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Technical Memorandum

To: Poly Met Mining Inc.
From: Tom Radue, Bethany Erfourth, and Kristin Alstadt
Subject: NorthMet Flotation Tailings Basin: Containment System Effects on Slope Stability
Date: April 19, 2013

The purpose of this memorandum is to provide the Minnesota Department of Natural Resources Division of Dam Safety (Dam Safety) information on the potential effects of Flotation Tailings Basin (FTB) Containment System (Containment System) installation on FTB dam stability. Results indicate that slope stability Factors of Safety remain at or above those required (as specified in NorthMet Geotechnical Modeling Work Plan (Work Plan) – Version 3), through Containment System construction and operations. As described within this memo, Containment System construction methods are selected to avoid construction-related impacts on slope stability.

Background

FTB slope stability analyses completed under the Work Plan and reported in the NorthMet Project Geotechnical Data Package Volume 1 – Version 4 (April 12, 2013), show that the proposed FTB design meets all required Factors of Safety. These analyses did not, however, include analysis of the effects of the Containment System on FTB slope stability. Barr conducted additional slope stability analyses to determine the potential effects of the Containment System on the Factors of Safety for the proposed FTB design. This Containment System stability analysis followed the analysis methods and geotechnical data selection approaches specified by the Work Plan. The Factors of Safety calculated by the Containment System stability analysis represent FTB dam stability during and after construction of the FTB Containment System.

The proposed design and construction sequence for the Flotation Tailings Basin (FTB) Containment System are detailed in the Water Management Plan Plant – Version 2, Section 2.1.4. The Containment System will be installed before the first lift of the FTB north dam is constructed. The Containment System includes a cutoff wall set back from the northern and western toe of slope of the FTB (Cells 1E and 2E) and Cell 2W (Figure 1 and Figure 2). The cutoff wall is accompanied by a collection trench located on the tailings basin side of the cutoff wall. The purpose of the Containment System is to capture water that seeps from the FTB and Cell 2W so that it can be treated.

