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20th August 2019

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

RE: KINTORE OPEN PIT – STABILITY ANALYSIS OF PIT SLOPE COMPRISING HISTORIC TAILINGS

Ground Control Engineering Pty Ltd (GCE) was engaged by Broken Hill Operations Pty Ltd (BHOP) to undertake a preliminary slope stability assessment for the pit slope in the Kintore Pit which is comprised of historic tailings. The slope forms the northern end-wall in the existing Kintore Pit and as such, will form the northern bounding wall during the proposed future placement of 'new' filtered, dry tailings in the Kintore Pit.

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

Yours sincerely,

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1 Introduction and Scope

GCE was requested by Broken Hill Operations Pty Ltd (BHOP) to undertake a geotechnical slope stability assessment of the historic tailings slope which forms the northern end-wall in the existing Kintore Pit. BHOP plans to backfill the Kintore Pit with filtered 'dry' tailings, whereby the historic tailings slope will form the northern bounding wall during placement of the tailings.

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

- Existing north wall pit slope, comprised of historic tailings, and;
- Various slope configurations incorporating the progressive filling of the pit with new tailings and associated potential transient groundwater saturation profiles.

2 Data Provided

BHOP provided GCE with the following data and report:

- Current 'as-built' pit surface as DXF file.
- Kintore Pit: Preliminary Decline Plug Design – Golder report, 17 October 2018 (Ref. 1)

3 Stability Analysis of Historic Tailings Slope

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.

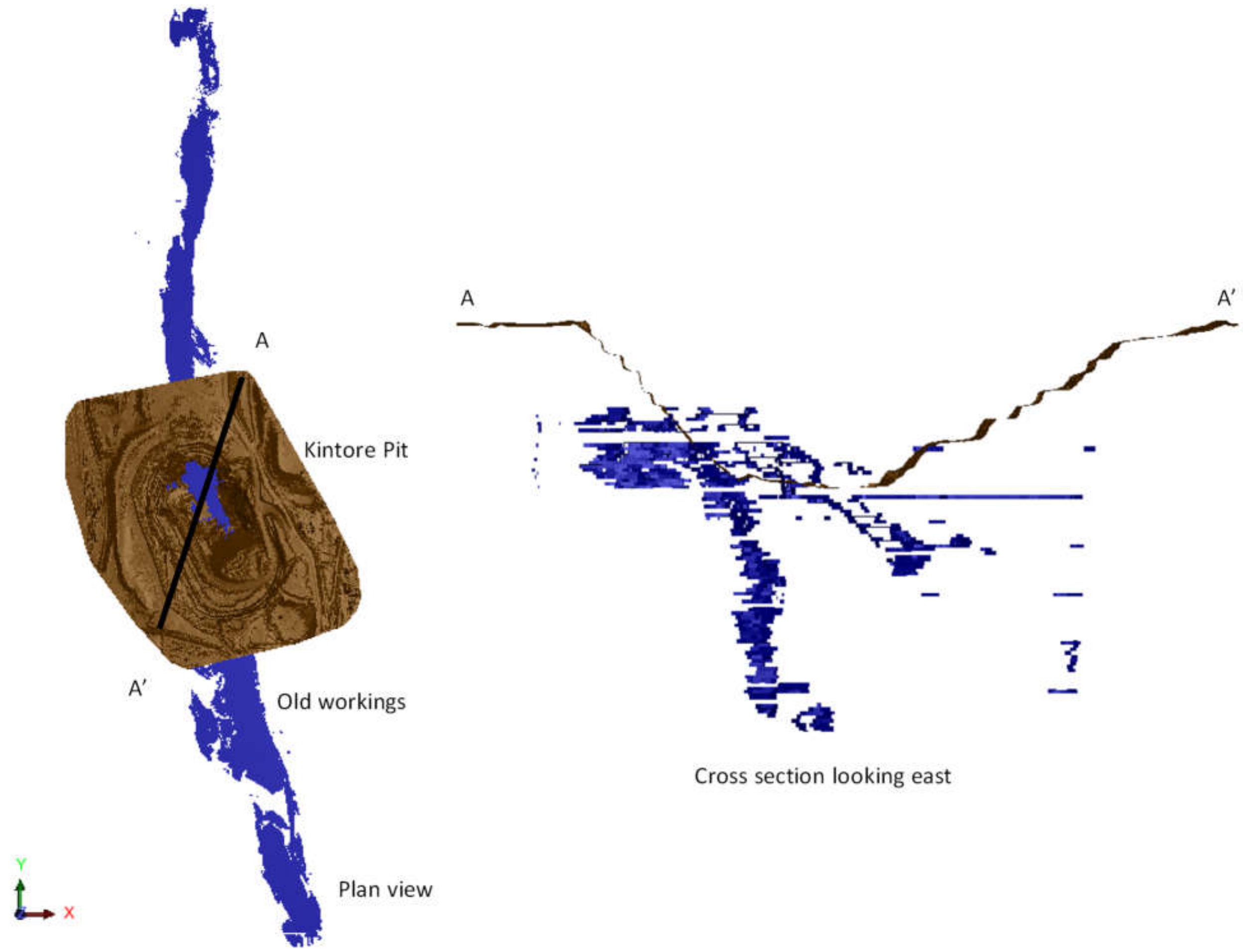
3.1 Modelling method

The industry standard 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 historic tailings slope is considered the most likely slope failure mechanism given the weak, consistent and structure-less material properties assigned to the remnant tailings. The remnant tailings have been modelled to behave similarly to massive weak rock and/or soil. There is no observed structure within the exposed tailings slope that may induce kinematic style failure mechanisms such as toppling, wedge or planar failure.

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 likely 'worst case' slope configurations, approximately perpendicular to the historic tailings slope and with consideration of the most likely failure mechanism.

The 2D modeling does not incorporate or quantify the stabilizing influence of confinement related to the circular pit geometry. The stability of the remnant tailings slope will likely be positively influenced by slope confinement geometry in the pit corner, as shown in Figure 1.

