Appendix 9

SAR North Pit Long Term Slope Stability Analysis

prepared by

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mine smarter

Report

Roswell Slope Stability Analysis
Alkane Resources Ltd

AMC Project 121046
27 August 2021

Unearth a smarter way

27 August 2021

Mr Simon Parsons
Alkane Resources Ltd
68 Kings Park Road
WEST PERTH
WA 6005

Roswell Slope Stability Analysis

Dear Simon

This report presents the findings of the scope of work detailed in AMC proposal MP21057 Roswell Slope Stability Analysis dated 17 July 2021.

We trust that this letter report meets your immediate requirements and please contact the undersigned of you have any queries.

Yours sincerely
Lianne McKenzie
Principal Geotechnical Consultant

Quality control

The signing of this statement confirms this report has been prepared and checked in accordance with the AMC Peer Review Process.

Project Manager	The signatory has given permission to use their signature in this AMC document Lianne McKenzie	27 August 2021 Date
Peer Reviewer	The signatory has given permission to use their signature in this AMC document Meredith Goss	27 August 2021 Date
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1 Introduction

1.1 Background

AMC Consultants Pty Ltd (AMC) was engaged by Alkane Resources Ltd (Alkane) to undertake geotechnical stability analyses on the proposed final slopes of the Roswell pit. AMC received the request for the advice in an email from Mr Simon Parsons of Alkane on 12 July 2021.

Geotechnical advice on the long-term stability of the Roswell pit slopes (which is also known as the north pit) is required for Alkane's mine rehabilitation studies and is part of the Tomingley Gold Extension Project (TGEP). The Roswell pit will be about 700 m wide by 630 m long and 300 m deep on completion. As part of Alkane's mine rehabilitation studies for TGEP, geotechnical advice on the long-term stability of the Roswell pit slopes is required.

AMC understands that the proposed final rehabilitation and post mining land use for the Roswell pit is a void that will be bunded and fenced. The pit immediately to the south of Roswell will be backfilled with mine waste.

1.2 Scope of work

The scope of work was to assess the long term geotechnical stability of the final rehabilitated landform slopes of the Roswell pit. AMC understand that the pit slopes proposed by the des_sar_combined_210422 design are intended to be the final rehabilitated landform. Hence, stability assessment was done on the slopes presented by the des_sar_combined_210422 design.

Scope of work completed was as per AMC proposal MP21057 Roswell Slope Stability Analysis dated 7 July 2021 and consisted of:

- Reviewing all the available geotechnical data relevant for the assessment of slope stability.
- Assessing potential long term pit slope failure mechanisms.
- Selecting critical cross-sectional locations appropriate for slope stability analyses.
- Undertaking stability analyses on the identified critical cross-sectional locations.
- Reporting on the results of slope stability analyses and providing comment on long term stability and suitability of the slopes as a final landform and if required options for slope remediation.

AMC imported wireframes available such as the pit design, topography and geology into the 3D visualisation software Leapfrog.

This scope of work did not involve the collection of data and slope stability analyses were based on existing data and information provided by Alkane.

2 Available data and information

Alkane has provided the following data and information for the scope of work:

- Pit design wireframe des_sar_combined_210422.
- Topography surface wireframe 2009_aam_contours_simplify.
- Dxf files of the location of the realigned Newell Highway (Design – Newell & Kyalite Export (210421) and mining lease (20210630_Proposed MLA).
- Proposed waste dump wireframe (sar_wre_v9).
- Alkane generated geological 3D wireframes:
  - base of alluvium (basecover_tgep_20210531).
  - base of saprolite (basesap_tgep_20210531).
  - base of oxidation (baseox_tgep_20210601).
  - inferred Roswell fault (Ros_Fault202010).
- Geotechnical reports:
  - WSP Australia (2021) Tomingley Gold Extension Project: review of pit slope design, unpublished letter, ref PS117941-GEO-LTR-006 Rev A.
  - WSP Australia (2021) Tomingley Gold Extension Project, San Antonio and Roswell Geotechnical Report, unpublished report, ref PS117942-GEO-REP-005 Rev B.
- Jacobs Australia Pty Limited (2021) Draft groundwater assessment report – Tomingley Gold Extension Project Groundwater Assessment, unpublished report.

