.68		NP	-	-	0.0	69.6	30.4	22.6	7.8					
	TI-B15	ST	15.5	16	Coarse Tailings		14.2				90.4		2.66		NP	-	-	0.0	54.9	15.1	10.1	5.0	8.3E-04	38	0.126		
	TI-B15	CA	21	21.5	Coarse Tailings		12.7				99.8		2.68		NP	-	-	0.0	80.6	19.4	13.3	6.1					
	TI-B15	CC-AC	28.5	29.5	Coarse Tailings		19.3						2.66		NP	-	-	0.0	65.4	34.6	24.4	10.2					
	TI-B15	CA (top)	31	31.5	Silty Sand		22.3	21.3																			
	TI-B15	CA (bottom)	31	31.5	Silty Sand	SM	17.1				101.8		2.71		NP	-	-	6.2	51.9	41.9	25.9	16.0					
	TI-B15	CA	41	41.5	Clayey Sand		11.4	10.1			87.1	88.1															
	TI-B15	CA (top)	46	46.5	Sandy Silt		25.8	24.0																			
	TI-B15	CA (bottom)	46	46.5	Sandy Silt	ML	17.3				99.3		2.81		NP	-	-	0.0	37.0	63.0	55.7	7.3					
	TI-B15	CA	56	56.5	Silty Clay		11.7	10.5			104.2	105.3															
	TI-B15	CA	66	66.5	Clayey Sand		12.7	11.8			100.7	101.5															
NORTH CELL	TI-B23	ST	15.5	15.75	Coarse Tailings		20.7	19.6			87.7		2.77					0.0	62.8	37.2	34.1	3.1					
	TI-B23	ST	17.25	17.5	Sandy Clay		22.5				101.9		2.73					0.0	31.1	68.9	46.5	22.5					
	TI-B23	ST	26	27	Lean Clay	CL	21.6				101.7		2.73		49	18	31	0.0	8.8	91.2	43.8	47.5			0.046		
	TI-B23	CA	45.2	45.7	Sandstone		13.8				108.7												2.4E-07	43			
	TI-B23	CA (Note 8)	65.5	66	Shale		10.2				103.0												9.7E-08	62			
	TI-B2	CA	6	6.5	Silty Sand with Gravel (Fill)		7.7				100.4		2.68					26.9	29.9	43.2	30.7	12.5					
	TI-B2	CA	11	11.5	Clayey Sand (fill)		24.5				75.9		2.73					0.0	65.4	34.6	30.3	4.3					
	TI-B2	CC-AC	13.5	14.5	Fine Tailings		41.7	*39.6*										0.0	23.1	76.9	49.2	27.7					
	TI-B2	CA	15	15.5	Silty Sand		6.9				90.4		2.68														
	TI-B2	CA	21	21.5	Silty Sand		7.0				91.4		2.74					0.0	82.9	17.1	11.5	5.6					
	TI-B2	CA	26	26.5	Lean Clay with Sand	CL	23.5				93.2				34	16	18	0.0	20.9	79.1	51.5	27.6					
	TI-B2	BULK	38.4	38.7	Sandstone		13.5				X																
DAM	TI-B3	CA	11	11.5	Silty Sand (dam)		5.1				108.4		2.64					5.4	74.7	19.9	13.5	6.4					
	TI-B3	CA	16	16.5	Silty Sand (dam)		4.7				105.3															-2.8 (2,236)	
	TI-B3	ST	21	22	Sandy Clay (dam)	CL	16.0				111.1				30	12	18	0.0	32.8	67.2	41.7	25.5				-0.03 (2,709)	32.2, 195
	TI-B3	CA	26	26.5	Sandy Clay (dam)		12.0				106.8				25	13	12										
	TI-B3	CA	31	31.5	Sandy Clay (dam)		16.1				108.4																
	TI-B3	ST (top)	35	36	Clayey Sand (dam)		10.5	10.2																			
	TI-B3	ST (bottom)	35	36	Clayey Sand (dam)	SC	14.7				102.2		2.67		23	14	9	2.1	50.2	47.7	30.9	16.8			-	-0.7 (4,608)	33.7, 135
	TI-B3	CA	41	41.5	Sandy Clay (dam)		21.5				90.6							0.0	33.8	66.2	41.7	24.5					
	TI-B3	CA	45.5	46	Sandy Clay (dam)		17.0	17.7			110.1	109.4															29.3, 293
	TI-B3	CA	46	46.5	Sandy Clay (dam)		18.0				104.8				28	13	15										
	TI-B3	ST	56	57	Lean Clay	CL	22.1	21.1			105.3	106.2	2.72		43	14	29	0.0	11.7	88.3	48.4	39.9				-1.5 (7,204)	22.2, 494
	TI-B3	CA	61	61.5	Silty Clay		25.8				99.0							0.0	22.0	78.0	54.9	23.1					

NOTES: (1) Material descriptions are based on field observations, and refined with laboratory data, if available. USCS classifications are provided only where sufficient laboratory data are available.

(2) SWCC tests conducted with pairs of specimens for each test.

(3) Flexible wall permeameter tests conducted at confining pressures representing confining stresses for the proposed design fill. Confining stresses were estimated as the existing overburden stress on the specimens (depth times total unit weight of material above) plus the maximum anticipated fill height for the location times the estimated total unit weight of fill.

(4) Specimen remolded to the in-situ water content and density of the Shelby tube sample from 10-12.5 for the SWCC.

(5) Remolded SWCC and permeability tests conducted on a 50-50 mixture of these two materials, remolded to the average measured density of the two CA samples.

(6) SWCC specimen remolded to the in-situ water content and density of the Shelby tube sample from 41-42 feet.

(7) Compression indices estimated using the maximum anticipated loading during fill placement and the range of loading during testing. Initial void ratios are calculated using the average specific gravity for all samples of 2.70.

(8) Clayshale sample had multiple horizontal fractures and was likely disturbed during sampling

(9) Sample Types: CC = continuous core, CC-AC = continuous core in acrylic liner, top/bottom indicates the specimen was taken from the top or bottom of the sample interval

(10) Values in italics were calculated based on the relationship (WC60=0.951(WC110)-.0611) between the water content results measured for 15 tailings samples at the two oven temperatures.*

(11) Shaded cells are alluvium

(12) Consolidated undrained (CU) triaxial shear, staged loading of one specimen with pore pressure measurements

ST = 3" diam. Shelby tube, CA = California sample

R = remolded

X = testing not possible, due to sample disturbance

LL = liquid limit, PL = plastic limit, PI = plasticity index