Goschen Mineral Sands and Rare Earths Project

Environment Effects Statement
Geotechnical Impact Assessment

Prepared for
VHM Limited

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Rev03

Table of Contents

1. Introduction 9
1.1 Requirement for an EES 9
2. Project description 9
2.1 Project overview 9
2.2 Project development 10
2.3 Key project components 12
3. Scoping 15
3.1 EES evaluation objectives and scoping requirements 15
4. Evaluation framework 17
4.1 Legislation, policy, guidelines, and standards 17
4.2 Assessment methodology 19
4.2.1 Assessment Criteria development for construction and operation 20
4.2.2 Rehabilitation / Post operation criteria 22
5. Consultation and engagement 23
6. Methodology 23
6.1 Overview of method 23
6.2 Study Area 25
6.3 Linkages to other technical reports 25
7. Existing environment 26
7.1 Location and topography 26
7.2 Geology 27
7.2.1 Regional geology 28
7.2.2 Site geology 29
7.2.3 Geological and geotechnical investigation 29
7.2.4 Outcome of assessment of the geological environment for potential effect on ground movement 30
7.3 Water 30
7.3.1 Drainage 30
7.3.2 Groundwater and aquifers 31
7.3.3 Surface water and overland flows 31
7.3.4 Water contribution to potential ground movement 32
7.4 Sensitive receptors 32
7.5 Limitations, uncertainties, and assumptions 33
7.5.1 Tailings 33
7.5.2 Offsite Infrastructure and Utilities 33
8. Risk assessment 34
8.1 Ground movement types (Elements) 34
8.2 Movement triggers (Causes) 35
8.3 Risk pathways 35
8.3.1 Pathway 1 and 2 – Slope Collapse (above ground and subsurface respectively) 35
8.3.2 Pathway 3 – Liquefaction – Earthquake 36
8.3.3 Pathway 4 – Deformation/Settlement/Heave 36
8.3.4 Pathway 5 - Dispersive soils 36
8.4 Risk assessment [summary of impacts] 37
9. Impacts assessment – General 39
9.1 Sensitive receptors - general 40
9.2 Impact risk pathways 40
9.2.1 Pathway 1- Slope collapse above ground - Stockpile locations 41

9.2.2 Pathway 2 - Slope collapse (subsurface) – Mine pit slopes ... 42
9.2.3 Pathway 3 – Liquefaction – Earthquake ... 43
9.2.4 Pathway 4 – Deformation/Settlement/Heave ... 44
9.2.5 Pathway 5 - Dispersive soils ... 46
10. Impact assessment – Location specific ... 49
10.1 Area 1 sensitive receptor No. 1 – Bennett Residence Shepherd Road - Eastern side of proposed mine operation ... 53
10.2 Area 1 sensitive receptor No. 2 - Bennett Road which bisects the proposed mine ... 53
10.3 Area 3 sensitive receptor No. 3 - Sensitive vegetation Area 3 ... 56
10.4 Area 3 sensitive receptor No. 4 - Thompsons Road which bisects the proposed mine ... 57
10.5 Sensitive receptor No. 5 - Mine area as private property after rehabilitation and closure ... 59
11. Summary of mitigation, monitoring, and contingency measures ... 59
11.1 Mitigation measures ... 59
11.2 Monitoring measures ... 61
12. Summary ... 63
13. Conclusion ... 64
14. References ... 65
15. Important information about your ground engineering report ... 67

List of figures

Figure 2-1:Goschen Project location ... 10
Figure 2-2: Mitigation hierarchy ... 11
Figure 2-3: Proposed Haulage Route to Ultima and water supply pipeline route ... 12
Figure 2-4: Area 1 Goschen Project ... 13
Figure 2-5: Area 3 Goschen Project ... 13
Figure 6-1: Overview of assessment framework ... 24
Figure 6-2: Receptors within the study area ... 25
Figure 7-1 Goschen Project area topography (reproduced from CDM Smith) ... 27
Figure 7-2: Structural zones of Victoria (Willocks and Moore, 1999). ... 28
Figure 7-3 Groundwater contours from CDM Smith technical report I. Groundwater (CDM Smith 2023) ... 31
Figure 7-4: 80m buffer around Goschen Project and vulnerable receptors ... 32
Figure 9-1 Stockpile Minimum Buffer Zone ... 41
Figure 9-2 Recommended proximity buffer distances for crest of pit slope ... 42
Figure 9-3: Model of settlement of tailings and overburden over time ... 45
Figure 9-4: Schematic cross section of the rehabilitated landform at closure ... 45
Figure 9-5: Indicative main tailings bund cell arrangement ... 46
Figure 10-1: Area 1 receptors vulnerable to ground movement within current risk criteria buffer distances ... 51
Figure 10-2: Area 3 receptors vulnerable to ground movement within current risk criteria buffer distances ... 52
Figure 10-3: Area 1 Main Pit Bennett Residence Shepherds Rd ... 53
Figure 10-4: Area 1 - Bennett Road location plan of impacted section which bisects the proposed mine ... 54
Figure 10-5: Draft Road closure and diversion plan ... 55
Figure 10-6: Sensitive vegetation receptors Area 3 ... 56
Figure 10-7: Area 3 - Thompson Road location plan of impacted section which bisects the proposed mine ... 57

List of Tables

Table 3-1: Scoping requirements relevant to geotechnical assessment 15
Table 4-1 Legislation, policy, guidelines, and standards relevant to the assessment 17
Table 4-2 Summary Table of FoS and PoF guidance based on Read and Stacey 2010 21
Table 4-3: Example design criteria for open pit walls (WA Minerals and Energy, 1999) 21
Table 8-1: Ground movement risks 34
Table 8-2: Geotechnical risks Assessed as Non-Credible 37
Table 8-3 Geotechnical risks assessed as credible events 39
Table 9-1 Summary of stability analyses results and the applicable buffer distances for stockpile and pit wall slopes 41
Table 9-2 Gypsum application rates 47
Table 10-1: Summary of location specific impacts 49
Table 11-1: Mitigation measures relevant to ground movement 60
Table 11-2: Monitoring measures relevant to ground movement 62

Appendices

1. **Appendix A** – Risk Assessments
2. **Appendix B –** pitt&sherry 2022, Geotechnical Investigation Factual and Interpretive Report – Goschen Project**.**
3. **Appendix C –** Design development of tailings storage facility
4. **Appendix D –** Seismicity and earthquake risk
5. **Appendix E –** Proposed GCMP Outline

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Executive Summary

Overview

This report presents the geotechnical impact assessment for VHM Limited's Goschen Rare Earth and Mineral Sands Project (the Project) mine, which is to be included as part of the Environment Effects Statement (EES) for the Project. The geotechnical impact assessment addresses specific environmental issues that are detailed in Section 4 of the Scoping Requirements (DELWP, 2019).

This report documents investigation, modelling and assessment of geotechnical risks and recommended mitigation measures from the construction, operation and ultimately rehabilitation of the mine, the pipeline and pumpstation at Kangaroo Lake. Geotechnical risks are those risks associated with ground movement.

The significance of the impacts has been assessed in accordance with the evaluation framework, based on applicable legislation, policy and standards and the evaluation objectives and environmental significance guidelines arising from the government terms of reference established to guide the assessments.

In relation to the evaluation objectives set out in the EES Scoping Requirements, the project would not have significant impacts due to ground movement.

Existing environment

The proposed mine project is situated within an area of broad gently undulating topography predominantly used for large scale farming activities. Most of the proposed mine project would occur on farmland paddocks, with remnant native vegetation existing within small communities within the project area and aligned along road reserves. Rural residences and various farming infrastructure including fences, sheds and dams are located over the Project area and surrounds.

The topography in the study area ranges from approximately 75 m to 125 m Australian Height Datum (AHD) and is characterised by a north–south-orientated ridge elevated around 100–125 m AHD.

The site topography is flat to gently sloping with limited clearly defined natural or manmade drainage systems or natural water courses passing over the mine site. Some, now decommissioned, channels previously traversed portions of the mine area.

Based on mine exploration drilling and geotechnical subsurface drilling, the Goschen site has relatively simple geology from a geotechnical perspective. Topsoil overlies clays and sandy/silty clays with discontinuous cemented areas presenting as weak and very weak sandstones within the overburden / cover sequence. The overburden overlies mineralised fine to medium sand which is the primary focus of the mining operation.

A groundwater impact assessment conducted as part of the EES (CDM Smith. 2023) identified a ground water table at depth, with proposed mineral extraction depths terminating before intersection. Local mounding may be intersected during operations, proposed to be managed through local dewatering,

The mine activities are in a seismically stable region with a local deep ground water table meaning a low probability of earthquake impact contributing to ground movement through liquefaction.

The proposed mine comprises the following main components:

- Within the immediate mine area:
  - Stockpiles, subsurface pits, processing plant, below ground tailings storage and rehabilitated areas.
- External to the mine boundary:
  - The existing road transport network, a pump station for water supply to the mine and pipeline for delivery of the process water.

Sensitive receptors which may be potentially affected by ground movement include:

- Remnant native vegetation within the mine site area.
- Public road network and infrastructure which transects or is adjacent to the mine operations.
- Private property including residences and farm infrastructure including dam storages; and
- The rehabilitated mined areas post closure.

Impact assessment findings

An iterative assessment was undertaken to evaluate potential impacts from ground movement, considering the existing environment within the study area and the proposed construction, operational and decommissioning activities.

The assessment found the following potential scenarios impacting on sensitive receptors relevant to the Project:

- Slope collapse or slide of above ground stockpiles and below ground pit slopes impacting the stability of ground support.
- Earthquake liquefying material which may be released.
- Deformation or heave of material directly affecting sensitive receptors or impacting stability of the supporting ground.
- Dispersive/sodic soil may contribute to erosion and distribution of material impacting on ground stability and uncontrolled movement of material; and
- In undertaking the impact assessment, incorporating geotechnical analysis for the slopes with application of modelled slope crest buffer zones, several of the above pathways were identified as not creating impacts to sensitive receptors. These events have been assessed as non-credible.

Mitigation and contingency measures

Potential impacts from ground movements due to the project can be avoided, minimised, or managed to required standards through the recommended mitigation measures.

It is recommended that the mine operation initially construct infrastructure and above ground stockpiles for topsoil, overburden and extracted ore material. Processing of ore and generation of a tailing slurry is recommended to commence when suitable empty pit volume is available sub surface to receive the treated material. Rehabilitation and remediation are recommended as soon as feasible during ongoing operations with overburden returned subsurface to cover tailings with subsequent topsoil redistribution. Recommended mitigation and contingency measures include:

- Comprehensive geotechnical design methodology and review using conservative elastic parameters and incorporate sensitivity assessments.
- Ensure mine pit floor is above groundwater table.
- Consideration of forces due to earthquake loading in slope/batter design where design life > 2 year. in the event of a low probability earthquake occurring any tailing breach is contained subsurface
- Recommendation that Ground Control Management Plan (GCMP) and a Storm Water Management Plan (SWMP) are established and implemented.
- Management of mine extraction and ore process timing to return tailings below ground level to progressive in pit storage system eliminates above ground storage of tailings and avoids or substantially reduces the risk to sensitive receptors with no risks or consequences outside of the pit.
- In pit void tailings storage to avoid the risk of a tailing breach reaching a sensitive receptor with suitable bunds to separate returned tailings from open pit working.
- The pit floor and base of mining operations to terminate above the groundwater table with any intersected mounding managed with local dewatering to avoid the risk of liquefaction.

