SRK Consulting (Canada) Inc.
2200–1066 West Hastings Street
Vancouver, BC V6E 3X2

T: +1.604.681.4196
F: +1.604.687.5532

vancouver@srk.com
www.srk.com

Memo

To:	Kevin Cymbalisty	**Client:**	Minto Explorations Ltd.
From:	Peter Mikes, P.Eng.	**Project No:**	1CM002.053
Reviewed By:	Erik Ketilson P.Eng.	**Date:**	February 1, 2017
Subject:	Main Pit Dump Stability Analysis Update		

1 Introduction

A stability analysis was completed on the Main Pit Dump (MPD) in July 2013 and documented in the report "Phase V/VI Main Pit Dump Physical Stability Assessment" (SRK 2013). The SRK (2013) report was approved by regulators as part of the Phase V/VI expansion. In 2015, an update to the stability analysis was completed (SRK 2015) to assess a modified design of the MPD based on a reduced storage volume, which was not constructed.

Additional revisions to the geometry of the MPD were required based on a further reduction in the dump volume to approximately 650,000 m^3 (from 2.174 Mm^3 in the original analysis) and a reduction in the dump footprint to avoid placement of waste rock over potential SAT material[1] in the Main Pit. Areas in the Main Pit with SAT material above the proposed long term water elevation of 786 m were avoided to allow for their potential relocation to areas in the pit below 786 m at closure.

A plan view of the revised MPD is provided in Figure 1, with further details of the exiting conditions and site history can be found in SRK (2013). The revised MPD has an ultimate crest elevation of approximately 835 m and an overall height of 20 m. The dump face has a slope of 1.3H:1V that is to be regraded to 3H:1V at closure.

SRK Consulting (Canada) Ltd. was retained by Minto to complete an additional analysis to assess stability of the MPD during operations. Please note that options for closure and potential modification or relocation of the SAT are still under review. Additional stability analysis to assess closure conditions are to be evaluated at a future date when designs for SAT relocation are established.

[1] SAT material is waste rock with a NP/AP ratio of less than 3.

2 Stability Analysis

2.1 Analysis Method

The stability analysis was completed using Slide 7.0, a commercially available limit equilibrium slope stability modeling software (Rockscience 2017). Traditional factor of safety (FOS) values were used to assess results. All results were analyzed using the Spencer method, which is a rigorous method that satisfies all three conditions of equilibrium (force equilibrium in the horizontal and vertical directions and the moment equilibrium condition). The 'auto refine' and block surface search methods were used for all cases, with the block search method focused along the inferred overburden shear zone. Further details of the south wall shear zone can be found in SRK (2013).

The assessment focused on mechanisms that drive overall slope failure, i.e. failures near the toe, deep seated failures, failures through the slide debris in the base of the pit, and failures along the inferred overburden shear zones. Small skin or surficial bench face failures (less than 5 m in depth) were not deemed critical to general dump stability and thus were not investigated in detail.

2.2 Design Criteria

The design criteria are based on the recommended Case B FOS listed in the "Mined Rock and Overburden Piles Investigation and Design Manual" (BC Mine Waste Rock Pile Research Committee 1991) and are presented in Table 1. Further details on the design criteria and the rational for use of Case B FOS values are provided in SRK (2013).

Table 1: BC Mined Rock and Overburden Pile Minimum Factor of Safety Guidelines (Case B)

Stability Condition	Suggested Minimum Design Values for FOS
Stability of Dump Surface	
Short-term (during construction)	1.0
Long-term (reclamation – abandonment)	1.1
Overall Stability (Deep Seated Stability)	
Short-term (static)	1.1 – 1.3
Long-term (static)	1.3
Pseudo-static (earthquake)	1.0

The design seismic event for the MPD is the 1:475 year event as per the BC Mine Waste Rock Pile Research Committee (1991) guidelines. The 2015 National Building Code Seismic Hazard Calculator (www.earthquakescanada.ca) was used to obtain a peak ground acceleration of 0.05g for this event.

2.3 Model Geometry

The MPD surface was provided by Minto Explorations Ltd. in December 2016.[2] Figure 1 presents the location of the critical sections (Sections A, B, C, and D) analyzed. These sections have the same names and locations as those analyzed in previous stability analyses (SRK 2013 and SRK 2015). Each section also includes tailings up to an elevation of 780 m based on bathymetry provided by Minto in January 2016[3], and a water table at an elevation of 786 m, which corresponds to the expected long-term water elevation in the pit.

2.4 Material Properties

The material properties used in the analysis are presented in Table 2. Details on the derivation of the material properties are provided in SRK (2014). The shear zone material properties were obtained from a back analysis of the south wall failure SRK (2014). All stability analyses were completed assuming unfrozen conditions.

Table 2: Material Properties

Material	Unit Weight (kN/m^3)	Cohesion (kPa)	Friction Angle (^{o})	Pore Pressure Ratio, Ru
Clay	17.7	0	19	-
Sandy silt	18.3	0	32	-
Slide debris	17.7	0	10	-
Waste Rock	20.6	0	37	-
Tailings	15	0	8	-
Shear zone material (see note 1)	17.7	0	10	50

Note(s):

(1) Shear zone material properties obtained through a back-analysis of the South Wall Failure SRK (2014).

