APPENDIX L
INTERFACE STABILITY

TECHNICAL MEMORANDUM

DATE: December 5, 2014

TO: Mark Peters, P.E.

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SUBJECT: Appendix L - Interface Stability Evaluation
Callahan Mine Superfund Site
Brooksville, Maine

PROJECT: 3612-11-2201

1.0 INTRODUCTION

AMEC Environment & Infrastructure, Inc. (AMEC) has performed an interface stability evaluation in support of the Draft Final Design for the Tailings Impoundment (OU3) at the Callahan Mine Superfund Site in Brooksville, Maine. The purpose of this evaluation is to establish the interface strength parameters necessary to provide for acceptable interface stability within the proposed low-permeability cover system.

This Technical Memorandum documents the work performed and presents the results of the evaluation. This memorandum is organized as follows:

- Section 2.0 briefly summarizes relevant project background information;
- Section 3.0 presents the methodology, assumptions, and results; and
- Section 4.0 provides conclusions and recommendations.

2.0 PROJECT BACKGROUND INFORMATION

Elevations reported herein are based on the North American Vertical Datum (NAVD) of 1988. Elevations are reported in units of feet. The horizontal datum is the Maine State Plane Coordinate System, East Zone, based on the North American Datum (NAD) of 1983.

2.1 Site Description

The former Callahan Mine property, an elongated 120-acre property oriented north-south, is located approximately 15 miles west of the Town of Blue Hill and 35 miles west of the

Town of Bar Harbor on the northwest side of the Cape Rosier peninsula on Penobscot Bay.

The former Callahan Mine was a hard-rock, open-pit mine developed in Goose Pond, a shallow tidal estuary of approximately 75 acres. Between approximately 1968 and 1972, Callahan mined approximately 5,000,000 tons of waste rock to access and remove approximately 800,000 tons of ore-bearing rock at the Site. Rock was blasted from inside the open pit and hauled out in trucks. Ore-grade rock was taken directly to on-site processing or to an ore storage area. Waste rock was either disposed of or used for construction projects, such as the construction of containment dams at the Tailings Impoundment. Tailings from the flotation mill were pumped as slurry to the Tailings Impoundment.

The Tailings Impoundment is located at the southern end of the Site, adjacent to a Salt Marsh at the edge of South Goose Pond. The impoundment encompasses an approximately 17-acre trapezoidal-shaped footprint. The impoundment contains fine sand, silt, and clay-sized rock particles (i.e., tailings) from the Callahan-era mining operations. The tailings are contained by a three-sided dam constructed against a sloping hillside. The existing ground surface elevation is roughly +75 feet along the crest of the dam and about +70 feet in central portions of the impoundment. The impoundment surface is concave and surface water ponds in the middle. The existing ground surface elevation averages about +15 feet along the eastern toe. The dam is a maximum of about 60 feet tall and has an average slope of about 1.3H-1.5H to 1V (horizontal to vertical). East of the toe, the existing ground surface slopes down gradually to the edge of the Salt Marsh/Goose Pond floodplain (at approximately elevation +7 feet).

The existing features and topography of the Tailings Impoundment are depicted in the Design Drawings.

2.2 Planned Remedial Action

The design objectives for the Tailings Impoundment remedy include the following:

- reduce the contaminant load to Goose Pond from surface water runoff and seep discharge from the Tailings Impoundment;
- stabilization measures (e.g., crest improvements, toe improvements, and/or dewatering) to improve both static and seismic stability and thereby minimize the potential for a slope failure to occur; and

- minimize truck traffic to and from the Site (a concern of local residents) by generating to the extent practicable, materials necessary for remedial construction from on-site sources.

A low-permeability cover system is proposed to reduce infiltration and thereby the runoff and discharge of metals-laden surface water and seepage of metals-contaminated groundwater from the Tailings Impoundment. These waters currently discharge to the Goose Pond estuary. The cover will minimize infiltration and facilitate the dewatering of the Tailings Impoundment to improve stability.

The planned cap limits/extents and grading are depicted in the Design Drawings. A maximum final grade/elevation of about +94.5 feet is indicated on the central-western area of the impoundment. From this apex, the western portion of the cap will slope downward gently at approximately 5% to the north and south, transitioning to 20% slopes near the impoundment dam perimeter. The eastern portion of the cap will slope downward at approximately 20% from west to east (toward a drainage swale feature). To the east of the swale, the cap will slope upward at approximately 33%, for a relatively short horizontal distance, and then transition to 3% near the eastern perimeter of the impoundment dam.

The following cap configuration (from the ground surface downward) and materials are planned:

- Stone (15 inches; D_{50} < 6-inches);
- Geocomposite drainage layer (GDL);
- Geomembrane [flexible membrane liner (FML)];
- Geosynthetic clay liner (GCL); and
- Subgrade (in-situ compacted tailings in cut areas and dewatered tailings/waste rock in fill areas).

3.0 INTERFACE STABILITY EVALUATION

AMEC performed this interface stability evaluation to establish interface strength requirements for cap geosynthetics, based on the planned cap configuration, materials, and grading.

3.1 Methodology

This evaluation is based primarily on methodology presented in the "Design of Lining and Cover System Side Slopes" (Druschel and Underwood, 1993), which is included as Attachment L-1. AMEC developed and utilized an in-house spreadsheet calculator to calculate an interface stability factor of safety (FS) based on the following force summation equation:

$$FS = \frac{\Sigma \text{ Resisting Forces}}{\Sigma \text{ Driving Forces}}$$

The effects of saturated cover soil conditions were calculated (if applicable) based on methodology presented in "Earth Slides on Geomembrane" (Stamatopoulos and Kotzlas, 1996). Similarly, a seismic coefficient equal to the peak ground acceleration (PGA) was included (if applicable) to represent the anticipated effect of the horizontal acceleration imposed by a seismic event. AMEC's spreadsheet calculator does not include any resistance generated by anchorage/tension in geosynthetic materials.

An infinite slope analysis was also included in this evaluation, given the relatively long (and flat) interior slopes and the relatively thin cap. Infinite slope analyses are considered appropriate for cases in which the slope length is much greater than the thickness of the cap. For infinite slope analyses, the FS is again defined as the resisting forces divided by the driving forces.

3.2 Evaluation Criteria

Table L-1 presents the minimum factors of safety for the interface to be considered stable.

Table L-1: Minimum Factors of Safety

Condition	Loading	Minimum Factor of Safety	
		Peak Strength	Residual Strength
Long-Term	Static	1.5	1.1
Long-Term	Seismic[1]	1.1	1.0
Construction	Static	1.3	1.1
Construction	Seismic[2]	1.1	1.0
Transient (short-term)	Static	1.3	1.1

Notes:

1. A PGA for a 2% probable exceedance (PE) in 50 years was applied for the long-term condition.
2. A PGA for a 10% PE in 50 years was applied for the construction condition.

3.3 Site-Specific Interfaces and Typical Interface Strength Parameters

Table L-2 identifies the site-specific interfaces (based on the planned cap materials) and presents typical strength parameters for each interface (based on literature values, geosynthetic manufacturers' specifications and/or testing databases, and AMEC's experience and engineering judgment).

Table L-2: Site-Specific Interfaces and Typical Interface Strength Parameters

Interface			Typical Interface Strength Parameters			
No.	Materials		Peak		Residual	
	General	Specific	δ (degrees)	Cohesion (psf)	δ (degrees)	Cohesion (psf)
1	Cover Soil	Stone	30	0	28	0
	GDL	NW[1] Geotextile				
2a	GDL	NW Geotextile	10	0	10	0
	FML	Smooth				
2b	GDL	NW Geotextile	28	0	22	0
	FML	Textured				
3a	FML	Smooth	10	0	10	0
	GCL[2]	NW Geotextile				
3b	FML	Textured	28	0	22	0
	GCL[2]	NW Geotextile				
4	GCL[2]	W[1] Geotextile	30	0	28	0
	Subgrade Soil	Tailings				

Notes:

1. NW = Nonwoven; W = Woven.

2. A reinforced GCL (i.e., needle-punched) is assumed such that the internal shear strength of the GCL is not a critical "interface" to evaluate. Should an unreinforced GCL be considered for use on this Site, it must be evaluated and tested relative to the interface performance requirements established herein.

3.4 Analysis and Results

AMEC performed separate analyses for the 5% slopes, 20% slopes, and 33% slopes. General assumptions, slope-specific inputs, and associated results are summarized in the subsections below.

3.4.1 General Assumptions/Input Parameters

The following cover soil thickness, unit weights, strength parameters, and drainage/seepage conditions are assumed, regardless of slope:

- Thickness of cover soils = 1.25 feet (15 inches);
- Unit weight of cover soils (moist) = 100 pounds/cubic foot (pcf);
- Unit weight of cover soils (saturated) = 125 pcf;
- Cover soil strength/friction angle = 41 degrees;
- Cover soil cohesion = 0 pounds/square foot (psf); and
- Seepage height above the GDL = Varies (slope dependent).
    - AMEC developed and utilized an in-house spreadsheet calculator to calculate seepage height above the GDL using methodology presented in Soong and Koerner (1997). Seepage can occur during a significant rain event (the GDL operates at capacity, cover soils become partially to fully saturated, and water flows downslope within the cover soils). Consequently, seepage forces will reduce interface stability FS. Spreadsheet calculator output files for the 5%, 20% and 33% slopes are presented in Attachment L-2. Basis for the input parameters utilized in the spreadsheet calculator is also presented in Attachment L-2.

Site-specific seismic coefficients are listed as follows (see Attachment L-3 for additional details):

- PGA for a 2% PE in 50 years (from USGS) = 0.15g x 0.5; and

- PGA for a 10% PE in 50 years (assumed) = 0.05g x 0.5.

3.4.2 5% Slopes

The following maximum slope configuration is expected for the 5% north/south oriented slopes, based on the planned cap grading:

- Slope, β_{up} = 5 percent = 2.9 degrees;
- Height, H_{up} = 30 feet (+/-);
- Length, $L_{up\text{-}horizontal}$ = 600 feet (+/-); and
- Seepage height above the GDL = 7 inches.

Considering the relatively long slope and relatively thin soil cover, the analysis of the 5% slopes conservatively ignored the resistance provided by the "toe" of the soil cover (i.e., the toe buttress per Druschel). This is represented (in the spreadsheet calculator) by inputting a cover soil shear strength, ϕ, of 0 degrees. For the long-term static loading condition, the analysis essentially becomes an infinite slope analysis (Tangent of δ / Tangent of β).

Table L-3 presents the estimated factors of safety for each interface, for the long-term static loading condition, based on typical interface strength parameters (Table L-2) and the assumptions/inputs described herein. The corresponding spreadsheet calculations are provided in Attachment L-4A.

Table L-3: Estimated Factors of Safety for Long-Term Static Conditions (5% Slopes)

Interface			Estimated Factors of Safety	
No.	Materials		Peak	Residual
	General	Specific	(FS $\geq$ 1.5 Required)	(FS > 1.1 Required)
1	Cover Soil	Stone	11.4	10.5
	GDL	NW[1] Geotextile		
2a	GDL	NW Geotextile	3.5	3.5
	FML	Smooth		
2b	GDL	NW Geotextile	10.5	8.0

	FML	Textured		
3a	FML	Smooth	3.5	3.5
	GCL[2]	NW Geotextile		
3b	FML	Textured	10.5	8.0
	GCL[2]	NW Geotextile		
4	GCL[2]	W[1] Geotextile	11.4	10.5
	Subgrade Soil	Tailings		

Notes:

1. NW = Nonwoven; W = Woven.
2. A reinforced GCL (i.e., needle-punched) is assumed such that the internal shear strength of the GCL is not a critical "interface" to evaluate. Should an unreinforced GCL be considered for use on this Site, it must be evaluated and tested relative to the interface performance requirements established herein.

The results presented in Table L-3 indicate that interfaces between a smooth FML and a nonwoven (or woven) geotextile (i.e., Interfaces 2a and 3a) will govern interface stability on the 5% slopes. As such, these interfaces were analyzed further to consider various site-specific loading conditions/scenarios (e.g., construction equipment, seismic loading, and transient conditions). Table L-4 provides a general description of the six scenarios considered. Table L-5 summarizes the spreadsheet input parameters and the required factors of safety for each scenario.

Table L-4: Description of Site-Specific Scenarios (5% Slopes)

Scenario No.	Condition	Evaluation	General Description
1	Long-Term	Static	Simulates the base/long-term condition. Already analyzed. Results are presented in Table L-3.
2	Long-Term	Seismic	Simulates base/long-term condition during a seismic event (50-year, 2% PE).
3	Construction	Static	Simulates equipment loading.

4	Construction	Seismic	Simulates equipment loading during a seismic event (50-year, 10% PE).
5	Transient	Static	Simulates a saturated slope (γ_t=γ_{sat}=125 pcf) but no seepage (for conditions that may occur during a spring thaw).
6	Transient	Static	Simulates a partially saturated slope (γ_t=γ_{sat}=125 pcf) with seepage (for conditions that may occur during a significant rain event).

Table L-5: Input Parameters for Site-Specific Scenarios (5% Slopes)

Scenario No.	Condition	Evaluation	Seep.	Equip. Loading	Cover Soil Properties			Min. FS Required	
					γ (pcf)	ϕ (deg)	c (psf)	Peak	Resid.
1	Long-Term	Static	No	No	100	41	0	1.5	1.1
2	Long-Term	Seismic	No	No	100	41	0	1.1	1.0
3	Construction	Static	No	Yes	100	41	0	1.3	1.1
4	Construction	Seismic	No	Yes	100	41	0	1.1	1.0
5	Transient	Static	No	No	125	41	0	1.3	1.1
6	Transient	Static	Yes	No	125	41	0	1.3	1.1

Notes:

1. Seep. = The GDL operates at capacity, and the cover soils become partially saturated and down slope seepage/flow occurs within the cover soils.
2. Equip. Loading = The effect of equipment loading (braking force) is considered. A D6K2 bulldozer weighing 30,750 pounds (4,400 pounds per unit width) with a length of 8.5 feet was utilized.

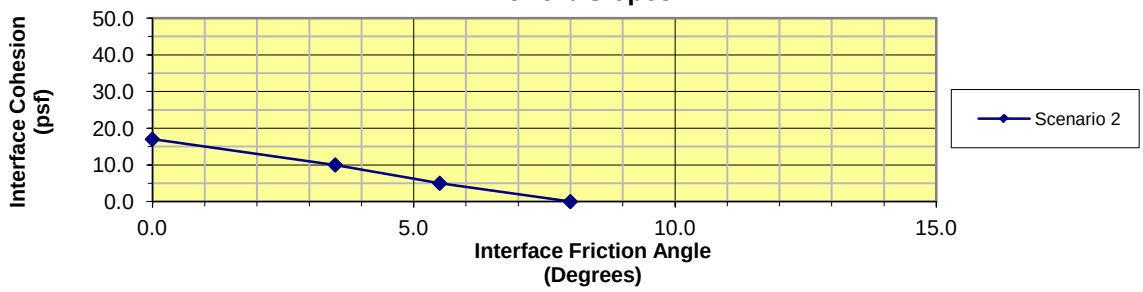
The interface strength parameters (Table L-2) for an interface between a smooth FML and non-woven (or woven) geotextile (i.e., Interfaces 2a and 3a) were utilized for the analysis of the six site-specific scenarios described herein. The results are summarized in Table L-6. The corresponding spreadsheet calculations are provided in Attachment L-4B.

Table L-6: Analysis/Results for Site-Specific Scenarios (5% Slopes)
Smooth FML/Geotextile Interface

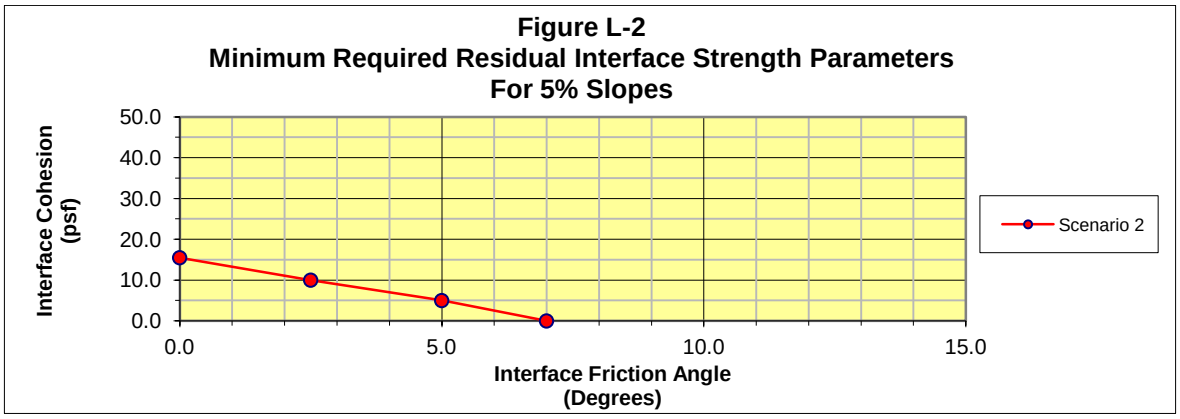
Scenario No.	Condition	Evaluation	Factors of Safety			
			Peak		Residual	
			Required	Estimated	Required	Estimated
1	Long-Term	Static	1.5	3.5	1.1	3.5
2	Long-Term	Seismic	1.1	1.4	1.0	1.4
3	Construction	Static	1.3	3.4	1.1	3.4
4	Construction	Seismic	1.1	2.3	1.0	2.3
5	Transient	Static	1.3	3.5	1.1	3.5
6	Transient	Static	1.3	2.8	1.1	2.8

The analysis/results presented in Table L-6 indicate that Scenario No. 2 (long-term seismic) controls the performance requirements for both the peak and residual strengths of a smooth FML/geotextile interface. As such, this scenario was analyzed further to establish the minimum required site-specific peak interface strength parameters (including the effects of interface cohesion) that will provide for acceptable interface stability on the 5% slopes. An iterative analysis was performed. The results of the peak strength iterations are presented in Figure L-1 below. The corresponding spreadsheet calculations are provided in Attachment L-4C.

Figure L-1
Minimum Required Peak Interface Strength Parameters
For 5% Slopes



An iterative analysis was also performed to establish the minimum required site-specific residual interface strength parameters (including the effects of interface cohesion), based on Scenario No. 2. The results of the residual strength iterations are presented in Figure L-2 below. The corresponding spreadsheet calculations are provided in Attachment L-4C.



3.4.3 20% Slopes

The following maximum slope configuration is expected for the 20% east/west oriented slopes, based on the planned cap grading:

- Slope, β_{down} = 20 percent = 11.3 degrees;
- Height, H_{down} = 40 feet;
- Length, $L_{down\text{-}horizontal}$ = 200 feet (+/-); and
- Seepage height above the GDL = 1 inch.

Considering the relatively long slope and relatively thin soil cover, the analysis of the 20% slopes conservatively ignored the resistance provided by the "toe" of the soil cover (i.e., the toe buttress per Druschel). This is represented (in the spreadsheet calculator) by inputting a cover soil shear strength, ϕ, of 0 degrees. For the long-term static loading condition, the analysis essentially becomes an infinite slope analysis (Tangent of δ / Tangent of β).

Table L-7 presents the estimated factors of safety for each interface, for the long-term static loading condition, based on typical interface strength parameters (Table L-2) and the assumptions/inputs described herein. The corresponding spreadsheet calculations are provided in Attachment L-5A.

Table L-7: Estimated Factors of Safety for Long-Term Static Conditions (20% Slopes)

Interface		Estimated Factors of Safety	
No.	Materials	Peak	Residual

	General	Specific	(FS ≥ 1.5 Required)	(FS > 1.1 Required)
1	Cover Soil	Stone	2.9	2.7
	GDL	NW[1] Geotextile		
2a	GDL	NW Geotextile	0.9	0.9
	FML	Smooth		
2b	GDL	NW Geotextile	2.7	2.0
	FML	Textured		
3a	FML	Smooth	0.9	0.9
	GCL[2]	NW Geotextile		
3b	FML	Textured	2.7	2.0
	GCL[2]	NW Geotextile		
4	GCL[2]	W[1] Geotextile	2.9	2.7
	Subgrade Soil	Tailings		

Notes:

1. NW = Nonwoven; W = Woven.
2. A reinforced GCL (i.e., needle-punched) is assumed such that the internal shear strength of the GCL is not a critical "interface" to evaluate. Should an unreinforced GCL be considered for use on this Site, it must be evaluated and tested relative to the interface performance requirements established herein.

The results presented in Table L-7 indicate that the FS estimated for interfaces between a smooth FML and a nonwoven (or woven) geotextile (i.e., Interfaces 2a and 3a) are well below the required FS. As such, textured FML will be required for the 20% slopes. Assuming a textured FML, it appears that the interface between textured FML and nonwoven geotextile (i.e., Interfaces 2b and 3b) will govern interface stability on the 20% slopes. As such, this interface was analyzed further to consider various site-specific loading conditions/scenarios (e.g., construction equipment, seismic loading, and transient conditions). Table L-8 provides a general description of the six scenarios considered. Table L-9 summarizes the spreadsheet input parameters and the required factors of safety for each scenario.

Table L-8: Description of Site-Specific Scenarios (20% Slopes)

Scenario No.	Condition	Evaluation	General Description
1	Long-Term	Static	Simulates the base/long-term condition. Already analyzed. Results are presented in Table L-7.
2	Long-Term	Seismic	Simulates base/long-term condition during a seismic event (50-year, 2% PE).
3	Construction	Static	Simulates equipment loading.
4	Construction	Seismic	Simulates equipment loading during a seismic event (50-year, 10% PE).
5	Transient	Static	Simulates a saturated slope (γ_t=γ_{sat}=125 pcf) but no seepage (for conditions that may occur during a spring thaw).
6	Transient	Static	Simulates a partially saturated slope (γ_t=γ_{sat}=125 pcf) with seepage (for conditions that may occur during a significant rain event).

Table L-9: Input Parameters for Site-Specific Scenarios (20% Slopes)

Scenario No.	Condition	Evaluation	Seep.	Equip. Loading	Cover Soil Properties			Min. FS Required	
					γ (pcf)	ϕ (deg)	c (psf)	Peak	Resid.
1	Long-Term	Static	No	No	100	41	0	1.5	1.1
2	Long-Term	Seismic	No	No	100	41	0	1.1	1.0
3	Construction	Static	No	Yes	100	41	0	1.3	1.1
4	Construction	Seismic	No	Yes	100	41	0	1.1	1.0
5	Transient	Static	No	No	125	41	0	1.3	1.1
6	Transient	Static	Yes	No	125	41	0	1.3	1.1

Notes:

1. Seep. = The GDL operates at capacity, and the cover soils become partially saturated and down slope seepage/flow occurs within the cover soils.

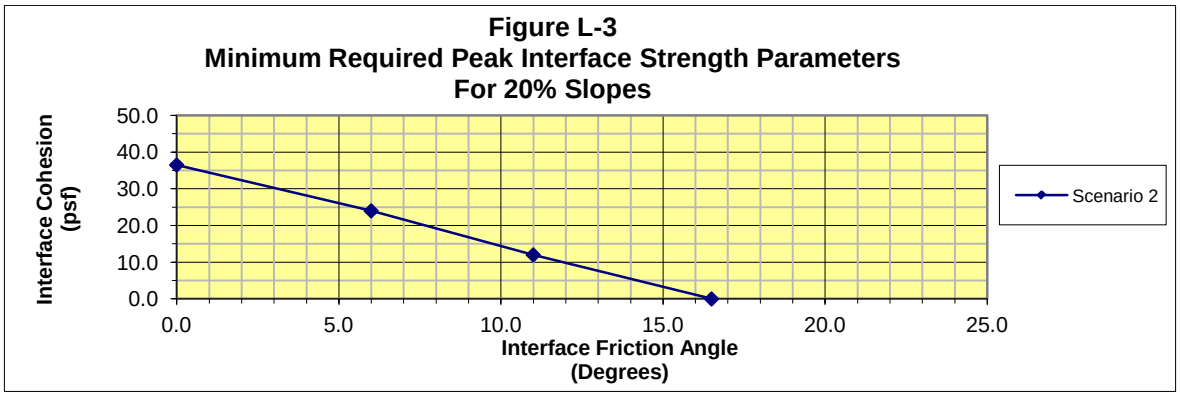
2. Equip. Loading = The effect of equipment loading (braking force) is considered. A D6K2 bulldozer weighing 30,750 pounds (4,400 pounds per unit width) with a length of 8.5 feet was utilized.

The interface strength parameters (Table L-2) for an interface between a textured FML and a geotextile (i.e., Interfaces 2b and 3b) were utilized for the analysis of the six site-specific scenarios described herein. The results are summarized in Table L-10. The corresponding spreadsheet calculations are provided in Attachment L-5B.

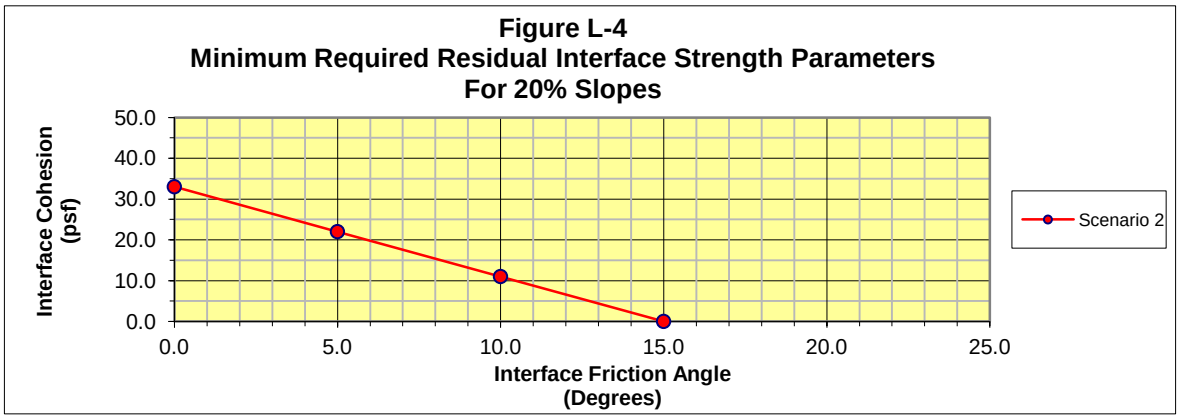
Table L-10: Analysis/Results for Site-Specific Scenarios (20% Slopes)
Textured FML/Geotextile Interface

Scenario No.	Condition	Evaluation	Factors of Safety			
			Peak		Residual	
			Required	Estimated	Required	Estimated
1	Long-Term	Static	1.5	2.7	1.1	2.0
2	Long-Term	Seismic	1.1	1.9	1.0	1.5
3	Construction	Static	1.3	2.6	1.1	2.0
4	Construction	Seismic	1.1	2.3	1.0	1.8
5	Transient	Static	1.3	2.7	1.1	2.0
6	Transient	Static	1.3	2.6	1.1	2.0

The analysis/results presented in Table L-10 indicate that Scenario No. 2 controls the performance requirements for both the peak and residual strengths of the textured FML/geotextile interface. As such, this scenario was analyzed further to establish the minimum required site-specific peak interface strength parameters (including the effects of interface cohesion) that will provide for acceptable interface stability. An iterative analysis was performed. The results of the peak strength iterations are presented in Figure L-3. The corresponding spreadsheet calculations are provided in Attachment L-5C.



An iterative analysis was also performed to establish the minimum required site-specific residual interface strength parameters (including the effects of interface cohesion), based on Scenario No. 2. The results of the residual strength iterations are presented in Figure L-4. The corresponding spreadsheet calculations are provided in Attachment L-5C.



3.4.4 33.3% Slopes

The following maximum slope configuration is expected for the relatively short 33.3% slopes, based on the planned cap grading:

- Slope, β_{down} = 33.3 percent = 18.4 degrees;
- Height, H_{down} = 14 feet;
- Length, $L_{down\text{-}horizontal}$ = 44 feet; and
- Seepage height above the GDL = 0.5 inches.

Table L-11 presents the estimated factors of safety for each interface, for the long-term static loading condition, based on typical interface strength parameters (Table L-2) and

the assumptions/inputs described herein. The corresponding spreadsheet calculations are provided in Attachment L-6A.

Table L-11: Estimated Factors of Safety for Long-Term Static Conditions (33.3% Slopes)

Interface			Estimated Factors of Safety	
No.	Materials		Peak	Residual
	General	Specific	(FS $\geq$ 1.5 Required)	(FS > 1.1 Required)
1	Cover Soil	Stone	1.9	1.7
	GDL	NW[1] Geotextile		
2a	GDL	NW Geotextile	0.7	0.7
	FML	Smooth		
2b	GDL	NW Geotextile	1.7	1.4
	FML	Textured		
3a	FML	Smooth	0.7	0.7
	GCL[2]	NW Geotextile		
3b	FML	Textured	1.7	1.4
	GCL[2]	NW Geotextile		
4	GCL[2]	W[1] Geotextile	1.9	1.7
	Subgrade Soil	Tailings		

Notes:

1. NW = Nonwoven; W = Woven.
2. A reinforced GCL (i.e., needle-punched) is assumed such that the internal shear strength of the GCL is not a critical "interface" to evaluate. Should an unreinforced GCL be considered for use on this Site, it must be evaluated and tested relative to the interface performance requirements established herein.

The results presented in Table L-11 indicate that the FS estimated for interfaces between a smooth FML and a nonwoven (or woven) geotextile (i.e., Interfaces 2a and 3a) are well below the required FS. As such, textured FML will be required for the 33.3% slopes. Assuming a textured FML, it appears that the interface between textured FML and nonwoven geotextile (i.e., Interfaces 2b and 3b) will govern interface stability on the

33.3% slopes. As such, this interface was analyzed further to consider various site-specific loading conditions/scenarios (e.g., construction equipment, seismic loading, and transient conditions). Table L-12 provides a general description of the six scenarios considered. Table L-13 summarizes the spreadsheet input parameters and the required factors of safety for each scenario.

Table L-12: Description of Site-Specific Scenarios (33.3% Slopes)

Scenario No.	Condition	Evaluation	General Description
1	Long-Term	Static	Simulates the base/long-term condition. Already analyzed. Results are presented in Table L-11.
2	Long-Term	Seismic	Simulates base/long-term condition during a seismic event (50-year, 2% PE).
3	Construction	Static	Simulates equipment loading.
4	Construction	Seismic	Simulates equipment loading during a seismic event (50-year, 10% PE).
5	Transient	Static	Simulates a saturated slope (γ_t=γ_{sat}=125 pcf) but no seepage (for conditions that may occur during a spring thaw).
6	Transient	Static	Simulates a partially saturated slope (γ_t=γ_{sat}=125 pcf) with seepage (for conditions that may occur during a significant rain event).

Table L-13: Input Parameters for Site-Specific Scenarios (33.3% Slopes)

Scenario No.	Condition	Evaluation	Seep.	Equip. Loading	Cover Soil Properties			Min. FS Required	
					γ (pcf)	ϕ (deg)	c (psf)	Peak	Resid.
1	Long-Term	Static	No	No	100	41	0	1.5	1.1

2	Long-Term	Seismic	No	No	100	41	0	1.1	1.0
3	Construction	Static	No	Yes	100	41	0	1.3	1.1
4	Construction	Seismic	No	Yes	100	41	0	1.1	1.0
5	Transient	Static	No	No	125	41	0	1.3	1.1
6	Transient	Static	Yes	No	125	41	0	1.3	1.1

Notes:

1. Seep. = The GDL operates at capacity, and the cover soils become partially saturated and down slope seepage/flow occurs within the cover soils.
2. Equip. Loading = The effect of equipment loading (braking force) is considered. A D6K2 bulldozer weighing 30,750 pounds (4,400 pounds per unit width) with a length of 8.5 feet was utilized.