3 Overview of the geotechnical model

3.1 Geotechnical horizons

The WSP geotechnical report presented five geotechnical horizons for Roswell. From the ground surface to depth, these horizons define the ground conditions at Roswell and include:

- Quaternary Alluvium (QA) consisting of brown sandy clays, sandy silty clays and minor sands and gravels.
- Tertiary Alluvium (TA) consisting of grey mottled red orange sandy clays and silty clays and sands.
- Saprolite defined as extremely weathered rock with soil consistency and relict geological structure.
- Weathered Rock (WR) consisting of oxidised and highly to moderately weathered rock.
- Slightly Weathered and Fresh Rock (SW/FR).

The spatial location of the above horizons is based on the Alkane generate 3D geological surfaces, where the base of TA is basecover_tgep_20210531, the base of Saprolite is base_tgep_20210531 and the base of weathered rock is baseox_tgep_20210601. The rock mass below the base of oxidation is mainly slightly weathered and fresh.

The base of QA is assumed to be 10 m below the ground level (bgl) in line with the previous WSP geotechnical report.

3.2 Groundwater

Based on the Jacobs draft groundwater report (Jacobs 2021) the groundwater regime at TEGP is characterised as a fractured rock aquifer system which hosts the regional water table and the system is conceptualised to be hydraulically disconnected from the overlying alluvial groundwater systems. Although, some small perched and discrete alluvial groundwater systems could exist.

Preliminary groundwater modelling (Jacobs 2021) predicted the final void equilibrium water levels to be at 180 m Australian Height Datum (AHD). First water strikes in exploration boreholes suggested that alluvium is likely to be predominantly unsaturated and strike depths were relatively consistent at 60 mbgl to 100 mbgl. This depth typically coincided with the transition from saprolite to weathered rock.

4 Slope stability

4.1 Discussion

In this report, AMC has provided the results of stability analyses on the proposed pit design and advice on possible future stability performance of the slopes post mine closure.

AMC emphasise that as mining of the Roswell pit has not commenced and the conditions of the rock mass that will ultimately form the final slopes are not yet confirmed, then the results of the analyses and the advice provided must be considered as preliminary. The long term stability of the final pit slopes could change and will be influenced by many aspects implemented during mining operation. It is recommended that long term stability be re-assessed progressively as new data becomes available during slope development and when the final pit is close to completion.

4.2 Potential failure mechanisms

Based on the WSP geotechnical assessment report, the controls on slope stability in Roswell were assessed as the following:

- Circular failure through the alluvium and saprolite.
- Circular failure or rotational failure through weathered rock mass.
- Combination of sliding along geological structure and rock mass failure through the saprolite and weathered rock mass.
- Structurally controlled failures along geological structures and relict structures including planar, sliding and wedge failure in the saprolite, weathered rock and slightly weathered and fresh rock.

Groundwater pressures will also play a role in the stability of the pit slopes.

4.3 Long-term failure mechanisms

The main mechanism that will contribute to long-term stability is the ongoing deterioration of the alluvium and saprolite and rock mass style failures at a bench and multi-bench scale within this material. The risk of rock mass style of failure occurring is increased if transient or high ground water pressures occur in the slope. Unravelling of weathered rock is also likely to occur over time.

