20th August 2019

Attn: Mr Eamonn Dare
Technical Services Superintendent
Broken Hill Operations Pty Ltd
BHOP Resources – Rasp Mine
130 Eyre Street
BROKEN HILL NSW 2880

Reference G0197

RE: KINTORE OPEN PIT – SLOPE STABILITY ANALYSIS OF EXISITING IN-PIT WASTE ROCK DUMP, DURING TAILINGS PLACEMENT

Ground Control Engineering Pty Ltd (GCE) was engaged by Broken Hill Operations (BHOP), Rasp Mine to undertake a slope stability assessment of the existing in-pit waste rock dump in the Kintore Pit. The waste rock dump slope will form the south-east bounding wall during the proposed placement of thickened 'dry' tailings in the Kintore Pit.

GCE conducted two-dimensional limit equilibrium analysis of the waste dump slope. The aim of the analysis was to assess the stability of the waste dump slope with varying tailings fill level and degree of potential water saturation. This summary report outlines the results of the modelling and key findings of the slope stability assessment.

Yours sincerely,

GROUND CONTROL ENGINEERING PTY LTD

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1 Introduction and Scope

GCE was requested by the Rasp Mine to undertake a geotechnical slope stability assessment of the existing waste rock dump in the Kintore Pit. BHOP plans to backfill the Kintore Pit with thickened 'dry' tailings, whereby the waste rock dump slope will form the south-east bounding wall during placement of the tailings.

The scope of work for this assessment incorporated two-dimensional slope stability analysis of the following:

- Existing waste rock slope configuration, and;
- Various waste rock slope configurations incorporating the progressive filling of the pit with tailings and associated potential transient groundwater saturation profiles.

2 Data Provided

BHOP provided GCE with the following data and report:

- Current pit surface including existing waste rock backfill area, as DXF file.
- Kintore Pit: Preliminary Decline Plug Design – Golder report, 17 October 2018 (Ref. 1)

3 Stability Analysis of Waste Rock Dump

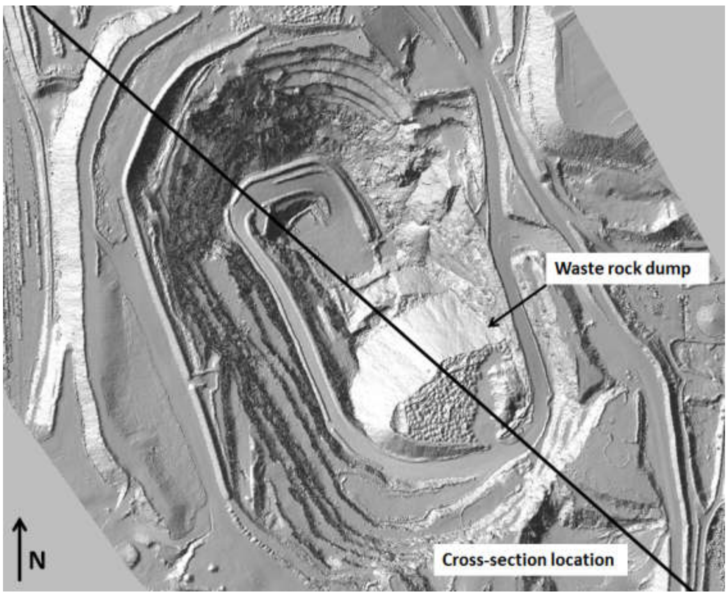
Sections 3.1 to 3.4 of this report describe the method, assumptions and parameters used in the slope stability analyses. The results and conclusions of the analyses are outlined in Sections 3.5, 3.6 and Appendix A.

3.1 Modelling method

The Rocscience Inc. software *Slide* was used to conduct limit equilibrium slope stability analyses of selected two-dimensional cross-sections of the Kintore Pit. Circular failure surfaces were generated using a grid search and analysed using the Bishop method to determine the slope Factor of Safety (FOS). Circular failure through the waste rock slope is considered the most likely slope failure mechanism.

The location of the section line where the cross-sections were generated for the analyses is shown in Figure 1. The location was selected by GCE to evaluate the 'worst case' slope configurations, approximately perpendicular to the waste rock slope and with consideration of the most likely failure mechanism.

Figure 1 Section line location with respect to existing as-built pit and waste rock dump



3.2 Slope configurations assessed

Three main slope configurations where assessed for stability, as described below and shown in Figures 2 to 4.

The cross-sections used in the *Slide* modelling incorporate the material boundaries, pit wall and waste dump geometry and inferred (potential) groundwater profiles.

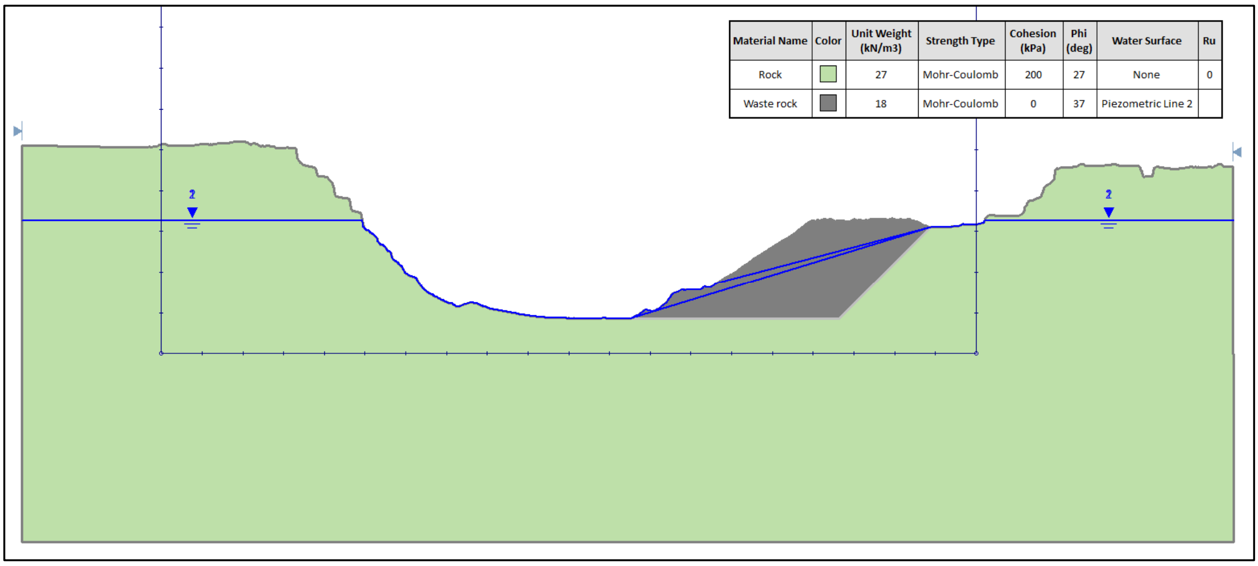
All slope configurations where run with three different groundwater cases, including a "dry" case. The groundwater and material properties applied in the models are described in Sections 3.3 and 3.4 of this report respectively.

