Calculations

Colon Mine Site Structural Fill

Charah, Inc.

Sanford, NC

November 2014

Table of Contents

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A

Settlement

Total Settlement
Elastic Settlement
Primary Consolidation Settlement
Secondary Compression Settlement
Attachments

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HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date: 10/27/14	
Subject:	Permit Application	Checked By:	**KP**	Date: **10/29/2014**	
Task:	Settlement Calculation - Total Settlement	Sheet:		Of:	8

Objective:

Estimate the settlement that will occur under the proposed Colon Mine structural fill when the structural fill has reached its final grades.

Background:

As part of the hydrogeological investigation for the site, 20 borings (subsequently converted to piezometers) were drilled in the vicinity of the proposed structural fill to characterize subsurface conditions. Foundation settlement was calculated at 12 of these boring locations (see Attachment A for logs) to determine the effect of settlement on the design liner grades. The elastic settlement was based on correlations with soil type and the estimated vertical stress on the soil. In addition to the elastic settlement, the primary and secondary settlement for clay layers were also estimated. Note these primary consolidation settlement calculations are conservative since they assume the foundation clays are normally consolidated and do not account for stress distribution. The "stiff" description of the foundation clay indicates that the clay is probably overconsolidated and therefore anticipated consolidation settlement is less than calculated.

References:

1. Naval Facilities Engineering Command (NAVFAC) (1986). *Design Manual 7.01 - Soil Mechanics* .
2. Geotrack Technologies, Inc. (2014). Physical Characterization Testing of Coal Combustion By-Products, Riverbend Steam Station

3. Qian, X., Koerner, R. M., & Gray, D. H. (). *Geotechnical Aspects of Landfill Design and Construction* . Upper Saddle River, New Jersey: Prentice Hall.

Steps - Primary Consolidation (Clay Soils)

1. Estimate the total settlement (Z_T) for each layer using the elastic settlement (Z_e), primary consolidation settlement (Z_c), secondary consolidation settlement (Z_α) and equation 12.24 (page 470) below from Reference 3.

$$Z_T = Z_e + Z_c + Z_\alpha$$

2. Repeat Step 1 for each soil layer. Add the total settlement for each layer together to get the total estimated settlement at that location based on information from the boring logs, recent surveys, and seasonal high groundwater levels.

$$Z_{T\ Total} = Z_{T\ layer\ n} + Z_{T\ layer\ n+1}$$

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date: 10/27/14	
Subject:	Permit Application	Checked By:	KP	Date: 10/29/2014	
Task:	Settlement Calculation - Total Settlement	Sheet:		Of:	8

Calculations

MW PZ-3

Layer	Boring Log Description	From Previous Calculations			Step 1
		Elastic Layer Settlement, Z_e (ft)	Primary Consolidation Settlement of Clay, Z_c (ft)	Secondary Compression Settlement of Caly Layer, Z_α (ft)	Total Settlement, Z_T (ft)
1	Hard, Reddish-brown, clayey silt	0.07	0.00	0.00	0.07
2	PWR	0.00	0.00	0.00	0.00
3	0	0.00	0.00	0.00	0.00
4	0	0.00	0.00	0.00	0.00
5	0	0.00	0.00	0.00	0.00
6	0	0.00	0.00	0.00	0.00
7	0	0.00	0.00	0.00	0.00

Step 2: Total Estimated Settlement for MW PZ-3 0.07 ft

MW PZ-4

Layer	Boring Log Description	From Previous Calculations			Step 1
		Elastic Layer Settlement, Z_e (ft)	Primary Consolidation Settlement of Clay, Z_c (ft)	Secondary Compression Settlement of Caly Layer, Z_α (ft)	Total Settlement, Z_T (ft)
1	Stiff, Brownish-yellow, silty clay	0.11	1.15	0.02	1.28
2	Very stiff, Red, clayey silt	0.12	0.00	0.00	0.12
3	PWR	0.00	0.00	0.00	0.00
4	0	0.00	0.00	0.00	0.00
5	0	0.00	0.00	0.00	0.00
6	0	0.00	0.00	0.00	0.00
7	0	0.00	0.00	0.00	0.00

Step 2: Total Estimated Settlement for MW PZ-4 1.4 ft

HDR Computation

Project: Charah Colon Mine Structural Fill	Computed By: TMY	Date: 10/27/14	
Subject: Permit Application	Checked By: **KP**	Date: **10/29/2014**	
Task: Settlement Calculation - Total Settlement	Sheet:	Of:	8

MW PZ-6

Layer	Boring Log Description	From Previous Calculations			Step 1
		Elastic Layer Settlement, Z_e (ft)	Primary Consolidation Settlement of Clay, Z_c (ft)	Secondary Compression Settlement of Caly Layer, Z_α (ft)	Total Settlement, Z_T (ft)
1	Very stiff, Dark reddish-gray, silty clay (above GW)	0.19	0.53	0.03	0.75
2	Very stiff, Dark reddish-gray, silty clay (below GW)	0.06	0.16	0.01	0.23
3	PWR	0.00	0.00	0.00	0.00
4	0	0.00	0.00	0.00	0.00
5	0	0.00	0.00	0.00	0.00
6	0	0.00	0.00	0.00	0.00
7	0	0.00	0.00	0.00	0.00

Step 2: Total Estimated Settlement for MW PZ-6 0.98 ft

MW PZ-8

Layer	Boring Log Description	From Previous Calculations			Step 1
		Elastic Layer Settlement, Z_e (ft)	Primary Consolidation Settlement of Clay, Z_c (ft)	Secondary Compression Settlement of Caly Layer, Z_α (ft)	Total Settlement, Z_T (ft)
1	Very stiff, Red, gravelly silt (above GW)	0.07	0.00	0.00	0.07
2	Very stiff, Red, gravelly silt (below GW)	0.02	0.00	0.00	0.02
3	PWR	0.00	0.00	0.00	0.00
4	0	0.00	0.00	0.00	0.00
5	0	0.00	0.00	0.00	0.00
6	0	0.00	0.00	0.00	0.00
7	0	0.00	0.00	0.00	0.00

Step 2: Total Estimated Settlement for MW PZ-8 0.09 ft

HDR Computation

Project: Charah Colon Mine Structural Fill		Computed By: TMY	Date: 10/27/14
Subject: Permit Application		Checked By: **KP**	Date: **10/29/2014**
Task: Settlement Calculation - Total Settlement		Sheet:	Of: 8

MW PZ-9

Layer	Boring Log Description	From Previous Calculations			Step 1
		Elastic Layer Settlement, Z_e (ft)	Primary Consolidation Settlement of Clay, Z_c (ft)	Secondary Compression Settlement of Caly Layer, Z_α (ft)	Total Settlement, Z_T (ft)
1	Stiff, Yellowish-brown, silty clay	0.09	0.32	0.02	0.43
2	Compact, Weak red, clayey sand (above GW)	0.05	0.00	0.00	0.05
3	Compact, Weak red, clayey sand (below GW)	0.07	0.00	0.00	0.07
4	PWR	0.00	0.00	0.00	0.00
5	0	0.00	0.00	0.00	0.00
6	0	0.00	0.00	0.00	0.00
7	0	0.00	0.00	0.00	0.00

Step 2: Total Estimated Settlement for MW PZ-9 0.55 ft

MW PZ-12

Layer	Boring Log Description	From Previous Calculations			Step 1
		Elastic Layer Settlement, Z_e (ft)	Primary Consolidation Settlement of Clay, Z_c (ft)	Secondary Compression Settlement of Caly Layer, Z_α (ft)	Total Settlement, Z_T (ft)
1	PWR	0.00	0.00	0.00	0.00
2	0	0.00	0.00	0.00	0.00
3	0	0.00	0.00	0.00	0.00
4	0	0.00	0.00	0.00	0.00
5	0	0.00	0.00	0.00	0.00
6	0	0.00	0.00	0.00	0.00
7	0	0.00	0.00	0.00	0.00

Step 2: Total Estimated Settlement for MW PZ-12 0 ft

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date: 10/27/14	
Subject:	Permit Application	Checked By:	**KP**	Date: **10/29/2014**	
Task:	Settlement Calculation - Total Settlement	Sheet:		Of:	8

MW PZ-13

Layer	Boring Log Description	From Previous Calculations			Step 1
		Elastic Layer Settlement, Z_e (ft)	Primary Consolidation Settlement of Clay, Z_c (ft)	Secondary Compression Settlement of Caly Layer, Z_α (ft)	Total Settlement, Z_T (ft)
1	Stiff, Red, sandy silt	0.06	0.00	0.00	0.06
2	Very hard, red, silty clay (below GW)	0.27	0.69	0.07	1.03
3	PWR	0.00	0.00	0.00	0.00
4	0	0.00	0.00	0.00	0.00
5	0	0.00	0.00	0.00	0.00
6	0	0.00	0.00	0.00	0.00
7	0	0.00	0.00	0.00	0.00
			Step 2: Total Estimated Settlement for MW PZ-13		1.09 ft

MW PZ-15

Layer	Boring Log Description	From Previous Calculations			Step 1
		Elastic Layer Settlement, Z_e (ft)	Primary Consolidation Settlement of Clay, Z_c (ft)	Secondary Compression Settlement of Caly Layer, Z_α (ft)	Total Settlement, Z_T (ft)
1	Very stiff, red, silty clay	0.14	0.48	0.03	0.65
2	Very hard, red, silty clay (below GW)	0.16	0.43	0.05	0.64
3	PWR	0.00	0.00	0.00	0.00
4	0	0.00	0.00	0.00	0.00
5	0	0.00	0.00	0.00	0.00
6	0	0.00	0.00	0.00	0.00
7	0	0.00	0.00	0.00	0.00
			Step 2: Total Estimated Settlement for MW PZ-15		1.29 ft

HDR Computation

Project: Charah Colon Mine Structural Fill	Computed By: TMY	Date: 10/27/14	
Subject: Permit Application	Checked By: **KP**	Date: **10/29/2014**	
Task: Settlement Calculation - Total Settlement	Sheet:	Of:	8

MW PZ-16

Layer	Boring Log Description	From Previous Calculations			Step 1
		Elastic Layer Settlement, Z_e (ft)	Primary Consolidation Settlement of Clay, Z_c (ft)	Secondary Compression Settlement of Caly Layer, Z_α (ft)	Total Settlement, Z_T (ft)
1	Stiff, Strong brown, clayey silt	0.06	0.00	0.00	0.06
2	Stiff, Yellowish-red, silty clay (above GW)	0.14	0.38	0.03	0.55
3	Very hard, Red, silty clay (below GW)	0.22	0.52	0.05	0.79
4	PWR	0.00	0.00	0.00	0.00
5	0	0.00	0.00	0.00	0.00
6	0	0.00	0.00	0.00	0.00
7	0	0.00	0.00	0.00	0.00
		Step 2: Total Estimated Settlement for MW PZ-16			1.4 ft

MW PZ-18

Layer	Boring Log Description	From Previous Calculations			Step 1
		Elastic Layer Settlement, Z_e (ft)	Primary Consolidation Settlement of Clay, Z_c (ft)	Secondary Compression Settlement of Caly Layer, Z_α (ft)	Total Settlement, Z_T (ft)
1	Very stiff, Red, silty clay	0.06	0.22	0.01	0.29
2	Hard, Red, clayey silt	0.12	0.00	0.00	0.12
3	PWR	0.00	0.00	0.00	0.00
4	0	0.00	0.00	0.00	0.00
5	0	0.00	0.00	0.00	0.00
6	0	0.00	0.00	0.00	0.00
7	0	0.00	0.00	0.00	0.00
		Step 2: Total Estimated Settlement for MW PZ-18			0.41 ft

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By: TMY	Date: 10/27/14
Subject:	Permit Application	Checked By: **KP**	Date: **10/29/2014**
Task:	Settlement Calculation - Total Settlement	Sheet:	Of: 8

MW PZ-19

Layer	Boring Log Description	From Previous Calculations			Step 1
		Elastic Layer Settlement, Z_e (ft)	Primary Consolidation Settlement of Clay, Z_c (ft)	Secondary Compression Settlement of Caly Layer, Z_α (ft)	Total Settlement, Z_T (ft)
1	Medium, Light brownish-gray, silty clay	1.37	0.45	0.02	1.84
2	Hard, Yellowish-brown, clayey silt (below GW)	0.32	0.00	0.00	0.32
3	PWR	0.00	0.00	0.00	0.00
4	0	0.00	0.00	0.00	0.00
5	0	0.00	0.00	0.00	0.00
6	0	0.00	0.00	0.00	0.00
7	0	0.00	0.00	0.00	0.00
			Step 2: Total Estimated Settlement for MW PZ-19		2.16 ft

MW PZ-20

Layer	Boring Log Description	From Previous Calculations			Step 1
		Elastic Layer Settlement, Z_e (ft)	Primary Consolidation Settlement of Clay, Z_c (ft)	Secondary Compression Settlement of Caly Layer, Z_α (ft)	Total Settlement, Z_T (ft)
1	Stiff, Red, sandy silty clay (above GW)	0.17	0.54	0.04	0.75
2	Stiff, Red, sandy silty clay (below GW)	0.11	0.27	0.04	0.42
3	PWR	0.00	0.00	0.00	0.00
4	0	0.00	0.00	0.00	0.00
5	0	0.00	0.00	0.00	0.00
6	0	0.00	0.00	0.00	0.00
7	0	0.00	0.00	0.00	0.00
			Step 2: Total Estimated Settlement for MW PZ-20		1.17 ft

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By: TMY	Date: 10/27/14
Subject:	Permit Application	Checked By: **KP**	Date: **10/29/2014**
Task:	Settlement Calculation - Total Settlement	Sheet:	Of: 8

Check Post-Settlement Liner Stresses:

Figure 1 shows the post-settlement basegrade slopes after accounting for the calculated total foundation settlement. Figure 1 shows that the greatest change in slope is anticipated to occur between PZ-16 and the inside base of the south perimeter berm (-1.40%). Assuming a linear relationship between settlement and liner strain along this section of basegrade, the maximum strain due to settlement is anticipated to be 1.40%. From GRI GM-13, the minimum average yield elongation for 60 mil textured HDPE geomembrane is 12%. Therefore, the anticipated strain on the base liner geomembrane will not be excessive.

Conclusion:

The settlement calculations are summarized on Figure 1 provided in the back of the calculations. The figure shows calculated total settlement ranged from zero at PZ-12 where essentially all the surface soils will be stripped down to the partially weathered rock which is assumed to be incompressible to a maximum of 2.16 ft of settlement at PZ-19. Based on the calculated settlement, a minimum of 4' post-settlement separation from groundwater will be maintained between the bottom of the proposed liner system and the seasonal-high water table. Figure 1 also shows the effect of the estimated foundation settlement on the proposed liner grades while conservatively assuming that there will be no settlement at the base of the perimeter berm. The calculated post-settlement grades indicate that positive drainage will be maintained on the liner system.

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Settlement Calculation - Elastic Settlement	Sheet:		Of:	26

Steps - Elastic Settlement

1. Determine the soil type (using Reference 1 and other references) and height of layer (H_o) based on the boring log, recent survey, and measured groundwater levels. Annotated boring logs for borings located within the footprint of the structural fill are included in Attachment A. Estimated groundwater contours for the site are provided in Attachment B. Top of liner and top of final cover elevations are provided in Attachments C and D, respectively. Assume no settlement occurs within Partially Weathered Rock (PWR).

2. Determine the wet unit weight (γ) based on the soil type and Table 6: Typical Values of Soil Index Properties (page 7.1-22) of Reference 4 provided in Attachment E. Use the average of the range of values in Table 6.

3. Determine the vertical stress (σ_{soil}) of the soil by multiplying the height of the soil by the unit weight from step 2 and subtracting the buoyant force due to the water if the layer is below the water table. If water is not present in the layer, set γ_{water} equal to zero.

$$\sigma_{soil} = \gamma_{soil} H_o - \gamma_{water} H_o$$

4. Determine the vertical stress ($\sigma_{m\ soil}$) of the soil at the midpoint of the soil layer.

$$\sigma_{m\ soil} = \frac{\sigma_{soil}}{2}$$

5. Determine the increment of vertical effective stress of the waste & cover on the soil ($\Delta\sigma_{waste\ \&\ cover}$) assuming the unit weight of the compacted ash (γash) is 83.8 pcf (See Slope Stability Calculations and Ref. 2), the height (Hash) varies across the site as shown in Attachment D, unit weight of the cover (γ_{cover}) is estimated to be 120 pcf and the height of the cover(H_{cover}) is 4 feet on sideslopes and 6 feet on the top slope.

$$\Delta\sigma_{ash\ \&\ cover} = \gamma_{ash} H_{ash} + \gamma_{cover} H_{cover}$$

6. Determine the total vertical stress due to soil (σ_T) at the midpoint of the soil considering the soil ($\sigma_{m\ soil}$) and soil layers above ($\sigma_{soil\ layers\ above}$).

$$\sigma_T = \sigma_{m\ soil} + \sigma_{soil\ layers\ above}$$

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Settlement Calculation - Elastic Settlement	Sheet:		Of:	26

7. Convert the total vertical stress (σ_T) from psf to psi.

$$\sigma_{T\,psi} = \sigma_T \times \frac{1\,ft^2}{144\,in^2}$$

8. Using the total vertical stress (σ_T) in psi and soil type, look up the elastic modulus of soil (E_s) and Poisson's ratio of soil (ν_s) in the Columns in Table 9.5 (page 310) of Reference 3 (Attachment F). Use 95% density columns for soils classified as dense, stiff or hard and 85% density for others.

9. Convert the elastic modulus of soil (E_S) from psi to psf.

$$E_{S\,psf} = E_S \times \frac{144\,in^2}{1\,ft^2}$$

10. Determine the constrained modulus of soil (M_S) using the elastic modulus of soil (E_s) and Poisson's ratio of soil (ν_s) and Equation 12.21 (page 470) of Reference 3.

$$M_s = \frac{E_s(1-\nu_s)}{(1+\nu_s)(1-2\nu_s)}$$

11. Determine the elastic settlement of soil layer (Ze) using the initial thickness of the soil layer (Ho), the increment of vertical effective stress ($\Delta\sigma$) and the constrained modulus of soil (Ms) and Equation 12.20 (page 469) of Reference 3.

$$Z_e = \left(\frac{\Delta\sigma}{M_s}\right) H_o$$

12. Repeat Steps 1 - 11 for each layer. Add the elastic settlement for each layer together to get the total estimated elastic settlement at that location based on information from the boring logs, recent surveys, and seasonal high groundwater levels.

$$Z_{e\,Total} = Z_{e\,layer\,n} + Z_{e\,layer\,n+1}$$

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Settlement Calculation - Elastic Settlement	Sheet:		Of:	26

Calculations

MW PZ-3

Top of Final Cover Elevation	328	ft	
Top of Liner Elevation	284.0	ft	
Natural Ground Elevation	296.20	ft	
Depth of Excavation to Top of Liner	12.2	ft	
Elevation of Partially Weathered Rock (PWR)	281.20	ft	(Assume No Settlement in PWR)
Groundwater Elevation	277.26	ft	(Groundwater is Below PWR - does not affect calc.)
Height of Ash & Cover	44	ft	(Top of Final Cover - Top of Liner)
Cover Thickness	6	ft	
Ash Thickness	38	ft	
Unit Weight of Ash	83.8	pcf	(Source: Reference 2)
Estimated Unit Weight of Cover	120	pcf	
Vertical Stress of Ash & Cover	3,904	psf	
Water Density	62.4	pcf	

Layer	Boring Log Description	Step 1		Step 2	Step 3	
		Soil Symbol	H_o (ft)	Unit Weight of Soil, γ_{soil} (pcf)	Unit Weight of Water, γ_{water} (pcf)	Vertical stress of Soil, σ_{soil} (psf)
1	Hard, Reddish-brown, clayey silt	MH	2.8	108.5	0	304
2	PWR					0
3						0
4						0
5						0
6						0
7						0

HDR Computation

Project: Charah Colon Mine Structural Fill	Computed By: TMY	Date:	10/27/2014
Subject: Permit Application	Checked By: **KP**	Date:	**10/29/2014**
Task: Settlement Calculation - Elastic Settlement	Sheet:	Of:	26

MW PZ-3 continued

Layer	Boring Log Description	Step 4 Vertical Stress at midpoint of Soil, $\sigma_{m\ soil}$ (psf)	Step 5 (see calculation above) Increment of Vertical Effective Stress of Ash & Cover, $\Delta\sigma ash_{\&\ cover}$ (psf)	Step 6 Total vertical stress due to soil, σ_T (psf)	Step 7 Total vertical stress on soil, $\sigma_{T\ psi}$ (psi)
1	Hard, Reddish-brown, clayey silt	152	3,904	152	1
2		0			0
3		0			0
4		0			0
5		0			0
6		0			0
7		0			0

MW PZ-3 continued

Layer	Boring Log Description	Step 8		Step 9	Step 10	Step 11
		Es (psi)	v_s	E_s (psf)	M_s (psf)	Z_e (ft)
1	Hard, Reddish-brown, clayey silt	400	0.42	57,600	147,042	0.07
2				0	0	
3				0	0	
4				0	0	
5				0	0	
6				0	0	
7				0	0	

Step 12: Total Estimated Elastic Settlement for MW-PZ-3 0.07 ft

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Settlement Calculation - Elastic Settlement	Sheet:		Of:	26

MW PZ-4

Top of Final Cover Elevation	329.5	ft	
Top of Liner Elevation	294.0	ft	
Natural Ground Elevation	296.82	ft	
Depth of Excavation to Top of Liner	2.82	ft	
Elevation of Partially Weathered Rock (PWR)	281.82	ft	(Assume No Settlement in PWR)
Groundwater Elevation	287.50	ft	(Groundwater is Below PWR - does not affect calc.)
Height of Ash & Cover	35.5	ft	(Top of Final Cover - Top of Liner)
Cover Thickness	6	ft	
Ash Thickness	29.5	ft	
Unit Weight of Ash	83.8	pcf	(Source: Reference 2)
Estimated Unit Weight of Cover	120	pcf	
Vertical Stress of Ash & Cover	3,192	psf	
Water Density	62.4	pcf	

Layer	Boring Log Description	Step 1		Step 2	Step 3	
		Soil Symbol	H_o (ft)	Unit Weight of Soil, γ_{soil} (pcf)	Unit Weight of Water, γ_{water} (pcf)	Vertical stress of Soil, σ_{soil} (psf)
1	Stiff, Brownish-yellow, silty clay	CH	5	113.5	0.0	568
2	Very stiff, Red, clayey silt	MH	7	108.5	62.4	323
3	PWR					0
4						0
5						0
6						0
7						0

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Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Settlement Calculation - Elastic Settlement	Sheet:		Of:	26

MW PZ-4 continued

Layer	Boring Log Description	Step 4 Vertical Stress at midpoint of Soil, $\sigma_{m\ soil}$ (psf)	Step 5 (see calculation above) Increment of Vertical Effective Stress of Ash & Cover, $\Delta\sigma ash_{\&\ cover}$ (psf)	Step 6 Total vertical stress due to soil, σ_T (psf)	Step 7 Total vertical stress on soil, $\sigma_{T\ psi}$ (psi)
1	Stiff, Brownish-yellow, silty clay	284	3,192	284	2
2	Very stiff, Red, clayey silt	162	3,192	730	5
3	PWR	0			0
4		0			0
5		0			0
6		0			0
7		0			0

MW PZ-4 continued

Layer	Boring Log Description	Step 8		Step 9	Step 10	Step 11
		Es (psi)	ν_s	E_s (psf)	M_s (psf)	Z_e (ft)
1	Stiff, Brownish-yellow, silty clay	400	0.42	57,600	147,042	0.11
2	Very stiff, Red, clayey silt	800	0.35	115,200	184,889	0.12
3	PWR			0	0	
4				0	0	
5				0	0	
6				0	0	
7				0	0	

Step 12: Total Estimated Elastic Settlement for MW PZ-4 0.23 ft

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	10/29/2014
Task:	Settlement Calculation - Elastic Settlement	Sheet:		Of:	26

MW PZ-6

Top of Final Cover Elevation	334	ft
Top of Liner Elevation	278.0	ft
Natural Ground Elevation	283.48	ft
Depth of Excavation to Top of Liner	5.48	ft
Elevation of Partially Weathered Rock (PWR)	251.78	ft (Assume No Settlement in PWR)
Groundwater Elevation	270.64	ft
Height of Ash & Cover	56	ft (Top of Final Cover - Top of Liner)
Cover Thickness	6	ft
Ash Thickness	50	ft
Unit Weight of Ash	83.8	pcf (Source: Reference 2)
Estimated Unit Weight of Cover	120	pcf
Vertical Stress of Ash & Cover	4,910	psf
Water Density	62.4	pcf

Layer	Boring Log Description	Step 1		Step 2	Step 3	
		Soil Symbol	H_o (ft)	Unit Weight of Soil, γ_{soil} (pcf)	Unit Weight of Water, γ_{water} (pcf)	Vertical stress of Soil, σ_{soil} (psf)
1	Very stiff, Dark reddish-gray, silty clay (above GW)	CL	7	123.5	0.0	865
2	Very stiff, Dark reddish-gray, silty clay (below GW)	CL	3	123.5	62.4	183
3	PWR					0
4						0
5						0
6						0
7						0

HDR Computation

Project: Charah Colon Mine Structural Fill	Computed By: TMY	Date:	10/27/2014
Subject: Permit Application	Checked By: **KP**	Date: **10/29/2014**	
Task: Settlement Calculation - Elastic Settlement	Sheet:	Of:	26

MW PZ-6 continued

Layer	Boring Log Description	Step 4	Step 5 (see calculation above)	Step 6	Step 7
		Vertical Stress at midpoint of Soil, $\sigma_{m\ soil}$ (psf)	Increment of Vertical Effective Stress of Ash & Cover, $\Delta\sigma ash_{\&\ cover}$ (psf)	Total vertical stress due to soil, σ_T (psf)	Total vertical stress on soil, $\sigma_{T\ psi}$ (psi)
1	Very stiff, Dark reddish-gray, silty clay (above GW)	433	4,910	433	3
2	Very stiff, Dark reddish-gray, silty clay (below GW)	92	4,910	958	7
3	PWR	0			0
4		0			0
5		0			0
6		0			0
7		0			0

MW PZ-6 continued

Layer	Boring Log Description	Step 8		Step 9	Step 10	Step 11
		Es (psi)	v_s	E_s (psf)	M_s (psf)	Z_e (ft)
1	Very stiff, Dark reddish-gray, silty clay (above GW)	800	0.35	115,200	184,889	0.19
2	Very stiff, Dark reddish-gray, silty clay (below GW)	1,100	0.32	158,400	226,667	0.06
3	PWR			0	0	
4				0	0	
5				0	0	
6				0	0	
7				0	0	

Step 12: Total Estimated Elastic Settlement for MW PZ-6 0.25 ft

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	10/29/2014
Task:	Settlement Calculation - Elastic Settlement	Sheet:		Of:	26

MW PZ-8

Top of Final Cover Elevation	331.5	ft
Top of Liner Elevation	281.5	ft
Natural Ground Elevation	302.56	ft
Depth of Excavation to Top of Liner	21.06	ft
Elevation of Partially Weathered Rock (PWR)	272.56	ft (Assume No Settlement in PWR)
Groundwater Elevation	274.75	ft
Height of Ash & Cover	50	ft (Top of Final Cover - Top of Liner)
Cover Thickness	6	ft
Ash Thickness	44	ft
Unit Weight of Ash	83.8	pcf (Source: Reference 2)
Estimated Unit Weight of Cover	120	pcf
Vertical Stress of Ash & Cover	4,407	psf
Water Density	62.4	pcf

Layer	Boring Log Description	Step 1		Step 2	Step 3	
		Soil Symbol	H_o (ft)	Unit Weight of Soil, γ_{soil} (pcf)	Unit Weight of Water, γ_{water} (pcf)	Vertical stress of Soil, σ_{soil} (psf)
1	Very stiff, Red, gravelly silt (above GW)	ML	7	108.5	0.0	760
2	Very stiff, Red, gravelly silt (below GW)	ML	2	108.5	62.4	92
3	PWR					0
4						0
5						0
6						0
7						0

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Settlement Calculation - Elastic Settlement	Sheet:		Of:	26

MW PZ-8 continued

Layer	Boring Log Description	Step 4	Step 5 (see calculation above)	Step 6	Step 7
		Vertical Stress at midpoint of Soil, $\sigma_{m\ soil}$ (psf)	Increment of Vertical Effective Stress of Ash & Cover, $\Delta\sigma ash_{\&\ cover}$ (psf)	Total vertical stress due to soil, σ_T (psf)	Total vertical stress on soil, $\sigma_{T\ psi}$ (psi)
1	Very stiff, Red, gravelly silt (above GW)	380	4,407	380	3
2	Very stiff, Red, gravelly silt (below GW)	46	4,407	806	6
3	PWR	0			0
4		0			0
5		0			0
6		0			0
7		0			0

MW PZ-8 continued

Layer	Boring Log Description	Step 8		Step 9	Step 10	Step 11
		Es (psi)	v_s	E_s (psf)	M_s (psf)	Z_e (ft)
1	Very stiff, Red, gravelly silt (above GW)	2,500	0.29	360,000	471,761	0.07
2	Very stiff, Red, gravelly silt (below GW)	2,500	0.29	360,000	471,761	0.02
3	PWR			0	0	
4				0	0	
5				0	0	
6				0	0	
7				0	0	

Step 12: Total Estimated Elastic Settlement for MW PZ-8 0.09 ft

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Settlement Calculation - Elastic Settlement	Sheet:		Of:	26

MW PZ-9

Top of Final Cover Elevation	314	ft
Top of Liner Elevation	275.5	ft
Natural Ground Elevation	285.74	ft
Depth of Excavation to Top of Liner	10.24	ft
Elevation of Partially Weathered Rock (PWR)	265.74	ft (Assume No Settlement in PWR)
Groundwater Elevation	269.02	ft
Height of Ash & Cover	38.5	ft (Top of Final Cover - Top of Liner)
Cover Thickness	4	ft
Ash Thickness	34.5	ft
Unit Weight of Ash	83.8	pcf (Source: Reference 2)
Estimated Unit Weight of Cover	120	pcf
Vertical Stress of Ash & Cover	3,371	psf
Water Density	62.4	pcf

Layer	Boring Log Description	Step 1		Step 2	Step 3	
		Soil Symbol	H_o (ft)	Unit Weight of Soil, γ_{soil} (pcf)	Unit Weight of Water, γ_{water} (pcf)	Vertical stress of Soil, σ_{soil} (psf)
1	Stiff, Yellowish-brown, silty clay	CL	4	123.5	0.0	494
2	Compact, Weak red, clayey sand (above GW)	SC	3	115.0	0.0	345
3	Compact, Weak red, clayey sand (below GW)	SC	4	115.0	62.4	210
4	PWR					0
5						0
6						0
7						0

HDR Computation

Project: Charah Colon Mine Structural Fill	Computed By: TMY	Date:	10/27/2014
Subject: Permit Application	Checked By: **KP**	Date: **10/29/2014**	
Task: Settlement Calculation - Elastic Settlement	Sheet:	Of:	26

MW PZ-9 continued

Layer	Boring Log Description	Step 4 Vertical Stress at midpoint of Soil, $\sigma_{m\ soil}$ (psf)	Step 5 (see calculation above) Increment of Vertical Effective Stress of Ash & Cover, $\Delta\sigma ash_{\&\ cover}$ (psf)	Step 6 Total vertical stress due to soil, σ_T (psf)	Step 7 Total vertical stress on soil, $\sigma_{T\ psi}$ (psi)
1	Stiff, Yellowish-brown, silty clay	247	3,371	247	2
2	Compact, Weak red, clayey sand (above GW)	173	3,371	667	5
3	Compact, Weak red, clayey sand (below GW)	105	3,371	945	7
4		0			0
5		0			0
6		0			0
7		0			0

MW PZ-9 continued

Layer	Boring Log Description	Step 8 Es (psi)	Step 8 ν_s	Step 9 E_s (psf)	Step 10 M_s (psf)	Step 11 Z_e (ft)
1	Stiff, Yellowish-brown, silty clay	400	0.42	57,600	147,042	0.09
2	Compact, Weak red, clayey sand (above GW)	800	0.35	115,200	184,889	0.05
3	Compact, Weak red, clayey sand (below GW)	800	0.35	115,200	184,889	0.07
4				0	0	
5				0	0	
6				0	0	
7				0	0	

Step 12: Total Estimated Elastic Settlement for MW PZ-9 0.21 ft

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Settlement Calculation - Elastic Settlement	Sheet:		Of:	26

MW PZ-12

Top of Final Cover Elevation	303	ft
Top of Liner Elevation	269.5	ft
Natural Ground Elevation	284.32	ft
Depth of Excavation to Top of Liner	14.82	ft
Elevation of Partially Weathered Rock (PWR)	269.32	ft (Assume No Settlement in PWR)
		Since Top of Liner el. ≈ PWR el. Assume no Elastic Settlement
Groundwater Elevation	253.72	ft (Groundwater is Below PWR - does not affect calc.)
Height of Ash & Cover	33.5	ft (Top of Final Cover - Top of Liner)
Cover Thickness	4	ft
Ash Thickness	29.5	ft
Unit Weight of Ash	83.8	pcf (Source: Reference 2)
Estimated Unit Weight of Cover	120	pcf
Vertical Stress of Ash & Cover	2,952	psf
Water Density	62.4	pcf

Layer	Boring Log Description	Step 1		Step 2	Step 3	
		Soil Symbol	H_o (ft)	Unit Weight of Soil, γ_{soil} (pcf)	Unit Weight of Water, γ_{water} (pcf)	Vertical stress of Soil, σ_{soil} (psf)
1	PWR				0.0	0
2					0.0	0
3					0.0	0
4						0
5						0
6						0
7						0

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Settlement Calculation - Elastic Settlement	Sheet:		Of:	26

MW PZ-12 continued

Layer	Boring Log Description	Step 4 Vertical Stress at midpoint of Soil, $\sigma_{m\ soil}$ (psf)	Step 5 (see calculation above) Increment of Vertical Effective Stress of Ash & Cover, $\Delta\sigma ash_{\&\ cover}$ (psf)	Step 6 Total vertical stress due to soil, σ_T (psf)	Step 7 Total vertical stress on soil, $\sigma_{T\ psi}$ (psi)
1	PWR	0	2,952	0	0
2	0	0	2,952	0	0
3	0	0	2,952	0	0
4		0			0
5		0			0
6		0			0
7		0			0

MW PZ-12 continued

Layer	Boring Log Description	Step 8		Step 9	Step 10	Step 11
		Es (psi)	ν_s	E_s (psf)	M_s (psf)	Z_e (ft)
1	PWR			0	0	
2	0			0	0	
3	0			0	0	
4				0	0	
5				0	0	
6				0	0	
7				0	0	

Step 12: Total Estimated Elastic Settlement for MW PZ-12 0 ft

HDR Computation

Project: Charah Colon Mine Structural Fill		Computed By: TMY	Date: 10/27/2014
Subject: Permit Application		Checked By: **KP**	Date: **10/29/2014**
Task: Settlement Calculation - Elastic Settlement		Sheet:	Of: 26

MW PZ-13

Top of Final Cover Elevation	335.5	ft
Top of Liner Elevation	290.0	ft
Natural Ground Elevation	293.48	ft
Depth of Excavation to Top of Liner	3.48	ft
Elevation of Partially Weathered Rock (PWR)	268.48	ft (Assume No Settlement in PWR)
Groundwater Elevation	283.44	ft
Height of Ash & Cover	45.5	ft (Top of Final Cover - Top of Liner)
Cover Thickness	6	ft
Ash Thickness	39.5	ft
Unit Weight of Ash	83.8	pcf (Source: Reference 2)
Estimated Unit Weight of Cover	120	pcf
Vertical Stress of Ash & Cover	4,030	psf
Water Density	62.4	pcf

Layer	Boring Log Description	Step 1		Step 2	Step 3	
		Soil Symbol	H_o (ft)	Unit Weight of Soil, γ_{soil} (pcf)	Unit Weight of Water, γ_{water} (pcf)	Vertical stress of Soil, σ_{soil} (psf)
1	Stiff, Red, sandy silt	ML	6	108.5	0.0	651
2	Very hard, red, silty clay (below GW)	CL	15	123.5	62.4	917
3	PWR					0
4						0
5						0
6						0
7						0

HDR Computation

Project: Charah Colon Mine Structural Fill	Computed By: TMY	Date:	10/27/2014
Subject: Permit Application	Checked By: **KP**	Date: **10/29/2014**	
Task: Settlement Calculation - Elastic Settlement	Sheet:	Of:	26

MW PZ-13 continued

Layer	Boring Log Description	Step 4	Step 5 (see calculation above)	Step 6	Step 7
		Vertical Stress at midpoint of Soil, $\sigma_{m\ soil}$ (psf)	Increment of Vertical Effective Stress of Ash & Cover, $\Delta\sigma ash_{\&\ cover}$ (psf)	Total vertical stress due to soil, σ_T (psf)	Total vertical stress on soil, $\sigma_{T\ psi}$ (psi)
1	Stiff, Red, sandy silt	326	4,030	326	2
2	Very hard, red, silty clay (below GW)	459	4,030	1,111	8
3	PWR	0			0
4		0			0
5		0			0
6		0			0
7		0			0

MW PZ-13 continued

Layer	Boring Log Description	Step 8		Step 9	Step 10	Step 11
		Es (psi)	ν_s	E_s (psf)	M_s (psf)	Z_e (ft)
1	Stiff, Red, sandy silt	1,800	0.34	259,200	398,955	0.06
2	Very hard, red, silty clay (below GW)	1,100	0.32	158,400	226,667	0.27
3	PWR			0	0	
4				0	0	
5				0	0	
6				0	0	
7				0	0	

Step 12: Total Estimated Elastic Settlement for MW PZ-13 0.33 ft

HDR Computation

Project: Charah Colon Mine Structural Fill	Computed By: TMY	Date:	10/27/2014
Subject: Permit Application	Checked By: **KP**	Date: 10/29/2014	
Task: Settlement Calculation - Elastic Settlement	Sheet:	Of:	26

MW PZ-15

Top of Final Cover Elevation	336	ft
Top of Liner Elevation	294.0	ft
Natural Ground Elevation	300.63	ft
Depth of Excavation to Top of Liner	6.63	ft
Elevation of Partially Weathered Rock (PWR)	275.63	ft (Assume No Settlement in PWR)
Groundwater Elevation	287.60	ft
Height of Ash & Cover	42	ft (Top of Final Cover - Top of Liner)
Cover Thickness	6	ft
Ash Thickness	36	ft
Unit Weight of Ash	83.8	pcf (Source: Reference 2)
Estimated Unit Weight of Cover	120	pcf
Vertical Stress of Ash & Cover	3,737	psf
Water Density	62.4	pcf

Layer	Boring Log Description	Step 1		Step 2	Step 3	
		Soil Symbol	H_o (ft)	Unit Weight of Soil, γ_{soil} (pcf)	Unit Weight of Water, γ_{water} (pcf)	Vertical stress of Soil, σ_{soil} (psf)
1	Very stiff, red, silty clay	CL	7	123.5	0.0	865
2	Very hard, red, silty clay (below GW)	CL	10	123.5	62.4	611
3	PWR					0
4						0
5						0
6						0
7						0

HDR Computation

Project: Charah Colon Mine Structural Fill	Computed By: TMY	Date:	10/27/2014
Subject: Permit Application	Checked By: **KP**	Date: **10/29/2014**	
Task: Settlement Calculation - Elastic Settlement	Sheet:	Of:	26

MW PZ-15 continued

Layer	Boring Log Description	Step 4	Step 5 (see calculation above)	Step 6	Step 7
		Vertical Stress at midpoint of Soil, $\sigma_{m\ soil}$ (psf)	Increment of Vertical Effective Stress of Ash & Cover, $\Delta\sigma ash_{\&\ cover}$ (psf)	Total vertical stress due to soil, σ_T (psf)	Total vertical stress on soil, $\sigma_{T\ psi}$ (psi)
1	Very stiff, red, silty clay	433	3,737	433	3
2	Very hard, red, silty clay (below GW)	306	3,737	1,172	8
3	PWR	0			0
4		0			0
5		0			0
6		0			0
7		0			0

MW PZ-15 continued

Layer	Boring Log Description	Step 8		Step 9	Step 10	Step 11
		Es (psi)	v_s	E_s (psf)	M_s (psf)	Z_e (ft)
1	Very stiff, red, silty clay	800	0.35	115,200	184,889	0.14
2	Very hard, red, silty clay (below GW)	1,100	0.32	158,400	226,667	0.16
3	PWR			0	0	
4				0	0	
5				0	0	
6				0	0	
7				0	0	

Step 12: Total Estimated Elastic Settlement for MW PZ-15 0.3 ft

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	10/29/2014
Task:	Settlement Calculation - Elastic Settlement	Sheet:		Of:	26

MW PZ-16

Top of Final Cover Elevation	317	ft
Top of Liner Elevation	273.0	ft
Natural Ground Elevation	270.63	ft
Depth of Excavation to Top of Liner	-2.37	ft (fill will be added to achieve liner grade)
Elevation of Partially Weathered Rock (PWR)	250.63	ft (Assume No Settlement in PWR)
Groundwater Elevation	262.23	ft
Height of Ash & Cover	44	ft (Top of Final Cover - Top of Liner)
Cover Thickness	6	ft
Ash Thickness	38	ft
Unit Weight of Ash	83.8	pcf (Source: Reference 2)
Estimated Unit Weight of Cover	120	pcf
Estimated Unit Weight of Fill	130	pcf
Vertical Stress of Ash & Cover & Fill	4,213	psf
Water Density	62.4	pcf

Layer	Boring Log Description	Step 1		Step 2	Step 3	
		Soil Symbol	H_o (ft)	Unit Weight of Soil, γ_{soil} (pcf)	Unit Weight of Water, γ_{water} (pcf)	Vertical stress of Soil, σ_{soil} (psf)
1	Stiff, Strong brown, clayey silt	MH	2	108.5	0.0	217
2	Stiff, Yellowish-red, silty clay (above GW)	CL	6	123.5	0.0	741
3	Very hard, Red, silty clay (below GW)	CL	12	123.5	62.4	733
4	PWR					0
5						0
6						0
7						0

HDR Computation

Project: Charah Colon Mine Structural Fill	Computed By: TMY	Date:	10/27/2014
Subject: Permit Application	Checked By: **KP**	Date: **10/29/2014**	
Task: Settlement Calculation - Elastic Settlement	Sheet:	Of:	26

MW PZ-16 continued

Layer	Boring Log Description	Step 4	Step 5 (see calculation above)	Step 6	Step 7
		Vertical Stress at midpoint of Soil, $\sigma_{m\ soil}$ (psf)	Increment of Vertical Effective Stress of Ash & Cover, $\Delta\sigma ash_{\&\ cover}$ (psf)	Total vertical stress due to soil, σ_T (psf)	Total vertical stress on soil, $\sigma_{T\ psi}$ (psi)
1	Stiff, Strong brown, clayey silt	109	4,213	109	1
2	Stiff, Yellowish-red, silty clay (above GW)	371	4,213	589	4
3	Very hard, Red, silty clay (below GW)	367	4,213	1,327	9
4		0			0
5		0			0
6		0			0
7		0			0

MW PZ-16 continued

Layer	Boring Log Description	Step 8		Step 9	Step 10	Step 11
		Es (psi)	v_s	E_s (psf)	M_s (psf)	Z_e (ft)
1	Stiff, Strong brown, clayey silt	400	0.42	57,600	147,042	0.06
2	Stiff, Yellowish-red, silty clay (above GW)	800	0.35	115,200	184,889	0.14
3	Very hard, Red, silty clay (below GW)	1,100	0.32	158,400	226,667	0.22
4				0	0	
5				0	0	
6				0	0	
7				0	0	

Step 12: Total Estimated Elastic Settlement for MW PZ-16 0.42 ft

HDR Computation

Project: Charah Colon Mine Structural Fill	Computed By: TMY	Date:	10/27/2014
Subject: Permit Application	Checked By: **KP**	Date: **10/29/2014**	
Task: Settlement Calculation - Elastic Settlement	Sheet:	Of:	26

MW PZ-18

Top of Final Cover Elevation	328	ft
Top of Liner Elevation	279.5	ft
Natural Ground Elevation	292.27	ft
Depth of Excavation to Top of Liner	12.77	ft
Elevation of Partially Weathered Rock (PWR)	272.27	ft (Assume No Settlement in PWR)
Groundwater Elevation	Dry	ft (Groundwater is Below PWR - does not affect calc.)
Height of Ash & Cover	48.5	ft (Top of Final Cover - Top of Liner)
Cover Thickness	6	ft
Ash Thickness	42.5	ft
Unit Weight of Ash	83.8	pcf (Source: Reference 2)
Estimated Unit Weight of Cover	120	pcf
Vertical Stress of Ash & Cover	4,282	psf
Water Density	62.4	pcf

Layer	Boring Log Description	Step 1		Step 2	Step 3	
		Soil Symbol	H_o (ft)	Unit Weight of Soil, γ_{soil} (pcf)	Unit Weight of Water, γ_{water} (pcf)	Vertical stress of Soil, σ_{soil} (psf)
1	Very stiff, Red, silty clay	CL	2	123.5	0.0	247
2	Hard, Red, clayey silt	MH	5	108.5	0.0	543
3	PWR					0
4						0
5						0
6						0
7						0

HDR Computation

Project: Charah Colon Mine Structural Fill	Computed By: TMY	Date:	10/27/2014
Subject: Permit Application	Checked By: **KP**	Date: **10/29/2014**	
Task: Settlement Calculation - Elastic Settlement	Sheet:	Of:	26

MW PZ-18 continued

Layer	Boring Log Description	Step 4 Vertical Stress at midpoint of Soil, $\sigma_{m\ soil}$ (psf)	Step 5 (see calculation above) Increment of Vertical Effective Stress of Ash & Cover, $\Delta\sigma ash_{\&\ cover}$ (psf)	Step 6 Total vertical stress due to soil, σ_T (psf)	Step 7 Total vertical stress on soil, $\sigma_{T\ psi}$ (psi)
1	Very stiff, Red, silty clay	124	4,282	124	1
2	Hard, Red, clayey silt	272	4,282	520	4
3	PWR	0			0
4		0			0
5		0			0
6		0			0
7		0			0

MW PZ-18 continued

Layer	Boring Log Description	Step 8		Step 9	Step 10	Step 11
		Es (psi)	ν_s	E_s (psf)	M_s (psf)	Z_e (ft)
1	Very stiff, Red, silty clay	400	0.42	57,600	147,042	0.06
2	Hard, Red, clayey silt	800	0.35	115,200	184,889	0.12
3	PWR			0	0	
4				0	0	
5				0	0	
6				0	0	
7				0	0	

Step 12: Total Estimated Elastic Settlement for MW PZ-18 0.18 ft

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Settlement Calculation - Elastic Settlement	Sheet:		Of:	26

MW PZ-19

Top of Final Cover Elevation	330.5	ft
Top of Liner Elevation	271.0	ft
Natural Ground Elevation	265.99	ft
Depth of Excavation to Top of Liner	-5.01	ft (fill will be added to achieve liner grade)
Elevation of Partially Weathered Rock (PWR)	250.99	ft (Assume No Settlement in PWR)
Groundwater Elevation	260.55	ft
Height of Ash & Cover	59.5	ft (Top of Final Cover - Top of Liner)
Cover Thickness	6	ft
Ash Thickness	53.5	ft
Unit Weight of Ash	83.8	pcf (Source: Reference 2)
Estimated Unit Weight of Cover	120	pcf
Estimated Unit Weight of Fill	130	pcf
Vertical Stress of Ash & Cover & Fill	5,855	psf
Water Density	62.4	pcf

Layer	Boring Log Description	Step 1		Step 2	Step 3	
		Soil Symbol	H_o (ft)	Unit Weight of Soil, γ_{soil} (pcf)	Unit Weight of Water, γ_{water} (pcf)	Vertical stress of Soil, σ_{soil} (psf)
1	Medium, Light brownish-gray, silty clay	CL	5	123.5	0.0	618
2	Hard, Yellowish-brown, clayey silt (below GW)	MH	10	108.5	62.4	461
3	PWR					0
4						0
5						0
6						0
7						0

HDR Computation

Project: Charah Colon Mine Structural Fill	Computed By: TMY	Date:	10/27/2014
Subject: Permit Application	Checked By: **KP**	Date: **10/29/2014**	
Task: Settlement Calculation - Elastic Settlement	Sheet:	Of:	26

MW PZ-19 continued

Layer	Boring Log Description	Step 4	Step 5 (see calculation above)	Step 6	Step 7
		Vertical Stress at midpoint of Soil, $\sigma_{m\ soil}$ (psf)	Increment of Vertical Effective Stress of Ash & Cover, $\Delta\sigma ash_{\&\ cover}$ (psf)	Total vertical stress due to soil, σ_T (psf)	Total vertical stress on soil, $\sigma_{T\ psi}$ (psi)
1	Medium, Light brownish-gray, silty clay	309	5,855	309	2
2	Hard, Yellowish-brown, clayey silt (below GW)	231	5,855	849	6
3	PWR	0			0
4		0			0
5		0			0
6		0			0
7		0			0

MW PZ-19 continued

Layer	Boring Log Description	Step 8		Step 9	Step 10	Step 11
		Es (psi)	v_s	E_s (psf)	M_s (psf)	Z_e (ft)
1	Medium, Light brownish-gray, silty clay	100	0.33	14,400	21,336	1.37
2	Hard, Yellowish-brown, clayey silt (below GW)	800	0.35	115,200	184,889	0.32
3	PWR			0	0	
4				0	0	
5				0	0	
6				0	0	
7				0	0	

Step 12: Total Estimated Elastic Settlement for MW PZ-19 1.69 ft

HDR Computation

Project: Charah Colon Mine Structural Fill	Computed By: TMY	Date:	10/27/2014
Subject: Permit Application	Checked By: **KP**	Date: **10/29/2014**	
Task: Settlement Calculation - Elastic Settlement	Sheet:	Of:	26

MW PZ-20

Top of Final Cover Elevation	328	ft
Top of Liner Elevation	293.5	ft
Natural Ground Elevation	296.51	ft
Depth of Excavation to Top of Liner	3.01	ft
Elevation of Partially Weathered Rock (PWR)	276.51	ft (Assume No Settlement in PWR)
Groundwater Elevation	284.12	ft
Height of Ash & Cover	34.5	ft (Top of Final Cover - Top of Liner)
Cover Thickness	6	ft
Ash Thickness	28.5	ft
Unit Weight of Ash	83.8	pcf (Source: Reference 2)
Estimated Unit Weight of Cover	120	pcf
Vertical Stress of Ash & Cover	3,108	psf
Water Density	62.4	pcf

Layer	Boring Log Description	Step 1		Step 2	Step 3	
		Soil Symbol	H_o (ft)	Unit Weight of Soil, γ_{soil} (pcf)	Unit Weight of Water, γ_{water} (pcf)	Vertical stress of Soil, σ_{soil} (psf)
1	Stiff, Red, sandy silty clay (above GW)	CL	10	123.5	0.0	1,235
2	Stiff, Red, sandy silty clay (below GW)	CL	8	123.5	62.4	489
3	PWR					0
4						0
5						0
6						0
7						0

HDR Computation

Project: Charah Colon Mine Structural Fill	Computed By: TMY	Date:	10/27/2014
Subject: Permit Application	Checked By: **KP**	Date: **10/29/2014**	
Task: Settlement Calculation - Elastic Settlement	Sheet:	Of:	26

MW PZ-20 continued

Layer	Boring Log Description	Step 4	Step 5 (see calculation above)	Step 6	Step 7
		Vertical Stress at midpoint of Soil, $\sigma_{m\ soil}$ (psf)	Increment of Vertical Effective Stress of Ash & Cover, $\Delta\sigma ash_{\&\ cover}$ (psf)	Total vertical stress due to soil, σ_T (psf)	Total vertical stress on soil, $\sigma_{T\ psi}$ (psi)
1	Stiff, Red, sandy silty clay (above GW)	618	3,108	618	4
2	Stiff, Red, sandy silty clay (below GW)	245	3,108	1,481	10
3	PWR	0			0
4		0			0
5		0			0
6		0			0
7		0			0

MW PZ-20 continued

Layer	Boring Log Description	Step 8		Step 9	Step 10	Step 11
		Es (psi)	ν_s	E_s (psf)	M_s (psf)	Z_e (ft)
1	Stiff, Red, sandy silty clay (above GW)	800	0.35	115,200	184,889	0.17
2	Stiff, Red, sandy silty clay (below GW)	1,100	0.32	158,400	226,667	0.11
3	PWR			0	0	
4				0	0	
5				0	0	
6				0	0	
7				0	0	

Step 12: Total Estimated Elastic Settlement for MW PZ-20 0.28 ft

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Settlement Calculation - Primary Consolidation Settlement	Sheet:		Of:	20

Steps - Primary Consolidation (Clay Soils)

1. Estimate the initial void ratio (e_{oi}) of the clay layer using the laboratory total porosity (n) values provided on the boring logs (Attachment A). Assume e_{oi} = 0.65 for CH material and 0.44 for CL material. Determine e_{oi} as follows:

$$e_{oi} = \frac{n}{1-n} \qquad where\ n = effective\ porosity$$

2. Estimate the primary compression index using the initial void ratio from Step 1 and the Equation below from Table 3 (page 7.1-224) of Reference 1.

$$C_C = 1.15(e_o - 0.35)$$

3. Conservatively assume the preconsolidation pressure (p_c) is equal to the initial vertical effective stress (σ_o) using the equation below.

$$p_c = \sigma_o = \sigma_{m\ soil} + \sigma_{soil\ layers\ above}$$

4. Determine the primary consolidation using the Equation 12.22 (page 470) below from Reference 3. Conservatively assume the clay is normally consolidated without preconsolidation pressure, therefore assume the recompression index (C_r) is equal to 0.

$$Z_c = C_r \times \frac{H_{oi}}{1+e_{oi}} \times \log\frac{p_c}{\sigma_o} + C_c \times \frac{H_{oi}}{1+e_{oi}} \times \log\frac{\sigma_o + \Delta\sigma}{p_c}$$

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Settlement Calculation - Primary Consolidation Settlement	Sheet:		Of:	20

Where:

Z_c = primary consolidation settlement of clay layer (ft)

H_o = initial thickness of clay layer (ft)

e_{oi} = initial void ratio of clay layer

C_r = recompression index

C_c = primary compression index

σ_o = initial vertical effective stress (lb/ft^2)

p_c = preconsolidation pressure (lb/ft^2)

$\Delta\sigma$ = increment of vertical effective stress (lb/ft^2)

4. Repeat Steps 1 - 4 for each clay layer. Add the primary consolidation settlement for each clay layer together to get the total estimated primary consolidation settlement at that location based on information from the boring logs, recent surveys, and seasonal high groundwater levels.

$$Z_{c\ Total} = Z_{c\ layer\ n} + Z_{c\ layer\ n+1}$$

Calculations

MW PZ-3

Layer	Boring Log Description	From Previous Calculation				
		Soil Symbol	H_o (ft)	Increment of Vertical Effective Stress, $\Delta\sigma$ (psf)	Vertical Stress at midpoint, $\sigma_{m\ soil}$ (psf)	Vertical Stress in soil layer, $\sigma_{soil\ layers}$ (psf)
1	Hard, Reddish-brown, clayey silt	MH	2.8	3,904	152	304
2	PWR	0	0.0	0	0	0
3		0	0.0	0	0	0
4		0	0.0	0	0	0
5		0	0.0	0	0	0
6		0	0.0	0	0	0

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Settlement Calculation - Primary Consolidation Settlement	Sheet:		Of:	20

7		0	0.0	0	0	0

MW PZ-3 continued

Layer	Boring Log Description	Step 1			Step 2	Step 3
		Minimum Void Ratio, e_{min}	Maximum Void Ratio, e_{max}	Initial Void Ratio, e_{oi}	Primary Compression Index, C_c	Preconsolidation Pressure, p_c (psf)
1	Hard, Reddish-brown, clayey silt					
2	PWR					
3	0					
4	0					
5	0					
6	0					
7	0					

MW PZ-3 continued

Layer	Boring Log Description	Step 3, Continued	Step 4	
		Initial Vertical Effective Stress on Soil, σ_o (psf)	Recompression Index, C_r	Primary Consolidation Settlement of Clay Layer, Z_c (ft)
1	Hard, Reddish-brown, clayey silt			
2	PWR			
3	0			
4	0			
5	0			
6	0			
7	0			

Step 4: Total Estimated Primary Consolidation Settlement for MW PZ-3 0 ft

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Settlement Calculation - Primary Consolidation Settlement	Sheet:		Of:	20

MW PZ-4

Layer	Boring Log Description	From Previous Calculation				
		Soil Symbol	H_o (ft)	Increment of Vertical Effective Stress, $\Delta\sigma$ (psf)	Vertical Stress at midpoint, $\sigma_{m\ soil}$ (psf)	Vertical Stress in soil layer, $\sigma_{soil\ layers}$ (psf)
1	Stiff, Brownish-yellow, silty clay	CH	5	3,192	284	568
2	Very stiff, Red, clayey silt	MH	7	3,192	162	323
3	PWR	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0

MW PZ-4 continued

Layer	Boring Log Description	Step 1			Step 2	Step 3
		Minimum Void Ratio, e_{min}	Maximum Void Ratio, e_{max}	Initial Void Ratio, e_{oi}	Primary Compression Index, C_c	Preconsolidation Pressure, p_c (psf)
1	Stiff, Brownish-yellow, silty clay			0.65	0.35	284
2	Very stiff, Red, clayey silt					
3	PWR					
4	0					
5	0					
6	0					
7	0					

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Settlement Calculation - Primary Consolidation Settlement	Sheet:		Of:	20

MW PZ-4 continued

Layer	Boring Log Description	Step 3, Continued	Step 4	
		Initial Vertical Effective Stress on Soil, σ_o (psf)	Recompression Index, C_r	Primary Consolidation Settlement of Clay Layer, Z_c (ft)
1	Stiff, Brownish-yellow, silty clay	284	0	1.15
2	Very stiff, Red, clayey silt			
3	PWR			
4	0			
5	0			
6	0			
7	0			

Step 4: Total Estimated Primary Consolidation Settlement for MW PZ-4 1.15 ft

MW PZ-6

Layer	Boring Log Description	From Previous Calculation				
		Soil Symbol	H_o (ft)	Increment of Vertical Effective Stress, $\Delta\sigma$ (psf)	Vertical Stress at midpoint, $\sigma_{m\ soil}$ (psf)	Vertical Stress in soil layer, $\sigma_{soil\ layers}$ (psf)
1	Very stiff, Dark reddish-gray, silty clay (above GW)	CL	7	4,910	433	865
2	Very stiff, Dark reddish-gray, silty clay (below GW)	CL	3	4,910	92	183
3	PWR	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Settlement Calculation - Primary Consolidation Settlement	Sheet:		Of:	20

MW PZ-6 continued

Layer	Boring Log Description	Step 1			Step 2	Step 3
		Minimum Void Ratio, e_{min}	Maximum Void Ratio, e_{max}	Initial Void Ratio, e_{oi}	Primary Compression Index, C_c	Preconsolidation Pressure, p_c (psf)
1	Very stiff, Dark reddish-gray, silty clay (above GW)			0.44	0.10	433
2	Very stiff, Dark reddish-gray, silty clay (below GW)			0.44	0.10	958
3	PWR					
4	0					
5	0					
6	0					
7	0					

MW PZ-6 continued

Layer	Boring Log Description	Step 3, Continued	Step 4	
		Initial Vertical Effective Stress on Soil, σ_o (psf)	Recompression Index, C_r	Primary Consolidation Settlement of Clay Layer, Z_c (ft)
1	Very stiff, Dark reddish-gray, silty clay (above GW)	433	0	0.53
2	Very stiff, Dark reddish-gray, silty clay (below GW)	958	0	0.16
3	PWR			
4	0			
5	0			
6	0			
7	0			

Step 4: Total Estimated Primary Consolidation Settlement for MW PZ-6 0.69 ft

HDR Computation

Project: Charah Colon Mine Structural Fill	Computed By: TMY	Date:	10/27/2014
Subject: Permit Application	Checked By: **KP**	Date:	**10/29/2014**
Task: Settlement Calculation - Primary Consolidation Settlement	Sheet:	Of:	20

MW PZ-8

Layer	Boring Log Description	From Previous Calculation				
		Soil Symbol	H_o (ft)	Increment of Vertical Effective Stress, $\Delta\sigma$ (psf)	Vertical Stress at midpoint, $\sigma_{m\ soil}$ (psf)	Vertical Stress in soil layer, $\sigma_{soil\ layers}$ (psf)
1	Very stiff, Red, gravelly silt (above GW)	ML	7	4,407	380	760
2	Very stiff, Red, gravelly silt (below GW)	ML	2	4,407	46	92
3	PWR	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0

MW PZ-8 continued

Layer	Boring Log Description	Step 1			Step 2	Step 3
		Minimum Void Ratio, e_{min}	Maximum Void Ratio, e_{max}	Initial Void Ratio, e_{oi}	Primary Compression Index, C_c	Preconsolidation Pressure, p_c (psf)
1	Very stiff, Red, gravelly silt (above GW)					
2	Very stiff, Red, gravelly silt (below GW)					
3	PWR					
4	0					
5	0					
6	0					
7	0					

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Settlement Calculation - Primary Consolidation Settlement	Sheet:		Of:	20

MW PZ-8 continued

Layer	Boring Log Description	Step 3, Continued	Step 4	
		Initial Vertical Effective Stress on Soil, σ_o (psf)	Recompression Index, C_r	Primary Consolidation Settlement of Clay Layer, Z_c (ft)
1	Very stiff, Red, gravelly silt (above GW)			
2	Very stiff, Red, gravelly silt (below GW)			
3	PWR			
4	0			
5	0			
6	0			
7	0			

Step 4: Total Estimated Primary Consolidation Settlement for MW PZ-8 0 ft

MW PZ-9

Layer	Boring Log Description	From Previous Calculation				
		Soil Symbol	H_o (ft)	Increment of Vertical Effective Stress, $\Delta\sigma$ (psf)	Vertical Stress at midpoint, $\sigma_{m\ soil}$ (psf)	Vertical Stress in soil layer, $\sigma_{soil\ layers}$ (psf)
1	Stiff, Yellowish-brown, silty clay	CL	4	3,371	247	494
2	Compact, Weak red, clayey sand (above GW)	SC	3	3,371	173	345
3	Compact, Weak red, clayey sand (below GW)	SC	4	3,371	105	210
4	PWR	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0

HDR Computation

Project: Charah Colon Mine Structural Fill	Computed By: TMY	Date:	10/27/2014
Subject: Permit Application	Checked By: **KP**	Date: **10/29/2014**	
Task: Settlement Calculation - Primary Consolidation Settlement	Sheet:	Of:	20

MW PZ-9 continued

Layer	Boring Log Description	Step 1			Step 2	Step 3
		Minimum Void Ratio, e_{min}	Maximum Void Ratio, e_{max}	Initial Void Ratio, e_{oi}	Primary Compression Index, C_c	Preconsolidation Pressure, p_c (psf)
1	Stiff, Yellowish-brown, silty clay			0.44	0.10	247
2	Compact, Weak red, clayey sand (above GW)					
3	Compact, Weak red, clayey sand (below GW)					
4	PWR					
5	0					
6	0					
7	0					

MW PZ-9 continued

Layer	Boring Log Description	Step 3, Continued	Step 4	
		Initial Vertical Effective Stress on Soil, σ_o (psf)	Recompression Index, C_r	Primary Consolidation Settlement of Clay Layer, Z_c (ft)
1	Stiff, Yellowish-brown, silty clay	247	0	0.32
2	Compact, Weak red, clayey sand (above GW)			
3	Compact, Weak red, clayey sand (below GW)			
4	PWR			
5	0			
6	0			
7	0			

Step 4: Total Estimated Primary Consolidation Settlement for MW PZ-9 0.32 ft

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Settlement Calculation - Primary Consolidation Settlement	Sheet:		Of:	20

MW PZ-12

Layer	Boring Log Description	From Previous Calculation				
		Soil Symbol	H_o (ft)	Increment of Vertical Effective Stress, $\Delta\sigma$ (psf)	Vertical Stress at midpoint, $\sigma_{m\ soil}$ (psf)	Vertical Stress in soil layer, $\sigma_{soil\ layers}$ (psf)
1	PWR	0	0	2,952	0	0
2	0	0	0	2,952	0	0
3	0	0	0	2,952	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0

MW PZ-12 continued

Layer	Boring Log Description	Step 1			Step 2	Step 3
		Minimum Void Ratio, e_{min}	Maximum Void Ratio, e_{max}	Initial Void Ratio, e_{oi}	Primary Compression Index, C_c	Preconsolidation Pressure, p_c (psf)
1	PWR					
2	0					
3	0					
4	0					
5	0					
6	0					
7	0					

HDR Computation

Project: Charah Colon Mine Structural Fill	Computed By: TMY	Date:	10/27/2014
Subject: Permit Application	Checked By: **KP**	Date:	**10/29/2014**
Task: Settlement Calculation - Primary Consolidation Settlement	Sheet:	Of:	20

MW PZ-12 continued

Layer	Boring Log Description	Step 3, Continued	Step 4	
		Initial Vertical Effective Stress on Soil, σ_o (psf)	Recompression Index, C_r	Primary Consolidation Settlement of Clay Layer, Z_c (ft)
1	PWR			
2	0			
3	0			
4	0			
5	0			
6	0			
7	0			

Step 4: Total Estimated Primary Consolidation Settlement for MW PZ-12 0 ft

MW PZ-13

Layer	Boring Log Description	From Previous Calculation				
		Soil Symbol	H_o (ft)	Increment of Vertical Effective Stress, $\Delta\sigma$ (psf)	Vertical Stress at midpoint, $\sigma_{m\ soil}$ (psf)	Vertical Stress in soil layer, $\sigma_{soil\ layers}$ (psf)
1	Stiff, Red, sandy silt	ML	6	4,030	326	651
2	Very hard, red, silty clay (below GW)	CL	15	4,030	459	917
3	PWR	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0

HDR Computation

Project: Charah Colon Mine Structural Fill	Computed By: TMY	Date:	10/27/2014
Subject: Permit Application	Checked By: **KP**	Date:	**10/29/2014**
Task: Settlement Calculation - Primary Consolidation Settlement	Sheet:	Of:	20

MW PZ-13 continued

Layer	Boring Log Description	Step 1			Step 2	Step 3
		Minimum Void Ratio, e_{min}	Maximum Void Ratio, e_{max}	Initial Void Ratio, e_{oi}	Primary Compression Index, C_c	Preconsolidation Pressure, p_c (psf)
1	Stiff, Red, sandy silt					
2	Very hard, red, silty clay (below GW)			0.44	0.10	1,111
3	PWR					
4	0					
5	0					
6	0					
7	0					

MW PZ-13 continued

Layer	Boring Log Description	Step 3, Continued	Step 4	
		Initial Vertical Effective Stress on Soil, σ_o (psf)	Recompression Index, C_r	Primary Consolidation Settlement of Clay Layer, Z_c (ft)
1	Stiff, Red, sandy silt			
2	Very hard, red, silty clay (below GW)	1,111	0	0.69
3	PWR			
4	0			
5	0			
6	0			
7	0			

Step 4: Total Estimated Primary Consolidation Settlement for MW PZ-13 0.69 ft

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Settlement Calculation - Primary Consolidation Settlement	Sheet:		Of:	20

MW PZ-15

Layer	Boring Log Description	From Previous Calculation				
		Soil Symbol	H_o (ft)	Increment of Vertical Effective Stress, $\Delta\sigma$ (psf)	Vertical Stress at midpoint, $\sigma_{m\ soil}$ (psf)	Vertical Stress in soil layer, $\sigma_{soil\ layers}$ (psf)
1	Very stiff, red, silty clay	CL	7	3,737	433	865
2	Very hard, red, silty clay (below GW)	CL	10	3,737	306	611
3	PWR	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0

MW PZ-15 continued

Layer	Boring Log Description	Step 1			Step 2	Step 3
		Minimum Void Ratio, e_{min}	Maximum Void Ratio, e_{max}	Initial Void Ratio, e_{oi}	Primary Compression Index, C_c	Preconsolidation Pressure, p_c (psf)
1	Very stiff, red, silty clay			0.44	0.10	433
2	Very hard, red, silty clay (below GW)			0.44	0.10	1,172
3	PWR					
4	0					
5	0					
6	0					
7	0					

HDR Computation

Project: Charah Colon Mine Structural Fill	Computed By: TMY	Date:	10/27/2014
Subject: Permit Application	Checked By: **KP**	Date:	**10/29/2014**
Task: Settlement Calculation - Primary Consolidation Settlement	Sheet:	Of:	20

MW PZ-15 continued

Layer	Boring Log Description	Step 3, Continued	Step 4	
		Initial Vertical Effective Stress on Soil, σ_o (psf)	Recompression Index, C_r	Primary Consolidation Settlement of Clay Layer, Z_c (ft)
1	Very stiff, red, silty clay	433	0	0.48
2	Very hard, red, silty clay (below GW)	1,172	0	0.43
3	PWR			
4	0			
5	0			
6	0			
7	0			

Step 4: Total Estimated Primary Consolidation Settlement for MW PZ-15 0.91 ft

MW PZ-16

Layer	Boring Log Description	From Previous Calculation				
		Soil Symbol	H_o (ft)	Increment of Vertical Effective Stress, $\Delta\sigma$ (psf)	Vertical Stress at midpoint, $\sigma_{m\ soil}$ (psf)	Vertical Stress in soil layer, $\sigma_{soil\ layers}$ (psf)
1	Stiff, Strong brown, clayey silt	MH	2	4,213	109	217
2	Stiff, Yellowish-red, silty clay (above GW)	CL	6	4,213	371	741
3	Very hard, Red, silty clay (below GW)	CL	12	4,213	367	733
4	PWR	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0

HDR Computation

Project: Charah Colon Mine Structural Fill	Computed By: TMY	Date:	10/27/2014
Subject: Permit Application	Checked By: **KP**	Date: **10/29/2014**	
Task: Settlement Calculation - Primary Consolidation Settlement	Sheet:	Of:	20

MW PZ-16 continued

Layer	Boring Log Description	Step 1			Step 2	Step 3
		Minimum Void Ratio, e_{min}	Maximum Void Ratio, e_{max}	Initial Void Ratio, e_{oi}	Primary Compression Index, C_c	Preconsolidation Pressure, p_c (psf)
1	Stiff, Strong brown, clayey silt					109
2	Stiff, Yellowish-red, silty clay (above GW)			0.44	0.10	589
3	Very hard, Red, silty clay (below GW)			0.44	0.10	1,327
4	PWR					
5	0					
6	0					
7	0					

MW PZ-16 continued

Layer	Boring Log Description	Step 3, Continued	Step 4	
		Initial Vertical Effective Stress on Soil, σ_o (psf)	Recompression Index, C_r	Primary Consolidation Settlement of Clay Layer, Z_c (ft)
1	Stiff, Strong brown, clayey silt	109	0	0.00
2	Stiff, Yellowish-red, silty clay (above GW)	589	0	0.38
3	Very hard, Red, silty clay (below GW)	1,327	0	0.52
4	PWR			
5	0			
6	0			
7	0			

Step 4: Total Estimated Primary Consolidation Settlement for MW PZ-16 0.9 ft

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Settlement Calculation - Primary Consolidation Settlement	Sheet:		Of:	20

MW PZ-18

Layer	Boring Log Description	From Previous Calculation				
		Soil Symbol	H_o (ft)	Increment of Vertical Effective Stress, $\Delta\sigma$ (psf)	Vertical Stress at midpoint, $\sigma_{m\ soil}$ (psf)	Vertical Stress in soil layer, $\sigma_{soil\ layers}$ (psf)
1	Very stiff, Red, silty clay	CL	2	4,282	124	247
2	Hard, Red, clayey silt	MH	5	4,282	272	543
3	PWR	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0

MW PZ-18 continued

Layer	Boring Log Description	Step 1			Step 2	Step 3
		Minimum Void Ratio, e_{min}	Maximum Void Ratio, e_{max}	Initial Void Ratio, e_{oi}	Primary Compression Index, C_c	Preconsolidation Pressure, p_c (psf)
1	Very stiff, Red, silty clay			0.44	0.10	124
2	Hard, Red, clayey silt					
3	PWR					
4	0					
5	0					
6	0					
7	0					

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Settlement Calculation - Primary Consolidation Settlement	Sheet:		Of:	20

MW PZ-18 continued

Layer	Boring Log Description	Step 3, Continued	Step 4	
		Initial Vertical Effective Stress on Soil, σ_o (psf)	Recompression Index, C_r	Primary Consolidation Settlement of Clay Layer, Z_c (ft)
1	Very stiff, Red, silty clay	124	0	0.22
2	Hard, Red, clayey silt			
3	PWR			
4	0			
5	0			
6	0			
7	0			

Step 4: Total Estimated Primary Consolidation Settlement for MW PZ-18 0.22 ft

MW PZ-19

Layer	Boring Log Description	From Previous Calculation				
		Soil Symbol	H_o (ft)	Increment of Vertical Effective Stress, $\Delta\sigma$ (psf)	Vertical Stress at midpoint, $\sigma_{m\ soil}$ (psf)	Vertical Stress in soil layer, $\sigma_{soil\ layers}$ (psf)
1	Medium, Light brownish-gray, silty clay	CL	5	5,855	309	618
2	Hard, Yellowish-brown, clayey silt (below GW)	MH	10	5,855	231	461
3	PWR	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Settlement Calculation - Primary Consolidation Settlement	Sheet:		Of:	20

MW PZ-19 continued

Layer	Boring Log Description	Step 1			Step 2	Step 3
		Minimum Void Ratio, e_{min}	Maximum Void Ratio, e_{max}	Initial Void Ratio, e_{oi}	Primary Compression Index, C_c	Preconsolidation Pressure, p_c (psf)
1	Medium, Light brownish-gray, silty clay			0.44	0.10	309
2	Hard, Yellowish-brown, clayey silt (below GW)					
3	PWR					
4	0					
5	0					
6	0					
7	0					

MW PZ-19 continued

Layer	Boring Log Description	Step 3, Continued	Step 4	
		Initial Vertical Effective Stress on Soil, σ_o (psf)	Recompression Index, C_r	Primary Consolidation Settlement of Clay Layer, Z_c (ft)
1	Medium, Light brownish-gray, silty clay	309	0	0.45
2	Hard, Yellowish-brown, clayey silt (below GW)			
3	PWR			
4	0			
5	0			
6	0			
7	0			

Step 4: Total Estimated Primary Consolidation Settlement for MW PZ-19 0.45 ft

HDR Computation

Project: Charah Colon Mine Structural Fill	Computed By: TMY	Date:	10/27/2014
Subject: Permit Application	Checked By: **KP**	Date:	**10/29/2014**
Task: Settlement Calculation - Primary Consolidation Settlement	Sheet:	Of:	20

MW PZ-20

Layer	Boring Log Description	From Previous Calculation				
		Soil Symbol	H_o (ft)	Increment of Vertical Effective Stress, $\Delta\sigma$ (psf)	Vertical Stress at midpoint, $\sigma_{m\ soil}$ (psf)	Vertical Stress in soil layer, $\sigma_{soil\ layers}$ (psf)
1	Stiff, Red, sandy silty clay (above GW)	CL	10	3,108	618	1,235
2	Stiff, Red, sandy silty clay (below GW)	CL	8	3,108	245	489
3	PWR	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0

MW PZ-20 continued

Layer	Boring Log Description	Step 1			Step 2	Step 3
		Minimum Void Ratio, e_{min}	Maximum Void Ratio, e_{max}	Initial Void Ratio, e_{oi}	Primary Compression Index, C_c	Preconsolidation Pressure, p_c (psf)
1	Stiff, Red, sandy silty clay (above GW)			0.44	0.10	618
2	Stiff, Red, sandy silty clay (below GW)			0.44	0.10	1,481
3	PWR					
4	0					
5	0					
6	0					
7	0					

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Settlement Calculation - Primary Consolidation Settlement	Sheet:		Of:	20

MW PZ-20 continued

Layer	Boring Log Description	Step 3, Continued	Step 4	
		Initial Vertical Effective Stress on Soil, σ_o (psf)	Recompression Index, C_r	Primary Consolidation Settlement of Clay Layer, Z_c (ft)
1	Stiff, Red, sandy silty clay (above GW)	618	0	0.54
2	Stiff, Red, sandy silty clay (below GW)	1,481	0	0.27
3	PWR			
4	0			
5	0			
6	0			
7	0			

Step 4: Total Estimated Primary Consolidation Settlement for MW PZ-20 0.81 ft

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By: TMY	Date: 10/27/2014
Subject:	Permit Application	Checked By: KP	Date: 10/29/2014
Task:	Settlement Calculation - Secondary Compression Settlement	Sheet:	Of: 19

Steps - Secondary Consolidation (Clay Soils)

1. Estimate the water content (w_n)using the equation below and Table 6 (page 7.1-22) of Reference 1 (Attachment E). Estimate the secondary consolidation compression index (C_α) using Figure 16 (page 7.1-237) of Reference 1 (Attachment G) and the estimated water content (w_n).

$$w_n = \frac{\gamma_{wet} - \gamma_{dry}}{\gamma_{dry}}$$

2. Estimate the initial thickness of the clay layer before starting secondary consolidation settlement (H_{os}) using the initial layer thickness (H_o),the elastic settlement (Z_e), the primary consolidation settlement (Z_c) and the equation below.

$$H_{os} = H_o - Z_e - Z_c$$

3. Determine the secondary compression using the Equation 12.23 (page 470) below from Reference 3. Assume the initial void ratio of the clay layer before secondary consolidation settlement is equal to the minimum void ratio in Table 6 (page 7.1-22) of Reference 1 (Attachment E).

$$Z_\alpha = C_\alpha \times \frac{H_{os}}{1 + e_{os}} \times \log\frac{t_2}{t_1}$$

Where:

Z_α = long-term secondary compression (ft)

e_{os} = initial void ratio of clay layer before starting secondary consolidation settlement

C_α = secondary consolidation compression index

H_{os} = initial thickness of clay layer before starting secondary consolidation settlement (ft)

t_1 = starting time of the time period for which long-term settlement of the layer is desired

t_2 = ending time of the time period for which long-term settlement of the layer is desired

assume t_1 = 1 year

assume t_2 = 100 years

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	KP	Date:	10/29/2014
Task:	Settlement Calculation - Secondary Compression Settlement	Sheet:		Of:	19

4. Repeat Steps 1 - 3 for each clay layer. Add the secondary compression settlement for each clay layer together to get the total estimated secondary compression settlement at that location based on information from the boring logs, recent surveys, and seasonal high groundwater levels.

$$Z_{\alpha\ Total} = Z_{\alpha\ layer\ n} + Z_{\alpha\ layer\ n+1}$$

Calculations

MW PZ-3

Layer	Boring Log Description		From Previous Calculations				Step 1
			Initial Layer Thickness, H_o (ft)	Elastic Layer Settlement, Z_e (ft)	Primary Consolidation Settlement of Clay, Z_c (ft)	Wet Unit Weight, γ_{wet} (pcf)	Minimum dry unit weight, $\gamma_{dry\ min}$ (pcf)
1	Hard, Reddish-brown, clayey silt		3	0.07	0.00	109	
2	PWR		0	0.00	0.00	0	
3		0	0	0.00	0.00	0	
4		0	0	0.00	0.00	0	
5		0	0	0.00	0.00	0	
6		0	0	0.00	0.00	0	
7		0	0	0.00	0.00	0	

MW PZ-3 continued

Layer	Boring Log Description		Step 1, continued				Step 2
			Maximum dry unit weight, $\gamma_{dry\ max}$ (pcf)	Average dry unit weight, $\gamma_{dry\ avg}$ (pcf)	water content, w_n	Secondary Consolidation Compression Index, C_α	Initial Thickness of Clay Layer before Secondary Settlement, H_{os} (ft)
1	Hard, Reddish-brown, clayey silt						
2	PWR						
3		0					
4		0					
5		0					
6		0					
7		0					

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	KP	Date:	10/29/2014
Task:	Settlement Calculation - Secondary Compression Settlement	Sheet:		Of:	19

MW PZ-3 continued

Layer	Boring Log Description	Step 3	
		Initial Void Ratio of Clay before Secondary Settlement, e_{os}	Secondary Compression Settlement of Clay Layer, Z_α (ft)
1	Hard, Reddish-brown, clayey silt		
2	PWR		
3	0		
4	0		
5	0		
6	0		
7	0		

Step 4: Total Estimated Secondary Compression Settlement for MW PZ-3 0 ft

MW PZ-4

Layer	Boring Log Description	From Previous Calculations				Step 1
		Initial Layer Thickness, H_o (ft)	Elastic Layer Settlement, Z_e (ft)	Primary Consolidation Settlement of Clay, Z_c (ft)	Wet Unit Weight, γ_{wet} (pcf)	Minimum dry unit weight, $\gamma_{dry\ min}$ (pcf)
1	Stiff, Brownish-yellow, silty clay	5	0.11	1.15	114	50
2	Very stiff, Red, clayey silt	7	0.12	0.00	109	
3	PWR	0	0.00	0.00	0	
4	0	0	0.00	0.00	0	
5	0	0	0.00	0.00	0	
6	0	0	0.00	0.00	0	
7	0	0	0.00	0.00	0	

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Settlement Calculation - Secondary Compression Settlement	Sheet:		Of:	19

MW PZ-4 continued

Layer	Boring Log Description	Step 1, continued				Step 2
		Maximum dry unit weight, $\gamma_{dry\ max}$ (pcf)	Average dry unit weight, $\gamma_{dry\ avg}$ (pcf)	water content, w_n	Secondary Consolidation Compression Index, C_α	Initial Thickness of Clay Layer before Secondary Settlement, H_{os} (ft)
1	Stiff, Brownish-yellow, silty clay	112	81	0.40	0.004	3.74
2	Very stiff, Red, clayey silt					
3	PWR					
4	0					
5	0					
6	0					
7	0					

MW PZ-4 continued

Layer	Boring Log Description	Step 3	
		Initial Void Ratio of Clay before Secondary Settlement, e_{os}	Secondary Compression Settlement of Clay Layer, Z_α (ft)
1	Stiff, Brownish-yellow, silty clay	0.50	0.02
2	Very stiff, Red, clayey silt		
3	PWR		
4	0		
5	0		
6	0		
7	0		

Step 4: Total Estimated Secondary Compression Settlement for MW PZ-4 0.02 ft

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By: TMY		Date:	10/27/2014
Subject:	Permit Application	Checked By:	KP	Date:	10/29/2014
Task:	Settlement Calculation - Secondary Compression Settlement	Sheet:		Of:	19

MW PZ-6

Layer	Boring Log Description	From Previous Calculations				Step 1
		Initial Layer Thickness, H_o (ft)	Elastic Layer Settlement, Z_e (ft)	Primary Consolidation Settlement of Clay, Z_c (ft)	Wet Unit Weight, γ_{wet} (pcf)	Minimum dry unit weight, $\gamma_{dry\ min}$ (pcf)
1	Very stiff, Dark reddish-gray, silty clay (above GW)	7	0.19	0.53	124	60
2	Very stiff, Dark reddish-gray, silty clay (below GW)	3	0.06	0.16	124	60
3	PWR	0	0.00	0.00	0	
4	0	0	0.00	0.00	0	
5	0	0	0.00	0.00	0	
6	0	0	0.00	0.00	0	
7	0	0	0.00	0.00	0	

MW PZ-6 continued

Layer	Boring Log Description	Step 1, continued				Step 2
		Maximum dry unit weight, $\gamma_{dry\ max}$ (pcf)	Average dry unit weight, $\gamma_{dry\ avg}$ (pcf)	water content, w_n	Secondary Consolidation Compression Index, C_α	Initial Thickness of Clay Layer before Secondary Settlement, H_{os} (ft)
1	Very stiff, Dark reddish-gray, silty clay (above GW)	135	98	0.30	0.003	6.28
2	Very stiff, Dark reddish-gray, silty clay (below GW)	135	98	0.30	0.003	2.78
3	PWR					
4	0					
5	0					
6	0					
7	0					

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	KP	Date:	10/29/2014
Task:	Settlement Calculation - Secondary Compression Settlement	Sheet:		Of:	19

MW PZ-6 continued

Layer	Boring Log Description	Step 3	
		Initial Void Ratio of Clay before Secondary Settlement, e_{os}	Secondary Compression Settlement of Clay Layer, Z_α (ft)
1	Very stiff, Dark reddish-gray, silty clay (above GW)	0.25	0.03
2	Very stiff, Dark reddish-gray, silty clay (below GW)	0.25	0.01
3	PWR		
4	0		
5	0		
6	0		
7	0		

Step 4: Total Estimated Secondary Compression Settlement for MW PZ-6 0.04 ft

MW PZ-8

Layer	Boring Log Description	From Previous Calculations				Step 1
		Initial Layer Thickness, H_o (ft)	Elastic Layer Settlement, Z_e (ft)	Primary Consolidation Settlement of Clay, Z_c (ft)	Wet Unit Weight, γ_{wet} (pcf)	Minimum dry unit weight, $\gamma_{dry\ min}$ (pcf)
1	Very stiff, Red, gravelly silt (above GW)	7	0.07	0.00	109	
2	Very stiff, Red, gravelly silt (below GW)	2	0.02	0.00	109	
3	PWR	0	0.00	0.00	0	
4	0	0	0.00	0.00	0	
5	0	0	0.00	0.00	0	
6	0	0	0.00	0.00	0	
7	0	0	0.00	0.00	0	

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	KP	Date:	10/29/2014
Task:	Settlement Calculation - Secondary Compression Settlement	Sheet:		Of:	19

MW PZ-8 continued

Layer	Boring Log Description	Step 1, continued				Step 2
		Maximum dry unit weight, $\gamma_{dry\ max}$ (pcf)	Average dry unit weight, $\gamma_{dry\ avg}$ (pcf)	water content, w_n	Secondary Consolidation Compression Index, C_α	Initial Thickness of Clay Layer before Secondary Settlement, H_{os} (ft)
1	Very stiff, Red, gravelly silt (above GW)					
2	Very stiff, Red, gravelly silt (below GW)					
3	PWR					
4	0					
5	0					
6	0					
7	0					

MW PZ-8 continued

Layer	Boring Log Description	Step 3	
		Initial Void Ratio of Clay before Secondary Settlement, e_{os}	Secondary Compression Settlement of Clay Layer, Z_α (ft)
1	Very stiff, Red, gravelly silt (above GW)		0.00
2	Very stiff, Red, gravelly silt (below GW)		0.00
3	PWR		
4	0		
5	0		
6	0		
7	0		

Step 4: Total Estimated Secondary Compression Settlement for MW PZ-8 0 ft

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	KP	Date:	10/29/2014
Task:	Settlement Calculation - Secondary Compression Settlement	Sheet:		Of:	19

MW PZ-9

Layer	Boring Log Description	From Previous Calculations				Step 1
		Initial Layer Thickness, H_o (ft)	Elastic Layer Settlement, Z_e (ft)	Primary Consolidation Settlement of Clay, Z_c (ft)	Wet Unit Weight, γ_{wet} (pcf)	Minimum dry unit weight, $\gamma_{dry\ min}$ (pcf)
1	Stiff, Yellowish-brown, silty clay	4	0.09	0.32	124	60
2	Compact, Weak red, clayey sand (above GW)	3	0.05	0.00	115	
3	Compact, Weak red, clayey sand (below GW)	4	0.07	0.00	115	
4	PWR	0	0.00	0.00	0	
5	0	0	0.00	0.00	0	
6	0	0	0.00	0.00	0	
7	0	0	0.00	0.00	0	

MW PZ-9 continued

Layer	Boring Log Description	Step 1, continued				Step 2
		Maximum dry unit weight, $\gamma_{dry\ max}$ (pcf)	Average dry unit weight, $\gamma_{dry\ avg}$ (pcf)	water content, w_n	Secondary Consolidation Compression Index, C_α	Initial Thickness of Clay Layer before Secondary Settlement, H_{os} (ft)
1	Stiff, Yellowish-brown, silty clay	135	98	0.30	0.003	3.59
2	Compact, Weak red, clayey sand (above GW)					
3	Compact, Weak red, clayey sand (below GW)					
4	PWR					
5	0					
6	0					
7	0					

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	KP	Date:	10/29/2014
Task:	Settlement Calculation - Secondary Compression Settlement	Sheet:		Of:	19

MW PZ-9 continued

Layer	Boring Log Description	Step 3: Initial Void Ratio of Clay before Secondary Settlement, e_{os}	Step 3: Secondary Compression Settlement of Clay Layer, Z_{α} (ft)
1	Stiff, Yellowish-brown, silty clay	0.25	0.02
2	Compact, Weak red, clayey sand (above GW)		
3	Compact, Weak red, clayey sand (below GW)		
4	PWR		
5	0		
6	0		
7	0		

Step 4: Total Estimated Secondary Compression Settlement for MW PZ-9 0.02 ft

MW PZ-12

Layer	Boring Log Description	From Previous Calculations: Initial Layer Thickness, H_o (ft)	Elastic Layer Settlement, Z_e (ft)	Primary Consolidation Settlement of Clay, Z_c (ft)	Wet Unit Weight, γ_{wet} (pcf)	Step 1: Minimum dry unit weight, $\gamma_{dry\ min}$ (pcf)
1	PWR	0	0.00	0.00	0	
2	0	0	0.00	0.00	0	
3	0	0	0.00	0.00	0	
4	0	0	0.00	0.00	0	
5	0	0	0.00	0.00	0	
6	0	0	0.00	0.00	0	
7	0	0	0.00	0.00	0	

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	KP	Date:	10/29/2014
Task:	Settlement Calculation - Secondary Compression Settlement	Sheet:		Of:	19

MW PZ-12 continued

Layer	Boring Log Description	Step 1, continued				Step 2
		Maximum dry unit weight, $\gamma_{dry\ max}$ (pcf)	Average dry unit weight, $\gamma_{dry\ avg}$ (pcf)	water content, w_n	Secondary Consolidation Compression Index, C_α	Initial Thickness of Clay Layer before Secondary Settlement, H_{os} (ft)
1	PWR					
2	0					
3	0					
4	0					
5	0					
6	0					
7	0					

MW PZ-12 continued

Layer	Boring Log Description	Step 3	
		Initial Void Ratio of Clay before Secondary Settlement, e_{os}	Secondary Compression Settlement of Clay Layer, Z_α (ft)
1	PWR		
2	0		
3	0		
4	0		
5	0		
6	0		
7	0		

Step 4: Total Estimated Secondary Compression Settlement for MW PZ-12 0 ft

HDR Computation

Project: Charah Colon Mine Structural Fill	Computed By: TMY	Date:	10/27/2014
Subject: Permit Application	Checked By: KP	Date:	10/29/2014
Task: Settlement Calculation - Secondary Compression Settlement	Sheet:	Of:	19

MW PZ-13

Layer	Boring Log Description	From Previous Calculations				Step 1
		Initial Layer Thickness, H_o (ft)	Elastic Layer Settlement, Z_e (ft)	Primary Consolidation Settlement of Clay, Z_c (ft)	Wet Unit Weight, γ_{wet} (pcf)	Minimum dry unit weight, $\gamma_{dry\ min}$ (pcf)
1	Stiff, Red, sandy silt	6	0.06	0.00	109	
2	Very hard, red, silty clay (below GW)	15	0.27	0.69	124	60
3	PWR	0	0.00	0.00	0	
4	0	0	0.00	0.00	0	
5	0	0	0.00	0.00	0	
6	0	0	0.00	0.00	0	
7	0	0	0.00	0.00	0	

MW PZ-13 continued

Layer	Boring Log Description	Step 1, continued				Step 2
		Maximum dry unit weight, $\gamma_{dry\ max}$ (pcf)	Average dry unit weight, $\gamma_{dry\ avg}$ (pcf)	water content, w_n	Secondary Consolidation Compression Index, C_α	Initial Thickness of Clay Layer before Secondary Settlement, H_{os} (ft)
1	Stiff, Red, sandy silt					
2	Very hard, red, silty clay (below GW)	135	98	0.30	0.003	14.04
3	PWR					
4	0					
5	0					
6	0					
7	0					

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	KP	Date:	10/29/2014
Task:	Settlement Calculation - Secondary Compression Settlement	Sheet:		Of:	19

MW PZ-13 continued

Layer	Boring Log Description		Step 3	
			Initial Void Ratio of Clay before Secondary Settlement, e_{os}	Secondary Compression Settlement of Clay Layer, Z_{α} (ft)
1	Stiff, Red, sandy silt			
2	Very hard, red, silty clay (below GW)		0.25	0.07
3	PWR			
4		0		
5		0		
6		0		
7		0		

Step 4: Total Estimated Secondary Compression Settlement for MW PZ-13 0.07 ft

MW PZ-15

Layer	Boring Log Description		From Previous Calculations				Step 1
			Initial Layer Thickness, H_o (ft)	Elastic Layer Settlement, Z_e (ft)	Primary Consolidation Settlement of Clay, Z_c (ft)	Wet Unit Weight, γ_{wet} (pcf)	Minimum dry unit weight, $\gamma_{dry\ min}$ (pcf)
1	Very stiff, red, silty clay		7	0.14	0.48	124	60
2	Very hard, red, silty clay (below GW)		10	0.16	0.43	124	60
3	PWR		0	0.00	0.00	0	
4		0	0	0.00	0.00	0	
5		0	0	0.00	0.00	0	
6		0	0	0.00	0.00	0	
7		0	0	0.00	0.00	0	

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Settlement Calculation - Secondary Compression Settlement	Sheet:		Of:	19

MW PZ-15 continued

Layer	Boring Log Description	Step 1, continued				Step 2
		Maximum dry unit weight, $\gamma_{dry\ max}$ (pcf)	Average dry unit weight, $\gamma_{dry\ avg}$ (pcf)	water content, w_n	Secondary Consolidation Compression Index, C_α	Initial Thickness of Clay Layer before Secondary Settlement, H_{os} (ft)
1	Very stiff, red, silty clay	135	98	0.30	0.003	6.38
2	Very hard, red, silty clay (below GW)	135	98	0.30	0.003	9.41
3	PWR					
4	0					
5	0					
6	0					
7	0					

MW PZ-15 continued

Layer	Boring Log Description	Step 3	
		Initial Void Ratio of Clay before Secondary Settlement, e_{os}	Secondary Compression Settlement of Clay Layer, Z_α (ft)
1	Very stiff, red, silty clay	0.25	0.03
2	Very hard, red, silty clay (below GW)	0.25	0.05
3	PWR		
4	0		
5	0		
6	0		
7	0		

Step 4: Total Estimated Secondary Compression Settlement for MW PZ-15 0.08 ft

HDR Computation

Project: Charah Colon Mine Structural Fill	Computed By: TMY	Date:	10/27/2014
Subject: Permit Application	Checked By: KP	Date:	10/29/2014
Task: Settlement Calculation - Secondary Compression Settlement	Sheet:	Of:	19

MW PZ-16

Layer	Boring Log Description		From Previous Calculations				Step 1
			Initial Layer Thickness, H_o (ft)	Elastic Layer Settlement, Z_e (ft)	Primary Consolidation Settlement of Clay, Z_c (ft)	Wet Unit Weight, γ_{wet} (pcf)	Minimum dry unit weight, $\gamma_{dry\ min}$ (pcf)
1	Stiff, Strong brown, clayey silt		2	0.06	0.00	109	
2	Stiff, Yellowish-red, silty clay (above GW)		6	0.14	0.38	124	60
3	Very hard, Red, silty clay (below GW)		12	0.22	0.52	124	60
4	PWR		0	0.00	0.00	0	
5		0	0	0.00	0.00	0	
6		0	0	0.00	0.00	0	
7		0	0	0.00	0.00	0	

MW PZ-16 continued

Layer	Boring Log Description		Step 1, continued				Step 2
			Maximum dry unit weight, $\gamma_{dry\ max}$ (pcf)	Average dry unit weight, $\gamma_{dry\ avg}$ (pcf)	water content, w_n	Secondary Consolidation Compression Index, C_α	Initial Thickness of Clay Layer before Secondary Settlement, H_{os} (ft)
1	Stiff, Strong brown, clayey silt						
2	Stiff, Yellowish-red, silty clay (above GW)		135	98	0.30	0.003	5.48
3	Very hard, Red, silty clay (below GW)		135	98	0.30	0.003	11.26
4	PWR						
5		0					
6		0					
7		0					

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	KP	Date:	10/29/2014
Task:	Settlement Calculation - Secondary Compression Settlement	Sheet:		Of:	19

MW PZ-16 continued

Layer	Boring Log Description	Step 3	
		Initial Void Ratio of Clay before Secondary Settlement, e_{os}	Secondary Compression Settlement of Clay Layer, Z_α (ft)
1	Stiff, Strong brown, clayey silt		
2	Stiff, Yellowish-red, silty clay (above GW)	0.25	0.03
3	Very hard, Red, silty clay (below GW)	0.25	0.05
4	PWR		
5	0		
6	0		
7	0		

Step 4: Total Estimated Secondary Compression Settlement for MW PZ-16 0.08 ft

MW PZ-18

Layer	Boring Log Description	From Previous Calculations				Step 1
		Initial Layer Thickness, H_o (ft)	Elastic Layer Settlement, Z_e (ft)	Primary Consolidation Settlement of Clay, Z_c (ft)	Wet Unit Weight, γ_{wet} (pcf)	Minimum dry unit weight, $\gamma_{dry\ min}$ (pcf)
1	Very stiff, Red, silty clay	2	0.06	0.22	124	60
2	Hard, Red, clayey silt	5	0.12	0.00	109	
3	PWR	0	0.00	0.00	0	
4	0	0	0.00	0.00	0	
5	0	0	0.00	0.00	0	
6	0	0	0.00	0.00	0	
7	0	0	0.00	0.00	0	

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By: TMY		Date:	10/27/2014
Subject:	Permit Application	Checked By:	KP	Date:	10/29/2014
Task:	Settlement Calculation - Secondary Compression Settlement	Sheet:		Of:	19

MW PZ-18 continued

Layer	Boring Log Description	Step 1, continued				Step 2
		Maximum dry unit weight, $\gamma_{dry\ max}$ (pcf)	Average dry unit weight, $\gamma_{dry\ avg}$ (pcf)	water content, w_n	Secondary Consolidation Compression Index, C_α	Initial Thickness of Clay Layer before Secondary Settlement, H_{os} (ft)
1	Very stiff, Red, silty clay	135	98	0.30	0.003	1.72
2	Hard, Red, clayey silt					
3	PWR					
4	0					
5	0					
6	0					
7	0					

MW PZ-18 continued

Layer	Boring Log Description	Step 3	
		Initial Void Ratio of Clay before Secondary Settlement, e_{os}	Secondary Compression Settlement of Clay Layer, Z_α (ft)
1	Very stiff, Red, silty clay	0.25	0.01
2	Hard, Red, clayey silt		
3	PWR		
4	0		
5	0		
6	0		
7	0		

Step 4: Total Estimated Secondary Compression Settlement for MW PZ-18 0.01 ft

HDR Computation

Project: Charah Colon Mine Structural Fill	Computed By: TMY	Date:	10/27/2014
Subject: Permit Application	Checked By: **KP**	Date:	**10/29/2014**
Task: Settlement Calculation - Secondary Compression Settlement	Sheet:	Of:	19

MW PZ-19

Layer	Boring Log Description	From Previous Calculations				Step 1
		Initial Layer Thickness, H_o (ft)	Elastic Layer Settlement, Z_e (ft)	Primary Consolidation Settlement of Clay, Z_c (ft)	Wet Unit Weight, γ_{wet} (pcf)	Minimum dry unit weight, $\gamma_{dry\ min}$ (pcf)
1	Medium, Light brownish-gray, silty clay	5	1.37	0.45	124	60
2	Hard, Yellowish-brown, clayey silt (below GW)	10	0.32	0.00	109	
3	PWR	0	0.00	0.00	0	
4	0	0	0.00	0.00	0	
5	0	0	0.00	0.00	0	
6	0	0	0.00	0.00	0	
7	0	0	0.00	0.00	0	

MW PZ-19 continued

Layer	Boring Log Description	Step 1, continued				Step 2
		Maximum dry unit weight, $\gamma_{dry\ max}$ (pcf)	Average dry unit weight, $\gamma_{dry\ avg}$ (pcf)	water content, w_n	Secondary Consolidation Compression Index, C_α	Initial Thickness of Clay Layer before Secondary Settlement, H_{os} (ft)
1	Medium, Light brownish-gray, silty clay	135	98	0.30	0.003	3.18
2	Hard, Yellowish-brown, clayey silt (below GW)					
3	PWR					
4	0					
5	0					
6	0					
7	0					

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	KP	Date:	10/29/2014
Task:	Settlement Calculation - Secondary Compression Settlement	Sheet:		Of:	19

MW PZ-19 continued

Layer	Boring Log Description	Step 3	
		Initial Void Ratio of Clay before Secondary Settlement, e_{os}	Secondary Compression Settlement of Clay Layer, Z_α (ft)
1	Medium, Light brownish-gray, silty clay	0.25	0.02
2	Hard, Yellowish-brown, clayey silt (below GW)		
3	PWR		
4	0		
5	0		
6	0		
7	0		

Step 4: Total Estimated Secondary Compression Settlement for MW PZ-19 0.02 ft

MW PZ-20

Layer	Boring Log Description	From Previous Calculations				Step 1
		Initial Layer Thickness, H_o (ft)	Elastic Layer Settlement, Z_e (ft)	Primary Consolidation Settlement of Clay, Z_c (ft)	Wet Unit Weight, γ_{wet} (pcf)	Minimum dry unit weight, $\gamma_{dry\ min}$ (pcf)
1	Stiff, Red, sandy silty clay (above GW)	10	0.17	0.54	124	60
2	Stiff, Red, sandy silty clay (below GW)	8	0.11	0.27	124	60
3	PWR	0	0.00	0.00	0	
4	0	0	0.00	0.00	0	
5	0	0	0.00	0.00	0	
6	0	0	0.00	0.00	0	
7	0	0	0.00	0.00	0	

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	KP	Date:	10/29/2014
Task:	Settlement Calculation - Secondary Compression Settlement	Sheet:		Of:	19

MW PZ-20 continued

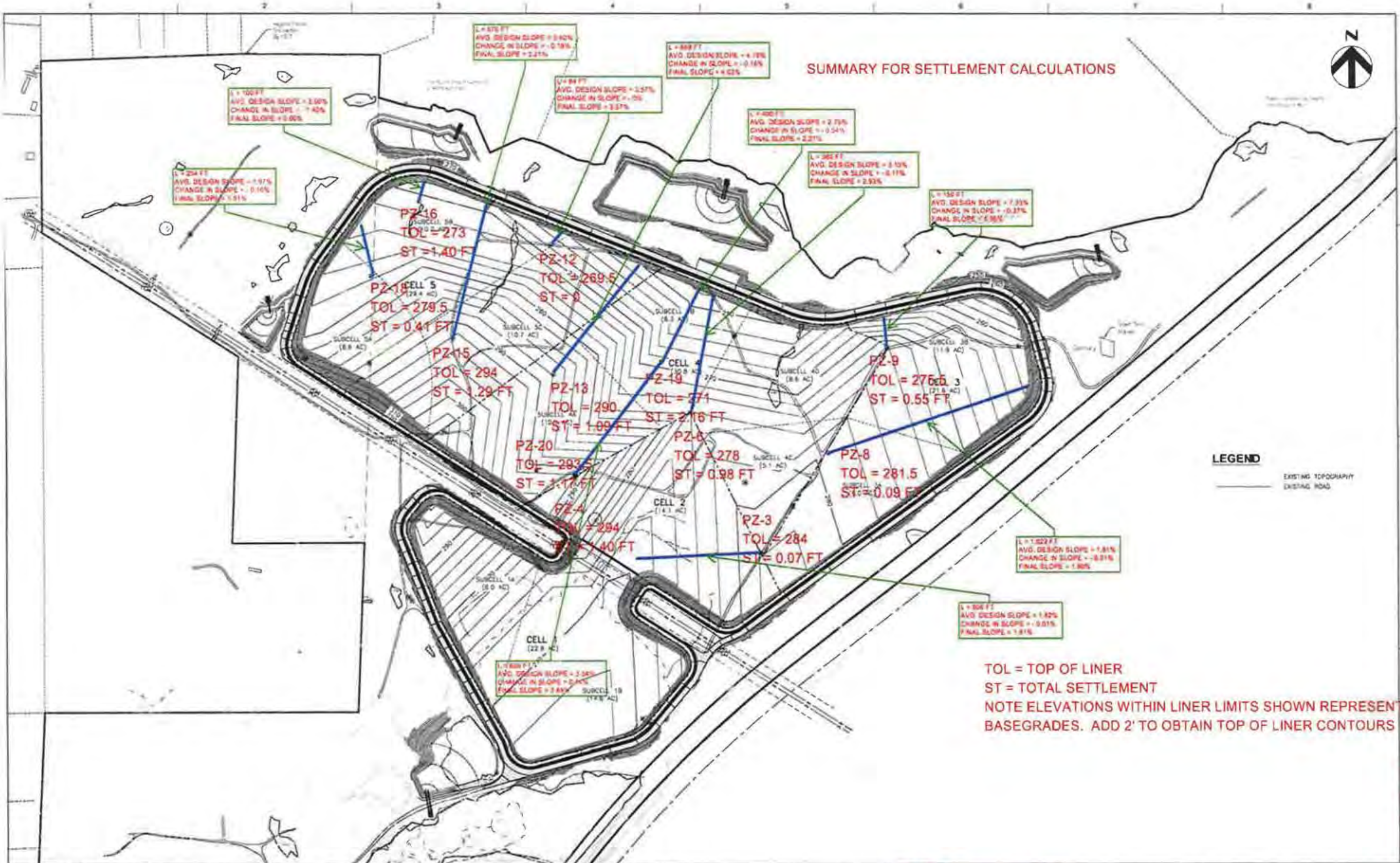
Layer	Boring Log Description	Step 1, continued				Step 2
		Maximum dry unit weight, $\gamma_{dry\ max}$ (pcf)	Average dry unit weight, $\gamma_{dry\ avg}$ (pcf)	water content, w_n	Secondary Consolidation Compression Index, C_α	Initial Thickness of Clay Layer before Secondary Settlement, H_{os} (ft)
1	Stiff, Red, sandy silty clay (above GW)	135	98	0.30	0.003	9.29
2	Stiff, Red, sandy silty clay (below GW)	135	98	0.30	0.003	7.62
3	PWR					
4	0					
5	0					
6	0					
7	0					

MW PZ-20 continued

Layer	Boring Log Description	Step 3	
		Initial Void Ratio of Clay before Secondary Settlement, e_{os}	Secondary Compression Settlement of Clay Layer, Z_α (ft)
1	Stiff, Red, sandy silty clay (above GW)	0.25	0.04
2	Stiff, Red, sandy silty clay (below GW)	0.25	0.04
3	PWR		
4	0		
5	0		
6	0		
7	0		

Step 4: Total Estimated Secondary Compression Settlement for MW PZ-20 0.08 ft

FIGURE 1



HDR

Charah

COLON MINE SITE STRUCTURAL FILL
SANFORD, NC

BASEGRADE PLAN
(BOTTOM OF SOIL LINER)

PROJECT MANAGER M.D. PLUMMER, P.E.

A 9/19/14 ISSUED FOR REVIEW

ISSUE DATE DESCRIPTION

PROJECT NUMBER

FILENAME 00C-03.dwg

SCALE 1"=200'

SHEET 00C-03

ATTACHMENT A

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Boring Log, PZ-3s and 3

(Page 1 of 1)

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

Date Started:	7/16/14
Date Completed:	7/16/14
Drilling Company:	Red Dog Drilling
Drillers Name:	Mark Seiler
NC Driller Certification:	2789A
Logged By:	Ross Kingman, P.G.
Drilling Method:	HSA; CME-45C
Top-of-Casing Elev.:	299.12'/299.29'
Ground Surface Elev.:	296.20'
Natural, Cut, Fill Grade:	slight cut

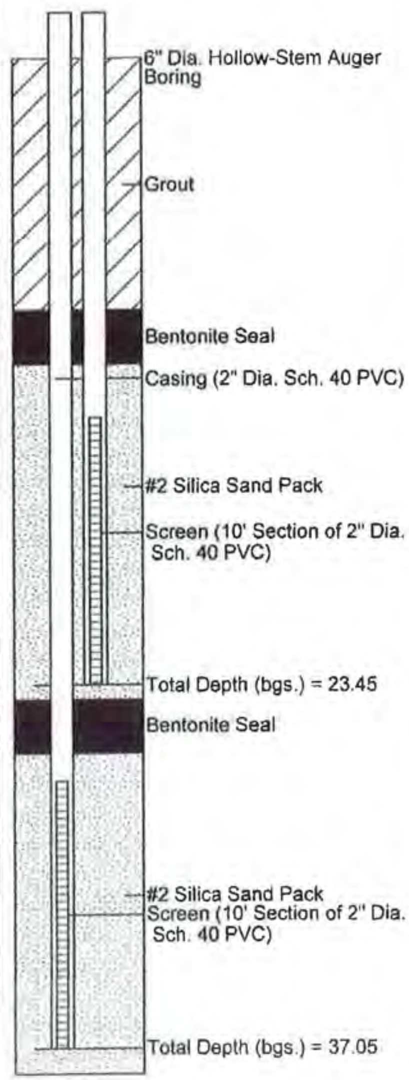
Water Levels
1 Hour = dry/36.11'bgs
24 Hours = dry/30.91' bgs

Sample Type
SS = Split Spoon
ST = Shelby Tube
RC = Rock Core
BAG = Bag Sample

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	296.2	4 6 8	SS,ST	16,24	moist; stiff; yellowish red (5YR 5/6) with light gray and orange yellow mottled; fine to coarse sandy gravelly clayey silt; low plasticity; cohesive; Soil Horizon; (Lab Results: PZ-3 UD (0-2'); USCS=CL; Sand=6.7%; Silt=52.8%; Clay=40.5%; Specific Gravity=2.67; Hydraulic Conductivity=2.42 x 10-6 cm/sec; Total Porosity=39.3%; Effectuve Porosity=2%; Atterberg Limits: PL=27, LL=48, PI=21)
5	291.2	7 8 11	SS	14	moist; very stiff; red (2.5YR 4/6) with white and brown specks; clayey fine to coarse sandy and gravelly silt; no plasticity; cohesive; Residuum
10	286.2	7 16 18	SS	14	dry; hard; reddish brown (2.5YR 5/4) with light orange and maroon mottles; clayey silt; no plasticity; cohesive; Residuum
15	281.2	15 44 50/3"	SS	16	moist; very hard; red (10R 5/6) with maroon mottles and vertical manganese fracture planes; clayey silt; no plasticity; cohesive; Partially Weathered Rock
20	276.2	50/6"	SS	7	dry; very hard; reddish brown (2.5YR 5/4) with olive green and white specks; fine to medium sandy silt with rock fragments; no plasticity; cohesive; Partially Weathered Rock
25	271.2	50/5"	SS	9	dry; very compact; reddish brown (2.5YR 5/4) with white and green specks; medium horizontal fissle; silty fine to coarse sand with gravel; no plasticity or cohesion; Partially Weathered Rock
30	266.2	50/2"	SS	5	dry; very hard; weak red (10R 5/3); highly horizontal fissle; fine mica sandy silt; no plasticity; cohesive; Partially Weathered Rock
35	261.2	50/5"	SS,BAG	6	moist; weak red (10R 4/3) with green, yellow and black specks and mottles; slightly clayey silty fine to coarse sand with phyllite gravel; no plasticity or cohesion; Partially Weathered Rock; (Lab Results: PZ-3 Bag (34-34.5'); USCS=SM; Gravel=12.8%; Sand=59.7%; Silt and Clay=27.5%; Effective Porosity=30%)
40	256.2				Auger Refual @ 38'
45					

Handwritten annotations: CL; CUT; MIX; PWR; TWL; 277.26

Well1: PZ-3s
Well2: PZ-3
TOC Elev.