Figure 1 Section line location with respect to existing as-built pit



Mine slope design is essentially governed by two factors:

1. The consequences of failure; and
2. The degree of inherent uncertainty.

To accommodate these two design factors, it is common practice to apply an appropriate Factor of Safety (FOS) and/or Probability of Failure (POF) to the design geometry of mine slopes. An example of FOS and POF design criteria is provided in Table 1. The design criteria have been developed from the Western Australian, Department of Mines, Industry Regulation and Safety (now DMIRS), Geotechnical Considerations in Open Pit Mines.

Table 1: Examples of design criteria for open pit walls

Wall Class	Consequence of Failure	Design FOS	Design POF	Pit Wall Examples
1	Not serious	Not applicable		Walls not carrying major infrastructure) where all potential failures can be contained within containment structures
2	Moderately serious	1.2	10%	Walls not carrying major infrastructure
-3	Serious	1.5	1%	Walls carrying major mine infrastructure (e.g. treatment plant, ROM pad, tailings structures)
4	Serious	2.0	0.30%	Permanent pit walls near public infrastructure and adjoining leases

As the fill slope will be effectively covered and buttressed by future tailings, a FOS of 1.3 was applied to reflect the temporary nature of the slope.

3.2 Slope configurations assessed

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

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

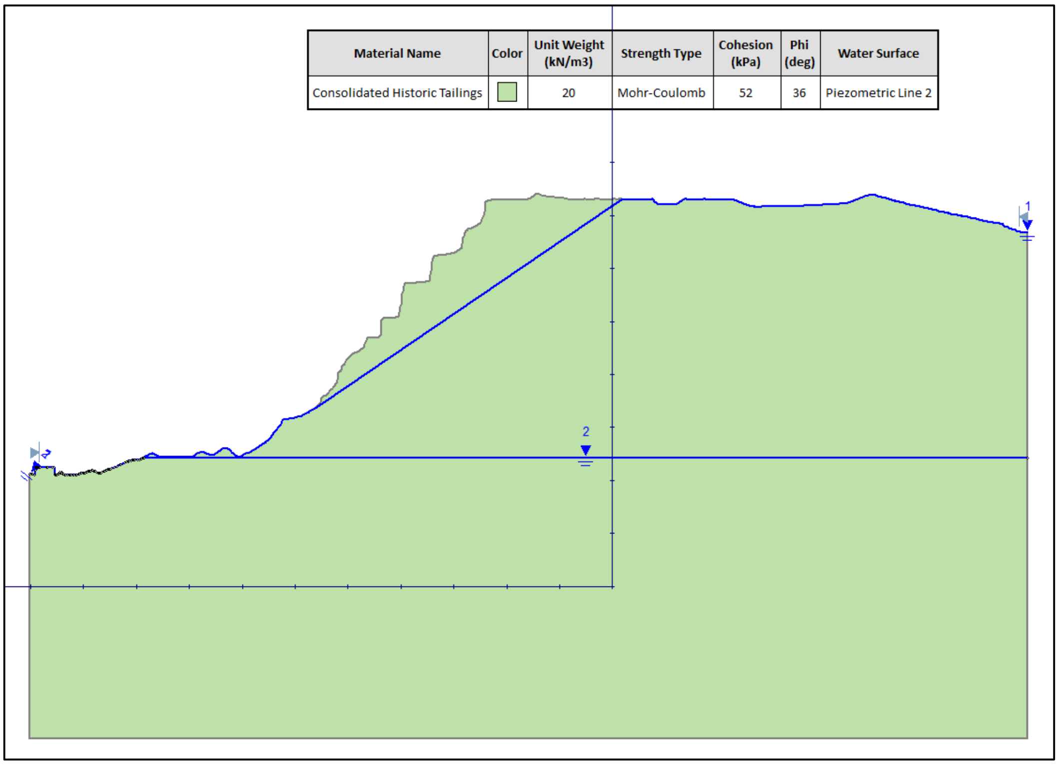
All slope configurations were run with three different groundwater cases, including a "dry" case. The groundwater and material properties applied in the models are described in Sections 3.3 and 3.4 of this report respectively.

NB: Static loading only has been modelled in the current slope stability assessment. The effects of seismic loading and water hammer (resulting from seismic loading) on the 'new' tailings proposed to be placed in the pit were considered in the report by Golder Ref. 1. Golder recommend the final design for the sealing plugs at the base of the Kintore Pit account for complete saturation of the material placed in the pit when full under static and seismic conditions.

<u>Slope configuration #1 – no 'new' tailings</u>:

Existing historic tailings pit wall slope, prior to commencement of backfilling pit with 'new' tailings, as shown in Figure 2.

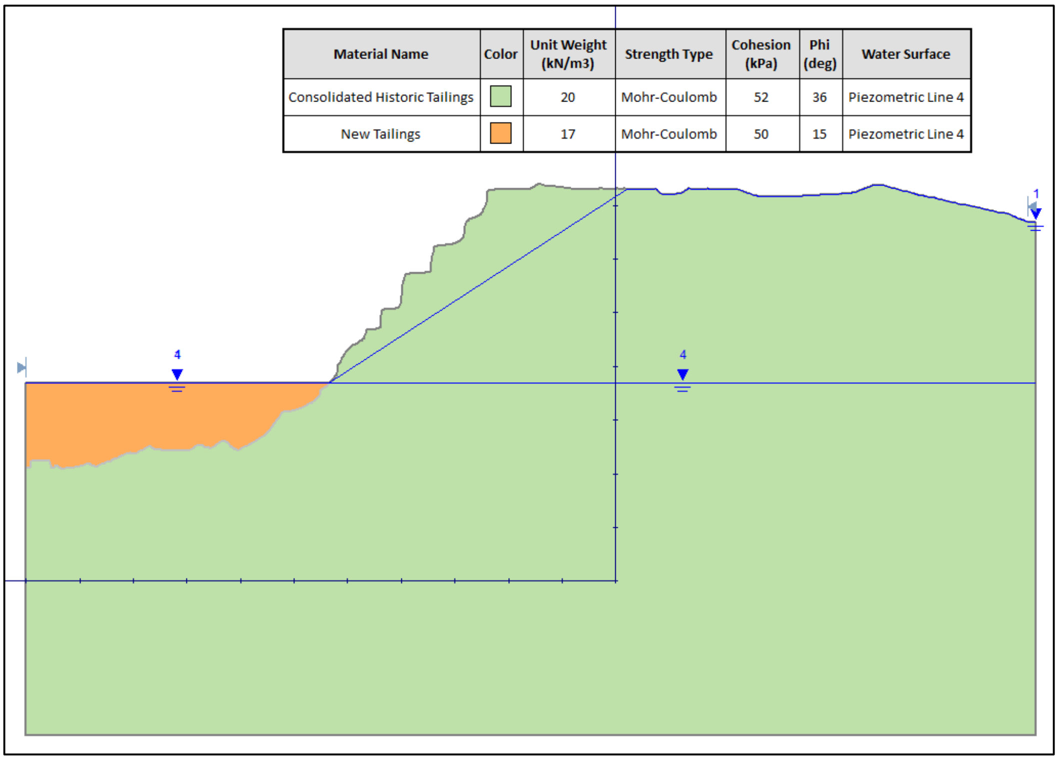
Figure 2 Slope configuration #1 – no ‘new’ tailings



