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Memo

To:	John Roberts, TMAC	**Client:**	TMAC Resources Inc.
From:	Lowell Wade, MSc, PEng Maritz Rykaart, PhD, PEng	**Project No:**	1CT022.002.100
Cc:		**Date:**	March 27, 2015
Subject:	Doris North Project: Waste Rock Storage Pile (Pad T) Reclamation and Security Brief to Doris North Type A Water License No. 2AM-DOH1323		

1 General

The Doris North Project (Project) is owned and operated by TMAC Resources Inc. (TMAC). The project is located on Inuit Owned Land administered by the Kitikmeot Inuit Association (KIA), in the West Kitikmeot Region of Nunavut, approximately 120 km south west of Cambridge Bay. The Doris North Project is authorized under the Nunavut Water Board (NWB) Type A Water Licence 2AM-DOH1323 (NWB 2013).

The closure and reclamation plan for the Project is described in the Doris North Closure and Remediation and Plan (SRK 2012). A revised waste rock and ore management plan (SRK 2015) calls for the construction of a 42,600 m^2 waste rock storage pile (Pad T) north of the portal and existing ore stockpile on Pads Q/H/J (Figure 1).

This memo describes the closure and reclamation plan for the Waste Rock Storage Pile (Pad T) and the incremental Security Estimate associated with construction of this surface infrastructure.

2 Pad T – Waste Rock Pile

According to the Doris North Closure and Reclamation and Plan (SRK 2012), all waste rock will to be sent back underground to be used as backfill. Subsequent changes associated with the Project being placed in Care and Maintenance allowed for any waste rock left on surface to be managed as follows:

- Consolidating, contouring and covering mineralized waste rock piles with an impermeable liner and a 0.3 m thick protective layer of crushed rock; or
- Relocating mineralized waste rock piles to the Tailings Impoundment Area to be deposited of sub-aqueously.

- Non-mineralized waste rock can be left in place provided it has been deemed to be physically stable.

Current plans allows for 188,000 t (105,000 m^3) of non-mineralized waste rock to be left on surface at closure. This waste rock will be located on Pad T. Stability analysis has confirmed that the waste rock piles will be physically stable in the long term, and therefore no significant stability related closure activity will need to be undertaken.

Just like all other rock fill pads on site, any exposed areas of Pad T, not covered by non-mineralized waste rock, will remain in place at closure, and only minimal regrading will be required to ensure positive drainage and prevent ponding.

The total incremental liability associated with Pad T is therefore CAD $6,000 in undiscounted 2014 Canadian dollars. This assumes 100% of the pad surface area requires regrading which is deemed conservative.

3 Closure

The total incremental liability associated with the Waste Rock Storage Pile (Pad T) is CAD $6,000 in undiscounted 2014 Canadian dollars. This has been calculated using the same principles and costing assumptions used in the current Doris North Closure and Reclamation and Plan (SRK 2012).

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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

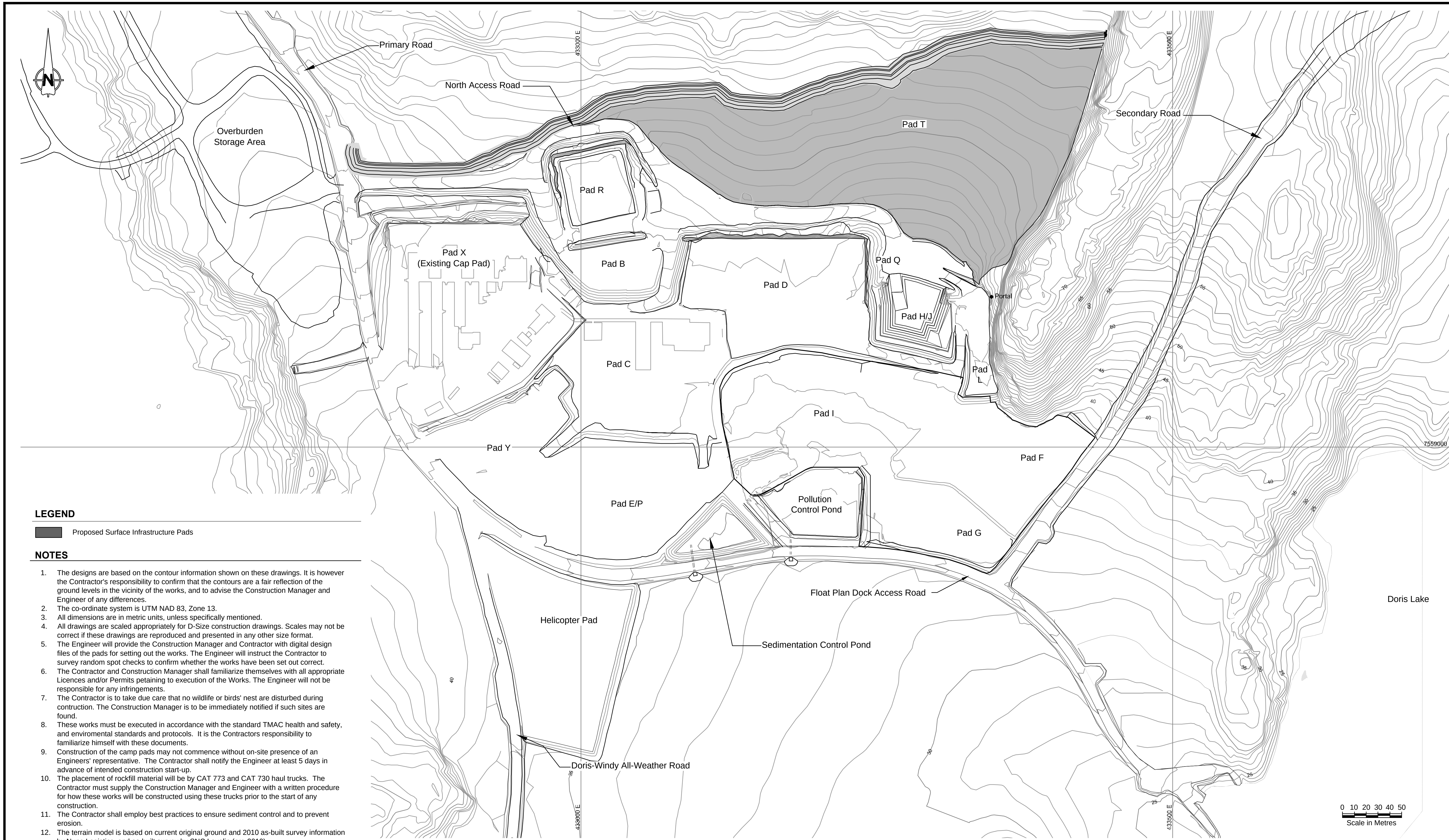
4 References

NWB, 2013. Nunavut Water Board Water Licence No: 2AM-DOH1323. Issued to TMAC Resources Inc., August 16, 2013.

SRK Consulting (Canada) Inc., 2012. Doris North Closure and Reclamation Plan. Report prepared for Hope Bay Mining Ltd., Project No. 1CH008.065. August 2012.

SRK Consulting (Canada) Inc., 2015. Hope Bay Project Doris North Waste Rock and Ore Management Plan – Revision 02. Report prepared for TMAC Resources Inc., Project No. 1CT022.002.100. March 2015.

Figure



LEGEND

Proposed Surface Infrastructure Pads

NOTES

1. The designs are based on the contour information shown on these drawings. It is however the Contractor's responsibility to confirm that the contours are a fair reflection of the ground levels in the vicinity of the works, and to advise the Construction Manager and Engineer of any differences.
2. The co-ordinate system is UTM NAD 83, Zone 13.
3. All dimensions are in metric units, unless specifically mentioned.
4. All drawings are scaled appropriately for D-Size construction drawings. Scales may not be correct if these drawings are reproduced and presented in any other size format.
5. The Engineer will provide the Construction Manager and Contractor with digital design files of the pads for setting out the works. The Engineer will instruct the Contractor to survey random spot checks to confirm whether the works have been set out correct.
6. The Contractor and Construction Manager shall familiarize themselves with all appropriate Licences and/or Permits petaining to execution of the Works. The Engineer will not be responsible for any infringements.
7. The Contractor is to take due care that no wildlife or birds' nest are disturbed during contruction. The Construction Manager is to be immediately notified if such sites are found.
8. These works must be executed in accordance with the standard TMAC health and safety, and enviromental standards and protocols. It is the Contractors responsibility to familiarize himself with these documents.
9. Construction of the camp pads may not commence without on-site presence of an Engineers' representative. The Contractor shall notify the Engineer at least 5 days in advance of intended construction start-up.
10. The placement of rockfill material will be by CAT 773 and CAT 730 haul trucks. The Contractor must supply the Construction Manager and Engineer with a written procedure for how these works will be constructed using these trucks prior to the start of any construction.
11. The Contractor shall employ best practices to ensure sediment control and to prevent erosion.
12. The terrain model is based on current original ground and 2010 as-built survey information by Nuna Logistics, and as-built survey by SNC Lavalin (pre-2010).
13. The lines on this drawing provides the final grade and elevation of the pads. These grades include an allowance for placing a 150mm thick layer of surfacing grade material on all surfaces. The Contractor must make the appropriate adjustments to the grades set out for the Works.
14. Construction shall be in accordance with the following Technical Specifications: Earthworks and Geotechnical Engineering, Hope Bay Project, Nunavut, Canada, revision G -Issue for Construction.
15. Notes in this drawing apply to all other active drawings.

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TMAC RESOURCES

Pad T Closure Plan

Doris North Camp Area

SRK JOB NO.: 1CT022.001

FILE NAME: 1CT022.001_PadT Fig 1.dwg

Doris North Project

DATE: Jan. 2015

APPROVED: LW

FIGURE: 1

C:\01_SITES\Hope Bay\Doris North\Pad T\1CT022.001_PadT Fig 1.dwg

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Memo

To:	John Roberts, TMAC	**Client:**	TMAC Resources Ltd.
From:	Peter Luedke, EIT Lowell Wade, MSc, PEng Maritz Rykaart, PhD, PEng.	**Project No:**	1CT022.002.100
Cc:		**Date:**	March 27, 2015
Subject:	Doris North Project: Waste Rock Storage Pile (Pad T) Stability Analysis		

1 Purpose

TMAC Resources is currently in the process of reviewing the waste rock storage requirements for the Doris North Project (Project) in the Kitikmeot Region of Nunavut, Canada. The four year mine life, of the Doris North Project, will have a total waste rock development of 556,000 t (309,000 m^3).

All waste rock will be stored on the new waste rock storage pad, referred to as Pad T, constructed immediately north of Pad Q and extends to the Doris North Camp Area Diversion Berm (SRK 2012). The use of Pad T will optimize waste rock handling and traffic flow, compared to the current practice of utilizing Pad I for waste rock storage. All existing waste rock, on Pad I, will be relocated to Pad T. Depending on the requirements for waste rock storage at any stage of the Project, Pad T may be used for additional waste rock storage or as general surface infrastructure pads, or any combination thereof.

To determine the stability of a waste rock storage pile, on Pad T, a stability analysis was carried out using the maximum amount of waste rock which can be stockpiled on Pad T. The maximum amount of waste rock that can be stockpiled, on Pad T, is 828,000 tonnes (460,000 m^3) which is 63% greater than is currently planned for.

Guidelines for mined rock and overburden piles suggest the waste rock storage pile, on Pad T, should meet minimum design values for Factors of Safety (FoS) presented in Table 1 (British Columbia Mine Waste Rock Pile Research Committee 1991). The ranges in FoS, for Cases A and B, reflect the different levels of confidence in understanding site conditions, material parameters, and consequences of instability.

Table 1. British Columbia Mine Dump Factor of Safety Guidelines

<table>
<tr><th rowspan="2">Stability Condition</th><th colspan="2">Suggested Minimum Design Values for Factor of Safety</th></tr>
<tr><th>Case A</th><th>Case B</th></tr>
<tr><td colspan="3">Stability of Waste Rock Pile Surface</td></tr>
<tr><td>Short-term (during construction) - (Stability Condition 1)</td><td>1.0</td><td>1.0</td></tr>
<tr><td>Long-term (reclamation – abandonment) – (Stability Condition 2)</td><td>1.2</td><td>1.1</td></tr>
<tr><td colspan="3">Overall Waste Rock Pile Stability (Deep Seated Stability)</td></tr>
<tr><td>Short-term (static) – (Stability Condition 3)</td><td>1.3 - 1.5</td><td>1.1 – 1.3</td></tr>
<tr><td>Long-term (static) – (Stability Condition 4)</td><td>1.5</td><td>1.3</td></tr>
<tr><td>Pseudo-Static (earthquake)[2]</td><td>1.1 – 1.3</td><td>1.0</td></tr>
<tr><td colspan="3">CASE A:
-Low level of confidence in critical analysis parameters
-Possibly unconservative interpretation of conditions, assumptions
-Severe consequences of failure
-Simplified stability analysis method (charts, simplified method of slices)
-Stability analysis method poorly simulates physical conditions
-Poor understanding of potential failure mechanism(s)</td></tr>
<tr><td colspan="3">CASE B:
-High level of confidence in critical analysis parameters
-Conservative interpretation of conditions, assumptions
-Minimal consequences of failure
-Rigorous stability analysis method
-Stability analysis method simulates physical conditions well
-High level of confidence in critical failure mechanism(s)</td></tr>
</table>

Notes:
1. A range of suggested minimum design values are given to reflect different levels of confidence in understanding site conditions, material parameters, consequences of instability, and other factors.
2. Where pseudo-static analyses, based on peak ground accelerations which have a 10% probability of exceedance in 50 years, yield FoS < 1.0, dynamic analysis of stress-strain response, and comparison of results with stress-strain characteristics of dump materials is recommended.