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Boring Log, PZ-4

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

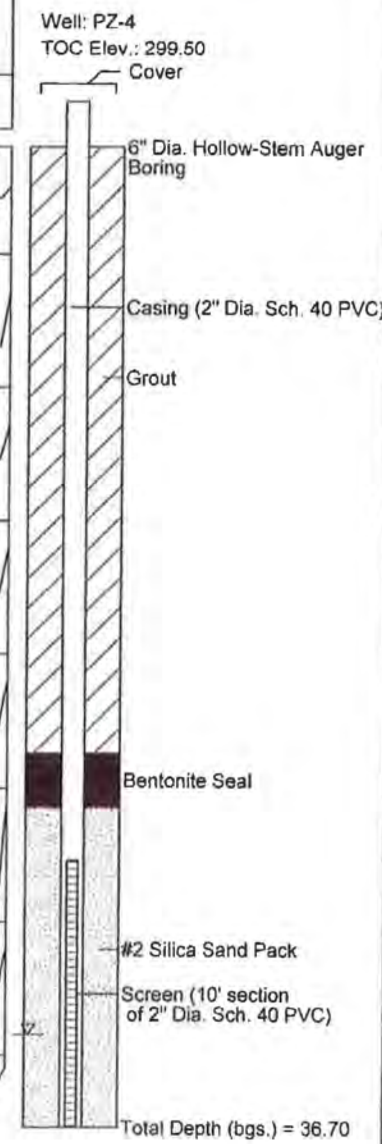
Date Started:	7/16/14	Logged By:	Ross Klingman, P.G.
Date Completed:	7/16/14	Drilling Method:	HSA; CME-45C
Drilling Company:	Red Dog Drilling	Top-of-Casing Elev.:	299.50'(Lawrence Survey)
Drillers Name:	Mark Seiler	Ground Surface Elev.:	296.82'(Lawrence Survey)
NC Driller Certification:	2789A	Natural, Cut, Fill Grade:	slight cut

Water Levels
▼ 1 Hour = dry
▽ 24 Hours = 33.22' bgs

Sample Type
SS = Split Spoon
ST = Shelby Tube
RC = Rock Core
BAG = Bag Sample

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	296.82	4 5 5	SS	14	moist; stiff; brownish yellow (10YR 6/8); fine to coarse sandy clayey silt with gravel; low plasticity; cohesive; Soil Horizon
5	291.82	4 5 6	SS,BAG	16	moist; stiff; brownish yellow (10YR 6/8) with rust mottles; silty clay; low plasticity; cohesive; Soil Horizon; (Lab Results: PZ-4 Bag (4-5.5'); USCS=CH; Sand=3.0%; Silt=50.9%; Clay=46.1%; Effective Porosity=2%; Atterberg Limits: PL=27, LL=60, PI=33)
10	286.82	9 9 12	SS	18	moist; very stiff; red (2.5YR 4/8) with olive green, rust, light gray and light purple mottled; gravelly clayey silt; no plasticity; cohesive; Residuum
15	281.82	27 50/5"	SS	12	dry; very hard; weak red (2.5YR 5/2) with light green specks; medium horizontal fissle; silt; no plasticity; cohesive; Partially Weathered Rock
20	276.82	29 50/3"	SS	12	dry; very hard; weak red (2.5YR 5/2) with white stringers and vertical black manganese fracture planes; silt; no plasticity; cohesive; Partially Weathered Rock
25	271.82	47 50/4"	SS, BAG	15	moist; very hard; red (2.5YR 4/6); highly horizontal fissle; very slightly clayey silt; no plasticity; cohesive; Partially Weathered Rock; (Lab Results: PZ-4 Bag (24-24.5'); USCS=CL; Sand=21.0%; Silt=61.6%; Clay=17.4%; Effective Porosity=11%; Atterberg Limits: PL=16, LL=31, PI=15)
30	266.82	34 50/2"	SS	20	moist; very hard; weak red (10R 4/2) with white, black and yellow specks and stringers; medium horizontal fissle; slightly clayey silt; no plasticity; cohesive; Partially Weathered Rock
35	261.82	50/0"	SS	0	No Recovery
40	256.82				
45					

Auger Refusal @ 36.7'



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Boring Log, PZ-6

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

Date Started:	7/17/14	Logged By:	Ross Klingman, P.G.
Date Completed:	7/17/14	Drilling Method:	HSA; CME-45C
Drilling Company:	Red Dog Drilling	Top-of-Casing Elev.:	286.13'(Lawrence Survey)
Drillers Name:	Mark Seiler	Ground Surface Elev.:	283.48'(Lawrence Survey)
NC Driller Certification:	2789A	Natural, Cut, Fill Grade:	slight cut

Water Levels
▼ 1 Hour = dry
▽ 24 Hours = 19.30' bgs

Sample Type
SS = Split Spoon
ST = Shelby Tube
RC = Rock Core
BAG = Bag Sample

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	283.48	3/5/8	SS	10	moist; medium compact; yellow (10YR 7/6); horizontal fissle; silt; no plasticity or cohesion; Soil Horizon
5	278.48	4/5/5	SS	13	moist; medium; pale yellow (2.5 Y 7/4) with light rust mottles; silty clay with roots; low plasticity; cohesive; Soil Horizon
10	273.48	7/11/15	SS	20	moist; very stiff; dark reddish gray (2.5YR 4/1) with white and yellow mottles; silty clay; low plasticity; cohesive; Residuum
			ST	7	moist; weak red (10R 4/4); clayey silt; no plasticity; cohesive; Residuum; (Lab Results: PZ-6 UD (10.5-11'); USCS=CL; Sand=11.3%, Silt=72.5%, Clay=16.2%; Specific Gravity=2.68; Hydraulic Conductivity=6.01 x 10-6 cm/sec; Total Porosity=30.7%; Effective Porosity=8%; Atterberg Limits: PL=23, LL=37, PI=14)
15	268.48	9/21/50/5"	SS	24	moist; very hard; red (2.5YR 4/6); fine to coarse sandy clayey silt with gravel and rock fragments; no plasticity; cohesive; Partially Weathered Rock
20	263.48	50/4"	SS,BAG	6	dry; very hard; dark reddish brown (2.5YR 4/1); silty medium to coarse sand with rounded phyllite gravel; no plasticity; cohesive; Partially Weathered Rock; (Lab Results: PZ-6 Bag (19-19.5'); USCS=SC; Sand=59.9%; Silt=27.1%; Clay=13.0%; Effective Porosity=16%; Atterberg Limits: PL=18, LL=33, PI=15)
25	258.48	50/1"	SS	1	moist; very hard; reddish brown (2.5YR 4/4); horizontal fissle; weathered mudstone; Partially Weathered Rock
30	253.48	50/.5"	SS	1	dry; very hard; weak red (2.5YR 5/2); horizontal fissle; sandy mudstone; Partially Weathered Rock
35	248.48	50/.5"	SS	1	dry; very hard; weak red (2.5YR 5/2); weathered silty conglomerate; Partially Weathered Rock
40	243.48				
45					

ML Cut JDL CL ▽ 270.64 PWR

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Boring Log, PZ-8

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

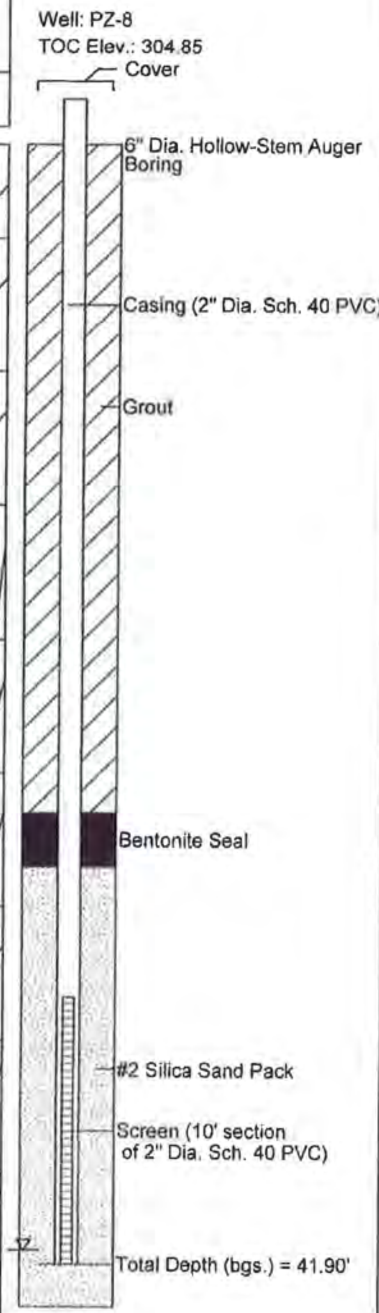
Date Started:	: 7/21/14	Logged By:	: Ross Klingman, P.G.
Date Completed:	: 7/21/14	Drilling Method:	: HSA; CME-550x
Drilling Company:	: Summit Engineering	Top-of-Casing Elev.:	: 304.85'(Lawrence Survey)
Drillers Name:	: Robert Cassell	Ground Surface Elev.:	: 302.56'(Lawrence Survey)
NC Driller Certification:	: 4143A	Natural, Cut, Fill Grade:	: slight cut

Water Levels
▼ 1 Hour = dry
▽ 24 Hours = 41.38' bgs

Sample Type
SS = Split Spoon
ST = Shelby Tube
RC = Rock Core
BAG = Bag Sample

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	302.56	4 5 8	SS	18	moist; stiff; strong brown (7.5Y 5/8) with white specks; silty clay; medium plasticity; cohesive; Residuum
5	297.56	3 4 6	SS	14	moist; stiff; red (2.5YR 4/6) with light orange mottles; silty clay; low plasticity; cohesive; Residuum
10	292.56	4 6 9	SS	15	moist; stiff; red (2.5YR 4/6); silty clay; low plasticity; cohesive; Residuum
15	287.56	10 13 13	SS,BAG	16	moist; very stiff; red (2.5YR 4/6) with orange mottles and black stringers; silty clay; low plasticity; cohesive; Residuum; (Lab Results: PZ-8 Bag (13.5-15'); USCS=CL; Sand=3.1%; Silt=68.1%; Clay=28.8%; Effective Porosity=3%; Atterberg Limits: PL=23, LL=39, PI=16)
20	282.56	9 13 17	SS	14	moist; very stiff; red (10R 4/8) with light gray and yellow mottles; clayey quartz and phyllite gravelly silt; no plasticity; cohesive; Residuum
25	277.56	8 13 15	SS	20	moist; very stiff; red (10R 4/6) with light gray and yellow mottles; clayey quartz and phyllite gravelly silt; no plasticity; cohesive; Residuum
30	272.56	9 27 50/5"	SS	20	moist; very hard; red (10R 4/8) with maroon mottles; silty clay; low plasticity; cohesive; Residuum
35	267.56	34 50/5"	SS	15	moist; very hard; red (10R 4/8) with maroon mottles; silty clay; low plasticity; cohesive; Residuum
40	262.56	50/5"	SS	12	dry; very compact; weak red (10R 4/4); clayey silty fine to coarse sand; no plasticity or cohesion; Partially Weathered Rock
45		50/5"	SS	10	moist; very hard; red (10R 4/8); highly horizontal fissle; silty clay; low plasticity; cohesive; Partially Weathered Rock

CL
CUT
TOC
ML
▽ 274.75
PWR



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Boring Log, PZ-9s and 9

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

Date Started:	7/21/14	Logged By:	Ross Klingman, P.G.
Date Completed:	7/21/14	Drilling Method:	HSA; CME-550x
Drilling Company:	Summit Engineering	Top-of-Casing Elev.:	288.11'/288.11'
Drillers Name:	Robert Cassell	Ground Surface Elev.:	285.74'
NC Driller Certification:	4143A	Natural, Cut, Fill Grade:	slight cut

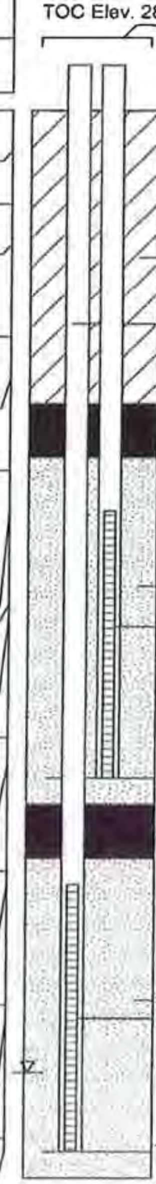
Water Levels
1 Hour = dry/dry
24 Hours = dry/36.03' bgs

Sample Type
SS = Split Spoon
ST = Shelby Tube
RC = Rock Core
BAG = Bag Sample

Well1: PZ-9s
Well2: PZ-9
TOC Elev. 288.11';

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	285.74	3 4 6	SS	16	moist; stiff; yellowish red (5YR 5/6) with rust mottles; silty clay; low plasticity; cohesive; Soil Horizon
5	280.74	3 4 8	SS	16	moist; stiff; light yellow brown (2.5 Y 6/3) with light orange mottles; silty clay; low plasticity; cohesive; Soil Horizon
10	275.74	3 4 7	SS	16	moist; stiff; light yellowish brown (2.5Y 6/3) with rust and maroon mottles; silty clay; low plasticity; cohesive; Soil Horizon
15	270.74	12 15 32	SS,BAG	22	dry; compact; weak red (10R 4/3) with white and gray specks; silty fine to coarse sand with phyllite gravel; no plasticity or plasticity; Residuum; (Lab Results: PZ-9 Bag (13.5-15'); USCS=SC; Gravel=0.4%; Sand=52.2; Silt=35.9; Clay=11.5%; Effective Porosity=17; Atterberg Limits: PL=20, LL=34, PI=14)
20	265.74	50/5"	SS	8	dry; very hard; weak red (10R 4/3); highly horizontal fissle; fine sandy silt; no plasticity; cohesive; Partially Weathered Rock
25	260.74	34 50/4"	SS	8	dry; very compact; weak red (10R 4/3) with white and gray specks; silty fine to coarse sand with phyllite gravel; no plasticity or cohesion; Partially Weathered Rock
30	255.74	50/5"	SS	8	dry; very compact; weak red (10R 4/3) with white and gray specks; silty fine to coarse sand with phyllite gravel; no plasticity or cohesion; Partially Weathered Rock
35	250.74	50/5"	SS	4	dry; very compact; weak red (10R 4/3) with white and gray specks; medium horizontal fissle; silty fine to coarse sand with phyllite gravel; no plasticity or cohesion; Partially Weathered Rock
40	245.74	50/5"	SS	8	dry; very hard; reddish brown (2.5YR 4/4); highly horizontal fissle, weathered mudstone; Partially Weathered Rock
45					

CL CUT SC 269.07 PWR



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Boring Log, PZ-12

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

Date Started: : 7/22/14
Date Completed: : 7/22/14
Drilling Company: : Summit Engineering
Drillers Name: : Robert Cassell
NC Driller Certification: : 4143A

Logged By: : Ross Klingman, P.G.
Drilling Method: : HSA; CME-550x
Top-of-Casing Elev.: : 287.15'(Lawrence Survey)
Ground Surface Elev.: : 284.32'(Lawrence Survey)
Natural, Cut, Fill Grade: : natural

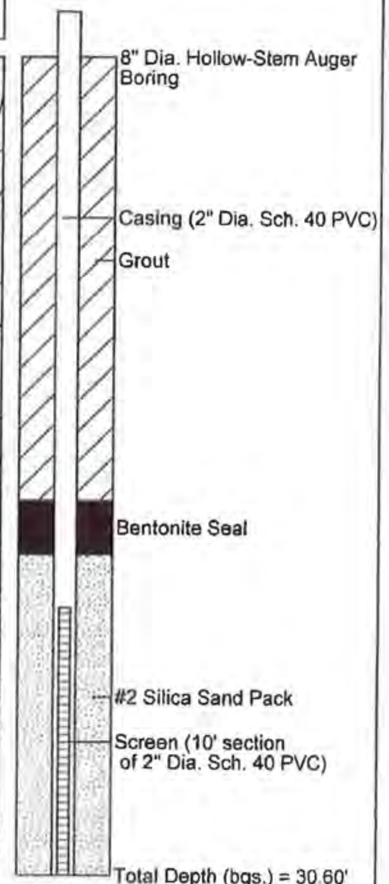
Water Levels
1 Hour = dry
24 Hours = dry

Sample Type
SS = Split Spoon
ST = Shelby Tube
RC = Rock Core
BAG = Bag Sample

Well: PZ-12
TOC Elev.: 287.15

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	284.32	2 3 4	SS	16	moist; medium; yellowish red (5YR 5/8) with brown mottles; clayey, quartz gravelly silt and silty clay; low plasticity; cohesive; Soil Horizon
5	279.32	4 5 8	SS	14	moist; stiff; reddish yellow (7.5YR 6/8) with rust and light gray mottles; silty clay; medium plasticity; cohesive; Soil Horizon
10	274.32	3 4 7	SS	13	moist; stiff; red (2.5YR 4/6) with green and black specks; fine to medium sandy clayey silt; low plasticity; cohesive; Residuum
15	269.32	5 26 50/4"	SS	15	moist; very hard; red (2.5YR 4/6) with green and black specks; medium horizontal fissle; mica sandy clayey silt; no plasticity; cohesive; Partially Weathered Rock
20	264.32	12 12 16	SS,BAG	21	moist; very stiff; red (2.5YR 4/6) with purple mottles; blocky; silty clay; no plasticity; cohesive; Residuum; (Lab Results: PZ-12 Bag (18.5-20'); USCS=CL; Sand=0.7%; Silt=66.5%; Clay=32.8%; Effective Porosity=2%; Atterberg Limits: PL=20, LL=42, PI=22)
25	259.32	50/3"	SS	8	dry; very hard; red (2.5YR 5/6); horizontal fissle; weathered fine sandy mudstone; Partially Weathered Rock
30	25[illegible].32 253.72	50/3"	SS	10	dry; very hard; red (2.5YR 5/6); horizontal fissle; weathered fine sandy mudstone; Partially Weathered Rock
35	249.32				
40	244.32				
45					

CL CUT MH PWR TOL



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Boring Log, PZ-13

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

Date Started:	7/22/14	Logged By:	Ross Klingman, P.G.
Date Completed:	7/22/14	Drilling Method:	HSA; CME-550x
Drilling Company:	Summit Engineering	Top-of-Casing Elev.:	296.59'(Lawrence Survey)
Drillers Name:	Robert Cassell	Ground Surface Elev.:	293.48'(Lawrence Survey)
NC Driller Certification:	4143A	Natural, Cut, Fill Grade:	natural

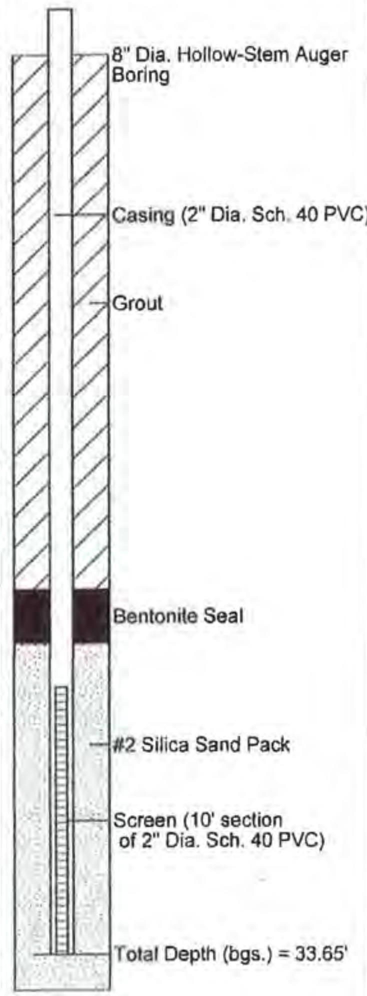
Water Levels
▼ 1 Hour = dry
▽ 24 Hours = dry

Sample Type
SS = Split Spoon
ST = Shelby Tube
RC = Rock Core
BAG = Bag Sample

Well: PZ-12
TOC Elev.: 296.59

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	293.48	3 3 5	SS,BAG	10	moist; medium compact; brownish yellow (10YR 6/6) with white specks; clayey silty quartz sandy gravel; no plasticity or cohesion; Soil Horizon; (Lab Results: PZ-13 Bag (0-1.5'); USCS=SC-SM; Gravel=36.1%; Sand=37.2%; Silt=19.4%; Clay=7.3%; Effective Porosity=25%; Atterberg Limits: PL=17, LL=21, PI=4)
		4 6 6	SS	21	moist; stiff; red (2.5YR 4/6); fine to medium sandy silt and silty clay layers; low plasticity; cohesive; Residuum
5	288.48				
		17 50/5"	SS	6	moist; very hard; red (2.5YR 4/6); silty clay with large quartz gravel; no plasticity; cohesive; Residuum
10	283.48				
		11 17 50/6"	SS	24	moist; very hard; weak red (10R 5/3) with light green mottles; medium horizontal fissle; silty clay; no plasticity; cohesive; Residuum
15	278.48				
		11 15 22	SS	20	moist; hard; pinkish gray (7.5YR 6/2) with black vertical and 45 degree planes; medium horizontal fissle; silty clay; no plasticity; cohesive; Residuum
20	273.48				
		11 50/6"	SS	18	moist; very hard; gray (7.5YR 5/1); medium horizontal fissle; silty clay; no plasticity; cohesive; Partially Weathered Rock
25	268.48				
		11 15 50/5"	SS	22	moist; very hard; gray (7.5YR 5/1); medium horizontal fissle; silty clay; no plasticity; cohesive; Residuum
30	263.48				
		50/1"	SS	3	dry; very hard; dark blueish gray (Gley 2 4/1); weathered mudstone; Partially Weathered Rock
35	258.48				
40	253.48				
45					

Auger Refusal @ 35'



SC-SM CUT TOC ML 283.40 CL PWR

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Boring Log, PZ-15s and 15

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

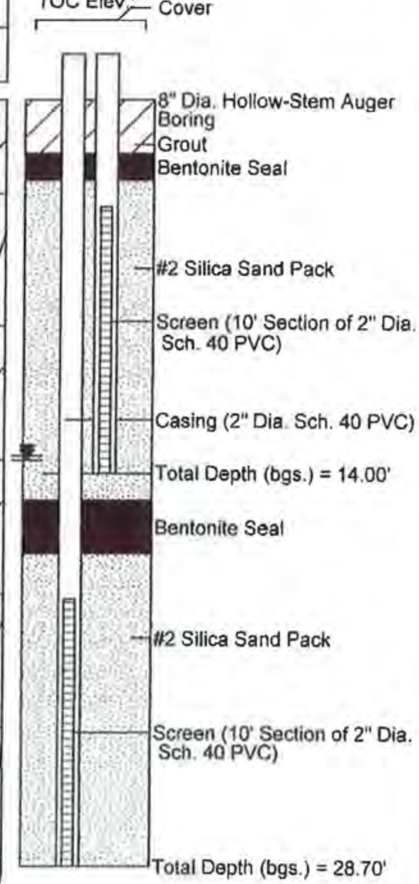
Date Started:	7/23/14	Logged By:	Ross Klingman, P.G.
Date Completed:	7/23/14	Drilling Method:	HSA; CME-550x
Drilling Company:	Summit Engineering	Top-of-Casing Elev.:	303.11'/303.24'
Drillers Name:	Robert Cassell	Ground Surface Elev.:	300.63'
NC Driller Certification:	4143A	Natural, Cut, Fill Grade:	natural

Water Levels
▼ 1 Hour = 13.48'/15.34' bgs
▽ 24 Hours = 13.65'/13.31' bgs

Sample Type
SS = Split Spoon
ST = Shelby Tube
RC = Rock Core
BAG = Bag Sample

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	300.63	5 6 6	SS	18	moist; medium; yellowish red (7.5YR 6/6); coarse quartz sandy silty clay; medium plasticity; cohesive; Soil Horizon
5	295.63	5 7 11	SS	20	moist; very stiff; yellow (10YR 7/6) with rust and orange mottles; coarse quartz sandy silty clay; low plasticity; cohesive; Soil Horizon
10	290.63	7 9 13	SS	21	moist; very stiff; red (2.5YR 4/6) with light gray and yellow mottles; silty clay; medium plasticity; cohesive; Residuum
15	285.63	12 17 28	SS	18	moist; hard; red (10R 4/6) with white specks; blocky; silty clay; low plasticity; cohesive; Residuum
20	280.63	24 50/4"	SS	18	moist; very hard; red (2.5YR 4/6) with white specks; blocky; silty clay; low plasticity; cohesive; Residuum
25	275.63	50/6"	SS,BAG	16	wet; very hard; red (10R 4/6) with white specks; medium horizontal fissle; silty clay; low plasticity; cohesive; Partially Weathered Rock; (Lab Results: PZ-15 Bag (23.5-24'): USCS=CL; Gravel=0.7%; Sand=4.5%; Silt=52.8%; Clay=19.9%; Effective Porosity=8; Atterberg Limits: PI=16, LL=32, PI=16)
30	270.63	50/5"	SS	18	wet; very hard; weak red (10R 5/4) with light gray specks; highly horizontal fissle; weathered mudstone; Partially Weathered Rock
35	265.63				
40	260.63				
45					

Well1: PZ-15s
Well2: PZ-15



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Boring Log, PZ-16

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

Date Started:	7/23/14	Logged By:	Ross Klingman, P.G.
Date Completed:	7/23/14	Drilling Method:	HSA; CME-550x
Drilling Company:	Summit Engineering	Top-of-Casing Elev.:	272.78'(Lawrence Survey)
Drillers Name:	Robert Cassell	Ground Surface Elev.:	270.63'(Lawrence Survey)
NC Driller Certification:	4143A	Natural, Cut, Fill Grade:	natural (drainage bottom)

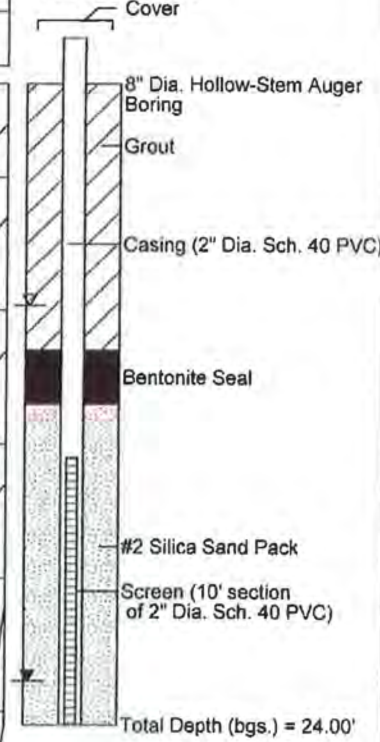
Water Levels
▼ 1 Hour = 22.35' bgs
▽ 24 Hours = 8.33' bgs

Sample Type
SS = Split Spoon
ST = Shelby Tube
RC = Rock Core
BAG = Bag Sample

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	270.63	4 5 6	SS	24	moist; stiff; strong brown (7.5YR 5/6) with white specks; quartz gravelly clayey silt; no plasticity; cohesive; Soil Horizon
5	265.63	3 5 5	SS	16	moist; stiff; yellowish red (5YR 4/6) with light gray mottles; silty clay; low plasticity; cohesive; Soil Horizon
10	260.63	32 35 39	SS	14	dry; very hard; dark red (10R 3/6); horizontal fissle; weathered mudstone; Residuum
15	255.63	17 31 50/5"	SS	16	moist; very hard; red (10R 4/6) with purple mottles; mica sandy silty clay; no plasticity; cohesive; Residuum
20	250.63	24 50/5"	SS,BAG	10	moist; very hard; red (10R 4/6) with purple mottles; silty clay; no plasticity; cohesive; Partially Weathered Rock; (Lab Results: PZ-16 Bag (18.5-20'): USCS=CL; Sand=3.1%; Silt=65.5%; Clay=31.4%; Effective Porosity=3; Atterberg Limits: PI=19, LL=38, PI=19)
25	245.63	50/3"	SS	6	wet; very hard; red (10R 4/6) with purple mottles; highly horizontal fissle; silty clay; no plasticity; cohesive; Partially Weathered Rock
30	240.63				
35	235.63				
40	230.63				
45					

223 FILL MH TOC 262.23 CL PWR

Well: PZ-16
TOC Elev.: 272.78



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Boring Log, PZ-18

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

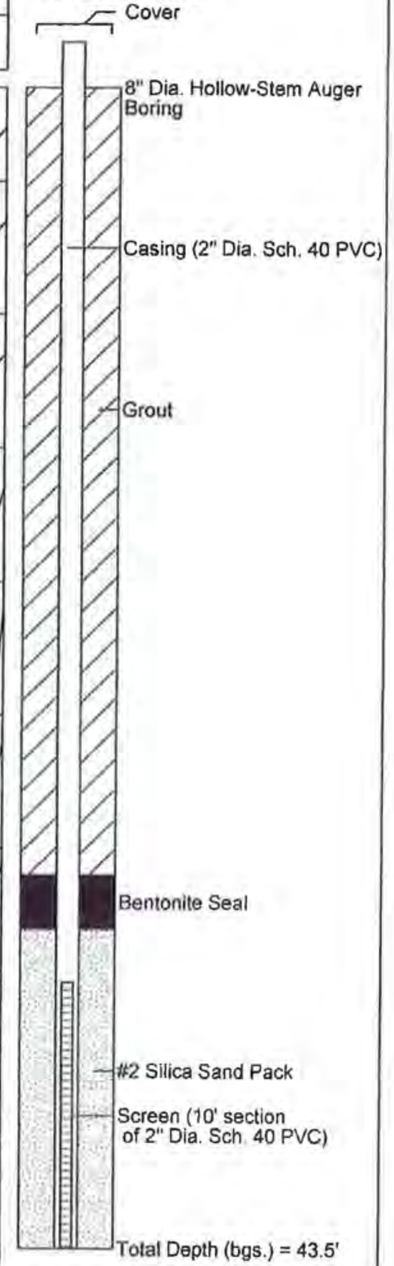
Date Started:	7/23/14	Logged By:	Ross Klingman, P.G.
Date Completed:	7/23/14	Drilling Method:	HSA; CME-550x
Drilling Company:	Summit Engineering	Top-of-Casing Elev.:	294.72'(Lawrence Survey)
Drillers Name:	Robert Cassell	Ground Surface Elev.:	292.27'(Lawrence Survey)
NC Driller Certification:	4143A	Natural, Cut, Fill Grade:	natural

Water Levels
▼ 1 Hour = dry
▽ 24 Hours = dry

Sample Type
SS = Split Spoon
ST = Shelby Tube
RC = Rock Core
BAG = Bag Sample

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	292.27	[illegible] 5	SS	22	moist; medium, brownish yellow (10R 6/6); slightly clayey silt; no plasticity; cohesive; Soil Horizon
5	287.27	4 4 5	SS	16	moist; stiff; reddish yellow (7.5YR 6/8) with tan and rust mottles; silty clay; medium plasticity; cohesive; Soil Horizon
10	282.27	5 7 12	SS	15	moist; very stiff; red (10R 4/8) with light green gray mottles; silty clay; low plasticity; cohesive; Residuum
15	277.27	27 21 24	SS	18	moist; hard; red (10R 4/8) with light green gray mottles; highly horizontal fissle; very fine sandy clayey silt; no plasticity; cohesive; Residuum
20	272.27	40 50/3"	SS,BAG	12	moist; very hard; red (10R 4/8) with light green gray mottles; highly horizontal fissle; very fine sandy clayey silt; no plasticity; cohesive; Partially Weathered Rock; (Lab Results: PZ-18 Bag (18.5-19.5'); USCS=CL; Sand=24.4%; Silt=55.7%; Clay=19.9%; Effective Porosity=8%; Atterberg Limits: PL=17, LL=32, PI=15)
25	267.27	9 50/3"	SS	10	moist; very hard; red (10R 4/8) with black horizontal planes; blocky and medium horizontal fissle; silty clay; no plasticity; cohesive; Partially Weathered Rock
30	262.27	50/6"	SS	6	moist; very hard; red (10R 4/8); highly horizontal fissle; weathered mudstone; Partially Weathered Rock
35	257.27	50/3"	SS	6	dry; very hard; weak red (10R 4/3); highly horizontal fissle; fine mica sandy silt; no plasticity; cohesive; Partially Weathered Rock
40	252.27	50/3"	SS	5	moist; very hard; red (10R 4/8); highly horizontal fissle; weathered mudstone; Partially Weathered Rock
45		50/3"	SS	4	moist; very hard; red (10R 4/8) with purple mottles; blocky; weathered mudstone; Partially Weathered Rock

Well: PZ-18
TOC Elev.: 294.72



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Boring Log, PZ-19

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

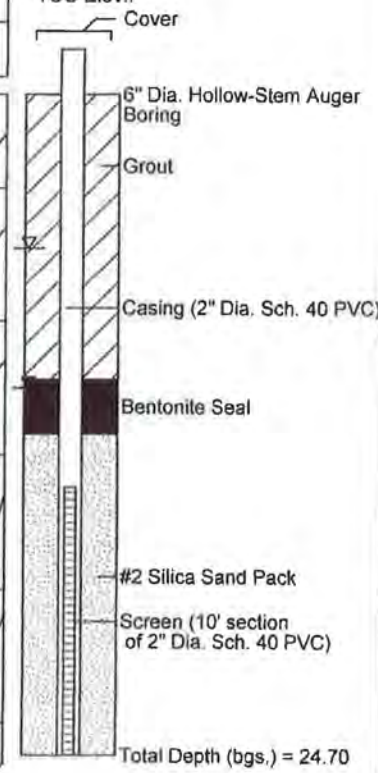
Date Started:	: 8/29/14	Logged By:	: Ross Klingman, P.G.
Date Completed:	: 8/29/14	Drilling Method:	: HSA; Geoprobe 7822
Drilling Company:	: Environmental Drilling & Probing	Top-of-Casing Elev.:	: (Lawrence Survey)
Drillers Name:	: Tommy Bolyard	Ground Surface Elev.:	: 265.99'(Lawrence Survey)
NC Driller Certification:	: 3307	Natural, Cut, Fill Grade:	: slight cut

Water Levels
- ▼ 1 Hour = 11.00' bgs
- ▽ 24 Hours = 5.75' bgs

Sample Type
- SS = Split Spoon
- ST = Shelby Tube
- RC = Rock Core
- BAG = Bag Sample

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	265.99	3 3 3 3	SS	24	wet; medium; light brownish gray (10YR 6/2) with light orange mottles; silty clay; medium plasticity; cohesive; Soil Horizon
5	260.99	1 1 1 2	SS	18	wet; soft; light brownish gray (10YR 6/2) with light orange mottles; silty clay; medium plasticity; cohesive; Soil Horizon
10	255.99	15 20 27	SS	17	moist; hard; yellowish brown (10YR 5/4); medium horizontal fissle; clayey silt; no plasticity; cohesive; Residuum
15	250.99	6 18 50/4"	SS	24	moist; very hard; yellowish brown (10YR 5/4) with black manganese planes; medium horizontal fissle; clayey silt; no plasticity; cohesive; Residuum
20	245.99	24 50/3"	SS	10	dry; very hard; brown (10YR 5/3); highly horizontal fissle; weathered mudstone; Partially Weathered Rock
25	240.99	14 14 50/3"	SS	12	wet; very hard; reddish brown (5YR 4/3); medium horizontal fissle; weathered mudstone; Partially Weathered Rock
30	235.99				
35	230.99				
40	225.99				
45					

Well: PZ-19
TOC Elev.:



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Boring Log, PZ-20

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

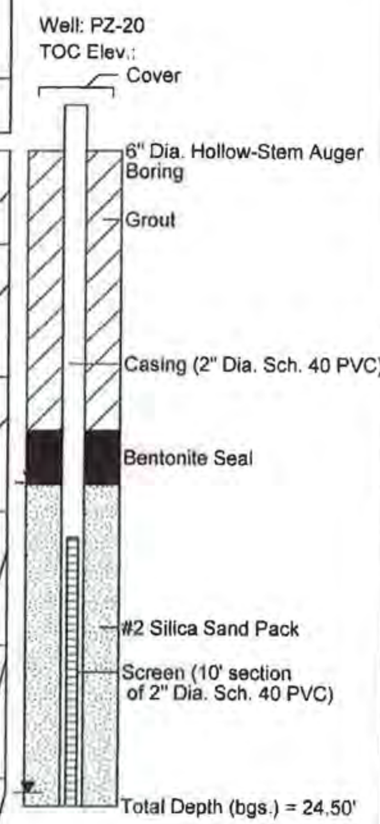
Date Started:	8/29/14	Logged By:	Ross Klingman, P.G.
Date Completed:	8/29/14	Drilling Method:	HSA; Geoprobe 7822
Drilling Company:	Environmental Drilling & Probing	Top-of-Casing Elev.:	(Lawrence Survey)
Drillers Name:	Tommy Bolyard	Ground Surface Elev.:	296.51'(Lawrence Survey)
NC Driller Certification:	3307	Natural, Cut, Fill Grade:	natural

Water Levels
▼ 1 Hour = 24.00' bgs
∇ 24 Hours = 12.44' bgs

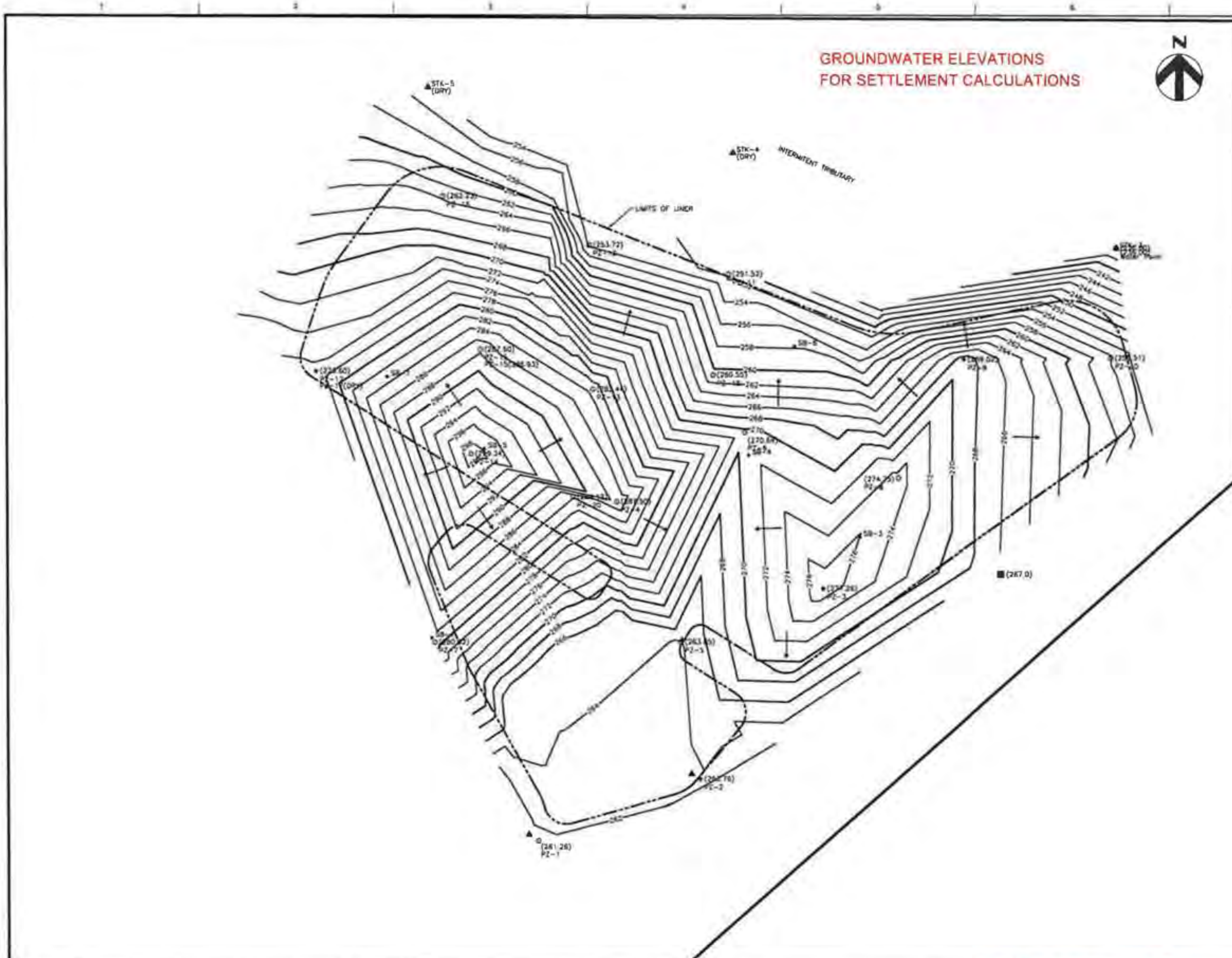
Sample Type
SS = Split Spoon
ST = Shelby Tube
RC = Rock Core
BAG = Bag Sample

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	296.51	3 3 3	SS	24	moist; medium; Red (2.5YR 4/6) with yellow mottles; fine sandy silty clay; low plasticity; cohesive; Soil Horizon
5	291.51	2 4 5	SS	24	moist; stiff; red (2.5YR 4/6) with yellow mottles; fine sandy silty clay; low plasticity; cohesive; Soil Horizon
10	286.51	5 5 6	SS	20	moist; stiff; red (2.5YR 4/6) with yellow mottles; mica sandy silty clay; low plasticity; cohesive; Soil Horizon
15	281.51	4 5 7	SS	18	very moist; stiff; weak red (10R 4/4) with white and light gray specks; phyllite and quartz gravelly sandy silty clay; no plasticity; cohesive; Residuum
20	276.51	50/3"	SS	8	dry; very hard; weak red (10R 4/4) with white and light gray specks; weathered mudstone; Partially Weathered Rock
25	271.51	50/4"	SS	8	wet; very hard; red (10R 4/6); highly horizontal fissle; mica sandy clayey silt; no plasticity; cohesive; Partially Weathered Rock
30	266.51				
35	261.51				
40	256.51				
45					

CUT TOC CL 284.12 PWR



ATTACHMENT B



NOTES:

1. SURVEY BASE MAP PREPARED BY LAWRENCE SURVEYING OF MONROE DATED AUGUST 21, 2014.
2. GROUNDWATER POTENTIOMETRIC CONTOURS GENERATED UTILIZING AUTOCAD DRAFTING AND INTERPOLATION SOFTWARE BY HDR ENGINEERING, INC. WITH OVERSIGHT BY ROSS KLINGMAN, P.E. WITH BUXTON ENGINEERING, INC.
3. GROUNDWATER CONTOURS WERE GENERATED WITH THE SHALLOWEST DEPTH BASED ON WATER LEVEL READINGS COLLECTED ON JULY 28 AND 29 2014, AUGUST 8 2014, AUGUST 21 2014 AND SEPTEMBER 3 2014. THE MOST ELEVATED GROUNDWATER LEVEL OCCURED ON AUGUST 21, 2014.
4. PIEZOMETER AVAILABLE INDICATING STABILIZED WATER LEVEL, POND AND TRIBUTARY SURFACE WATER ELEVATIONS AND CONSERVATIVE INFERRED WATER LEVELS AT PIEZOMETER PZ-10 (~10 FEET BELOW GROUND SURFACE) INFERRED DEPTH TO WATER LEVELS ALONG FIVE DRAINAGE FEATURES (~3 FEET BELOW GROUND SURFACE) ON NORTH AND WEST SIDE OF SITE, A GROUNDWATER ELEVATION OF 253; AT PZ-12 AND AN INFERRED WETLAND GROUNDWATER ELEVATION OF 267.0 (~5 FEET BELOW GROUND SURFACE) ON EAST PROPERTY BOUNDARY. WATER LEVELS @ PZ-19 AND PZ-20 OBTAINED ON SEPTEMBER 3, 2014

LEGEND

⊙	SINGLE SHALLOW OR INTERMEDIATE PIEZOMETER
⊕	NESTED SHALLOW AND INTERMEDIATE PIEZOMETER PAIR
⊕	NESTED INTERMEDIATE AND DEEP PIEZOMETER PAIR (WITH ROCK CORE)
•	GEOTECHNICAL SOIL BORING (GEOTRACK) (APPROX. LOCATIONS FOR B-2, B-4 & B-5)
▲	SURFACE WATER STAKE
■	INFERRED WETLAND GROUNDWATER ELEVATIONS
(277.26')	TOP OF WATER ELEVATION (8-21-14)
—270—	GROUNDWATER POTENTIOMETRIC CONTOUR
--270--	INFERRED GROUNDWATER POTENTIOMETRIC CONTOUR
←	GROUNDWATER FLOW DIRECTION
*	WATER LEVEL ELEVATION UTILIZED TO GENERATE POTENTIOMETRIC MAP

HDR

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440 S. Church St. Suite 1000
Charlotte, NC 28202-2075
704.338.6700

ISSUE	DATE	DESCRIPTION	PROJECT MANAGER	
A	09/19/2014	ISSUED FOR REVIEW		M.G. PLUMMER, P.E.
				R. KLINGMAN, P.E.
				J. DAIA
			PROJECT NUMBER	

Charah®

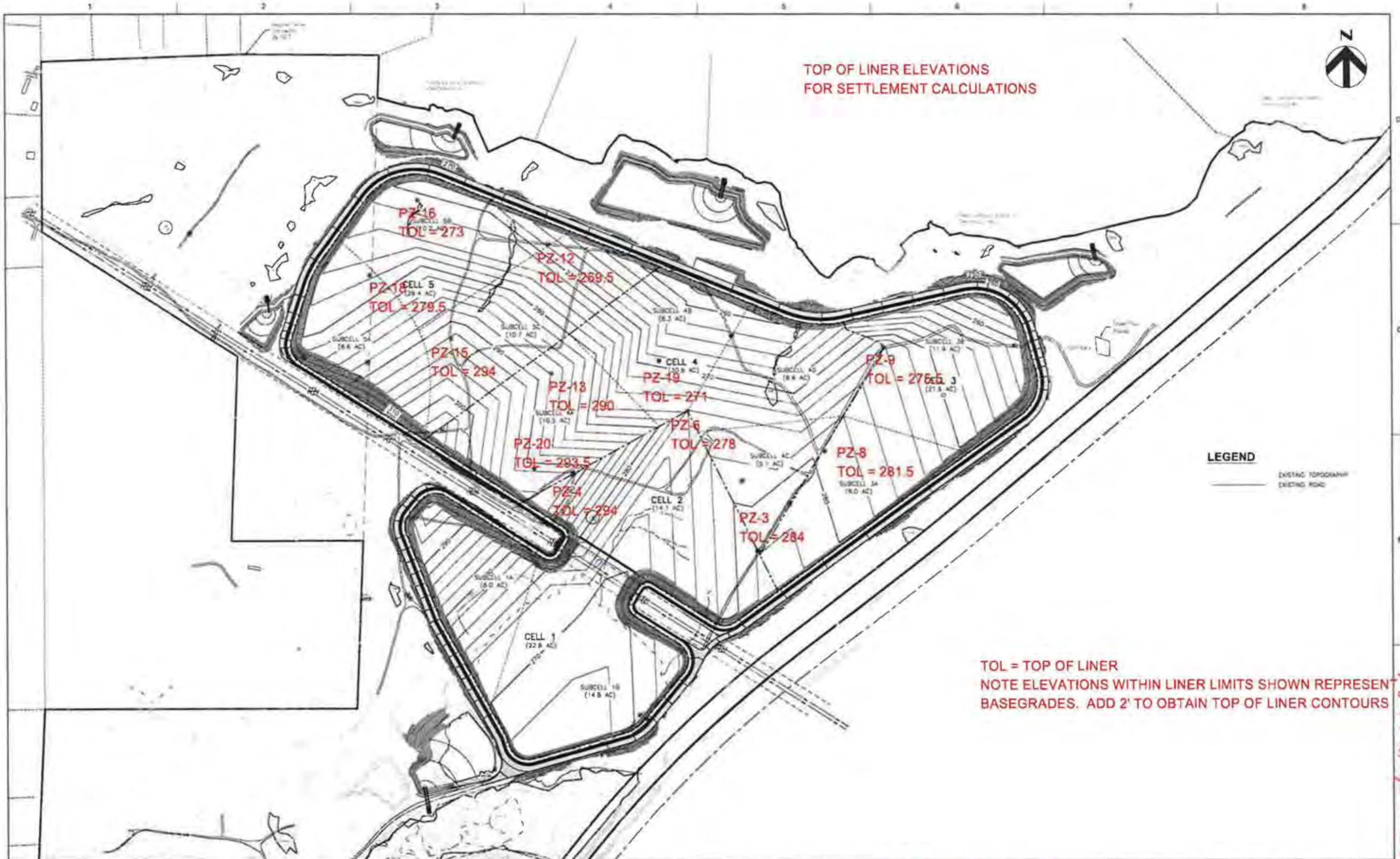
COLON MINE SITE STRUCTURAL FILL
SANFORD, NC

GROUNDWATER POTENTIOMETRIC MAP

FILENAME 00G-04.dwg
SCALE 1"=200'

SHEET 00G-04

ATTACHMENT C



HDR

PROJECT MANAGER	W.D. PLUMMER, P.E.
	J. DAUL
PROJECT NUMBER	

ISSUE	DATE	DESCRIPTION
A	9/19/14	ISSUED FOR REVIEW

Charah

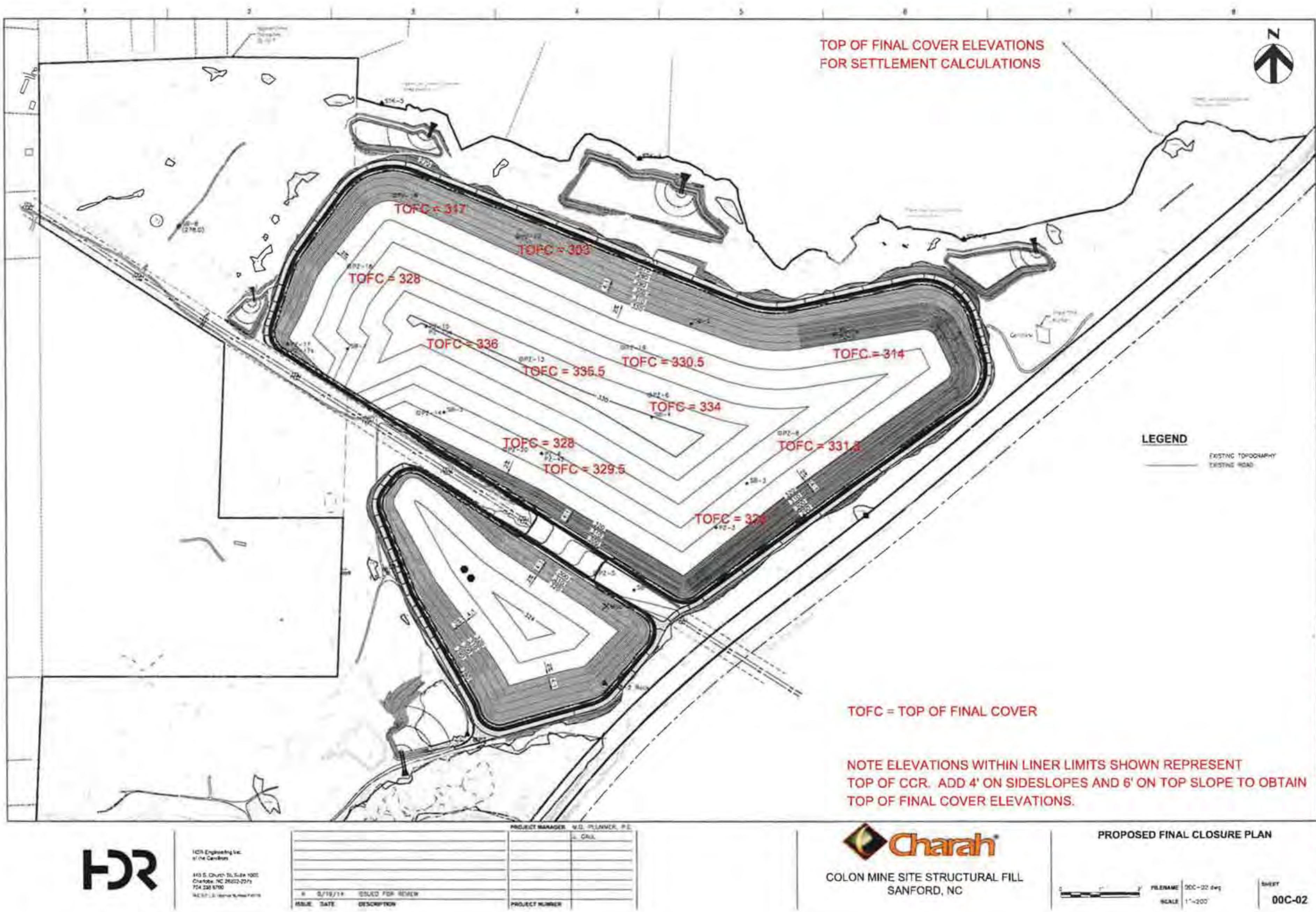
COLON MINE SITE STRUCTURAL FILL
SANFORD, NC

BASEGRADE PLAN (BOTTOM OF SOIL LINER)

FILENAME 00C-03.dwg
SCALE 1"=200'

SHEET 00C-03

ATTACHMENT D



ATTACHMENT E

TABLE 6
Typical Values of Soil Index Properties

	Particle Size and Gradation				Voids(1)					Unit Weight(2) (lb./cu.ft.)						
	Approximate Size Range (mm)		Approx. D_{10} (mm)	Approx. Range Uniform Coefficient C_u	Void Ratio			Porosity (%)		Dry Weight			Wet Weight		Submerged Weight	
	D_{max}	D_{min}			e_{max} loose	e_{cr}	e_{min} dense	n_{max} loose	n_{min} dense	Min loose	100% Mod. AASHO	Max dense	Min loose	Max dense	Min loose	Max dense
GRANULAR MATERIALS																
Uniform Materials																
a. Equal spheres (theoretical values)	-	-	-	1.0	0.92	-	0.35	47.6	26	-	-	-	-	-	-	-
b. Standard Ottawa SAND	0.84	0.59	0.67	1.1	0.80	0.75	0.50	44	33	92	-	110	93	131	57	69
c. Clean, uniform SAND (fine or medium)	-	-	-	1.2 to 2.0	1.0	0.80	0.40	50	29	83	115	118	84	136	52	73
ML, MH d. Uniform, inorganic SILT	0.05	0.005	0.012	1.2 to 2.0	1.1	-	0.40	52	29	80	-	118	81 (Avg. 108.5)	136	51	73
Well-graded Materials																
SC, SM a. Silty SAND	2.0	0.005	0.02	5 to 10	0.90	-	0.30	47	23	87	122	127	88 (Avg. 115.0)	142	54	79
b. Clean, fine to coarse SAND	2.0	0.05	0.09	4 to 6	0.95	0.70	0.20	49	17	85	132	138	86	148	53	86
c. Micaceous SAND	-	-	-	-	1.2	-	0.40	55	29	76	-	120	77	138	48	76
d. Silty SAND & GRAVEL	100	0.005	0.02	15 to 300	0.85	-	0.14	46	12	89	-	146(3)	90	155(3)	56	92
MIXED SOILS																
CL Sandy or Silty CLAY	2.0	0.001	0.003	10 to 30	1.8	-	0.25	64	20	60 (Avg. 97.5)	130	135	100 (Avg. 123.5)	147	38	85
Skip-graded Silty CLAY with stones or rk fgmts	250	0.001	-	-	1.0	-	0.20	50	17	84	-	140	115 (Avg. 133)	151	53	89
Well-graded GRAVEL, SAND, SILT & CLAY mixture	250	0.001	0.002	25 to 1000	0.70	-	0.13	41	11	100	140	148(4)	125	156(4)	62	94
CLAY SOILS																
CH CLAY (30%-50% clay sizes)	0.05	0.5μ	0.001	-	2.4	-	0.50	71	33	50	105	112	94 (Avg. 113.5)	133	31	71
Colloidal CLAY (-0.002 mm: 50%)	0.01	10Å	-	-	12	-	0.60	92	37	13	90	106	71	128	8	66
ORGANIC SOILS																
Organic SILT	-	-	-	-	3.0	-	0.55	75	35	40	-	110	87	131	25	69
Organic CLAY (30% - 50% clay sizes)	-	-	-	-	4.4	-	0.70	81	41	30		100	81	125	18	62

Source: Ref. 1

ATTACHMENT F

Young's modulus of soil, E_s, and the constrained modulus of soil, M_s, where E_s and D_s are related through Poisson's ratio of soil, v_s, by

$$M_s = \frac{E_s \cdot (1 - \nu_s)}{(1 + \nu_s)(1 - 2 \cdot \nu_s)} \tag{9.27}$$

where M_s = constrained modulus of soil, lb/ft^2 or kN/m^2;
E_s = elastic modulus of soil, lb/ft^2 or kN/m^2; and
ν_s = Poisson's ratio of soil.

The studies and analyses by Neilson (1967), Allgood and Takahashi (1972), and Hartely and Duncan (1987) indicated that for

$$E' = k \cdot M_s \tag{9.28}$$

the value of k may vary from 0.7 to 2.3. Using $k = 1.5$ as a representative value and $\nu_s = 0.3$, in addition to combining Equations 9.27 and 9.28 yields the following relationship between the elastic modulus of the pipe and soil (Selig, 1990):

$$E' = 2 \cdot E_s \tag{9.29}$$

The values of elastic parameters, E_s and ν_s, can be found in Table 9.5 according to different percents of density from a standard Proctor compaction test (ASTM D698).

TABLE 9.5 Elastic Soil Parameters (Selig, 1990)

Soil Type	Stress Level		85% Standard Density			95% Standard Density		
			E_s			E_s		
	psi	kPa	psi	MPa	ν_s	psi	MPa	ν_s
SW, SP, GW, GP	1	7	1,300	9	0.26	1,600	11	0.40
	5	35	2,100	14	0.21	4,100	28	0.29
	10	70	2,600	18	0.19	6,000	41	0.24
	20	140	3,300	23	0.19	8,600	59	0.23
	40	280	4,100	28	0.23	13,000	90	0.25
	60	420	4,700	32	0.28	16,000	110	0.29
GM, SM, ML, and GC, SC with < 20% fines	1	7	600	4	0.25	1,800	12	0.34
	5	35	700	5	0.24	2,500	17	0.29
	10	70	800	6	0.23	2,900	20	0.27
	20	140	850	6	0.30	3,200	22	0.29
	40	280	900	6	0.38	3,700	25	0.32
	60	420	1,000	7	0.41	4,100	28	0.35
CH CL, MH, GC, SC	1	7	100	1	0.33	400	3	0.42
	5	35	250	2	0.29	800	6	0.35
	10	70	400	3	0.28	1,100	8	0.32
	20	140	600	4	0.25	1,300	9	0.30
	40	280	700	5	0.35	1,400	10	0.35
	60	420	800	6	0.40	1,500	10	0.38

Source: Ref. 3

9.4.2 Pipe Wall Buckling

Buckling can occur
flexible pipes subject
pressures in compact
conduit (e.g., high v
resisting buckling.

Most conduits
resistance. An exact
elastic medium entai
of uncertainties in t
solution is not neces
cal formula for comp

Where,
P_{cr} = critical
E' = modul
μ = Poisso
E = modul
I = mome
in^4/in
r = mean

Because $I = t^3$,

where

ATTACHMENT G

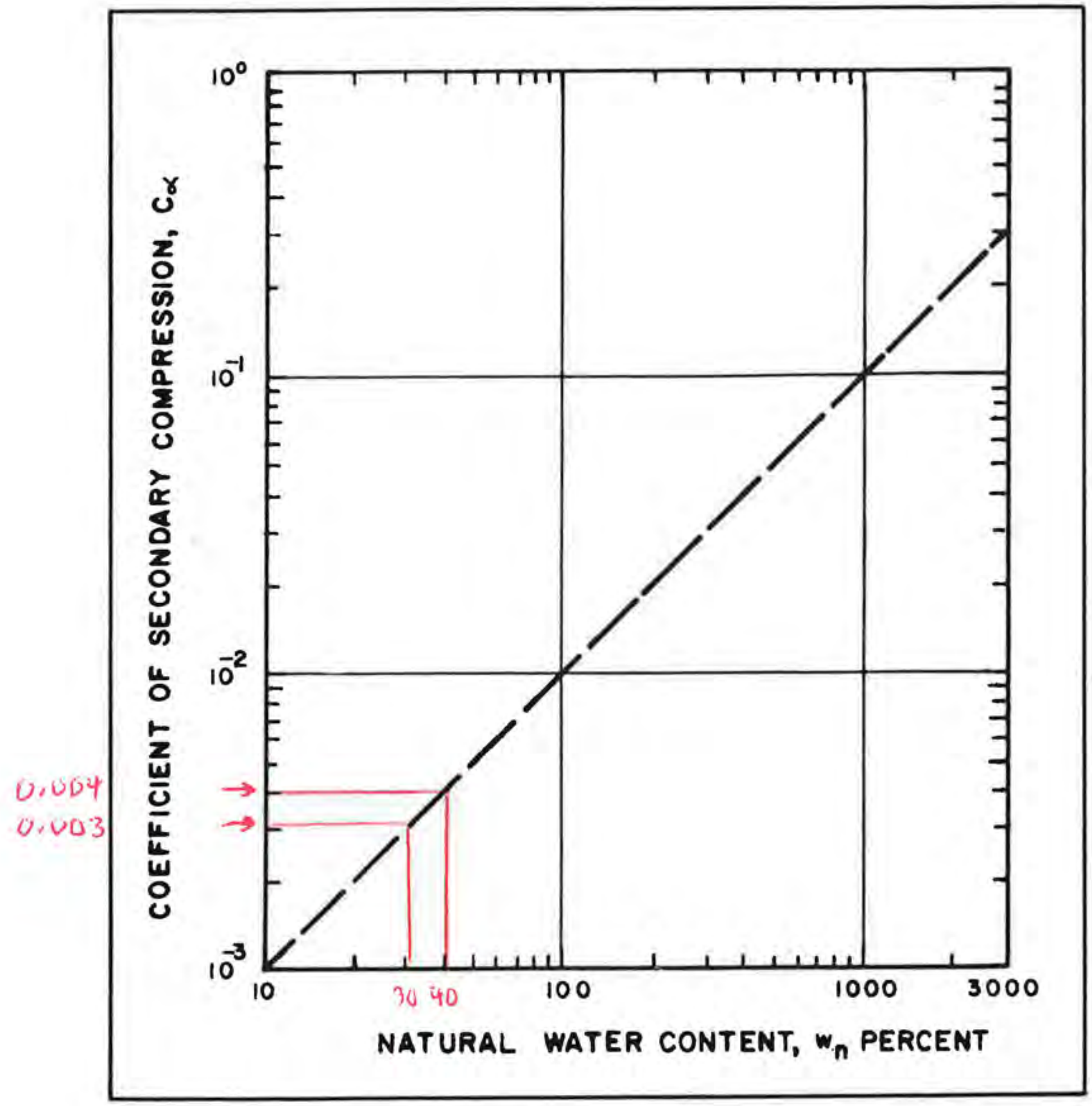


FIGURE 16
Coefficient of Secondary Compression as Related to Natural Water Content

Source: Ref. 1

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B

Stability

Slope Stability Analysis
Final Cover Veneer Stability (Options 1 and 2)
Operational Cover Veneer Stability

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HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Slope Stability Analyses	Sheet:		Of:	3

Objective:

Evaluate the slope stability of the proposed coal ash structural fill. Evaluate both global stability of the foundation soils, the stability of the structural fill ash slope, and the sliding block stability of the ash along the bottom liner system using PCSTABL 5M and the STEDwin editor (Ref. 3).

References:

1. Naval Facilities Engineering Command (1986). Design Manual 7.01 - Soil Mechanics.
2. Bowles, J.E. (1984). Physical and Geotechnical Properties of Soils. McGraw-Hill.
3. Van Aller, H.W. (1999 - 2013). STEDwin 2.88 (32 bit), The Smart Editor for PCSTABL 5M. Annapolis Engineering Software.
4. Naval Facitities Engineering Command (1982). Design Manual 7.02 - Foundations and Earth Structures.

5. Koerner, G.R. and D. Narejo (2005). Direct Shear Database of Geosynthetic-to-Geosynthetic and Geosynthetic-to-Soil Interfaces. GRI Report #30.

Steps:

1. Estimate subsurface conditions beneath the structural fill using soil boring logs provided by Buxton Environmental, Inc. (see Attachment A). Based on the boring logs, the typical soil profile for the site consists of approximately 5' soil horizon consisting of medium silty and clayey soils underlain by approximately 10' of stiff residuum. Hard partially weathered rock (PWR) underlies the residuum. For the purposes of global stability, it is assumed that failure surfaces will not penetrate the PWR. The estimated intervals of the soil horizon, residuum, and PWR are shown in Attachment A.

2. Estimate the coal ash parameters for input into PCSTABL 5M using physical characterization testing information provided by Charah for samples obtained at the Riverbend Steam Station. This testing information, performed by Geotrack Technologies, Inc., is provided in Attachment B. An estimate of the compacted unit weight (γ) of the ash was obtained based on the results of a standard Proctor test assuming the material would be placed at maximum dry density and optimum moisture content. Total and effective stress strength properties of the coal ash were obtained from the Triaxial Shear Test reports provided in Attachment B. The total stress parameters are applicable for undrained conditions when loading occurs over a relatively short time which leads to the development of excess pore water pressures within the ash. The effective stress parameters are applicable for drained conditions when loading occurs over a sufficient amount of time to allow excess pore water pressures to dissipate. Since typical hydraulic conductivity values for fly ash generally range between 1x10-4 to 1x10-5 cm/sec, it is not clear whether undrained or drained conditions will develop within the ash therefore both sets of parameters were analyzed. The assumed values for unit weight (γ), friction angle (φ), and cohesion (c) for the ash are provided below:

Compacted Ash (Total Stress): γ = 83.8 pcf, φ = 8˚ , c = 4,300 psf
Compacted Ash (Effective Stress): γ = 83.8 pcf, φ = 22˚ , c = 2,600 psf

3. Estimate foundation soil parameters for input into PCSTABL 5M. Use Ref. 1 to correlate γ based with soil type (see Attachment C). From information provided in soil borings (Attachment A), which includes geotechnical laboratory classification data, use Attachments D and E to correlate total and effective stress parameters for the soil horizon and residuum, respectively (see Ref. 2). Note that in Attachment D, c = 1/2 q_u where q_u is the unconfined compressive strength of the soil. Since the PWR at the site is classified as "hard" with blowcounts generally in excess of 50/6in, it is assumed that failure surfaces will not enter the PWR and therefore parameters were not assigned to this layer. Since the foundation soils are generally fine grained at the site, it is not clear whether undrained or drained conditions will develop within the soils, therefore both sets of parameters were analyzed. The assumed values for unit weight (γ), friction angle (φ), and cohesion (c) for the foundation soils are provided below:

Soil Horizon (Total Stress): γ = 120 pcf, φ =0˚ , c = 470 psf
Soil Horizon (Effective Stress): γ = 120 pcf, φ = 31˚ , c = 0
Residuum (Total Stress): γ = 130 pcf, φ =0˚ , c = 1,045 psf
Residuum (Effective Stress): γ = 130 pcf, φ = 32˚ , c = 0 psf

4. Estimate soil parameters for the compacted soil berm that will be constructed along the perimeter of the structural fill. Assume on site soils consisting of predominantly clayey and silt soils will be used. Use Attachment F (Ref. 1) to obtain obtain estimated strength parameters and Attachment C to estimate γ as shown below:

Compacted Clayey Fill: γ = 125 pcf, φ = 28˚ , c = 1,800 psf

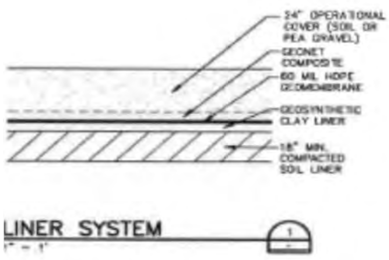
HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	**KP**	Date:	**10/29/2014**
Task:	Slope Stability Analyses	Sheet:		Of:	3

5. Estimate soil parameters for the final cover soils. Since a variety of soils may be used for final cover and considering that a high degree of compaction of the final cover probably can not be achieved without the risk of damaging the underlying geomembrane, conservatively assume the following parameters:

Final Cover soils: γ = 120 pcf, φ = 30˚ , c = 0 psf

6. Determine critical liner interface for sliding block analyses. A detail of the proposed liner system is provided below. Determine typical interface strength parameters for each interface based on Attachment G (Ref. 5) for each interface as shown below. Use peak parameters which are appropriate to use before failure initiates. Based on this information, the critical (i.e. lowest strength) interface is between the textured 60 mil HDPE geomembrane and the saturated cohesive soil. Therefore, use these parameters for the critical interface.



Geocomposite/Granular Soil Interface: φ = 33˚ , c = 0
Critical → Geocomposite/Textured HDPE Interface: φ = 26˚ , c = 0
Textured HDPE/Saturated Reinforced GCL: φ = 23˚ , c = 167 psf
Saturated Reinforced GCL/Saturated Cohesive Soil: φ = 29˚ , c = 0

7. Determine most critical cross-section for stability analysis. Factors to consider include proposed ash height, liner slope, foundation conditions, perimeter berm height, and water table location. Using this criteria, a critical stability section was selected along the northern side of the structural fill. The location of this section is shown superimposed on the Basegrade Plan (Attachment H), the Proposed Final Closure Plan (Attachment I), and a groundwater contour map (Attachment J). This section (north slope) represents the greatest depth of waste that will be placed and therefore the greatest amount of driving forces leading to potential failure. The section also represents an area where the perimeter berm will be constructed above existing grade and therefore there will be less buttressing effect at the toe of the slope.

8. Determine the peak ground accelleration for the site for use in the seismic stability analyses. From Attachment K (Ref. 6), the estimated peak ground acceleration for the site with a 2% probability of exceedance in 50 years (equivalent to 10% probability of exceedance in 250 years) is 0.09g. This values was entered as a horizontal pseudo-static coefficient in the PCSTABL 5M seismic analyses.

9. Using the information developed in Steps 1 through 7, input the data into PCSTABL 5M using the STEDwin editor (Ref. 3). Evaluate the both the global stability of the foundation soils beneath the structural fill as well as the stability of the ash slope and sliding block failure along the bottom liner system.

Results/Conclusions

Plots showing the output results from the PCSTABL 5M analyses for the global, ash slope, and sliding block stability under both static and seismic conditions are attached to this calculation. The minimum factors of safety are summarized in the table below. The most critical analysis was for the sliding block failure along the bottom liner system under effective stress conditions with factors of safety of 4.33 and 3.03 for static and seismic conditions, respectively. The generally accepted minimum static and seismic factors of safety for landfill stability are 1.5 and 1.0, respectively. Since the calculated factors of safety exceed the minimum acceptable, the proposed structural fill is adequately stable.

Since the interface shear strength parameters for the liner system components can vary significantly based on soil and product properties, it is helpful to determine the minimum φ value required for the interfaces to achieve an adequate factor of safety. The last two plots show the minimum φ required to achieve factors of safety of 1.5 and 1.0 for static and seismic analyses, respectively. The plots show that along the critical cross section, very little friction is required along the bottom liner interfaces due to the buttressing effect of the perimeter berm. Due to variations of slope along the structural fill liner system and temporary loading conditions during filling, however, it is recommended that a minimum bottom liner interface φ of 26 be required. This requirement should be confirmed by project specific interface shear strength testing.

HDR Computation

Project:	Charah Colon Mine Structural Fill	Computed By:	TMY	Date:	10/27/2014
Subject:	Permit Application	Checked By:	KP	Date:	10/29/2014
Task:	Slope Stability Analyses	Sheet:		Of:	3

Analysis	Static FS	Seismic FS	
Global/Static/Total Stress	4.72	3.21	
Global/Static/Effective Stress	4.95	3.49	
Ash Slope/Static/Total Stress	4.50	3.08	
Ash Slope/Static/Effective Stress	5.20	3.69	
Sliding Block/Static/Total Stress	5.02	3.55	
Sliding Block/Static/Effective Stress	4.33	3.03	←Critical Analysis

Minimum φ Required for Static FS = 1.5 0˚

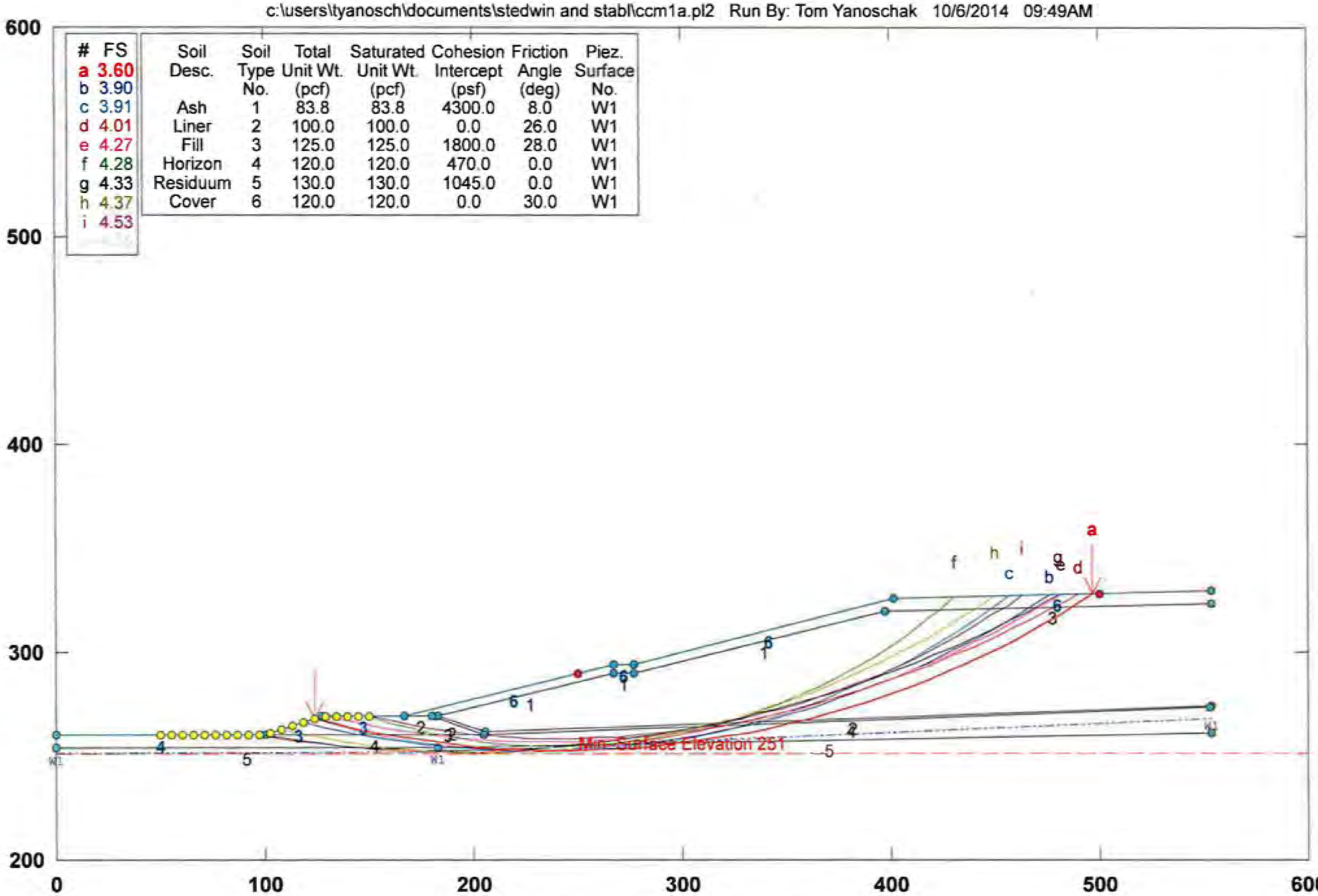
Minimum φ Required for Seismic FS = 1.0 0˚

Charah Colon Mine Structural Fill Global - Static (Total Stress)

c:\users\tyanosch\documents\stedwin and stabl\ccm1a.pl2 Run By: Tom Yanoschak 10/6/2014 09:49AM

#	FS
a	3.60
b	3.90
c	3.91
d	4.01
e	4.27
f	4.28
g	4.33
h	4.37
i	4.53

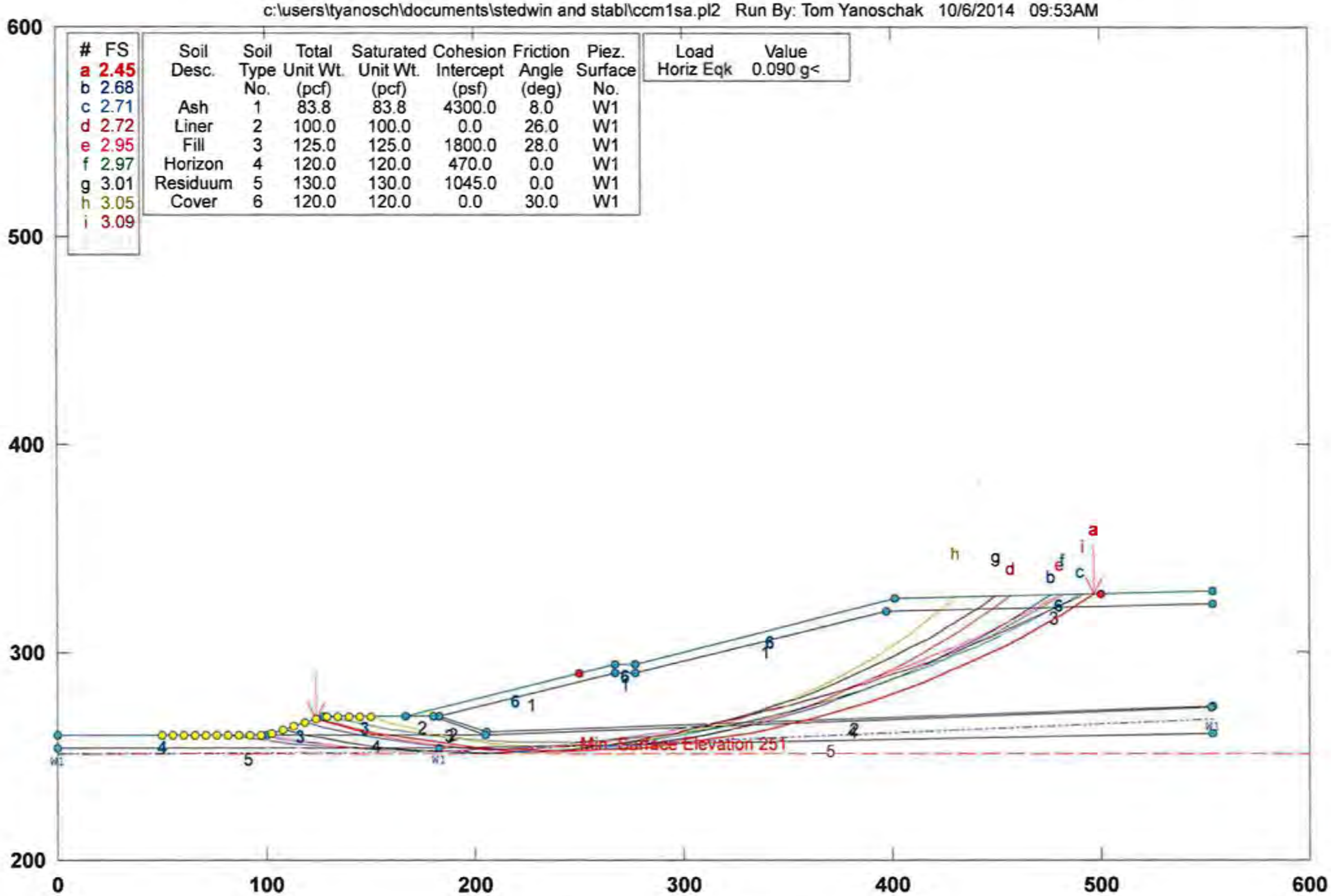
Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Ash	1	83.8	83.8	4300.0	8.0	W1
Liner	2	100.0	100.0	0.0	26.0	W1
Fill	3	125.0	125.0	1800.0	28.0	W1
Horizon	4	120.0	120.0	470.0	0.0	W1
Residuum	5	130.0	130.0	1045.0	0.0	W1
Cover	6	120.0	120.0	0.0	30.0	W1



PCSTABL5M/si FSmin=3.60
Safety Factors Are Calculated By The Modified Bishop Method

Charah Colon Mine Structural Fill Global - Seismic (Total Stress)

c:\users\tyanosch\documents\stedwin and stabl\ccm1sa.pl2 Run By: Tom Yanoschak 10/6/2014 09:53AM

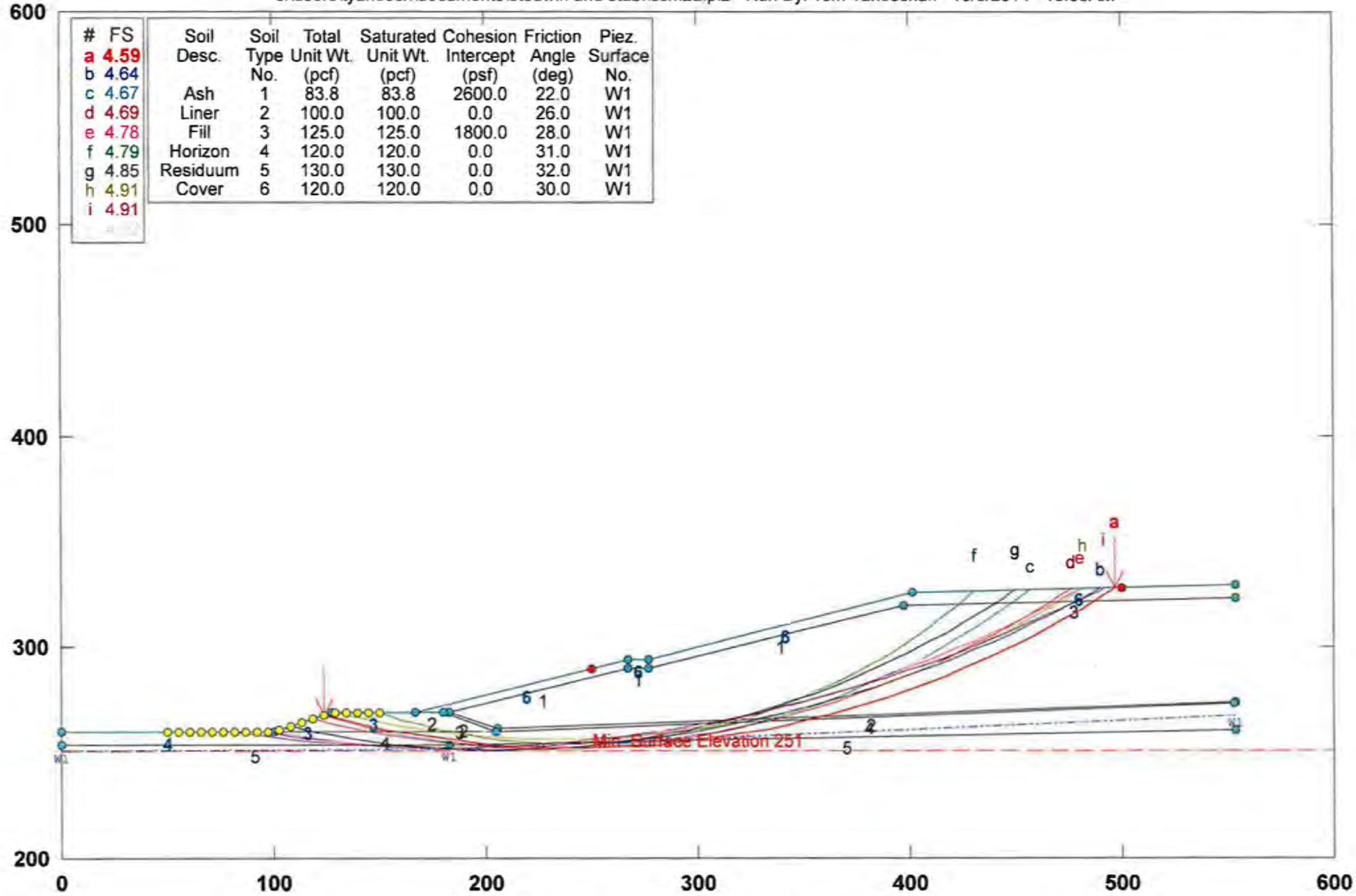


PCSTABL5M/si FSmin=2.45

Safety Factors Are Calculated By The Modified Bishop Method

Charah Colon Mine Structural Fill Global - Static (Effective Stress)

c:\users\tyanosch\documents\stedwin and stabl\ccm2a.pl2 Run By: Tom Yanoschak 10/6/2014 10:30AM

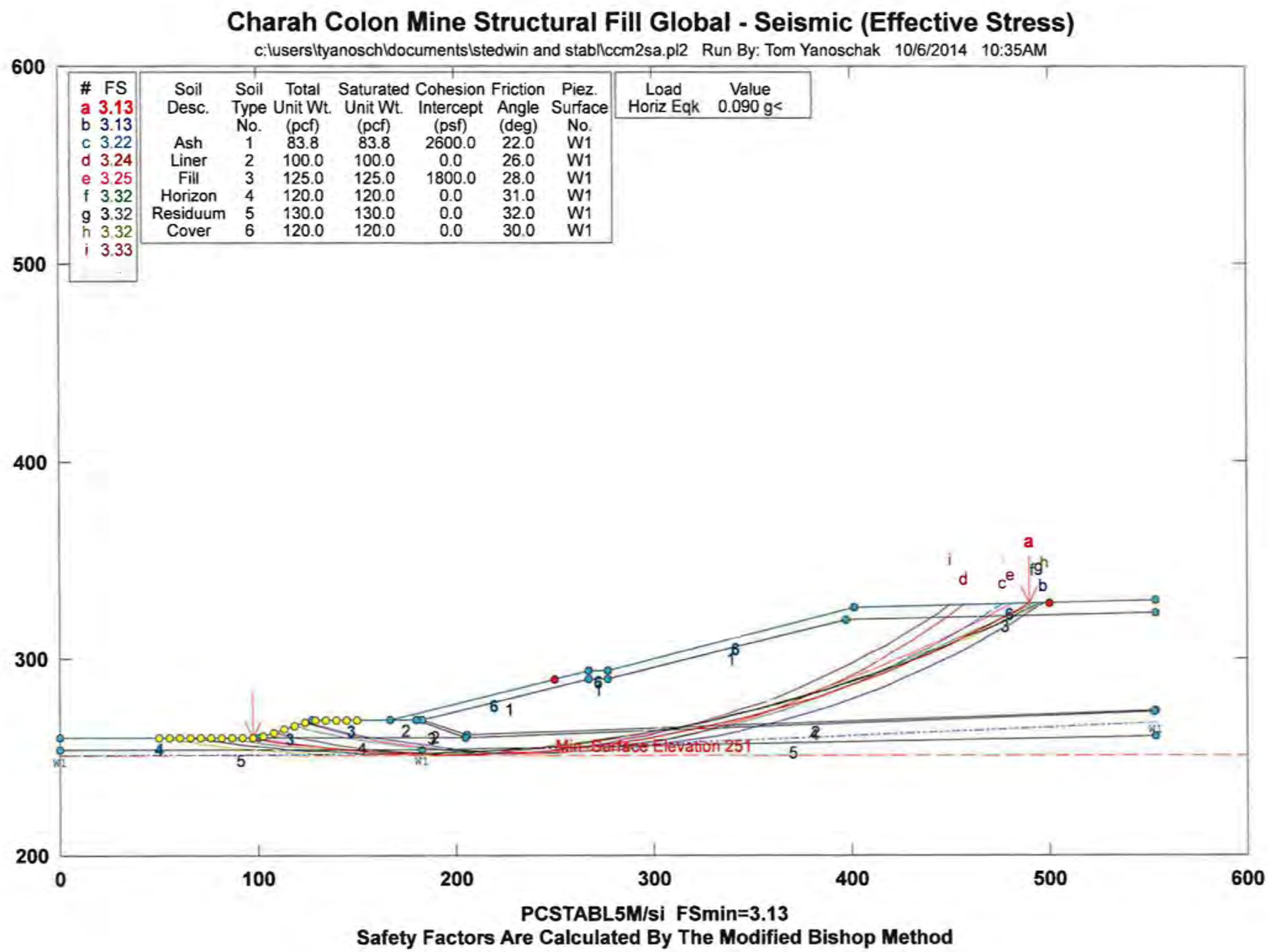


#	FS
a	4.59
b	4.64
c	4.67
d	4.69
e	4.78
f	4.79
g	4.85
h	4.91
i	4.91

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Ash	1	83.8	83.8	2600.0	22.0	W1
Liner	2	100.0	100.0	0.0	26.0	W1
Fill	3	125.0	125.0	1800.0	28.0	W1
Horizon	4	120.0	120.0	0.0	31.0	W1
Residuum	5	130.0	130.0	0.0	32.0	W1
Cover	6	120.0	120.0	0.0	30.0	W1

PCSTABL5M/si FSmin=4.59

Safety Factors Are Calculated By The Modified Bishop Method


Charah Colon Mine Structural Fill Global - Seismic (Effective Stress)
c:\users\tyanosch\documents\stedwin and stabl\ccm2sa.pl2 Run By: Tom Yanoschak 10/6/2014 10:35AM
FS
a 3.13
b 3.13
c 3.22
d 3.24
e 3.25
f 3.32
g 3.32
h 3.32
i 3.33
Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Piez. Surface No.
Ash 1 83.8 83.8 2600.0 22.0 W1
Liner 2 100.0 100.0 0.0 26.0 W1
Fill 3 125.0 125.0 1800.0 28.0 W1
Horizon 4 120.0 120.0 0.0 31.0 W1
Residuum 5 130.0 130.0 0.0 32.0 W1
Cover 6 120.0 120.0 0.0 30.0 W1
Load | Value
Horiz Eqk 0.090 g<
Min Surface Elevation 251
600
500
400
300
200
0
100
200
300
400
500
600
PCSTABL5M/si FSmin=3.13
Safety Factors Are Calculated By The Modified Bishop Method

Charah Colon Mine Structural Fill Ash Slope - Static (Total Stress)

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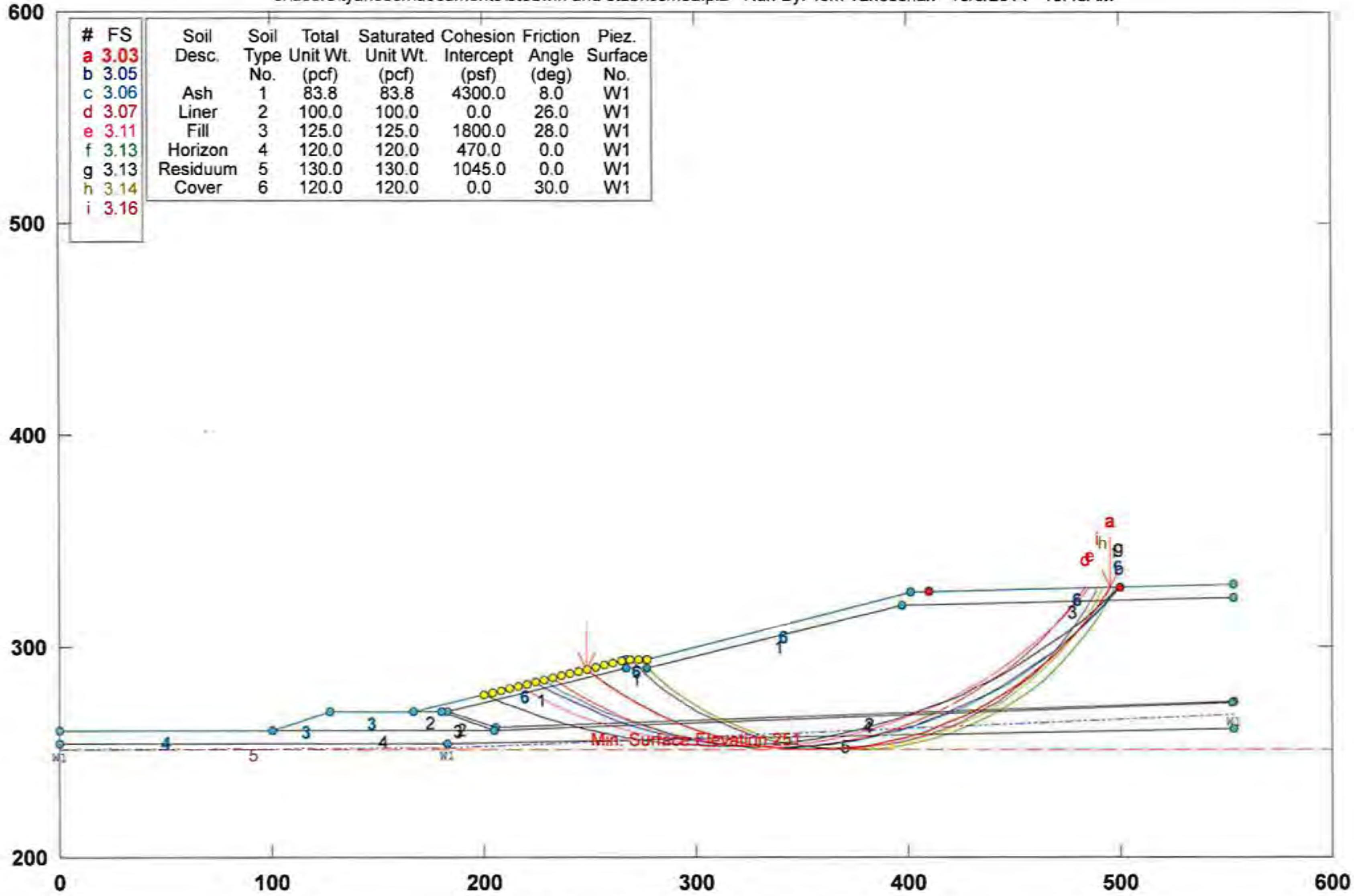


#	FS
a	3.03
b	3.05
c	3.06
d	3.07
e	3.11
f	3.13
g	3.13
h	3.14
i	3.16

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Ash	1	83.8	83.8	4300.0	8.0	W1
Liner	2	100.0	100.0	0.0	26.0	W1
Fill	3	125.0	125.0	1800.0	28.0	W1
Horizon	4	120.0	120.0	470.0	0.0	W1
Residuum	5	130.0	130.0	1045.0	0.0	W1
Cover	6	120.0	120.0	0.0	30.0	W1

PCSTABL5M/si FSmin=3.03

Safety Factors Are Calculated By The Modified Bishop Method

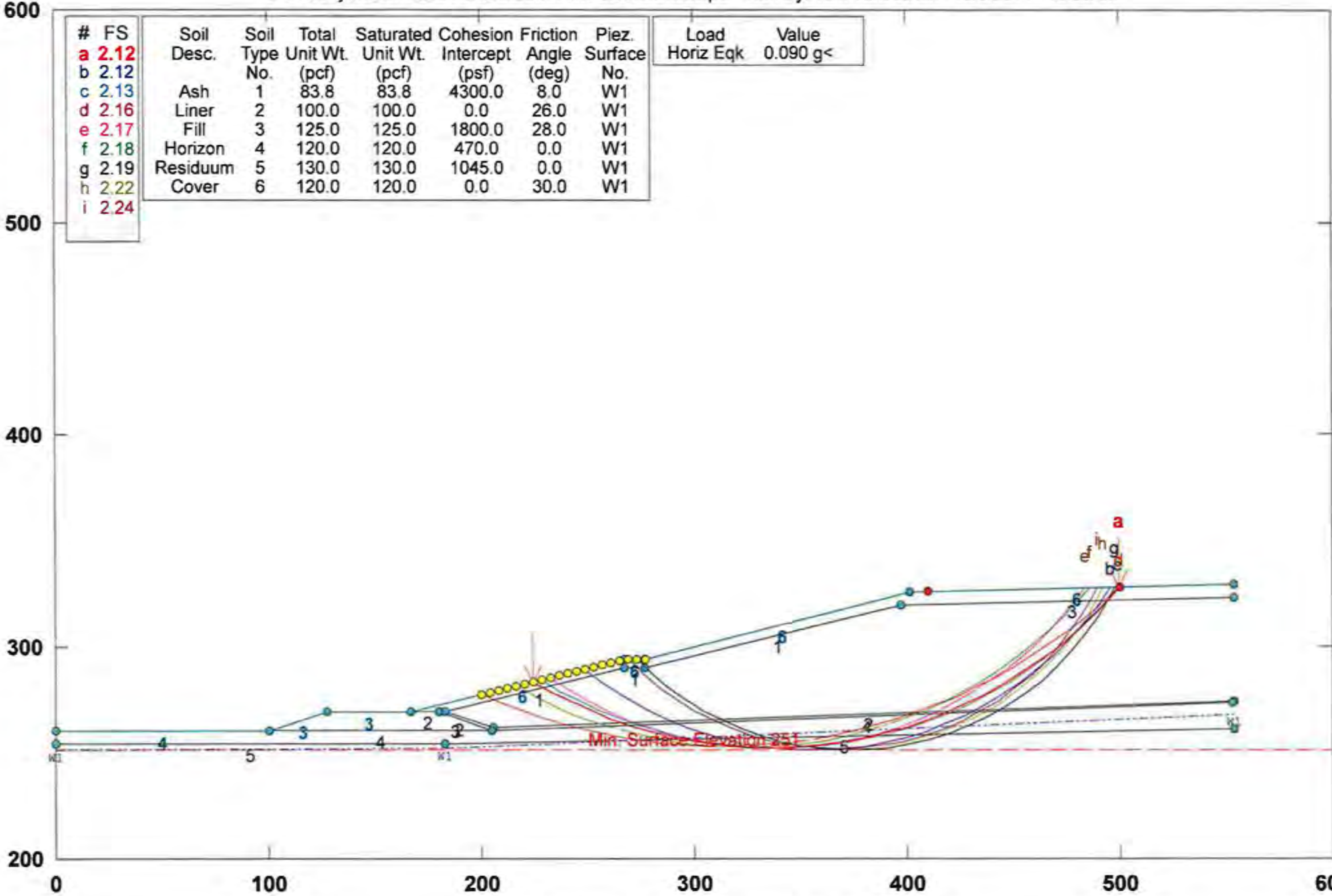
Charah Colon Mine Structural Fill Ash Slope - Seismic (Total Stress)

c:\users\tyanosch\documents\stedwin and stabl\ccm3as.pl2 Run By: Tom Yanoschak 10/6/2014 10:50AM

#	FS
a	2.12
b	2.12
c	2.13
d	2.16
e	2.17
f	2.18
g	2.19
h	2.22
i	2.24

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Ash	1	83.8	83.8	4300.0	8.0	W1
Liner	2	100.0	100.0	0.0	26.0	W1
Fill	3	125.0	125.0	1800.0	28.0	W1
Horizon	4	120.0	120.0	470.0	0.0	W1
Residuum	5	130.0	130.0	1045.0	0.0	W1
Cover	6	120.0	120.0	0.0	30.0	W1

Load	Value
Horiz Eqk	0.090 g<



PCSTABL5M/si FSmin=2.12

Safety Factors Are Calculated By The Modified Bishop Method

Charah Colon Mine Structural Fill Ash Slope - Static (Effective Stress)

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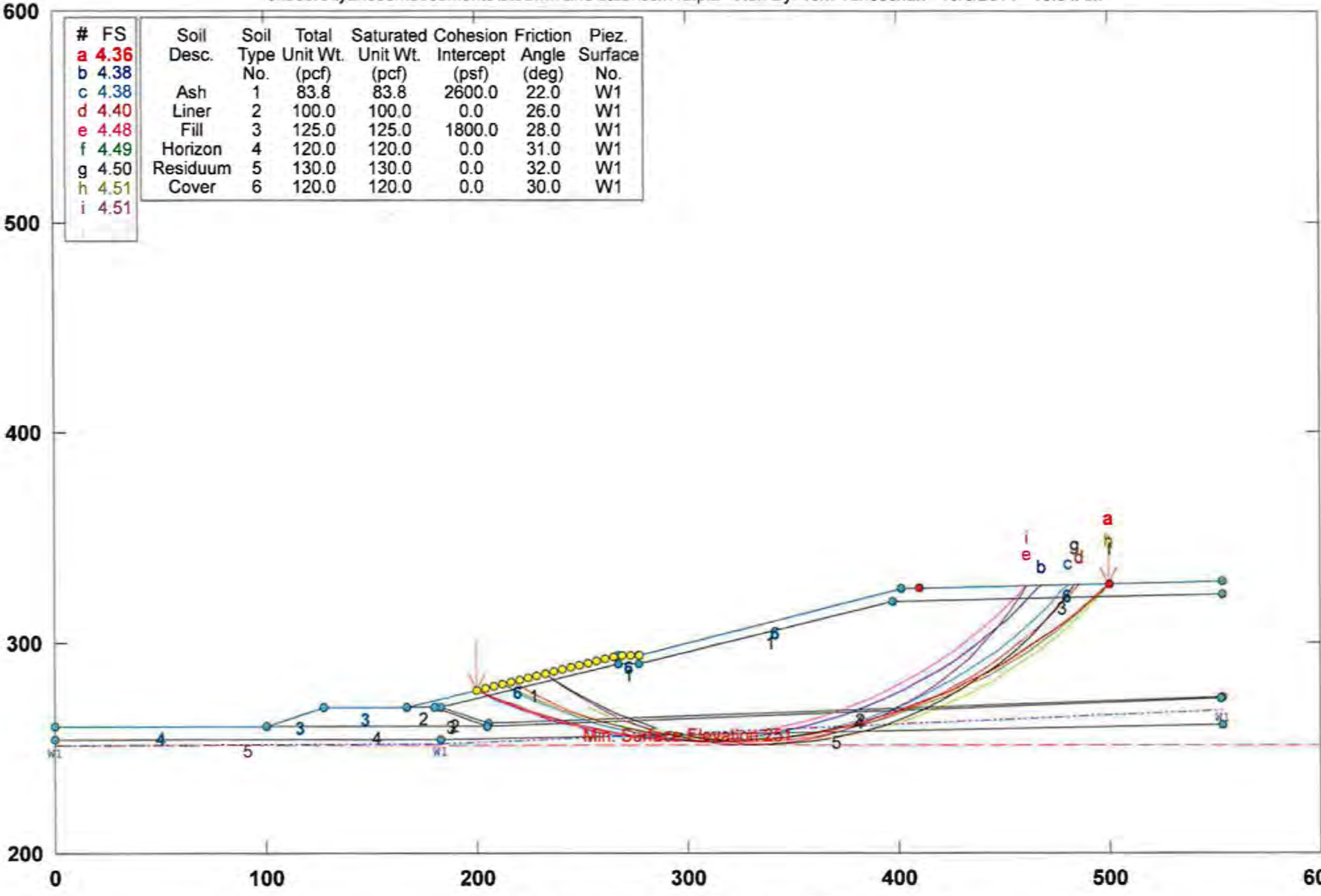
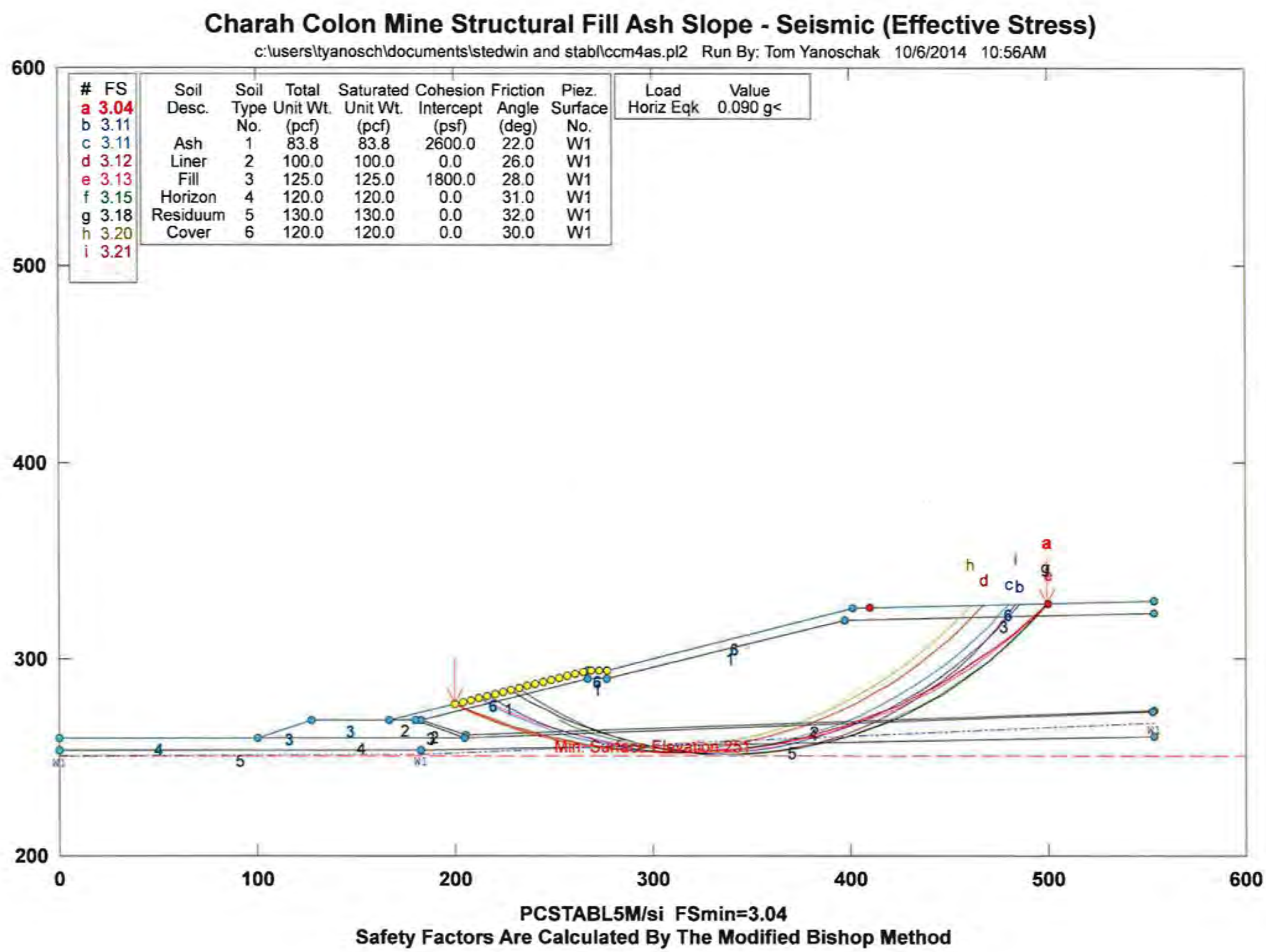


PCSTABL5M/si FSmin=4.36

Safety Factors Are Calculated By The Modified Bishop Method


Charah Colon Mine Structural Fill Ash Slope - Seismic (Effective Stress)
c:\users\tyanosch\documents\stedwin and stabl\ccm4as.pl2 Run By: Tom Yanoschak 10/6/2014 10:56AM

#	FS
a	3.04
b	3.11
c	3.11
d	3.12
e	3.13
f	3.15
g	3.18
h	3.20
i	3.21

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Ash	1	83.8	83.8	2600.0	22.0	W1
Liner	2	100.0	100.0	0.0	26.0	W1
Fill	3	125.0	125.0	1800.0	28.0	W1
Horizon	4	120.0	120.0	0.0	31.0	W1
Residuum	5	130.0	130.0	0.0	32.0	W1
Cover	6	120.0	120.0	0.0	30.0	W1

Load	Value
Horiz Eqk	0.090 g<

Min. Surface Elevation 251
600
500
400
300
200
0
100
200
300
400
500
600
PCSTABL5M/si FSmin=3.04
Safety Factors Are Calculated By The Modified Bishop Method

Charah Colon Mine Structural Fill Sliding Block - Static (Total Stress)