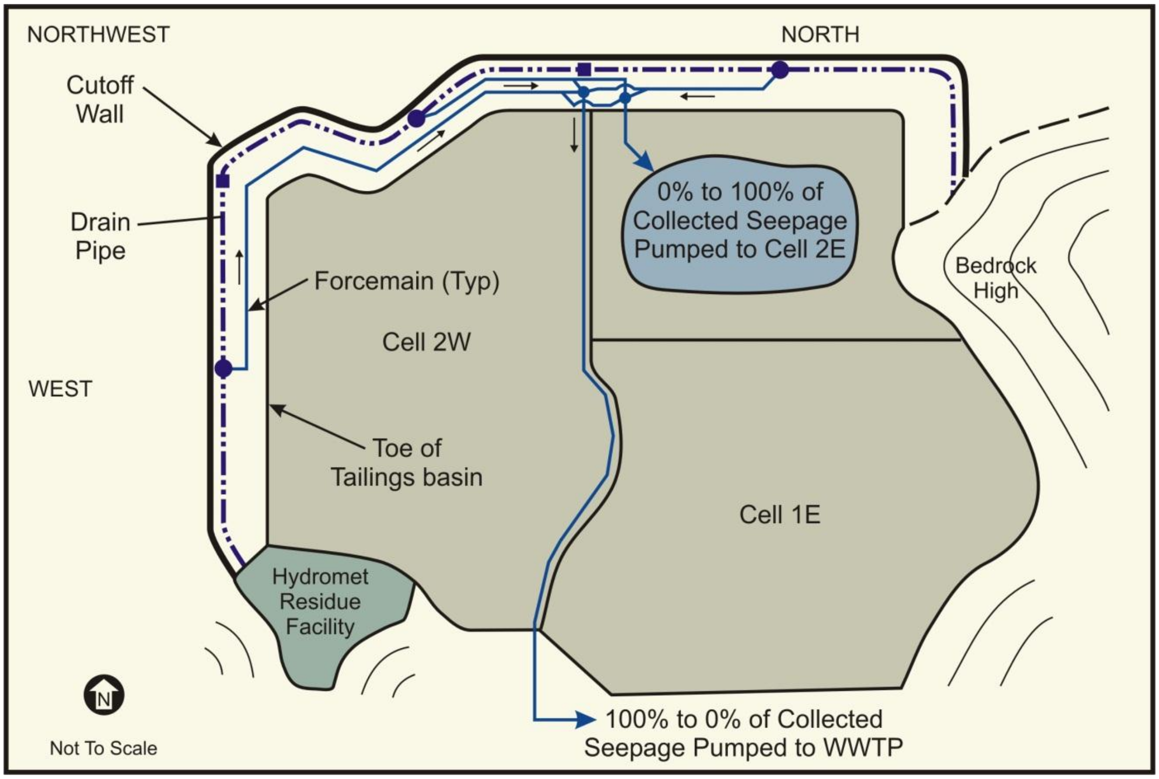


Figure 1 **Conceptual Plan View: FTB Groundwater Containment System**

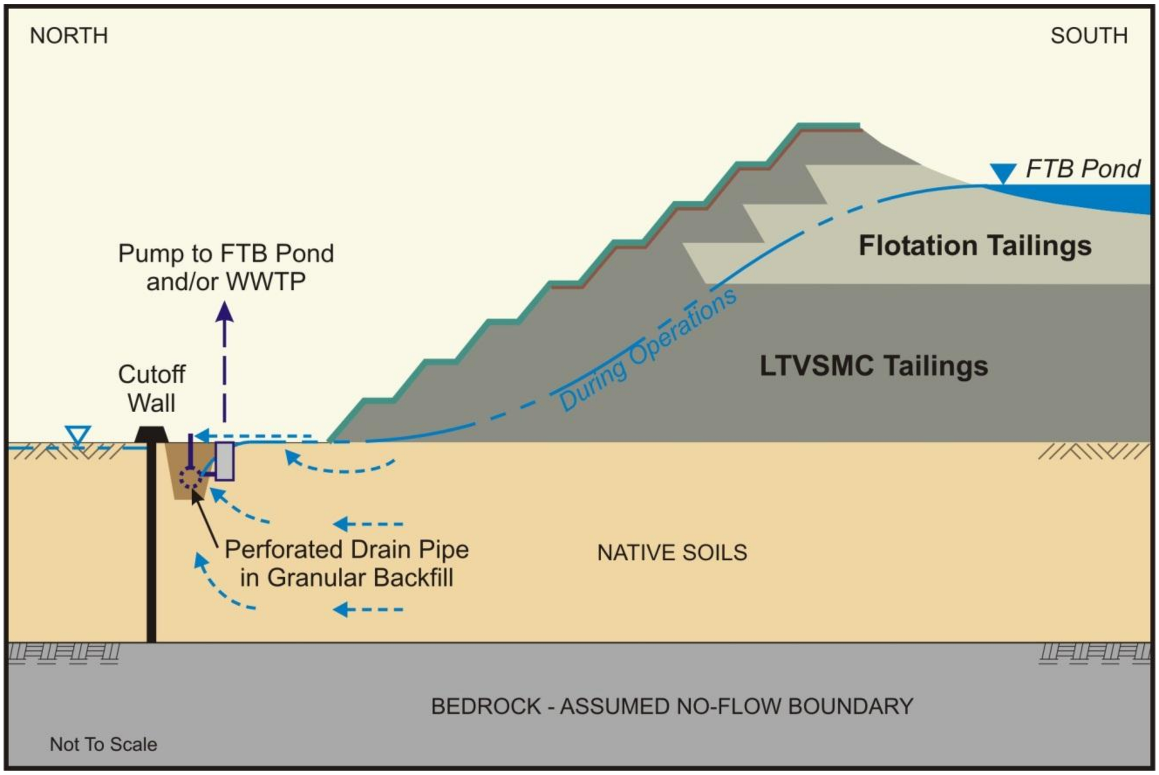


Figure 2 **Conceptual Cross-Section: FTB Containment System**

The following summarizes the general installation approach anticipated for each of the primary Containment System components. The system will be constructed in the sequence presented (Manholes, Collection Trench, Cutoff Wall) so that system dewatering can be initiated if needed prior to the cutoff wall completion. Further, the construction methods and sequence are selected to maintain effective stress stability conditions throughout construction and operation; hence, Effective Stress Stability Analysis (ESSA) has been performed. ESSA analyses are appropriate because:

- trenchless construction techniques are proposed as described later in this memorandum,
- the collection trench when in operation will draw down water levels on the tailings basin side of the cutoff wall only several feet, thereby representing a minimal change in hydraulic and soil stress conditions at the tailings basin, and
- in the unlikely event of a prolonged collection system failure, water levels on the tailings basin side of the cutoff would only rise to at or just above current water levels (due to

elevation control by the cutoff), again representing a minimal change in hydraulic conditions and soil stress conditions at the tailings basin.

For consistency with other slope stability analyses performed for the FTB as presented in Geotechnical Data Package – Vol. 1 – Ver. 4, it has also been assumed that an unknown triggering mechanism induces liquefaction and analyses have been performed to confirm achievement of a Factor of Safety ≥ 1.1 for post-triggering slope stability applying design liquefied shear strengths to all LTVSMC fine tailings and slimes and all Flotation Tailings below the top of the capillary zone.

The following is a summary of the primary components of the Containment System:

- Manholes – the manholes will generally be installed using typical excavation and backfill techniques, with an average excavation depth at each manhole of 15 feet. Sheet piling or shoring will be used to isolate manhole installation locations from surrounding soils and to minimize construction dewatering requirements.
- Collection Trench – the collection trench will be constructed using trenchless technology such as that provided by DeWind One-Pass Trenching of Zeeland, Michigan. The trench depth has not yet been finalized, but we assume an average depth of 8 feet to prevent system freezing and maintain operations through-out winter (exact depth will be determined during final design and construction). With one-pass trenching excavated material is immediately replaced with the collection trench drain pipe and granular fill and the need to maintain an open dewatered trench for construction is eliminated. The excavated soils will be used for other construction purposes or placed in the FTB.
- Cutoff Wall – the cutoff wall will be constructed using trenchless in-situ construction techniques whereby a mechanical mixer is inserted into the ground along the cutoff wall alignment. As the mixer ‘walks’ down the cutoff wall alignment, it mixes the soil along the cutoff wall location with bentonite. The soil-bentonite mixing occurs in-situ and an open trench is not utilized. DeWind One-Pass Trenching again is an example of a company that provides such services. Additional subsurface exploration will be

performed prior cutoff wall construction to select a route that avoids cobbles and boulders.

Slope Stability Analysis Methods

Slope stability for a system installed via the planned in-situ construction has been modeled. The seepage and slope stability modeling was performed using the GeoStudio suite of geotechnical software to determine if predicted existing and proposed conditions are stable. The Containment System stability analysis was performed based on the configuration of the native soils, the existing tailings basin and the planned FTB dams along a cross-section through the north dam of Cell 2E, referred to as Cross-Section F. This cross-section is the critical cross-section – in other words, the calculated Factors of Safety for the proposed design are lower for this cross-section than what is anticipated for all other cross-sections that will be analyzed as part of permitting.

Three models were developed for the Containment System stability analysis. The Existing Conditions Configuration and the Future Dam Configuration. The Existing Conditions Configuration is used for the ESSA analysis to assess potential slope stability impacts of the Containment System along the north side of Cell 2E prior FTB operations. The Future Dam Configuration model is used to assess how the Containment System might affect slope stability when the FTB dams are at maximum height, for ESSA and in the event of an unknown triggering mechanism. These models are also taken as a surrogate for modeling potential slope stability impacts along the north and west side of Cell 2W. This assumption is valid on the basis of the outcomes of the slope stability modeling. As subsequently presented, the slope stability failure surface in the Cell 2E existing conditions model occurs within the existing dam, which has a slope configuration mirroring that for the lower portion of Cell 2W.