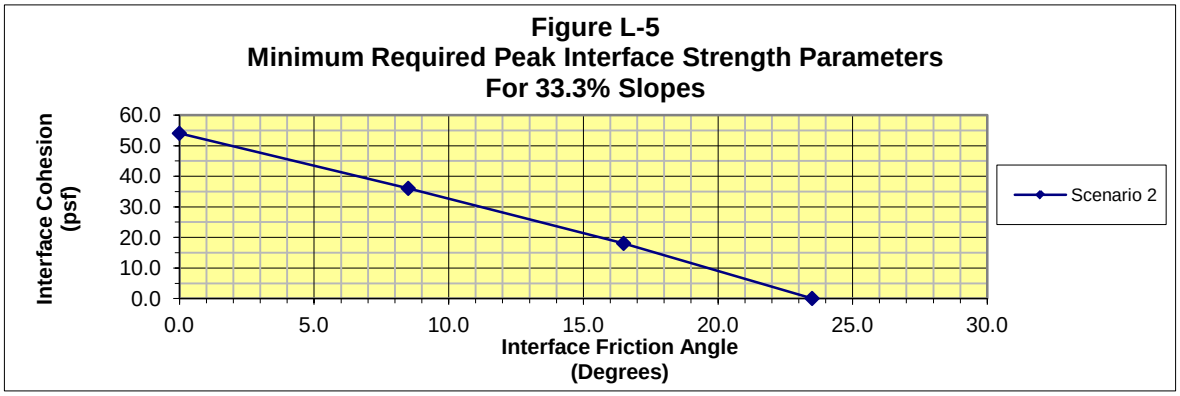
The interface strength parameters (Table L-2) for an interface between a textured FML and a geotextile (i.e., Interfaces 2b and 3b) were utilized for the analysis of the six site-specific scenarios described herein. The results are summarized in Table L-14. The corresponding spreadsheet calculations are provided in Attachment L-6B.

Table L-14: Analysis/Results for Site-Specific Scenarios (33.3% Slopes)
Textured FML/Geotextile Interface

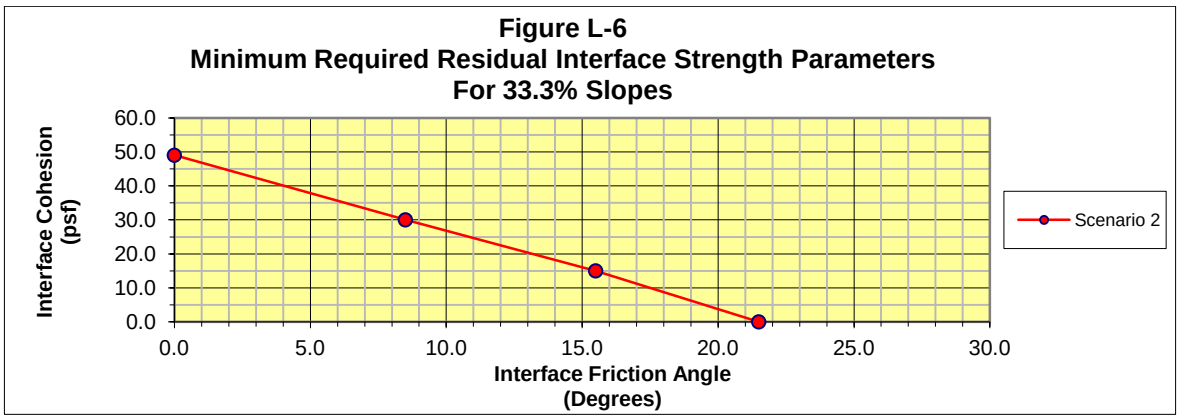
Scenario No.	Condition	Evaluation	Factors of Safety			
			Peak		Residual	
			Required	Estimated	Required	Estimated
1	Long-Term	Static	1.5	1.7	1.1	1.4
2	Long-Term	Seismic	1.1	1.4	1.0	1.1
3	Construction	Static	1.3	1.6	1.1	1.3
4	Construction	Seismic	1.1	1.5	1.0	1.2
5	Transient	Static	1.3	1.7	1.1	1.4
6	Transient	Static	1.3	1.7	1.1	1.3

The analysis/results presented in Table L-14 indicate that Scenario No. 2 controls the performance requirements for both the peak and residual strengths of the textured FML/geotextile interface. As such, this scenario was analyzed further to establish the minimum required site-specific peak interface strength parameters (including the effects of interface cohesion) that will provide for acceptable interface stability. An iterative analysis

was performed. The results of the peak strength iterations are presented in Figure L-5. The corresponding spreadsheet calculations are provided in Attachment L-6C.



An iterative analysis was also performed to establish the minimum required site-specific residual interface strength parameters (including the effects of interface cohesion), based on Scenario No. 2. The results of the residual strength iterations are presented in Figure L-6. The corresponding spreadsheet calculations are provided in Attachment L-6C.



4.0 CONCLUSIONS AND RECOMMENDATIONS

The subsections below summarize conclusions for each slope configuration and outline a recommended project-specific conformance testing program (relative to interface testing).

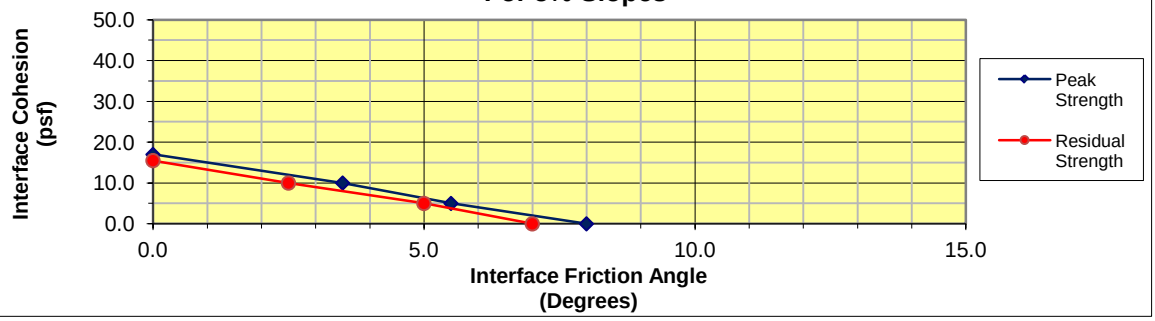
4.1 5% Slopes

The analyses performed for the 5% slopes indicate the following minimum required interface strength parameters (assuming no cohesion):

- Peak Strength = 8.0 degrees; and
- Residual Strength = 7.0 degrees.

A reduction in the peak and/or residual friction angles may be justified based on the inclusion of interface cohesion. Figure L-7 summarizes the required interface strength parameters (including the effect of interface cohesion). Figure L-7 will be used to convey both peak and residual interface strength requirements to the Contractor. Interface friction test results which plot above and to the right the respective peak/residual strength line will provide adequate interface strength to provide for acceptable interface stability on the 5% slopes.

Figure L-7
Minimum Required Interface Strength Parameters
For 5% Slopes



The results of this evaluation indicate that both smooth and textured FMLs are suitable (from an interface friction standpoint) for slopes of 5% or less. Literature values and/or historic testing data indicate that interface strengths of 10 degrees or more are typical for smooth FML tested in conjunction with nonwoven and/or woven geotextiles at low normal stresses. Even lower bound interface strengths of 8 degrees (based on literature/historic testing) would meet the minimum strengths established herein. If a smooth FML is used, project-specific testing in conjunction with nonwoven or woven geotextile is recommended.

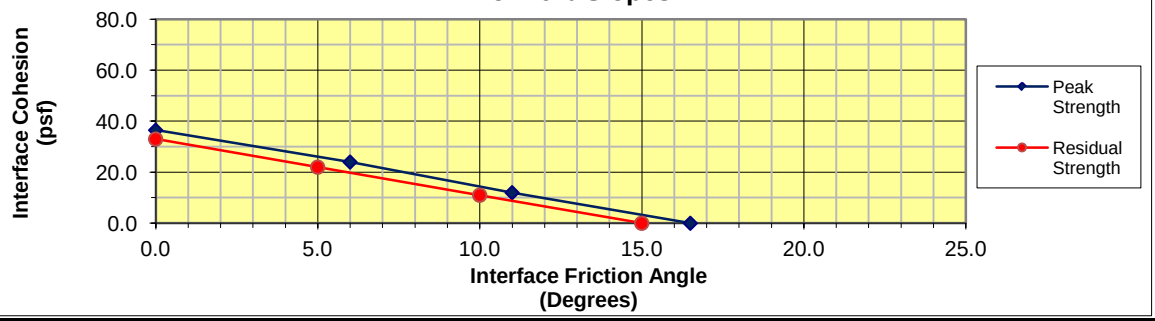
4.2 20% Slopes

The analyses performed for the 20% slopes indicate the following minimum required interface strength parameters (assuming no cohesion):

- Peak Strength = 16.5 degrees; and
- Residual Strength = 15.0 degrees.

A reduction in the peak and/or residual friction angles may be justified based on the inclusion of interface cohesion. Figure L-8 summarizes the required interface strength parameters (including the effect of interface cohesion). Figure L-8 will be used to convey both peak and residual interface strength requirements to the Contractor. Interface friction test results which plot above and to the right the respective peak/residual strength line will provide adequate interface strength to provide for acceptable interface stability on the 20% slopes.

Figure L-8
Minimum Required Interface Strength Parameters
For 20% Slopes



The results of this evaluation indicate that smooth FML is not suitable (from an interface friction standpoint) for the 20% slopes, based on typical literature values and/or historic testing data. Textured FML will be required for 20% slopes. Furthermore, project-specific interface testing is recommended for the geosynthetic to geosynthetic interfaces planned for 20% slopes.

4.3 33.3% Slopes

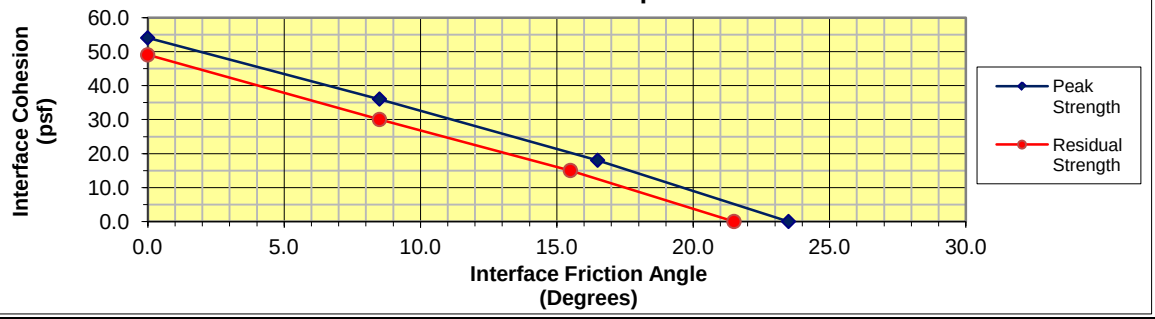
The analyses performed for the 33.3% slopes indicate the following minimum required interface strength parameters (assuming no cohesion):

- Peak Strength = 23.5 degrees; and
- Residual Strength = 21.5 degrees.

A reduction in the peak and/or residual friction angles may be justified based on the inclusion of interface cohesion. Figure L-9 summarizes the required interface strength parameters (including the effect of interface cohesion). Figure L-9 will be used to convey both peak and residual interface strength requirements to the Contractor. Interface friction test results which plot above and to the right the respective peak/residual strength line will

provide adequate interface strength to provide for acceptable interface stability on the 33.3% slopes.

Figure L-9
Minimum Required Interface Strength Parameters
For 33.3% Slopes



The results of this evaluation indicate that smooth FML is not suitable (from an interface friction standpoint) for the 33.3% slopes, based on typical literature values and/or historic testing data. Textured FML will be required for 33.3% slopes. Furthermore, project-specific interface testing is recommended for the geosynthetic to geosynthetic interfaces planned for 33.3% slopes.

4.4 Interface Testing Requirements

Site-specific interface friction testing will be required in accordance with the project specifications to satisfy the recommendations developed herein. Furthermore, interface friction testing must be supported by transmissivity testing of the GDL because the drainage requirements represent a critical component of this interface friction evaluation. Testing procedures, testing frequency, and reporting requirements are detailed in the project specifications. In general, the interface friction testing is to be performed with the following conditions (see project specifications for more details):

1. Interface friction testing must be performed in accordance with ASTM D5321-12 “Standard Test Method for Determining the Shear Strength of Soil-Geosynthetic and Geosynthetic-Geosynthetic Interfaces by Direct Shear” and ASTM D6243-13 “Standard Test Method for Determining the Internal and Interface Shear Resistance of Geosynthetic Clay Liner by Direct Shear”, as applicable. Test frequencies should be as listed or at any change in geosynthetic materials.
2. Report all data as required by the referenced testing standard and/or project specifications. In addition, “residual strength values” [i.e., large-displacement strain (minimum of 20%) or maximum displacement of test equipment, as

approved by the design engineer] should be provided. Furthermore, the condition of the GDL, FML, and/or GVL must be reported (i.e., did it rip/tear along surfaces or at connections to the shear box). Damage at the connections will constitute an unacceptable test.

3. Testing results obtained during construction will need to be evaluated by the design engineer, using the figures and methods described herein, to make an assessment of all materials (all materials must be evaluated as a system), and to determine acceptability.

4. GDL/Smooth FML Interface, if applicable:

    - Site-specific interface testing should be conducted a minimum frequency of 1 test. Test frequency should be re-evaluated upon receipt of initial test results;
    - Site-specific cover soils should be used;
    - For testing purposes, three confining stresses of 1, 2, and 4 psi are recommended;
    - A displacement/shearing rate of 0.04 inches/minute under non-inundated conditions is recommended;
    - Testing should be performed with the following configuration (top to bottom): top plate, cover soil, GDL, smooth FML, bottom plate;
    - Report both peak and residual/large-displacement values; and
    - Acceptance of interface friction testing results should be determined by the design engineer by plotting the project-specific test results on Figure L-7 for use on 5% slopes.

5. GDL/Textured FML Interface:

    - Site-specific interface testing should be conducted at the frequency of 1 test/75,000 square feet (minimum of 3 tests). Test frequency should be re-evaluated upon receipt of initial test results;
    - The asperity of the textured geomembrane should be measured/recorded prior to testing (based on median value of at least 4 tests completed on the sample);
    - Textured geomembrane should be tested in the cross-machine direction;

- Site-specific cover soils should be used;
- For testing purposes, three confining stresses of 1, 2, and 4 psi are recommended;
- A displacement/shearing rate of 0.04 inches/minute under non-inundated conditions is recommended;
- Testing should be performed with the following configuration (top to bottom): top plate, cover soil, GDL, textured FML, bottom plate;
- Report both peak and residual/large-displacement values; and
- Acceptance of interface friction testing results should be determined by the design engineer by plotting the project-specific test results on Figure L-7 for use on 5% slopes, Figure L-8 for use on 20 % slopes, or Figure L-9 for use on 33.3% slopes.

6. Textured FML/GCL Interface:

- Site-specific interface testing should be conducted at the frequency of 1 test/75,000 square feet (minimum of 3 tests). Test frequency should be re-evaluated upon receipt of initial test results;
- The asperity of the textured geomembrane should be measured/recorded prior to testing (based on median value of at least 4 tests completed on the sample);
- Textured geomembrane should be tested in the cross-machine direction;
- The GCL should be hydrated with de-ionized water for a minimum of 48 hours at the target normal stress prior to testing;
- Site-specific cover soils should be used, as applicable;
- For testing purposes, three confining stresses of 1, 2, and 4 psi are recommended;
- A displacement/shearing rate of 0.04 inches/minute under non-inundated conditions is recommended;
- Testing should be performed with the following configuration (top to bottom): top plate, textured FML, GCL (nonwoven side up), bottom plate;
- Report both peak and residual/large-displacement values;

- Acceptance of interface friction testing results should be determined by the design engineer by plotting results on Figure L-7 for use on 5% slopes, Figure L-8 for use on 20 % slopes, or Figure L-9 for use on 33.3% slopes.

5.0 REFERENCES

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ATTACHMENT L-1

DRUSCHEL METHODOLOGY

Design of Lining and Cover System Sideslopes

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E.R. Underwood
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ABSTRACT

In this paper, a design methodology is presented for evaluating the stability of various lining and cover sideslope configurations. Traditional sliding-block analysis is the basis of the methodology, but it has been expanded to include seepage forces, equipment loads, geosynthetic anchorage, and factors of safety. As an aid to "real world" application of the methodology, equations are included in this paper to simplify the working analysis of stability and to allow the optimization of factors such as slope geometry, strength, and applied loads. In addition, figures are included that show the maximum slope height attainable for a range of slope angles, interface frictions, soil strengths, soil layer thicknesses, seepage depths, equipment loads, and geosynthetic anchorages. Use of this methodology is demonstrated in a project example in which slope angles are balanced against bench heights, soil characteristics, geosynthetic anchorage, and economics.

GLOSSARY OF SYMBOLS

The symbols used in the text, figures, and equations that appear in this paper are explained in the following list.

H	=	sideslope height
T_c	=	cover soil thickness
β	=	sideslope angle
γ_w	=	unit weight of water (62.4 lbs/ft^3)
γ_c	=	unit weight of cover soil
δ	=	interface friction angle
δ_m	=	interface friction angle (mobilized)
ϕ	=	soil shear strength angle
ϕ_m	=	soil shear strength angle (mobilized)
W_2	=	weight of sideslope soil
W_1	=	weight of toe buttress soil
W_e	=	weight of equipment on the sideslope
F_b	=	equipment braking force

T_w	=	thickness of seepage
W_{w1}	=	weight of seepage water in toe buttress
W_{w2}	=	weight of seepage water in sideslope soil
F_s	=	seepage force
F_a	=	geosynthetic anchorage force
F_1	=	toe buttress reaction force
F_2	=	sideslope reaction force
P	=	sideslope-toe buttress reaction force

INTRODUCTION

The capacity of a waste-containment facility such as a landfill is determined by the facility's area, height, and sideslope angles. Although the area and height are usually determined by property limits and regulations, the sideslope angle is based on engineering judgment and operational performance. Steeper sideslopes provide greater capacity, and greater capacity provides higher profits, so the sideslope angle should be as steep as possible. However, when the sideslope angle is too steep, the protective soil cover can become unstable and slide down slope. At best, such movement increases maintenance costs. At its worst, such movement can destroy a containment facility and cause its premature closure. Designs must balance the need for capacity against the risk of failure.

STABILITY ANALYSIS

Typical modern liner and cover systems consist of both soil and geosynthetic materials in a layered arrangement. When a liner or cover system becomes unstable, stronger overlying layers will tend to remain somewhat intact and slide over the weaker layers. Because the slope length is much greater than the liner or cover system thickness, the system can be modeled by a block sliding on an inclined plane. Figure 1 shows a sideslope with forces that typically act on it.

The sliding-block analysis is a traditional geotechnical technique in which all the forces acting on the sliding block are summed and the resultant must equal zero for the block to be stable. Sliding-block analysis is similar to the infinite slope analysis, another traditional geotechnical technique, but includes the contribution of the slope change at the bottom of the sideslope, described below as the toe buttress force. Factors of safety for sliding block analysis are developed by evaluating the shear strengths required to balance the forces and achieve stability. A full discussion of sliding-block analysis may be found in Lambe & Whitman (1969) or U.S. Navy (1986). Each of the forces that affects sideslope stability is briefly discussed below.

Interface Shear Strength. In any liner or cover system, the weakest interface governs stability. From the many studies of interface friction (for example, Martin, et al. [1984], Saxena and Wong [1984], Williams and Houlihan [1986], Negussey, et al. [1989], O'Rourke, et al. [1990], Mitchell, et al. [1990], and Yegian and Lahlaf [1992]), two classes of commonly encountered interface strengths have emerged: low-strength interfaces and high-strength interfaces.

Low-Strength Interfaces

Geotextile-geomembrane
Geonet-geomembrane
Geotextile-geonet (unless heat-bonded) — δ = 6 to 9 degrees
Geomembrane-clay(saturated)

High-Strength Interfaces

Sand-geomembrane
Sand-geotextile — δ = 15 to 18 degrees
Clay-geotextile

Factors of Safety. Factors of safety are calculated on the basis of the ratio of the actual shear strength to the mobilized shear strength (that is, the shear strength required for stability):

$$\text{Factor of safety} = \frac{\tan \phi}{\tan \phi_m} \text{ or } \frac{\tan \delta}{\tan \delta_m} \qquad \text{(Equation 1)}$$

Alternatively, a factor of safety can be set and maximum values of ϕ_m and δ_m calculated. This value may be used in the sliding block model to determine the maximum conditions (that is, H or β) that can be tolerated while still maintaining the factor of safety.

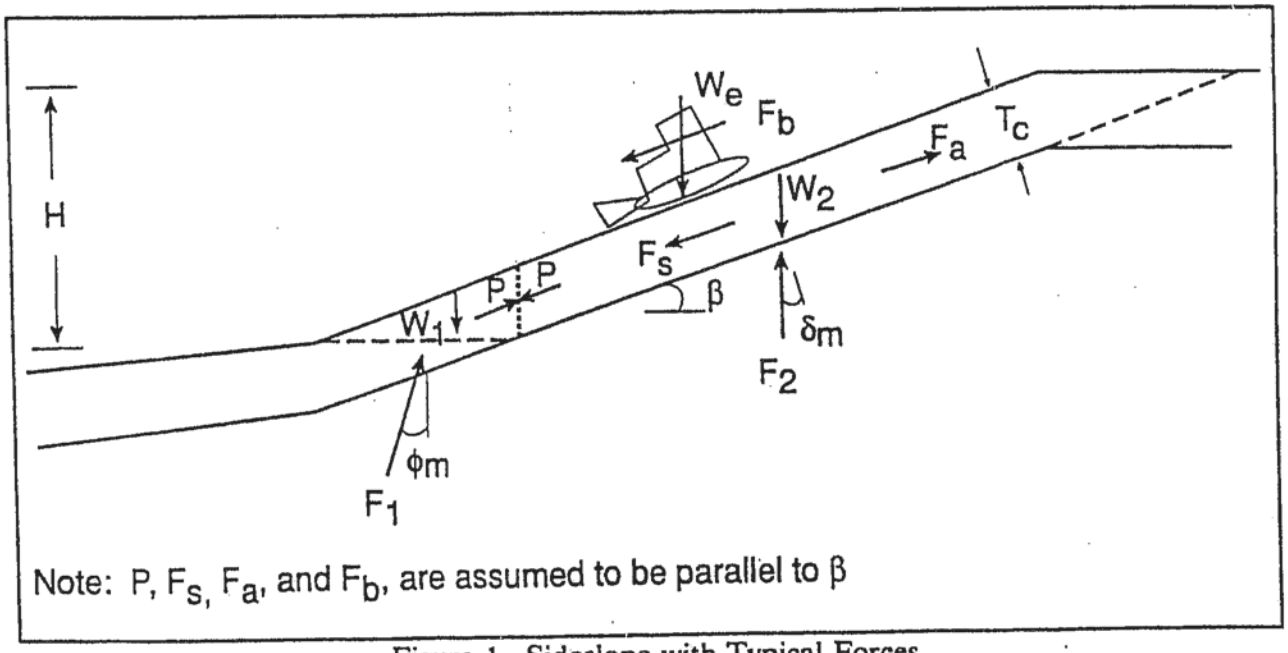

Figure 1. Sideslope with Typical Forces

One important point about shear strength values used for evaluation of cover and liner systems: because each material used in the system has a different shear stress-displacement response, peak or ultimate strengths may occur at different strain levels, or not at all. For this reason, residual shear strengths instead of peak strengths are strongly recommended for use in all slope evaluations.

Toe Buttress. Multilayered geosynthetic or composite liners and covers that have low-strength interfaces (δ values in the range of 6 to 9 degrees) are especially prone to stability problems. What allows liner and cover systems with low-strength interfaces to be stable when $\beta > \delta$? The answer lies with the soil cover at the bottom of the slope, through which any failure surface must propagate. This wedge of soil acts as a toe buttress, holding back the soil cover and increasing its stability. The strength of an effective toe buttress is provided by the friction developed along the failure surface. This friction is a function of ϕ and a combination of W_1 and P (the force of the soil cover acting on the wedge as it tries to slide). While the reaction force is determined graphically, W_1 is given by the following equation:

$$W_1 = \frac{\gamma_c T_c^2}{2 \sin \beta \cos \beta} \qquad \text{(Equation 2)}$$

More detail on the effect of the toe buttress on stability may be found in Beech and Giroud (1989).

Soil Cover. W_2 can be calculated using the following equation:

$$W_2 = \frac{\gamma_c T_c}{\sin \beta}\left(H - \frac{T_c}{2 \cos \beta}\right) \qquad \text{(Equation 3)}$$

This equation addresses soil covers of uniform thickness. It should be noted that this equation also reflects a simplifying assumption in that the upper end of the failure plane passes through the cover soil, but this length is treated as if it has the same strength as the interface. This is a conservative assumption because the actual strength is generally higher.

Equipment Load. Equipment that operates on the sideslope has a static weight, W_e, that acts in the same manner as W_2. However, additional forces are generated by acceleration and braking of the equipment as it moves on the sideslope. Koerner and Richardson (1987) suggest that these forces be treated as a separate braking force, F_b, equal to 30 percent of the equipment's weight and acting downslope, parallel to the interface. While a gross simplification, this approximation is sufficient to allow for the effects of equipment of different sizes. Intuitively, we know there must be a difference in the effects of a D-4 and a D-7 bulldozer, since there is a threefold increase in weight but only a moderately larger footprint.

W_e is calculated using the equipment weight divided by the contact width. The contact width is simply the width over which the load is distributed to the interface of interest. Because soil arching typically will mobilize the zone of soil between the tracks, the contact width may be based on the full width of the equipment.

Seepage Force. F_s is treated as a negative static load on the basis of the buoyancy applied to the cover soil. Simply put, the buoyancy normally reduces frictional shear stress because of the reduction in effective stress normally applied to the sliding plane. Instead of applying the reduction to the strength parameters as is done in most areas of soil mechanics, Lambe and Whitman (1969) suggest using a negative resisting force. A major assumption of this approach is that the seepage is parallel to the slope and of uniform thickness. The seepage force may then be calculated in the same way as the soil loads, changing only T_w.

$$W_{w1} = \frac{\gamma_w T_w^2}{2 \sin\beta \cos\beta} \qquad \text{(Equation 4)}$$

$$W_{w2} = \frac{\gamma_w T_w}{\sin\beta}\left(H - \frac{T_w}{2 \cos\beta}\right) \qquad \text{(Equation 5)}$$

$$F_s = W_{w1} \tan\phi_m + W_{w2} \cos\beta \tan\delta_m \qquad \text{(Equation 6)}$$

It should be noted that no interwedge force exists with seepage because water can sustain no shear stress.

Geosynthetic Anchorage. F_a represents the force provided by geogrids or by high-strength geotextiles anchored at the top of the slope. Strengths typically are taken from the 2 percent strain level of the geosynthetics, a level that generally can be accommodated by the other components of a liner or cover system. The direction of F_a is parallel to the slope and upward. Anchorage trenches or other means of attachment must be sufficiently strong to keep the geogrid or geotextile from pulling out. Geomembranes, geonets, and general-use geotextiles should not be considered for F_a because useful levels of strength would require unacceptable levels of strain.

Earthquake Force. While beyond the scope of this paper, pseudo-static earthquake forces can be applied easily, parallel to the slope. The earthquake force, which is equal to the soil weight multiplied by the acceleration factor (percentage of gravity), is entered into the model as a negative geosynthetic anchorage force. Soil and interface shear strengths should reflect appropriate factors of safety.

Reaction Forces. Reaction forces include P, F_1, and F_2 and are a function of the static equilibrium. These variables drop out of the calculations through some physical and mathematical relationships.

STABILITY CALCULATION

All forces are plotted on a force vector diagram, as shown in Figure 2. The magnitudes of the reaction forces are unknown, but their directions are set by the problem geometry. We can eliminate F_1 and F_2 by using Newton's first law, which states that the sum of the forces in any direction must equal zero for stability to exist. Therefore, the forces perpendicular to F_1 in Polygon 1 and perpendicular to F_2 in Polygon 2 are each summed and set equal to zero. Solving the remaining terms for P sets up the next step.

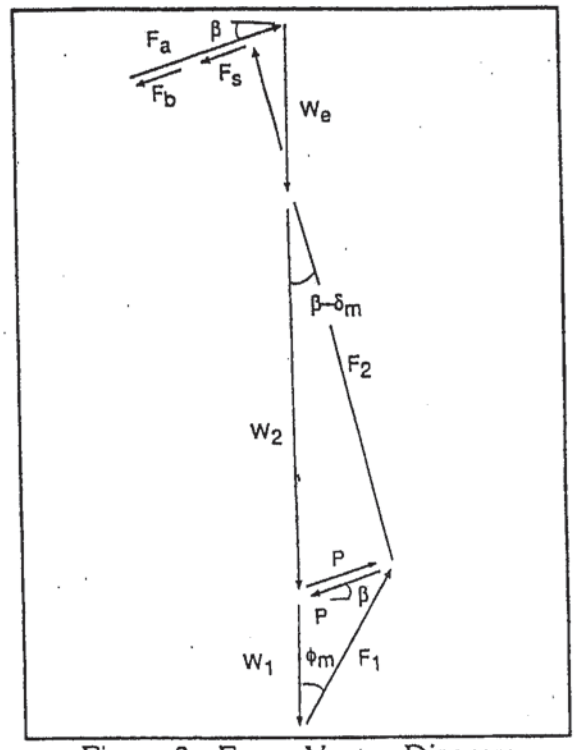

Figure 2. Force Vector Diagram

$$\text{Polygon 1:} \quad P = \frac{W_1 \sin\phi_m}{\cos(\beta + \phi_m)} \qquad \text{(Equation 7)}$$

$$\text{Polygon 2:} \quad P = \frac{(W_e + W_2)\sin(\beta - \delta_m)}{\cos\delta_m} + F_b + F_s - F_a \qquad \text{(Equation 8)}$$

Equations 7 and 8 are now equated, and P drops out:

$$\frac{W_1 \sin\phi_m}{\cos(\beta + \phi_m)} = \frac{(W_e + W_2)\sin(\beta - \delta_m)}{\cos\delta_m} + F_b + F_s - F_a \quad \text{Equation 9)}$$

Equation 9 can be rearranged to solve for F_a:

$$F_a = F_b + F_s + \frac{(W_e + W_2)\sin(\beta - \delta_m)}{\cos\delta_m} - \frac{W_1 \sin\phi_m}{\cos(\beta + \phi_m)} \quad \text{(Equation 10)}$$

Equation 10 provides the basis for the overall method. Simply stated, if anchorage forces are positive in value, the slope is not stable without them. Solving for F_a to equal zero will give the maximum stable height for a particular set of slope conditions.