2.5 Cases Considered

The stability analysis considered the following conditions:

1. Current conditions;
2. Static conditions following construction of the MPD; and,
3. Pseudo-static conditions following construction of the MPD.

[2] Internally, Minto refers to this MPD design as revision 4.3.
[3] No significant tailings deposition into the Main Pit has occurred in 2016.

3 Results

A summary of the slope stability results are presented in Table 3 with Stage 2 to 5 results provided in Figures 2 to 5.

Table 3: Slope Stability Results

Condition	Description	Target FOS	Calculated Factor of Safety			
			A-A	B-B	C-C	D-D
1	Current conditions	-	2.7	4.7	1.4	2.4
2	MPD constructed – Static conditions	1.1	1.3	1.2	1.4	2.0
3	MPD constructed – Pseudo-static conditions	1.0	1.0	1.1	1.3	1.4

FOS values for the revised MPD remain above minimum FOS requirements under static and pseudo-static loading conditions prior to closure.

4 References

Minto Explorations Ltd., 2014. Minto Mine Phase V/VI Expansion Waste Rock and Overburden Management Plan. November.

Rocscience, Inc., 2017. Slide 7.0, 2-Dimensional Limit Equilibrium Slope Stability Analysis Software, Toronto, Ontario.

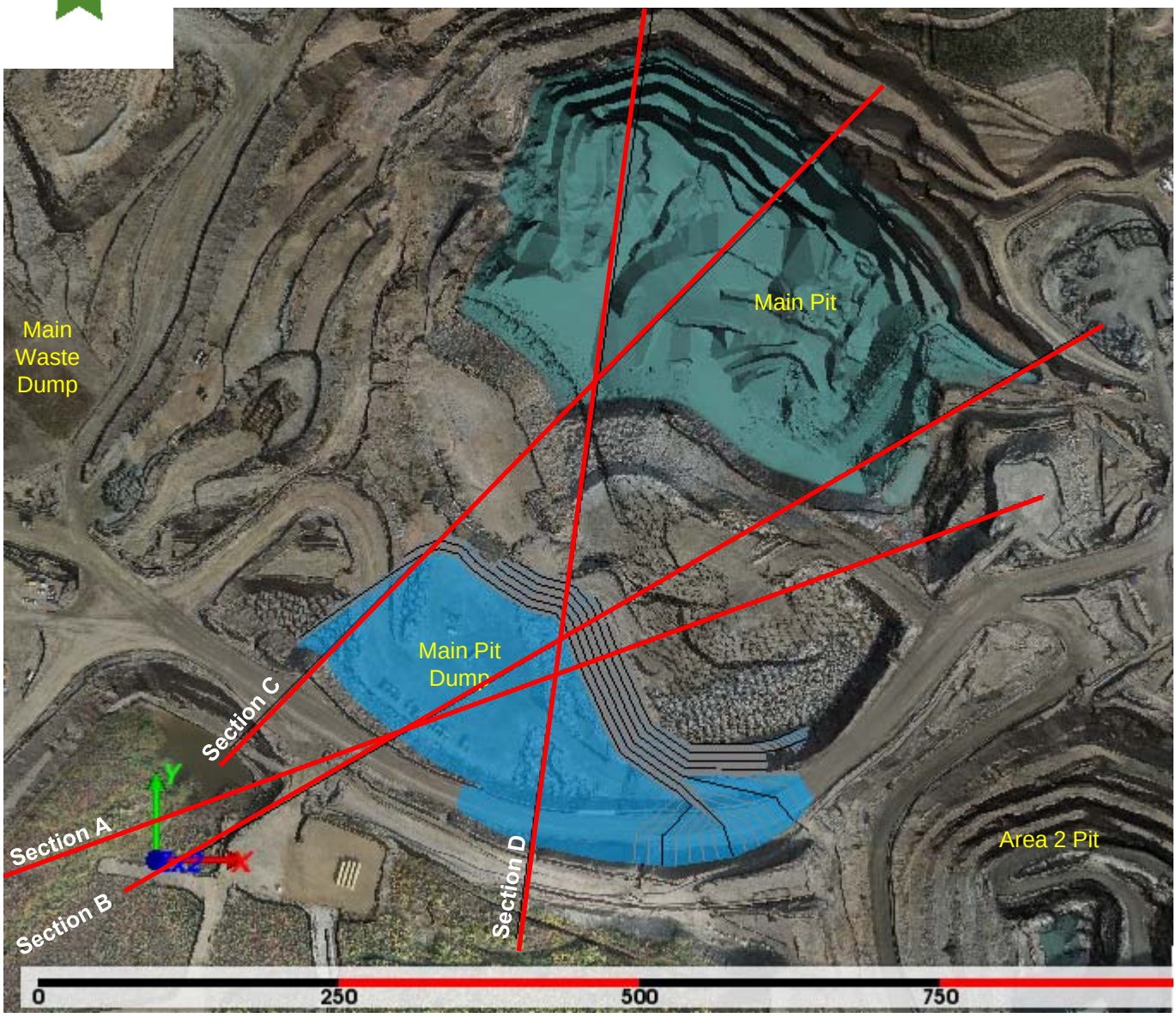
SRK Consulting (Canada) Inc., 2012. Detailed Review of Foundation Performance at the South Waste Dump and Stability of the Main Pit South Wall. Report prepared for Minto Explorations Ltd. SRK Project Number: 219500.050. November.