For stability modeling the collection trench and/or cutoff wall are offset approximately 260 feet from the existing toe of dam. One objective of the final design of the cutoff wall will be to identify areas of shallower bedrock to serve as a lower cutoff for the system, thereby limiting the overall cutoff wall depth and cost. Hence, final cutoff wall offset distance from the toe of dam will be somewhat variable depending on future findings about bedrock depth. For this analysis, the cutoff wall is modeled as 42 feet deep, terminating at top of bedrock. This is an estimated maximum depth to bedrock at the cutoff wall location; actual depth to bedrock will require confirmation during construction. The cutoff wall was assumed to be 3 feet thick and was modeled with material properties similar to those of a slurry wall, with unit weight of 70 pcf and cohesion of 50 psf. The remaining tailings basin and native stratigraphy seepage parameters and material strength design parameters are based on previously established design models used for stability analysis presented in Geotechnical Data Package – Volume 1 – Version 4. The phreatic surface within the existing dam has previously been calibrated with available data from piezometers installed in the perimeter dam along Cross-Section F. Two conditions were modeled:

- With the water table modeled at ground surface from the toe of the dam to the cutoff wall to simulate a condition with the collection system temporarily inactive (e.g., such as in the event of an abnormally long power outage).
- With the collection system operating with active extraction of water from the collection system.

Beyond the cutoff wall, the wetlands area was modeled with a water table at 2 feet below ground surface as used in other stability models presented in Geotechnical Data Package – Volume 1 – Version 4.

Stability Analysis Outcomes

The slope stability analysis was conducted using SLOPE/W, part of the GeoStudio 2007 Version 7.19 software package. SLOPE/W uses limit equilibrium theory to compute the Factor of Safety of earth and rock slopes while analyzing complex geometry, stratigraphy, and loading conditions. Spencer’s method was used to calculate the Factor of Safety of the tailings basin and FTB dams with Containment System constructed using a 20-foot minimum slip surface depth. The grid and radius search criterion was used for this analysis. With the grid and radius search technique, the grid of the center of slip circles (or center of blocks) and radii (or ends of blocks) are established by the user, and the computer program then searches for the circle or block yielding the lowest factor of safety. After the grid and radius slip surface was found, optimization was used to determine a minimum factor of safety to identify the most critical, non-circular failure surface.

Potential failure surfaces and Factors of Safety were determined for drained conditions and for liquefied conditions under the assumption of an unknown triggering event inducing liquefaction of all LTVSMC fine tailings and slimes and all Flotation Tailings below the top of the capillary zone.

The drained condition is typically considered a long-term case in which loading is slow enough (or the material has high enough permeability) that no shear-induced pore pressures are able to develop during loading. The drained conditions applies to this analysis of Containment System construction impacts because the Containment System will be constructed before Flotation Tailings are placed in the FTB and the existing LTVSMC dams are currently in a long-term stable drained state. Further, trenchless construction technology and temporary braced excavations are proposed so that open dewatered excavations that could induce undrained loading conditions will not be present. As noted previously, conditions of an unknown trigger for liquefaction have also been considered. The Factor of Safety specified in the Work Plan for drained condition (ESSA) is F.S. $\geq$ 1.5 and for the liquefied condition is F.S $\geq$ 1.1. Table 1 provides a summary of the stability results. The model outputs are attached as Figure 3 through Figure 8.

Table 1 Summary of Containment System Stability Results

Dam Condition Modeled	Soil Stress Conditions	Collection System (Active/Inactive)	Target Factor of Safety	Modeled Factor of Safety
Existing Conditions Configuration	ESSA (Fig. 1)	Inactive	1.5	2.1
Existing Conditions Configuration	ESSA (Fig. 2)	Active	1.5	2.5
Future Dam Configuration – Section F	ESSA (Fig. 3)	Inactive	1.5	3.4 (1)
Future Dam Configuration – Section F	ESSA (Fig. 4)	Active	1.5	3.9 (1)
Future Dam Configuration – Section F	All Saturated Contractive Soils Liquefied to $USSR_{Liq}$ (Fig. 5)	Inactive	1.1	1.1
Future Dam Configuration – Section F	All Saturated Contractive Soils Liquefied to $USSR_{Liq}$ (Fig. 6)	Active	1.1	1.1

(1) Buttress-slough FS = 2.3

The Factor of Safety results are above the target slope stability Factor of Safety values for ESSA. The lowest Factor of Safety value for ESSA conditions was 2.1; above the target of 1.5. The Factor of Safety value for the liquefaction case was 1.1; at the target of 1.1. Note that some results are fractionally lower than the results reported in NorthMet Project Geotechnical Data Package Volume 1 – Version 4. The lower results only apply during extended interruptions of collection system operations due to temporary blockage of seepage.