- Pit slopes and stockpile locations to be separated by suitable buffer distance from vulnerable receptors; and
- Management of rehabilitation and long term stockpiles and basins to be incorporated in the ongoing mine operation to minimise open exposures and potential dispersive soil impacts and return affected mine areas to a safe, stable, and sustainable landform capable of supporting land uses currently operating on adjacent lands.

Glossary

Term	Definition
FoS	Factor of safety against a failure of a slope or batter
PoF	Probability of failure – The failure probability PoF is defined as the probability for exceeding a limit state within a defined reference time period.
GCMP	Ground Control Management Plan
SWMP	Stormwater Management Plan
CMP	Construction Management Plan
RECP	Rolled Erosion Control Product
Dispersive/sodic soils	Dispersive soils are soils that are easily erodible and segregate in water
Turkeys Nest tailings storage	Above ground, circular or ovoid in plan, tailings containment facility
Solar Pond	Shallow slimes drying facility using evaporation and heat from the sun to reduce the moisture content
FEED	Front end engineering and design – Post feasibility study engineering phase to advance understanding and define project specific requirements
Liquefaction	Process where saturated loosely packed sediments weaken under strong ground shaking (earthquakes)
cdm	Co-deposited material - Tailings
CBR	Californian Bearing Ratio – penetration test used to evaluate the subgrade strength of roads and pavements
Permeability	The property of soil which permits percolation
Creep	The time dependent deformation behaviour of soil under constant compressive stress
Consolidation	Consolidation is the gradual reduction in the volume of a partly or fully saturated soil under sustained loading and is mainly due to the expulsion of water from the soil pores.
Shear Strength	The maximum resistance of a soil to shearing stress
Relative Density	Compactness of the soil in comparison to a standard

Frequently used symbols in geotechnical engineering

Symbol	Definition	Symbol	Definition
AASS	Actual acid sulfate soil	PASS	Potential acid sulfate soil
BH	Bore hole	PI or I_P	Plasticity index
BS	Bulk distrusted sample	PL or w_P	Plastic Limit
c	Cohesion of a soil	PS	Piston sample
c'	Effective cohesion	PP	Pocket Penetrometer Test
c_v	Coefficient of consolidation	PQ	85mm diameter drill core (double tube wireline)
C_c	Coefficient of curvature	PQ3	83.1mm diameter drill core (triple tube wireline)
C_u	Coefficient of uniformity	q	Overburden pressure
CPT	Cone Penetration Test	q'	Effective overburden pressure
CPTu	Cone Penetration Test with pore pressure measurement (piezocone)	q_c	Cone resistance
D_{10}	Grain sizes for which 10% of the soil grains are smaller	q_d	VEDCP (PANDA) cone resistance
D_{30}	Grain sizes for which 30% of the soil grains are smaller	q_u	Unconfined compressive strength
D_{60}	Grain sizes for which 60% of the soil grains are smaller	Q	Wet density
DS	Disturbed sample (small)	Q_d	Dry density
DCP	Dynamic Cone Penetrometer Test	rw	Full penetration over any 150mm interval is achieved by SPT rod weight only
DMT	Flat Plate Dilatometer Test	R_d	Dry density ratio
e	Void ratio	RMU	Significant zone dominated by one rock type with one dominant weathering grade
E	Young's modulus (ratio of axial stress to axial strain)	$RQD_{per\ CR}$	Rock quality designation (ratio calculated per length of core run)
E_s	Modulus of elasticity	$RQD_{per\ RMU}$	Rock quality designation (ratio calculated per length of specific rock mass unit)
ES	Environmental Sample	s_u	Shear strength of a soil, (often $s_u = q_u / 2$)
ECN	Emerson Class Number	S	Degree of saturation
f_s	Cone skin friction	SPT	Standard Penetration Test
F_R	Cone friction ratio	TP	Test pit
FVS	Field Vane Shear Test	TCR	Total core recovery (%)
GSL	Ground surface level	u	Pore water pressure
hb	No measurable penetration, or the SPT hammer is bouncing for five consecutive blow	u_2	Pore water pressure measured at the tip of a piezocone (CPTu)
hw	Full penetration over any 150mm interval is achieved by SPT hammer and rod weight only	UCS	Uniaxial compressive strength test
HQ	63.5mm diameter drill core(double tube wireline)	U50	Undisturbed 50mm diameter tube sample
HQ3	61.1mm diameter drill core(triple tube wireline)	U75	Undisturbed 75mm diameter tube sample
I_D	Density index (cohesionless soil)	U100	Undisturbed 100mm diameter tube sample
I_{s50}	Point load strength index	VC	Vibro core
$I_{s50\ (A)}$	Axial point load strength index	VEDCP	Variable Energy Cone Penetration Test (PANDA)
$I_{s50\ (D)}$	Diametral point load strength index	w	Moisture content of a soil
$I_{s50\ (L)}$	Irregular (lump) point load strength index	w_{opt}	Optimum moisture content (OMC)
k	Coefficient of permeability	WS	Water sample
K	Ratio of lateral to vertical stress	WLS	Weighted linear shrinkage
K_a	Active earth pressure	WPI	Weighted plasticity index
K_p	Passive earth pressure	z	Depth of interest from ground surface level (GSL)
LL or W_L	Liquid Limit %	**Greek symbol**	**Definition**
LS	Linear Shrinkage	γ	Unit weight of material
m_v	Coefficient of volume decrease	γ'	Effective unit weight of material
MDD	Maximum dry density	ε	Strain
n	Porosity	ν	Poisson's ratio
N	SPT Penetration Resistance, (blows per final 300mm penetration)	ρ	Density
N_P	DCP Penetration Resistance, (blows per 300mm penetration, depth recorded at centre of interval)	σ	Pressure or stress
NQ	47.6mm diameter drill core (double tube wireline)	σ'	Effective pressure or stress
NQ3	45.1mm diameter drill core (triple tube wireline)	τ	Shear stress
NMLC	51.9 mm diameter drill core (triple tube wireline)	φ	Angle of internal friction
OCR	Overconsolidation ratio	φ'	Effective angle of internal friction

1. Introduction

1.1 Requirement for an EES

VHM Limited's Goschen Rare Earth and Mineral Sands Project (the Goschen Project) was referred to the Minister for Planning to seek advice on the need for an EES under the Environment Effects Act 1978 (Vic) (EE Act).

On 10 October 2018, the Minister for Planning decided that an EES was required on the basis that the Goschen Project has the potential for a range of significant environmental effects.

On 19 December 2018 under delegated authority from the Minister for the Environment, the Department of the Environment and Energy (now referred to as the Department of Climate Change, Energy, the Environment and Water (DCCEEW)) made a decision that the Goschen Project is a controlled action under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) and would require assessment and a decision about whether approval should be given under the EPBC Act. DCCEEW also confirmed the Victorian Government's advice that the Goschen Project will be assessed under a bilateral agreement under the EE Act.

This document provides a geotechnical technical assessment for the proposed Goschen Project for use in informing the EES. This document describes assessment of potential ground movement and consequent impacts or harm to the environment associated with the proposed Goschen Project.

2. Project description

2.1 Project overview

The Goschen Project is an approximately 20-25 year rare earth and mineral sands mine and processing facility. VHM has been developing the Goschen Project in the context of a rapidly growing global demand for rare earths. One of the world's largest, highest grade zircon, rutile and rare earth mineral deposits is in the Loddon Mallee region of Victoria in Australia. VHM intends to establish the Goschen Project to mine these deposits and process to produce and market a range of products to national and international consumers.

The mine footprint has been restricted to avoid intersection with groundwater and significant areas of remnant native vegetation. VHM will implement a staged development approach. Initially developing phase 1 consisting of a mining unit plant (MUP), wet concentrator plant (WCP), rare earth mineral concentrate (REMC) flotation plant and a hydrometallurgical plant (AREM) that will further refine the REMC that is produced at the Goschen Project. The construction phase will be programmed to be well in advance of processing with ore stored in a stockpile adjacent to the MUP and fed into the process as the processing rate reaches full operating capacity. The mining rate would be varied to match storage availability. The product suite for phase 1 consists of a zircon/titania heavy mineral concentrate (HMC) and mixed rare earth carbonate (MREC).

Phase 2 will commence approximately 2 years post-production and consist of an additional mineral separation plant (MSP) and, subject to prevailing market circumstances at that time, hot acid leach (HAL) and chrome removal circuit, that will produce additional products such as premium zircon, zircon concentrate, HiTi rutile, HiTi leucoxene, LoTi leucoxene, low chromium ilmenite.

Goschen Project is located approximately 4 hours' drive (275 kilometres) northwest of Melbourne and 30 minutes (35 km) south of Swan Hill within Gannawarra Shire (Figure 2-1).

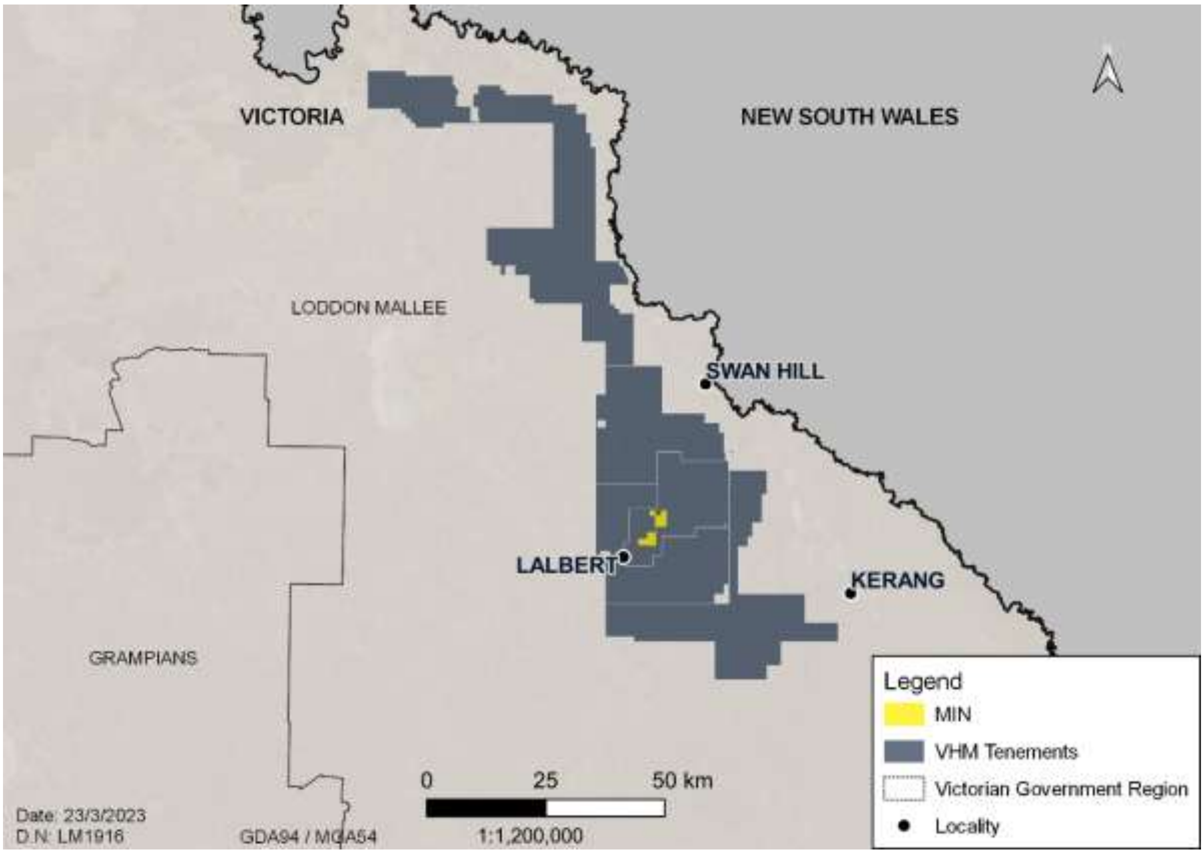

Figure 2-1:Goschen Project location

2.2 Project development

It is recognised that there are opportunities to avoid and minimise environmental impacts during the many stages of project development. During project inception and early design development stages of the Goschen Project, decisions relating to geotechnical considerations informed the location and components of the design and construction techniques which has enabled impacts to be significantly avoided and minimised in accordance with the hierarchy presented in Figure 2-2.