SRK Consulting (Canada) Inc., 2013. *Phase V/VI Main Pit Dump Physical Stability Assessment.* Prepared for: Minto Explorations Ltd. SRK Project Number: 1CM002.012.012. November.

SRK Consulting (Canada) Inc., 2014. *Review of Geotechnical Strength Properties at Minto Mine.* Prepared for: Minto Explorations Ltd. SRK Project Number: 1CM002.018.110. July 17.

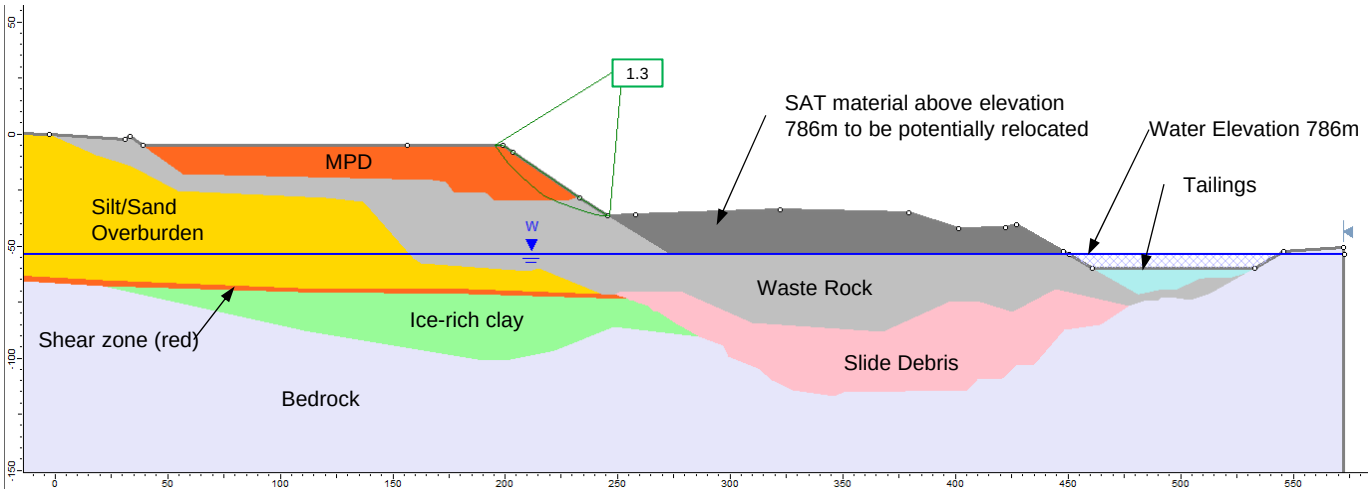
SRK Consulting (Canada) Inc., 2015. *Update to the Main Pit Dump Physical Stability Assessment.* Prepared for: Minto Explorations Ltd. SRK Project Number: 1CM002.003.0701. February 26.