To make the calculation, insert the actual values for F_b, F_s, W_1, and W_2:

$$F_a = [\,0.3W_e\,] + \left[\frac{\gamma_w T_w^2 \tan\phi_m}{2\sin\beta\cos\beta} + \frac{\gamma_w T_w \cos\beta \tan\delta_m}{\sin\beta}\left(H - \frac{T_w}{2\cos\beta}\right)\right]$$
$$+ \left[\frac{W_e \sin(\beta-\delta_m)}{\cos\delta_m}\right] + \left[\frac{\gamma_c T_c \sin(\beta-\delta_m)}{\sin\beta\cos\delta_m}\left(H - \frac{T_c}{2\cos\beta}\right)\right] \quad \text{(Equation 11)}$$
$$- \left[\frac{\gamma_c T_c^2 \sin\phi_m}{2\sin\beta\cos\beta\cos(\beta+\phi_m)}\right]$$

Equation 11 may be expanded as follows:

$$F_a = W_e\left[0.3 + \frac{\sin(\beta-\delta_m)}{\cos\delta_m}\right] + \left[\frac{\gamma_w T_w^2 \tan\phi_m}{2\sin\beta\cos\beta} + \frac{\gamma_w T_w H \cos\beta \tan\delta_m}{\sin\beta} - \frac{\gamma_w T_w^2 \cos\beta \tan\delta_m}{2\sin\beta\cos\beta}\right]$$
$$- \left[\frac{\gamma_c T_c^2 \sin\phi_m}{2\sin\beta\cos\beta\cos(\beta+\phi_m)} + \frac{\gamma_c T_c^2 \sin(\beta-\delta_m)}{2\sin\beta\cos\delta_m\cos\beta} - \frac{\gamma_c T_c H \sin(\beta-\delta_m)}{\sin\beta\cos\delta_m}\right]$$

(Equation 12)

For a slope 6 meters (20 feet) high, two configurations are considered. The first configuration is a 4:1 (β = 14.0 degrees) straight slope. The second configuration has two 3:1 slopes (β = 18.3 degrees), each 3 meters (10 feet) high, separated by a bench 6 meters (20 feet) wide. Constants for this example are:

- ϕ = 35 degrees (maximum residual value)
- δ = 12 degrees (maximum residual value)
- T_w = 76 mm (0.25 feet)
- γ_c = 19.6 kN/m^3 (125 lbs/ft^3)
- W_e = 0

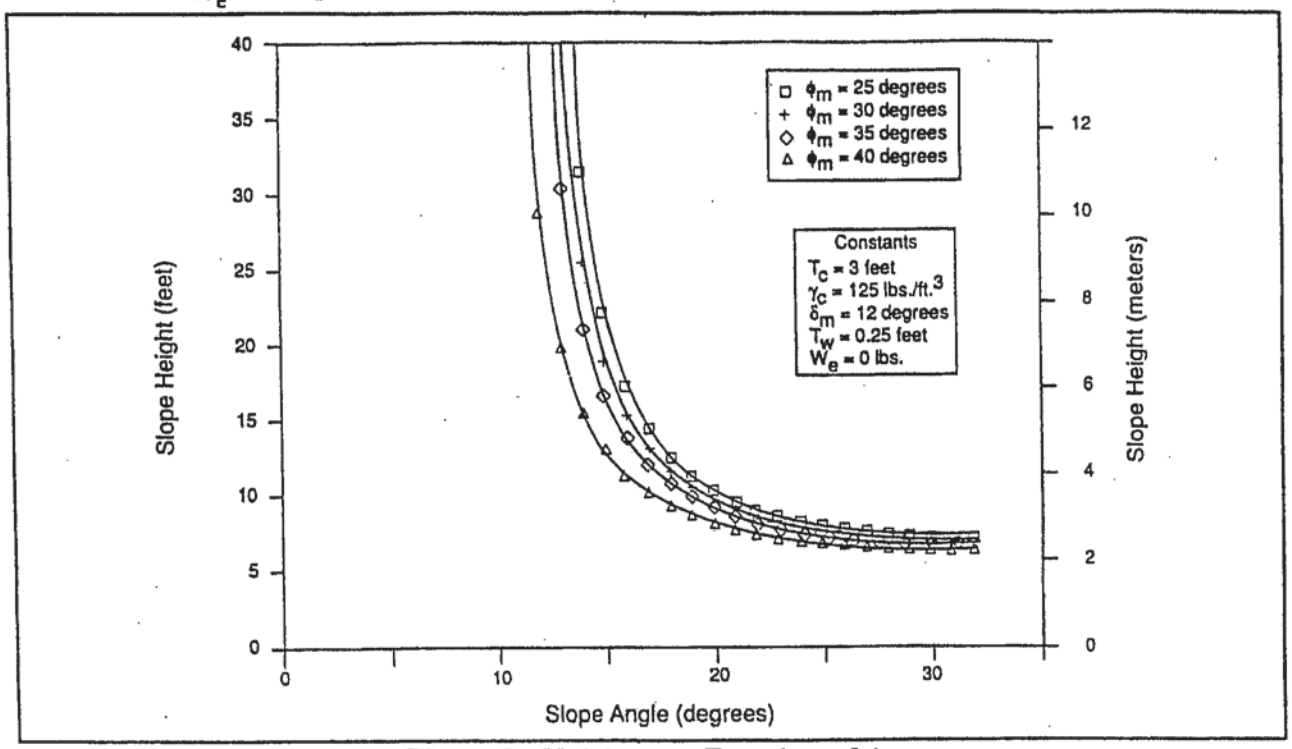

Figure 5. Height as a Function of ϕ_m

In the example, several combinations of T_c and F_a are evaluated to find a design that minimizes costs and maximizes performance while providing a minimum safety factor (FS) of 1.25. The safety factor is determined by finding the highest mobilized strength levels for which F_a equals zero or less. Different combinations of ϕ_m and δ_m, calculated using the same factor of safety for each combination, are inserted into the equation until F_a equals zero.

Table 1 shows the results of the evaluation. Factors of safety for slopes with no geosynthetic anchorage are given, as well as the value of F_a, which is required to provide a factor of safety of at least 1.25 for each of the thinner soil covers. The thinnest T_c to provide a factor of safety of 1.25 without any geosynthetic anchorage is 1.30 meters (4.25 feet) for the 4:1 slope and 1.07 meters (3.5 feet) for the 3:1 slopes with the intermediate bench. These results may be used

in evaluating the relative cost benefit of geosynthetic anchorage and various thicknesses of soil cover in order to optimize the design.

Table 1. Evaluation Results (Example)

Cover Soil Thickness (T_c)	4:1 Slope, H = 6 Meters (20 Feet)		3:1 Slope, H = 3 Meters (10 Feet)	
	FS for $F_a = 0$	F_a Required for FS = 1.25	FS for $F_a = 0$	F_a Required for FS = 1.25
0.61 m (2 ft.)	<1.00	14.83 kN/m (1,009 lbs/ft)	<1.00	7.73 kN/m (526 lbs/ft)
0.91 m (3 ft.)	1.11	11.89 kN/m (809 lbs/ft)	1.16	3.68 kN/m (250 lbs/ft)
1.22 m (4 ft.)	1.22	3.07 kN/m (209 lbs/ft)	1.37	0
1.52 m (5 ft.)	1.34	0	1.60	0

F_a = Geosynthetic anchorage force; FS = Factor of safety;
kN/m = KiloNewtons/meter

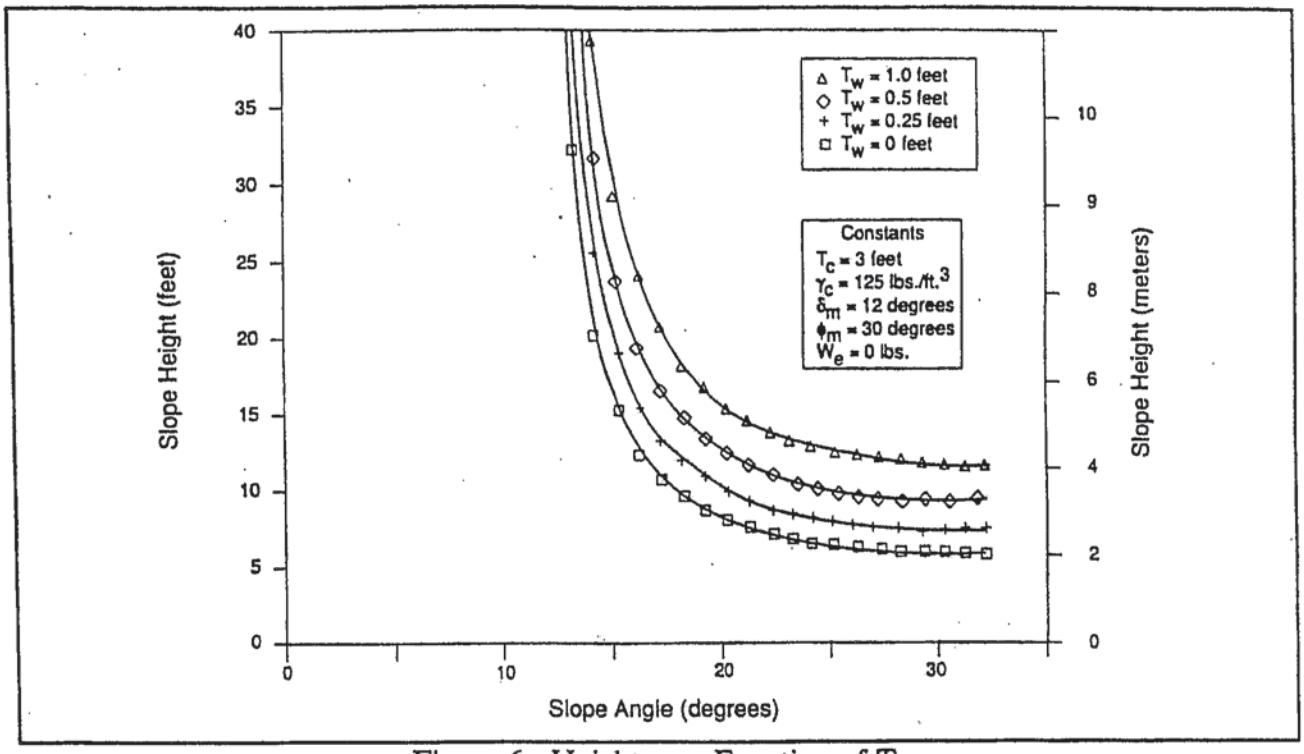

Figure 6. Height as a Function of T_w

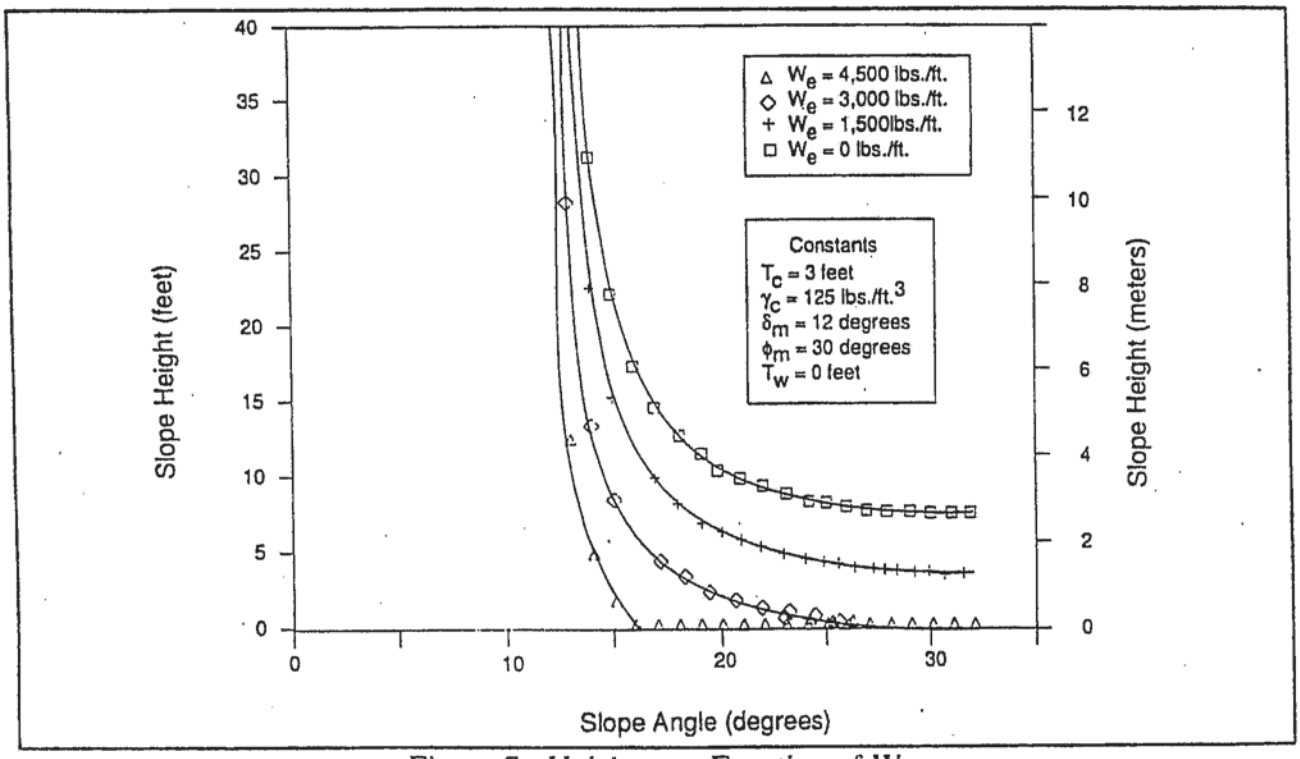

Figure 7. Height as a Function of W_c

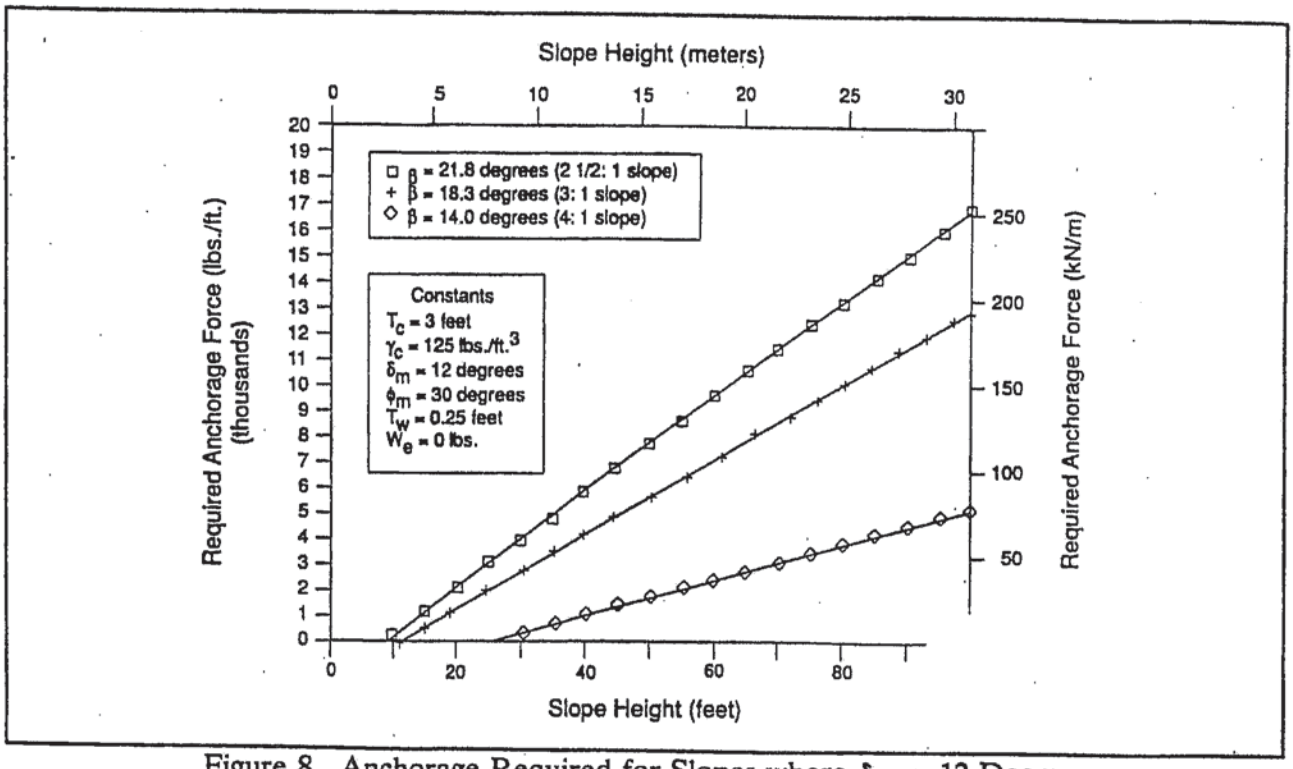

Figure 8. Anchorage Required for Slopes where δ_m = 12 Degrees

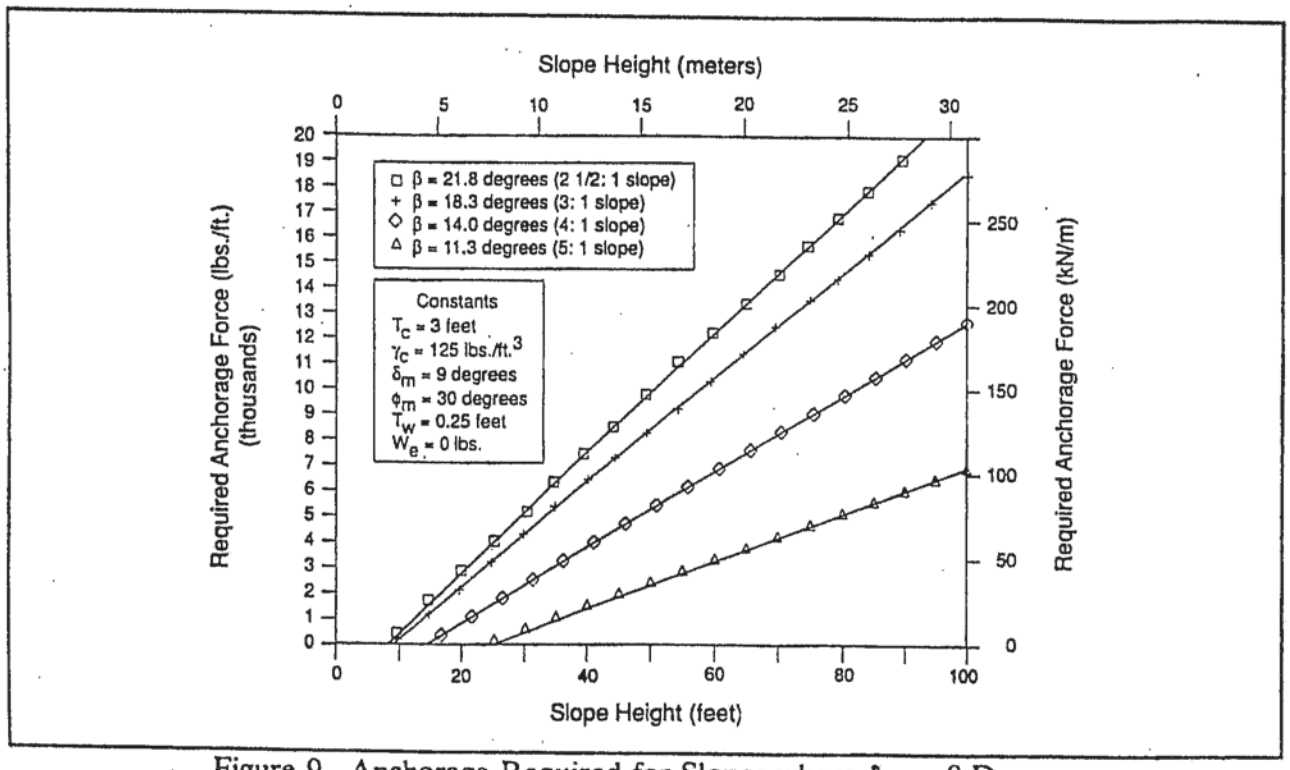

Figure 9. Anchorage Required for Slopes where δ_m = 9 Degrees

SUMMARY

The stability of lining and cover system sideslopes can be evaluated using a design methodology that is described in this paper. This methodology is based on the traditional sliding-block analysis, but has been expanded to include seepage forces, equipment loads, geosynthetic anchorage, and factors of safety. Equations are included in this paper to simplify application of the methodology to "real world" situations and to allow the optimization of factors such as slope geometry, strength, and applied loads.

Figures are presented to show the maximum stable slope height attainable at given slope angles for a range of slope characteristics and external loads. Geosynthetic anchorage can be used to achieve a stable slope, and figures are presented to show the relationship between slope height and required anchorage force (F_a) for various slopes. A project example is included to demonstrate how a landfill sideslope can be designed for best performance.

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WDCP295/003.51

ATTACHMENT L-2

SITE-SPECIFIC SEEPAGE ANALYSIS

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

DRAINAGE LAYER EVALUATION

(Ref: "THE DESIGN OF DRAINAGE SYSTEMS OVER GEOSYNTHETICALLY LINED SLOPES", GRI Report #19, June 17, 1997)

Project Name: MDOT - Callahan Mine Superfund Site **Completed by:** NDL **Checked by:** TCC
Project No.: 3612112201 **Date:** 9/2014 **Date:** 9/2014

Comments: 5% (20H:1V) Slope; SKAPS Transnet 250 GDL

Input Data:

Design Parameters:

100-yr, 6-hr storm = 4.50 inches
Slope = 0.05 ($\Delta Y / \Delta X$)
Slope Angle, β = 2.86 degrees

General Parameters/Variables:

Ps_{horiz}	Ps	ω	i	$Trans_d$	k_d	h_d	$k_{c.s.}$	$h_{c.s.}$	P	RC	FS x RF
ft	m	m	gradient	m^2/sec	m/sec	m	m/sec	m	(mm/hr)		
600.00	183.1	1.00	0.050	3.80E-04	5.98E-02	6.35E-03	1.00E-01	0.38	19.05	0.1	8.0

Where;

Ps_{horiz} = pipe spacing (or slope length, L); measured from plan view
Ps = pipe spacing (or slope length, L); along the slope
ω = width of slope section (assume 1 meter)
i = flow gradient = sin β
k_d = permeability of drainage material
h_d = thickness of the drainage material
$Trans_d$ = transmissivity of drainage composite
$k_{c.s.}$ = permeability of cover soil
$h_{c.s.}$ = thickness of cover soil
P = probable maximum (hourly) precipitation
RC = runoff coefficient

Factor of Safety/Reduction Factors:

References:
1) Richardson, Giroud, and Zhao, 2000, "Design of Lateral Drainage Systems for Landfills."
2) GRI Standard - GC8, "Determination of the Allowable Flow Rate of a Drainage Composite."
3) Giroud, Zornberg, and Zhao, 2000, "Hydraulic Design of Liquid Collection Layers."
4) Manufacturer's Product Data (based on long-term testing).

FS x RF = Drainage Safety Factor (FS_d) x Intrusion Reduction (RF_{in}) x Creep Reduction (RF_{cr}) x Biological Clogging Reduction (RF_{bc}) x Chemical Clogging Reduction (RFcc)

FS_d =	2.0
RF_{in} =	2.0
RF_{cr} =	1.1
RF_{bc} =	1.7
RF_{cc} =	1.1

Calculations:

PERC Calculation:

PERC = P x (1-RC)

Where;

PERC = percolation, mm/hr
P = probable maximum (hourly) precipitation, mm/hr
RC = runoff coefficient = percentage of precipitation that does not reach the drainage material

when P(1-RC) > $k_{c.s.}$, PERC = $k_{c.s.}$	360000.00	mm/hr
when P(1-RC) $\leq$ $k_{c.s.}$, PERC = as calculated	17.15	mm/hr

FLUX Calculation:

PERC	β	$FLUX_{reqd}$
mm/hr	degrees	m^3/hr
17.15	2.86	3.14

$FLUX_{allow}$	k_d
m^3/hr	m/hr
0.07	215.43

$FLUX^*_{allow}$	k^*_d
m^3/hr	m/hr
0.01	26.98

* Values reduced to incorporate Factor of Safety (FS) and Reduction Factors (RF). These values are used in the calculations.

Where;

PERC = percolation, mm/hr
β = slope angle
$FLUX_{reqd}$ = actual flow rate per unit width of slope
$FLUX_{reqd}$ = (PERC / 1000) x L (cos β) x ω
$FLUX_{allow}$ = allowable flow rate of the drainage layer per unit width of slope
$FLUX_{allow} = k_d \times i \times h_d$ $FLUX^*_{allow} = k^*_d \times i \times h_d$

Average Head Buildup Above Geomembrane Calculation:

Where;

h_{avg} = average head buildup above the geomembrane
DLC = drainage layer capacity
DLC = ($FLUX^*_{allow}$ / $FLUX_{reqd}$)
When $h_{avg} \leq h_d$, i.e., DLC $\geq$ 1.0 (the ave phreatic surface is within the drainage layer).
h_{avg} = 2.3275 m
When $h_{avg} > h_d$, i.e., DLC < 1.0 (the ave phreatic surface level is within the cover soil layer).
h_{avg} = 0.1803 m
PSR = parallel submergence ratio
PSR = h_{avg} / (hc.s. + h_d)

Output:

DLC
0.0027

h_{avg}	$h_{c.s.} + h_d$	PSR
m	m	
0.1803	0.3874	0.4654

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

DRAINAGE LAYER EVALUATION

(Ref: "THE DESIGN OF DRAINAGE SYSTEMS OVER GEOSYNTHETICALLY LINED SLOPES", GRI Report #19, June 17, 1997)

Project Name: MDOT - Callahan Mine Superfund Site **Completed by:** NDL **Checked by:** TCC
Project No.: 3612112201 **Date:** 9/2014 **Date:** 9/2014

Comments: 20% (5H:1V) Slope; SKAPS Transnet 250 GDL

Input Data:

Design Parameters:

100-yr, 6-hr storm = 4.50 inches
Slope = 0.20 ($\Delta Y / \Delta X$)
Slope Angle, β = 11.31 degrees

General Parameters/Variables:

Ps_{horiz}	Ps	ω	i	$Trans_d$	k_d	h_d	$k_{c.s.}$	$h_{c.s.}$	P	RC	FS x RF
ft	m	m	gradient	m^2/sec	m/sec	m	m/sec	m	(mm/hr)		
200.00	62.2	1.00	0.196	3.40E-04	5.35E-02	6.35E-03	1.00E-01	0.38	19.05	0.1	8.0

Where;

Ps_{horiz} = pipe spacing (or slope length, L); measured from plan view
Ps = pipe spacing (or slope length, L); along the slope
ω = width of slope section (assume 1 meter)
i = flow gradient = sin β
k_d = permeability of drainage material
h_d = thickness of the drainage material
$Trans_d$ = transmissivity of drainage composite
$k_{c.s.}$ = permeability of cover soil
$h_{c.s.}$ = thickness of cover soil
P = probable maximum (hourly) precipitation
RC = runoff coefficient

Factor of Safety/Reduction Factors:

References:
1) Richardson, Giroud, and Zhao, 2000, "Design of Lateral Drainage Systems for Landfills."
2) GRI Standard - GC8, "Determination of the Allowable Flow Rate of a Drainage Composite."
3) Giroud, Zornberg, and Zhao, 2000, "Hydraulic Design of Liquid Collection Layers."
4) Manufacturer's Product Data (based on long-term testing).

FS x RF = Drainage Safety Factor (FS_d) x Intrusion Reduction (RF_{in}) x Creep Reduction (RF_{cr}) x Biological Clogging Reduction (RF_{bc}) x Chemical Clogging Reduction (RFcc)

FS_d =	2.0
RF_{in} =	2.0
RF_{cr} =	1.1
RF_{bc} =	1.7
RF_{cc} =	1.1

Calculations:

PERC Calculation:

PERC = P x (1-RC)

Where;

PERC = percolation, mm/hr
P = probable maximum (hourly) precipitation, mm/hr
RC = runoff coefficient = percentage of precipitation that does not reach the drainage material

when P(1-RC) > $k_{c.s.}$, PERC = $k_{c.s.}$ — 360000.00 mm/hr
when P(1-RC) $\leq k_{c.s.}$, PERC = as calculated — 17.15 mm/hr

FLUX Calculation:

PERC	β	$FLUX_{reqd}$
mm/hr	degrees	m^3/hr
17.15	11.31	1.05

$FLUX_{allow}$	k_d
m^3/hr	m/hr
0.24	192.76

$FLUX^*_{allow}$	k^*_d
m^3/hr	m/hr
0.03	24.14

* Values reduced to incorporate Factor of Safety (FS) and Reduction Factors (RF). These values are used in the calculations.

Where;

PERC = percolation, mm/hr
β = slope angle
$FLUX_{reqd}$ = actual flow rate per unit width of slope
$FLUX_{reqd}$ = (PERC / 1000) x L (cos β) x ω
$FLUX_{allow}$ = allowable flow rate of the drainage layer per unit width of slope
$FLUX_{allow} = k_d \times i \times h_d$ $FLUX^*_{allow} = k^*_d \times i \times h_d$

Average Head Buildup Above Geomembrane Calculation:

Where;

h_{avg} = average head buildup above the geomembrane
DLC = drainage layer capacity
DLC = ($FLUX^*_{allow}$ / $FLUX_{reqd}$)
When $h_{avg} \leq h_d$, i.e., DLC $\geq$ 1.0 (the ave phreatic surface is within the drainage layer).
h_{avg} = 0.2208 m
When $h_{avg} > h_d$, i.e., DLC < 1.0 (the ave phreatic surface level is within the cover soil layer).
h_{avg} = 0.0207 m
PSR = parallel submergence ratio
PSR = h_{avg} / (hc.s. + h_d)

Output:

DLC
0.0288

h_{avg}	$h_{c.s.} + h_d$	PSR
m	m	
0.0207	0.3874	0.0535

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

DRAINAGE LAYER EVALUATION

(Ref: "THE DESIGN OF DRAINAGE SYSTEMS OVER GEOSYNTHETICALLY LINED SLOPES", GRI Report #19, June 17, 1997)

Project Name: MDOT - Callahan Mine Superfund Site **Completed by:** NDL **Checked by:** TCC
Project No.: 3612112201 **Date:** 9/2014 **Date:** 9/2014

Comments: 33% (3H:1V) Slope; SKAPS Transnet 250 GDL

Input Data:

Design Parameters:

100-yr, 6-hr storm = 4.50 inches
Slope = 0.33 ($\Delta Y / \Delta X$)
Slope Angle, β = 18.26 degrees

General Parameters/Variables:

Ps_{horiz}	Ps	ω	i	$Trans_d$	k_d	h_d	$k_{c.s.}$	$h_{c.s.}$	P	RC	FS x RF
ft	m	m	gradient	m^2/sec	m/sec	m	m/sec	m	(mm/hr)		
45.00	14.4	1.00	0.313	3.00E-04	4.72E-02	6.35E-03	1.00E-01	0.38	19.05	0.1	8.0

Where;

Ps_{horiz} = pipe spacing (or slope length, L); measured from plan view
Ps = pipe spacing (or slope length, L); along the slope
ω = width of slope section (assume 1 meter)
i = flow gradient = sin β
k_d = permeability of drainage material
h_d = thickness of the drainage material
$Trans_d$ = transmissivity of drainage composite
$k_{c.s.}$ = permeability of cover soil
$h_{c.s.}$ = thickness of cover soil
P = probable maximum (hourly) precipitation
RC = runoff coefficient

Factor of Safety/Reduction Factors:

References:
1) Richardson, Giroud, and Zhao, 2000, "Design of Lateral Drainage Systems for Landfills."
2) GRI Standard - GC8, "Determination of the Allowable Flow Rate of a Drainage Composite."
3) Giroud, Zornberg, and Zhao, 2000, "Hydraulic Design of Liquid Collection Layers."
4) Manufacturer's Product Data (based on long-term testing).