2 Slope Stability Assessment

2.1 Material Properties

2.1.1 Overburden Material Properties

The general overburden profile consists of a thin veneer of hummocky organic soil covered by tundra heath vegetation. Under this organic layer is a layer of marine silts and clays (i.e. silty clay and clayey silt) typically between 5 and 20 m thick. Where the overburden exceeds 20 m in thickness, it appears to be underlain by clayey moraine till, which contains moderate amounts of cobbles and boulders. The bedrock contact zone consists of a relatively thin rubble zone of weathered blocky host rock (SRK 2009).

Pad T will be constructed on permafrost soils (i.e. directly onto the tundra) and is designed to promote freeze-back, thereby minimizing long-term environmental effects from possible acid rock drainage and/or metal leaching. Permafrost soils will provide suitable foundation conditions for waste rock piles, provided the foundation remains frozen. SRK (2006) presents the thermal analysis for the site that demonstrates the viability of this approach. The slope stability model was set up using the geotechnical properties, provided in SRK (2011a), for marine silts and clays as the foundation soils.

2.1.2 Borrow Properties

The physical properties of the Run-of-Quarry (ROQ) material for the Project have not been measured, but the physical properties used in the stability analyses are based on a comparison of the Project's ROQ material with similar materials as reported in the literature and SRK's internal database.

The ROQ used in the construction of Pad T will be placed directly on the tundra surface in accordance with SRK's Technical Specifications for the Project (SRK 2011b). The geotechnical properties of the ROQ and the waste rock pile are provided in SRK (2011a).

2.2 Model Setup

A slope stability model was set up in RocScience Slide (Version 6) (RocScience 2014) using the three types of materials described above. Table 2 summarizes the material properties used in the analyses. The properties used are consistent with previous analyses such as the Doris North Pad U Waste Rock Stability Analysis (SRK 2011c) and the Doris Creek Bridge Abutments stability analysis (SRK 2010).

Table 2: Material Properties Summarized from SRK (2011a)

Parameter		Marine Silt and Clay	Run of Quarry (Pad T)	Waste Rock Pile
Moist Unit Weight (kN/m^3)		18.5	20	20
Degree of Saturation		85%	30%	30%
Porosity		0.52	0.30	0.30
Volumetric Water Content		0.44	0.09	0.09
Unfrozen	Apparent Cohesion c' (kPa)	0	0	0
	Friction Angle, φ^{0}	30	40	39
Frozen	Apparent Cohesion c' (kPa)	112	5	n/a
	Friction Angle, φ^{0}	26	40	n/a

For the stability analyses, it was assumed that Pad T protects the permafrost in the marine silts and clays that it sits atop. Pad T and the waste rock pile is conservatively assumed to be unfrozen. This is conservative since in the long term freeze back will occur in both the pad and the waste rock pile.

A critical cross-section through the waste rock pile based on the slope of the foundation and ultimate waste rock pile height was selected to create the model used to run the analyses (Figure 1). The modeled cross-section is shown in Figure 2.

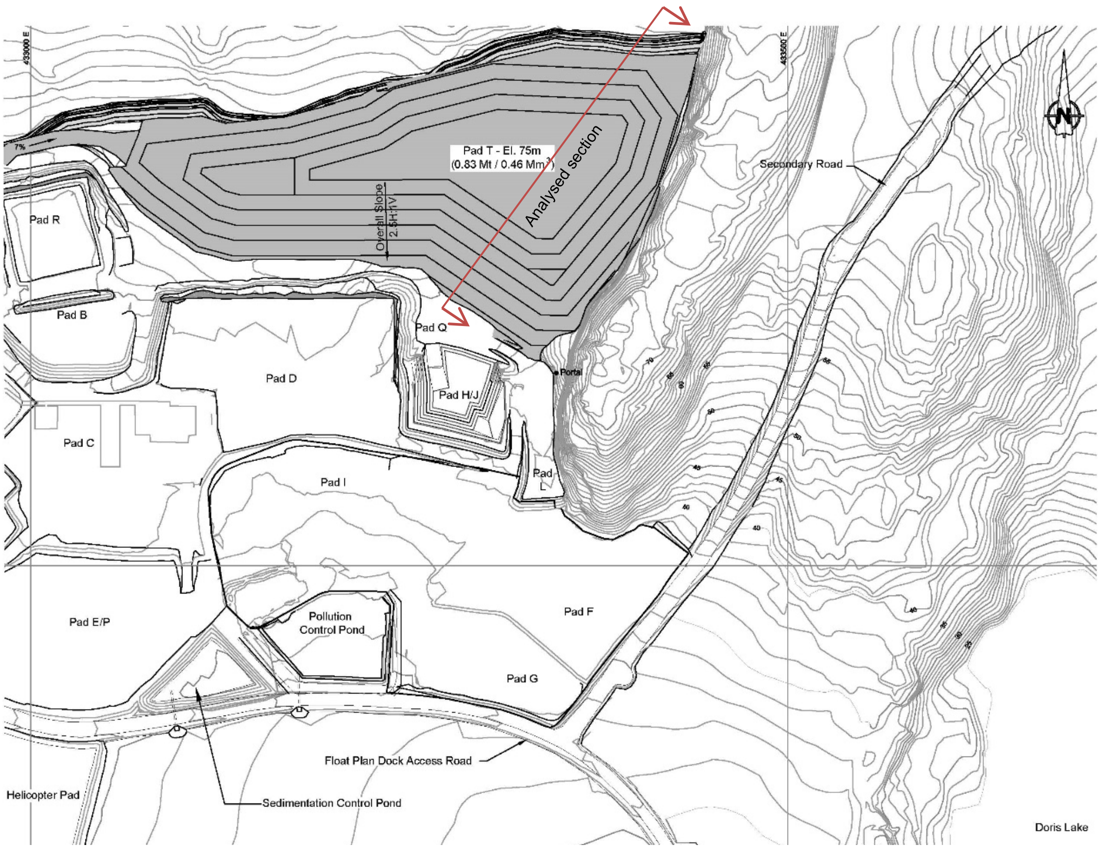

Figure 1. Plan View of the Section used as a Critical Section for Analysis (Figure taken from SRK 2014).

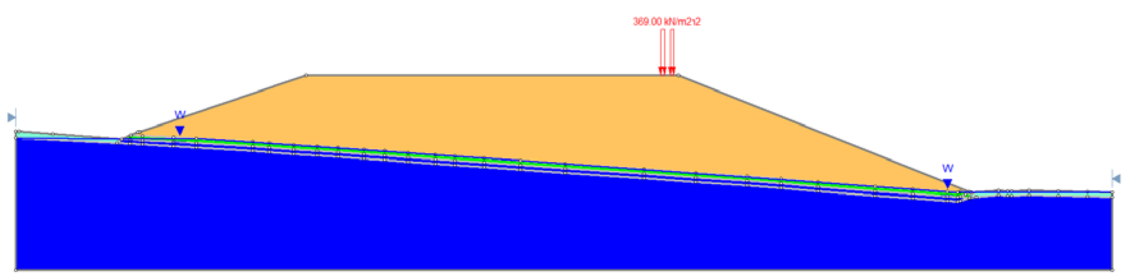

Figure 2. Section View of the Critical Section used for the Analyses in RocScience Slide.

2.3 Methodology

The stability, of the waste rock stockpile also took into consideration haul truck wheel loads applied near the crest of the waste rock stockpile. The loaded Sandvik TH540 was assumed to be the heaviest vehicle driving on the waste rock pile. The wheel loading calculation for the

TH540 haul truck is included as Attachment 1. For analysis purposes, the wheel loading was applied at a minimum of 1 m to the crest of the waste rock pile.

The slope stability of the waste rock pile was evaluated under four stability conditions listed in Table 1. The following three stability analyses were evaluated:

- Short-term (during construction) (Stability Condition 1): This stability case considers the stability of the waste rock pile surface with the truck loading applied at the crest of the waste rock pile.

- Long-term (reclamation/abandonment/static) (Stability Conditions 2 and 4): This stability case considers the stability of the waste rock pile surface and the overall waste rock pile stability without the haul truck wheel loads near the crest.

- Short-term (static) (Stability Conditions 3): This stability case considers the stability of the overall waste rock pile with the truck loading applied at the crest of the waste rock pile and only is analysed for deep seated stability by forcing the slip-surface to a particular path or certain depth.

The slope stability analyses were carried out using the Spencer Limit Equilibrium Method and the results checked using the Morgenstern-Price Limit Equilibrium Methods. These limit equilibrium methods satisfy all limit equilibrium conditions. Each differs in its assumptions. Spencer's method makes the least static assumptions while Morgenstern-Price method assumes the side forces follow a prescribed function, side forces can vary from slice to slice (ASCE 2002) and is considered to be more conservative.

Multiple analyses for each Limit Equilibrium Method were completed using the Auto-Refine (circular or non-circular), Block Search, and Simulated Annealing Slip-Surface Search Functions available within RocScience Slide. These Slip-Surface Search Functions are the methods by which Rocscience Slide identifies the critical slip surface(s). Additional refinement to the Slip-Surface Search Functions was applied by using constraints such as Entry-Exit, Minimum Depth or Optimized Search. The slip surface functions selected for each load case were based on the observed variability of the results and refinement of the slip surface mode.

The Project site is located in a stable seismic zone of Canada with low peak ground accelerations (SRK 2011a). Because of this, a pseudo-static stability analysis under seismic conditions was not assessed.

3 Results

The range of FoS calculated for each Stability Analysis is presented in Table 3 while all the results for all Stability Analyses are provided in Attachment 2. Although there is a good understanding of site conditions, material parameters, and consequences of instability, which suggests the waste rock stockpile, Pad T should meet the FoS required for Case B, as the calculated FoS was found to exceed those listed for Case A as well.

Table 3. Waste Rock Pile Stability Analysis Results

Stability Analysis	Suggested FoS (Case A)	Suggested FoS (Case B)	Calculated FoS	Comment
Short-term (during construction) (Stability Condition 1)	1.0	1.0	1.0 – 1.5	Shallow crest failures due to haul truck wheel loads 1 m from crest of waste rock pile.
Long-term (reclamation/ abandonment/ static) (Stability Conditions 2 and 4)	1.2 & 1.5	1.1 & 1.3	2.0	Shallow skin failures along the outer slope of the waste rock pile due to haul truck wheel loads 1 m from the crest of the waste rock pile. Deep seated slip surfaces found to have a FoS > 2.0.
Short-term (static) (Stability Conditions 3)	1.3 – 1.5	1.1 – 1.3	1.9 – 2.0	Larger slip surface initiating beneath the applied load.

3.1 Short-term (during construction) (Stability Condition 1)

Based on the Guidelines for mined rock and overburden piles (BCMDC, 1991), the FoS for the Short-term (during construction) (Stability Condition 1) must be 1.0. This FoS was met and exceeded for all but one analysis conducted for this Stability Condition. A minimum FoS of 0.9 was calculated using the Auto-Refine (Non-Circular) Search Function under Entry/Exit and Optimized Search Constraints. To determine the significance of this result, the bearing capacity of the waste rock pile was evaluated.

To eliminate the shallow crest failures, due to the haul truck wheel loads, the bearing capacity of the waste rock stockpile was evaluated to determine the distance which the wheels of a loaded haul truck must be from the crest of the waste rock stockpile, to achieve a FoS of 1.0. It was determined the wheels of a haul truck must not be within 1.2 m of the crest of the waste rock pile (Attachment 3). This means appropriate safety measures should be put in place to make sure the haul trucks must stop a minimum distance of 1.2 m from the edge of the waste rock pile.

A sensitivity analysis was also carried out for the lowest FoS = 0.9 (i.e. the Short-term (during construction) (Stability Condition 1) using the Auto-Refine (Non-Circular) Search Function under Entry/Exit and Optimized Search Constraints) by varying both the friction angle of the waste rock and the distance between the nearest haul truck wheel load and the crest of the waste rock pile. By increasing the waste rock pile's angle of friction, the FoS was found to increase from 0.9 (at a Friction Angle, φ^{0} = 39) to over 1.1 (at a Friction Angle, φ^{0} = 47) (Figure 3). By increasing the distance of the wheel loads from the crest of the waste rock pile, the FoS was found to increase from 0.9 (at a distance of 1 m) to over 1.7 (as a distance of 4 m) (Figure 4).