Figures

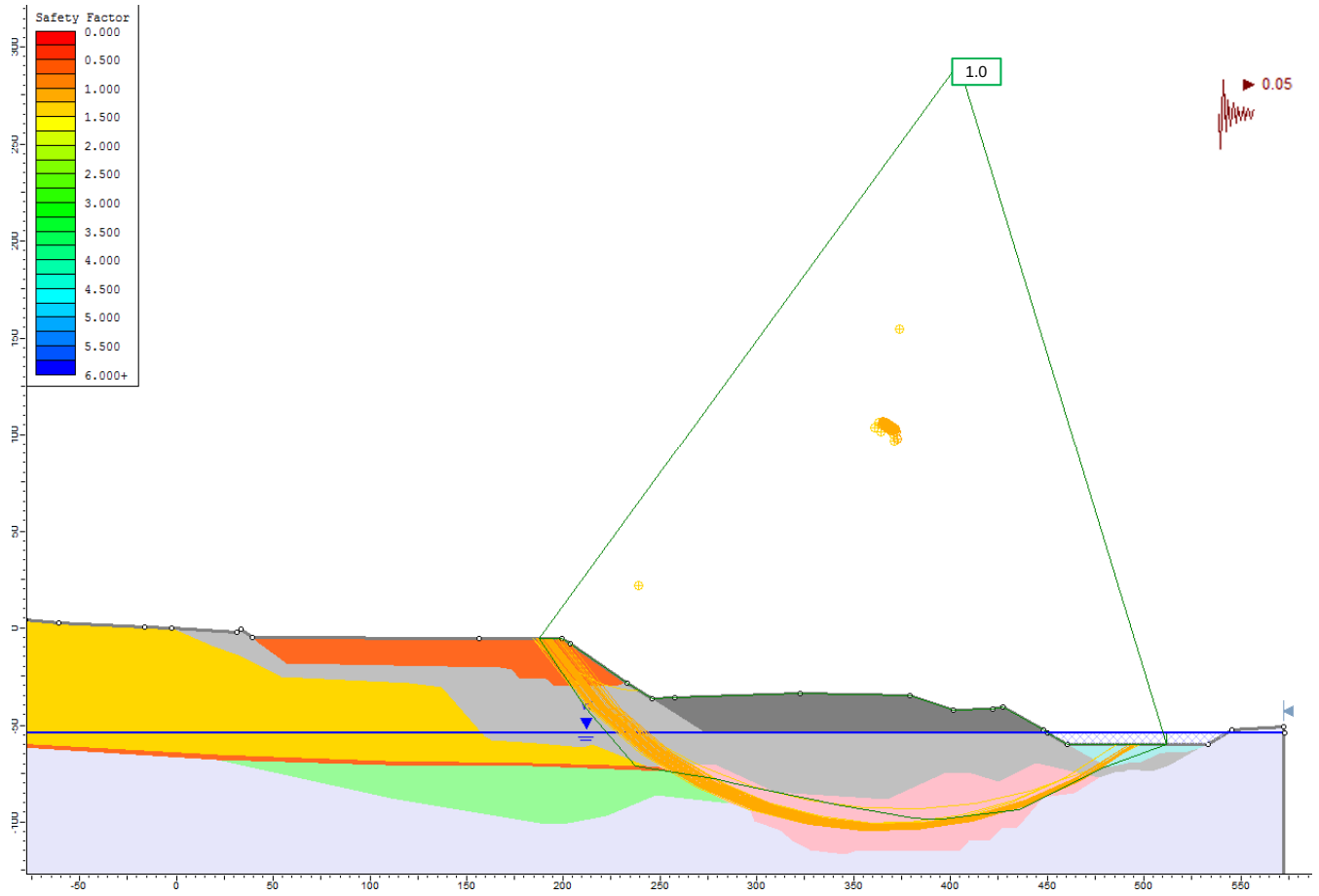


Notes
1. Plan shows the 2014 orthophoto overlain onto the November 2016 topographic surface.
2. Main Pit Dump design is Revision 4.2 provided by Minto in December 17, 2016.

srk consulting	capstone MINTO MINE OPERATED BY MINTO EXPLORATIONS LTD.	MPD Stability Analysis
		Site Plan and Section Location
Job No: 1CM002.053 Filename: Figures_MPDRev4-2_StabilityAnalysis.pptx	Minto Mine	Date: February 2017 | Prepared by: PHM | Figure: **1**