Conclusions

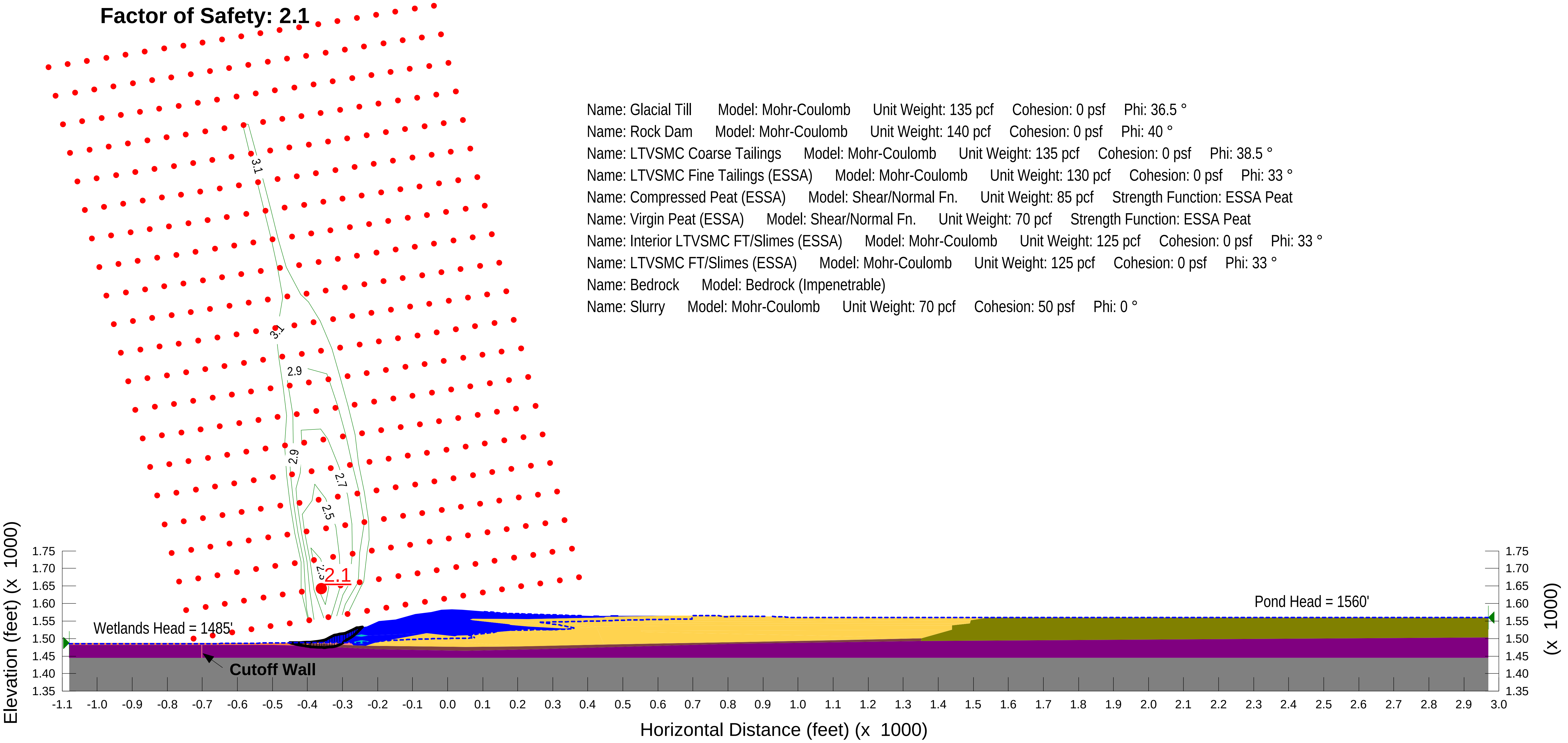
As demonstrated by the slope stability Factors of Safety reported in Table 1, computed slope stability safety factors at Cross-Section F with the Containment System in place meet safety factor requirements.

Field geotechnical conditions and piezometer readings should be monitored throughout Containment System construction to confirm that the conditions actually encountered mimic the conditions that have been modeled, with construction method adjustments made as needed to maintain the required slope stability throughout Containment System construction and operation.

Figure 3. Section F - Existing Conditions: Cutoff Wall - Drain System Idle (ESSA)

PolyMet Flotation Tailings Basin
Section F
Date Last Saved: 4/11/2013
File Name: Section_F-Existing - Cutoff Wall.gsz

Case: ESSA (Grid & Radius)
Design Values - Yield ESSA strength
Grid & Radius, Optimized



Name: Glacial Till Model: Mohr-Coulomb Unit Weight: 135 pcf Cohesion: 0 psf Phi: 36.5 °
Name: Rock Dam Model: Mohr-Coulomb Unit Weight: 140 pcf Cohesion: 0 psf Phi: 40 °
Name: LTVSMC Coarse Tailings Model: Mohr-Coulomb Unit Weight: 135 pcf Cohesion: 0 psf Phi: 38.5 °
Name: LTVSMC Fine Tailings (ESSA) Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion: 0 psf Phi: 33 °
Name: Compressed Peat (ESSA) Model: Shear/Normal Fn. Unit Weight: 85 pcf Strength Function: ESSA Peat
Name: Virgin Peat (ESSA) Model: Shear/Normal Fn. Unit Weight: 70 pcf Strength Function: ESSA Peat
Name: Interior LTVSMC FT/Slimes (ESSA) Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion: 0 psf Phi: 33 °
Name: LTVSMC FT/Slimes (ESSA) Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion: 0 psf Phi: 33 °
Name: Bedrock Model: Bedrock (Impenetrable)
Name: Slurry Model: Mohr-Coulomb Unit Weight: 70 pcf Cohesion: 50 psf Phi: 0 °

Project #23690862-037

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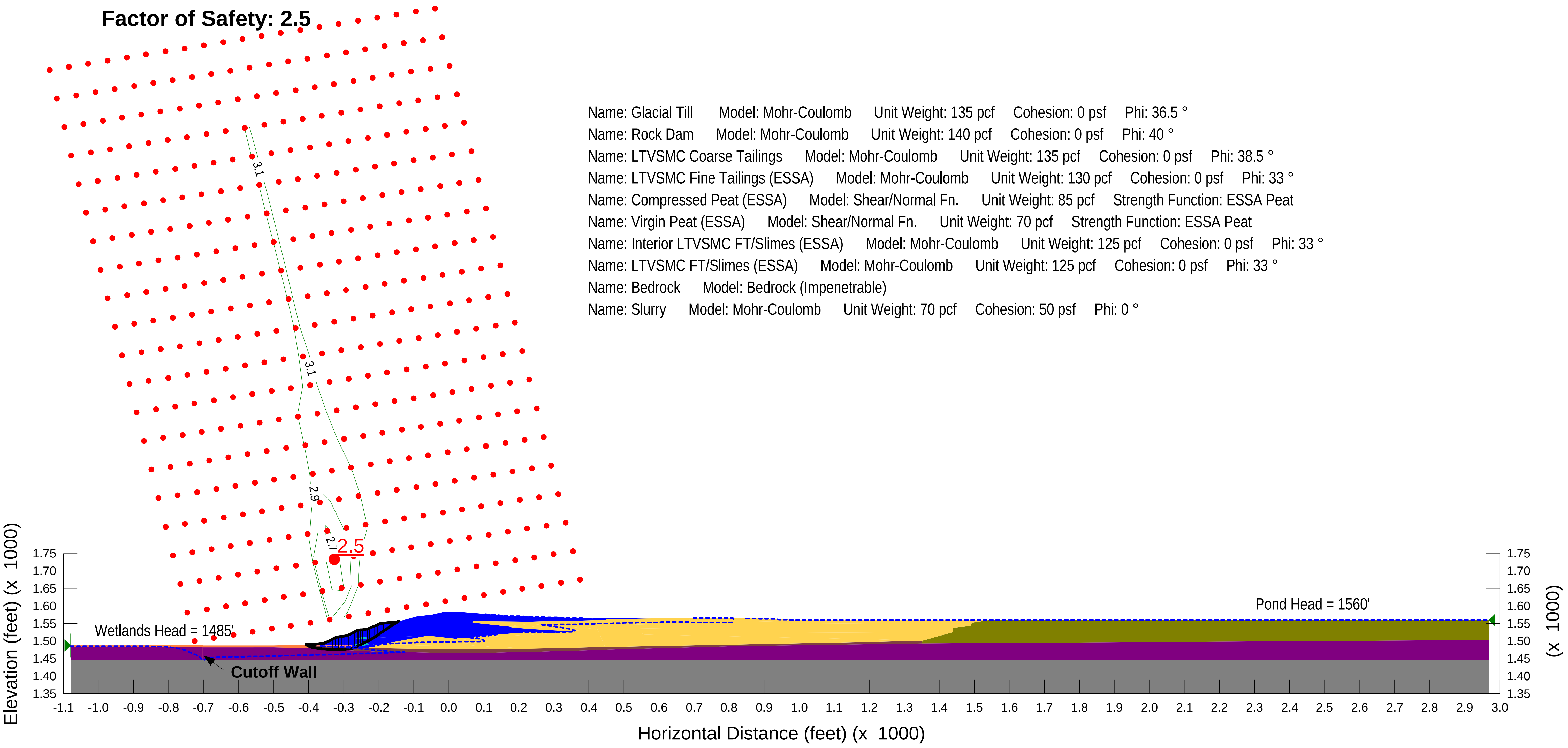
Figure 4. Section F - Existing Conditions: Cutoff Wall - Pumping (ESSA)