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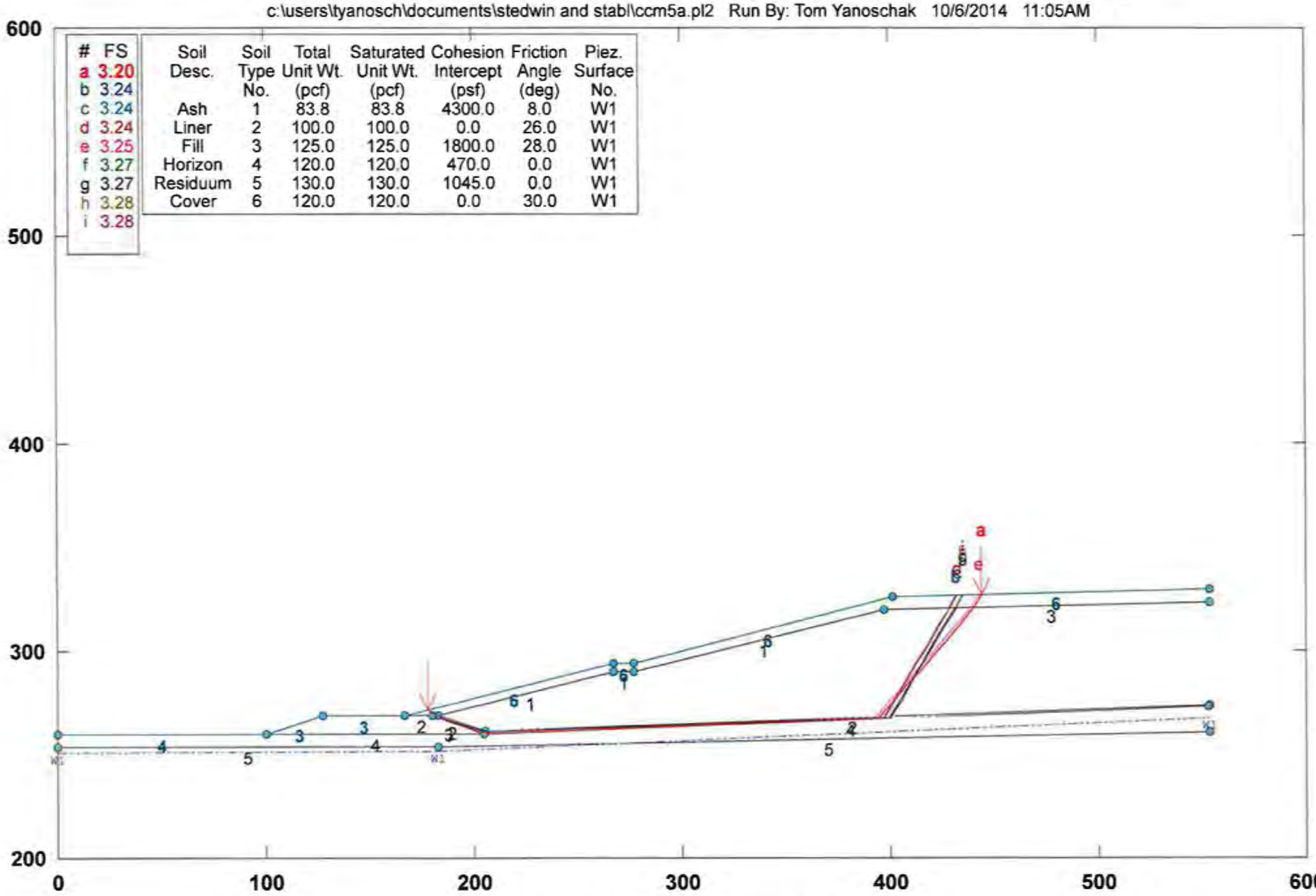

PCSTABL5M/si FSmin=3.20

Safety Factors Are Calculated By The Modified Janbu Method for the case of c & phi both > 0

Charah Colon Mine Structural Fill Sliding Block - Seismic (Total Stress)

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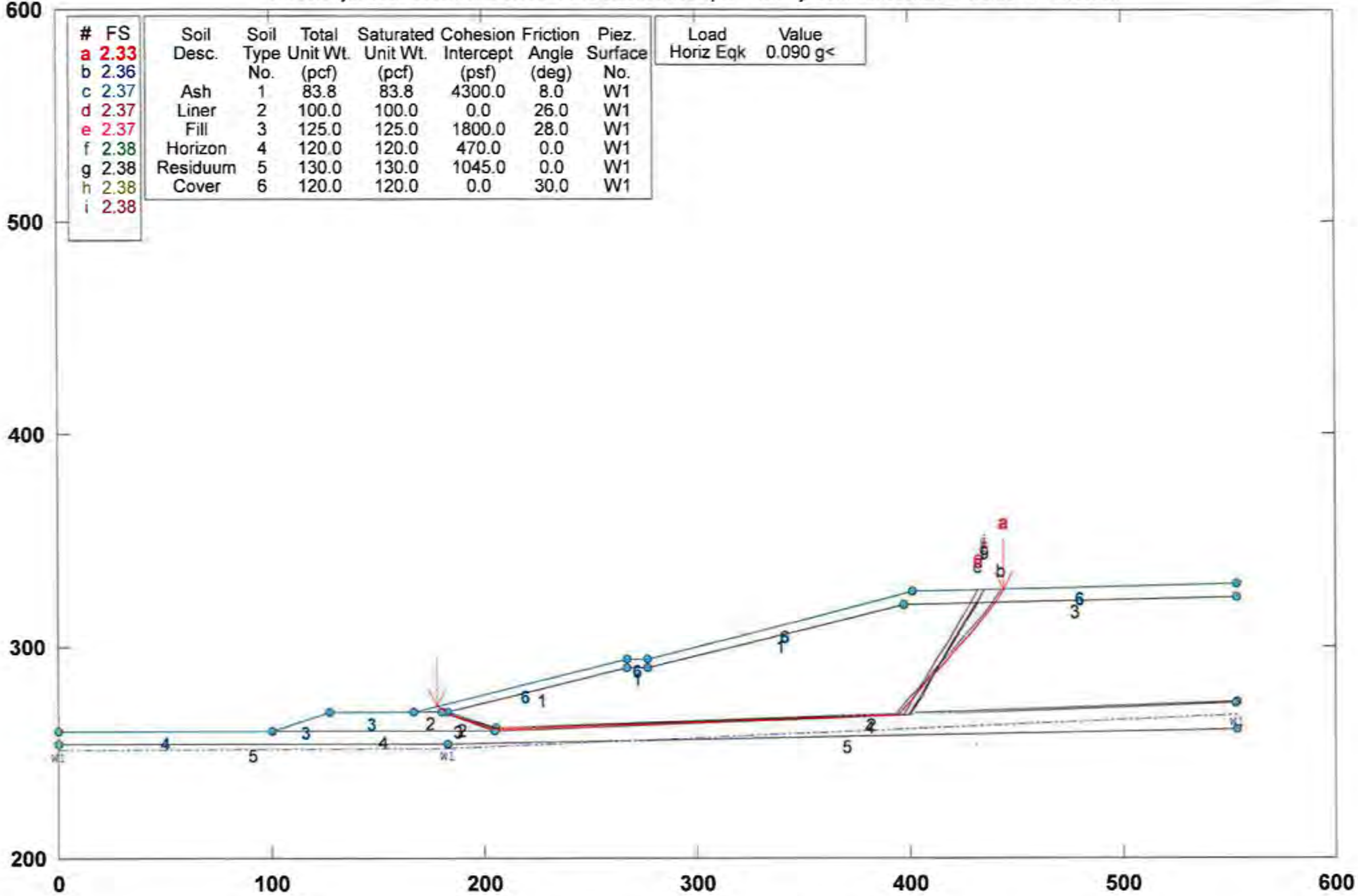


#	FS
a	2.33
b	2.36
c	2.37
d	2.37
e	2.37
f	2.38
g	2.38
h	2.38
i	2.38

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Ash	1	83.8	83.8	4300.0	8.0	W1
Liner	2	100.0	100.0	0.0	26.0	W1
Fill	3	125.0	125.0	1800.0	28.0	W1
Horizon	4	120.0	120.0	470.0	0.0	W1
Residuum	5	130.0	130.0	1045.0	0.0	W1
Cover	6	120.0	120.0	0.0	30.0	W1

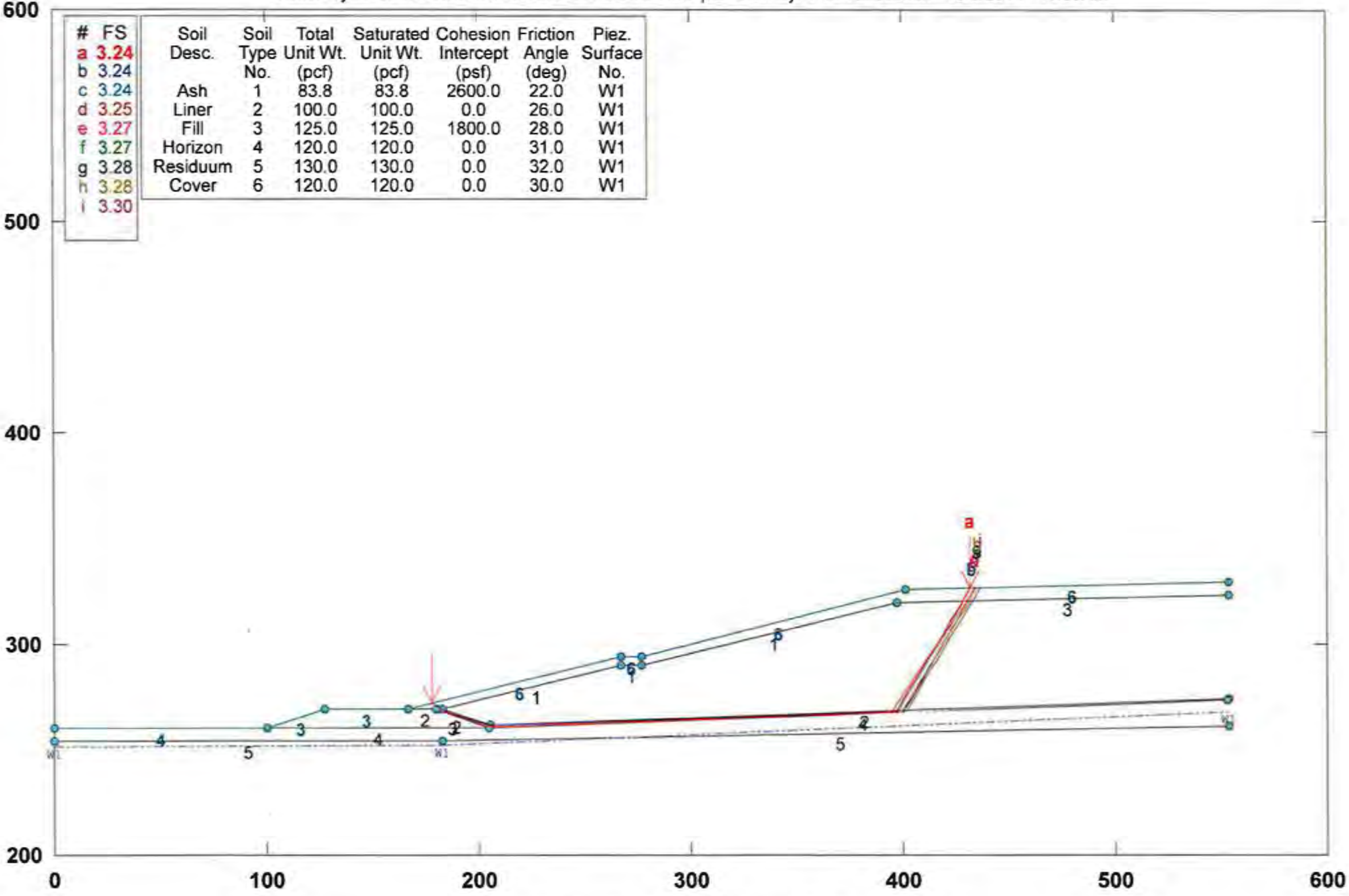
Load	Value
Horiz Eqk	0.090 g<

PCSTABL5M/si FSmin=2.33

Safety Factors Are Calculated By The Modified Janbu Method for the case of c & phi both > 0

Charah Colon Mine Structural Fill Sliding Block - Static (Effectiv Stress)

c:\users\tyanosch\documents\stedwin and stabl\ccm6a.pl2 Run By: Tom Yanoschak 10/6/2014 11:09AM



Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Ash	1	83.8	83.8	2600.0	22.0	W1
Liner	2	100.0	100.0	0.0	26.0	W1
Fill	3	125.0	125.0	1800.0	28.0	W1
Horizon	4	120.0	120.0	0.0	31.0	W1
Residuum	5	130.0	130.0	0.0	32.0	W1
Cover	6	120.0	120.0	0.0	30.0	W1

PCSTABL5M/si FSmin=3.24

Safety Factors Are Calculated By The Modified Janbu Method for the case of c & phi both > 0

Charah Colon Mine Structural Fill Sliding Block - Seismi (Effectiv Stress)

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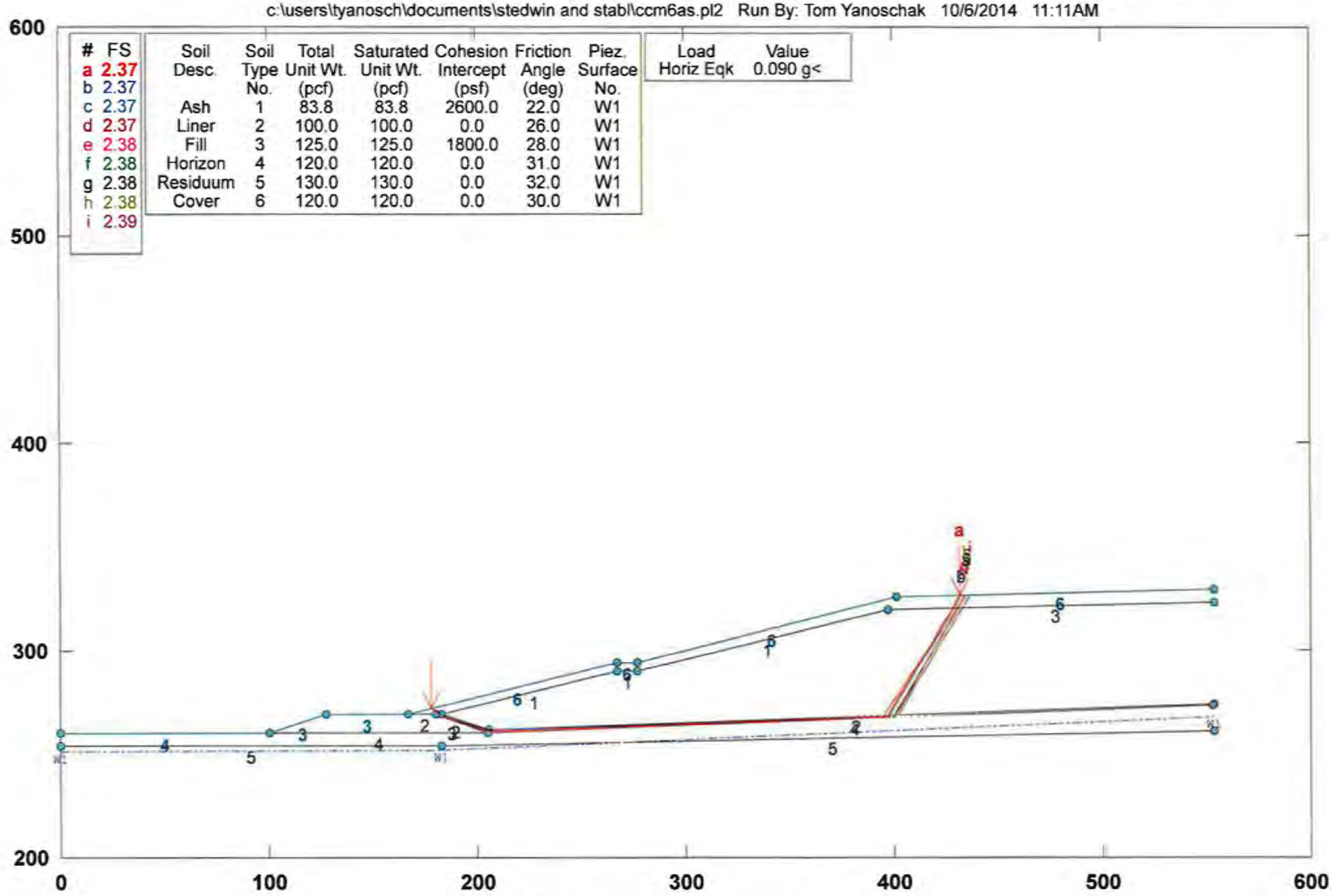

PCSTABL5M/si FSmin=2.37

Safety Factors Are Calculated By The Modified Janbu Method for the case of c & phi both > 0

Charah Colon Mine Structural Fill Sliding Block - Static (Min Liner Phi)

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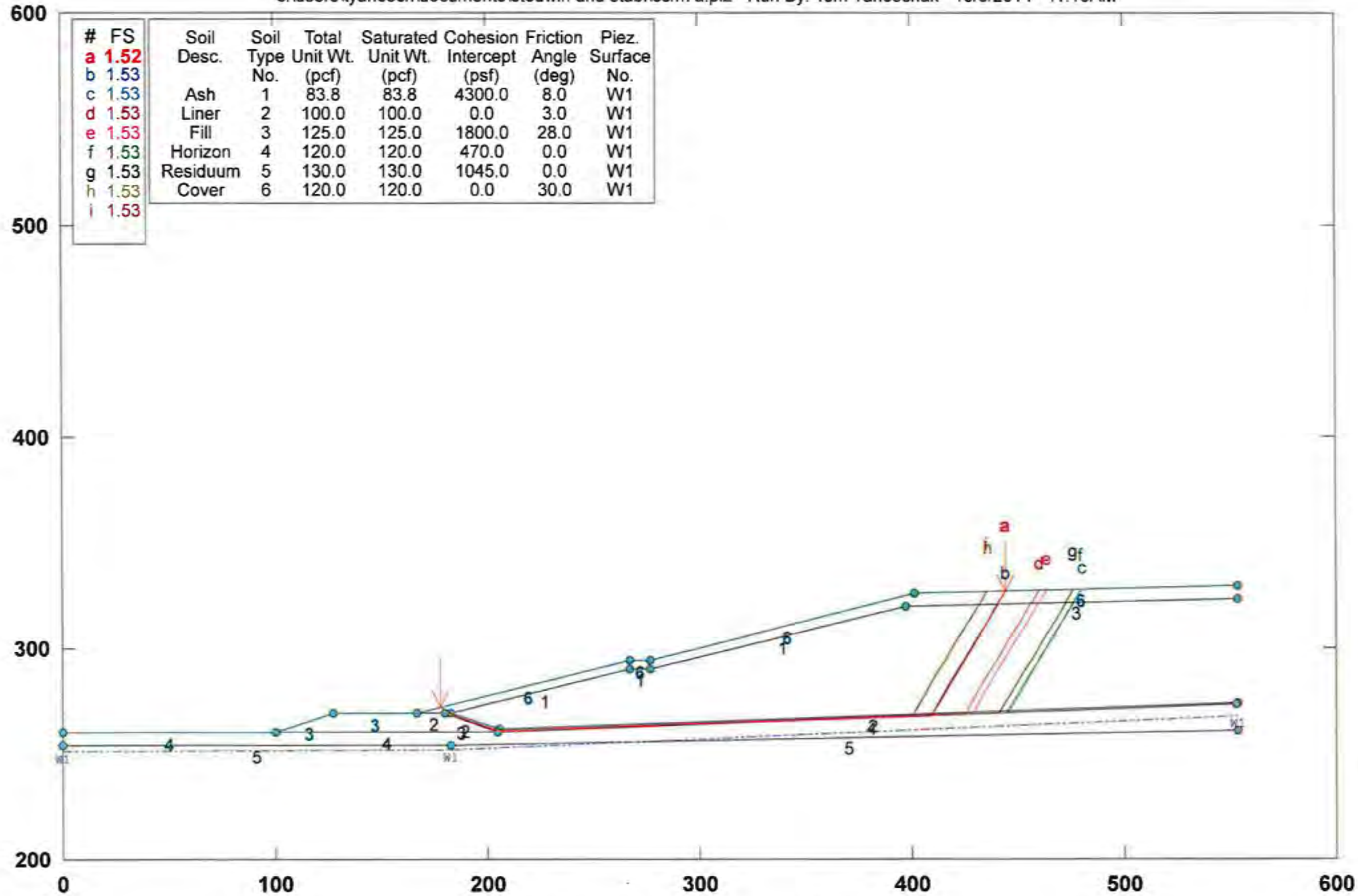
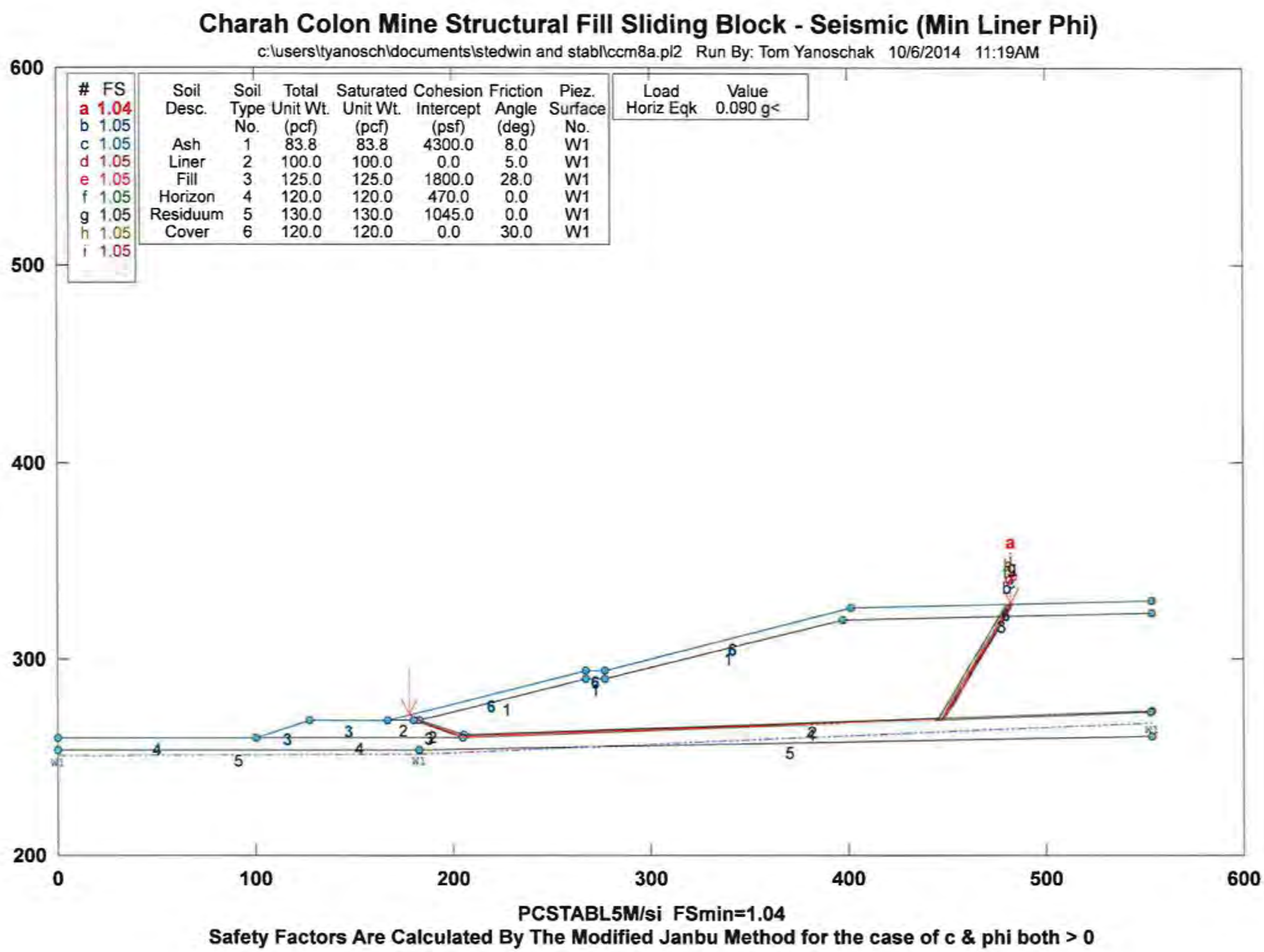


PCSTABL5M/si FSmin=1.52

Safety Factors Are Calculated By The Modified Janbu Method for the case of c & phi both > 0


Charah Colon Mine Structural Fill Sliding Block - Seismic (Min Liner Phi)
c:\users\tyanosch\documents\stedwin and stabl\ccm8a.pl2 Run By: Tom Yanoschak 10/6/2014 11:19AM
FS
a 1.04
b 1.05
c 1.05
d 1.05
e 1.05
f 1.05
g 1.05
h 1.05
i 1.05
Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Piez. Surface No.
Ash 1 83.8 83.8 4300.0 8.0 W1
Liner 2 100.0 100.0 0.0 5.0 W1
Fill 3 125.0 125.0 1800.0 28.0 W1
Horizon 4 120.0 120.0 470.0 0.0 W1
Residuum 5 130.0 130.0 1045.0 0.0 W1
Cover 6 120.0 120.0 0.0 30.0 W1
Load Value
Horiz Eqk 0.090 g<
600
500
400
300
200
0
100
200
300
400
500
600
PCSTABL5M/si FSmin=1.04
Safety Factors Are Calculated By The Modified Janbu Method for the case of c & phi both > 0

ATTACHMENT A

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Boring Log, PZ-1

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

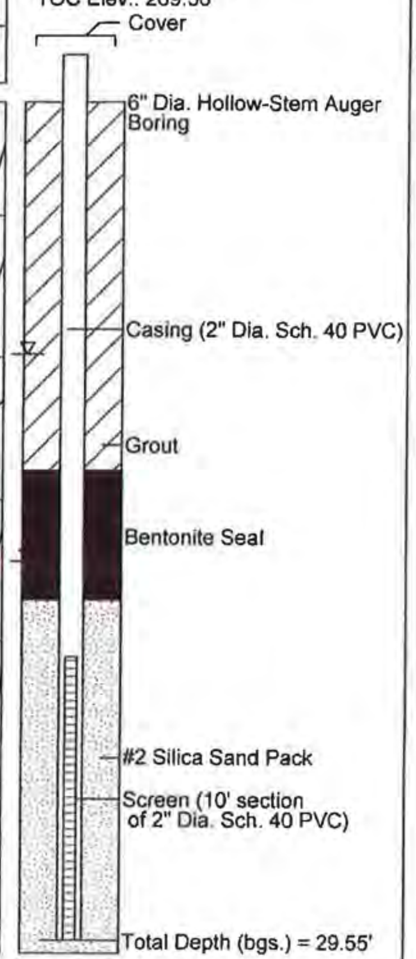
Date Started:	7/15/14	Logged By:	Ross Klingman, P.G.
Date Completed:	7/15/14	Drilling Method:	HSA; CME-45C
Drilling Company:	Red Dog Drilling	Top-of-Casing Elev.:	269.36'(Lawrence Survey)
Drillers Name:	Mark Seiler	Ground Surface Elev.:	266.78'(Lawrence Survey)
NC Driller Certification:	2789A	Natural, Cut, Fill Grade:	Fill (road bed)

Water Levels
- ▼ 1 Hour = 16.17' bgs
- ▽ 24 Hours = 8.89' bgs

Sample Type
- SS = Split Spoon
- ST = Shelby Tube
- RC = Rock Core
- BAG = Bag Sample

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	266.78	4 32 35 (67)	SS	14	dry; very hard; red (2.5YR 4/6) with brown mottles; fine to carse sandy silty clay with brick gravel fragments; cohesive; medium plasticity; Fill (CH CL)
5	261.78	5 7 9 (16)	SS	16	moist; very stiff; reddish brown (2.5 YR 4/3) with orange and yellow mottles and black vertical stringers; quartz gravelly silty clay; high plasticity; cohesive; Fill (CL)
10	256.78	7 5 8 (13)	SS	18	moist; stiff; reddish yellow (5YR 6/6) with white and rust mottles and stringers; silty clay; medium plasticity; cohesive; Fill (CL)
15	251.78	17 50/4"	SS	10	moist; very hard; yellowish red (5YR 4/6) with black stringers; horizontal fissle; very fine mica sandy silty clay with large quartz gravel; low plasticity; cohesive; Partially Weathered Rock
20	246.78	7 50/4"	SS,BAG	8	dry; very compact; red (2.5YR 4/6); clayey silty medium sand; no plasticity or cohesion; Partially Weathered Rock; (Lab Results: PZ-1 Bag (19-20'); USCS=SC; Gravel=12.1%; Sand=58.9%; Silt=22.7%; Clay=6.3%; Effective Porosity=26%; Atterberg Limits: PL=17, LL=29, PI=12)
25	241.78	41 50/1"	SS, BAG	10	dry; very compact; weak red (2.5YR 4/6) with white mottles and specks; horizontal fissle; quartz gravelly clayey silt; low plasticity; cohesive; Partially Weathered Rock; (Lab Results: PZ-1 Bag (24-25'); USCS=CL; Sand=38.9%; Silt=47.1%; Clay=14.0%; Effective Porosity=15%; Atterberg Limits: PL=17, LL=30, PI=13)
30	236.78	50/.5"	SS	4	wet; weak red (10R 4/4); weathered mudstone with quartz and phyllite gravel; Partially Weathered Rock
					Auger Refusal @ 30'
35	231.78				
40	226.78				
45					

Margin notes (handwritten): Fill CL (0–10'); CL (10'); PWR (15').



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Boring Log, PZ-2s and 2

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

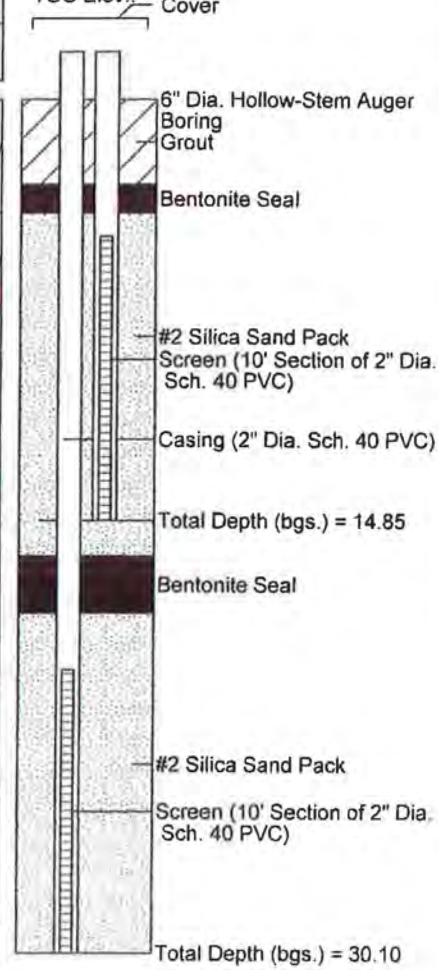
Date Started:	7/15/14	Logged By:	Ross Klingman, P.G.
Date Completed:	7/16/14	Drilling Method:	HSA; CME-45C
Drilling Company:	Red Dog Drilling	Top-of-Casing Elev.:	276.93'/276.84'
Drillers Name:	Mark Seiler	Ground Surface Elev.:	274.31'
NC Driller Certification:	2789A	Natural, Cut, Fill Grade:	Fill (road bed)

Water Levels
▼ 1 Hour = dry/16.10' bgs
▽ 24 Hours = dry/11.84' bgs

Sample Type
SS = Split Spoon
ST = Shelby Tube
RC = Rock Core
BAG = Bag Sample

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	274.31	17 18 24	SS	21	dry; compact; reddish yellow (7.5YR 6/8); horizontal fissle; clayey silt with gravel and brick fragments; no plasticity or cohesion; Fill
5	269.31	14 8 18	SS	20	moist; very stiff; brown (10YR 5/3) with gray and white mottles; quartz gravelly fine sandy clayey silt with roots and organic odor; low plasticity; cohesive; Fill
10	264.31	4 4 6	SS,ST	20,24	moist; stiff; brownish yellow (10YR 6/6) with light gray and light orange mottles; coarse quartz sandy clayey silt; low plasticity; cohesive; Flood Plain; (Lab Results: PZ-2 UD (9-11'); USCS=CH; Gravel=2.1%; Sand=15.3%; Silt= 40.2%; Clay=42.4%; Specific Gravity=2.66' Hydraulic Conductivity= 6.23 x 10-5 cm/sec; Total Porosity=40.7%; Effective Porosity=2%; Atterberg Limits: PL=25, LL=50; PI=25)
15	259.31	30 50/4"	SS	12	dry; very hard; yellowish red (5YR 4/6) with black manganese horizontal planes between fissle layers; clayey silt; low plasticity; cohesive; Partially Weathered Rock
20	254.31	12 13 20	SS	16	moist; hard; red (2.5YR 5/6) with yellow stringers; silty clay; low plasticity; cohesive; Residuum
25	249.31	26 20 30	SS	18	moist; hard; reddish brown (2.5YR 5/4) with light green gray and black stringers; horizontal fissle; fine sandy clayey silt; low plasticity; cohesive; Residuum
30	244.31	17 22 50/2"	SS,BAG	14	wet; very hard; red (2.5YR 4/8); silty clay; low plasticity; cohesive; Partially Weathered Rock; (Lab Results: PZ-2 Bag (29-30.5'); USCS=CL; Sand=2.2%; Silt=70.7%; Clay=27.1%; Effective Porosity=4; Atterberg Limits= PL=22, LL=43, PI=21)
					Auger Refusal @ 30.5'
35	239.31				
40	234.31				
45					

Well1: PZ-2s
Well2: PZ-2
TOC Elev.:



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Boring Log, PZ-3s and 3

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

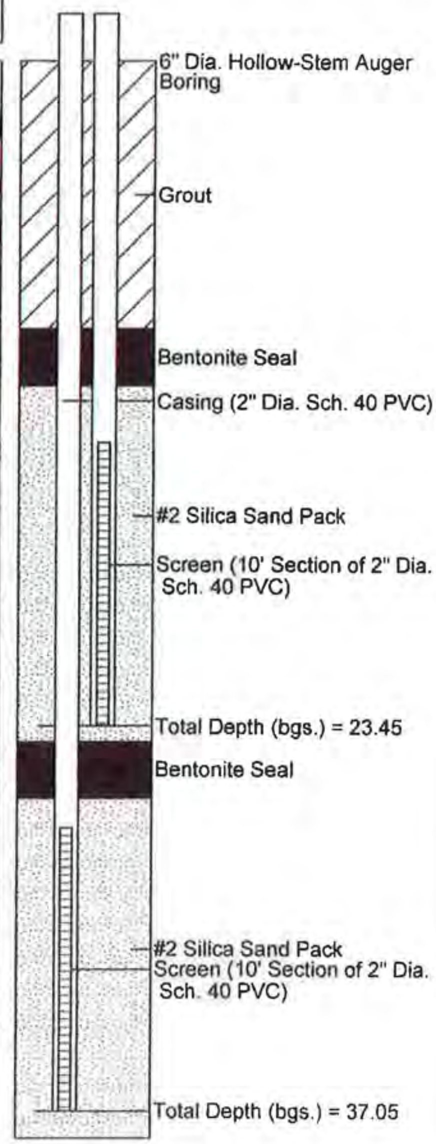
Date Started:	: 7/16/14	Logged By:	: Ross Klingman, P.G.
Date Completed:	: 7/16/14	Drilling Method:	: HSA; CME-45C
Drilling Company:	: Red Dog Drilling	Top-of-Casing Elev.:	: 299.12'/299.29'
Drillers Name:	: Mark Seiler	Ground Surface Elev.:	: 296.20'
NC Driller Certification:	: 2789A	Natural, Cut, Fill Grade:	: slight cut

Water Levels
- 1 Hour = dry/36.11'bgs
- 24 Hours = dry/30.91' bgs

Sample Type
- SS = Split Spoon
- ST = Shelby Tube
- RC = Rock Core
- BAG = Bag Sample

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	296.2	4 6 8	SS,ST	16,24	moist; stiff; yellowish red (5YR 5/6) with light gray and orange yellow mottled; fine to coarse sandy gravelly clayey silt; low plasticity; cohesive; Soil Horizon; (Lab Results: PZ-3 UD (0-2'); USCS=CL; Sand=6.7%; Silt=52.8%; Clay=40.5%; Specific Gravity=2.67; Hydraulic Conductivity=2.42 x 10-6 cm/sec; Total Porosity=39.3%; Effectuve Porosity=2%; Atterberg Limits: PL=27, LL=48, PI=21)
5	291.2	7 8 11	SS	14	moist; very stiff; red (2.5YR 4/6) with white and brown specks; clayey fine to coarse sandy and gravelly silt; no plasticity; cohesive; Residuum
10	286.2	7 16 16	SS	14	dry; hard; reddish brown (2.5YR 5/4) with light orange and maroon mottles; clayey silt; no plasticity; cohesive; Residuum
15	281.2	15 44 50/3"	SS	16	moist; very hard; red (10R 5/6) with maroon mottles and vertical manganese fracture planes; clayey silt; no plasticity; cohesive; Partially Weathered Rock
20	276.2	50/6"	SS	7	dry; very hard; reddish brown (2.5YR 5/4) with olive green and white specks; fine to medium sandy silt with rock fragments; no plasticity; cohesive; Partially Weathered Rock
25	271.2	50/5"	SS	9	dry; very compact; reddish brown (2.5YR 5/4) with white and green specks; medium horizontal fissle; silty fine to coarse sand with gravel; no plasticity or cohesion; Partially Weathered Rock
30	266.2	50/2"	SS	5	dry; very hard; weak red (10R 5/3); highly horizontal fissle; fine mica sandy silt; no plasticity; cohesive; Partially Weathered Rock
35	261.2	50/5"	SS,BAG	6	moist; weak red (10R 4/3) with green, yellow and black specks and mottles; slightly clayey silty fine to coarse sand with phyllite gravel; no plasticity or cohesion; Partially Weathered Rock; (Lab Results: PZ-3 Bag (34-34.5'); USCS=SM; Gravel=12.8%; Sand=59.7%; Silt and Clay=27.5%; Effective Porosity=30%)
40	256.2				Auger Refual @ 38'
45					

Well1: PZ-3s
Well2: PZ-3
TOC Elev. Cover



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Boring Log, PZ-4

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

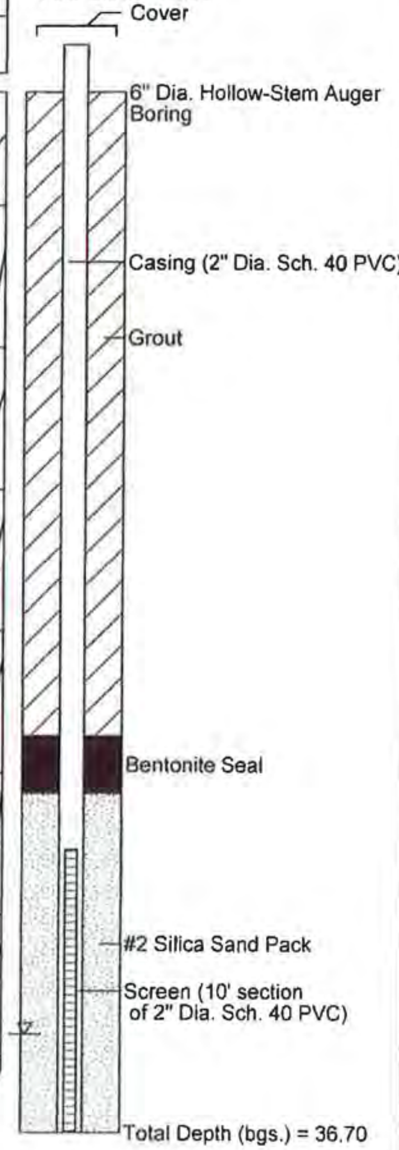
Date Started:	7/16/14	Logged By:	Ross Klingman, P.G.
Date Completed:	7/16/14	Drilling Method:	HSA; CME-45C
Drilling Company:	Red Dog Drilling	Top-of-Casing Elev.:	299.50'(Lawrence Survey)
Drillers Name:	Mark Seiler	Ground Surface Elev.:	296.82'(Lawrence Survey)
NC Driller Certification:	2789A	Natural, Cut, Fill Grade:	slight cut

Water Levels
- ▼ 1 Hour = dry
- ▽ 24 Hours = 33.22' bgs

Sample Type
- SS = Split Spoon
- ST = Shelby Tube
- RC = Rock Core
- BAG = Bag Sample

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	296.82	4 5 5	SS	14	moist; stiff; brownish yellow (10YR 6/8); fine to coarse sandy clayey silt with gravel; low plasticity; cohesive; Soil Horizon
5	291.82	4 5 6	SS,BAG	16	moist; stiff; brownish yellow (10YR 6/8) with rust mottles; silty clay; low plasticity; cohesive; Soil Horizon; (Lab Results: PZ-4 Bag (4-5.5'); USCS=CH; Sand=3.0%; Silt=50.9%; Clay=46.1%; Effective Porosity=2%; Atterberg Limits: PL=27, LL=60, PI=33)
10	286.82	9 9 12	SS	18	moist; very stiff; red (2.5YR 4/8) with olive green, rust, light gray and light purple mottled; gravelly clayey silt; no plasticity; cohesive; Residuum
15	281.82	27 50/5"	SS	12	dry; very hard; weak red (2.5YR 5/2) with light green specks; medium horizontal fissle; silt; no plasticity; cohesive; Partially Weathered Rock
20	276.82	29 50/3"	SS	12	dry; very hard; weak red (2.5YR 5/2) with white stringers and vertical black manganese fracture planes; silt; no plasticity; cohesive; Partially Weathered Rock
25	271.82	47 50/4"	SS, BAG	15	moist; very hard; red (2.5YR 4/6); highly horizontal fissle; very slightly clayey silt; no plasticity; cohesive; Partially Weathered Rock; (Lab Results: PZ-4 Bag (24-24.5'); USCS=CL; Sand=21.0%; Silt=61.6%; Clay=17.4%; Effective Porosity=11%; Atterberg Limits: PL=16, LL=31, PI=15)
30	266.82	34 50/2"	SS	20	moist; very hard; weak red (10R 4/2) with white, black and yellow specks and stringers; medium horizontal fissle; slightly clayey silt; no plasticity; cohesive; Partially Weathered Rock
35	261.82	50/0"	SS	0	No Recovery
					Auger Refusal @ 36.7'
40	256.82				
45					

Well: PZ-4
TOC Elev.: 299.50



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Boring Log, PZ-4D

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

Date Started:	7/16/14	Logged By:	Ross Klingman, P.G.
Date Completed:	7/16/14	Drilling Method:	HSA; Geoprobe 8040DT
Drilling Company:	Geologic Exploration	Top-of-Casing Elev.:	299.76'(Lawrence Survey)
Drillers Name:	Johnny Burr	Ground Surface Elev.:	297 25'(Lawrence Survey)
NC Driller Certification:	3098A	Natural, Cut, Fill Grade:	slight cut

Water Levels
- ▼ 1 Hour = dry
- ▽ 24 Hours = 35.00' bgs

Sample Type
- SS = Split Spoon
- ST = Shelby Tube
- RC = Rock Core
- BAG = Bag Sample

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	297.25				Advance 10" diameter Hollow-Stem Augers from 0-35' See Boring Log PZ-4 for lithologic information from 0-36.5'
5	292.25				
10	287.25				
15	282.25				
20	277.25				
25	272.25				
30	267.25				
35	262.25				Auger Refusal @ 35' Advance 5 5/8" diameter mud-rotary drilling from 35-45', (layered rock and soil from 35-42'; moderately competent rock from 42-45')
40	257.25				
45	252.25				Advance HQ rock core (3 5/8" outer diameter) from 45-55' *1st Run from 45-50' (23.5" Recovery; RQD=39.2%; Rock Mass Quaility=Poor) Upper 9" core (blocky mudstone with healed 80 degree fracture; grading downward to muddy coarse sandstone) Lower 14.5" core (muddy sandy conglomerate; consiting of horizontally oriented rounded phyllite discs and rounded quartz gravel)
50	247.25				
55	242.25				
60	237.25				*2nd Run (50-55') (45" Recovery; RQD=23.3%; Rock Mass Quality=Very Poor) Broken conglomerate as above (4" total length); grading downward into blocky mudstone with horizontal fractures every 1.5 to 5" (37.5" total length); grading downward into muddy coarse sandstone (3.5" length total)
65	232.25				
70					

Well: PZ-4D
TOC Elev.: 299.76

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Boring Log, PZ-5

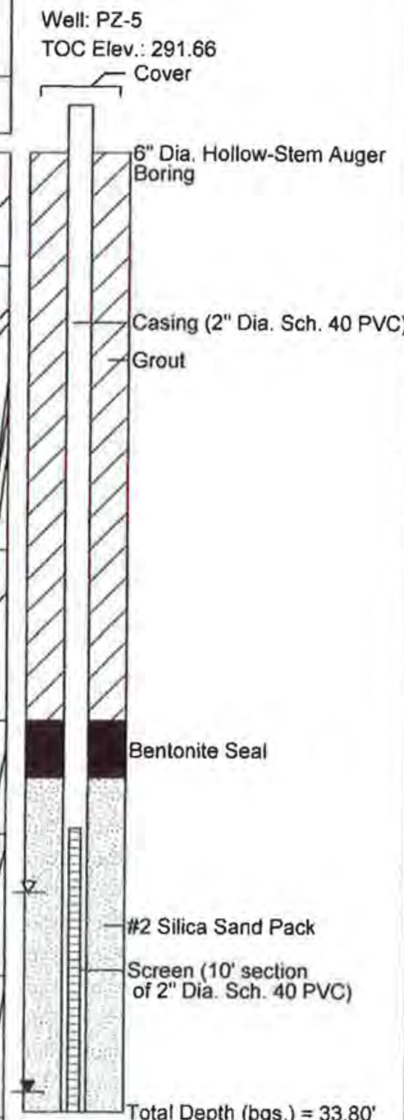
Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

Date Started:	7/17/14	Logged By:	Ross Klingman, P.G.
Date Completed:	7/17/14	Drilling Method:	HSA; CME-45C
Drilling Company:	Red Dog Drilling	Top-of-Casing Elev.:	291.66'(Lawrence Survey)
Drillers Name:	Mark Seiler	Ground Surface Elev.:	289.11'(Lawrence Survey)
NC Driller Certification:	2789A	Natural, Cut, Fill Grade:	slight cut

Water Levels
- ▼ 1 Hour = 33.10' bgs
- ▽ 24 Hours = 26.06' bgs

Sample Type
- SS = Split Spoon
- ST = Shelby Tube
- RC = Rock Core
- BAG = Bag Sample

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	289.11	3 5 6	SS	16	moist; stiff; yellow (10YR 7/8) with light orange mottles; silty clay; medium plasticity; cohesive; Soil Horizon
5	284.11	3 4 5	SS	19	wet; stiff; red (2.5YR 5/6) with yellow and light gray mottles; silty clay; low plasticity; cohesive; Soil Horizon
			ST	24	moist; red (2.5YR 4/6); clayey silt and silty clay; low plasticity; cohesive; Residuum; (Lab Results: PZ-5 UD (6-8'); USCS=CL; Sand=2.2%; Silt=62.1%; Clay=35.7%; Specific Gravity=2.69; Hydraulic Conductivity=2.43 x 10-7 cm/sec; Total Porosity=30.6%; Effective Porosity=2%; Atterberg Limits: PL=26, LL=48, PI=22)
10	279.11	10 22 37	SS	15	moist; very hard; red (2.5YR 4/6); medium horizontal fissle; clayey silt; low plasticity; cohesive; Residuum
15	274.11	12 31 32	SS	18	moist; very hard; red (2.5YR 4/6); medium horizontal fissle; clayey silt; low plasticity; cohesive; Residuum
20	269.11	33 50/5"	SS	14	moist; very hard; weak red (10R 4/3) with dark gray mottles; blocky horizontal fissle; silty clay; no plasticity; cohesive; Partially Weathered Rock
25	264.11	50/6"	SS	14	moist; very hard; red (10R 4/6); highly horizontal fissle; slightly clayey silt; no plasticity; cohesive; Partially Weathered Rock
30	259.11	50/2"	SS	5	moist; very hard; red (10R 4/6) with gray pods; highly horizontal fissle; slightly clayey silt; no plasticity; cohesive; Partially Weathered Rock
35	254.11	50/6"	SS,BAG	8	wet; very hard; red (10R 4/6) with gray pods; highly horizontal fissle; slightly clayey silt; no plasticity; cohesive; Partially Weathered Rock; (Lab Results: PZ-5 Bag (34-34.5'); USCS=CL; Sand 13.7%; Silt=73.6; Clay=12.7%; Effective Porosity=8; Atterberg Limits: PL=20, LL=32, PI=12)
40	249.11				
45					



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Boring Log, PZ-6

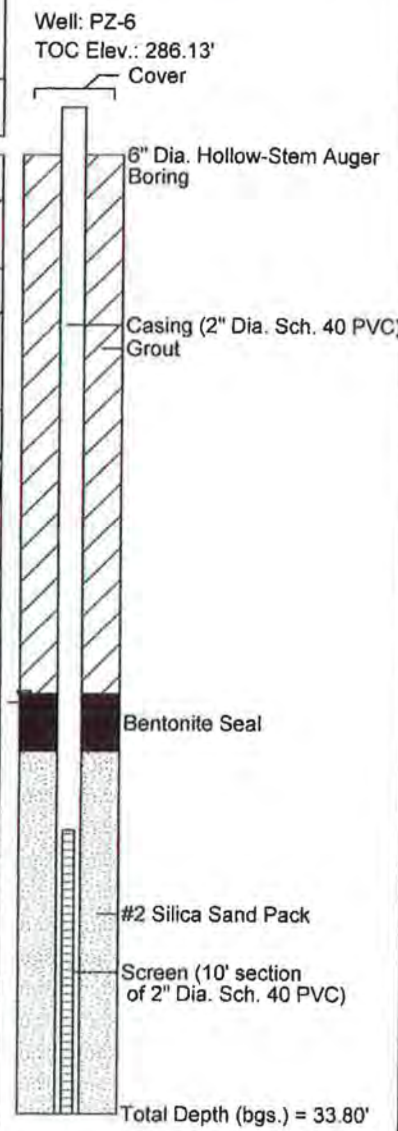
Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

Date Started:	7/17/14	Logged By:	Ross Klingman, P.G.
Date Completed:	7/17/14	Drilling Method:	HSA; CME-45C
Drilling Company:	Red Dog Drilling	Top-of-Casing Elev.:	286.13'(Lawrence Survey)
Drillers Name:	Mark Seiler	Ground Surface Elev.:	283.48'(Lawrence Survey)
NC Driller Certification:	2789A	Natural, Cut, Fill Grade:	slight cut

Water Levels
- ▼ 1 Hour = dry
- ▽ 24 Hours = 19.30' bgs

Sample Type
- SS = Split Spoon
- ST = Shelby Tube
- RC = Rock Core
- BAG = Bag Sample

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	283.48	3 5 8	SS	10	moist; medium compact; yellow (10YR 7/6); horizontal fissle; silt; no plasticity or cohesion; Soil Horizon
5	278.48	4 3 5	SS	13	moist; medium; pale yellow (2.5 Y 7/4) with light rust mottles; silty clay with roots; low plasticity; cohesive; Soil Horizon
10	273.48	7 11 15	SS	20	moist; very stiff; dark reddish gray (2.5YR 4/1) with white and yellow mottles; silty clay; low plasticity; cohesive; Residuum
			ST	7	moist; weak red (10R 4/4); clayey silt; no plasticity; cohesive; Residuum; (Lab Results: PZ-6 UD (10.5-11'); USCS=CL; Sand=11.3%, Silt=72.5%, Clay=16.2%; Specific Gravity=2.68; Hydraulic Conductivity=6.01 x 10-6 cm/sec; Total Porosity=30.7%; Effective Porosity=8%; Atterberg Limits: PL=23, LL=37, PI=14)
15	268.48	9 21 50/5"	SS	24	moist; very hard; red (2.5YR 4/6); fine to coarse sandy clayey silt with gravel and rock fragments; no plasticity; cohesive; Partially Weathered Rock
20	263.48	50/4"	SS,BAG	6	dry; very hard; dark reddish brown (2.5YR 4/1); silty medium to coarse sand with rounded phyllite gravel; no plasticity; cohesive; Partially Weathered Rock; (Lab Results: PZ-6 Bag (19-19.5'); USCS=SC; Sand=59.9%; Silt=27.1%; Clay=13.0%; Effective Porosity=16%; Atterberg Limits: PL=18, LL=33, PI=15)
25	258.48	50/1"	SS	1	moist; very hard; reddish brown (2.5YR 4/4); horizontal fissle; weathered mudstone; Partially Weathered Rock
30	253.48	50/.5"	SS	1	dry; very hard; weak red (2.5YR 5/2); horizontal fissle; sandy mudstone; Partially Weathered Rock
35	248.48	50/.5"	SS	1	dry; very hard; weak red (2.5YR 5/2); weathered silty conglomerate; Partially Weathered Rock
40	243.48				
45					



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Boring Log, PZ-7

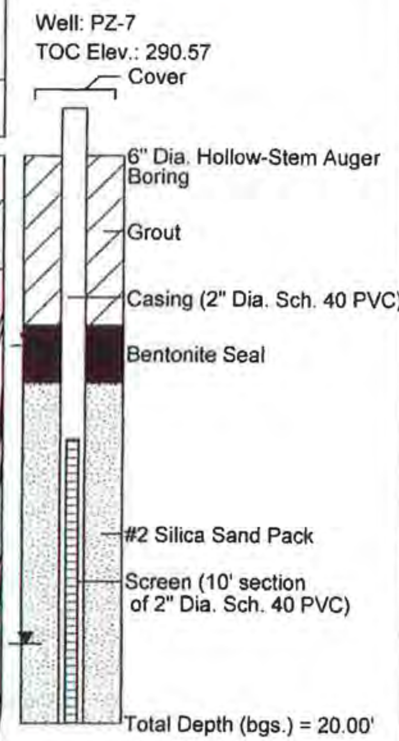
Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

Date Started:	: 7/17/14	Logged By:	: Ross Klingman, P.G.
Date Completed:	: 7/17/14	Drilling Method:	: HSA
Drilling Company:	: Red Dog Drilling	Top-of-Casing Elev.:	: 290.57'(Lawrence Survey)
Drillers Name:	: Mark Seiler	Ground Surface Elev.:	: 287.92'(Lawrence Survey)
NC Driller Certification:	: 2789A	Natural, Cut, Fill Grade:	: slight cut

Water Levels
- ▼ 1 Hour = 17.20' bgs
- ▽ 24 Hours = 6.69' bgs

Sample Type
- SS = Split Spoon
- ST = Shelby Tube
- RC = Rock Core
- BAG = Bag Sample

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	287.92	3 3 5	SS	16	moist; medium; light yellowish brown (2.5Y 6/3); fine to coarse sandy clayey silt with roots; no plasticity; cohesive; Soil Horizon
5	282.92	5 8 12	SS	12	moist; very stiff; reddish brown (%YR 5/4) with light gray mottles; blocky; fine to coarse sandy silty clay; low plasticity; cohesive; Residuum
			ST	24	
10	277.92	11 13 15	SS	20	moist; reddish brown (5YR 5/4) with light gray mottles; blocky; fine to coarse sandy silty clay; low plasticity; cohesive; Residuum; (Lab Results: PZ-7 UD (6-8'); USCS=CL; Sand=3.2%; Silt=67.5%; Clay=29.3%; Specific Gravity=2.74; Hydraulic Conductivity=1.76 x 10-6 cm/sec; Total Porosity=30.1; Effective Porosity=3; Atterberg Limits: PL=24, LL=40, PI=16)
		50/6"	SS,BAG	15	moist/wet; very stiff; reddish brown (5YR 5/4) with vertical black manganese planes; silty clay; low plasticity; cohesive; Residuum
15	272.92				moist/wet; very hard; red (2.5YR 5/8); highly horizontal fissle; clayey silt; no plasticity; cohesive; Partially Weathered Rock; (Lab Results: PZ-7 Bag (14-14.5); USCS=CL; Sand=0.4%; Silt=76.8%; Clay=22.8%; Effective Porosity=4%; Atterberg Limits: PL=22, LL=41, PI=19)
		50/1"	SS	3	
20	267.92				wet; very hard; reddish brown (5YR 5/4); highly horizontal fissle; weathered sandy mud stone; Partially Weathered Rock
25	262.92				
30	257.92				
35	252.92				
40	247.92				
45					



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Boring Log, PZ-8

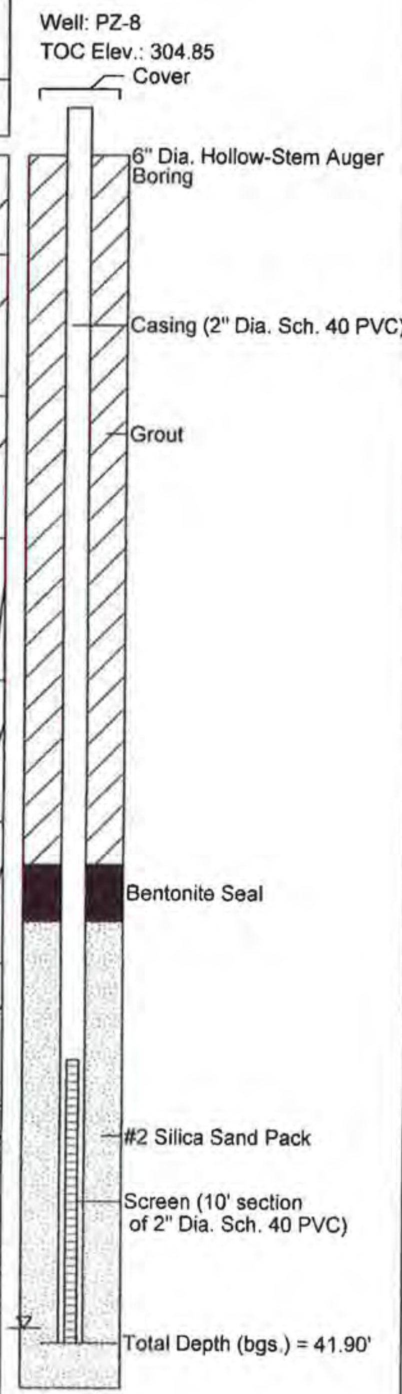
Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

Date Started:	7/21/14	Logged By:	Ross Klingman, P.G.
Date Completed:	7/21/14	Drilling Method:	HSA; CME-550x
Drilling Company:	Summit Engineering	Top-of-Casing Elev.:	304.85'(Lawrence Survey)
Drillers Name:	Robert Cassell	Ground Surface Elev.:	302.56'(Lawrence Survey)
NC Driller Certification:	4143A	Natural, Cut, Fill Grade:	slight cut

Water Levels
- ▼ 1 Hour = dry
- ▽ 24 Hours = 41.38' bgs

Sample Type
- SS = Split Spoon
- ST = Shelby Tube
- RC = Rock Core
- BAG = Bag Sample

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	302.56	4 5 8	SS	18	moist; stiff; strong brown (7.5Y 5/8) with white specks; silty clay; medium plasticity; cohesive; Residuum
5	297.56	3 4 6	SS	14	moist; stiff; red (2.5YR 4/6) with light orange mottles; silty clay; low plasticity; cohesive; Residuum
10	292.56	4 6 9	SS	15	moist; stiff; red (2.5YR 4/6); silty clay; low plasticity; cohesive; Residuum
15	287.56	10 13 13	SS,BAG	16	moist; very stiff; red (2.5YR 4/6) with orange mottles and black stringers; silty clay; low plasticity; cohesive; Residuum; (Lab Results: PZ-8 Bag (13.5-15'); USCS=CL; Sand=3.1%; Silt=68.1%; Clay=28.8%; Effective Porosity=3%; Atterberg Limits: PL=23, LL=39, PI=16)
20	282.56	9 13 17	SS	14	moist; very stiff; red (10R 4/8) with light gray and yellow mottles; clayey quartz and phyllite gravelly silt; no plasticity; cohesive; Residuum
25	277.56	8 13 15	SS	20	moist; very stiff; red (10R 4/6) with light gray and yellow mottles; clayey quartz and phyllite gravelly silt; no plasticity; cohesive; Residuum
30	272.56	9 27 50/5"	SS	20	moist; very hard; red (10R 4/8) with maroon mottles; silty clay; low plasticity; cohesive; Residuum
35	267.56	34 50/5"	SS	15	moist; very hard; red (10R 4/8) with maroon mottles; silty clay; low plasticity; cohesive; Residuum
40	262.56	50/5"	SS	12	dry; very compact; weak red (10R 4/4); clayey silty fine to coarse sand; no plasticity or cohesion; Partially Weathered Rock
45		50/5"	SS	10	moist; very hard; red (10R 4/8); highly horizontal fissle; silty clay; low plasticity; cohesive; Partially Weathered Rock



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Boring Log, PZ-9s and 9

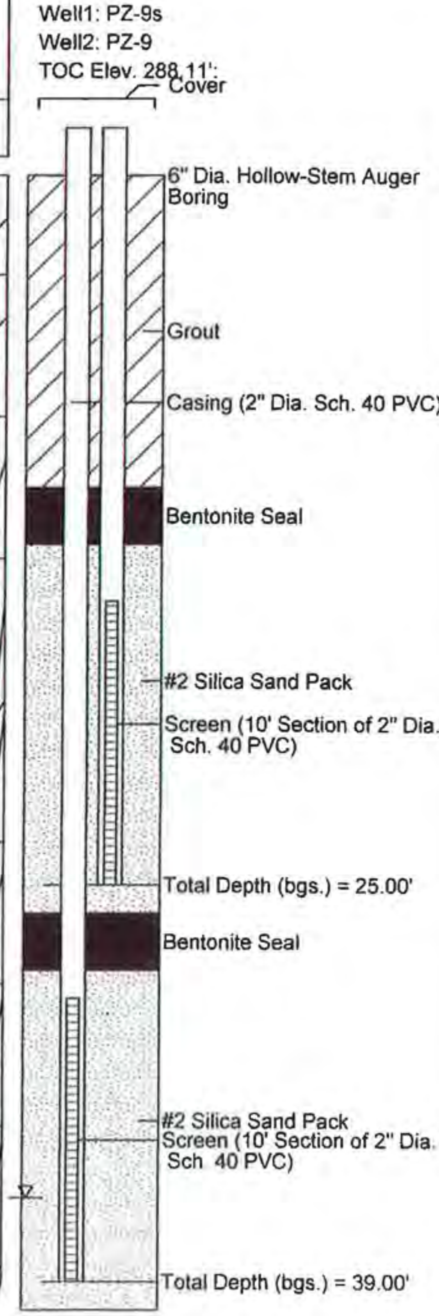
Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

Date Started:	7/21/14	Logged By:	Ross Klingman, P.G.
Date Completed:	7/21/14	Drilling Method:	HSA; CME-550x
Drilling Company:	Summit Engineering	Top-of-Casing Elev.:	288.11'/288.11'
Drillers Name:	Robert Cassell	Ground Surface Elev.:	285.74'
NC Driller Certification:	4143A	Natural, Cut, Fill Grade:	slight cut

Water Levels
- ▼ 1 Hour = dry/dry
- ▽ 24 Hours = dry/36.03' bgs

Sample Type
- SS = Split Spoon
- ST = Shelby Tube
- RC = Rock Core
- BAG = Bag Sample

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	285.74	3 4 6	SS	16	moist; stiff; yellowish red (5YR 5/6) with rust mottles; silty clay; low plasticity; cohesive; Soil Horizon
5	280.74	3 4 8	SS	16	moist; stiff; light yellow brown (2.5 Y 6/3) with light orange mottles; silty clay; low plasticity; cohesive; Soil Horizon
10	275.74	3 4 7	SS	16	moist; stiff; light yellowish brown (2.5Y 6/3) with rust and maroon mottles; silty clay; low plasticity; cohesive; Soil Horizon
15	270.74	12 15 32	SS,BAG	22	dry; compact; weak red (10R 4/3) with white and gray specks; silty fine to coarse sand with phyllite gravel; no plasticity or plasticity; Residuum; (Lab Results: PZ-9 Bag (13.5-15'); USCS=SC; Gravel=0.4%; Sand=52.2; Silt=35.9; Clay=11.5%; Effective Porosity=17; Atterberg Limits: PL=20, LL=34, PI=14)
20	265.74	50/5"	SS	8	dry; very hard; weak red (10R 4/3); highly horizontal fissle; fine sandy silt; no plasticity; cohesive; Partially Weathered Rock
25	260.74	34 50/4"	SS	8	dry; very compact; weak red (10R 4/3) with white and gray specks; silty fine to coarse sand with phyllite gravel; no plasticity or cohesion; Partially Weathered Rock
30	255.74	50/5"	SS	6	dry; very compact; weak red (10R 4/3) with white and gray specks; silty fine to coarse sand with phyllite gravel; no plasticity or cohesion; Partially Weathered Rock
35	250.74	50/5"	SS	4	dry; very compact; weak red (10R 4/3) with white and gray specks; medium horizontal fissle; silty fine to coarse sand with phyllite gravel; no plasticity or cohesion; Partially Weathered Rock
40	245.74	50/5"	SS	8	dry; very hard; reddish brown (2.5YR 4/4); highly horizontal fissle; weathered mudstone; Partially Weathered Rock
45					



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Boring Log, PZ-10

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

Date Started:	7/21/14	Logged By:	Ross Klingman, P.G.
Date Completed:	7/21/14	Drilling Method:	HSA; CME-550x
Drilling Company:	Summit Engineering	Top-of-Casing Elev.:	266.51'(Lawrence Survey)
Drillers Name:	Robert Cassell	Ground Surface Elev.:	263.48'(Lawrence Survey)
NC Driller Certification:	4143A	Natural, Cut, Fill Grade:	slight cut

Water Levels
▼ 1 Hour = dry
▽ 24 Hours = dry

Sample Type
SS = Split Spoon
ST = Shelby Tube
RC = Rock Core
BAG = Bag Sample

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	263.48	3 5 6 6 (11)	SS	24	moist; stiff; reddish yellow (7.5YR 6/6) with light gray and rust mottles; silty clay; no plasticity; cohesive; Soil Horizon (CL)
5	258.48	11 13 14 (27)	SS	14	dry; very stiff; red (2.5YR 4/8) with maroon and light gray mottles; clayey fine sandy silt; no plasticity; cohesive; Residuum (MH)
10	253.48	13 50/4"	SS	12	dry; very hard; red (2.5YR 4/6) with black vertical planes; blocky; silty clay; no plasticity; cohesive; Partially Weathered Rock (CL)
15	248.48	50/3"	SS	3	dry; very hard; red (2.5YR 4/6) with black vertical planes; highly horizontal fissle; mica sandy silty clay; low plasticity; cohesive; Partially Weathered Rock
20	243.48	50/1"	SS	2	dry; very compact; weak red (10R 5/3); silty fine to coarse sand with quartz and phyllite gravel; no plasticity or cohesion; Partially Weathered Rock
25	238.48	50/6"	SS	12	dry; very hard; red (10R 4/6); highly horizontal fissle; silty clay; no plasticity; cohesive; Partially Weathered Rock
30	233.48	29 10 16	SS,BAG	18	moist; very hard; red (10R 4/6) with light orange mottles; highly horizontal fissle; silty clay; no plasticity; cohesive; Residuum; (Lab Results: PZ-10 Bag (28.5-30'); USCS=CL; Sand=5.7%; Silt=74.0%; Clay=20.3%; Effective Porosity=5%; Atterberg Limits: PL=18, LL=36; PI=18)
35	228.48				
40	223.48				
45					

Well: PZ-10
TOC Elev.: 266.51

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Boring Log, PZ-11

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

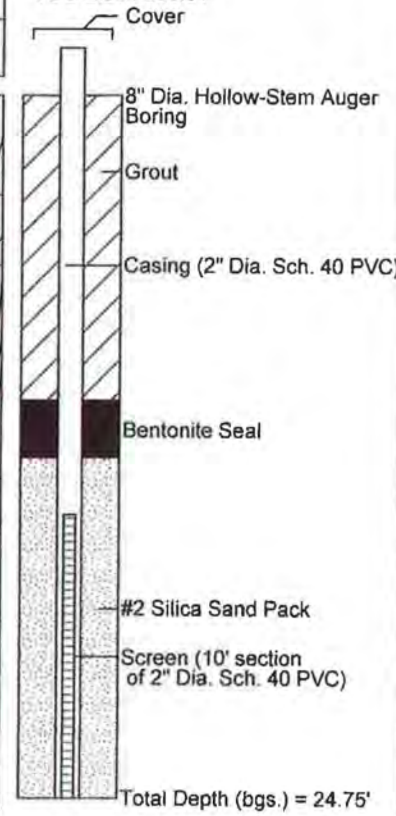
Date Started:	: 7/22/14	Logged By:	: Ross Klingman, P.G.
Date Completed:	: 7/22/14	Drilling Method:	: HSA; CME-550x
Drilling Company:	Summit Engineering	Top-of-Casing Elev.:	: 262.30'(Lawrence Survey)
Drillers Name:	Robert Cassell	Ground Surface Elev.:	: 259.56'(Lawrence Survey)
NC Driller Certification:	: 4143A	Natural, Cut, Fill Grade:	: natural (drainage bottom)

Water Levels
▼ 1 Hour = dry
▽ 24 Hours = 19.59' bgs

Sample Type
SS = Split Spoon
ST = Shelby Tube
RC = Rock Core
BAG = Bag Sample

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	263.48	3 7 9	SS	20	moist; very stiff; reddish yellow (7.5YR 6/8) with rust and light gray mottles; quartz gravelly fine to coarse sandy clayey silt; no plasticity; cohesive; Soil Horizon
5	258.48	3 7 5	SS	17	moist; stiff; yellowish red (5YR 4/6) with light gray mottles; fine mica sandy clayey silt; no plasticity; cohesive; Soil Horizon
			ST	6	dry; red (2.5YR 4/6), mica and quartz sandy silt; low plasticity; cohesive; Residuum; (Lab Results: PZ-11 UD (6-6.5'); USCS=SM; Gravel=4.8%; Sand=65.5%; Silt=22.6%; Clay=7.1%; Specific Gravity=2.71; Hydraulic Conductivity=3.86 x 10-6 cm/sec; Total Porosity=19.7%; Effective Porosity=25%)
10	253.48	39 50/3"	SS	12	dry; very hard; weak red (10R 4/3); silty fine to coarse sand with gravel; no plasticity; cohesive; Partially Weathered Rock
15	248.48	16 38 50/6"	SS	15	moist; very hard; red (2.5YR 4/6) with black and purple mottles; medium horizontal fissle; silty clay; no plasticity; cohesive; Partially Weathered Rock
20	243.48	15 36 50/4"	SS	20	moist; very hard; red (2.5YR 4/6) with black and purple mottles; highly horizontal fissle; silty clay; no plasticity; cohesive; Partially Weathered Rock
25	238.48	20 10 8	SS,BAG	16	wet; very stiff; red (2.5YR 4/6) with black and purple mottles; highly horizonatl fissle; silty clay with rock and gravel layers; no plasticity; cohesive; Residuum
30	233.48				
35	228.48				
40	223.48				
45					

Well: PZ-10
TOC Elev.: 266.51



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Boring Log, PZ-12

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

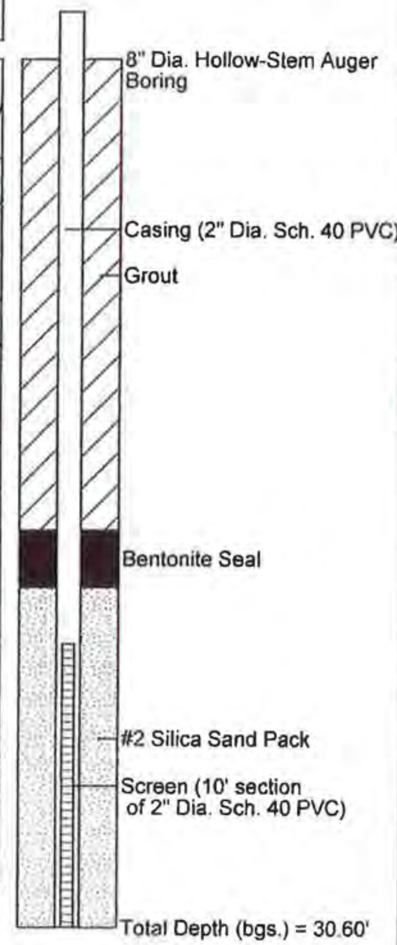
Date Started:	7/22/14	Logged By:	Ross Klingman, P.G.
Date Completed:	7/22/14	Drilling Method:	HSA; CME-550x
Drilling Company:	Summit Engineering	Top-of-Casing Elev.:	287.15'(Lawrence Survey)
Drillers Name:	Robert Cassell	Ground Surface Elev.:	284.32'(Lawrence Survey)
NC Driller Certification:	4143A	Natural, Cut, Fill Grade:	natural

Water Levels
- ▼ 1 Hour = dry
- ▽ 24 Hours = dry

Sample Type
- SS = Split Spoon
- ST = Shelby Tube
- RC = Rock Core
- BAG = Bag Sample

Well: PZ-12
TOC Elev.: 287.15

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	284.32	3 3 4	SS	16	moist; medium; yellowish red (5YR 5/8) with brown mottles; clayey, quartz gravelly silt and silty clay; low plasticity; cohesive; Soil Horizon
5	279.32	4 5 8	SS	14	moist; stiff; reddish yellow (7.5YR 6/8) with rust and light gray mottles; silty clay; medium plasticity; cohesive; Soil Horizon
10	274.32	3 4 7	SS	13	moist; stiff; red (2.5YR 4/6) with green and black specks; fine to medium sandy clayey silt; low plasticity; cohesive; Residuum
15	269.32	5 26 50/4"	SS	15	moist; very hard; red (2.5YR 4/6) with green and black specks; medium horizontal fissle; mica sandy clayey silt; no plasticity; cohesive; Partially Weathered Rock
20	264.32	12 13 16	SS,BAG	21	moist; very stiff; red (2.5YR 4/6) with purple mottles; blocky; silty clay; no plasticity; cohesive; Residuum; (Lab Results: PZ-12 Bag (18.5-20'); USCS=CL; Sand=0.7%; Silt=66.5%; Clay=32.8%; Effective Porosity=2%; Atterberg Limits: PL=20, LL=42, PI=22)
25	259.32	50/3"	SS	8	dry; very hard; red (2.5YR 5/6); horizontal fissle; weathered fine sandy mudstone; Partially Weathered Rock
30	254.32	50/3"	SS	10	dry; very hard; red (2.5YR 5/6); horizontal fissle; weathered fine sandy mudstone; Partially Weathered Rock
35	249.32				
40	244.32				
45					



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Boring Log, PZ-13

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

Date Started:	7/22/14	Logged By:	Ross Klingman, P.G.
Date Completed:	7/22/14	Drilling Method:	HSA; CME-550x
Drilling Company:	Summit Engineering	Top-of-Casing Elev.:	296.59'(Lawrence Survey)
Drillers Name:	Robert Cassell	Ground Surface Elev.:	293.48'(Lawrence Survey)
NC Driller Certification:	4143A	Natural, Cut, Fill Grade:	natural

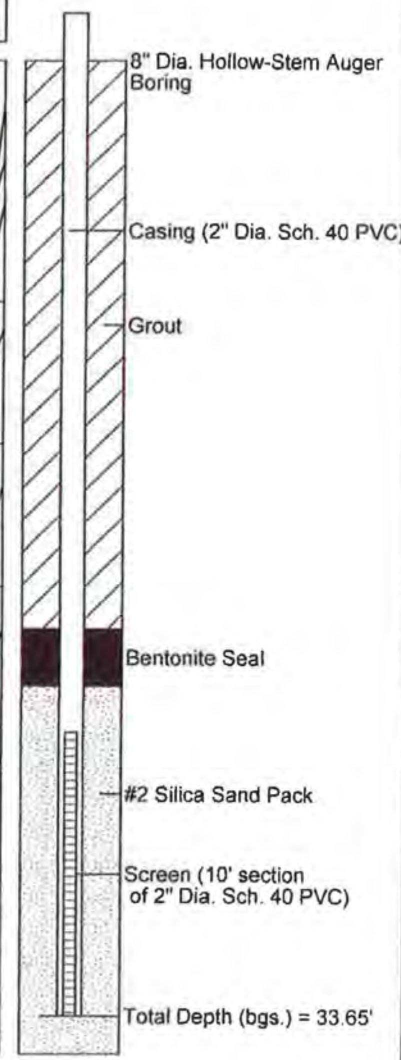
Water Levels
▼ 1 Hour = dry
▽ 24 Hours = dry

Sample Type
SS = Split Spoon
ST = Shelby Tube
RC = Rock Core
BAG = Bag Sample

Well: PZ-12
TOC Elev.: 296.59

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	293.48	3 5 8	SS,BAG	10	moist; medium compact; brownish yellow (10YR 6/6) with white specks; clayey silty quartz sandy gravel; no plasticity or cohesion; Soil Horizon; (Lab Results: PZ-13 Bag (0-1.5'); USCS=SC-SM; Gravel=36.1%; Sand=37.2%; Silt=19.4%; Clay=7.3%; Effective Porosity=25%; Atterberg Limits: PL=17, LL=21, PI=4)
5	288.48	4 6 6	SS	21	moist; stiff; red (2.5YR 4/6); fine to medium sandy silt and silty clay layers; low plasticity; cohesive; Residuum
10	283.48	17 50/5"	SS	6	moist; very hard; red (2.5YR 4/6); silty clay with large quartz gravel; no plasticity; cohesive; Residuum
15	278.48	11 17 50/6"	SS	24	moist; very hard; weak red (10R 5/3) with light green mottles; medium horizontal fissle; silty clay; no plasticity; cohesive; Residuum
20	273.48	11 15 22	SS	20	moist; hard; pinkish gray (7.5YR 6/2) with black vertical and 45 degree planes; medium horizontal fissle; silty clay; no plasticity; cohesive; Residuum
25	268.48	11 50/6"	SS	18	moist; very hard; gray (7.5YR 5/1); medium horizontal fissle; silty clay; no plasticity; cohesive; Partially Weathered Rock
30	263.48	11 15 50/5"	SS	22	moist; very hard; gray (7.5YR 5/1); medium horizontal fissle; silty clay; no plasticity; cohesive; Residuum
35	258.48	50/1"	SS	3	dry; very hard; dark blueish gray (Gley 2 4/1); weathered mudstone; Partially Weathered Rock
40	253.48				
45					

Auger Refusal @ 35'



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Boring Log, PZ-14

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

Date Started:	7/23/14	Logged By:	Ross Klingman, P.G.
Date Completed:	7/23/14	Drilling Method:	HSA; CME-550x
Drilling Company:	Summit Engineering	Top-of-Casing Elev.:	322.15'(Lawrence Survey)
Drillers Name:	Robert Cassell	Ground Surface Elev.:	319.44'(Lawrence Survey)
NC Driller Certification:	4143A	Natural, Cut, Fill Grade:	natural

Water Levels
▼ 1 Hour = dry
▽ 24 Hours = dry

Sample Type
SS = Split Spoon
ST = Shelby Tube
RC = Rock Core
BAG = Bag Sample

Well: PZ-14
TOC Elev.: 322.15

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	319.44	3 6 7 (13)	SS	16	moist; stiff; reddish yellow (7.5YR 6/8) with rust and light gray mottles; gravelly silty clay; low plasticity; cohesive; Soil Horizon (CL)
5	314.44	4 5 6 (11)	SS	18	moist; stiff; reddish yellow (7.5YR 6/8) with rust and light gray mottles; gravelly silty clay; low plasticity; cohesive; Soil Horizon (CL)
			ST	12	moist; reddish yellow (7.5YR 6/8) with rust and light gray mottles; large quartz gravelly silty clay; low plasticity; cohesive; Soil Horizon; (Lab Results: PZ-14 UD (6-7'); USCS=CH; Gravel=1.8%; Sand=18.4%; Silt=37.7; Clay=42.1%; Specific Gravity=2.67; Hydraulic Conductivity=1.35 x 10-7 cm/sec; Total Porosity=38.6%; Effective Porosity=2%; Atterburg Limits: PI=28, LL=55, PI=27) (CH)
10	309.44	5 6 8 (14)	SS	15	
					moist; stiff; red (10R 4/6) with white specks; clayey quartz gravelly fine to coarse sandy silt; no plasticity, cohesive; Residuum (ML)
15	304.44	6 8 10 (18)	SS	18	moist; very stiff; red (10R 4/6) with white specks; clayey quartz gravelly fine to coarse sandy silt; no plasticity; cohesive; Residuum (ML)
20	299.44	6 7 11 (18)	SS	20	moist; very stiff; red (10R 4/8); silty clay; low plasticity; cohesive; Residuum (CL)
25	294.44	18 21 43 (64)	SS	18	moist; very hard; weak red (10R 5/3) with white and gray specks; fine to medium sandy silty clay; low plasticity; cohesive; Residuum (CL)
30	289.44	50/5"	SS	10	dry; very hard; red (10R 4/6); medium horizontal fissle; clayey fine to medium sandy silt; no plasticity; cohesive; Partially Weathered Rock (PWR)
35	284.44	50/1"	SS	6	moist; very hard; weak red (10R 4/6); highly horizontal fissle; weathered mudstone; Partially Weathered Rock
40	279.44	50/0"	SS	1	moist; very hard; weak red (10R 4/3); highly horizontal fissle; weathered mudstone; Partially Weathered Rock
					Auger Refusal @ 39'
45					

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Boring Log, PZ-15s and 15

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

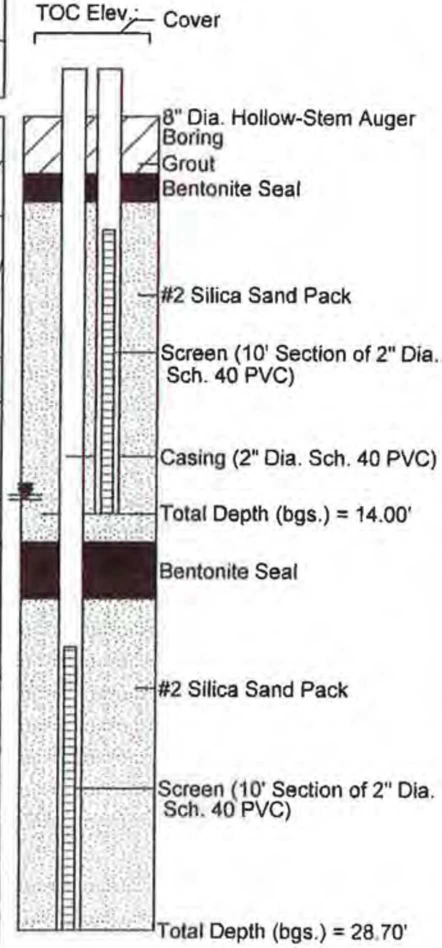
Date Started:	7/23/14	Logged By:	Ross Klingman, P.G.
Date Completed:	7/23/14	Drilling Method:	HSA; CME-550x
Drilling Company:	Summit Engineering	Top-of-Casing Elev.:	303.11'/303.24'
Drillers Name:	Robert Cassell	Ground Surface Elev.:	300.63'
NC Driller Certification:	4143A	Natural, Cut, Fill Grade:	natural

Water Levels
- 1 Hour = 13.48'/15.34' bgs
- 24 Hours = 13.65'/13.31' bgs

Sample Type
- SS = Split Spoon
- ST = Shelby Tube
- RC = Rock Core
- BAG = Bag Sample

Well1: PZ-15s
Well2: PZ-15

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	300.63	5 6 6 (12)	SS	18	moist; medium; yellowish red (7.5YR 6/6); coarse quartz sandy silty clay; medium plasticity; cohesive; Soil Horizon (CL)
5	295.63	5 7 11 (18)	SS	20	moist; very stiff; yellow (10YR 7/6) with rust and orange mottles; coarse quartz sandy silty clay; low plasticity; cohesive; Soil Horizon (CL)
10	290.63	7 9 13 (22)	SS	21	moist; very stiff; red (2.5YR 4/6) with light gray and yellow mottles; silty clay; medium plasticity; cohesive; Residuum (CL)
15	285.63	12 17 28 (45)	SS	18	moist; hard; red (10R 4/6) with white specks; blocky; silty clay; low plasticity; cohesive; Residuum (CL)
20	280.63	24 50/4" (50+)	SS	18	moist; very hard; red (2.5YR 4/6) with white specks; blocky; silty clay; low plasticity; cohesive; Residuum (CL)
25	275.63	50/6"	SS BAG	16	wet; very hard; red (10R 4/6) with white specks; medium horizontal fissle; silty clay; low plasticity; cohesive; Partially Weathered Rock; (Lab Results: PZ-15 Bag (23.5-24'): USCS=CL; Gravel=0.7%; Sand=4.5%; Silt=52.8%; Clay=19.9%; Effective Porosity=8; Atterberg Limits: PI=16, LL=32, PI=16)
30	270.63	50/5"	SS	18	wet; very hard; weak red (10R 5/4) with light gray specks; highly horizontal fissle; weathered mudstone; Partially Weathered Rock
35	265.63				
40	260.63				
45					



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Boring Log, PZ-16

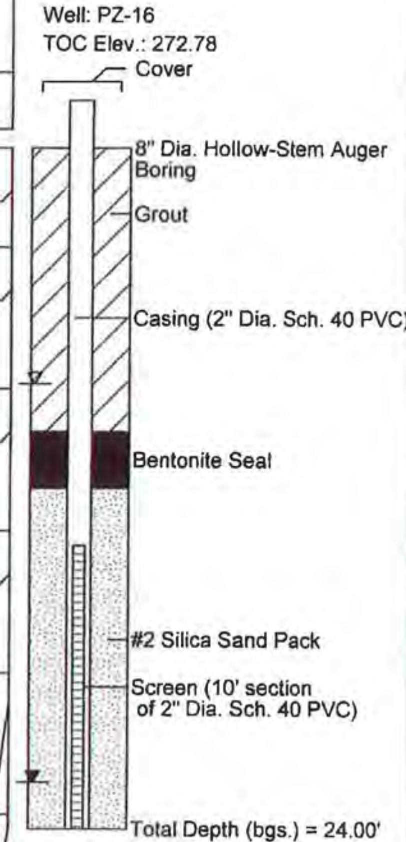
Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

Date Started:	7/23/14	Logged By:	Ross Klingman, P.G.
Date Completed:	7/23/14	Drilling Method:	HSA; CME-550x
Drilling Company:	Summit Engineering	Top-of-Casing Elev.:	272.78'(Lawrence Survey)
Drillers Name:	Robert Cassell	Ground Surface Elev.:	270.63'(Lawrence Survey)
NC Driller Certification:	4143A	Natural, Cut, Fill Grade:	natural (drainage bottom)

Water Levels
▼ 1 Hour = 22.35' bgs
▽ 24 Hours = 8.33' bgs

Sample Type
SS = Split Spoon
ST = Shelby Tube
RC = Rock Core
BAG = Bag Sample

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	270.63	4 5 6	SS	24	moist; stiff; strong brown (7.5YR 5/6) with white specks; quartz gravelly clayey silt; no plasticity; cohesive; Soil Horizon
5	265.63	3 5 5	SS	16	moist; stiff; yellowish red (5YR 4/6) with light gray mottles; silty clay; low plasticity; cohesive; Soil Horizon
10	260.63	32 35 39	SS	14	dry; very hard; dark red (10R 3/6); horizontal fissle; weathered mudstone; Residuum
15	255.63	17 31 50/5"	SS	16	moist; very hard; red (10R 4/6) with purple mottles; mica sandy silty clay; no plasticity; cohesive; Residuum
20	250.63	24 50/5"	SS,BAG	10	moist; very hard; red (10R 4/6) with purple mottles; silty clay; no plasticity; cohesive; Partially Weathered Rock; (Lab Results: PZ-16 Bag (18.5-20'): USCS=CL; Sand=3.1%; Silt=65.5%; Clay=31.4%; Effective Porosity=3; Atterberg Limits: PI=19, LL=38, PI=19)
25	245.63	50/3"	SS	6	wet; very hard; red (10R 4/6) with purple mottles; highly horizontal fissle; silty clay; no plasticity; cohesive; Partially Weathered Rock
30	240.63				
35	235.63				
40	230.63				
45					



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Boring Log, PZ-17s and 17

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

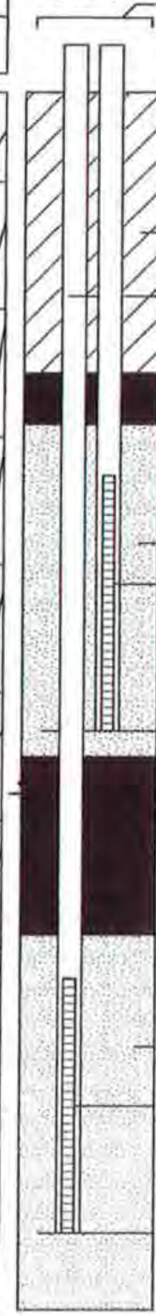
Date Started:	7/23/14	Logged By:	Ross Klingman, P.G.
Date Completed:	7/23/14	Drilling Method:	HSA; CME-550x
Drilling Company:	Summit Engineering	Top-of-Casing Elev.:	306.62'/306.56'
Drillers Name:	Robert Cassell	Ground Surface Elev.:	304.00'
NC Driller Certification:	4143A	Natural, Cut, Fill Grade:	natural

Water Levels
- 1 Hour = dry/27.44"
- 24 Hours = dry/27.46" bgs

Sample Type
- SS = Split Spoon
- ST = Shelby Tube
- RC = Rock Core
- BAG = Bag Sample

Well1: PZ-17s
Well2: PZ-17
TOC Elev. :

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	304	3 4 5	SS	24	moist; stiff; reddish brown (5YR 4/4); silty clay; medium plasticity; cohesive; Residuum
5	299	3 5 7	SS	16	moist; stiff; reddish brown (5YR 4/4); silty clay with mudstone rock fragments; medium plasticity; cohesive; Residuum
10	294	50/4"	SS	14	dry; very hard; reddish brown (2.5YR 5/4); highly horizontal fissle; weathered mudstone; Partially Weathered Rock
15	289	50/6"	SS	8	ddry; very hard; reddish brown (2.5YR 5/4); highly horizontal fissle; weathered mudstone; Partially Weathered Rock
20	284	29 50/2"	SS	12	dry; very hard; reddish brown (2.5YR 5/4); highly horizontal fissle; weathered mudstone; Partially Weathered Rock
25	279	18 34 26	SS	18	dry; very hard; weak red (2.5YR 4/2); medium horizontal fissle; weathered mudstone; Residuum
30	274	25 50/3"	SS	12	dry; very hard; weak red (2.5YR 4/2); medium horizontal fissle; weathered mica sandy mudstone; Partially Weathered Rock
35	269	50/3"	SS	8	dry; very hard; weak red (2.5YR 4/2); medium horizontal fissle; weathered mica sandy mudstone; Partially Weathered Rock
40	264	50/4"	SS	6	very moist; very hard; weak red (2.5YR 4/2); blocky; fine sandy clayey silt; no plasticity; cohesive; Partially Weathered Rock
45	259	39 50/3"	SS,BAG	14	wet; very hard; reddish brown (2.5YR 4/4); medium horizontal fissle; weathered mudstone; Partially Weathered Rock; (Lab Results: PZ-17 Bag (43.5-44.5'); USCS=CL; Sand=40.2%; Silt=48.9%; Clay=10.9%; Effective Porosity=16%; Atterberg Limits: PL=19, LL=32, PI=13)
50					



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Boring Log, PZ-18

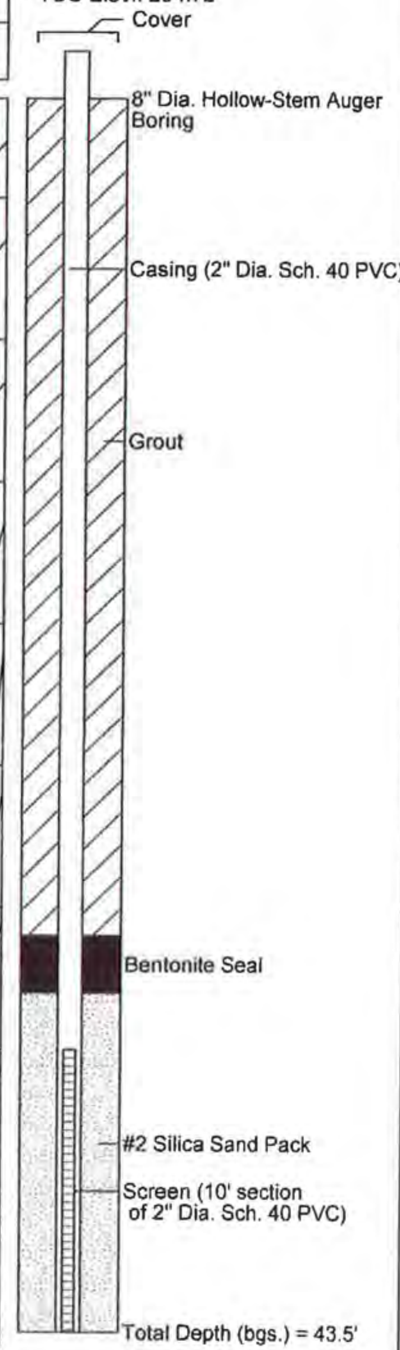
Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

Date Started:	7/23/14	Logged By:	Ross Klingman, P.G.
Date Completed:	7/23/14	Drilling Method:	HSA; CME-550x
Drilling Company:	Summit Engineering	Top-of-Casing Elev.:	294.72'(Lawrence Survey)
Drillers Name:	Robert Cassell	Ground Surface Elev.:	292.27'(Lawrence Survey)
NC Driller Certification:	4143A	Natural, Cut, Fill Grade:	natural

Water Levels
▼ 1 Hour = dry
▽ 24 Hours = dry

Sample Type
SS = Split Spoon
ST = Shelby Tube
RC = Rock Core
BAG = Bag Sample

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	292.27	1 5	SS	22	moist; medium, brownish yellow (10R 6/6); slightly clayey silt; no plasticity; cohesive; Soil Horizon
5	287.27	4 4 5	SS	16	moist; stiff; reddish yellow (7.5YR 6/8) with tan and rust mottles; silty clay; medium plasticity; cohesive; Soil Horizon
10	282.27	5 7 12	SS	15	moist; very stiff; red (10R 4/8) with light green gray mottles; silty clay; low plasticity; cohesive; Residuum
15	277.27	27 21 24	SS	18	moist; hard; red (10R 4/8) with light green gray mottles; highly horizontal fissle; very fine sandy clayey silt; no plasticity; cohesive; Residuum
20	272.27	40 50/3"	SS,BAG	12	moist; very hard; red (10R 4/8) with light green gray mottles; highly horizontal fissle; very fine sandy clayey silt; no plasticity; cohesive; Partially Weathered Rock; (Lab Results: PZ-18 Bag (18.5-19.5'); USCS=CL; Sand=24.4%; Silt=55.7%; Clay=19.9%; Effective Porosity=8%; Atterberg Limits: PL=17, LL=32, PI=15)
25	267.27	9 50/3"	SS	10	moist; very hard; red (10R 4/8) with black horizontal planes; blocky and medium horizontal fissle; silty clay; no plasticity; cohesive; Partially Weathered Rock
30	262.27	50/6"	SS	6	moist; very hard; red (10R 4/8); highly horizontal fissle; weathered mudstone; Partially Weathered Rock
35	257.27	50/3"	SS	6	dry; very hard; weak red (10R 4/3); highly horizontal fissle; fine mica sandy silt; no plasticity; cohesive; Partially Weathered Rock
40	252.27	50/3"	SS	5	moist; very hard; red (10R 4/8); highly horizontal fissle; weathered mudstone; Partially Weathered Rock
45		50/3"	SS	4	moist; very hard; red (10R 4/8) with purple mottles; blocky; weathered mudstone; Partially Weathered Rock



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Boring Log, PZ-19

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

Date Started:	8/29/14	Logged By:	Ross Klingman, P.G.
Date Completed:	8/29/14	Drilling Method:	HSA; Geoprobe 7822
Drilling Company:	Environmental Drilling & Probing	Top-of-Casing Elev.:	(Lawrence Survey)
Drillers Name:	Tommy Bolyard	Ground Surface Elev.:	265.99'(Lawrence Survey)
NC Driller Certification:	3307	Natural, Cut, Fill Grade:	slight cut

Water Levels
- ▼ 1 Hour = 11.00' bgs
- ▽ 24 Hours = 5.75' bgs

Sample Type
- SS = Split Spoon
- ST = Shelby Tube
- RC = Rock Core
- BAG = Bag Sample

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	265.99	3 2 3 (5)	SS	24	wet; medium; light brownish gray (10YR 6/2) with light orange mottles; silty clay; medium plasticity; cohesive; Soil Horizon (CL)
5	260.99	1 1 2 (3)	SS	18	wet; soft; light brownish gray (10YR 6/2) with light orange mottles; silty clay; medium plasticity; cohesive; Soil Horizon (CL)
10	255.99	15 20 27 (47)	SS	17	moist; hard; yellowish brown (10YR 5/4); medium horizontal fissle; clayey silt; no plasticity; cohesive; Residuum (MH)
15	250.99	6 18 50/4"	SS	24	moist; very hard; yellowish brown (10YR 5/4) with black manganese planes; medium horizontal fissle; clayey silt; no plasticity; cohesive; Residuum (MH)
20	245.99	24 50/3"	SS	10	dry; very hard; brown (10YR 5/3); highly horizontal fissle; weathered mudstone; Partially Weathered Rock
25	240.99	14 14 50/3"	SS	12	wet; very hard; reddish brown (5YR 4/3); medium horizontal fissle; weathered mudstone; Partially Weathered Rock
30	235.99				
35	230.99				
40	225.99				
45					

Fill 5H CL MH PWR

Well: PZ-19
TOC Elev.:

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Boring Log, PZ-20

(Page 1 of 1)

Sanford Mine Reclamation Site
1303 Brickyard Road
Sanford, North Carolina

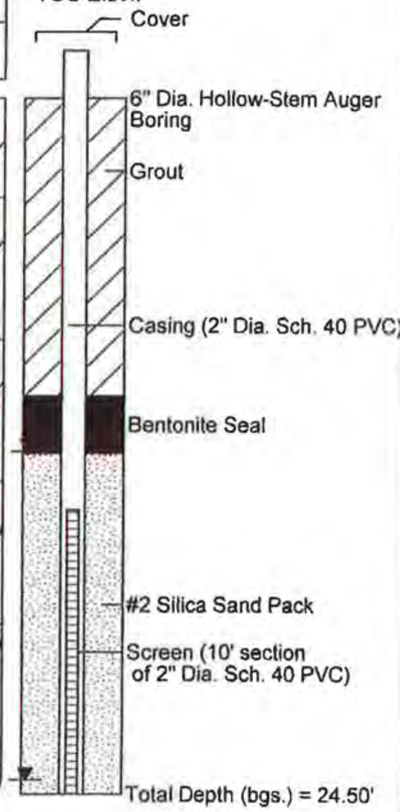
Date Started:	8/29/14	Logged By:	Ross Klingman, P.G.
Date Completed:	8/29/14	Drilling Method:	HSA; Geoprobe 7822
Drilling Company:	Environmental Drilling & Probing	Top-of-Casing Elev.:	(Lawrence Survey)
Drillers Name:	Tommy Bolyard	Ground Surface Elev.:	296.51'(Lawrence Survey)
NC Driller Certification:	3307	Natural, Cut, Fill Grade:	natural

Water Levels
1 Hour = 24.00' bgs
24 Hours = 12.44' bgs

Sample Type
SS = Split Spoon
ST = Shelby Tube
RC = Rock Core
BAG = Bag Sample

Well: PZ-20
TOC Elev.:

Depth (feet bgs.)	Elevation (feet asl.)	Blow Count/6-inches	Sampler Type	Recovery (in.)	Lithologic Description
0	296.51	2 3 3	SS	24	moist; medium; Red (2.5YR 4/6) with yellow mottles; fine sandy silty clay; low plasticity; cohesive; Soil Horizon
5	291.51	2 4 5	SS	24	moist; stiff; red (2.5YR 4/6) with yellow mottles; fine sandy silty clay; low plasticity; cohesive; Soil Horizon
10	286.51	5 5 6	SS	20	moist; stiff; red (2.5YR 4/6) with yellow mottles; mica sandy silty clay; low plasticity; cohesive; Soil Horizon
15	281.51	4 5 7	SS	18	very moist; stiff; weak red (10R 4/4) with white and light gray specks; phyllite and quartz gravelly sandy silty clay; no plasticity; cohesive; Residuum
20	276.51	50/3"	SS	8	dry; very hard; weak red (10R 4/4) with white and light gray specks; weathered mudstone; Partially Weathered Rock
25	271.51	50/4"	SS	8	wet; very hard; red (10R 4/6); highly horizontal fissle; mica sandy clayey silt; no plasticity; cohesive; Partially Weathered Rock
30	266.51				
35	261.51				
40	256.51				
45					



ATTACHMENT B

GEOTRACK Technologies, Inc.

3620 Pelham Road, PMB #292 Phone: 864-329-0013
Greenville, SC 29615-5044 FAX: 864-329-0014

June 30, 2014

Charah, Inc
12601 Plantside Drive
Louisville, KY 40299

Attention: Mr. Norman E. Divers, III

Re; Physical Characterization Testing of Coal Combustion By-products
Riverbend Steam Station
Mount Holly, NC
GeoTrack Project No. 14-3425-N

Ladies and Gentlemen:

GeoTrack Technologies, Inc. has completed characterization testing of a sample from the referenced plant, and we present the results herein. The work was performed as a preliminary evaluation of whether the material is satisfactory for use as structural fill at the Charlotte-Douglas Airport, Area C. This letter presents a brief summary of the procedures and presents the testing results.

Project Description: The material in question includes coal combustion by-products that might include a mixture of fly ash and bottom ash that are collected and discharged to holding ponds on the power plant property. The combined combustion by-products (hereinafter referred to as CCB's) are proposed for use in an engineered fill. The engineered fill will be constructed by excavating native soils, constructing a composite (membrane) liner, placing the CCB as compacted fill, and covering the fill with a combination of a membrane cap and compacted soil. Subsequent uses of the completed fill have not been finalized; we anticipate that the property could be developed as part of nearby airport expansion, for commercial purposes (retail development, light industrial, etc), or to reclaim land that was previously excavated for other purposes.

Sampling Procedures: GeoTrack visited the power plant on May 15, 2014 and collected CCB samples. Grab samples were collected from the pond nearest the plant site (a wet pond). The sample locations included the northern corner, at the primary effluent structure, and the diagonally opposite corner, near the primary influent. Those locations were selected because they provided access to the CCB. Most areas of the exposed CCB were saturated and soft to both vehicular and pedestrian traffic.

Sampling was performed using procedures in general conformance with ASTM C 311 (ASTM D 75) for physical testing. The physical test sample was split in accordance with ASTM procedures and subjected to various laboratory tests. The physical (engineering) tests included classification tests, strength tests, and consolidation tests.

Portions of the samples were also placed in laboratory-prepared containers in accordance with applicable EPA SW846 procedures for the chemical analyses. The chemical analyses are reported separately.

Physical (Engineering) Testing: Table 1 presents the physical (engineering) tests performed, the applicable test methods, and the results. Where applicable, individual test reports are attached. Detailed evaluation of the engineering characteristics is beyond the scope of this report, and the suitability of the various properties is dependent upon final site geometry and fill usage; however, a few comments are offered based upon our preliminary review of the test results.

The grain size characteristics and specific gravity are within expected ranges based on general experience with similar CCB's. The material consists predominantly of silt-sized particles that are essentially cohesionless in nature. Atterberg limits tests indicate the material to be non-plastic despite the fine grained size characteristics. The sand content of the sample might be influenced by the bottom ash content of this CCB.

The Standard Proctor Maximum Dry Density achieved for this sample (56.6 pounds per cubic foot (pcf) at an optimum moisture content of 48 percent) was low relative to the range typically achieved for similar products. The Proctor curve is relatively flat, indicating the material is not sensitive to moisture content. The compaction curve indicates that 95 percent compaction can be theoretically achieved with the standard Proctor compactive effort over a range of moisture contents spanning greater than 10 percent. Our experience indicates considerable variability in densities, moisture contents, etc. might be expected, and these properties are most likely influenced by long-term variations in plant procedures and the flow/sedimentation processes within the pond.

Three separate specimens were collected from the bulk sample and tested for field moisture content. They were selected based on their proximity to the prevailing water level within the pond at the time of sampling (collected from above and below the water surface). They ranged from 50.0 to 92.2 percent by dry weight. The average of the three moisture contents was 73.3 percent. While this average moisture content is well above the optimum moisture content, the wide variation in collected samples indicates that significant reductions in moisture content can occur simply by passively draining the materials. Also, more active moisture adjustment should require minor effort within temporary stockpiles and in the fill lifts.

Despite the low compacted dry density, the strength properties of this sample are favorable for most routine engineering applications. Three sets of strength properties were derived from two separate strength tests. The tests simulate both drained (effective or long-term) and undrained (total or short-term loading) conditions that might be experienced in service. The undrained strength test results indicate short-term strengths that varied, but are characteristic of fine grained materials. The undrained strength tests exhibited strength envelops that are combinations of cohesion and internal friction. They exhibited undrained cohesion ranging from moderate to high (C = 1,900 to 4,300 pounds per square foot; psf), with corresponding angles of internal friction ranging from low to moderate (Ø = 8 to 27°). In combination, the two sets of computed undrained strength parameters represent moderately high overall strength characteristics.

The effective (drained) strength properties reported by the laboratory (C = 2,600 psf and Ø = 22°) based on a "best-fit" strength envelope were uncharacteristic of cohesionless materials. That result is assessed to be the result of scatter in the laboratory results, which is common with earthen materials. Often CCB materials and similar fine-grained, non-plastic materials exhibit low to non-existent cohesion, and the strength is derived almost entirely from internal friction. The reported drained parameters are more characteristic of undrained behavior; however, review of the graphical results indicates the drained test is subject to interpretation. A strength envelope drawn through the graphical origin (C = 0) and tangent to the lowest failure circle indicates a relatively high angle of internal friction (Ø = 39°), with little deviation from the other failure circles. That adjusted strength envelop is both characteristic of non-plastic, cohesionless materials, and relatively high internal strength. The adjusted test results are similar to drained strengths of CCB materials sampled from other plants. The laboratory interpretation and adjusted strength parameters are shown in attachments.

Similarly, the consolidation test results indicate settlement characteristics of the CCB's will be favorable. With total strain of less than 3 percent and 4 percent at applied pressures of 8 and 16 kips per square foot (psf), respectively, the material has characteristics of low compressibility. Our experience indicates that the settlement characteristics will be comparable, or more favorable (less compressible) than, typical area soils.

Closing: GeoTrack is pleased to be of service to you on this project. Please call if you have any questions concerning this letter or if we may provide additional assistance.

Respectfully submitted,
GeoTrack Technologies, Inc.

David D. Wilson, P.E.
Senior Engineer
NC Registration No. 17088

TABLE 1 – PHYSICAL/ENGINEERING CHARACTERISTICS
RIVERBEND STEAM STATION
GEOTRACK PROJECT NO. 14-3425-N

Physical/Engineering Characteristic	**Test Method**	**Test Result/ Applicable Parameters**	**Remarks**
Grain Size Distribution	ASTM 422	22 Percent Sand 72 Percent Silt 6 Percent Clay *Grain Size Distribution Attached*	Sieve and Hydrometer
Specific Gravity	ASTM 854	Specific Gravity: $G_s = 2.13$	
Water Content	ASTM D 2216	Field Moisture Content: w = 73.3 %	Moisture Content at Time of Sampling – Note 5
Compaction	ASTM D 698	Maximum Dry Density: $\gamma_{d\,max}$ = 56.6 pcf Optimum Moisture Cont.: w_{opt} = 48.0 % *Moisture Density Relationship Attached*	Standard Proctor Compaction Test
Strength:			
Shear Strength	ASTM 4767	Total Cohesion: C = 4.3 ksf Total Angle of Int. Friction: = 8° Eff. Cohesion: C'= 2.6 ksf Eff. Angle of Int. Friction: Ø' = 22° *Triaxial Shear Test Report Attached*	Consolidated Undrained Triaxial Shear Test with Pore Pressure Measurements Note 3 Note 4
Compressive Strength	ASTM 2850	Total Cohesion: C = 1.9 ksf Total Angle of Int. Friction: Ø = 27° *Triaxial Shear Test Report Attached*	Unconsolidated Undrained Triaxial Shear Test. Unconfined Compressive Strength not Meaningful for Ash Samples Note 3
Compressibility	ASTM D 2435	*Consolidation Test Report Attached*	Note 3

See notes on next page

Notes:
1. Sample collected May 15, 2014
2. The referenced ASTM procedures are as suggested in ASTM E 2277, and common geotechnical practice.
3. Tests performed on specimens remolded in the laboratory to approx. 95% of the Standard Proctor Maximum Dry Density at approximately the Optimum Moisture Content.
4. An alternative strength envelope derived from the test data is shown graphically in the attachments.
5. The reported field moisture content is the average of three separate specimens with moisture contents ranging from 50.0 to 92.2 %.