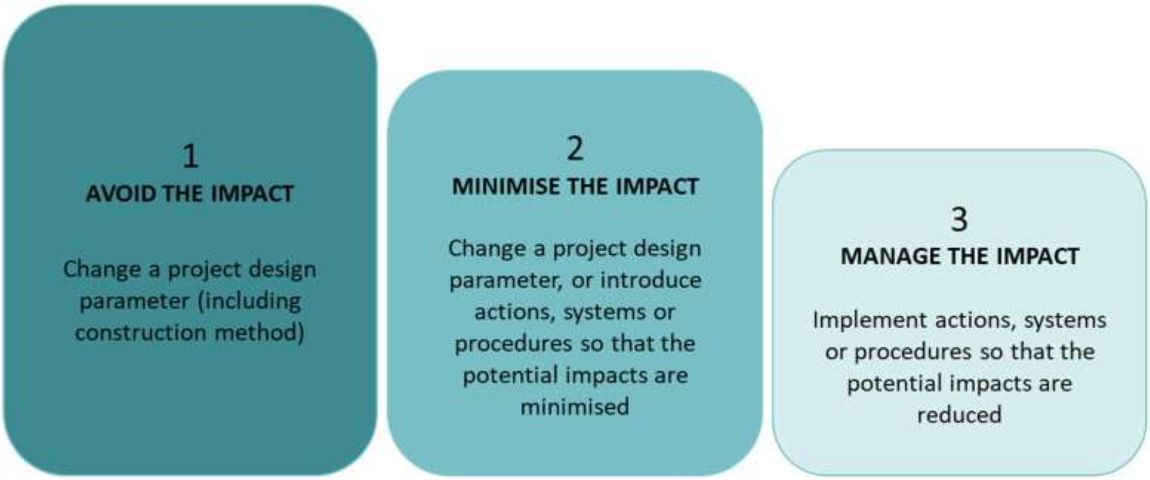

Figure 2-2: Mitigation hierarchy

Avoidance and minimisation of social and environmental impacts is central to the project's decision making and as such, the Goschen project will continue to be refined in response to technical requirements and potential environmental and social impacts identified during the development phase.

This was considered in the preparation of a project description which is found at Chapter 2. A description of how geotechnical assessment and investigation has contributed to avoidance of impacts can be found in sections 8 to 11.

Examples of avoidance measures implemented in the design include the decision to create vegetation protection zones within the project (mining area), restricting mining operations to daylight hours only to avoid noise related impacts to certain receptors, and restricting mining to depths above the water table to avoid impacts to the groundwater table. Avoidance measure implemented to minimise harm from potential ground movements include utilisation of available space in the mine area to locate above ground stockpiles away from sensitive receptors, wherever practicable to locate pit crests at distances from sensitive receptors to provide appropriate factors of safety and to optimise the mine extraction and processing time frames to enable processed tailings to be returned to sub surface storage avoiding potential harm from uncontrolled surface release.

With regard to geotechnical investigations and assessment the Goschen project has considered an iterative design process assessing material parameters and design options incorporating timing considerations for construction, operation and rehabilitation of the mine infrastructure including processing facilities, open excavations and tailing management within sub surface tailings storage facilities (TSF).

Consideration has been given to potential surface and subsurface impacts with the outcomes aimed at avoiding or minimising most potential effects using initial material stockpiling and subsequent subsurface storage with progressive rehabilitation. Multiple design iterations have been implemented to avoid or minimise potential environmental effects that may have arisen through exposure to geotechnical risks.

After opportunities to avoid impact were incorporated into the project, mitigation and minimisation measures were developed to manage identified risks.

A feature of the mitigation process implemented is a result with mine features and operations developed with potential environmental effects predominantly avoided through location and placement. The designed operation provides:

- Initial stockpiling of first extracted overburden material to long term storage piles, with a short-term stockpile of ore material.
- Early return of overburden and processed material to exhausted pits for below surface storage and material management and pit refill.

- Ongoing rehabilitation; and
- Where long term surface stockpiling is unavoidable these features are designed with factors of safety to locate them distal to sensitive environmental receptors such that the residual potential risk of impact is low.

2.3 Key project components

The Goschen Project site consists of a heavy mineral sand mining and processing operation that will produce several heavy mineral concentrates (HMC) and a range of critical rare earth minerals. Water for processing will be extracted from a proposed pump station east of the mine site and piped to the site (Figure 2-3). The proposed haulage route will be from the mine to the depot at Ultima (Figure 2-3). Mining is proposed to be undertaken across two defined mining areas known as Area 1 and Area 3 (Figure 2-4 and Figure 2-5).