NB: Static loading only has been modelled in the current stability assessment. GCE recommends that the impact of seismic loading is considered as part of a more comprehensive stability assessment.

<u>Slope configuration #1 - no tailings</u>:

Existing waste rock dump slope, prior to commencement of backfilling pit with tailings, as shown in Figure 2.

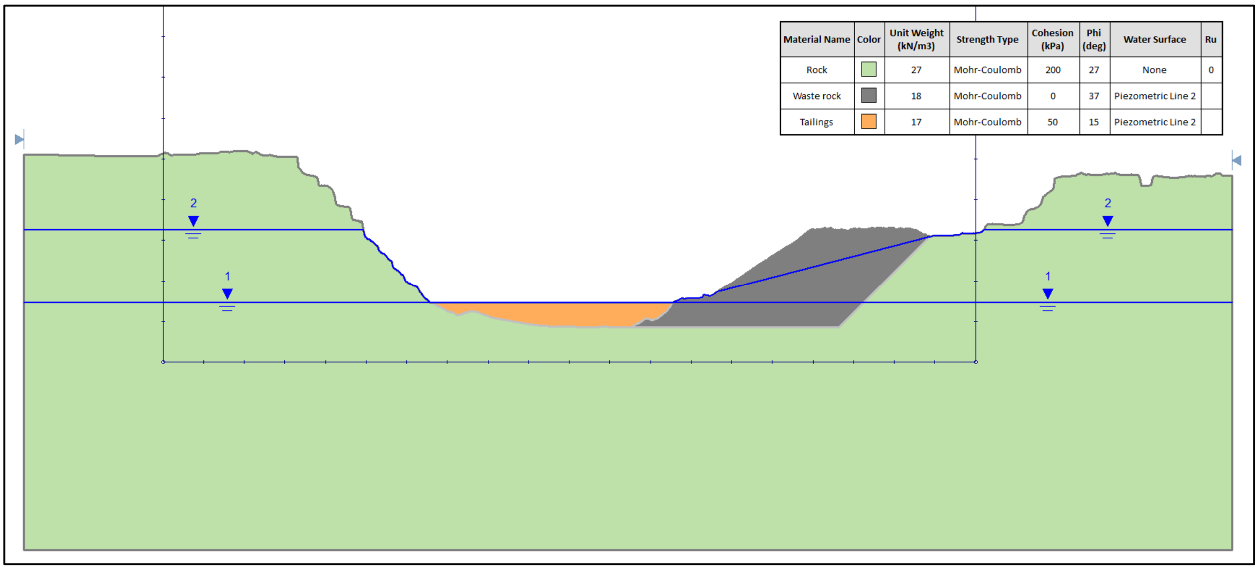
Figure 2 Slope configuration #1 – no tailings



Slope configuration #2 - 15m of tailings:

Placement of 15m of tailings in the pit, adjacent to the existing waste rock dump slope, as shown in Figure 3.

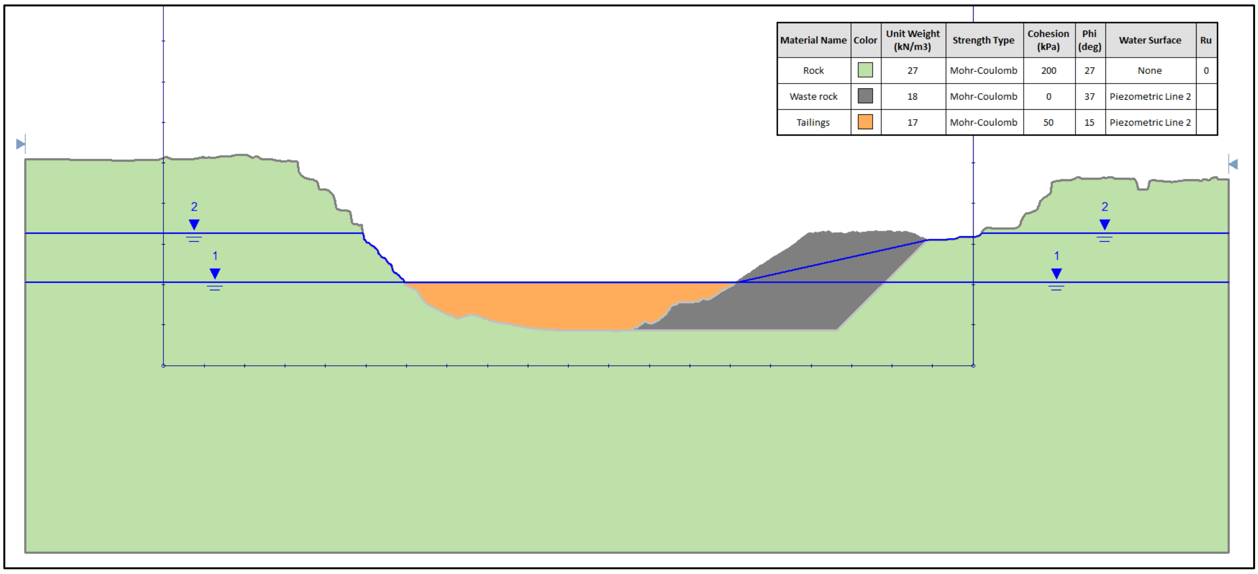
Figure 3 Slope configuration #2 - 15m of tailings



Slope configuration #3 - 30m of tailings:

Placement of 30m of tailings in the pit, adjacent to the existing waste rock dump slope, as shown in Figure 3.