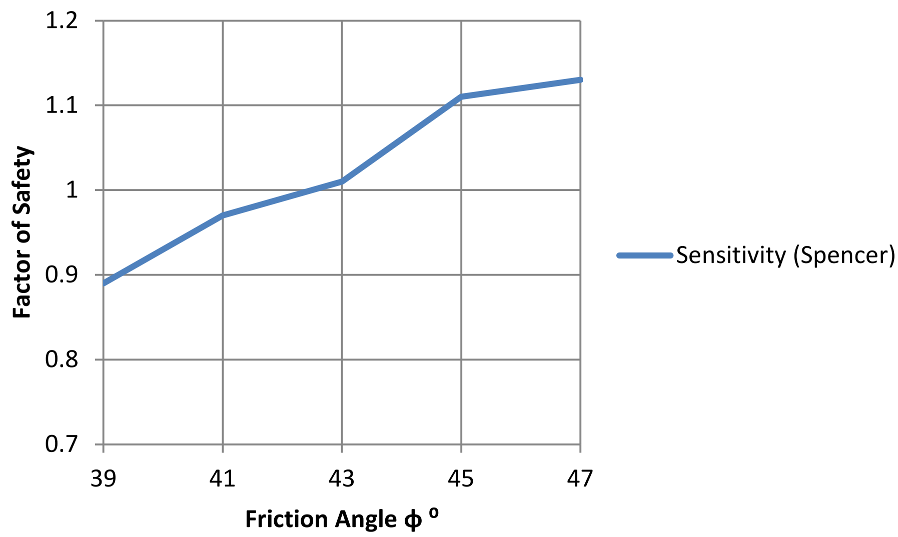

Figure 3. FoS v. Waste Rock Pile's Angle of Friction

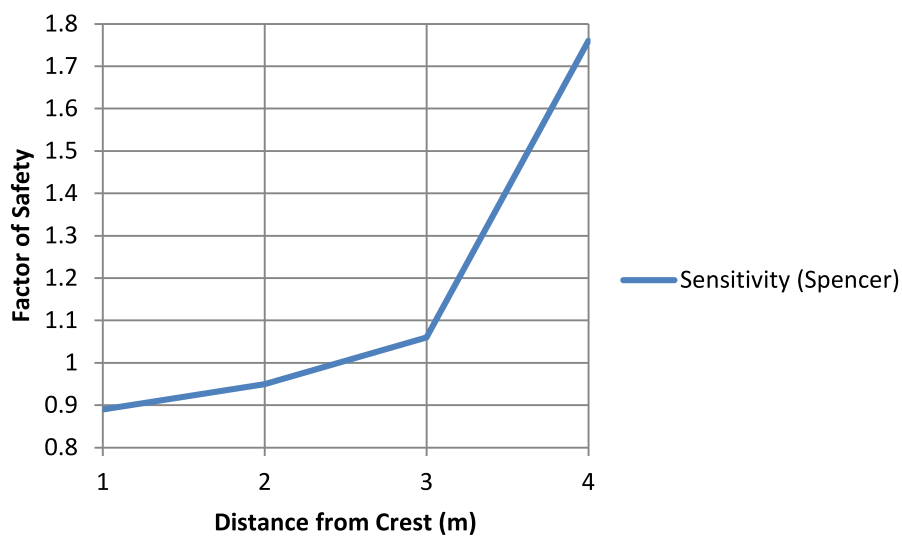

Figure 4. FoS v. Distance of Wheel Loads from the Crest of the Waste Rock Pile

3.2 Long-term (Reclamation/Abandonment/Static) (Stability Conditions 2 and 4)

The failure surfaces which provided the lowest FoS, under Stability Condition 1, were analysed under Stability Condition 2. It was found that all slip surfaces occurred as shallow skin failures along the outer slope of the waste rock pile due to haul truck wheel loads 1 m from the crest of the waste rock pile. As this analysis searched the entire dump, and the FoS generally increased with depth, there was no further analysis carried out for deep seated failures without haul truck loading (Stability Condition 4).

3.3 Short-term (static) (Stability Conditions 3)

Deep seated slip surfaces (Stability Condition 3) were considered with the haul truck wheel loads applied 1 m from the crest of the waste rock pile. Analyses were carried out using a minimum depth of 7 and 10 m, as a constraint to force the critical slip surface to depth and a focus search window for the Block Slip Search Function to focus on a deeper area than the unrefined optimized search would.

4 Waste Rock Pile Stability Rating

A Dump Stability Rating (DSR) for the waste rock pile, on Pad T, was also completed in accordance with the guidelines set by the British Columbia Mine Waste Rock Pile Research Committee (1991). For frozen foundation conditions the stability rating for the waste rock pile, on Pad T, is 250 (Class I Stability). The rating selection is presented in Appendix D. The level of slope stability analyses presented in Section 3 was completed in accordance with the DSR Recommended Level of Effort shown in Attachment 4.

5 Discussion

The results of the slope stability analysis for three stability analyses which were evaluated can be summarized as follows:

<u>Short-term (during construction) (Stability Condition 1)</u>: The minimum required FoS of 1.0 was met and exceeded for all but one analysis conducted for this Stability Condition. The Auto-Refine (Non-Circular) Search Function under Entry/Exit and Optimized Search Constraints had a FoS of 0.9. Based on all the slope stability analyses, the bearing capacity analysis, and sensitivity analyses along with some assessment of conservative aspects of the model, the FoS of 0.9 indicates a safe setback distance of a minimum 1.2 m, from the crest of the waste rock pile, must be maintained for the safe operation of the haul truck dumping waste rock at the crest of the waste rock pile.

The results of these slope stability and bearing capacity analyses indicate a minimum safe distance from the crest of the waste rock pile, of a minimum of 1.2 m, should be maintained for haul trucks dumping waste rock close to the crest of the waste rock pile. This minimum distance, of 1.2 m, from the crest of the waste rock pile is based on a FoS of 1.0 and does not take into consideration any additional distance from the crest of the waste rock pile that should be maintained for operational safety.

<u>Long-term (reclamation/abandonment/static) (Stability Conditions 2 and 4):</u> All stability analyses conducted, for this Stability Condition, had a FoS of 2.0 which exceeds the recommended FoS of 1.1. The entire waste rock pile was searched for potential slip surfaces and deep seated failures. The results of these analyses had FoS greater than 2.0. For this reason, no additional analyses were conducted for Stability Condition 4.

Short-term (static) (Stability Conditions 3): Slip surfaces were forced to a minimum depth of 7 to 10 m for a search focus window near the base of the waste rock pile resulted in FoS of 1.9 to 2.0 which exceeds the recommended FoS of 1.1.

The results of the slope stability analyses discussed above, can be considered to be conservative. The slope stability analyses assumes the wheel loads are applied along the entire crest of the crest of the waste rock pile (i.e. the assumption of a plane strain problem) and does not take into consideration the wheel loads are, in fact, a point load. Additional resistance, to a slope failure, can be achieved when a three dimensional slip surface is considered; however, these analyses do not make an allowance for this.

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6 References

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Attachment 1

Sandvik TH540 Underground Haul Truck Wheel Loads

Wheel load approximation for the Sandvik TH540			Reference
Operating Weight	34700	kg	(1)
Payload Capacity	40000	kg	(1)
Gross operating weight	74700	kg	(1)
Max operating weight	82700	kg	(2)
Loaded front axel weight	37200	kg	
% of gross operating weight	49.8%		
Loaded front rear weight	37500	kg	
% of gross operating weight	50.2%		
Front axel maximum weight	41184	kg	
Rear axel weight	41516	kg	
Load on each front tire	202.0072	kN	
Load on each rear tire	203.6363	kN	
Tire static loaded width	743	mm	(3)
Static loaded radius	784	mm	(3)
Assumed Contact length	743	mm	
Contact Area of one tire	0.552049	m2	
Ground pressure applied by each rear tire	368.87	kPa	

(1) Details on the Sandvik TH540 can be found in the Technical specs online

http://www.miningandconstruction.sandvik.com/sandvik/5100/SAM/Internet/cl01023.nsf/Alldocs/Products*5CLoad*and*haul*machines*5CUnderground*trucks*2ASandvik*40/$FILE/Sandvik%20TH540%20techspec.pdf

(2) 10-10-20 Payload Policy documents

Weight Calculation extracted from the Caterpillar 10-10-20 Payload Policy documents applied to the Sandvik Specs

Empty Chassis Weight (ECW) + Body and Liner = Empty Machine Weight (EMW) + Debris Fuel Attachments = Empty Operating Weight (EOW)

Target Gross Machine Weight (TGMW) -Empty Operating Weight (EOW) = Target Payload (TP)

Target Payload (TP) x 1.2 + Empty Operating Weight (EOW) < Maximum Gross Machine Weight (MGMW)

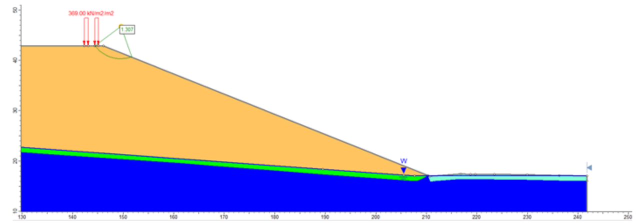
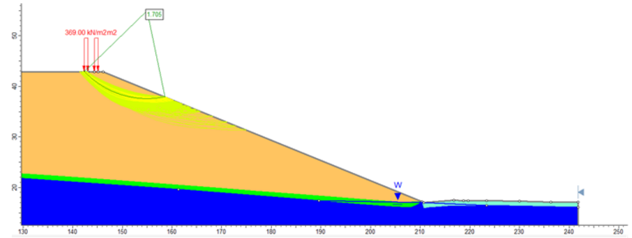
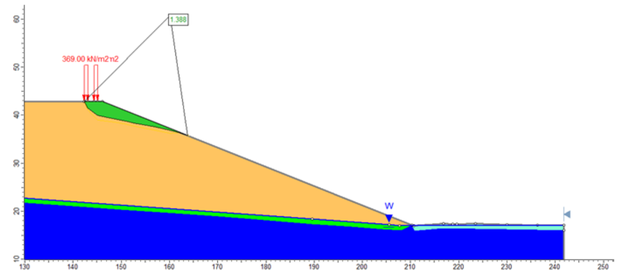
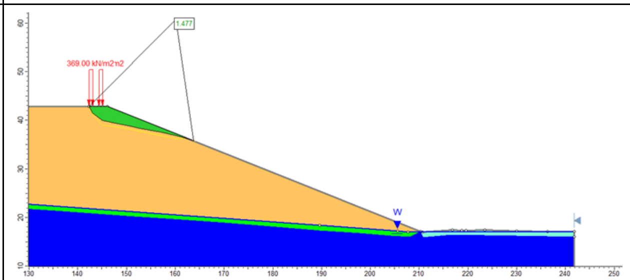
(3) Bridgestone tire specifications VLTS (26.5R25)

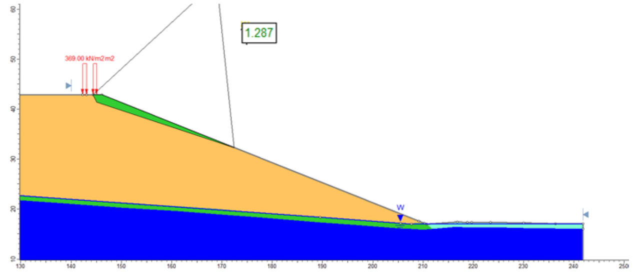
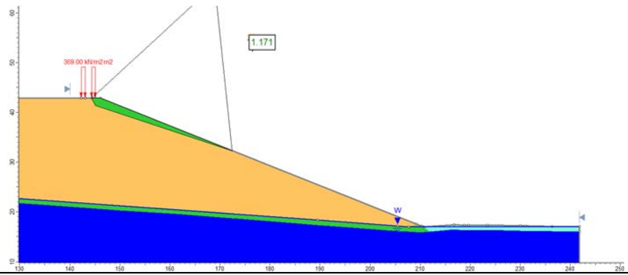
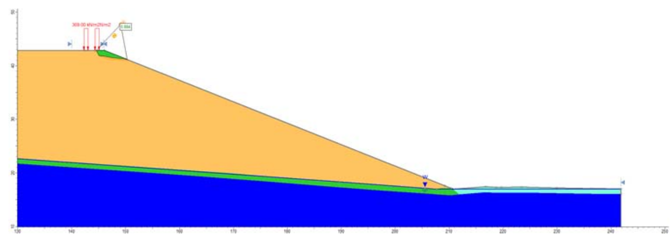
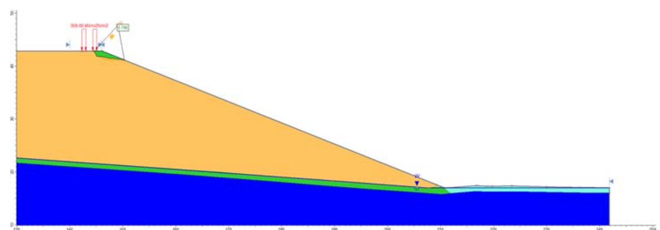
http://www.bridgestone.com/products/speciality_tires/off_the_road/products/pdf/brochure_earth_010.pdf

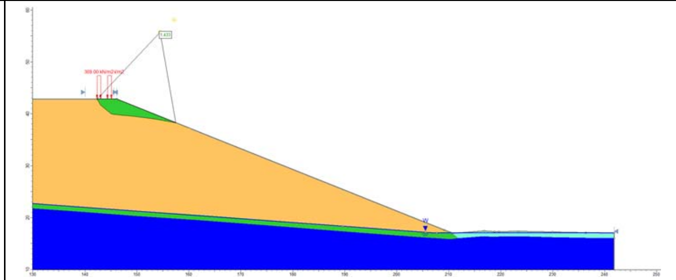
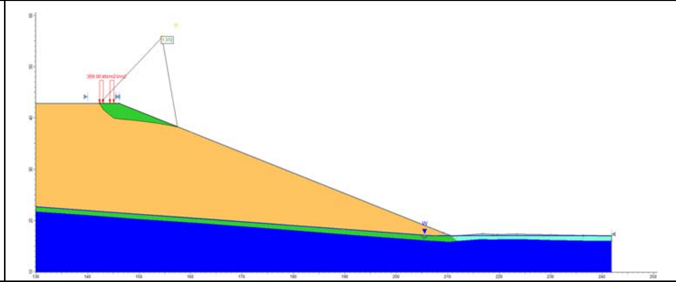
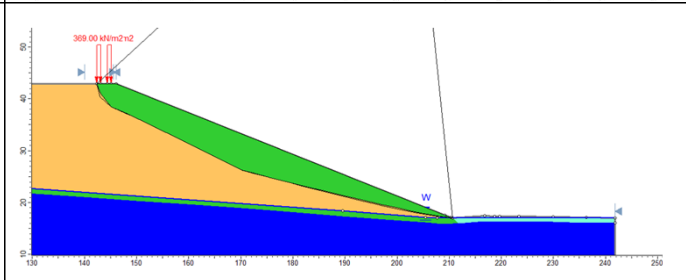
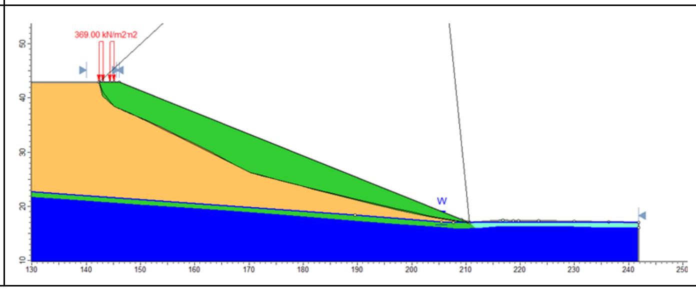
Attachment 2