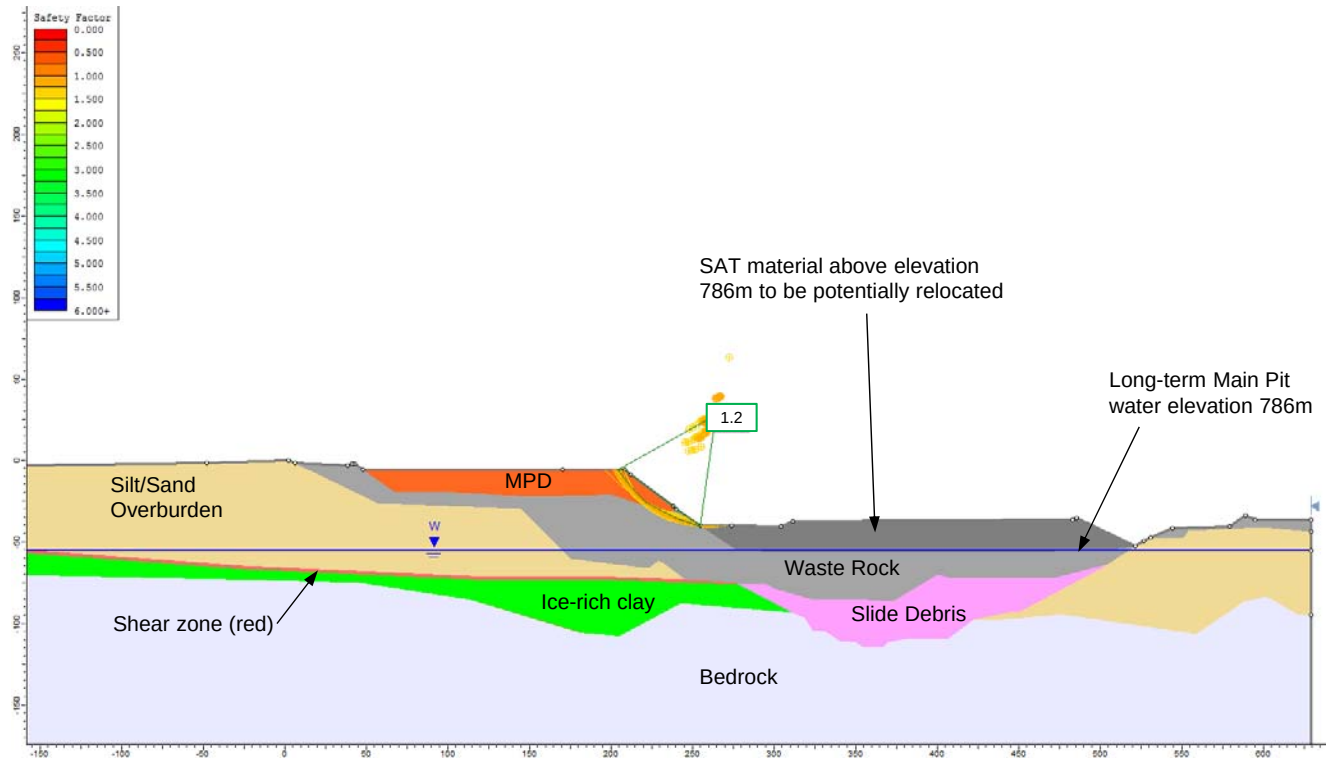


Static Conditions - FOS = 1.3

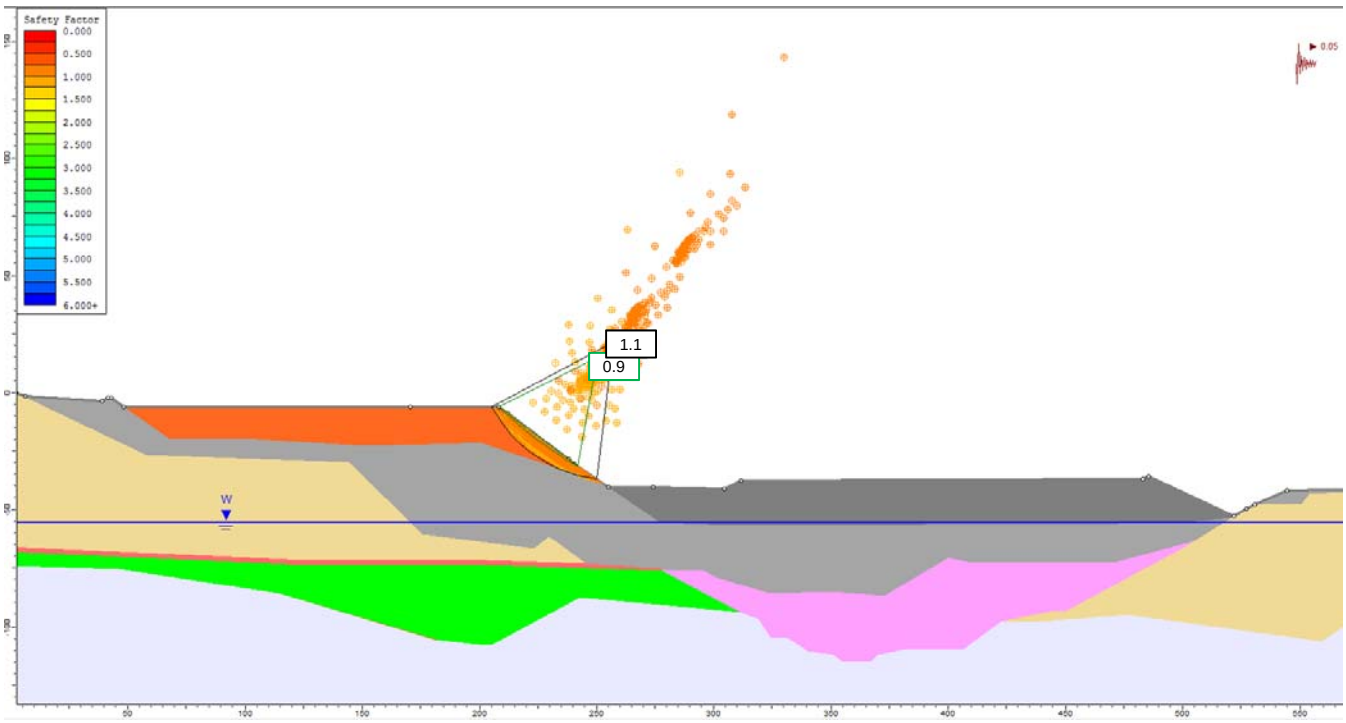


Pseudo-static Conditions - FOS = 1.0

srk consulting	Capstone MINTO MINE OPERATED BY MINTO EXPLORATIONS LTD.	MPD Stability Analysis		
		Section A Results		
Job No: 1CM002.053 Filename: Figures_MPDRev4-2_StabilityAnalysis.pptx	Minto Mine	Date: February 2017	Prepared by: PHM	Figure: **2**