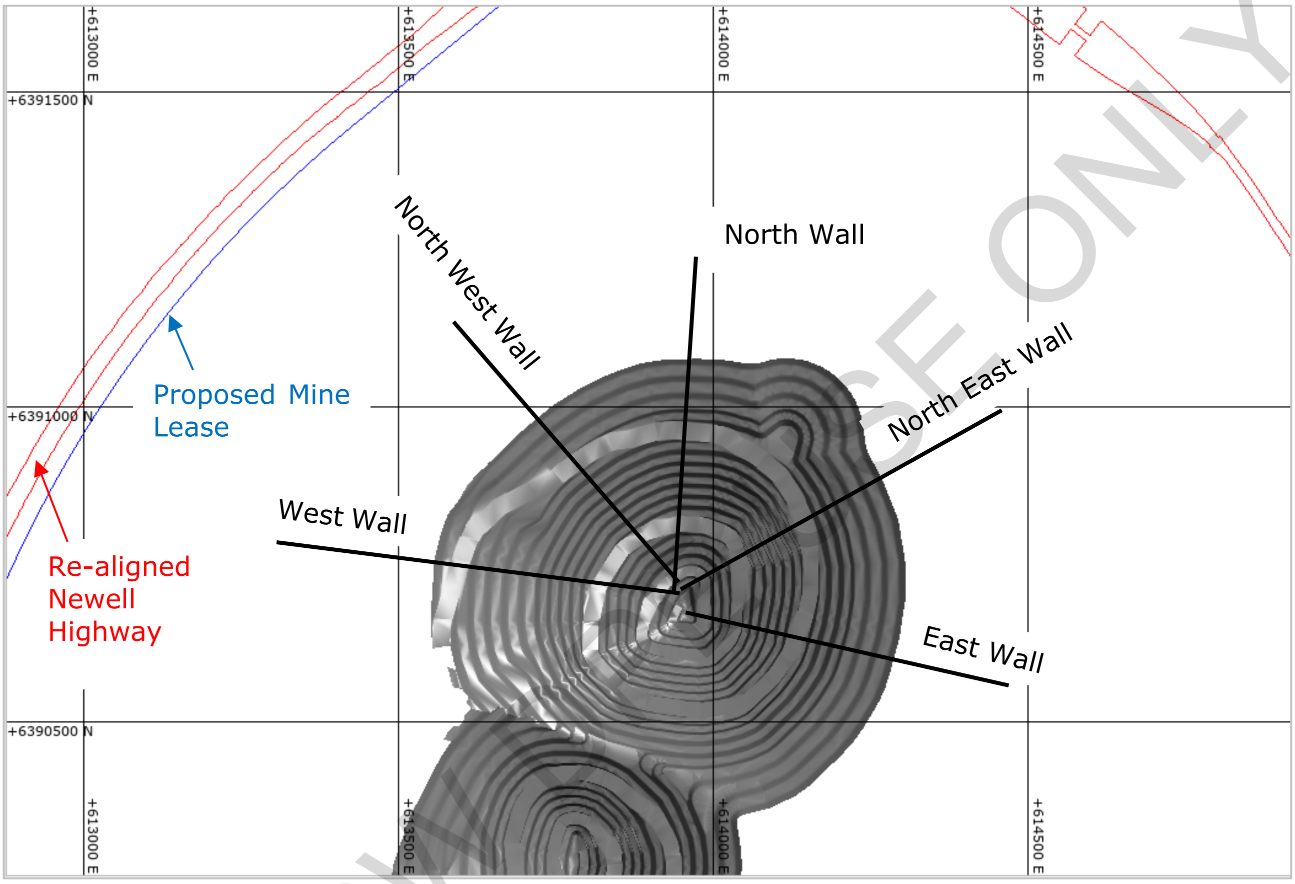
Past studies in the Tomingley pits have indicated that the alluvium and saprolite soils are highly dispersive, sodic and often non-saline (PSM 2016). As the geological environment at Roswell is similar to Tomingley, it is not unreasonable to assume that the alluvium and saprolite exposed in the slopes at Roswell will also be dispersive. Exposed or disturbed dispersive soils have a high erosion potential when in contact with water. Without implementation of management measures, such as good surface water drainage and re-vegetation, long-term erosion has the potential to lay the slopes back at nominally 20º through the alluvium and saprolite. An assessment of the long-term erosion impacts on the Roswell slopes is not part of this scope of work. AMC understand that Alkane have engaged specialised soil scientists Landloch Pty Ltd to conduct this assessment.

4.4 Slope stability analyses

4.4.1 Methodology and assumptions

AMC carried out limit equilibrium analyses using SLIDE[1] to assess a Factor of Safety (FOS) for the proposed Roswell slopes at the cross-sectional locations shown in Figure 4.1

Figure 4.1 Cross-sectional location of the analyses



An analysis on the proposed south wall was not warranted as the pit immediately to the south will be backfilled with mine waste and the slope will comprise slightly weathered to fresh rock.

Analyses assumed:

- A circular style failure through the alluvium, saprolite and weathered rock horizons.
- A groundwater profile that represents the water level in the pit post-closure, based on the Jacobs draft report this is 180 mRL.