Slope configuration #2 - 25m of ‘new’ tailings:

Placement of 25m of ‘new’ tailings in the pit, adjacent to the existing historic tailings pit wall slope, as shown in Figure 3.

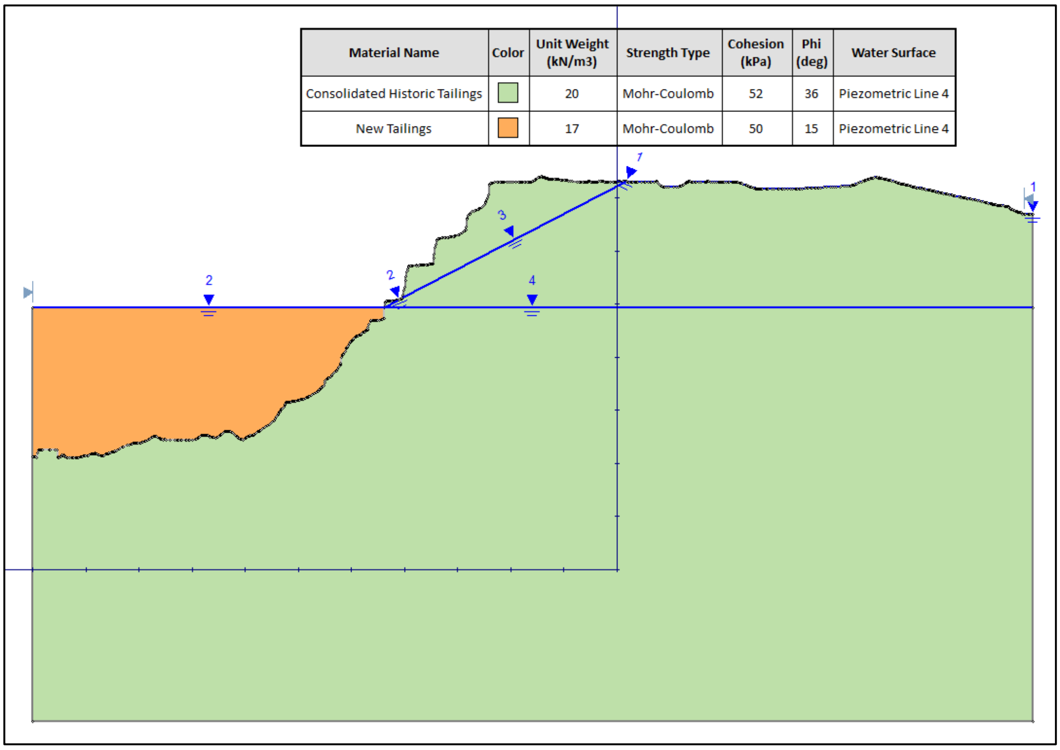
Figure 3 Slope configuration #2 - 25m of ‘new’ tailings



Slope configuration #3 - 50m of ‘new’ tailings:

Placement of 50m of ‘new’ tailings in the pit, adjacent to the existing historic tailings pit wall slope, as shown in Figure 3.

Figure 4 Slope configuration #3 - 50m of ‘new’ tailings



3.3 Material properties

The estimated material properties assigned to each material type used in the modelling are outlined in Table 1. The properties assigned to the historic tailings, comprising the existing north pit wall slope, are based on a combination of laboratory testing and back-analysis of slope performance.

Representative samples of the historic tailings slope material were collected on site for subsequent laboratory testing. The testing included:

- 2 x UCS tests – dry samples
- 3 x UCS tests – saturated samples
- 1 x Direct Shear test

The number and location of samples was limited by slope access constraints.

The material properties outlined in Table 1 were derived from the combination of direct shear testing, saturated and unsaturated UCS testing of intact samples from the existing fill slope and on GCE precedent experience of comparable materials and understanding of the slope performance to date.

Figure 5 shows the UCS samples before and after UCS testing.

Figure 5 Unsaturated UCS test samples

Test 1

Intact sample

Crushed sample

Test 2

Intact sample

Crushed sample

Figure 6 Saturated UCS test results

Intact sample

Crushed sample

The insitu material was successfully tested under dry conditions, however, total disintegration and strength loss was observed under saturated conditions.

Table 1 Material shear strength properties

Material Type	Unit Weight (kN/m^3)	UCS (kPa)	Cohesion (kPa)	Friction Angle
Historic tailings slope (unsaturated)	20	222	52	36°
Historic tailings slope (saturated)	20	0	1.3	0°
'New' tailings (estimated)	17		50	36°

3.4 Groundwater

GCE understands that all water inflow will be removed from the pit via an installed drainage system and that groundwater will not be allowed to accumulate at the bottom of the pit or in the pit wall slopes. However, the groundwater profile and potential fluctuation following major rainfall events in the area of the Kintore Pit is currently not well defined as there are no groundwater monitoring bores in the vicinity of the tailings slope and Kintore Pit. There may be periods after heavy rainfall events where part of the historic tailings slope and 'new' tailings will be saturated and a transient piezometric surface may 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 'new' tailings, applying to both the 'new' tailings and the historic tailings slope.
3. "Sloped from top of new tailings to 50m setback from pit crest" – a sloping piezometric surface is applied from a 50m setback from the pit crest, down to the level of the top of the tailings, applying to both the 'new' tailings and the historic tailings slope.