FS x RF = Drainage Safety Factor (FS_d) x Intrusion Reduction (RF_{in}) x Creep Reduction (RF_{cr}) x Biological Clogging Reduction (RF_{bc}) x Chemical Clogging Reduction (RFcc)

FS_d =	2.0
RF_{in} =	2.0
RF_{cr} =	1.1
RF_{bc} =	1.7
RF_{cc} =	1.1

Calculations:

PERC Calculation:

PERC = P x (1-RC)

Where;

PERC = percolation, mm/hr
P = probable maximum (hourly) precipitation, mm/hr
RC = runoff coefficient = percentage of precipitation that does not reach the drainage material

when P(1-RC) > $k_{c.s.}$, PERC = $k_{c.s.}$ — 360000.00 mm/hr
when P(1-RC) $\leq k_{c.s.}$, PERC = as calculated — 17.15 mm/hr

FLUX Calculation:

PERC	β	$FLUX_{reqd}$
mm/hr	degrees	m^3/hr
17.15	18.26	0.24

$FLUX_{allow}$	k_d
m^3/hr	m/hr
0.34	170.08

$FLUX^*_{allow}$	k^*_d
m^3/hr	m/hr
0.04	21.30

* Values reduced to incorporate Factor of Safety (FS) and Reduction Factors (RF). These values are used in the calculations.

Where;

PERC = percolation, mm/hr
β = slope angle
$FLUX_{reqd}$ = actual flow rate per unit width of slope
$FLUX_{reqd}$ = (PERC / 1000) x L (cos β) x ω
$FLUX_{allow}$ = allowable flow rate of the drainage layer per unit width of slope
$FLUX_{allow} = k_d \times i \times h_d$ $FLUX^*_{allow} = k^*_d \times i \times h_d$

Average Head Buildup Above Geomembrane Calculation:

Where;

h_{avg} = average head buildup above the geomembrane
DLC = drainage layer capacity
DLC = ($FLUX^*_{allow}$ / $FLUX_{reqd}$)
When $h_{avg} \leq h_d$, i.e., DLC $\geq$ 1.0 (the ave phreatic surface is within the drainage layer).
h_{avg} = 0.0352 m
When $h_{avg} > h_d$, i.e., DLC < 1.0 (the ave phreatic surface level is within the cover soil layer).
h_{avg} = 0.0081 m
PSR = parallel submergence ratio
PSR = h_{avg} / (hc.s. + h_d)

Output:

DLC
0.1802

h_{avg}	$h_{c.s.} + h_d$	PSR
m	m	
0.0081	0.3874	0.0208

U.S. DEPARTMENT OF COMMERCE
LUTHER H. HODGES, Secretary

WEATHER BUREAU
F. W. REICHELDERFER, Chief

TECHNICAL PAPER NO. 40

RAINFALL FREQUENCY ATLAS OF THE UNITED STATES

for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years

Prepared by
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Cooperative Studies Section, Hydrologic Services Division
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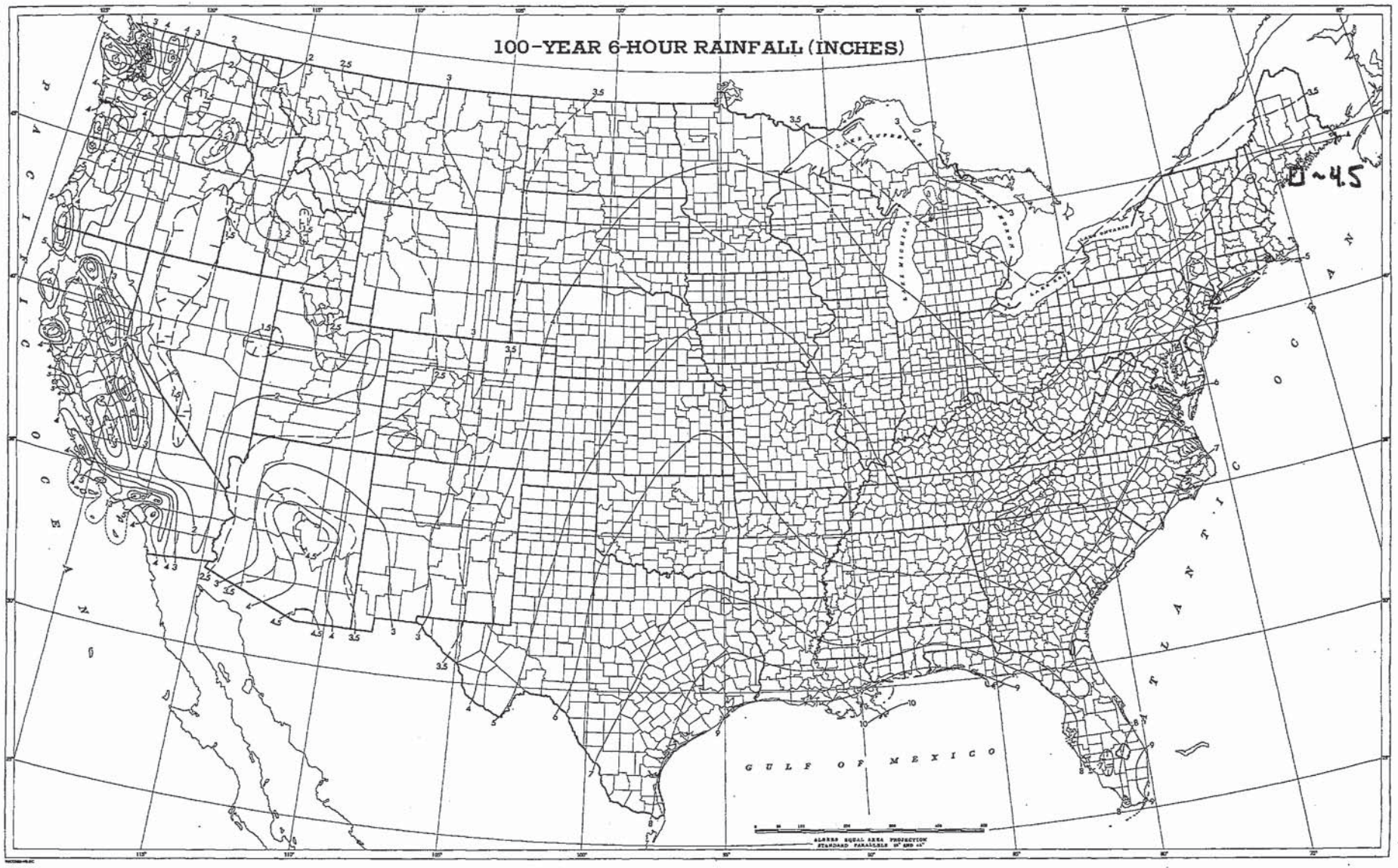
100-YEAR 6-HOUR RAINFALL (INCHES)
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
D ~4.5

An Introduction to Geotechnical Engineering

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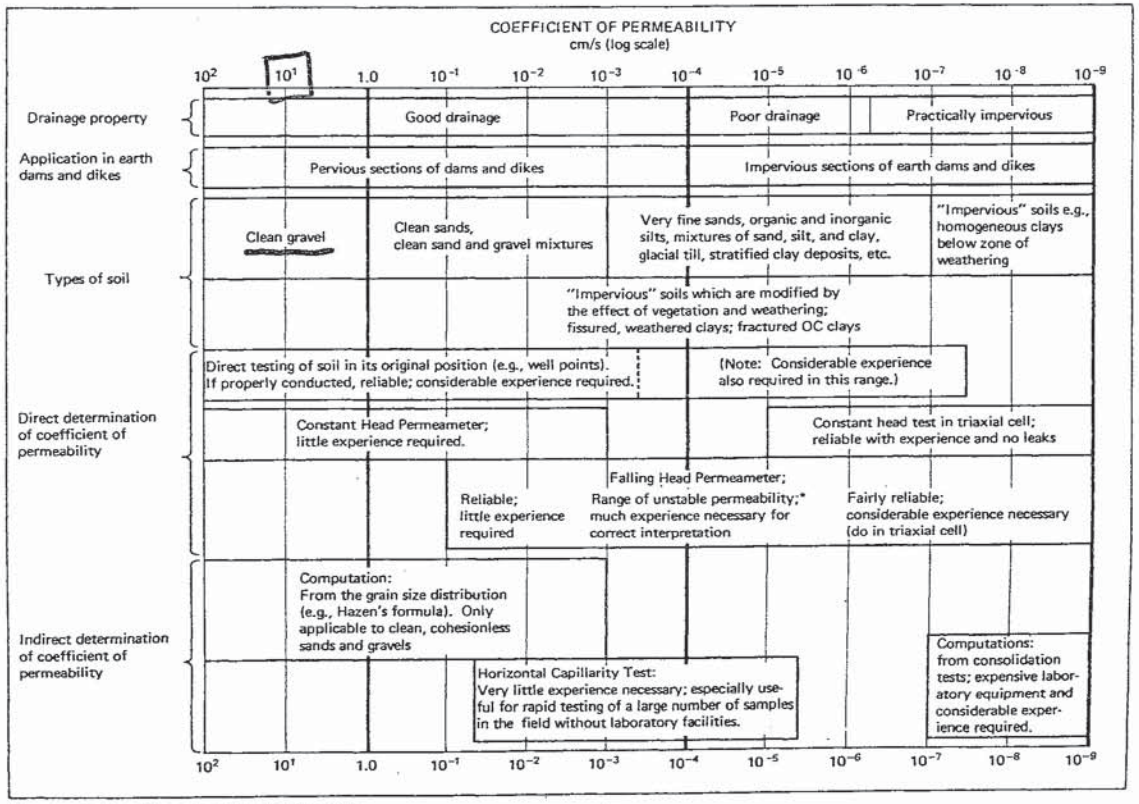

*Due to migration of fines, channels, and air in voids.

Fig. 7.6 Permeability, drainage, soil type, and methods to determine the coefficient of permeability (after A. Casagrande, 1938, with minor additions).

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SKAPS TRANSNET™ (TN)
HDPE GEOCOMPOSITE 250

SKAPS TRANSNET™ geocomposite consists of SKAPS GeoNet made from HDPE resin with non-woven polypropylene geotextile fabric heat bonded on both sides of the the geonet.

Property	Test Method	Unit	Required Value		Qualifier
			With 6 oz.	With 8 oz.	
Geonet					
Thickness	ASTM D 5199	mil.	250±15	250±15	Range
Carbon Black	ASTM D 4218	%	2 to 3	2 to 3	Range
Tensile Strength	ASTM D 5035	lb/in	50	50	Minimum
Melt Flow	ASTM D 1238[3]	g/10 min.	1	1	Minimum
Density	ASTM D 1505	g/cm^3	0.94	0.94	Minimum
Transmissivity[1]	ASTM D 4716	$m^2/sec.$	$2.5x10^{-3}$	$2.5x10^{-3}$	MARV[2]
Composite					
Ply Adhesion (Minimum)	ASTM D7005	lb/in	0.5	0.5	MARV
Ply Adhesion (Average)	ASTM D7005	lb/in	1	1	MARV
Transmissivity[1]	ASTM D 4716	m^2/sec	$2x10^{-4}$	$2x10^{-4}$	MARV
Geotextile					
Fabric Weight	ASTM D 5261	oz/yd^2	6	8	MARV
Grab Strength	ASTM D 4632	lbs	160	225	MARV
Grab Elongation	ASTM D 4632	%	50	50	MARV
Tear Strength	ASTM D 4533	lbs	65	90	MARV
Puncture Resistance	ASTM D 4833	lbs	95	130	MARV
CBR Puncture	ASTM D 6241	lbs	475	650	MARV
Water Flow Rate	ASTM D 4491	gpm/ft^2	125	100	MARV
Permittivity	ASTM D 4491	sec^{-1}	1.63	1.26	MARV
Permeability	ASTM D 4491	cm/sec	0.3	0.3	MARV
AOS	ASTM D 4751	US Sieve	70	80	MARV

Notes:

1. Transmissivity measured using water at 21 ± 2ºC (70 ± 4ºF) with a gradient of 0.1 and a confining pressure of 10000 psf between stainless steel plates after 15 minutes. Values may vary between individual labs.
2. MARV is statistically defined as mean minus two standard deviations and it is the value which is exceeded by 97.5% of all the test data.
3. Condition 190/2.16

This information is provided for reference purposes only and is not intended as a warranty or guarantee. SKAPS assumes no liability in connection with the use of this information.

SKAPS Industreis
571 Industrial Parkway
Commerce, GA 30529
Phone: 706-336-7000
www.skaps.com

Date: August 28, 2012

Subject: Transmissivity Values for Various SKAPS Products

To whom it may concern:

SKAPS geocomposite materials conforms to following transmissivity values when tested as per ASTM D 4716

Product	Gradient	Duration (hrs)	Transmissivity[1] (m^2/sec)	Qualifier
TN 220-2-6	0.1	100	2.0×10^{-4}	MARV
*TN 250-2-6			3.8×10^{-4}	MARV
TN 270-2-6			1.0×10^{-3}	MARV
TN 330-2-6			1.6×10^{-3}	MARV
TN 220-2-6	0.33		1.5×10^{-4}	MARV
*TN 250-2-6			3.0×10^{-4}	MARV
TN 270-2-6			7.0×10^{-4}	MARV
TN 330-2-6			1.2×10^{-3}	MARV

Note:

(1) Transmissivity measured using water at 21 $\pm$ 2^{0}C (70 $\pm$ 4^{0}F) with various gradient and a confining pressure of 1,000 psf between sand and liner after 100 hours.

Appendix A: Hydrologic soil groups

Soils are classified into hydrologic soil groups (HSG's) to indicate the minimum rate of infiltration obtained for bare soil after prolonged wetting. The HSG's, which are A, B, C, and D, are one element used in determining runoff curve numbers (see chapter 2). For the convenience of TR-55 users, exhibit A-1 lists the HSG classification of United States soils.

The infiltration rate is the rate at which water enters the soil at the soil surface. It is controlled by surface conditions. HSG also indicates the transmission rate—the rate at which the water moves within the soil. This rate is controlled by the soil profile. Approximate numerical ranges for transmission rates shown in the HSG definitions were first published by Musgrave (USDA 1955). The four groups are defined by SCS soil scientists as follows:

Group A soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission (greater than 0.30 in/hr).

Group B soils have moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15-0.30 in/hr).

Group C soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission (0.05-0.15 in/hr).

Group D soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0-0.05 in/hr).

In exhibit A-1, some of the listed soils have an added modifier; for example, "Abrazo, gravelly." This refers to a gravelly phase of the Abrazo series that is found in SCS soil map legends.

Disturbed soil profiles

As a result of urbanization, the soil profile may be considerably altered and the listed group classification may no longer apply. In these circumstances, use the following to determine HSG according to the texture of the new surface soil, provided that significant compaction has not occurred (Brakensiek and Rawls 1983):

HSG	*Soil textures*
A	Sand, loamy sand, or sandy loam
B	Silt loam or loam
C	Sandy clay loam
D	Clay loam, silty clay loam, sandy clay, silty clay, or clay

Drainage and group D soils

Some soils in the list are in group D because of a high water table that creates a drainage problem. Once these soils are effectively drained, they are placed in a different group. For example, Ackerman soil is classified as A/D. This indicates that the drained Ackerman soil is in group A and the undrained soil is in group D.

APPENDIX D-12: Runoff Coefficients for the Rational Formula by Hydrologic Soil Group and Slope

Runoff Coefficients for the Rational Formula by Hydrologic Soil Group and Slope

Range *

Land use	A			B			C			D		
	0–2%	2–6%	6%+	0–2%	2–6%	6%+	0–2%	2–6%	6%+	0–2%	2–6%	6%+
Cultivated land	0.08	0.13	0.16	0.11	0.15	0.21	0.14	0.19	0.26	0.18	0.23	0.31
	0.14	0.18	0.22	0.16	0.21	0.28	0.20	0.25	0.34	0.24	0.29	0.41
Pasture	0.12	0.20	0.30	0.18	0.28	0.37	0.24	0.34	0.44	0.30	0.40	0.50
	0.15	0.25	0.37	0.23	0.34	0.45	0.30	0.42	0.52	0.37	0.50	0.62
Meadow	0.10	0.16	0.25	0.14	0.22	0.30	0.20	0.28	0.36	0.24	0.30	0.40
	0.14	0.22	0.30	0.20	0.28	0.37	0.26	0.35	0.44	0.30	0.40	0.50
Forest	0.05	0.08	0.11	0.08	0.11	0.14	0.10	0.13	0.16	0.12	0.16	0.20
	0.08	0.11	0.14	0.10	0.14	0.18	0.12	0.16	0.20	0.15	0.20	0.25
Residential												
Lot size $\frac{1}{8}$ acre	0.25	0.28	0.31	0.27	0.30	0.35	0.30	0.33	0.38	0.33	0.36	0.42
(0.05 ha)	0.33	0.37	0.40	0.35	0.39	0.44	0.38	0.42	0.49	0.41	0.45	0.54
Lot size $\frac{1}{4}$ acre	0.22	0.26	0.29	0.24	0.29	0.33	0.27	0.31	0.36	0.30	0.34	0.40
(0.10 ha)	0.30	0.34	0.37	0.33	0.37	0.42	0.36	0.40	0.47	0.38	0.42	0.52
Lot size $\frac{1}{3}$ acre	0.19	0.23	0.26	0.22	0.26	0.30	0.25	0.29	0.34	0.28	0.32	0.39
(0.13 ha)	0.28	0.32	0.35	0.30	0.35	0.39	0.33	0.38	0.45	0.36	0.40	0.50
Lot size $\frac{1}{2}$ acre	0.16	0.20	0.24	0.19	0.23	0.28	0.22	0.27	0.32	0.26	0.30	0.37
(0.2 ha)	0.25	0.29	0.32	0.28	0.32	0.36	0.31	0.35	0.42	0.34	0.38	0.48
Lot size 1 acre	0.14	0.19	0.22	0.17	0.21	0.26	0.20	0.25	0.31	0.24	0.29	0.35
(0.4 ha)	0.22	0.26	0.29	0.24	0.28	0.34	0.28	0.32	0.40	0.31	0.35	0.46
Industrial	0.67	0.68	0.68	0.68	0.68	0.69	0.68	0.69	0.69	0.69	0.69	0.70
	0.85	0.85	0.86	0.85	0.86	0.86	0.86	0.86	0.87	0.86	0.86	0.88
Commercial	0.71	0.71	0.72	0.71	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
	0.88	0.88	0.89	0.89	0.89	0.89	0.89	0.89	0.90	0.89	0.89	0.90
Streets	0.70	0.71	0.72	0.71	0.72	0.74	0.72	0.73	0.76	0.73	0.75	0.78
	0.76	0.77	0.79	0.80	0.82	0.84	0.84	0.85	0.89	0.89	0.91	0.95
Open space	0.05	0.10	0.14	0.08	0.13	0.19	0.12	0.17	0.24	0.16	0.21	0.28
	* 0.11	0.16	0.20	0.14	0.19	0.26	0.18	0.23	0.32	0.22	0.27	0.39
Parking	0.85	0.86	0.87	0.85	0.86	0.87	0.85	0.86	0.87	0.85	0.86	0.87
	0.95	0.96	0.97	0.95	0.96	0.97	0.95	0.96	0.97	0.95	0.96	0.97

*First row of each entry gives runoff coefficients for storm recurrence intervals less than 25 years; second row gives runoff coefficients for storm recurrence intervals of 25 years or more.

(Source: Rawls et.al., 1981)

Figure D.12. Runoff Coefficients for the Rational Formula.

(Source: Rawls et al., 1981, and Browne, 1990)

* Conservatively assume 0.10 for all slopes

ATTACHMENT L-3

SITE-SPECIFIC SEISMIC HAZARD MAPPING DATA

JOB NO. 3612112201 SHEET 1 OF 9
PHASE — TASK —
JOB NAME Callahan Mine - Tailings Impoundment
BY TCC DATE 07/31/14
CHECKED BY DATE

amec
511 Congress Street Suite 200
Portland, ME 04101
+1 (207) 775-5401 Fax +1 (207) 772-4762

PSEUDO-STATIC (SEISMIC) INTERFACE STABILITY EVALUATION

A. Peak Ground Acceleration (PGA)

1. Site-Specific Coordinates (Latitude / Longitude)

   - 44.342° N
   - 68.805° W

   } See Sheet 2

2. USGS Earthquake Hazard Program 2014 Seismic Hazard Mapping Data

   - 2% PE in 50 Years ≡ 10% PE 250 Years
     - See Sheet 3 for map data. (Conterminous US only)
     - Detailed mapping not yet available.
     - Map is inconclusive
     - ∴ See raw USGS data files
     - See Sheets 4 & 5
     - From Gridded Hazard Map Data for 2% PE in 50 years:

W	N	PGA (%g)
68.850	44.350	0.149929
68.800	44.350	0.146623
68.850	44.300	0.145332
68.800	44.300	0.142139

3. Interpolate PGA for between gridded data to establish Site-Specific Coordinates.

   - See Sheet 6
   - USGS PGA for Site-Specific Coordinates = 0.146g

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Your guide to the outdoors.

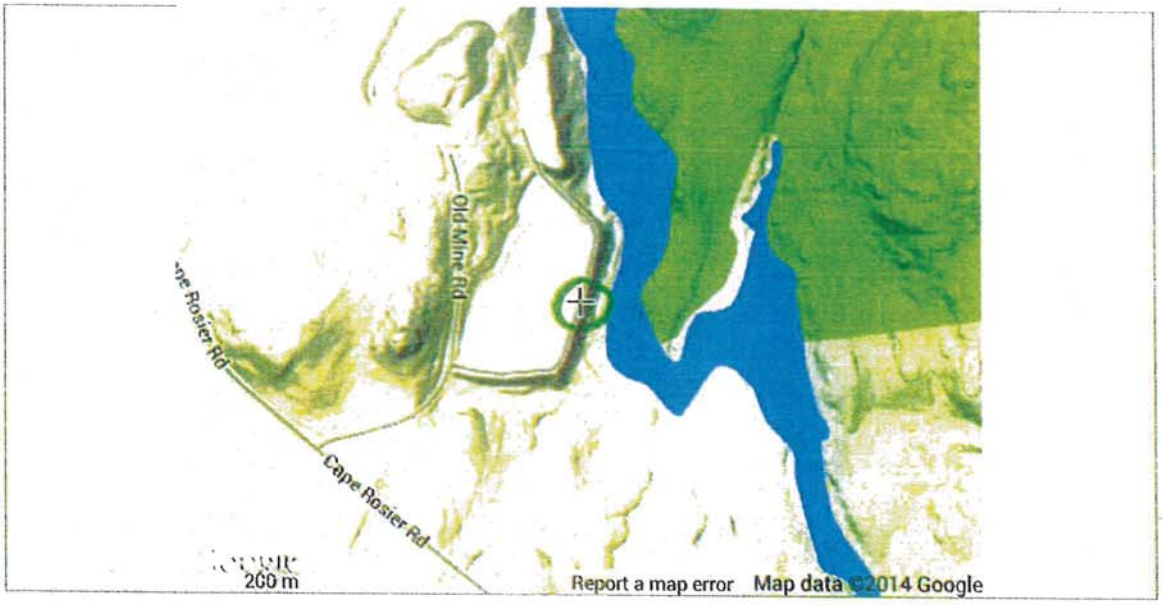
Sheet 2 of 9

For full access, login o

Maine Topo Maps & Topographic Map Data for Maine State

Find Maine topo maps & topographic map data by clicking on the map or searching for maps by state or feature.

Save to My Maps Map Size: Like 18 Tweet 0 Print Portrait | Print La



START
3 steps to
1. Click
2. Free A
3. Get Fr

Search Topo

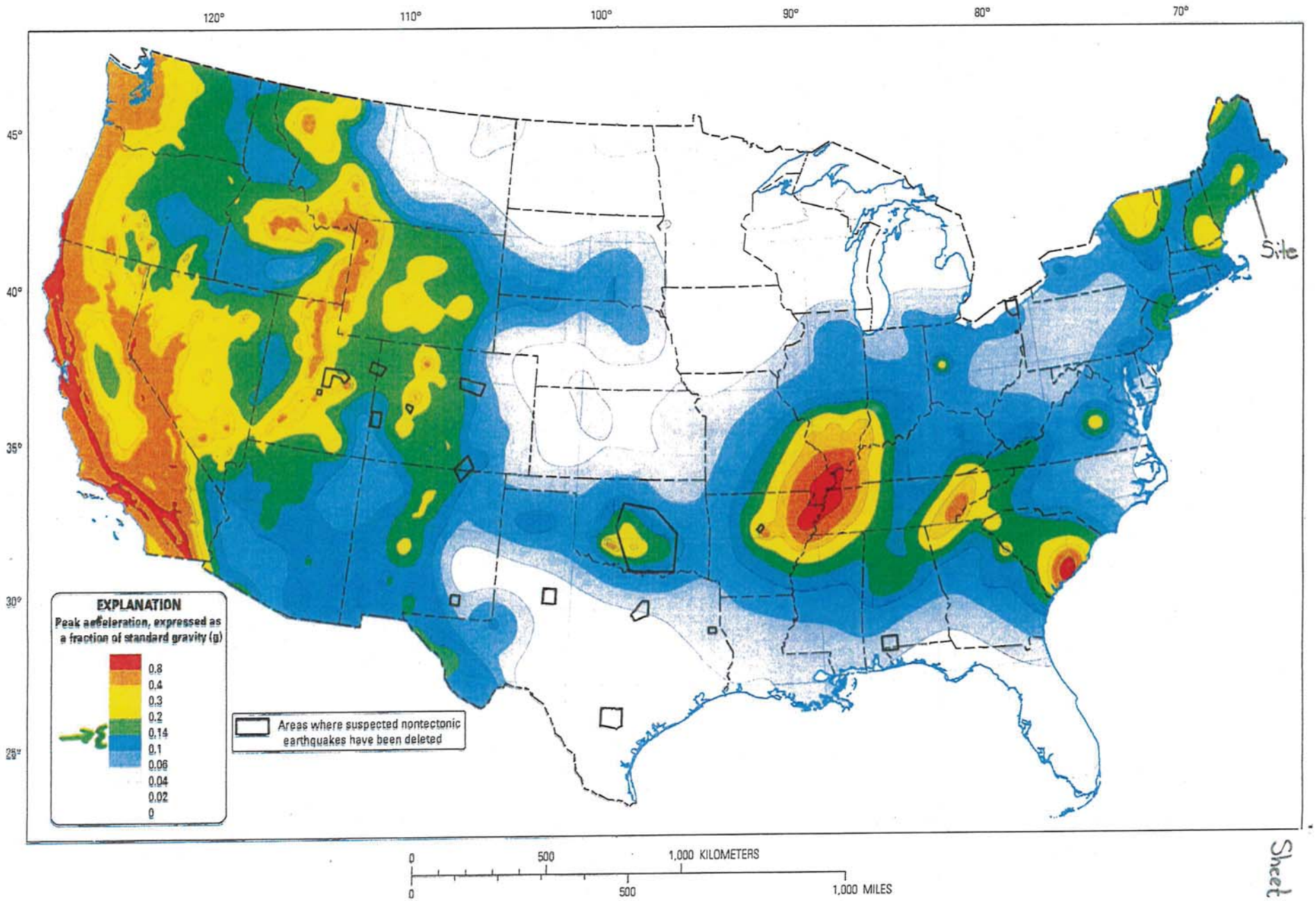
Center: 44.3422°N 68.8047°W
Elevation at center: 59 feet (18 meters)
Quad:
Drg Name:
Drg Source Scale:
Projection: NAD83/WGS84

Display format:
Decimal Degrees
Hide center marker

Feature Nam
All States
Select Featu
Search

TRY IT FREE
Access to over 55,000 Trail Guides and USGS Topo Maps

Ads by Google



Sheet 3 of 9

Two-percent probability of exceedance in 50 years map of peak ground acceleration

Earthquake Hazards Program

2014 NSHM Gridded Data

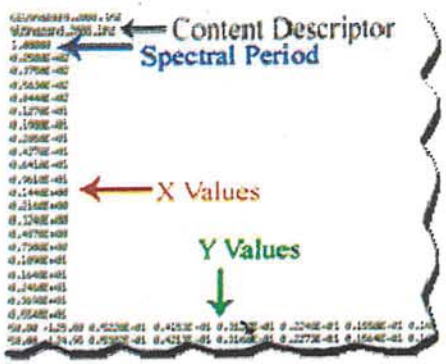
These files contain space-delimited, rectangular gridded data over the Conterminous 48 States in 0.05 degree increments in longitude (x-value) and latitude (y-value). See below for more information about the format of these data files.

Download Data Files

Data Type	Spectral Acceleration	Probability of Exceedance	Download
Gridded Hazard Map	Peak Ground Acceleration	2% in 50 years	Text (3.9MB)
Hazard Curve Data	5 Hz (0.2 sec)	N/A	Text (30.1MB)
Hazard Curve Data	1 Hz (1 sec)	N/A	Text (32.9MB)
Hazard Curve Data	Peak Ground Acceleration	N/A	Text (34.5MB)

Data File Formats

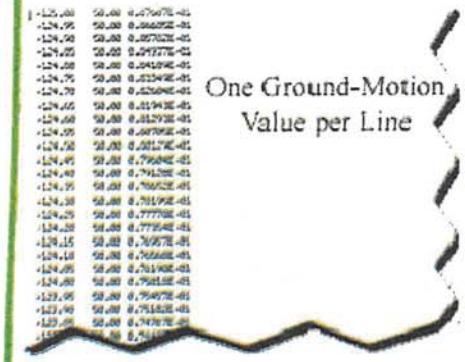
"Hazard Curves" Files



Sheet 4 of 9

These files contain hazard curves for the gridded geographic points as described above. All the hazard curves in the file share the same set of x-values (intensity measure levels). The first two lines tell you that these files contain data for both the western and central and eastern United States. The third line specifies the spectral period (in seconds) used when computing the hazard curves for the file. The following lines (with 1 value per line) contain the x-values (intensity measure levels) for all the curves in the file. Subsequent lines contain hazard curves with a single geographic point per line. The first two values specify the latitude and longitude (respectively) for the curve while subsequent values (on that same line) contain mean annual frequencies of exceedance ordered corresponding to the x-values at the top of the file.

"X% in 50 Years" Files



These files contain ground motion values for the gridded geographic points as described above. The ground motion units are in g where 1g = 980.5 cm/s/s and are defined for the B/C boundary (V_s^{30} = 760 m/s). Data contained in these files specify a single geographic point per line starting with longitude and latitude values (respectively), with the third and final value of each line specifying the ground motion for that geographic point.

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Sheet 5 of 9

2014 USGS SEISMIC HAZARD MAPPING DATA
(From Gridded Data; USGS Website)

Project: Callahan Mine - Tailings Impoundment
Location: Brooksville, Maine

Raw Data (from USGS)			Site-Specific Data (Interpolated)						
Westing	Northing	PGA	Westing	Northing	PGA	Westing	Northing	PGA	0.5*PGA
68.850	44.350	0.150	68.805	44.350	0.147	68.805	44.342	0.146	0.073
68.800	44.350	0.147							
68.850	44.300	0.145	68.805	44.300	0.142				
68.800	44.300	0.142							

Prepared By/Date: TCC 0'7/30/14
Checked By/Date: NDL 08/01/14

JOB NO. 3612112201 SHEET 7 OF 9
PHASE TASK
JOB NAME Callahan Mine
BY NDL DATE 9/2014
CHECKED BY DATE

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511 Congress Street Suite 200
Portland, ME 04101
+1 (207) 775-5401 Fax +1 (207) 772-4762

SEISMIC STABILITY EVALUATION - INTERFACE

B. PGA - 10% Probability in 50 years

1. 2014 data/mapping for 10% probability of occurance in 50 years PGA not yet available from USGS.