Figure 4 Slope configuration #3 - 30m of tailings



3.3 Material properties

The estimated material properties assigned to each material type used in the modelling are outlined in Table 1.

It must be noted that the properties outlined in Table 1 are estimates only, based on GCE precedent experience of comparable materials and from the Golder report; Kintore Pit: Preliminary Decline Plug Design –17 October 2018.

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Table 1 Material shear strength properties (estimated)

Material Type	Unit Weight (kN/m^3)	Cohesion (kPa)	Friction Angle
Rock (in-situ Gneiss)	27	200	27°
Waste rock	18	0	37°
Tailings	17	50	15°

3.4 Groundwater

GCE understands that all water inflow will be removed from the pit via an effective drainage system and that groundwater will not accumulate at the bottom of the pit or in the tailings and waste rock slope(s). However, the groundwater profile and potential fluctuation following major rainfall events in the area of the Kintore Pit must be considered during the filling of the Kintore pit with classified tailings.. There may be periods after heavy rainfall events where part of the waste rock slope and tailings will be saturated and a transient piezometric surface will be present within the slope.

To assess the impact that groundwater may have on slope stability, three main groundwater conditions were modelled as follows:

1. “Dry” – No groundwater applied in the model. This scenario is used as a reference to assess the base case stability of the slope and the subsequent sensitivity of the modelled failure paths to the introduction of groundwater.
2. “Flat” – a horizontal piezometric surface is applied at the level of the top of the tailings, applying to both the tailings and waste rock materials.
3. “Sloped from top of waste rock” – a sloping piezometric surface is applied from the top of the waste rock, down to the level of the top of the tailings, applying to both the tailings and waste rock materials.

3.5 Summary of waste rock slope stability assessment results

The results of the stability modelling are presented in Appendix A and summarised as follows:

(Factor of Safety is abbreviated as FOS.)

<u>Slope configuration #1 - no tailings</u>:

- Very minor, shallow, sloughing style instability is indicated at FOS < 1. This may manifest as minor riling, which is typical of waste rock slopes.
- At FOS = 1.3, very shallow circular failure (sloughing) is indicated for both the “dry” and “water sloped from top of waste rock to pit floor” scenarios.
- The “worst case” transient groundwater scenario whereby a sloping piezometric surface is applied from the top of the waste rock, down to the mid-level of the slope indicates moderate slope scale instability at FOS < 1. This represents a significant reduction in slope stability from the dry condition.

However, the waste rock slope is understood by GCE to be free draining and hence this worst case groundwater scenario is considered to be very unlikely.

Slope configuration #2 - 15m of tailings:

- At FOS = 1.3, very shallow circular style failure (sloughing) is indicated for both the "dry" and "flat", piezometric surface at the level of the top of the tailings, scenarios.
- The "flat" piezometric surface scenario indicates potential for slope scale instability (relatively shallow) at FOS = 1.36. Potential for circular failure resulting in floor heave through the tailings is indicated at FOS = 1.81.
- The "worst case" transient groundwater scenario whereby a sloping piezometric surface is applied from the top of the waste rock, down to the top of the tailings indicates potential for slope scale failure at FOS = 1.17. In this case, potential for circular failure resulting in floor heave through the tailings is indicated at FOS = 1.39.

Slope configuration #3 - 30m of tailings:

- At FOS = 1.3, very shallow circular style failure (sloughing) is indicated for all groundwater scenarios modelled.
- Potential for slope scale instability (upper exposed slope above tailings only) is indicated at FOS = 1.52. Potential for circular failure resulting in floor heave through the tailings is indicated at FOS = 1.65 in the "worst case" transient groundwater scenario.

3.6 Findings and recommendations

The following comments relate to the analyses and FOS results outlined in Sections 3.1 to 3.5 and Appendix A.

- The slope stability analyses conducted by GCE indicates that current, free draining, waste rock dump slope has a FOS for overall slope scale stability of greater than 1.3.
- Generally speaking, the placement of 'dry' tailings at the base of existing waste rock dump slope is expected to increase the stability of the slope.
- The modelling highlights the potential for shallow, circular style failure (sloughing) in all cases. This may materialise as minor rilling, which is typical of waste rock slopes. GCE recommends that a large bund is installed along the length of the toe of the waste rock dump during placement of tailings to shield against rockfall from the adjacent slope. The bund will need to be progressively moved and re-established as the level of the tailings backfill rises in the pit.
- The slope stability model incorporating 15m of tailings (slope configuration model #2) and the "worst case" transient groundwater scenario, whereby a sloping piezometric surface is applied from the top of the waste rock, down to the top of the tailings, indicates potential for slope scale failure at FOS = 1.17. In this case, potential for circular failure resulting in floor heave through the tailings is indicated at FOS = 1.39.