Alkane provided updated geological 3D wireframes to assess the spatial location of the geotechnical horizons. Analyses did not consider the impact on stability posed by the Roswell fault. Based on the preliminary data available on the condition and location of the fault, the potential for long-term stability issues due to the fault is most likely low.

In AMCs experience and industry guidelines for open pit stability (Read & Stacey 2009) the failure path for a FOS of 1.5 proves an appropriate indication of the extent of slope that may experience failure in the long-term.

[1] Limit equilibrium analysis software developed by Rocscience

4.4.2 Adopted material strength parameters

Analyses used the material properties assessed for the alluvium, saprolite, weathered rock and fresh rock presented by WSP in the geotechnical report (WSP 2021). Table 4.1 presents the material shear strength parameters adopted.

Table 4.1 Adopted material shear strength parameters for Roswell

Geotechnical Horizon	Density (kN/m^3)	Shear Strength Parameters	
		Cohesion (kPa)	Friction Angle (°)
Quaternary Alluvium	18	31	13
Tertiary Alluvium	20	42	21
Saprolite	20	37	23
Weathered Rock	22	UCS = 2 MPa, GSI[1] = 40, mi[2] = 20	
Slightly Weathered and Fresh Rock	28	UCS = 110 MPa, GSI = 70, mi = 20	

1. Geological Strength Index
2. Intact parameter

4.4.3 Results

Appendix A presents the results of the analyses done to assess the extent of slope that may experience failure in the long-term. Based on a FOS of 1.5, Table 4.2 below summarises the potential long-term crest failure distance back from the crest.

Table 4.2 Potential long-term failure distance back from the crest

Section Location	Potential long-term crest cut back
East Wall	68 m
North Wall	58 m
North East Wall	58 m
North West Wall[a]	9 m
West Wall	47 m

a. Localised failure within the Quaternary Alluvium (upper 10 m).

Analyses for the North West Wall indicated localised failure within the Quaternary Alluvium (upper 10 m) and no multi-bench scale failure through the alluvium, saprolite and weathered rock. This result was controlled by the geotechnical horizon anticipated to be exposed in the pit slope at that location which consisted of more of the slope having weathered rock with a higher shear strength (about a 74 m thickness) compared to saprolite (a soil with a low shear strength and about a 4 m thickness). Although analyses did not indicate a significant failure of the crest in the long-term, unravelling of the weathered rock will occur over time.

AMC highlight that the slope stability analyses results are dependent on the 3D geological surfaces base of alluvium, base of saprolite and base of oxidation inferred by Alkane. It is important to understand that with future data collection, such as more drilling investigations and in pit mapping, the extent of these horizons will change. In addition to this, it is difficult to analyse for structurally controlled failures in the saprolite and weathered rock prior to pit development due to difficulties in obtaining meaningful data. For these reasons, it is recommended that long-term slope stability be re-addressed when significant changes are made to the 3D geological surfaces and once mining has progressed and exposed the alluvium, saprolite and weathered rock horizons in the Roswell pit. The collection of geological structure data in the saprolite and weathered rock will be important as the pit develops to confirm slope long term stability.

5 Conclusion

Based on the results of stability analyses done at representative cross-sectional locations within the proposed Roswell pit, the potential long-term crest failure due to rock mass failures in the alluvium, saprolite and weathered rock is between about 47 m to 68 m.

It is recommended that long-term slope stability be re-addressed when the Jacobs groundwater report is finalised, significant changes are made to the 3D geological surfaces and once mining has progressed and exposed the alluvium, saprolite and weathered rock horizons in the Roswell pit. Geotechnical mapping during pit development will be important to understand geological structure in the saprolite and rock and will assist in confirming the long term stability of the Roswell slope.

References

Jacobs Australia Pty Limited 2021, Draft groundwater assessment report – Tomingley Gold Extension Project Groundwater Assessment, unpublished report.