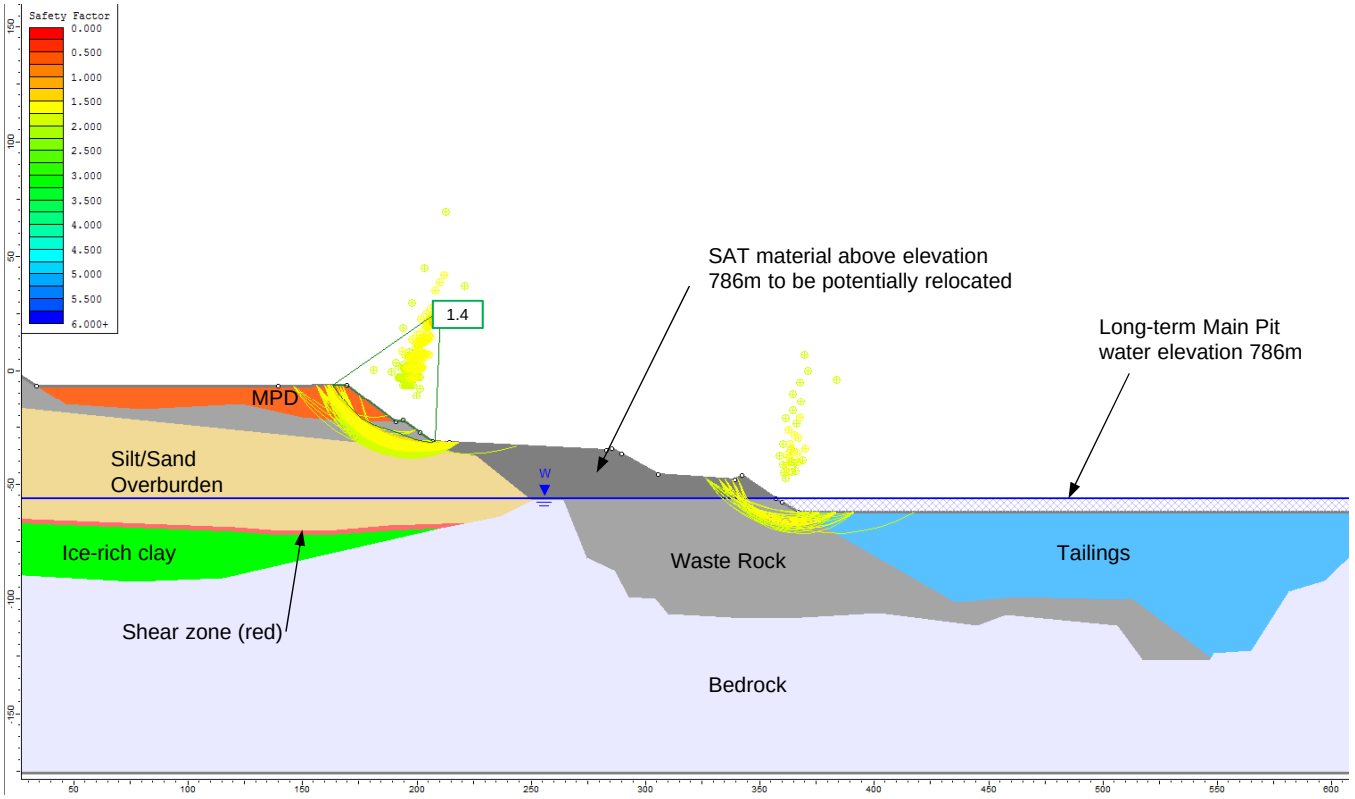


Static conditions - FOS = 1.2; Figure plots all circular failure surfaces with a FOS less than 1.3.