GCE understands that the historic tailings slope has been observed at Rasp over a number of years to be effectively free draining and it is assumed to be highly permeable. As such, groundwater condition number 3 as described above is considered to be an unlikely, transient, "worst case" scenario.

Material testing conducted has highlighted the potential for disintegration of the historic tailings material when saturated with water. BHOP should consider the potential for slope washout at the toe of the historic tailings slope following significant rainfall events. Water must not be allowed to accumulate and 'pond' at the toe of the historic tailings slope while placing 'new' tailings in the pit.

3.5 Summary of slope stability assessment results

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

(Factor of Safety is abbreviated as FOS.)

Slope configuration #1 - no 'new' tailings:

- Dry case and horizontal piezometric surface case
    - No failure surfaces are indicated at FOS < 1.
    - Minimum FOS = 1.142, corresponding to a multi-batter slope scale circular failure surface with moderate depth of failure. This indicates that, with the estimated material properties applied, the existing dry slope is relatively close to the threshold of stability.
    - At FOS < 1.3, numerous potential multi-batter slope scale failure surfaces are indicated.
- Sloped piezometric surface case
    - Significant reduction in slope stability from the dry condition. However, as described in Section 3.4, the historic tailings slope is understood by GCE to be highly permeable, effectively free draining, and hence this worst case groundwater scenario is considered to be unlikely.

Slope configuration #2 - 25m of 'new' tailings:

- Dry case and horizontal piezometric surface case
    - No failure surfaces are indicated at FOS < 1.
    - Minimum FOS = 1.164, corresponding to a multi-batter slope scale failure surface from the top of the 'new' tailings to the pit crest. This indicates that, with the estimated material properties applied, the slope is relatively close to the threshold of instability.
    - At FOS < 1.3, numerous potential multi-batter slope scale failure surfaces are indicated. However, slope stability is somewhat increased from slope configuration #1 - no 'new' tailings case.
- Sloped piezometric surface case
    - Significant slope scale instability at FOS = 1.116. In this case, potential for circular failure resulting in significant floor heave through the tailings is indicated at FOS < 1.3.

Slope configuration #3 - 50m of tailings:

- Dry case and horizontal piezometric surface case
    - No failure surfaces are indicated at FOS < 1.
    - Minimum FOS = 1.421, corresponding to a multi-batter slope scale failure surface from the top of the 'new' tailings to the pit crest.
    - At FOS <1.3, no failure surface is indicated. Slope stability is significantly increased from slope configurations #1 and #2.
- Sloped piezometric surface case
    - No material change or reduction in slope stability from the dry condition.

3.6 Conclusions and recommendations

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

- The preliminary slope stability analyses conducted by GCE highlights the potential for slope scale instability of the historic tailings slope forming the north wall of the Kintore Pit under certain hydrogeological conditions.

- The placement of 'dry' tailings at the base of existing historic tailings slope is expected to increase the stability of the slope. Particularly when the filled depth in the pit reaches 50m or greater.

- Circular failure or composite failure with a major circular component appears to be the most likely potential failure mechanism.

- Horizontal piezometric groundwater surfaces incorporated at various levels in the modelling, have minimal impact on the stability of the historic tailings slope.

- When a potential "worst case" sloped piezometric groundwater surface is incorporated at various levels in the modelling it has been shown to significantly reduce the stability of the historic tailings slope. Modelling of the current slope configuration #1 where no 'new' tailings have been placed in the pit, indicates a minimum FOS = 0.875 for the sloped groundwater case. However, GCE understands that the historic tailings slope has been observed by Rasp over a number of years to be effectively free draining and the consolidated tailings material is permeable. As such, the sloped groundwater surface incorporated in the modelling is currently considered to be a relatively unlikely, "worst case", transient groundwater scenario.

- Given the reduction in slope stability indicated by the modelling for the sloped groundwater scenarios, GCE recommends that Rasp determine an appropriate stand-off period and procedure following rainfall events or if pooled water is observed at the base of the tailings slope, whereby the tailings slope (crest and toe) will be isolated and access to the pit will be restricted until any accumulated groundwater has drained from the pit walls. These restrictions are required while filtered tailings are being placed in the Kintore Pit and personnel access is required.

- The installation of groundwater monitoring bores in the tailings slope is recommended to ensure that the level of piezometric surface remains below the "worst case" modelling configuration.

- GCE recommends that a large bund (minimum 2m height) is installed along the length of the toe of the historic tailings slope during placement of 'new' tailings to provide a barrier against minor rockfall from the adjacent slopes. The bund will need to be progressively moved and re-established as the level of the tailings backfill rises in the pit.

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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DOCUMENT CHANGE CONTROL

Version	Description of changes/amendments	Author(s)	Date
DRAFT01	Draft report	C. Byrne, C. Tucker	11/04/19
DRAFT02	Draft report	C. Byrne, C. Tucker	12/05/19
DRAFT03	Draft report	C. Byrne, C. Tucker	
DRAFT04	Draft report	C. Byrne, C. Tucker	06/08/19

DOCUMENT REVIEW AND SIGN OFF

Version	Reviewer	Position	Signature	Date
DRAFT02	C.Tucker	Principal Geotechnical Engineer		12/05/19
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DRAFT02	C.Tucker	Principal Geotechnical Engineer		06/08/19
V04 FINAL	C.Tucker	Principal Geotechnical Engineer		20/08/19