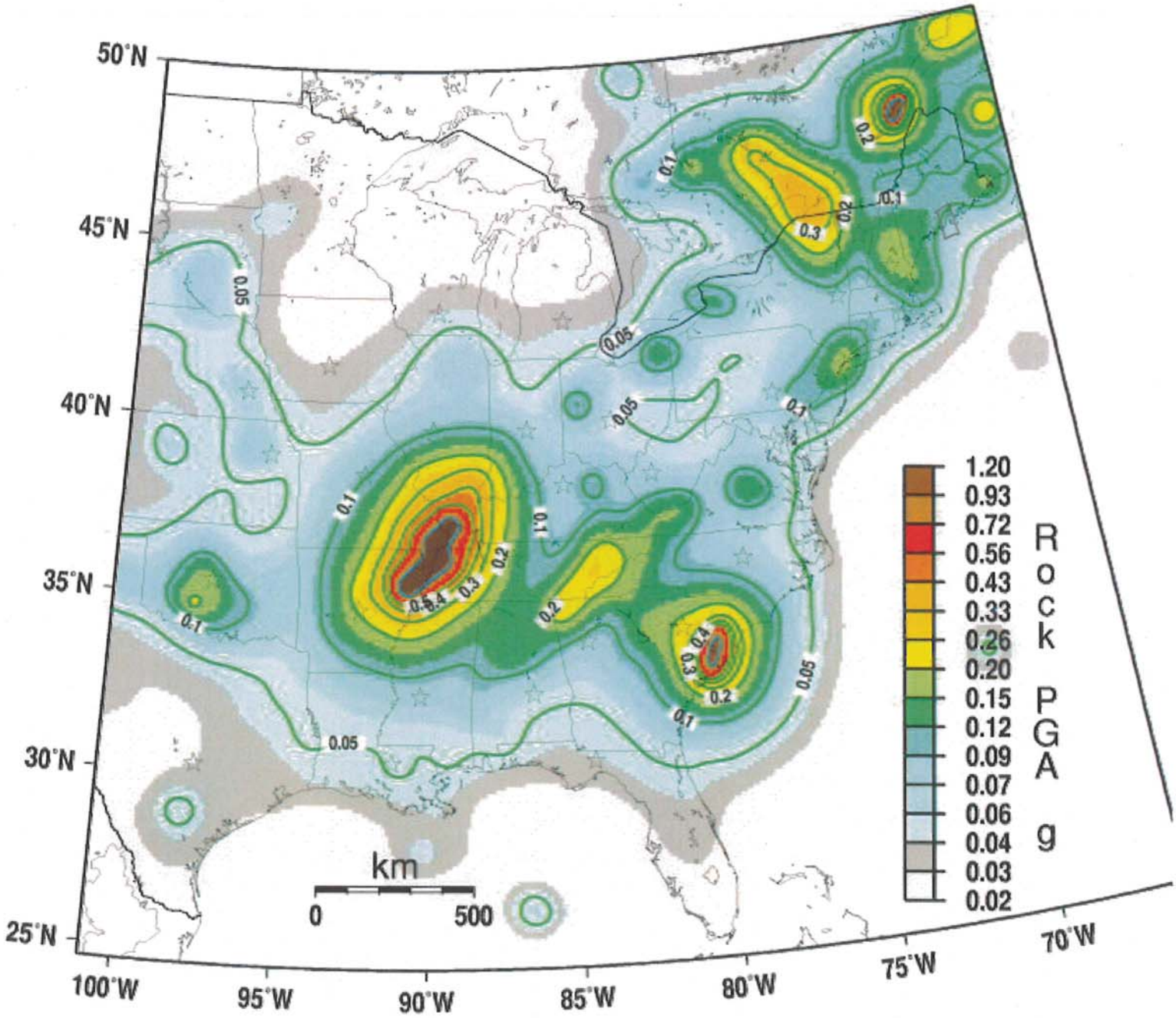
2. 2008 USGS Seismic Hazard Mapping is available for PGA 2%/50yr and 10%/50yr.

   - 2%/50yr PGA ≈ 0.092g (Sheet 8)
   - 10%/50yr PGA ≈ 0.03g (Sheet 9)

3. Approach to estimate 2014 10%/50yr PGA:

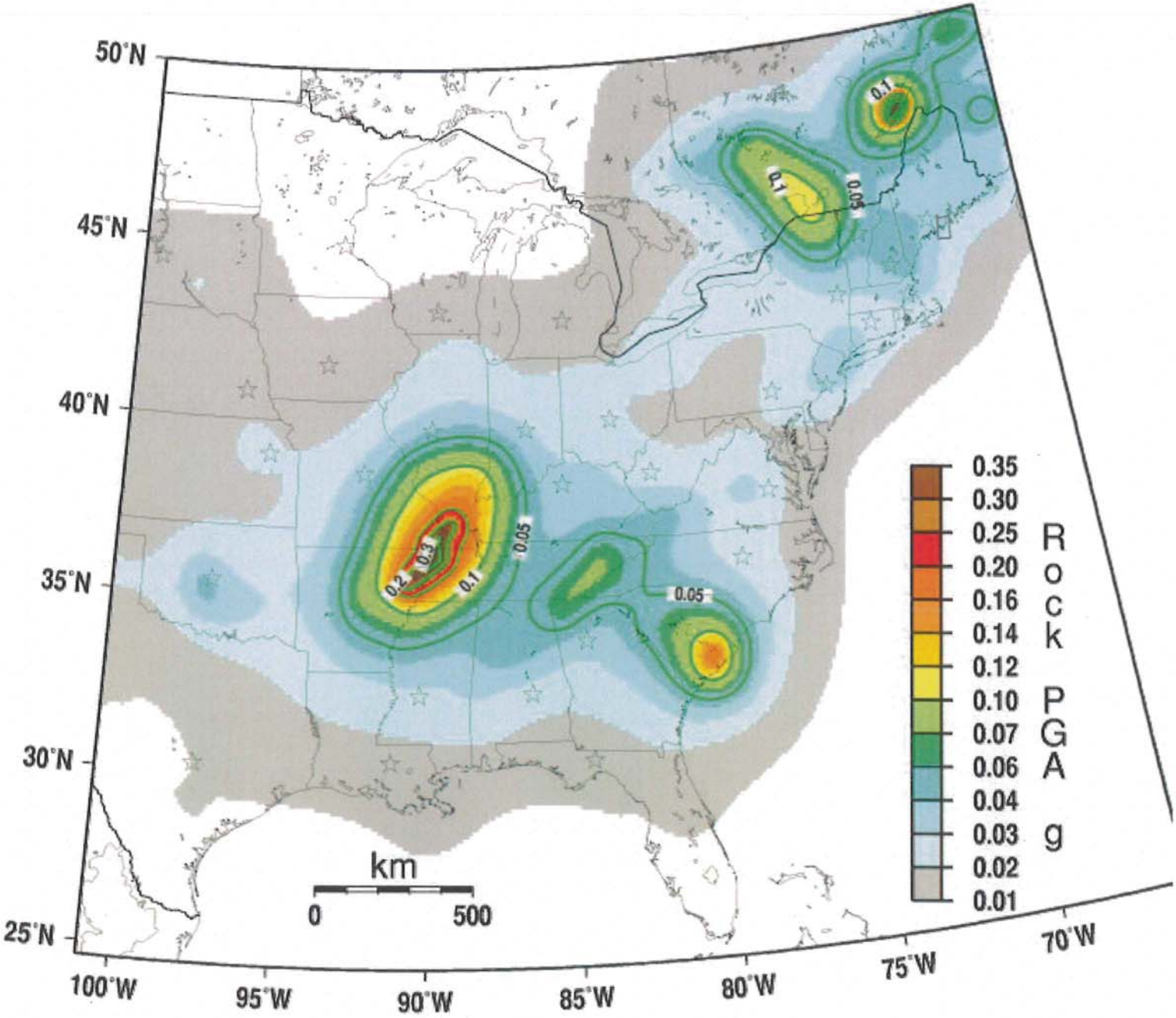
   - Increase 2008 10%/50yr PGA by same percent increase as 2%/50yr PGA from 2008 → 2014.
   - $\frac{0.146g - 0.092g}{0.092g} = 59\%$ increase
   - $1.59 \times 0.03g = 0.048 \cong \underline{\underline{0.05g}}$

PGA with 2%/50 yr PE, 2008



GMT Apr 11 15:37 PGA 2%50yr PE. BC rock site condition

CEUS PGA 10%/50 years, 2008



GMT May 2 10:59 PGA 10%50yr PE using half-wt on NMSZ cluster models. Stars: state capitals.

ATTACHMENT L-4

SPREADSHEET CALCULATOR OUTPUT
5% SLOPES

ATTACHMENT L-4A

SPREADSHEET CALCULATOR OUTPUT
5% SLOPES

4 Interfaces: Long-Term Static Conditions

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

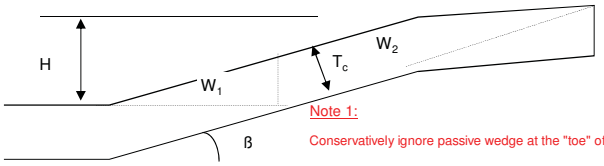
Comments: 5% Slopes; Long-Term; Static; Interface No. 1; Peak

		Inputs				
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore =	1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf			
γ_c	Weight of cover soil	100.0	pcf			
	Saturated weight of cover	125.0	pcf			
T_w	Thickness of seepage	0.0	feet			
ß	slope angle (beta)	2.9	degrees			
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).			
δ	Interface shear strength	**30.0**	degrees			
	Cohesion @ interface	0.0	psf			
	Cohesion of cover soil	0.0	psf			
H	Slope Height	30.0	feet	Therefore, the slope length =	593 ft	
W_e	Equipment Weight	0.0	pounds			
	Equipment width	0.0	width in feet			

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.50000	0.86603	0.57735

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**11.4**	**11.4**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**11.4**	**11.4**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	3.4	3.4



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{\text{passive} + \text{center} + \text{equipment} + \text{cohesion}}{\text{seepage} + \text{equipment} + \text{center} + \text{seismic}}$$

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{0.00 + 41{,}847.45 + 0.00 + 0.00}{0.00 + 0.00 + 3{,}671.77 + 0.00}$$

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

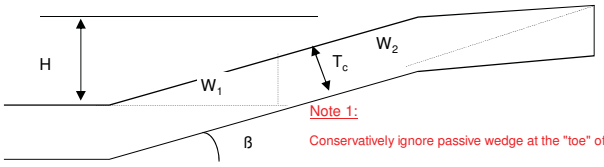
Comments: 5% Slopes; Long-Term; Static; Interface No. 1; Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	2.9	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**28.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	30.0	feet	Therefore, the slope length = 593 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.46947	0.88295	0.53171

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**10.5**	**10.5**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**10.5**	**10.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	3.2	3.2



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 38,539.31 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 3,671.77 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

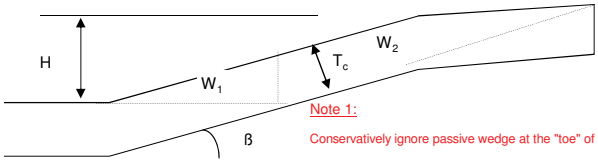
Comments: 5% Slopes; Long-Term; Static; Interface No. 2a (Smooth FML); Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	2.9	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**10.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	30.0	feet	Therefore, the slope length = 593 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.17365	0.98481	0.17633

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**3.5**	**3.5**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**3.5**	**3.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	1.0	1.0



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 12,780.52 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 3,671.77 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

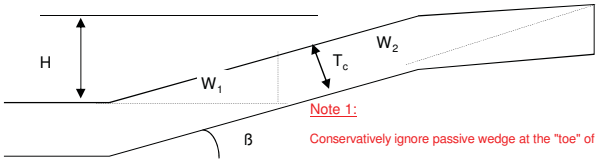
Comments: 5% Slopes; Long-Term; Static; Interface No. 2a (Smooth FML); Residual

		Inputs				
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore =	1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf			
γ_c	Weight of cover soil	100.0	pcf			
	Saturated weight of cover	125.0	pcf			
T_w	Thickness of seepage	0.0	feet			
ß	slope angle (beta)	2.9	degrees			
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).			
δ	Interface shear strength	**10.0**	degrees			
	Cohesion @ interface	0.0	psf			
	Cohesion of cover soil	0.0	psf			
H	Slope Height	30.0	feet	Therefore, the slope length =	593 ft	
W_e	Equipment Weight	0.0	pounds			
	Equipment width	0.0	width in feet			

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.17365	0.98481	0.17633

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**3.5**	**3.5**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**3.5**	**3.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	1.0	1.0



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 12,780.52 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 3,671.77 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

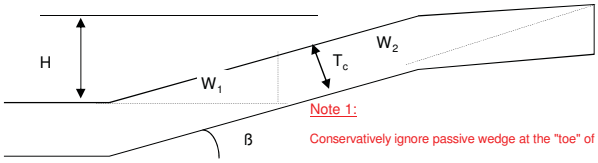
Comments: 5% Slopes; Long-Term; Static; Interface No. 2b (Textured FML); Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	2.9	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**28.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	30.0	feet	Therefore, the slope length = 593 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.46947	0.88295	0.53171

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**10.5**	**10.5**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**10.5**	**10.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	3.2	3.2



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS =	Sum of Resisting Forces	=	0.00	+	38,539.31	+	0.00	+	0.00
	Sum of Driving Forces	=	0.00	+	0.00	+	3,671.77	+	0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

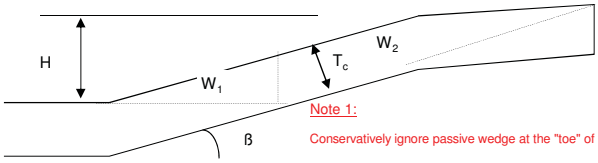
Comments: 5% Slopes; Long-Term; Static; Interface No. 2b (Textured FML); Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	2.9	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**22.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	30.0	feet	Therefore, the slope length = 593 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.37461	0.92718	0.40403

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**8.0**	**8.0**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**8.0**	**8.0**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	2.4	2.4



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 29,284.59 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 3,671.77 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

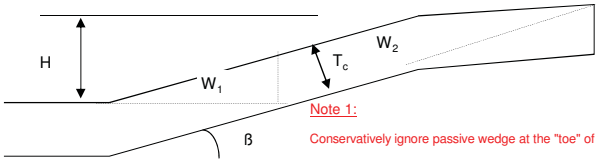
Comments: 5% Slopes; Long-Term; Static; Interface No. 3a (Smooth FML); Peak

		Inputs				
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore =	1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf			
γ_c	Weight of cover soil	100.0	pcf			
	Saturated weight of cover	125.0	pcf			
T_w	Thickness of seepage	0.0	feet			
ß	slope angle (beta)	2.9	degrees			
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).			
δ	Interface shear strength	**10.0**	degrees			
	Cohesion @ interface	0.0	psf			
	Cohesion of cover soil	0.0	psf			
H	Slope Height	30.0	feet	Therefore, the slope length =	593 ft	
W_e	Equipment Weight	0.0	pounds			
	Equipment width	0.0	width in feet			

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.17365	0.98481	0.17633

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**3.5**	**3.5**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**3.5**	**3.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	1.0	1.0



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 12,780.52 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 3,671.77 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

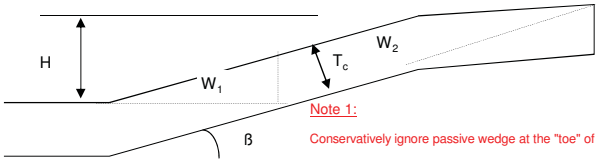
Comments: 5% Slopes; Long-Term; Static; Interface No. 3a (Smooth FML); Residual

		Inputs				
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore =	1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf			
γ_c	Weight of cover soil	100.0	pcf			
	Saturated weight of cover	125.0	pcf			
T_w	Thickness of seepage	0.0	feet			
ß	slope angle (beta)	2.9	degrees			
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).			
δ	Interface shear strength	**10.0**	degrees			
	Cohesion @ interface	0.0	psf			
	Cohesion of cover soil	0.0	psf			
H	Slope Height	30.0	feet	Therefore, the slope length =	593 ft	
W_e	Equipment Weight	0.0	pounds			
	Equipment width	0.0	width in feet			

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.17365	0.98481	0.17633

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**3.5**	**3.5**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**3.5**	**3.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	1.0	1.0



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 12,780.52 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 3,671.77 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

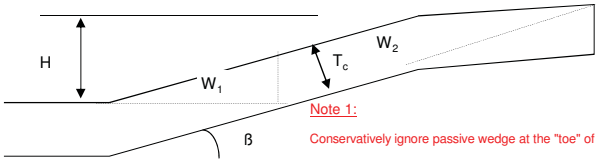
Comments: 5% Slopes; Long-Term; Static; Interface No. 3b (Textured FML); Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	2.9	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**28.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	30.0	feet	Therefore, the slope length = 593 ft	
W_e	Equipment Weight	0.0	pounds	A D7 bulldozer = 8236 lbs	
	Equipment width	0.0	width in feet	A D7 bulldozer = 12.9 ft	

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.46947	0.88295	0.53171

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**10.5**	**10.5**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**10.5**	**10.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	3.2	3.2



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 38,539.31 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 3,671.77 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

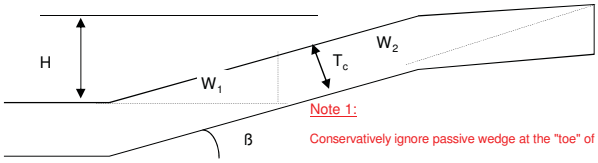
Comments: 5% Slopes; Long-Term; Static; Interface No. 3b (Textured FML); Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	2.9	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**22.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	30.0	feet	Therefore, the slope length = 593 ft	
W_e	Equipment Weight	0.0	pounds	A D7 bulldozer = 8236 lbs	
	Equipment width	0.0	width in feet	A D7 bulldozer = 12.9 ft	

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.37461	0.92718	0.40403

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**8.0**	**8.0**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**8.0**	**8.0**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	2.4	2.4



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 29,284.59 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 3,671.77 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

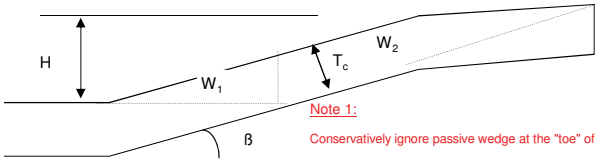
Comments: 5% Upper Slopes; Long-Term; Static; Interface No. 4; Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	2.9	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**30.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	30.0	feet	Therefore, the slope length =	593 ft
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.50000	0.86603	0.57735

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**11.4**	**11.4**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**11.4**	**11.4**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	3.4	3.4



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 41,847.45 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 3,671.77 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

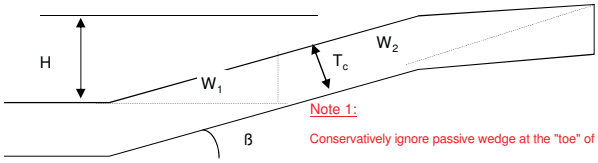
Comments: 5% Upper Slopes; Long-Term; Static; Interface No. 4; Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	2.9	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**28.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	30.0	feet	Therefore, the slope length =	593 ft
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.46947	0.88295	0.53171

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**10.5**	**10.5**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**10.5**	**10.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	3.2	3.2



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 38,539.31 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 3,671.77 + 0.00

ATTACHMENT L-4B

SPREADSHEET CALCULATOR OUTPUT
5% SLOPES

Critical Interface(s): Site-Specific Scenarios

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

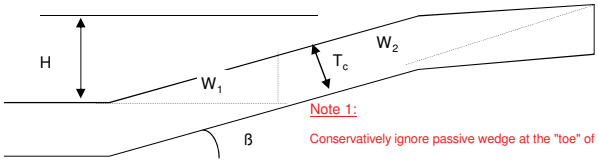
Comments: 5% Slopes; Long-Term; Static; Scenario No. 1; Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	2.9	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**10.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	30.0	feet	Therefore, the slope length = 593 ft	
W_e	Equipment Weight/Width	0.0	pounds/ft width		
	Equipment Length	0.0	Length in feet		

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.17365	0.98481	0.17633

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**3.5**	**3.5**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**3.5**	**3.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	1.0	1.0



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 12,780.52 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 3,671.77 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

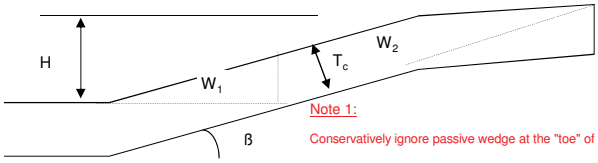
Comments: 5% Slopes; Long-Term; Static; Scenario No. 1; Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	2.9	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**10.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	30.0	feet	Therefore, the slope length =	593 ft
W_e	Equipment Weight/Width	0.0	pounds/ft width		
	Equipment Length	0.0	Length in feet		

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.17365	0.98481	0.17633

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**3.5**	**3.5**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**3.5**	**3.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	1.0	1.0



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 12,780.52 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 3,671.77 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

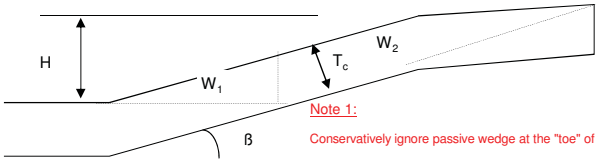
Comments: 5% Slopes; Long-Term; Seismic; Scenario No. 2; Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	2.9	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**10.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	30.0	feet	Therefore, the slope length = 593 ft	
W_e	Equipment Weight/Width	0.0	pounds/ft width		
	Equipment Length	0.0	Length in feet		

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.17365	0.98481	0.17633

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.4**	**1.4**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**3.5**	**3.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	1.0	1.0



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50 from USEPA RCRA Subtitle D (258), Seismic Design Guidance for Municipal Solid Waste Landfill Facilities, 1995
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 5443.11

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 12,780.52 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 3,671.77 + 5443.11

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

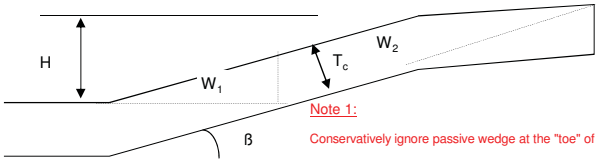
Comments: 5% Slopes; Long-Term; Seismic; Scenario No. 2; Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	2.9	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**10.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	30.0	feet	Therefore, the slope length = 593 ft	
W_e	Equipment Weight/Width	0.0	pounds/ft width		
	Equipment Length	0.0	Length in feet		

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.17365	0.98481	0.17633

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.4**	**1.4**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**3.5**	**3.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	1.0	1.0



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50 from USEPA RCRA Subtitle D (258), Seismic Design Guidance for Municipal Solid Waste Landfill Facilities, 1995
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 5443.11

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 12,780.52 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 3,671.77 + 5443.11

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

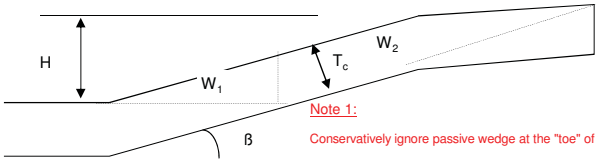
Comments: 5% Slopes; Construction; Static; Scenario No. 3; Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	2.9	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**10.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	30.0	feet	Therefore, the slope length = 593 ft	
W_e	Equipment Weight/Width	4400.0	pounds/ft width	A D6K2 bulldozer = 30,750 lbs (4,400 pounds per unit width)	
	Equipment Length	8.5	Length in feet	A D6K2 bulldozer = 8.5 ft	

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.17365	0.98481	0.17633

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**3.4**	**3.4**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**3.5**	**3.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	1.0	1.0



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 11.00 feet (assuming a 1:1 pressure distribution with depth)
W_e = 399.88 pounds per foot of slope width = equipment load/static weight
F_b = 119.97 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 12,780.52 + 70.42 + 0.00
Sum of Driving Forces = 0.00 + 140.20 + 3,671.77 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

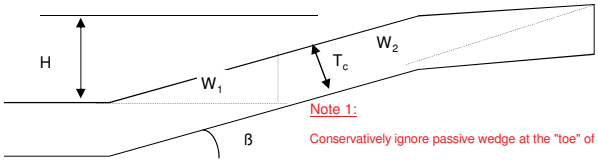
Comments: 5% Slopes; Construction; Static; Scenario No. 3; Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	2.9	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**10.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	30.0	feet	Therefore, the slope length = 593 ft	
W_e	Equipment Weight/Width	4400.0	pounds/ft width	A D6K2 bulldozer = 30,750 lbs (4,400 pounds per unit width)	
	Equipment Length	8.5	Length in feet	A D6K2 bulldozer = 8.5 ft	

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.17365	0.98481	0.17633

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**3.4**	**3.4**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**3.5**	**3.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	1.0	1.0



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 11.00 feet (assuming a 1:1 pressure distribution with depth)
W_e = 399.88 pounds per foot of slope width = equipment load/static weight
F_b = 119.97 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 12,780.52 + 70.42 + 0.00
Sum of Driving Forces = 0.00 + 140.20 + 3,671.77 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

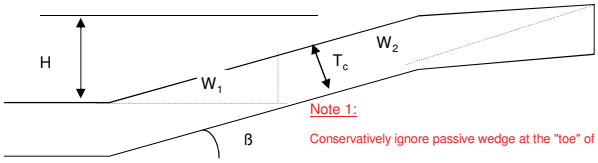
Comments: 5% Slopes; Construction; Seismic; Scenario No. 4; Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	2.9	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**10.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	30.0	feet	Therefore, the slope length = 593 ft	
W_e	Equipment Weight/Width	4400.0	pounds/ft width	A D6K2 bulldozer = 30,750 lbs (4,400 pounds per unit width)	
	Equipment Length	8.5	Length in feet	A D6K2 bulldozer = 8.5 ft	

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.17365	0.98481	0.17633

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**2.3**	**2.3**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**3.5**	**3.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	1.0	1.0



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 11.00 feet (assuming a 1:1 pressure distribution with depth)
W_e = 399.88 pounds per foot of slope width = equipment load/static weight
F_b = 119.97 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.050 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.025 seismic coefficient (a_{max} * K)
$k_s W_2$ = 1814.37

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 12,780.52 + 70.42 + 0.00
Sum of Driving Forces = 0.00 + 140.20 + 3,671.77 + 1814.37

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

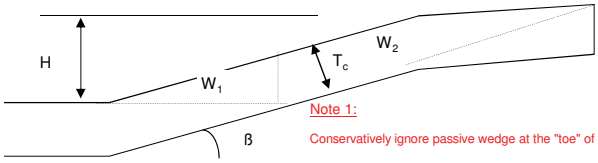
Comments: 5% Slopes; Construction; Seismic; Scenario No. 4; Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	2.9	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**10.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	30.0	feet	Therefore, the slope length = 593 ft	
W_e	Equipment Weight/Width	4400.0	pounds/ft width	A D6K2 bulldozer = 30,750 lbs (4,400 pounds per unit width)	
	Equipment Length	8.5	Length in feet	A D6K2 bulldozer = 8.5 ft	

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.17365	0.98481	0.17633

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**2.3**	**2.3**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**3.5**	**3.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	1.0	1.0



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

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Area of the load at interface = 11.00 feet (assuming a 1:1 pressure distribution with depth)
W_e = 399.88 pounds per foot of slope width = equipment load/static weight
F_b = 119.97 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.050 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.025 seismic coefficient (a_{max} * K)
$k_s W_2$ = 1814.37

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 12,780.52 + 70.42 + 0.00
Sum of Driving Forces = 0.00 + 140.20 + 3,671.77 + 1814.37

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

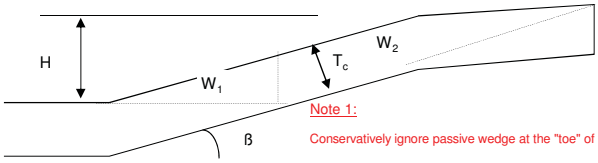
Comments: 5% Slopes; Transient (Saturated Cover); Static; Scenario No. 5; Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	125.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	2.9	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**10.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	30.0	feet	Therefore, the slope length = 593 ft	
W_e	Equipment Weight/Width	0.0	pounds/ft width		
	Equipment Length	0.0	Length in feet		

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.17365	0.98481	0.17633

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**3.5**	**3.5**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**3.5**	**3.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	1.7	1.7



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,932.71 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 90,718.56 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 15,975.64 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 4,589.72 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

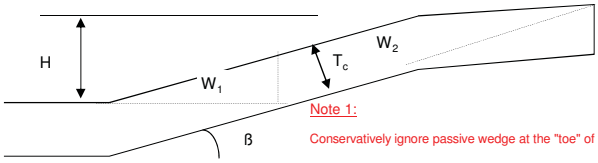
Comments: 5% Slopes; Transient (Saturated Cover); Static; Scenario No. 5; Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	125.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	2.9	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**10.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	30.0	feet	Therefore, the slope length =	593 ft
W_e	Equipment Weight/Width	0.0	pounds/ft width		
	Equipment Length	0.0	Length in feet		

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.17365	0.98481	0.17633

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**3.5**	**3.5**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**3.5**	**3.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	1.7	1.7



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

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Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 15,975.64 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 4,589.72 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

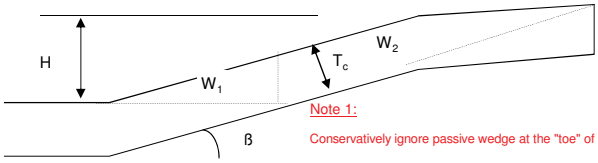
Comments: 5% Slopes; Transient (Partially Saturated Cover with Seepage); Static; Scenario No. 6; Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	125.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.6	feet		
ß	slope angle (beta)	2.9	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**10.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	30.0	feet	Therefore, the slope length = 593 ft	
W_e	Equipment Weight/Width	0.0	pounds/ft width		
	Equipment Length	0.0	Length in feet		

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.17365	0.98481	0.17633

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**2.8**	**2.8**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**3.5**	**3.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	1.7	1.7



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,932.71 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 90,718.56 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 1,091.38 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 15,975.64 + 0.00 + 0.00
Sum of Driving Forces = 1,091.38 + 0.00 + 4,589.72 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

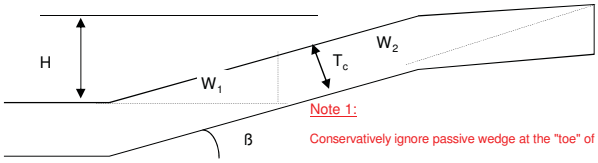
Comments: 5% Slopes; Transient (Partially Saturated Cover with Seepage); Static; Scenario No. 6; Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	125.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.6	feet		
ß	slope angle (beta)	2.9	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**10.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	30.0	feet	Therefore, the slope length = 593 ft	
W_e	Equipment Weight/Width	0.0	pounds/ft width		
	Equipment Length	0.0	Length in feet		

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.17365	0.98481	0.17633

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**2.8**	**2.8**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**3.5**	**3.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	1.7	1.7



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,932.71 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 90,718.56 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 1,091.38 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 15,975.64 + 0.00 + 0.00
Sum of Driving Forces = 1,091.38 + 0.00 + 4,589.72 + 0.00