Moisture - Density Report

S&ME
Quality Assurance

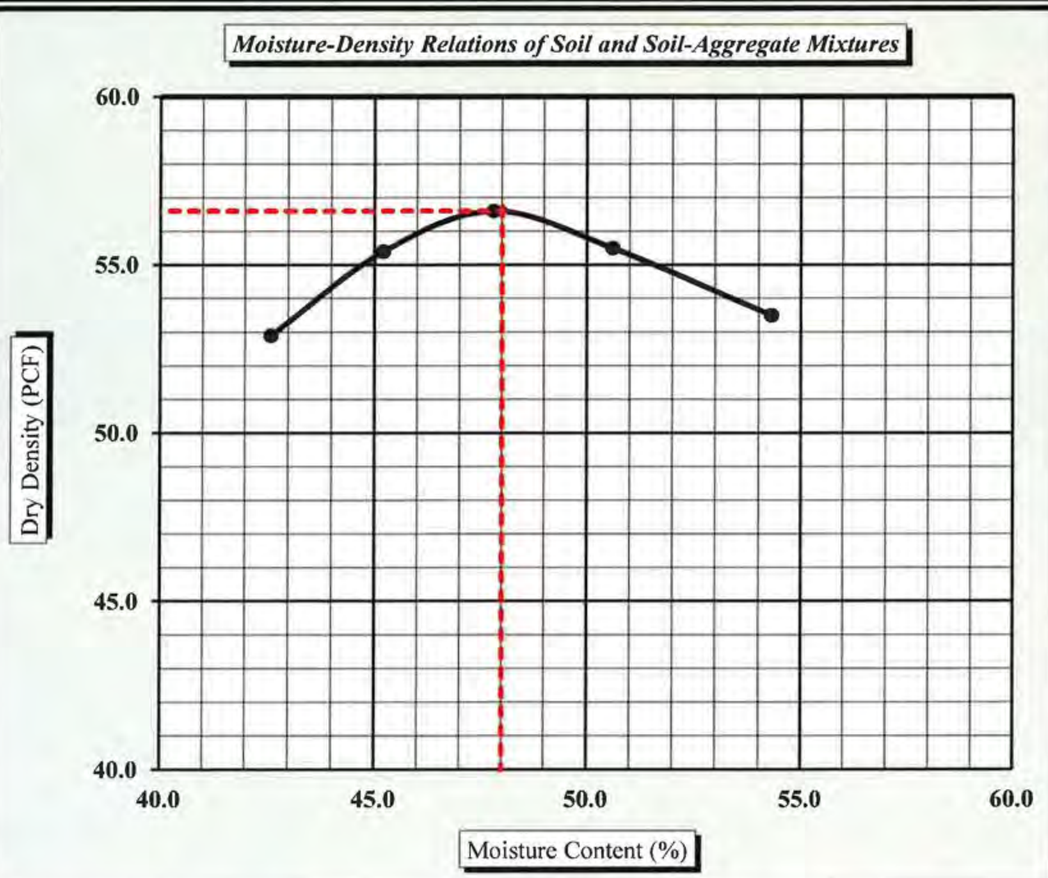
S&ME, Inc. - Greenville 281 Fairforest Way Greenville, SC 29607

S&ME Project #:	**1263-10-195**	Report Date:	6/02/14
Project Name:	Geotrack Technologies, Inc. - 14-3425-N	Test Date:	5/30/14
Client Name:	3620 Pelham Road, PMB #292 Greenville, SC 29615		
Client Address:	336 Longview Drive Piedmont, South Carolina 29673		

Boring #:	N/A	Log #:	44g	Sample Date:	5/15/14
Location:	Riverbend Pond	Type:	Bulk	Depth:	N/A
Sample Description:	Coal Ash				

Maximum Dry Density 56.6 PCF. **Optimum Moisture Content 48.0%**

ASTM D 698 -- Method A



Soil Properties

Natural Moisture Content	**N/A**
Specific Gravity of Soil (D 854)	**N/A**
Liquid Limit	-
Plastic Limit	**NP**
Plastic Index	**NP**

% Passing

3/4"	-
3/8"	-
#4	99.9%
#10	
#40	
#60	
#100	
#200	

Oversize Fraction

Bulk Gravity	
% Moisture	
% Oversize	
MDD	
Opt. MC	

Moisture-Density Curve Displayed: Fine Fraction ☒ Corrected for Oversize Fraction (ASTM D 4718) ☐
Sieve Size used to separate the Oversize Fraction: #4 Sieve ☒ 3/8 inch Sieve ☐ 3/4 inch Sieve ☐
Mechanical Rammer ☐ Manual Rammer ☒ Moist Preparation ☐ Dry Preparation ☒

References / Comments / Deviations:

ASTM D 2216: Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
ASTM D 698: Laboratory Compaction Characteristics of Soil Using Standard Effort

Brian Vaughan, P.E.	[signature]	Location Coordinator	6/02/14
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D422-3
Revision No. 0
Revision Date: 02/20/08

Particle Size Analysis of Soils

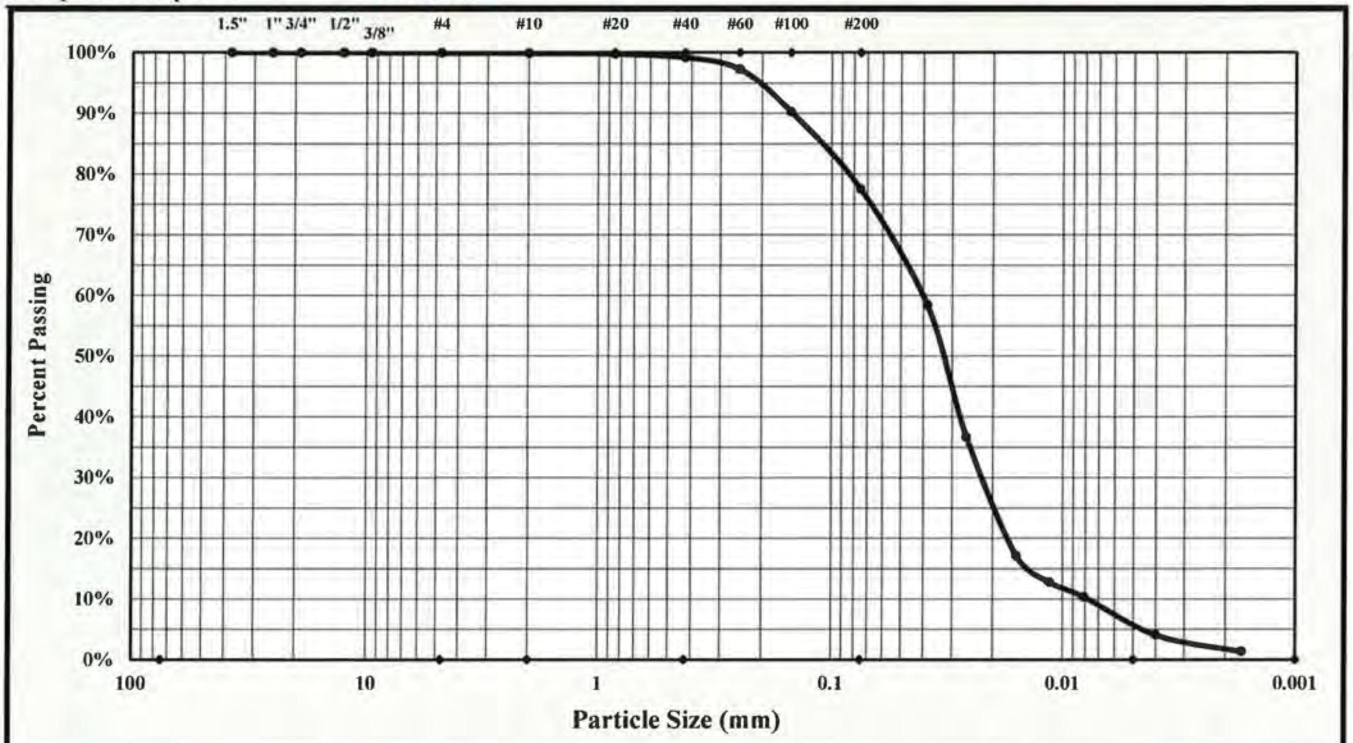
ASTM D 422

Quality Assurance

S&ME, Inc. - Greenville 281 Fairforest Way Greenville, SC 29607

S&ME Project #:	1263-10-195			Report Date:	6/05/14
Project Name:	Geotrack Technologies, Inc. - 14-3425-N			Test Date(s):	6/02 - 6/05/14
Client Name:	Geotrack Technologies, Inc.				
Address:	3620 Pelham Road, PMB #292 Greenville, SC 29615				
Boring #:	N/A	Log #:	44g	Sample Date:	5/15/14
Location:	Riverbend Pond	Type:	Bulk	Sample Depth:	N/A

Sample Description: Coal Ash



Cobbles	< 300 mm (12") and > 75 mm (3")	Fine Sand	< 0.425 mm and > 0.075 mm (#200)
Gravel	< 75 mm and > 4.75 mm (#4)	Silt	< 0.075 and > 0.005 mm
Coarse Sand	< 4.75 mm and >2.00 mm (#10)	Clay	< 0.005 mm
Medium Sand	< 2.00 mm and > 0.425 mm (#40)	Colloids	< 0.001 mm

Maximum Particle Size:	.425 mm	Gravel:	0.1%	Silt	71.9%
Silt & Clay (% Passing #200):	77.5%	Total Sand:	22.4%	Clay	5.7%
Specific Gravity	2.130	Moisture Content		Colloids	1.0%
Liquid Limit	-	Plastic Limit	NP	Plastic Index	NP
Coarse Sand:	0.0%	Medium Sand:	0.7%	Fine Sand:	21.7%

Description of Sand and Gravel: Rounded ☐ Angular ☐ Hard & Durable ☐ Soft ☒ Weathered & Friable ☐

Mechanical Stirring Apparatus A — Dispersion Period: 1 min. — Dispersing Agent: Sodium Hexametaphosphate: 40 g./ Liter

References / Comments / Deviations: ASTM D 4318, D 854, D 2487

Brian Vaughan, P.E.	Brian Vaughan	Location Coordinator	6/05/14
Technical Responsibility	*Signature*	*Position*	*Date*

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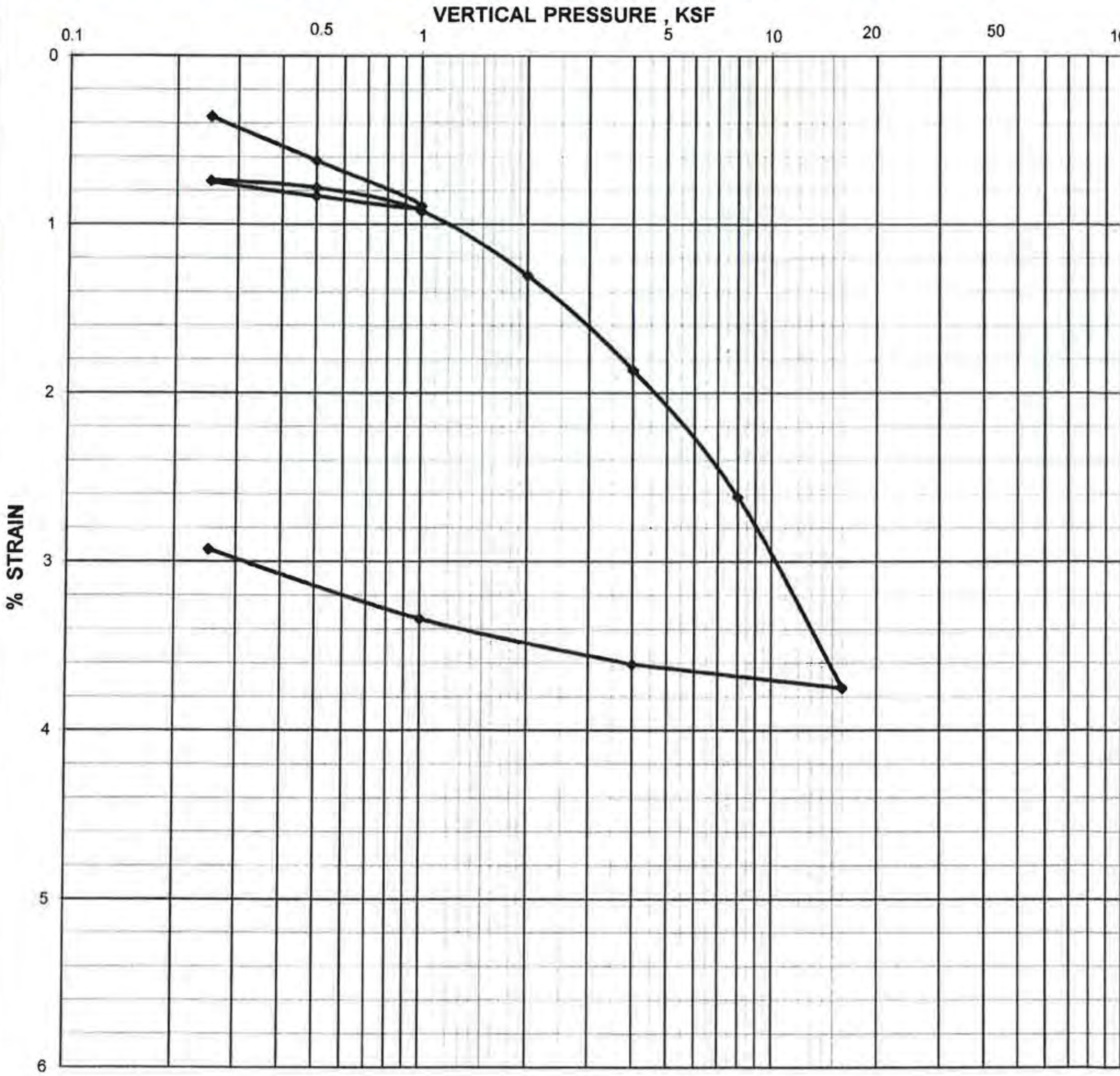
CONSOLIDATION TEST REPORT

(ASTM D 2435)

Project Name :	Geotrack Technologies, Inc. - 14-3425-N				
Project No. :	**1263-10-195**			**Report Date:**	6/13/2014
Client Name :	Geotrack Technologies, Inc.			**Boring No.:**	N/A
Client Address :	3620 Pelham Road, PMB #292 Greenville, SC 29615			**Depth/Elev.:**	N/A
Initial Wet Density, γ_{wet}, pcf :	79.6	**Load vs. Time Plot :**	Log of time	**Sample Type:**	Bulk
Initial Void Ratio, e_o :	1.472	**Final Void Ratio, e_f :**	1.400	**Log No.:**	44g
Initial Saturation, S_O, % :	69.4	**Final Saturation, S_f, % :**	100.0	**Sp. Gravity , G_S :**	2.13
Initial Dry Density, γ_{DRY}, pcf :	53.8	**Final Dry Density, γ_{DRY}, pcf :**	54.7	**Estimated Preconsolidation**	
Initial Moisture Content, %.:	48.0	**Final Moisture Content, %.:**	67.1	**Stress, P_c, ksf :**	1.0
Liquid Limit, % :	-	**Plasticity Index, % :**	NP	**Fines, % :**	77.5
Sample Description :	Coal Ash				
Remolded Properties :	Specimen was remolded to 95% of maximum dry density at about 0% wet of optimum				

Notes: Loading Schedule - as requested by client (ksf)- 0.25, 0.5, 1.0, 0.5, 0.25, 0.5, 1.0, 2.0, 4.0, 8.0, 16.0, 4.0, 1.0, 0.25



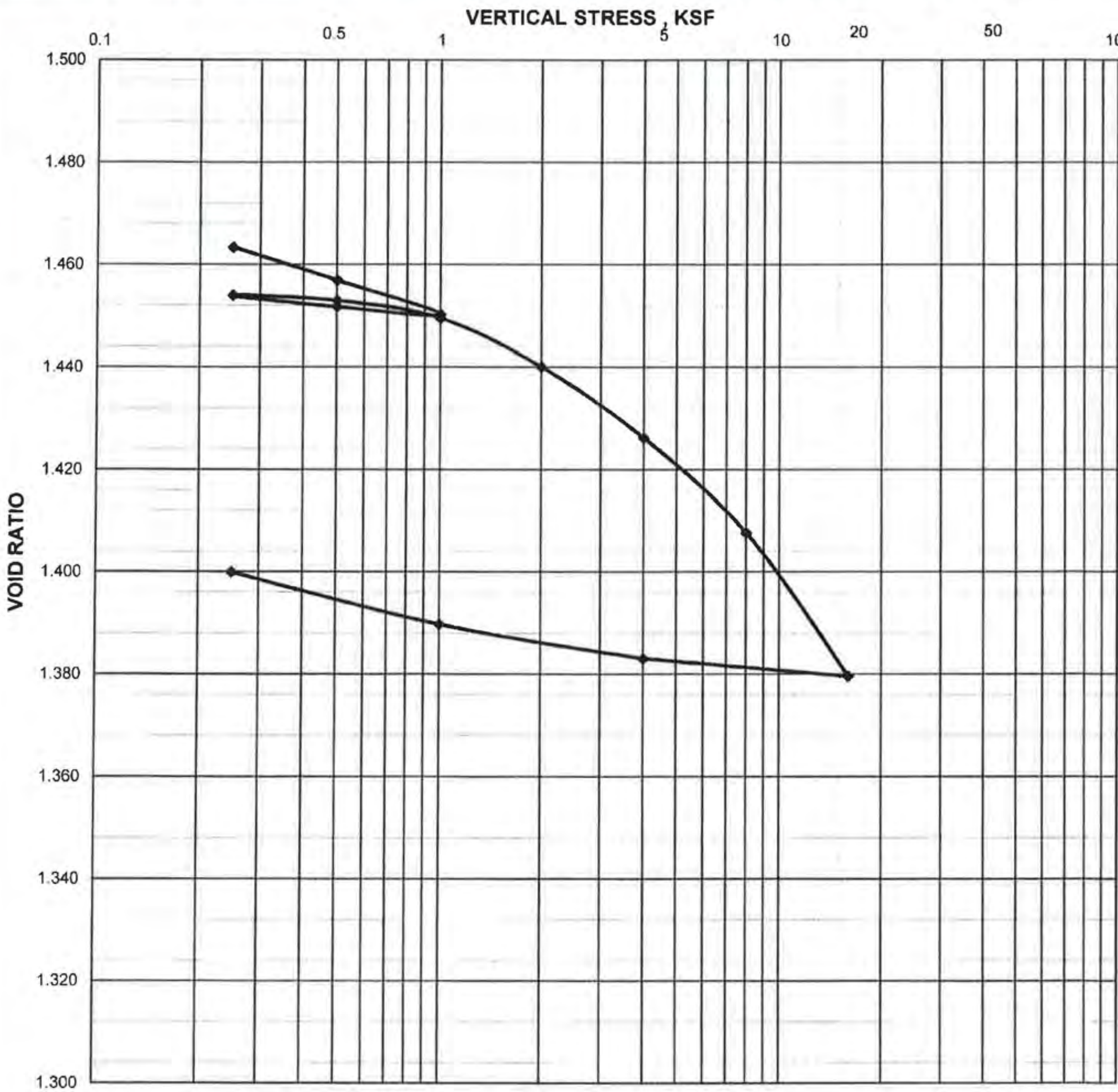
CONSOLIDATION TEST REPORT

S&ME

(ASTM D 2435)

Project Name :	Geotrack Technologies, Inc. - 14-3425-N				
Project No. :	**1263-10-195**			**Report Date:**	6/13/2014
Client Name :	Geotrack Technologies, Inc.			**Boring No.:**	N/A
Client Address :	3620 Pelham Road, PMB #292 Greenville, SC 29615			**Depth/Elev.:**	N/A
Initial Wet Density, γ_{wet}, pcf :	79.6	**Load vs. Time Plot :**	Log of time	**Sample Type:**	Bulk
Initial Void Ratio, e_o :	1.472	**Final Void Ratio, e_f :**	1.400	**Log No.:**	44g
Initial Saturation, S_O, % :	69.4	**Final Saturation, S_f, % :**	100.0	**Sp. Gravity, G_S :**	2.13
Initial Dry Density, γ_{DRY}, pcf :	53.8	**Final Dry Density, γ_{DRY}, pcf :**	54.7	**Estimated Preconsolidation**	
Initial Moisture Content, %.:	48.0	**Final Moisture Content, %.:**	67.1	**Stress, P_e, ksf :**	1
Liquid Limit, % :	-	**Plasticity Index, % :**	NP	**Fines, % :**	77.5
Sample Description :	Coal Ash				
Remolded Properties :	Specimen was remolded to 95% of maximum dry density at about 0% wet of optimum				

Notes: Loading Schedule - as requested by client (ksf)- 0.25, 0.5, 1.0, 0.5, 0.25, 0.5, 1.0, 2.0, 4.0, 8.0, 16.0, 4.0, 1.0, 0.25



S&ME

TRIAXIAL SHEAR TEST REPORT
(ASTM D 2850)
Unconsolidated Undrained

AASHTO R18

REV4,1/13/04

Project Name:	Geotrack Technologies, Inc. - 14-3425-N		
Project No.:	1263-10-195	**Report Date:**	06/10/14
Client Name:	Geotrack Technologies, Inc.	**Test Date:**	6/9/14
Client Address:	3620 Pelham Road, PMB #292 Greenville, SC 29615		
Boring #: N/A	**Depth / Elev. :** N/A	**Log #:** 44g	**Type:** Bulk
Sample Location :	Riverbend Pond		
Sample Description :	Coal Ash		
LL, % : -	**PI , % :** NP	**Percent Passing #200 :** 77.5	**G_s :** 2.130

SPECIMEN PROPERTIES

		INITIAL				FINAL		
SPECIMEN NO.		**1**	**2**	**3**		**1**	**2**	**3**
DIAMETER , INCHES	D_o	2.82	2.81	2.82	D_c	N/A	N/A	N/A
HEIGHT , INCHES	H_o	6.04	6.02	6.03	H_c	N/A	N/A	N/A
WATER CONTENT, %	W_o	48.0	48.0	48.0	W_c	N/A	N/A	N/A
DRY DENSITY, PCF	γ_{dryo}	53.7	53.9	53.7	γ_{dryc}	N/A	N/A	N/A
SATURATION ,%	S_o	69.2	69.8	69.3	S_c	N/A	N/A	N/A
VOID RATIO	e_o	1.477	1.464	1.476	e_c	N/A	N/A	N/A

TEST PARAMETERS , TEST TYPE : UU

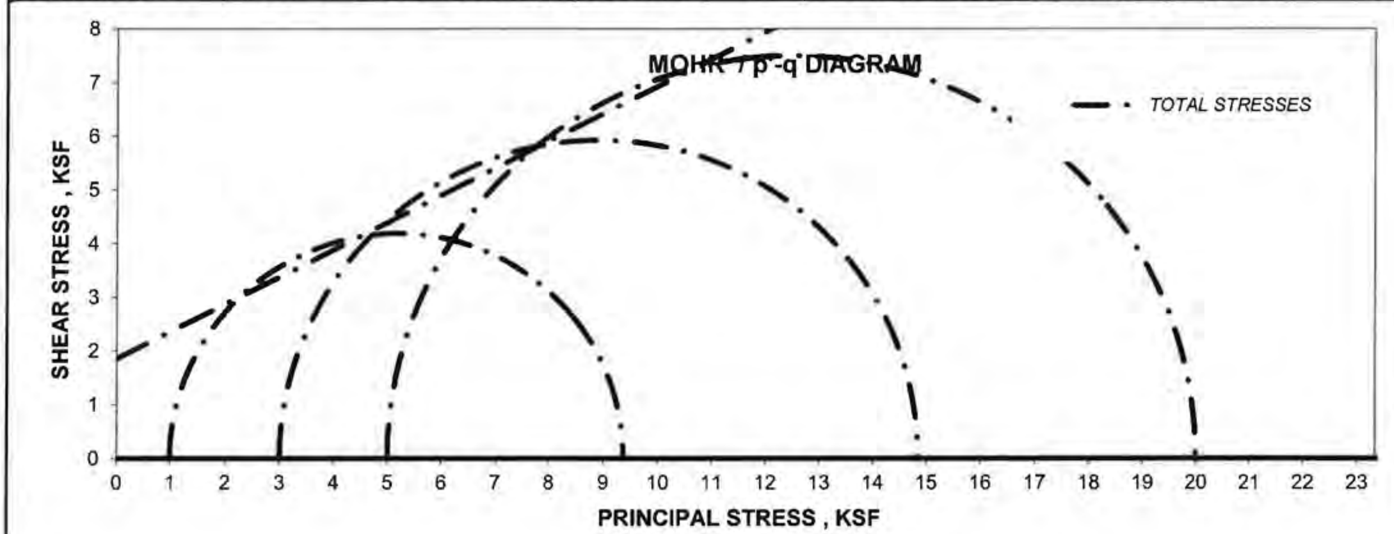
SPECIMEN NO.		**1**	**2**	**3**
B Value		N/A	N/A	N/A
BACK PRESSURE, ksf	U_o	7.2	7.2	7.2
CONFINING PRESSURE , ksf	σ_3	1.0	3.0	5.0
MAX. DEVIATOR STRESS ,ksf	σ_1-σ_3	8.4	11.9	15.0
ULT. DEVIATOR STRESS , ksf	σ_1-σ_3	8.4	10.7	14.8
Specimen Shape @ Failure	Sheared			

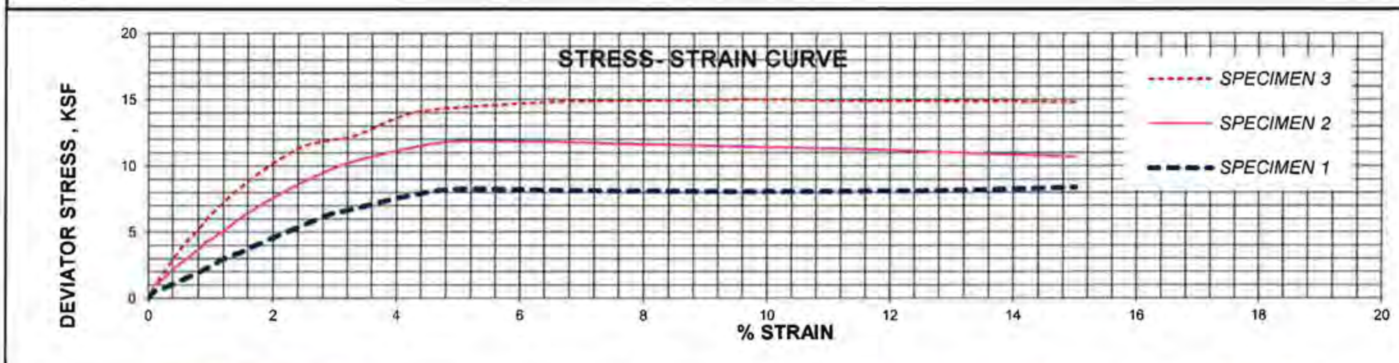
CONTROLLED : Strain @ 1.0 % per minute

PROCTOR TYPE : *Standard ,* **MAXIMUM DRY DENSITY , PCF :** *56.6* **,OPTIMUM MOISTURE CONTENT , % :** *48.0*

REMOLDED : ***Specimens were remolded to 95 % of maximum dry density at about 0.0 % wet of o.m.c.***

SHEAR STRENGTH PARAMETERS	TOTAL		EFFECTIVE	
	COHESION , C (ksf) :	1.9	**APPARENT COHESION , (ksf) :**	N/A
	ANGLE OF INTER. FRICTION, Φ(DEGREES)	27	**ANGLE OF INTER. FRICTION, Φ' (DEGREES) :**	N/A





Brian Vaughan, P.E.	[signature]	Location Coordinator	06/10/14
Technical Responsibility	*Signature*	*Position*	*Date*

TRIAXIAL SHEAR TEST REPORT

(ASTM D 4767)

REV4,1/13/04

Project Name:	Geotrack Technologies, Inc. - 14-3425-N				
Project No.:	**1263-10-195**			**Report Date:**	06/10/14
Client Name:	Geotrack Technologies, Inc.			**Test Date:**	6/02 - 6/10/14
Client Address:	3620 Pelham Road, PMB #292 Greenville, SC 29615				
Boring No. :	N/A	**Depth / Elev. :**	N/A	**Sample No . :**	44g **Type:** Bulk
Sample Location :	Riverbend Pond				
Sample Description :	Coal Ash				
LL, % :	-	**PI , % :**	NP	**Percent Passing #200 :**	77.5 **G_s :** 2.130

SPECIMEN PROPERTIES		INITIAL				AFTER CONSOLIDATION		
SPECIMEN NO.		**1**	**2**	**3**		**1**	**2**	**3**
DIAMETER , INCHES	D_o	2.82	2.82	2.82	D_c	2.81	2.79	2.79
HEIGHT , INCHES	H_o	6.03	6.01	6.01	H_c	6.00	5.96	5.95
WATER CONTENT, %	W_o	48.0	48.0	48.0	W_c	67.6	65.8	65.0
DRY DENSITY, PCF	γ_{dryo}	53.8	53.9	54.0	γ_{dryc}	54.5	55.4	55.8
SATURATION ,%	S_o	69.4	69.7	70.0	S_c	100.0	100.0	100.0
VOID RATIO	e_o	1.472	1.468	1.461	e_c	1.439	1.401	1.384

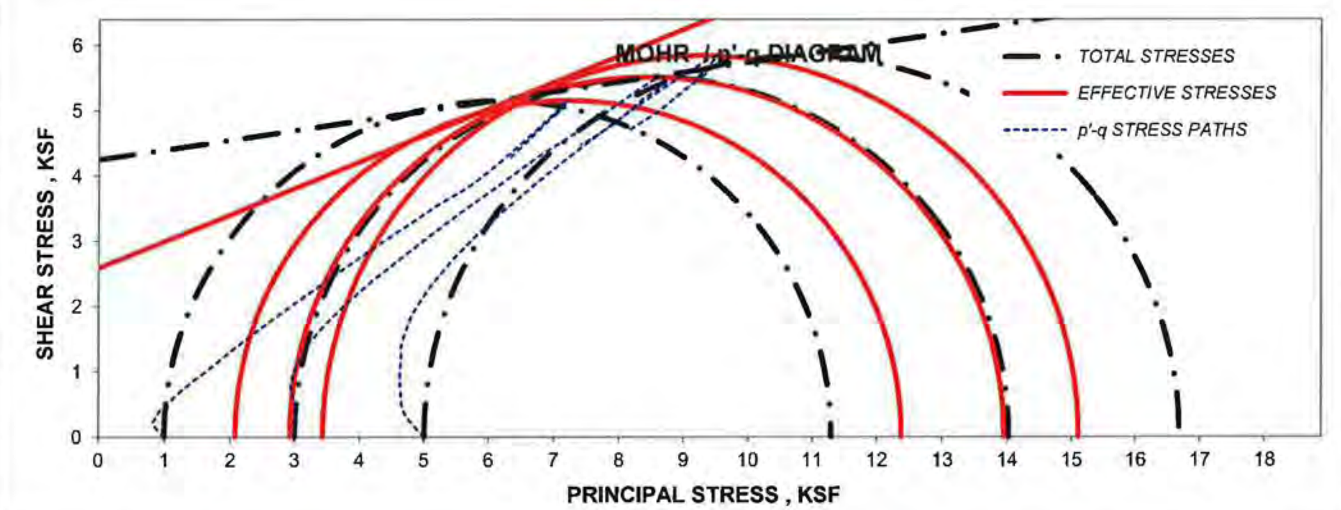
TEST PARAMETERS , TEST TYPE : CU/PP				
SPECIMEN NO.		**1**	**2**	**3**
B Value		0.95	0.95	0.95
BACK PRESSURE, ksf	U_o	7.2	7.2	7.2
CONFINING PRESSURE , ksf	σ_3	1.0	3.0	5.0
MAX. DEVIATOR STRESS ,ksf	$\sigma_1-\sigma_3$	10.3	11.0	11.7
ULT. DEVIATOR STRESS , ksf	$\sigma_1-\sigma_3$	8.5	9.0	9.4
Specimen Shape @ Failure	Sheared			

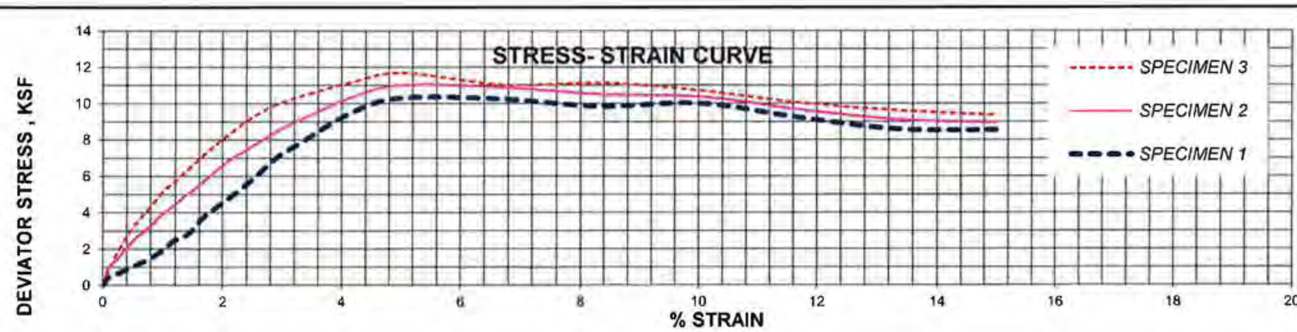
CONTROLLED : Strain @ 0.02 % per minute T50, Minutes = 18.0

PROCTOR TYPE : ***Standard* , MAXIMUM DRY DENSITY , PCF :** *56.6* **,OPTIMUM MOISTURE CONTENT , % :** *48.0*

REMOLDED : ***Specimens were remolded to 95 % of maximum dry density at about 0.0 % wet of o.m.c.***

SHEAR STRENGTH PARAMETERS	TOTAL		EFFECTIVE	
	COHESION , C (ksf) :	4.3	**APPARENT COHESION , (ksf) :**	2.6
	ANGLE OF INTER. FRICTION, Φ(DEGREES)	8	**ANGLE OF INTER. FRICTION, Φ' (DEGREES) :**	22





Brian Vaughan, P.E.	*[signature]*	Location Coordinator	06/10/14
Technical Responsibility	*Signature*	*Position*	*Date*

TRIAXIAL SHEAR TEST REPORT

(ASTM D 4767)

REV4,1/13/04

Project Name:	Geotrack Technologies, Inc. - 14-3425-N		
Project No.:	**1263-10-195**	**Report Date:**	06/10/14
Client Name:	Geotrack Technologies, Inc.	**Test Date:**	6/02 - 6/10/14
Client Address:	3620 Pelham Road, PMB #292 Greenville, SC 29615		
Boring No. :	N/A — **Depth / Elev. :** N/A	**Sample No . :**	44g — **Type:** Bulk
Sample Location :	Riverbend Pond		
Sample Description :	Coal Ash		
LL, % :	- — **PI , % :** NP	**Percent Passing #200 :**	77.5 — **G_s :** 2.130

SPECIMEN PROPERTIES		INITIAL			AFTER CONSOLIDATION			
SPECIMEN NO.		**1**	**2**	**3**		**1**	**2**	**3**
DIAMETER , INCHES	D_o	2.82	2.82	2.82	D_c	2.81	2.79	2.79
HEIGHT , INCHES	H_o	6.03	6.01	6.01	H_c	6.00	5.96	5.95
WATER CONTENT, %	W_o	48.0	48.0	48.0	W_c	67.6	65.8	65.0
DRY DENSITY, PCF	γ_{dryo}	53.8	53.9	54.0	γ_{dryc}	54.5	55.4	55.8
SATURATION ,%	S_o	69.4	69.7	70.0	S_c	100.0	100.0	100.0
VOID RATIO	e_o	1.472	1.468	1.461	e_c	1.439	1.401	1.384

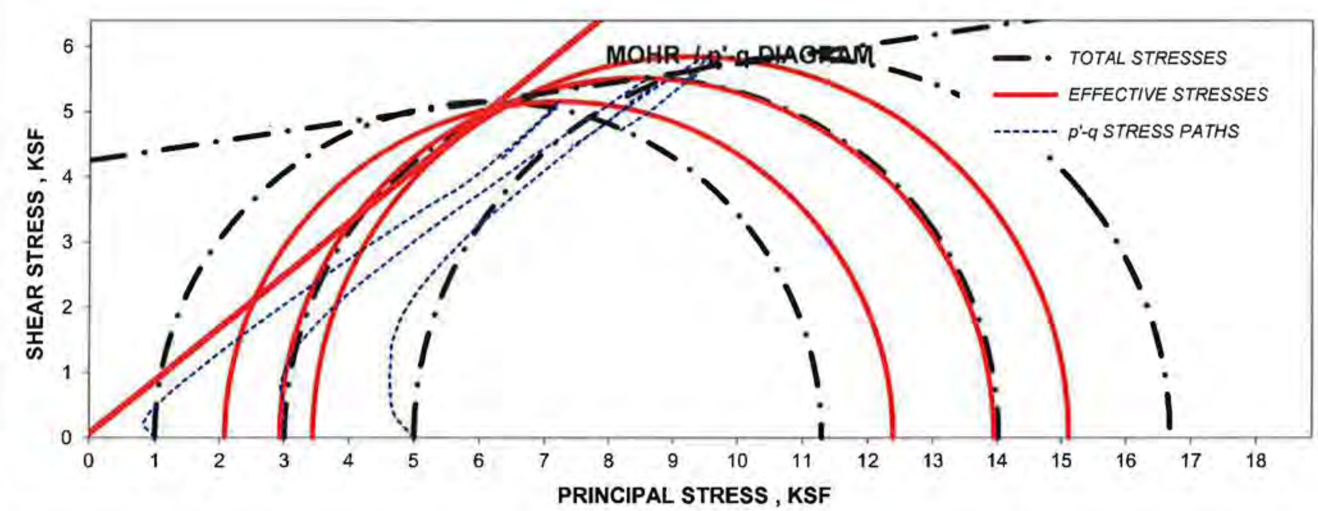
TEST PARAMETERS , TEST TYPE : CU/PP				
SPECIMEN NO.		**1**	**2**	**3**
B Value		0.95	0.95	0.95
BACK PRESSURE, ksf	U_o	7.2	7.2	7.2
CONFINING PRESSURE , ksf	σ_3	1.0	3.0	5.0
MAX. DEVIATOR STRESS ,ksf	$\sigma_1-\sigma_3$	10.3	11.0	11.7
ULT. DEVIATOR STRESS , ksf	$\sigma_1-\sigma_3$	8.5	9.0	9.4
Specimen Shape @ Failure	Sheared			

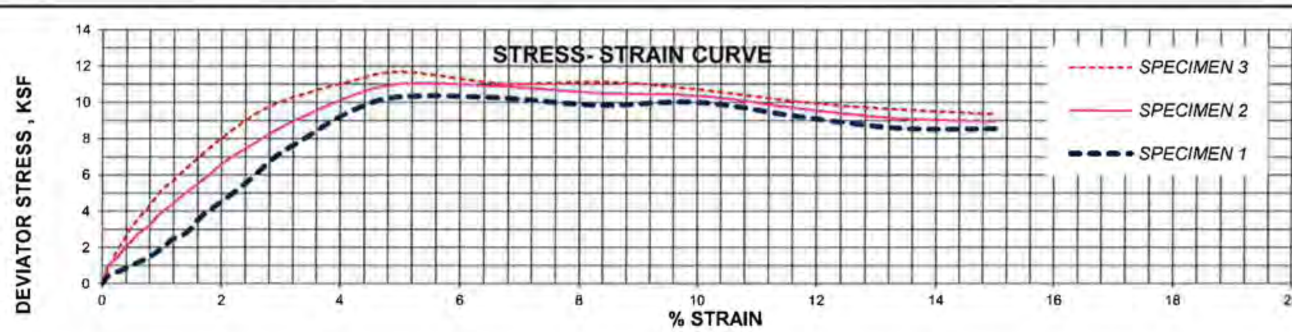
CONTROLLED : Strain @ 0.02 % per minute — T50, Minutes = 18.0

PROCTOR TYPE : *Standard* , **MAXIMUM DRY DENSITY , PCF :** *56.6* **,OPTIMUM MOISTURE CONTENT , %** : *48.0*

REMOLDED : *Specimens were remolded to* ***95*** *% of maximum dry density at about* ***0.0*** *% wet of o.m.c.*

SHEAR STRENGTH PARAMETERS	TOTAL		EFFECTIVE (ALT. FAILURE INTERPRETATION)	
	COHESION , C (ksf) :	4.3	APPARENT COHESION , (ksf) :	0
	ANGLE OF INTER. FRICTION, Φ(DEGREES)	8	ANGLE OF INTER. FRICTION, Φ' (DEGREES) :	39





Brian Vaughan, P.E. — *Technical Responsibility*

Signature

Location Coordinator — *Position*

06/10/14 — *Date*

ATTACHMENT C

TABLE 6
Typical Values of Soil Index Properties

	Particle Size and Gradation				Voids(1)					Unit Weight(2) (lb./cu.ft.)						
	Approximate Size Range (mm)		Approx. D_{10} (mm)	Approx. Range Uniform Coefficient C_u	Void Ratio			Porosity (%)		Dry Weight			Wet Weight		Submerged Weight	
	D_{max}	D_{min}			e_{max} loose	e_{cr}	e_{min} dense	n_{max} loose	n_{min} dense	Min loose	100% Mod. AASHO	Max dense	Min loose	Max dense	Min loose	Max dense
GRANULAR MATERIALS																
Uniform Materials																
a. Equal spheres (theoretical values)	-	-	-	1.0	0.92	-	0.35	47.6	26	-	-	-	-	-	-	-
b. Standard Ottawa SAND	0.84	0.59	0.67	1.1	0.80	0.75	0.50	44	33	92	-	110	93	131	57	69
c. Clean, uniform SAND (fine or medium)	-	-	-	1.2 to 2.0	1.0	0.80	0.40	50	29	83	115	118	84	136	52	73
d. Uniform, inorganic SILT	0.05	0.005	0.012	1.2 to 2.0	1.1	-	0.40	52	29	80	-	118	81	136	51	73
Well-graded Materials																
a. Silty SAND	2.0	0.005	0.02	5 to 10	0.90	-	0.30	47	23	87	122	127	88	142	54	79
b. Clean, fine to coarse SAND	2.0	0.05	0.09	4 to 6	0.95	0.70	0.20	49	17	85	132	138	86	148	53	86
c. Micaceous SAND	-	-	-	-	1.2	-	0.40	55	29	76	-	120	77	138	48	76
d. Silty SAND & GRAVEL	100	0.005	0.02	15 to 300	0.85	-	0.14	46	12	89	-	146(3)	90	155(3)	56	92
MIXED SOILS																
Sandy or Silty CLAY	2.0	0.001	0.003	10 to 30	1.8	-	0.25	64	20	60	130	135	100	147	38	85
Skip-graded Silty CLAY with stones or rk fgmts	250	0.001	-	-	1.0	-	0.20	50	17	84	-	140	115	151	53	89
Well-graded GRAVEL, SAND, SILT & CLAY mixture	250	0.001	0.002	25 to 1000	0.70	-	0.13	41	11	100	140	148(4)	125	156(4)	62	94
CLAY SOILS																
CLAY (30%-50% clay sizes)	0.05	0.5μ	0.001	-	2.4	-	0.50	71	33	50	105	112	94	133	31	71
Colloidal CLAY (-0.002 mm: 50%)	0.01	10Å	-	-	12	-	0.60	92	37	13	90	106	71	128	8	66
ORGANIC SOILS																
Organic SILT	-	-	-	-	3.0	-	0.55	75	35	40	-	110	87	131	25	69
Organic CLAY (30% - 50% clay sizes)	-	-	-	-	4.4	-	0.70	81	41	30		100	81	125	18	62

See Ref. 1

a height of 760 mm (30 in).

ıg of the falling weight onto the ding to the ground surface, the *test*. The free fall and height of · of drill rigs use a rope wrapped ı the rope which then tightens on rope until the weight is visually ne the rope is released with the ;estion around the power pulley count will be obtained. Several ıechanical hoist-trip device. This factors such as pushing a rock, : pressures also contribute error ducible in situ).

ow count $N \geq 100$. The log may indicating 70 blows for 150 mm :ration. Large blow counts both :ause rapid equipment wear and refusal" by ASTM at 100 assists ȝ firm to better identify drilling

tigate the status of cohesionless ly used in both cohesionless and ! types of foundations. In loose available to aid in retaining the ithout falling out of the sampler

the string of rods, the sampler lay (see Fig. 6-3*a*) the recovered ısually immediately tested for (Fig. 6-3*a*) or a portable field ıally stored in small glass jars ımple depth, and blow count *N*. as necessary for sieve analyses, :rg limits. The boxes of samples ıboratory for a stated period of

ɔroperties have been proposed. than guesses. For example, in ıost meaningless. The estimate

ATTACHMENT D

Table 6-1 Standard penetration test (SPT) correlations

Strength correlations will be given in later chapters as needed. Values shown are primarily for "order of magnitude."

Cohesionless Soil				
N	0–10	11–30	31–50	>50
Unit weight γ, kN/m³	12–16	14–18	16–20	18–23
Angle of friction ϕ	25–32	28–36	30–40	>35
State	Loose	Medium	Dense	Very dense
Relative density D_r	see Eq. (6-3) and Eq. (6-4) since depends on $p_0 = \gamma y$			

1kn/m³ = 6.36 pcf

Cohesive Soil					
N	<4	4–6	6–15	16–25	>25
Unit weight† γ, kN/m³	14–18	16–18	16–18	16–20	>20
q_u, kPa†	<25	20–50	30–60	40–200	>100
Consistency	Very soft	Soft	Medium	Stiff	Hard

† Values heavily dependent on water content.

SOIL HORIZON RESIDUUM

for angle of internal friction ϕ is generally conservative, and (as noted in Chap. 13) it is common to estimate ϕ as 30 to 32° for many projects.

The relative density D_r is often related to N but is often a very poor correlation. This results from N being somewhat project- and site-dependent and from D_r being rather tenuous to define (or reliably compute). As a consequence of this and some recent work which seems promising, it was decided not to include D_r in Table 6-1, but rather provide the current "best estimate" equations.

According to Marcusson and Bieganousky (1977)

$$D_r = 0.086 + 0.0083(2311 + 222N - 711(OCR) - C_1\sigma'_v)^{1/2} \tag{6-3}$$

and according to Fardis and Veneziano (1981), who applied much of the data used to develop Eq. (6-3), the relationship is

$$\ln N = C_2 + 2.06 \ln D_r + C_3 \ln \sigma'_v \tag{6-4}$$

where $C_1 = 7.7$ for σ'_v in kPa; 53 for psi units

C_2 = depth function which should be determined at a site by measuring N and D_r†

$C_3 = 0.222$ for σ'_v in kPa; 0.442 for psi units

OCR = overconsolidation ratio defined by Eq. (11-2)

Both of these equations are based on regression analyses. Equation (6-3) is based on four dissimilar soils and a large number of tests and claims a 78 percent reliability with a ± 0.075 standard deviation.

Example 6-2 Given: the SPT blow count at a depth of 4 m is 12. The soil is very sandy with traces of gravel and has an estimated unit weight $\gamma = 17.9$ kN/m³. The soil is damp but above the water table.

† If no correlation is made for C_2, use the value of $C_2 = 2.67$ obtained from the data base used for the equation.

See Ref. 2

as glacial till clays and those found in the *B* horizon of residual deposits, are of medium sensitivity. A few glacial clays and most fresh-water deposits are very sensitive. A few of the fresh-water and marine deposits are quick. The sensitivity of the large majority of cohesive deposits will range from 2 to 8. Sensitivities greater or less than this are much less commonly encountered. Most quick clays seem to be found (or at least reported) in Canada and Scandinavia.

13-10 EMPIRICAL METHODS FOR SHEAR STRENGTH

Numerous correlations for shear strength or shear strength parameters have been proposed in the literature. Several will be presented here to illustrate some of those available.

One of the earliest correlations is that between the SPT (Sec. 6-9) and the unconfined compression strength, as was illustrated in Table 6-1.

Correlations between ϕ and plasticity index I_P are shown in Fig. 13-20. A relationship between ϕ and percent clay fraction (Skempton, 1964) is shown in Fig. 13-21. Both of these curves should be used cautiously, as there are several major exceptions which can be found in the literature as well as substantial scatter in the data points used to establish the curves. For routine soil work, however, particularly in regions where w_L is on the order of 20 to 45 and I_P on the order of 15 to 30, these curves will be reasonably reliable.

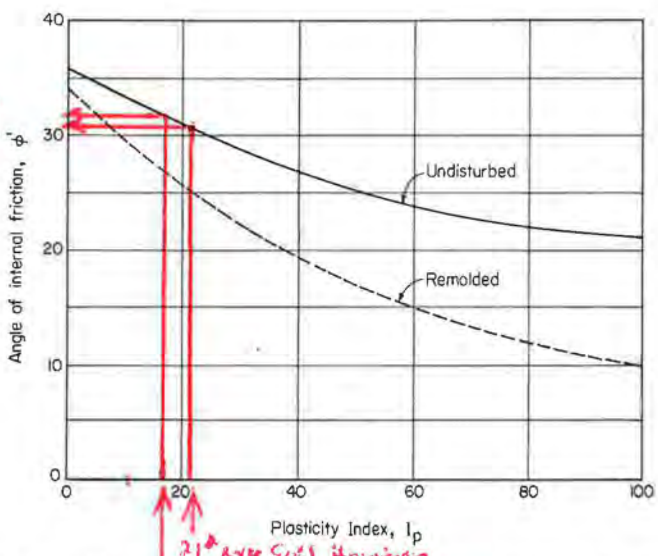


Figure 13-20 Correlation between angle of internal friction ϕ' (true) and plasticity index for both undisturbed and remolded soil. *(After Bjerrum and Simons, 1960.)*

16 Avg. Residuum

See Ref. 2

ATTACHMENT E

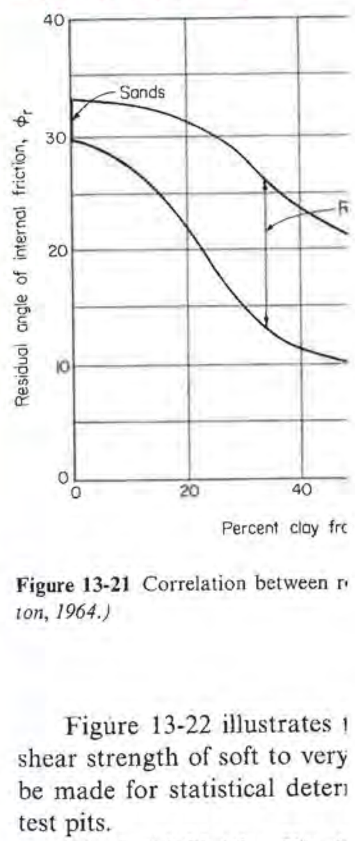


Figure 13-21 Correlation between r
ton, 1964.)

Figure 13-22 illustrates
shear strength of soft to very
be made for statistical deter
test pits.

Figure 13-23 (also Fig. 6
can be used in test pits or
where a person can be low
works well in any fine-graine
free location, pushes the pis

Figure 13-22 The torvane.

ATTACHMENT F

TABLE 1
Typical Properties of Compacted Soils

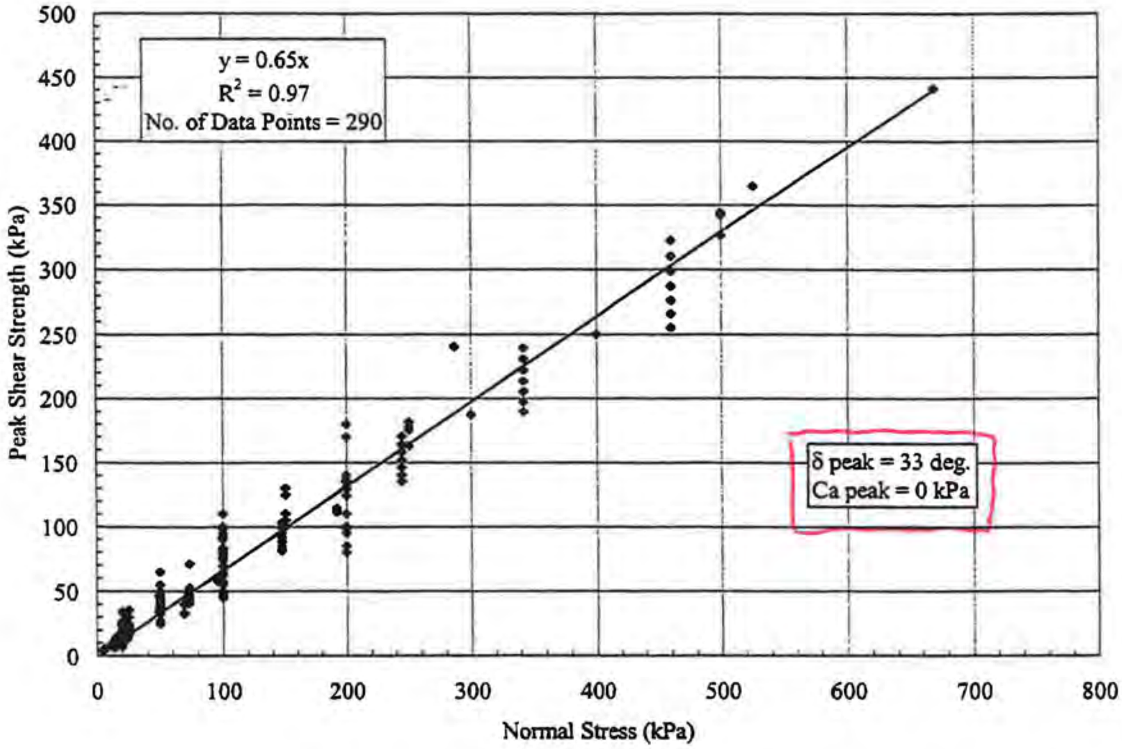
Group Symbol	Soil Type	Range of Maximum Dry Unit Weight, pcf	Range of Optimum Moisture, Percent	Typical Value of Compression: At 1.4 tsf (20 psi), Percent of Original Height	Typical Value of Compression: At 3.6 tsf (50 psi), Percent of Original Height	Typical Strength Characteristics: Cohesion (as compacted) psf	Typical Strength Characteristics: Cohesion (saturated) psf	Typical Strength Characteristics: Ø (Effective Stress Envelope Degrees)	Typical Strength Characteristics: Tan Ø	Typical Coefficient of Permeability ft./min.	Range of CBR Values	Range of Subgrade Modulus k ~~lbs/cu in.~~ psi/in
GW	Well graded clean gravels, gravel-sand mixtures.	125 - 135	11 - 8	0.3	0.6	0	0	>38	>0.79	5 x 10^{-2}	40 - 80	300 - 500
GP	Poorly graded clean gravels, gravel-sand mix	115 - 125	14 - 11	0.4	0.9	0	0	>37	>0.74	10^{-1}	30 - 60	250 - 400
GM	Silty gravels, poorly graded gravel-sand-silt.	120 - 135	12 - 8	0.5	1.1	.....	.....	>34	>0.67	>10^{-6}	20 - 60	100 - 400
GC	Clayey gravels, poorly graded gravel-sand-clay.	115 - 130	14 - 9	0.7	1.6	.....	.....	>31	>0.60	>10^{-7}	20 - 40	100 - 300
SW	Well graded clean sands, gravelly sands.	110 - 130	16 - 9	0.6	1.2	0	0	38	0.79	>10^{-3}	20 - 40	200 - 300
SP	Poorly graded clean sands, sand-gravel mix.	100 - 120	21 - 12	0.8	1.4	0	0	37	0.74	>10^{-3}	10 - 40	200 - 300
SM	Silty sands, poorly graded sand-silt mix.	110 - 125	16 - 11	0.8	1.6	1050	420	34	0.67	5 x >10^{-5}	10 - 40	100 - 300
SM-SC	Sand-silt clay mix with slightly plastic fines.	110 - 130	15 - 11	0.8	1.4	1050	300	33	0.66	2 x >10^{-6}	5 - 30	100 - 300
SC	Clayey sands, poorly graded sand-clay-mix.	105 - 125	19 - 11	1.1	2.2	1550	230	31	0.60	5 x >10^{-7}	5 - 20	100 - 300
ML	Inorganic silts and clayey silts.	95 - 120	24 - 12	0.9	1.7	1400	190	32	0.62	>10^{-5}	15 or less	100 - 200
ML-CL	Mixture of inorganic silt and clay.	100 - 120	22 - 12	1.0	2.2	1350	460	32	0.62	5 x >10^{-7}	.....	
CL	Inorganic clays of low to medium plasticity.	95 - 120	24 - 12	1.3	2.5	1800	270	28	0.54	>10^{-7}	15 or less	50 - 200
OL	Organic silts and silt-clays, low plasticity.	80 - 100	33 - 21	.....	.....	.....	.....	.....	.....	.....	5 or less	50 - 100
MH	Inorganic clayey silts, elastic silts.	70 - 95	40 - 24	2.0	3.8	1500	420	25	0.47	5 x >10^{-7}	10 or less	50 - 100
CH	Inorganic clays of high plasticity	75 - 105	36 - 19	2.6	3.9	2150	230	19	0.35	>10^{-7}	15 or less	50 - 150
OH	Organic clays and silty clays	65 - 100	45 - 21	.....	.....	.....	.....	.....	.....	.....	5 or less	25 - 100

Notes:

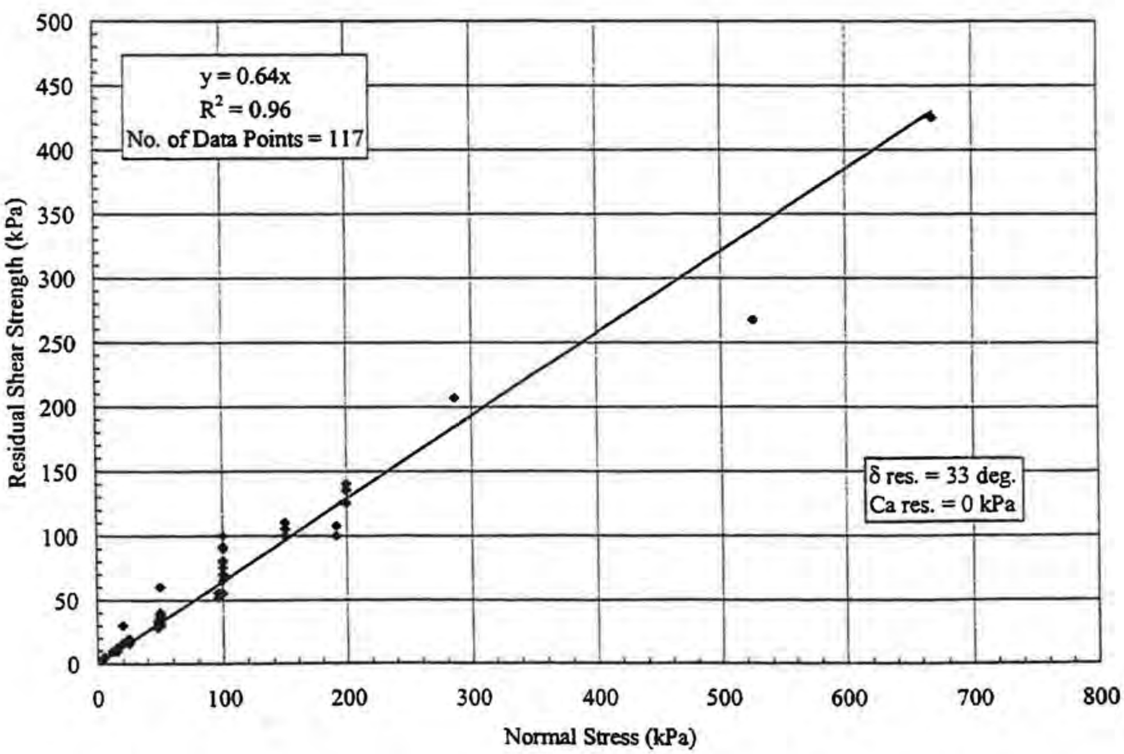
1. All properties are for condition of "Standard Proctor" maximum density, except values of k and CBR which are for "modified Proctor" maximum density.
2. Typical stength characteristics are for effective strength envelopes and are obtained from USBR data.
3. Compression values are for vertical loading with complete lateral confinement.
4. (>) indicates that typical property is greater than the value shown.
   (..) indicates insufficient data available for an estimate.

See Ref. 4

ATTACHMENT G

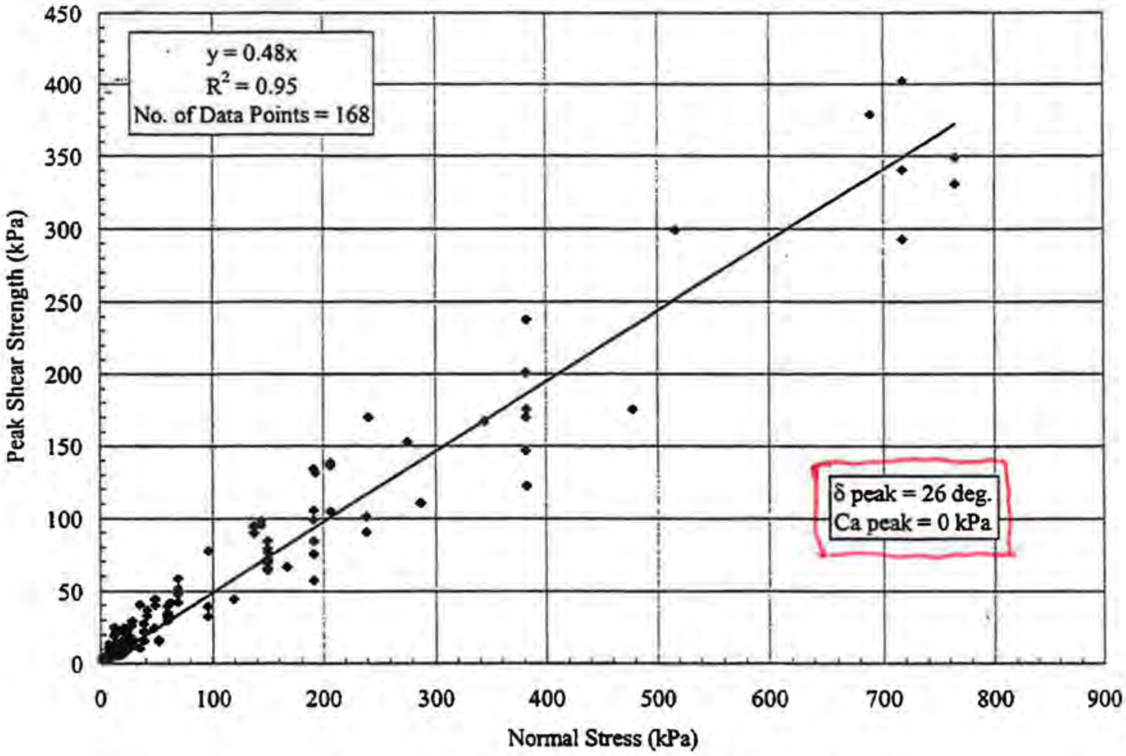


Appendix Figure 8a – Peak Shear Strength; NW-NP Geotextile against Granular Soil.

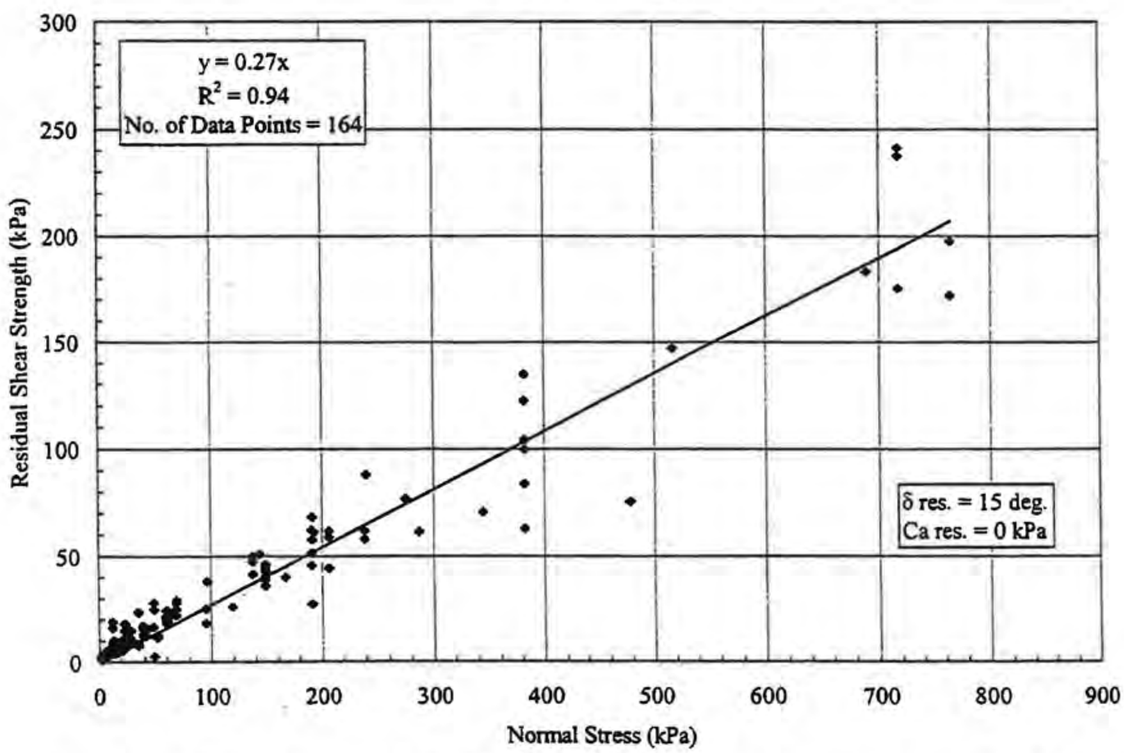


Appendix Figure 8b – Residual Shear Strength; NW-NP Geotextile against Granular Soil.

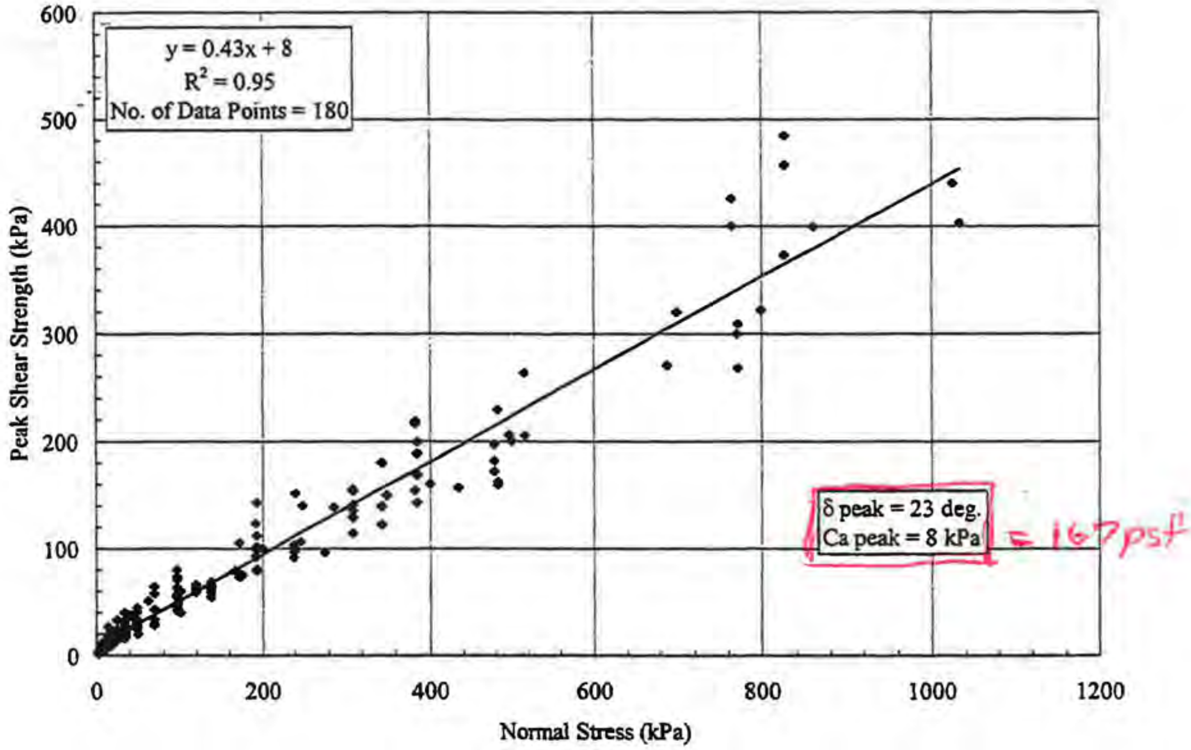
See Ref. 5



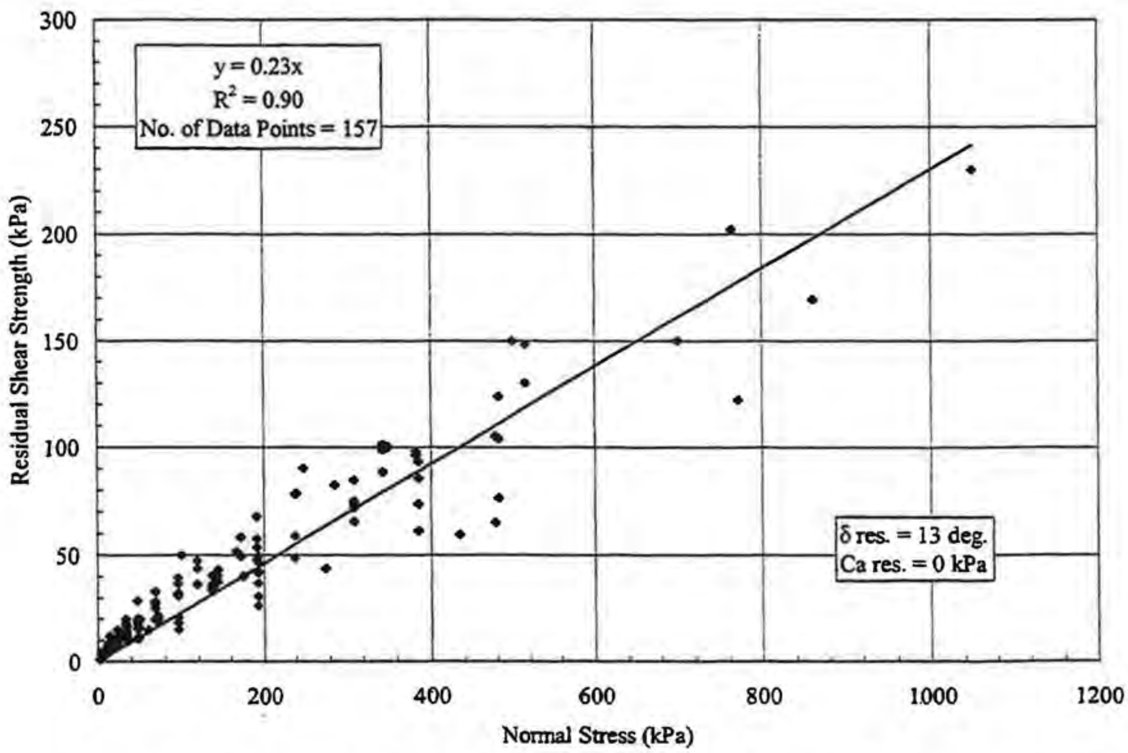
Appendix Figure 2i – Peak Shear Strength; Textured HDPE against NW-NP Geotextile on a Drainage Geocomposite.



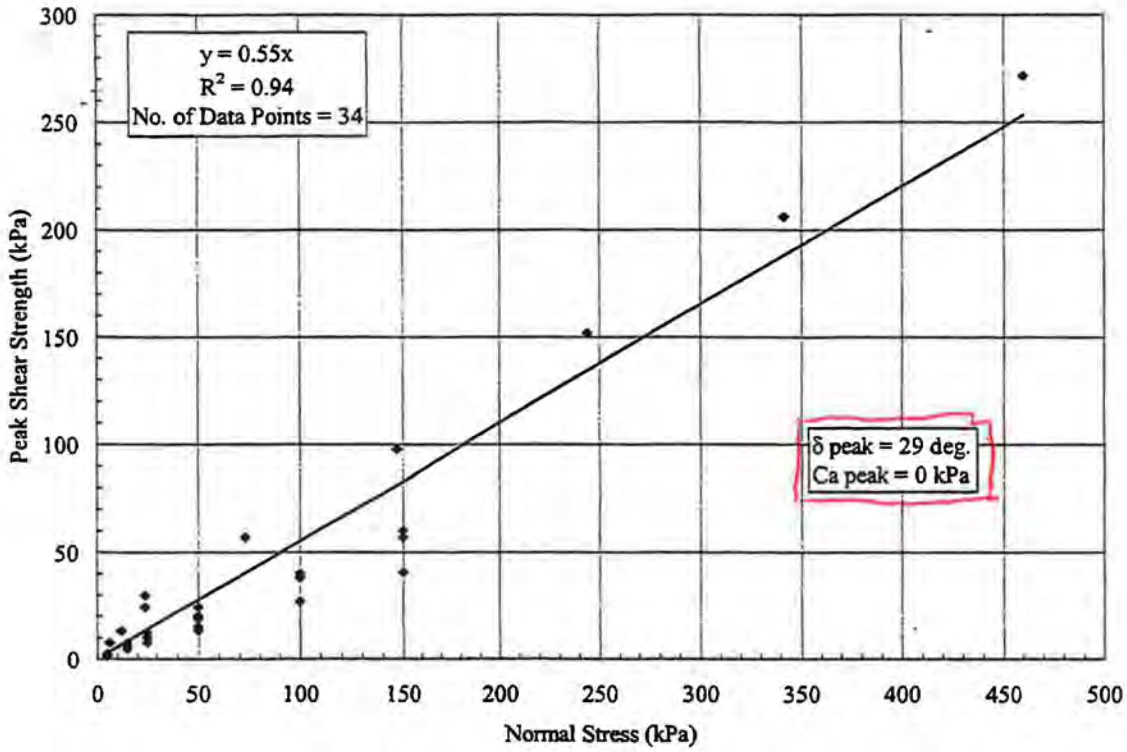
Appendix Figure 2j – Residual Shear Strength; Textured HDPE against NW-NP Geotextile on a Drainage Geocomposite.



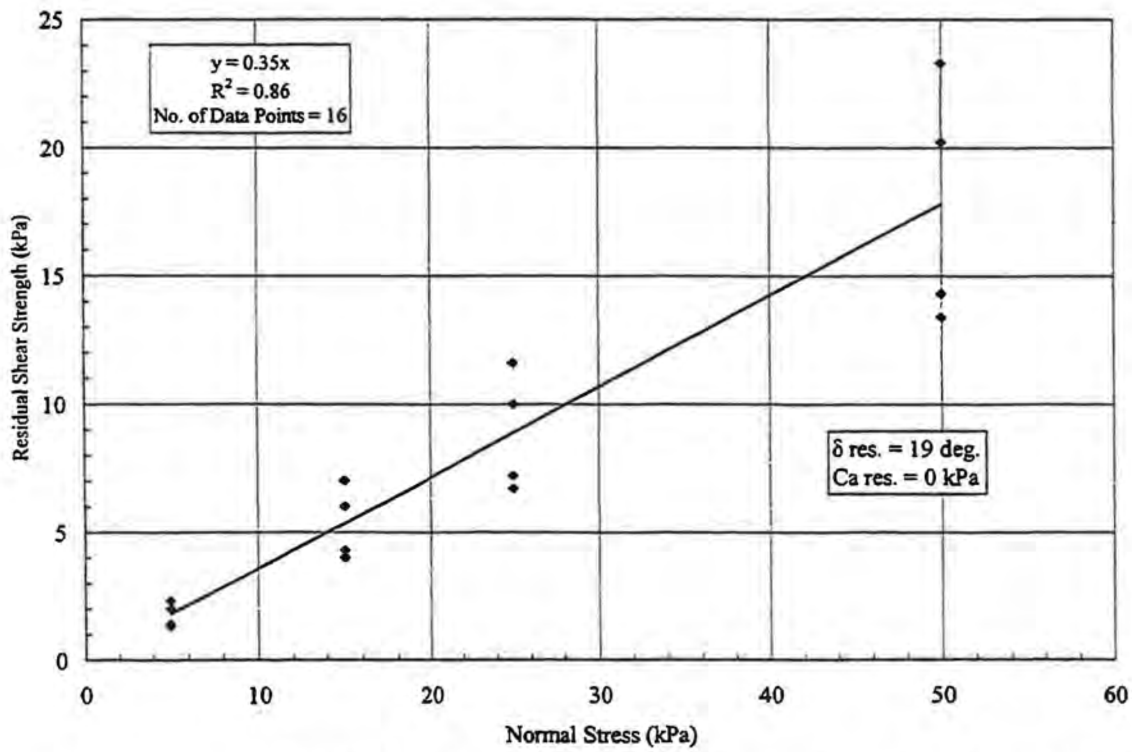
Appendix Figure 11a - Peak Shear Strength; Textured HDPE against NW-NP Side of Fabric-Reinforced GCL.



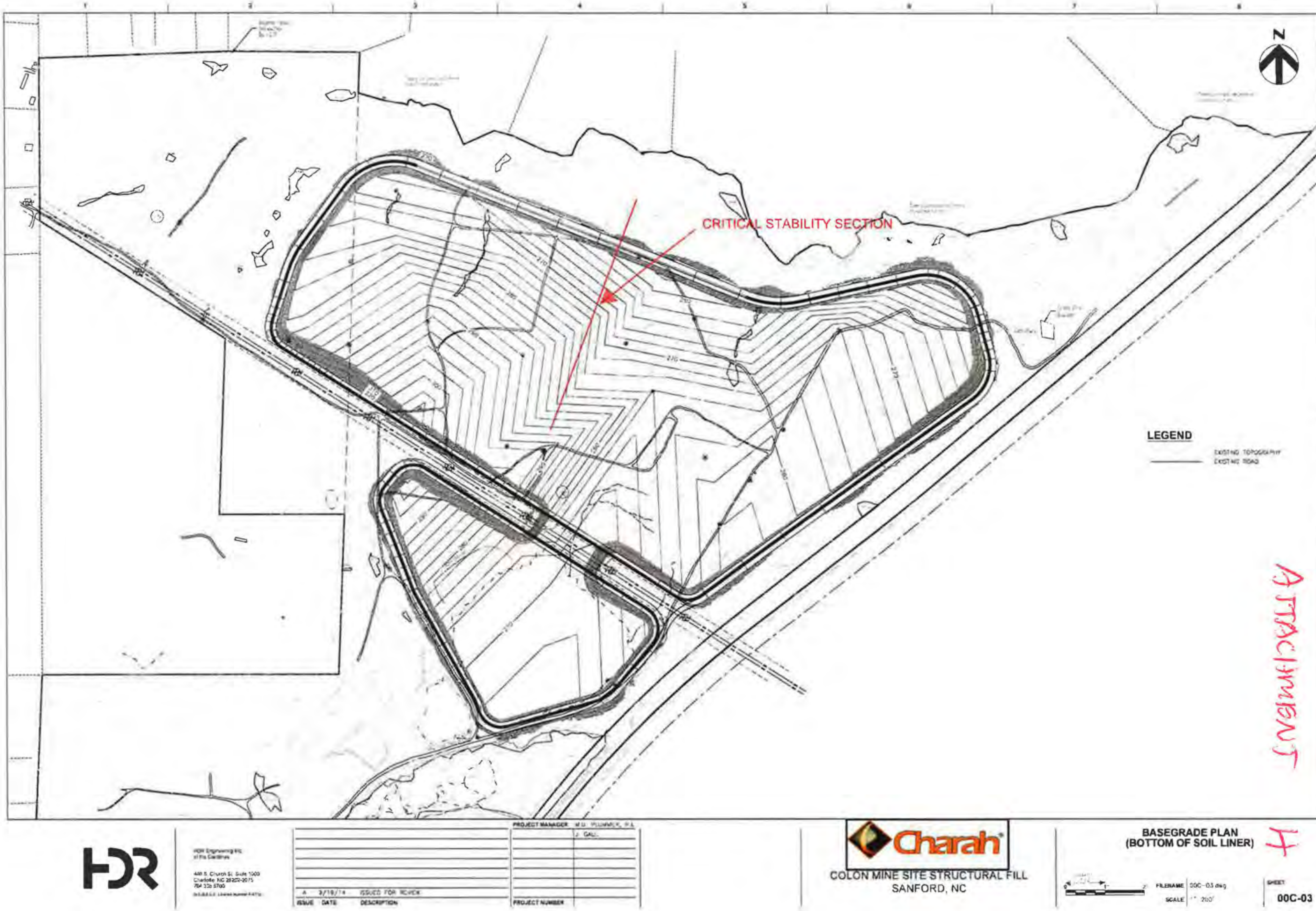
Appendix Figure 11b - Residual Shear Strength; Textured HDPE against NW-NP Side of Fabric-Reinforced GCL.



Appendix Figure 9e - Peak Shear Strength; Woven Geotextile against Cohesive Soil.



Appendix Figure 9f - Residual Shear Strength; Woven Geotextile against Cohesive Soil.


CRITICAL STABILITY SECTION
LEGEND
EXISTING TOPOGRAPHY
EXISTING ROAD
N
ATTACHMENT 4
HDR
PROJECT MANAGER
PROJECT NUMBER
A 9/18/14 ISSUED FOR REVIEW
ISSUE DATE DESCRIPTION
Charah
COLON MINE SITE STRUCTURAL FILL
SANFORD, NC
BASEGRADE PLAN
(BOTTOM OF SOIL LINER)
FILENAME 00C-03.dwg
SCALE 1" = 200'
SHEET
00C-03

HDR

HDR Engineering Inc. of the Carolinas
440 S. Church St, Suite 1000
Charlotte, NC 28202-2075
704.338.6700

ISSUE	DATE	DESCRIPTION
A	9/19/14	ISSUED FOR REVIEW

PROJECT MANAGER: M.D. PLUMMER, P.E.
J. CALL
PROJECT NUMBER

Charah®

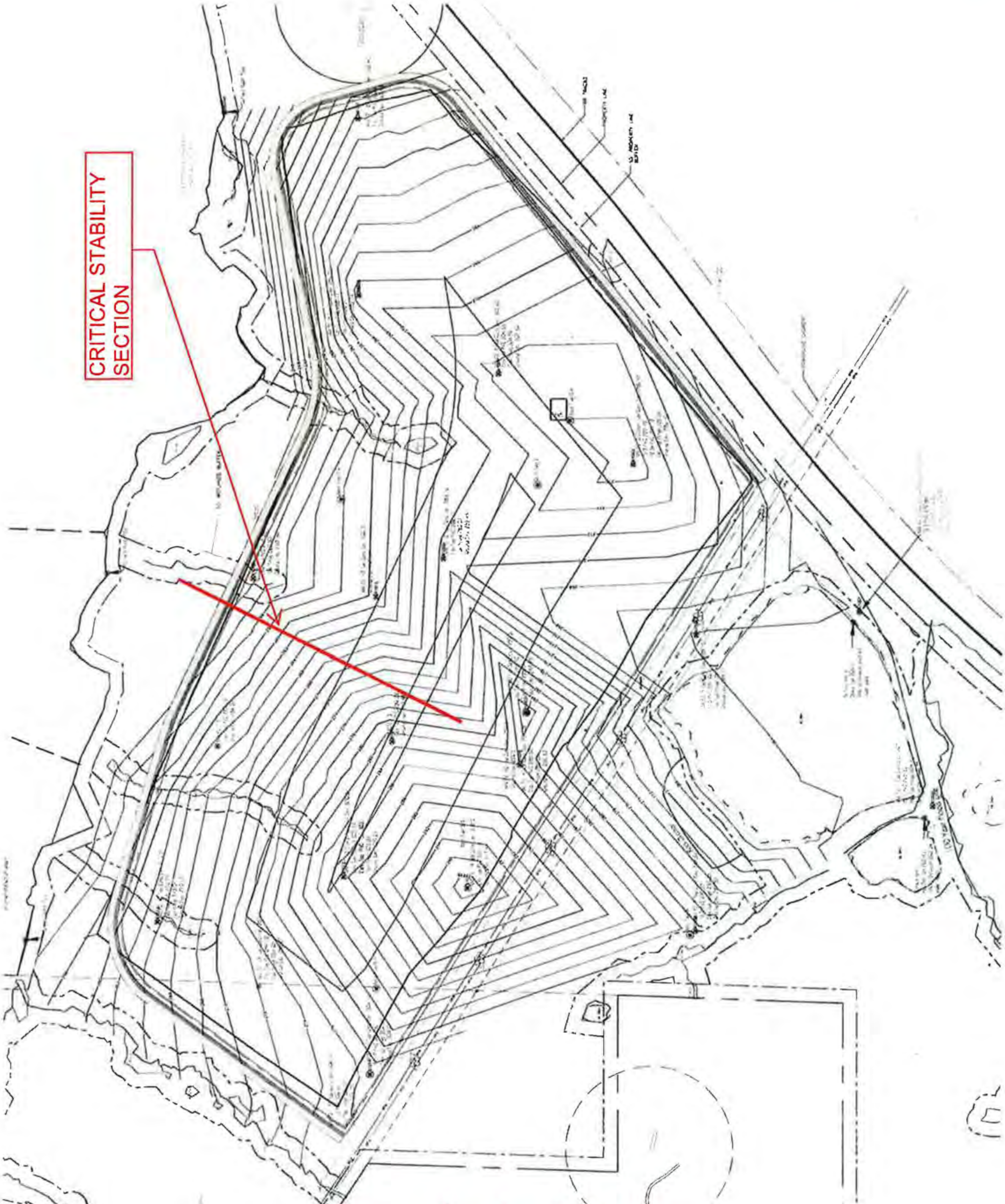
COLON MINE SITE STRUCTURAL FILL
SANFORD, NC

PROPOSED FINAL CLOSURE PLAN

FILENAME: 00C-02.dwg
SCALE: 1"=200'

SHEET: 00C-02

ATTACHMENT J



Groundwater Contours

ATTACHMENT K

Earthquake Hazards Program

US Seismic Hazard 2008

Layers Tools

Hazard maps

Transparency

Peak ground acceleration (%g) with 10% probability of exceedance in 50 years

* Peak ground acceleration (%g) with 2% probability of exceedance in 50 years

0.2-second acceleration with 10% probability of exceedance in 50 years

0.2-second acceleration with 2% probability of exceedance in 50 years

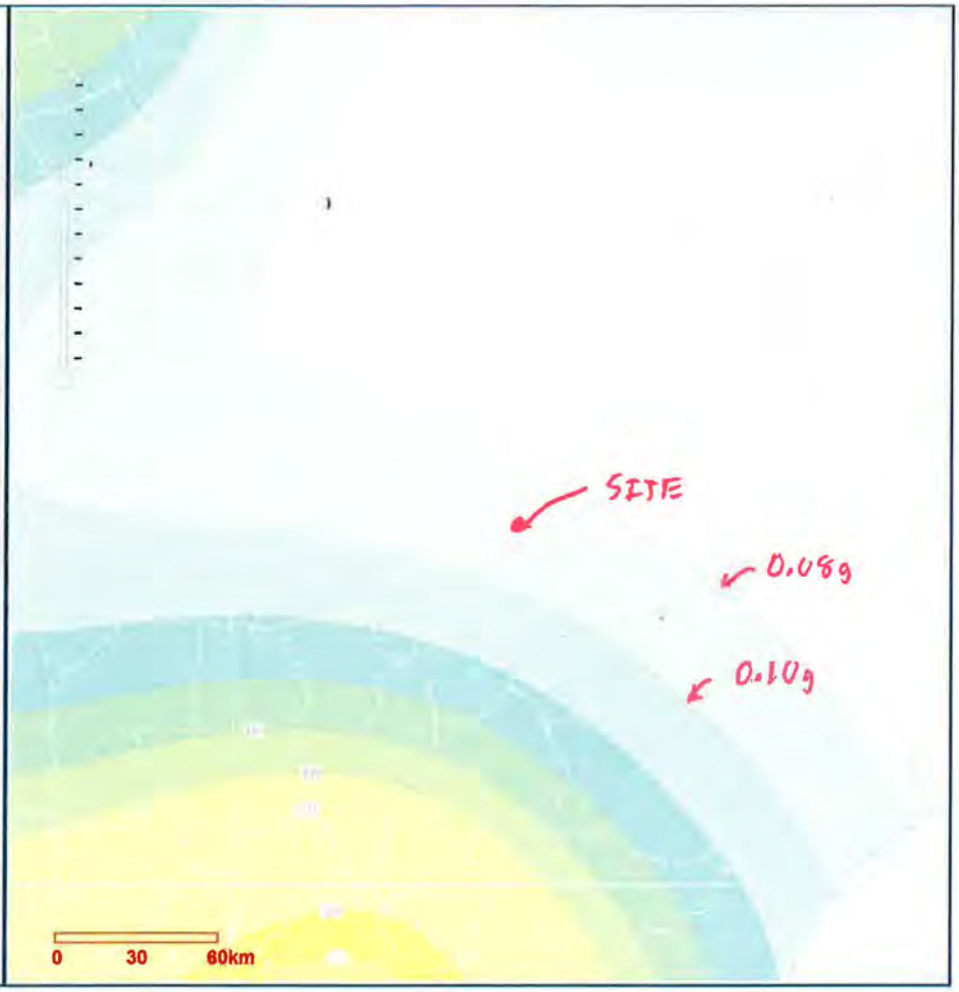
1.0-second acceleration with 10% probability of exceedance in 50 years

1.0-second acceleration with 2% probability of exceedance in 50 years

Hazard map faults

Basemap

Transparency



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HDR Computation

		Job Number	453925-235691-018	**No.**	
Project	Charah Colon Mine Structural Fill	**Computed**	TMY	**Date**	10/27/2014
Subject	Permit Application	**Checked**	KP	**Date**	10/29/2014
Task	Final Cover Veneer Stability (Option 1)	**Sheet**	1	**Of**	3

Objective: Determine the smallest interface friction angle allowable to meet dynamic and static factors of safety for final cover stability due to sliding for Option 1 final cover (see second page of calc.)

References:

1. Matasovic, N. (1991), "Selection of Method for Seismic Slope Stability Analysis," Proc. 2nd International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, St. Louis, Vol. 2, pp. 1057-1062.

2. Koerner, G.R. and D. Narejo (2005). Direct Shear Database of Geosynthetic-to-Geosynthetic and Geosynthetic-to-Soil Interfaces. GRI Report #30.

Calculations:

Infinite slope:

$$FS = \frac{\text{Resisting Moment (RM)}}{\text{Driving Moment (DM)}}$$

$$FS = \frac{\left(\frac{c}{\gamma z \cos^2 \beta}\right) + \tan\phi\left(1 - \gamma_w \frac{z - d_w}{\gamma z}\right) - k_g \tan\beta \tan\phi}{k_g + \tan\beta}$$

Where:

FS = Factor of Safety

k_g = seismic coefficient (=0 for static stability)

γ = unit weight of cover soil

c = cohesion of cover soil

γ_w = unit weight of water

z = depth to failure surface

d_w = depth to seepage surface (=z if slope is dry)

β = slope angle of cover

ϕ = interface friction angle

Given:

γ =	120	lb/ft^3	
γ_w =	62.4	lb/ft^3	
z =	4.0	ft	
Slope, M =	4	H:1V	
c =	0.0	lb/ft^2	
Depth to Water =	2.50	ft	Assume lateral seepage is contained within lower 18" layer of higher permeability soil in final cover.
Ground surface acceleration =	0.09	(seismic coefficient)	USGS National Seismic Hazards Map - 2008 showing peak horizontal acceleration with a 2% probability of exceedance in 50 years. See Attachment A.
Ground surface acceleration =	0	(static)	

HDR Computation

Job Number	453925-235691-018	**No.**	
Project	Charah Colon Mine Structural Fill	**Computed** TMY	**Date** 10/27/2014
Subject	Permit Application	**Checked** KP	**Date** 10/29/2014
Task	Final Cover Veneer Stability (Option 1)	**Sheet** 2	**Of** 3

Solution:

β = 14.04 degrees

Dynamic Conditions (k_g = 0.09)

Dynamic FS Against Sliding: (EPA Guidance Document EPA/600/R-95/051 - RCRA Subtitle D (258) Seismic Design Guidelines for MSW Landfill Facilities page 102 requires a minimum factor of safety of 1.0)

FS_{min} = 1.0 Dynamic conditions

ϕ (°)	RM	DM	FS	
5	0.068	0.340	0.20	
10	0.138	0.340	0.41	
15	0.210	0.340	0.62	
20	0.285	0.340	0.84	
23.4	0.339	0.340	1.00	← CRITICAL
30	0.452	0.340	1.33	
35	0.548	0.340	1.61	

Static Conditions (k_g = 0)

Static FS Against Sliding:

FS_{min} = 1.5 Static conditions

ϕ (°)	RM	DM	FS	
5	0.070	0.250	0.28	
10	0.142	0.250	0.57	
15	0.216	0.250	0.86	
20	0.293	0.250	1.17	
25	0.375	0.250	1.50	← CRITICAL
30	0.465	0.250	1.86	
35	0.564	0.250	2.25	

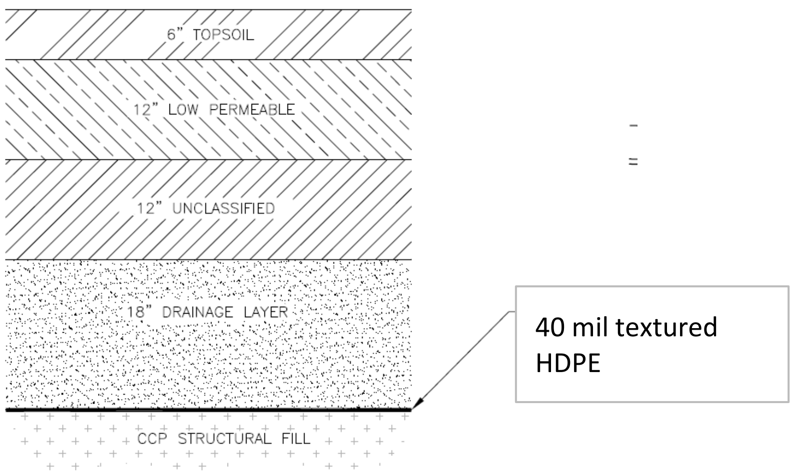
HDR Computation

Job Number	453925-235691-018	**No.**	
Project	Charah Colon Mine Structural Fill	**Computed** TMY	**Date** 10/27/2014
Subject	Permit Application	**Checked** KP	**Date** 10/29/2014
Task	Final Cover Veneer Stability (Option 1)	**Sheet** 3	**Of** 3

Conclusion:

A minimum interface friction angle of 25 degrees between the components of the final cover system is necessary for stability.

Determine if components of proposed final cover system are capable of achieving the minimum friction angle using typical values of φ for each interface from Attachment B (Ref. 2).



Textured Geomembrane/Granular Soil: φ = 34˚ , c = 0 psf

From the typical values above, the proposed materials to be used for final cover construction are capable of achieving the minimum required friction angle. This should be verified, however, with project specific lab testing.

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HDR Computation

		Job Number	453925-235691-018	**No.**	
Project	Charah Colon Mine Structural Fill	**Computed**	TMY	**Date**	10/22/2014
Subject	Permit Application	**Checked**	KP	**Date**	10/29/2014
Task	Final Cover Veneer Stability (Option 2)	**Sheet**	1	**Of**	3

Objective: Determine the smallest interface friction angle allowable to meet dynamic and static factors of safety for final cover stability due to sliding for Option 2 final cover (see second page of calc.)

References:

1. Matasovic, N. (1991), "Selection of Method for Seismic Slope Stability Analysis," Proc. 2nd International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, St. Louis, Vol. 2, pp. 1057-1062.

2. Koerner, G.R. and D. Narejo (2005). Direct Shear Database of Geosynthetic-to-Geosynthetic and Geosynthetic-to-Soil Interfaces. GRI Report #30.

Calculations:

Infinite slope:

$$FS = \frac{\text{Resisting Moment (RM)}}{\text{Driving Moment (DM)}}$$

$$FS = \frac{\left(\frac{c}{\gamma z \cos^2 \beta}\right) + \tan\phi\left(1 - \gamma_w \frac{z - d_w}{\gamma z}\right) - k_g \tan\beta \tan\phi}{k_g + \tan\beta}$$

Where:

FS = Factor of Safety

k_g = seismic coefficient (=0 for static stability)

γ = unit weight of cover soil

c = cohesion of cover soil

γ_w = unit weight of water

z = depth to failure surface

d_w = depth to seepage surface (=z if slope is dry)

β = slope angle of cover

ϕ = interface friction angle

Given:

γ =	120	lb/ft^3
γ_w =	62.4	lb/ft^3
z =	4.0	ft
Slope, M =	4	H:1V
c =	0.0	lb/ft^2
Depth to Water =	4.00	ft
Ground surface acceleration =	0.09	(seismic coefficient)
Ground surface acceleration =	0	(static)

Assume lateral seepage is contained within geocomposite.

USGS National Seismic Hazards Map - 2008 showing peak horizontal acceleration with a 2% probability of exceedance in 50 years. See Attachment A.

HDR Computation

Job Number	453925-235691-018	No.	
Project	Charah Colon Mine Structural Fill	Computed	TMY
Date	10/22/2014		
Subject	Permit Application	Checked	KP
Date	10/29/2014		
Task	Final Cover Veneer Stability (Option 2)	Sheet	2
Of	3		

Solution:

β = 14.04 degrees

Dynamic Conditions (k_g = 0.09)

Dynamic FS Against Sliding: (EPA Guidance Document EPA/600/R-95/051 - RCRA Subtitle D (258) Seismic Design Guidelines for MSW Landfill Facilities page 102 requires a minimum factor of safety of 1.0)

FS_{min} = 1.0 Dynamic conditions

ϕ (°)	RM	DM	FS	
5	0.086	0.340	0.25	
10	0.172	0.340	0.51	
15	0.262	0.340	0.77	
19.2	0.340	0.340	1.00	← CRITICAL
25	0.456	0.340	1.34	
30	0.564	0.340	1.66	
35	0.684	0.340	2.01	

Static Conditions (k_g = 0)

Static FS Against Sliding:

FS_{min} = 1.5 Static conditions

ϕ (°)	RM	DM	FS	
5	0.087	0.250	0.35	
10	0.176	0.250	0.71	
15	0.268	0.250	1.07	
20.5	0.374	0.250	1.50	← CRITICAL
25	0.466	0.250	1.87	
30	0.577	0.250	2.31	
35	0.700	0.250	2.80	

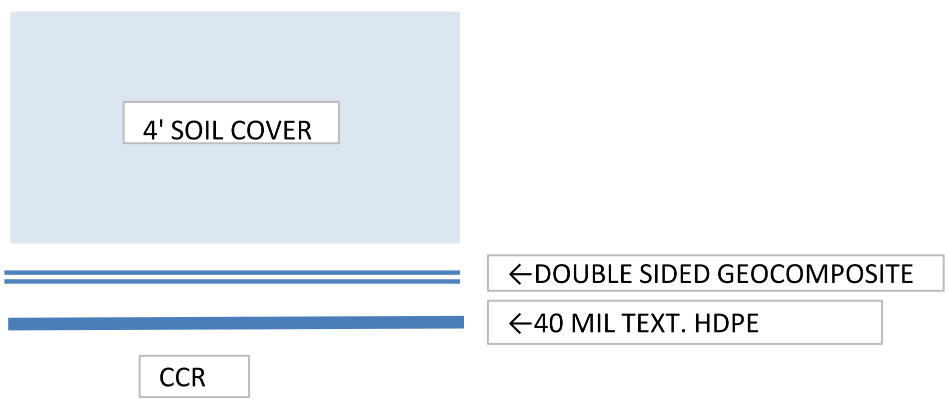
HDR Computation

		Job Number	453925-235691-018	**No.**	
Project	Charah Colon Mine Structural Fill	**Computed**	TMY	**Date**	10/22/2014
Subject	Permit Application	**Checked**	KP	**Date**	10/29/2014
Task	Final Cover Veneer Stability (Option 2)	**Sheet**	3	**Of**	3

Conclusion:

A minimum interface friction angle of 20.5 degrees between the components of the final cover system is necessary for stability.

Determine if components of proposed final cover system are capable of achieving the minimum friction angle using typical values of φ for each interface from Attachment B (Ref. 2).



Textured Geomembrane/Granular Soil: φ = 34˚ , c = 0 psf

Textured Geomembrane/Geocomposite: φ = 26˚ , c = 0 psf

Geocomposite/Soil Cover: φ = 30˚ , c = 104 psf

From the typical values above, the proposed materials to be used for final cover construction are capable of achieving the minimum required friction angle. This should be verified, however, with project specific lab testing.

ATTACHMENT A

Earthquake Hazards Program

US Seismic Hazard 2008

Layers Tools

Hazard maps

Transparency

Peak ground acceleration (%g) with 10% probability of exceedance in 50 years

* Peak ground acceleration (%g) with 2% probability of exceedance in 50 years

0.2-second acceleration with 10% probability of exceedance in 50 years

0.2-second acceleration with 2% probability of exceedance in 50 years

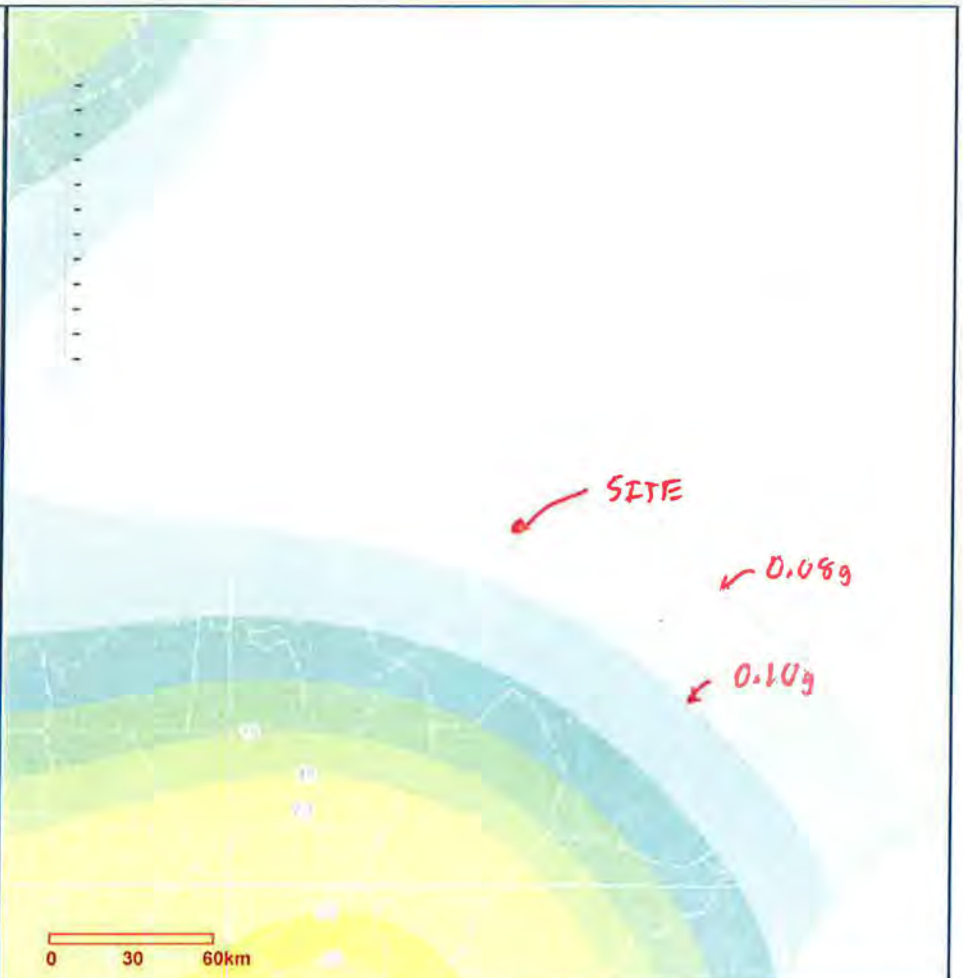
1.0-second acceleration with 10% probability of exceedance in 50 years

1.0-second acceleration with 2% probability of exceedance in 50 years

Hazard map faults

Basemap

Transparency



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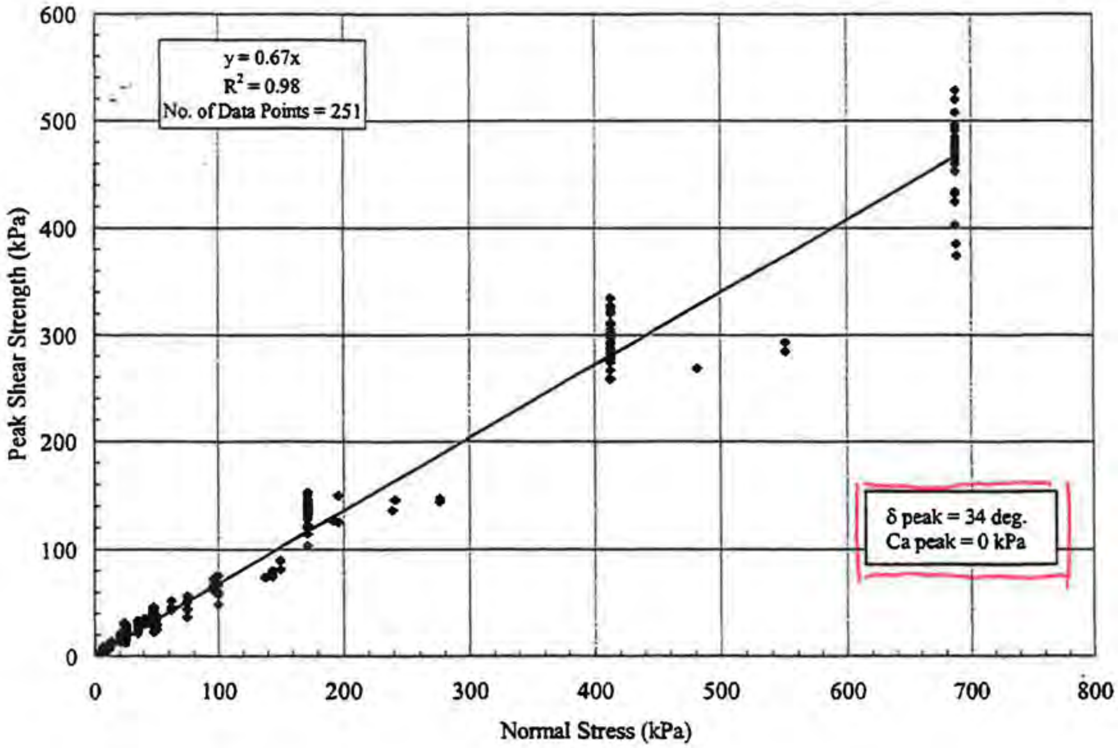
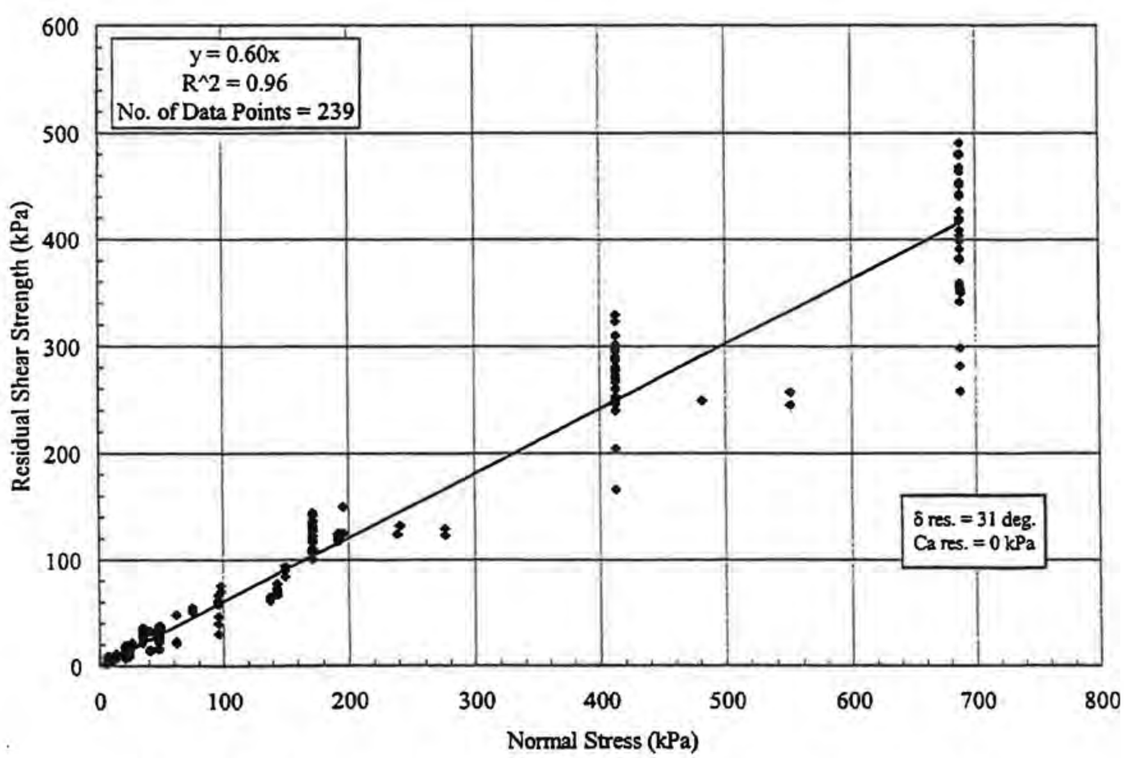
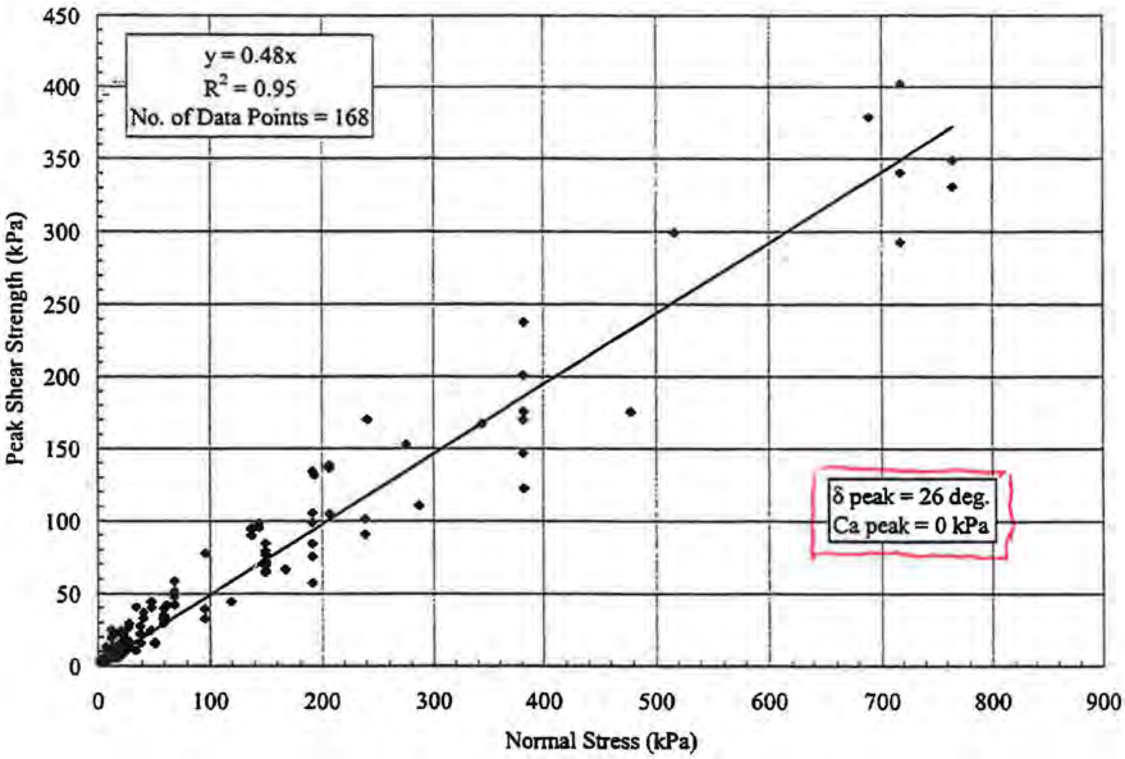
ATTACHMENT B



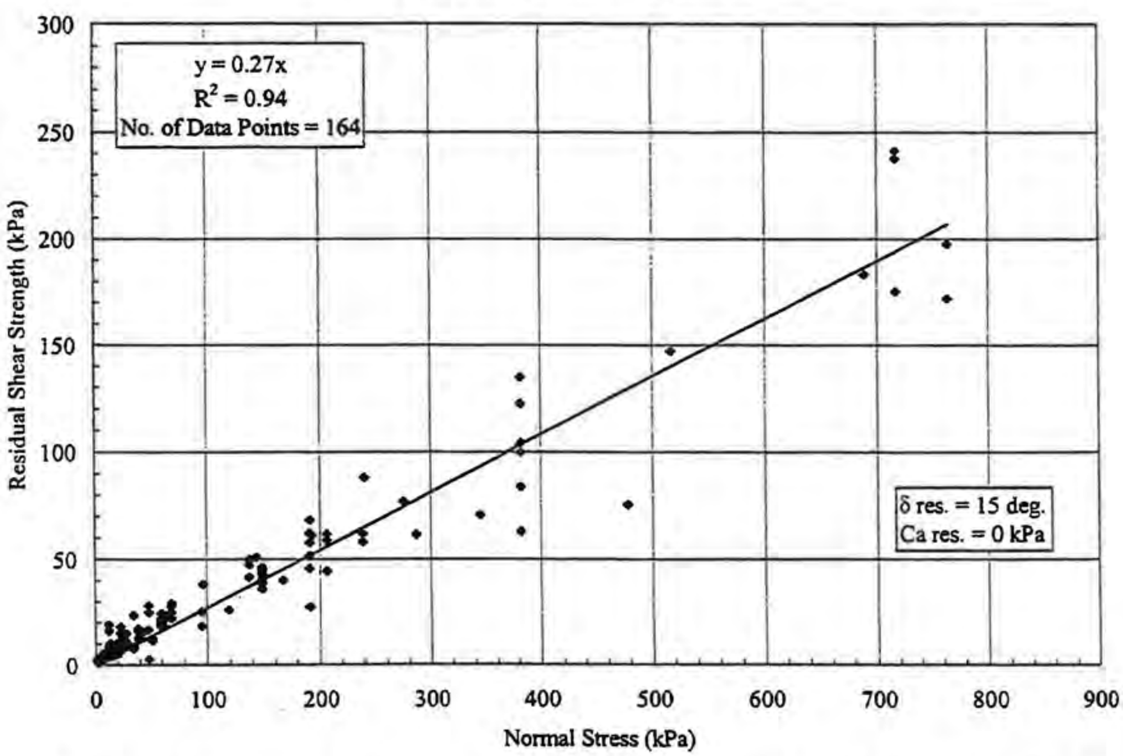
Appendix Figure 2a – Peak Shear Strength; Textured HDPE against Granular Soil.