APPENDIX A

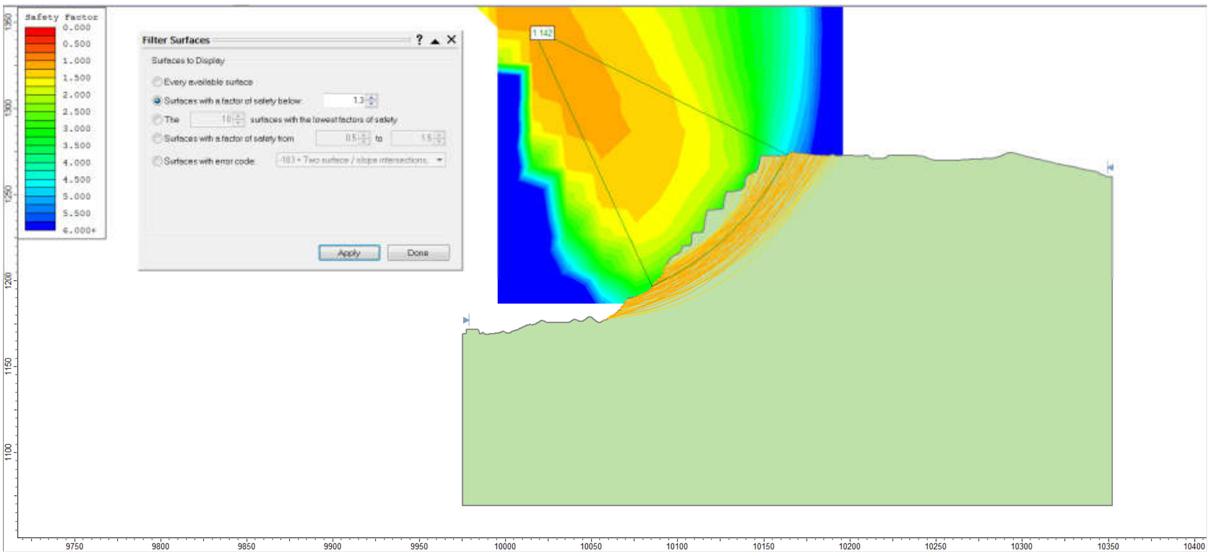
Kintore Pit Historic Tailings Slope Stability Modelling Results Summary

Consolidated tailings: c = 52, phi = 36

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

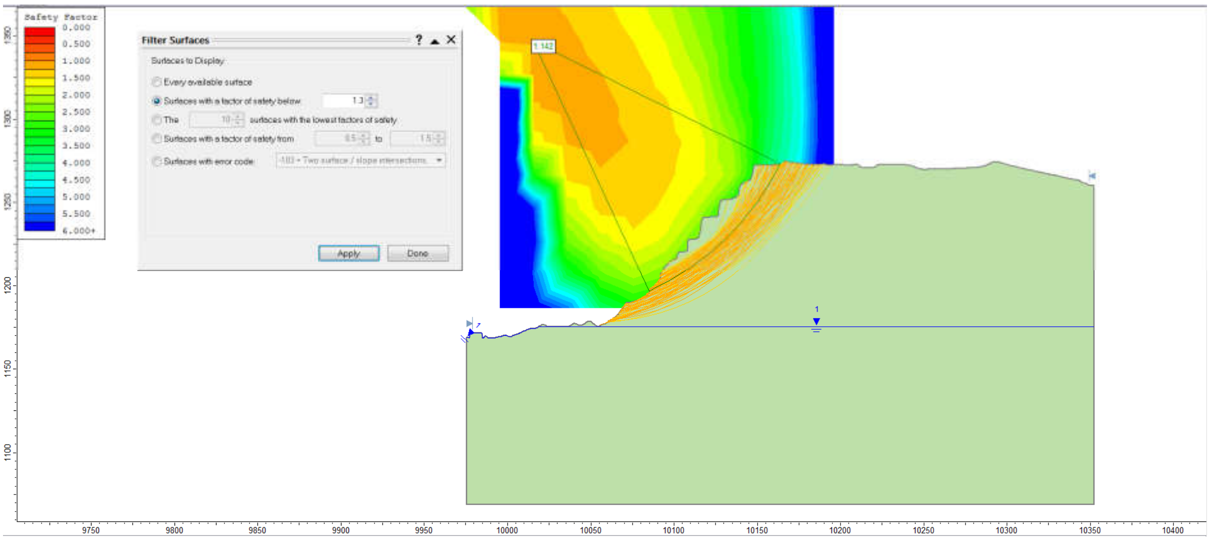
A. No tailings, no water

- FOS min = 1.142, multi-batter slope scale failure.
- FOS < 1.3, numerous failure surfaces indicating significant slope scale failure potential.



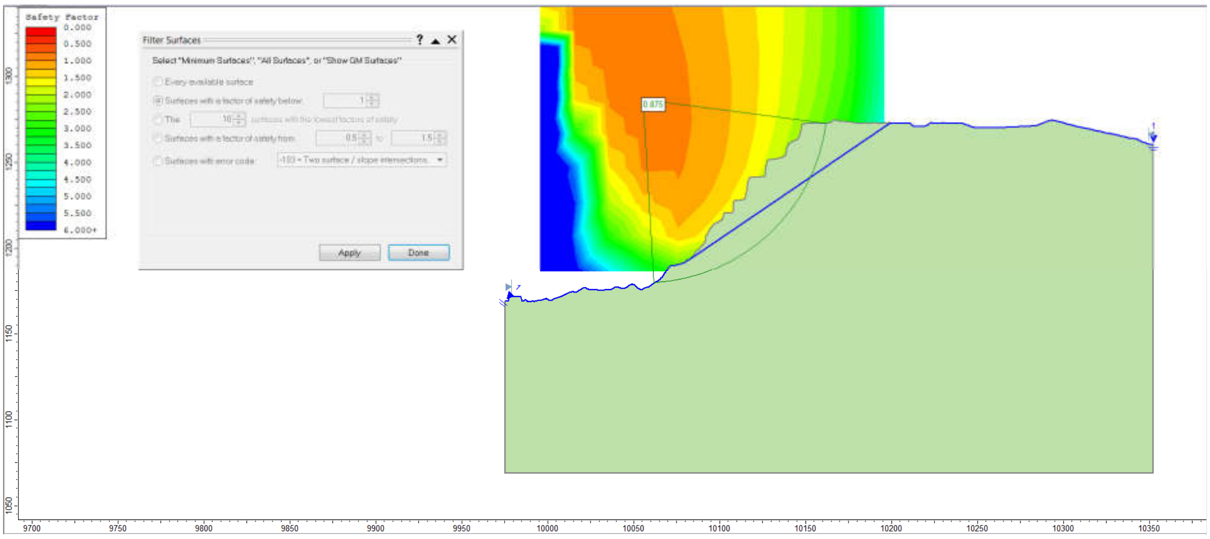
B. No tailings, horizontal water table at base of pit