ATTACHMENT L-4C

SPREADSHEET CALCULATOR OUTPUT
5% SLOPES

Interface Performance Requirements: Design Iterations

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

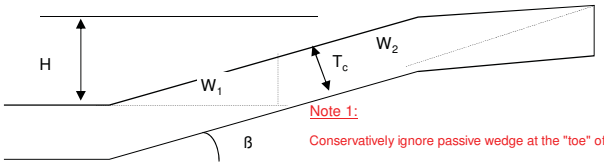
Comments: 5% Slopes; Long-Term; Seismic; Establish Design/Performance Requirements; Peak Strength; Iteration 1

		Inputs				
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore =	1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf			
γ_c	Weight of cover soil	100.0	pcf			
	Saturated weight of cover	125.0	pcf			
T_w	Thickness of seepage	0.0	feet			
ß	slope angle (beta)	2.9	degrees			
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).			
δ	Interface shear strength	**8.0**	degrees			
	Cohesion @ interface	**0.0**	psf			
	Cohesion of cover soil	0.0	psf			
H	Slope Height	30.0	feet	Therefore, the slope length =	593 ft	
W_e	Equipment Weight	0.0	pounds			
	Equipment width	0.0	width in feet			

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.13917	0.99027	0.14054

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.1**	**1.1**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**2.8**	**2.8**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.8	0.8



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 5443.11

Factor or Safety Methodology Summary:

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{\text{passive} + \text{center} + \text{equipment} + \text{cohesion}}{\text{seepage} + \text{equipment} + \text{center} + \text{seismic}}$$

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{0.00 + 10{,}186.67 + 0.00 + 0.00}{0.00 + 0.00 + 3{,}671.77 + 5443.11}$$

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

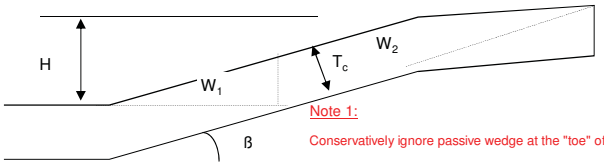
Comments: 5% Slopes; Long-Term; Seismic; Establish Design/Performance Requirements; Peak Strength; Iteration 2

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	2.9	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**5.5**	degrees		
	Cohesion @ interface	**5.0**	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	30.0	feet	Therefore, the slope length = 593 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.09585	0.99540	0.09629

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.8**	**1.1**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.8
Static	Infinite slope (interface, based on δ)	**1.9**	**2.7**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.6
Static	Infinite slope w/seepage (interface, based on δ)	0.6	1.2



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 2841.31 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
2841.31

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 5443.11

Factor or Safety Methodology Summary:

FS =	Sum of Resisting Forces	=	passive	+	center	+	equipment	+	cohesion
	Sum of Driving Forces	=	seepage	+	equipment	+	center	+	seismic
FS =	Sum of Resisting Forces	=	0.00	+	6,979.21	+	0.00	+	2,841.31
	Sum of Driving Forces	=	0.00	+	0.00	+	3,671.77	+	5443.11

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

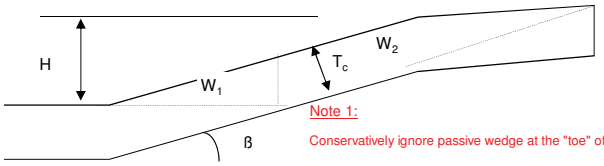
Comments: 5% Slopes; Long-Term; Seismic; Establish Design/Performance Requirements; Peak Strength; Iteration 3

		Inputs				
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore =	1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf			
γ_c	Weight of cover soil	100.0	pcf			
	Saturated weight of cover	125.0	pcf			
T_w	Thickness of seepage	0.0	feet			
ß	slope angle (beta)	2.9	degrees			
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).			
δ	Interface shear strength	**3.5**	degrees			
	Cohesion @ interface	**10.0**	psf			
	Cohesion of cover soil	0.0	psf			
H	Slope Height	30.0	feet	Therefore, the slope length =	593 ft	
W_e	Equipment Weight	0.0	pounds			
	Equipment width	0.0	width in feet			

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.06105	0.99813	0.06116

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.5**	**1.1**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	1.6
Static	Infinite slope (interface, based on δ)	**1.2**	**2.8**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	1.3
Static	Infinite slope w/seepage (interface, based on δ)	0.4	1.6



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 5682.61 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
5682.61

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 5443.11

Factor or Safety Methodology Summary:

FS =	Sum of Resisting Forces	=	passive	+	center	+	equipment	+	cohesion
	Sum of Driving Forces	=	seepage	+	equipment	+	center	+	seismic
FS =	Sum of Resisting Forces	=	0.00	+	4,433.18	+	0.00	+	5,682.61
	Sum of Driving Forces	=	0.00	+	0.00	+	3,671.77	+	5443.11

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

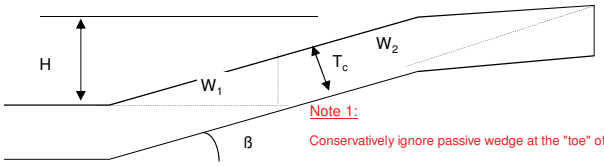
Comments: 5% Slopes; Long-Term; Seismic; Establish Design/Performance Requirements; Peak Strength; Iteration 4

		Inputs				
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore =	1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf			
γ_c	Weight of cover soil	100.0	pcf			
	Saturated weight of cover	125.0	pcf			
T_w	Thickness of seepage	0.0	feet			
ß	slope angle (beta)	2.9	degrees			
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).			
δ	Interface shear strength	**0.0**	degrees			
	Cohesion @ interface	**17.0**	psf			
	Cohesion of cover soil	0.0	psf			
H	Slope Height	30.0	feet	Therefore, the slope length =	593 ft	
W_e	Equipment Weight	0.0	pounds			
	Equipment width	0.0	width in feet			

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.00000	1.00000	0.00000

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.0**	**1.1**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	2.7
Static	Infinite slope (interface, based on δ)	**0.0**	**2.7**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	2.2
Static	Infinite slope w/seepage (interface, based on δ)	0.0	2.2



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 9660.44 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
9660.44

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 5443.11

Factor or Safety Methodology Summary:

FS =	Sum of Resisting Forces	=	passive	+	center	+	equipment	+	cohesion
	Sum of Driving Forces	=	seepage	+	equipment	+	center	+	seismic
FS =	Sum of Resisting Forces	=	0.00	+	0.00	+	0.00	+	9,660.44
	Sum of Driving Forces	=	0.00	+	0.00	+	3,671.77	+	5443.11

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

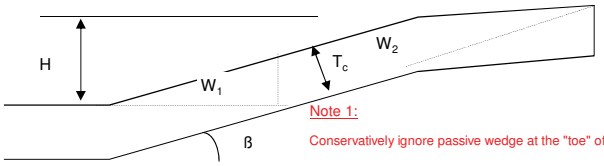
Comments: 5% Slopes; Long-Term; Seismic; Establish Design/Performance Requirements; Residual Strength; Iteration 1

		Inputs				
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore =	1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf			
γ_c	Weight of cover soil	100.0	pcf			
	Saturated weight of cover	125.0	pcf			
T_w	Thickness of seepage	0.0	feet			
ß	slope angle (beta)	2.9	degrees			
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).			
δ	Interface shear strength	**7.0**	degrees			
	Cohesion @ interface	**0.0**	psf			
	Cohesion of cover soil	0.0	psf			
H	Slope Height	30.0	feet	Therefore, the slope length =	593 ft	
W_e	Equipment Weight	0.0	pounds			
	Equipment width	0.0	width in feet			

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.12187	0.99255	0.12278

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.0**	**1.0**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**2.4**	**2.4**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.7	0.7



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 5443.11

Factor or Safety Methodology Summary:

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{\text{passive} + \text{center} + \text{equipment} + \text{cohesion}}{\text{seepage} + \text{equipment} + \text{center} + \text{seismic}}$$

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{0.00 + 8{,}899.66 + 0.00 + 0.00}{0.00 + 0.00 + 3{,}671.77 + 5443.11}$$

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

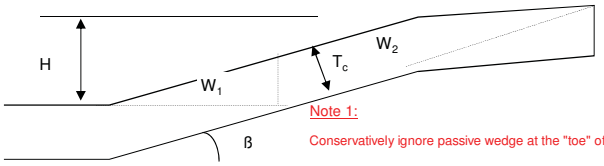
Comments: 5% Slopes; Long-Term; Seismic; Establish Design/Performance Requirements; Residual Strength; Iteration 2

		Inputs				
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore =	1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf			
γ_c	Weight of cover soil	100.0	pcf			
	Saturated weight of cover	125.0	pcf			
T_w	Thickness of seepage	0.0	feet			
ß	slope angle (beta)	2.9	degrees			
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).			
δ	Interface shear strength	**5.0**	degrees			
	Cohesion @ interface	**5.0**	psf			
	Cohesion of cover soil	0.0	psf			
H	Slope Height	30.0	feet	Therefore, the slope length =	593 ft	
W_e	Equipment Weight	0.0	pounds			
	Equipment width	0.0	width in feet			

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.08716	0.99619	0.08749

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.7**	**1.0**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.8
Static	Infinite slope (interface, based on δ)	**1.7**	**2.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.6
Static	Infinite slope w/seepage (interface, based on δ)	0.5	1.2



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 2841.31 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
2841.31

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 5443.11

Factor or Safety Methodology Summary:

FS =	Sum of Resisting Forces	=	passive	+	center	+	equipment	+	cohesion
	Sum of Driving Forces	=	seepage	+	equipment	+	center	+	seismic
FS =	Sum of Resisting Forces	=	0.00	+	6,341.34	+	0.00	+	2,841.31
	Sum of Driving Forces	=	0.00	+	0.00	+	3,671.77	+	5443.11

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

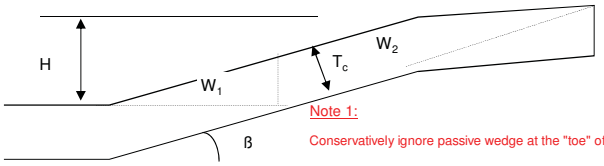
Comments: 5% Slopes; Long-Term; Seismic; Establish Design/Performance Requirements; Residual Strength; Iteration 3

		Inputs				
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore =	1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf			
γ_c	Weight of cover soil	100.0	pcf			
	Saturated weight of cover	125.0	pcf			
T_w	Thickness of seepage	0.0	feet			
ß	slope angle (beta)	2.9	degrees			
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).			
δ	Interface shear strength	**2.5**	degrees			
	Cohesion @ interface	**10.0**	psf			
	Cohesion of cover soil	0.0	psf			
H	Slope Height	30.0	feet	Therefore, the slope length =	593 ft	
W_e	Equipment Weight	0.0	pounds			
	Equipment width	0.0	width in feet			

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.04362	0.99905	0.04366

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.3**	**1.0**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	1.6
Static	Infinite slope (interface, based on δ)	**0.9**	**2.4**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	1.3
Static	Infinite slope w/seepage (interface, based on δ)	0.3	1.5



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 5682.61 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
5682.61

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 5443.11

Factor or Safety Methodology Summary:

FS =	Sum of Resisting Forces	=	passive	+	center	+	equipment	+	cohesion
	Sum of Driving Forces	=	seepage	+	equipment	+	center	+	seismic
FS =	Sum of Resisting Forces	=	0.00	+	3,164.63	+	0.00	+	5,682.61
	Sum of Driving Forces	=	0.00	+	0.00	+	3,671.77	+	5443.11

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

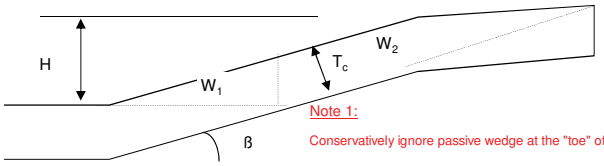
Comments: 5% Slopes; Long-Term; Seismic; Establish Design/Performance Requirements; Residual Strength; Iteration 4

		Inputs				
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore =	1.25 feet (vertical)
γ_w	Wt. of Water	62.4	pcf			
γ_c	Weight of cover soil	100.0	pcf			
	Saturated weight of cover	125.0	pcf			
T_w	Thickness of seepage	0.0	feet			
ß	slope angle (beta)	2.9	degrees			
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).			
δ	Interface shear strength	**0.0**	degrees			
	Cohesion @ interface	**15.5**	psf			
	Cohesion of cover soil	0.0	psf			
H	Slope Height	30.0	feet	Therefore, the slope length =	593 ft	
W_e	Equipment Weight	0.0	pounds			
	Equipment width	0.0	width in feet			

SIN	COS	TAN
0.05059	0.99872	0.05066
0.00000	1.00000	0.00000
0.00000	1.00000	0.00000

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.0**	**1.0**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	2.5
Static	Infinite slope (interface, based on δ)	**0.0**	**2.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	2.0
Static	Infinite slope w/seepage (interface, based on δ)	0.0	2.0



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 1,546.17 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 72,574.85 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.50 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 568.26 feet Interface cohesion = 8808.05 pounds per foot of slope width
Ltoe= 24.71 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
8808.05

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 5443.11

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 0.00 + 0.00 + 8,808.05
Sum of Driving Forces = 0.00 + 0.00 + 3,671.77 + 5443.11

ATTACHMENT L-5

SPREADSHEET CALCULATOR OUTPUT
20% SLOPES

ATTACHMENT L-5A

SPREADSHEET CALCULATOR OUTPUT
20% SLOPES

4 Interfaces: Long-Term Static Conditions

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

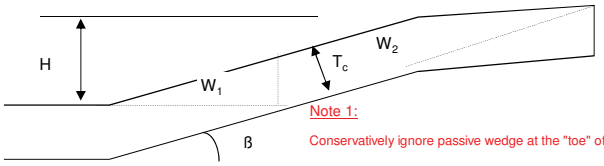
Comments: 20% Slopes; Long-Term; Static; Interface No. 1; Peak

		Inputs				
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore =	1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf			
γ_c	Weight of cover soil	100.0	pcf			
	Saturated weight of cover	125.0	pcf			
T_w	Thickness of seepage	0.0	feet			
ß	slope angle (beta)	11.3	degrees			
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).			
δ	Interface shear strength	**30.0**	degrees			
	Cohesion @ interface	0.0	psf			
	Cohesion of cover soil	0.0	psf			
H	Slope Height	40.0	feet	Therefore, the slope length =	204 ft	
W_e	Equipment Weight	0.0	pounds			
	Equipment width	0.0	width in feet			

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.50000	0.86603	0.57735

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**2.9**	**2.9**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**2.9**	**2.9**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.9	0.9



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 14,216.59 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 4,920.33 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

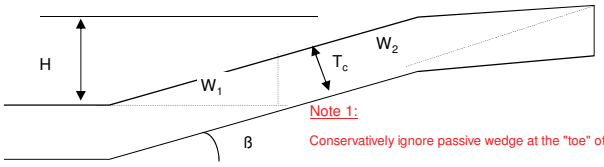
Comments: 20% Slopes; Long-Term; Static; Interface No. 1; Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**28.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.46947	0.88295	0.53171

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**2.7**	**2.7**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**2.7**	**2.7**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.8	0.8



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 13,092.73 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 4,920.33 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

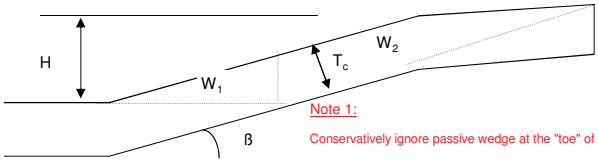
Comments: 20% Slopes; Long-Term; Static; Interface No. 2a (Smooth FML); Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**10.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.17365	0.98481	0.17633

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.9**	**0.9**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**0.9**	**0.9**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.3	0.3



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS =	Sum of Resisting Forces	=	passive	+	center	+	equipment	+	cohesion
	Sum of Driving Forces	=	seepage	+	equipment	+	center	+	seismic
FS =	Sum of Resisting Forces	=	0.00	+	4,341.85	+	0.00	+	0.00
	Sum of Driving Forces	=	0.00	+	0.00	+	4,920.33	+	0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

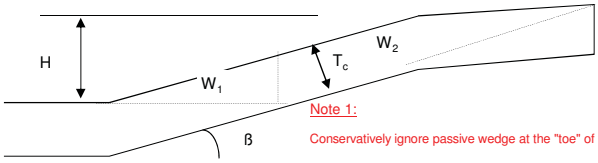
Comments: 20% Slopes; Long-Term; Static; Interface No. 2a (Smooth FML); Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**10.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.17365	0.98481	0.17633

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.9**	**0.9**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**0.9**	**0.9**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.3	0.3



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 4,341.85 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 4,920.33 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

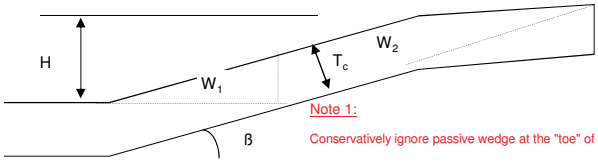
Comments: 20% Slopes; Long-Term; Static; Interface No. 2b (Textured FML); Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**28.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.46947	0.88295	0.53171

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**2.7**	**2.7**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**2.7**	**2.7**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.8	0.8



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 13,092.73 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 4,920.33 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

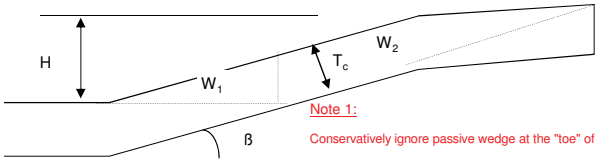
Comments: 20% Slopes; Long-Term; Static; Interface No. 2b (Textured FML); Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**22.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.37461	0.92718	0.40403

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**2.0**	**2.0**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**2.0**	**2.0**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.6	0.6



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS =	Sum of Resisting Forces	=	passive	+	center	+	equipment	+	cohesion
	Sum of Driving Forces	=	seepage	+	equipment	+	center	+	seismic
FS =	Sum of Resisting Forces	=	0.00	+	9,948.68	+	0.00	+	0.00
	Sum of Driving Forces	=	0.00	+	0.00	+	4,920.33	+	0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

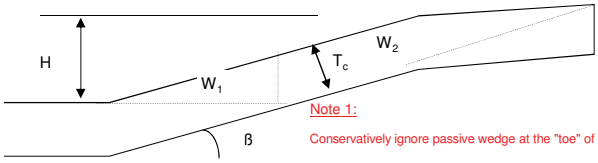
Comments: 20% Slopes; Long-Term; Static; Interface No. 3a (Smooth FML); Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**10.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.17365	0.98481	0.17633

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.9**	**0.9**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**0.9**	**0.9**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.3	0.3



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 4,341.85 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 4,920.33 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

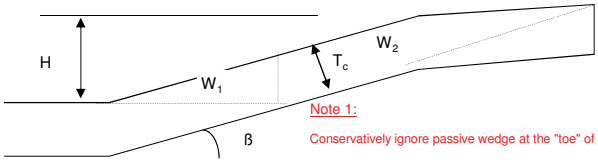
Comments: 20% Slopes; Long-Term; Static; Interface No. 3a (Smooth FML); Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**10.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.17365	0.98481	0.17633

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.9**	**0.9**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**0.9**	**0.9**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.3	0.3



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 4,341.85 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 4,920.33 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

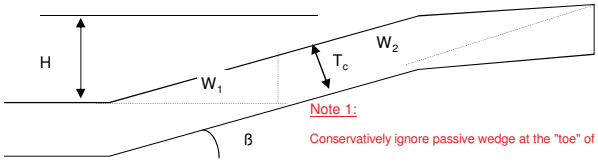
Comments: 20% Slopes; Long-Term; Static; Interface No. 3b (Textured FML); Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**28.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.46947	0.88295	0.53171

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**2.7**	**2.7**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**2.7**	**2.7**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.8	0.8



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 13,092.73 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 4,920.33 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

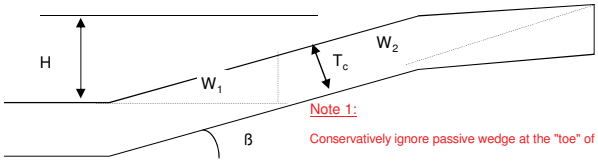
Comments: 20% Slopes; Long-Term; Static; Interface No. 3b (Textured FML); Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**22.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.37461	0.92718	0.40403

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**2.0**	**2.0**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**2.0**	**2.0**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.6	0.6



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

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W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

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Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS =	Sum of Resisting Forces	=	passive	+	center	+	equipment	+	cohesion
	Sum of Driving Forces	=	seepage	+	equipment	+	center	+	seismic
FS =	Sum of Resisting Forces	=	0.00	+	9,948.68	+	0.00	+	0.00
	Sum of Driving Forces	=	0.00	+	0.00	+	4,920.33	+	0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

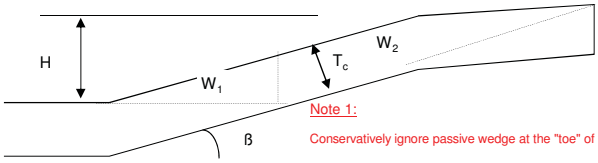
Comments: 20% Upper Slopes; Long-Term; Static; Interface No. 4; Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**30.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.50000	0.86603	0.57735

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**2.9**	**2.9**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**2.9**	**2.9**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.9	0.9



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 14,216.59 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 4,920.33 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

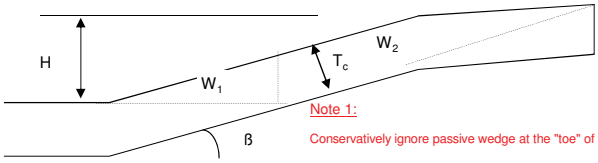
Comments: 20% Upper Slopes; Long-Term; Static; Interface No. 4; Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**28.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.46947	0.88295	0.53171

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**2.7**	**2.7**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**2.7**	**2.7**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.8	0.8



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 13,092.73 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 4,920.33 + 0.00

ATTACHMENT L-5B

SPREADSHEET CALCULATOR OUTPUT
20% SLOPES

Critical Interface(s): Site-Specific Scenarios

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

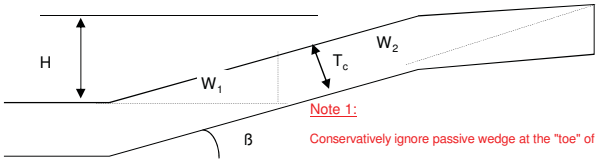
Comments: 20% Slopes; Long-Term; Static; Scenario No. 1; Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**28.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight/ft Width	0.0	pounds/ft width		
	Equipment Length	0.0	Length in feet		

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.46947	0.88295	0.53171

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**2.7**	**2.7**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**2.7**	**2.7**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.8	0.8



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 13,092.73 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 4,920.33 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

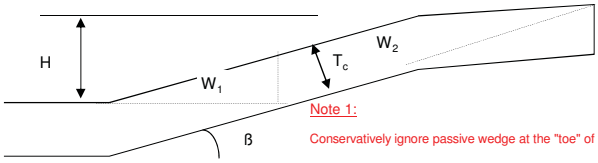
Comments: 20% Slopes; Long-Term; Static; Scenario No. 1; Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**22.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight/ft Width	0.0	pounds/ft width		
	Equipment Length	0.0	Length in feet		

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.37461	0.92718	0.40403

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**2.0**	**2.0**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**2.0**	**2.0**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.6	0.6



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS =	Sum of Resisting Forces	=	passive	+	center	+	equipment	+	cohesion
	Sum of Driving Forces	=	seepage	+	equipment	+	center	+	seismic
FS =	Sum of Resisting Forces	=	0.00	+	9,948.68	+	0.00	+	0.00
	Sum of Driving Forces	=	0.00	+	0.00	+	4,920.33	+	0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

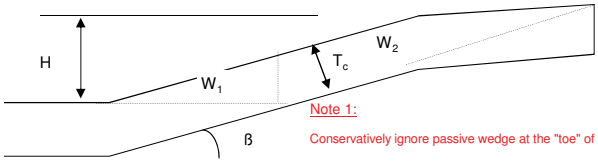
Comments: 20% Slopes; Long-Term; Seismic; Scenario No. 2; Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**28.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight/ft Width	0.0	pounds/ft width		
	Equipment Length	0.0	Length in feet		

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.46947	0.88295	0.53171

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.9**	**1.9**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**2.7**	**2.7**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.8	0.8



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50 from USEPA RCRA Subtitle D (258), Seismic Design Guidance for Municipal Solid Waste Landfill Facilities, 1995
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 1883.30

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 13,092.73 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 4,920.33 + 1883.30

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

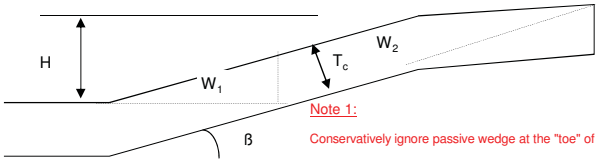
Comments: 20% Slopes; Long-Term; Seismic; Scenario No. 2; Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**22.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight/ft Width	0.0	pounds/ft width		
	Equipment Length	0.0	Length in feet		

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.37461	0.92718	0.40403

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.5**	**1.5**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**2.0**	**2.0**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.6	0.6



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50 from USEPA RCRA Subtitle D (258), Seismic Design Guidance for Municipal Solid Waste Landfill Facilities, 1995
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 1883.30

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 9,948.68 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 4,920.33 + 1883.30

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

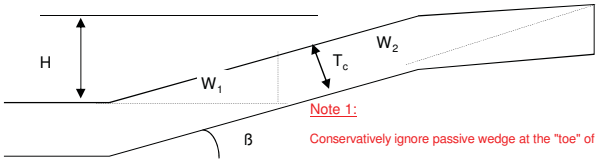
Comments: 20% Slopes; Construction; Static; Scenario No. 3; Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**28.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight/ft Width	4400.0	pounds/ft width	A D6K2 bulldozer = 30,750 lbs (4,400 pounds per unit width)	
	Equipment Length	8.5	Length in feet	A D6K2 bulldozer = 8.5 ft	

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.46947	0.88295	0.53171

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**2.6**	**2.6**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**2.7**	**2.7**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.8	0.8



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 11.05 feet (assuming a 1:1 pressure distribution with depth)
W_e = 398.21 pounds per foot of slope width = equipment load/static weight
F_b = 119.46 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 13,092.73 + 207.63 + 0.00
Sum of Driving Forces = 0.00 + 197.49 + 4,920.33 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

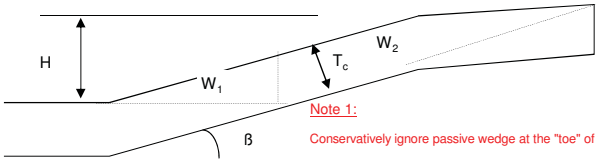
Comments: 20% Slopes; Construction; Static; Scenario No. 3; Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**22.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight/ft Width	4400.0	pounds/ft width	A D6K2 bulldozer = 30,750 lbs (4,400 pounds per unit width)	
	Equipment Length	8.5	Length in feet	A D6K2 bulldozer = 8.5 ft	

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.37461	0.92718	0.40403

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**2.0**	**2.0**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**2.0**	**2.0**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.6	0.6



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 11.05 feet (assuming a 1:1 pressure distribution with depth)
W_e = 398.21 pounds per foot of slope width = equipment load/static weight
F_b = 119.46 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 9,948.68 + 157.77 + 0.00
Sum of Driving Forces = 0.00 + 197.49 + 4,920.33 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

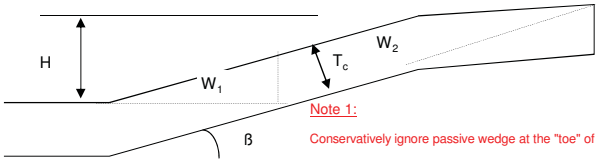
Comments: 20% Slopes; Construction; Seismic; Scenario No. 4; Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**28.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight/ft Width	4400.0	pounds/ft width	A D6K2 bulldozer = 30,750 lbs (4,400 pounds per unit width)	
	Equipment Length	8.5	Length in feet	A D6K2 bulldozer = 8.5 ft	

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.46947	0.88295	0.53171

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**2.3**	**2.3**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**2.7**	**2.7**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.8	0.8



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 11.05 feet (assuming a 1:1 pressure distribution with depth)
W_e = 398.21 pounds per foot of slope width = equipment load/static weight
F_b = 119.46 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.050 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.025 seismic coefficient (a_{max} * K)
$k_s W_2$ = 627.77

Factor or Safety Methodology Summary:

FS =	Sum of Resisting Forces	=	passive	+	center	+	equipment	+	cohesion
	Sum of Driving Forces	=	seepage	+	equipment	+	center	+	seismic
FS =	Sum of Resisting Forces	=	0.00	+	13,092.73	+	207.63	+	0.00
	Sum of Driving Forces	=	0.00	+	197.49	+	4,920.33	+	627.77

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

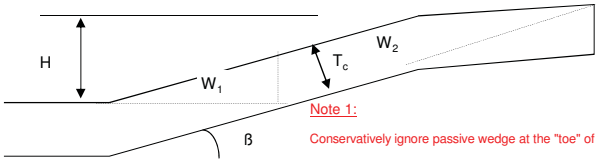
Comments: 20% Slopes; Construction; Seismic; Scenario No. 4; Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**22.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight/ft Width	4400.0	pounds/ft width	A D6K2 bulldozer = 30,750 lbs (4,400 pounds per unit width)	
	Equipment Length	8.5	Length in feet	A D6K2 bulldozer = 8.5 ft	

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.37461	0.92718	0.40403

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.8**	**1.8**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**2.0**	**2.0**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.6	0.6



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 11.05 feet (assuming a 1:1 pressure distribution with depth)
W_e = 398.21 pounds per foot of slope width = equipment load/static weight
F_b = 119.46 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.050 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.025 seismic coefficient (a_{max} * K)
$k_s W_2$ = 627.77

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 9,948.68 + 157.77 + 0.00
Sum of Driving Forces = 0.00 + 197.49 + 4,920.33 + 627.77

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

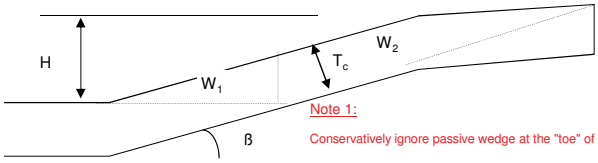
Comments: 20% Slopes; Transient (Saturated Cover); Static; Scenario No. 5; Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	125.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**28.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight/ft Width	0.0	pounds/ft width		
	Equipment Length	0.0	Length in feet		

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.46947	0.88295	0.53171

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**2.7**	**2.7**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**2.7**	**2.7**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	1.3	1.3



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 508.24 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 31,388.28 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 16,365.92 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 6,150.41 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

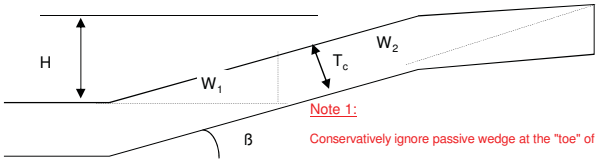
Comments: 20% Slopes; Transient (Saturated Cover); Static; Scenario No. 5; Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	125.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**22.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight/ft Width	0.0	pounds/ft width		
	Equipment Length	0.0	Length in feet		

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.37461	0.92718	0.40403

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**2.0**	**2.0**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**2.0**	**2.0**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	1.0	1.0



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 508.24 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 31,388.28 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 12,435.85 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 6,150.41 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