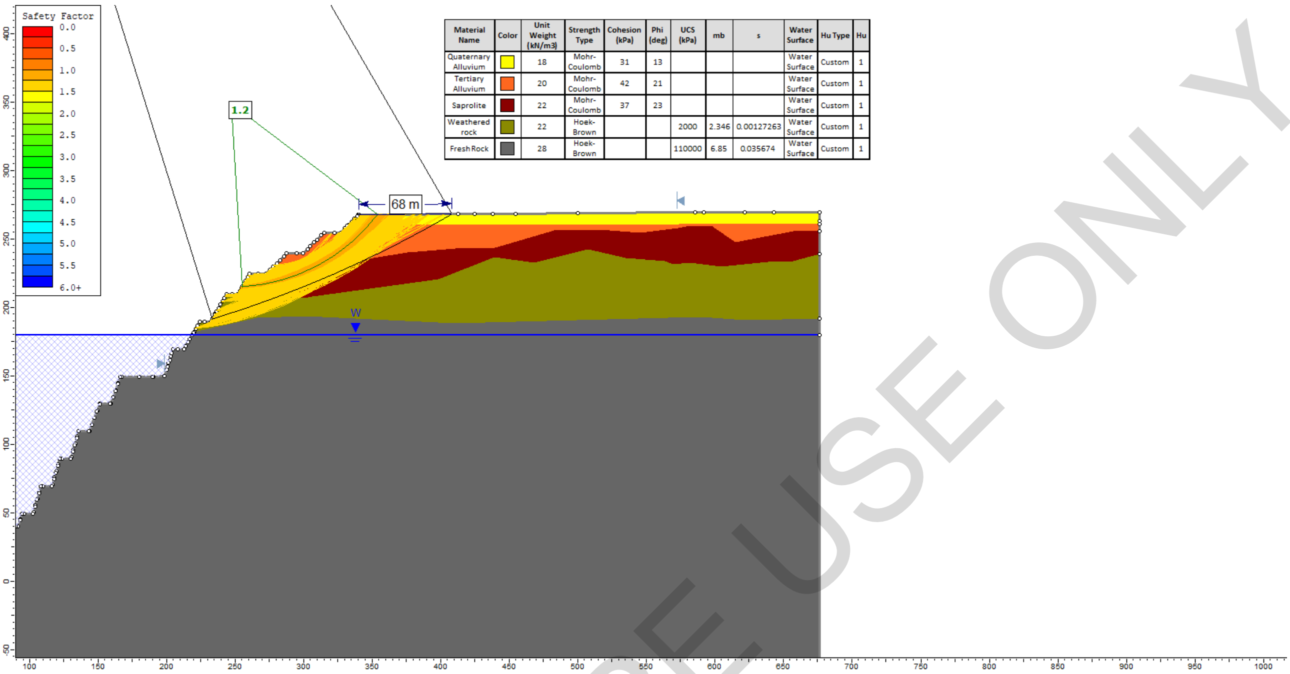
Read, J., Stacey, P., & CSIRO (Australia). (2009). *Guidelines for open pit slope design*. Collingwood, Vic: CSIRO Publishing.

WSP Australia 2021, Tomingley Gold Extension Project: review of pit slope design, unpublished letter, ref PS117941-GEO-LTR-006 Rev A.

WSP Australia 2021, Tomingley Gold Extension Project, San Antonio and Roswell Geotechnical Report, unpublished report, ref PS117942-GEO-REP-005 RevB.