PolyMet Flotation Tailings Basin
Section F
Date Last Saved: 4/19/2013
File Name: Section_F-Existing - Cutoff Wall_pumping.gsz

Case: ESSA (Grid & Radius)
Design Values - Yield ESSA strength
Grid & Radius, Optimized



Name: Glacial Till Model: Mohr-Coulomb Unit Weight: 135 pcf Cohesion: 0 psf Phi: 36.5 °
Name: Rock Dam Model: Mohr-Coulomb Unit Weight: 140 pcf Cohesion: 0 psf Phi: 40 °
Name: LTVSMC Coarse Tailings Model: Mohr-Coulomb Unit Weight: 135 pcf Cohesion: 0 psf Phi: 38.5 °
Name: LTVSMC Fine Tailings (ESSA) Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion: 0 psf Phi: 33 °
Name: Compressed Peat (ESSA) Model: Shear/Normal Fn. Unit Weight: 85 pcf Strength Function: ESSA Peat
Name: Virgin Peat (ESSA) Model: Shear/Normal Fn. Unit Weight: 70 pcf Strength Function: ESSA Peat
Name: Interior LTVSMC FT/Slimes (ESSA) Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion: 0 psf Phi: 33 °
Name: LTVSMC FT/Slimes (ESSA) Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion: 0 psf Phi: 33 °
Name: Bedrock Model: Bedrock (Impenetrable)
Name: Slurry Model: Mohr-Coulomb Unit Weight: 70 pcf Cohesion: 50 psf Phi: 0 °

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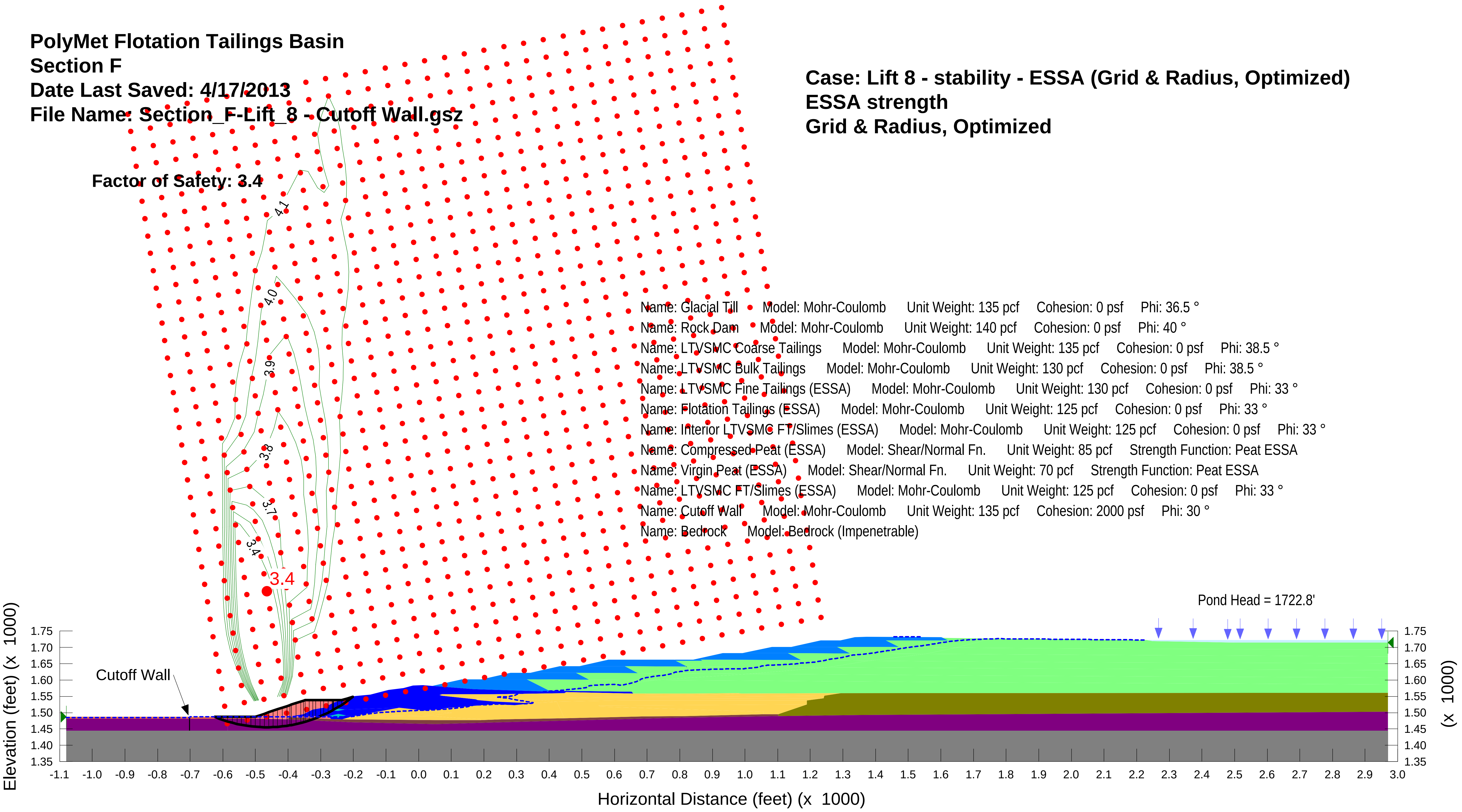
Figure 5. Section F - Cell 2W Lift 8: Cutoff Wall - Drain System Idle (ESSA)