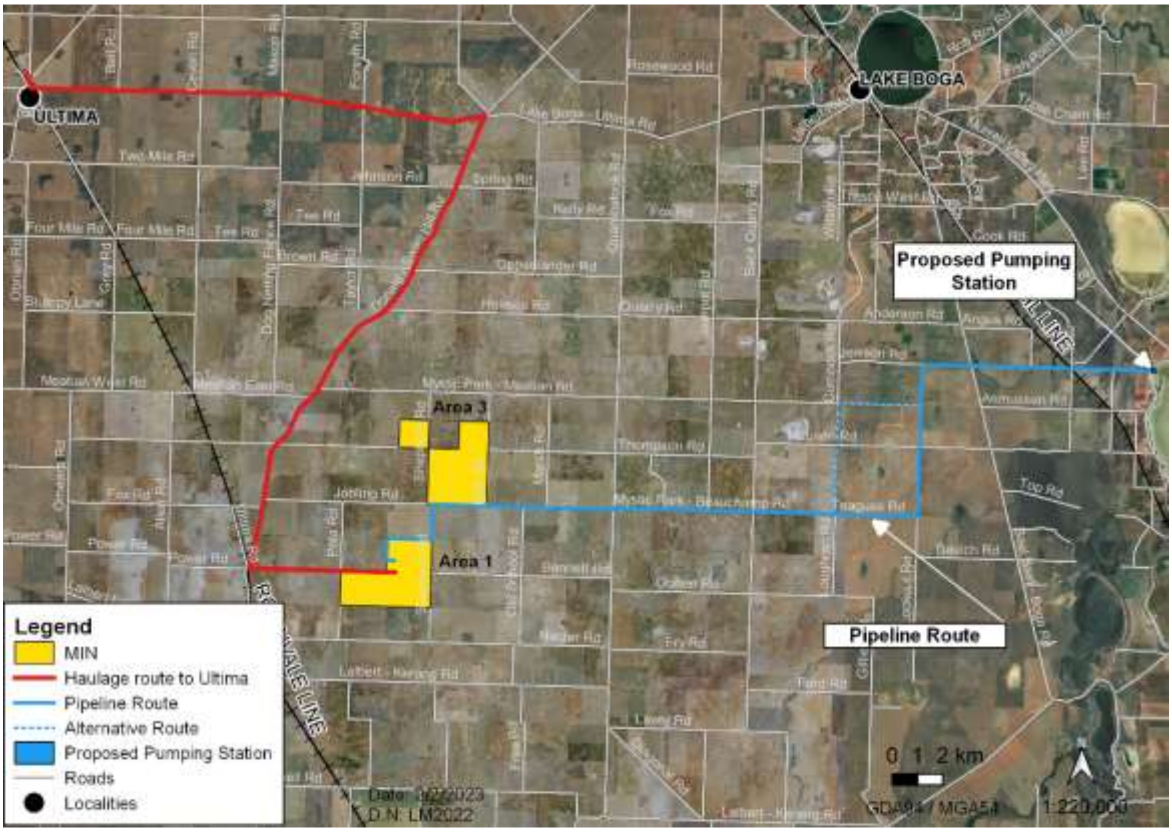

Figure 2-3: Proposed Haulage Route to Ultima and water supply pipeline route

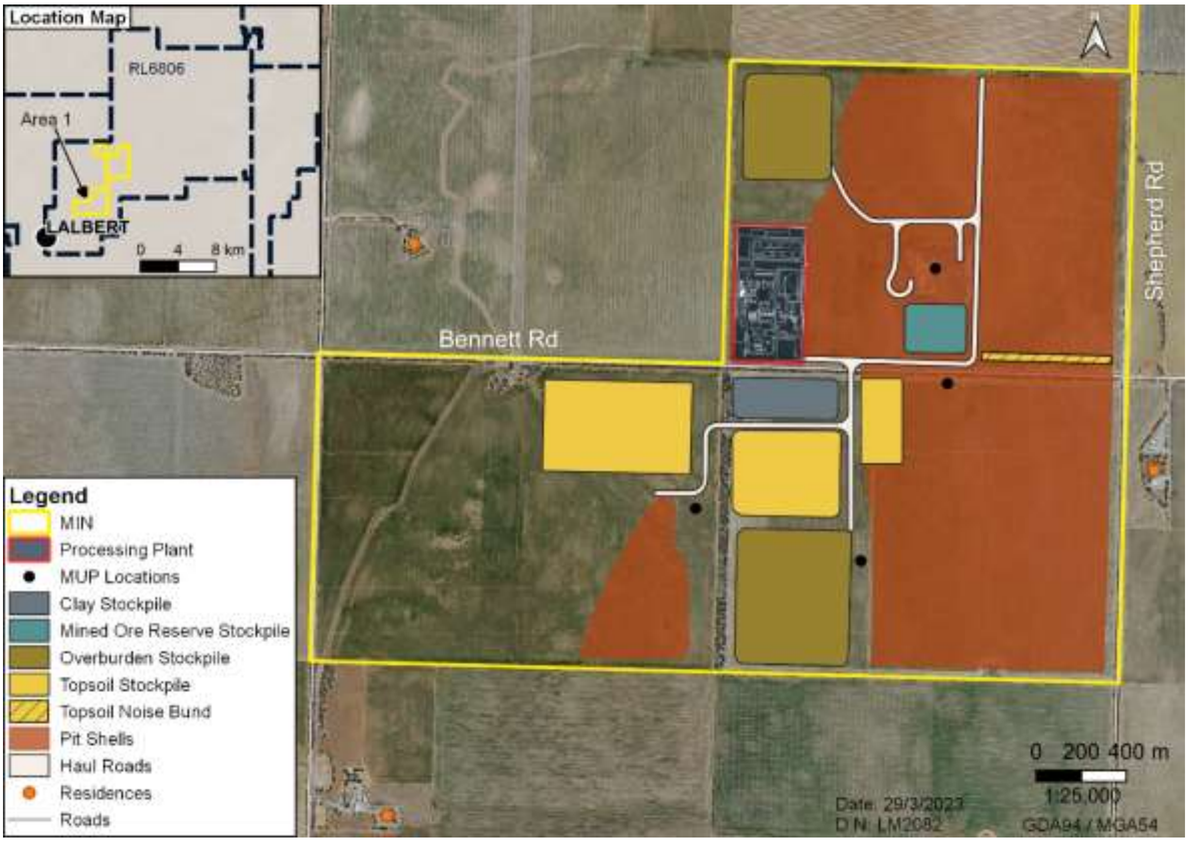

Figure 2-4: Area 1 Goschen Project

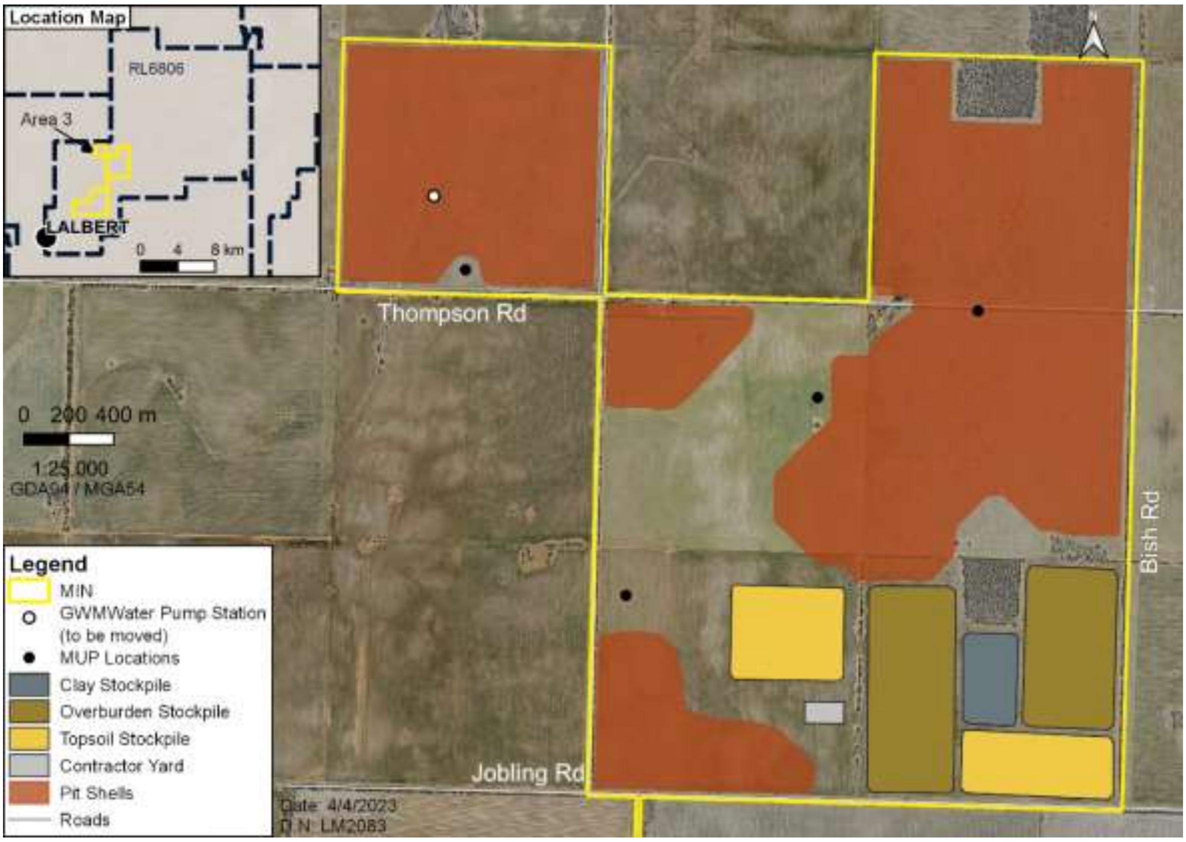

Figure 2-5: Area 3 Goschen Project

The key components that make up the Goschen Project are described below.

Mining – Mining will take approximately 20-25 years at 5M tonnes of ore produced per year and will occur only above groundwater (no dewatering) across approximately 1,479 hectares of farmland using conventional open cut mining methods of excavation, load, and haul.

Processing – Heavy mineral sands and rare earths ore will be separated via an on-site WCP and MSP to generate a Rare Earth Mineral Concentrate (REMC). Refining of the REMC on-site is limited to hydrometallurgical extraction to produce a mixed rare earth carbonate. Tailings from the various mineral processes will be homogenised and placed back into the ore zone earlier mined.

Rehabilitation – The mined areas will be progressively backfilled in a staged manner, with tailings dewatered in-pit to allow overburden and topsoil placement in a profile that reinstates the background soil structure. This will result in the ability for a return to the current agricultural land uses within 3 years.

Power – Electrical power needed for mining and processing will be produced on-site from dual fuel diesel/LNG fired power generators, with a gradual evolution over the life of mine to renewables, hydrogen and/or battery as technologies and commercial viability increase. Heat energy for the on-site gas fired appliances shall be provided from an extension of the distribution network from the main LNG storage and regasification system.

Water - Water will be required for construction earthworks, processing, dust suppression and rehabilitation. Up to 4.5 GL a year will be needed for the start-up of the Project. Water will be sourced from Goulburn Murray Water (GMW) from a new pumpstation at Kangaroo Lake via the open water market. A 38 km underground pipeline is proposed beneath existing local road easements as shown in Figure 2-3.

Transport – Final products shall be containerised in 20ft sealed sea containers on site and exported via Melbourne Port using road and/or rail-based land logistics solutions. Ultima will provide intermodal rail solution, to reach the shipping export ports.

3. Scoping

3.1 EES evaluation objectives and scoping requirements

The Scoping Requirements (DELWP, 2018) for the Goschen Project set out the specific environmental matters the project must address to satisfy the Victorian assessment and approval requirements.

The scoping requirements include a set of evaluation objectives. These objectives identify the desired outcomes to be achieved in managing the potential impacts of constructing and operating the project in accordance with the *Ministerial guidelines for assessment of environmental effects* under the EE Act.

Under Section 1.2 of the scoping requirements, and relevant to the Geotechnical Assessment and associated impacts on land stability and soil productivity, this report addresses:

- The effects on land stability and erosion associated with the construction and operation of the project, including progressive rehabilitation works; and
- Feasible alternatives capable of substantially meeting the project's geotechnical and tailings management objectives to determine the current preferred option.

The aspects from the scoping requirements relevant to the evaluation objective are shown in Table 3-1 as well as the location where these items have been addressed in this report.

The underlying theme of the mine design has been to utilise the space within the mine lease efficiently and to contain potential hazards to within the mine lease. Management of potential harm avoids exposure of sensitive receptors to hazards and where potential exposure is unavoidable minimises potential harm by mitigation measures incorporating factors of safety and probability of failure in the design of component geometry and locations.

Table 3-1: Scoping requirements relevant to geotechnical assessment

Aspect	Scoping requirement	Section addressed
Key issues	Identify key issues or risks that the project poses to the achievement of the draft evaluation objective. In addition to addressing the highlighted issues, the proponent might undertake an environmental risk assessment.	8, Appendix A
	Potential erosion, sedimentation and landform stability effects during construction, operation, rehabilitation and post-closure.	8, 9, 10
Existing environment	Characterise the existing environment to underpin impact assessments having regard to the level of risk. Any risk assessment by the proponent could guide the necessary data acquisition.	7, 8
	Characterise the physical and chemical properties of the project area soils/mine geological materials including the potential environmental risks (e.g. potential for erosion, salinity, nutrients and acidification).	7,8, 9, Appendix B

Aspect	Scoping requirement	Section addressed
Assessment of likely effects	Assess the likely effects of the project on the existing environment and evaluate their significance.	8, Appendix A
	Use appropriate methods, including modelling, to identify and evaluate effects of the project and feasible alternatives on groundwater and surface water environments, including: • potential erosion, sedimentation, and landform stability effects of the project.	4.2, 9.2, Appendix B
	Assess potential safety hazards to the public arising from the project.	8, 9, Appendix A
Design and mitigation measures	Present design and mitigation measures that could substantially reduce and/or mitigate the risk of significant effects. Note that an assessment of residual effects (post mitigation) and their significance will be required to illustrate the effectiveness of the proposed mitigation measure.	9, 10
	Describe alternative mine configurations to access mineral sands reserves (including location of the project's infrastructure) and strategies for management and disposal of tailings and waste material to avoid and minimise impacts and potential sterilisation of future reserves.	9.2 Appendix C
	Describe alternative methods of site preparation which could optimise site rehabilitation, including potential for future productive land uses.	9, 10
	Describe proposed design options and measures which could avoid or minimise significant effects on beneficial uses of surface water, groundwater and downstream water environments, accounting for climate risks and the potential effects of climate change, during the project construction, operations, decommissioning and post-closure phases.	11
Approach to manage performance	Propose performance objectives and management to evaluate whether the project's effects are maintained within permissible levels and propose contingency approaches if they are not.	9, 10, 11

4. Evaluation framework

The assessment will consider legislation, policy, and standards relevant along with specific assessment criteria that have been derived for the purposes of the study.

The principal legislation governing the mining industry in Victoria is the Mineral Resources (Sustainable Development) Act 1990 (MRSDA) and the associated Mineral Resources (Sustainable Development) (Mineral Industries) Regulations 2019 (Regulations). The Minister for Resources (Victorian Government) and the Earth Resources Regulation (ERR) Branch of the Department of Jobs, Precincts and Regions (now Department of Energy, Environment and Climate Action (DEECA)) are responsible for administering the MRSDA and Regulations.

Geotechnical investigations have been undertaken generally in accordance with Australian Standard AS 1726:2017 for geotechnical site investigations of soils and rocks including for the evaluation of material parameters.

4.1 Legislation, policy, guidelines, and standards

The legislation, policy, guidelines, and standards relevant to the assessment are summarised in Table 4-1.