4 References

1. Golder, (2018) '*Kintore Pit: Preliminary Decline Plug Design*', Ref 1896230-017-R-Rev0, 17 October 2018

DOCUMENT INFORMATION

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Project No.	
Distribution	PDF to client, for review and comment

DOCUMENT CHANGE CONTROL

Version	Description of changes/amendments	Author(s)	Date
DRAFT01	Draft report	C. Byrne	19/03/19
FINAL	Final report – no changes requested	C. Byrne / C. Tucker	20/08/19
FINAL	As above, change CBH to BHOP	C. Byrne / C. Tucker	18/09/20

DOCUMENT REVIEW AND SIGN OFF

Version	Reviewer	Position	Signature	Date
DRAFT01	C.Tucker	Principal Geotechnical Engineer		19/03/19
FINAL	C.Tucker	Principal Geotechnical Engineer		20/08/19

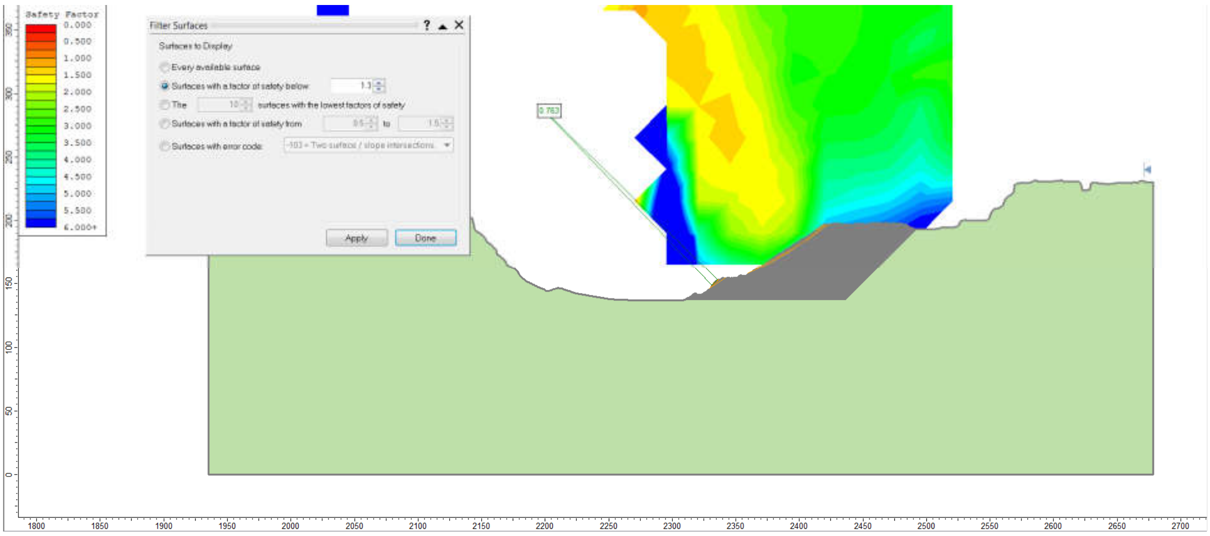
APPENDIX A

Kintore Pit Waste Rock Slope Stability Modelling Results Summary

<u>Slope configuration #1 - no tailings</u>:

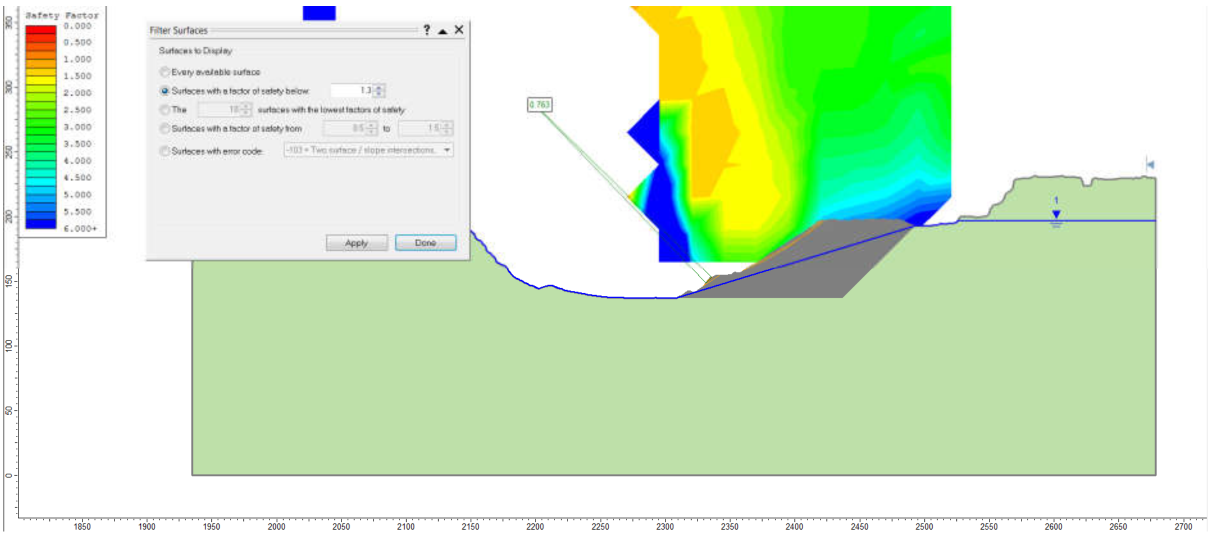
A. No tailings, no water

- FOS min = 0.763, very shallow, minor sloughing failure only
- FOS < 1.3, shallow sloughing only



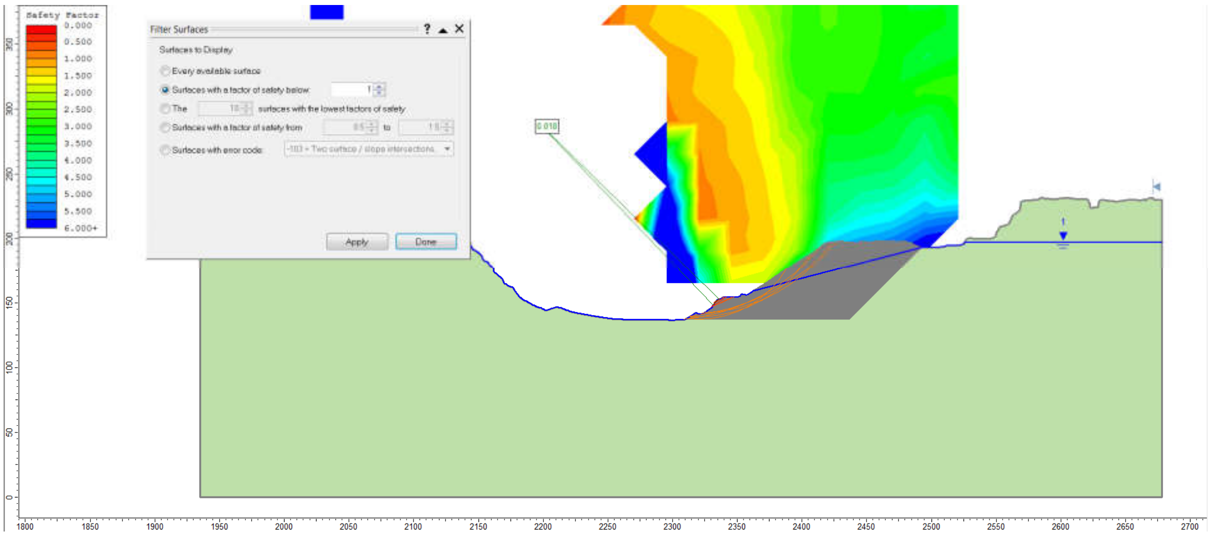
B. No tailings, water sloped from top of waste rock to pit floor