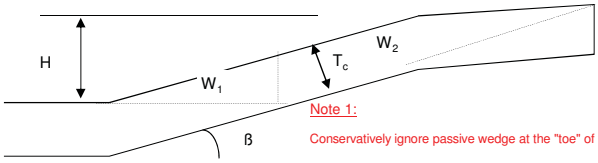
Comments: 20% Slopes; Transient (Partially Saturated Cover with Seepage); Static; Scenario No. 6; Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	125.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.08	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**28.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight/ft Width	0.0	pounds/ft width		
	Equipment Length	0.0	Length in feet		

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.46947	0.88295	0.53171

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**2.6**	**2.6**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**2.7**	**2.7**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	1.3	1.3



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 508.24 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 31,388.28 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 207.17 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 16,365.92 + 0.00 + 0.00
Sum of Driving Forces = 207.17 + 0.00 + 6,150.41 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

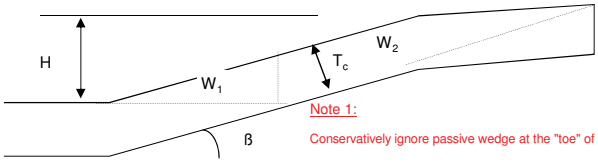
Comments: 20% Slopes; Transient (Partially Saturated Cover with Seepage); Static; Scenario No. 6; Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	125.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.08	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**22.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight/ft Width	0.0	pounds/ft width		
	Equipment Length	0.0	Length in feet		

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.37461	0.92718	0.40403

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**2.0**	**2.0**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**2.0**	**2.0**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	1.0	1.0



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 508.24 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 31,388.28 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 207.17 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS =	Sum of Resisting Forces	=	passive	+	center	+	equipment	+	cohesion
	Sum of Driving Forces	=	seepage	+	equipment	+	center	+	seismic
FS =	Sum of Resisting Forces	=	0.00	+	12,435.85	+	0.00	+	0.00
	Sum of Driving Forces	=	207.17	+	0.00	+	6,150.41	+	0.00

ATTACHMENT L-5C

SPREADSHEET CALCULATOR OUTPUT
20% SLOPES

Interface Performance Requirements: Design Iterations

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project:	Callahan Mine Superfund Site	Project Number:	3612112201	Calcs:	NDL
	Brooksville, Maine	Date:	09/2014	Chk'd:	SJR

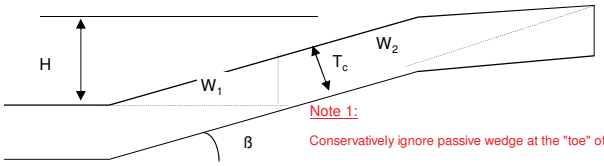
Comments: 20% Slopes; Long-Term; Seismic; Establish Design/Performance Requirements; Peak Strength; Iteration 1

		Inputs				
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore =	1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf			
γ_c	Weight of cover soil	100.0	pcf			
	Saturated weight of cover	125.0	pcf			
T_w	Thickness of seepage	0.0	feet			
ß	slope angle (beta)	11.3	degrees			
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).			
δ	Interface shear strength	**16.5**	degrees			
	Cohesion @ interface	**0.0**	psf			
	Cohesion of cover soil	0.0	psf			
H	Slope Height	40.0	feet	Therefore, the slope length =	204 ft	
W_e	Equipment Weight	0.0	pounds			
	Equipment width	0.0	width in feet			

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.28402	0.95882	0.29621

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.1**	**1.1**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**1.5**	**1.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.4	0.4



Note 1:

Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 =	406.59	pounds per foot of slope width	= weight of passive wedge/toe buttress
W_2 =	25,110.63	pounds per foot of slope width	= weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface =	2.55	feet	(assuming a 1:1 pressure distribution with depth)
W_e =	0.00	pounds per foot of slope width	= equipment load/static weight
F_b =	0.00	pounds per foot of slope width	= equipment braking force (30% of equipment weight)
			From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs =	0.00	pounds per foot of slope width	= seepage force (Stamatopoulos)

Cohesion Force:

Lc =	197.76	feet	Interface cohesion =	0.00	pounds per foot of slope width
Ltoe=	6.38	feet	Toe/soil cohesion =	0.00	pounds per foot of slope width
				0.00	

Seismic Force

a_{max} =	0.150	a_{max} = peak horiz. ground acceleration @ Site
K =	0.50	
k_s =	0.075	seismic coefficient (a_{max} * K)
$k_s W_2$ =	1883.30	

Factor or Safety Methodology Summary:

FS =	Sum of Resisting Forces	=	passive	+	center	+	equipment	+	cohesion
	Sum of Driving Forces	=	seepage	+	equipment	+	center	+	seismic
FS =	Sum of Resisting Forces	=	0.00	+	7,293.92	+	0.00	+	0.00
	Sum of Driving Forces	=	0.00	+	0.00	+	4,920.33	+	1883.30

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

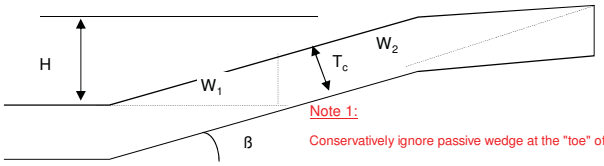
Comments: 20% Slopes; Long-Term; Seismic; Establish Design/Performance Requirements; Peak Strength; Iteration 2

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**11.0**	degrees		
	Cohesion @ interface	**12.0**	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.19081	0.98163	0.19438

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.7**	**1.1**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.5
Static	Infinite slope (interface, based on δ)	**1.0**	**1.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.4
Static	Infinite slope w/seepage (interface, based on δ)	0.3	0.7



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 2373.10 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
2373.10

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 1883.30

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 4,786.39 + 0.00 + 2,373.10
Sum of Driving Forces = 0.00 + 0.00 + 4,920.33 + 1883.30

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

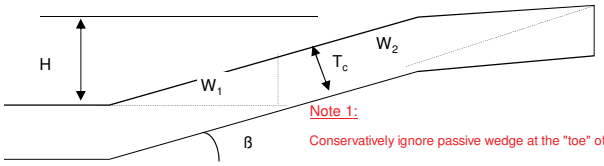
Comments: 20% Slopes; Long-Term; Seismic; Establish Design/Performance Requirements; Peak Strength; Iteration 3

		Inputs				
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore =	1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf			
γ_c	Weight of cover soil	100.0	pcf			
	Saturated weight of cover	125.0	pcf			
T_w	Thickness of seepage	0.0	feet			
ß	slope angle (beta)	11.3	degrees			
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).			
δ	Interface shear strength	**6.0**	degrees			
	Cohesion @ interface	**24.0**	psf			
	Cohesion of cover soil	0.0	psf			
H	Slope Height	40.0	feet	Therefore, the slope length =	204 ft	
W_e	Equipment Weight	0.0	pounds			
	Equipment width	0.0	width in feet			

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.10453	0.99452	0.10510

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.4**	**1.1**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	1.0
Static	Infinite slope (interface, based on δ)	**0.5**	**1.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.8
Static	Infinite slope w/seepage (interface, based on δ)	0.2	0.9



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 4746.20 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
4746.20

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 1883.30

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces / Sum of Driving Forces = passive + center + equipment + cohesion / seepage + equipment + center + seismic

FS = Sum of Resisting Forces / Sum of Driving Forces = 0.00 + 2,588.07 + 0.00 + 4,746.20 / 0.00 + 0.00 + 4,920.33 + 1883.30

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

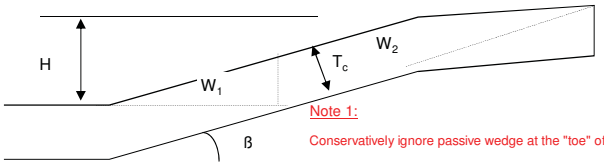
Comments: 20% Slopes; Long-Term; Seismic; Establish Design/Performance Requirements; Peak Strength; Iteration 4

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**0.0**	degrees		
	Cohesion @ interface	**36.5**	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.00000	1.00000	0.00000

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.0**	**1.1**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	1.5
Static	Infinite slope (interface, based on δ)	**0.0**	**1.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	1.2
Static	Infinite slope w/seepage (interface, based on δ)	0.0	1.2



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 7218.18 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
7218.18

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 1883.30

Factor or Safety Methodology Summary:

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{\text{passive} + \text{center} + \text{equipment} + \text{cohesion}}{\text{seepage} + \text{equipment} + \text{center} + \text{seismic}}$$

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{0.00 + 0.00 + 0.00 + 7{,}218.18}{0.00 + 0.00 + 4{,}920.33 + 1883.30}$$

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

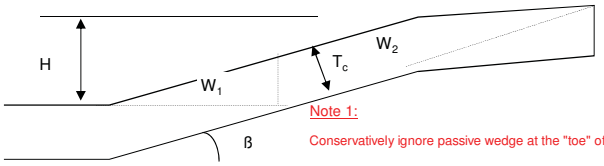
Comments: 20% Slopes; Long-Term; Seismic; Establish Design/Performance Requirements; Residual Strength; Iteration 1

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**15.0**	degrees		
	Cohesion @ interface	**0.0**	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.25882	0.96593	0.26795

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.0**	**1.0**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**1.3**	**1.3**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.4	0.4



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 1883.30

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 0.00 + 6,597.94 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 4,920.33 + 1883.30

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

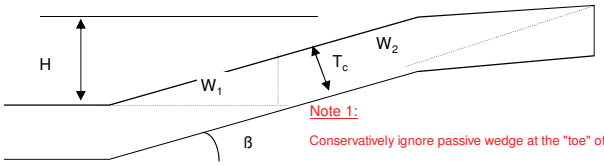
Comments: 20% Slopes; Long-Term; Seismic; Establish Design/Performance Requirements; Residual Strength; Iteration 2

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**10.0**	degrees		
	Cohesion @ interface	**11.0**	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.17365	0.98481	0.17633

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.6**	**1.0**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.4
Static	Infinite slope (interface, based on δ)	**0.9**	**1.3**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.4
Static	Infinite slope w/seepage (interface, based on δ)	0.3	0.6



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 2175.34 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
2175.34

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 1883.30

Factor or Safety Methodology Summary:

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{\text{passive} + \text{center} + \text{equipment} + \text{cohesion}}{\text{seepage} + \text{equipment} + \text{center} + \text{seismic}}$$

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{0.00 + 4{,}341.85 + 0.00 + 2{,}175.34}{0.00 + 0.00 + 4{,}920.33 + 1883.30}$$

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

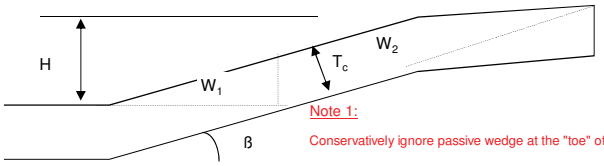
Comments: 20% Slopes; Long-Term; Seismic; Establish Design/Performance Requirements; Residual Strength; Iteration 3

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**5.0**	degrees		
	Cohesion @ interface	**22.0**	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.08716	0.99619	0.08749

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.3**	**1.0**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.9
Static	Infinite slope (interface, based on δ)	**0.4**	**1.3**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.7
Static	Infinite slope w/seepage (interface, based on δ)	0.1	0.9



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 4350.69 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
4350.69

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 1883.30

Factor or Safety Methodology Summary:

FS =	Sum of Resisting Forces	=	passive	+	center	+	equipment	+	cohesion
	Sum of Driving Forces	=	seepage	+	equipment	+	center	+	seismic
FS =	Sum of Resisting Forces	=	0.00	+	2,154.31	+	0.00	+	4,350.69
	Sum of Driving Forces	=	0.00	+	0.00	+	4,920.33	+	1883.30

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

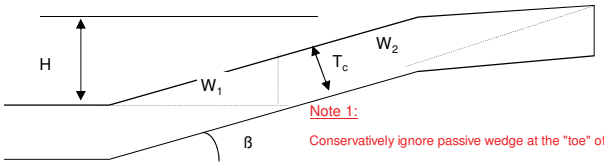
Comments: 20% Slopes; Long-Term; Seismic; Establish Design/Performance Requirements; Residual Strength; Iteration 4

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.27 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	11.3	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**0.0**	degrees		
	Cohesion @ interface	**33.0**	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	40.0	feet	Therefore, the slope length = 204 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.19595	0.98061	0.19982
0.00000	1.00000	0.00000
0.00000	1.00000	0.00000

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.0**	**1.0**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	1.3
Static	Infinite slope (interface, based on δ)	**0.0**	**1.3**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	1.1
Static	Infinite slope w/seepage (interface, based on δ)	0.0	1.1



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 406.59 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 25,110.63 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.55 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 197.76 feet Interface cohesion = 6526.03 pounds per foot of slope width
Ltoe= 6.38 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
6526.03

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 1883.30

Factor or Safety Methodology Summary:

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{\text{passive} + \text{center} + \text{equipment} + \text{cohesion}}{\text{seepage} + \text{equipment} + \text{center} + \text{seismic}}$$

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{0.00 + 0.00 + 0.00 + 6{,}526.03}{0.00 + 0.00 + 4{,}920.33 + 1883.30}$$

ATTACHMENT L-6

SPREADSHEET CALCULATOR OUTPUT
33.3% SLOPES

ATTACHMENT L-6A

SPREADSHEET CALCULATOR OUTPUT
33.3% SLOPES

4 Interfaces: Long-Term Static Conditions

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

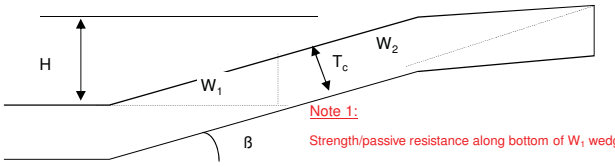
Comments: 33.3% Slopes; Long-Term; Static; Interface No. 1; Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	18.4	degrees		
ϕ	Soil shear strength	41.0	degrees (See Note 1 below).		
δ	Interface shear strength	**30.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	14.0	feet	Therefore, the slope length = 44 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.31565	0.94888	0.33266
0.65606	0.75471	0.86929
0.50000	0.86603	0.57735

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.9**	**1.9**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	2.6	2.6
Static	Infinite slope (interface, based on δ)	**1.7**	**1.7**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.8	0.8
Static	Infinite slope w/seepage (interface, based on δ)	0.5	0.5



Note 1:
Strength/passive resistance along bottom of W_1 wedge based on soil shear strength.

Weights of wedges (Drushel Methodology):

W_1 = 260.84 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 5,283.29 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.63 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 226.75 + 2,894.37 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 1,667.67 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

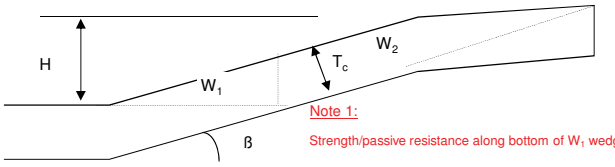
Comments: 33.3% Slopes; Long-Term; Static; Interface No. 1; Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	18.4	degrees		
ϕ	Soil shear strength	41.0	degrees (See Note 1 below).		
δ	Interface shear strength	**28.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	14.0	feet	Therefore, the slope length = 44 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.31565	0.94888	0.33266
0.65606	0.75471	0.86929
0.46947	0.88295	0.53171

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.7**	**1.7**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	2.6	2.6
Static	Infinite slope (interface, based on δ)	**1.6**	**1.6**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.8	0.8
Static	Infinite slope w/seepage (interface, based on δ)	0.5	0.5



Note 1:
Strength/passive resistance along bottom of W_1 wedge based on soil shear strength.

Weights of wedges (Drushel Methodology):

W_1 = 260.84 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 5,283.29 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.63 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 226.75 + 2,665.56 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 1,667.67 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

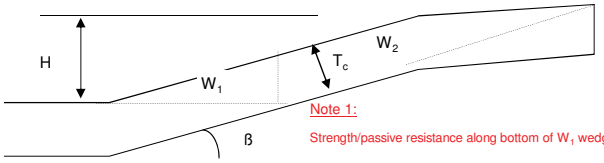
Comments: 33.3% Slopes; Long-Term; Static; Interface No. 2a (Smooth FML); Peak

		Inputs				
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore =	1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf			
γ_c	Weight of cover soil	100.0	pcf			
	Saturated weight of cover	125.0	pcf			
T_w	Thickness of seepage	0.0	feet			
ß	slope angle (beta)	18.4	degrees			
ϕ	Soil shear strength	41.0	degrees (See Note 1 below).			
δ	Interface shear strength	**10.0**	degrees			
	Cohesion @ interface	0.0	psf			
	Cohesion of cover soil	0.0	psf			
H	Slope Height	14.0	feet	Therefore, the slope length =	44 ft	
W_e	Equipment Weight	0.0	pounds			
	Equipment width	0.0	width in feet			

SIN	COS	TAN
0.31565	0.94888	0.33266
0.65606	0.75471	0.86929
0.17365	0.98481	0.17633

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.7**	**0.7**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	2.6	2.6
Static	Infinite slope (interface, based on δ)	**0.5**	**0.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.8	0.8
Static	Infinite slope w/seepage (interface, based on δ)	0.2	0.2



Note 1:
Strength/passive resistance along bottom of W_1 wedge based on soil shear strength.

Weights of wedges (Drushel Methodology):

W_1 = 260.84 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 5,283.29 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.63 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 226.75 + 883.96 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 1,667.67 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

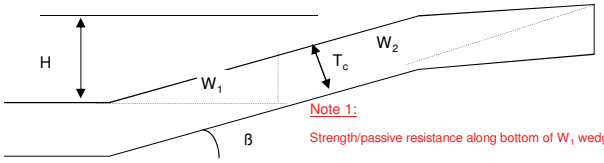
Comments: 33.3% Slopes; Long-Term; Static; Interface No. 2a (Smooth FML); Residual

		Inputs				
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore =	1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf			
γ_c	Weight of cover soil	100.0	pcf			
	Saturated weight of cover	125.0	pcf			
T_w	Thickness of seepage	0.0	feet			
ß	slope angle (beta)	18.4	degrees			
ϕ	Soil shear strength	41.0	degrees (See Note 1 below).			
δ	Interface shear strength	**10.0**	degrees			
	Cohesion @ interface	0.0	psf			
	Cohesion of cover soil	0.0	psf			
H	Slope Height	14.0	feet	Therefore, the slope length =	44 ft	
W_e	Equipment Weight	0.0	pounds			
	Equipment width	0.0	width in feet			

SIN	COS	TAN
0.31565	0.94888	0.33266
0.65606	0.75471	0.86929
0.17365	0.98481	0.17633

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.7**	**0.7**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	2.6	2.6
Static	Infinite slope (interface, based on δ)	**0.5**	**0.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.8	0.8
Static	Infinite slope w/seepage (interface, based on δ)	0.2	0.2



Note 1:
Strength/passive resistance along bottom of W_1 wedge based on soil shear strength.

Weights of wedges (Drushel Methodology):

W_1 = 260.84 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 5,283.29 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.63 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 226.75 + 883.96 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 1,667.67 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

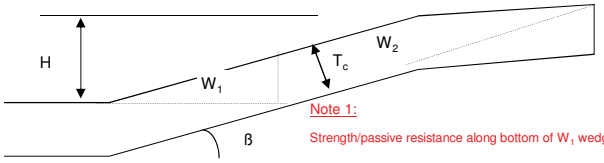
Comments: 33.3% Slopes; Long-Term; Static; Interface No. 2b (Textured FML); Peak

		Inputs				
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore =	1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf			
γ_c	Weight of cover soil	100.0	pcf			
	Saturated weight of cover	125.0	pcf			
T_w	Thickness of seepage	0.0	feet			
ß	slope angle (beta)	18.4	degrees			
ϕ	Soil shear strength	41.0	degrees (See Note 1 below).			
δ	Interface shear strength	**28.0**	degrees			
	Cohesion @ interface	0.0	psf			
	Cohesion of cover soil	0.0	psf			
H	Slope Height	14.0	feet	Therefore, the slope length =	44 ft	
W_e	Equipment Weight	0.0	pounds			
	Equipment width	0.0	width in feet			

SIN	COS	TAN
0.31565	0.94888	0.33266
0.65606	0.75471	0.86929
0.46947	0.88295	0.53171

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.7**	**1.7**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	2.6	2.6
Static	Infinite slope (interface, based on δ)	**1.6**	**1.6**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.8	0.8
Static	Infinite slope w/seepage (interface, based on δ)	0.5	0.5



Note 1:
Strength/passive resistance along bottom of W_1 wedge based on soil shear strength.

Weights of wedges (Drushel Methodology):

W_1 = 260.84 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 5,283.29 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.63 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 226.75 + 2,665.56 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 1,667.67 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

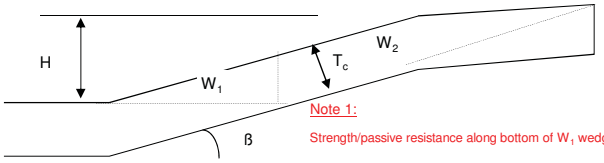
Comments: 33.3% Slopes; Long-Term; Static; Interface No. 2b (Textured FML); Residual

		Inputs				
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore =	1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf			
γ_c	Weight of cover soil	100.0	pcf			
	Saturated weight of cover	125.0	pcf			
T_w	Thickness of seepage	0.0	feet			
ß	slope angle (beta)	18.4	degrees			
ϕ	Soil shear strength	41.0	degrees (See Note 1 below).			
δ	Interface shear strength	**22.0**	degrees			
	Cohesion @ interface	0.0	psf			
	Cohesion of cover soil	0.0	psf			
H	Slope Height	14.0	feet	Therefore, the slope length =	44 ft	
W_e	Equipment Weight	0.0	pounds			
	Equipment width	0.0	width in feet			

SIN	COS	TAN
0.31565	0.94888	0.33266
0.65606	0.75471	0.86929
0.37461	0.92718	0.40403

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.4**	**1.4**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	2.6	2.6
Static	Infinite slope (interface, based on δ)	**1.2**	**1.2**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.8	0.8
Static	Infinite slope w/seepage (interface, based on δ)	0.4	0.4



Note 1:
Strength/passive resistance along bottom of W_1 wedge based on soil shear strength.

Weights of wedges (Drushel Methodology):

W_1 = 260.84 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 5,283.29 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.63 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 226.75 + 2,025.46 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 1,667.67 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

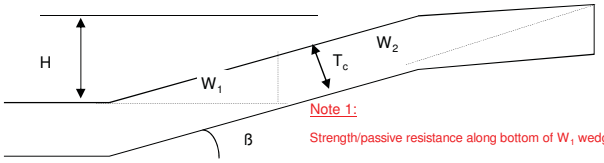
Comments: 33.3% Slopes; Long-Term; Static; Interface No. 3a (Smooth FML); Peak

		Inputs				
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore =	1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf			
γ_c	Weight of cover soil	100.0	pcf			
	Saturated weight of cover	125.0	pcf			
T_w	Thickness of seepage	0.0	feet			
ß	slope angle (beta)	18.4	degrees			
ϕ	Soil shear strength	41.0	degrees (See Note 1 below).			
δ	Interface shear strength	**10.0**	degrees			
	Cohesion @ interface	0.0	psf			
	Cohesion of cover soil	0.0	psf			
H	Slope Height	14.0	feet	Therefore, the slope length =	44 ft	
W_e	Equipment Weight	0.0	pounds			
	Equipment width	0.0	width in feet			

SIN	COS	TAN
0.31565	0.94888	0.33266
0.65606	0.75471	0.86929
0.17365	0.98481	0.17633

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.7**	**0.7**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	2.6	2.6
Static	Infinite slope (interface, based on δ)	**0.5**	**0.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.8	0.8
Static	Infinite slope w/seepage (interface, based on δ)	0.2	0.2



Note 1:
Strength/passive resistance along bottom of W_1 wedge based on soil shear strength.

Weights of wedges (Drushel Methodology):

W_1 = 260.84 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 5,283.29 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.63 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 226.75 + 883.96 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 1,667.67 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

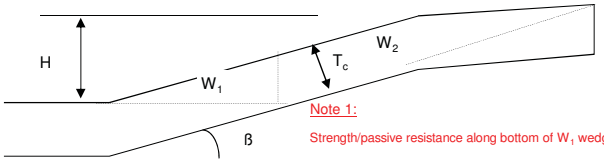
Comments: 33.3% Slopes; Long-Term; Static; Interface No. 3a (Smooth FML); Residual

		Inputs				
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore =	1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf			
γ_c	Weight of cover soil	100.0	pcf			
	Saturated weight of cover	125.0	pcf			
T_w	Thickness of seepage	0.0	feet			
ß	slope angle (beta)	18.4	degrees			
ϕ	Soil shear strength	41.0	degrees (See Note 1 below).			
δ	Interface shear strength	**10.0**	degrees			
	Cohesion @ interface	0.0	psf			
	Cohesion of cover soil	0.0	psf			
H	Slope Height	14.0	feet	Therefore, the slope length =	44 ft	
W_e	Equipment Weight	0.0	pounds			
	Equipment width	0.0	width in feet			

SIN	COS	TAN
0.31565	0.94888	0.33266
0.65606	0.75471	0.86929
0.17365	0.98481	0.17633

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.7**	**0.7**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	2.6	2.6
Static	Infinite slope (interface, based on δ)	**0.5**	**0.5**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.8	0.8
Static	Infinite slope w/seepage (interface, based on δ)	0.2	0.2



Note 1:
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0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 226.75 + 883.96 + 0.00 + 0.00
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This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

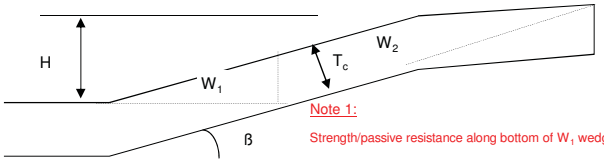
Comments: 33.3% Slopes; Long-Term; Static; Interface No. 3b (Textured FML); Peak

		Inputs				
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore =	1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf			
γ_c	Weight of cover soil	100.0	pcf			
	Saturated weight of cover	125.0	pcf			
T_w	Thickness of seepage	0.0	feet			
ß	slope angle (beta)	18.4	degrees			
ϕ	Soil shear strength	41.0	degrees (See Note 1 below).			
δ	Interface shear strength	**28.0**	degrees			
	Cohesion @ interface	0.0	psf			
	Cohesion of cover soil	0.0	psf			
H	Slope Height	14.0	feet	Therefore, the slope length =	44 ft	
W_e	Equipment Weight	0.0	pounds			
	Equipment width	0.0	width in feet			

SIN	COS	TAN
0.31565	0.94888	0.33266
0.65606	0.75471	0.86929
0.46947	0.88295	0.53171

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.7**	**1.7**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	2.6	2.6
Static	Infinite slope (interface, based on δ)	**1.6**	**1.6**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.8	0.8
Static	Infinite slope w/seepage (interface, based on δ)	0.5	0.5



Note 1:
Strength/passive resistance along bottom of W_1 wedge based on soil shear strength.

Weights of wedges (Drushel Methodology):

W_1 = 260.84 pounds per foot of slope width = weight of passive wedge/toe buttress
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Area of the load at interface = 2.63 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 226.75 + 2,665.56 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 1,667.67 + 0.00

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INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

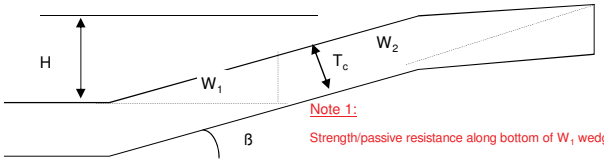
Comments: 33.3% Slopes; Long-Term; Static; Interface No. 3b (Textured FML); Residual

		Inputs				
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore =	1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf			
γ_c	Weight of cover soil	100.0	pcf			
	Saturated weight of cover	125.0	pcf			
T_w	Thickness of seepage	0.0	feet			
ß	slope angle (beta)	18.4	degrees			
ϕ	Soil shear strength	41.0	degrees (See Note 1 below).			
δ	Interface shear strength	**22.0**	degrees			
	Cohesion @ interface	0.0	psf			
	Cohesion of cover soil	0.0	psf			
H	Slope Height	14.0	feet	Therefore, the slope length =	44 ft	
W_e	Equipment Weight	0.0	pounds			
	Equipment width	0.0	width in feet			

SIN	COS	TAN
0.31565	0.94888	0.33266
0.65606	0.75471	0.86929
0.37461	0.92718	0.40403

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.4**	**1.4**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	2.6	2.6
Static	Infinite slope (interface, based on δ)	**1.2**	**1.2**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.8	0.8
Static	Infinite slope w/seepage (interface, based on δ)	0.4	0.4



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Strength/passive resistance along bottom of W_1 wedge based on soil shear strength.

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From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 226.75 + 2,025.46 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 1,667.67 + 0.00

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INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

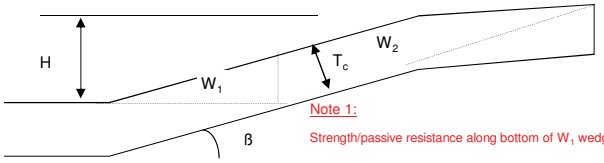
Comments: 33.3% Upper Slopes; Long-Term; Static; Interface No. 4; Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	18.4	degrees		
ϕ	Soil shear strength	41.0	degrees (See Note 1 below).		
δ	Interface shear strength	**30.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	14.0	feet	Therefore, the slope length = 44 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.31565	0.94888	0.33266
0.65606	0.75471	0.86929
0.50000	0.86603	0.57735

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.9**	**1.9**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	2.6	2.6
Static	Infinite slope (interface, based on δ)	**1.7**	**1.7**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.8	0.8
Static	Infinite slope w/seepage (interface, based on δ)	0.5	0.5



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Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 226.75 + 2,894.37 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 1,667.67 + 0.00

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γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
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ϕ	Soil shear strength	41.0	degrees (See Note 1 below).		
δ	Interface shear strength	**28.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	14.0	feet	Therefore, the slope length = 44 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.31565	0.94888	0.33266
0.65606	0.75471	0.86929
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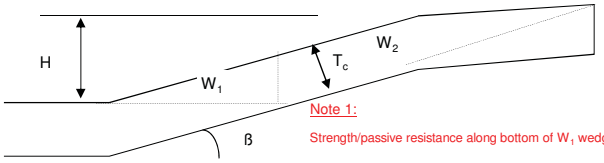
CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.7**	**1.7**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	2.6	2.6
Static	Infinite slope (interface, based on δ)	**1.6**	**1.6**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.8	0.8
Static	Infinite slope w/seepage (interface, based on δ)	0.5	0.5



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Seismic Force

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K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 226.75 + 2,665.56 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 1,667.67 + 0.00

ATTACHMENT L-6B

SPREADSHEET CALCULATOR OUTPUT
33.3% SLOPES

Critical Interface(s): Site-Specific Scenarios

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

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Brooksville, ME

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Date: 09/2014

Calcs: NDL
Chk'd: SJR

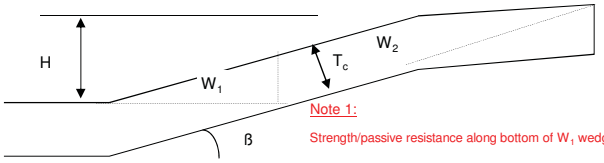
Comments: 33.3% Slopes; Long-Term; Static; Scenario No. 1; Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	18.4	degrees		
ϕ	Soil shear strength	41.0	degrees (See Note 1 below).		
δ	Interface shear strength	**28.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	14.0	feet	Therefore, the slope length =	44 ft
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.31565	0.94888	0.33266
0.65606	0.75471	0.86929
0.46947	0.88295	0.53171

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.7**	**1.7**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	2.6	2.6
Static	Infinite slope (interface, based on δ)	**1.6**	**1.6**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.8	0.8
Static	Infinite slope w/seepage (interface, based on δ)	0.5	0.5



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Seismic Force

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K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 226.75 + 2,665.56 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 1,667.67 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

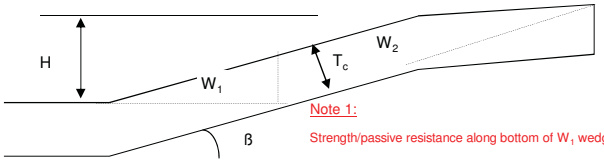
Comments: 33.3% Slopes; Long-Term; Static; Scenario No. 1; Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	18.4	degrees		
ϕ	Soil shear strength	41.0	degrees (See Note 1 below).		
δ	Interface shear strength	**22.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	14.0	feet	Therefore, the slope length = 44 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.31565	0.94888	0.33266
0.65606	0.75471	0.86929
0.37461	0.92718	0.40403

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.4**	**1.4**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	2.6	2.6
Static	Infinite slope (interface, based on δ)	**1.2**	**1.2**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.8	0.8
Static	Infinite slope w/seepage (interface, based on δ)	0.4	0.4



Note 1:
Strength/passive resistance along bottom of W_1 wedge based on soil shear strength.