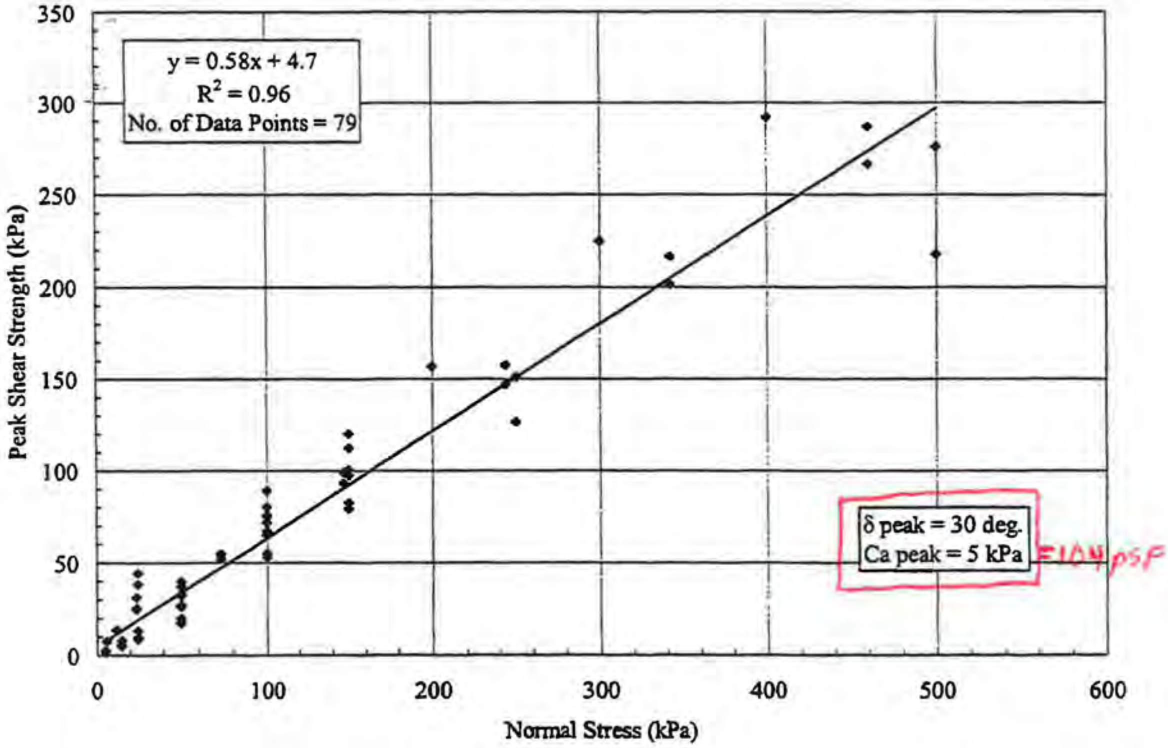
Appendix Figure 2b – Residual Shear Strength; Textured HDPE against Granular Soil.



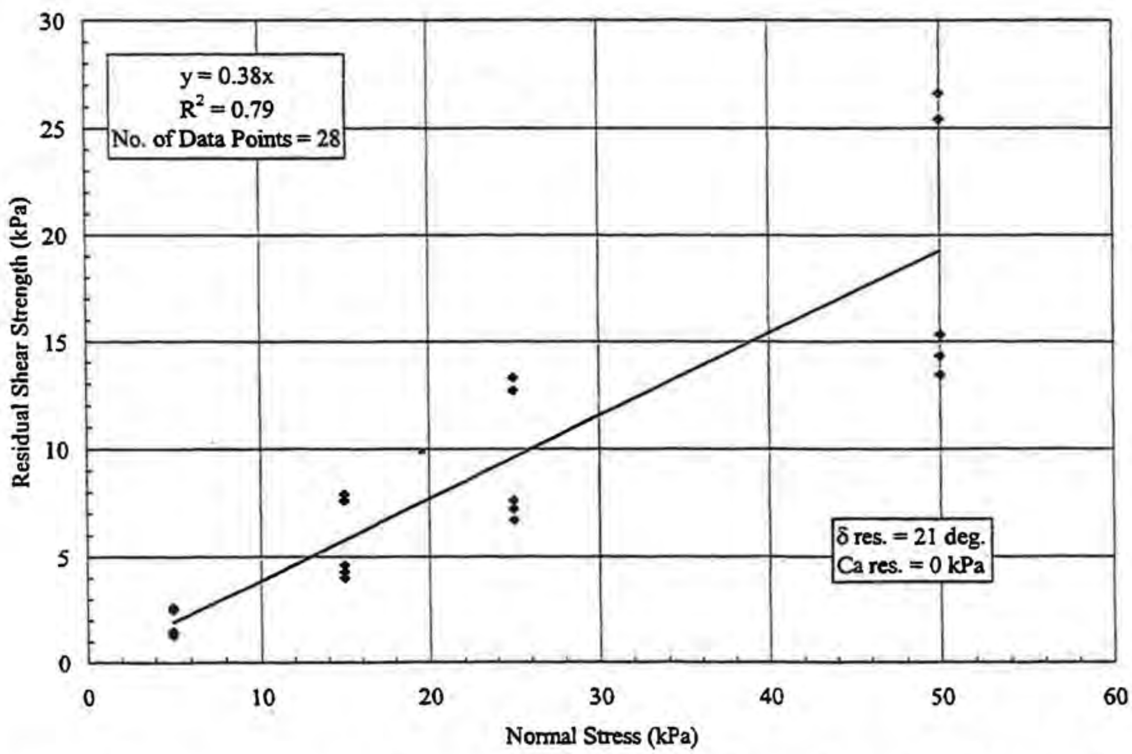
Appendix Figure 2i – Peak Shear Strength; Textured HDPE against NW-NP Geotextile on a Drainage Geocomposite.



Appendix Figure 2j – Residual Shear Strength; Textured HDPE against NW-NP Geotextile on a Drainage Geocomposite.



Appendix Figure 9a - Peak Shear Strength; NW-NP Geotextile against Cohesive Soil.



Appendix Figure 9b - Residual Shear Strength; NW-NP Geotextile against Cohesive Soil.

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HDR Computation

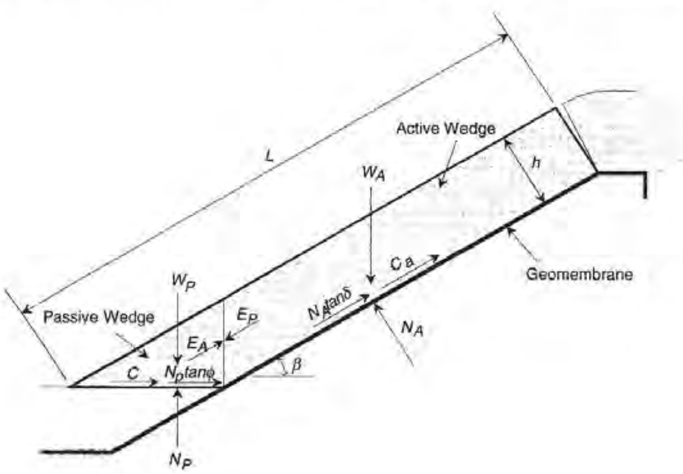
Job Number	453925-235691-018			**No.**	
Project	Charah Colon Mine Structural Fill	**Computed**	TMY	**Date**	10/1/2014
Subject	Permit Application	**Checked**	**KP**	**Date**	**10/29/2014**
Task	Operational Cover Stability	**Sheet**	1	**Of**	3

Objective: Determine the operational cover stability due to sliding for a 3H:1V slope.

References:
1. "Designing with Geosynthetics"; Robert M. Koerner
2. "Cover Soil Slope Stability Involving Geosynthetic Interfaces", GRI Report #18
3. Slope Stability Analyses, Charah Colon Mine Structural Fill Permit Application, HDR 2014

Calculations: Finite Slope Analysis

Koerner RM. Designing with Geogrids: Veneer Cover Soils Figure 3.23. In: Designing with Geosynthetics. Upper Saddle River, NJ: Prentice Hall; 1998:373.



Active:

$$W_A = \gamma h^2\left(\frac{L}{h} - \frac{1}{\sin\beta} - \frac{\tan\beta}{2}\right)$$

$$N_A = W_A \cos\beta$$

$$C_a = c_a\left(L - \frac{h}{\sin\beta}\right)$$

$$a = \left(W_A - N_A\cos\beta\right)\cos\beta$$

$$b = -\left[\left(W_A - N_A\cos\beta\right)\sin\beta\tan\phi + \left(N_A\tan\delta + C_a\right)\sin\beta\cos\beta + \sin\beta\left(C + W_P\tan\phi\right)\right]$$

$$c = \left(N_a\tan\delta + C_a\right)\sin^2\beta\tan\phi$$

$$FS = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

Passive:

$$W_P = \frac{\gamma h^2}{\sin 2\beta}$$

$$C = \frac{ch}{\sin\beta}$$

Where:

W_A = total weight of active wedge
W_P = total weight of passive wedge
N_A = effective force normal to the failure plane of the active wedge
γ = unit weight of cover soil
h = thickness of cover soil
L = length of slope measured along the geosynthetic
β = soil slope angle beneath the geosynthetic
ϕ = friction angle of cover soil
δ = minimum allowable interface friction angle between slope liner system components
c_a = minumum allowable adhesive force between slope liner system components
C = cohesive force along the failure plane of the passive wedge
c = cohesion of cover soil

Given:	Slope, M =	3	H:1V	
	Max Structural Fill Depth, H =	34.0	ft	(Measurement taken near southwest corner of main fill)
	c_a =	0	lb/ft^2	(Conservatively assume = 0)
	c =	0	lb/ft^2	(Assume = 0 to account for potential development of tension cracks)
Solution:	L =	107.5	ft	
	β =	18.4	degrees	

Operational Cover Soil Condition (Assume 24" of CCR will be placed over bottom liner prior to general filling)

Inputs	h =	2	ft	
	γ =	83.8	lb/ft^3	(Fly ash wet density based on 100% standard Proctor compaction, See Ref. 3)
	ϕ =	22.0	degrees	(Based on triaxial tests on compacted fly ash, effective stress conditions, see Ref. 3)
	δ =	22.0	degrees	(Adjust to obtain minimum allowable FS = 1.3, see Note below)
Outputs	W_A =	16,899.3	lb/ft	
	N_A =	16,035.3	lb/ft	
	C_a =	0.0	lb/ft	
	W_P =	559.6	lb/ft	
	C =	0.0	lb/ft	
	a =	1,597.7	lb/ft	
	b =	-2,226.5	lb/ft	
	c =	260.8	lb/ft	

FS = 1.3

Note: A minimum Factor of Safety of 1.3 is required as recommended by Reference 2
for temporary slopes in non-hazardous waste landfills.

HDR Computation

Job Number	453925-235691-018	**No.**	
Project	Charah Colon Mine Structural Fill	**Computed** TMY	**Date** 10/1/2014
Subject	Permit Application	**Checked** KP	**Date** 10/29/2014
Task	Operational Cover Stability	**Sheet** 3	**Of** 3

Conclusion:

Based on the inputs used, the operational cover soil consisting of 24" of fly ash will be acceptable as long as the geosynthetic components of the bottom liner system achieve a minimum friction angle of 22 ˚(conservatively neglecting cohesion along the interface). The slope stability calculations for the project (Ref. 3) indicate that the critical interface (Geocomposite/Textured HDPE) friction angle for the proposed bottom liner design using typical values for similar materials is 26˚. Therefore, the stability of the operational cover over the proposed bottom liner design should not be an issue. The unit weight and friction angle of the material placed on the sideslope as well as the frictional properties of the geosynthetic materials must be confirmed with the assumptions in this calculation.

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C

Geosynthetics

Geosynthetic Stresses
Design Anchor Trench

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HDR Computation

Job Number 453925-235691-018		**No.**	
Project Charah Colon Mine Structural Fill	**Computed** TMY	**Date**	10/2/2014
Subject Permit Application	**Checked** KP	**Date**	10/29/2014
Task Geosynthetic Stresses	**Sheet**	**Of**	

Objective: Determine the stresses in the geosynthetics of the base liner system.

References:

1. Sharma, H. D., & Lewis, S. P. (1994). *Waste Containment Systems, Waste Stabilization, and Landfills: Design and Evaluation* . New York: John Wiley & Sons, Inc.
2. Koerner, G.R., & Narejo, D. (2005). *Direct Shear Database of Geosynthetic-t0-Geosynthetic and geosynthetic-to-Soil Interfaces,* GRI Report #30.
3. HDR (2014). Slope Stability Analyses, Charah Colon Mine Structural Fill Permit Application.

Layer	Material	Thickness (in)	Tensile Strength (lbs/in)*	Allowable Stress (psi)	*Assumed* Allowable stress, σ, psi	Interface Friction		Factor of Safety, Due to:			
						Between surfaces (Ref. 2 - see Attachment A)	°	Self Weight	Operational Cover	Waste	Operational Equipment
Geocomposite	GSE PermaNet UL Geocomposite	0.34	100	294	294	Between Nonwoven, needle-punched Geotextile and Textured HDPE	26	No Stress	No Stress	No Stress	No Stress
Geomembrane	GSE HD Textured	0.06	126	2,100	2,100	Between Textured HDPE and Nonwoven, needle-punched Geotextile of the GCL	23	No Stress	No Stress	No Stress	No Stress
GCL	GSE BentoLiner CNSL Data Sheet	0.3	40	133	133	Between Nonwoven Needlepunched Geotextile and Clay Subgrade beneath GCL	29	No Stress	No Stress	No Stress	No Stress

Input Parameters

Sideslopes =	3 H:1V					
Sideslope Angle, β =	18.43 °		Geotextile Thickness, t_{GTEX} =	0.02 in	0.002 ft (assumed)
Max Slope Height, H =	24 ft		Geonet Thickness, t_{GNET} =	0.3 in	0.03 ft
Density of water, ρ_w =	62.4 lbs/ft^3		GCL Thickness, t_{GCL} =	0.3 in	0.03 ft
Geomembrane Thickness, t_{GMB} =	0.06 in	0.005 ft			
Geotextile Mass per Unit Area =	8 oz/yd^2 =	0.06 lb/ft^2		12 in/ft	
				144 oz/yd^2 per lb/ft^2	

* Use yield strength for geomembrane.

Results/Conclusions: The results indicate that for each condition evaluated, there will be no stress developed within the geosynthetics. The frictional resistance between the materials will therefore be sufficient to resist the forces developed during construction and structural fill construction without stressing the components. This is compatible with standard liner system design practices.

HDR Computation

Job Number	453925-235691-018	**No.**	
Project	Charah Colon Mine Structural Fill	**Computed** TMY	**Date** 10/2/2014
Subject	Permit Application	**Checked** KP	**Date** 10/29/2014
Task	Geosynthetic Stresses - Stress Due to Self Weight	**Sheet**	**Of**

Case 1: Stress Due to Self Weight

$W = \frac{SG\ \gamma_w\ t\ (1 \times H)}{\sin\beta}$ Ref. 1, Page 394

$\sigma_{TA} = \frac{W \sin\beta - F}{1 \times t}$ Ref. 1, Page 394

$F = W_{Total}\cos\beta\tan\delta$ Ref. 1, Page 395

Factor of Safety, $FS = \frac{\sigma_y\ (allowable)}{\sigma_{TA}}$

Whree:

W = geomembrane weight
SG = specific gravity of geomembrane
γ_w = unit wieght of water 62.4 lb/ft^3
σ_{TA} = Applied Tensile Stress
β = slope
F = interface frictional strength between geomembrane and underlying material
t = geomembrane thickness
δ = interface friction angle between geomembrane and underlying material
H = slope height

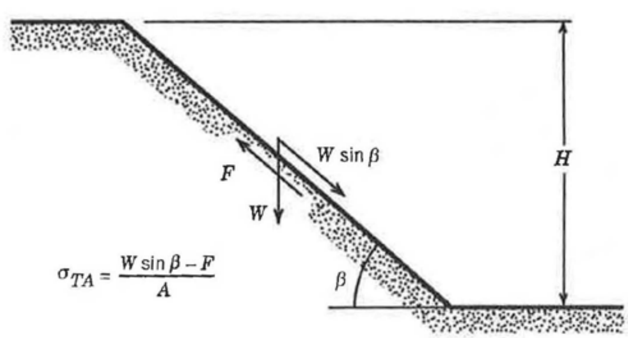


Figure 8.12 Free-body diagram for geomembrane self-weight calculations.

Source of Figure 8.12:
Ref. 1, Page 395

Length of Slope, $L = \frac{H}{\sin\beta}$

H = 34 feet
L = 107.5 feet

ρ_{water} = 1,000 kg/m^3
ρ_{water} = 1.0 g/cm^3

Conversions

0.000001	m^3/cm^3
1000	g/kg
144	in^2/ft^2

$SG = \frac{\rho_{sample}}{\rho_{water}}$

Where:

SG = Specific Gravity
ρ_{sample} = Density of Sample
ρ_{water} = Density of Water

$W = \rho Va$

Where:

W = Weight
ρ = Density
V = Volume
a = Acceleration 9.81 m/s^2

V = L(1 x t)

HDR Computation

Job Number	453925-235691-018	No.	
Project	Charah Colon Mine Structural Fill	Computed	TMY
Date	10/2/2014		
Subject	Permit Application	Checked	KP
Date	10/29/2014		
Task	Geosynthetic Stresses - Stress Due to Self Weight	Sheet	
Of			

Sideslope Angle, β = 18.43 °

	Geocomposite*	Geomembrane	GCL**	Geotextile	Geonet
Density, ρ (g/cm^3)		0.94			0.94
Specific Gravity, SG (Unitless)		0.94			0.94
Weight, W (lbs)	169.61	31.53	120.23	5.97	157.66
Thickness, t (ft)	0.03	0.005	0.03		0.03
$\sigma_{Allowable}$ (psi)	294	2,100	133		

*Weight of Geocomposite is equal to the weight of the geonet plus the weight of the geotextiles on either side of the geonet.

**The weight of the GCL is determined from the weight of a roll (2,600 lbs) divided by the surface area of the roll (2,325 ft^2) to get a pound per ft^2. The pound per ft^2 is multiplied by a 1 foot wide by length of the slope strip to determine the weight of the geotextile.

Interface	Range of δ (°)	Source & Description	Actual δ (°)
$\delta_{Soil - Geocomposite}$	22 - 40	Ref 2 Figure 13a: Nonwoven, needle-punched Geotextile vs Granular Soil	27
$\delta_{Geocomposite - Geomembrane}$	15 - 33	Ref 2 Figure 2i: Nonwoven, needle-punched Geotextile vs Textured HDPE	26
$\delta_{Geomembrane - GCL}$	15 - 33	Ref 2 Figure 11a: Nonwoven, needle-punched Geotextile (top of hydrated GCL) vs Textured HDPE	23
$\delta_{GCL - Clay Soil Liner}$	15 - 28	Ref 2 Figure 9e: Woven geotextile (bottom of GCL) vs Clay Soil	29

(not applicable for self weight calcs.)

<u>Geocomposite - Geomembrane Interface</u>

$W = W_{geocomposite}$

W = 169.61 lb

Geocomposite thickness, t_{GT} = 0.03 ft

δ = 26 degrees

F = 78 lb

σ_{Actual} = -877 lb/ft^2

σ_{Actual} = -6 psi

$\sigma_{Allowable}$ = 294 psi

FS = No Stress

<u>Geomembrane - GCL Interface</u>

$W = W_{geomembrane} + W_{geocomposite}$

W = 201.14 lb

Geomembrane thickness, t_{GM} = 0.01 ft

δ = 23 degrees

F = 81 lb/ft

σ_{Actual} = -3,478 lb/ft^2

σ_{Actual} = -24 psi

$\sigma_{Allowable}$ = 2,100 psi

FS = No Stress

HDR Computation

Job Number	453925-235691-018			**No.**	
Project	Charah Colon Mine Structural Fill	**Computed**	TMY	**Date**	10/2/2014
Subject	Permit Application	**Checked**	KP	**Date**	10/29/2014
Task	Geosynthetic Stresses - Stress Due to Self Weight	**Sheet**		**Of**	

GCL - Clay Soil Liner Interface

$W = W_{geomembrane} + W_{geocomposite} + W_{GCL}$

W =	321.38	lb/ft
GCL thickness, t_{GCL} =	0.03	ft
δ =	29	degrees
F =	169	lb/ft
σ_{Actual} =	-2,695	lb/ft^2
σ_{Actual} =	-19	psi
$\sigma_{Allowable}$ =	133	psi
FS =	**No Stress**	

HDR Computation

Job Number	453925-235691-018	No.	

Project	Charah Colon Mine Structural Fill	**Computed**	TMY	**Date**	10/2/2014
Subject	Permit Application	**Checked**	KP	**Date**	10/29/2014
Task	Geosynthetic Stresses - Stress Due to Operational Cover	**Sheet**		**Of**	

Case 2: Stress due to Operational Cover

Operational Cover Density, ρ_{OC} = 84 lb/ft^3 (fly ash wet density based on 100% standard Proctor compaction, See Ref. 3)

Operational Cover Thickness, t_{OC} = 24 in (assumes 2' protective layer of ash will be placed over liner prior to general filling)

F_D = W sinβ — Driving Force

F_R = W cosβ tanδ_L — (frictional force)

Tension = F_D - F_R — lb/ft — 144 in^2/ft^2

Stress = Tension/t/144 — psi — 12 in/ft

Geocomposite - Geomembrane Interface

W = $W_{Geocomposite}$ from Self Weight + Operational Cover over length of slope

170 lb/ft $W_{Geocomposite}$ from Self Weight

18,020 lb/ft Operational Cover over length of slope

W = 18,190 lb/ft

Geocomposite thickness, t_{GT} = 0.03 ft

δ_L = 26 degrees

F_D = 5,752 lb/ft

F_R = 8,416 lb/ft

$T_{Geocomposite}$ = 0 lb/ft

σ_{Actual} = 0 psi

$\sigma_{Allowable}$ = 294 psi

FS = No Stress

Geomembrane - GCL Interface

W = $W_{Geocomposite}$ + $W_{Geomembrane}$ from Self Weight + Operational Cover over length of slope

201 lb/ft $W_{Geocomposite}$ + $W_{geomembrane}$ from Self Weight

18,020 lb/ft Operational Cover over length of slope

W = 18,221 lb/ft

Geomembrane thickness, t_{GM} = 0.01 ft

δ_L = 23 degrees

F_D = 5,762 lb/ft

F_R = 7,337 lb/ft

$T_{Geomembrane}$ = 0 lb/ft

σ_{Actual} = 0 psi

$\sigma_{Allowable}$ = 2,100 psi

FS = No Stress

HDR Computation

		Job Number	453925-235691-018	**No.**	
Project	Charah Colon Mine Structural Fill	**Computed**	TMY	**Date**	10/2/2014
Subject	Permit Application	**Checked**	KP	**Date**	10/29/2014
Task	Geosynthetic Stresses - Stress Due to Operational Cover	**Sheet**		**Of**	

GCL - Clay Soil Liner Interface

$W = W_{Geocomposite} + W_{Geomembrane} + W_{GCL}$ from Self Weight + Operational Cover over length of slope

321 lb/ft $W_{Geocomposite} + W_{Geomembrane} + W_{GCL}$ from Self Weight

18,020 lb/ft Operational Cover over length of slope

$W =$ 18,341 lb/ft

GCL thickness, $t_{GCL} =$ 0.03 ft

$\delta_L =$ 29 degrees

$F_D =$ 5,800 lb/ft

$F_R =$ 9,645 lb/ft

$T_{GCL} =$ 0 lb/ft

$\sigma_{Actual} =$ 0 psi

$\sigma_{Allowable} =$ 133 psi

FS = No Stress

HDR Computation

Job Number	453925-235691-018	**No.**	
Project	Charah Colon Mine Structural Fill	**Computed** TMY	**Date** 10/2/2014
Subject	Permit Application	**Checked** KP	**Date** 10/29/2014
Task	Geosynthetic Stresses - Stress Due to Structural Fill	**Sheet**	**Of**

Case 3: Stress due to Operational Cover and 10' Lift of Structural Fill

Ash Density, ρash = 84 lb/ft^3 (ash wet density based on 100% standard Proctor compaction, See Ref. 3)
Ash Thickness, tash = 10 feet

$F_D = W \sin\beta$ Driving Force
$F_R = W \cos\beta \tan\delta_L$ (frictional force)
Tension = $F_D - F_R$ lb/ft 144 in^2/ft^2
Stress = Tension/t/144 psi 12 in/ft

Geocomposite - Geomembrane Interface

$W = W_{Geocomposite}$ from Self Weight + Operational Cover + 10' Ash over length of slope
18,190 lb/ft $W_{Geocomposite}$ and $W_{Operational\ Cover}$
90,315 lb/ft Ash over length of slope
W = 108,504 lb/ft
Geocomposite thickness, t_{GT} = 0.03 ft
δ_L = 26 degrees
F_D = 34,312 lb/ft
F_R = 50,205 lb/ft
$T_{Geocomposite}$ = 0 lb/ft
σ_{Actual} = 0 psi
$\sigma_{Allowable}$ = 294 psi

FS = No Stress

Geomembrane - GCL Interface

$W = W_{Geocomposite} + W_{Geomembrane}$ from Self Weight + Operational Cover over length of slope
18,221 lb/ft $W_{Cperatonal\ Cover} + W_{Geocomposite} + W_{geomembrane}$
90,315 lb/ft Ash over length of slope
W = 108,536 lb/ft
Geomembrane thickness, t_{GM} = 0.01 ft
δ_L = 23 degrees
F_D = 34,322 lb/ft
F_R = 43,706 lb/ft
$T_{Geomembrane}$ = 0 lb/ft
σ_{Actual} = 0 psi
$\sigma_{Allowable}$ = 2,100 psi

FS = No Stress

GCL - Clay Soil Liner Interface

$W = W_{Geocomposite} + W_{Geomembrane} + W_{GCL}$ from Self Weight + Operational Cover over length of slope

	18,341	lb/ft $W_{Operational\ Cover} + W_{Geocomposite} + W_{Geomembrane} + W_{GCL}$
	90,315	lb/ft Asg over length of slope
W =	108,656	lb/ft
GCL thickness, t_{GCL} =	0.03	ft
δ_L =	29	degrees
F_D =	34,360	lb/ft
F_R =	57,138	lb/ft
T_{GCL} =	0	lb/ft
σ_{Actual} =	0	psi
$\sigma_{Allowable}$ =	133	psi

FS = No Stress

Case 4: Stress due to Operational Equipment

CAT D6R WH Waste Handler

Operating Wt. =	45,370	lb	(Assumed to be typical of equipment placing operation cover with contact pressure less than 10 psi)
Ground Contact Area =	4,564	in^2	
Contact pressure =	9.9	psi	

F_D = W sinβ Driving Force

F_R = W cosβ tanδ_L (frictional force) 144 in^2/ft^2

Tension = $F_D - F_R$ lb/ft 12 in/ft

Stress = Tension/t/144 psi

Geocomposite - Geomembrane Interface

W = $W_{geocomposite} + W_{Operational\ Cover} +$ WAsh + $W_{Operational\ Equipment}$

	108,504	lb/ft WAsh + $W_{Geocomposite} + W_{Operational\ Cover}$
	1,431	lb/ft, $W_{Operational\ Equipment}$
W =	109,936	lb/ft
Geocomposite thickness, t_{GT} =	0.03	ft
δ_L =	26	degrees
F_u =	34,765	lb
F_L =	50,868	lb
$T_{Geocomposite}$ =	0	lb
σ_{Actual} =	0	psi
$\sigma_{Allowable}$ =	294	psi

FS = No Stress

Geomembrane - GCL Interface

W = $W_{Geomembrane} + W_{Geocomposite} + W_{Operational\ Cover} +$ WAsh + $W_{Operational\ Equipment}$

	108,536	lb/ft WAsh + $W_{Cperatonal\ Cover} + W_{Geocomposite} + W_{geomembrane}$
	1,431	lb/ft, $W_{Operational\ Equipment}$
W =	109,967	lb/ft
Geomembrane thickness, t_{GM} =	0.01	ft
δ_L =	23	degrees
F_u =	34,775	lb
F_L =	44,283	lb
$T_{Geomembrane}$ =	0	lb
σ_{Actual} =	0	psi
$\sigma_{Allowable}$ =	2,100	psi

FS = No Stress

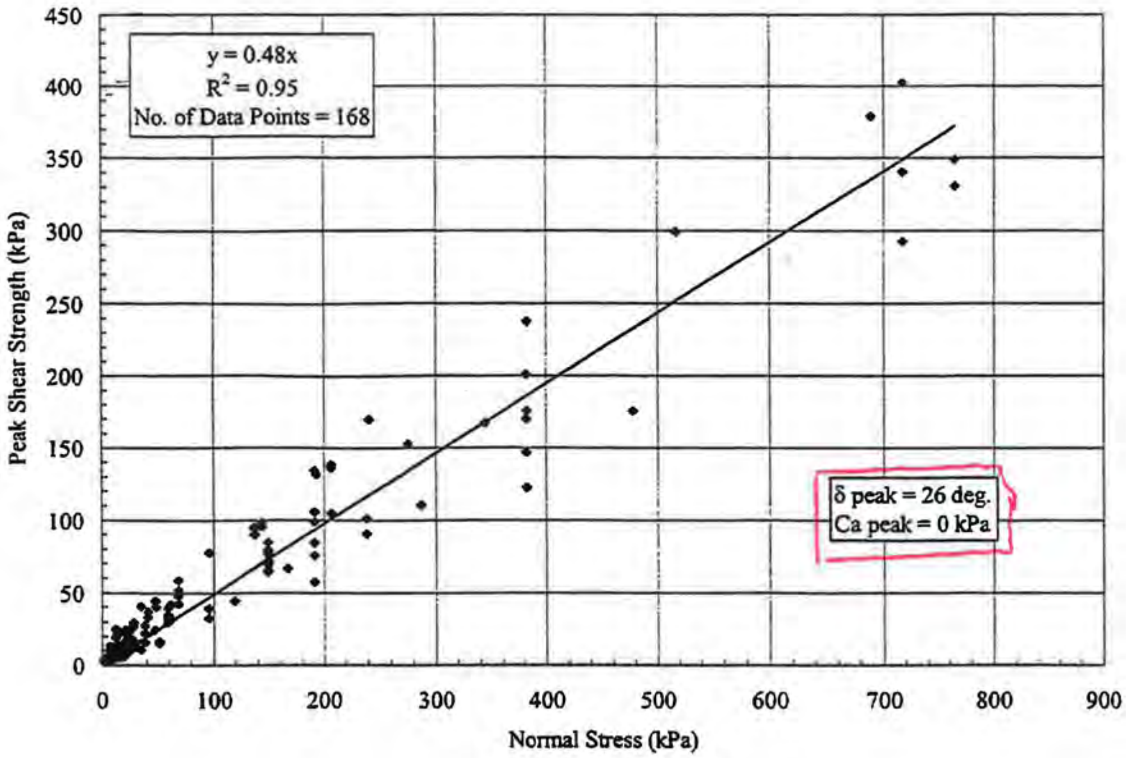
GCL - Clay Soil Liner Interface

$W = W_{GCL} + W_{Geomembrane} + W_{Geocomposite} + W_{Operational\ Cover} + WAsh + W_{Operational\ Equipment}$

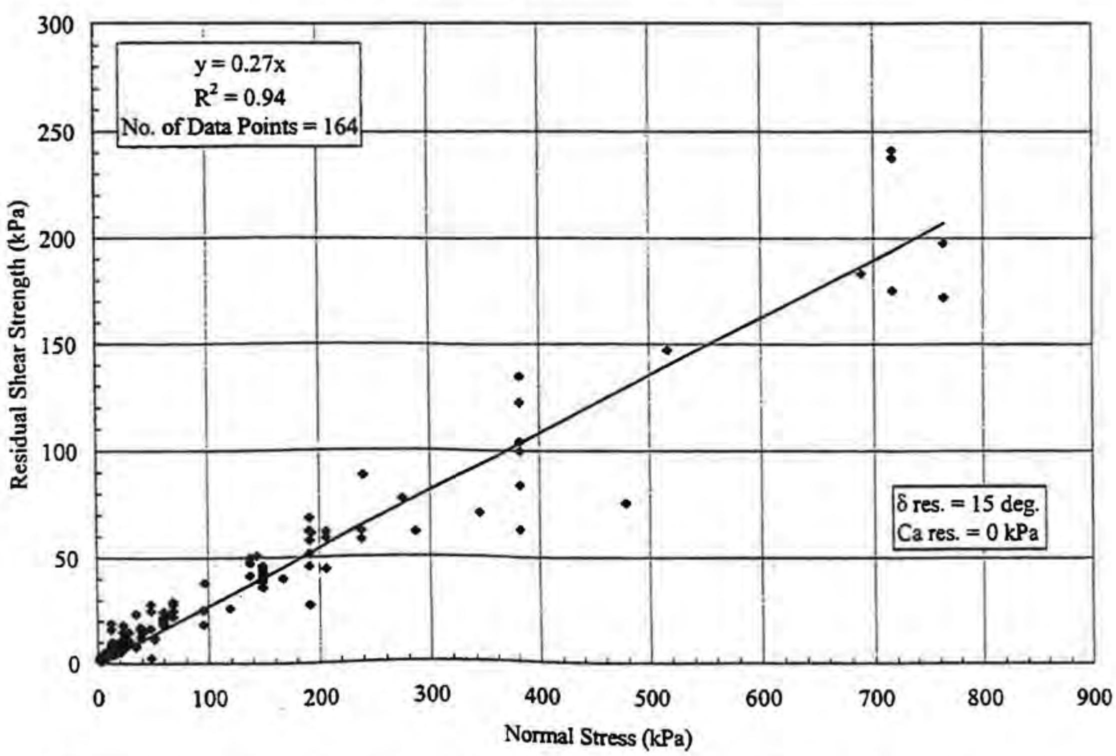
	108,656	lb/ft WAsh + $W_{Operational\ Cover}$ + $W_{Geocomposite}$ + $W_{Geomembrane}$ + W_{GCL}
	1,431	lb/ft, $W_{Operational\ Equipment}$
W =	110,087	lb/ft
GCL thickness, t_{GCL} =	0.03	ft
δ_L =	29	degrees
F_u =	34,813	lb
F_L =	57,891	lb
T_{GCL} =	0	lb
σ_{Actual} =	0	psi
$\sigma_{Allowable}$ =	133	psi

FS = No Stress

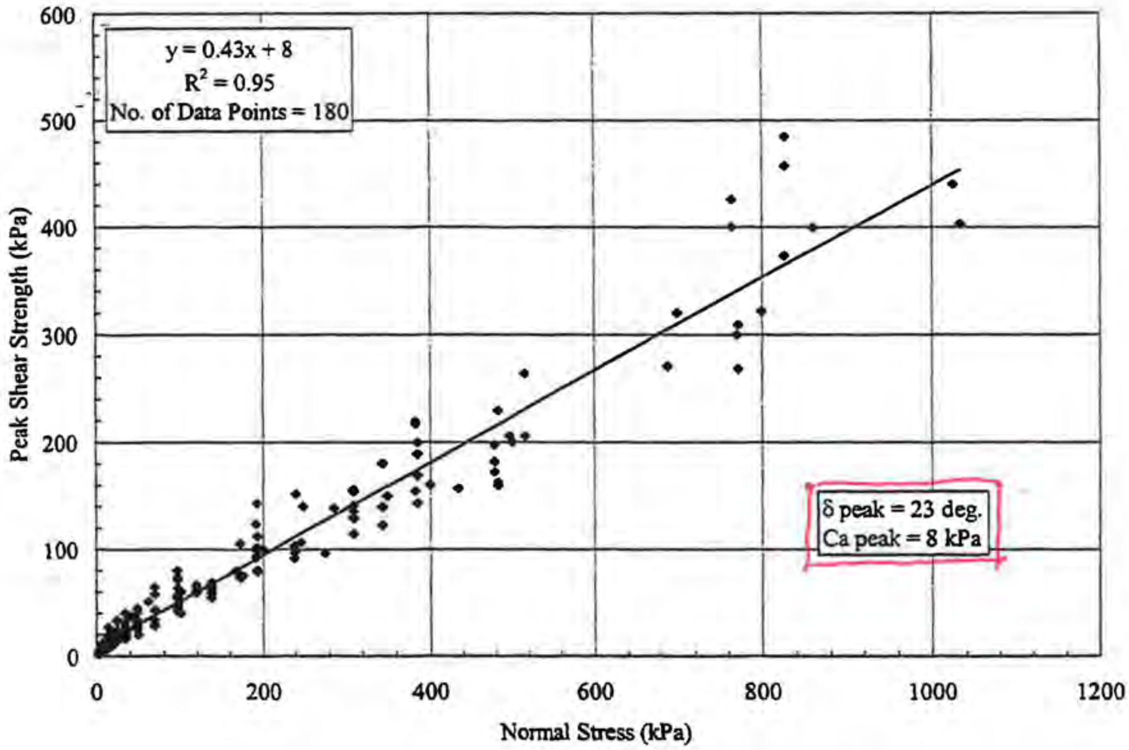
ATTACHMENT A



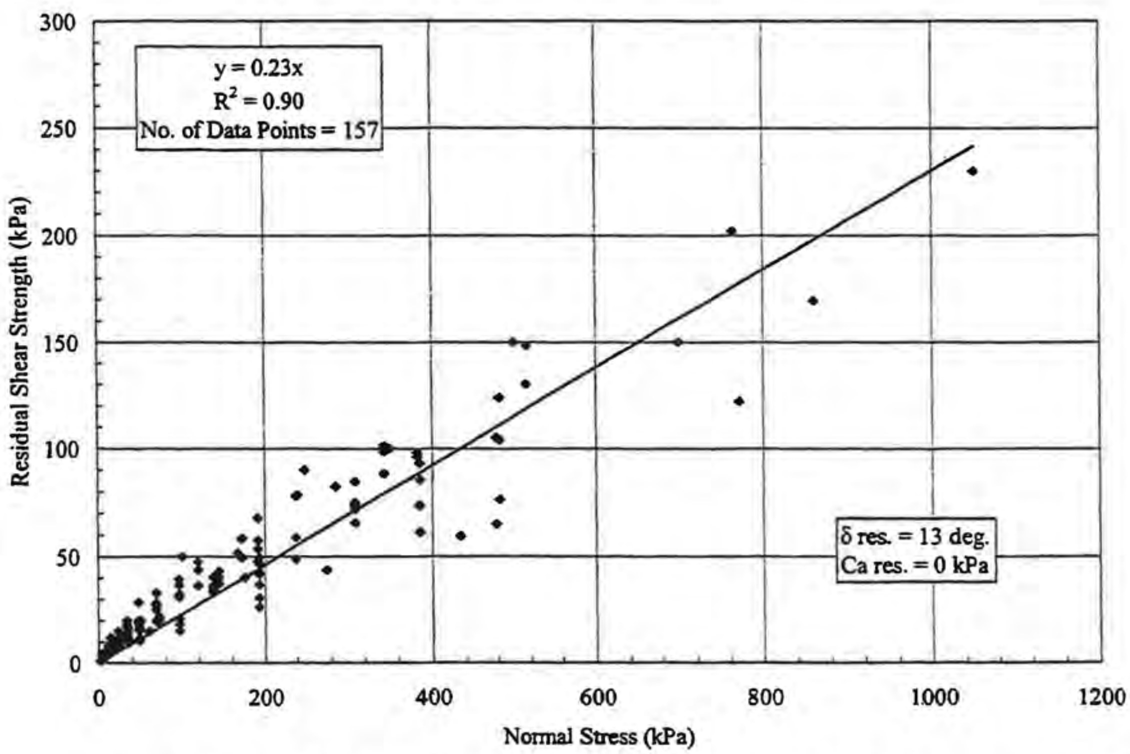
Appendix Figure 2i – Peak Shear Strength; Textured HDPE against NW-NP Geotextile on a Drainage Geocomposite.



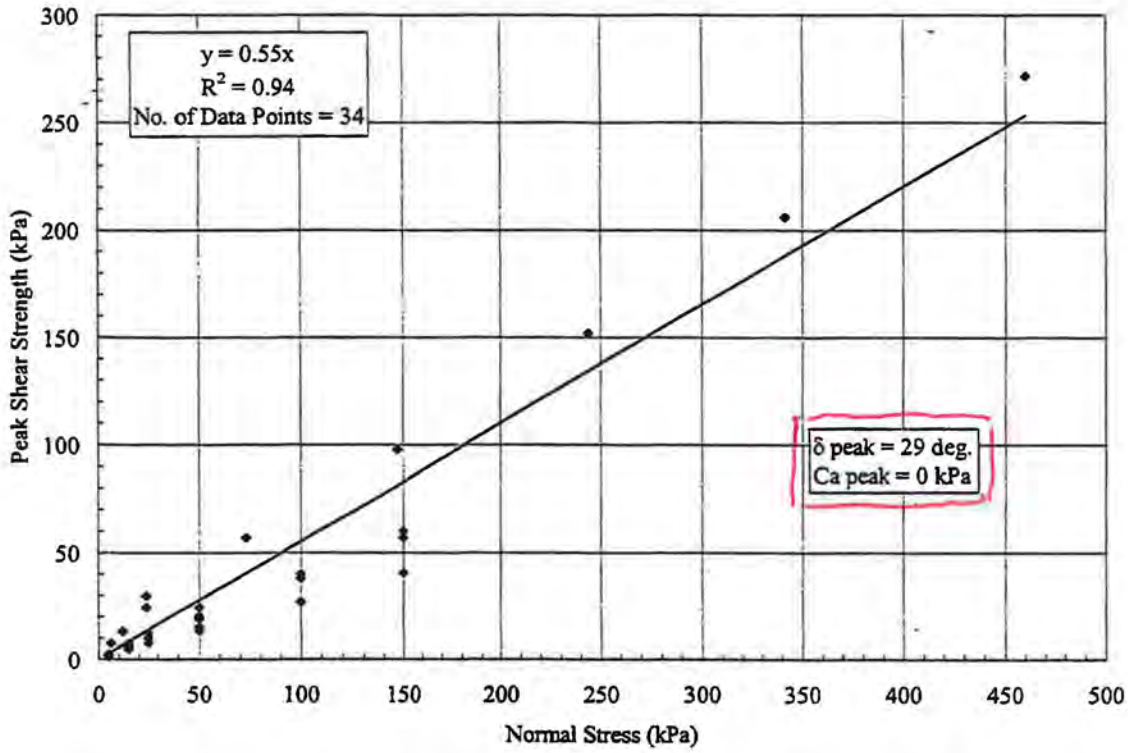
Appendix Figure 2j – Residual Shear Strength; Textured HDPE against NW-NP Geotextile on a Drainage Geocomposite.



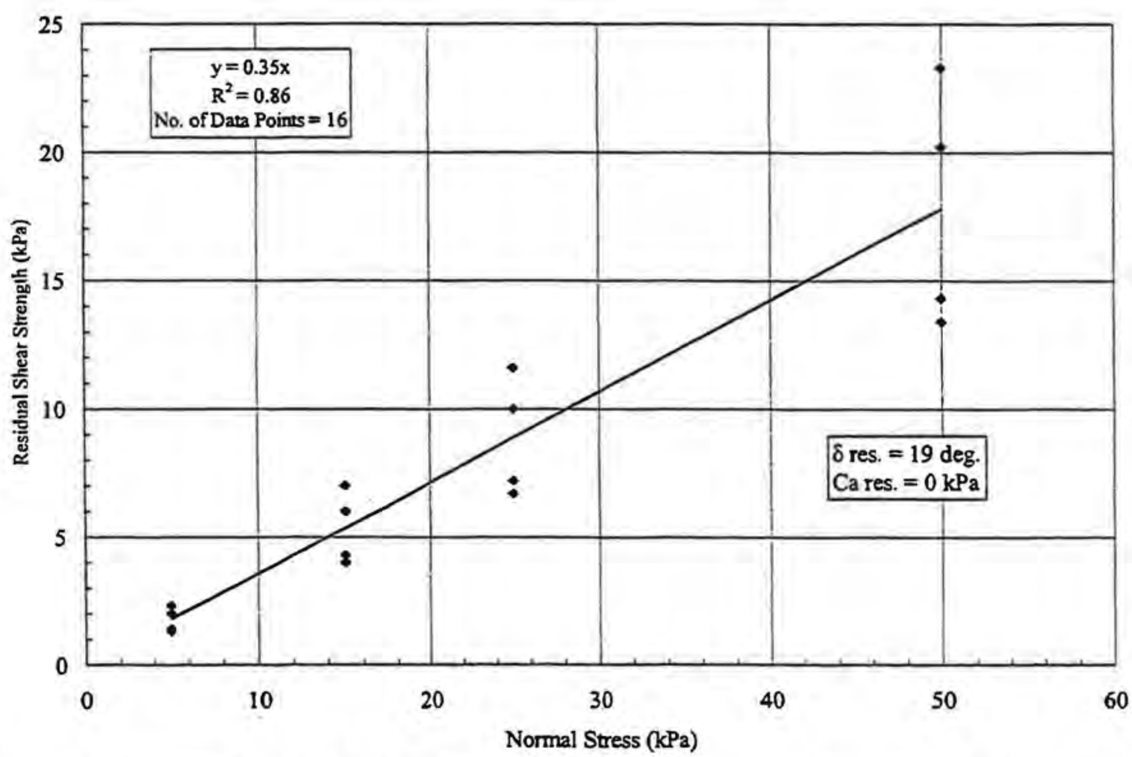
Appendix Figure 11a - Peak Shear Strength; Textured HDPE against NW-NP Side of Fabric-Reinforced GCL.



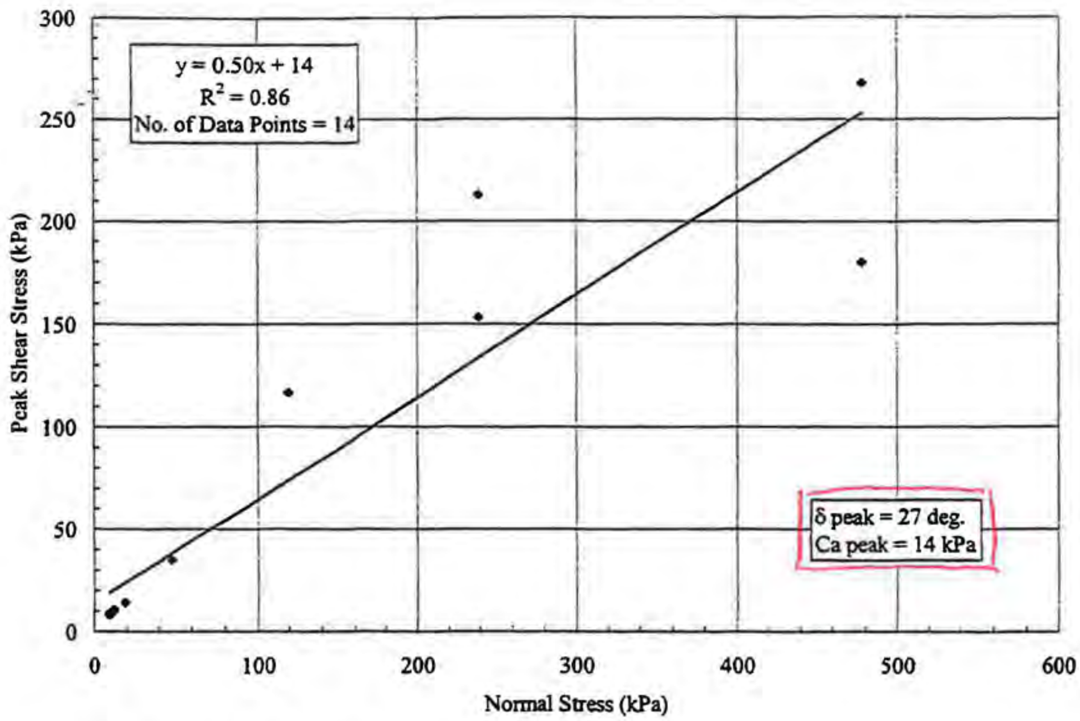
Appendix Figure 11b - Residual Shear Strength; Textured HDPE against NW-NP Side of Fabric-Reinforced GCL.



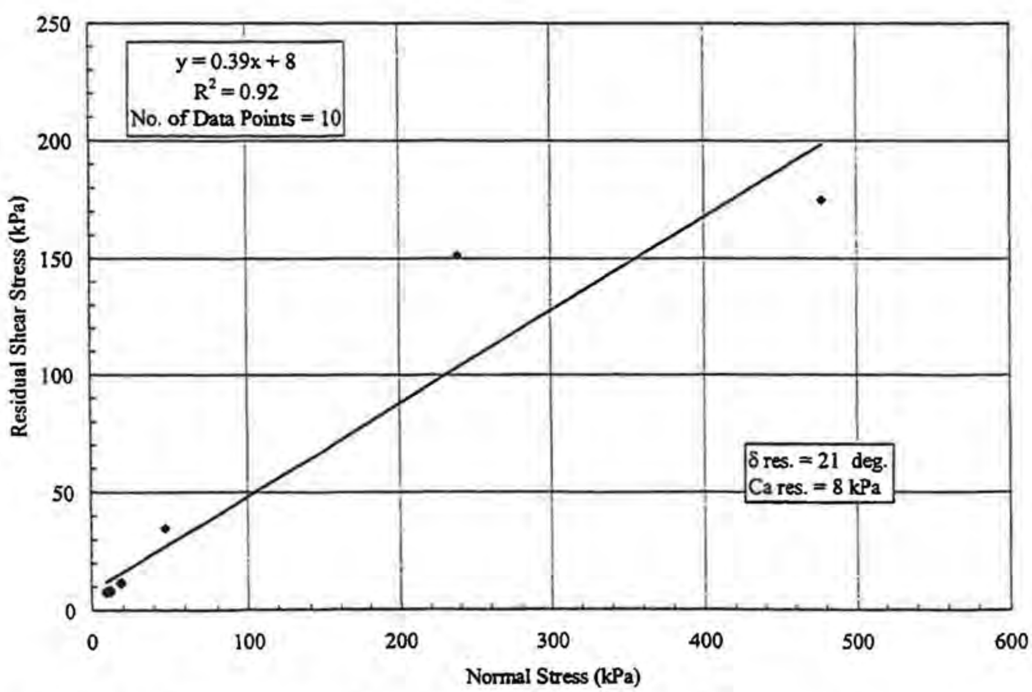
Appendix Figure 9e - Peak Shear Strength; Woven Geotextile against Cohesive Soil.



Appendix Figure 9f - Residual Shear Strength; Woven Geotextile against Cohesive Soil.



Appendix Figure 13a - Peak Shear Strength; Drainage Geocomposite against Granular Soil.



Appendix Figure 13b - Residual Shear Strength; Drainage Geocomposite against Granular Soil.

HDR Computation

Job Number	453925-235691-018			**No.**	
Project	Charah Colon Mine Structural Fill	**Computed**	TMY	**Date**	10/2/2014
Subject	Permit Application	**Checked**	**KP**	**Date**	**10/29/2014**
Task	Design Anchor Trench	**Sheet**		**Of**	

Objective: Determine the maximum allowable anchor trench dimensions to allow geomembrane pullout before yield stress is exceeded. Evaluate cases for runout only and also anchor trench.

Reference:
1. Koerner, G.R. and D. Nareho. "Direct Shear Database of Geosynthetic-to-Geosynthetic and Geosynthetic-to-Soil Interfaces", GRI Report #30, June 2005
2. Koerner, Robert M., "Designing with Geosynthetics," Prentice Hall, Upper Saddle River, New Jersey, 4th edition, pp. 487-491.

Calculations: *Without Trench (Runout only):* Ref. 2

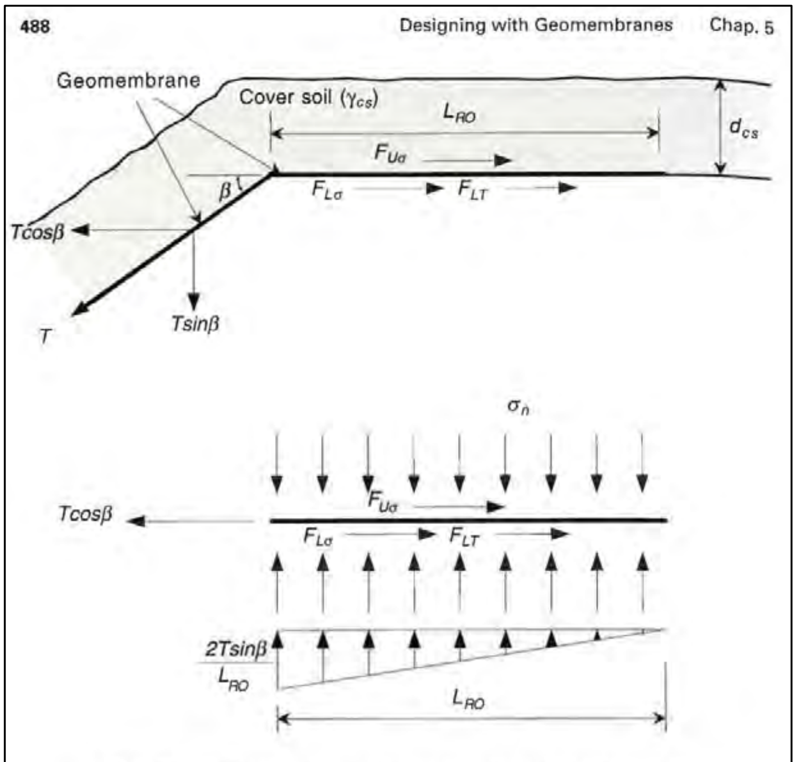


Figure 5.30 Cross section of geomembrane runout section and related stresses and forces involved.

Figure 5.30 is from Reference 2

$$L_{RO} = \frac{T_{ALLOW}(\cos\beta - \sin\beta\tan\delta_L)}{\sigma_N(\tan\delta_U + \tan\delta_L)}$$

Where:

T_{ALLOW} = allowable force in geomembrane stress = $\sigma_{ALLOW}t$, where

σ_{ALLOW} = allowable stress in geomembrane, and

t = thickness of geomembrane;

β = side slope angle;

σ_N = applied normal stress from cover soil;

δ_U = angle of shearing resistance between geomembrane and upper material; and

δ_L = angle of shearing resistance between geomembrane and underlying material; and

L_{RO} = length of geomembrane runout.

thickness of cover soil =	24	in	(assumed Max.)
unit weight of cover soil =	120	lb/ft^3	(typical for silty clay)
σ_N =	240	lb/ft^2	
δ_U =	0.0	B/c the geocomposite/soil moves along with the geomembrane as it deforms	
δ_L =	23.0	See Attachment A (Ref. 1). Conservatively neglect cohesion at interface. Non-woven side of GCL against textured HDPE.	

FS =	1.2	, desired FS
σ_{ULT} =	126	lb/in (from specs - yield)
σ_{ULT} =	2,211	psi
σ_{ALLOW} =	1,842	psi
t =	0.057	in
T_{ALLOW} =	1,260	lb/ft
β =	3	H:1V
β =	18.43	degrees

L_{RO} = 10.1 ft

This represents largest runout w/o anchor trench.

HDR Computation

Job Number	453925-235691-018			**No.**	
Project	Charah Colon Mine Structural Fill	**Computed**	TMY	**Date**	10/2/2014
Subject	Permit Application	**Checked**	KP	**Date**	10/29/2014
Task	Design Anchor Trench	**Sheet**		**Of**	

With Runout Length & Trench: Ref. 2

490 Designing with Geomembranes Chap. 5

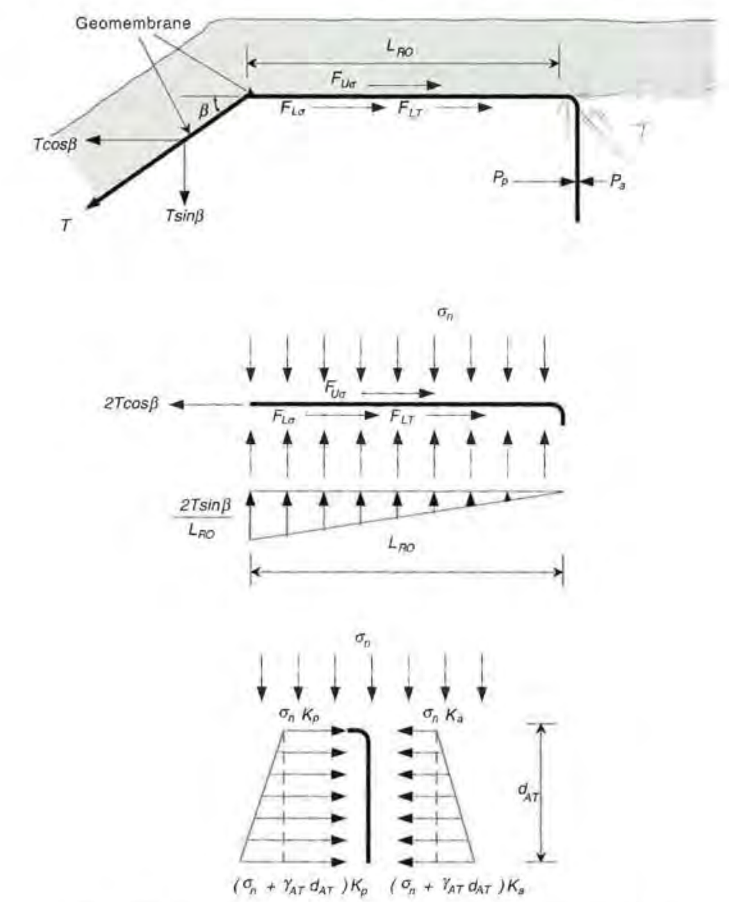


Figure 5.31 Cross section of geomembrane runout section with anchor trench and related stresses and forces involved.

Where:

T_{ALLOW} = allowable force in geomembrane stress = $\sigma_{ALLOW}t$, where

σ_{ALLOW} = allowable stress in geomembrane, and

t = thickness of geomembrane;

β = side slope angle;

$F_{U\sigma}$ = shear force above geomembrane due to cover soil

$F_{L\sigma}$ = shear force below geomembrane due to cover soil

F_{LT} = shear force below geomembrane due to vertical component of T_{ALLOW}

P_A = active each pressure against the backfill side of the anchor trench

P_P = passive earth pressure against the in-situ side of the anchor trench

γ_{AT} = unit weight of soil in anchor trench

d_{AT} = depth of anchor trench

σ_N = applied normal stress from cover soil;

K_A = coefficient of active earth pressure = $\tan^2(45-\phi/2)$

K_P = coefficient of passive earth pressure = $\tan^2(45+\phi/2)$

ϕ = angle of shearing resistance of respective soil

$T_{ALLOW}\cos\beta = F_{U\sigma} + F_{L\sigma} + F_{LT} - P_A + P_P$

$P_A = (0.5\gamma_{AT}d_{AT} + \sigma_N)K_A d_{AT}$

$P_P = (0.5\gamma_{AT}d_{AT} + \sigma_N)K_P d_{AT}$

$F_{U\sigma} = \sigma_N \tan\delta_U (L_{RO})$
= 0.0 L_{RO}

$F_{L\sigma} = \sigma_N \tan\delta_L (L_{RO})$
= 101.9 L_{RO}

$F_{LT} = T_{ALLOW}\sin\beta\tan\delta_L$
= 169.1 lb/ft

γ_{AT} = 120 lb/ft^3

σ_N = 240 lb/ft^2

ϕ = 30 °, assumed

K_A = 0.3333

K_P = 3.0000

HDR Computation

Job Number	453925-235691-018	**No.**	
Project	Charah Colon Mine Structural Fill	**Computed** TMY	**Date** 10/2/2014
Subject	Permit Application	**Checked** KP	**Date** 10/29/2014
Task	Design Anchor Trench	**Sheet**	**Of**

TRY L_{RO} = 2 ft

P_A = (80.4 d_{AT} + 240) x (K_A x d_{AT})

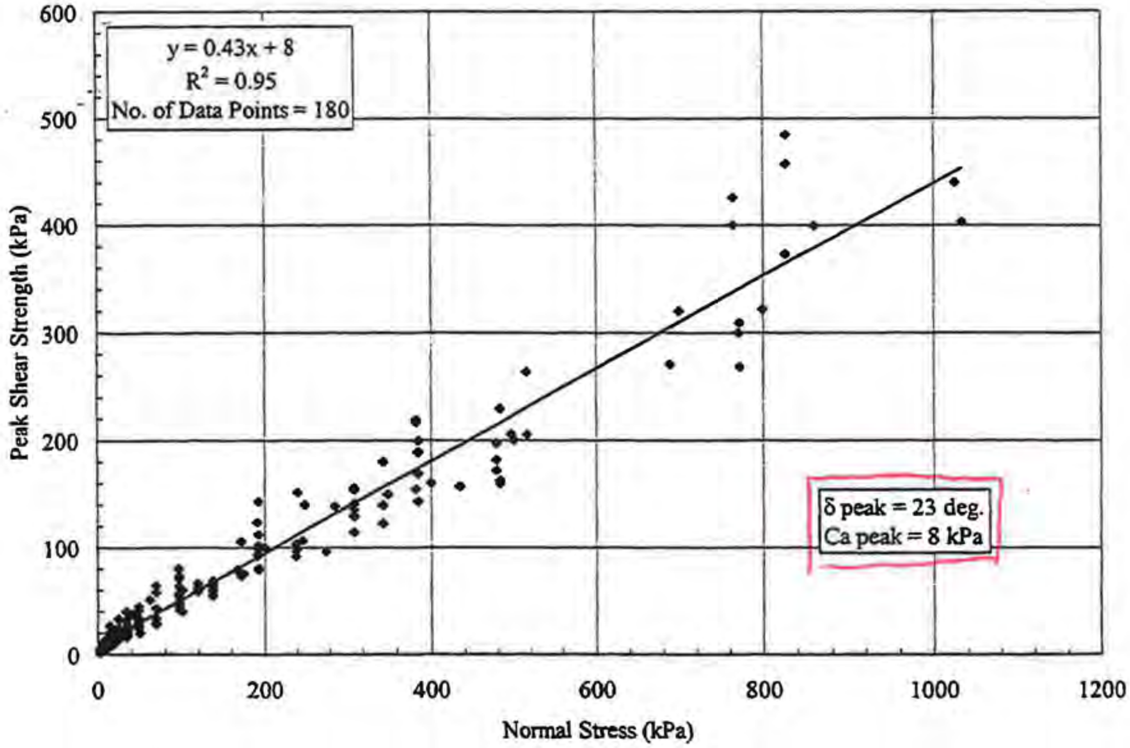
P_P = (80.4 d_{AT} + 240) x (K_P x d_{AT})

$T_{ALLOW}\cos\beta$	=	$F_{U\sigma} + F_{L\sigma} + F_{LT} - P_A + P_P$								
$T_{ALLOW}\cos\beta$	=		$F_{U\sigma} + F_{L\sigma} + F_{LT}$ - (	80.4	d_{AT} +	240	) x (K_A x d_{AT}) + (	80.4	d_{AT} + 240	) x (K_P x d_{AT})
1,195	=		$F_{U\sigma} + F_{L\sigma} + F_{LT}$ -	26.8	d_{AT}^2 -	80	d_{AT} +	241.2	d_{AT}^2 + 720	d_{AT}
1,195	=	372.9	-	214.4	d_{AT}^2 +	640	d_{AT}			
0	=	-822.5	-	214.4	d_{AT}^2 +	640	d_{AT}			
0	=	0	When d_{AT} =	0.970	ft	(adjust dAT until right side of equation = 0)				

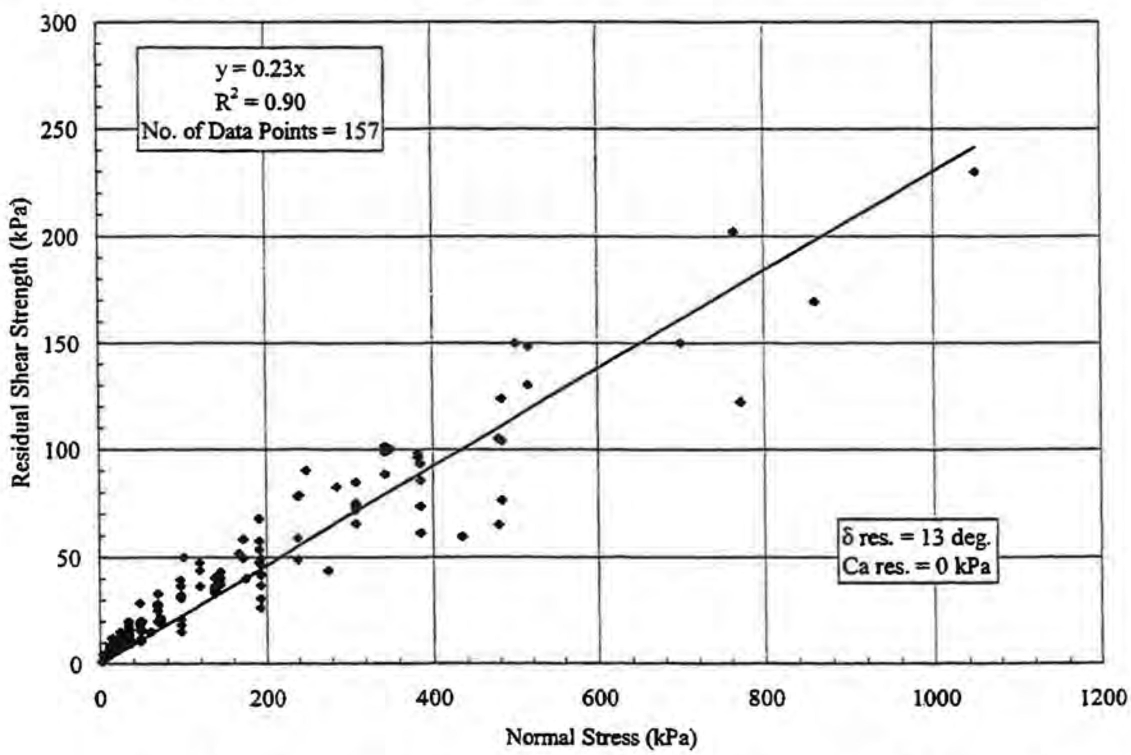
d_{AT} =	**1.0**	**ft**
L_{RO} =	**2**	**ft**

Use d_{AT} = 1.0 ft and L_{RO} =2.0 ft. Since calcs are based on yield stress, extra FS is included.

ATTACHMENT A



Appendix Figure 11a - Peak Shear Strength; Textured HDPE against NW-NP Side of Fabric-Reinforced GCL.



Appendix Figure 11b - Residual Shear Strength; Textured HDPE against NW-NP Side of Fabric-Reinforced GCL.

D

Leachate Collection System

Design of Leachate Collection System
Pipe Sizing
Pipe Stresses
Pipe Perforations
Pipe Capacity
Leachate Storage Capacity

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Design of Leachate Collection System

The HELP model Version 3.95D is used to design the leachate collection system for the Colon Mine Site in Sanford, NC. This section presents the design assumptions, decisions, background data, and calculations for the water balance model. The section outlines efforts to establish leachate generation rates and maximum hydraulic heads on the liner. The leachate generation rates established per acre should be used to design the leachate collection and removal system (LCRS).

The structural fill liner will consist of the following components, from bottom to top:

- 18-inch compacted soil liner
- GCL
- 60-mil HDPE primary liner
- 300-mil biplanar drainage geocomposite

The final cover system of the structural fill is designed based on high permeable soil as a drainage layer (Option 1) and an alternate final cover with geocomposite as a drainage layer (Option 2). Charah will select the final cover for implementation during construction based on material availability. Accordingly, the structural fill final cover will consist from bottom to top:

Final Cover Option 1

Top Deck

- 40 mil liner
- 2.5-feet drainage layer with $1.0x10^{-4}$ cm/s (minimum) permeability
- 2-feet non-specified soil layer
- 1-foot low permeability soil layer with $3x10^{-7}$ cm/s (maximum) permeability
- 6-inch top soil layer

Side Slopes

- 40 mil liner
- 1.5-feet drainage layer with $1.0x10^{-4}$ cm/s (minimum) permeability
- 1-foot non-specified soil layer
- 1-foot low permeability soil layer with $3.5x10^{-7}$ cm/s (maximum) permeability
- 6-inch top soil layer

Final Cover Option 2

Top Deck

- 40 mil liner
- 250 mil GSE FabriNet HF or equal Geocomposite Drainage Layer
- 5.5-foot low permeability soil layer with $4x10^{-5}$ cm/s (maximum) permeability
- 6-inch top soil layer

Side Slopes

- 40 mil liner
- 250 mil GSE FabriNet HF or equal Geocomposite Drainage Layer

- 3.5-foot low permeability soil layer with $4x10^{-5}$ cm/s (maximum) permeability
- 6-inch top soil layer

HELP Model Scenarios and Input Data

- Scenario 1 modeled a 20-foot depth of ash on the floor of prepared liner based on 5-year simulation period. The purpose of this model was to demonstrate that the head on the liner would be less than the thickness of the geocomposite when there was a relatively shallow lift of waste.
- Scenario 2 modeled two 20-foot lifts based on 5-year simulation period. The initial moisture content of 1st lift was adjusted based on final moisture contents obtained from Scenario 1. The purpose of this model was to demonstrate that the head on the liner would be less than the thickness of the geocomposite after the second lift.
- Scenario 3 modeled three 20-foot lifts based on 5-year simulation period. The initial moisture content of 1st and 2nd lifts were adjusted based on final moisture contents obtained from Scenario 2. The purpose of this model was to demonstrate that the head on the liner would be less than the thickness of the geocomposite after the final lift.
- Scenario 4 modeled leachate production after closure below the top deck area of the structural fill based on Closure Option 1. In addition, the model confirmed that the capacity of drainage layer in the final cover was not exceeded.
- Scenario 5 modeled leachate production after closure below the side slopes of the structural fill based on Closure Option 1. In addition, the model confirmed that the capacity of drainage layer in the final cover side slope was not exceeded.
- Scenario 6 modeled leachate production after closure below the top deck area of the structural fill based on Closure Option 2. HELP model confirmed that the drainage layer capacity is exceeded. Accordingly it is appropriate to assume that the entire cover soil is saturated on the top deck. This should not have a drastic impact as long as veneer stability requirements are met.
- Scenario 7 modeled leachate production after closure below the side slopes of the structural fill based on Closure Option 2. In addition, the model confirmed that the capacity of drainage layer in the final cover side slope was not exceeded.

Each scenario was modeled as a 1-acre area. A major goal for the modeling was to demonstrate that the drainage layer capacity is not exceeded. The second aim of the modeling was to estimate leachate production. The table provided in Attachment 1 summarizes the model input data, and summarizes the results of the scenarios. HELP model output files for scenarios 1-5 are presented in Attachment 2. Scenarios 6 and 7 are included separately in Attachment 5 for the alternate cover option

Temperature and solar radiation data were synthetically generated using coefficients from Raleigh, NC. Evapotranspiration data from Raleigh, NC was used in all scenarios. Sanford is located approximately 35 miles southeast of Raleigh, NC and should be accurately represented by weather data generated from Raleigh.

Material Properties and Structural Fill Geometry

Base grades for the Facility will slope to the leachate collection sumps at 2.0 percent (average) on the floor of the cells. The maximum flow path for leachate in the leachate drainage layer geocomposite will be 950 feet, at which point the leachate will enter an interceptor perforated pipe surrounded by gravel trench for conveyance to the sumps.

Final grades for the Facility will slope at 2.0 percent (average) on the top deck and 25 percent on the side slopes. The maximum flow path when the slope is at 2 percent should be 500 feet and at 25 percent should be 140 feet. Note that at 2 percent, the drainage layer thickness is 2.5 feet and at 25 percent the drainage layer thickness is 1.5 feet for the closure Option 1. The same geocomposite 250 mil thick is proposed for top deck and side slope for closure Option 2.

Material properties were set as follows:

- Initial moisture content for ash after placement at the cell is set at optimum moisture content based on proctor test data. The moisture content was adjusted for existing ash layers based on previous scenarios. Refer to Attachment 4 for physical properties of material.
- Default model parameters were used for the final cover layers and subgrade. Note the permeability for final cover layers was manually adjusted.
- Structural fill base liner was modeled as material texture 35, HDPE.
- Structural fill final cover liner was modeled as material texture 36, LLDPE
- Pinhole density for the membrane liners was set at 1 per acre.
- Installation defects were set at 1 per acre for the membrane liners, reflective of generally good installation procedures.
- Membrane liner placement quality was assumed to be “good”.
- Structural fill base leachate drainage layer was modeled as material texture 34, except the transmissivity was modified to reflect select material properties (Refer to Attachment 3). Transmissivity of the geocomposite should be determined based on site-specific ash and loading before selecting the material for installation.

A detailed calculation of the bottom liner geocomposite’s required hydraulic conductivity is contained in Attachment 3. The maximum overburden pressure, based on100 pcf density and approximately 50 foot ash/soil mixture is 5000 psf.

The select material for alternate final cover in Option 2 is included with model data and supporting information in Attachment 5. It should be noted that overall thickness of the soil above the liner material is the same as cover Option 1. A geocomposite is added instead of a soil drainage layer.

Model Outputs and Conclusions

The table provided in Attachment 1 summarizes the model outputs for each of the scenarios considered. The model demonstrates that the proposed design will comply with applicable design standards. More specifically,

- The peak head on HDPE bottom liner in any scenario is 0.253 inch, less than the retained thickness of the geocomposite.
- The peak head on the final cover HDPE is less than the thickness of the drainage layer.
- Maximum leachate generated during filling is 539 cf/acre/day.
- Maximum leachate generated after closure is 6.02 cf/acre/day (Option 1)
- Average leachate generated after closure is 1221 cf/acre/year (Option 1)
- Maximum leachate generated after closure is 16.347 cf/acre/day (Option 2)
- Average leachate generated after closure is 26.6 cf/acre/year (Option 2)
- Maximum drainage length in the bottom liner is 950 feet
- Maximum drainage length on the top deck of the structural fill cover is 500 feet
- Maximum drainage length on the side slope of the structural fill cover is 140 feet

All calculations associated with leachate generation are based on cover Option 1. If cover Option 2 is selected for implementation, then the subsequent analysis performed using leachate generation rates for Option 1 could be considered conservative since average leachate generated after closure is substantially less for Option 2 than Option 1.

Assumptions

- Adjustment to basegrade slope due to subgrade settlement is neglected.
- Ash properties based on available data to HDR from test data for similar material.
- Dry density of ash approximately equal to density of water.

Attachment 1

Summary of Model Input Data and Results

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Attachment 1
HELP Model Results
Charah Colon Mine Site

Input Data

Parameter	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
SCS runoff curve number	91.21	91.21	91.21	89	89	89	89
fraction of area allowing runoff (%)	100	100	100	100	100	100	100
area simulated (acres)	1	1	1	1	1	1	1
Ash k (cm/sec)	1.6x10^-4	1.6x10^-4	1.6x10^-4	1.6x10^-4	1.6x10^-4	1.6x10^-4	1.6x10^-4
subgrade thickness (inches)	18	18	18	18	18	18	18
geocomposite thickness (inches)	0.3	0.3	0.3	0.3	0.3	0.3	0.3
geocomposite hydr. conductivity (cm/sec)	9.7	9.7	9.7	9.7	9.7	9.7	9.7
bottom liner drainage layer slope (%)	2	2	2	2	2	2	2
bottom liner drainage length (feet)	950	950	950	950	950	950	950
HDPE liner thickness (mils)	60	60	60	60	60	60	60
liner pinhole density (holes/acre)	1	1	1	1	1	1	1
liner installation defects (holes/acre)	1	1	1	1	1	1	1
liner placement quality	good	good	good	good	good	good	good
recirculation? (amount recirculated)	N	N	N	N	N	N	N
cap drainage layer thickness (inches)	NA	NA	NA	30	18	0.25	0.25
cap drainage layer k (cm/sec)	NA	NA	NA	1.0x10^-4	1.0x10^-4	4.76	2.76
cap liner thickness (mils)	NA	NA	NA	40	40	40	40
cap liner pinhole density (holes/acre)	NA	NA	NA	1	1	1	1
cap liner installation defects (holes/acre)	NA	NA	NA	1	1	1	1
cap liner placement quality	NA	NA	NA	good	good	good	good
number of years simulated	5	5	5	100	100	100	100

Output Data

average annual leachate collected in collection layer (ft^3)	43,760	40,522	40,235	1,221	352	26.60	1
average annual head on primary base liner (inches)	2.90E-02	2.60E-02	2.60E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
peak day leachate collected in collection layer (ft^3)	539	262	251	6	3	16.4	0
peak day head on primary base liner (inches)	2.53E-01	1.30E-01	1.24E-01	4.00E-02	4.00E-02	4.00E-02	3.90E-02
peak day head on cap liner (inches)	NA	NA	NA	29.864	17.732	45.5	0.077
waste final moisture content (%) - layer 1	0.2332	0.2332	0.2332	NA	NA	NA	NA
waste final moisture content (%) - layer 2	NA	0.2518	0.2518	NA	NA	NA	NA
waste final moisture content (%) - layer 3	NA	NA	0.2534	NA	NA	NA	NA

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Attachment 2

HELP Model Output Files (Scenarios 1-5)

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```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                                                                          **
**              HELP Version 3.95 D          (10 August 2012)               **
**                               developed at                               **
**        Institute of Soil Science, University of Hamburg, Germany         **
**                                 based on                                 **
**              US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************
```

TIME: 13.33 DATE: 7.10.2014

```
 PRECIPITATION DATA FILE:       C:\HDR_Projects\Sanford\HELP\Charah Sanford.d4
 TEMPERATURE DATA FILE:         C:\HDR_Projects\Sanford\HELP\Charah Sanford.d7
 SOLAR RADIATION DATA FILE:     C:\HDR_Projects\Sanford\HELP\Charah Sanford.d13
 EVAPOTRANSPIRATION DATA F. 1: C:\HDR_Projects\Sanford\HELP\Charah Sanford.d11
 SOIL AND DESIGN DATA FILE  1: C:\HDR_Projects\Sanford\HELP\Charh Colon-first
lift.d10
 OUTPUT DATA FILE:              C:\HDR_Projects\Sanford\HELP\charah colon-first
lift-rev.out
```

****

TITLE: Coal Ash-First Lift (20-feet)

****

WEATHER DATA SOURCES

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR RALEIGH NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.55	3.43	3.69	2.91	3.67	3.66
4.38	4.44	3.29	2.73	2.87	3.14

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR RALEIGH NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
39.60	41.60	49.30	59.50	67.20	73.90
77.70	77.00	71.00	59.70	50.00	42.00

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR RALEIGH NORTH CAROLINA
AND STATION LATITUDE = 35.87 DEGREES

****

LAYER DATA 1

VALID FOR 5 YEARS

NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
WERE SPECIFIED BY THE USER.

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

```
THICKNESS                    =    240.00   INCHES
POROSITY                     =      0.5410 VOL/VOL
FIELD CAPACITY               =      0.1870 VOL/VOL
WILTING POINT                =      0.0470 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.3100 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1600E-03 CM/SEC
```

LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

```
THICKNESS                    =      0.26   INCHES
POROSITY                     =      0.8500 VOL/VOL
FIELD CAPACITY               =      0.0100 VOL/VOL
WILTING POINT                =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=       9.700     CM/SEC
SLOPE                        =      2.00   PERCENT
DRAINAGE LENGTH              =    950.0    FEET
```

LAYER 3

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

```
THICKNESS                    =      0.06   INCHES
EFFECTIVE SAT. HYD. CONDUCT.=      0.2000E-12 CM/SEC
```

```
FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD
```

LAYER 4

```
              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  16
THICKNESS                    =     18.00   INCHES
POROSITY                     =      0.4270 VOL/VOL
FIELD CAPACITY               =      0.4180 VOL/VOL
WILTING POINT                =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-06 CM/SEC
```

****

GENERAL DESIGN AND EVAPORATIVE ZONE DATA 1

VALID FOR 5 YEARS

```
NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
         SOIL DATA BASE USING SOIL TEXTURE # 9 WITH BARE
         GROUND CONDITIONS, A SURFACE SLOPE OF  2.% AND
         A SLOPE LENGTH OF 1000. FEET.

SCS RUNOFF CURVE NUMBER            =     91.21
FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =      1.000  ACRES
EVAPORATIVE ZONE DEPTH             =     18.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =      5.580  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =      9.738  INCHES
FIELD CAPACITY OF EVAPORATIVE ZONE =      3.366  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =      0.846  INCHES
SOIL EVAPORATION ZONE DEPTH        =     18.000  INCHES
INITIAL SNOW WATER                 =      0.000  INCHES
INITIAL INTERCEPTION WATER         =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =     82.089  INCHES
TOTAL INITIAL WATER                =     82.089  INCHES
TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR
```

****

EVAPOTRANSPIRATION DATA 1

VALID FOR 5 YEARS

```
NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
         RALEIGH              NORTH CAROLINA
    STATION LATITUDE                          =  35.87 DEGREES
    MAXIMUM LEAF AREA INDEX                   =   4.50
    START OF GROWING SEASON (JULIAN DATE)     =     86
```

```
END OF GROWING SEASON (JULIAN DATE)    =    310
EVAPORATIVE ZONE DEPTH                 =  18.0  INCHES
AVERAGE ANNUAL WIND SPEED              =   7.70 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY  =  66.0  %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY  =  70.0  %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY  =  78.0  %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY  =  72.0  %
```

****

****

FINAL WATER STORAGE AT END OF YEAR 5

LAYER	(INCHES)	(VOL/VOL)
1	55.9666	0.2332
2	0.0105	0.0412
3	0.0000	0.0000
4	7.6860	0.4270

TOTAL WATER IN LAYERS	63.663
SNOW WATER	0.000
INTERCEPTION WATER	0.000
TOTAL FINAL WATER	63.663

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 5

	(INCHES)	(CU. FT.)
PRECIPITATION	5.22	18948.600
RUNOFF	3.575	12975.5439
DRAINAGE COLLECTED FROM LAYER 2	0.14852	539.13129
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000000	0.00058
AVERAGE HEAD ON TOP OF LAYER 3	0.128	
MAXIMUM HEAD ON TOP OF LAYER 3	0.253	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	12.8 FEET	

SNOW WATER	1.67	6061.1177
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3724	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0470	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

****

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 5

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.26	2.82	4.37	2.63	3.53	5.42
	4.57	6.26	2.81	3.77	2.52	2.90
STD. DEVIATIONS	2.96	0.95	1.30	1.89	2.64	1.99
	2.29	5.93	1.69	2.69	1.66	1.28
RUNOFF						
TOTALS	0.489	0.242	0.579	0.162	0.373	0.551
	0.513	1.443	0.529	0.574	0.313	0.395
STD. DEVIATIONS	0.785	0.166	0.386	0.281	0.776	0.349
	0.414	2.668	0.737	0.741	0.326	0.378
POTENTIAL EVAPOTRANSPIRATION						
TOTALS	1.892	2.205	3.293	4.787	6.327	6.770
	7.049	5.890	4.466	3.365	2.345	1.543
STD. DEVIATIONS	0.140	0.177	0.179	0.403	0.445	0.263
	0.410	0.413	0.352	0.062	0.182	0.125
ACTUAL EVAPOTRANSPIRATION						
TOTALS	1.187	1.542	2.190	3.150	4.680	3.930
	4.571	3.686	2.519	1.200	0.892	0.784
STD. DEVIATIONS	0.110	0.158	0.278	0.672	1.241	1.381
	1.214	1.481	1.114	0.273	0.214	0.166
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	1.0808	0.9755	0.7979	1.0852	1.2494	1.2199
	1.2469	1.1912	0.8960	0.8655	0.8652	0.5817

STD. DEVIATIONS	1.3066	1.4152	0.8021	0.7541	0.8702	0.7798
	0.4728	0.2582	0.2120	0.0940	0.3263	0.2376

LATERAL DRAINAGE RECIRCULATED FROM LAYER 2 INTO L. 1

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.0301	0.0299	0.0222	0.0313	0.0348	0.0351
	0.0348	0.0332	0.0258	0.0241	0.0249	0.0162
STD. DEVIATIONS	0.0364	0.0437	0.0224	0.0217	0.0243	0.0225
	0.0132	0.0072	0.0061	0.0026	0.0094	0.0066

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	44.86 (9.753)	162856.3	100.00
RUNOFF	6.163 (4.6070)	22371.77	13.737
POTENTIAL EVAPOTRANSPIRATION	49.932 (0.3704)	181254.19	
ACTUAL EVAPOTRANSPIRATION	30.331 (1.0151)	110100.95	67.606
LATERAL DRAINAGE COLLECTED FROM LAYER 2	12.05520 (6.28163)	43760.371	26.87054
DRAINAGE RECIRCULATED FROM LAYER 2 INTO L. 1	0.00000 (0.00000)	0.000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00002 (0.00001)	0.058	0.00004
AVERAGE HEAD ON TOP OF LAYER 3	0.029 (0.015)		

CHANGE IN WATER STORAGE	-3.685	(8.1517)	-13376.83	-8.214

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                                                                          **
**              HELP Version 3.95 D          (10 August 2012)               **
**                                developed at                              **
**        Institute of Soil Science, University of Hamburg, Germany         **
**                                  based on                                **
**              US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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```

TIME: 13.28   DATE: 7.10.2014

```
 PRECIPITATION DATA FILE:      C:\HDR_Projects\Sanford\HELP\Charah Sanford.d4
 TEMPERATURE DATA FILE:        C:\HDR_Projects\Sanford\HELP\Charah Sanford.d7
 SOLAR RADIATION DATA FILE:    C:\HDR_Projects\Sanford\HELP\Charah Sanford.d13
 EVAPOTRANSPIRATION DATA F. 1: C:\HDR_Projects\Sanford\HELP\Charah Sanford.d11
 SOIL AND DESIGN DATA FILE  1: C:\HDR_Projects\Sanford\HELP\Charh Colon-second
lift.d10
 OUTPUT DATA FILE:             C:\HDR_Projects\Sanford\HELP\Charah Colon-second
lift.out
```

****

TITLE: Charah Colon - Second Lift

****

WEATHER DATA SOURCES

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR   RALEIGH   NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.55	3.43	3.69	2.91	3.67	3.66
4.38	4.44	3.29	2.73	2.87	3.14

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR   RALEIGH   NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

Charah Colon-second lift

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
39.60	41.60	49.30	59.50	67.20	73.90
77.70	77.00	71.00	59.70	50.00	42.00

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR RALEIGH NORTH CAROLINA
AND STATION LATITUDE = 35.87 DEGREES

****

LAYER DATA 1

VALID FOR 5 YEARS

NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
WERE SPECIFIED BY THE USER.

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS = 240.00 INCHES
POROSITY = 0.5410 VOL/VOL
FIELD CAPACITY = 0.1870 VOL/VOL
WILTING POINT = 0.0470 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.3100 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.= 0.1600E-03 CM/SEC

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS = 240.00 INCHES
POROSITY = 0.5410 VOL/VOL
FIELD CAPACITY = 0.1870 VOL/VOL
WILTING POINT = 0.0470 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.2332 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.= 0.1600E-03 CM/SEC

LAYER 3

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS = 0.26 INCHES
POROSITY = 0.8500 VOL/VOL
FIELD CAPACITY = 0.0100 VOL/VOL
WILTING POINT = 0.0050 VOL/VOL

Charah Colon-second lift

```
INITIAL SOIL WATER CONTENT  =      0.0380 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=       9.700     CM/SEC
SLOPE                       =      2.00   PERCENT
DRAINAGE LENGTH             =    950.0    FEET
```

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

```
THICKNESS                   =      0.06   INCHES
EFFECTIVE SAT. HYD. CONDUCT.=      0.2000E-12 CM/SEC
FML PINHOLE DENSITY         =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD
```

LAYER 5

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16

```
THICKNESS                   =     18.00   INCHES
POROSITY                    =      0.4270 VOL/VOL
FIELD CAPACITY              =      0.4180 VOL/VOL
WILTING POINT               =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-06 CM/SEC
```

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GENERAL DESIGN AND EVAPORATIVE ZONE DATA 1

VALID FOR 5 YEARS

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 9 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 1000. FEET.

```
SCS RUNOFF CURVE NUMBER             =     91.21
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
EVAPORATIVE ZONE DEPTH              =     18.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      5.580  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      9.738  INCHES
FIELD CAPACITY OF EVAPORATIVE ZONE  =      3.366  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      0.846  INCHES
SOIL EVAPORATION ZONE DEPTH         =     18.000  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL INTERCEPTION WATER          =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =    138.064  INCHES
TOTAL INITIAL WATER                 =    138.064  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR
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EVAPOTRANSPIRATION DATA 1

VALID FOR 5 YEARS

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
RALEIGH NORTH CAROLINA

STATION LATITUDE	=	35.87 DEGREES
MAXIMUM LEAF AREA INDEX	=	4.50
START OF GROWING SEASON (JULIAN DATE)	=	86
END OF GROWING SEASON (JULIAN DATE)	=	310
EVAPORATIVE ZONE DEPTH	=	18.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	7.70 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	66.0 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.0 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	78.0 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	72.0 %

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FINAL WATER STORAGE AT END OF YEAR 5

LAYER	(INCHES)	(VOL/VOL)
1	55.9666	0.2332
2	60.4315	0.2518
3	0.0146	0.0570
4	0.0000	0.0000
5	7.6860	0.4270
TOTAL WATER IN LAYERS	124.099	
SNOW WATER	0.000	
INTERCEPTION WATER	0.000	
TOTAL FINAL WATER	124.099	

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 5

(INCHES) (CU. FT.)

PRECIPITATION	5.22	18948.600
RUNOFF	3.575	12975.5439
DRAINAGE COLLECTED FROM LAYER 3	0.07225	262.26297
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.000000	0.00030
AVERAGE HEAD ON TOP OF LAYER 4	0.062	
MAXIMUM HEAD ON TOP OF LAYER 4	0.130	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	0.0 FEET	
SNOW WATER	1.67	6061.1177
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3724	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0470	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 5

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.26	2.82	4.37	2.63	3.53	5.42
	4.57	6.26	2.81	3.77	2.52	2.90
STD. DEVIATIONS	2.96	0.95	1.30	1.89	2.64	1.99
	2.29	5.93	1.69	2.69	1.66	1.28
RUNOFF						
TOTALS	0.489	0.242	0.579	0.162	0.373	0.551
	0.513	1.443	0.529	0.574	0.313	0.395
STD. DEVIATIONS	0.785	0.166	0.386	0.281	0.776	0.349
	0.414	2.668	0.737	0.741	0.326	0.378
POTENTIAL EVAPOTRANSPIRATION						
TOTALS	1.892	2.205	3.293	4.787	6.327	6.770
	7.049	5.890	4.466	3.365	2.345	1.543

STD. DEVIATIONS	0.140	0.177	0.179	0.403	0.445	0.263
	0.410	0.413	0.352	0.062	0.182	0.125

ACTUAL EVAPOTRANSPIRATION

TOTALS	1.187	1.542	2.190	3.150	4.680	3.930
	4.571	3.686	2.519	1.200	0.892	0.784
STD. DEVIATIONS	0.110	0.158	0.278	0.672	1.241	1.381
	1.214	1.481	1.114	0.273	0.214	0.166

LATERAL DRAINAGE COLLECTED FROM LAYER 3

TOTALS	1.1436	0.9410	0.9548	0.8997	0.5998	0.7245
	0.8315	0.8484	0.9490	1.1838	0.9934	1.0936
STD. DEVIATIONS	0.4081	0.4523	0.5742	0.4406	0.3203	0.3806
	0.6442	0.6530	0.6533	0.7719	0.5072	0.3708

LATERAL DRAINAGE RECIRCULATED FROM LAYER 3 INTO L. 1

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 5

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0319	0.0288	0.0266	0.0259	0.0167	0.0209
	0.0232	0.0236	0.0273	0.0330	0.0286	0.0305
STD. DEVIATIONS	0.0114	0.0139	0.0160	0.0127	0.0089	0.0110
	0.0180	0.0182	0.0188	0.0215	0.0146	0.0103

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	44.86 (9.753)	162856.3	100.00
RUNOFF	6.163 (4.6070)	22371.77	13.737

POTENTIAL EVAPOTRANSPIRATION	49.932	(0.3704)	181254.19	
ACTUAL EVAPOTRANSPIRATION	30.331	(1.0151)	110100.95	67.606
LATERAL DRAINAGE COLLECTED FROM LAYER 3	11.16312	(1.54445)	40522.133	24.88214
DRAINAGE RECIRCULATED FROM LAYER 3 INTO L. 1	0.00000	(0.00000)	0.000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.00002	(0.00000)	0.054	0.00003
AVERAGE HEAD ON TOP OF LAYER 4	0.026	(0.004)		
CHANGE IN WATER STORAGE	-2.793	(6.0314)	-10138.60	-6.225

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**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                                                                          **
**              HELP Version 3.95 D          (10 August 2012)               **
**                                developed at                              **
**        Institute of Soil Science, University of Hamburg, Germany        **
**                                  based on                                **
**              US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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TIME: 13.33   DATE: 7.10.2014

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 PRECIPITATION DATA FILE:      C:\HDR_Projects\Sanford\HELP\Charah Sanford.d4
 TEMPERATURE DATA FILE:        C:\HDR_Projects\Sanford\HELP\Charah Sanford.d7
 SOLAR RADIATION DATA FILE:    C:\HDR_Projects\Sanford\HELP\Charah Sanford.d13
 EVAPOTRANSPIRATION DATA F. 1: C:\HDR_Projects\Sanford\HELP\Charah Sanford.d11
 SOIL AND DESIGN DATA FILE  1: C:\HDR_Projects\Sanford\HELP\Charah Colon-third
lift.d10
 OUTPUT DATA FILE:             C:\HDR_Projects\Sanford\HELP\Charah Colon-thrid
lift.out
```

****

TITLE: Charah Colon- Final Lift

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WEATHER DATA SOURCES

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR   RALEIGH   NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.55	3.43	3.69	2.91	3.67	3.66
4.38	4.44	3.29	2.73	2.87	3.14

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR   RALEIGH   NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

Charah Colon-thrid lift

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
39.60	41.60	49.30	59.50	67.20	73.90
77.70	77.00	71.00	59.70	50.00	42.00

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR RALEIGH NORTH CAROLINA AND STATION LATITUDE = 35.87 DEGREES

****

LAYER DATA 1

VALID FOR 5 YEARS

NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE SPECIFIED BY THE USER.

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	240.00 INCHES
POROSITY	=	0.5410 VOL/VOL
FIELD CAPACITY	=	0.1870 VOL/VOL
WILTING POINT	=	0.0470 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3100 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.	=	0.1600E-03 CM/SEC

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	240.00 INCHES
POROSITY	=	0.5410 VOL/VOL
FIELD CAPACITY	=	0.1870 VOL/VOL
WILTING POINT	=	0.0470 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2332 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.	=	0.1600E-03 CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	240.00 INCHES
POROSITY	=	0.5410 VOL/VOL
FIELD CAPACITY	=	0.1870 VOL/VOL
WILTING POINT	=	0.0470 VOL/VOL

```
INITIAL SOIL WATER CONTENT  =      0.2518 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1600E-03 CM/SEC


                       LAYER  4
                       --------

             TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.26   INCHES
POROSITY                    =      0.8500 VOL/VOL
FIELD CAPACITY              =      0.0100 VOL/VOL
WILTING POINT               =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0503 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=       9.700     CM/SEC
SLOPE                       =      2.00   PERCENT
DRAINAGE LENGTH             =    950.0    FEET


                       LAYER  5
                       --------

             TYPE 4 - FLEXIBLE MEMBRANE LINER
               MATERIAL TEXTURE NUMBER  35
THICKNESS                   =      0.06   INCHES
EFFECTIVE SAT. HYD. CONDUCT.=      0.2000E-12 CM/SEC
FML PINHOLE DENSITY         =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD


                       LAYER  6
                       --------

               TYPE 3 - BARRIER SOIL LINER
               MATERIAL TEXTURE NUMBER  16
THICKNESS                   =     18.00   INCHES
POROSITY                    =      0.4270 VOL/VOL
FIELD CAPACITY              =      0.4180 VOL/VOL
WILTING POINT               =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-06 CM/SEC
```

****

GENERAL DESIGN AND EVAPORATIVE ZONE DATA   1

VALID FOR   5 YEARS

```
NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
         SOIL DATA BASE USING SOIL TEXTURE # 9 WITH BARE
         GROUND CONDITIONS, A SURFACE SLOPE OF  2.% AND
         A SLOPE LENGTH OF 1000. FEET.