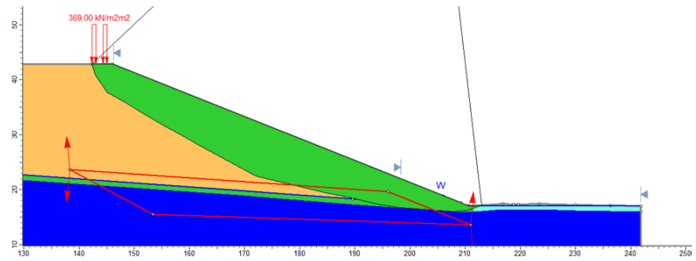
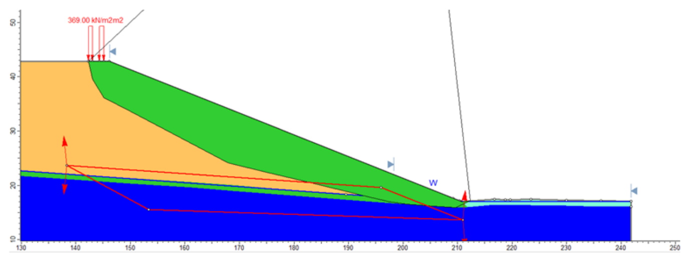
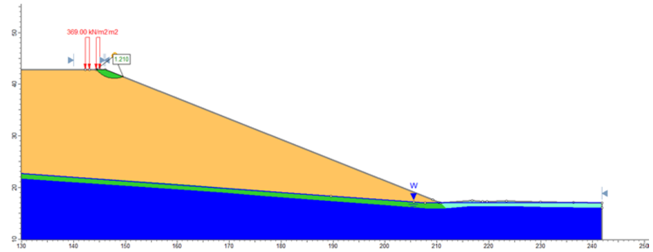
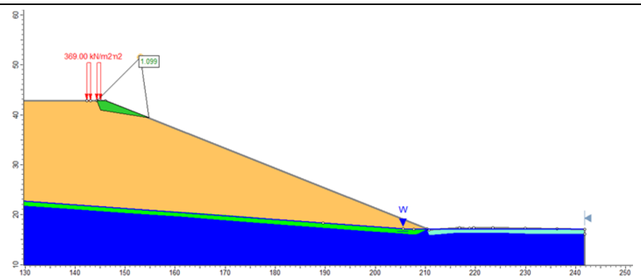
Summary of Slope Stability Analyses

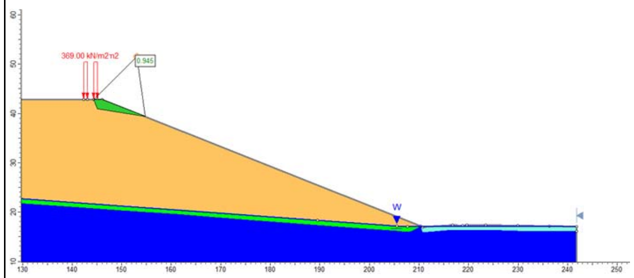
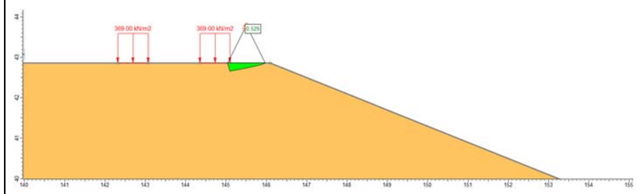
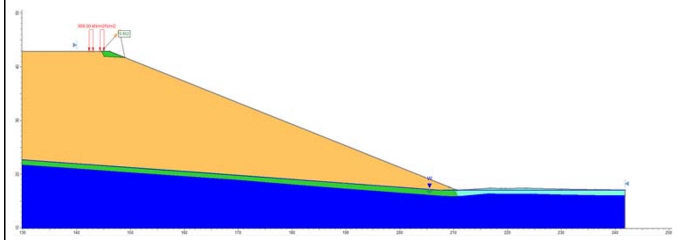
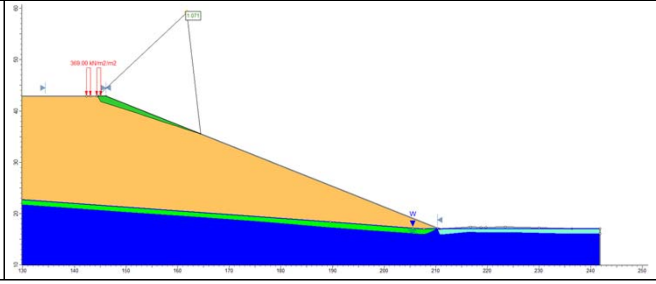
Stability Analysis with Wheel Loading Applied.

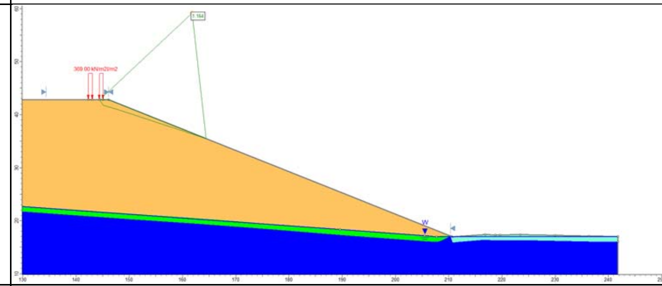
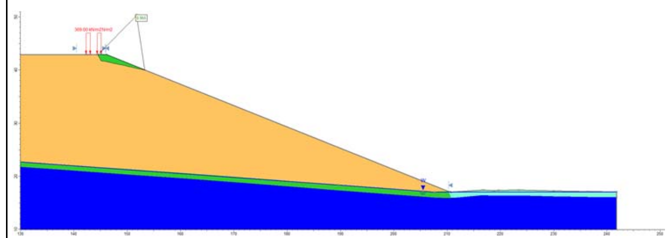
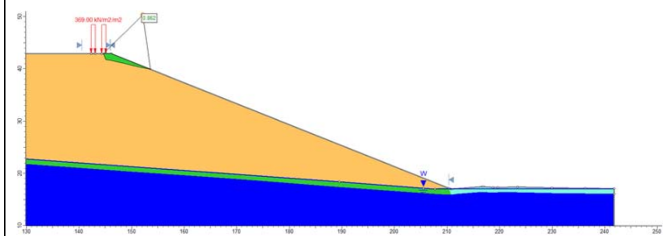
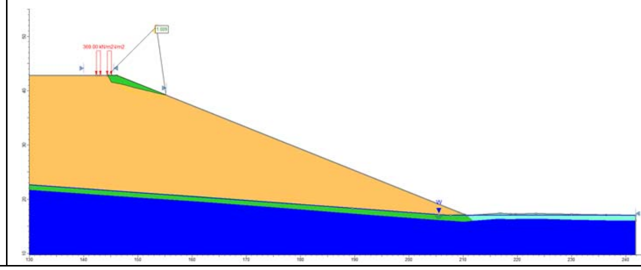
Run #	Stability Condition	Limit equilibrium Method	Minimum FoS	Search Function	Additional Refinement Options	Other Notes	Critical Slip Surface
1	Stability Condition 1	Spencer	1.3	Auto-Refine (Circular)	-	-	
2	Stability Condition 1	Morgenstern-Price	1.7	Auto-Refine (Circular)	-	Minimum 1m depth	
3	Stability Condition 1	Morgenstern-Price	1.4	Auto-Refine (Non-circular)	-	-	
4	Stability Condition 1	Spencer	1.5	Auto-Refine (Non-circular)	-	-	

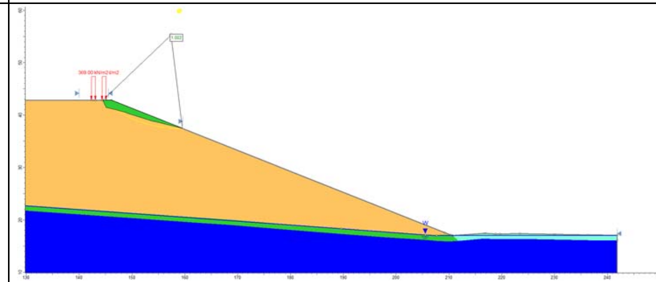
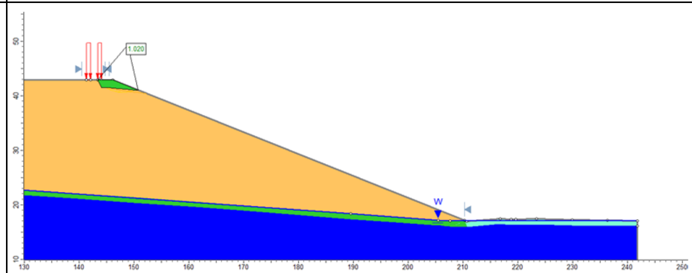
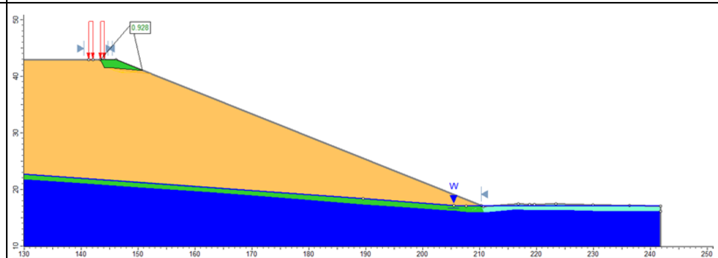
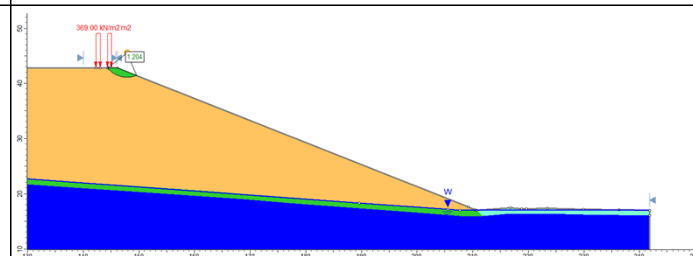
Run #	Stability Condition	Limit equilibrium Method	Minimum FoS	Search Function	Additional Refinement Options	Other Notes	Critical Slip Surface
5	Stability Condition 1	Spencer	1.3	Auto-Refine (Non-circular)	Optimized	-	
6	Stability Condition 1	Morgenstern-Price	1.2	Auto-Refine (Non-circular)	Optimized	-	
7	Stability Condition 1	Spencer	0.9	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	-	
8	Stability Condition 1	Morgenstern-Price	0.8	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	-	

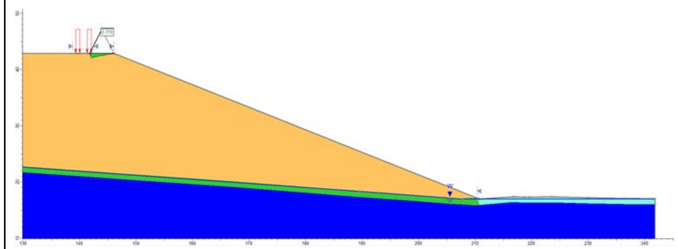
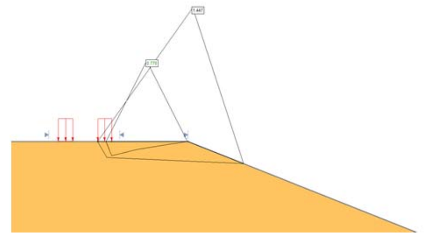
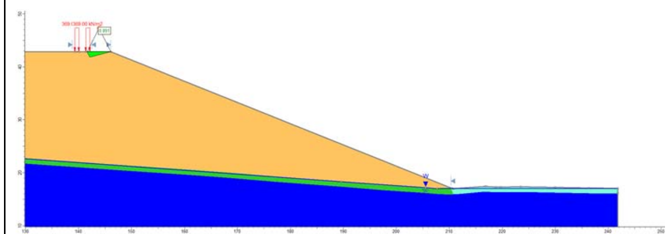
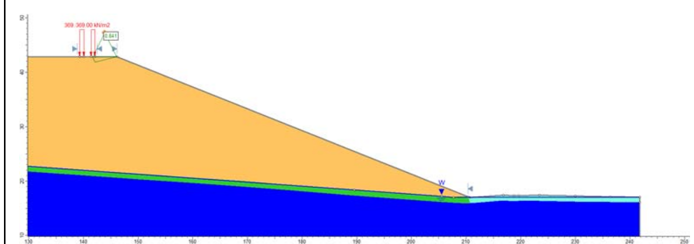
Run #	Stability Condition	Limit equilibrium Method	Minimum FoS	Search Function	Additional Refinement Options	Other Notes	Critical Slip Surface
9	Stability Condition 1	Spencer	1.4	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	Minimum 3m depth	
10	Stability Condition 1	Morgenstern-Price	1.4	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	Minimum 3m depth	
11	Stability Condition 3	Spencer	1.9	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	Minimum 7m depth	
12	Stability Condition 3	Morgenstern-Price	1.9	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	Minimum 7m depth	