PolyMet Flotation Tailings Basin
Section F
Date Last Saved: 4/17/2013
File Name: Section_F-Lift_8 - Cutoff Wall.gsz

Case: Lift 8 - stability - ESSA (Grid & Radius, Optimized)
ESSA strength
Grid & Radius, Optimized

Factor of Safety: 3.4

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Name: LTVSMC Coarse Tailings Model: Mohr-Coulomb Unit Weight: 135 pcf Cohesion: 0 psf Phi: 38.5 °
Name: LTVSMC Bulk Tailings Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion: 0 psf Phi: 38.5 °
Name: LTVSMC Fine Tailings (ESSA) Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion: 0 psf Phi: 33 °
Name: Flotation Tailings (ESSA) Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion: 0 psf Phi: 33 °
Name: Interior LTVSMC FT/Slimes (ESSA) Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion: 0 psf Phi: 33 °
Name: Compressed Peat (ESSA) Model: Shear/Normal Fn. Unit Weight: 85 pcf Strength Function: Peat ESSA
Name: Virgin Peat (ESSA) Model: Shear/Normal Fn. Unit Weight: 70 pcf Strength Function: Peat ESSA
Name: LTVSMC FT/Slimes (ESSA) Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion: 0 psf Phi: 33 °
Name: Cutoff Wall Model: Mohr-Coulomb Unit Weight: 135 pcf Cohesion: 2000 psf Phi: 30 °
Name: Bedrock Model: Bedrock (Impenetrable)

Project #23690862-037

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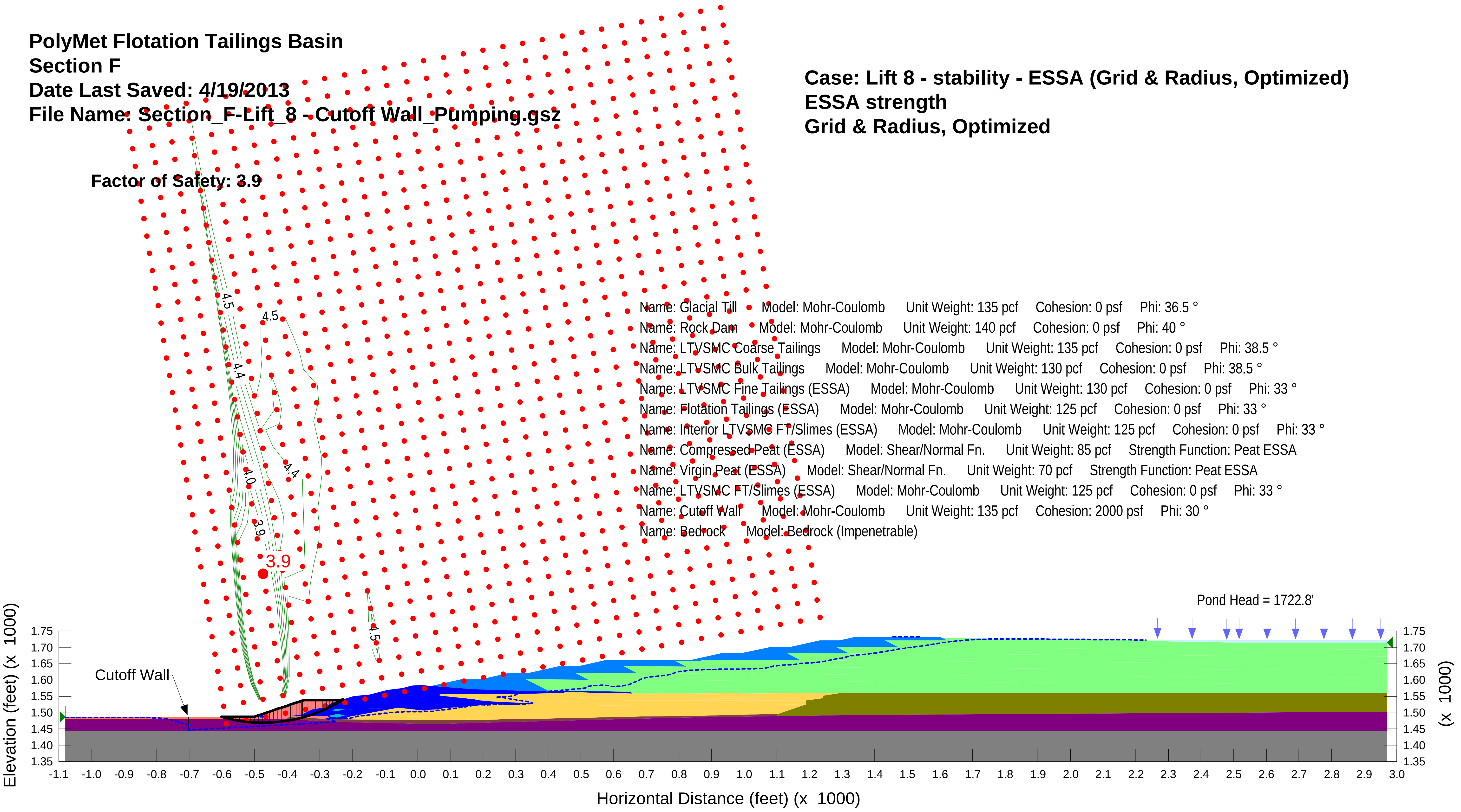
Figure 6. Section F - Cell 2W Lift 8: Cutoff Wall - Pumping (ESSA)