- FOS min = 0.763, very shallow, minor sloughing failure only
- FOS < 1.3, shallow sloughing only
- No change from dry condition



C. No tailings, water sloped from top of waste rock to mid slope ("worst case")

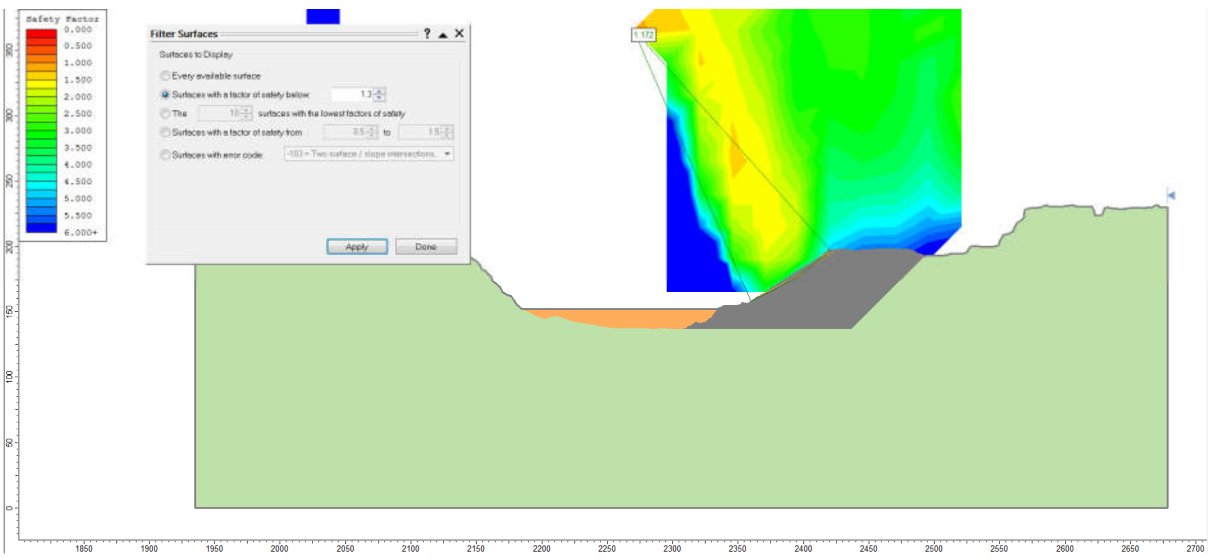
- FOS min = 0.018, very shallow, minor failure only
- FOS < 1.0, moderate slope scale failure indicated
- Significant reduction in stability from dry condition. However, would require large rainfall event.



Slope configuration #2 - 15m of tailings:

A. 15m tailings, no water

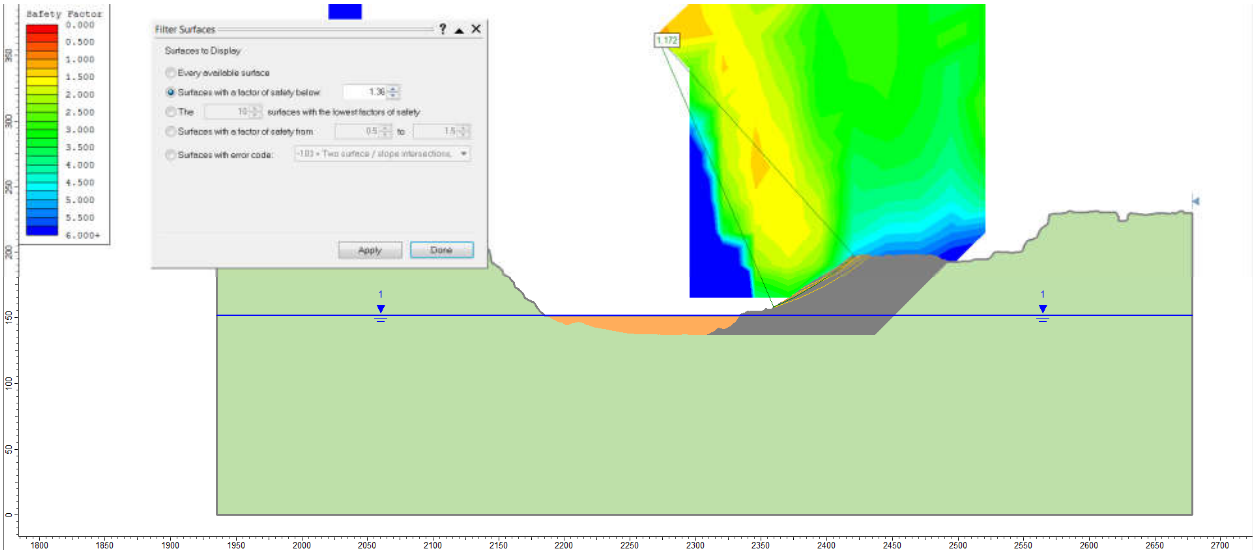
- FOS min = 1.172, shallow, sloughing failure only
- FOS < 1.3, shallow sloughing only
- Tailings increase stability of overall waste slope when dry