Table 4-1 Legislation, policy, guidelines, and standards relevant to the assessment

Document title	Summary	Relevance to the project
Commonwealth government		
AS/NZS ISO 31000:2009 Risk management - Principles and guidelines.	Describes the principles, framework and process that allow risk to be managed effectively.	Internationally agreed terminology and criteria against which the effectiveness of risk management activity can be judged.
ANCOLD – Guidelines on Tailings Dams – Planning, Design, Construction, Operation and Closure – Revision 1 (July 2019).	Produced for the guidance of experienced practitioners who are required to apply their own professional skill and judgement in its application	Used for reference in aspects of the proposed tailings bund design.
The Austroads Guides to Road Design (AGRD).	Ensure national consistency and standardisation for all road work.	Reference for minimising and avoiding effects of ground movements.
Australian Standard AS 1726:2017.	Describes methodology for geotechnical site investigations of soils and rocks including for the evaluation of material parameters.	Investigations and material parameter assessment undertaken generally in accordance with the standard.
Victorian government		
Mineral Resources (Sustainable Development) Act 1990 (MRSDA).	One of the objectives of the *Mineral Resources (Sustainable Development) Act 1990* (Vic.) (MRSDA) is to ensure that risks posed to the environment, to members of the public, or to land, property or infrastructure by work being done under a licence or extractive industry work authority are identified and are eliminated or minimised to as low as reasonably practicable.	To achieve the objective, geotechnical risks at the site are required to be assessed due to the potential for geotechnical hazards to adversely impact elements at risk such as people and property both within and external to the site.

Document title	Summary	Relevance to the project
Mineral Resources (Sustainable Development) (Mineral Industries) Regulations 2019.	Set clear work plan and rehabilitation plan requirements to better manage risks associated with mining and minerals exploration.	Prescribes procedures, details, royalties and other matters. Sets out components to be accounted for in a rehabilitation plan.
Guidelines		
Guidelines for the assessment of geotechnical risks in open pit mines - Earth Resources Page last updated: 02 Jun 2021.	To assist mine owners in Victoria in: • Understanding risk concepts. • Identifying geotechnical risks associated with mine developments. • Developing assessments of the scale of the perceived risks. • Developing control measures to reduce risks to a level as low as practically possible.	Provides the technical information required for geotechnical risk including during rehabilitation and how to reduce them.
VicRoads Supplements (VRS) to the Austroads Guide to Road Design (AGRD).	provide additional information, clarification or jurisdiction specific information and procedures that have not been addressed in the AGRD.	VicRoads uses the Austroads Guides as a key reference, in conjunction with supplementary information, to ensure national consistency and standardisation for all road work. Relevant for minimising and avoiding effects of ground movements
Preparation of Work Plans and Work Plan Variations Guideline for Mining Projects December 2020 (version 1.3).	Provides information on when a work plan or variation is required, what content is required, and the steps for seeking approval.	Relates to risk treatment planning.
AS/NZS 2033:2008 Installation of polyethylene pipe systems	Specifies methods for handling, storage, installation, testing and commissioning of polyethylene (PE) pipelines, above or below ground, for pressure and non-pressure applications conveying liquids.	Describes requirements for pipe installation and backfilling relevant to the raw water pipeline
AS/NZS 2032:2006 Installation of PVC pipe systems	Proposes methods for handling, storage, installation, testing and commissioning of polyvinyl chloride (PVC) pipelines, above or below ground, for pressure and non-pressure applications conveying liquids.	Describes requirements for pipe installation and backfilling relevant to the raw water pipeline
AS/NZS 2566.2:2002 (R2016) Buried Flexible pipelines - Installation	Specifies requirements for the installation, field testing and commissioning of buried flexible pipelines with structural design in accordance with AS/NZS 2566.1.	Describes requirements for pipe installation and backfilling relevant to the raw water pipeline

Document title	Summary	Relevance to the project
Technical Guideline - Design and Management of Tailings Storage Facilities (2017).	The guideline aims to ensure that the management of Tailings Storage Facilities (TSF) and associated tailings from mining and extractive industries in Victoria is undertaken in a manner that is safe and protects the environment.	Describes requirement for design of tailings storage for consideration in design of the in pit tailings process and bund designs.
Best Practice Erosion and Sediment Control (BPESC).	Provides guidance for management of erosion and sediment.	Minimisation of potential ground movement incorporates management of water flows and minimisation of erosion and sediment discharge.
Robin Fell, 2014 Geotechnical Engineering of Dams.	Provides guidance on broad ranging issues associated with slope stability, material parameters and geotechnical and ground movement risks.	Referred for bund and slope design.
Mark Hawley and John Cunning 2017. Guidelines for Mine Waste Dump and Stockpile Design	Guidelines for Mine Waste Dump and Stockpile Design is a comprehensive, practical guide to the investigation, design, operation and monitoring of mine waste dumps, dragline spoils and major stockpiles associated with large open pit mines.	Referred in geotechnical design of stockpiles for the Goschen project.
John Read, Peter Stacey 2010. Guidelines for Open Pit Slope Design	Guidelines for Open Pit Slope Design is an outcome of the Large Open Pit (LOP) project, an international research and technology transfer project on the stability of rock slopes in open pit mines. The purpose of the book is to link innovative mining geomechanics research with best practice.	Referred in geotechnical design of pit slopes, berms and benches and assessment of appropriate factors of safety and probability of failure values.

4.2 Assessment methodology

The geotechnical hazards that may occur during construction, operation and post closure generally relate to the slope stability in the open pit walls, in the overburden stockpile slopes and which may occur during pump station and pipeline construction. For the purposes of this assessment, construction related risks are principally considered to be part of the operations phase, as development of the open pits and the stockpiles will occur progressively during the operating life of the mine. A slope stability assessment of the proposed open pit walls comprising soil and overburden stockpile slopes has been undertaken to inform the geotechnical risk assessment. For this geotechnical impact assessment, the three project phases include the following components:

Construction Phase:

- Process plant.
- Containment ponds and water storages.
- Internal haul road.
- Diversion drains.
- Local road upgrades; and
- Pump station and pipeline.

Operation:

- Pit wall establishment.
- Tailings bund construction.
- Stockpile construction – initial topsoil, overburden, and preliminary ore pile for processing.
- Tailing placement and ongoing bund developments; and
- Progressive rehabilitation of overburden and restoration of overlying material during mining operations.

Decommissioning/rehabilitation:
(On exhaustion of mineral resource and rehabilitation / closure after subsequent depletion of any stockpiles)

- Decommissioning, demolition and removal of process plant and all ancillary infrastructure (water storages, administration blocks, workshop/maintenance areas; and
- Rehabilitation of the process areas. Note progressive rehabilitation of active mine areas has been managed during mine operations.

4.2.1 Assessment Criteria development for construction and operation

One of the key criteria underpinning ground movement management is analysis of potential failure mechanisms. Ground movements for all the construction, operations and rehabilitation are influenced by slope stability for:

- Stockpiles
- Pit walls
- Batters and bunds

The assessment criteria adopted for exposed and constructed slopes are limits on Factor of Safety (FoS) against failure and the probability of failure (PoF).

The desk top research undertaken as part of this assessment has not identified a fixed or single figure criterion which has been adopted in the mining industry. This is different to other industries say for example State Road Authorities which have mandatory minimum Factors of Safety for slopes.

From our research and experience the mining industry determines acceptance criteria on a case-by-case basis. The selection is guided by:

- Published guidelines.
- The quality of the geotechnical data.
- The level of perceived risk.
- Service life.
- Client requirements; and
- Economic impacts.

The determination of an acceptable FoS and acceptable PoF for the various aspects of the mine was based on the following published guidelines as well as consideration of the risks, and design life of the pit walls (less than 12 months and only 2 to 3 months at their full design height).

A key reference in selecting appropriate acceptance criteria was Read & Stacey (2010) John Read, Peter Stacey 2010. Guidelines for Open Pit Slope Design. Appendix B – pitt&sherry 2022, Geotechnical Investigation Factual and Interpretive Report – Goschen Project Section 8.2 Acceptance Criteria provides a comprehensive review of guidance in the selection of FoS and PoF for mine sites. The below provides a summary of this review and its applicability to the

Goschen project.

Table 4-2 Summary Table of FoS and PoF guidance based on Read and Stacey 2010

Read and Stacey 2010 Table	FoS and PoS	Goschen Project compliance
Table 9.2	FoS 1.5	FoS of 1.6 Adopted
Table 9.3	FoS of 1.6 variance of PoF from 1% to 10%	FoS 1.6 however Minimum PoF exceeded noting that the Goschen project material properties have been conservatively selected and the PoF analysis varies the material properties below these conservative values (ie conservatism on top of conservatism outcome).
Table 9.4	Potentially Unstable Monitoring required	Goschen pit wall are managed in accordance with a comprehensive GCMP which includes requirement for monitoring.
Table 9.5	PoF of 1.5-5%	PoF >1.5 Goschen project 0%-5%
Table 9.6	PoF of <15%	Goschen project 0%-5%
Table 9.7	FoS >1.3 and a PoF <12%	Goschen project FoS 1.6 and PoF 0%-5%

The desktop study reviewed additional guidelines used in the industry such as the extract from Western Australia Department of Mineral and Energy, Geotechnical considerations in Open Pit Mines, Guidelines (1999).

Table 4-3: Example design criteria for open pit walls (WA Minerals and Energy, 1999)

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	0.3%	Permanent pit walls near public infrastructure and adjoining leases.

It is important to note that the mine pit walls for the Goschen project do not carry major mine or major public infrastructure. A number of the pit walls are however adjacent to rural roads and public infrastructure. Any failure which extended to the roads or public infrastructure would be moderately serious. Based on this reference a minimum FoS of 1.2 with a PoF of 10% could be acceptable.

Guidelines used in civil works projects indicate a FoS of between 1.25 and 1.5 are accepted for temporary and permanent works respectively (Temporary works with a service life less than 2 years).

Appendix B – Geotechnical Investigation Factual and Interpretive Report – Goschen Project Section 8.8 Comparison to RMS, AGS and First Principles Slope Risk Assessment Methodologies (pitt&sherry 2022), provides site specific risk assessments using these nationally accepted systems. The key findings of the assessments are summarised in the following dot points:

- As the key element assessed is the risk to road users the RMS methodology is considered to be the most appropriate methodology. It gives the most robust method for assessment given the uncertainties associated with likelihood of failure and has the most research behind the assessment of temporal probability and vulnerability with respect to road users. The result of this assessment is the **lowest (safest) category possible in that methodology.**

- Taking a more general view the AGS methodology has been the standard for risk assessment of slope instability in Australia since its publication in 2007. The result of this assessment is **three orders of magnitude lower (safer) than the upper limit for acceptable risk.**

As an additional example, the Queensland Department of Main roads requires 1.3 FoS for temporary slopes on public roads and 1.5 FoS for permanent slopes on public road formations.

In summary and considering the above research and assessments the following has been adopted for Goschen Mine pit walls:

- Minimum FoS for slips with a design life of 12 to 24 months and routine monitoring & surveillance - 1.6 FoS.
- Maximum PoF for slips at pit walls with a design life of around 12 to 24 months and routine monitoring - PoF 5%.
- Minimum FoS for slips on pit walls including convex and concave changes in wall alignment with a design life less than 12 months and routine monitoring and surveillance - 1.6 FoS.
- Maximum PoF for slips at pit walls including convex and concave changes in wall alignment with a design life of around 12 to 24 months and routine monitoring - PoF 5%.