Weights of wedges (Drushel Methodology):

W_1 = 260.84 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 5,283.29 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.63 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 226.75 + 2,025.46 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 1,667.67 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

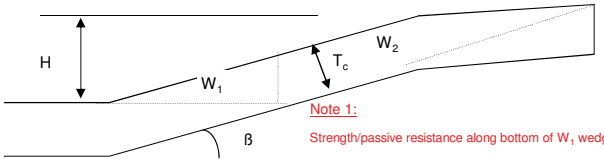
Comments: 33.3% Slopes; Long-Term; Seismic; Scenario No. 2; Peak

		Inputs				
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore =	1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf			
γ_c	Weight of cover soil	100.0	pcf			
	Saturated weight of cover	125.0	pcf			
T_w	Thickness of seepage	0.0	feet			
ß	slope angle (beta)	18.4	degrees			
ϕ	Soil shear strength	41.0	degrees (See Note 1 below).			
δ	Interface shear strength	**28.0**	degrees			
	Cohesion @ interface	0.0	psf			
	Cohesion of cover soil	0.0	psf			
H	Slope Height	14.0	feet	Therefore, the slope length =	44 ft	
W_e	Equipment Weight	0.0	pounds			
	Equipment width	0.0	width in feet			

SIN	COS	TAN
0.31565	0.94888	0.33266
0.65606	0.75471	0.86929
0.46947	0.88295	0.53171

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.4**	**1.4**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	2.6	2.6
Static	Infinite slope (interface, based on δ)	**1.6**	**1.6**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.8	0.8
Static	Infinite slope w/seepage (interface, based on δ)	0.5	0.5



Note 1:
Strength/passive resistance along bottom of W_1 wedge based on soil shear strength.

Weights of wedges (Drushel Methodology):

W_1 = 260.84 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 5,283.29 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.63 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50 from USEPA RCRA Subtitle D (258), Seismic Design Guidance for Municipal Solid Waste Landfill Facilities, 1995
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 396.25

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 226.75 + 2,665.56 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 1,667.67 + 396.25

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

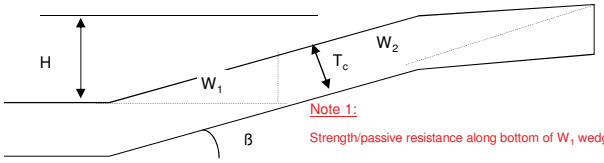
Comments: 33.3% Slopes; Long-Term; Seismic; Scenario No. 2; Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	18.4	degrees		
ϕ	Soil shear strength	41.0	degrees (See Note 1 below).		
δ	Interface shear strength	**22.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	14.0	feet	Therefore, the slope length =	44 ft
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.31565	0.94888	0.33266
0.65606	0.75471	0.86929
0.37461	0.92718	0.40403

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.1**	**1.1**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	2.6	2.6
Static	Infinite slope (interface, based on δ)	**1.2**	**1.2**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.8	0.8
Static	Infinite slope w/seepage (interface, based on δ)	0.4	0.4



Note 1:
Strength/passive resistance along bottom of W_1 wedge based on soil shear strength.

Weights of wedges (Drushel Methodology):

W_1 = 260.84 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 5,283.29 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.63 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50 from USEPA RCRA Subtitle D (258), Seismic Design Guidance for Municipal Solid Waste Landfill Facilities, 1995
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 396.25

Factor or Safety Methodology Summary:

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{\text{passive} + \text{center} + \text{equipment} + \text{cohesion}}{\text{seepage} + \text{equipment} + \text{center} + \text{seismic}}$$

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{226.75 + 2{,}025.46 + 0.00 + 0.00}{0.00 + 0.00 + 1{,}667.67 + 396.25}$$

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

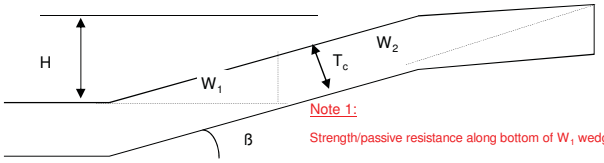
Comments: 33.3% Slopes; Construction; Static; Scenario No. 3; Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	18.4	degrees		
ϕ	Soil shear strength	41.0	degrees (See Note 1 below).		
δ	Interface shear strength	**28.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	14.0	feet	Therefore, the slope length = 44 ft	
W_e	Equipment Weight/Width	4400.0	pounds/ft width	A D6K2 bulldozer = 30,750 lbs (4,400 pounds per unit width)	
	Equipment Length	8.5	length in feet	A D6K2 bulldozer = 8.5 ft	

SIN	COS	TAN
0.31565	0.94888	0.33266
0.65606	0.75471	0.86929
0.46947	0.88295	0.53171

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.6**	**1.6**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	2.6	2.6
Static	Infinite slope (interface, based on δ)	**1.6**	**1.6**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.8	0.8
Static	Infinite slope w/seepage (interface, based on δ)	0.5	0.5



Note 1:
Strength/passive resistance along bottom of W_1 wedge based on soil shear strength.

Weights of wedges (Drushel Methodology):

W_1 = 260.84 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 5,283.29 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 11.13 feet (assuming a 1:1 pressure distribution with depth)
W_e = 395.16 pounds per foot of slope width = equipment load/static weight
F_b = 118.55 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 226.75 + 2,665.56 + 199.37 + 0.00
Sum of Driving Forces = 0.00 + 243.28 + 1,667.67 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

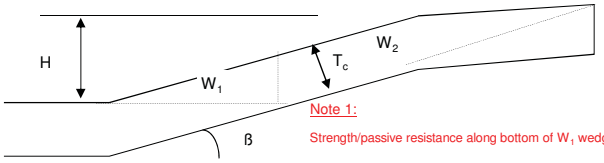
Comments: 33.3% Slopes; Construction; Static; Scenario No. 3; Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	18.4	degrees		
ϕ	Soil shear strength	41.0	degrees (See Note 1 below).		
δ	Interface shear strength	**22.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	14.0	feet	Therefore, the slope length = 44 ft	
W_e	Equipment Weight/Width	4400.0	pounds/ft width	A D6K2 bulldozer = 30,750 lbs (4,400 pounds per unit width)	
	Equipment Length	8.5	length in feet	A D6K2 bulldozer = 8.5 ft	

SIN	COS	TAN
0.31565	0.94888	0.33266
0.65606	0.75471	0.86929
0.37461	0.92718	0.40403

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.3**	**1.3**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	2.6	2.6
Static	Infinite slope (interface, based on δ)	**1.2**	**1.2**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.8	0.8
Static	Infinite slope w/seepage (interface, based on δ)	0.4	0.4



Note 1:
Strength/passive resistance along bottom of W_1 wedge based on soil shear strength.

Weights of wedges (Drushel Methodology):

W_1 = 260.84 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 5,283.29 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 11.13 feet (assuming a 1:1 pressure distribution with depth)
W_e = 395.16 pounds per foot of slope width = equipment load/static weight
F_b = 118.55 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 226.75 + 2,025.46 + 151.49 + 0.00
Sum of Driving Forces = 0.00 + 243.28 + 1,667.67 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

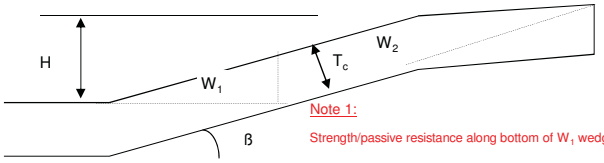
Comments: 33.3% Slopes; Construction; Seismic; Scenario No. 4; Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	18.4	degrees		
ϕ	Soil shear strength	41.0	degrees (See Note 1 below).		
δ	Interface shear strength	**28.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	14.0	feet	Therefore, the slope length = 44 ft	
W_e	Equipment Weight/Width	4400.0	pounds/ft width	A D6K2 bulldozer = 30,750 lbs (4,400 pounds per unit width)	
	Equipment Length	8.5	length in feet	A D6K2 bulldozer = 8.5 ft	

SIN	COS	TAN
0.31565	0.94888	0.33266
0.65606	0.75471	0.86929
0.46947	0.88295	0.53171

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.5**	**1.5**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	2.6	2.6
Static	Infinite slope (interface, based on δ)	**1.6**	**1.6**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.8	0.8
Static	Infinite slope w/seepage (interface, based on δ)	0.5	0.5



Note 1:
Strength/passive resistance along bottom of W_1 wedge based on soil shear strength.

Weights of wedges (Drushel Methodology):

W_1 = 260.84 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 5,283.29 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 11.13 feet (assuming a 1:1 pressure distribution with depth)
W_e = 395.16 pounds per foot of slope width = equipment load/static weight
F_b = 118.55 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.050 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.025 seismic coefficient (a_{max} * K)
$k_s W_2$ = 132.08

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 226.75 + 2,665.56 + 199.37 + 0.00
Sum of Driving Forces = 0.00 + 243.28 + 1,667.67 + 132.08

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

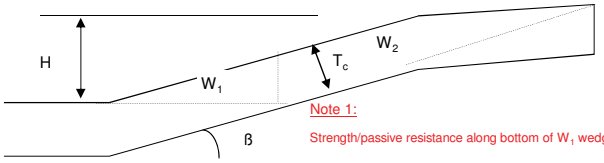
Comments: 33.3% Slopes; Construction; Seismic; Scenario No. 4; Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	18.4	degrees		
ϕ	Soil shear strength	41.0	degrees (See Note 1 below).		
δ	Interface shear strength	**22.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	14.0	feet	Therefore, the slope length = 44 ft	
W_e	Equipment Weight/Width	4400.0	pounds/ft width	A D6K2 bulldozer = 30,750 lbs (4,400 pounds per unit width)	
	Equipment Length	8.5	length in feet	A D6K2 bulldozer = 8.5 ft	

SIN	COS	TAN
0.31565	0.94888	0.33266
0.65606	0.75471	0.86929
0.37461	0.92718	0.40403

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.2**	**1.2**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	2.6	2.6
Static	Infinite slope (interface, based on δ)	**1.2**	**1.2**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.8	0.8
Static	Infinite slope w/seepage (interface, based on δ)	0.4	0.4



Note 1:
Strength/passive resistance along bottom of W_1 wedge based on soil shear strength.

Weights of wedges (Drushel Methodology):

W_1 = 260.84 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 5,283.29 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 11.13 feet (assuming a 1:1 pressure distribution with depth)
W_e = 395.16 pounds per foot of slope width = equipment load/static weight
F_b = 118.55 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.050 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.025 seismic coefficient (a_{max} * K)
$k_s W_2$ = 132.08

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 226.75 + 2,025.46 + 151.49 + 0.00
Sum of Driving Forces = 0.00 + 243.28 + 1,667.67 + 132.08

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

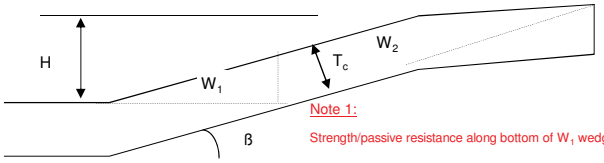
Comments: 33.3% Slopes; Transient (Saturated Cover); Static; Scenario No. 5; Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	125.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	18.4	degrees		
ϕ	Soil shear strength	41.0	degrees (See Note 1 below).		
δ	Interface shear strength	**28.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	14.0	feet	Therefore, the slope length =	44 ft
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.31565	0.94888	0.33266
0.65606	0.75471	0.86929
0.46947	0.88295	0.53171

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.7**	**1.7**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	2.6	2.6
Static	Infinite slope (interface, based on δ)	**1.6**	**1.6**
Static	Infinite slope w/seepage (soil, based on ϕ)	1.3	1.3
Static	Infinite slope w/seepage (interface, based on δ)	0.8	0.8



Note 1:
Strength/passive resistance along bottom of W_1 wedge based on soil shear strength.

Weights of wedges (Drushel Methodology):

W_1 = 326.05 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 6,604.11 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.63 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 283.43 + 3,331.95 + 0.00 + 0.00
Sum of Driving Forces = 0.00 + 0.00 + 2,084.58 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

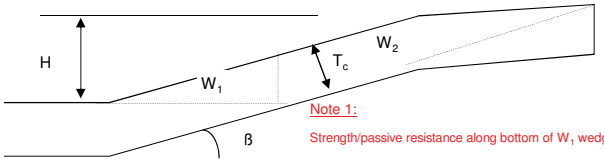
Comments: 33.3% Slopes; Transient (Saturated Cover); Static; Scenario No. 5; Residual

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	125.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	18.4	degrees		
ϕ	Soil shear strength	41.0	degrees (See Note 1 below).		
δ	Interface shear strength	**22.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	14.0	feet	Therefore, the slope length = 44 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.31565	0.94888	0.33266
0.65606	0.75471	0.86929
0.37461	0.92718	0.40403

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.4**	**1.4**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	2.6	2.6
Static	Infinite slope (interface, based on δ)	**1.2**	**1.2**
Static	Infinite slope w/seepage (soil, based on ϕ)	1.3	1.3
Static	Infinite slope w/seepage (interface, based on δ)	0.6	0.6



Note 1:
Strength/passive resistance along bottom of W_1 wedge based on soil shear strength.

Weights of wedges (Drushel Methodology):

W_1 = 326.05 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 6,604.11 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.63 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS =	Sum of Resisting Forces	=	passive	+	center	+	equipment	+	cohesion
	Sum of Driving Forces	=	seepage	+	equipment	+	center	+	seismic
FS =	Sum of Resisting Forces	=	283.43	+	2,531.82	+	0.00	+	0.00
	Sum of Driving Forces	=	0.00	+	0.00	+	2,084.58	+	0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

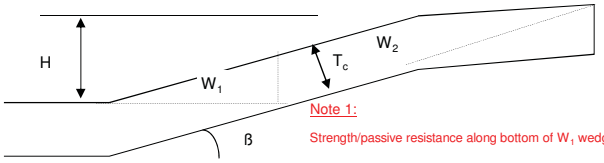
Comments: 33.3% Slopes; Transient (Partially Saturated Cover with Seepage); Static; Scenario No. 6; Peak

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	125.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.04	feet		
ß	slope angle (beta)	18.4	degrees		
ϕ	Soil shear strength	41.0	degrees	(See Note 1 below).	
δ	Interface shear strength	**28.0**	degrees		
	Cohesion @ interface	0.0	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	14.0	feet	Therefore, the slope length = 44 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.31565	0.94888	0.33266
0.65606	0.75471	0.86929
0.46947	0.88295	0.53171

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.7**	**1.7**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	2.6	2.6
Static	Infinite slope (interface, based on δ)	**1.6**	**1.6**
Static	Infinite slope w/seepage (soil, based on ϕ)	1.3	1.3
Static	Infinite slope w/seepage (interface, based on δ)	0.8	0.8



Note 1:
Strength/passive resistance along bottom of W_1 wedge based on soil shear strength.

Weights of wedges (Drushel Methodology):

W_1 = 326.05 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 6,604.11 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.63 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 36.69 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 283.43 + 3,331.95 + 0.00 + 0.00
Sum of Driving Forces = 36.69 + 0.00 + 2,084.58 + 0.00

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, ME

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

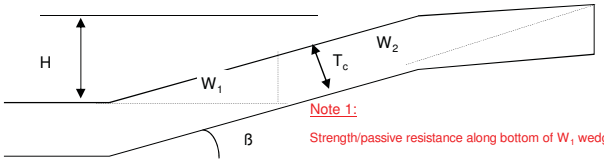
Comments: 33.3% Slopes; Transient (Partially Saturated Cover with Seepage); Static; Scenario No. 6; Residual

		Inputs				
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore =	1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf			
γ_c	Weight of cover soil	125.0	pcf			
	Saturated weight of cover	125.0	pcf			
T_w	Thickness of seepage	0.04	feet			
ß	slope angle (beta)	18.4	degrees			
ϕ	Soil shear strength	41.0	degrees (See Note 1 below).			
δ	Interface shear strength	**22.0**	degrees			
	Cohesion @ interface	0.0	psf			
	Cohesion of cover soil	0.0	psf			
H	Slope Height	14.0	feet	Therefore, the slope length =	44 ft	
W_e	Equipment Weight	0.0	pounds			
	Equipment width	0.0	width in feet			

SIN	COS	TAN
0.31565	0.94888	0.33266
0.65606	0.75471	0.86929
0.37461	0.92718	0.40403

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.3**	**1.3**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	2.6	2.6
Static	Infinite slope (interface, based on δ)	**1.2**	**1.2**
Static	Infinite slope w/seepage (soil, based on ϕ)	1.3	1.3
Static	Infinite slope w/seepage (interface, based on δ)	0.6	0.6



Note 1:
Strength/passive resistance along bottom of W_1 wedge based on soil shear strength.

Weights of wedges (Drushel Methodology):

W_1 = 326.05 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 6,604.11 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.63 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 36.69 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.000 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.000 seismic coefficient (a_{max} * K)
$k_s W_2$ = 0.00

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces = passive + center + equipment + cohesion
Sum of Driving Forces = seepage + equipment + center + seismic

FS = Sum of Resisting Forces = 283.43 + 2,531.82 + 0.00 + 0.00
Sum of Driving Forces = 36.69 + 0.00 + 2,084.58 + 0.00

ATTACHMENT L-6C

SPREADSHEET CALCULATOR OUTPUT
33.3% SLOPES

Interface Performance Requirements: Design Iterations

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

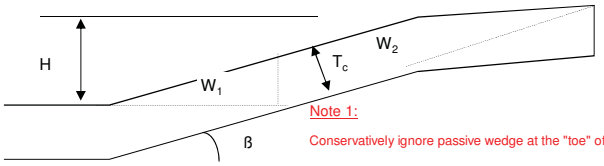
Comments: 33.3% Slopes; Long-Term; Seismic; Establish Design/Performance Requirements; Peak Strength; Iteration 1

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	18.4	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**23.5**	degrees		
	Cohesion @ interface	**0.0**	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	14.0	feet	Therefore, the slope length = 44 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.31565	0.94888	0.33266
0.00000	1.00000	0.00000
0.39875	0.91706	0.43481

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.1**	**1.1**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**1.3**	**1.3**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.4	0.4



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 260.84 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 5,283.29 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.63 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 396.25

Factor or Safety Methodology Summary:

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{\text{passive} + \text{center} + \text{equipment} + \text{cohesion}}{\text{seepage} + \text{equipment} + \text{center} + \text{seismic}}$$

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{0.00 + 2{,}179.80 + 0.00 + 0.00}{0.00 + 0.00 + 1{,}667.67 + 396.25}$$

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

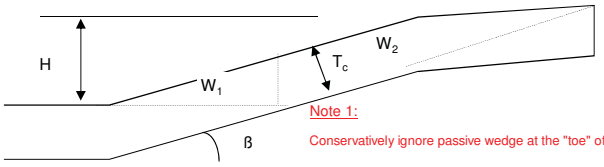
Comments: 33.3% Slopes; Long-Term; Seismic; Establish Design/Performance Requirements; Peak Strength; Iteration 2

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	18.4	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**16.5**	degrees		
	Cohesion @ interface	**18.0**	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	14.0	feet	Therefore, the slope length = 44 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.31565	0.94888	0.33266
0.00000	1.00000	0.00000
0.28402	0.95882	0.29621

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.7**	**1.1**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.5
Static	Infinite slope (interface, based on δ)	**0.9**	**1.3**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.4
Static	Infinite slope w/seepage (interface, based on δ)	0.3	0.6



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 260.84 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 5,283.29 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.63 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 727.07 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
727.07

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 396.25

Factor or Safety Methodology Summary:

FS =	Sum of Resisting Forces	=	passive	+	center	+	equipment	+	cohesion
	Sum of Driving Forces	=	seepage	+	equipment	+	center	+	seismic
FS =	Sum of Resisting Forces	=	0.00	+	1,484.97	+	0.00	+	727.07
	Sum of Driving Forces	=	0.00	+	0.00	+	1,667.67	+	396.25

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

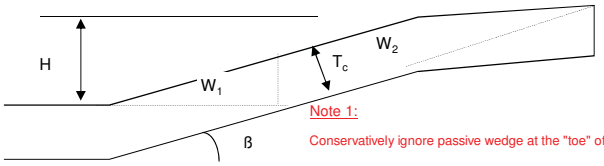
Comments: 33.3% Slopes; Long-Term; Seismic; Establish Design/Performance Requirements; Peak Strength; Iteration 3

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	18.4	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**8.5**	degrees		
	Cohesion @ interface	**36.0**	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	14.0	feet	Therefore, the slope length = 44 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.31565	0.94888	0.33266
0.00000	1.00000	0.00000
0.14781	0.98902	0.14945

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.4**	**1.1**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.9
Static	Infinite slope (interface, based on δ)	**0.4**	**1.4**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.7
Static	Infinite slope w/seepage (interface, based on δ)	0.1	0.9



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 260.84 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 5,283.29 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.63 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 1454.15 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
1454.15

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 396.25

Factor or Safety Methodology Summary:

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{\text{passive} + \text{center} + \text{equipment} + \text{cohesion}}{\text{seepage} + \text{equipment} + \text{center} + \text{seismic}}$$

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{0.00 + 749.23 + 0.00 + 1{,}454.15}{0.00 + 0.00 + 1{,}667.67 + 396.25}$$

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

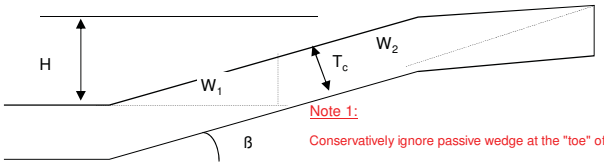
Comments: 33.3% Slopes; Long-Term; Seismic; Establish Design/Performance Requirements; Peak Strength; Iteration 4

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	18.4	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**0.0**	degrees		
	Cohesion @ interface	**54.0**	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	14.0	feet	Therefore, the slope length = 44 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.31565	0.94888	0.33266
0.00000	1.00000	0.00000
0.00000	1.00000	0.00000

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.0**	**1.1**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	1.4
Static	Infinite slope (interface, based on δ)	**0.0**	**1.4**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	1.1
Static	Infinite slope w/seepage (interface, based on δ)	0.0	1.1



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 260.84 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 5,283.29 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.63 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 2181.22 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
2181.22

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 396.25

Factor or Safety Methodology Summary:

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{\text{passive} + \text{center} + \text{equipment} + \text{cohesion}}{\text{seepage} + \text{equipment} + \text{center} + \text{seismic}}$$

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{0.00 + 0.00 + 0.00 + 2{,}181.22}{0.00 + 0.00 + 1{,}667.67 + 396.25}$$

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

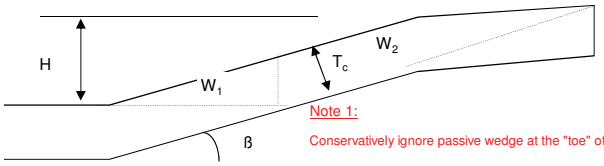
Comments: 33.3% Slopes; Long-Term; Seismic; Establish Design/Performance Requirements; Residual Strength; Iteration 1

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	18.4	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**21.5**	degrees		
	Cohesion @ interface	**0.0**	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	14.0	feet	Therefore, the slope length = 44 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.31565	0.94888	0.33266
0.00000	1.00000	0.00000
0.36650	0.93042	0.39391

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**1.0**	**1.0**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.0
Static	Infinite slope (interface, based on δ)	**1.2**	**1.2**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.0
Static	Infinite slope w/seepage (interface, based on δ)	0.4	0.4



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 260.84 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 5,283.29 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.63 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 0.00 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
0.00

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 396.25

Factor or Safety Methodology Summary:

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{\text{passive} + \text{center} + \text{equipment} + \text{cohesion}}{\text{seepage} + \text{equipment} + \text{center} + \text{seismic}}$$

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{0.00 + 1{,}974.75 + 0.00 + 0.00}{0.00 + 0.00 + 1{,}667.67 + 396.25}$$

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

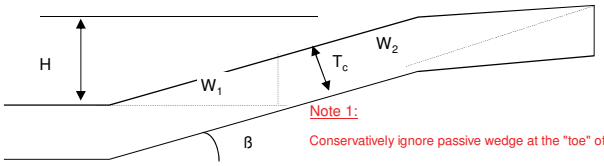
Comments: 33.3% Slopes; Long-Term; Seismic; Establish Design/Performance Requirements; Residual Strength; Iteration 2

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	18.4	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**15.5**	degrees		
	Cohesion @ interface	**15.0**	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	14.0	feet	Therefore, the slope length = 44 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.31565	0.94888	0.33266
0.00000	1.00000	0.00000
0.26724	0.96363	0.27732

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.7**	**1.0**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.4
Static	Infinite slope (interface, based on δ)	**0.8**	**1.2**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.3
Static	Infinite slope w/seepage (interface, based on δ)	0.3	0.6



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 260.84 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 5,283.29 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.63 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 605.89 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
605.89

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 396.25

Factor or Safety Methodology Summary:

FS = Sum of Resisting Forces / Sum of Driving Forces = passive + center + equipment + cohesion / seepage + equipment + center + seismic

FS = Sum of Resisting Forces / Sum of Driving Forces = 0.00 + 1,390.28 + 0.00 + 605.89 / 0.00 + 0.00 + 1,667.67 + 396.25

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

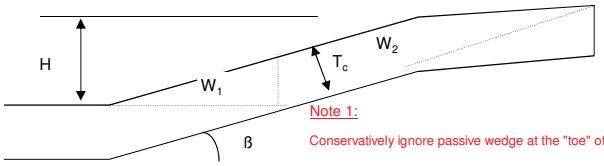
Comments: 33.3% Slopes; Long-Term; Seismic; Establish Design/Performance Requirements; Residual Strength; Iteration 3

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	18.4	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**8.5**	degrees		
	Cohesion @ interface	**30.0**	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	14.0	feet	Therefore, the slope length = 44 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.31565	0.94888	0.33266
0.00000	1.00000	0.00000
0.14781	0.98902	0.14945

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.4**	**1.0**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	0.8
Static	Infinite slope (interface, based on δ)	**0.4**	**1.2**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	0.6
Static	Infinite slope w/seepage (interface, based on δ)	0.1	0.7



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 260.84 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 5,283.29 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.63 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 1211.79 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
1211.79

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 396.25

Factor or Safety Methodology Summary:

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{\text{passive} + \text{center} + \text{equipment} + \text{cohesion}}{\text{seepage} + \text{equipment} + \text{center} + \text{seismic}}$$

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{0.00 + 749.23 + 0.00 + 1{,}211.79}{0.00 + 0.00 + 1{,}667.67 + 396.25}$$

AMEC ENVIRONMENT & INFRASTRUCTURE, INC.

INTERFACE FRICTION ANALYSIS

This spreadsheet evaluates the factor of safety for interface stability for landfill cover system design.

Project: Callahan Mine Superfund Site
Brooksville, Maine

Project Number: 3612112201
Date: 09/2014

Calcs: NDL
Chk'd: SJR

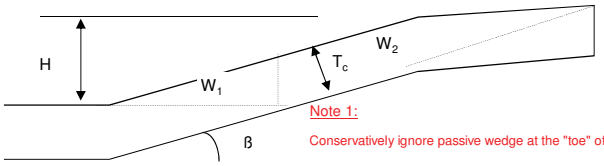
Comments: 33.3% Slopes; Long-Term; Seismic; Establish Design/Performance Requirements; Residual Strength; Iteration 4

		Inputs			
T_c	Soil Cover Thickness	1.3	feet	(perpendicular to liner)	Therefore = 1.32 feet (vertical)
γ_w	Wt. of Water	62.4	pcf		
γ_c	Weight of cover soil	100.0	pcf		
	Saturated weight of cover	125.0	pcf		
T_w	Thickness of seepage	0.0	feet		
ß	slope angle (beta)	18.4	degrees		
ϕ	Soil shear strength	0.0	degrees (See Note 1 below).		
δ	Interface shear strength	**0.0**	degrees		
	Cohesion @ interface	**49.0**	psf		
	Cohesion of cover soil	0.0	psf		
H	Slope Height	14.0	feet	Therefore, the slope length = 44 ft	
W_e	Equipment Weight	0.0	pounds		
	Equipment width	0.0	width in feet		

SIN	COS	TAN
0.31565	0.94888	0.33266
0.00000	1.00000	0.00000
0.00000	1.00000	0.00000

CALCULATED FACTORS OF SAFETY

		No Interface Cohesion	with Interface Cohesion
Druschel Method		**0.0**	**1.0**
Infinite Slope			
Static	Infinite slope (soil, based on ϕ)	0.0	1.2
Static	Infinite slope (interface, based on δ)	**0.0**	**1.2**
Static	Infinite slope w/seepage (soil, based on ϕ)	0.0	1.0
Static	Infinite slope w/seepage (interface, based on δ)	0.0	1.0



Note 1:
Conservatively ignore passive wedge at the "toe" of this very long slope (via soil shear strength = 0 degrees).

Weights of wedges (Drushel Methodology):

W_1 = 260.84 pounds per foot of slope width = weight of passive wedge/toe buttress
W_2 = 5,283.29 pounds per foot of slope width = weight of center wedge/side slope soil

Equipment Loading (Drushel Methodology):

Area of the load at interface = 2.63 feet (assuming a 1:1 pressure distribution with depth)
W_e = 0.00 pounds per foot of slope width = equipment load/static weight
F_b = 0.00 pounds per foot of slope width = equipment braking force (30% of equipment weight)
From Drushel (1993), after Koerner and Richardson (1987)

Seepage Force:

Fs = 0.00 pounds per foot of slope width = seepage force (Stamatopoulos)

Cohesion Force:

Lc = 40.39 feet Interface cohesion = 1979.26 pounds per foot of slope width
Ltoe= 3.96 feet Toe/soil cohesion = 0.00 pounds per foot of slope width
1979.26

Seismic Force

a_{max} = 0.150 a_{max} = peak horiz. ground acceleration @ Site
K = 0.50
k_s = 0.075 seismic coefficient (a_{max} * K)
$k_s W_2$ = 396.25

Factor or Safety Methodology Summary:

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{\text{passive} + \text{center} + \text{equipment} + \text{cohesion}}{\text{seepage} + \text{equipment} + \text{center} + \text{seismic}}$$

$$FS = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} = \frac{0.00 + 0.00 + 0.00 + 1{,}979.26}{0.00 + 0.00 + 1{,}667.67 + 396.25}$$