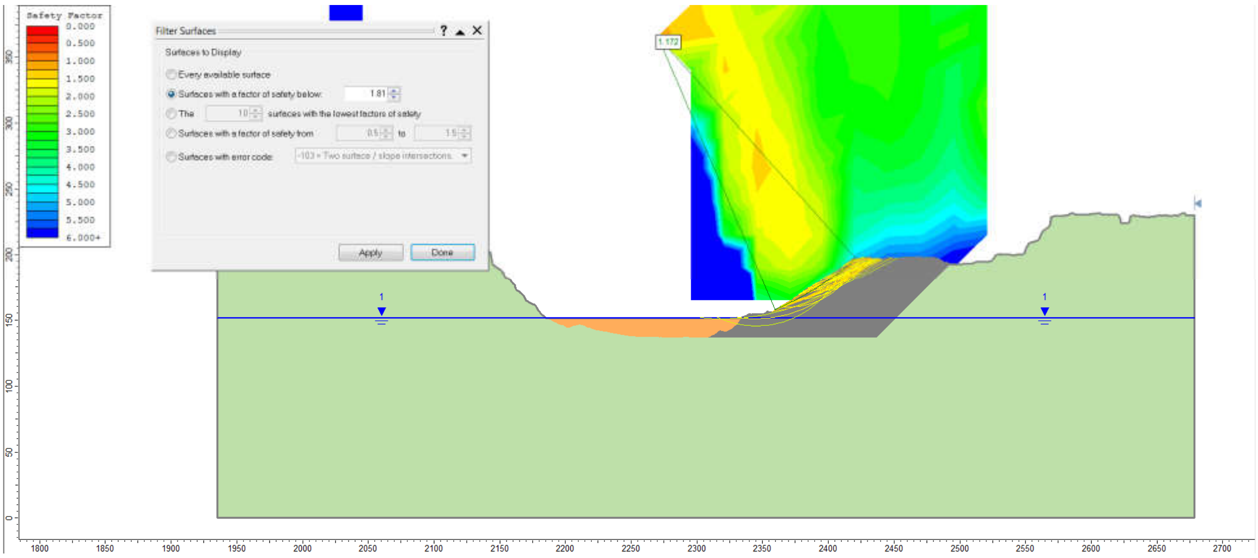
B. 15m tailings, water flat at top of tailings

- FOS min = 1.172, shallow, sloughing failure only, no change from dry condition
- FOS for slope scale failure = 1.36, tailings increase stability of overall waste slope
- FOS < 1.3, minor slope scale shallow sloughing failure indicated
- FOS for floor heave in tailings = 1.81

Slope scale failure case shown below (FOS=1.36):



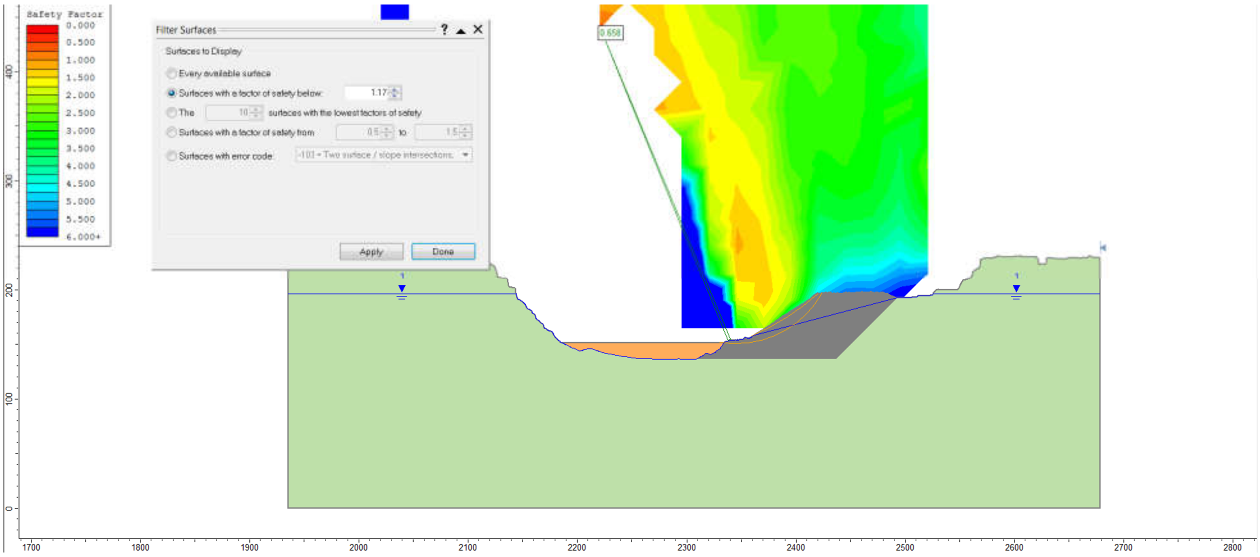
Floor heave through tailings case shown below (FOS=1.81):