Run #	Stability Condition	Limit equilibrium Method	Minimum FoS	Search Function	Additional Refinement Options	Other Notes	Critical Slip Surface
13	Stability Condition 3	Spencer	2.0	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	Minimum 10m depth	
14	Stability Condition 3	Morgenstern-Price	2.0	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	Minimum 10m depth	
15	Stability Condition 1	Morgenstern-Price	1.2	Auto-Refine (Circular)	Entry/Exit Constrained	-	
16	Stability Condition 1	Spencer	1.1	Simulated Annealing	Optimized	-	

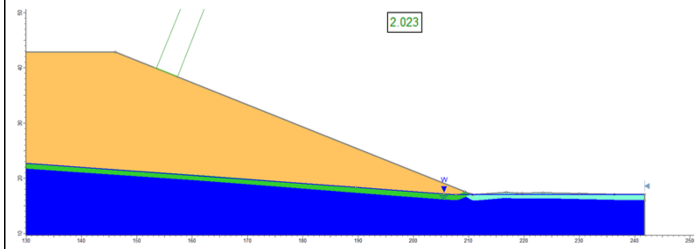
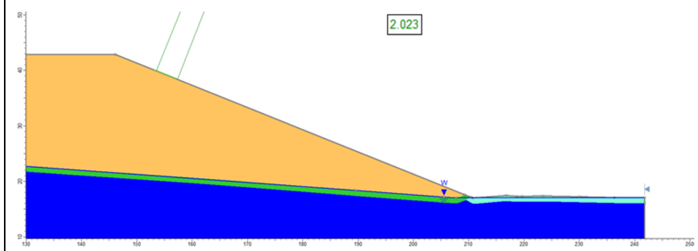
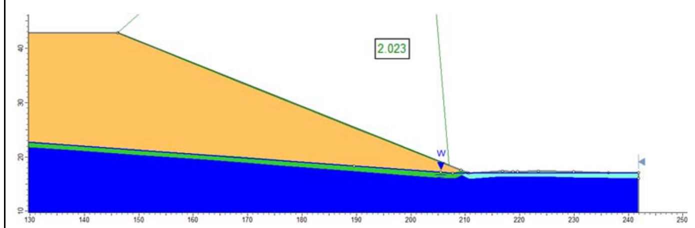
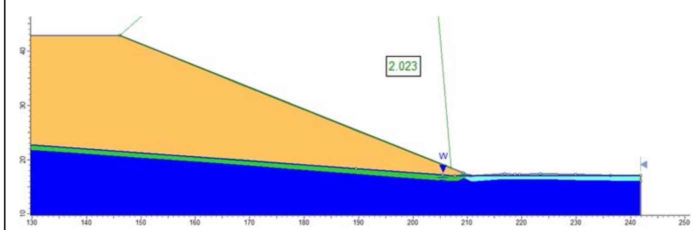
Run #	Stability Condition	Limit equilibrium Method	Minimum FoS	Search Function	Additional Refinement Options	Other Notes	Critical Slip Surface
17	Stability Condition 1	Morgenstern-Price	0.9	Simulated Annealing	Optimized	-	
18	Stability Condition 1	Spencer	0.5	Simulated Annealing	Optimized	-	 The scale of this section view is increased to allow visibility of the failure surface
19	Stability Condition 1	Spencer	0.9	Simulated Annealing	Optimized	Minimum 1m depth	
20	Stability Condition 1	Morgenstern-Price	1.1	Block Slip	Optimized Entry/Exit Constrained	-	

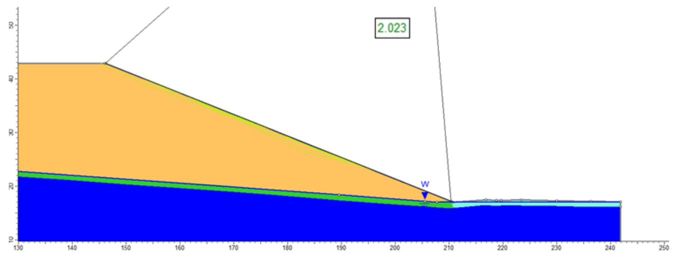
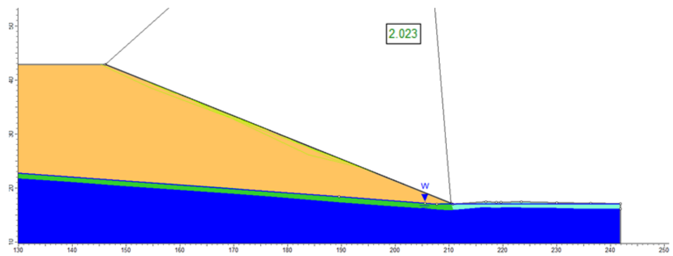
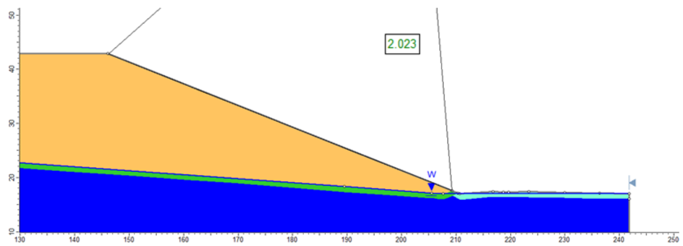
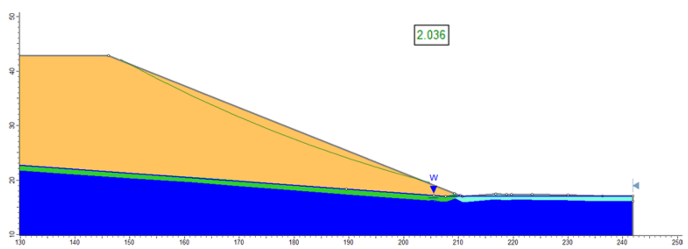
Run #	Stability Condition	Limit equilibrium Method	Minimum FoS	Search Function	Additional Refinement Options	Other Notes	Critical Slip Surface
21	Stability Condition 1	Spencer	1.2	Block Slip	Optimized Entry/Exit Constrained	-	
22	Stability Condition 1	Spencer	1.0	Block Slip	Optimized Entry/Exit Constrained	-	
23	Stability Condition 1	Morgenstern-Price	0.9	Block Slip	Optimized Entry/Exit Constrained	-	
24	Stability Condition 1	Spencer	1.0	Auto Refine (Non-circular)	Optimized Entry/Exit Constrained	-	

Run #	Stability Condition	Limit equilibrium Method	Minimum FoS	Search Function	Additional Refinement Options	Other Notes	Critical Slip Surface
25	Stability Condition 1	Morgenstern-Price	1.0	Block Slip	Optimized Entry/Exit Constrained	-	
26	Stability Condition 1 (Modified for comparison)	Spencer	1.0	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	Load Setback 2m	
27	Stability Condition 1 (Modified for comparison)	Morgenstern-Price	0.9	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	Load Setback 2m	
28	Stability Condition 1 (Modified for comparison)	Spencer	1.2	Auto-Refine (Non-circular)	Entry/Exit Constrained	Load Setback 2m	

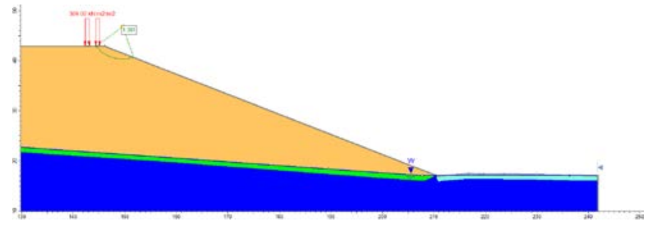
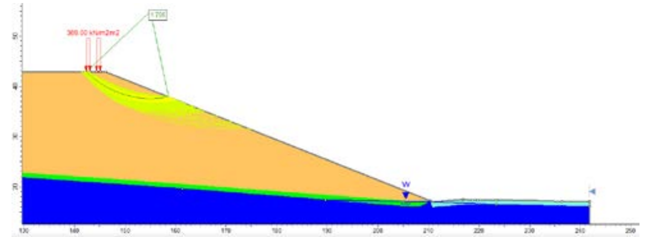
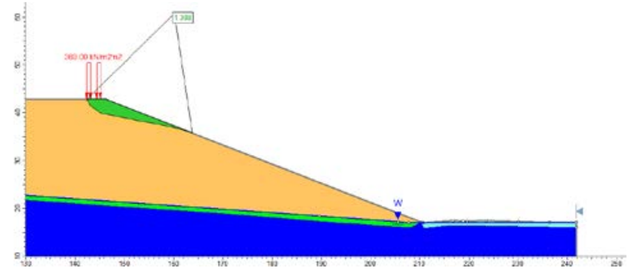
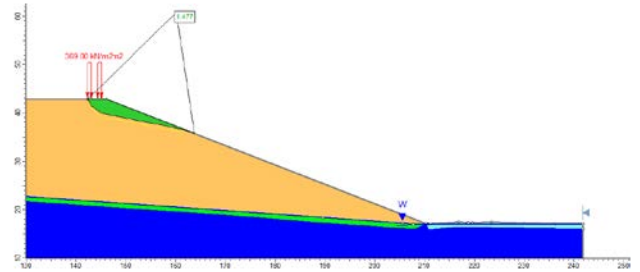
Run #	Stability Condition	Limit equilibrium Method	Minimum FoS	Search Function	Additional Refinement Options	Other Notes	Critical Slip Surface
29	Stability Condition 1 (Modified for comparison)	Morgenstern-Price	0.8	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	Load Setback 4m	
30	Stability Condition 1 (Modified for comparison)	Morgenstern-Price	1.5	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	Load Setback 4m	 The scale of this section view is increased to allow visibility of the failure surface
31	Stability Condition 1 (Modified for comparison)	Spencer	0.9	Simulated Annealing	Optimized Entry/Exit Constrained	Load Setback 4m	
32	Stability Condition 1 (Modified for comparison)	Morgenstern-Price	0.8	Simulated Annealing	Optimized Entry/Exit Constrained	Load Setback 4m	

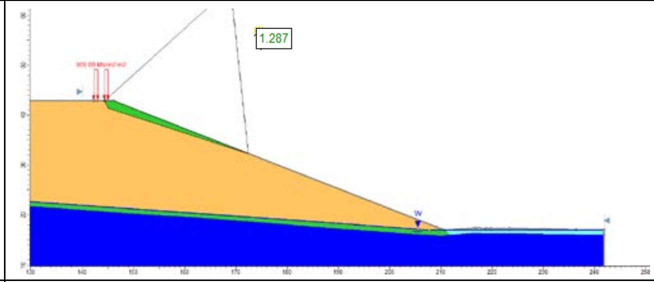
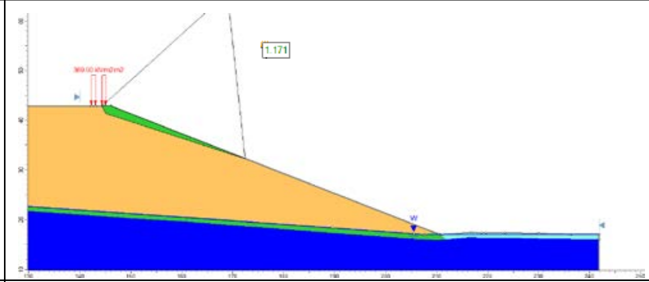
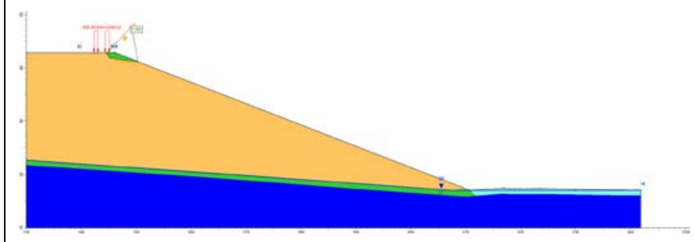
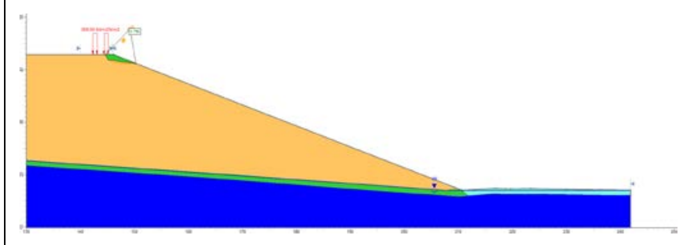
Stability Analysis with No Wheel Loading Applied.