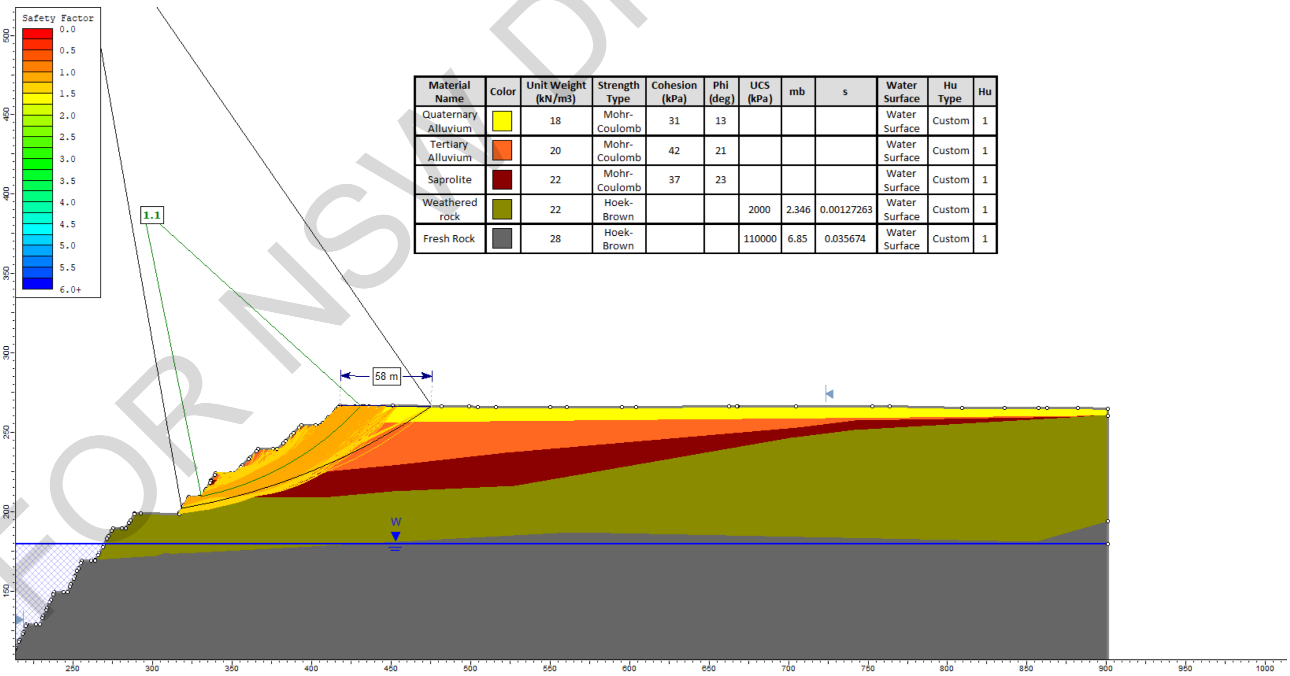
Appendix A
Results of Slope Stability Analyses

Figure A1 Roswell pit East Wall slope stability analysis



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	UCS (kPa)	mb	s	Water Surface	Hu Type	Hu
Quaternary Alluvium		18	Mohr-Coulomb	31	13				Water Surface	Custom	1
Tertiary Alluvium		20	Mohr-Coulomb	42	21				Water Surface	Custom	1
Saprolite		22	Mohr-Coulomb	37	23				Water Surface	Custom	1
Weathered rock		22	Hoek-Brown			2000	2.346	0.00127263	Water Surface	Custom	1
Fresh Rock		28	Hoek-Brown			110000	6.85	0.035674	Water Surface	Custom	1

Figure A2 Roswell pit North Wall slope stability analysis



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	UCS (kPa)	mb	s	Water Surface	Hu Type	Hu
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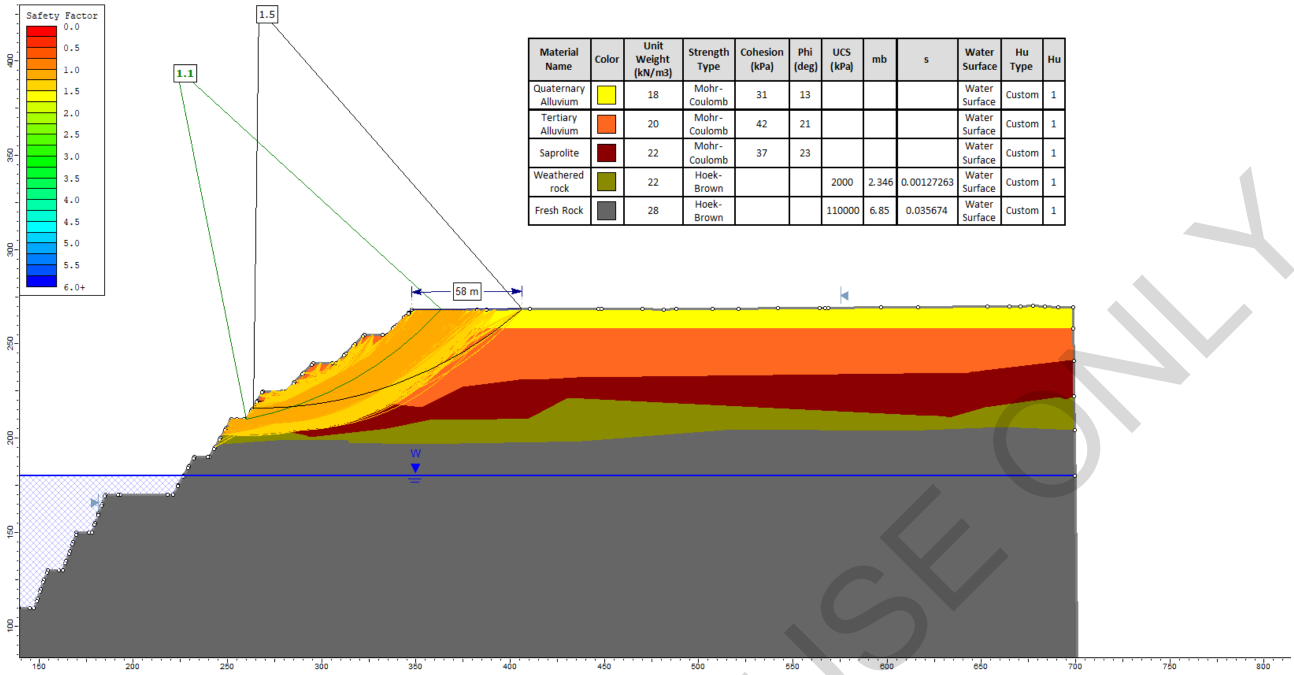
Saprolite		22	Mohr-Coulomb	37	23				Water Surface	Custom	1
Weathered rock		22	Hoek-Brown			2000	2.346	0.00127263	Water Surface	Custom	1
Fresh Rock		28	Hoek-Brown			110000	6.85	0.035674	Water Surface	Custom	1