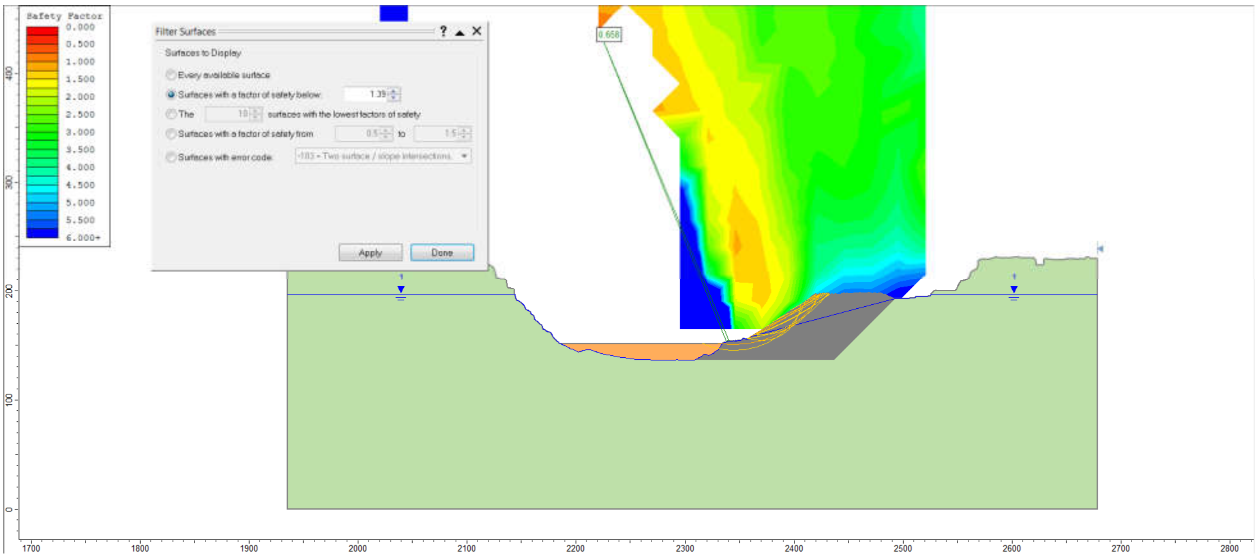
C. 15m tailings, water sloped from top of waste rock to top of tailings (“worst case”)

- FOS min = 0.658, very shallow, minor failure only
- FOS for slope scale failure = 1.17
- FOS < 1.3, moderate slope scale failure indicated
- FOS for floor heave in tailings = 1.39

Slope scale failure case shown below (FOS=1.17):



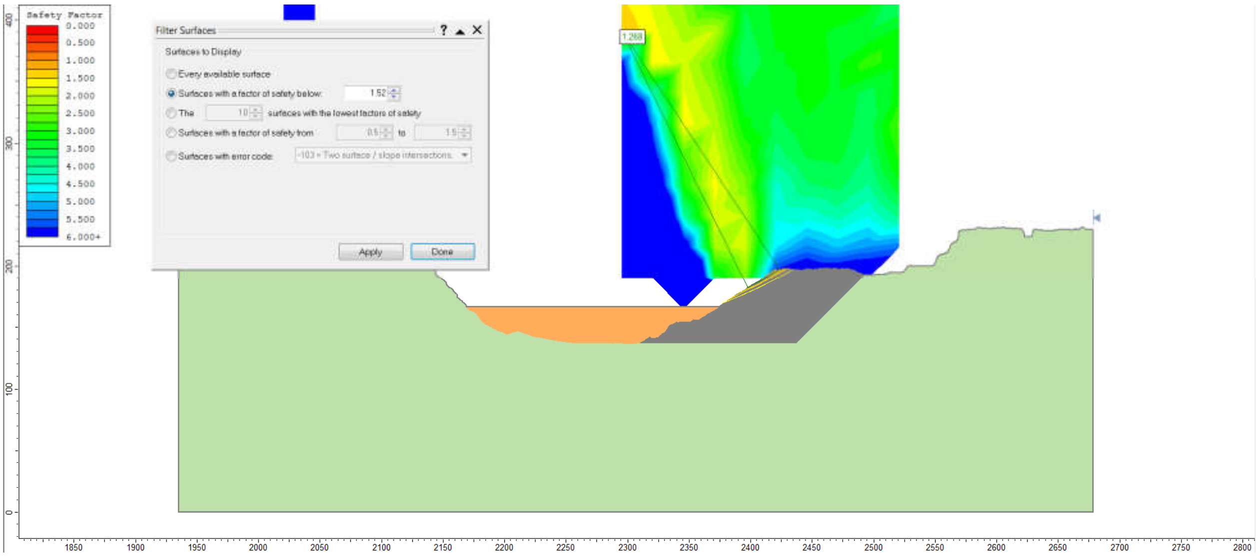
Floor heave through tailings case shown below (FOS=1.39):



Slope configuration #3 - 30m of tailings:

A. 30m tailings, no water

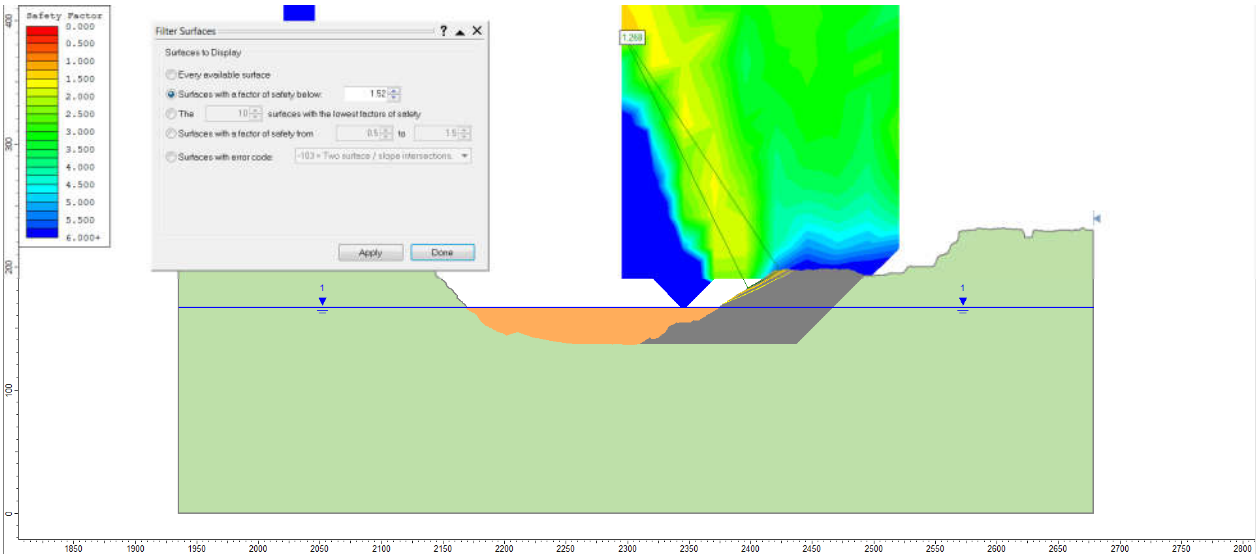
- FOS min = 1.268, very minor, shallow, sloughing failure only
- FOS < 1.3, very minor, shallow, sloughing failure only
- FOS for slope scale failure = 1.52 (upper exposed slope interval above tailings only), tailings increase stability of overall waste slope.
- FOS for floor heave in tailings = 1.83
- Tailings increase stability of overall waste slope when dry