Note

- The material parameters selected for design, based on geotechnical investigation, insitu testing and laboratory testing were conservatively selected. These are reported in detail in Appendix B – pitt&sherry 2022, Geotechnical Investigation Factual and Interpretive Report – Goschen Project Section 7 Material Properties
- The selection of a single FoS of 1.6 for all pit wall slopes was deliberate and conservative ensuring that in operation that the mining team will have a simple criterion for all locations and arrangements and to minimise confusion related to localised changes in wall alignments.
- Assessment of PoF involves varying the strength properties assigned to materials which introduces substantial over conservatism on the low side range of values as the variation is centred around the selected material property ie conservatism on conservatism.

The risk of ground movement effects on the public, public land and land use and sensitive environmental receptors have been managed through application of the FoS and PoF to determine appropriate buffer zones around mine elements (stockpile toes or pit slope crests) outside of which the risk has been classified as acceptable and noted as a non-credible event that will not create ground movement that will impact a sensitive receptor. These are detailed in Section 8.

Additional criterion underpinning ground movement management is analysis of potential failure mechanisms. Ground movements for all the construction, operations and rehabilitation are influenced by:

- Trench stability of excavations for services and foundations excavations.
- Settlement and dispersive soils for backfilling of trenches and excavation over dig areas

The assessment criteria adopted for trench excavation is Safe Work Australia's Code of Practice - Excavation Work - March 2015

The assessment criteria for settlement and dispersive soils are addressed in Pitt&sherry 2023.

4.2.2 Rehabilitation / Post operation criteria

The fundamental criteria adopted for the design and planning of mine closure and post mining land use is that the landform must be safe, stable, and sustainable and be capable of supporting land uses currently operating on adjacent lands.

Mine Decommissioning/rehabilitation will be implemented in accordance with the following regulation, standards, and guidelines:

- Guidelines for the assessment of geotechnical risks in open pit mines - Earth Resources – Requirements, recommended practice, and practical guidance under Mineral Resources (Sustainable Development) Act 1990 - Earth Resources Regulation 2014; and
- Guideline for Mining & Prospecting Projects - Preparation of Rehabilitation Plans February 2020 | Version 1.0 Earth Resources Regulation.

5. Consultation and engagement

Consultation and stakeholder engagement has been undertaken for the Goschen Project with a broad range of community participants and stakeholders. key issues raised by community relate to:

- Settlement post closure.
- Settlement post construction of pipeline.

The complete summary of issues raised during stakeholder engagement undertaken for this EES is presented in Chapter 22.

6. Methodology

6.1 Overview of method

This section describes the method that was used to assess the potential ground movement impacts of the project. Figure 6-1 shows an overview of the assessment method. A risk-based approach was applied to prioritise the key issues for assessment and inform measures to avoid, minimise and offset potential effects.

The approach used in the assessment has been guided by the evaluation framework that applies to the project comprising the regulatory framework (that is, applicable legislation and policy) as well as the scoping requirements set by the Victorian Minister for Planning.

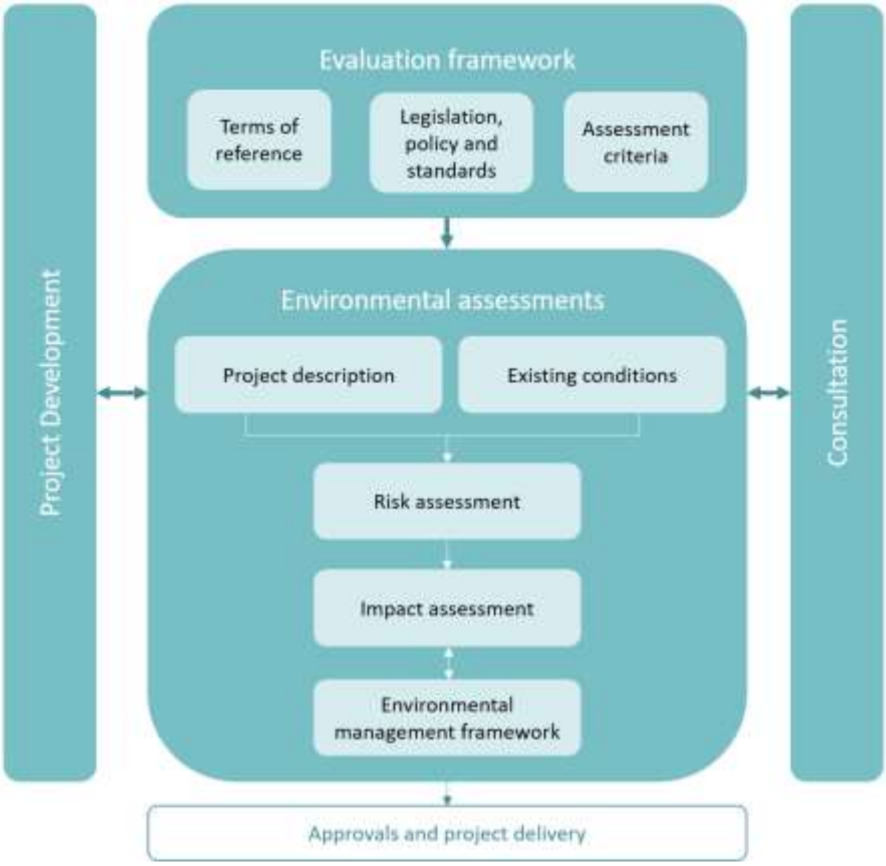

Figure 6-1: Overview of assessment framework

The environmental assessments were undertaken according to the following steps:

- Establishment of a study area and characterisation of existing environment.
- Review of the project description, comprising the key project components (including locations and form), proposed construction and operation activities (in the context of existing environment) and decommissioning activities to determine the location, type, timing, intensity, duration, and spatial distribution of potential project interactions with sensitive receptors.
- An initial risk based analysis to evaluate the potential effects of proposed project activities and their likelihood of occurring (considering initial mitigation measures) to determine the relative importance of environmental impacts associated with the project and therefore prioritise issues for attention in the subsequent assessment of impacts. Initial mitigation measures would include measures that are common industry practice or required to meet legislation.
- Determination of suitable Factors of Safety (FOS) and Probability of Failure (POF) criteria for geotechnical events and identify features exposed to risk and likelihoods of those factors of safety being exceeded. The criteria were applied to identify appropriate buffer zones within which the potential impacts on public safety, the environment, land, property, and infrastructure were subject to further examination.
- An assessment of impacts that examines the severity, extent, and duration of the potential impacts and considers the sensitivity and significance of the affected receptors.
- Evaluation of predicted outcomes against benchmarks and criteria such as those described in applicable legislation, policy, and standards.
- Evaluation of the potential for cumulative impacts (where relevant) caused by impacts of the Goschen Project in combination with impacts of other existing and proposed projects that may have an overall significant impact on the same environmental assed measures to address potential residual environmental impacts including

magnitude, duration, and extent, taking into account the proposed mitigation measures.

6.2 Study Area

The study area for this geotechnical assessment includes those areas in proximity to the proposed open pit mining and associated stockpile production plus associated processing and treatment infrastructure.

The Goschen Project has mapped key features within an approximate 5 km distance from the mining extraction and processing locations. including environmental features (flora/fauna and others) public and private properties and infrastructure.

Based on the geotechnical analysis the area potentially affected by ground movement is restricted to features no further than 30m from the proposed mine boundary. However, to ensure potential receptors are not omitted from assessment the geotechnical assessment area extends to 200m from proposed mine project property boundaries. Figure 6-2 below indicates the proposed mine areas for which the geotechnical risk assessment is focussed.

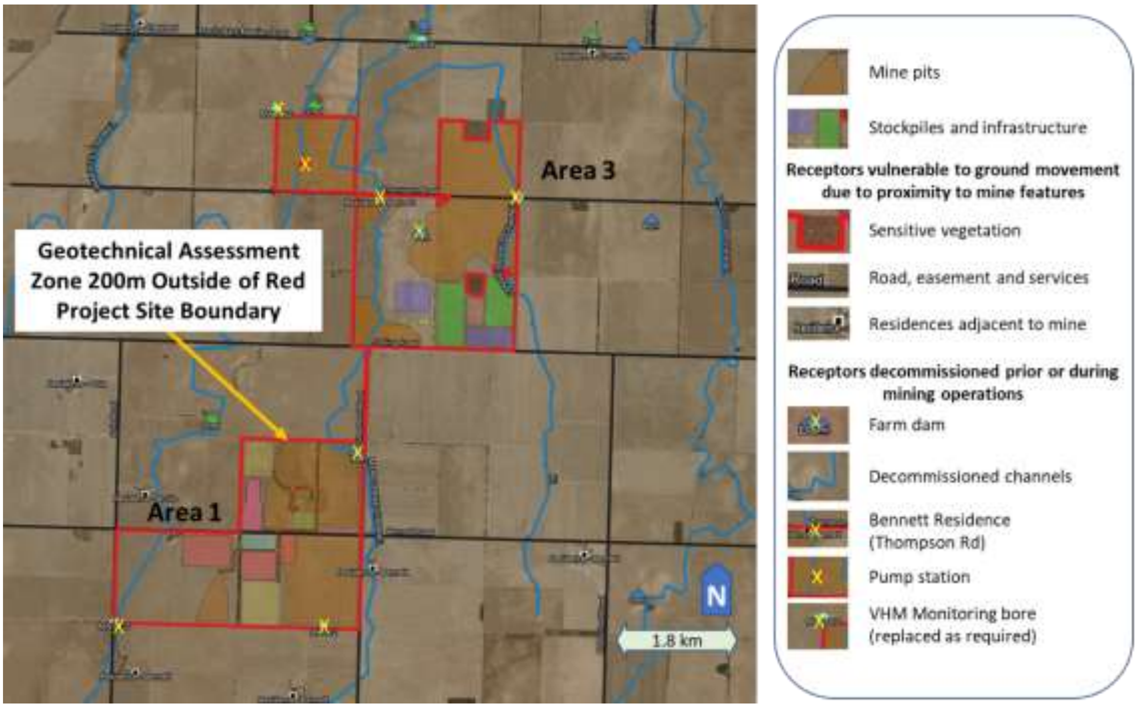

Figure 6-2: Receptors within the study area

The impact assessment also addresses any potential geotechnical impacts associated with 2 off site areas:

- The Kangaroo Lake pumpstation and the associated pipeline corridor along the local roads as shown in Figure 2-3: Proposed Haulage Route to Ultima and water supply pipeline route; and
- The proposed haulage route from the mine site to the Ultima freight yard as shown in Figure 2-3.

6.3 Linkages to other technical reports

This geotechnical assessment report has interdependencies with many other technical assessment reports in relation to the assessment of impacts associated with:

- Surface water - EES Technical Report H2 - Mine Site Surface Water. (Pitt&sherry. 2023a).

- Groundwater - EES Technical Report - CDM Smith – I. Groundwater. (CDM Smith. 2023).
- Soils and landforms - EES Technical Report – SLR - M. Soils and Land Resources. (SLR Consulting 2023).
- Draft Rehabilitation Management Plan - EES Technical Report - Pitt&sherry – P. Rehabilitation and Closure. (Pitt&sherry 2023).