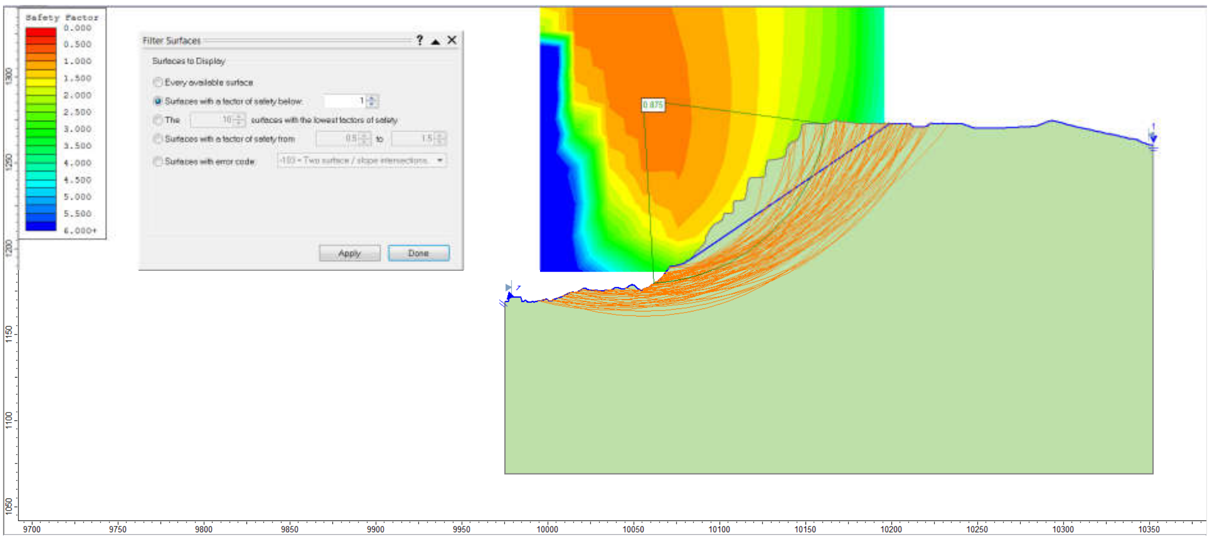
- FOS min = 1.142, multi-batter slope scale failure.
- FOS < 1.3, numerous failure surfaces indicating significant slope scale failure potential.
- No material change from dry condition.



C. No tailings, water sloped from base of pit to 50m setback from pit crest ("worst case")

- FOS min = 0.875, significant multi-batter slope scale failure indicated.
- FOS < 1.0, significant slope scale failure, including floor heave indicated.
- Significant reduction in stability from dry condition. Low likelihood, transient groundwater condition.