Figure A1 Roswell pit North East Wall slope stability analysis



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	UCS (kPa)	mb	s	Water Surface	Hu Type	Hu
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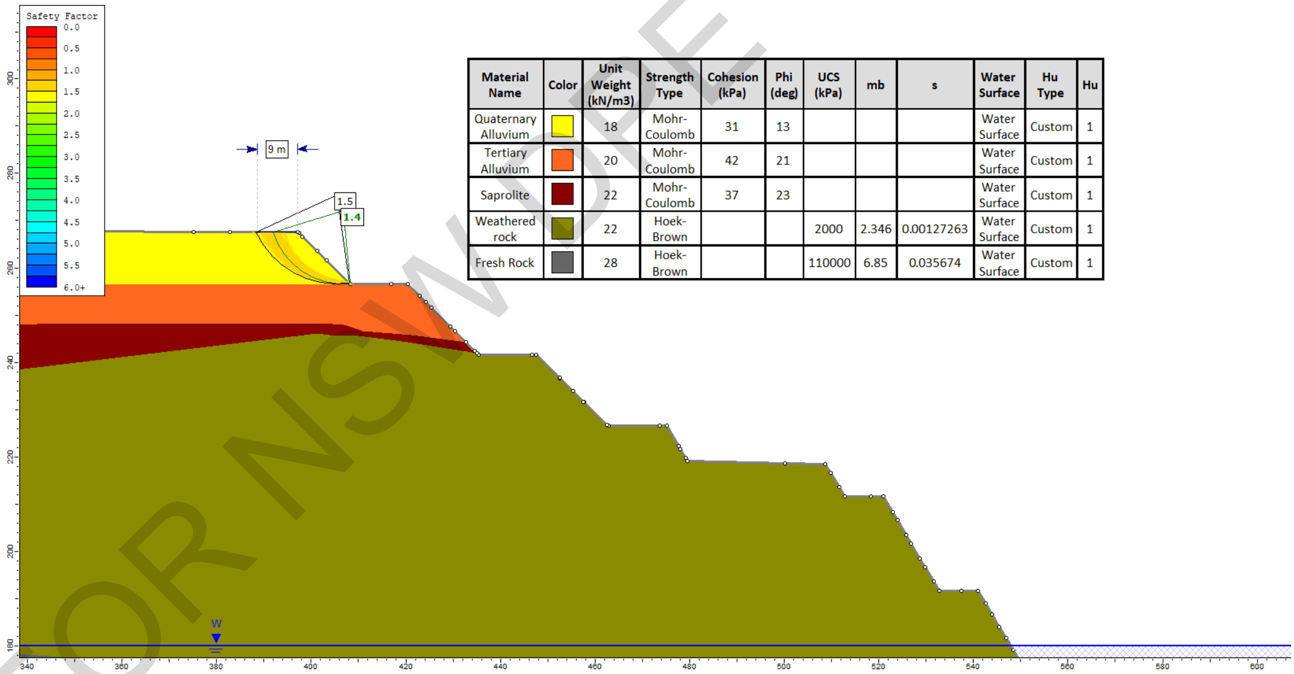
Tertiary Alluvium		20	Mohr-Coulomb	42	21				Water Surface	Custom	1
Saprolite		22	Mohr-Coulomb	37	23				Water Surface	Custom	1
Weathered rock		22	Hoek-Brown			2000	2.346	0.00127263	Water Surface	Custom	1
Fresh Rock		28	Hoek-Brown			110000	6.85	0.035674	Water Surface	Custom	1