The ground movement specialists undertaking this assessment worked collaboratively to evaluate these potential impacts and design suitable mitigation measures to be adopted by the Goschen Project.

7. Existing environment

Understanding of the existing environment within the broad Goschen Project area is important when considering their contribution to potential ground movement leading to environmental harm.

Assessment of existing environmental components for the purposes of this geotechnical assessment has included, but is not necessarily limited to, review of the following environmental features:

- Topography.
- Geology.
- Water; and
- Sensitive receptors.

The following sections provide overviews of the contribution of the above features to potential ground movement, with further detail.

7.1 Location and topography

The proposed Goschen Project is situated within an area of broad very gently undulating topography currently predominantly used for large scale farming activities. Most of the proposed mine project would occur on farmland, with remnant native vegetation existing within small communities within the project area and aligned along road reserves. Rural residences are located over the project area and surrounds.

The topography in the study area ranges from approximately ~105mAHD to ~115mAHD in Area from ~110mAHD to ~120mAHD in Area 3 and is characterised by a north–south-orientated ridge elevated around 100–125 m AHD that can be seen transecting the proposed pit areas as shown in Figure 7-1.

The topography of the site is gently sloping and has limited clearly defined natural or manmade drainage systems or natural water courses passing over the mine site. A number of previously decommissioned water bearing channels traverse portions of the mine area.

The lack of large cuttings, valleys and steep slopes means that there are no surface landslide features or areas where there is significant erosion observable on the surface. From the geotechnical perspective, this means that there are limited current opportunities to observe exposed sub surface lithologies and their material behaviour. Consequently, subsurface geotechnical investigation and sampling is necessary to identify how the deposition of the layers has formed the landscape, any sub surface structures that may affect excavations in the ground and to obtain suitable material for testing to confirm material geotechnical parameters.

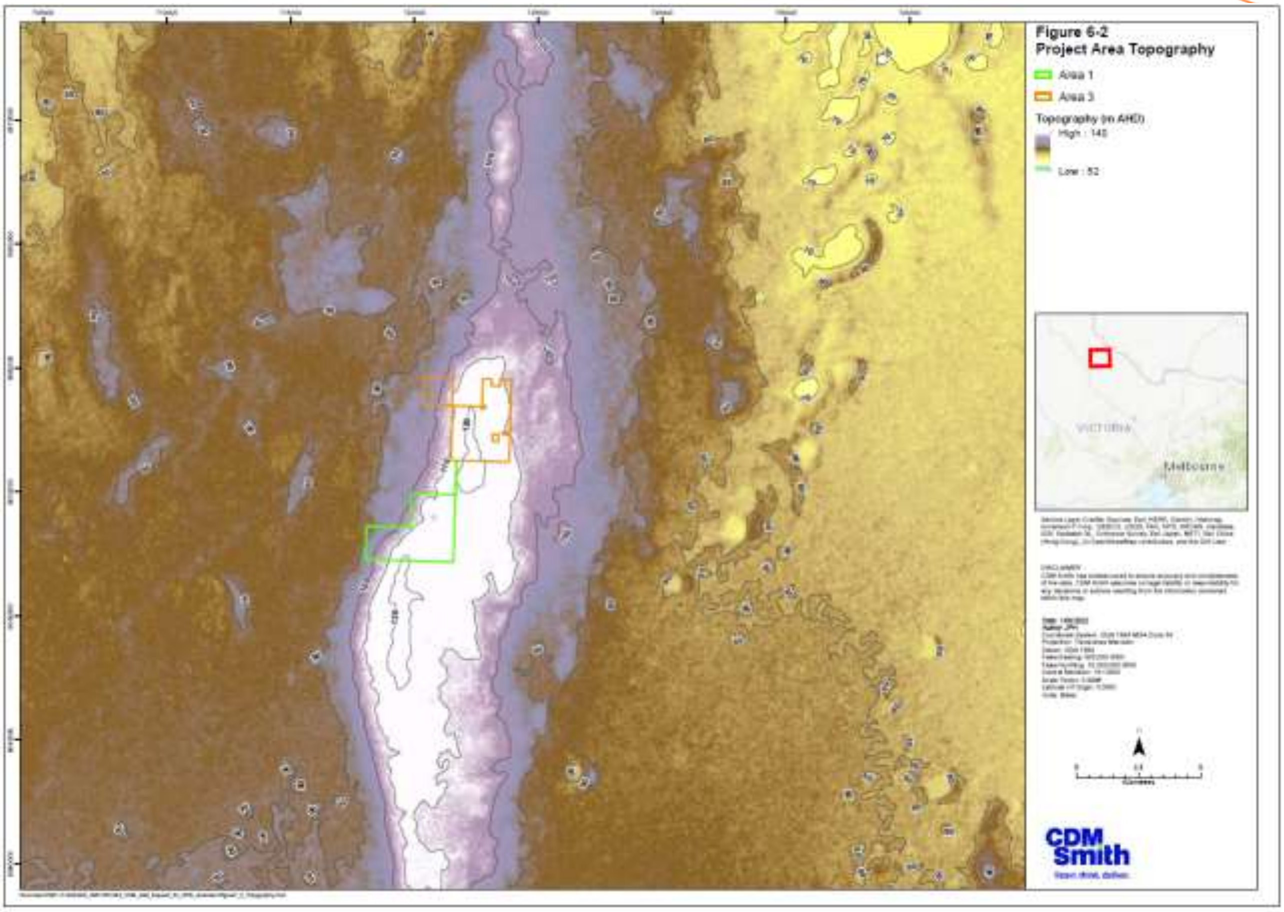

Figure 7-1 Goschen Project area topography (reproduced from CDM Smith)

7.2 Geology

The Goschen site has a relatively simple lithology. From the geotechnical perspective there is topsoil over clays and silty sands and discontinuous areas of cemented sands which in places represent as weak and very weak sandstones. These layers have been considered as overburden or the cover sequence. These layers overlie the mineralised fine to medium sand which is the layer that is of primary interest to the mining operation.

- The topsoil and its handling and health as a growing medium has been addressed in the specialist soil technical reporting. It is recommended that the ground control and rehabilitation management planning incorporate the specialist advice.
- The silty sands and cemented sands identified as subsurface materials are, from a geotechnical point of view, classed as bulk fill materials.
- The zones of silty and sandy clay within the overburden represent an important source of construction material which it is recommended are appropriate for use as tailings bund construction material as well as for construction of minor bunds, ponds, and possibly base layers for haul roads.
- It is understood that the current mine planning is for the mineralised sand to be temporarily stockpiled. The mineralised sand following processing will constitute the main component of the tailings. As such, it is critical that the material properties, both as a bulk mined material, and as a component of the tailings are understood; and
- The base of the pit, and therefore the tailings containment areas are located within subsurface geology layers and understanding of the permeability and bearing characteristics of those material are important to inform design for trafficability of mine equipment over placed material and for tailing consolidation.

An understanding of the regional and local geology is important to inform design considerations on expected subsurface material or structural features which may affect the potential for ground movement within the mine area.

7.2.1 Regional geology

The Goschen Project is located within the Bendigo and Stawell structural zones which are separated by the Avoca Fault, as shown in Figure 7-2. The Goschen mineralisation is within the near-surface Tertiary Loxton Sand. The deposit has both sheet-style and strandline mineralisation within original fluvial, marginal marine and marine environments.

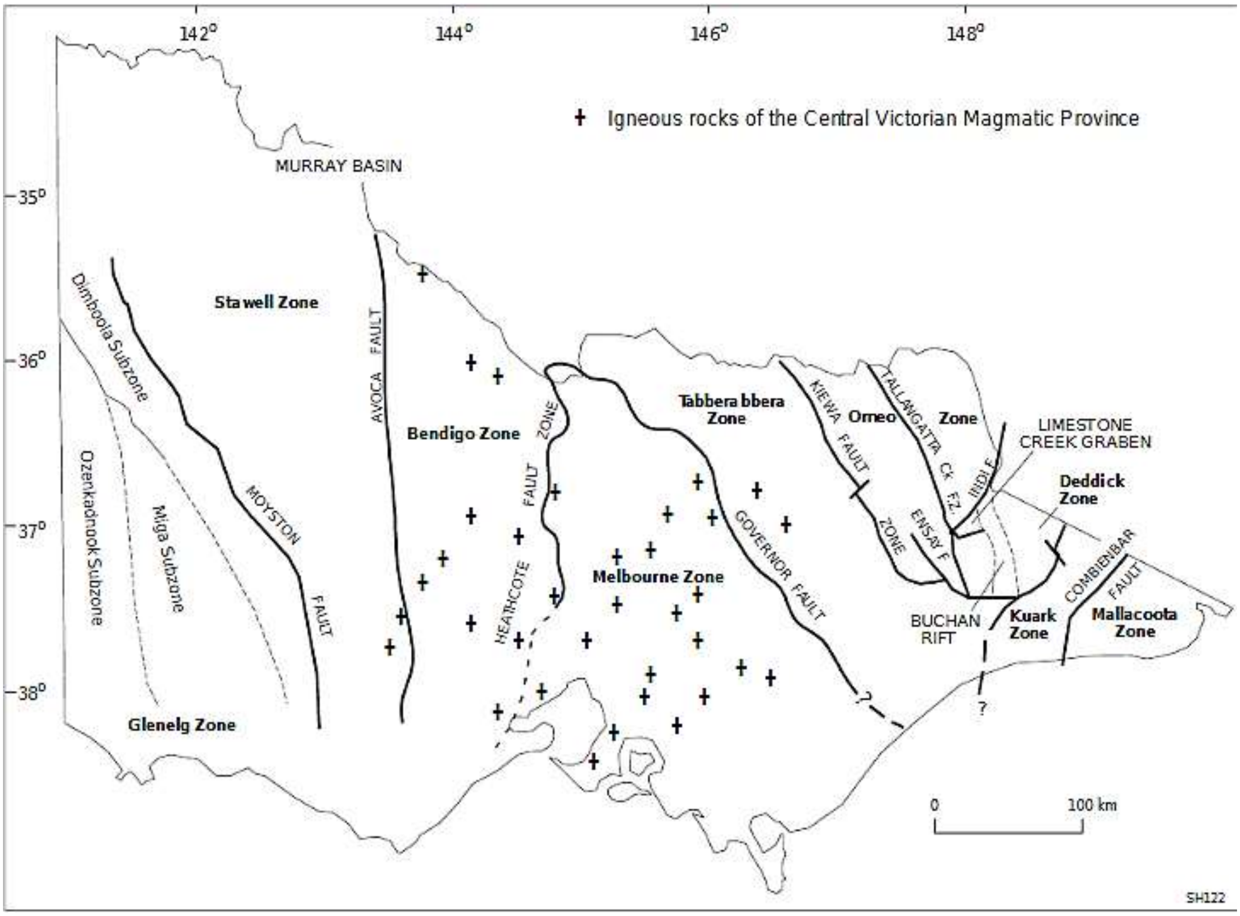

Figure 7-2: Structural zones of Victoria (Willocks and Moore, 1999).

The Tertiary sediments are generally flat-lying and unconformably overlie Proterozoic and Paleozoic basement rocks which are 88 to 175 m below the surface in the Goschen Project area and will not be intersected by current mining plans. The sediments are overlain by a thin layer of Quaternary aeolian and fluviolacustrine sediments.