SCS RUNOFF CURVE NUMBER            =     91.21
FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
```

```
AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
EVAPORATIVE ZONE DEPTH              =     18.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      5.580  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      9.738  INCHES
FIELD CAPACITY OF EVAPORATIVE ZONE  =      3.366  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      0.846  INCHES
SOIL EVAPORATION ZONE DEPTH         =     18.000  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL INTERCEPTION WATER          =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =    198.499  INCHES
TOTAL INITIAL WATER                 =    198.499  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR
```

****

EVAPOTRANSPIRATION DATA   1

VALID FOR   5 YEARS

```
NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
         RALEIGH             NORTH CAROLINA
    STATION LATITUDE                         =  35.87 DEGREES
    MAXIMUM LEAF AREA INDEX                  =   4.50
    START OF GROWING SEASON (JULIAN DATE)    =     86
    END OF GROWING SEASON (JULIAN DATE)      =    310
    EVAPORATIVE ZONE DEPTH                   =  18.0  INCHES
    AVERAGE ANNUAL WIND SPEED                =   7.70 MPH
    AVERAGE 1ST QUARTER RELATIVE HUMIDITY    =  66.0  %
    AVERAGE 2ND QUARTER RELATIVE HUMIDITY    =  70.0  %
    AVERAGE 3RD QUARTER RELATIVE HUMIDITY    =  78.0  %
    AVERAGE 4TH QUARTER RELATIVE HUMIDITY    =  72.0  %
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FINAL WATER STORAGE AT END OF YEAR   5

LAYER	(INCHES)	(VOL/VOL)
1	55.9666	0.2332
2	60.4315	0.2518
3	60.8212	0.2534
4	0.0237	0.0925
5	0.0000	0.0000
6	7.6860	0.4270

TOTAL WATER IN LAYERS   184.929

SNOW WATER   0.000

INTERCEPTION WATER 0.000

TOTAL FINAL WATER 184.929

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 5

	(INCHES)	(CU. FT.)
PRECIPITATION	5.22	18948.600
RUNOFF	3.575	12975.5439
DRAINAGE COLLECTED FROM LAYER 4	0.06941	251.96625
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000000	0.00029
AVERAGE HEAD ON TOP OF LAYER 5	0.060	
MAXIMUM HEAD ON TOP OF LAYER 5	0.124	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	0.0 FEET	
SNOW WATER	1.67	6061.1177
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3724	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0470	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 5

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.26	2.82	4.37	2.63	3.53	5.42
	4.57	6.26	2.81	3.77	2.52	2.90

STD. DEVIATIONS	2.96	0.95	1.30	1.89	2.64	1.99
	2.29	5.93	1.69	2.69	1.66	1.28

RUNOFF

TOTALS	0.489	0.242	0.579	0.162	0.373	0.551
	0.513	1.443	0.529	0.574	0.313	0.395
STD. DEVIATIONS	0.785	0.166	0.386	0.281	0.776	0.349
	0.414	2.668	0.737	0.741	0.326	0.378

POTENTIAL EVAPOTRANSPIRATION

TOTALS	1.892	2.205	3.293	4.787	6.327	6.770
	7.049	5.890	4.466	3.365	2.345	1.543
STD. DEVIATIONS	0.140	0.177	0.179	0.403	0.445	0.263
	0.410	0.413	0.352	0.062	0.182	0.125

ACTUAL EVAPOTRANSPIRATION

TOTALS	1.187	1.542	2.190	3.150	4.680	3.930
	4.571	3.686	2.519	1.200	0.892	0.784
STD. DEVIATIONS	0.110	0.158	0.278	0.672	1.241	1.381
	1.214	1.481	1.114	0.273	0.214	0.166

LATERAL DRAINAGE COLLECTED FROM LAYER 4

TOTALS	0.8115	0.7209	0.9860	1.0041	1.1498	1.2343
	1.1582	0.9416	0.8917	0.7623	0.6258	0.7979
STD. DEVIATIONS	0.3187	0.4343	0.2879	0.2251	0.4042	0.2733
	0.5172	0.4840	0.5784	0.5968	0.5074	0.2368

LATERAL DRAINAGE RECIRCULATED FROM LAYER 4 INTO L. 1

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 5

AVERAGES	0.0226	0.0222	0.0275	0.0289	0.0321	0.0356
	0.0323	0.0262	0.0257	0.0212	0.0180	0.0222
STD. DEVIATIONS	0.0089	0.0135	0.0080	0.0065	0.0113	0.0079

0.0144 0.0135 0.0167 0.0166 0.0146 0.0066

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 5

	INCHES		CU. FEET	PERCENT
PRECIPITATION	44.86	(9.753)	162856.3	100.00
RUNOFF	6.163	(4.6070)	22371.77	13.737
POTENTIAL EVAPOTRANSPIRATION	49.932	(0.3704)	181254.19	
ACTUAL EVAPOTRANSPIRATION	30.331	(1.0151)	110100.95	67.606
LATERAL DRAINAGE COLLECTED FROM LAYER 4	11.08410	(4.20841)	40235.270	24.70600
DRAINAGE RECIRCULATED FROM LAYER 4 INTO L. 1	0.00000	(0.00000)	0.000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00001	(0.00000)	0.054	0.00003
AVERAGE HEAD ON TOP OF LAYER 5	0.026	(0.010)		
CHANGE IN WATER STORAGE	-2.714	(7.1433)	-9851.73	-6.049

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                                                                          **
**              HELP Version 3.95 D          (10 August 2012)               **
**                               developed at                               **
**        Institute of Soil Science, University of Hamburg, Germany         **
**                                 based on                                 **
**              US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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TIME: 18.32   DATE: 7.10.2014

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 PRECIPITATION DATA FILE:      C:\HDR_Projects\Sanford\HELP\Charah Sanford.d4
 TEMPERATURE DATA FILE:        C:\HDR_Projects\Sanford\HELP\Charah Sanford.d7
 SOLAR RADIATION DATA FILE:    C:\HDR_Projects\Sanford\HELP\Charah Sanford.d13
 EVAPOTRANSPIRATION DATA F. 1: C:\HDR_Projects\Sanford\HELP\Charah Sanford.d11
 SOIL AND DESIGN DATA FILE  1: C:\HDR_Projects\Sanford\HELP\Charah Colon-Final
Cover-top deck-rev1.d10
 OUTPUT DATA FILE:             C:\HDR_Projects\Sanford\HELP\Charah colon-final
cover-top deck-rev1.out
```

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TITLE: Final Cover System-Top Deck Model

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WEATHER DATA SOURCES

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR   RALEIGH   NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.55	3.43	3.69	2.91	3.67	3.66
4.38	4.44	3.29	2.73	2.87	3.14

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR   RALEIGH   NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

Charah colon-final cover-top deck-rev1

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
39.60	41.60	49.30	59.50	67.20	73.90
77.70	77.00	71.00	59.70	50.00	42.00

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR RALEIGH NORTH CAROLINA
AND STATION LATITUDE = 35.87 DEGREES

****

LAYER DATA 1

VALID FOR 100 YEARS

NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 9

THICKNESS	=	6.00 INCHES
POROSITY	=	0.5010 VOL/VOL
FIELD CAPACITY	=	0.2840 VOL/VOL
WILTING POINT	=	0.1350 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4663 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.	=	0.1900E-03 CM/SEC

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 5.00
FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00 INCHES
POROSITY	=	0.4750 VOL/VOL
FIELD CAPACITY	=	0.3780 VOL/VOL
WILTING POINT	=	0.2650 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4070 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.	=	0.3000E-06 CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 12

THICKNESS	=	24.00 INCHES
POROSITY	=	0.4710 VOL/VOL

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FIELD CAPACITY              =      0.3420 VOL/VOL
WILTING POINT               =      0.2100 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.3420 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.4200E-04 CM/SEC


                        LAYER  4
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     30.00   INCHES
POROSITY                    =      0.3980 VOL/VOL
FIELD CAPACITY              =      0.2440 VOL/VOL
WILTING POINT               =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.2440 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-03 CM/SEC
SLOPE                       =      2.00   PERCENT
DRAINAGE LENGTH             =    500.0    FEET


                        LAYER  5
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  36
THICKNESS                   =      0.04   INCHES
EFFECTIVE SAT. HYD. CONDUCT.=      0.4000E-12 CM/SEC
FML PINHOLE DENSITY         =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD


                        LAYER  6
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =    720.00   INCHES
POROSITY                    =      0.5410 VOL/VOL
FIELD CAPACITY              =      0.1870 VOL/VOL
WILTING POINT               =      0.0470 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.1870 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1600E-03 CM/SEC


                        LAYER  7
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.26   INCHES
POROSITY                    =      0.8500 VOL/VOL
FIELD CAPACITY              =      0.0100 VOL/VOL
WILTING POINT               =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=       9.700     CM/SEC
SLOPE                       =      2.00   PERCENT
DRAINAGE LENGTH             =    950.0    FEET
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                         LAYER  8
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              TYPE 4 - FLEXIBLE MEMBRANE LINER
                MATERIAL TEXTURE NUMBER  35
   THICKNESS                     =      0.06   INCHES
   EFFECTIVE SAT. HYD. CONDUCT.=      0.2000E-12 CM/SEC
   FML PINHOLE DENSITY           =      1.00   HOLES/ACRE
   FML INSTALLATION DEFECTS      =      1.00   HOLES/ACRE
   FML PLACEMENT QUALITY         =  3 - GOOD


                         LAYER  9
                         --------

            TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER  17
   THICKNESS                     =      0.25   INCHES
   POROSITY                      =      0.7500 VOL/VOL
   FIELD CAPACITY                =      0.7470 VOL/VOL
   WILTING POINT                 =      0.4000 VOL/VOL
   INITIAL SOIL WATER CONTENT    =      0.7470 VOL/VOL
   EFFECTIVE SAT. HYD. CONDUCT.=      0.3000E-08 CM/SEC


                         LAYER 10
                         --------

                TYPE 3 - BARRIER SOIL LINER
                MATERIAL TEXTURE NUMBER  16
   THICKNESS                     =     18.00   INCHES
   POROSITY                      =      0.4270 VOL/VOL
   FIELD CAPACITY                =      0.4180 VOL/VOL
   WILTING POINT                 =      0.3670 VOL/VOL
   INITIAL SOIL WATER CONTENT    =      0.4270 VOL/VOL
   EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-06 CM/SEC


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                GENERAL DESIGN AND EVAPORATIVE ZONE DATA   1
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                        VALID FOR 100 YEARS


        NOTE:  SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

        SCS RUNOFF CURVE NUMBER              =     89.00
        FRACTION OF AREA ALLOWING RUNOFF     =    100.0    PERCENT
        AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
        EVAPORATIVE ZONE DEPTH               =     18.0    INCHES
        INITIAL WATER IN EVAPORATIVE ZONE   =      7.682  INCHES
        UPPER LIMIT OF EVAPORATIVE STORAGE  =      8.706  INCHES
        FIELD CAPACITY OF EVAPORATIVE ZONE  =      6.240  INCHES
        LOWER LIMIT OF EVAPORATIVE STORAGE  =      3.990  INCHES
        SOIL EVAPORATION ZONE DEPTH          =     18.000  INCHES
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INITIAL SNOW WATER	=	0.000	INCHES
INITIAL INTERCEPTION WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	165.726	INCHES
TOTAL INITIAL WATER	=	165.726	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

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EVAPOTRANSPIRATION DATA 1

VALID FOR 100 YEARS

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
RALEIGH NORTH CAROLINA

STATION LATITUDE	=	35.87	DEGREES
MAXIMUM LEAF AREA INDEX	=	4.50	
START OF GROWING SEASON (JULIAN DATE)	=	86	
END OF GROWING SEASON (JULIAN DATE)	=	310	
EVAPORATIVE ZONE DEPTH	=	18.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	7.70	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	66.0	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.0	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	78.0	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	72.0	%

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	2.6508	0.4418
2	4.4217	0.3685
3	8.2079	0.3420
4	8.5919	0.2864
5	0.0000	0.0000
6	134.6400	0.1870
7	0.0031	0.0121
8	0.0000	0.0000
9	0.1867	0.7470
10	7.6860	0.4270
TOTAL WATER IN LAYERS	166.388	

SNOW WATER	0.000
INTERCEPTION WATER	0.000
TOTAL FINAL WATER	166.388

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	5.22	18948.600
RUNOFF	4.833	17545.1348
DRAINAGE COLLECTED FROM LAYER 4	0.00049	1.78363
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.001659	6.02173
AVERAGE HEAD ON TOP OF LAYER 5	21.677	
MAXIMUM HEAD ON TOP OF LAYER 5	29.864	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	155.4 FEET	
DRAINAGE COLLECTED FROM LAYER 7	0.00166	6.01989
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.000000	0.00003
AVERAGE HEAD ON TOP OF LAYER 8	0.001	
MAXIMUM HEAD ON TOP OF LAYER 8	0.040	
LOCATION OF MAXIMUM HEAD IN LAYER 7 (DISTANCE FROM DRAIN)	0.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 10	0.000000	0.00003
AVERAGE HEAD ON TOP OF LAYER 10	0.000	
SNOW WATER	3.56	12918.0498
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4837	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.2217	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.66	3.21	3.90	3.07	3.53	3.90
	4.28	4.91	3.41	2.84	2.99	2.98
STD. DEVIATIONS	1.92	1.63	1.42	1.34	1.84	2.01
	1.90	2.75	2.13	1.73	1.84	1.56
RUNOFF						
TOTALS	1.951	1.639	1.558	0.830	0.718	0.500
	0.534	1.096	0.749	0.870	1.285	1.422
STD. DEVIATIONS	1.642	1.571	1.181	0.819	0.982	0.781
	0.868	1.654	1.177	1.202	1.452	1.261
POTENTIAL EVAPOTRANSPIRATION						
TOTALS	1.867	2.198	3.605	4.849	6.329	7.019
	6.807	6.063	4.589	3.407	2.162	1.609
STD. DEVIATIONS	0.176	0.222	0.268	0.325	0.284	0.302
	0.314	0.271	0.277	0.205	0.168	0.131
ACTUAL EVAPOTRANSPIRATION						
TOTALS	1.172	1.469	2.293	2.572	4.813	4.165
	3.712	3.562	2.432	1.124	0.918	0.872
STD. DEVIATIONS	0.231	0.271	0.348	0.542	0.852	1.452
	1.167	1.070	0.877	0.298	0.230	0.206
LATERAL DRAINAGE COLLECTED FROM LAYER 4						
TOTALS	0.0071	0.0064	0.0071	0.0072	0.0079	0.0080
	0.0082	0.0080	0.0076	0.0076	0.0072	0.0073
STD. DEVIATIONS	0.0025	0.0023	0.0024	0.0024	0.0027	0.0026
	0.0027	0.0026	0.0025	0.0025	0.0024	0.0025
LATERAL DRAINAGE RECIRCULATED FROM LAYER 4 INTO L. 1						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 5						
TOTALS	0.0270	0.0244	0.0270	0.0271	0.0295	0.0295
	0.0303	0.0297	0.0283	0.0287	0.0273	0.0277

STD. DEVIATIONS	0.0081	0.0073	0.0078	0.0077	0.0083	0.0081
	0.0084	0.0082	0.0078	0.0080	0.0076	0.0077

LATERAL DRAINAGE COLLECTED FROM LAYER 7

TOTALS	0.0270	0.0244	0.0270	0.0270	0.0295	0.0295
	0.0303	0.0297	0.0283	0.0287	0.0273	0.0277
STD. DEVIATIONS	0.0081	0.0073	0.0078	0.0077	0.0083	0.0081
	0.0084	0.0082	0.0078	0.0080	0.0076	0.0077

LATERAL DRAINAGE RECIRCULATED FROM LAYER 7 INTO L. 6

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 8

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 10

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 5

AVERAGES	10.1284	10.0229	10.1310	10.5554	11.2798	11.6938
	11.6026	11.3571	11.1184	10.8841	10.6540	10.4281
STD. DEVIATIONS	3.5670	3.5107	3.4581	3.5694	3.7780	3.8541
	3.8275	3.7561	3.6872	3.6195	3.5529	3.4874

DAILY AVERAGE HEAD ON TOP OF LAYER 8

AVERAGES	0.0008	0.0007	0.0008	0.0008	0.0008	0.0008
	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
STD. DEVIATIONS	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002

DAILY AVERAGE HEAD ON TOP OF LAYER 10

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES	CU. FEET	PERCENT
PRECIPITATION	42.69 (6.985)	154963.6	100.00
RUNOFF	13.151 (5.1884)	47736.91	30.805
POTENTIAL EVAPOTRANSPIRATION	50.506 (0.9138)	183335.89	
ACTUAL EVAPOTRANSPIRATION	29.106 (2.5840)	105656.12	68.181
LATERAL DRAINAGE COLLECTED FROM LAYER 4	0.08963 (0.02930)	325.344	0.20995
DRAINAGE RECIRCULATED FROM LAYER 4 INTO L. 1	0.00000 (0.00000)	0.000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.33643 (0.09240)	1221.230	0.78808
AVERAGE HEAD ON TOP OF LAYER 5	10.821 (3.536)		
LATERAL DRAINAGE COLLECTED FROM LAYER 7	0.33642 (0.09240)	1221.202	0.78806
DRAINAGE RECIRCULATED FROM LAYER 7 INTO L. 6	0.00000 (0.00000)	0.000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.00000 (0.00000)	0.009	0.00001
AVERAGE HEAD ON TOP OF LAYER 8	0.001 (0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 10	0.00000 (0.00000)	0.009	0.00001
AVERAGE HEAD ON TOP OF LAYER 10	0.000 (0.000)		
CHANGE IN WATER STORAGE	0.007 (0.8117)	24.05	0.016

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charah colon final cover side slope-rev2

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**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                                                                          **
**              HELP Version 3.95 D          (10 August 2012)               **
**                               developed at                               **
**        Institute of Soil Science, University of Hamburg, Germany         **
**                                 based on                                 **
**              US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
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**                                                                          **
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TIME: 18.29   DATE: 7.10.2014

PRECIPITATION DATA FILE: C:\HDR_Projects\Sanford\HELP\Charah Sanford.d4
TEMPERATURE DATA FILE: C:\HDR_Projects\Sanford\HELP\Charah Sanford.d7
SOLAR RADIATION DATA FILE: C:\HDR_Projects\Sanford\HELP\Charah Sanford.d13
EVAPOTRANSPIRATION DATA F. 1: C:\HDR_Projects\Sanford\HELP\Charah Sanford.d11
SOIL AND DESIGN DATA FILE 1: C:\HDR_Projects\Sanford\HELP\Charah Colon-Final Cover-side slope-rev2.d10
OUTPUT DATA FILE: C:\HDR_Projects\Sanford\HELP\charah colon final cover side slope-rev2.out

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TITLE: Final Cover System-Side Slope

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WEATHER DATA SOURCES

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR   RALEIGH   NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.55	3.43	3.69	2.91	3.67	3.66
4.38	4.44	3.29	2.73	2.87	3.14

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR   RALEIGH   NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
39.60	41.60	49.30	59.50	67.20	73.90
77.70	77.00	71.00	59.70	50.00	42.00

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR RALEIGH NORTH CAROLINA
AND STATION LATITUDE = 35.87 DEGREES

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LAYER DATA 1

VALID FOR 100 YEARS

NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 9

THICKNESS = 6.00 INCHES
POROSITY = 0.5010 VOL/VOL
FIELD CAPACITY = 0.2840 VOL/VOL
WILTING POINT = 0.1350 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.4612 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.= 0.1900E-03 CM/SEC

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 5.00
FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS = 12.00 INCHES
POROSITY = 0.4750 VOL/VOL
FIELD CAPACITY = 0.3780 VOL/VOL
WILTING POINT = 0.2650 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.4281 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.= 0.3500E-06 CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 12

THICKNESS = 12.00 INCHES
POROSITY = 0.4710 VOL/VOL

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FIELD CAPACITY              =      0.3420 VOL/VOL
WILTING POINT               =      0.2100 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.3420 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.4200E-04 CM/SEC


                        LAYER  4
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     18.00   INCHES
POROSITY                    =      0.3980 VOL/VOL
FIELD CAPACITY              =      0.2440 VOL/VOL
WILTING POINT               =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.2440 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-03 CM/SEC
SLOPE                       =     25.00   PERCENT
DRAINAGE LENGTH             =    140.0    FEET


                        LAYER  5
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  36
THICKNESS                   =      0.04   INCHES
EFFECTIVE SAT. HYD. CONDUCT.=      0.4000E-12 CM/SEC
FML PINHOLE DENSITY         =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD


                        LAYER  6
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =    360.00   INCHES
POROSITY                    =      0.5410 VOL/VOL
FIELD CAPACITY              =      0.1870 VOL/VOL
WILTING POINT               =      0.0470 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.1870 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1600E-03 CM/SEC


                        LAYER  7
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.26   INCHES
POROSITY                    =      0.8500 VOL/VOL
FIELD CAPACITY              =      0.0100 VOL/VOL
WILTING POINT               =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=       9.700     CM/SEC
SLOPE                       =      2.00   PERCENT
DRAINAGE LENGTH             =    950.0    FEET
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                         LAYER  8
                         --------

               TYPE 4 - FLEXIBLE MEMBRANE LINER
                 MATERIAL TEXTURE NUMBER  35
    THICKNESS                   =      0.06   INCHES
    EFFECTIVE SAT. HYD. CONDUCT.=      0.2000E-12 CM/SEC
    FML PINHOLE DENSITY         =      1.00   HOLES/ACRE
    FML INSTALLATION DEFECTS    =      1.00   HOLES/ACRE
    FML PLACEMENT QUALITY       =  3 - GOOD


                         LAYER  9
                         --------

             TYPE 1 - VERTICAL PERCOLATION LAYER
                 MATERIAL TEXTURE NUMBER  17
    THICKNESS                   =      0.25   INCHES
    POROSITY                    =      0.7500 VOL/VOL
    FIELD CAPACITY              =      0.7470 VOL/VOL
    WILTING POINT               =      0.4000 VOL/VOL
    INITIAL SOIL WATER CONTENT  =      0.7470 VOL/VOL
    EFFECTIVE SAT. HYD. CONDUCT.=      0.3000E-08 CM/SEC


                         LAYER 10
                         --------

                 TYPE 3 - BARRIER SOIL LINER
                 MATERIAL TEXTURE NUMBER  16
    THICKNESS                   =     18.00   INCHES
    POROSITY                    =      0.4270 VOL/VOL
    FIELD CAPACITY              =      0.4180 VOL/VOL
    WILTING POINT               =      0.3670 VOL/VOL
    INITIAL SOIL WATER CONTENT  =      0.4270 VOL/VOL
    EFFECTIVE SAT. HYD. CONDUCT.=      0.1000E-06 CM/SEC


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           GENERAL DESIGN AND EVAPORATIVE ZONE DATA   1
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                        VALID FOR 100 YEARS


          NOTE:  SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

         SCS RUNOFF CURVE NUMBER             =     89.00
         FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
         AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
         EVAPORATIVE ZONE DEPTH              =     18.0    INCHES
         INITIAL WATER IN EVAPORATIVE ZONE   =      7.905  INCHES
         UPPER LIMIT OF EVAPORATIVE STORAGE  =      8.706  INCHES
         FIELD CAPACITY OF EVAPORATIVE ZONE  =      6.240  INCHES
         LOWER LIMIT OF EVAPORATIVE STORAGE  =      3.990  INCHES
         SOIL EVAPORATION ZONE DEPTH         =     18.000  INCHES
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charah colon final cover side slope-rev2

INITIAL SNOW WATER	=	0.000	INCHES
INITIAL INTERCEPTION WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	91.596	INCHES
TOTAL INITIAL WATER	=	91.596	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

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EVAPOTRANSPIRATION DATA 1

VALID FOR 100 YEARS

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
RALEIGH NORTH CAROLINA

STATION LATITUDE	=	35.87 DEGREES
MAXIMUM LEAF AREA INDEX	=	4.50
START OF GROWING SEASON (JULIAN DATE)	=	86
END OF GROWING SEASON (JULIAN DATE)	=	310
EVAPORATIVE ZONE DEPTH	=	18.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	7.70 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	66.0 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.0 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	78.0 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	72.0 %

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	2.6102	0.4350
2	4.5800	0.3817
3	4.1039	0.3420
4	4.4983	0.2499
5	0.0000	0.0000
6	67.3200	0.1870
7	0.0026	0.0103
8	0.0000	0.0000
9	0.1867	0.7470
10	7.6860	0.4270

TOTAL WATER IN LAYERS 90.988

SNOW WATER	0.000
INTERCEPTION WATER	0.000
TOTAL FINAL WATER	90.988

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	5.22	18948.600
RUNOFF	4.806	17446.6719
DRAINAGE COLLECTED FROM LAYER 4	0.00943	34.22776
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.000862	3.12959
AVERAGE HEAD ON TOP OF LAYER 5	9.896	
MAXIMUM HEAD ON TOP OF LAYER 5	17.732	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	6.7 FEET	
DRAINAGE COLLECTED FROM LAYER 7	0.00086	3.12944
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.000000	0.00003
AVERAGE HEAD ON TOP OF LAYER 8	0.001	
MAXIMUM HEAD ON TOP OF LAYER 8	0.040	
LOCATION OF MAXIMUM HEAD IN LAYER 7 (DISTANCE FROM DRAIN)	0.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 10	0.000000	0.00003
AVERAGE HEAD ON TOP OF LAYER 10	0.000	
SNOW WATER	3.56	12918.0498
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4837	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.2217	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.66	3.21	3.90	3.07	3.53	3.90
	4.28	4.91	3.41	2.84	2.99	2.98
STD. DEVIATIONS	1.92	1.63	1.42	1.34	1.84	2.01
	1.90	2.75	2.13	1.73	1.84	1.56
RUNOFF						
TOTALS	1.853	1.556	1.462	0.775	0.728	0.492
	0.525	1.077	0.731	0.825	1.206	1.324
STD. DEVIATIONS	1.603	1.548	1.152	0.790	0.970	0.766
	0.871	1.627	1.161	1.166	1.399	1.226
POTENTIAL EVAPOTRANSPIRATION						
TOTALS	1.867	2.198	3.605	4.849	6.329	7.019
	6.807	6.063	4.589	3.407	2.162	1.609
STD. DEVIATIONS	0.176	0.222	0.268	0.325	0.284	0.302
	0.314	0.271	0.277	0.205	0.168	0.131
ACTUAL EVAPOTRANSPIRATION						
TOTALS	1.183	1.473	2.295	2.565	4.698	4.302
	3.738	3.566	2.440	1.142	0.932	0.885
STD. DEVIATIONS	0.236	0.275	0.361	0.505	0.822	1.496
	1.197	1.086	0.887	0.308	0.238	0.211
LATERAL DRAINAGE COLLECTED FROM LAYER 4						
TOTALS	0.0275	0.0447	0.0901	0.1126	0.1179	0.1038
	0.0880	0.0710	0.0556	0.0464	0.0362	0.0302
STD. DEVIATIONS	0.0139	0.0320	0.0555	0.0597	0.0586	0.0493
	0.0421	0.0341	0.0268	0.0225	0.0176	0.0147
LATERAL DRAINAGE RECIRCULATED FROM LAYER 4 INTO L. 1						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 5						
TOTALS	0.0041	0.0057	0.0101	0.0121	0.0126	0.0114
	0.0101	0.0085	0.0070	0.0061	0.0050	0.0044

STD. DEVIATIONS	0.0017	0.0032	0.0052	0.0054	0.0054	0.0046
	0.0041	0.0035	0.0028	0.0025	0.0021	0.0018

LATERAL DRAINAGE COLLECTED FROM LAYER 7

TOTALS	0.0041	0.0056	0.0101	0.0120	0.0127	0.0114
	0.0101	0.0085	0.0070	0.0061	0.0050	0.0044
STD. DEVIATIONS	0.0017	0.0031	0.0051	0.0054	0.0054	0.0046
	0.0041	0.0035	0.0029	0.0025	0.0021	0.0018

LATERAL DRAINAGE RECIRCULATED FROM LAYER 7 INTO L. 6

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 8

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 10

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 5

AVERAGES	0.9299	1.6609	3.0516	3.9395	3.9916	3.6306
	2.9788	2.4039	1.9443	1.5712	1.2678	1.0224
STD. DEVIATIONS	0.4721	1.1815	1.8796	2.0889	1.9856	1.7258
	1.4251	1.1541	0.9369	0.7601	0.6159	0.4988

DAILY AVERAGE HEAD ON TOP OF LAYER 8

AVERAGES	0.0001	0.0002	0.0003	0.0003	0.0004	0.0003
	0.0003	0.0002	0.0002	0.0002	0.0001	0.0001
STD. DEVIATIONS	0.0000	0.0001	0.0001	0.0002	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

DAILY AVERAGE HEAD ON TOP OF LAYER 10

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES		CU. FEET	PERCENT
PRECIPITATION	42.69	(6.985)	154963.6	100.00
RUNOFF	12.555	(5.1002)	45572.88	29.409
POTENTIAL EVAPOTRANSPIRATION	50.506	(0.9138)	183335.89	
ACTUAL EVAPOTRANSPIRATION	29.220	(2.6210)	106069.01	68.448
LATERAL DRAINAGE COLLECTED FROM LAYER 4	0.82403	(0.40705)	2991.227	1.93028
DRAINAGE RECIRCULATED FROM LAYER 4 INTO L. 1	0.00000	(0.00000)	0.000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.09713	(0.04005)	352.576	0.22752
AVERAGE HEAD ON TOP OF LAYER 5	2.366	(1.169)		
LATERAL DRAINAGE COLLECTED FROM LAYER 7	0.09713	(0.04002)	352.564	0.22751
DRAINAGE RECIRCULATED FROM LAYER 7 INTO L. 6	0.00000	(0.00000)	0.000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.00000	(0.00000)	0.009	0.00001
AVERAGE HEAD ON TOP OF LAYER 8	0.000	(0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 10	0.00000	(0.00000)	0.009	0.00001
AVERAGE HEAD ON TOP OF LAYER 10	0.000	(0.000)		
CHANGE IN WATER STORAGE	-0.006	(0.9656)	-22.07	-0.014

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Attachment 3

Leachate Collection Geocomposite Hydraulic Conductivity Determination

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HDR Engineering, Inc.		Job No.	No.
Project	Sanford Mine Bottom Liner	Computed K. Perera	Date 9/30/2014
Task	Hydraulic Conductivity and Drainage Layer Capacity	Checked TMY	Date 10/22/14

Problem

Determine the hydraulic conductivity and drainage capacity of the geocomposite drainage layer in the bottom liner system.

Transmissivity Calculations

Bottom liner from bottom to top: 18"Compacted soil liner-GCL - 60-mil HDPE - Double-sided Geocomposite - CCP

Determine 100-hour transmissivity (Θ_{100}).

Use GSE 300-mil GSE Coal Drain or equivalent (see attached cut sheet with product specifications).

$$\Theta_{allow} = \frac{\Theta_{100}}{RF_{CR} * RF_{CC} * RF_{BC}}$$

$$\Theta_{allow} = \Theta_{req} \cdot FS_D$$

$$\Theta_{req} = k \cdot b$$

where,

- Θ_{allow} = minimum allowable transmissivity of geocomposite (cm^2/s)
- Θ_{req} = required transmissivity for site (cm^2/s)
- FS_D = overall factor of safety for drainage
- Θ_{100} = transmissivity after 100 hrs. under expected load (cm^2/s)
- RF_{CR} = reduction factor for creep deformation
- RF_{CC} = reduction factor for chemical clogging
- RF_{BC} = reduction factor for biological clogging
- k = saturated hydraulic conductivity (cm/s)
- b = thickness of geonet (cm)

Information based on product data for GSE Coal Drain 300 mil. Site specific testing is recommended before selecting the material for installation to confirm minimum transmissivity.

Parameters	Geocomposite (300-mil) @ 5,000 psf (1)
Slope	0.02
FS_D (2)	2.0
RF_{CR} (2)	1.06
RF_{CC} (2)	1.8
RF_{BC} (2)	1.2
Θ_{100} (m^2/s)	0.0033
Θ_{allow} (cm^2/s)	14.82
Θ_{req} (cm^2/s)	7.41
Manufactured Thickness (mils)	300
Manufactured Thickness (cm)	0.76
Design Hydraulic Conductivity (cm/s)	9.7
Retained Final Thickness (mils)	256.5

Notes:

1. psf = pounds per square foot
2. Reduction factors based on HDR experience and information provided by GSE.

19103 Gundle Road
Houston, Texas 77073

[o] 281.443.8564
[F] 281.875.6010
800.435.2008

GSE ENVIRONMENTAL™

October 1, 2014

Kanishka Perera, Ph.D., P.E.
HDR
200 W. Forsyth Street
Jacksonville, Florida 32202

RE: CoalDrain FabriNet Geocomposite Transmissivity (ASTM D 4716) Results
Duke Energy Landfill Cell Construction, North Carolina

Dear Mr. Perera,

As requested, GSE Environmental, LLC has summarized transmissivity test results for 300 mil CoalDrain FabriNet Geocomposite. CoalDrain Geocomposite is specifically designed to minimize clogging, piping and the intrusion of non-cohesive fine-grained material into the landfill leachate collection system. It is a 300 mil thick biplanar geonet structure with an innovative composite fabric to serve as a filter against fine material such as fly ash and gypsum. Testing was conducted in accordance with ASTM D 4716 *Standard Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head*.

Please note that the following Transmissivity test results are based on these boundary conditions: 100-hours at a Gradient of 0.02 using water at 20°C (68°F) between Fly Ash/Geocomposite/Geomembrane boundaries.

Normal Load (psf)	Transmissivity (m^2/s)	Thickness Retained (%)	Creep Reduction Factor
5,000	3.3×10^{-3}	95	1.06

Thickness Retained and Creep Reduction Factor are based on conventional 10,000-hour geonet creep data. The maximum recommended design load on 300 mil biplanar CoalDrain FabriNet Geocomposite is about 15,000 psf.

Please contact me at (502) 209-0325 should you wish to discuss or have questions.

Respectfully,

Steven M. Mayes, P.E.
Senior Technical Manager, North America

SMM2013001

PRODUCT DATA SHEET

GSE CoalDrain 300 mil Geocomposite (Double-Sided)

GSE CoalDrain geocomposite consists of a 300 mil thick GSE HyperNet geonet heat-laminated with a non-woven geotextile on the bottom side and an innovative composite fabric on the top side. The top geotextile serves as filter against fine materials like coal ash and FGD gypsum while the core serves the drainage function. The innovative geocomposite has been tested extensively in the laboratory and the field and has been proven to meet the performance requirements of an effective filter against coal combustion residuals.

[*]

AT THE CORE:
A high flow geocomposite that effectively filters coal combustion residuals.

Product Specifications

Tested Property	Test Method	Frequency	Minimum Average Roll Value[1]
Geocomposite			
Transmissivity[2], gal/min/ft (m^2/sec)	ASTM D 4716	1/540,000 ft^2	4.35 (9 X 10^{-4})
Ply Adhesion, lb/in	ASTM D 7005	1/50,000 ft^2	0.5
Geonet Core[1,3] – GSE HyperNet 300			
Geonet Core Thickness, mil	ASTM D 5199	1/50,000 ft^2	300
Density, g/cm^3	ASTM D 1505	1/50,000 ft^2	0.94
Tensile Strength (MD), lb/in	ASTM D 7179	1/50,000 ft^2	75
Carbon Black Content, %	ASTM D 4218	1/50,000 ft^2	2.0
Compressive Strength, psf	ASTM D 6364	1/540,000 ft^2	25,000
Top Composite Geotextile[1,3]			
Structure	Hybrid monolithic woven-nonwoven needlepunched		
Mass per Unit Area, oz/yd^2	ASTM D 5261	1/90,000 ft^2	14
Grab Tensile Strength, lb	ASTM D 4632	1/90,000 ft^2	200
Puncture Strength, lb	ASTM D 4833	1/90,000 ft^2	100
Trapezoidal Tear Strength, lb	ASTM D 4533	1/90,000 ft^2	85
AOS, US Sieve (mm)	ASTM D 4751	1/540,000 ft^2	170 (0.088)
Permittivity, (sec^{-1})	ASTM D 4491	1/500,000 ft^2	0.3
Water Flow Rate, gpm/ft^2	ASTM D 4491	1/500,000 ft^2	20
UV Resistance, % retained	ASTM D 4355 (after 500 hours)	per formulation	70
Field Basin Tests		per formulation	see note[5]

[Product specifications continued on back]

[*]

AT THE CORE:
A high flow geocomposite that effectively filters coal combustion residuals.

ProductSpecifications[continued]

Tested Property	Test Method	Frequency	Minimum Average Roll Value[(1)]
Bottom Geotextile			
Mass per Unit Area, oz/yd^2	ASTM D 5261	1/90,000 ft^2	6
Grab Tensile Strength, lb	ASTM D 4632	1/90,000 ft^2	160
Grab Elongation	ASTM D 4632	1/90,000 ft^2	50%
CBR Puncture Strength, lb	ASTM D 6241	1/90,000 ft^2	435
Trapezoidal Tear Strength, lb	ASTM D 4533	1/90,000 ft^2	65
AOS, US Sieve (mm)	ASTM D 4751	1/540,000 ft^2	70 (0.212)
Permittivity, (sec^{-1})	ASTM D 4491	1/540,000 ft^2	1.5
Water Flow Rate, gpm/ft^2	ASTM D 4491	1/540,000 ft^2	110
UV Resistance, % retained	ASTM D 4355 (after 500 hours)	per formulation	70
TYPICAL ROLL DIMENSIONS[(4)]			
Roll Width, ft			15.0
Roll Length, ft			160
Roll Area, ft^2			2,400

NOTES:
- [(1)]All geotextile are minimum average roll values except AOS which is maximum average roll value and UV resistance is typical value. Geonet core thickness is nominal value.
- [(2)]Gradient of 0.1, normal load of 10,000 psf, water at 70° F between steel plates for 15 minutes. Contact GSE for performance transmissivity value for use in design.
- [(3)]Component properties prior to lamination.
- [(4)]Roll widths and lengths have a tolerance of ±1%.
- [(5)]Filter compatibility with a minimum of three types of CCP materials (fly ash, stabilized FGD, and FGD gypsum) under simulated field conditions.

GSE is a leading manufacturer and marketer of geosynthetic lining products and services. We've built a reputation of reliability through our dedication to providing consistency of product, price and protection to our global customers.

Our commitment to innovation, our focus on quality and our industry expertise allow us the flexibility to collaborate with our clients to develop a custom, purpose-fit solution.

[DURABILITY RUNS DEEP] For more information on this product and others, please visit us at GSEworld.com, call 800.435.2008 or contact your local sales office.

GSE ENVIRONMENTAL™

Attachment 4

Physical Properties of Ash

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GEOTRACK Technologies, Inc.

3620 Pelham Road, PMB #292 Phone: 864-329-0013
Greenville, SC 29615-5044 FAX: 864-329-0014

June 30, 2010

Charah, Inc
307 Townpark Circle
Unit M, Suite 100
Louisville, KY 40243

Attention: Mr. Bobby Raia

Re; Coal Combustion By-product Characterization Testing
Asheville Airport Area 4
Asheville, NC
GeoTrack Project No. 10-2626-N

Ladies and Gentlemen:

GeoTrack Technologies, Inc. has completed characterization testing of an ash sample for the referenced project, and we present the results herein. The work was performed to address several items in the ASTM E 2277-03 Compliance Spread Sheet, as proposed on April 9, 2010, and amended. This letter presents a brief summary of the procedures and presents the testing results.

Project Description and Sampling: The material in question includes coal combustion by-products from the Asheville Steam Electric Power Plant, in Buncombe County, NC. We understand that the combustion by-products include a mixture of fly ash and bottom ash that are collected and discharged to holding ponds on the power plant property. The combined combustion by-products (hereinafter referred to as CCB's) are proposed for use in an engineered fill on the southwest portion of the Asheville Regional Airport property (Asheville Airport Area 4).

GeoTrack visited the power plant on April 12, 2010 and collected a sample the CCB. A grab sample was collected from the second stage pond (the *dry* pond) using procedures in conformance with ASTM C 311 (ASTM D 75) for the physical testing. Additionally, a portion of the sample was sampled and placed in laboratory-prepared containers in accordance with applicable EPA SW846 procedures for the chemical analysis.

The chemical analysis sample was immediately placed on ice, as required, and transported to Prism Laboratories in Charlotte, NC for chemical analyses as described in subsequent sections of this report. The physical test sample was split in accordance with ASTM procedures and subjected to various tests as described in subsequent sections.

Physical Testing: Table 1 presents the physical (engineering) tests performed, the applicable test methods, and the results. Where applicable, individual test reports are attached. Detailed evaluation of the engineering characteristics is beyond the scope of this report, and the suitability of the various properties is dependent upon final fill usage; however, a few comments are offered based upon our cursory review of the test results.

The grain size characteristics and specific gravity are within expected ranges based on general experience with similar CCB's. The material consists predominantly of silt-sized particles that are essentially cohesionless in nature. The sand content of the sample is most likely influenced by the bottom ash content of this CCB, as a pure fly ash sample would be expected to be more uniformly graded and have a higher silt content.

The Standard Proctor Maximum Dry Density achieved for this sample (70.7 pounds per cubic foot, pcf) was on the low end of the range typically achieved for similar products. The Proctor curve is relatively flat, indicating the material is not sensitive to moisture content. The compaction test results varied significantly from test results obtained by GeoTrack from CCB's placed in Area 1 (which were also variable). These results indicate considerable variability in densities, moisture contents, etc. might be expected, and these properties are most likely influenced by daily plant procedures and handling of the source stockpiles.

The field moisture content of this sample was 28.5 percent, which is 1.6 percent dry of the material's Standard Proctor Maximum Dry Density. This moisture content is within the optimal range recommended for effective compaction. This result indicates moisture adjustment requirements should be minimal, but they will be influenced by prevailing weather and drying that occurs during transportation.

Despite the low compacted dry density, the strength properties of this sample are favorable for most routine engineering applications. The strength properties for both drained (effective or long-term) and undrained (total or short-term loading) conditions are comparable to area soils compacted to equivalent specifications. The effective strength ($Ø=34^{\circ}$), in particular, is on the high end of the range typically achieved for area soils. Similarly, the consolidation test results indicate settlement characteristics of the CCB's will be comparable, or more favorable (less compressible) than, typical area soils. The hydraulic conductivity is also comparable to naturally-occurring soils in the site area.

Chemical Testing: The attached Tables 2 through 2C present the chemical analyses performed, the applicable test methods, and a summary of the results. For clarity, most compounds not detected are not included in the tables except for comparison between the analytical methods. The complete list of SPLP metals results are shown in Table 2B for comparison to regulatory limits. The complete laboratory reports are also attached.

Total metals are summarized in Table 2A. Total constituent concentrations are difficult to interpret, and to our knowledge, no strict regulatory limits apply to those analyses. The table contains comparisons to the limits stated in the Distribution of Residual Solids (503 Exempt) Permit issued to Progress Energy Carolinas, Inc. by the State of North Carolina. Only the Arsenic concentration (83 mg/kg) slightly exceeded the permit concentration (75 mg/kg).

Tables 2B and 2C are summaries of concentrations of detected constituents from the SPLP and TCLP analyses, respectively (SPLP Sulfate, Nitrate, and Nitrite concentrations are summarized in Table 2). Those tables include comparisons to two lists of regulatory limits: the permit limits and the NC 2L limits. The concentrations after extraction for both methods are well below the permit limits for all analyzed compounds.

Four metals (Arsenic, Barium, Chromium, and Selenium) exceeded the 2L limits for the SPLP procedure, and three metals (Arsenic, Barium, and Selenium) exceeded the 2L limits from the TCLP procedure. However, the 2L limits are meant to reflect groundwater or surface water concentrations (drinking water standards) and not necessarily concentrations of liquids within the engineered fill mass (essentially leachate concentrations). The 2L standards are referenced in those tables only to illustrate the low constituent concentrations resulting from the analytical methods.

Groundwater modeling is underway to estimate constituent concentrations in the nearest surface water stream to the Area 4 fill (Phases 1 and 1A). The modeling is being performed using the SPLP concentrations, since that procedure more closely simulates leachate generation in the proposed engineered fill (the TCLP procedure more closely resembles a municipal landfill environment). The modeling results will be presented separately upon completion.

The analytical results were below laboratory detection limits for all organic compounds analyzed (including pesticides, semi-volatiles, and volatiles), except methylene chloride. That compound is a very common laboratory contaminant, and we do not believe the concentration represents an actual specimen concentration.

Slope Stability: The physical test results were reviewed for general engineering behavioral characteristics. Slope stability analyses were performed on similar CCB engineered fills, using strength characteristics similar, or less favorable, than the results on this sample. Based on those tasks, we recommend maximum final slopes, within the CCB fill mass and including the cover layer(s) of 3H:1V or less. This slope is recommended to provide both static (long-term) and seismic stability of the engineered fill mass.

Published literature indicates textured flexible membranes can develop friction resistance along the surface mimicking the internal shear strength of the soil. As such, we recommend textured liners for the sloping portions (greater than 10 percent) of the liners and covers. If desired, smooth liners could be considered for the flat and gently sloping portions of the fill system.

Similarly, we recommend that a needle-punched geosynthetic clay liner (GCL) be used to provide adequate shear strength along sloping portions of the fill base.

Detailed slope stability analyses can be performed for specific slopes and liner components, if desired, for the Area 4 fill, once the site design is completed.

Compaction Specifications - Performance Specifications: Performance specifications are the preferred method for assuring construction quality for engineered fills and liner systems.

The physical test results indicate strength, hydraulic conductivity, and compressibility characteristics of the CCB's are similar to fills made up of naturally occurring soils in the project area. As such, CCB's and cover compaction specifications equivalent to customary requirements will result in a fill embankment satisfactory for most engineered applications, including pavement support, slope stability and maintenance, and light to moderately loaded structures as may be proposed for use by the airport facility.

For Area 4, the following table presents our recommendations for compacting and testing the CCB fill and earthen components of the engineered fill system.

CCB/Soil Compaction and Testing Recommendations

Specification or QA/QC Activity	Test Method	Recommended Frequency
CCB Engineered Fill:		
Minimum Compaction Specification	ASTM D 698	95 Percent Standard Proctor Maximum Dry Density
Moisture Range at Compaction	ASTM D 2216 ASTM D 4959	-3 to +3 % Optimum Moisture Content
Field Density Test and Moisture Frequency	ASTM D 2937 ASTM D 1556 ASTM D 2922	1 test per 1,000 cubic yards of CCB placed (4 min. per visit)
Compaction (Proctor) Test Frequency	ASTM D 698	1 test per 10,000 cubic yards of CCB's (or observed change in properties)
Earth Components of Liner Systems:		
Minimum Compaction Specification	ASTM D 698	95 Percent Standard Proctor Maximum Dry Density
Moisture Range at Compaction	ASTM D 2216 ASTM D 4959	0 to +3 % Optimum Moisture Content
Field Density Test and Moisture Frequency	ASTM D 2937 ASTM D 1556 ASTM D 2922	5 tests per acre per foot thickness, or fraction thereof (4 min. per visit)
Compaction (Proctor) Test Frequency	ASTM D 698	1 test per 5,000 cubic yards of soils (or observed change in properties)
Grain Size Atterberg Limits	ASTM D 422 ASTM D 4318	1 test per 5,000 cubic yards
Hydraulic Conductivity Sampled from Completed Liner	ASTM D 698	1 test per acre per foot

The test results and general experience indicate that CCB properties are not especially sensitive to compaction moisture content; therefore, moisture contents occasionally varying outside of the recommended limits would be acceptable as long as the recommended minimum compaction requirement is achieved.

We understand the most likely future use of a portion of the engineered fill will be an aircraft taxiway or runway (a heavy-duty pavement application). Earthen pavement subgrades achieve most favorable elastic deflection and pavement subgrade (CBR) properties when compacted at or slightly dry of their optimum moisture contents. Also, final pavement design and construction requirements might exceed the general engineered fill recommendations herein. If final pavement subgrade soils are to be placed as part of this fill project, the final one to two feet of the soil cover should be compacted to the specifications for that application.

In lieu of specific specifications or guidelines, we recommend that the final pavement subgrade soils be compacted to at least 100 percent of the material's Standard Proctor Maximum Dry Density, with compaction moisture contents between optimum and 3 percent dry of optimum. It should be noted that cover layers serving as hydraulic barriers achieve most favorable seepage properties if compacted slightly wet of optimum, so a zoned final grading plan might be advisable (one zone for cover purposes and one zone for final pavement support). More specific recommendations could be provided upon completion of a draft grading plan.

Recommendations concerning other components of the engineered fill system will be provided in a CQA document under separate cover. Those components include flexible membrane (HDPE) liners and covers, geosynthetic clay liners (GCL's), and drainage layers.

Closing: GeoTrack is pleased to be of service to you on this project. Please call if you have any questions concerning this letter or if we may provide additional assistance.

Respectfully submitted,
GeoTrack Technologies, Inc.

David D. Wilson, P.E.
Senior Engineer
NC Registration No. 17088

Attachments

Cc Mr. Norman Divers

TABLE 1 – 6.3 PHYSICAL/ENGINEERING CHARACTERISTICS
ASHEVILLE AIRPORT AREA 4
GEOTRACK PROJECT NO. 10-2626-N

Physical/Engineering Characteristic	**Test Method**	**Test Result/ Applicable Parameters**	**Remarks**
6.3.1 Grain Size Distribution	ASTM 422	17 Percent Sand 78 Percent Silt 6 Percent Clay *Grain Size Distribution Attached*	Sieve and Hydrometer
6.3.2 Specific Gravity	ASTM 854	Specific Gravity: $G_s = 2.21$	
6.3.3 Water Content	ASTM D 2216	Field Moisture Content: w = 28.5 %	Moisture Content at Time of Sampling
6.3.4 Compaction	ASTM D 698	Maximum Dry Density: $\gamma_{d\ max} = 70.7$ pcf Optimum Moisture Cont.: $w_{opt} = 31.1$ % *Moisture Density Relationship Attached*	Standard Proctor Compaction Test on combined fly ash and bottom ash sample
6.3.5 Strength:			
6.3.5.1 Shear Strength	ASTM 4767	Total Cohesion: C = 0.90 ksf Total Angle of Int. Friction: = 13° Eff. Cohesion: C'= 0 Eff. Angle of Int. Friction: Ø' = 34° *Triaxial Shear Test Report Attached*	Consolidated Undrained Triaxial Shear Test with Pore Pressure Measurements Note 3
6.3.5.2 Compressive Strength	ASTM 2850	Total Cohesion: C = 0.60 ksf Total Angle of Int. Friction: Ø = 19.5° *Triaxial Shear Test Report Attached*	Unconsolidated Undrained Triaxial Shear Test. Unconfined Compressive Strength not Meaningful for Ash Samples Note 3
6.3.6 Hydraulic Conductivity	ASTM D 5084	Hyd. Conductivity: $k = 1.6 \times 10^{-4}$ cm/sec	Note 3
6.3.7 Compressibility	ASTM D 2435	*Consolidation Test Report Attached*	Note 3

Notes:
1. Sample collected April 12, 2010
2. The section numbers refer to the applicable section of ASTM E 2277, as referenced in the Compliance Spread Sheet
3. Tests performed on specimens remolded in the laboratory to approximately 95 percent of the Standard Proctor Maximum Dry Density at approximately the Optimum Moisture Content.

Attachment 5

HELP Model and Supporting Information for Alternate Final Cover

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```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                                                                          **
**              HELP Version 3.95 D          (10 August 2012)               **
**                                developed at                              **
**        Institute of Soil Science, University of Hamburg, Germany         **
**                                  based on                                **
**              US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************
```

TIME: 14.09   DATE: 16.10.2014

```
 PRECIPITATION DATA FILE:      C:\HDR_Projects\Sanford\HELP\Charah Sanford.d4
 TEMPERATURE DATA FILE:        C:\HDR_Projects\Sanford\HELP\Charah Sanford.d7
 SOLAR RADIATION DATA FILE:    C:\HDR_Projects\Sanford\HELP\Charah Sanford.d13
 EVAPOTRANSPIRATION DATA F. 1: C:\HDR_Projects\Sanford\HELP\Charah Sanford.d11
 SOIL AND DESIGN DATA FILE  1: C:\HDR_Projects\Sanford\HELP\charah colon final
cover-top deck rev7.d10
 OUTPUT DATA FILE:             C:\HDR_Projects\Sanford\HELP\charah colon final cover
top deck-rev7.out
```

****

TITLE: Final Cover Side Slope- Top Soil and Subsoil Option

****

WEATHER DATA SOURCES

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR   RALEIGH   NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.55	3.43	3.69	2.91	3.67	3.66
4.38	4.44	3.29	2.73	2.87	3.14

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR   RALEIGH   NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
39.60	41.60	49.30	59.50	67.20	73.90
77.70	77.00	71.00	59.70	50.00	42.00

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR RALEIGH NORTH CAROLINA
AND STATION LATITUDE = 35.87 DEGREES

****

LAYER DATA 1

VALID FOR 100 YEARS

NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 9

```
THICKNESS                    =      6.00   INCHES
POROSITY                     =      0.5010 VOL/VOL
FIELD CAPACITY               =      0.2840 VOL/VOL
WILTING POINT                =      0.1350 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2864 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1900E-03 CM/SEC
```

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 5.00
FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

```
THICKNESS                    =     66.00   INCHES
POROSITY                     =      0.4710 VOL/VOL
FIELD CAPACITY               =      0.3420 VOL/VOL
WILTING POINT                =      0.2100 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.3962 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.4000E-04 CM/SEC
```

LAYER 3

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

```
THICKNESS                    =      0.21   INCHES
POROSITY                     =      0.8500 VOL/VOL
```

```
FIELD CAPACITY              =      0.0100 VOL/VOL
WILTING POINT               =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.2366 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=       4.760     CM/SEC
SLOPE                       =      2.00   PERCENT
DRAINAGE LENGTH             =    500.0    FEET


                        LAYER  4
                        --------

             TYPE 4 - FLEXIBLE MEMBRANE LINER
               MATERIAL TEXTURE NUMBER  36
THICKNESS                   =      0.04   INCHES
EFFECTIVE SAT. HYD. CONDUCT.=      0.4000E-12 CM/SEC
FML PINHOLE DENSITY         =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD


                        LAYER  5
                        --------

           TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER   0
THICKNESS                   =    720.00   INCHES
POROSITY                    =      0.5410 VOL/VOL
FIELD CAPACITY              =      0.1870 VOL/VOL
WILTING POINT               =      0.0470 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.1870 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1600E-03 CM/SEC


                        LAYER  6
                        --------

             TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.26   INCHES
POROSITY                    =      0.8500 VOL/VOL
FIELD CAPACITY              =      0.0100 VOL/VOL
WILTING POINT               =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=       9.700     CM/SEC
SLOPE                       =      2.00   PERCENT
DRAINAGE LENGTH             =    950.0    FEET


                        LAYER  7
                        --------

             TYPE 4 - FLEXIBLE MEMBRANE LINER
               MATERIAL TEXTURE NUMBER  35
THICKNESS                   =      0.06   INCHES
EFFECTIVE SAT. HYD. CONDUCT.=      0.2000E-12 CM/SEC
FML PINHOLE DENSITY         =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD
```

LAYER 8

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.25 INCHES
POROSITY	=	0.7500 VOL/VOL
FIELD CAPACITY	=	0.7470 VOL/VOL
WILTING POINT	=	0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.7470 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.	=	0.3000E-08 CM/SEC

LAYER 9

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16

THICKNESS	=	18.00 INCHES
POROSITY	=	0.4270 VOL/VOL
FIELD CAPACITY	=	0.4180 VOL/VOL
WILTING POINT	=	0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4270 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.	=	0.1000E-06 CM/SEC

****

GENERAL DESIGN AND EVAPORATIVE ZONE DATA 1

VALID FOR 100 YEARS

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER	=	89.00	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	18.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	6.047	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	8.658	INCHES
FIELD CAPACITY OF EVAPORATIVE ZONE	=	5.808	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	3.330	INCHES
SOIL EVAPORATION ZONE DEPTH	=	18.000	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL INTERCEPTION WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	170.434	INCHES
TOTAL INITIAL WATER	=	170.434	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

****

EVAPOTRANSPIRATION DATA 1

VALID FOR 100 YEARS

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
RALEIGH NORTH CAROLINA

STATION LATITUDE	=	35.87 DEGREES
MAXIMUM LEAF AREA INDEX	=	4.50
START OF GROWING SEASON (JULIAN DATE)	=	86
END OF GROWING SEASON (JULIAN DATE)	=	310
EVAPORATIVE ZONE DEPTH	=	18.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	7.70 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	66.0 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.0 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	78.0 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	72.0 %

****

****

FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	1.6981	0.2830
2	25.2440	0.3825
3	0.0505	0.2404
4	0.0000	0.0000
5	134.6400	0.1870
6	0.0026	0.0101
7	0.0000	0.0000
8	0.1867	0.7470
9	7.6860	0.4270
TOTAL WATER IN LAYERS	169.508	
SNOW WATER	0.000	
INTERCEPTION WATER	0.000	
TOTAL FINAL WATER	169.508	

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	5.22	18948.600
RUNOFF	3.036	11019.6533
DRAINAGE COLLECTED FROM LAYER 3	0.23231	843.27509
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.003584	13.00886
AVERAGE HEAD ON TOP OF LAYER 4	36.103	
MAXIMUM HEAD ON TOP OF LAYER 4	45.513	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	192.0 FEET	
DRAINAGE COLLECTED FROM LAYER 6	0.00450	16.34715
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000000	0.00003
AVERAGE HEAD ON TOP OF LAYER 7	0.004	
MAXIMUM HEAD ON TOP OF LAYER 7	0.040	
LOCATION OF MAXIMUM HEAD IN LAYER 6 (DISTANCE FROM DRAIN)	0.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000000	0.00003
AVERAGE HEAD ON TOP OF LAYER 9	0.000	
SNOW WATER	3.56	12918.0498
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4229	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1850	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

****

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.66	3.21	3.90	3.07	3.53	3.90
	4.28	4.91	3.41	2.84	2.99	2.98

STD. DEVIATIONS	1.92	1.63	1.42	1.34	1.84	2.01
	1.90	2.75	2.13	1.73	1.84	1.56

RUNOFF

TOTALS	0.404	0.309	0.281	0.126	0.222	0.257
	0.301	0.592	0.389	0.271	0.312	0.267
STD. DEVIATIONS	0.494	0.441	0.290	0.173	0.366	0.359
	0.405	0.773	0.535	0.375	0.408	0.325

POTENTIAL EVAPOTRANSPIRATION

TOTALS	1.867	2.198	3.605	4.849	6.329	7.019
	6.807	6.063	4.589	3.407	2.162	1.609
STD. DEVIATIONS	0.176	0.222	0.268	0.325	0.284	0.302
	0.314	0.271	0.277	0.205	0.168	0.131

ACTUAL EVAPOTRANSPIRATION

TOTALS	1.126	1.432	2.315	3.407	4.019	3.563
	3.856	3.727	2.573	1.138	0.890	0.842
STD. DEVIATIONS	0.223	0.258	0.346	0.593	1.288	1.442
	1.389	1.305	1.047	0.316	0.222	0.212

LATERAL DRAINAGE COLLECTED FROM LAYER 3

TOTALS	1.7591	1.8285	1.6542	1.2669	0.8305	0.4630
	0.1506	0.0958	0.1801	0.2473	0.4566	1.1402
STD. DEVIATIONS	1.0680	1.1811	0.9776	0.7343	0.3596	0.2408
	0.2059	0.2376	0.5424	0.4872	0.6767	1.1167

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0013	0.0027	0.0008	0.0005	0.0003	0.0002
	0.0001	0.0000	0.0003	0.0001	0.0002	0.0008
STD. DEVIATIONS	0.0023	0.0078	0.0011	0.0005	0.0001	0.0001
	0.0001	0.0001	0.0021	0.0002	0.0004	0.0018

LATERAL DRAINAGE COLLECTED FROM LAYER 6

TOTALS	0.0011	0.0025	0.0012	0.0005	0.0003	0.0002
	0.0001	0.0000	0.0003	0.0001	0.0002	0.0008
STD. DEVIATIONS	0.0019	0.0062	0.0038	0.0006	0.0001	0.0001
	0.0001	0.0001	0.0021	0.0002	0.0004	0.0018

PERCOLATION/LEAKAGE THROUGH LAYER 7

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 9

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.2629	0.7898	0.1304	0.0592	0.0248	0.0143
	0.0045	0.0029	0.0695	0.0097	0.0257	0.1590
STD. DEVIATIONS	0.6663	2.6631	0.2749	0.1407	0.0108	0.0074
	0.0062	0.0071	0.6525	0.0347	0.0846	0.5056

DAILY AVERAGE HEAD ON TOP OF LAYER 7

AVERAGES	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0001	0.0002	0.0001	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001

DAILY AVERAGE HEAD ON TOP OF LAYER 9

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES		CU. FEET	PERCENT
PRECIPITATION	42.69	(6.985)	154963.6	100.00
RUNOFF	3.730	(1.7277)	13541.61	8.739
POTENTIAL EVAPOTRANSPIRATION	50.506	(0.9138)	183335.89	
ACTUAL EVAPOTRANSPIRATION	28.888	(3.1727)	104864.87	67.671
LATERAL DRAINAGE COLLECTED FROM LAYER 3	10.07277	(3.63240)	36564.148	23.59531
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00733	(0.01028)	26.610	0.01717
AVERAGE HEAD ON TOP OF LAYER 4	0.129	(0.277)		
LATERAL DRAINAGE COLLECTED	0.00733	(0.01028)	26.603	0.01717

```
  FROM LAYER  6

 PERCOLATION/LEAKAGE THROUGH     0.00000 (  0.00000)         0.007     0.00000
  LAYER  7

 AVERAGE HEAD ON TOP             0.000   (    0.000)
  OF LAYER  7

 PERCOLATION/LEAKAGE THROUGH     0.00000 (  0.00000)         0.007     0.00000
  LAYER  9

 AVERAGE HEAD ON TOP             0.000   (    0.000)
  OF LAYER  9

 CHANGE IN WATER STORAGE        -0.009   (  1.6409)        -33.62     -0.022

*******************************************************************************
*******************************************************************************
```

charah colon final cover-side slope rev7

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                                                                          **
**              HELP Version 3.95 D          (10 August 2012)               **
**                                developed at                              **
**        Institute of Soil Science, University of Hamburg, Germany         **
**                                  based on                                **
**              US HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************
```

TIME: 14.11 DATE: 16.10.2014

PRECIPITATION DATA FILE: C:\HDR_Projects\Sanford\HELP\Charah Sanford.d4
TEMPERATURE DATA FILE: C:\HDR_Projects\Sanford\HELP\Charah Sanford.d7
SOLAR RADIATION DATA FILE: C:\HDR_Projects\Sanford\HELP\Charah Sanford.d13
EVAPOTRANSPIRATION DATA F. 1: C:\HDR_Projects\Sanford\HELP\Charah Sanford.d11
SOIL AND DESIGN DATA FILE 1: C:\HDR_Projects\Sanford\HELP\charah colon final cover-side slope rev7.d10
OUTPUT DATA FILE: C:\HDR_Projects\Sanford\HELP\charah colon final cover-side slope rev7.out

****

TITLE: Final Cover Side Slope- Top Soil and Subsoil Option

****

WEATHER DATA SOURCES

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR RALEIGH NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.55	3.43	3.69	2.91	3.67	3.66
4.38	4.44	3.29	2.73	2.87	3.14

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR RALEIGH NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
39.60	41.60	49.30	59.50	67.20	73.90
77.70	77.00	71.00	59.70	50.00	42.00

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR RALEIGH NORTH CAROLINA
AND STATION LATITUDE = 35.87 DEGREES

****

LAYER DATA 1

VALID FOR 100 YEARS

NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 9

```
THICKNESS                    =      6.00   INCHES
POROSITY                     =      0.5010 VOL/VOL
FIELD CAPACITY               =      0.2840 VOL/VOL
WILTING POINT                =      0.1350 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2868 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1900E-03 CM/SEC
```

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 5.00
FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

```
THICKNESS                    =     42.00   INCHES
POROSITY                     =      0.4710 VOL/VOL
FIELD CAPACITY               =      0.3420 VOL/VOL
WILTING POINT                =      0.2100 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.3923 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.4000E-04 CM/SEC
```

LAYER 3

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

```
THICKNESS                    =      0.21   INCHES
POROSITY                     =      0.8500 VOL/VOL
```

```
FIELD CAPACITY              =      0.0100 VOL/VOL
WILTING POINT               =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0345 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=       2.760     CM/SEC
SLOPE                       =     25.00   PERCENT
DRAINAGE LENGTH             =    140.0    FEET
```

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 36

```
THICKNESS                   =      0.04   INCHES
EFFECTIVE SAT. HYD. CONDUCT.=      0.4000E-12 CM/SEC
FML PINHOLE DENSITY         =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD
```

LAYER 5

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER   0

```
THICKNESS                   =    360.00   INCHES
POROSITY                    =      0.5410 VOL/VOL
FIELD CAPACITY              =      0.1870 VOL/VOL
WILTING POINT               =      0.0470 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.1870 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=      0.1600E-03 CM/SEC
```

LAYER 6

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER   0

```
THICKNESS                   =      0.26   INCHES
POROSITY                    =      0.8500 VOL/VOL
FIELD CAPACITY              =      0.0100 VOL/VOL
WILTING POINT               =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.=       9.700     CM/SEC
SLOPE                       =      2.00   PERCENT
DRAINAGE LENGTH             =    950.0    FEET
```

LAYER 7

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

```
THICKNESS                   =      0.06   INCHES
EFFECTIVE SAT. HYD. CONDUCT.=      0.2000E-12 CM/SEC
FML PINHOLE DENSITY         =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD
```

LAYER 8

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.25 INCHES
POROSITY	=	0.7500 VOL/VOL
FIELD CAPACITY	=	0.7470 VOL/VOL
WILTING POINT	=	0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.7470 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.	=	0.3000E-08 CM/SEC

LAYER 9

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16

THICKNESS	=	18.00 INCHES
POROSITY	=	0.4270 VOL/VOL
FIELD CAPACITY	=	0.4180 VOL/VOL
WILTING POINT	=	0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4270 VOL/VOL
EFFECTIVE SAT. HYD. CONDUCT.	=	0.1000E-06 CM/SEC

****

GENERAL DESIGN AND EVAPORATIVE ZONE DATA 1

VALID FOR 100 YEARS

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER	=	89.00	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	18.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	6.074	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	8.658	INCHES
FIELD CAPACITY OF EVAPORATIVE ZONE	=	5.808	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	3.330	INCHES
SOIL EVAPORATION ZONE DEPTH	=	18.000	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL INTERCEPTION WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	93.398	INCHES
TOTAL INITIAL WATER	=	93.398	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

****

EVAPOTRANSPIRATION DATA 1

VALID FOR 100 YEARS

```
       NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
                RALEIGH             NORTH CAROLINA
           STATION LATITUDE                          =  35.87 DEGREES
           MAXIMUM LEAF AREA INDEX                   =   4.50
           START OF GROWING SEASON (JULIAN DATE)     =    86
           END OF GROWING SEASON (JULIAN DATE)       =   310
           EVAPORATIVE ZONE DEPTH                    =  18.0  INCHES
           AVERAGE ANNUAL WIND SPEED                 =   7.70 MPH
           AVERAGE 1ST QUARTER RELATIVE HUMIDITY     =  66.0  %
           AVERAGE 2ND QUARTER RELATIVE HUMIDITY     =  70.0  %
           AVERAGE 3RD QUARTER RELATIVE HUMIDITY     =  78.0  %
           AVERAGE 4TH QUARTER RELATIVE HUMIDITY     =  72.0  %

******************************************************************************



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                   FINAL WATER STORAGE AT END OF YEAR  100
------------------------------------------------------------------------------

                    LAYER        (INCHES)       (VOL/VOL)
                    -----        --------       ---------
                      1            1.6985         0.2831