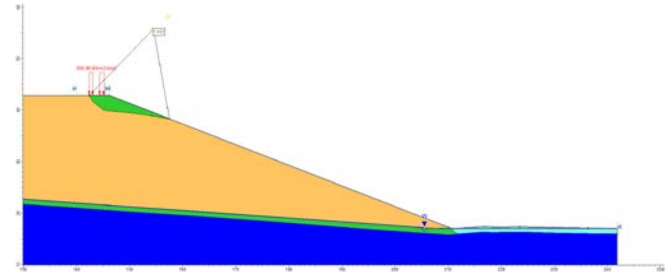
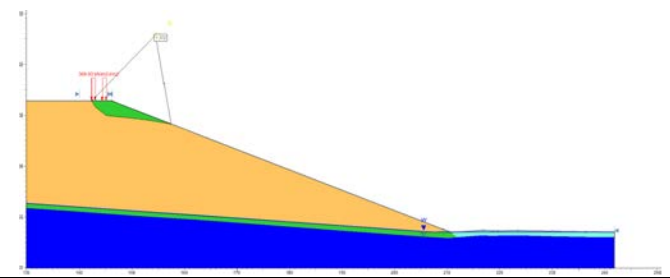
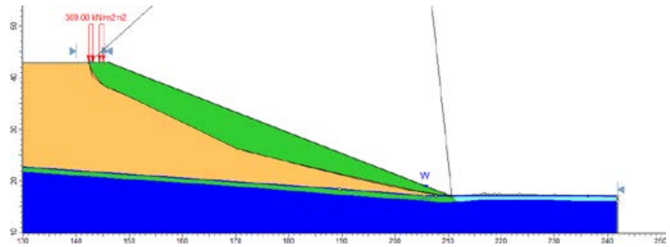
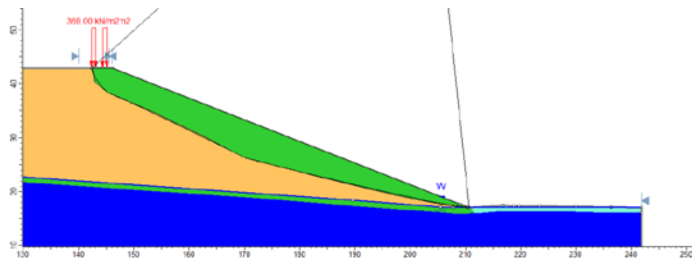
Run #	Stability Condition	Limit equilibrium Method	Minimum FoS	Search Function	Additional Refinement Options	Other Notes	Critical Slip Surface
33	Stability Condition 2	Spencer	2.0	Auto-Refine (Circular)	Entry/Exit Constrained	-	
34	Stability Condition 2	Morgenstern-Price	2.0	Auto-Refine (Circular)	Entry/Exit Constrained	-	
35	Stability Condition 2	Spencer	2.0	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	-	
36	Stability Condition 2	Morgenstern-Price	2.0	Auto-Refine (Circular)	Optimized Entry/Exit Constrained	-	

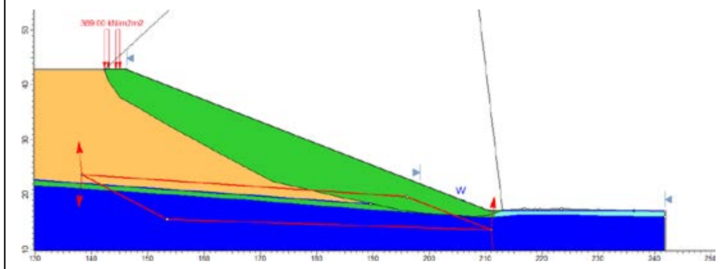
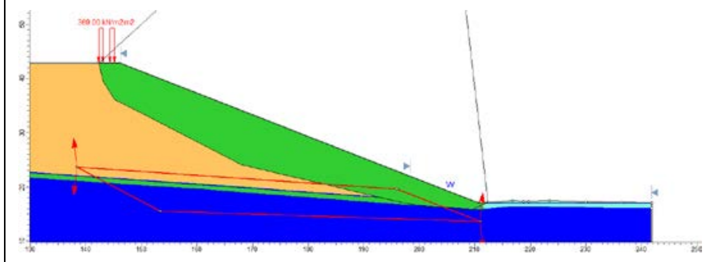
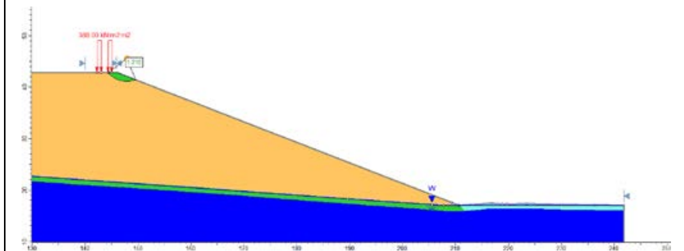
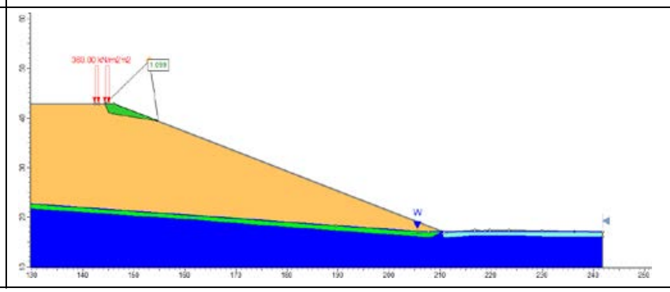
Run #	Stability Condition	Limit equilibrium Method	Minimum FoS	Search Function	Additional Refinement Options	Other Notes	Critical Slip Surface
37	Stability Condition 2	Spencer	2.0	Block Slip	Optimized Search window over entire slope	The ten lowest surfaces are also shown	
38	Stability Condition 2	Morgenstern-Price	2.0	Block Slip	Optimized Search window over entire slope	The ten lowest surfaces are also shown	
39	Stability Condition 2	Spencer	2.0	Simulated Annealing	-	Shallow Skin Failure	
40	Stability Condition 2 (Modified for Comparison)	Spencer	2.0	Auto-Refine (Circular)	-	Minimum 1m Depth	

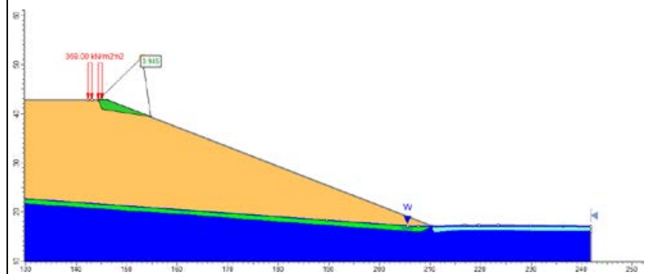
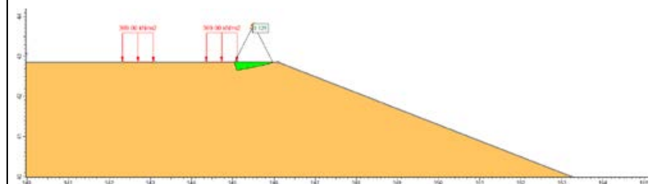
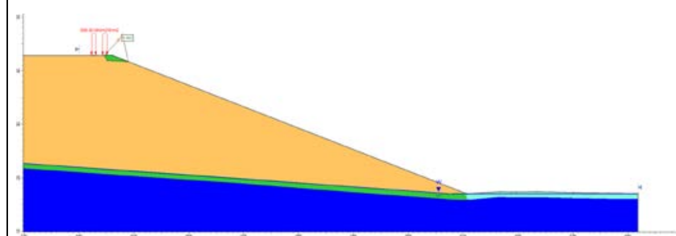
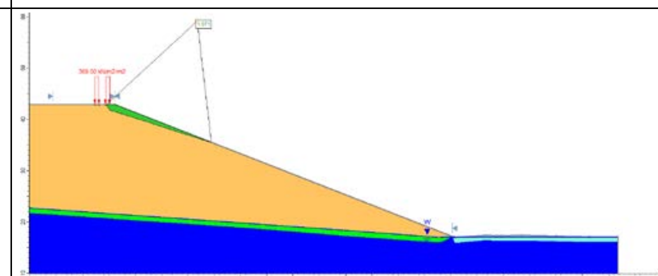
Stability Analysis with Wheel Loading Applied.

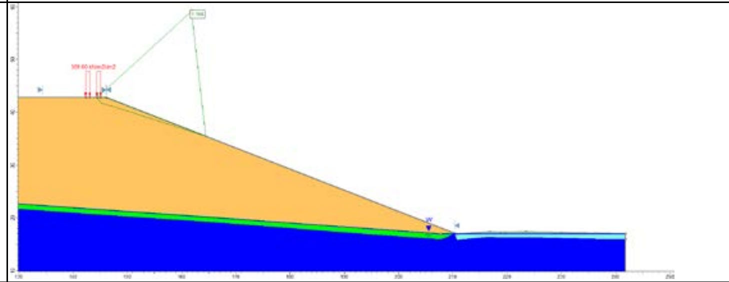
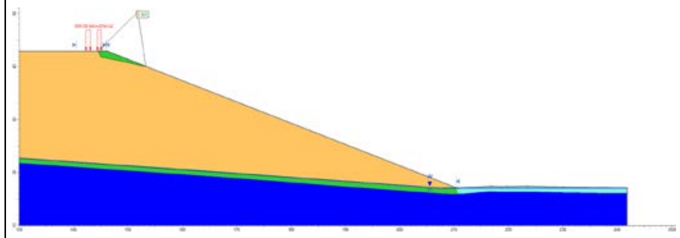
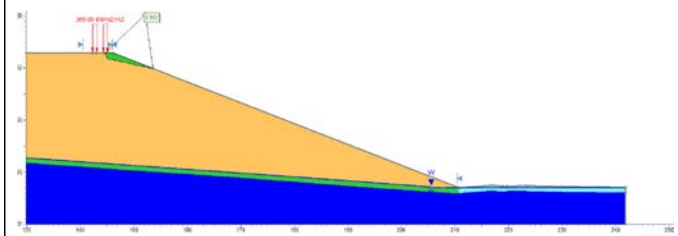
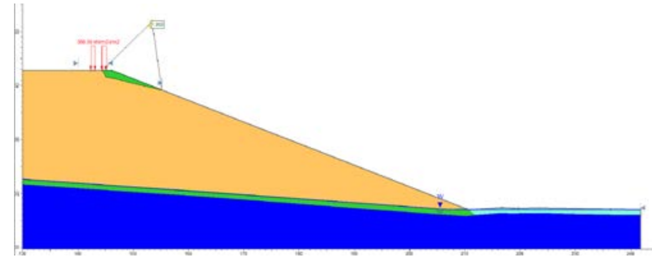
Run #	Stability Condition	Limit equilibrium Method	Minimum FoS	Search Function	Additional Refinement Options	Other Notes	Critical Slip Surface
1	Stability Condition 1	Spencer	1.3	Auto-Refine (Circular)	-	-	
2	Stability Condition 1	Morgenstern-Price	1.7	Auto-Refine (Circular)	-	Minimum 1m depth	
3	Stability Condition 1	Morgenstern-Price	1.4	Auto-Refine (Non-circular)	-	-	
4	Stability Condition 1	Spencer	1.5	Auto-Refine (Non-circular)	-	-	

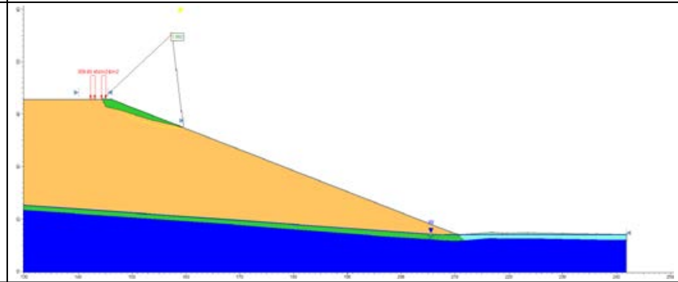
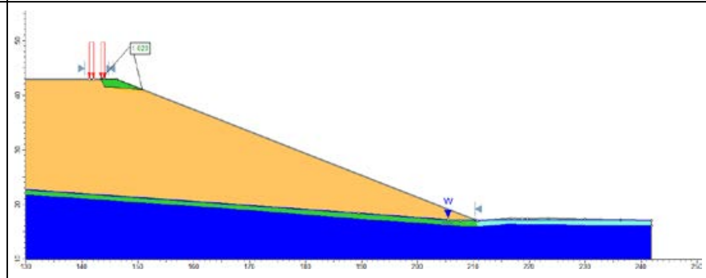
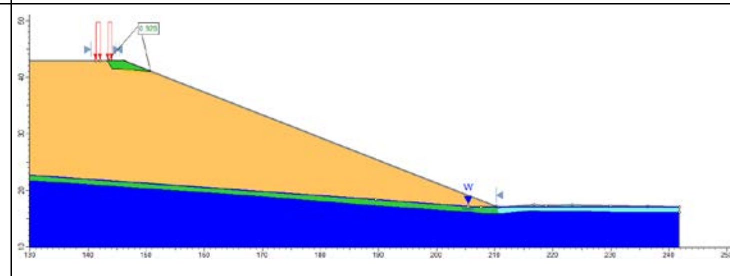
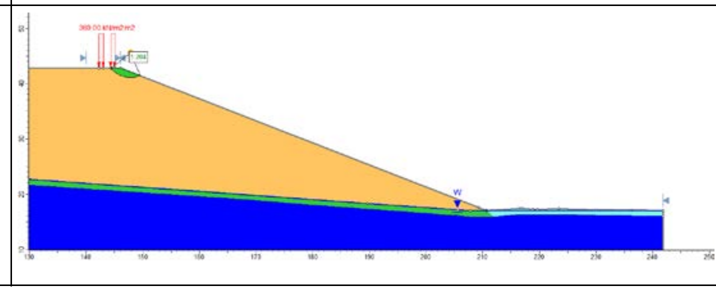
Run #	Stability Condition	Limit equilibrium Method	Minimum FoS	Search Function	Additional Refinement Options	Other Notes	Critical Slip Surface
5	Stability Condition 1	Spencer	1.3	Auto-Refine (Non-circular)	Optimized	-	
6	Stability Condition 1	Morgenstern-Price	1.2	Auto-Refine (Non-circular)	Optimized	-	
7	Stability Condition 1	Spencer	0.9	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	-	
8	Stability Condition 1	Morgenstern-Price	0.8	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	-	