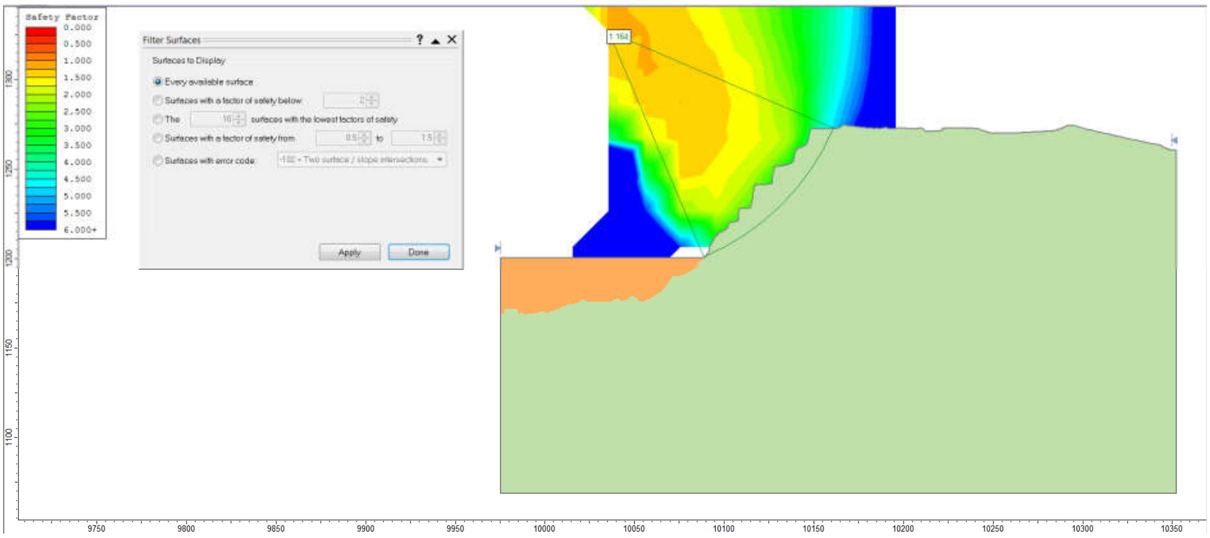


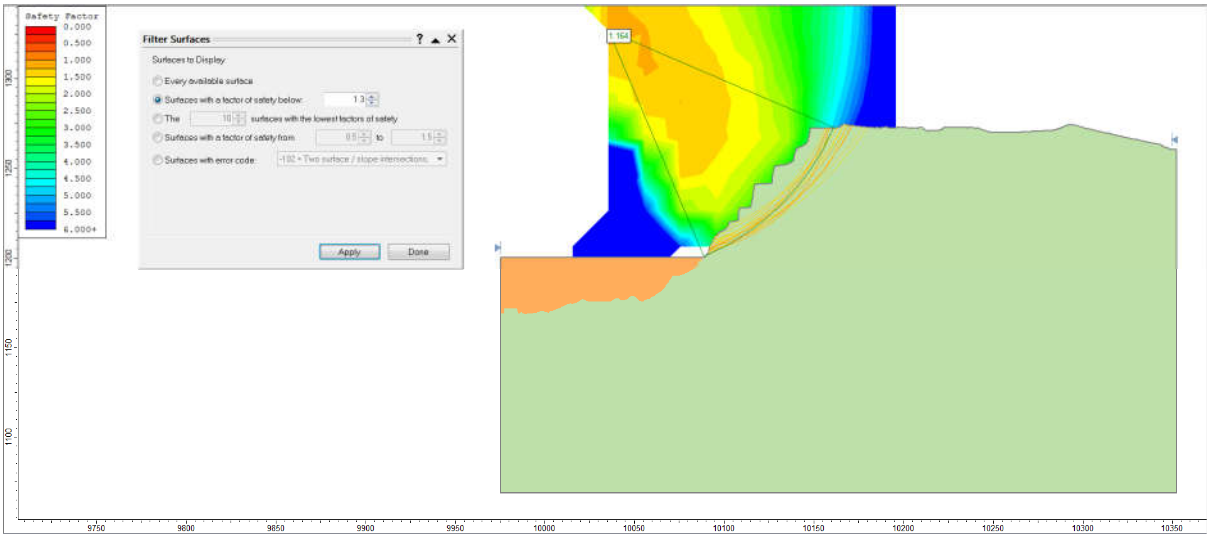


Slope configuration #2 - 25m of 'new' tailings:

A. 25m tailings, no water

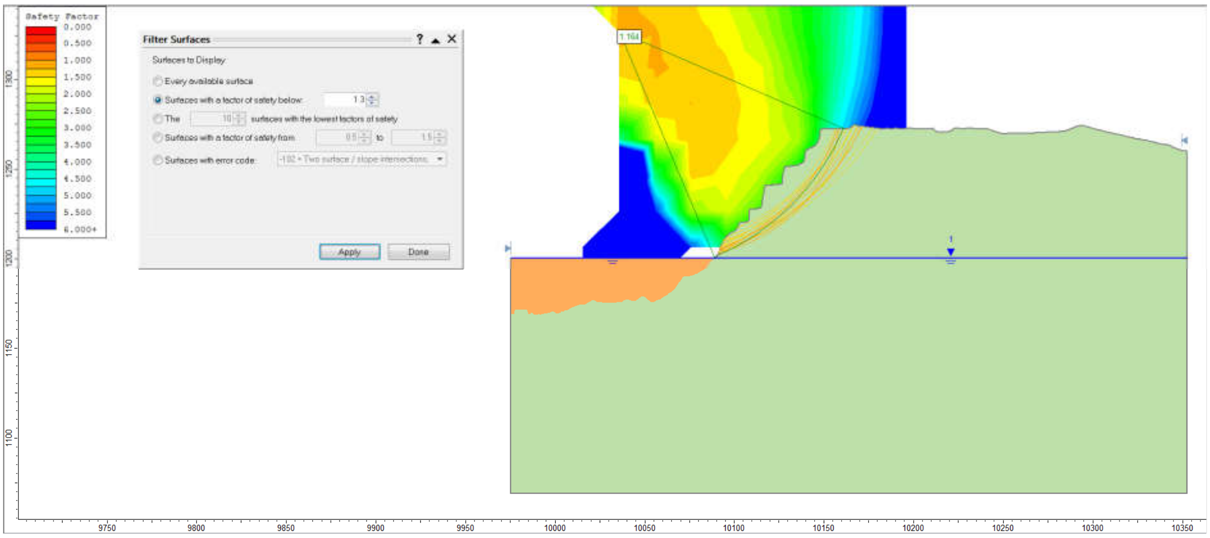
- FOS min = 1.164, slope scale failure
- FOS < 1.3, significant slope scale failure indicated. However, stability slightly increased from 'no tailings' case. i.e. current slope configuration.





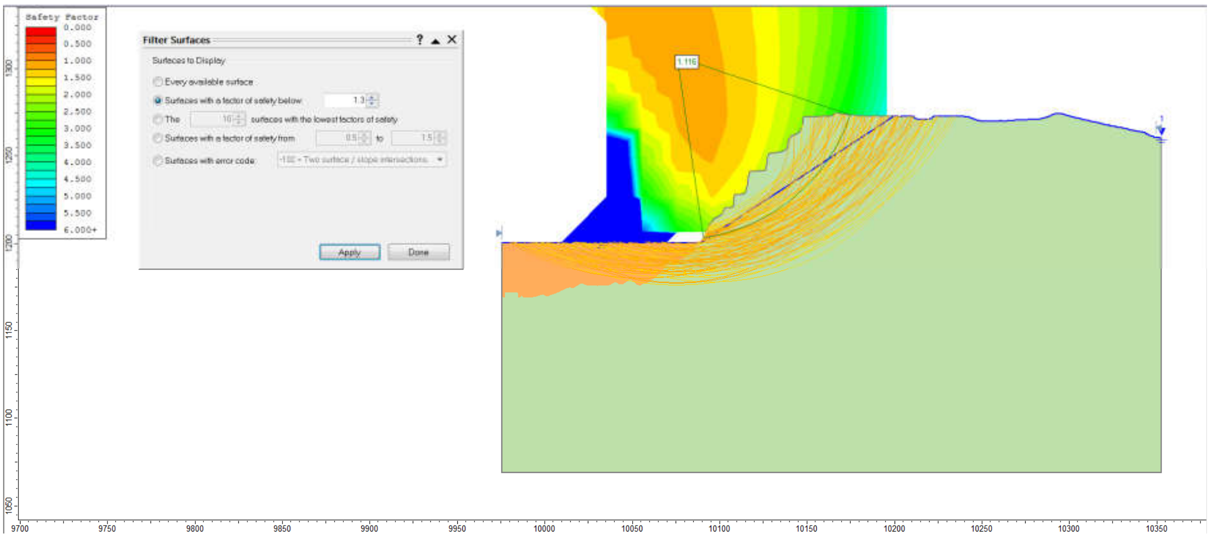
B. 25m tailings, horizontal water table at top of tailings

- FOS min = 1.164, slope scale failure.
- FOS < 1.3, significant slope scale failure indicated.
- No material change from dry condition.