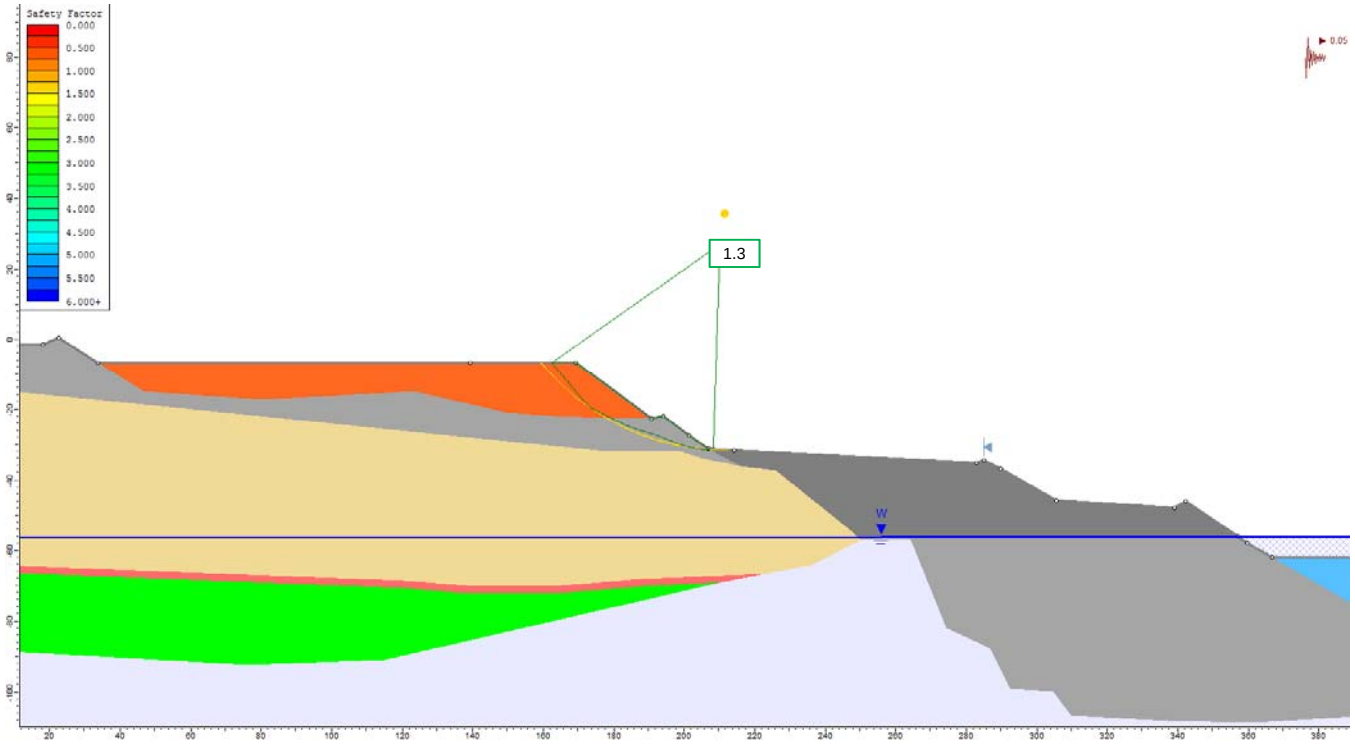


Pseudo-static conditions – FOS = 1.1; Note: the minimum FOS is 0.9 for a failure of the dump face. The figure plots all circular failure surfaces with a FOS less than 1.1.

srk consulting	capstone MINTO MINE OPERATED BY MINTO EXPLORATIONS LTD.	MPD Stability Analysis **Section B Results**
Job No: 1CM002.053 Filename: Figures_MPDRev4-2_StabilityAnalysis.pptx	Minto Mine	Date: February 2017 | Prepared by: PHM | Figure: **3**



Static Conditions - FOS = 1.4; Figure plots all circular failure surfaces with a FOS less than 1.5.



Pseudo-static conditions - FOS = 1.3.