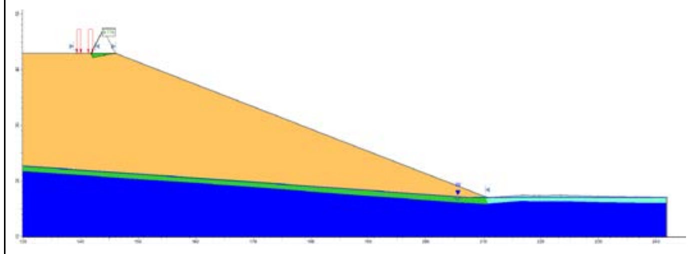
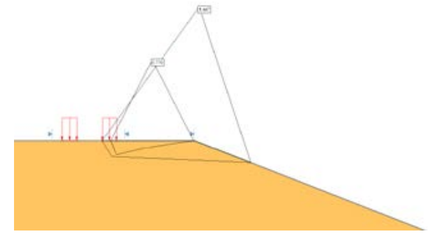
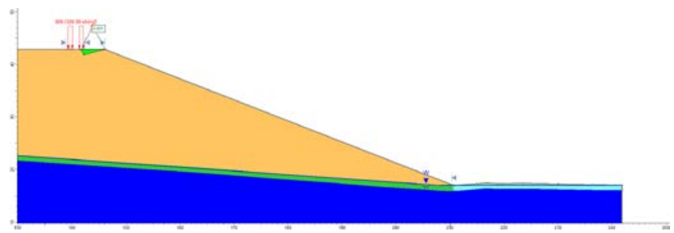
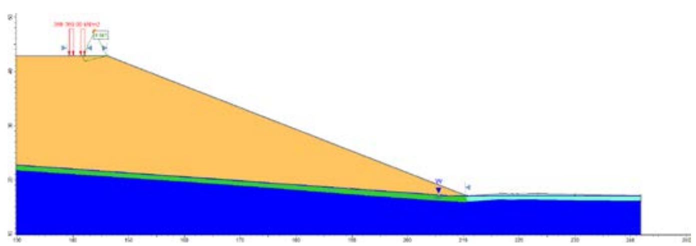
Run #	Stability Condition	Limit equilibrium Method	Minimum FoS	Search Function	Additional Refinement Options	Other Notes	Critical Slip Surface
9	Stability Condition 1	Spencer	1.4	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	Minimum 3m depth	
10	Stability Condition 1	Morgenstern-Price	1.4	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	Minimum 3m depth	
11	Stability Condition 3	Spencer	1.9	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	Minimum 7m depth	
12	Stability Condition 3	Morgenstern-Price	1.9	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	Minimum 7m depth	

Run #	Stability Condition	Limit equilibrium Method	Minimum FoS	Search Function	Additional Refinement Options	Other Notes	Critical Slip Surface
13	Stability Condition 3	Spencer	2.0	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	Minimum 10m depth	
14	Stability Condition 3	Morgenstern-Price	2.0	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	Minimum 10m depth	
15	Stability Condition 1	Morgenstern-Price	1.2	Auto-Refine (Circular)	Entry/Exit Constrained	-	
16	Stability Condition 1	Spencer	1.1	Simulated Annealing	Optimized	-	

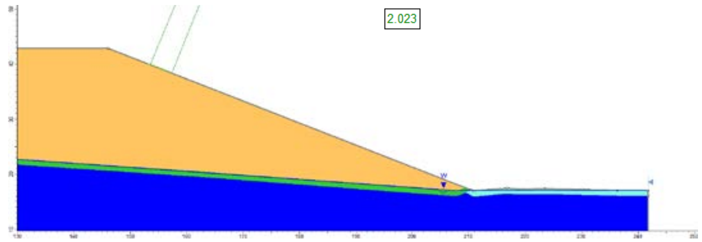
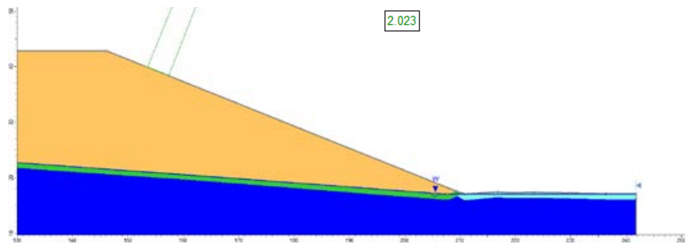
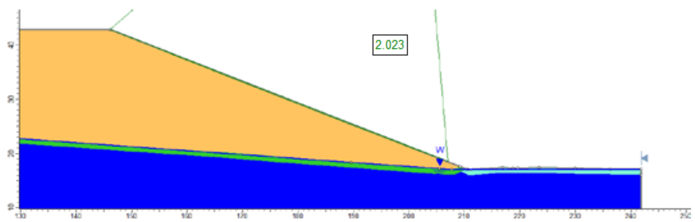
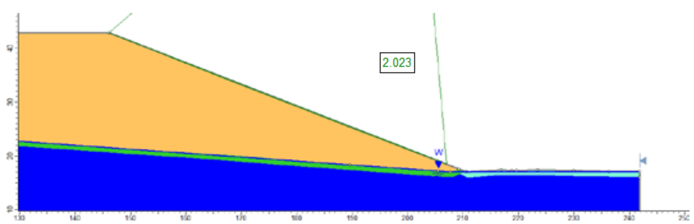
Run #	Stability Condition	Limit equilibrium Method	Minimum FoS	Search Function	Additional Refinement Options	Other Notes	Critical Slip Surface
17	Stability Condition 1	Morgenstern-Price	0.9	Simulated Annealing	Optimized	-	
18	Stability Condition 1	Spencer	0.5	Simulated Annealing	Optimized	-	 The scale of this section view is increased to allow visibility of the failure surface
19	Stability Condition 1	Spencer	0.9	Simulated Annealing	Optimized	Minimum 1m depth	
20	Stability Condition 1	Morgenstern-Price	1.1	Block Slip	Optimized Entry/Exit Constrained	-	

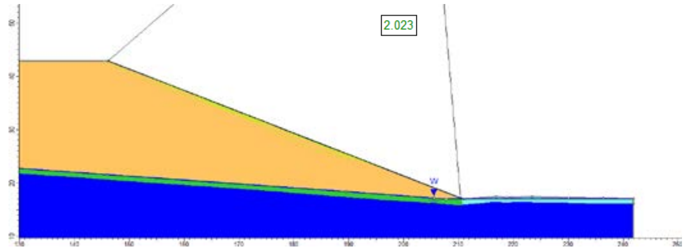
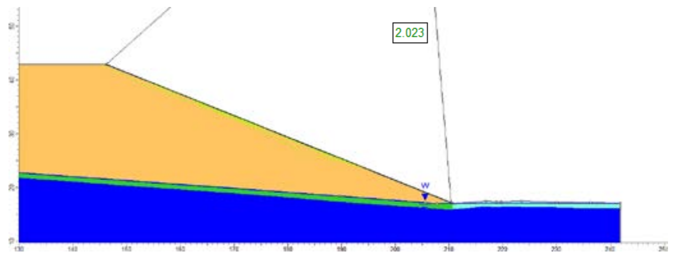
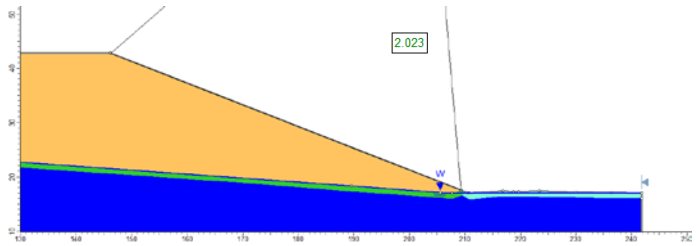
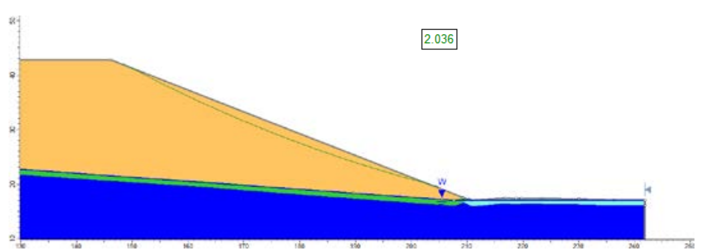
Run #	Stability Condition	Limit equilibrium Method	Minimum FoS	Search Function	Additional Refinement Options	Other Notes	Critical Slip Surface
21	Stability Condition 1	Spencer	1.2	Block Slip	Optimized Entry/Exit Constrained	-	
22	Stability Condition 1	Spencer	1.0	Block Slip	Optimized Entry/Exit Constrained	-	
23	Stability Condition 1	Morgenstern-Price	0.9	Block Slip	Optimized Entry/Exit Constrained	-	
24	Stability Condition 1	Spencer	1.0	Auto Refine (Non-circular)	Optimized Entry/Exit Constrained	-	

Run #	Stability Condition	Limit equilibrium Method	Minimum FoS	Search Function	Additional Refinement Options	Other Notes	Critical Slip Surface
25	Stability Condition 1	Morgenstern-Price	1.0	Block Slip	Optimized Entry/Exit Constrained	-	
26	Stability Condition 1 (Modified for comparison)	Spencer	1.0	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	Load Setback 2m	
27	Stability Condition 1 (Modified for comparison)	Morgenstern-Price	0.9	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	Load Setback 2m	
28	Stability Condition 1 (Modified for comparison)	Spencer	1.2	Auto-Refine (Non-circular)	Entry/Exit Constrained	Load Setback 2m	

Run #	Stability Condition	Limit equilibrium Method	Minimum FoS	Search Function	Additional Refinement Options	Other Notes	Critical Slip Surface
29	Stability Condition 1 (Modified for comparison)	Morgenstern-Price	0.8	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	Load Setback 4m	
30	Stability Condition 1 (Modified for comparison)	Morgenstern-Price	1.5	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	Load Setback 4m	 The scale of this section view is increased to allow visibility of the failure surface
31	Stability Condition 1 (Modified for comparison)	Spencer	0.9	Simulated Annealing	Optimized Entry/Exit Constrained	Load Setback 4m	
32	Stability Condition 1 (Modified for comparison)	Morgenstern-Price	0.8	Simulated Annealing	Optimized Entry/Exit Constrained	Load Setback 4m	

Stability Analysis with No Wheel Loading Applied.

Run #	Stability Condition	Limit equilibrium Method	Minimum FoS	Search Function	Additional Refinement Options	Other Notes	Critical Slip Surface
33	Stability Condition 2	Spencer	2.0	Auto-Refine (Circular)	Entry/Exit Constrained	-	
34	Stability Condition 2	Morgenstern-Price	2.0	Auto-Refine (Circular)	Entry/Exit Constrained	-	
35	Stability Condition 2	Spencer	2.0	Auto-Refine (Non-circular)	Optimized Entry/Exit Constrained	-	
36	Stability Condition 2	Morgenstern-Price	2.0	Auto-Refine (Circular)	Optimized Entry/Exit Constrained	-	

Run #	Stability Condition	Limit equilibrium Method	Minimum FoS	Search Function	Additional Refinement Options	Other Notes	Critical Slip Surface
37	Stability Condition 2	Spencer	2.0	Block Slip	Optimized Search window over entire slope	The ten lowest surfaces are also shown	
38	Stability Condition 2	Morgenstern-Price	2.0	Block Slip	Optimized Search window over entire slope	The ten lowest surfaces are also shown	
39	Stability Condition 2	Spencer	2.0	Simulated Annealing	-	Shallow Skin Failure	
40	Stability Condition 2 (Modified for Comparison)	Spencer	2.0	Auto-Refine (Circular)	-	Minimum 1m Depth	

Attachment 3

Bearing Capacity Failure Calculation

SRK Consulting
Engineers and Scientists

Project No. 1CT022.001 Site Hope Bay - Pad T
Prepared by PDL Date Nov 20/14
Approved by ______ Date ______
Subject Bearing capacity shallow failure check Sheet 1 of 3

Bearing capacity near edge of Waste rock pile

Tire contact area 0.743m x 0.743m = 0.552 m^2
Load on rear tires (each) = 203.6 kN

Ground pressure = 369 kPa

from Terzaghi's Bearing Capacity Theory (square footing)

$$q_{ult} = 1.3c' N_c + \sigma'_{z0} N_q + 0.4 \gamma' B N_\gamma$$

$$= 0 + 0 + 0.4(20) \cdot 0.743 \cdot 99.7 = \underline{\underline{592.8 \text{ kPa}}}$$

$$N_\gamma = \frac{2(N_q+1)\tan\phi'}{1+0.4\sin 4\phi'}$$

$$N_q = \frac{e^{2\pi(0.75-\phi'/360)\tan\phi'}}{2\cos^2(45+\phi'/2)} = \frac{e^{2\pi(0.75-39/360)\tan(39)}}{2\cos^2(45+39/2)} = 70.6$$

$$N_\gamma = \frac{2(70.6+1)\tan(39)}{1+0.4\sin(4(39))} = 99.7$$

$$FOS = \frac{q_{ult}}{q_{Tire}} = \frac{592.8}{369} = 1.61$$

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Engineers and Scientists

Project No. 1CT002.001 Site Hope Bay Pad T
Prepared by PDL Date Nov 20/14
Approved by ______ Date ______
Subject ______ Sheet 2 of 3

$N_c = (N_d - 1)\cot(\phi) = (55.96-1)\cot(39) = \underline{67.87}$

$N_d = e^{\pi \tan(\phi)} \cdot \tan^2(45+\frac{1}{2}\phi) = e^{\pi \tan(39)} \cdot \tan^2(45+\frac{1}{2}(39)) = \underline{55.96}$