                      2           15.8912         0.3784

                      3            0.0045         0.0215

                      4            0.0000         0.0000

                      5           67.3200         0.1870

                      6            0.0026         0.0100

                      7            0.0000         0.0000

                      8            0.1867         0.7470

                      9            7.6860         0.4270

    TOTAL WATER IN LAYERS         92.790

    SNOW WATER                     0.000

    INTERCEPTION WATER             0.000

    TOTAL FINAL WATER             92.790

******************************************************************************



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                PEAK DAILY VALUES FOR YEARS    1 THROUGH  100
------------------------------------------------------------------------------
```

	(INCHES)	(CU. FT.)
PRECIPITATION	5.22	18948.600
RUNOFF	3.211	11655.5000
DRAINAGE COLLECTED FROM LAYER 3	0.74226	2694.39526
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000012	0.04331
AVERAGE HEAD ON TOP OF LAYER 4	0.028	
MAXIMUM HEAD ON TOP OF LAYER 4	0.077	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	0.0 FEET	
DRAINAGE COLLECTED FROM LAYER 6	0.00001	0.03708
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000000	0.00002
AVERAGE HEAD ON TOP OF LAYER 7	0.000	
MAXIMUM HEAD ON TOP OF LAYER 7	0.039	
LOCATION OF MAXIMUM HEAD IN LAYER 6 (DISTANCE FROM DRAIN)	0.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000000	0.00002
AVERAGE HEAD ON TOP OF LAYER 9	0.000	
SNOW WATER	3.56	12918.0498
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4338	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1850	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.66	3.21	3.90	3.07	3.53	3.90
	4.28	4.91	3.41	2.84	2.99	2.98

STD. DEVIATIONS	1.92	1.63	1.42	1.34	1.84	2.01
	1.90	2.75	2.13	1.73	1.84	1.56

RUNOFF

TOTALS	0.428	0.332	0.302	0.135	0.226	0.261
	0.309	0.606	0.401	0.283	0.333	0.281
STD. DEVIATIONS	0.520	0.474	0.314	0.189	0.376	0.367
	0.419	0.806	0.558	0.395	0.441	0.341

POTENTIAL EVAPOTRANSPIRATION

TOTALS	1.867	2.198	3.605	4.849	6.329	7.019
	6.807	6.063	4.589	3.407	2.162	1.609
STD. DEVIATIONS	0.176	0.222	0.268	0.325	0.284	0.302
	0.314	0.271	0.277	0.205	0.168	0.131

ACTUAL EVAPOTRANSPIRATION

TOTALS	1.126	1.432	2.314	3.413	4.090	3.579
	3.866	3.734	2.580	1.135	0.887	0.841
STD. DEVIATIONS	0.223	0.258	0.348	0.588	1.287	1.451
	1.395	1.310	1.047	0.314	0.221	0.212

LATERAL DRAINAGE COLLECTED FROM LAYER 3

TOTALS	1.9347	1.7383	1.6107	1.0547	0.5151	0.1299
	0.0548	0.0987	0.1975	0.2796	0.7483	1.4381
STD. DEVIATIONS	1.0786	1.2296	0.9777	0.6318	0.3415	0.2339
	0.1718	0.3064	0.5136	0.5977	0.9110	1.1331

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

LATERAL DRAINAGE COLLECTED FROM LAYER 6

TOTALS	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 7

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 9

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0024	0.0023	0.0020	0.0013	0.0006	0.0002
	0.0001	0.0001	0.0003	0.0003	0.0009	0.0018
STD. DEVIATIONS	0.0013	0.0016	0.0012	0.0008	0.0004	0.0003
	0.0002	0.0004	0.0007	0.0007	0.0012	0.0014

DAILY AVERAGE HEAD ON TOP OF LAYER 7

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

DAILY AVERAGE HEAD ON TOP OF LAYER 9

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES		CU. FEET	PERCENT
PRECIPITATION	42.69	(6.985)	154963.6	100.00
RUNOFF	3.899	(1.8278)	14152.28	9.133
POTENTIAL EVAPOTRANSPIRATION	50.506	(0.9138)	183335.89	
ACTUAL EVAPOTRANSPIRATION	28.996	(3.2020)	105256.68	67.923
LATERAL DRAINAGE COLLECTED FROM LAYER 3	9.80048	(3.58097)	35575.734	22.95748
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00028	(0.00009)	1.019	0.00066
AVERAGE HEAD ON TOP OF LAYER 4	0.001	(0.000)		
LATERAL DRAINAGE COLLECTED	0.00028	(0.00009)	1.014	0.00065

FROM LAYER 6				
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.00000	(0.00000)	0.005	0.00000
AVERAGE HEAD ON TOP OF LAYER 7	0.000	(0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.00000	(0.00000)	0.005	0.00000
AVERAGE HEAD ON TOP OF LAYER 9	0.000	(0.000)		
CHANGE IN WATER STORAGE	-0.006	(1.3059)	-22.09	-0.014

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HDR Engineering, Inc.		Job No	No.
Project: Sanford Mine Final Cover		Computed: K. Perera	Date: 10/16/2014
Task: Hydraulic Conductivity and Drainage Layer Capacity		Checked: TY	Date: 11/6/14

Problem

Determine the hydraulic conductivity and drainage capacity of the geocomposite drainage layer in the final cover top deck

Transmissivity Calculations

Final cover liner from bottom to top: 40-mil LLPE - Double-sided Geocomposite - 5.5 Ft low permeability soil- 6-inch top soil

Determine 100-hour transmissivity (Θ_{100})

Use GSE 250-mil GSE FabriNet HF or equivalent (see attached cut sheet with product specifications).

$$\Theta_{allow} = \frac{\Theta_{100}}{RF_{CR} * RF_{CC} * RF_{BC}}$$

$$\Theta_{allow} = \Theta_{req} \cdot FS_D$$

$$\Theta_{req} = k \cdot b$$

where,

- Θ_{allow} = minimum allowable transmissivity of geocomposite (cm^2/s)
- Θ_{req} = required transmissivity for site (cm^2/s)
- FS_D = overall factor of safety for drainage
- Θ_{100} = transmissivity after 100 hrs. under expected load (cm^2/s)
- RF_{CR} = reduction factor for creep deformation
- RF_{CC} = reduction factor for chemical clogging
- RF_{BC} = reduction factor for biological clogging
- k = saturated hydraulic conductivity (cm/s)
- b = thickness of geonet (cm)

Information based on product data for GSE FabriNet HF 250mil. Site specific testing is recommended before selecting the material for installation to confirm minimum transmissivity.

Parameters	Geocomposite (250-mil) @ 1,000 psf (1)
Slope	0.25
FS_D (2)	2.0
RF_{CR} (2)	1.02
RF_{CC} (2)	1.1
RF_{BC} (2)	1.4
Θ_{100} (m^2/s)	0.00095
Θ_{allow} (cm^2/s)	6.05
Θ_{req} (cm^2/s)	3.02
Manufactured Thickness (mils)	250
Manufactured Thickness (cm)	0.64
Design Hydraulic Conductivity (cm/s)	4.76
Retained Final Thickness (mils)	213.8

Notes:

1. psf = pounds per square foot
2. Reduction factors based on HDR experience and information provided by GSE.

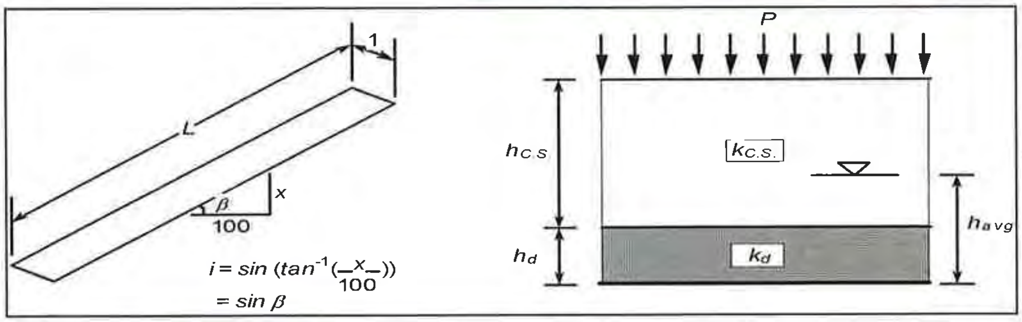
HDR Engineering, Inc.

Project: Sanford Mine Final Cover	Job No		No.
Task: Hydraulic Conductivity and Drainage Layer Capacity	Computed: K. Perera		Date: 10/16/2014
	Checked: TY		Date: 11/6/14

HDR

Drainage Capacity Calculations:

Selected Geocomposite: 250-mil double-sided GSE FabriNet HF or Similar



Input	Value	Unit	Calculated	Value	Unit
L =	152.0	m	i =	0.0200	
β =	1.1	°	$L(\cos\beta)$ =	151.97	m
$h_{C.S.}$ (Depth of Cover Soil)=	1829	mm	$h_{C.S}$ =	1.8290	m
h_d (Depth of Drainage Layer)=	5.4	mm	h_d =	0.0054	m
$k_{C.S.}$ (Specification)=	4.0E-05	cm/s	$h_{C.S} + h_d$ =	1.8344	m
k_d =	4.76E+00	cm/s			
P, Rainfall Intensity =	208.03	mm/hr	$k_{C.S.}$ =	4.0E-07	m/s
RC, Runoff Coefficient =	0.1		k_d =	4.8E-02	m/s

Where:
L = Max drainage length of slope measured along geomembrane (calculated from drawings)

β = Side Slope angle (maximum value)
k = Hydraulic Conductivity
P = Rainfall Intensity (From FDOT Drainage Manual)
RC = Runoff Coefficient (conservative assumption)

q_i, *Percolation through cover soil* = 1.44 mm/hr
($q_i = k_{C.S.} \times 60$ s/min $\times 60$ min/hr $\times 10$ mm/cm)

$$q_i = \begin{cases} k_{cover} & \text{if } P(1-RC) \geq k_{cover} \\ P(1-RC) & \text{if } P(1-RC) < k_{cover} \end{cases}$$

Actual runoff = 206.59 mm/hr (Rainfall Intensity - Percolation through cover)

$FLUX_{actual} = q_i \times L(\cos\beta) = 0.219$ m^2/hr

$FLUX_{allow} = k_d \times h_d \times \sin\beta = 0.019$ m^2/hr

Drainage Layer Capacity ($FLUX_{allow} / FLUX_{actual}$) = **0.0850**

Conclusions:

- The saturated hydraulic conductivity of the geocomposite is calculated to be 4.76 cm/s.
- The drainage layer capacity is sufficient for the geocomposite in the final cover for 25-year storm event.

HDR Engineering, Inc.

Project: Sanford Mine Final Cover	Job No.	No.
Task: Hydraulic Conductivity and Drainage Layer Capacity	Computed: K. Perera	Date: 10/14/2014
	Checked: TY	Date: 11/6/14

HDR

Problem

Determine the hydraulic conductivity and drainage capacity of the geocomposite drainage layer in the final cover side slope.

Transmissivity Calculations

Final cover liner from bottom to top: 40-mil LLPE - Double-sided Geocomposite - 3.5-ft low permeability soil- 6-inch top soil

Determine 100-hour transmissivity (Θ_{100}).

Use GSE 250-mil GSE Fabrinet HF or equivalent (see attached cut sheet with product specifications).

$$\Theta_{allow} = \frac{\Theta_{100}}{RF_{CR} * RF_{CC} * RF_{BC}}$$

$$\Theta_{allow} = \Theta_{req} \cdot FS_D$$

$$\Theta_{req} = k \cdot b$$

where,

- Θ_{allow} = minimum allowable transmissivity of geocomposite (cm^2/s)
- Θ_{req} = required transmissivity for site (cm^2/s)
- FS_D = overall factor of safety for drainage
- Θ_{100} = transmissivity after 100 hrs. under expected load (cm^2/s)
- RF_{CR} = reduction factor for creep deformation
- RF_{CC} = reduction factor for chemical clogging
- RF_{BC} = reduction factor for biological clogging
- k = saturated hydraulic conductivity (cm/s)
- b = thickness of geonet (cm)

Information based on product data for GSE FabriNet HF 250 mil. Site specific testing is recommended before selecting the material for installation to confirm minimum transmissivity.

Parameters	Geocomposite (250-mil) @ 1,000 psf (1)
Slope	0.25
FS_D (2)	2.0
RF_{CR} (2)	1.02
RF_{CC} (2)	1.1
RF_{BC} (2)	1.4
Θ_{100} (m^2/s)	0.00055
Θ_{allow} (cm^2/s)	3.50
Θ_{req} (cm^2/s)	1.75
Manufactured Thickness (mils)	250
Manufactured Thickness (cm)	0.64
Design Hydraulic Conductivity (cm/s)	2.76
Retained Final Thickness (mils)	213.8

Notes:

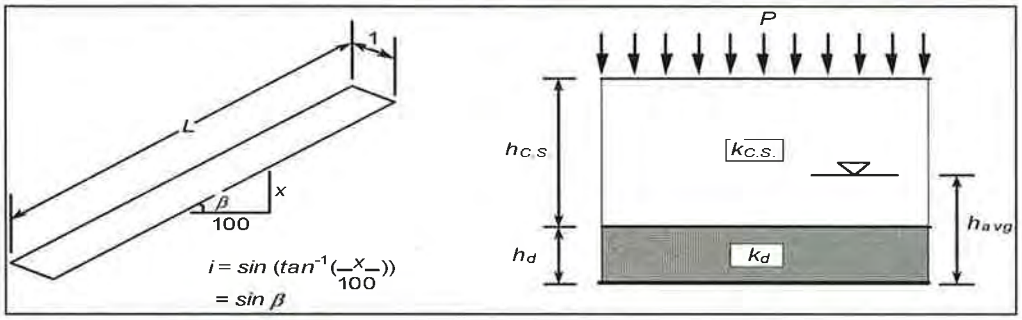
1. psf = pounds per square foot
2. Reduction factors based on HDR experience and information provided by GSE.

HDR Engineering, Inc.

Job No		No.	HDR
Project	Sanford Mine Final Cover		
Task	Hydraulic Conductivity and Drainage Layer Capacity		
Computed	K. Perera	Date	10/14/2014
Checked	TY	Date	11/6/14

Drainage Capacity Calculations:

Selected Geocomposite: 250-mil double-sided GSE FabriNet HF or Similar



L =	42.6	m	i =	0.2425		
β =	14.0	°	$L(\cos\beta)$ =	41.29	m	Where: L = Max drainage length of slope measured along geomembrane (calculated from drawings)
$h_{C.S.}$ (Depth of Cover Soil)=	1219	mm	$h_{C.S.}$ =	1.2192	m	
h_d (Depth of Drainage Layer)=	5.4	mm	h_d =	0.0054	m	β = Side Slope angle (maximum value)
$k_{C.S}$ (Specification)=	4.0E-05	cm/s	$h_{C.S.}+h_d$ =	1.2246	m	k = Hydraulic Conductivity
k_d =	2.76E+00	cm/s				P = Rainfall Intensity (From FDOT Drainage Manual)
P, Rainfall Intensity =	208.03	mm/hr	$k_{C.S}$ =	4.0E-07	m/s	RC = Runoff Coefficient (conservative assumption)
RC, Runoff Coefficient =	0.1		k_d =	2.8E-02	m/s	

q_i, *Percolation through cover soil* = 1.44 mm/hr

($q_i = k_{C.S.} \times$ 60 s/min × 60 min/hr × 10 mm/cm)

$$q_i = \begin{cases} k_{cover}, & \text{if } P(1-RC) \geq k_{cover} \\ P(1-RC), & \text{if } P(1-RC) < k_{cover} \end{cases}$$

Actual runoff = 206.59 mm/hr (Rainfall Intensity - Percolation through cover)

$FLUX_{actual} = q_i \times L(\cos\beta)$ = 0.059 m^2/hr

$FLUX_{allow} = k_d \times h_d \times \sin\beta$ = 0.130 m^2/hr

Drainage Layer Capacity ($FLUX_{allow}$ / $FLUX_{actual}$) = **2.1857**

Conclusions:

- The saturated hydraulic conductivity of the geocomposite is calculated to be 2.76 cm/s.
- The drainage layer capacity is sufficient for the geocomposite in the final cover for 25-year storm event.

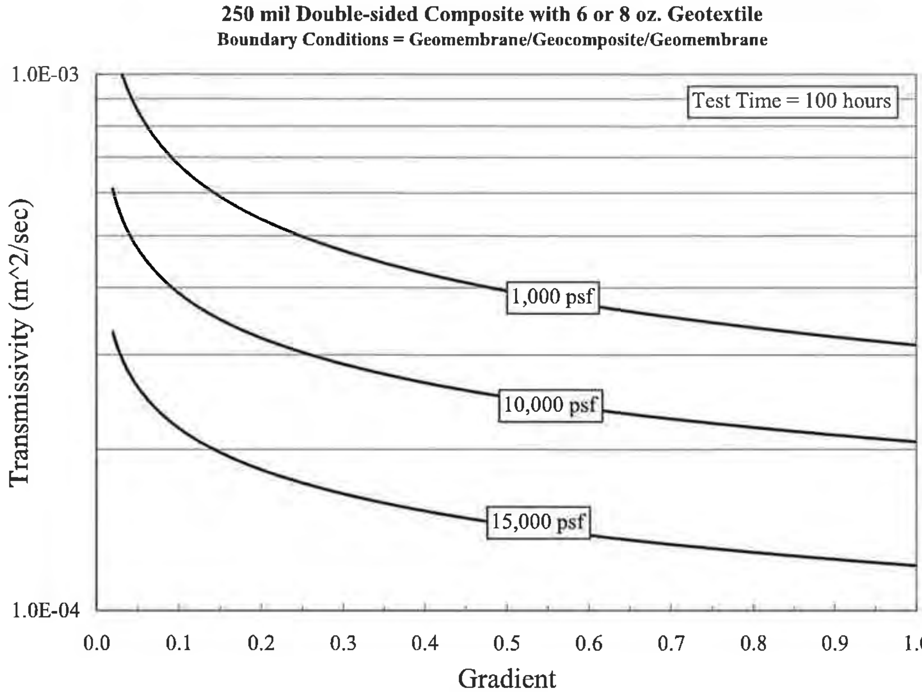


Figure A-5. Performance Transmissivity of a 250 mil GSE HyperNet HF geonet between Plates.

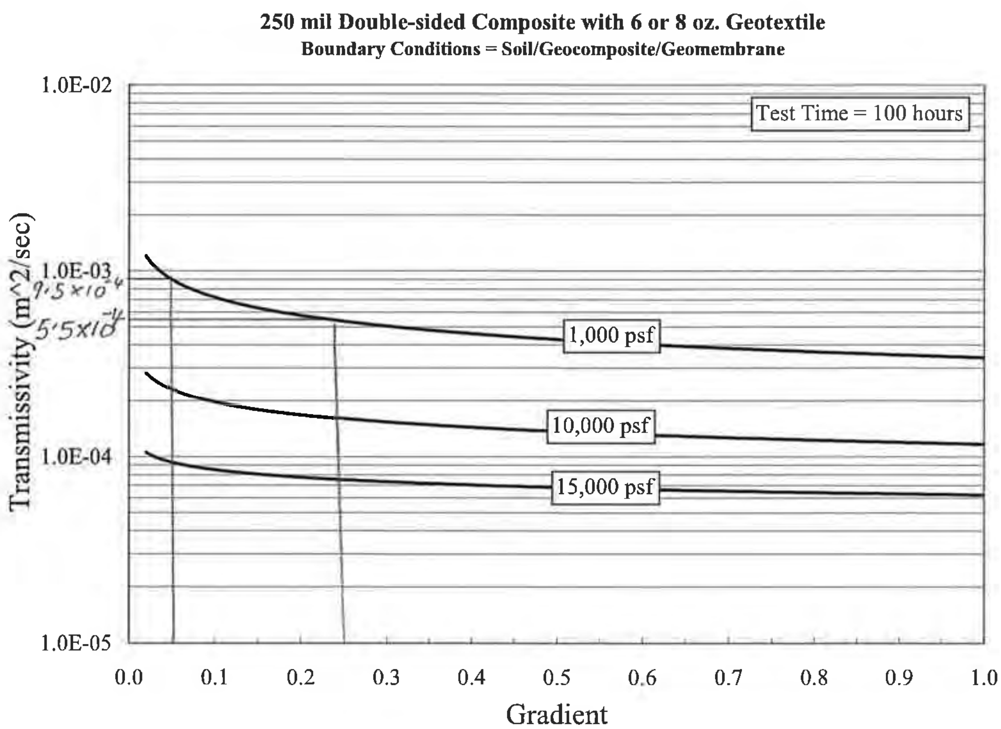


Figure A-6. Performance Transmissivity of a 250 mil GSE FabriNet HF geocomposite under Sand.

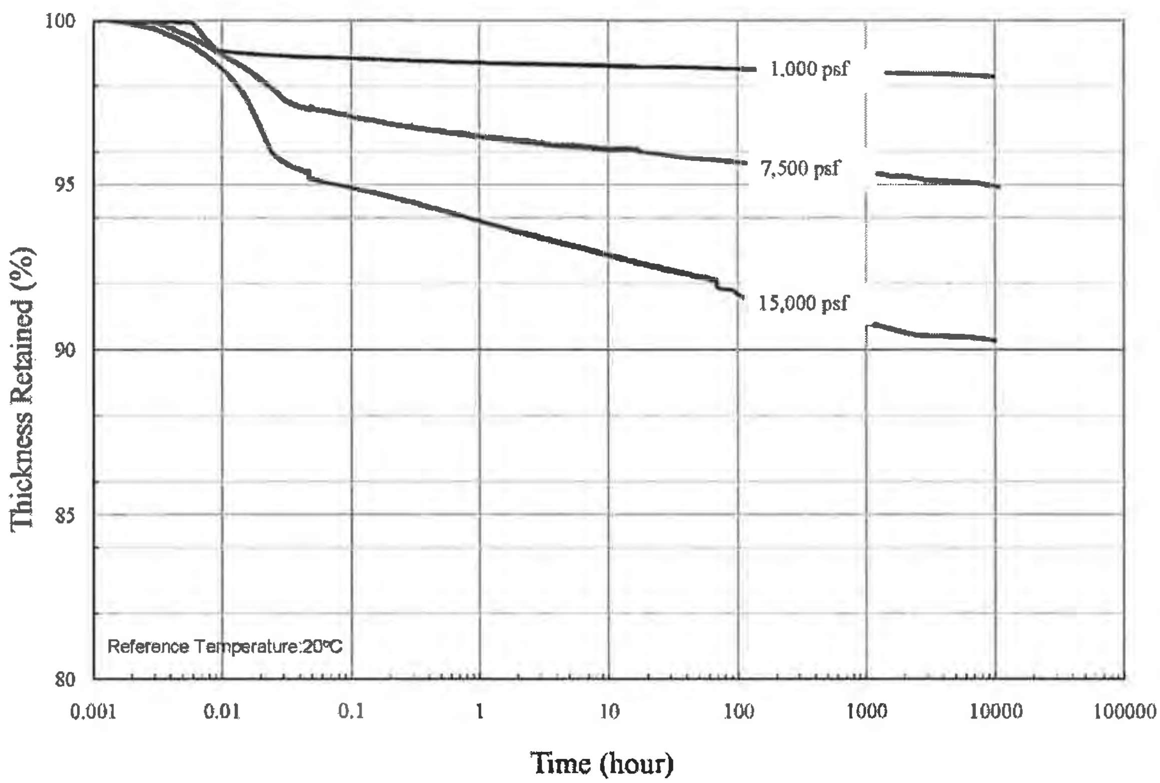


Figure B-3. Creep Curves for a 300 mil GSE HyperNet UF geonet.

Table B-3. Creep Reduction Factors for a 300 mil GSE HyperNet UF geonet from 100 hours to 50 Years.

use 1.02

Stress (psf)	Creep Reduction Factor
1,000	1.00
5,000	1.06
15,000	1.19

The long term performance of a lateral drain requires a larger initial transmissivity, θ_{LTIS}, than that obtained from the design equations, $\theta_{req'd}$. This process was initially quantified by Koerner (1998) as follows:

$$FS = \frac{\theta_{LTIS}}{\theta_{req'd}} \qquad \text{Eq. 3.2}$$

$$\theta_{LTIS} = \frac{\theta_{measured}}{RF_{in} \cdot RF_{cr} \cdot RF_{cc} \cdot RF_{bc}} \qquad \text{Eq. 3.3}$$

where FS is the overall safety factor for drainage, θ_{LTIS} is the long-term-in-soil hydraulic transmissivity of the drainage geocomposite, $\theta_{req'd}$ is the required transmissivity (e.g., for MTG= $3*10^{-5}$ m^3/sec-m), $\theta_{measured}$ is the transmissivity measured in accordance with ASTM D4716, and RF are service reduction factors described as follows:

- RF_{in} = reduction factor for elastic deformation, or intrusion of the adjacent geotextiles into the drainage channel.
- RF_{cr} = reduction factor for creep deformation of the drainage core and/or adjacent geotextile into the drainage channel.
- RF_{cc} = reduction factor for chemical clogging and/or precipitation of chemicals in the drainage core space.
- RF_{bc} = reduction factor for biological clogging in the drainage core space.

Suggested empirical default values of the reduction factors are listed in Table 3.1 (Koerner, 1998). Currently, laboratory testing can be performed to evaluate RF_{in} and RF_{cr} on a site and drainage composite specific basis. Such testing is discussed in this chapter.

Table 3.1 Recommended preliminary reduction factor values for determining allowable flow rate or transmissivity of geonets (Koerner, 1998)

Application area	RF_{in}	RF_{cr}	RF_{cc}	RF_{bc}
Surface water drains for covers	1.3 - 1.5	1.1 - 1.4	1.0 - 1.2	1.2 – 1.5
Leachate Collection and Removal Systems (LCRS)	1.5 - 2.0	1.4 - 2.0	1.5 - 2.0	1.5 - 2.0
Leachate Detection Systems (LDS)	1.5 - 2.0	1.4 - 2.0	1.5 - 2.0	1.5 - 2.0

While the above total safety factors may appear to be very conservative there may be long-term service reduction factors not accounted for. For instance, Figure 3.1 shows extensive root penetration into a geonet that was recovered from a failed landfill cover. The root penetration was so dense that the transmissivity of the geonet drainage core was essentially reduced to zero. The authors feel that root penetration in cover lateral drains can be minimized only by using high capacity drainage composites that quickly remove water from the drain so that roots are not attracted within the core.

Ref:
Richardson G.N., Giroud J.P and Zhao A. (2000)
Design of Lateral drainage ~~[illegible]~~ Systems for Landfills.

It is often desirable to develop a composite runoff coefficient based on the percentage of different types of surfaces in the drainage areas. Composites can be made with the values from Table 2.2 by using percentages of different land uses, as illustrated in Equation 2.2. In addition, more detailed composites can be made with coefficients for different surface types such as roofs, asphalt, and concrete streets, drives and walks. The composite procedure can be applied to an entire drainage area or to typical "sample" blocks as a guide to the selection of reasonable values of the coefficient for an entire area.

Equation 2.2 Composite C

$$\text{Composite C} = \frac{C1*A1 + C2*A2 + \ldots Cx*Ax}{A1 + A2 + \ldots Ax}$$

2.2.3 Rainfall Intensity

The rainfall intensity (I) is the average rainfall rate in in./hr for a duration equal to the time of concentration for a selected return period. Once a particular return period has been selected for design and a time of concentration calculated for the drainage area, the rainfall intensity can be determined from the intensity-duration-frequency (IDF) data for the City of Raleigh given in Table 2.3.

Intensity used when determining drainage layer capacity

Table 2.3 Intensity – Duration - Frequency Table
City of Raleigh, NC
(Developed by Dr. H.R. Malcom, North Carolina State University, Dept. of Civil Engineering, and the authors based on NOAA HYDRO-35 and USWB TP-40)

	Frequency (Yrs)					
Duration	2	5	10	25	50	100
5 mins	5.76	6.58	7.22	8.19	8.96	9.72
10	4.76	5.54	6.13	7.01	7.71	8.40
15	4.04	4.74	5.25	6.03	6.64	7.24
20	3.47	4.12	4.64	5.42	5.93	6.47
30	2.70	3.28	3.71	4.32	4.80	5.28
40	2.28	2.77	3.15	3.70	4.08	4.48
50	1.94	2.38	2.71	3.19	3.53	3.88
60	1.70	2.12	2.41	2.84	3.17	3.50
90	1.22	1.52	1.74	2.06	2.29	2.53
2 hr	0.95	1.20	1.37	1.62	1.81	2.00
3	0.71	0.89	1.02	1.21	1.35	1.50
6	0.44	0.56	0.65	0.77	0.86	0.96
12	0.26	0.33	0.39	0.46	0.52	0.57
24	0.15	0.19	0.22	0.27	0.30	0.33

HDR Computation

		Job Number	453925-235691-018	**No.**	
Project	Charah Colon Mine Site	**Computed**	MDP	**Date**	10/4/2014
Subject	Permit Application	**Checked**	**KP**	**Date**	11/6/2014
Task	Leachate Pipe Sizing	**Sheet**	1	**Of**	2

Objective:

Determine the required leachate collection pipe sizing.

References:

1. "Waste Containment Systems, Waste Stabilization, and Landfills; Design and Evaluation"; Hari Sharma and Sangeeta Lewis; p. 466.
2. "Elements of Urban Stormwater Design"; H. Rooney Malcom; p. I-10

Calculations:

$$D_{REQD} = 16\left[\frac{Qn}{\sqrt{s}}\right]^{\frac{3}{8}}$$ (Ref. 2)

Volume (ft^3) = Peak Daily Volume (ft^3/acre) x Area (acre)
Peak Daily Volume is from the HELP Model runs

Q = Volume/time (convert to ft^3/sec)

Where:

D_{REQD} = theoretical pipe diamter (in.) for just-full flow
n = Manning roughness coefficient (dimensionless
s = longitudinal slope (ft/ft)
Q = Required flow volume to drain in 24 hrs. (cfs)

Inputs:

Peak Daily Volume* =	539	ft^3 leachate collected over 1 acre in 24 hours	12	in/foot
n =	0.009	Ref. 1, Table 9.3, p. 472 (HDPE)	43,560	square feet/acre
			24	hours/day
			60	min/hour
			60	sec/min

* Peak Daily Volume from HELP model run for 20' ash with geocomposite as lateral drainage feature.

HDR Computation

Job Number	453925-235691-018	**No.**	
Project	Charah Colon Mine Site	**Computed** MDP	**Date** 10/4/2014
Subject	Permit Application	**Checked** **KP**	**Date** 11/6/2014
Task	Leachate Pipe Sizing	**Sheet** 2	**Of** 2

Outputs:

Pipe Use	Area (AC)**	Volume (ft^3)	Q (ft^3/sec)***	Minimum Slope	D_{REQD} (in)	**D_{ACT} (in)**	Check
Cell 1 Header	28.9	15,577	0.180	0.50%	3.9	**8**	ok
Subcell 1A Header	8.0	4,312	0.050	0.50%	2.4	**8**	ok
Subcell 3A Header	8.0	4,312	0.050	1.50%	2.0	**8**	ok
Subcell 3B Header	21.6	11,642	0.135	2.00%	2.7	**8**	ok
Subcell 4C Header	5.1	2,749	0.032	0.80%	1.9	**8**	ok
Subcell 4D Header	13.7	7,384	0.085	3.30%	2.1	**8**	ok
Subcell 4A Header	10.5	5,660	0.066	1.60%	2.1	**8**	ok
Subcell 4B Header	18.8	10,133	0.117	2.00%	2.5	**8**	ok
Subcell 5A Header	8.6	4,635	0.054	0.50%	2.5	**8**	ok
Subcell 5B Header	18.8	10,133	0.117	0.50%	3.3	**8**	ok
Subcell 5C Header	29.5	15,901	0.184	1.00%	3.4	**8**	ok

** Denotes maximum drainage area for all laterals.

*** Assumes the entire area will be drained in a 24 hour period

Conclusion:

An 8-inch pipe is adequate for the expected pipe slopes.

HDR Computation

		Job Number	No.
Project	Charah Colon Mine Site	Computed MDP	Date 11/6/14
Subject	Drainage Calculations	Checked KP	Date 11/6/14
Task	Leachate Pipe Stresses	Sheet 1	Of 1

Objective: Determine the leachate collection pipe stresses due to static (overburden) and dynamic (equipment

References:
1. "Polyethylene Piping Systems Manual" by Driscopipe
2. "Waste Containment Systems, Waste Stabilization, and Landfills: Design and Evaluation" by Hari D. Sharma and Sangeeta P. Lewis, 1994
3. "An Introduction to Geotechnical Engineering" by Holtz & Kovacs

Calculations:

STATIC LOADS

Wall Crushing

$$S_A = \frac{P_T(SDR-1)}{2}$$ Ref. 1

$$FS = \frac{1{,}500 \text{ psi}}{S_A}$$ Ref. 1

Goal $FS \geq 1.8$

Where:
- S_A = Actual compressive stress (psi)
- SDR = Standard Dimension Ratio
- P_T = Total external pressure on the top of the pipe (psi
- 1,500 psi = Compressive yield strength of HDPE pipe

Overburden:	Thickness (ft)	Unit Weight (lb/ft^3)	
CCR:	90	75	Riverbend (56.6 pcf)
Vegetative Cover Layer:	6	120	

Maximum Vertical Stress, P_T = 52 psi

SDR	S_A (psi)	FS	Comment
26.0	648.4	2.31	Okay
21.0	518.8	2.89	Okay
17.0	415.0	3.61	Okay
11.0	259.4	5.78	Okay

Wall Buckling

$$P_C = \frac{2.32E}{SDR^3}$$ Ref. 1

$$P_{CB} = 0.8\sqrt{E'^*P_C}$$ Ref. 1

$$FS = \frac{P_{CB}}{P_T}$$ Ref. 1

Goal $FS \geq 2.0$ Ref. 2

Where:
- P_C = Hydrostatic, critical-collapse differential pressure (psi)
- E = Stress and time dependent tensile modulus of elasticity (psi (approximately 35,000 psi)
- P_{CB} = Critical buckling soil pressure at the top of the pipe (psi)
- E' = Soil Modulus (psi)

SDR	E (psi)	P_C (psi)	E' (psi)	P_{CB} (psi)	FS	Comment
26.0	35,000	4.62	1,500	66.60	1.28	Below criteria
21.0	35,000	8.77	1,500	91.75	1.77	Below criteria
17.0	35,000	16.53	1,500	125.96	2.43	Okay
11.0	35,000	61.01	1,500	242.01	4.67	Okay

SDR 17 meets the minimum static load criteria

HDR Computation

Job Number	No.

Project Charah Colon Mine Site		**Computed** MDP	**Date** 11/6/14
Subject Drainage Calculations		**Checked** KLP	**Date** 11/6/14
Task Leachate Pipe Stresses		**Sheet** 1	**Of** 1

Calculations:

Use SDR 11 from crushing and buckling analysis

DYNAMIC LOADS (Minimum Factor of Safety = 1.4)

Point Loads

$$P_P = \frac{3WZ^3}{2\pi Z^5}$$

Ref. 1

Where:

P_P = Point Load (psi)

W = 1.5 x Superimposed surface load (lb)

Z = load to top of pipe (ft)

Minimum Cover Soil = 8 ft

Equipment	Weight (lbs)	Number of Tires	P_P (psi)	S_A (psi)	FS	Comment
950 Wheel Loader	48,628	4	136.0	680.2	2.21	Okay
627F Scraper	128,550	4	359.6	1798.2	0.83	No Good
621 Scraper	118,700	4	332.1	1660.4	0.90	No Good
815B Compactor	44,175	4	123.6	617.9	2.43	Okay
825C Compactor	71,429	4	199.8	999.2	1.50	Okay

Line Loads:

$$P_L = \frac{2WZ^3}{\pi Z^4}$$

Ref. 3

Where:

P_L = Line Load (psi)

W = 1.5 x Superimposed surface load (lb)

Z = load to top of pipe (ft)

Minimum Cover Soil = 1.75 ft

Equipment	Weight (lbs)	Track Length (ft)	P_L (psi)	S_A (psi)	FS	Comment
D4H LGP (III) Bulldozer	27,500	8.58	72.9	364.4	4.12	Okay
D6H LGP (II) Bulldozer	45,400	10.67	96.7	483.7	3.10	Okay
D9R Bulldozer	106,538	11.50	210.6	1053.2	1.42	Okay
953 Track Loader	37,560	7.50	113.9	569.3	2.63	Okay
963 Track Loader	48,914	8.08	137.6	688.2	2.18	Okay

HDR Computation

Project:	Charah Colon Mine Site	Computed: MSP	Date: 11/6/14
Subject:	Drainage Calculations	Checked KP	Date 11/6/14
Task:	Ensure that pipe perforations are sufficent for pipe flows	Sheet 1	Of 1

Objective

Determine the perforations in the collection pipes

Equations

$Q = C_d * A (2 * g * h)^{0.5}$ Orifice Equation

Cd = 0.6	Typical Default value	7.84052	gals/cf
g = 32.2	ft/sec^2, gravity	60	sec/min
A =	sf, cross sectional area of pipe	86400	sec/day
h =	ft, driving head		

HELP Model Avg Annual Lateral Drainage Collected	43,761.1	cf/yr/ac	0.001	cfs/acre
HELP Model Peak Daily Lateral Drainage Collected	539.0	cf/day/ac	0.006	cfs/acre

Calculations

Check Inlet Control of perforations for pipe under peak condition

Basis	Area to Drain (Acres)	Q (cfs)	Pipe Diameter (in)	# of holes per ft of pipe	Hole Diameter (in)	Length (ft)	Inlet Cross Sectional Area (sf)	Required Head to fill pipe, h (in)	Depth of liquid @ pipe (in)
Entire Site	119	0.74	8	30	3/8	14	0.3	2.7	6.7
Largest Cell	37	0.23	8	30	3/8	3	0.1	5.8	9.8
Largest Subcell	15	0.09	8	30	3/8	2	0.0	2.1	6.1
Entire Site	119	0.74	6	30	3/8	14	0.3	2.7	5.7
Largest Cell	37	0.23	6	30	3/8	3	0.1	5.8	8.8
Largest Subcell	15	0.09	6	30	3/8	2	0.0	2.1	5.1

Only 10 inch depth of liquid is required to fill the pipe at the design flow rate, assumming liquid is available

Conclusion

There is adequate redundancy in pipe perforations to handle expected flows.

HDR Computation

	Job Number		No.
Project Charah Colon Mine Site	Computed MSP		Date 11/6/14
Subject Drainage Calculations	Checked KP		Date 11/6/14
Task Leachate Collection Pipe	Sheet 1		Of 2

Objective: Determine if the leachate pipes and perforations are large enough to handle the peak daily leachate flow.

References:

1. Malcom, H. Rooney (1989). *Elements of Urban Stormwater Design*. Raleigh: NC State Univ.
2. Sharma, H. D., & Lewis, S. P. (1994). *Waste Containment Systems, Waste Stabilization, and Landfills: Design and Evaluation*. New York: John Wiley & Sons, Inc.

Calculations:

Eq. 1 $$Q = C_d A\sqrt{2gh}$$ Reference 1

Eq. 2 $$A = \pi\left(\frac{d}{2}\right)^2$$

Conversion factors
- 7.48 gal/cf
- 60 s/min
- 60 min/hr
- 24 hr/day
- 12 in/ft
- 43,560 sf/acre

Where:
- Q = Flow Rate (cfs)
- C_d = Coefficient of Discharge (dimensionless)
- A = Cross-sectional Area of Orifice (sf)
- g = gravity (ft/s^2)
- h = head (ft)
- d = diameter of opening (ft)

Given:

Select the Flow Rate per Acre based on HELP model runs

$Q_{peak\ daily}$ = 539.00 cf/acre/day From HELP model run: 20' of ash
$Q_{peak\ daily}$ = 2.80 gal/acre/min

SDR	Pipe Size (inches)	
11	6	8

Maximum Drainage distance = 950 feet
Area of Drainage per foot of pipe = 950 sf
Area of Drainage per foot of pipe = 0.022 ac
Required Drainage per foot of pipe = 0.061 gpm (actual flow rate per acre for the drainage area of the pipe)

Determine the maximum allowable flow in the pipe based on the perforations in the pipe and a maximum head

Diameter of perforation, $d_{perforation}$ = 0.375 in
$d_{perforation}$ = 0.03125 ft
$A_{perforation}$ = 0.00077 ft^2

Using Equation 1, determine the flow in the pipe

C_d = 0.6 typical default value (Ref. 1)
$A_{perforation}$ = 0.00077 ft^2
g = 32.2 ft/s^2
h = 8 in
h = 0.67 ft

The maximum head on the liner is 12 inches. The pipe is 8 inches in diameter. The head was therefore assumed to be from the center of the pipe to 12 inches above the liner.

$Q_{perforation}$ = 0.003 cfs
$Q_{perforation}$ = 1.35 gpm per perforation
Number of Perforations per foot of pipe = 30 perforations per foot of pipe
$Q_{per\ foot\ of\ pipe}$ = **40.60 gpm**

Required Flow Rate		**Allowable Flow Rate**
gpm	**<**	**gpm**
0.061		**40.60**

Conclusion:
The allowable flow rate is greater than the required flow rate. Therefore the allowable flow rate based on pipe perforations will be sufficient to meet the actual expected flow rate.

HDR Computation

	Job Number		No.
Project Charah Colon Mine Site		Computed *[initials]*	Date 11/6/14
Subject Drainage Calculations		Checked KP	Date 11/6/14
·k Leachate Collection Pipe		Sheet 2	Of 2

Determine the maximum allowable flow in the pipe based on the pipe size and flowing full

Eq. 3 $$Q = \left(\frac{D}{16}\right)^{\frac{8}{3}} \frac{\sqrt{s}}{n}$$ Reference 1

Where:
Q = Flow Rate (cfs)
D = Theoretical Pipe Diameter (in) for just-full flow
n = Manning roughness coefficient (dimensionless)
s = Longitudinal slope (ft/ft)

D = 8 in
n = 0.009 Reference 2, page 472

Slope	Allowable Q (cfs)	Allowable Q (gpm)	Check
0.10%	0.55	248	Allowable Q is greater than Required Q
0.25%	0.87	393	Allowable Q is greater than Required Q
0.50%	1.24	555	Allowable Q is greater than Required Q
0.75%	1.52	680	Allowable Q is greater than Required Q
1.00%	1.75	785	Allowable Q is greater than Required Q
1.25%	1.96	878	Allowable Q is greater than Required Q
1.50%	2.14	962	Allowable Q is greater than Required Q
1.75%	2.31	1,039	Allowable Q is greater than Required Q
2.00%	2.47	1,111	Allowable Q is greater than Required Q
2.25%	2.62	1,178	Allowable Q is greater than Required Q
2.50%	2.77	1,242	Allowable Q is greater than Required Q
2.75%	2.90	1,302	Allowable Q is greater than Required Q
3.00%	3.03	1,360	Allowable Q is greater than Required Q
3.25%	3.15	1,416	Allowable Q is greater than Required Q
3.50%	3.27	1,469	Allowable Q is greater than Required Q
3.75%	3.39	1,521	Allowable Q is greater than Required Q

Conclusion:
The allowable flow rate is greater than the required flow rate for slopes 0.1% and above. Smaller pipe slopes were not run, but it is assumed that the bottom slope will not be smaller than 0.25% accounting for settlement. Therefore the allowable flow based on pipe size will be sufficient to meet the actual

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Ckd MDA
1/6/14

Determination of Leachate Collection Pipe Capacity

Subject: Leachate Collection Pipe Flow Capacity for Colon Mine Site

Author: Kanishka Perera, PE

Date: 10/02/2014

Checked By:

Date:

Scope:

Evaluate the maximum flow capacity of the leachate collection lines.

References:

1. Merritt, F.S., Standard Handbook for Civil Engineers, 3rd Ed., McGraw-Hill, New York, 1983.
2. CP Chem Performance Pipe "Municipal & Industrial Series/IPS Pipe Data," May 2001.

Basis:

- The leachate collection pipes are proposed to consist of 6-inch and 8-inch diameter SDR-11 HDPE pipes. The 8-inch pipes have a nominal outer diameter (OD) equal to 8.625-inches and an average inner diameter (ID) equal to 6.963-inches. The 6-inch pipes have a nominal OD equal to 6.625-inches and an average ID equal to 5.349-inches. The pipes must have adequate flow capacity to transport the leachate to the sumps. The flow capacity should be compared to the maximum amount of leachate expected to be generated.
- Expected leachate flow rates were determined by using the Hydrologic Evaluation of Landfill Performance (HELP) program.

Results:

Leachate collection and conveyance system should be designed based on 8-inch diameter SDR 11 HDPE pipe.

Analysis:

Leachate collection pipe design based on peak leachate generation rate:

The leachate collection pipe system capacity analysis is based upon the cell layout and leachate collection pipe layout shown on the top of liner sheets. The leachate generation rate used to size the leachate collection pipes was based on a HELP run consisting of 20 ft coal combustion product (CCP). The following parameters were also entered into the HELP model:

- No recirculation;
- Open cell conditions;
- The initial moisture content at 31%. ;
- The drainage length entered into the model was 950 feet with an average slope of 2%. The leachate collection system has been designed to meet this requirement;

The results of the HELP run predict that the peak daily drainage discharging from CCP is 539 cf/acre (2.80 gpm per acre). The largest area draining to a leachate collection pipe consist combined Cells 1 & 2 with 36.9 acres. Using a maximum generation rate of 2.80 gpm per acre and an area of 36.9 acres, the total flow rate to a collection pipe is 103.32 gpm.

$Q_{peak\ day\ avg}$ = 103.32gpm

The following analysis illustrates the capacity of both the 6-inch and 8-inch leachate collection lines.

Manning's coefficient for HDPE pipe (n) is 0.009

The spreadsheet below calculates flow capacity in gpm based on Manning's Equation for HDPE pipes:

$$Qp = (1.49/n)\ A(R_H^{2/3})S^{0.5}$$

where:
Qp = pipe capacity (gpm)
n = Manning's roughness coefficient
R_H = hydraulic radius
A = pipe cross-sectional area
S = slope of the pipe

Full Pipe Flow at Varying Slope
Manning's Formula
$Q=1.49/n*Rh^{2/3}*A*s^{1/2}$

	6-inch SDR 11	6-inch SDR 11	8-inch SDR 11	8-inch SDR 11	10-inch SDR 11	10-inch SDR 11	12-inch SDR 11	12-inch SDR 11	
I.D. (in.)	5.349	5.349	6.963	6.963	8.679	8.679	10.293	10.293	
Slope (ft/ft)	Qp (gpm)	Vp (fps)	Qp (gpm)	Vp (fps)	Qp (gpm)	Vp (fps)	Qp (gpm)	Vp (fps)	
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	n = 0.009 for HDPE Pipe
0.005	189.9	2.7	383.6	3.2	690.2	3.7	1087.7	4.2	
0.01	268.5	3.8	542.4	4.6	976.1	5.3	1538.2	5.9	Rh/D = 0.25 for full flow
0.015	328.9	4.7	664.4	5.6	1195.4	6.5	1883.9	7.3	
0.02	379.7	5.4	767.1	6.5	1380.4	7.5	2175.3	8.4	

All pipe segments within the fill area will maintain a minimum 0.5% slope. As shown in the above table, an HDPE SDR-11, 6-inch pipe with an average inner diameter equal to 5.349-inch at a minimum slope of 0.5% has a capacity of 190 gpm. Therefore, a 6-inch pipe can accommodate the maximum leachate generation rate from a maximum drainage area of 36.9 acres.

Analysis based on Leachate/Stormwater Collection:

For initial stormwater/leachate drainage, assuming 5.28 inch depth in 24 hr 10 year storm event for Raleigh, NC, approximately 19,166 cf/ac/day of stormwater is collected. Total volume of stormwater/leachate collected within a 14.8 acre subcell is 283,662 cf. The subcell has a storage capacity of 590,000 cf.

An 8-inch diameter pipe with 0.5% slope can convey 383 gpm. Considering a FS of 2, the pipe capacity is 191.5 gpm. Accordingly, a 283,662 cf of storage volume will be emptied in approximately 7.7 days assuming no other rain events during that period.

Accordingly 8-inch leachate collection pipe is required to accommodate leachate/stormwater based on a 14.8 acre open cell considering 7.7 day storage period.

Analysis for solid wall leachate conveyance pipe:

The header is designed based on the leachate generated from largest cell, Cell 5. The Area of Cell 5 is approximately 30 acres. At 539 cf/day generation rate, the header should be designed based on 16,170 cf/day (84 gal/min). Considering a FS of 2, would yield a design flow rate 168 gpm. This is less than storm drainage collected in an active cell and the dimensions of the conveyance pipe is governed by initial stormwater/leachate collection.

For the Raleigh area the design rainfall depths and runoff depths for the 24 hour design storm are as follows:

Table 2-5 Runoff Depth for Raleigh (in)

24 hours storm with Ia = 0.2*S

Frequency, yr	2	5	10	25	50	100
Rainfall, in	**3.60**	**4.56**	**5.28**	**6.48**	**7.2**	**8.0**
CN 60	0.58	1.05	1.47	2.24	2.75	3.33
65	0.81	1.37	1.84	2.71	3.26	3.89
70	1.07	1.72	2.25	3.19	3.79	4.46
75	1.37	2.10	2.68	3.69	4.33	5.04
80	1.72	2.51	3.14	4.22	4.88	5.63
85	2.10	2.96	3.63	4.76	5.44	6.21
90	2.54	3.45	4.15	5.31	6.02	6.81
95	3.04	3.98	4.70	5.89	6.60	7.40
98	3.37	4.32	5.04	6.24	6.96	7.76

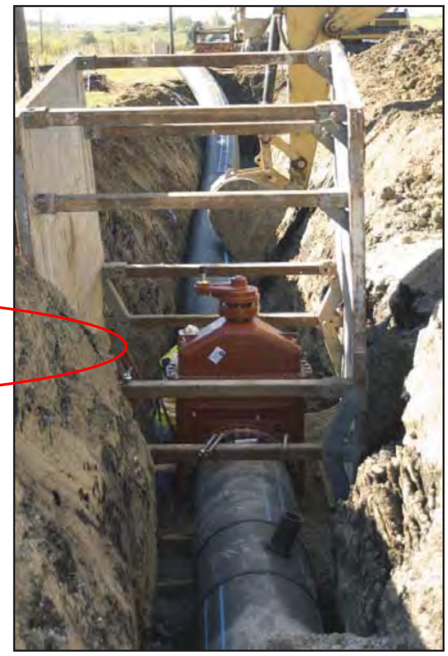
The CN is used to determine the initial abstraction, Ia, in Table 2-6. Ia/P is then computed using Figure 2.6.

PERFORMANCE ADVANTAGES OF DRISCOPLEX® 4000/4100 PIPE

Stripes

Stripes allow easy field identification of pipe. DriscoPlex® 4000 (DIPS) pipe comes standard with three pairs of blue stripe, but lavender, green, and no stripes is optional. The standard DriscoPlex® 4100 (IPS) is black, but blue, lavender and green striping is optional with 4 single stripes at 90 degrees apart.

Flow



DriscoPlex® 4000/4100 pipes are characterized as hydraulically smooth and typically have an absolute surface roughness (ε) of 0.000005 ft. The Hazen-Williams Friction Factor (C) equals 150 to 155 for polyethylene pipes. Even though the inside diameter of polyethylene pipe may be smaller for the same nominal size as metallic or concrete pipes, flow is often equal or greater through polyethylene pipe. For example, an 8" DR17 DriscoPlex® 4000 pipe has a lower pressure drop per given flow rate than an 8" CL350 concrete lined DI pipe (C equals 120). For gravity flow, the n-factor in the Manning equation is typically taken as 0.009 for clear water and 0.010 for sanitary sewer. For design information, see the *Handbook of Polyethylene Pipe*, Chapter 6.

Surge Pressure

When it comes to surges, polyethylene has two advantages over most piping materials. 1) As Table 3 shows, it has the capacity to handle surge pressures significantly in excess of its pressure rating. 2) It also has the lowest surge pressure of all common water pipes. For example, a 5 ft/sec velocity change in a DR17 Polyethylene pipe will produce a 56 psi surge, in a DR18 PVC pipe the surge is 88 psi, and in a Class 50 DI pipe the surge is 268 psi. Thus, with polyethylene pipe there are lower surge pressures and less wear and tear on valves, hydrants, and other system components and, when surges occur, HDPE pipes may be quite capable of handling them with a lower Pressure Class (PC) than required for other materials.

Fatigue

Repeated surges will cause fatigue stress in pipelines. This is particularly significant in certain thermoplastic pipes, excluding polyethylene. Fortunately, polyethylene has an excellent resistance to fatigue. The projected design life for DriscoPlex® 4000/4100 pipes exceeds 100 years for pipe operating at a velocity of 4 fps with a surge frequency of 4 times per hour continuously. See Bulletin PP-402, *Working Pressure Rating and Fatigue Life*.

Comparison with Other Piping Products

Polyethylene's superior performance is due to its fused joint, toughness, and flexibility. Comparisons of polyethylene to other piping materials based on PC alone can lead to costly over-designs, since the definition of "Pressure Class" varies from material to material (see AWWA C906, C905, etc). When correctly incorporating HDPE's lower surge magnitudes, higher surge allowances, and greater fatigue strength into the design, the PC required for HDPE may be much lower than the PC required for other pipe materials.

Performance Pipe, a division of Chevron Phillips Chemical Company LP | 5085 W. Park Blvd | Suite 500 | Plano, TX 75093 | Phone: 800-527-0662 | Fax: 972-599-7348

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Determination of Leachate Storage Capacity

Subject: Leachate Storage Capacity for Colon Mine Site

Author: Kanishka Perera, PE

Date: 10/06/2014

Checked By: MD

Date: 11/6/14

Scope:

Evaluate storage capacity of leachate tanks.

References:

1. Stormwater Design Manual, City of Raleigh.

Basis:

- Charah proposed 2X50,000 gal tanks to store leachate
- Check the capacity based on open cell condition considering 2-year, 24-hr rain event.
- Check the capacity based on maximum average leachate generation obtained from Hydrologic Evaluation of Landfill Performance (HELP) model.

Results:

The results indicated that proposed storage tanks will provide approximately 7 day storage capacity based on maximum average leachate generation.

Analysis:

Determination of storage capacity based on average annual leachate collection rate:

From HELP model Scenario 1, maximum average annual leachate collection = 43,761 cf/acre

Therefore, 14.8 acre subcell could generate = 647,662 cf/year
= 13,273 gal/day

Considering 100,000 gal capacity, on-site storage capability = 7.5 days

Note that, above estimate is based on average leachate generation rate and the storage capacity could be significantly less if peak day leachate generation rates are used. Therefore, Charah should arrange leachate trucking capabilities during peak demands.

Determination of storage capacity based on 2-year, 24-hr rain event:

Depth of 2-year, 24-hr rain event	= 3.6 inches
Based on 14.8 acre subcell, total leachate/stormwater collected	= 193,406 cf
	=1,446,677 gal

Since the leachate storage tank capacity is 100,000 gal, the storage provided may not be sufficient to handle stormwater/leachate generated during the initial stages of filling of a subcell.

Storage area within a subcell	= 590,000 cf
	=4,413,200 gal

Since the subcell storage capacity is greater than leachate/stormwater collected, storage capacity of the tanks is governed by average leachate generation rates based on HELP model. It is recommended to begin ash fill within a subcell at the perforated leachate collection pipe. This will slow down the process of collecting initial leachate/stormwater at the sump area. The ash fill within a cell should be progressed to provided 100% runoff away from the cell. Depending on the methods of filling, leachate pumping from a subcell may be needed to empty the active cells to facilitate filling. A temporary rain cover may be needed to avoid stormwater getting contact with ash.

E

Stormwater

Subcell Divider Berms
Stormwater Pipe Perforations and Sizing
Stormwater Management System
Sediment Basins

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HDR Computation

Job Number	453925-235691-018	No.	

Project	Charah Colon Mine Site	**Computed**	MDP	**Date**	10/7/2014
Subject	Permit Application	**Checked**	**EAW**	**Date**	11/6/2014
Task	Subcell Divider Berms	**Sheet**		**Of**	

Objective: Determine Available Volume given subcell berm height
*Assumes a pyramid shape

$$V = \frac{1}{3} hwl$$

Where:
V = Volume of pyramid (ft^3)
h = Height of the pyramid (ft)
wl = width times length to get the Area of the bottom of the pyramid (ft^2)

Subcell 1A Berm Height = 4 ft

	Elevation (ft)	Area (ac)	Area (ft^2)	Volume (ft^3)
base	0	0.0	0	
top	4	2.19	95,360	127,146
	Total Available Volume for 1A =			127,146

Subcell 1B Berm Height = 3 ft

	Elevation (ft)	Area (ac)	Area (ft^2)	Volume (ft^3)
base	0	0.0	0	
top	3	6.63	288,595	288,595
	Total Available Volume for 1B =			288,595

Subcell 2 Berm Height = 5 ft

	Elevation (ft)	Area (ac)	Area (ft^2)	Volume (ft^3)
base	0	0.0	0	
top	5	6.41	279,164	465,273
	Total Available Volume for 2 =			465,273

HDR Computation

Job Number	453925-235691-018	**No.**	
Project	Charah Colon Mine Site	**Computed** MDP	**Date** 10/7/2014
Subject	Permit Application	**Checked** EAW	**Date** 11/6/2014
Task	Subcell Divider Berms	**Sheet**	**Of**

Subcell 3A Berm Height = 7.5 ft

	Elevation (ft)	Area (ac)	Area (ft^2)	Volume (ft^3)
base	0	0.0	0	
top	7.5	3.83	166,645	416,613
	Total Available Volume for 3A =			416,613

Subcell 3B Berm Height = 6 ft

	Elevation (ft)	Area (ac)	Area (ft^2)	Volume (ft^3)
base	0	0.0	0	
top	6	0.87	37,946	75,891
	Total Available Volume for 3B =			75,891

Subcell 4A Berm Height = 6 ft

	Elevation (ft)	Area (ac)	Area (ft^2)	Volume (ft^3)
base	0	0.0	0	
top	6	1.77	77,041	154,083
	Total Available Volume for 4A =			154,083

Subcell 4B Berm Height = 6 ft

	Elevation (ft)	Area (ac)	Area (ft^2)	Volume (ft^3)
base	0	0.0	0	
top	6	2.04	88,871	177,742
	Total Available Volume for 4B =			177,742

Subcell 4C Berm Height = 4 ft

	Elevation (ft)	Area (ac)	Area (ft^2)	Volume (ft^3)
base	0	0.0	0	
top	4	3.89	169,256	225,675
	Total Available Volume for 4C =			225,675

HDR Computation

Job Number	453925-235691-018	**No.**	

Project	Charah Colon Mine Site	**Computed**	MDP	**Date**	10/7/2014
Subject	Permit Application	**Checked**	EAW	**Date**	11/6/2014
Task	Subcell Divider Berms	**Sheet**		**Of**	

Subcell 4D Berm Height = 6 ft

	Elevation (ft)	Area (ac)	Area (ft^2)	Volume (ft^3)
base	0	0.0	0	
top	6	1.49	64,806	129,611
	Total Available Volume for 4D =			129,611

Subcell 5A Berm Height = 6 ft

	Elevation (ft)	Area (ac)	Area (ft^2)	Volume (ft^3)
base	0	0.0	0	
top	6	2.14	93,244	186,488
	Total Available Volume for 5A =			186,488

Subcell 5B Berm Height = 8 ft

	Elevation (ft)	Area (ac)	Area (ft^2)	Volume (ft^3)
base	0	0.0	0	
top	8	3.43	149,544	398,783
	Total Available Volume for 5B =			398,783

Subcell 5C Berm Height = 8 ft

	Elevation (ft)	Area (ac)	Area (ft^2)	Volume (ft^3)
base	0	0.0	0	
top	8	1.66	72,321	192,855
	Total Available Volume for 5C =			192,855

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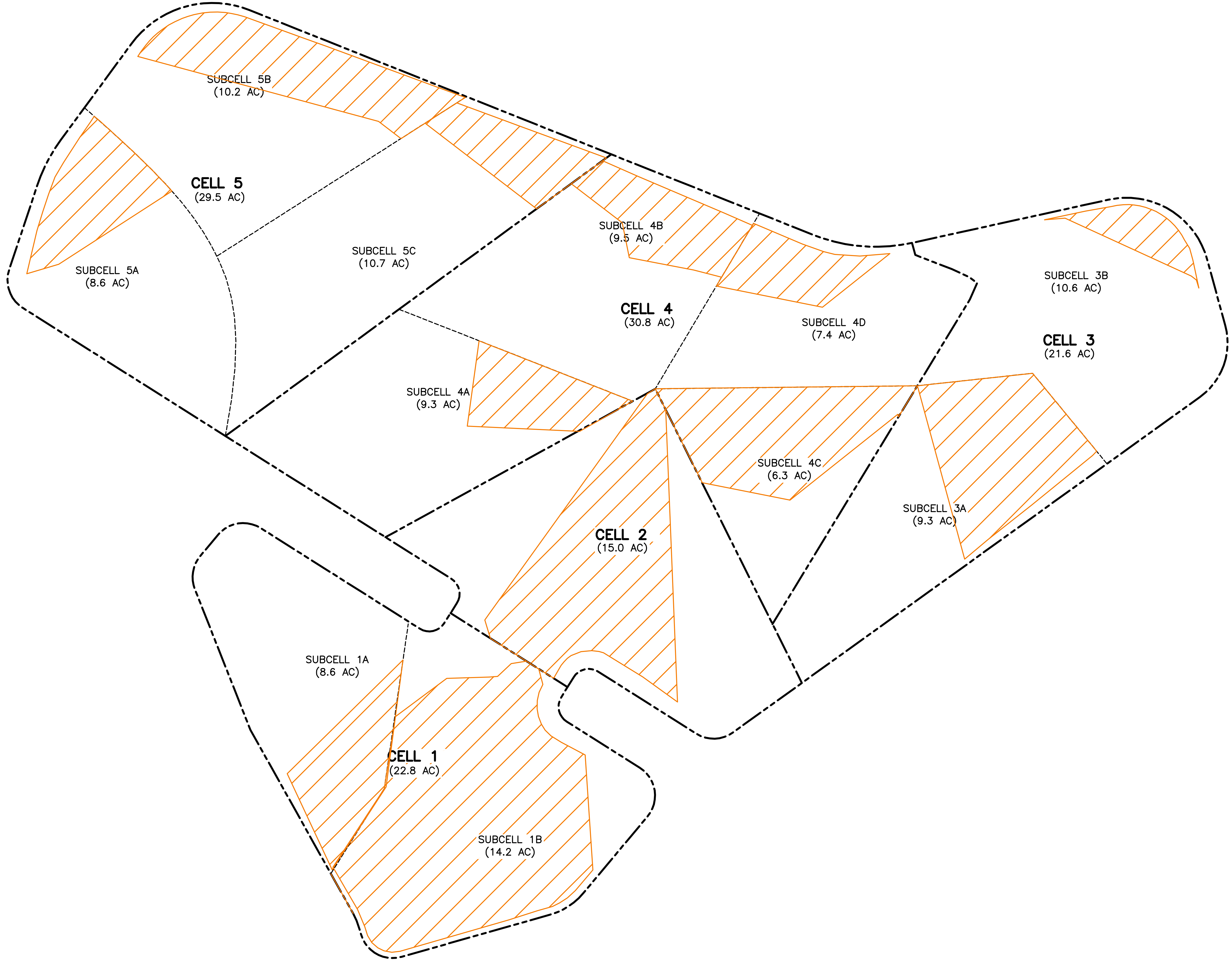

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HDR Computation

Job Number	453925-235691-018	**No.**	
Project Charah Colon Mine Site	**Computed** MDP	**Date** 11/5/2014	
Subject Permit Application	**Checked** EAW	**Date** 11/6/2014	
Task Stormwater Pipe Perforation & Size Calcs	**Sheet**	**Of**	

Objective: Determine if the leachate pipes and perforations are large enough to handle the 10 year 24 hour storm event.

References:

1. Malcom, H. Rooney (1989). *Elements of Urban Stormwater Design* . Raleigh: NC State Univ.
2. Sharma, H. D., & Lewis, S. P. (1994). *Waste Containment Systems, Waste Stabilization, and Landfills: Design and Evaluation* . New York: John Wiley & Sons, Inc.

Calculations:

Eq. 1 $$Q = C_d A \sqrt{2gh}$$ Reference 1

Where:
- Q = Flow Rate (cfs)
- C_d = Coefficient of Discharge (dimensionless)
- A = Cross-sectional Area of Orifice
- g = gravity (ft/s^2)
- h = head (ft)

7.48	gal/cf	12	in/ft
60	s/min	43,560	sf/acre
60	min/hr		
24	hr/day		

Determine the actual Flow Rate per Acre based on HELP model runs

Intensity $_{10yr,24hr}$ =	5.62	inches
Maximum Subcell Size =	14.8	acres
Storm Event Q_{cfs} =	301,929	cf/acre/day
Q_{gpm} =	1568.46	gal/acre/min
Maximum Drainage distance =	950	feet
Area of Drainage per foot of pipe =	950	sf
Area of Drainage per foot of pipe =	0.022	ac
Required Drainage per foot of pipe =	**34.207**	**gpm (actual flow rate per acre for the drainage area of the pipe)**

HDR Computation

Job Number	453925-235691-018	**No.**	
Project Charah Colon Mine Site	**Computed** MDP	**Date** 11/5/2014	
Subject Permit Application	**Checked** EAW	**Date** 11/6/2014	
Task Stormwater Pipe Perforation & Size Calcs	**Sheet**	**Of**	

Determine the maximum allowable flow in the pipe based on the perforations into the pipe and a maximum head

Diameter of perforation, $d_{perforation}$ = 0.375 in

$d_{perforation}$ = 0.03125 ft

Eq. 2

$$A = \pi \left(\frac{d}{2} \right)^2$$

$A_{perforation}$ = 0.00077 ft^2

Using Equation 1, determine the flow in the pipe

C_d = 0.6 typical default value (Ref. 1)

$A_{perforation}$ = 0.00077 ft^2

g = 32.2 ft/s^2

h = 8 in

h = 0.67 ft

The pipe is 8 inches in diameter. The head was assumed to be from the center of the pipe to 12 inches above the liner.

$Q_{perforation}$ = 0.003 cfs

$Q_{perforation}$ = 1.35 gpm per perforation

Number of Perforations per foot of pipe = 30 perforations per foot of pipe

$Q_{per\ foot\ of\ pipe}$ = 40.60 gpm

Required Flow Rate gpm		**Allowable Flow Rate gpm**
34.207	**<**	**40.60**

Conclusion:
The allowable flow rate is greater than the required flow rate. Therefore the allowable flow rate based on pipe perforations will be sufficient to meet the actual expected flow rate. Sufficient volume can get into the pipe through the orifices.

HDR Computation

Job Number	453925-235691-018	No.	
Project Charah Colon Mine Site		**Computed** MDP	**Date** 11/5/2014
Subject Permit Application		**Checked** EAW	**Date** 11/6/2014
Task Stormwater Pipe Perforation & Size Calcs		**Sheet**	**Of**

Determine the maximum allowable flow in the pipe based on the pipe size and flowing full

Eq. 3
$$Q = \left(\frac{D}{16}\right)^{\frac{8}{3}} \frac{\sqrt{s}}{n}$$
Reference 1

Where:
Q = Flow Rate (cfs)
D = Theoretical Pipe Diameter (in) for just-full flow
n = Manning roughness coefficient (dimensionless)
s = Longitudinal slope (ft/ft)

D = 8 in
n = 0.009 Reference 2, page 472

Slope	Allowable Q (cfs)	Allowable Q (gpm)	Check
0.10%	0.55	248	Allowable Q is greater than Required Q
0.25%	0.87	393	Allowable Q is greater than Required Q
0.50%	1.24	555	Allowable Q is greater than Required Q
0.75%	1.52	680	Allowable Q is greater than Required Q
1.00%	1.75	785	Allowable Q is greater than Required Q
1.25%	1.96	878	Allowable Q is greater than Required Q
1.50%	2.14	962	Allowable Q is greater than Required Q
1.75%	2.31	1,039	Allowable Q is greater than Required Q
2.00%	2.47	1,111	Allowable Q is greater than Required Q
2.25%	2.62	1,178	Allowable Q is greater than Required Q
2.50%	2.77	1,242	Allowable Q is greater than Required Q
2.75%	2.90	1,302	Allowable Q is greater than Required Q
3.00%	3.03	1,360	Allowable Q is greater than Required Q
3.25%	3.15	1,416	Allowable Q is greater than Required Q
3.50%	3.27	1,469	Allowable Q is greater than Required Q
3.75%	3.39	1,521	Allowable Q is greater than Required Q

Conclusion:
The allowable flow rate is greater than the required flow rate for slopes 0.1% and above. Smaller pipe slopes were not run, but it is assumed that the bottom slope will not be smaller than 2% accounting for settlement. Therefore the allowable flow based on pipe size will be sufficient to meet the actual expected flow rate.

Project:	Sanford Mine	Computed	PAW	Date	11/3/14
Subject:	Permit Application	Checked	EAW	Date	11/6/14
Task:	Drainage - Time of Concentration	Sheet		Of	

Objective Determine the Time of Concentration based on the proposed top of fill grades.

References

1. "Elements of Urban Stormwater Design" by H. Rooney Malcom, P.E.

Equations

Time of Concentration, (t_c) is the longest time of flow from points on the watershed ridge to the outlet of the watershed.

$$t_c = \frac{[L^3 / H]^{0.385}}{128}$$

Time of Concentration, (min) = t_c
Hydraulic length of watershed, (ft) = L
Elevation change along length, (ft) = H

Cells 2-5

Flow Path 1

Hydraulic length of watershed L (ft) =	1,371
Peak Elevation of watershed (ft) =	330
Low Elevation of watershed (ft) =	260
Elevation change along length H (ft) =	70
t_c (min) =	**6.4**

Flow Path 2

Hydraulic length of watershed L (ft) =	3,449
Peak Elevation of watershed (ft) =	328
Low Elevation of watershed (ft) =	268
Elevation change along length H (ft) =	60
t_c (min) =	**19.7**

Flow Path 3

Hydraulic length of watershed L (ft) =	2,657
Peak Elevation of watershed (ft) =	330
Low Elevation of watershed (ft) =	245
Elevation change along length H (ft) =	85
t_c (min) =	**12.7**

Cell 1

Flow Path 1

Hydraulic length of watershed L (ft) =	1,660
Peak Elevation of watershed (ft) =	322
Low Elevation of watershed (ft) =	270
Elevation change along length H (ft) =	52
t_c (min) =	**8.9**

CONCLUSION

Most of the drainage ara is within the Flow Path 1 and 3 areas.
Use a Time of Concentration of 10-Minutes

Project: Sanford Mine		Computed PAW	Date 11/03/14
Subject: Permit Application		Checked EUW	Date 11/6/14
Task: Drainage - Perimeter Channels		Sheet	Of

Objective Design the stormwater channels around the perimeter of the structural fill for the 25-yr storm.
Assume sideslope swales and/or sloe drains are installed as fill progresses. This will minimize the drainage area.

References

1. NC Erosion and Sediment Control Planning and Design Manual.
2. "Elements of Urban Stormwater Design" by H. Rooney Malcom, P.E.
3. NCDOT Standard Specifications for Roads and Structures
4. North American Green Product Brochure version 4.11
5. East Coast Erosion Blankets (ECS-1)
6. Maccaferri
7. Green Armor Systems
8. NOAA Atlas 14, Volume 2, Version 3 (Sanford, NC)

Equations

Normal Depth Procedure (Manning's Eqn) Ref 2

$Z_{av} = AR^{2/3}$ Area (A) = $bd + z\,d^2$

$Z_{req} = Q\,n / 1.49s^{0.5}$ $R = \text{Area} \,/\, (b+2d(z^2+1)^{0.5})$

$AR^{2/3} = Q\,n/\ 1.49s^{0.5}$ Avg Shear Stress (T) = d*s*unit weight of water

Q (cfs) = CIA $Z_{av} = Z_{req}$

Channel Design

Min Channel Freeboard =	0.2	ft		
Inside Channel Side Slope =	2	(enter X for X:1)		
Outside Channel Side Slope =	2	(enter X for X:1)		
Bottom Width, b =	4	ft		
Runoff Coeff (initial)=	0.60	Ag land, smooth	Ref 1
Runoff Coeff (permanent)=	0.25	Pasture, Sandy	Ref 1
I (in/hr) =	6.76	25-yr, 10-min Design Storm (Sanford, NC)	Ref 8

Various Lining Types *Depth of Flow is not specified for Manning's' n

Lining Type	Lining Description	Manning's n depths of 0-0.5 ft	Manning's n depths of 0.5-2.0 ft	Vp (ft/sec)	Allowable Shear Stress (psf)
A	Jute Net (HEC-15)		0.015	2.0	0.45
B	Erosion Control Blanket Single Net (Curlex 1)		0.034	5.0	1.55
C	Erosion Control Blanket, Straw w/ Single Net (Ref 4)*		0.025	6.7	1.50
D	Erosion Control Blanket Double Net (Curlex HV)		0.026	10.0	1.65
E	Ordinary Firm Loam (Ref 2)	0.023	0.020	3.5	2.0
F	Grass Lined (Ref 1)*		0.030	5.0	2.0
G	6" Rip Rap (Ref 2, Ref 1)		0.069	9.0	2.0
H	GreenArmor 7010 (vegetated)		0.034	16.0	8.0
I	Unvegetated Turf Reinforcement Mat (TRM) (NAG C350)		0.025	9.5	2.25
J	Class D Phase 2 (Partially vegetated) TRM (NAG C350)		0.048	14.0	3.34
K	12" Rip Rap (Ref 2, Ref 1)		0.078	12.5	4.0
L	Class B Phase 3 (Fully vegetated) TRM (NAG C350)		0.048	18.0	5.7
M	Reno Mattress (6-inch, unvegetated) Ref 6		0.0277	13.8	4.3
N	Reno Mattress (6-inch, vegetated) Ref 6		0.050	13.8	8.35
O	Smart Ditch (Pre-formed HDPE channel)		0.022	-	-
P	Concrete (HEC-15, EPA 832-F-99-002)		0.013	25.0	10.0

Drainage Area is measured in plan view and does not account slope. Refer to sheet "Channels" for drainage areas.
Select Lining System for each channel slope that will handle the design flow when vegetated and when initially placed

Project:	Sanford Mine	Computed	PAW	Date	11/03/14
Subject:	Permit Application	Checked	EAW	Date	11/6/14
Task:	Drainage - Perimeter Channels	Sheet		Of	

Node	Drainage Area (acres)	elev 2	elev 1	length (ft)	Channel Slope	Channel Side Slope Inside (X:1)	Channel Side Slope Outside (X:1)	Bottom Width, b (ft)
DI #1	0.96	324	294	529	5.7%	2	2	4
DI #2	2.9	288	279	823	1.1%	2	2	4
DI #3W	5.2	280	269	1,100	1.0%	2	2	4
DI #3E	2.3	270	269	530	0.2%	2	2	4
DI #5W	3.2	280	259	643	3.3%	2	2	4
DI #5S	3.8	282	259	614	3.7%	2	2	4
DI #6 N	3.1	297	288	600	1.5%	2	2	4
DI #6 W a	8.2	322	296	1,034	2.5%	2	2	4
DI #6 W b	12.4	294	288	676	0.9%	2	2	4
Cell 1 N	5.3	290	284	558	1.1%	2	2	4
DI #7E	38.6	278	272	706	0.8%	2	2	4
DI #7W	4.1	276	271	434	1.2%	2	2	4

	Channel Location	Flow Q (cfs)	Lining Type	Z_{req}	Flow Depth d (ft)	Cross Sectional Area (sf)	R	Z_{av}	Velocity (ft/sec)	Avg Shear Stress (lb/sf)	Comment
Initial Lining											
	DI #1	3.9	E	0.22	0.17	0.75	0.16	0.22	5.2	0.6	Need Liner
	DI #2	11.8	E	1.51	0.53	2.69	0.42	1.51	4.4	0.4	Need Liner
	DI #3W	21.1	E	2.83	0.75	4.15	0.56	2.83	5.1	0.5	Need Liner
	DI #3E	9.3	E	2.88	0.76	4.20	0.57	2.88	2.2	0.1	OK
	DI #5W	13.0	E	0.96	0.41	1.98	0.34	0.96	6.6	0.8	Need Liner
	DI #5S	15.4	E	1.07	0.44	2.13	0.36	1.07	7.3	1.0	Need Liner
	DI #6 N	12.6	E	1.38	0.50	2.53	0.40	1.38	5.0	0.5	Need Liner
	DI #6 W a	33.3	E	2.82	0.75	4.14	0.56	2.82	8.0	1.2	Need Liner
	DI #6 W b	50.3	E	7.17	1.24	8.04	0.84	7.17	6.3	0.7	Need Liner
	Cell 1 N	21.5	E	2.78	0.75	4.10	0.56	2.78	5.2	0.5	Need Liner
	DI #7E	156.6	E	22.80	2.22	18.72	1.34	22.80	8.4	1.2	Need Liner
	DI #7W	16.6	E	2.08	0.64	3.35	0.49	2.08	5.0	0.5	Need Liner
Temp Lining											
	DI #1	3.9	C	0.27	0.20	0.86	0.18	0.27	4.5	0.7	OK
	DI #2	11.8	C	1.89	0.60	3.14	0.47	1.89	3.8	0.4	OK
	DI #3W	21.1	C	3.54	0.85	4.86	0.62	3.54	4.3	0.5	OK
	DI #3E	9.3	C	3.60	0.86	4.92	0.63	3.60	1.9	0.1	OK
	DI #5W	13.0	C	1.21	0.47	2.31	0.38	1.21	5.6	1.0	OK
	DI #5S	15.4	C	1.34	0.50	2.48	0.40	1.34	6.2	1.2	OK
	DI #6 N	12.6	C	1.72	0.57	2.94	0.45	1.72	4.3	0.5	OK
	DI #6 W a	33.3	C	3.52	0.85	4.84	0.62	3.52	6.9	1.3	Need Diff Liner
	DI #6 W b	50.3	C	8.96	1.38	9.37	0.92	8.86	5.4	0.8	OK
	Cell 1 N	21.5	C	3.48	0.84	4.80	0.62	3.48	4.5	0.6	OK
	DI #7E	156.6	C	28.49	2.47	22.07	1.47	28.49	7.1	1.3	Need Liner
	DI #7W	16.6	C	2.60	0.72	3.91	0.54	2.60	4.3	0.5	OK

Project: Sanford Mine		Computed PAW	Date 11/03/14
Subject: Permit Application		Checked EAW	Date 11/6/14
Task: Drainage - Perimeter Channels		Sheet	Of

Channel Location	Flow Q (cfs)	Lining Type	Z_{req}	Flow Depth d (ft)	Cross Sectional Area (sf)	R	Z_{av}	Velocity (ft/sec)	Avg Shear Stress (lb/sf)	Comment
Permanent Lining										
DI #1	1.6	F	0.14	0.13	0.57	0.12	0.14	2.9	0.5	OK
DI #2	4.9	F	0.94	0.41	1.95	0.34	0.94	2.5	0.3	OK
DI #3W	8.8	F	1.77	0.58	3.00	0.45	1.77	2.9	0.4	OK
DI #3E	3.9	F	1.80	0.59	3.03	0.46	1.80	1.3	0.1	OK
DI #5W	5.4	F	0.60	0.31	1.44	0.27	0.60	3.7	0.6	OK
DI #5S	6.4	F	0.67	0.33	1.55	0.28	0.67	4.1	0.8	OK
DI #6 N	5.2	F	0.86	0.38	1.84	0.32	0.86	2.9	0.4	OK
DI #6 W a	13.9	F	1.76	0.58	2.98	0.45	1.76	4.6	0.9	OK
DI #6 W b	21.0	F	4.48	0.97	5.74	0.69	4.48	3.7	0.5	OK
Cell 1 N	9.0	F	1.74	0.57	2.96	0.45	1.74	3.0	0.4	OK
DI #7E	65.2	F	14.25	1.76	13.25	1.12	14.25	4.9	0.9	OK
DI #7W	6.9	F	1.30	0.49	2.43	0.39	1.30	2.9	0.4	OK

Select an appropriate temp liner for DI 6W a and DI #7E

Channel Location	Channel Slope	Lining Type	Z_{req}	Flow Depth d (ft)	Cross Sectional Area (sf)	R	Z_{av}	Velocity (ft/sec)	Avg Shear Stress (lb/sf)	Comment
DI #6 W a	2.5%	H	4.72	0.99	5.96	0.71	4.72	0.7	1.6	OK
DI #7E	0.8%	H	12.27	1.63	11.88	1.05	12.27	0.5	0.9	OK

CONCLUSION

Channel	Inside Channel (X:1)	Outside Channel (X:1)	Bottom Width, b (ft)	Slope (%)	Min Depth (ft)	Build Depth (ft)	Top Width (ft)	Temporary Lining	Permanent Lining
DI #1	2	2	4	5.7%	1.2	2	12	Straw w/ Single Net	Grass Lined
DI #2	2	2	4	1.1%	0.8	2	12	Straw w/ Single Net	Grass Lined
DI #3W	2	2	4	1.0%	1.1	2	12	Straw w/ Single Net	Grass Lined
DI #3E	2	2	4	0.2%	1.1	2	12	Straw w/ Single Net	Grass Lined
DI #5W	2	2	4	3.3%	0.7	2	12	Straw w/ Single Net	Grass Lined
DI #5S	2	2	4	3.7%	0.7	2	12	Straw w/ Single Net	Grass Lined
DI #6 N	2	2	4	1.5%	0.8	2	12	Straw w/ Single Net	Grass Lined
DI #6 W a	2	2	4	2.5%	1.2	2	12	GreenArmor 7010	Grass Lined
DI #6 W b	2	2	4	0.9%	1.6	2	12	Straw w/ Single Net	Grass Lined
Cell 1 N	2	2	4	1.1%	1.0	2	12	Straw w/ Single Net	Grass Lined
DI #7E	2	2	4	0.8%	2.7	3	16	GreenArmor 7010	Grass Lined
DI #7W	2	2	4	1.2%	0.9	2	12	Straw w/ Single Net	Grass Lined

Though Channel DI #6Wa & DI #7E requires a heavier temporary liner than the other channels, the permanent liner for all channels is grass. Therefore, using the Straw w/ Single Net could be used but additional maintenance of the channel may be necessary until grass is established.

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Project:	Sanford Mine	Computed	PAW	Date	11/03/14
Subject:	Permit Application	Checked	EAW	Date	11/6/14
Task:	Drainage - Sideslope Swales	Sheet		Of	

Objective Design the sideslope channels on the structural fill for the 25-yr storm.

References

1. NC Erosion and Sediment Control Planning and Design Manual.
2. "Elements of Urban Stormwater Design" by H. Rooney Malcom, P.E.
3. NCDOT Standard Specifications for Roads and Structures
4. North American Green Product Brochure version 4.11
5. East Coast Erosion Blankets (ECS-1)
6. Maccaferri
7. Green Armor Systems
8. NOAA Atlas 14, Volume 2, Version 3 (Sanford, NC)

Equations

Normal Depth Procedure (Manning's Eqn) Ref 2

$Z_{av} = AR^{2/3}$ Area (A) = $bd + z\,d^2$

$Z_{req} = Q\,n / 1.49s^{0.5}$ $R = \text{Area} / (b+2d(z^2+1)^{0.5})$

$AR^{2/3} = Q\,n / 1.49s^{0.5}$ Avg Shear Stress (T) = d*s*unit weight of water

$Q\ (cfs) = CIA$

$Z_{av} = Z_{req}$

Channel Design

Min Channel Freeboard =	0.2	ft	
Inside Channel Side Slope =	Varies	(enter X for X:1)	
Outside Channel Side Slope =	Varies	(enter X for X:1)	
Bottom Width, b =	Varies	ft	
Runoff Coeff (initial)=	0.60	Ag land, smooth	Ref 1
Runoff Coeff (permanent)=	0.25	Pasture, Sandy	Ref 1
I (in/hr) =	6.76	25-yr, 10-min Design Storm (Sanford, NC)	Ref 8

Various Lining Types

Lining Type	Lining Description	Manning's n depths of 0-0.5 ft	Manning's n depths of 0.5-2.0 ft	Vp (ft/sec)	Allowable Shear Stress (psf)
A	Jute Net (HEC-15)		0.015	2.0	0.45
B	Erosion Control Blanket Single Net (Curlex 1)		0.034	5.0	1.55
C	Erosion Control Blanket, Straw w/ Single Net (Ref 4)*		0.025	6.7	1.50
D	Erosion Control Blanket Double Net (Curlex HV)		0.026	10.0	1.65
E	Ordinary Firm Loam (Ref 2)	0.023	0.020	3.5	2.0
F	Grass Lined (Ref 1)*		0.030	5.0	2.0
G	6" Rip Rap (Ref 2, Ref 1)		0.069	9.0	2.0
H	GreenArmor 7010 (unvegetated)		0.034	12.0	3.3
I	Unvegetated Turf Reinforcement Mat (TRM) (NAG C350)		0.025	9.5	2.25
J	Class D Phase 2 (Partially vegetated) TRM (NAG C350)		0.048	14.0	3.34
K	12" Rip Rap (Ref 2, Ref 1)		0.078	12.5	4.0
L	Class B Phase 3 (Fully vegetated) TRM (NAG C350)		0.048	18.0	5.7
M	Reno Mattress (6-inch, unvegetated) Ref 6		0.0277	13.8	4.3
N	Reno Mattress (6-inch, vegetated) Ref 6		0.050	13.8	8.35
O	Smart Ditch (Pre-formed HDPE channel)		0.022	-	-
P	Concrete (HEC-15, EPA 832-F-99-002)		0.013	25.0	10.0

*Depth of Flow is not specified for Manning's' n

Project:	Sanford Mine	Computed	PAW	Date	11/03/14
Subject:	Permit Application	Checked	Ecw	Date	11/6/14
Task:	Drainage - Sideslope Swales	Sheet		Of	

Drainage Area is measured in plan view and does not account slope.
Select Lining System for each channel slope that will handle the design flow when vegetated and when initially placed

Channel Location	Drainage Area (acres)	Channel Slope	Channel Side Slope Inside (X:1)	Channel Side Slope Outside (X:1)	Bottom Width, b (ft)	
Sideslope	13.3	2.0%	4	4	0	Largest Drainage Area (DI #5 on the Slope Drain Areas)
Diversion Berm	7.5	0.25%	2	2	0	Largest Drainage Area (DI #3)

Channel Location	Flow Q (cfs)	Lining Type	Z_{req}	Flow Depth d (ft)	Cross Sectional Area (sf)	R	Z_{av}	Velocity (ft/sec)	Avg Shear Stress (lb/sf)	Comment
	Initial Lining									
Sideslope	53.9	E	5.12	1.31	6.91	0.64	5.12	7.8	1.6	Need Liner
Diversion Berm	30.4	E	8.17	2.07	8.59	0.93	8.17	3.5	0.3	Need Liner
	Temp Lining									
Sideslope	53.9	C	6.40	1.43	8.17	0.69	6.40	6.6	1.8	Needs Liner
Diversion Berm	30.4	C	10.21	2.25	10.16	1.01	10.21	3.0	0.4	OK

Channel Location	Flow Q (cfs)	Lining Type	Z_{req}	Flow Depth d (ft)	Cross Sectional Area (sf)	R	Z_{av}	Velocity (ft/sec)	Avg Shear Stress (lb/sf)	Comment
	Permanent Lining									
Sideslope	22.5	F	3.20	1.10	4.86	0.53	3.20	4.6	1.4	OK
Diversion Berm	12.7	F	5.10	1.74	6.04	0.78	5.10	2.1	0.3	OK

CONCLUSION

	Side Slope Inside Channel (X:1)	Side Slope Outside Channel (X:1)	Bottom Width, b (ft)	Min to Construct Slope (%)	Min to Construct Depth (ft)	Min to Construct Top Width (ft)
Sideslope	4	4	0	2.0%	1.1	8.8
Diversion Berm	2	2	0	0.25%	1.7	6.9

Though the Straw w/ Single Net temporary liner for the sideslope is greater than the allowable shear stress, since it a tmeporary condtion and the permanent liner is grass, the Straw w/ Single Net will work but the channel will need to be monitored and maintained until vegetation is extablished.

Channels to have a temporary liner (Straw w/ Single Net)
Permanent liner is grass.

Project:	Sanford Mine	Computed PAW	Date 11/03/14
Subject:	Permit Application	Checked: EGM	Date: 11/6/14
Task:	Drainage - Slope Drains	Sheet:	Of:

Objective: Size the slope drains for the 25-year storm.

Equations:

Q (cfs) = CIA

Runoff Coeff (initial)= 0.60 Ag land, smooth

Runoff Coeff (permanent)= 0.25 Pasture, Sandy

I (in/hr) = 6.76 25-yr, 10-min Design Storm (Sanford, NC)

Drainage Area (acres) = **Use largest drainage area**

Drainage area to pipe is in "post" condition

Manning's

$$D_{REQD} = 16\left[\frac{Qn}{\sqrt{s}}\right]^{\frac{3}{8}}$$

Theoretical Size for pipe flowing full

D = Pipe diameter (inches)

Q = Peak Flow (cfs)

0.012 = n, Manning's Roughness Coefficient for ADS CPP

s = Pipe Slope (ft fall / ft run)

Orifice $Q = C_d * A * (2gh)^{0.5}$

Q (cfs) = Discharge

0.60 = C_d Coefficient of Discharge (dimensionless)

A (sf) = Cross Sectional Area of Flow at the orifice entrance

32.2 = Acceleration of Gravity g (ft/sec^2)

h (ft) = driving head measured from centroid of the orifice (pipe) to the water surface

"Driving Headwater Rqd for Total Flow" is the depth of water above the centerline of the pipe required to achieve the flow.
"Driving Head Available" is the depth of the channel from the center of the pipe to the top of the channel.

Allowable head 2.5 feet (depth of channel)

Scenario	Pipe Slope (ft fall / ft run)	Drainage Area (acres)	Flow Q (cfs)	Theoretical Size for pipe (in)	Pipe Dia Selected (in)	Cross Sectional Area of orifice (sf)	Driving Headwater Rqd for Total Flow (ft)	Driving Head Available (ft)	Manning's Possible Discharge Q (cfs)	Comments
Sideslope	25%	13.3	22.5	12.7	18	1.8	7.0	1.8	57.0	This assumes entire area trying to get into the pipe though some is already in the pipe due to sideslope swales.
Sideslope	25%	7	11.8	10.0	18	1.8	1.9	1.8	57.0	This is drainage from only the sideslope swale.
Diversion Berm	1.0%	2	3.4	11.4	12	0.8	0.8	2.0	3.9	
Diversion Berm	1.0%	7.5	12.7	18.7	18	1.8	2.2	1.8	11.4	

Conclusion:
Use 18" corrugated plastic pipe (smooth wall)

Project:	Sanford Mine	Computed:	PAW	Date 11/03/14
Subject:	Permit Application	Checked	[signature]	Date 11/6/14
Task:	Drainage - Drop Inlets	Sheet		Of

Objective: Size the drop inlet outlet pipe and grates for the 25-year storm.

References:

1. Elements of Urban Stormwater Design, H. Rooney Malcom, P.E.

Equations:

$Q = C_d * A (2 * g * h)^{0.5}$ Orifice Equation

- Q = cfs, discharge (based on permanent condition)
- C_d = 0.59 coefficient of discharge — Ref 1, p III-11
- g = 32.2 ft/sec^2, gravity
- h = ft, driving head measured from the center of the pipe
- A = sf, cross sectional open area

	Open area (A)	Grate	Manufacturer
A	3.6	V-3610-7	East Jordan Iron Works
B	4.8	R-1792-KG	Neenah
C	6.0	R-3531-A	Neenah

Allowable head 2.0 feet (depth of channel)

Max Flow from Slope Drains 22.5 cfs

Check for inlet control

Channel Location	Perimeter Channel Side 1	Side 2	Slope Drain Flow (cfs)	Total Flow (cfs)		Grate	Open Area (sf)	Required head(ft)	
DI #1	1.6		22.5	24.1	C	R-3531-A	6.0	0.7	Ok
DI #2	4.9		22.5	27.4	C	R-3531-A	6.0	0.9	Ok
DI #3	8.8	3.9	22.5	35.2	C	R-3531-A	6.0	1.5	Ok
DI #4	Mininimal Flow								
DI #5	5.4	6.4	22.5	34.3	C	R-3531-A	6.0	1.5	Ok
DI #6	5.2	21.0	22.5	48.7	C	R-3531-A	6.0	2.9	Problem
DI #7	65.2	6.9	22.5	94.6	C	R-3531-A	6.0	11.1	Problem

Cut the flow in half then determine the required grate inlet area

DI #6	24.3	0.59	C	R-3531-A	6.0	0.7	Ok
DI #7	47.3	0.59	C	R-3531-A	6.0	2.8	Problem

DI #7	65.2	0.59	2 large grates will be necessary	9.8	2.0	Ok

Project:	Sanford Mine	Computed:	PAW	Date 11/03/14
Subject:	Permit Application	Checked	Sow	Date 11/6/14
Task:	Drainage - Drop Inlets	Sheet		Of

Size the Outlet culvert

$D=16*(Qn/s^{0.5})^{3/8}$ Theoretical Pipe Size (in) for pipe flowing full

D = Pipe diameter (inches)
Q = Peak Flow (cfs)
n = 0.013 Manning's Roughness Coefficient for RCP
s = Pipe Slope (ft fall / ft run)

Check pipe size based on Gravity Flow

	DI #1	DI #2	DI #3	DI #4	DI #5	DI #6	DI #7
Q (cfs) =	24.1	27.4	35.2	10.0	34.3	48.7	94.6
Number of pipes	1	1	1	1	1	1	2
Slope (%) =	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
Theoretical Diameter (in) =	24.6	25.8	28.3	17.7	28.0	32.0	31.6
Culvert Diameter (in) =	30	30	30	18	30	36	36

Conclusion:

For DI #1, #2, #3, #4, and #5 use a grate with 6 sf open area and a 30" RCP Outlet
For DI #6 use a two grates each with 6 sf open area and a 36" RCP Outlet
For DI #7, use two grates with 12 sf open area and 2- 36" RCP Outlet

Project:	Sanford Mine	Computed:	PAW	Date 11/03/14
Subject:	Permit Application	Checked	Scew	Date 11/6/14
Task:	Drainage - Drop Inlet across Power Line Right-of-Way	Sheet		Of

Objective: Design the grate, drop inlet and culvert for the power line right-of-way crossing for the 25-year storm.

References: 1. Elements of Urban Stormwater Design, H. Rooney Malcom, P.E.

Equations:

Q (cfs) = CIA

Runoff Coeff (initial)=	0.60	Ag land, smooth
Runoff Coeff (permanent)=	0.25	Pasture, Sandy
I (in/hr) =	6.76	25-yr, 10-min Design Storm (Sanford, NC)
A (acres) =	27.6	
Q initial (cfs) =	111.95	
Q permanent (cfs) =	46.64	

Orifice Equation

$Q = C_d * A (2 * g * h)^{0.5}$

Q = cfs, discharge (based on permanent condition)

C_d = coefficient of discharge 0.59 Ref 1, p III-11

g = 32.2 ft/sec^2, gravity

h = ft, driving head measured from the center of the pipe

A = sf, cross sectional open area

Type	Open area (A)	Perimeter of grate	Grate	Manufacturer
A	3.6	10.4	V-3610-7	East Jordan Iron Works
B	4.8	12.1	R-1792-KG	Neenah
C	6.0	13	R-3531-A	Neenah

Weir Equation

$Q = C_w * L * H^{1.5}$

Q (cfs) = Discharge

3.2 = Cw Weir Coefficient (dimensionless)

varies = L (ft) Length of weir measured along crest

H (ft) = driving head (crest of the weir to the water surface)

Allowable head 2.0 feet (depth of channel)

Check for inlet control

	Q (cfs)	C_d or C_w		Grate	Open Area (sf)	Required head(ft)		
Initial	111.95	0.59	C	R-3531-A	6.0	15.5	Problem	Remove grate. Assume weir.
Initial	111.95	3.2	C	R-3531-A	13.0	1.9	Ok	
Permanent	46.6	0.59	C	R-3531-A	6.0	2.7	Problem	Divide the flow
Permanent	23.3	0.59	C	R-3531-A	6.0	0.7	Ok	

Project:	Sanford Mine	Computed:	PAW	Date 11/03/14
Subject:	Permit Application	Checked	Gcw	Date 11/6/14
Task:	Drainage - Drop Inlet across Power Line Right-of-Way	Sheet		Of

Size the Outlet culvert

$D=16*(Qn/s^{0.5})^{3/8}$ Theoretical Pipe Size (in) for pipe flowing full

D = Pipe diameter (inches)
Q = Peak Flow (cfs)
n = 0.013 Mannings Roughness Coefficient for RCP
s = Pipe Slope (ft fall / ft run)

DI Rim Elev	288
Depth of DI	3
DI bottom Elev	285
Culvert Invert In	285
Culvert Invert Out	282
Culvert Length	206
Slope	1.5%

Check pipe size based on Gravity Flow

	Initial Flow	Half of Initial Flow	Permanent Flow	Half of Permanent Flow
Q (cfs) =	111.95	55.97	46.6	23.32
Theoretical Diameter (in) =	40.7	31.4	29.3	22.6
Culvert Diameter (in) =	42	30	30	24

Conclusion:

Use a grate with a minimum inlet area of 6 sf .
Use 2 24" RCP culverts out of the drop inlets at 1.5% slope.

Project:	Sanford Mine	Computed PAW	Date 11/03/14
Subject:	Permit Application	Checked: Eew	Date: 11/6/14
Task:	Drainage - Apron Outlets	Sheet	Of

Objective: Design the apron outlets for the drop inlets for the 25-year storm.

References:

1. "Elements of Urban Stormwater Design" by H. Rooney Malcom, P.E.
2. North Carolina Erosion and Sediment Control Planning and Design Manual

Equations:

Determine Tailwater conditions to size apron
Use Normal Depth Procedure (Manning's Eqn.) Ref 1, II-7

$Z_{av} = AR^{2/3}$ Area (A) = bd + z d^2

$Z_{req} = Q\,n / 1.49s^{0.5}$ $R = \text{Area} \;/\; (b+2d(z^2+1)^{0.5})$

$AR^{2/3} = Q\,n / \; 1.49s^{0.5}$ Avg Shear Stress (T) = d*s*unit weight of water

$Z_{av} = Z_{req}$

n =	0.104	6-Inch Rip Rap Lined Channel (for depths of 0 to 0.5 ft)	Ref 2
n =	0.069	6-Inch Rip Rap Lined Channel (for depths of 0.5 to 2 ft)	Ref 2
Vp (ft/sec) =	9	Permissible Velocity for lining	Ref 2
Side Slope (z) =	6	enter X for X:1 (assumed)	
s (ft/ft) =	1.0%	Outlet Slope (assumed)	
Diameter (in) =	varies	Drop Inlet Culvert	
Bottom Width (ft) =	10	Assumed	

Flows (Q) based on the "Manning's Possible Discharge Q (cfs)" from the pipe calcualation.
For the Perm Rd North, the flow is doubles since there are 2 pipes.

0.5* Barrel Diameter (ft) =	1.25	Ref 2, 8.06.1
0.5* Barrel Diameter (ft) =	1.50	
Minimum Tailwater Conditions:	Flow Depth (d) < 0.5*Diameter of Culvert	Ref 2 8.06a
Maximum Tailwater Conditions:	Flow Depth (d) > 0.5*Diameter of Culvert	Ref 2 8.06b

Diameter (in)	Q (cfs)	Z_{req}	Flow Depth, d (ft)	Cross Sectional Area (sf)	R (ft)	Z_{av}	Velocity (ft/sec)	Tailwater
30	35.2	16.28	1.13	18.9	0.80	16.28	1.9	Min
36	48.7	22.54	1.33	23.9	0.91	22.54	2.0	Min

Size the aprons for each pipe using Ref 2:
The discharge on Figure 8.06a do not intersect the pipe size. Use the minimum length.

Conclusion:

Culvert Diameter (ft)	Entrance (ft)	Length (ft)	Outlet Width (ft)	Median Rip Rap Size (ft) d_{50}	Selected Rip Rap Size (in)
2.5	7.5	16	19	0.5	Class B
3	9	20	23	0.5	Class B

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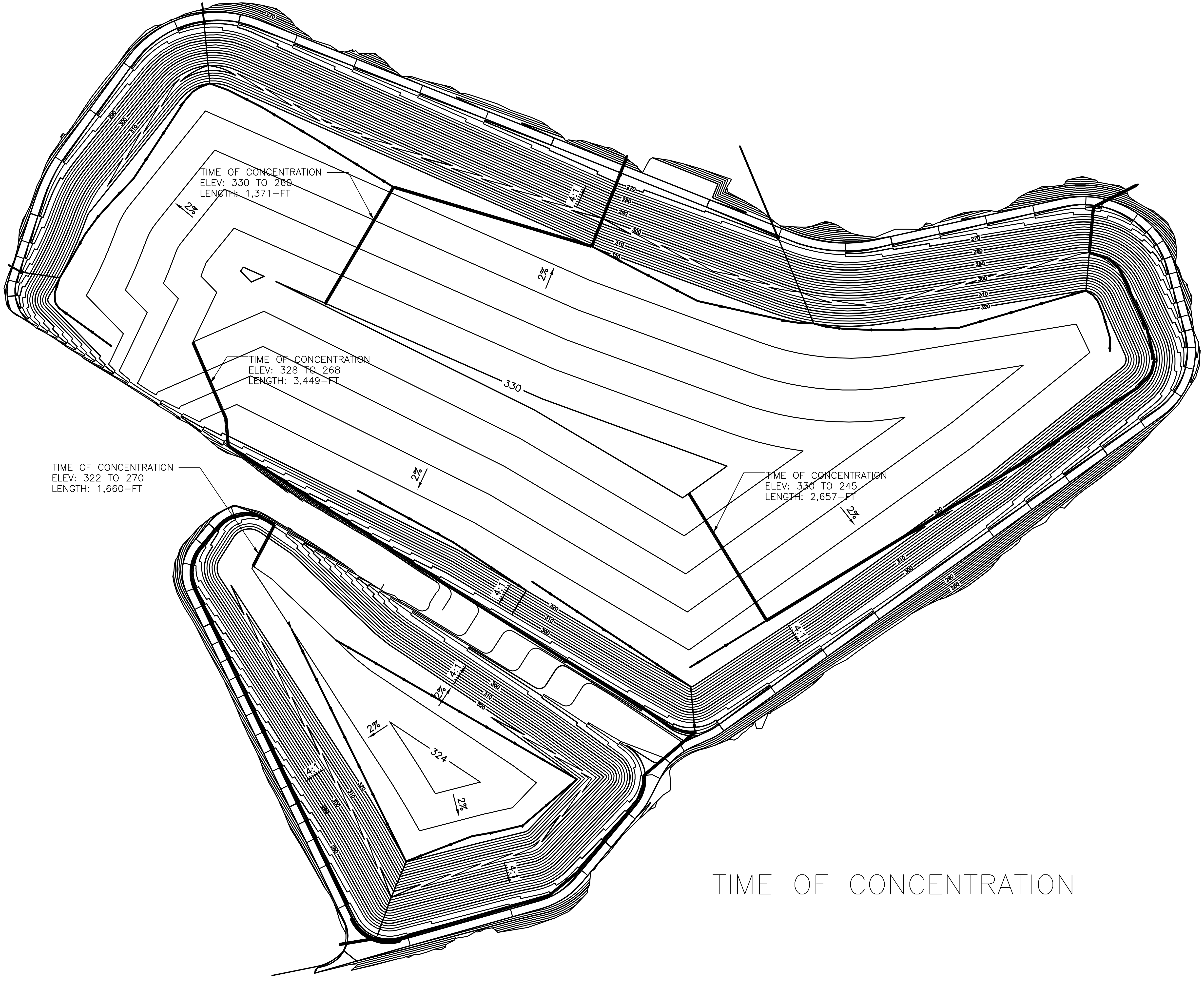

TIME OF CONCENTRATION

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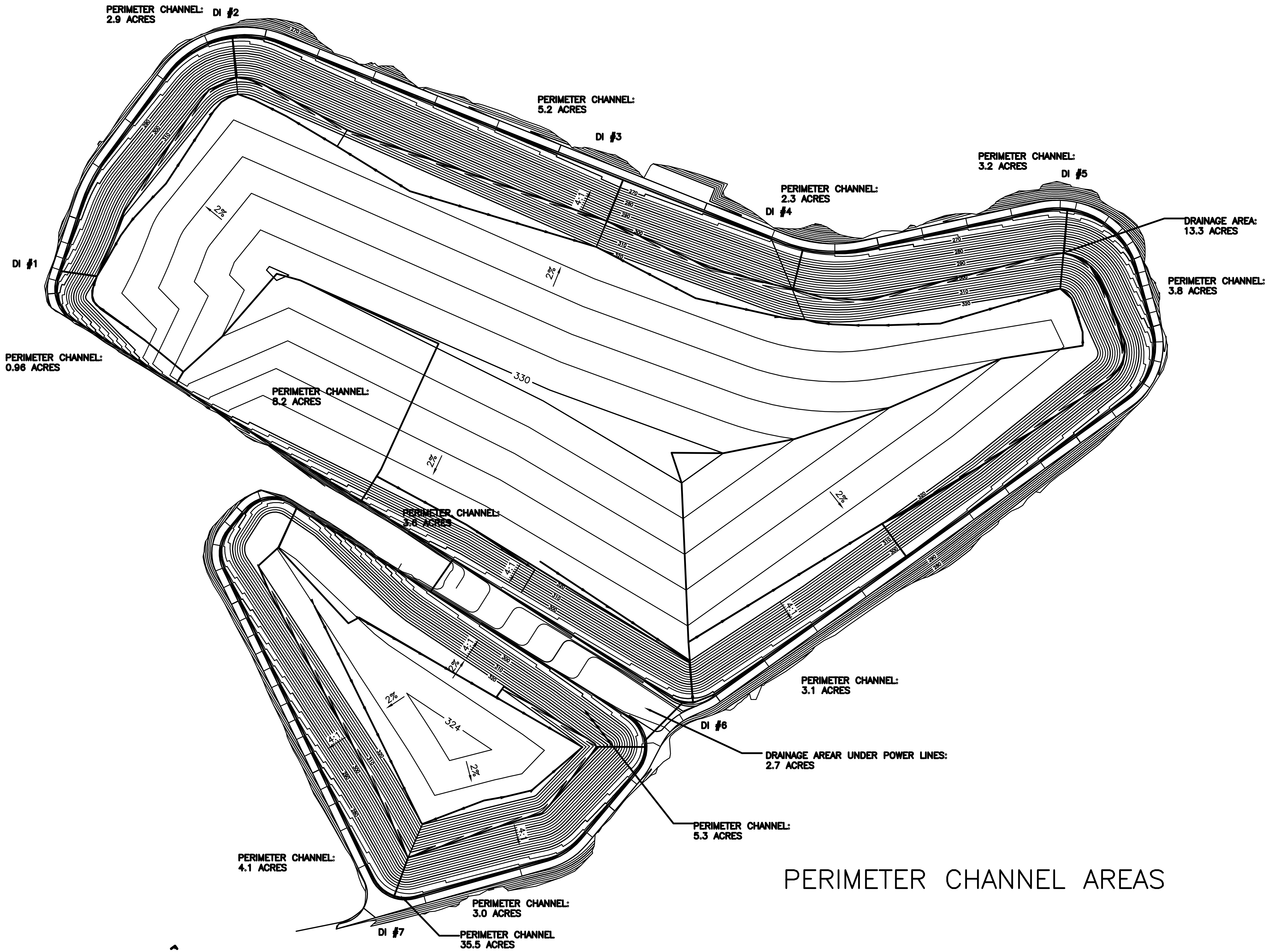

PERIMETER CHANNEL AREAS

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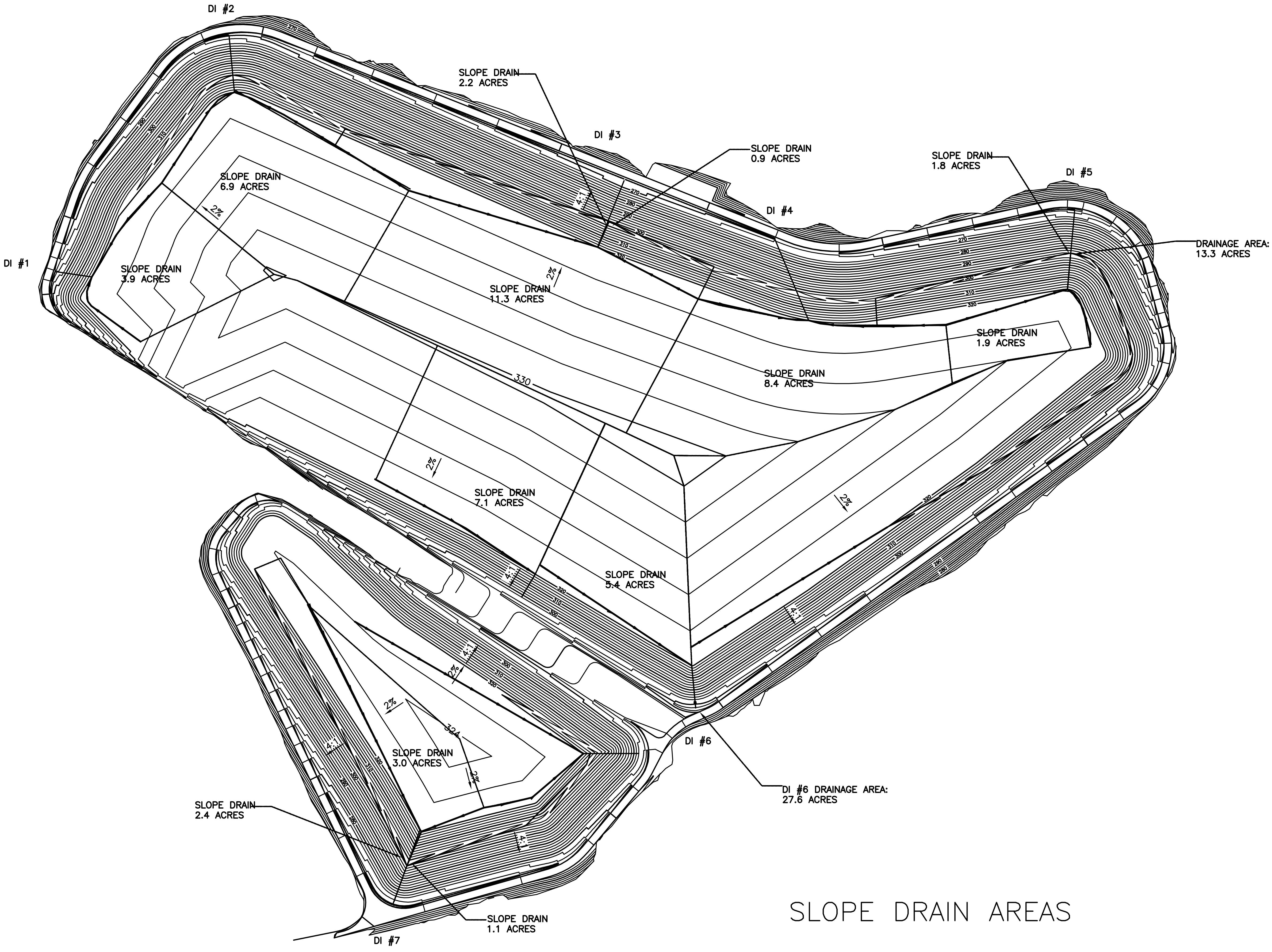

SLOPE DRAIN AREAS

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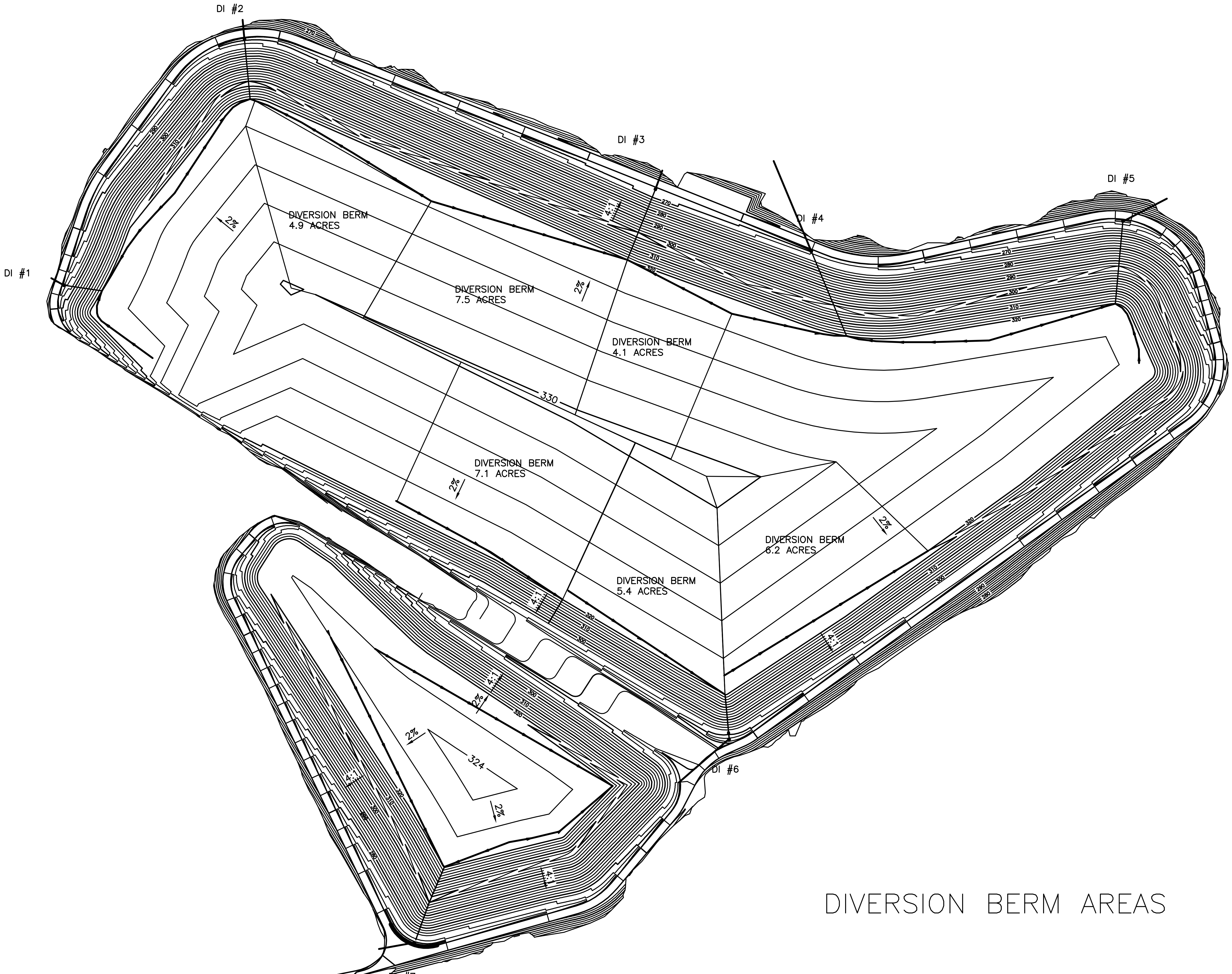


DIVERSION BERM AREAS

POINT PRECIPITATION FREQUENCY ESTIMATES

G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches/hour)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	5.10 (4.66-5.62)	6.04 (5.51-6.64)	7.00 (6.38-7.70)	7.69 (7.00-8.45)	8.48 (7.68-9.31)	9.01 (8.14-9.89)	9.52 (8.53-10.4)	9.95 (8.88-10.9)	10.4 (9.23-11.4)	10.8 (9.48-11.8)
10-min	4.08 (3.72-4.48)	4.82 (4.40-5.31)	5.60 (5.11-6.17)	6.15 (5.60-6.76)	6.76 (6.12-7.42)	7.18 (6.48-7.87)	7.56 (6.78-8.28)	7.88 (7.03-8.64)	8.26 (7.30-9.05)	8.50 (7.46-9.33)
15-min	3.40 (3.10-3.74)	4.04 (3.69-4.45)	4.72 (4.31-5.20)	5.19 (4.72-5.70)	5.71 (5.17-6.27)	6.06 (5.47-6.64)	6.37 (5.72-6.98)	6.63 (5.92-7.27)	6.92 (6.13-7.59)	7.11 (6.24-7.81)
30-min	2.33 (2.13-2.56)	2.79 (2.55-3.07)	3.36 (3.06-3.69)	3.76 (3.42-4.13)	4.23 (3.83-4.64)	4.56 (4.12-5.00)	4.88 (4.38-5.34)	5.16 (4.61-5.66)	5.51 (4.87-6.04)	5.76 (5.06-6.32)
60-min	1.45 (1.33-1.60)	1.75 (1.60-1.93)	2.15 (1.96-2.37)	2.45 (2.23-2.69)	2.82 (2.55-3.09)	3.09 (2.79-3.39)	3.36 (3.01-3.68)	3.62 (3.23-3.97)	3.95 (3.50-4.33)	4.20 (3.69-4.61)
2-hr	0.856 (0.776-0.951)	1.04 (0.940-1.15)	1.29 (1.17-1.43)	1.48 (1.34-1.64)	1.73 (1.55-1.91)	1.92 (1.71-2.12)	2.10 (1.87-2.33)	2.29 (2.02-2.53)	2.53 (2.21-2.80)	2.72 (2.35-3.01)
3-hr	0.605 (0.550-0.672)	0.733 (0.666-0.814)	0.915 (0.831-1.02)	1.06 (0.957-1.17)	1.25 (1.12-1.38)	1.40 (1.25-1.54)	1.55 (1.37-1.71)	1.70 (1.50-1.88)	1.91 (1.66-2.11)	2.08 (1.79-2.30)
6-hr	0.363 (0.331-0.401)	0.439 (0.401-0.484)	0.549 (0.500-0.606)	0.636 (0.577-0.700)	0.753 (0.679-0.827)	0.846 (0.758-0.928)	0.942 (0.837-1.03)	1.04 (0.915-1.14)	1.18 (1.02-1.29)	1.29 (1.10-1.41)
12-hr	0.214 (0.195-0.236)	0.258 (0.236-0.286)	0.325 (0.296-0.359)	0.378 (0.342-0.417)	0.452 (0.406-0.496)	0.511 (0.456-0.560)	0.573 (0.506-0.627)	0.638 (0.558-0.698)	0.730 (0.627-0.799)	0.804 (0.681-0.880)
24-hr	0.125 (0.116-0.134)	0.151 (0.141-0.162)	0.190 (0.177-0.204)	0.220 (0.205-0.236)	0.262 (0.242-0.281)	0.295 (0.273-0.316)	0.328 (0.303-0.353)	0.364 (0.334-0.390)	0.412 (0.377-0.442)	0.449 (0.410-0.483)
2-day	0.073 (0.068-0.078)	0.088 (0.082-0.094)	0.109 (0.102-0.117)	0.126 (0.117-0.136)	0.150 (0.138-0.161)	0.168 (0.155-0.180)	0.187 (0.172-0.201)	0.206 (0.189-0.222)	0.233 (0.213-0.251)	0.254 (0.231-0.274)
3-day	0.051 (0.048-0.055)	0.062 (0.058-0.066)	0.077 (0.071-0.082)	0.088 (0.082-0.095)	0.104 (0.097-0.112)	0.117 (0.108-0.126)	0.130 (0.120-0.140)	0.144 (0.132-0.154)	0.162 (0.148-0.174)	0.177 (0.161-0.190)
4-day	0.041 (0.038-0.044)	0.049 (0.046-0.052)	0.060 (0.056-0.065)	0.069 (0.065-0.074)	0.082 (0.076-0.088)	0.092 (0.085-0.098)	0.102 (0.094-0.109)	0.112 (0.103-0.120)	0.127 (0.116-0.136)	0.138 (0.125-0.148)
7-day	0.027 (0.025-0.029)	0.032 (0.030-0.034)	0.039 (0.036-0.042)	0.044 (0.041-0.048)	0.052 (0.048-0.056)	0.058 (0.054-0.062)	0.064 (0.060-0.069)	0.071 (0.065-0.076)	0.080 (0.073-0.085)	0.087 (0.079-0.093)
10-day	0.021 (0.020-0.023)	0.025 (0.024-0.027)	0.031 (0.029-0.033)	0.035 (0.032-0.037)	0.040 (0.037-0.043)	0.044 (0.041-0.047)	0.049 (0.045-0.052)	0.053 (0.049-0.057)	0.059 (0.055-0.063)	0.064 (0.059-0.068)
20-day	0.014 (0.014-0.015)	0.017 (0.016-0.018)	0.020 (0.019-0.021)	0.022 (0.021-0.024)	0.026 (0.024-0.027)	0.028 (0.026-0.030)	0.031 (0.029-0.033)	0.034 (0.031-0.036)	0.037 (0.034-0.039)	0.040 (0.037-0.042)
30-day	0.012 (0.011-0.013)	0.014 (0.013-0.015)	0.016 (0.015-0.017)	0.018 (0.017-0.019)	0.020 (0.019-0.022)	0.022 (0.021-0.024)	0.024 (0.022-0.025)	0.026 (0.024-0.027)	0.028 (0.026-0.030)	0.030 (0.028-0.032)
45-day	0.010 (0.010-0.011)	0.012 (0.011-0.013)	0.014 (0.013-0.014)	0.015 (0.014-0.016)	0.017 (0.016-0.017)	0.018 (0.017-0.019)	0.019 (0.018-0.020)	0.020 (0.019-0.022)	0.022 (0.021-0.023)	0.023 (0.022-0.025)
60-day	0.009 (0.009-0.010)	0.011 (0.010-0.011)	0.012 (0.011-0.013)	0.013 (0.012-0.014)	0.014 (0.014-0.015)	0.015 (0.015-0.016)	0.016 (0.016-0.017)	0.017 (0.016-0.018)	0.019 (0.018-0.020)	0.020 (0.018-0.021)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Back to Top

PF graphical

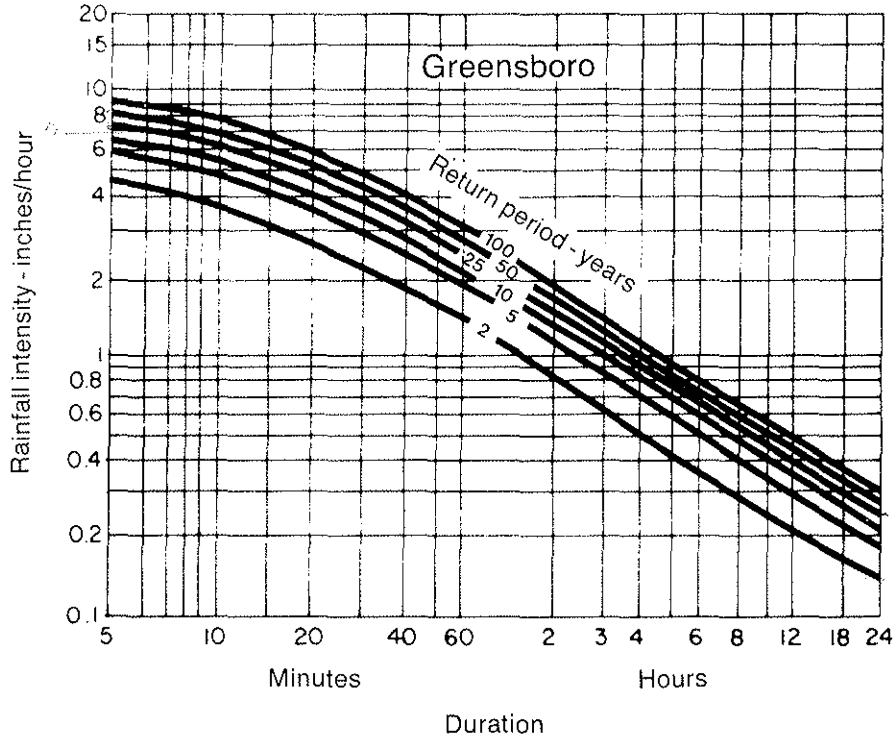


Figure 8.03d Rainfall intensity duration curves—Greensboro.

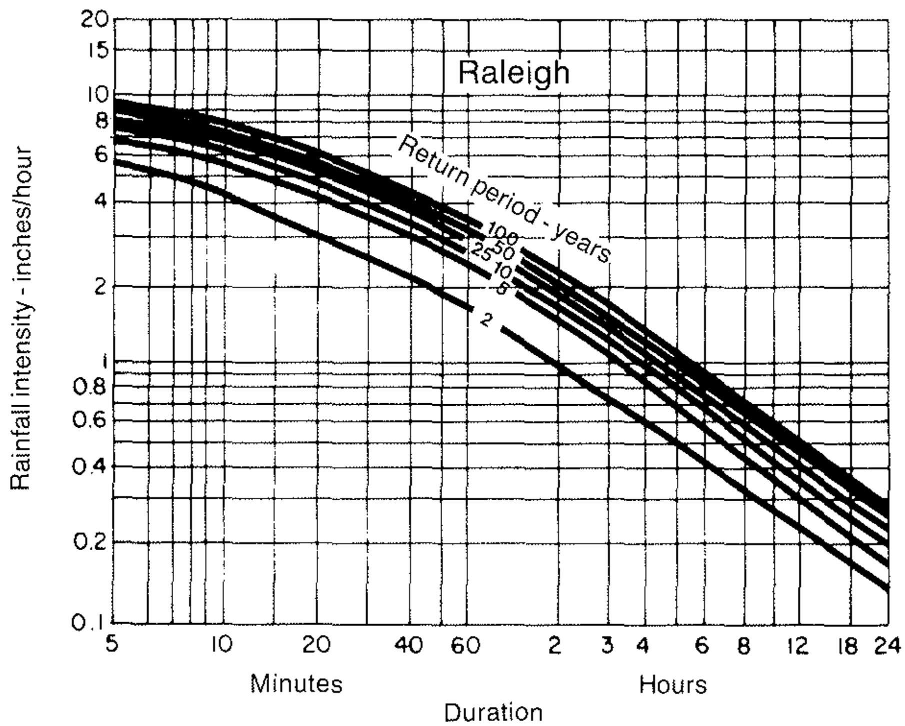


Figure 8.03e Rainfall intensity duration curves—Raleigh.

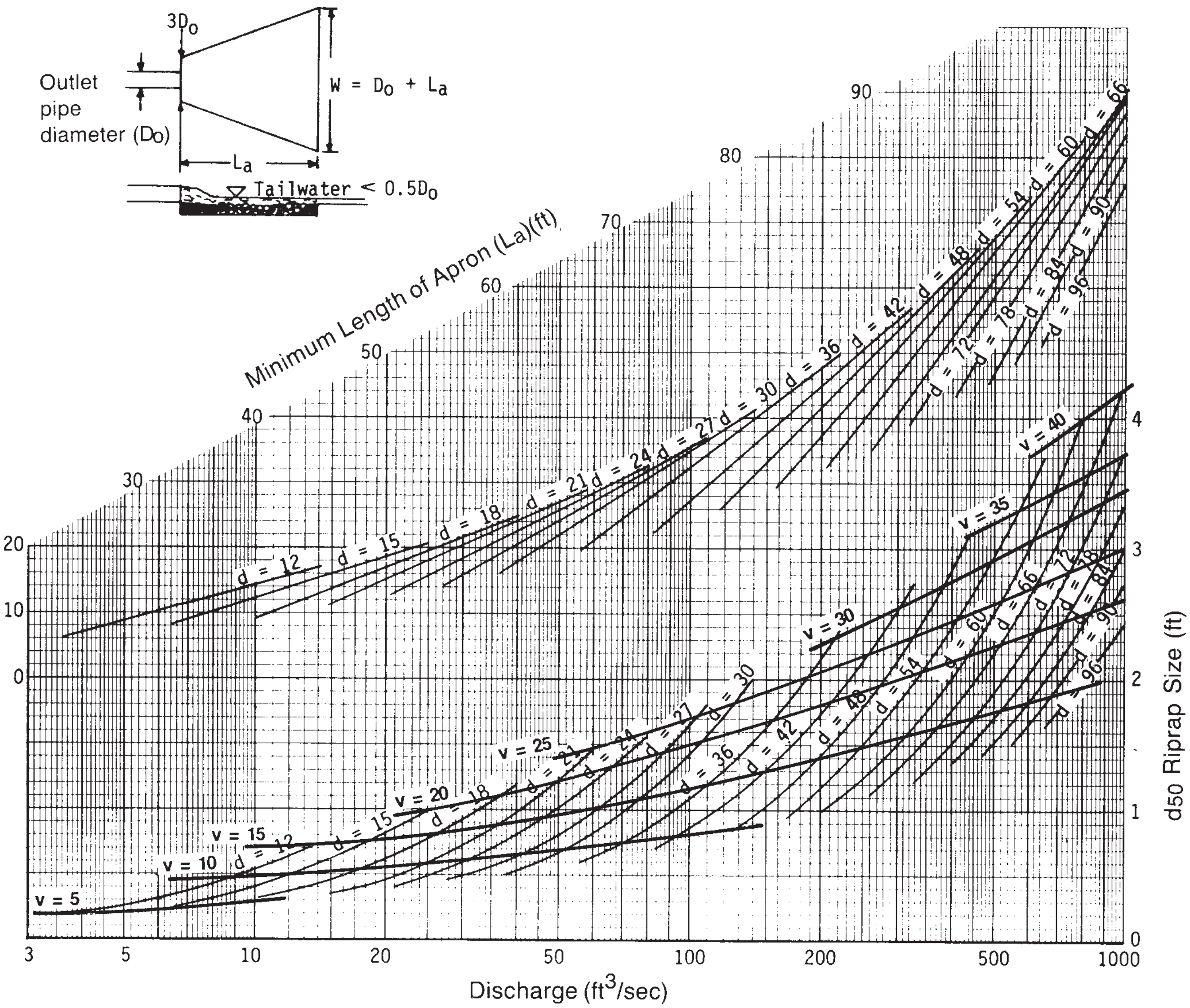
Table 8.03b
Value of Runoff Coefficient (C) for Rational Formula

Land Use	C
Business:	
Downtown areas	0.70-0.95
Neighborhood areas	0.50-0.70
Residential:	
Single-family areas	0.30-0.50
Multi units, detached	0.40-0.60
Multi units, Attached	0.60-0.75
Suburban	0.25-0.40
Industrial:	
Light areas	0.50-0.80
Heavy areas	0.60-0.90
Parks, cemeteries	0.10-0.25
Playgrounds	0.20-0.35
Railroad yard areas	0.20-0.40
Unimproved areas	0.10-0.30
Streets:	
Asphalt	0.70-0.95
Concrete	0.80-0.95
Brick	0.70-0.85
Drives and walks	0.75-0.85
Roofs	0.75-0.85

Land Use	C
Lawns:	
Sandy soil, flat, 2%	0.05-0.10
Sandy soil, ave.,	0.10-0.15
2-7%	0.15-0.20
Sandy soil, steep,	0.13-0.17
7%	0.18-0.22
Heavy soil, flat, 2%	0.25-0.35
Heavy soil, ave.,	
2-7%	
Heavy soil, steep,	
7%	0.30-0.60
	0.20-0.50
Agricultural land:	
Bare packed soil	0.30-0.60
Smooth	0.20-0.50
Rough	0.20-0.40
Cultivated rows	0.10-0.25
Heavy soil no crop	
Heavy soil with	0.15-0.45
crop	0.05-0.25
Sandy soil no crop	0.05-0.25
Sandy soil with	
crop	0.10-0.25
Pasture	
Heavy soil	0.15-0.45
Sandy soil	0.05-0.25
Woodlands	0.05-0.25

NOTE: The designer must use judgement to select the appropriate C value within the range for the appropriate land use. Generally, larger areas with permeable soils, flat slopes, and dense vegetation should have lowest C values. Smaller areas with slowly permeable soils, steep slopes, and sparse vegetation should be assigned highest C values.