PolyMet Flotation Tailings Basin
Section F
Date Last Saved: 4/19/2013
File Name: Section_F-Lift_8 - Cutoff Wall_Pumping.gsz

Case: Lift 8 - stability - ESSA (Grid & Radius, Optimized)
ESSA strength
Grid & Radius, Optimized

Factor of Safety: 3.9



Name: Glacial Till Model: Mohr-Coulomb Unit Weight: 135 pcf Cohesion: 0 psf Phi: 36.5 °
Name: Rock Dam Model: Mohr-Coulomb Unit Weight: 140 pcf Cohesion: 0 psf Phi: 40 °
Name: LTVSMC Coarse Tailings Model: Mohr-Coulomb Unit Weight: 135 pcf Cohesion: 0 psf Phi: 38.5 °
Name: LTVSMC Bulk Tailings Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion: 0 psf Phi: 38.5 °
Name: LTVSMC Fine Tailings (ESSA) Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion: 0 psf Phi: 33 °
Name: Flotation Tailings (ESSA) Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion: 0 psf Phi: 33 °
Name: Interior LTVSMC FT/Slimes (ESSA) Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion: 0 psf Phi: 33 °
Name: Compressed Peat (ESSA) Model: Shear/Normal Fn. Unit Weight: 85 pcf Strength Function: Peat ESSA
Name: Virgin Peat (ESSA) Model: Shear/Normal Fn. Unit Weight: 70 pcf Strength Function: Peat ESSA
Name: LTVSMC FT/Slimes (ESSA) Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion: 0 psf Phi: 33 °
Name: Cutoff Wall Model: Mohr-Coulomb Unit Weight: 135 pcf Cohesion: 2000 psf Phi: 30 °
Name: Bedrock Model: Bedrock (Impenetrable)

Project #23690862-037

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Figure 7. Fully Liquefied Section F - Cell 2W Lift 8: Cutoff Wall - Drainage System Idle (LIQ)

PolyMet Flotation Tailings Basin
Cross-Section F
Date Last Saved: 4/17/2013
File Name: Slanted bedrock-SecF_Lift8_LIQ_v4Buttress.gsz

Grid & Radius Optimized

Name: Glacial Till Model: Mohr-Coulomb Unit Weight: 135 pcf Cohesion: 0 psf Phi: 36.5 °
Name: Compressed Peat Model: S=f(overburden) Unit Weight: 85 pcf Tau/Sigma Ratio: 0.23
Name: Virgin Peat Model: S=f(overburden) Unit Weight: 70 pcf Tau/Sigma Ratio: 0.23
Name: Rock Dam Model: Mohr-Coulomb Unit Weight: 140 pcf Cohesion: 0 psf Phi: 40 °
Name: LTVSMC Coarse Tailings Model: Mohr-Coulomb Unit Weight: 135 pcf Cohesion: 0 psf Phi: 38.5 °
Name: LTVSMC Fine Tailings Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion: 0 psf Phi: 33 °
Name: LTVSMC Bulk Tailings Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion: 0 psf Phi: 38.5 °
Name: Flotation Tailings (Liquefied) Model: S=f(overburden) Unit Weight: 125 pcf Tau/Sigma Ratio: 0.12
Name: Flotation Tailings (ESSA) Model: Mohr-Coulomb Unit Weight: 125 pcf Cohesion: 0 psf Phi: 33 °
Name: Interior LTVSMC FT/Slimes (Liquefied) Model: S=f(overburden) Unit Weight: 125 pcf Tau/Sigma Ratio: 0.1
Name: LTVSMC FT/Slimes (Liquefied) Model: S=f(overburden) Unit Weight: 125 pcf Tau/Sigma Ratio: 0.1
Name: Bedrock Model: Bedrock (Impenetrable)
Name: Cutoff Wall Model: Mohr-Coulomb Unit Weight: 135 pcf Cohesion: 2000 psf Phi: 30 °