C. 25m tailings, water sloped from top of tailings to 50m setback from pit crest ("worst case")

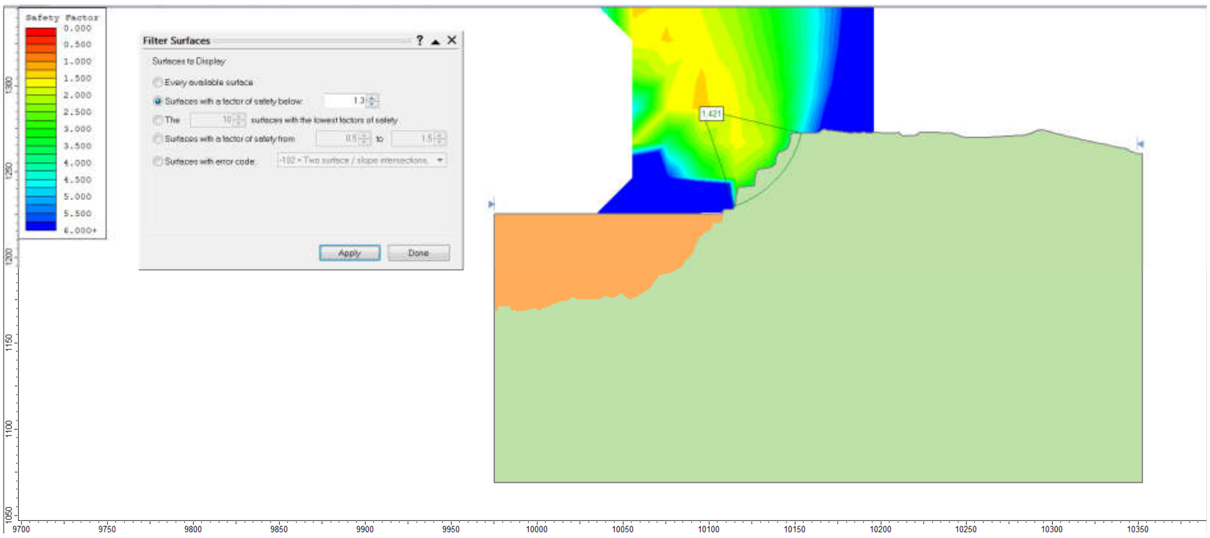
- FOS min = 1.116, slope scale failure.
- FOS < 1.3, significant slope scale failure, including floor heave indicated.
- Significant reduction in stability from dry condition. Low likelihood, transient groundwater condition.



Slope configuration #3 - 50m of 'new' tailings:

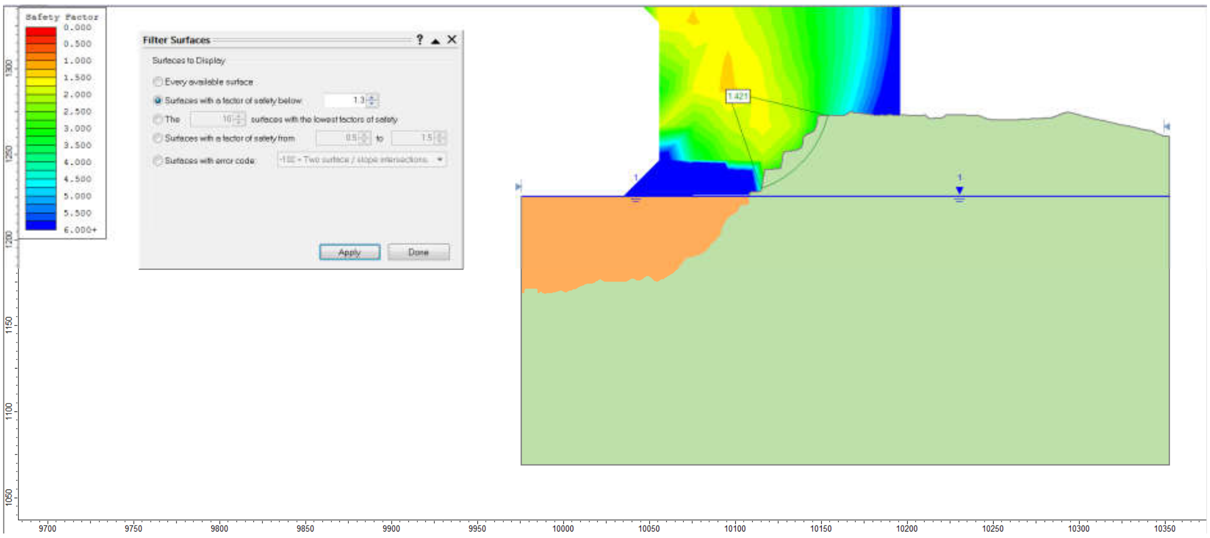
A. 50m tailings, no water

- FOS min = 1.421, slope scale failure to top of tailings.
- FOS < 1.3, no failure surfaces indicated. Stability significantly increased from 'no tailings' case. i.e. current slope configuration.



B. 50m tailings, horizontal water table at top of tailings

- FOS min = 1.421, slope scale failure to top of tailings.
- FOS < 1.3, no failure surfaces indicated.
- No change from dry condition.



C. 50m tailings, water sloped from top of tailings to 50m setback from pit crest ("worst case")

- FOS min = 1.420, slope scale failure to top of tailings.
- FOS < 1.3, no failure surfaces indicated.
- No material change from dry condition.