$N_b = (N_d - 1)\tan\phi = (55.96-1)\tan(39) = \underline{44.50}$

$\beta = 21.8^\circ$ (2.5:1)

$\sigma_0 f = C \cdot N_c \cdot \nu_c \cdot K_c \cdot \lambda_c + \gamma_1 d' N_d \cdot \nu_d \cdot K_d \cdot \lambda_d + \gamma_2 \cdot b' \cdot N_b \cdot \nu_b \cdot K_b \cdot \lambda_b$ (C = 0)

$$\lambda_c = \frac{N_d \cdot e^{-0.0349 \cdot \beta \cdot \tan\phi} - 1}{N_d - 1} = \frac{55.96 \cdot e^{-0.0349 \cdot 21.8 \cdot \tan(39)} - 1}{55.96-1} = \boxed{0.5317}$$

$\lambda_d = (1-\tan\beta)^{1.9} = (1-\tan 21.8)^{1.9} = \boxed{0.3789}$

$\lambda_b = (1-0.5\tan\beta)^6 = (1-0.5\tan 21.8)^6 = \boxed{0.2627}$

$\phi > 0$ $\quad \nu_c = \frac{\nu_d \cdot N_d - 1}{N_d - 1} = \frac{(1.629 \cdot 55.96) - 1}{(55.96-1)} = \boxed{1.641}$

$\nu_d = 1 + \frac{b}{a}\sin\phi$ $\quad$ where $\frac{b}{a} = 1$ $\quad = 1 + \sin 39$ $\quad \boxed{1.629}$

$\nu_b = 1 - 0.3 \cdot \frac{b}{a} = \boxed{0.7}$

$K_c = K_d = K_b = 1$ (applied force Normal to surface)

$d' = d + 0.8 \cdot B_0 \tan\beta = 0 + 0.8 \cdot \tan(21.8) \cdot B_0$

$B_0 = 2$ m $\quad d' = 0.64$ m

$B_0 = 3$ m $\quad d' = 0.96$ m

$B_0 = 4$ m $\quad d' = 1.28$ m

$B_0 = 5.55$ m $\quad d' = 1.78$ m (1)

Distance to edge of slip surface

for $\beta = 0$, $d' = d = 0$ case

$\lambda_b = (1-0.5\tan(0))^6 = 1$

$\nu_b = 0.7$ (as above)

$N_b = 44.5$ (as above)

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Project No. 1CT022.001 Site Hope Bay Pad T
Prepared by PDL Date Nov 20/14
Approved by ______ Date ______
Subject ______ Sheet 3 of 3

σ_{of} with d' for $B_o = 2$ $d' = 0.64\,m$

$$\sigma_{of} = 0 + \gamma_1 d' N_d \cdot \nu_d \cdot k_d \cdot \lambda_d + \gamma_2 \cdot b' \cdot N_b \cdot \nu_b \cdot K_b \cdot \lambda_b$$

$$= 0 + 20 \cdot 0.64 \cdot 55.96 \cdot 1.629 \cdot 1 \cdot 0.3789 + \ldots$$

$$\ldots + 20 \cdot 0.743 \cdot 44.5 \cdot 0.7 \cdot 1 \cdot 0.2623$$

$\sigma_{of_d} =$ 563.5 kPa

$\sigma_{of}(d' = d) = 0 + 0 + 20 \cdot 0.743 \cdot 44.5 \cdot 0.7 \cdot =$

$\sigma_{of}(d' = d)_{\beta = 0}$ 462.9 kPa

Try with $B_o = 5.55\,m$ $d' = d = 0$ $\beta = 0$

$\sigma_{of}(d' = d) = 0 + 0 + 20 \cdot 0.743 \cdot 44.5 \cdot 0.7 \cdot 1 = 462.9$ kPa

Distance does not affect the $\beta = 0$, $d' = d = 0$ check case

$B_o = 5.55\,m$ $d' = 1.78\,m$ ① from page 2

$\sigma_{of} = 20 \cdot 1.78 \cdot 55.96 \cdot 1.629 \cdot 1 \cdot 0.3789 + 20 \cdot 0.743 \cdot 44.5 \cdot 0.7 \cdot 1 \cdot 0.2622$
$= 1348$ kPa

as d' is the only variable affected by the distance B_o solve for B_o where $\frac{\sigma_{of}}{q} = 1$ using Spreadsheet.

$B_o = 1.12\,m$ $d' = 0.358$ $\sigma_{of} = 369$ kpa

Bearing capacity vs distance to crest check

Soil unit weight (γ)	20	kN/m3
Φ	39.0	deg.
Slope angle β	21.8	deg.
Load width	0.74	m
Distance from crest B_o	1.12	m
depth of applied load d	0	m
effective depth d'	0.36	m
Bearing Capcity σ_{of}	369.4	kPa

$$\sigma_{0f} = c \cdot N_c \cdot \nu_c \cdot \kappa_c \cdot \lambda_c + \gamma_1 \cdot d' \cdot N_d \cdot \nu_d \cdot \kappa_d \cdot \lambda_d + \gamma_2 \cdot b' \cdot N_b \cdot \nu_b \cdot \kappa_b \cdot \lambda_b$$

Equation Factors

Nc	67.87
Nd	55.96
Nb	44.5

λc	0.5317
λd	0.3789
λb	0.2622

νc	1.641
νd	1.629
νb	0.7

κc	1
κd	1
κb	1

From the text
Turke, Henner. Statik im Erdbau 3. Auflage, Berlin, 1999, Pages 100-103

Attachment 4

British Columbia Waste Rock Pile Research Committee – Dump Stability Rating

Structure Name: Pad T - Frozen Foundation

Key Factor Affecting Stability	Conditions	Description	Rating Points
Dump height	<50m		0
Dump Volume	Small	< 1 million BCM's	0
Dump slope	Flat	<26 deg.	0
Foundation Slope	Flat	<10%	0
Degree of confinement	Moderately Confined	-Natural benches or terraces on slope -Even slopes, limited natural topographical diversity -Heaped, sidehill or broad valley or cross-valley fills	50
Foundation Type	Intermediate	- Intermediate between competent and weak -Soils gain strength with consolation -Adverse pore pressures dissipate if loading rate controlled	100
Dump Material Quality	High	- Strong, durable - Less than about 10% fines	0
Method of Construction	Favorable	- Thin lifts (<25m thick), wide platforms -Dumping along contours -Ascending construction -Wrap-arounds or terraces	0
Piezometric and Climatic Conditions	Intermediate	- Moderate piezometric pressures, some seeps in foundation - Limited development of phreatic surface in dump possible - Moderate precipitation - High infiltration into dump - Discontinuous snow or ice lenses or layers in dump	100
Dumping rate	Slow	- <25 BCM's per lineal metre of crest per day - Crest advancementrate < 0.1m per day	0
Seismicity	Low	Seismic Risk Zone 0 and 1	0
		Dump Stability Rating (DSR)	

Dump Stability Class	Failure Hazard	Recommended Level of Effort for Investigation, Design and Construction	Dump Rating (DSR)
1	**Negligible**	- Basic site reconaissance, baseline documentation -Minimal lab testing - Routine check of stability, possibly using charts - Minimal restriction on construction - Visual monitoring only	**250**
Comments:			

Based on the BC Mine Waste Rock Pile Research Committee; Mined Rock and Overburden Piles Investigation and Design Manual, Interm Guidelines, May 1991.

LOW SALT UNDERGROUND BRINE WATER USE PROCEDURE

PURPOSE

The purpose of this Procedure is to describe TMAC's approach to minimizing brine water use. Minimizing salt use underground is necessary to realize cost savings and minimize effects arising from excessive salt use. High levels of salt inhibit freezing and can be toxic to the environment. In a permafrost environment, the former is key to waste stabilization and infrastructure integrity. The effects of excessive salt use include:

- Impacts to structural integrity of infrastructure components arising from ground thaw.
- Increased/alternative need for wastewater treatment and disposal.
- Increased challenges with waste (waste rock, tails) disposal and stabilization.
- Decrease in potential to reuse/repurpose materials (i.e. waste rock use for construction).

Implementation of this Procedure will minimize these effects.

This Procedure outlines:

- Brine composition, mixing and storage;
- Dust suppression and muck pile management;
- Drilling and cuttings management;
- Bolt inflation; and
- Underground geological mapping.

SCOPE

This Procedure applies to all underground drilling (including development, bolting and exploration) and dust suppression. This Procedure is to be implemented throughout all underground drilling.

DRAFT

Author:	P. Christman	To Be Reviewed:	December 2015
Approved by:	F. Varley, D. King	Print Date:	Nov 2014

RESPONSIBILITY

Title or Position	Key Responsibilities
Mine Manager	Ensure the procedures for brine management are maintained current and communicated to Underground Supervisor and Exploration Drilling Supervisor and Geology Supervisor
Underground Supervisor	Provide brine management procedure to Drillers, Bolters and other miners. Ensure mine-supplied equipment required for compliant brine management is available and resources are in place to maintain equipment. Receive and review brine management reports from Operators. Train operators in compliant brine management. Maintain training records. Audit dust suppression techniques. Review findings with Operators.
Drilling Foreman	Train drillers in compliant brine management. Maintain training records. Audit brine management procedures. Review findings with Drillers and Underground Supervisor.
Geology Supervisor	Train mine geologists and technicians in compliant brine management. Maintain training records. Audit brine management procedures.
Mine Geologists and Technicians	Implement brine management procedures (Mapping).
Drillers and Bolters	Implement brine management procedures (drilling and bolting).
Miners and Operators	Implement brine management procedures (dust suppression).

DRAFT

SAFETY

All personnel working underground must receive training and induction in accordance with site standards. Standard underground PPE must be worn at all times. In addition to standard procedures, there are safety concerns particular to the procedures outlined herein. These, along with their respective mitigation steps, are summarized in Table 1.

Table 1. Potential risks and mitigation measures associated with implementation of the Low Salt Underground Drilling Procedure.

POTENTIAL RISK	MITIGATION MEASURES
Encountering steel rod, wire mesh, or other sharp debris in muck	• Always wear gloves when sampling. • Use a hand scoop or shovel for sampling where possible.
Loose or sharp rocks	• Scale first, scale well, and scale frequently. • Wear gloves at all time when sampling or scaling.
Heavy equipment operating underground	• Check with underground supervisor prior to going underground or to surface storage pads. • Communicate with workers nearby upon arrival at underground or surface worksite. • Carry a radio and notify mining personnel of changes in location or work plan.

DRAFT

PROCEDURES

1. *Brine Composition, Mixing and Storage*

Brine mixing tanks can include multiple 13,400 L tanks for exploration or 6,700 L for development.

Brine mixing tanks will either be located underground in the permafrost environment at -8°C (year round temperature), or in a contained enclosure reducing exposure to outdoor ambient temperature in winter. At this temperature underground or in a sheltered environment, lower salinity concentration brine can be used to keep the brine in liquid form up to -10°C. This approach removes the need to oversaturate the solution to keep it in liquid form.

With reference to the following phase diagram (Figure 1; DOW Calcium Chloride handbook), a 15 weight percent solution shall be utilized.

2. *Dust Suppression and Muck Pile Management*

Hose nozzle atomizers (nozzle that produces a fine mist) and/or a fogger will be used to create mist "curtain" for dust suppression at the muck pile prior to scooping. This decreases the amount of brine water used and the residual amount of salt in the waste rock.

It is not acceptable to use an open nozzle for dust suppression, nor is it acceptable to leave the hose running while not in use.

3. *Drilling and Cuttings Management*

Exploration Drilling

Conventional underground diamond drills are used for exploration. Brine water used for drilling is collected at the drift face in sumps and recycled underground by the brine water sump and pumping system. Most of this brine water is recycled but some is lost to fractures in the rock. Every opportunity to maximize brine recycle and reduce loss will be pursued.

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Development Drilling

Jumbo drills and bolter drills equipped with water mist flushing systems will be utilized for development drilling. This system uses pressure and flow regulators and check valves to control the ratio of brine water and air going to the drill. The brine water and air is turned to mist in a mixing chamber and another regulating valve controls the mist going to the drill. This approach reduces the overall amount of brine used, while still washing cuttings from the holes and cooling the drill bits and steel.

Brine water used for drilling is collected at the drift face in sumps and recycled underground by the brine water sump and pumping system. Most of this brine water is recycled but some is lost to fractures in the rock. Every opportunity to maximize brine recycle and reduce loss will be pursued.

4. *Bolt Inflation*

According to TMAC's Ground Control Management Plan (insert document reference) swellex type inflatable friction bolts will be utilised. Brine water will be used to drill the bolt holes and inflate the bolts. A non-conventional swellex pump, the SWX DCS Fluid Recovery Kit swellex pump may be utilised as it is a closed system that recovers and recycles the water used for bolt inflation.

Brine water used for bolting is collected at the pump and recycled underground by the brine water sump and pumping system. Most of this brine water is recycled but some is lost to fractures in the rock. Every opportunity to maximize brine recycle and reduce loss will be pursued.

5. *Underground Mapping*

Brine water may be used to wash the back and walls prior to completing geological mapping underground. This is required to ensure geological features are visible and these features can be mapped for grade management and ground control purposes. The mine geologist and technicians will use the minimum amount of brine water required to clean the back and walls to ensure accurate mapping.

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Brine water used for mapping is collected at the pump and recycled underground by the brine water sump and pumping system. Most of this brine water is recycled but some is lost to fractures in the rock. Every opportunity to maximize brine recycle and reduce loss will be pursued.

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Figure 1 — Phase Diagram for $CaCl_2$ and Water Solutions