Factor of Safety: 1.10

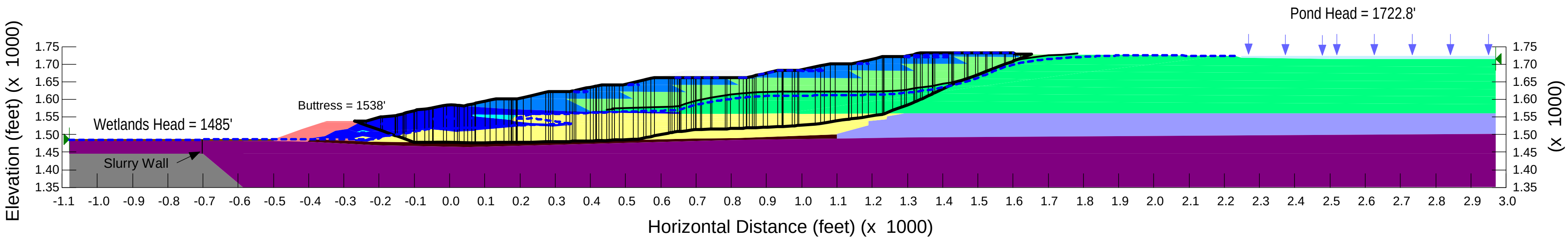

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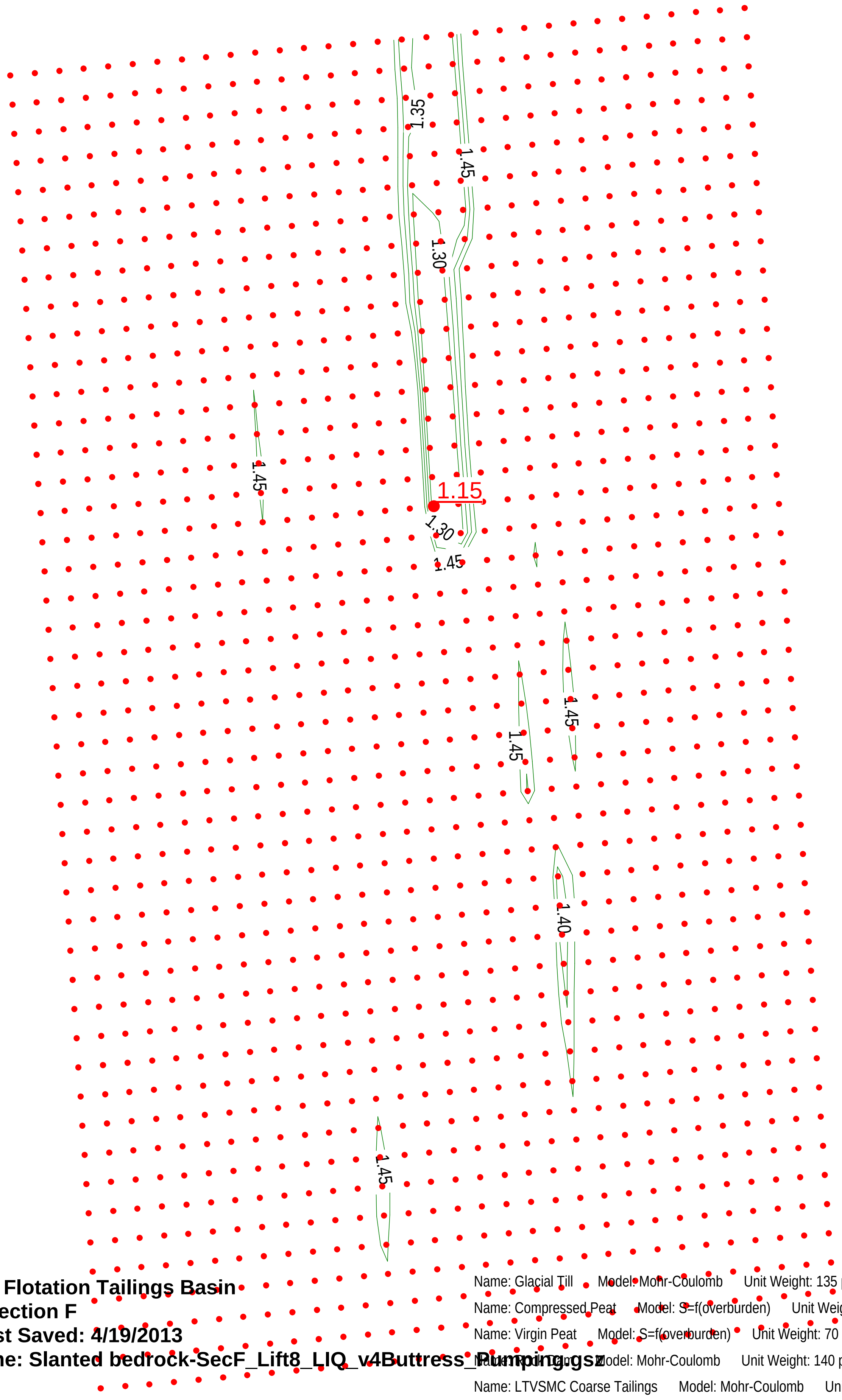
Figure 8. Fully Liquefied Section F - Cell 2W Lift 8: Cutoff Wall - Pumping (LIQ)



PolyMet Flotation Tailings Basin
Cross-Section F
Date Last Saved: 4/19/2013
File Name: Slanted bedrock-SecF_Lift8_LIQ_v4Buttress_Pumping.gsz

Grid & Radius Optimized

Factor of Safety: 1.15

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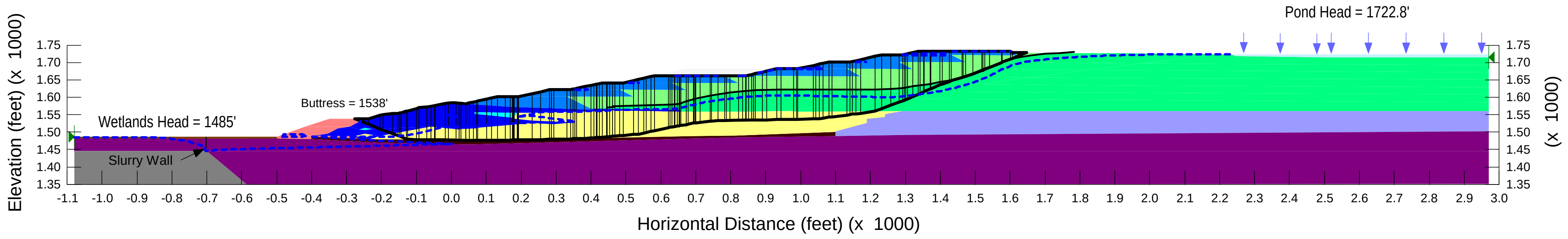
Name: Virgin Peat   Model: S=f(overburden)   Unit Weight: 70 pcf   Tau/Sigma Ratio: 0.23
Name: Rock Dam   Model: Mohr-Coulomb   Unit Weight: 140 pcf   Cohesion: 0 psf   Phi: 40 °
Name: LTVSMC Coarse Tailings   Model: Mohr-Coulomb   Unit Weight: 135 pcf   Cohesion: 0 psf   Phi: 38.5 °
Name: LTVSMC Fine Tailings   Model: Mohr-Coulomb   Unit Weight: 130 pcf   Cohesion: 0 psf   Phi: 33 °
Name: LTVSMC Bulk Tailings   Model: Mohr-Coulomb   Unit Weight: 130 pcf   Cohesion: 0 psf   Phi: 38.5 °
Name: Flotation Tailings (Liquefied)   Model: S=f(overburden)   Unit Weight: 125 pcf   Tau/Sigma Ratio: 0.12
Name: Flotation Tailings (ESSA)   Model: Mohr-Coulomb   Unit Weight: 125 pcf   Cohesion: 0 psf   Phi: 33 °
Name: Interior LTVSMC FT/Slimes (Liquefied)   Model: S=f(overburden)   Unit Weight: 125 pcf   Tau/Sigma Ratio: 0.1
Name: LTVSMC FT/Slimes (Liquefied)   Model: S=f(overburden)   Unit Weight: 125 pcf   Tau/Sigma Ratio: 0.1
Name: Bedrock   Model: Bedrock (Impenetrable)
Name: Cutoff Wall   Model: Mohr-Coulomb   Unit Weight: 135 pcf   Cohesion: 2000 psf   Phi: 30 °



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