Source: American Society of Civil Engineers



Curves may not be extrapolated.

Figure 8.06a Design of outlet protection protection from a round pipe flowing full, minimum tailwater condition (T_w < 0.5 diameter).

SEDIMENT BASIN CALCULATIONS			
CHARAH - SANFORD			
HDR PROJECT NO.:	235691		
DATE:	09.30.14	BY:	RMB
REVISED:	11.05.14	RVW:	PW

Basin #1 (Ph-1)

Phase 2 controls Basin #1 Design

FAIRCLOTH SKIMMER TYPE BASIN DESIGN WITH RISER

NCDENR? 1 ← IF Yes, Type: 1

DRAINAGE AREAS/REQ'D STORAGE			
Total drainage area (TDA)		5.4	ac
Disturbed area(DA)		5.4	ac
Rqd sediment storage	(1800xDA)	9756	cf

ESTIMATED BASIN SIZE (RECTANGULAR)		
	Length(ft)	Width(ft)
Bottom	151	67
Top	169	85

BASIN CONFIGURATION		
Proposed sediment depth	3	ft
Depth of flow over spillway	1	ft
Bottom elevation of basin	283	msl
Sediment Storage elevation	286	msl
Spillway crest	286	msl
Top of Berm	289	msl
Emergency Spillway Elevation	287	msl
DESIGN FLOW (SEE HYDROGRAPHS)		
10yr Computed flow from site, 'Q' =	32.86	cfs

PLANNED BASIN SIZE (REFER TO EROSION CONTROL PLAN)

Elev.	Area (SF)	Cumulative Volume (CF)
283	13792	0
284	15414	14603
285	17133	30877
286	18947	48917
287	21463	69122
288	23731	91719
289	26305	116737
X	X	#VALUE!
X	X	#VALUE!
X	X	#VALUE!

FAIRCLOTH SKIMMER DESIGN TABLE

4	Skimmer Size (inches)
0.333	Head on Skimmer (feet)
2	Orifice Size (1/4 inch increments)
1.83	Dewatering Time (days)
	Suggest about 3 days

Skimmer Size (Inches)
1.5
2
2.5
3
4
5
6
8

BASIN EFFICIENCY			
Sediment storage required:	9756	cf	
Sediment storage provided:	48917	cf	OKAY
Surface area required:	14294.1	sf	
Surface area provided:	18947	sf	OKAY

SPILLWAY DESIGN

RISER SPILLWAY DESIGN

Riser diameter:	36 in	Flow Depth:	1 ft
Orifice Flow:	32.00 cfs	Controlling:	Orifice
Weir Flow:	58.40 cfs	Controlling>Q10?	OKAY

EMERGENCY SPILLWAY SIZE (L=Q/(C*h^1.5))			
100yr Flow from site, Q100 =	53.13		
Q100 Flow - Flow through Barrel =	17		
C	3	L=	16
h	0.5		

Barrel diameter	30	in
Barrel slope (ft/ft)	0.01	ft/ft
Barrel length(ft)	50	ft
Barrel invert in	283	
Barrel invert out	282.5	

Flow through barrel 36 cfs

(Note: Flow determined using outlet control and pipe 80% full)

BARREL FLOW>Q10? OKAY

CONCRETE ANCHOR SIZE

Length of exposed outlet pipe	10	ft
Buoyancy =	4386	lbs
Required Volume of Anchor =	30.3	cf
Actual Volume of Anchor=	45.375	cf

Safety factor	1.2	
Anchor width	5.5	ft
Anchor Length	5.5	ft
Anchor Thickness	1.5	ft

OKAY

SEDIMENT BASIN CALCULATIONS				Basin #1 (Ph-2)
CHARAH - SANFORD				Phase 2 controls Basin #1 Design
HDR PROJECT NO.:	235691			
DATE: 09.30.14		BY:	RMB	
REVISED: 11.05.14		RVW:	PW	

FAIRCLOTH SKIMMER TYPE BASIN DESIGN WITH RISER

NCDENR? 1 ← IF Yes, Type: 1

DRAINAGE AREAS/REQ'D STORAGE			
Total drainage area (TDA)		9.3	ac
Disturbed area(DA)		9.3	ac
Rqd sediment storage	(1800xDA)	16794	cf

ESTIMATED BASIN SIZE (RECTANGULAR)		
	Length(ft)	Width(ft)
Bottom	176	79
Top	194	97

BASIN CONFIGURATION		
Proposed sediment depth	3	ft
Depth of flow over spillway	1	ft
Bottom elevation of basin	283	msl
Sediment Storage elevation	286	msl
Spillway crest	286	msl
Top of Berm	289	msl
Emergency Spillway Elevation	287	msl
DESIGN FLOW (SEE HYDROGRAPHS)		
10yr Computed flow from site, 'Q' =	43.09	cfs

PLANNED BASIN SIZE		(REFER TO EROSION CONTROL PLAN)
Elev.	Area (SF)	Cumulative Volume (CF)
283	13792	0
284	15414	14603
285	17133	30877
286	18947	48917
287	21463	69122
288	23731	91719
289	26305	116737
X	X	#VALUE!
X	X	#VALUE!
X	X	#VALUE!

FAIRCLOTH SKIMMER DESIGN TABLE

4	Skimmer Size (inches)
0.333	Head on Skimmer (feet)
2	Orifice Size (1/4 inch increments)
3.15	Dewatering Time (days)
	Suggest about 3 days

Skimmer Size (Inches)
1.5
2
2.5
3
4
5
6
8

BASIN EFFICIENCY			
Sediment storage required:	16794	cf	
Sediment storage provided:	48917	cf	OKAY
Surface area required:	18744.15	sf	
Surface area provided:	18947	sf	OKAY

SPILLWAY DESIGN

RISER SPILLWAY DESIGN					
Riser diameter:	48	in	Flow Depth:	1	ft
Orifice Flow:	42.00	cfs	Controlling:	Orifice	
Weir Flow:	77.87	cfs	Controlling>Q10?	OKAY	

EMERGENCY SPILLWAY SIZE (L=Q/(C*h^1.5))			
100yr Flow from site, Q100 =	70.07		
Q100 Flow - Flow through Barrel =	20		
C	3	L=	19
h	0.5		

Barrel diameter	36	in
Barrel slope (ft/ft)	0.01	ft/ft
Barrel length(ft)	50	ft
Barrel invert in	283	
Barrel invert out	282.5	

Flow through barrel 50 cfs

(Note: Flow determined using outlet control and pipe 80% full)

BARREL FLOW>Q10? OKAY

Velocity= 7.04 fps

CONCRETE ANCHOR SIZE					
Length of exposed outlet pipe	10	ft	Safety factor	1.2	
Buoyancy =	6763	lbs	Anchor width	6	ft
Required Volume of Anchor =	46.6	cf	Anchor Length	6	ft
Actual Volume of Anchor=	63	cf	Anchor Thickness	1.75	ft
OKAY					

SEDIMENT BASIN CALCULATIONS			
CHARAH - SANFORD			
HDR PROJECT NO.:	235691		
DATE: 09.30.14		BY:	RMB
REVISED: 11.05.14		RVW:	PW

Basin #2 (Ph-1)

Phase 1 controls Basin #2 Design

FAIRCLOTH SKIMMER TYPE BASIN DESIGN WITH RISER

NCDENR? 1 ← IF Yes, Type: 1

DRAINAGE AREAS/REQ'D STORAGE			
Total drainage area (TDA)		17.6	ac
Disturbed area(DA)		17.6	ac
Rqd sediment storage	(1800xDA)	31680	cf

ESTIMATED BASIN SIZE (RECTANGULAR)		
	Length(ft)	Width(ft)
Bottom	279	130
Top	297	148

BASIN CONFIGURATION		
Proposed sediment depth	3	ft
Depth of flow over spillway	1	ft
Bottom elevation of basin	259	msl
Sediment Storage elevation	262	msl
Spillway crest	262	msl
Top of Berm	265	msl
Emergency Spillway Elevation	263	msl
DESIGN FLOW (SEE HYDROGRAPHS)		
10yr Computed flow from site, 'Q' =	101.32	cfs
1/2 10yr Computed flow from site, 'Q' =	50.66	cfs

PLANNED BASIN SIZE (REFER TO EROSION CONTROL PLAN)		
Elev.	Area (SF)	Cumulative Volume (CF)
259	37790	0
260	40921	39356
261	44109	81871
262	47355	127603
263	50658	176609
264	54018	228947
265	57435	284674
X	X	#VALUE!
X	X	#VALUE!
X	X	#VALUE!

FAIRCLOTH SKIMMER DESIGN TABLE		Skimmer Size (Inches)
4	Skimmer Size (inches)	1.5
0.333	Head on Skimmer (feet)	2
2	Orifice Size (1/4 inch increments)	2.5
2.97	Dewatering Time (days)	3
	Suggest about 3 days	4
		5
		6
		8

Note: Divided Sediment Storage by 2 (one skimmer/riser)

BASIN EFFICIENCY			
Sediment storage required:	31680	cf	
Sediment storage provided:	127603	cf	OKAY
Surface area required:	44074.2	sf	
Surface area provided:	47355	sf	OKAY

SPILLWAY DESIGN (Note: Need 2 risers; therefore split flow)			
RISER SPILLWAY DESIGN			
Riser diameter:	60 in	Flow Depth:	1 ft
Orifice Flow:	53.00 cfs	Controlling:	Orifice
Weir Flow:	97.34 cfs	Controlling>Q10?	OKAY

EMERGENCY SPILLWAY SIZE (L=Q/(C*h^1.5))			
100yr Flow from site, Q100 =	164.22		
Q100 Flow - Flow through Barrel =	15		
C	3	L=	14
h	0.5		

Barrel diameter	48	in
Barrel slope (ft/ft)	0.01	ft/ft
Barrel length(ft)	50	ft
Barrel invert in	259	
Barrel invert out	258.5	

Flow through barrel 75 cfs
(Note: Flow determined using outlet control and pipe 80% full)
BARREL FLOW>Q10? OKAY
Velocity= 5.94 fps

CONCRETE ANCHOR SIZE		
Length of exposed outlet pipe	10	ft
Buoyancy =	11517	lbs
Required Volume of Anchor =	79.4	cf
Actual Volume of Anchor=	98	cf
OKAY		

Safety factor	1.2	
Anchor width	7	ft
Anchor Length	7	ft
Anchor Thickness	2	ft

SEDIMENT BASIN CALCULATIONS				Basin #2 (Ph-2)
CHARAH - SANFORD				Phase 1 controls Basin #2 Design
HDR PROJECT NO.:	235691			
DATE: 09.30.14		BY:	RMB	
REVISED: 11.05.14		RVW:	PW	

FAIRCLOTH SKIMMER TYPE BASIN DESIGN WITH RISER

NCDENR? **1** ← IF Yes, Type: **1**

DRAINAGE AREAS/REQ'D STORAGE			
Total drainage area (TDA)		14.8	ac
Disturbed area(DA)		14.8	ac
Rqd sediment storage	(1800xDA)	26676	cf

ESTIMATED BASIN SIZE (RECTANGULAR)		
	Length(ft)	Width(ft)
Bottom	275	129
Top	293	147

BASIN CONFIGURATION		
Proposed sediment depth	3	ft
Depth of flow over spillway	1	ft
Bottom elevation of basin	259	msl
Sediment Storage elevation	262	msl
Spillway crest	262	msl
Top of Berm	265	msl
Emergency Spillway Elevation	263	msl
DESIGN FLOW (SEE HYDROGRAPHS)		
10yr Computed flow from site, 'Q' =	98.71	cfs
1/2 10yr Computed flow from site, 'Q' =	49.355	cfs

PLANNED BASIN SIZE (REFER TO EROSION CONTROL PLAN)		
Elev.	Area (SF)	Cumulative Volume (CF)
259	37790	0
260	40921	39356
261	44109	81871
262	47355	127603
263	50658	176609
264	54018	228947
265	57435	284674
X	X	#VALUE!
X	X	#VALUE!
X	X	#VALUE!

FAIRCLOTH SKIMMER DESIGN TABLE		Skimmer Size (Inches)
4	Skimmer Size (inches)	1.5
0.333	Head on Skimmer (feet)	2
2	Orifice Size (1/4 inch increments)	2.5
2.50	Dewatering Time (days)	3
	Suggest about 3 days	4
		5
		6
		8

BASIN EFFICIENCY			
Sediment storage required:	26676	cf	
Sediment storage provided:	127603	cf	OKAY
Surface area required:	42938.85	sf	
Surface area provided:	47355	sf	OKAY

Note: Divided Sediment Storage by 2 (one skimmer/riser)

SPILLWAY DESIGN (Note: Need 2 risers; therefore split flow)			
RISER SPILLWAY DESIGN			
Riser diameter:	60 in	Flow Depth:	1 ft
Orifice Flow:	53.00 cfs	Controlling:	Orifice
Weir Flow:	97.34 cfs	Controlling>Q10?	OKAY

EMERGENCY SPILLWAY SIZE (L=Q/(C*h^1.5))			
100yr Flow from site, Q100 =			128.64
Q100 Flow - Flow through Barrel =			-21
C=3.0	h = 1	L=	-7
Note: Q25 handled by Riser/Barrel			

Barrel diameter	48	in
Barrel slope (ft/ft)	0.01	ft/ft
Barrel length(ft)	50	ft
Barrel invert in	259	
Barrel invert out	258.5	

Flow through barrel 75 cfs (Each)

(Note: Flow determined using outlet control and pipe 80% full)

BARREL FLOW>Q10? OKAY

CONCRETE ANCHOR SIZE					
Length of exposed outlet pipe	10	ft	Safety factor	1.2	
Buoyancy =	11517	lbs	Anchor width	7	ft
Required Volume of Anchor =	79.4	cf	Anchor Length	7	ft
Actual Volume of Anchor=	98	cf	Anchor Thickness	2	ft
OKAY					

SEDIMENT BASIN CALCULATIONS				Basin #3 (Ph-1)
CHARAH - SANFORD				
HDR PROJECT NO.:	235691			
DATE:	09.30.14	BY:	RMB	
REVISED:	11.05.14	RVW:	PW	

FAIRCLOTH SKIMMER TYPE BASIN DESIGN WITH RISER

NCDENR? 1 ← IF Yes, Type: 1

DRAINAGE AREAS/REQ'D STORAGE			
Total drainage area (TDA)		3.1	ac
Disturbed area(DA)		3.1	ac
Rqd sediment storage	(1800xDA)	5562	cf

ESTIMATED BASIN SIZE (RECTANGULAR)		
	Length(ft)	Width(ft)
Bottom	116	49
Top	134	67

BASIN CONFIGURATION		
Proposed sediment depth	3	ft
Depth of flow over spillway	1	ft
Bottom elevation of basin	244	msl
Sediment Storage elevation	247	msl
Spillway crest	247	msl
Top of Berm	250	msl
Emergency Spillway Elevation	248	msl
DESIGN FLOW (SEE HYDROGRAPHS)		
10yr Computed flow from site, 'Q' =	20.51	cfs

PLANNED BASIN SIZE (REFER TO EROSION CONTROL PLAN)		
Elev.	Area (SF)	Cumulative Volume (CF)
244	4877	0
245	6254	5566
246	7709	12547
247	9244	21024
248	10857	31074
249	12549	42777
250	14321	56212
X	X	#VALUE!
X	X	#VALUE!
X	X	#VALUE!

FAIRCLOTH SKIMMER DESIGN TABLE

		Skimmer Size (Inches)
3	Skimmer Size (inches)	1.5
0.25	Head on Skimmer (feet)	2
1.25	Orifice Size (1/4 inch increments)	2.5
3.08	Dewatering Time (days)	3
	Suggest about 3 days	4
		5
		6
		8

BASIN EFFICIENCY		
Sediment storage required:	5562	cf
Sediment storage provided:	21024	cf OKAY
Surface area required:	8921.85	sf
Surface area provided:	9244	sf OKAY

SPILLWAY DESIGN

RISER SPILLWAY DESIGN

Riser diameter:	30 in	Flow Depth:	1 ft
Orifice Flow:	26.00 cfs	Controlling:	Orifice
Weir Flow:	48.67 cfs	Controlling>Q10?	OKAY

EMERGENCY SPILLWAY SIZE (L=Q/(C*h^1.5))

100yr Flow from site, Q100 =	31.93		
Q100 Flow - Flow through Barrel =	9		
C	3	L=	9
h	0.5		

Barrel diameter	24	in
Barrel slope (ft/ft)	0.01	ft/ft
Barrel length(ft)	50	ft
Barrel invert in	244	
Barrel invert out	243.5	

Flow through barrel 23 cfs
(Note: Flow determined using outlet control and pipe 80% full)
BARREL FLOW>Q10? OKAY
Velocity= 7.25 fps

CONCRETE ANCHOR SIZE

Length of exposed outlet pipe	10	ft	Safety factor	1.2	
Buoyancy =	2879	lbs	Anchor width	4.5	ft
Required Volume of Anchor =	19.9	cf	Anchor Length	4.5	ft
Actual Volume of Anchor=	30.375	cf	Anchor Thickness	1.5	ft

OKAY

SEDIMENT BASIN CALCULATIONS			
CHARAH - SANFORD			
HDR PROJECT NO.:	235691		
DATE: 09.30.14		BY:	RMB
REVISED: 11.05.14		RVW:	PW

Basin #4 (Ph-1)

FAIRCLOTH SKIMMER TYPE BASIN DESIGN WITH RISER

NCDENR? 1 ← IF Yes, Type: 1

DRAINAGE AREAS/REQ'D STORAGE			
Total drainage area (TDA)		12.7	ac
Disturbed area(DA)		12.7	ac
Rqd sediment storage	(1800xDA)	22860	cf

ESTIMATED BASIN SIZE (RECTANGULAR)		
	Length(ft)	Width(ft)
Bottom	242	112
Top	260	130

BASIN CONFIGURATION		
Proposed sediment depth	3	ft
Depth of flow over spillway	1	ft
Bottom elevation of basin	261	msl
Sediment Storage elevation	264	msl
Spillway crest	264	msl
Top of Berm	267	msl
Emergency Spillway Elevation	265	msl
DESIGN FLOW (SEE HYDROGRAPHS)		
10yr Computed flow from site, 'Q' =	77.74	cfs
1/2 10yr Computed flow from site, 'Q' =	38.87	cfs

PLANNED BASIN SIZE (REFER TO EROSION CONTROL PLAN)		
Elev.	Area (SF)	Cumulative Volume (CF)
261	26486	0
262	29254	27870
263	32108	58551
264	35046	92128
265	38057	128680
266	41127	168272
267	44258	210964
X	X	#VALUE!
X	X	#VALUE!
X	X	#VALUE!

FAIRCLOTH SKIMMER DESIGN TABLE		
3	Skimmer Size (inches)	Skimmer Size
0.25	Head on Skimmer (feet)	(Inches)
1.75	Orifice Size (1/4 inch increments)	1.5
3.23	Dewatering Time (days)	2
	Suggest about 3 days	2.5
		3
	Note: Divided Sediment Storage by 2 (one skimmer/riser)	4
		5
		6
		8

BASIN EFFICIENCY			
Sediment storage required:	22860	cf	
Sediment storage provided:	92128	cf	OKAY
Surface area required:	33816.9	sf	
Surface area provided:	35046	sf	OKAY

SPILLWAY DESIGN (Note: Need 2 risers; therefore split flow)				
RISER SPILLWAY DESIGN				
Riser diameter:	48 in	Flow Depth:	1 ft	
Orifice Flow:	42.00 cfs	Controlling:	Orifice	
Weir Flow:	77.87 cfs	Controlling>Q10?	OKAY	

EMERGENCY SPILLWAY SIZE (L=Q/(C*h^1.5))			
100yr Flow from site, Q100 =			122.75
Q100 Flow - Flow through Barrel =			23
C	3	L=	22
h	0.5		

Barrel diameter	36	in
Barrel slope (ft/ft)	0.01	ft/ft
Barrel length(ft)	50	ft
Barrel invert in	261	
Barrel invert out	260.5	

Flow through barrel 50 cfs

(Note: Flow determined using outlet control and pipe 80% full)

BARREL FLOW>Q10? OKAY

Velocity= 7.04 fps

CONCRETE ANCHOR SIZE					
Length of exposed outlet pipe	10	ft	Safety factor	1.2	
Buoyancy =	6763	lbs	Anchor width	6	ft
Required Volume of Anchor =	46.6	cf	Anchor Length	6	ft
Actual Volume of Anchor=	63	cf	Anchor Thickness	1.75	ft
OKAY					

SEDIMENT BASIN CALCULATIONS			
CHARAH - SANFORD			
HDR PROJECT NO.:	235691		
DATE:	*09.30.14*	BY:	*RMB*
REVISED:	*11.05.14*	RVW:	*PW*

Basin #5 (Ph-1)

Phase 1 controls Basin #5 Design

FAIRCLOTH SKIMMER TYPE BASIN DESIGN WITH RISER

NCDENR? 1 ← IF Yes, Type: **1**

DRAINAGE AREAS/REQ'D STORAGE			
Total drainage area (TDA)		*49.4*	*ac*
Disturbed area(DA)		*49.4*	*ac*
Rqd sediment storage	(1800xDA)	88992	*cf*

ESTIMATED BASIN SIZE (RECTANGULAR)		
	Length(ft)	*Width(ft)*
Bottom	*494*	*238*
Top	*512*	*256*

BASIN CONFIGURATION		
Proposed sediment depth	*3*	*ft*
Depth of flow over spillway	*2*	*ft*
Bottom elevation of basin	*255*	*msl*
Sediment Storage elevation	*258*	*msl*
Spillway crest	*258*	*msl*
Top of Berm	*262*	*msl*
Emergency Spillway Elevation	*260*	*msl*
DESIGN FLOW (SEE HYDROGRAPHS)		
10yr Computed flow from site, 'Q' =	*301.78*	*cfs*
1/2 10yr Computed flow from site, 'Q' =	*150.89*	*cfs*

PLANNED BASIN SIZE (REFER TO EROSION CONTROL PLAN)		
Elev.	*Area (SF)*	*Cumulative Volume (CF)*
255	*118763*	*0*
256	*124341*	*121552*
257	*129979*	*248712*
258	*135678*	*381541*
259	*141437*	*520098*
260	*147256*	*664445*
261	*153136*	*814641*
262	*X*	*#VALUE!*
X	*X*	*#VALUE!*
X	*X*	*#VALUE!*

FAIRCLOTH SKIMMER DESIGN TABLE

4	Skimmer Size (inches)	Skimmer Size
0.333	Head on Skimmer (feet)	(Inches)
3.25	Orifice Size (1/4 inch increments)	1.5
3.16	Dewatering Time (days)	2
	Suggest about 3 days	2.5
		3
	Note: Divided Sediment Storage by 2 (one skimmer/riser)	4
		5
		6
		8

BASIN EFFICIENCY		
Sediment storage required:	*88992*	*cf*
Sediment storage provided:	*381541*	*cf OKAY*
Surface area required:	131274.3	sf
Surface area provided:	*135678*	*sf OKAY*

SPILLWAY DESIGN (Note: Need 2 risers; therefore split flow)

RISER SPILLWAY DESIGN

Riser diameter:	*72 in*	*Flow Depth:*	*2 ft*
Orifice Flow:	*187.00 cfs*	*Controlling:*	*Orifice*
Weir Flow:	*330.38 cfs*	*Controlling>Q10?*	*OKAY*

EMERGENCY SPILLWAY SIZE (L=Q/(C*h^1.5))			
100yr Flow from site, Q100 =			476.49
Q100 Flow - Flow through Barrel =			*157*
C	3	L=	52
h	1		

Barrel diameter	*60*	*in*
Barrel slope (ft/ft)	*0.025*	*ft/ft*
Barrel length(ft)	*50*	*ft*
Barrel invert in	*255*	
Barrel invert out	*253.75*	

Flow through barrel *160 cfs*

(Note: Flow determined using outlet control and pipe 80% full)

BARREL FLOW>Q10? *OKAY*

Velocity= *8.13 fps*

CONCRETE ANCHOR SIZE					
Length of exposed outlet pipe	*10*	*ft*	*Safety factor*	*1.2*	
Buoyancy =	*17545*	*lbs*	*Anchor width*	*8*	*ft*
Required Volume of Anchor =	*121.0*	*cf*	*Anchor Length*	*8*	*ft*
Actual Volume of Anchor=	*160*	*cf*	*Anchor Thickness*	*2.5*	*ft*
OKAY					

SEDIMENT BASIN CALCULATIONS				
CHARAH - SANFORD				
HDR PROJECT NO.:	235691			
DATE:	09.30.14	BY:	RMB	
REVISED:	11.05.14	RVW:	PW	

Basin #5 (Ph-2)

Phase 1 controls Basin #5 Design

FAIRCLOTH SKIMMER TYPE BASIN DESIGN WITH RISER

NCDENR? 1 ← IF Yes, Type: 1

DRAINAGE AREAS/REQ'D STORAGE			
Total drainage area (TDA)		42.1	ac
Disturbed area(DA)		42.1	ac
Rqd sediment storage	(1800xDA)	75708	cf

ESTIMATED BASIN SIZE (RECTANGULAR)		
	Length(ft)	Width(ft)
Bottom	451	216
Top	469	234

BASIN CONFIGURATION		
Proposed sediment depth	3	ft
Depth of flow over spillway	2	ft
Bottom elevation of basin	255	msl
Sediment Storage elevation	258	msl
Spillway crest	258	msl
Top of Berm	262	msl
Emergency Spillway Elevation	260	msl
DESIGN FLOW (SEE HYDROGRAPHS)		
10yr Computed flow from site, 'Q' =	252.52	cfs
1/2 10yr Computed flow from site, 'Q' =	126.26	cfs

PLANNED BASIN SIZE (REFER TO EROSION CONTROL PLAN)

Elev.	Area (SF)	Cumulative Volume (CF)
255	118763	0
256	124341	121552
257	129979	248712
258	135678	381541
259	141437	520098
260	147256	664445
261	153136	814641
262	X	#VALUE!
X	X	#VALUE!
X	X	#VALUE!

FAIRCLOTH SKIMMER DESIGN TABLE

		Skimmer Size (Inches)
4	Skimmer Size (inches)	1.5
0.333	Head on Skimmer (feet)	2
3.25	Orifice Size (1/4 inch increments)	2.5
2.69	Dewatering Time (days)	3
	Suggest about 3 days	4
		5
		6
		8

Note: Divided Sediment Storage by 2 (one skimmer/riser)

BASIN EFFICIENCY			
Sediment storage required:	75708	cf	
Sediment storage provided:	381541	cf	OKAY
Surface area required:	109846.2	sf	
Surface area provided:	135678	sf	OKAY

SPILLWAY DESIGN (Note: Need 2 risers; therefore split flow)

RISER SPILLWAY DESIGN

Riser diameter:	72 in	Flow Depth:		2 ft
Orifice Flow:	187.00 cfs	Controlling:	Orifice	
Weir Flow:	330.38 cfs	Controlling>Q10?	OKAY	

EMERGENCY SPILLWAY SIZE (L=Q/(C*h^1.5))

100yr Flow from site, Q100 =	402.08		
Q100 Flow - Flow through Barrel =	83		
C	3	L=	28
h	1		

Barrel diameter	60	in
Barrel slope (ft/ft)	0.025	ft/ft
Barrel length(ft)	50	ft
Barrel invert in	255	
Barrel invert out	253.75	

Flow through barrel 160 cfs
(Note: Flow determined using outlet control and pipe 80% full)
BARREL FLOW>Q10? OKAY
Velocity= 8.13 fps

CONCRETE ANCHOR SIZE

Length of exposed outlet pipe	10	ft	Safety factor	1.2	
Buoyancy =	17545	lbs	Anchor width	8	ft
Required Volume of Anchor =	121.0	cf	Anchor Length	8	ft
Actual Volume of Anchor=	160	cf	Anchor Thickness	2.5	ft

OKAY

SEDIMENT BASIN CALCULATIONS				Basin #6 (Ph-1)
CHARAH - SANFORD				
HDR PROJECT NO.:	235691			
DATE: 09.30.14		BY:	RMB	
REVISED: 11.05.14		RVW:	PW	

FAIRCLOTH SKIMMER TYPE BASIN DESIGN WITH RISER

NCDENR? 1 ← IF Yes, Type: 1

DRAINAGE AREAS/REQ'D STORAGE			
Total drainage area (TDA)		15.3	ac
Disturbed area(DA)		15.3	ac
Rqd sediment storage	(1800xDA)	27522	cf

ESTIMATED BASIN SIZE (RECTANGULAR)		
	Length(ft)	Width(ft)
Bottom	267	125
Top	285	143

BASIN CONFIGURATION		
Proposed sediment depth	3	ft
Depth of flow over spillway	2	ft
Bottom elevation of basin	249	msl
Sediment Storage elevation	252	msl
Spillway crest	252	msl
Top of Berm	256	msl
Emergency Spillway Elevation	254	msl
DESIGN FLOW (SEE HYDROGRAPHS)		
10yr Computed flow from site, 'Q' =	93.6	cfs

PLANNED BASIN SIZE (REFER TO EROSION CONTROL PLAN)

Elev.	Area (SF)	Cumulative Volume (CF)
249	30723	0
250	34084	32404
251	37519	68205
252	41027	107478
253	44808	150396
254	48997	197298
255	52981	248287
256	X	#VALUE!
X	X	#VALUE!
X	X	#VALUE!

FAIRCLOTH SKIMMER DESIGN TABLE

4	Skimmer Size (inches)
0.333	Head on Skimmer (feet)
2.5	Orifice Size (1/4 inch increments)
3.30	Dewatering Time (days)
	Suggest about 3 days

Skimmer Size (Inches)
1.5
2
2.5
3
4
5
6
8

BASIN EFFICIENCY			
Sediment storage required:	27522	cf	
Sediment storage provided:	107478	cf	OKAY
Surface area required:	40716	sf	
Surface area provided:	41027	sf	OKAY

SPILLWAY DESIGN

RISER SPILLWAY DESIGN

Riser diameter:	60 in	Flow Depth:		2 ft
Orifice Flow:	156.00 cfs	Controlling:	Orifice	
Weir Flow:	275.32 cfs	Controlling>Q10?	OKAY	

EMERGENCY SPILLWAY SIZE (L=Q/(C*h^1.5))

100yr Flow from site, Q100 =			147.78
Q100 Flow - Flow through Barrel =			49
C=3.0	h = 1	L=	16

Barrel diameter	48	in
Barrel slope (ft/ft)	0.01	ft/ft
Barrel length(ft)	50	ft
Barrel invert in	249	
Barrel invert out	248.5	

Flow through barrel 99 cfs
(Note: Flow determined using outlet control and pipe 80% full)
BARREL FLOW>Q10? OKAY
Velocity= 7.90 fps

CONCRETE ANCHOR SIZE

Length of exposed outlet pipe	10	ft	Safety factor	1.2	
Buoyancy =	11517	lbs	Anchor width	7	ft
Required Volume of Anchor =	79.4	cf	Anchor Length	7	ft
Actual Volume of Anchor=	98	cf	Anchor Thickness	2	ft

OKAY

SEDIMENT BASIN CALCULATIONS				Basin #7 (Ph-1)
CHARAH - SANFORD				Phase 2 controls Basin #7 Design
HDR PROJECT NO.:	235691			
DATE: 09.30.14		BY:	RMB	
REVISED: 11.05.14		RVW:	PW	

FAIRCLOTH SKIMMER TYPE BASIN DESIGN WITH RISER

NCDENR? 1 ← IF Yes, Type: 1

DRAINAGE AREAS/REQ'D STORAGE			
Total drainage area (TDA)		16.4	ac
Disturbed area(DA)		12.5	ac
Rqd sediment storage	(1800xDA)	29466	cf

ESTIMATED BASIN SIZE (RECTANGULAR)		
	Length(ft)	Width(ft)
Bottom	255	118
Top	273	136

BASIN CONFIGURATION		
Proposed sediment depth	3	ft
Depth of flow over spillway	2	ft
Bottom elevation of basin	238	msl
Sediment Storage elevation	241	msl
Spillway crest	241	msl
Top of Berm	245	msl
Emergency Spillway Elevation	243	msl
DESIGN FLOW (SEE HYDROGRAPHS)		
10yr Computed flow from site, 'Q' =	85.59	cfs

PLANNED BASIN SIZE (REFER TO EROSION CONTROL PLAN)		
Elev.	Area (SF)	Cumulative Volume (CF)
238	49034	0
239	52537	50786
240	56098	105103
241	59717	163011
242	63393	224566
243	67128	289826
244	70920	358850
245	X	#VALUE!
X	X	#VALUE!
X	X	#VALUE!

FAIRCLOTH SKIMMER DESIGN TABLE

4	Skimmer Size (inches)
0.333	Head on Skimmer (feet)
2.75	Orifice Size (1/4 inch increments)
2.92	Dewatering Time (days)
	Suggest about 3 days

Skimmer Size (Inches)
1.5
2
2.5
3
4
5
6
8

BASIN EFFICIENCY			
Sediment storage required:	29466	cf	
Sediment storage provided:	163011	cf	OKAY
Surface area required:	37231.65	sf	
Surface area provided:	59717	sf	OKAY

SPILLWAY DESIGN

RISER SPILLWAY DESIGN					
Riser diameter:	60	in	Flow Depth:	2	ft
Orifice Flow:	156.00	cfs	Controlling:	Orifice	
Weir Flow:	275.32	cfs	Controlling>Q10?	OKAY	

EMERGENCY SPILLWAY SIZE (L=Q/(C*h^1.5))			
100yr Flow from site, Q100 =			144.24
Q100 Flow - Flow through Barrel =			45
C=3.0	h = 1	L=	15

Barrel diameter	48	in
Barrel slope (ft/ft)	0.01	ft/ft
Barrel length(ft)	50	ft
Barrel invert in	238	
Barrel invert out	237.5	

Flow through barrel 99 cfs

(Note: Flow determined using outlet control and pipe 80% full)

BARREL FLOW>Q10? OKAY

Velocity= 7.90 fps

CONCRETE ANCHOR SIZE					
Length of exposed outlet pipe	10	ft	Safety factor	1.2	
Buoyancy =	11517	lbs	Anchor width	7.5	ft
Required Volume of Anchor =	79.4	cf	Anchor Length	7.5	ft
Actual Volume of Anchor=	112.5	cf	Anchor Thickness	2	ft
OKAY					

SEDIMENT BASIN CALCULATIONS				Basin #7 (Ph-2)
CHARAH - SANFORD				Phase 2 controls Basin #7 Design
HDR PROJECT NO.:	235691			
DATE: 09.30.14	BY:	RMB		
REVISED: 11.05.14	RVW:	PW		

FAIRCLOTH SKIMMER TYPE BASIN DESIGN WITH RISER

NCDENR? 1 ← IF Yes, Type: 1

DRAINAGE AREAS/REQ'D STORAGE			
Total drainage area (TDA)		33.1	ac
Disturbed area(DA)		29.3	ac
Rqd sediment storage	(1800xDA)	59598	cf

ESTIMATED BASIN SIZE (RECTANGULAR)		
	Length(ft)	Width(ft)
Bottom	324	153
Top	342	171

BASIN CONFIGURATION		
Proposed sediment depth	3	ft
Depth of flow over spillway	2	ft
Bottom elevation of basin	238	msl
Sediment Storage elevation	241	msl
Spillway crest	241	msl
Top of Berm	245	msl
Emergency Spillway Elevation	243	msl
DESIGN FLOW (SEE HYDROGRAPHS)		
10yr Computed flow from site, 'Q' =	134.71	cfs
1/2 10yr Computed flow from site, 'Q' =	67.355	cfs

PLANNED BASIN SIZE (REFER TO EROSION CONTROL PLAN)

Elev.	Area (SF)	Cumulative Volume (CF)
238	49034	0
239	52537	50786
240	56098	105103
241	59717	163011
242	63393	224566
243	67128	289826
244	70920	358850
245	X	#VALUE!
X	X	#VALUE!
X	X	#VALUE!

FAIRCLOTH SKIMMER DESIGN TABLE

		Skimmer Size (Inches)
4	Skimmer Size (inches)	1.5
0.333	Head on Skimmer (feet)	2
2.75	Orifice Size (1/4 inch increments)	2.5
2.96	Dewatering Time (days)	3
	Suggest about 3 days	4
		5
		6
		8

Note: Divided Sediment Storage by 2 (one skimmer/riser)

BASIN EFFICIENCY			
Sediment storage required:	59598	cf	
Sediment storage provided:	163011	cf	OKAY
Surface area required:	58598.85	sf	
Surface area provided:	59717	sf	OKAY

SPILLWAY DESIGN (Note: Need 2 risers; therefore split flow)

RISER SPILLWAY DESIGN

Riser diameter:	54 in	Flow Depth:	2 ft
Orifice Flow:	140.00 cfs	Controlling:	Orifice
Weir Flow:	247.79 cfs	Controlling>Q10?	OKAY

EMERGENCY SPILLWAY SIZE (L=Q/(C*h^1.5))

100yr Flow from site, Q100 =	230.4		
Q100 Flow - Flow through Barrel =	71		
C	3	L=	24
h	1		

Barrel diameter	42	in
Barrel slope (ft/ft)	0.01	ft/ft
Barrel length(ft)	50	ft
Barrel invert in	238	
Barrel invert out	237.5	

Flow through barrel 80 cfs

(Note: Flow determined using outlet control and pipe 80% full)

BARREL FLOW>Q10? OKAY

Velocity= 8.31 fps

CONCRETE ANCHOR SIZE

Length of exposed outlet pipe	10	ft
Buoyancy =	8981	lbs
Required Volume of Anchor =	61.9	cf
Actual Volume of Anchor=	85.75	cf

Safety factor	1.2	
Anchor width	7	ft
Anchor Length	7	ft
Anchor Thickness	1.75	ft

OKAY

SEDIMENT BASIN CALCULATIONS				Basin #8 (Ph-1)
CHARAH - SANFORD				
HDR PROJECT NO.:	235691			
DATE: 09.30.14		BY:	RMB	
REVISED: 11.05.14		RVW:	PW	

FAIRCLOTH SKIMMER TYPE BASIN DESIGN WITH RISER

NCDENR? 1 ← IF Yes, Type: 1

DRAINAGE AREAS/REQ'D STORAGE			
Total drainage area (TDA)		11.8	ac
Disturbed area(DA)		11.8	ac
Rqd sediment storage	(1800xDA)	21150	cf

ESTIMATED BASIN SIZE (RECTANGULAR)		
	Length(ft)	Width(ft)
Bottom	231	106
Top	249	124

BASIN CONFIGURATION		
Proposed sediment depth	3	ft
Depth of flow over spillway	1	ft
Bottom elevation of basin	273	msl
Sediment Storage elevation	276	msl
Spillway crest	276	msl
Top of Berm	279	msl
Emergency Spillway Elevation	277	msl
DESIGN FLOW (SEE HYDROGRAPHS)		
10yr Computed flow from site, 'Q' =	71.25	cfs

PLANNED BASIN SIZE (REFER TO EROSION CONTROL PLAN)

Elev.	Area (SF)	Cumulative Volume (CF)
273	5639	0
274	18291	11965
275	28277	35249
276	38333	68554
277	47710	111576
278	59010	164936
279	69292	229087
X	X	#VALUE!
X	X	#VALUE!
X	X	#VALUE!

FAIRCLOTH SKIMMER DESIGN TABLE

3	Skimmer Size (inches)
0.25	Head on Skimmer (feet)
2.5	Orifice Size (1/4 inch increments)
2.93	Dewatering Time (days)
	Suggest about 3 days

Skimmer Size (Inches)
1.5
2
2.5
3
4
5
6
8

BASIN EFFICIENCY			
Sediment storage required:	21150	cf	
Sediment storage provided:	68554	cf	OKAY
Surface area required:	30993.75	sf	
Surface area provided:	38333	sf	OKAY

SPILLWAY DESIGN

RISER SPILLWAY DESIGN

Riser diameter:	60	in	Flow Depth:	1	ft
Orifice Flow:	53.00	cfs	Controlling:	Orifice	
Weir Flow:	97.34	cfs	Controlling>Q10?	OKAY	

EMERGENCY SPILLWAY SIZE (L=Q/(C*h^1.5))

100yr Flow from site, Q100 =			115.17
Q100 Flow - Flow through Barrel =			27
C=3.0	h = 1	L=	9

Barrel diameter	48	in
Barrel slope (ft/ft)	0.02	ft/ft
Barrel length(ft)	50	ft
Barrel invert in	273	
Barrel invert out	272	

Flow through barrel 88 cfs

(Note: Flow determined using outlet control and pipe 80% full)

BARREL FLOW>Q10? OKAY

Velocity= 6.99 fps

CONCRETE ANCHOR SIZE

Length of exposed outlet pipe	10	ft	Safety factor	1.2	
Buoyancy =	11517	lbs	Anchor width	7.5	ft
Required Volume of Anchor =	79.4	cf	Anchor Length	7.5	ft
Actual Volume of Anchor=	112.5	cf	Anchor Thickness	2	ft

OKAY

SEDIMENT BASIN CALCULATIONS				Basin #9 (Ph-1)
CHARAH - SANFORD				Phase 2 controls Basin #9 Design
HDR PROJECT NO.:	235691			
DATE: 09.30.14		BY:	RMB	
REVISED: 11.05.14		RVW:	PW	

FAIRCLOTH SKIMMER TYPE BASIN DESIGN WITH RISER

NCDENR? 1 ← IF Yes, Type: 1

DRAINAGE AREAS/REQ'D STORAGE			
Total drainage area (TDA)		62.8	ac
Disturbed area(DA)		46.7	ac
Rqd sediment storage	(1800xDA)	112950	cf

ESTIMATED BASIN SIZE (RECTANGULAR)		
	Length(ft)	Width(ft)
Bottom	338	160
Top	356	178

BASIN CONFIGURATION		
Proposed sediment depth	3	ft
Depth of flow over spillway	2	ft
Bottom elevation of basin	262	msl
Sediment Storage elevation	265	msl
Spillway crest	265	msl
Top of Berm	269	msl
Emergency Spillway Elevation	267	msl
DESIGN FLOW (SEE HYDROGRAPHS)		
10yr Computed flow from site, 'Q' =	145.7	cfs
1/2 10yr Computed flow from site, 'Q' =	72.85	cfs

PLANNED BASIN SIZE (REFER TO EROSION CONTROL PLAN)		
Elev.	Area (SF)	Cumulative Volume (CF)
262	88670	0
263	92409	90540
264	96226	184857
265	100091	283016
266	103992	385057
267	107938	491022
268	111933	600958
X	X	#VALUE!
X	X	#VALUE!
X	X	#VALUE!

FAIRCLOTH SKIMMER DESIGN TABLE

		Skimmer Size (Inches)
5	Skimmer Size (inches)	1.5
0.333	Head on Skimmer (feet)	2
4.25	Orifice Size (1/4 inch increments)	2.5
2.35	Dewatering Time (days)	3
	Suggest about 3 days	4
		5
		6
		8

Note: Divided Sediment Storage by 2 (one skimmer/riser)

BASIN EFFICIENCY			
Sediment storage required:	112950	cf	
Sediment storage provided:	283016	cf	OKAY
Surface area required:	63379.5	sf	
Surface area provided:	100091	sf	OKAY

SPILLWAY DESIGN (Note: Need 2 risers; therefore split flow)

RISER SPILLWAY DESIGN

Riser diameter:	54 in	Flow Depth:		2 ft
Orifice Flow:	140.00 cfs	Controlling:	Orifice	
Weir Flow:	247.79 cfs	Controlling>Q10?	OKAY	

EMERGENCY SPILLWAY SIZE (L=Q/(C*h^1.5))

100yr Flow from site, Q100 =			280.49
Q100 Flow - Flow through Barrel =			131
C=3.0	h = 1	L=	44

Barrel diameter	42	in
Barrel slope (ft/ft)	0.0125	ft/ft
Barrel length(ft)	100	ft
Barrel invert in	262	
Barrel invert out	260.75	

Flow through barrel 75 cfs

(Note: Flow determined using outlet control and pipe 80% full)

BARREL FLOW>Q10? OKAY

Velocity= 7.75 fps

CONCRETE ANCHOR SIZE					
Length of exposed outlet pipe	10	ft	Safety factor	1.2	
Buoyancy =	8981	lbs	Anchor width	7.5	ft
Required Volume of Anchor =	61.9	cf	Anchor Length	7.5	ft
Actual Volume of Anchor=	84.375	cf	Anchor Thickness	1.5	ft
OKAY					

SEDIMENT BASIN CALCULATIONS				Basin #9 (Ph-2)
CHARAH - SANFORD				Phase 2 controls Basin #9 Design
HDR PROJECT NO.:	235691			
DATE: 09.30.14		BY:	RMB	
REVISED: 11.05.14		RVW:	PW	

FAIRCLOTH SKIMMER TYPE BASIN DESIGN WITH RISER

NCDENR? 1 ← IF Yes, Type: 1

DRAINAGE AREAS/REQ'D STORAGE			
Total drainage area (TDA)		85.9	ac
Disturbed area(DA)		65.9	ac
Rqd sediment storage	(1800xDA)	154656	cf

ESTIMATED BASIN SIZE (RECTANGULAR)		
	Length(ft)	Width(ft)
Bottom	399	190
Top	417	208

BASIN CONFIGURATION		
Proposed sediment depth	3	ft
Depth of flow over spillway	2	ft
Bottom elevation of basin	262	msl
Sediment Storage elevation	265	msl
Spillway crest	265	msl
Top of Berm	269	msl
Emergency Spillway Elevation	267	msl
DESIGN FLOW (SEE HYDROGRAPHS)		
10yr Computed flow from site, 'Q' =	199.5	cfs
1/2 10yr Computed flow from site, 'Q' =	99.75	cfs

PLANNED BASIN SIZE (REFER TO EROSION CONTROL PLAN)		
Elev.	Area (SF)	Cumulative Volume (CF)
262	88670	0
263	92409	90540
264	96226	184857
265	100091	283016
266	103992	385057
267	107938	491022
268	111933	600958
X	X	#VALUE!
X	X	#VALUE!
X	X	#VALUE!

FAIRCLOTH SKIMMER DESIGN TABLE		
5	Skimmer Size (inches)	Skimmer Size
0.333	Head on Skimmer (feet)	(Inches)
4.25	Orifice Size (1/4 inch increments)	1.5
3.21	Dewatering Time (days)	2
	Suggest about 3 days	2.5
		3
		4
		5
		6
		8

Note: Divided Sediment Storage by 2 (one skimmer/riser)

BASIN EFFICIENCY			
Sediment storage required:	154656	cf	
Sediment storage provided:	283016	cf	OKAY
Surface area required:	86782.5	sf	
Surface area provided:	100091	sf	OKAY

SPILLWAY DESIGN (Note: Need 2 risers; therefore split flow)				
RISER SPILLWAY DESIGN				
Riser diameter:	72 in	Flow Depth:		2 ft
Orifice Flow:	187.00 cfs	Controlling:	Orifice	
Weir Flow:	330.38 cfs	Controlling>Q10?	OKAY	

EMERGENCY SPILLWAY SIZE (L=Q/(C*h^1.5))			
100yr Flow from site, Q100 =			384.06
Q100 Flow - Flow through Barrel =			150
C=3.0	h = 1	L=	50

Barrel diameter	54	in
Barrel slope (ft/ft)	0.0125	ft/ft
Barrel length(ft)	100	ft
Barrel invert in	262	
Barrel invert out	260.75	

Flow through barrel 117 cfs

(Note: Flow determined using outlet control and pipe 80% full)

BARREL FLOW>Q10? OKAY

Velocity= 7.37 fps

CONCRETE ANCHOR SIZE					
Length of exposed outlet pipe	10	ft	Safety factor	1.2	
Buoyancy =	15217	lbs	Anchor width	8	ft
Required Volume of Anchor =	104.9	cf	Anchor Length	8	ft
Actual Volume of Anchor=	128	cf	Anchor Thickness	2	ft
OKAY					

NOAA Atlas 14, Volume 2, Version 3
Location name: Sanford, North Carolina, US*
Latitude: 35.5361°, Longitude: -79.1459°
Elevation: 297 ft*
* source: Google Maps

POINT PRECIPITATION FREQUENCY ESTIMATES

G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.425 (0.388–0.468)	0.503 (0.459–0.553)	0.583 (0.532–0.642)	0.641 (0.583–0.704)	0.707 (0.640–0.776)	0.751 (0.678–0.824)	0.793 (0.711–0.869)	0.829 (0.740–0.909)	0.870 (0.769–0.953)	0.900 (0.790–0.987)
10-min	0.680 (0.620–0.747)	0.804 (0.733–0.885)	0.934 (0.852–1.03)	1.03 (0.933–1.13)	1.13 (1.02–1.24)	1.20 (1.08–1.31)	1.26 (1.13–1.38)	1.31 (1.17–1.44)	1.38 (1.22–1.51)	1.42 (1.24–1.56)
15-min	0.849 (0.775–0.934)	1.01 (0.922–1.11)	1.18 (1.08–1.30)	1.30 (1.18–1.42)	1.43 (1.29–1.57)	1.52 (1.37–1.66)	1.59 (1.43–1.75)	1.66 (1.48–1.82)	1.73 (1.53–1.90)	1.78 (1.56–1.95)
30-min	1.17 (1.06–1.28)	1.40 (1.27–1.54)	1.68 (1.53–1.85)	1.88 (1.71–2.06)	2.12 (1.91–2.32)	2.28 (2.06–2.50)	2.44 (2.19–2.67)	2.58 (2.30–2.83)	2.76 (2.44–3.02)	2.88 (2.53–3.16)
60-min	1.45 (1.33–1.60)	1.75 (1.60–1.93)	2.15 (1.96–2.37)	2.45 (2.23–2.69)	2.82 (2.55–3.09)	3.09 (2.79–3.39)	3.36 (3.01–3.68)	3.62 (3.23–3.97)	3.95 (3.50–4.33)	4.20 (3.69–4.61)
2-hr	1.71 (1.55–1.90)	2.07 (1.88–2.30)	2.58 (2.34–2.87)	2.96 (2.67–3.28)	3.45 (3.10–3.82)	3.83 (3.42–4.24)	4.20 (3.73–4.65)	4.58 (4.03–5.06)	5.06 (4.42–5.60)	5.44 (4.71–6.02)
3-hr	1.82 (1.65–2.02)	2.20 (2.00–2.45)	2.75 (2.50–3.05)	3.18 (2.87–3.52)	3.74 (3.36–4.14)	4.19 (3.74–4.63)	4.64 (4.11–5.13)	5.11 (4.49–5.64)	5.74 (4.99–6.35)	6.24 (5.36–6.90)
6-hr	2.17 (1.99–2.40)	2.63 (2.40–2.90)	3.29 (3.00–3.63)	3.81 (3.46–4.19)	4.51 (4.07–4.95)	5.07 (4.54–5.56)	5.64 (5.01–6.18)	6.23 (5.48–6.83)	7.05 (6.12–7.72)	7.70 (6.60–8.44)
12-hr	2.57 (2.35–2.84)	3.11 (2.84–3.44)	3.91 (3.56–4.32)	4.56 (4.13–5.02)	5.44 (4.89–5.98)	6.16 (5.49–6.75)	6.90 (6.10–7.56)	7.69 (6.72–8.41)	8.80 (7.56–9.62)	9.69 (8.21–10.6)
24-hr	3.00 (2.80–3.22)	3.62 (3.38–3.89)	4.55 (4.24–4.89)	5.28 (4.91–5.67)	6.28 (5.82–6.75)	7.07 (6.54–7.59)	7.88 (7.27–8.46)	8.72 (8.03–9.37)	9.88 (9.05–10.6)	10.8 (9.85–11.6)
2-day	3.49 (3.25–3.75)	4.20 (3.92–4.52)	5.25 (4.88–5.64)	6.07 (5.64–6.52)	7.18 (6.65–7.71)	8.06 (7.45–8.66)	8.97 (8.26–9.63)	9.90 (9.09–10.6)	11.2 (10.2–12.0)	12.2 (11.1–13.1)
3-day	3.70 (3.44–3.96)	4.45 (4.15–4.77)	5.52 (5.14–5.92)	6.36 (5.91–6.82)	7.52 (6.96–8.06)	8.44 (7.78–9.04)	9.37 (8.63–10.0)	10.3 (9.49–11.1)	11.7 (10.7–12.5)	12.7 (11.6–13.7)
4-day	3.90 (3.64–4.18)	4.69 (4.37–5.02)	5.79 (5.39–6.19)	6.66 (6.19–7.12)	7.86 (7.27–8.41)	8.81 (8.12–9.42)	9.78 (8.99–10.5)	10.8 (9.89–11.6)	12.2 (11.1–13.0)	13.2 (12.0–14.2)
7-day	4.49 (4.20–4.80)	5.36 (5.02–5.74)	6.54 (6.11–6.99)	7.47 (6.97–7.99)	8.76 (8.15–9.35)	9.78 (9.07–10.4)	10.8 (10.0–11.6)	11.9 (11.0–12.7)	13.4 (12.3–14.3)	14.5 (13.3–15.6)
10-day	5.12 (4.82–5.46)	6.10 (5.73–6.50)	7.34 (6.89–7.81)	8.31 (7.79–8.85)	9.62 (8.99–10.2)	10.6 (9.92–11.3)	11.7 (10.9–12.4)	12.7 (11.8–13.6)	14.2 (13.1–15.1)	15.3 (14.1–16.3)
20-day	6.89 (6.49–7.33)	8.14 (7.66–8.64)	9.62 (9.04–10.2)	10.8 (10.1–11.4)	12.4 (11.6–13.1)	13.6 (12.7–14.4)	14.8 (13.8–15.8)	16.1 (14.9–17.1)	17.8 (16.5–19.0)	19.1 (17.6–20.4)
30-day	8.57 (8.09–9.09)	10.1 (9.50–10.7)	11.7 (11.1–12.5)	13.0 (12.2–13.8)	14.7 (13.8–15.6)	16.0 (15.0–17.0)	17.3 (16.2–18.4)	18.5 (17.3–19.7)	20.3 (18.8–21.6)	21.6 (20.0–23.0)
45-day	10.9 (10.4–11.5)	12.8 (12.1–13.5)	14.6 (13.9–15.4)	16.0 (15.2–16.9)	17.9 (16.9–18.9)	19.3 (18.2–20.3)	20.6 (19.4–21.8)	22.0 (20.6–23.2)	23.7 (22.2–25.1)	25.1 (23.4–26.5)
60-day	13.0 (12.4–13.7)	15.2 (14.5–16.0)	17.2 (16.3–18.1)	18.8 (17.8–19.8)	20.8 (19.7–21.9)	22.3 (21.1–23.5)	23.7 (22.4–25.0)	25.1 (23.7–26.5)	26.9 (25.3–28.5)	28.3 (26.6–30.0)

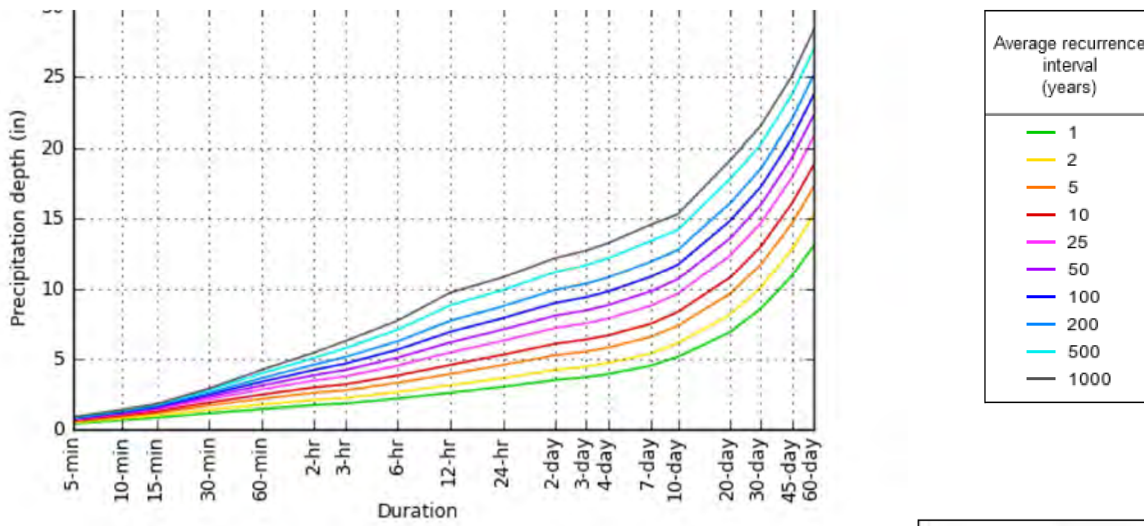
[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

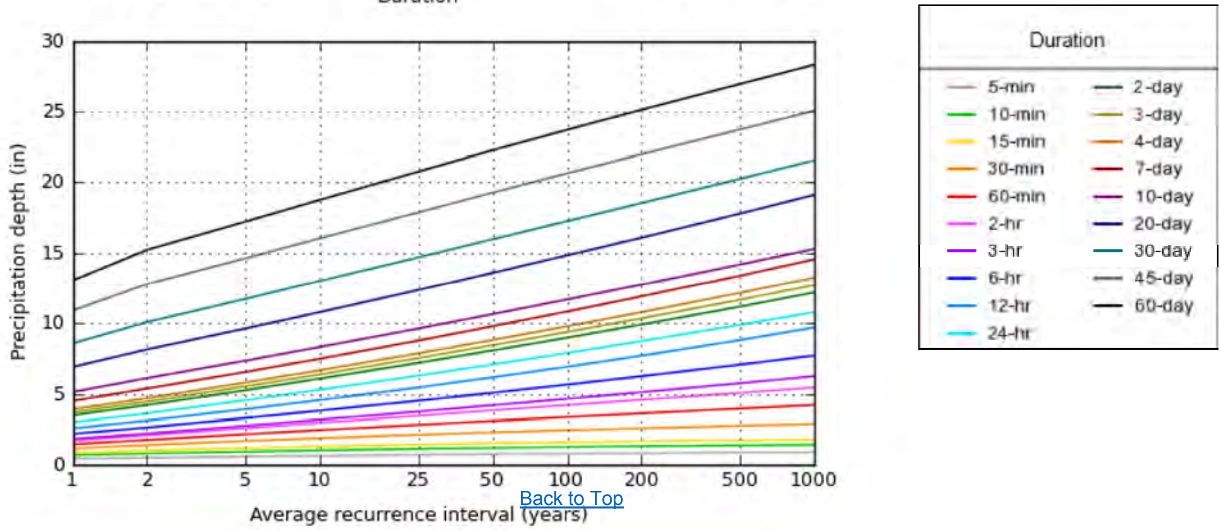
Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Back to Top

PF graphical





Back to Top

NOAA Atlas 14, Volume 2, Version 3 Created (GMT): Tue Sep 16 15:17:33 2014

Maps & aerials

Small scale terrain

Large scale terrain

Large scale aerial

[Back to Top](#)

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[Office of Hydrologic Development](#)
1325 East West Highway
Silver Spring, MD 20910
Questions?: HDSC.Questions@noaa.gov

Table 2-2a Runoff curve numbers for urban areas [1]

Cover description: Cover type and hydrologic condition	Average percent impervious area [2]	Curve numbers for hydrologic soil group: A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) [3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) [4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation) [5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

1 Average runoff condition, and $I_a = 0.2S$.
2 The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
3 CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
4 Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
5 Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

BASIN #1

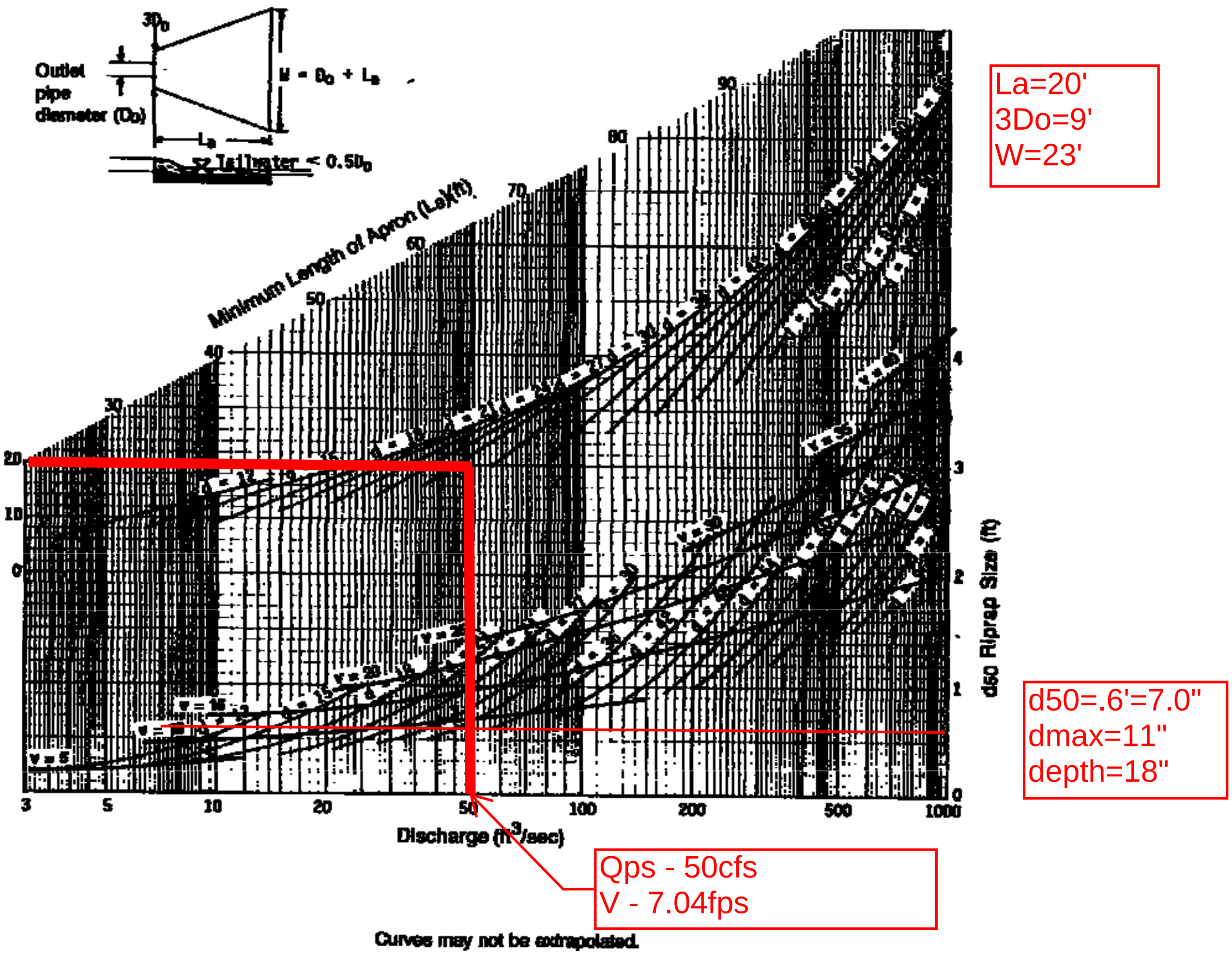
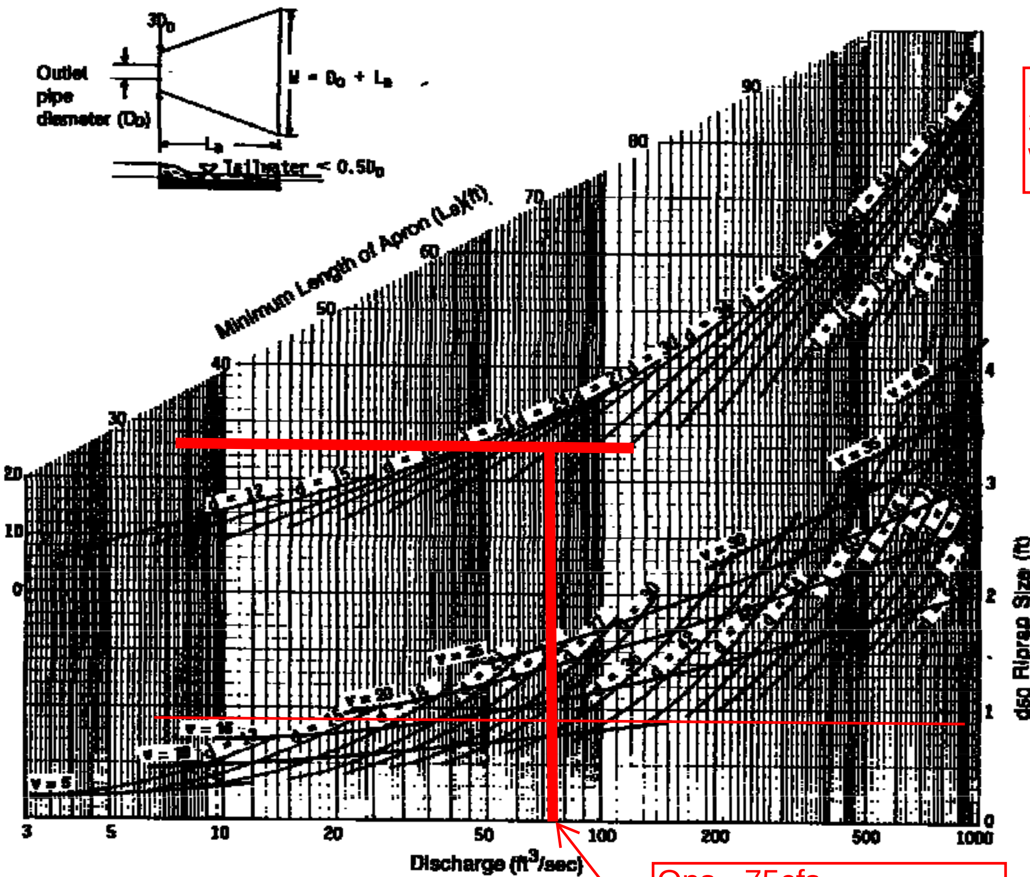


Figure 4.5-2 Design of Riprap Apron under Minimum Tailwater Conditions
(Source: USDA, SCS, 1975)

BASIN #2

NOTE: CALC IS FOR EACH OF TWO OUTLETS.
TOTAL DIMENSIONS ARE:
La=26', W=38', Outlet end=20'



La=26'
3Do=12'
W=30'

d50=.9'=11.0"
dmax=16"
depth=24"

Qps - 75cfs
V - 5.94fps

Curves may not be extrapolated.

Figure 4.5-2 Design of Riprap Apron under Minimum Tailwater Conditions
(Source: USDA, SCS, 1975)

BASIN #3

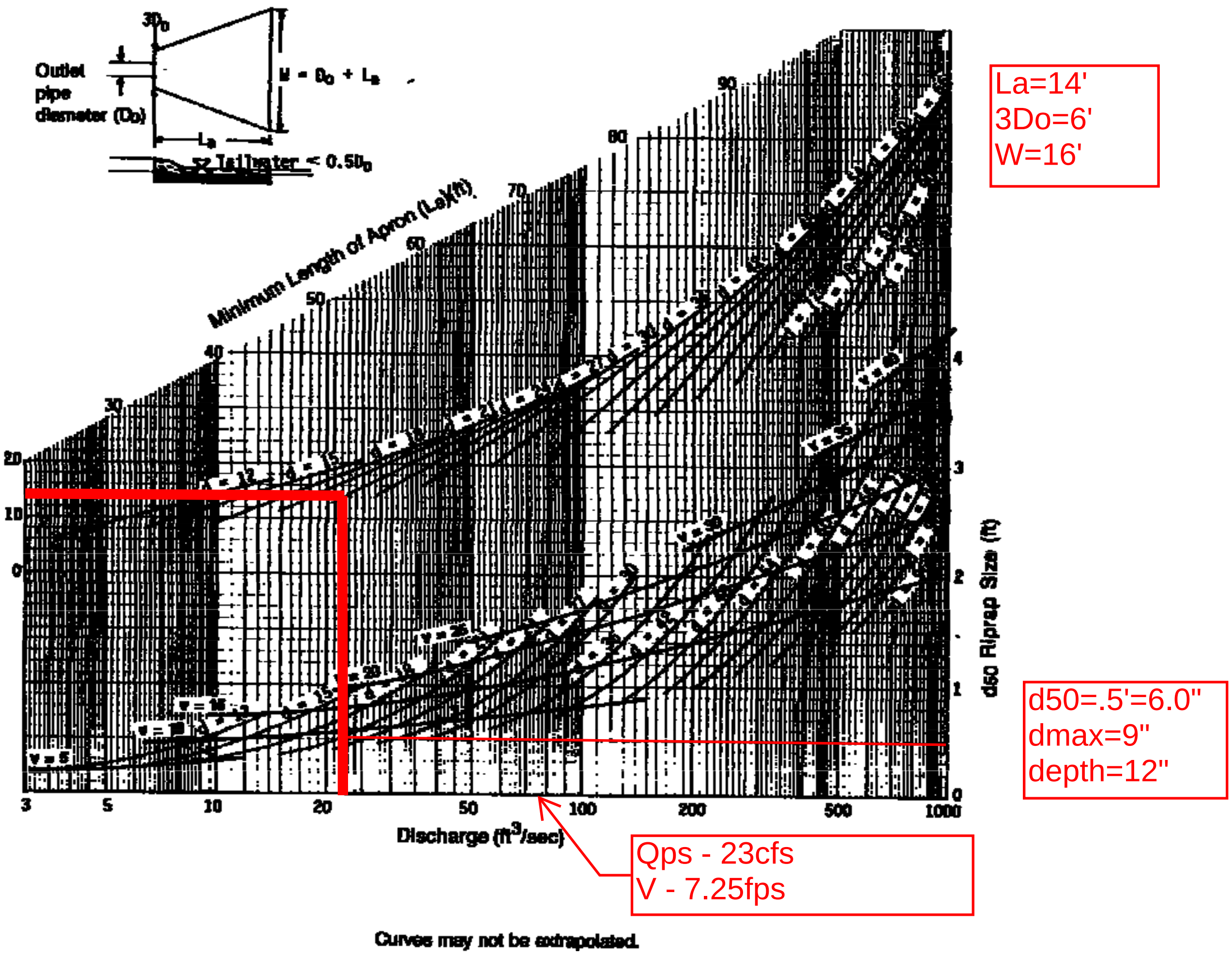
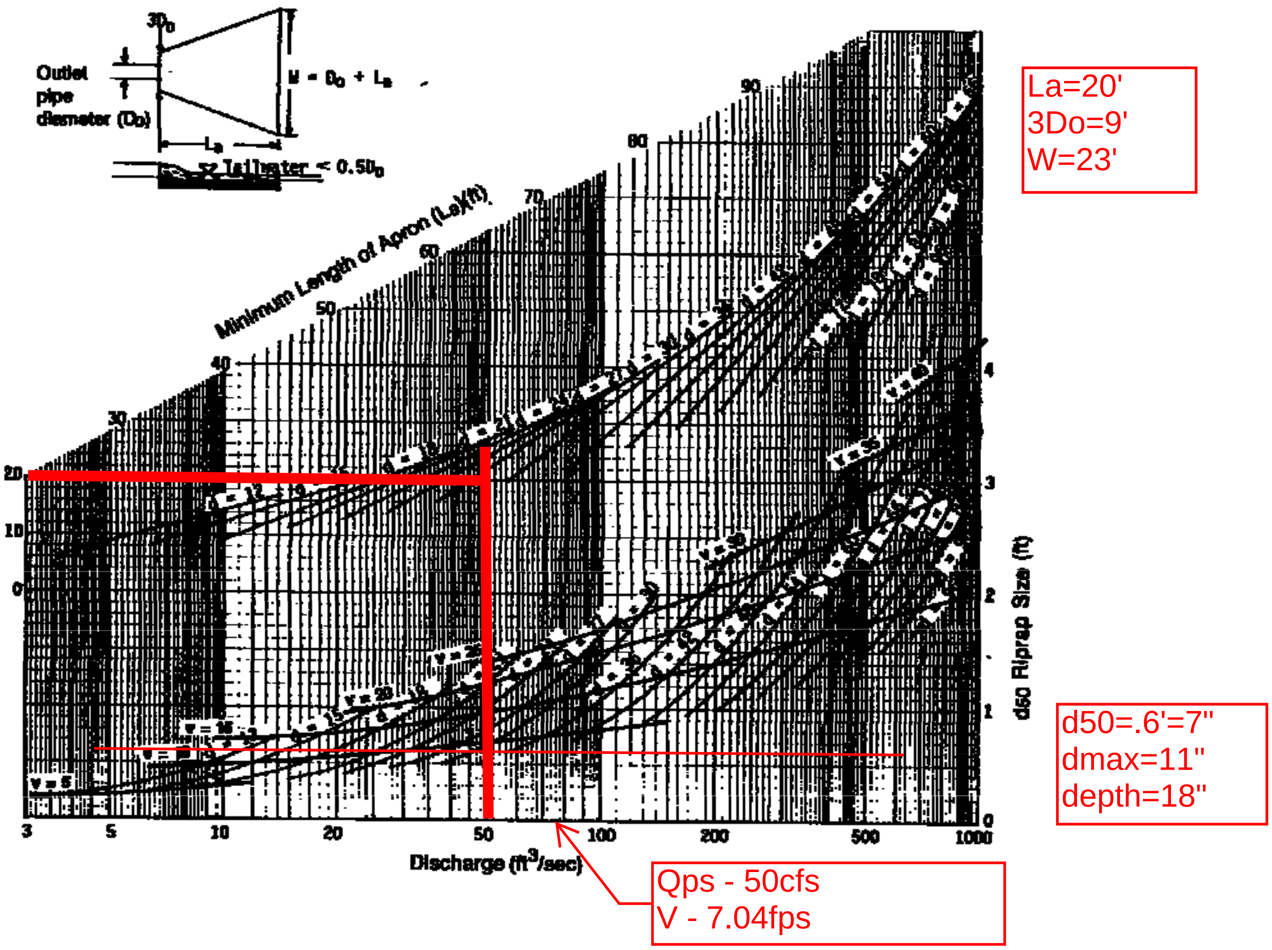


Figure 4.5-2 Design of Riprap Apron under Minimum Tailwater Conditions
(Source: USDA, SCS, 1975)

BASIN #4

NOTE: CALC IS FOR EACH OF TWO OUTLETS.
TOTAL DIMENSIONS ARE:
La=20', W=29', Outlet end=15'

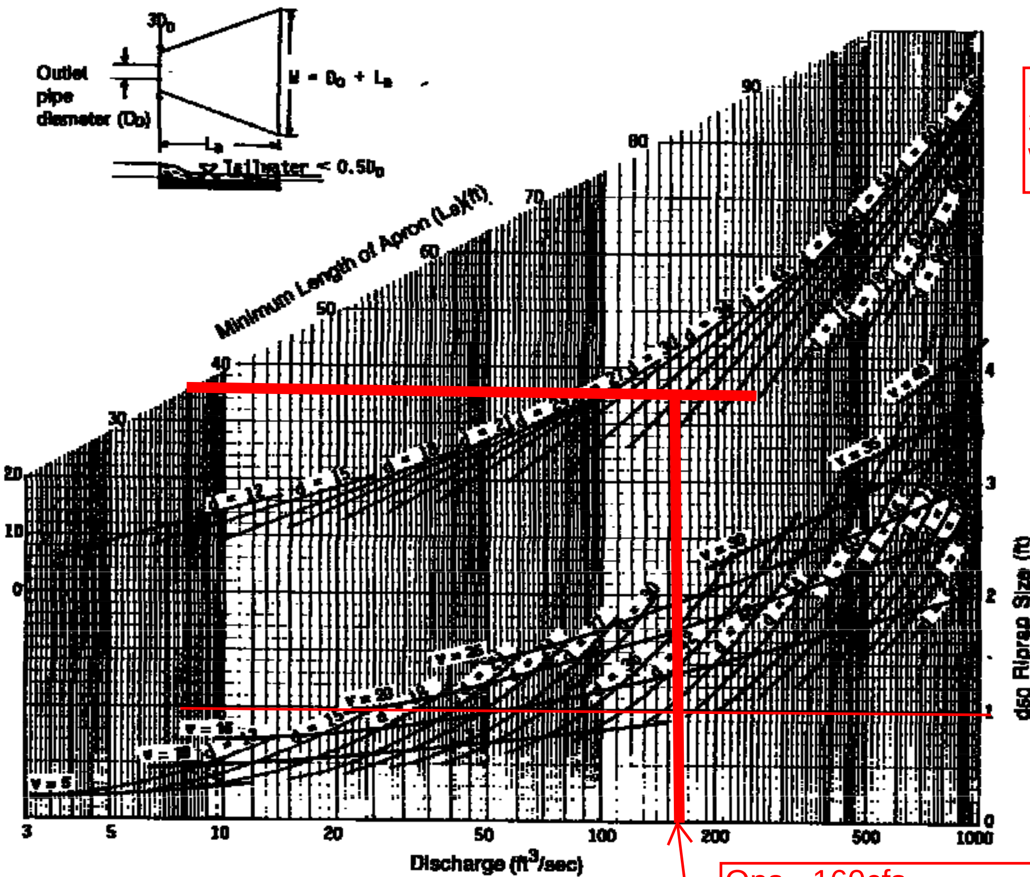


Curves may not be extrapolated.

Figure 4.5-2 Design of Riprap Apron under Minimum Tailwater Conditions
(Source: USDA, SCS, 1975)

BASIN #5

NOTE: CALC IS FOR EACH OF TWO OUTLETS.
TOTAL DIMENSIONS ARE:
La=38', W=53', Outlet end=25'



La=38'
3Do=15'
W=43'

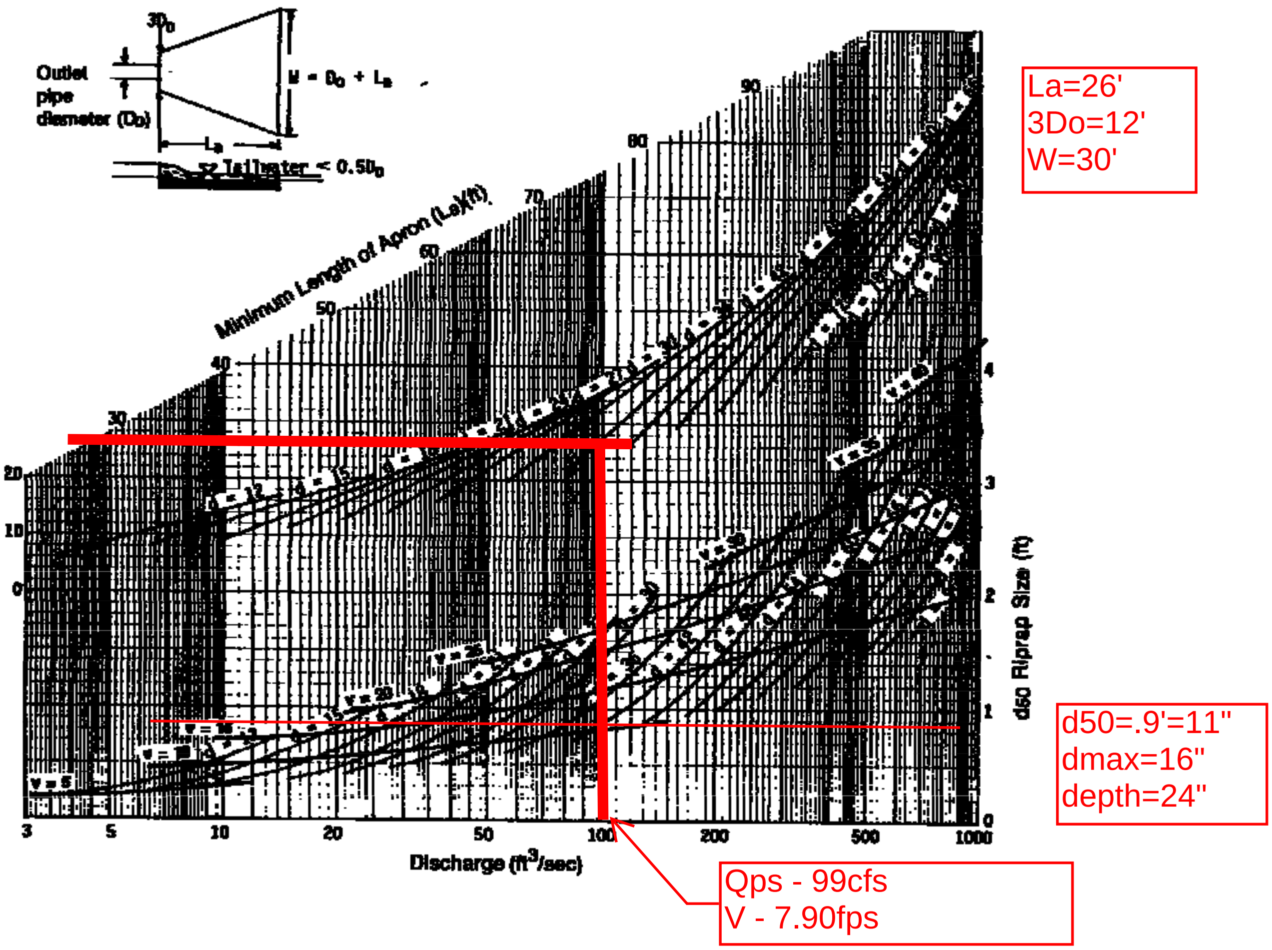
d50=1'=12"
dmax=18"
depth=24"

Qps - 160cfs
V - 8.13fps

Curves may not be extrapolated.

Figure 4.5-2 Design of Riprap Apron under Minimum Tailwater Conditions
(Source: USDA, SCS, 1975)

BASIN #6

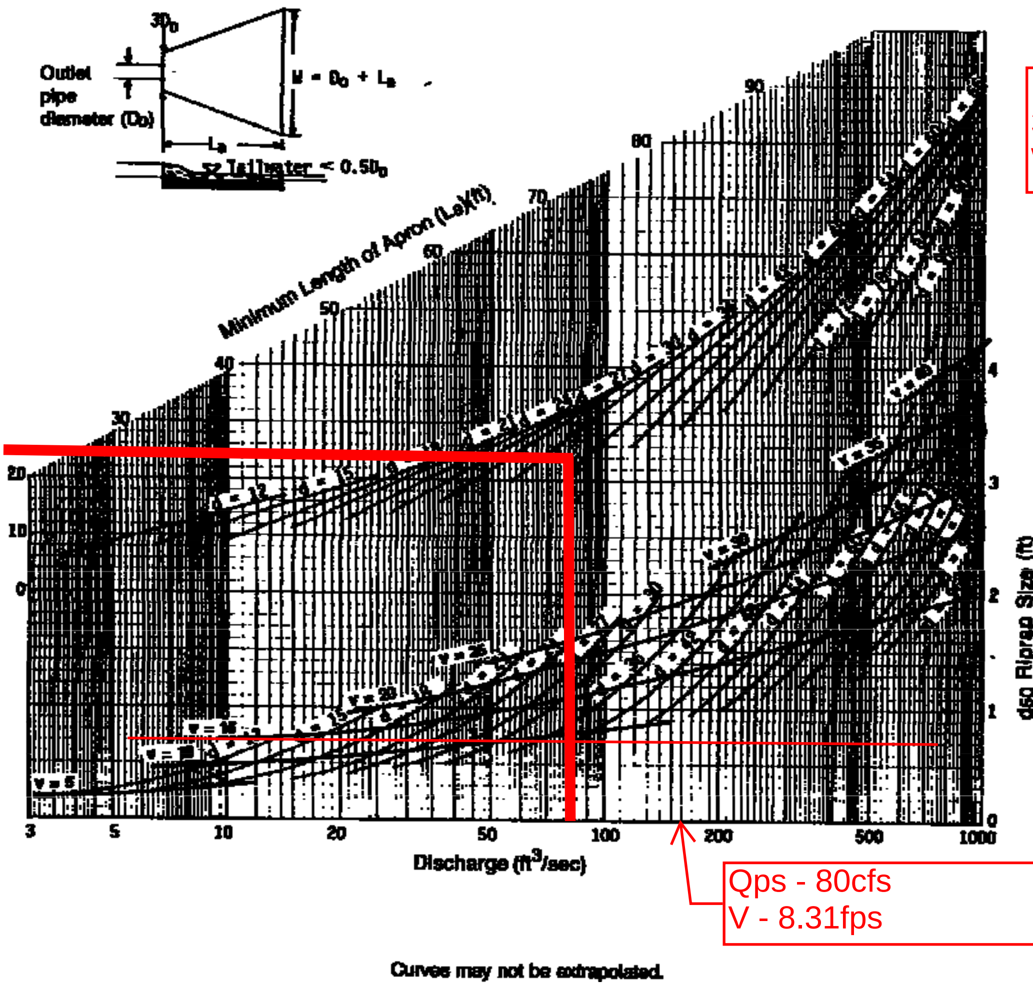


Curves may not be extrapolated.

Figure 4.5-2 Design of Riprap Apron under Minimum Tailwater Conditions
(Source: USDA, SCS, 1975)

BASIN #7

NOTE: CALC IS FOR EACH OF TWO OUTLETS.
TOTAL DIMENSIONS ARE:
La=24', W=35', Outlet end=18'



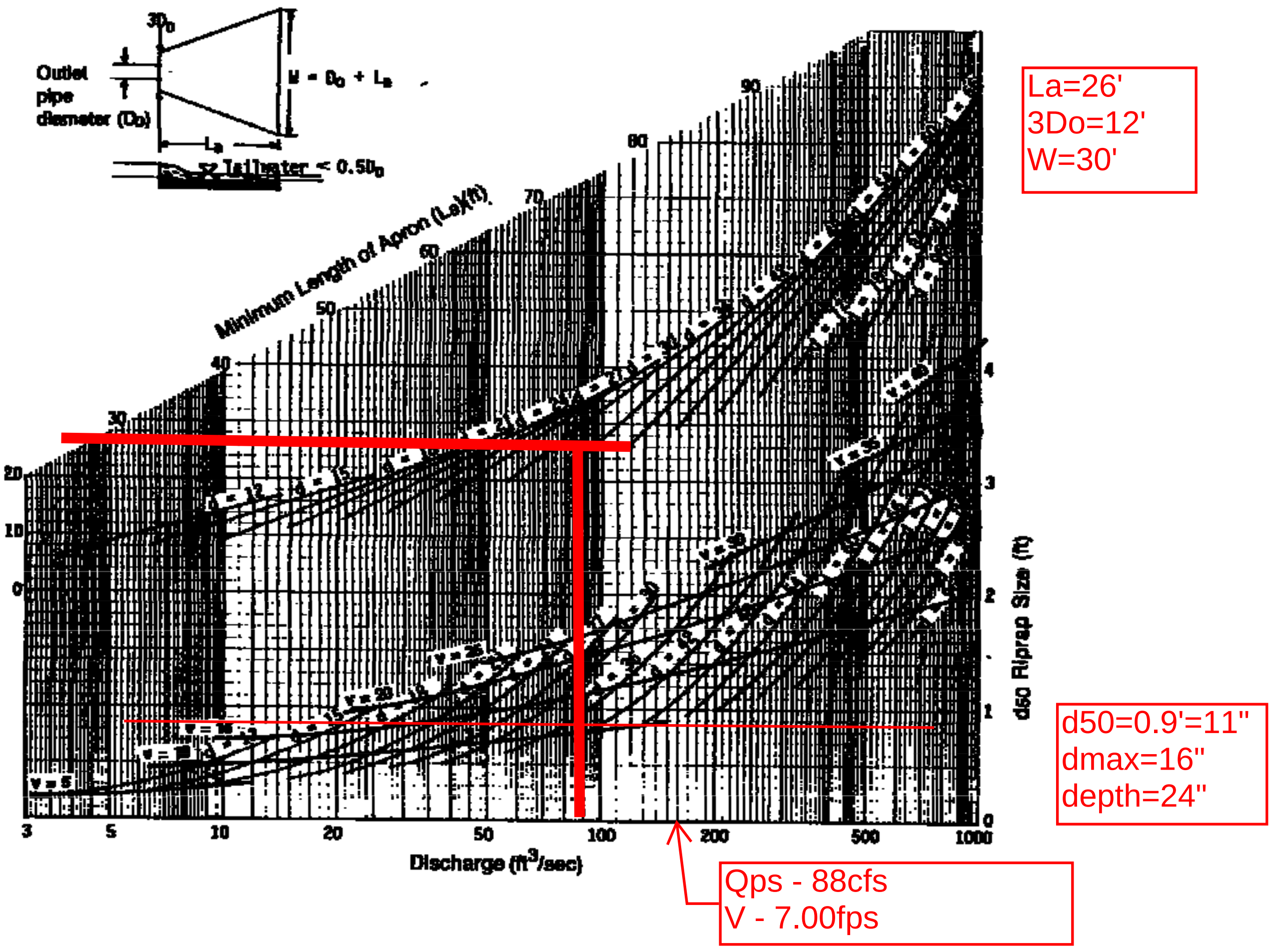
La=24'
3Do=10.5'
W=27.5'

d50=0.7'=8"
dmax=12"
depth=18"

Qps - 80cfs
V - 8.31fps

Figure 4.5-2 Design of Riprap Apron under Minimum Tailwater Conditions
(Source: USDA, SCS, 1975)

BASIN #8

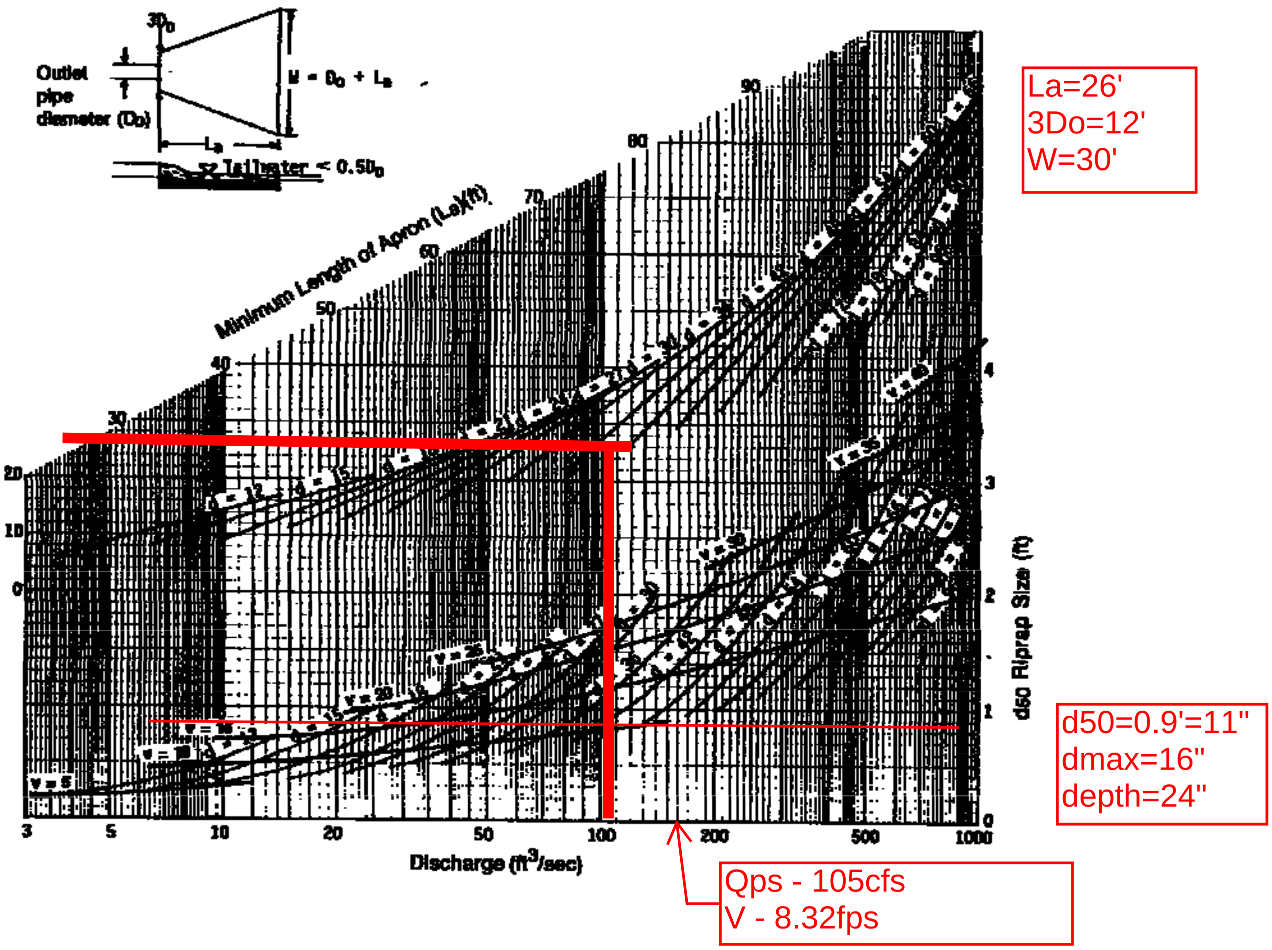


Curves may not be extrapolated.

Figure 4.5-2 Design of Riprap Apron under Minimum Tailwater Conditions
(Source: USDA, SCS, 1975)

BASIN #9

NOTE: CALC IS FOR EACH OF TWO OUTLETS.
TOTAL DIMENSIONS ARE:
La=26', W=38', Outlet end=20'



Curves may not be extrapolated.

Figure 4.5-2 Design of Riprap Apron under Minimum Tailwater Conditions
(Source: USDA, SCS, 1975)

United States Department of Agriculture

NRCS

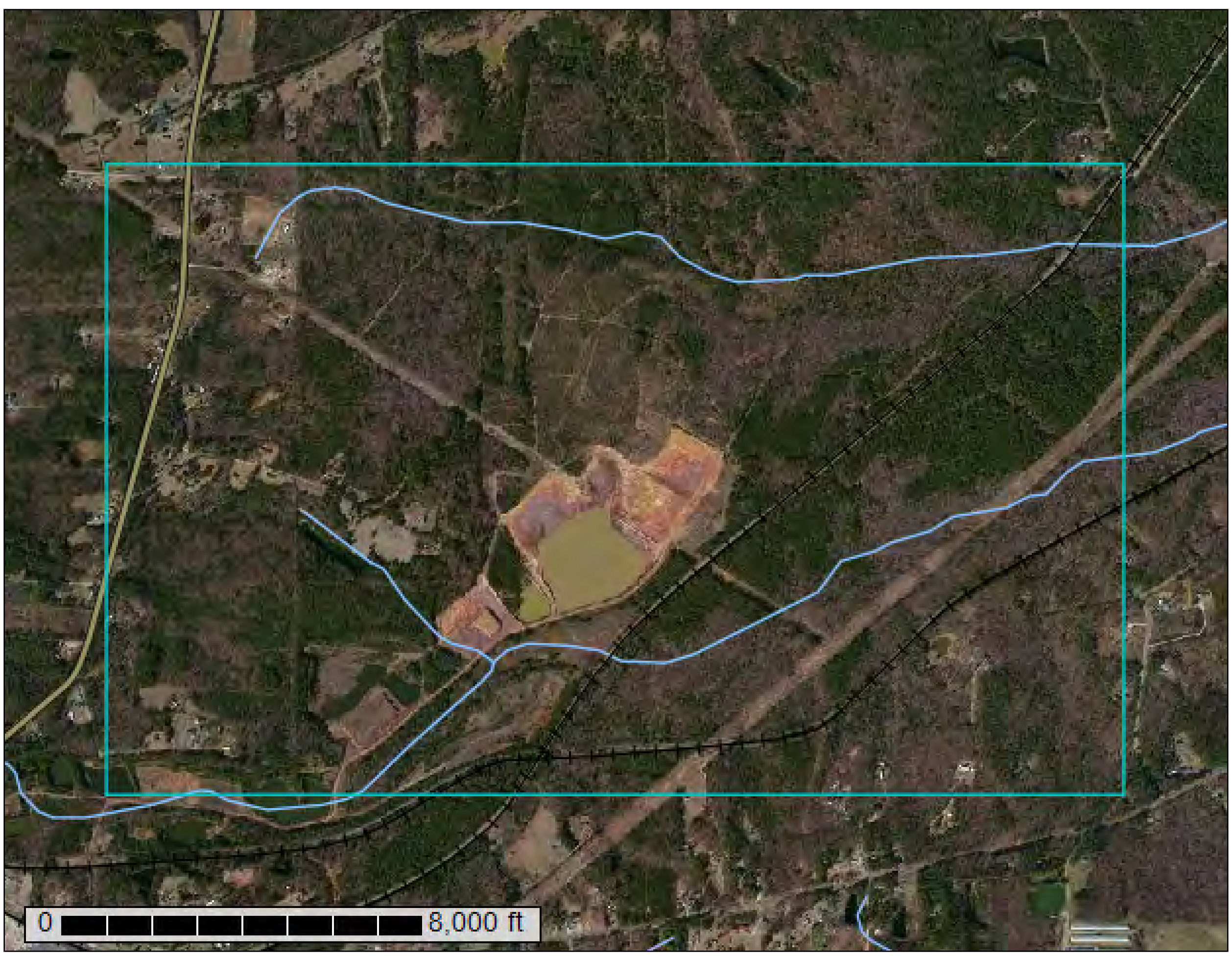
Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for

Lee County, North Carolina

Sanford



September 16, 2014

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (http://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

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Contents

How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

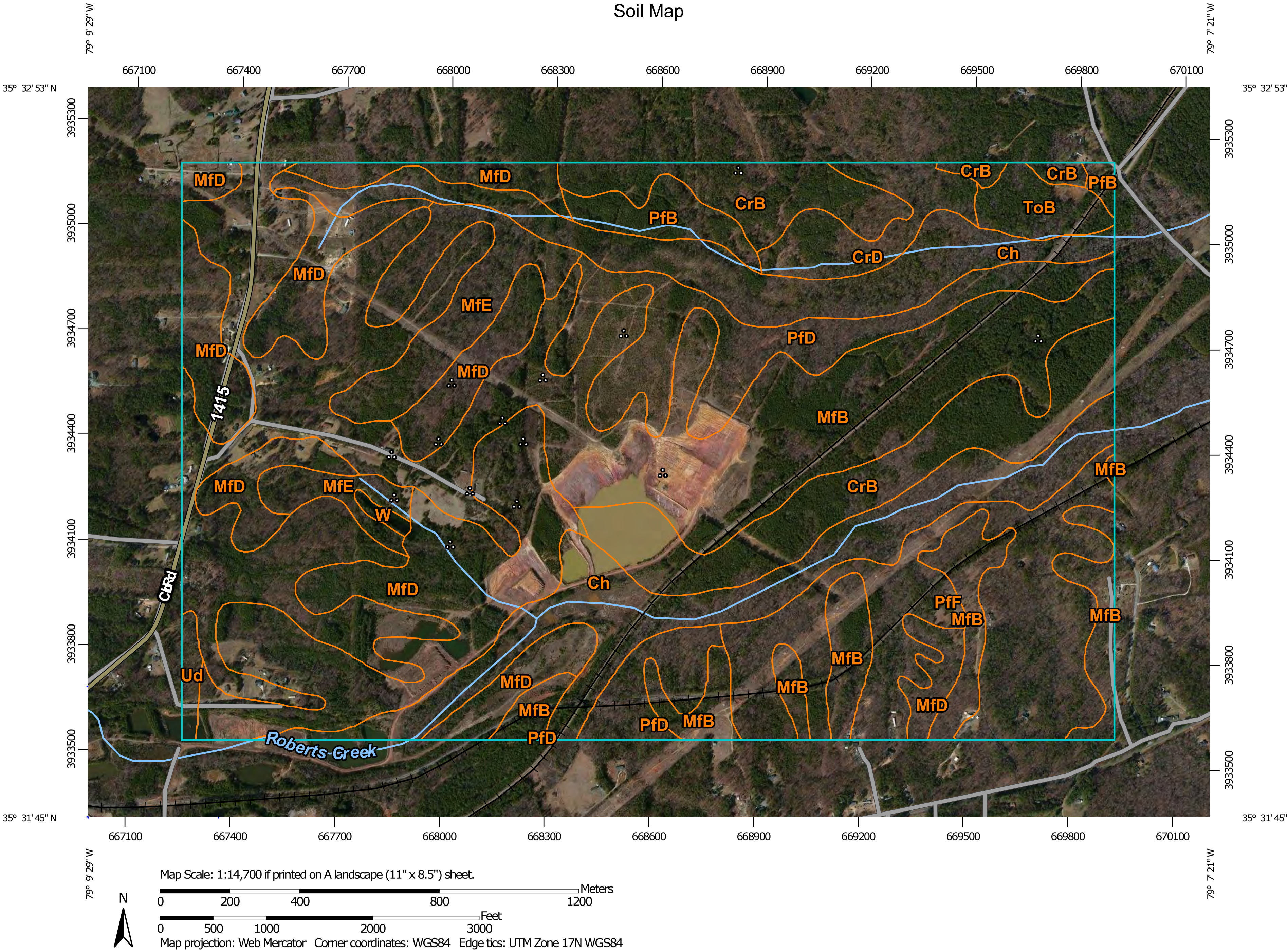
Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Soil Map


79° 9' 29" W
79° 7' 21" W
35° 32' 53" N
35° 31' 45" N
667100
667400
667700
668000
668300
668600
668900
669200
669500
669800
670100
3935300
3935000
3934700
3934400
3934100
3933800
3933500
MfD
MfE
W
Ud
PfB
CrB
CrD
ToB
Ch
PfD
MfB
PfF
1415
Roberts Creek
Map Scale: 1:14,700 if printed on A landscape (11" x 8.5") sheet.
Meters
0
200
400
800
1200
Feet
0
500
1000
2000
3000
N
Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 17N WGS84

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Lee County, North Carolina
Survey Area Data: Version 11, Dec 16, 2013

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Feb 11, 2011—Apr 2, 2011

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Lee County, North Carolina (NC105)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
Ch	Chewacla silt loam, 0 to 2 percent slopes, frequently flooded	144.6	13.2%
CrB	Creedmoor fine sandy loam, 2 to 8 percent slopes	101.3	9.3%
CrD	Creedmoor fine sandy loam, 8 to 15 percent slopes	24.5	2.2%
MfB	Mayodan fine sandy loam, 2 to 8 percent slopes	344.6	31.6%
MfD	Mayodan fine sandy loam, 8 to 15 percent slopes	205.8	18.9%
MfE	Mayodan fine sandy loam, 15 to 25 percent slopes	50.6	4.6%
PfB	Pinkston silt loam, 2 to 8 percent slopes	17.6	1.6%
PfD	Pinkston silt loam, 8 to 15 percent slopes	76.9	7.0%
PfF	Pinkston silt loam, 15 to 40 percent slopes	104.9	9.6%
ToB	Tillery fine sandy loam, 1 to 4 percent slopes, rarely flooded	14.5	1.3%
Ud	Udorthents, loamy	4.4	0.4%
W	Water	1.9	0.2%
Totals for Area of Interest		**1,091.4**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Lee County, North Carolina

Ch—Chewacla silt loam, 0 to 2 percent slopes, frequently flooded

Map Unit Setting

National map unit symbol: 2mz3q
Elevation: 200 to 1,400 feet
Mean annual precipitation: 37 to 60 inches
Mean annual air temperature: 59 to 66 degrees F
Frost-free period: 200 to 240 days
Farmland classification: Prime farmland if drained and either protected from flooding or not frequently flooded during the growing season

Map Unit Composition

Chewacla and similar soils: 87 percent
Minor components: 13 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Chewacla

Setting

Landform: Flood plains
Down-slope shape: Concave
Across-slope shape: Linear
Parent material: Loamy alluvium derived from igneous and metamorphic rock

Typical profile

A - 0 to 4 inches: silt loam
Bw1 - 4 to 26 inches: silty clay loam
Bw2 - 26 to 38 inches: loam
Bw3 - 38 to 60 inches: clay loam
C - 60 to 80 inches: loam

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Somewhat poorly drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: About 6 to 24 inches
Frequency of flooding: Frequent
Frequency of ponding: None
Available water storage in profile: High (about 11.5 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4w
Hydrologic Soil Group: B/D

Minor Components

Congaree

Percent of map unit: 8 percent
Landform: Flood plains
Down-slope shape: Linear

Across-slope shape: Linear

Wehadkee, undrained

Percent of map unit: 5 percent
Landform: Depressions on flood plains
Down-slope shape: Concave
Across-slope shape: Linear

CrB—Creedmoor fine sandy loam, 2 to 8 percent slopes

Map Unit Setting

National map unit symbol: 3t5w
Elevation: 200 to 1,400 feet
Mean annual precipitation: 37 to 60 inches
Mean annual air temperature: 59 to 66 degrees F
Frost-free period: 200 to 240 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Creedmoor and similar soils: 90 percent
Minor components: 8 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Creedmoor

Setting

Landform: Interfluves
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Interfluve
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Residuum weathered from shale and siltstone and/or mudstone and/or sandstone

Typical profile

Ap - 0 to 14 inches: fine sandy loam
Bt1 - 14 to 29 inches: silty clay loam
Bt2 - 29 to 56 inches: silty clay
BCg - 56 to 72 inches: loam
Cr - 72 to 96 inches: weathered bedrock

Properties and qualities

Slope: 2 to 8 percent
Depth to restrictive feature: 72 to 100 inches to paralithic bedrock
Natural drainage class: Moderately well drained
Runoff class: High
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
Depth to water table: About 18 to 24 inches
Frequency of flooding: None
Frequency of ponding: None

Sodium adsorption ratio, maximum in profile: 13.0
Available water storage in profile: Moderate (about 8.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2e
Hydrologic Soil Group: C/D

Minor Components

Mayodan

Percent of map unit: 8 percent
Landform: Interfluves
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Interfluve
Down-slope shape: Convex
Across-slope shape: Convex

CrD—Creedmoor fine sandy loam, 8 to 15 percent slopes

Map Unit Setting

National map unit symbol: 3t5x
Elevation: 200 to 1,400 feet
Mean annual precipitation: 37 to 60 inches
Mean annual air temperature: 59 to 66 degrees F
Frost-free period: 200 to 240 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Creedmoor and similar soils: 85 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Creedmoor

Setting

Landform: Hillslopes on ridges
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Residuum weathered from shale and siltstone and/or mudstone and/or sandstone

Typical profile

Ap - 0 to 14 inches: fine sandy loam
Bt1 - 14 to 29 inches: silty clay loam
Bt2 - 29 to 56 inches: silty clay
BCg - 56 to 72 inches: loam
Cr - 72 to 96 inches: weathered bedrock
R - 96 to 100 inches: unweathered bedrock

Properties and qualities

Slope: 8 to 15 percent
Depth to restrictive feature: 72 to 100 inches to paralithic bedrock
Natural drainage class: Moderately well drained
Runoff class: High
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
Depth to water table: About 18 to 24 inches
Frequency of flooding: None
Frequency of ponding: None
Sodium adsorption ratio, maximum in profile: 13.0
Available water storage in profile: Moderate (about 8.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3e
Hydrologic Soil Group: C/D

MfB—Mayodan fine sandy loam, 2 to 8 percent slopes

Map Unit Setting

National map unit symbol: 3t64
Elevation: 200 to 1,400 feet
Mean annual precipitation: 37 to 60 inches
Mean annual air temperature: 59 to 66 degrees F
Frost-free period: 200 to 240 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Mayodan and similar soils: 85 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Mayodan

Setting

Landform: Interfluves
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Interfluve
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Residuum weathered from mudstone and/or shale and siltstone and/or sandstone

Typical profile

Ap - 0 to 6 inches: fine sandy loam
BE - 6 to 9 inches: sandy clay loam
Bt - 9 to 33 inches: clay
BC - 33 to 40 inches: sandy clay loam
C - 40 to 80 inches: sandy clay loam

Properties and qualities

Slope: 2 to 8 percent

Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Sodium adsorption ratio, maximum in profile: 7.0
Available water storage in profile: High (about 9.3 inches)

Interpretive groups
Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2e
Hydrologic Soil Group: B

MfD—Mayodan fine sandy loam, 8 to 15 percent slopes

Map Unit Setting
National map unit symbol: 3t65
Elevation: 200 to 1,400 feet
Mean annual precipitation: 37 to 60 inches
Mean annual air temperature: 59 to 66 degrees F
Frost-free period: 200 to 240 days
Farmland classification: Farmland of statewide importance

Map Unit Composition
Mayodan and similar soils: 85 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Mayodan

Setting
Landform: Hillslopes on ridges
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Residuum weathered from mudstone and/or shale and siltstone and/or sandstone

Typical profile
Ap - 0 to 6 inches: fine sandy loam
BE - 6 to 9 inches: sandy clay loam
Bt - 9 to 33 inches: clay
BC - 33 to 40 inches: sandy clay loam
C - 40 to 80 inches: sandy clay loam

Properties and qualities
Slope: 8 to 15 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained

Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Sodium adsorption ratio, maximum in profile: 7.0
Available water storage in profile: High (about 9.3 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3e
Hydrologic Soil Group: B

MfE—Mayodan fine sandy loam, 15 to 25 percent slopes

Map Unit Setting

National map unit symbol: 3t66
Elevation: 200 to 1,400 feet
Mean annual precipitation: 37 to 60 inches
Mean annual air temperature: 59 to 66 degrees F
Frost-free period: 200 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Mayodan and similar soils: 80 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Mayodan

Setting

Landform: Hillslopes on ridges
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Residuum weathered from mudstone and/or shale and siltstone and/or sandstone

Typical profile

Ap - 0 to 6 inches: fine sandy loam
BE - 6 to 9 inches: sandy clay loam
Bt - 9 to 33 inches: clay
BC - 33 to 40 inches: sandy clay loam
C - 40 to 80 inches: sandy clay loam

Properties and qualities

Slope: 15 to 25 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: High

Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Sodium adsorption ratio, maximum in profile: 7.0
Available water storage in profile: High (about 9.3 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4e
Hydrologic Soil Group: B

PfB—Pinkston silt loam, 2 to 8 percent slopes

Map Unit Setting

National map unit symbol: 3t6c
Elevation: 200 to 1,400 feet
Mean annual precipitation: 37 to 60 inches
Mean annual air temperature: 59 to 66 degrees F
Frost-free period: 200 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Pinkston and similar soils: 90 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Pinkston

Setting

Landform: Interfluves
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Interfluve
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Residuum weathered from mudstone and/or shale and siltstone and/or sandstone

Typical profile

A - 0 to 6 inches: silt loam
Bw - 6 to 16 inches: silt loam
C - 16 to 38 inches: silt loam
R - 38 to 80 inches: unweathered bedrock

Properties and qualities

Slope: 2 to 8 percent
Depth to restrictive feature: 20 to 40 inches to lithic bedrock
Natural drainage class: Well drained
Runoff class: High
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
Depth to water table: More than 80 inches

Frequency of flooding: None
Frequency of ponding: None
Sodium adsorption ratio, maximum in profile: 13.0
Available water storage in profile: Low (about 4.5 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3e
Hydrologic Soil Group: C

PfD—Pinkston silt loam, 8 to 15 percent slopes

Map Unit Setting

National map unit symbol: 3t6d
Elevation: 200 to 1,400 feet
Mean annual precipitation: 37 to 60 inches
Mean annual air temperature: 59 to 66 degrees F
Frost-free period: 200 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Pinkston and similar soils: 85 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Pinkston

Setting

Landform: Hillslopes on ridges
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Residuum weathered from mudstone and/or shale and siltstone and/or sandstone

Typical profile

A - 0 to 6 inches: silt loam
Bw - 6 to 16 inches: silt loam
C - 16 to 38 inches: silt loam
R - 38 to 80 inches: unweathered bedrock

Properties and qualities

Slope: 8 to 15 percent
Depth to restrictive feature: 20 to 40 inches to lithic bedrock
Natural drainage class: Well drained
Runoff class: High
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Sodium adsorption ratio, maximum in profile: 13.0

Available water storage in profile: Low (about 4.5 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4e
Hydrologic Soil Group: C

PfF—Pinkston silt loam, 15 to 40 percent slopes

Map Unit Setting

National map unit symbol: 3t6f
Elevation: 200 to 1,400 feet
Mean annual precipitation: 37 to 60 inches
Mean annual air temperature: 59 to 66 degrees F
Frost-free period: 200 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Pinkston and similar soils: 80 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Pinkston

Setting

Landform: Hillslopes on ridges
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Residuum weathered from mudstone and/or shale and siltstone and/or sandstone

Typical profile

A - 0 to 6 inches: silt loam
Bw - 6 to 16 inches: silt loam
C - 16 to 38 inches: silt loam
R - 38 to 80 inches: unweathered bedrock

Properties and qualities

Slope: 15 to 40 percent
Depth to restrictive feature: 20 to 40 inches to lithic bedrock
Natural drainage class: Well drained
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Sodium adsorption ratio, maximum in profile: 13.0
Available water storage in profile: Low (about 4.5 inches)

Interpretive groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: C

ToB—Tillery fine sandy loam, 1 to 4 percent slopes, rarely flooded

Map Unit Setting

National map unit symbol: 2ml49
Elevation: 200 to 1,400 feet
Mean annual precipitation: 37 to 60 inches
Mean annual air temperature: 59 to 66 degrees F
Frost-free period: 200 to 240 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Tillery and similar soils: 90 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Tillery

Setting

Landform: Stream terraces
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loamy alluvium derived from igneous and metamorphic rock

Typical profile

Ap - 0 to 7 inches: fine sandy loam
Bt - 7 to 48 inches: silty clay loam
Cg - 48 to 80 inches: silt loam

Properties and qualities

Slope: 1 to 4 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Moderately well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: About 18 to 30 inches
Frequency of flooding: Rare
Frequency of ponding: None
Available water storage in profile: Moderate (about 8.9 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2e
Hydrologic Soil Group: C

Ud—Udorthents, loamy

Map Unit Setting

National map unit symbol: 3t6p
Elevation: 200 to 1,400 feet
Mean annual precipitation: 37 to 60 inches
Mean annual air temperature: 50 to 66 degrees F
Frost-free period: 145 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Udorthents, loamy, and similar soils: 85 percent
Minor components: 8 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Udorthents, Loamy

Setting

Landform: Hillslopes on ridges
Landform position (two-dimensional): Shoulder, summit, backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Loamy and clayey human transported material derived from igneous, metamorphic and sedimentary rock

Typical profile

C - 0 to 80 inches: sandy clay loam

Properties and qualities

Slope: 0 to 25 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Very low to high (0.00 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Moderate (about 8.4 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7e
Hydrologic Soil Group: C

Minor Components

Urban land

Percent of map unit: 8 percent
Landform: Hillslopes on ridges
Landform position (two-dimensional): Summit, shoulder, backslope

Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Convex

W—Water

Map Unit Composition

Water: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Water

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 8w

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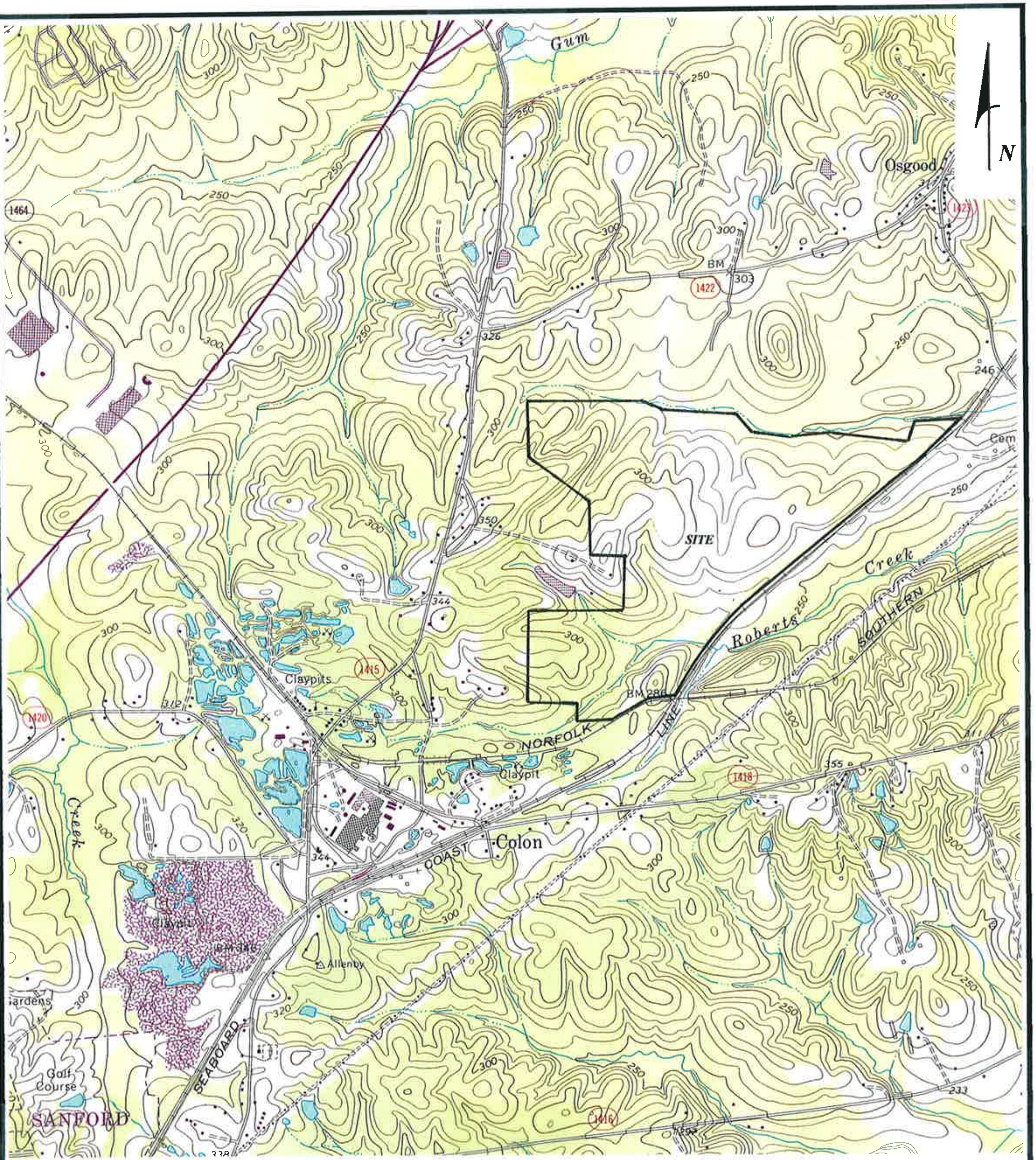

Scale

0 Feet 2,000

Source: 1970 USGS Colon, NC
Topographic Quadrangle

Colon Mine Reclamation Fill Site 1303 Brickyard Road Sanford, North Carolina		Site Location Map

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F

Earthwork

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HDR Computation

Project	Colon Mine Site Structural Fill	**Computed**	SF	**Date**	11/6/14
Subject	Permit Application	**Checked**	[signature]	**Date**	11/6/14
Task	Earthwork Calculations	**Sheet**	1	**Of**	3

Objective:

Determine the structural fill capacity and soil requirements

Inputs/Assumptions:

Overbuild :	0.1	ft (assumed overbuild for all soil layers)
	12	in per ft
	43,560	sf per acre
	27	cf per cy

Calculations:

Area of Structural Fill Footprint :	5,155,867	sf (source: AutoCAD from PAW on Nov. 5, 2014 - measured from the construction baseline)
Area of Structural Fill Footprint (to use in calculations) :	118	acres
Capacity (from basegrade to top of CCP) :	7,356,391	cy (Source: AutoCAD from JEG on Oct. 23, 2014)
Capacity (from basegrade to top of CCP - to use in calculations) :	7,356,000	cy
Approximate Disturbed Area :	6,010,096	sf (source: AutoCAD from JEG on Oct. 23, 2014)
Approximate Disturbed Area :	138	acres

Base Liner System

Base Liner System Thickness :	18	in
Base Liner System Volume :	305,000	cy
Available Airspace Capacity for Ash Placement :	7,051,000	cy

Earthwork

Cut to get to basegrades :	1,781,466	cy (Source: AutoCAD from JEG on Oct. 23, 2014)
Cut to get to basegrades (to use in calculations) :	1,781,000	cy
Fill to get to basegrades :	237,960	cy (Source: AutoCAD from JEG on Oct. 23, 2014)
Fill to get to basegrades (to use in basegrades) :	238,000	cy
Soil Remaining after basegrade grading :	1,543,000	cy

Cap Area (Disregards additional area due to slope factor)

Top of Structural Fill Area - North Side:	2,952,700	sf (source: AutoCAD from JEG on Oct. 23, 2014)
Top of Structural Fill Area - South Side:	439,609	sf (source: AutoCAD from JEG on Oct. 23, 2014)
Top of Structural Fill Area :	78	acres
Side Slopes of Structural Fill Area :	40	acres

HDR Computation

Project	Colon Mine Site Structural Fill	**Computed**	SJF	**Date**	11/6/14
Subject	Permit Application	**Checked**	[illegible]	**Date**	11/6/14
Task	Earthwork Calculations	**Sheet**	2	**Of**	3

Cap System: Soil and Geomembrane (no Geocomposite Drainage Layer)

See drawings for soil permeability requirements

Topsoil Thickness :	6 in
Topsoil Area :	118 acres
Topsoil Volume :	114,000 cy
Low Permeable Soil Thickness :	12 in
Low Permeable Soil Area :	118 acres
Low Permeable Soil Volume :	209,000 cy
Top Unclassified Soil Thickness :	24 in
Top Unclassified Soil Area :	78 acres
Top Unclassified Soil Volume :	264,000 cy
Side Slope Unclassified Soil Thickness :	12 in
Side Slope Unclassified Soil Area :	40 acres
Side Slope Unclassified Soil Volume :	71,000 cy
Top Drainage Soil Layer Thickness :	30 in
Top Drainage Soil Layer Area :	78 acres
Top Drainage Soil Layer Volume :	327,000 cy
Side Slope Drainage Soil Layer Thickness :	18 in
Side Slope Drainage Soil Layer Area :	40 acres
Side Slope Drainage Soil Layer Volume :	103,000 cy

Total Soil Required for Cap System :	1.1 million cy
Total Soil Required for Base Liner System:	305,000 cy

Remaining Soil for Cap System with soil and geomembrane (no geocomposite drainage layer)

Soil Remaining after Completion of Structural Fill :	138,000 cy	Assumes soils located onsite are appropriate for all soil components of the base liner and cap system.

Cap System: Soil, Geocomposite Drainage Layer, and Geomembrane

See drawings for soil permeability requirements

Topsoil Thickness :	6 in
Topsoil Area :	118 acres
Topsoil Volume :	114,000 cy
Top Unclassified Soil Thickness :	66 in
Top Unclassified Soil Area :	78 acres
Top Unclassified Soil Volume :	705,000 cy
Side Slope Unclassified Soil Thickness :	42 in
Side Slope Unclassified Soil Area :	40 acres
Side Slope Unclassified Soil Volume :	232,000 cy

HDR Computation

Project	Colon Mine Site Structural Fill	**Computed**	SF	**Date**	11/6/14
Subject	Permit Application	**Checked**	[signature]	**Date**	11/6/14
Task	Earthwork Calculations	**Sheet**	3	**Of**	3

Total Soil Required for Cap System :	1.1 million cy
Total Soil Required for Base Liner System:	305,000 cy

Remaining Soil for Cap System with soil, geocomposite drainage layer, and geomembrane

Soil Remaining after Completion of Structural Fill :	138,000 cy

Assumes soils located onsite are appropriate for all soil components of the base liner and cap system.

Cut/Fill Report

Generated: 2014-10-23 15:33:30

By user: jgaul

Drawing: C:\pwworking\tpa\d0602589\C:\pwworking\tpa\d0602589\Colon Mine Working R4.dwg

Volume Summary

Name	Type	Cut Factor	Fill Factor	2d Area (Sq. Ft.)	Cut (Cu. Yd.)	Fill (Cu. Yd.)	Net (Cu. Yd.)
T1	full	1.000	1.000	5124663.89	23.34	7356390.66	7356367.32<Fill>

Totals

	2d Area (Sq. Ft.)	Cut (Cu. Yd.)	Fill (Cu. Yd.)	Net (Cu. Yd.)
Total	5124663.89	23.34	7356390.66	7356367.32<Fill>

* Value adjusted by cut or fill factor other than 1.0

Area of Liner = 5155866.7981sf as measured by Philip Westmoreland on 11/5/14

Volume from basegrade to top of CCP. Need to subtract 18" of Clay in order to get CCP capacity.

Cut/Fill Report

Generated: 2014-10-23 14:56:44

By user: jgaul

Drawing: C:\pwworking\tpa\d0602589\C:\pwworking\tpa\d0602589\Colon Mine Working R4.dwg

Total disturbed area (includes basegrades, berms, etc.)
↳ use this # because the # below has extra area due to triangulation

Volume Summary

Name	Type	Cut Factor	Fill Factor	2d Area (Sq. Ft.)	Cut (Cu. Yd.)	Fill (Cu. Yd.)	Net (Cu. Yd.)
T1	full	1.000	1.000	6010095.89	1285.64	7372865.71	7371580.07<Fill>
T2	full	1.000	1.000	6039097.14	1781466.15	237959.93	1543506.22<Cut>

Totals

	2d Area (Sq. Ft.)	Cut (Cu. Yd.)	Fill (Cu. Yd.)	Net (Cu. Yd.)
Total	12049193.03	1782751.79	7610825.65	5828073.85<Fill>

* Value adjusted by cut or fill factor other than 1.0

Cut & Fill numbers to get to basegrades

According to John Gaul
T1 compared the ~~closeout~~ closure surface to the basegrade surface (including berms, etc.).
T2 compared the existing topography surface to the basegrade surface (including berms, etc.).

Futrell, Sarah

From:	Gaul, John
Sent:	Thursday, October 23, 2014 4:02 PM
To:	Futrell, Sarah
Subject:	Top Area for Sanford
Categories:	Charah

Sarah,

Top Area for North side (Bigger unit) – 2,952,699.74 = 67.78 Ac.

Top Area for South side (Smaller unit) – 439,609.46 = 10.09 Ac.

John Gaul
Civil Design Technician

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G

Financial Assurance

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November 11, 2014

Mr. Norman Divers
Senior Engineer
12601 Plantside Drive
Louisville, KY 40299

RE: Colon Mine Site Structural Fill
Financial Assurance Estimate
HDR Project No. 235691

Dear Mr. Divers,

North Carolina General Statute (NCGS) §130A-309.217 (a) requires that a financial assurance be established to ensure sufficient funds are available for a structural fill for facility closure, post-closure care, corrective action, and to satisfy any potential liability for sudden and non-sudden accidental occurrences. The purpose of this letter is to provide an estimate of the expenses to meet the financial assurance requirements in NCGS §130A-309.217.

Closure

The cost for closure is provided per acre in the Closure and Post-Closure Plan in the permit application for the Colon Mine Site Structural Fill. There are two different types of final cover caps that can be built over the Colon Mine Site Structural Fill. In addition, the final cover cap thickness varies based on the location of the cap; whether on top of the structural fill or on the side slope of the structural fill. The highest final cover cap estimate in the Closure and Post-Closure Plan is $171,300 per acre (for a cap with a geocomposite on the top of the structural fill) and the largest area requiring closure at any time to be 45 acres. Therefore approximately $7,708,500 needs to be set aside in order to cover the closure costs for the largest area requiring closure at any time at the Colon Mine Site Structural Fill.

Post-Closure Care

The cost for post-closure care is provided in the Closure and Post-Closure Plan in the permit application for the Colon Mine Site Structural Fill. The Closure and Post-Closure Plan estimates a post-closure care cost of $2,916,000.

Corrective Action

The Corrective Action costs assume a one time release, which includes assessment monitoring, an assessment of corrective measure report/selection of a remedy, and implementation of corrective action. It is assumed that corrective action occurs in post-closure and that monitored natural attenuation would be the selected remedy. The total cost for corrective action is estimated to be approximately $1,383,400. The North Carolina Department of Environment and Natural Resources

440 S Church Street, Suites 900 & 1000, Charlotte, NC 28202-2075
(704) 338-6700

Division of Waste Management requires that at least $2 million be set aside for corrective action for solid waste management facilities. Because the state is requiring a permit be obtained from the Division of Waste Management, HDR has assumed that the $2 million corrective action threshold also applies to structural fills.

Total

The total amount to be set aside for financial assurance is $12,624,500, as detailed in the calculation below.

Closure Costs	$7,708,500
Post-Closure Costs	$2,916,000
Corrective Action Costs	$2,000,000
Total Costs	**$12,624,500**

If you have any questions about this cost estimate, please feel free to contact me at (704) 338-6700.

Sincerely,
HDR Engineering Inc., of the Carolinas

Michael D. Plummer, PE
Project Manager

Enclosures

Closure Cost Estimate – Soil/Geomembrane Cap

The following is an estimate of closure costs; actual costs may vary.

				Soil/Geomembrane Cap					
				Top			Side Slope		
Item	Description	Unit Price	Unit	Thickness (in)	Quantity	Total	Thickness (in)	Quantity	Total
1	Mobilization, Administration & Bonds	4%	of Items 2-9		4%	$ 4,000		4%	$ 3,200
2	Surveying & Control	$ 1,600	Acres		1	$ 1,600		1	$ 1,600
3	Topsoil Layer	$ 11.60	CY	6	900	$ 10,400	6	900	$ 10,400
4	Low Permeable Soil Layer*	$ 6.70	CY	12	1,700	$ 11,400	12	1,700	$ 11,400
5	Unclassified Soil Layer*	$ 6.70	CY	24	3,300	$ 22,100	12	1,700	$ 11,400
6	Drainage Soil Layer*	$ 6.70	CY	30	4,100	$ 27,500	18	2,500	$ 16,800
7	Geocomposite Drainage Layer	$ 0.70	SF		0	$ -		0	$ -
8	Geomembrane (40 mil double sided textured polyethylene)	$ 0.60	SF		43,560	$ 26,100		43,560	$ 26,100
9	Seeding/Fertilizing/Mulching	$ 1,500	Acre		1	$ 1,500		1	$ 1,500
10	Contingency	10%	of Items 1-9		10%	$ 10,500		10%	$ 8,200
11	Engineering - Plans & Specs	6%	of Items 1-9		6%	$ 6,300		6%	$ 4,900
12	CQA & Certification	6%	of Items 1-9		6%	$ 6,300		6%	$ 4,900
13	Construction Management	5%	of Items 1-9		5%	$ 5,200		5%	$ 4,100
					Cost Per Acre	$ 132,900		Cost Per Acre	$ 104,500

*The permeabilities for the soil layers may be different; however, the costs have been assumed to be the same with the exception of the topsoil.

Closure Cost Estimate – Soil/Geocomposite Drainage Layer/Geomembrane Cap

The following is an estimate of closure costs; actual costs may vary.

				Soil/Geocomposite Drainage Layer/Geomembrane Cap					
				Top			Side Slope		
Item	Description	Unit Price	Unit	Thickness (in)	Quantity	Total	Thickness (in)	Quantity	Total
1	Mobilization, Administration & Bonds	4%	of Items 2-9		4%	$ 5,200		4%	$ 4,300
2	Surveying & Control	$ 1,600	Acres		1	$ 1,600		1	$ 1,600
3	Topsoil Layer	$ 11.60	CY	6	900	$ 10,400	6	900	$ 10,400
4	Low Permeable Soil Layer*	$ 6.70	CY	66	8,900	$ 59,600	42	5,700	$ 38,200
5	Unclassified Soil Layer*	$ 6.70	CY		0	$ -		0	$ -
6	Drainage Soil Layer*	$ 6.70	CY		0	$ -		0	$ -
7	Geocomposite Drainage Layer	$ 0.70	SF		43,560	$ 30,500		43,560	$ 30,500
8	Geomembrane (40 mil double sided textured polyethylene)	$ 0.60	SF		43,560	$ 26,100		43,560	$ 26,100
9	Seeding/Fertilizing/Mulching	$ 1,500	Acre		1	$ 1,500		1	$ 1,500
10	Contingency	10%	of Items 1-9		10%	$ 13,500		10%	$ 11,300
11	Engineering - Plans & Specs	6%	of Items 1-9		6%	$ 8,100		6%	$ 6,800
12	CQA & Certification	6%	of Items 1-9		6%	$ 8,100		6%	$ 6,800
13	Construction Management	5%	of Items 1-9		5%	$ 6,700		5%	$ 5,600
					Cost Per Acre	$ 171,300		Cost Per Acre	$ 143,100

*The permeabilities for the soil layers may be different; however, the costs have been assumed to be the same with the exception of the topsoil.

Annual Post-Closure Care Cost Estimate

The following is an estimate of post-closure costs; actual costs may vary.

1	Quarterly Site Inspections	4	Events	$5,000	$20,000
2	Cap System Maintenance				
	a. Seeding/Fertilizing/Mulching	1	acres	$1,500	$1,500
	b. Topsoil Replacement	400	CY	$11.60	$4,600
	c. Protective Cover Replacement	400	CY	$6.70	$2,700
3	Stormwater Management	1	LS	$2,000	$2,000
4	Stormwater Monitoring	2	Events	$1,200	$2,400
5	Utilities	12	Events	$500	$6,000
6	Mowing	2	Events	$2,850	$5,700
7	Fence Repairs and Security	1	LS	$500	$500
8	Administration	1	Events	$2,000	$2,000
9	Leachate System Maintenance	1	Events	$2,500	$2,500
10	Leachate Collection and Treatment	1,085,600	gallons	$0.0235	$25,500
11	Water Quality Monitoring & Report	2	Events	$6,000	$12,000
12	Groundwater Monitoring System Maintenance	1	Events	$1,000	$1,000
13	Contingency	10%		$88,400	$8,800
	Annual Total				$97,200
	30-YR Total				$2,916,000

Estimated Corrective Measure Costs For the Colon Mine Site Structural Fill

Colon Mine Site Structural Fill		$ 1,383,422
Detection Monitoring (15A NCAC 13B .1633)	**2014**	
(Not included in Financial Assurance)	$ -	
Assessment Monitoring (15A NCAC 13B .1634)		
Planning	$ 25,000	
Drilling	$ 13,950	
Drilling Report	$ 4,000	
Sampling	$ 37,988	
Sampling Report	$ 40,000	
Assessment of Corrective Measure Report/ Selection of Remedy (15A NCAC 13B .1635 and .1636)		
Report	$ 60,000	
Implementation of Corrective Action (15A NCAC 13B .1637) (assumed remedy is MNA)		
Corrective Action Sampling	$ 562,484	
Report	$ 520,000	
MNA Report	$ 120,000	

Assumptions:

1. Assumes Corrective Actions begin in 2021, the beginning of the post-closure care period.
2. Assumes Corrective Actions end in 2050, the end of the post-closure care period.

Assessment Costs

Planning Costs

Total $ 25,000

Item	Quantity	Unit
Senior Professional	4	hours
Registered Professional	40	hours
Project Professional	80	hours
CAD Operator	16	hours
Administration	16	hours

Drilling Costs

Total $ 6,975 per well

Item	Quantity	Unit			Unit Price			Total
Drilling Services (1 day)								
Drill Rig Mobilization	1	each	at	$	570.00	per each	$	570.00
Auger Boring (0-50 ft depth) 4.25 ID Augers	50	feet	at	$	10.00	per foot	$	500.00
Rock Coring - Set Up, per hole	10	each	at	$	100.00	per each	$	1,000.00
NQ Coring	10	feet	at	$	15.00	per foot	$	150.00
Installation of Type II Monitor Well, 2-inch	60	feet	at	$	37.00	per foot	$	2,220.00
Above Grade Protective Casing, 2-inch wells	1	each	at	$	130.00	per each	$	130.00
Steam Cleaner	1	day	at	$	130.00	per day	$	130.00
Water Trailer	1	day	at	$	52.00	per day	$	52.00
Drilling Oversight (1 day)								
Project Professional	4	hours	at	$	120.00	per hour	$	480.00
Mileage	150	miles	at	$	0.50	per mile	$	75.00

Assessment Costs

Well Development and Slug Testing (1 day)								
Project Professional	8	hours	at	$	120.00	per hour	$	960.00
Mileage	150	miles	at	$	0.50	per mile	$	75.00
Water Level Meter	1	day	at	$	25.00	per day	$	25.00
Pressure Transducer and Data Logger	1	day	at	$	50.00	per day	$	50.00
Battery Operated Well Pump	1	day	at	$	50.00	per day	$	50.00
Well Survey								
Subcontracted Survey Cost	1	each	at	$	508.00	per each	$	508.00

Drilling Report Costs

Total $ 4,000 per well

Item	Quantity	Unit
Registered Professional	2	hours
Project Professional	10	hours
CAD Operator	4	hours
Administration	8	hours

Sampling Costs

Item	Quantity	Unit			Unit Price			Total	
Field Work (1 event)									
Technician Time (2 techs)	16	hours	at	$	95.00	per hour	$	1,520.00	
Mileage	300	miles	at	$	0.50	per mile	$	150.00	
Water Level Probe	2	day	at	$	25.00	per day	$	50.00	
pH Meter	2	day	at	$	51.00	per day	$	102.00	
Conductivity Meter	2	day	at	$	51.00	per day	$	102.00	
Disposable Teflon Bailers	2	day	at	$	230.00	per day	$	460.00	
Disposables (Tubing, Gloves, Ropes, etc)	2	day	at	$	130.00	per day	$	260.00	
						Total	**$**	**2,644.00**	**per event**

Assessment Costs

Analytical (4 events)

Appendix II - Volatiles	1 each	at	$	90.00	per each	$	90.00	Not included because VOCs are not expected from CCP
Appendix II - Semi Volatiles	1 each	at	$	180.00	per each	$	180.00	Not included because VOCs are not expected from CCP
Appendix II - Pesticides/PCB	1 each	at	$	105.00	per each	$	105.00	
Appendix II - Herbacides	1 each	at	$	105.00	per each	$	105.00	
Appendix II - Metals	1 each	at	$	105.00	per each	$	105.00	
Appendix II - CN	1 each	at	$	20.00	per each	$	20.00	
Appendix II - Sulfide	1 each	at	$	18.00	per each	$	18.00	
					Total	**$**	**623.00**	**per well**

Samping Report Costs

Total **$ 10,000** per semi-annual report

Item	Quantity	Unit
Senior Professional	2	hours
Registered Professional	24	hours
Project Professional	16	hours
CAD Operator	4	hours
Administration	12	hours

ACM Report/Selection of Remedy Costs

Total Sampling Report Cost	$ 60,000

Corrective Action Sampling Costs

Assumes Corrective Action is MNA

Sampling Costs

Item	Quantity	Unit		Unit Price		Total	
Field Work (1 event)							
Technician Time (2 techs)	16	hours	at	$ 95.00	per hour	$ 1,520.00	
Mileage	300	miles	at	$ 0.50	per mile	$ 150.00	
Water Level Probe	2	day	at	$ 25.00	per day	$ 50.00	
pH Meter	2	day	at	$ 51.00	per day	$ 102.00	
Conductivity Meter	2	day	at	$ 51.00	per day	$ 102.00	
Disposable Teflon Bailers	2	day	at	$ 230.00	per day	$ 460.00	
Disposables (Tubing, Gloves, Ropes, etc)	2	day	at	$ 130.00	per day	$ 260.00	
					Total	**$ 2,644.00**	**per event**
Analytical							
Appendix II - Volatiles	1	each	at	$ 90.00	per each	$ 90.00	Not included because VOCs are not expected from CCP
Appendix II - Semi Volatiles	1	each	at	$ 180.00	per each	$ 180.00	Not included because VOCs are not expected from CCP
Appendix II - Pesticides/PCB	1	each	at	$ 105.00	per each	$ 105.00	
Appendix II - Herbacides	1	each	at	$ 105.00	per each	$ 105.00	
Appendix II - Metals	1	each	at	$ 105.00	per each	$ 105.00	
Appendix II - CN	1	each	at	$ 20.00	per each	$ 20.00	
Appendix II - Sulfide	1	each	at	$ 18.00	per each	$ 18.00	
					Total	**$ 353.00**	**per well**

Corrective Action Sampling Costs

Assumes Corrective Action is MNA

MNA Analytical								
Nitrate	1 each	at	$	12.00	per each	$	12.00	
Iron	1 each	at	$	15.00	per each	$	15.00	
Sulfate	1 each	at	$	20.00	per each	$	20.00	
Sulfide	1 each	at	$	20.00	per each	$	20.00	
Methane, Ethane, Ethene, CO_2	1 each	at	$	90.00	per each	$	90.00	
TOC/BOD/COD	1 each	at	$	100.00	per each	$	100.00	
Alkalinity	1 each	at	$	13.00	per each	$	13.00	
Chloride	1 each	at	$	10.00	per each	$	10.00	
Volatile Fatty Acids	1 each	at	$	110.00	per each	$	110.00	
					Total	**$**	**390.00**	**per well**

Sampling Report Costs

Total **$ 10,000** per semi-annual report

Item	Quantity	Unit
Senior Professional	2	hours
Registered Professional	24	hours
Project Professional	16	hours
CAD Operator	4	hours
Administration	12	hours

Corrective Action Sampling Costs

Assumes Corrective Action is MNA

MNA Report

MNA Report Costs

Total **$ 20,000** every five years

Item	Quantity	Unit
Senior Professional	4	hours
Registered Professional	48	hours
Project Professional	32	hours
CAD Operator	8	hours
Administration	24	hours

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