Figure A2 Roswell pit North West Wall slope stability analysis



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	UCS (kPa)	mb	s	Water Surface	Hu Type	Hu
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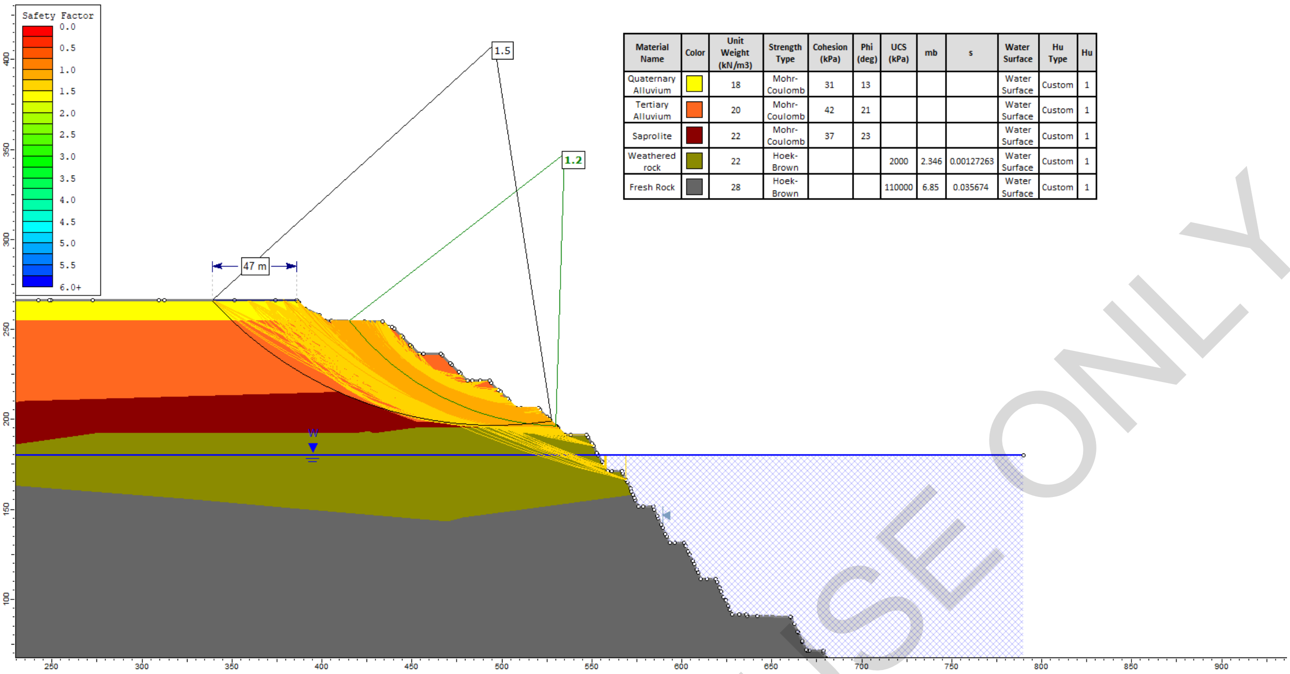
Saprolite		22	Mohr-Coulomb	37	23				Water Surface	Custom	1
Weathered rock		22	Hoek-Brown			2000	2.346	0.00127263	Water Surface	Custom	1
Fresh Rock		28	Hoek-Brown			110000	6.85	0.035674	Water Surface	Custom	1

Figure A3 Roswell pit West Wall slope stability analysis



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