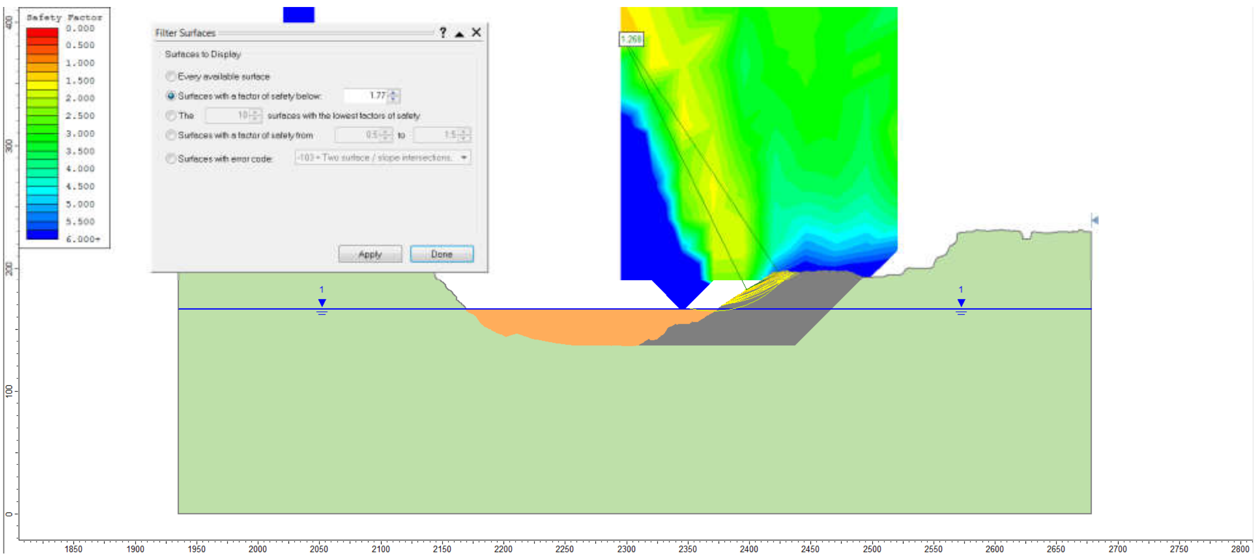
B. 30m tailings, water flat at top of tailings

- FOS min = 1.268, very minor, shallow, sloughing failure only
- FOS < 1.3, very minor, shallow, sloughing failure only
- FOS slope scale = 1.52 (upper exposed slope interval above tailings only), tailings increase stability of overall waste slope.
- FOS for floor heave in tailings = 1.77, reduction from 1.83 when dry. Not significant.
- Tailings increase stability of overall waste slope

Slope scale failure case shown below (FOS=1.52):



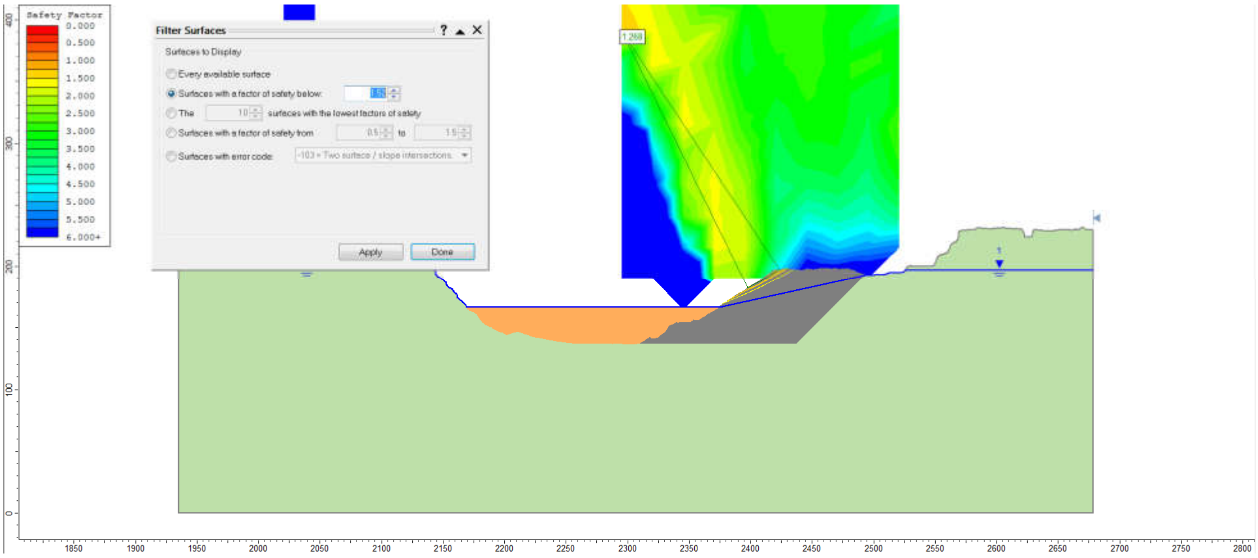
Floor heave through tailings case shown below (FOS=1.77):



C. 30m tailings, water sloped from top of waste rock to top of tailings ("worst case")

- FOS min = 1.268, very minor, shallow, sloughing failure only
- FOS < 1.3, very minor, shallow, sloughing failure only
- FOS for slope scale failure = 1.52 (upper exposed slope above tailings only), tailings increase stability of overall waste slope.
- FOS for floor heave in tailings = 1.65, reduction from 1.83 when dry. Not overly significant.
- Tailings increase stability of overall waste slope

Slope scale failure case shown below (FOS=1.52):



Floor heave through tailings case shown below (FOS=1.65):