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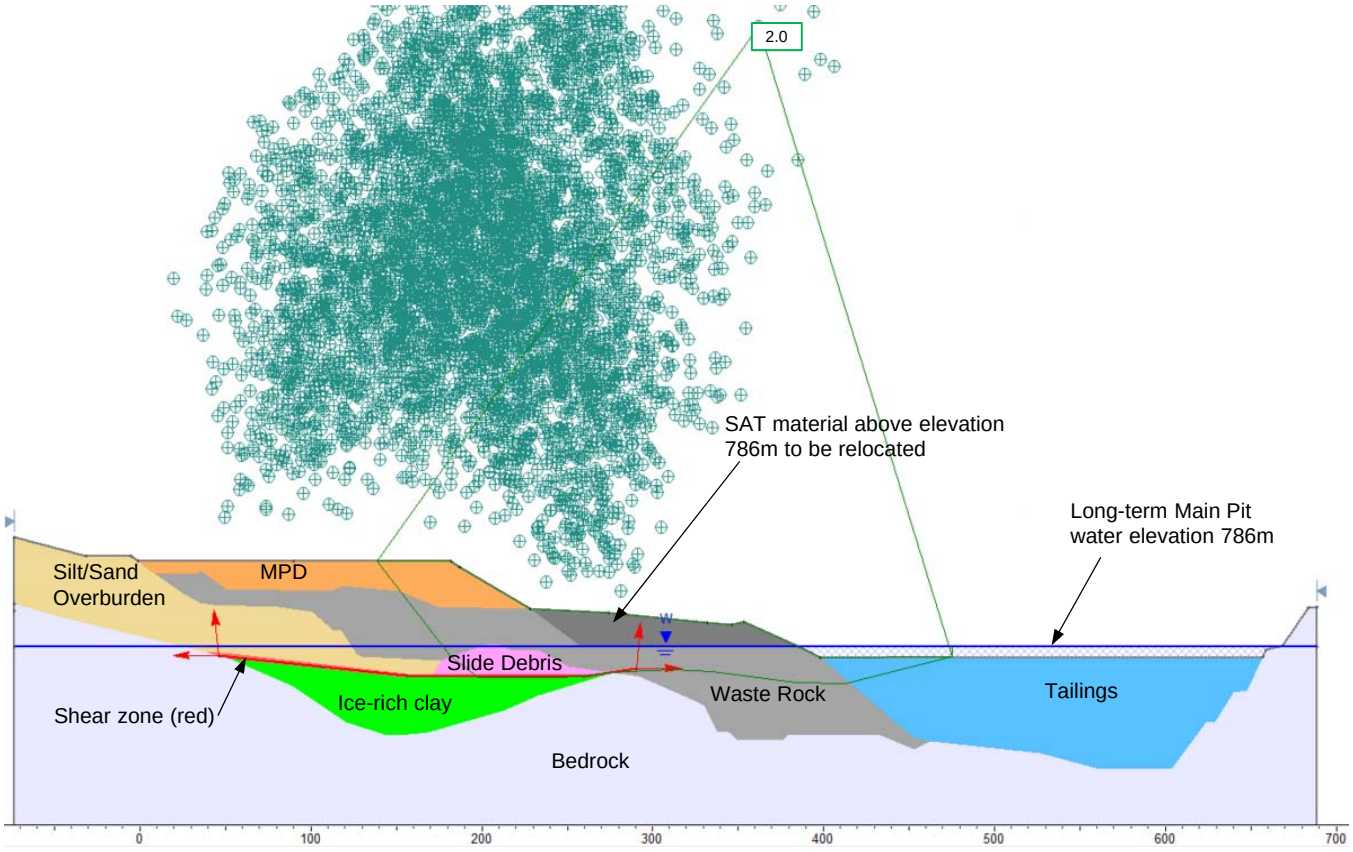
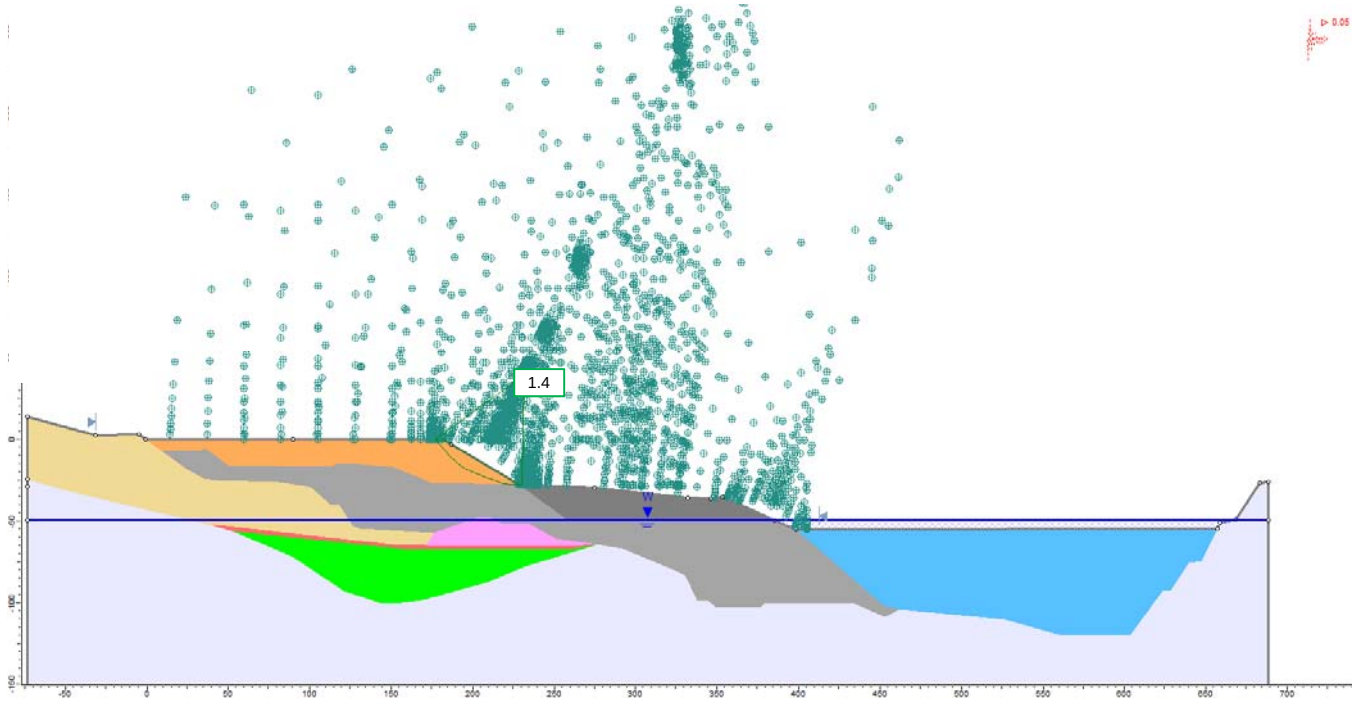
		Section C Results		
Job No: 1CM002.053 Filename: Figures_MPDRev4-2_StabilityAnalysis.pptx	Minto Mine	Date: February 2017	Prepared by: PHM	Figure: 4



Static Conditions - FOS = 2.0



Pseudo-static conditions – FOS = 1.4

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		Section D Results		
Job No: 1CM002.053 Filename: Figures_MPDRev4-2_StabilityAnalysis.pptx	Minto Mine	Date: February 2017	Prepared by: PHM	Figure: **5**