Sheet style mineralisation extends for 14 km north–south by 15 km east–west, with each mineralised horizon (3 to 4 horizons identified) having an average thickness of between approximately 2 m to 3 m. The mineralised sands have been described by Mason (2008) as yellow/brown to grey, very fine to coarse, unconsolidated to weakly cemented, well sorted quartz sand with varying content of clay and silt.

7.2.2 Site geology

The outcropping geology at the site is comprised of a thin quaternary cover of sandy clay and ranges from approximately 5–10 m. The quaternary material overlays the Loxton Sand (formerly 'Loxton–Parilla Sand/s'), which hosts the target mineralisation zone. This unit consists of a typically well-sorted, fine- to medium grained-, quartz rich- sand) and has an average thickness of 50 m across the basin.

In the broader, general study area, the Loxton Sand overlays the Geera Clay, which separates the Loxton Sand from the Renmark Group. The Geera Clay is comprised of massive clays of low plasticity with minor sand and silt horizons. Drilling investigations undertaken by CDM Smith (2021) identified the Geera Clay to be prominent across the site with a thickness ranging from 32–46 m. Field observations are typically consistent with VHM drill hole data with encountered depths ranging from 43–56 m below ground level (BGL). This suggests that the Loxton Sand is thinner in the vicinity of the Goschen Project site than regional mapping indicates and that the Geera Clay is more extensive than regional mapping shows.

The Renmark Group consists of fluvio-lacustrine sediments comprising gravels, sand, silt, and clay (GeoScience, Australia, 2017) and is divided into the upper Olney Formation and the lower Warina Sand.

- The Olney Formation is typically poorly consolidated and comprises carbonaceous clay, with minor silts and sands, as well as beds of brown coal and peat (GeoScience, Australia, 2017). No brown coal or peat beds were identified during drilling investigations completed by CDM Smith; and
- The Warina Sand is also typically poorly consolidated and comprises carbonaceous sand, clay, and silt sequences. CDM Smith drilling investigations identified several bands of green laminated shale at depths of 110–120 m BGL.

The Victorian aquifer framework (VAF) indicates that the Renmark Group is 33 m thick at the site. In the general study area, the Renmark Group rests unconformably on pre-Tertiary sedimentary basement rocks and granitic plutons. The Goschen Project site is on a basement high, with the VAF indicating a basement elevation of 6 m AHD. The basement high is likely due to a granitic intrusion in the basement rocks (Lake Boga granite). The site stratigraphy is summarised below:

- Topsoil/Quaternary - Loam and sandy clay – 5-10m thick.
- Loxton-Parilla Sand - Coarse-grained to gravelly quarts-rich sand – 35-55m thick.
- Geera Clay - Dark grey/black clay of low plasticity – 32-46m thick.
- Olney Formation - Dark grey/black silty clay of low plasticity – 13-25m thick; and
- Warina Sand - Coarse-grained sand with clayey interbeds, minor shale.

VHM geologists have interpreted a basement fault which has experienced movement during and after deposition of the Geera Clay and Loxton Sand, resulting in a step change in thickness and elevation of these units. The fault forms the western edge of the Cannie Ridge and coincides with the interpreted edge of the Lake Boga granite pluton. The elevation of the top of the Geera Clay is 10–15 m lower on the western side of the fault.

7.2.3 Geological and geotechnical investigation

Extensive investigations have been undertaken of the geology, lithology, and geotechnical parameters for the proposed mine. Full detail on the investigations completed to date are provided in the Geotechnical Investigation Factual and Interpretive Report attached as Appendix B (pitt&sherry. 2022b) The investigation incorporates comprehensive assessment of material properties including strengths and other characteristics of in situ and stockpiled materials, informing pit or stockpile designs.

7.2.4 Outcome of assessment of the geological environment for potential effect on ground movement

The investigation and assessment undertaken indicates that the presence of significantly weaker material strengths is considered unlikely.

The extensive drilling program has not encountered any very weak structures and the geological age, intersected geological formations in the area and historical performance of the area suggests that a significant departure from the identified and expected material with potential to contribute to ground movement is unlikely.

7.3 Water

The likelihood and consequence of ground movements can be strongly influenced by the presence of water and the degree of saturation of the soil or rock.

7.3.1 Drainage

- The gently sloping topography of the site supports overland flow and small drains along the paddock boundaries and along the roads to manage overland flow during storm events. The mine will construct suitable drainage paths and create new internal drains on stockpiles and in and around the pit walls (pitt&sherry 2022a).
- Drainage of adjacent road networks includes sections of gravel roads with variable quality drainage
- The pump station is in an area of disturbed flat land adjacent to Kangaroo Lake with overland flow to the lake
- The proposed pipeline corridor is aligned along predominantly flat existing road networks with variable quality drainage.

7.3.2 Groundwater and aquifers

CDM Smith undertook a detailed groundwater study as part of the EES (CDM Smith 2022) that included an assessment of groundwater depth across the site. The groundwater contours prior to mining are represented in Figure 2-1 below. The average groundwater level across Area 1 and Area 3 in 64.5m AHD and this value has been used in design. The western side of the Area 1 and Area 3 pit shells will be less than this level ranging from 63mAHD to 64mAHD.

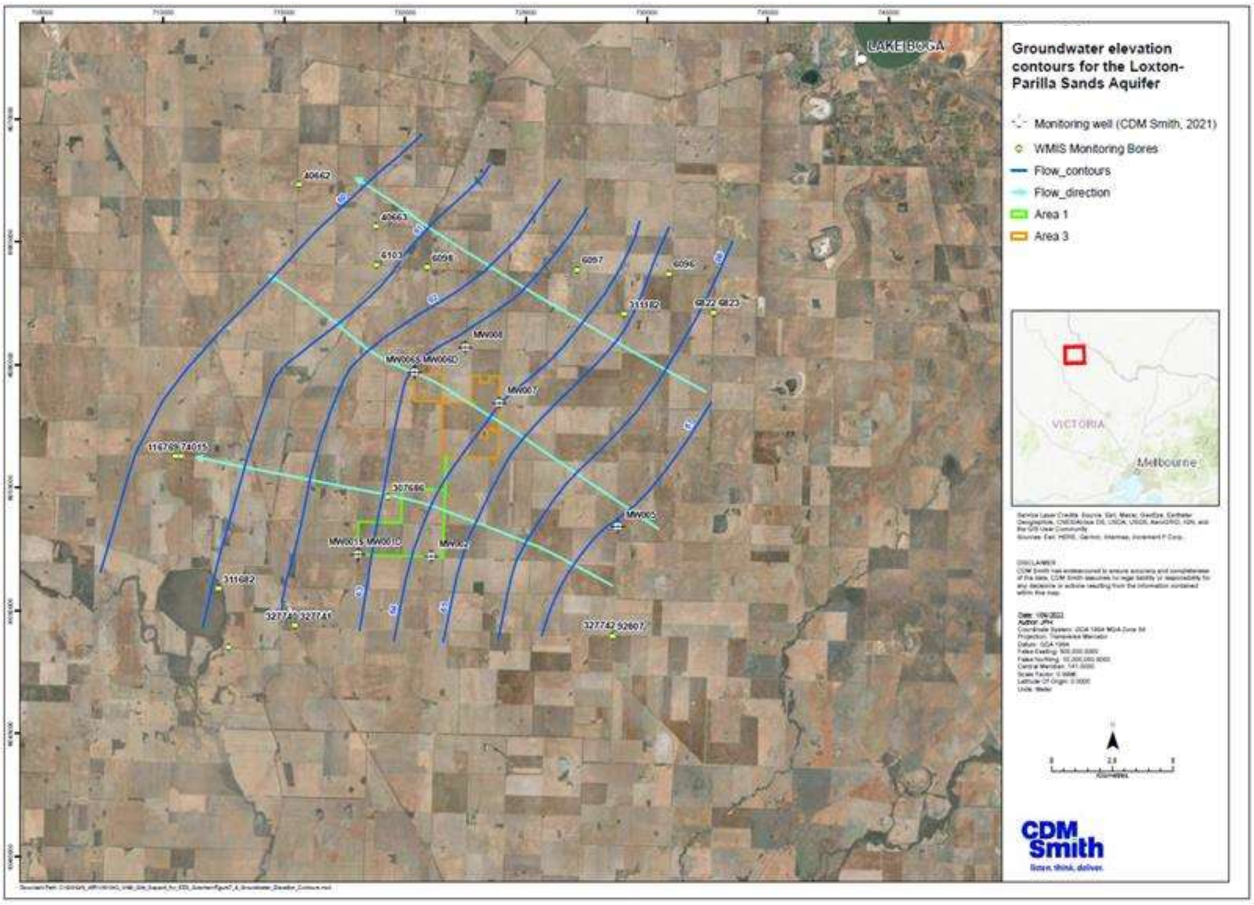

Figure 7-3 Groundwater contours from CDM Smith technical report I. Groundwater (CDM Smith 2023)

Note monitoring bores shown in Figure 7-3 are registered, but not considered sensitive receptors. These monitoring bores are owned by VHM and are all outside the mine footprint and thus will be retain for long term monitoring purposes.

The surface levels across Area 1 vary from ~105m AHD to ~115m AHD and Area 3 varies from ~110m AHD to ~120m AHD. Pit depth have been set to remain well above these the average groundwater level across Area 1 and Area 3 of ~64.5mAHD.

CDM Smith identify that as the mine advances and tailings deposition increases there is a likelihood of groundwater mounding. This groundwater mounding has at this stage not been modelled at the mining block level however it is suggested that it could mean that in some areas groundwater may intersect the pit floor. It is intended that where this occurs that a system of dewatering bores will be installed to ensure that groundwater is maintained at a level of nominally 1m below pit floor. This system is currently under investigation and will be incorporated into FEED.

7.3.3 Surface water and overland flows

There were once many stock and domestic channels that bisected the retention area, formerly delivering water to the region. All these channels within the proposed mine site have been decommissioned (filled to almost ground level, in some cases a small depression remains).

7.3.4 Water contribution to potential ground movement

The existing water table and surface flows have been assessed to inform the mine design and operation planning. This is discussed in detail in EES. Technical Report - CDM Smith – I. Groundwater (CDM Smith 2023).

There have been no identified perched water tables encountered in the subsurface drilling investigation programs to date which would intersect mine workings.

There is potential for overland flow to cause erosion of dispersive soils in areas where excavation and ground disturbance has occurred. This is addressed in the technical reports, H1 Surface Water, (Water Technology 2023) and the Draft Rehabilitation Management Plan (Pitt&sherry 2023).

7.4 Sensitive receptors

Based on the assessments a range of potential public safety, environmental and infrastructure receptors were identified within proximity to the proposed mine. Figure 7-4 below indicates receptors potentially vulnerable to ground movement within 200m of the mine project boundary.

Receptors within the 200m geotechnical assessment zone of the project boundary includes features such as:

- Public road networks and infrastructure services within road easements.
- Various private property features including sheds and residences.
- Private property (farmland) (land outside the mine project boundary excluding road easements).
- Sensitive vegetation.

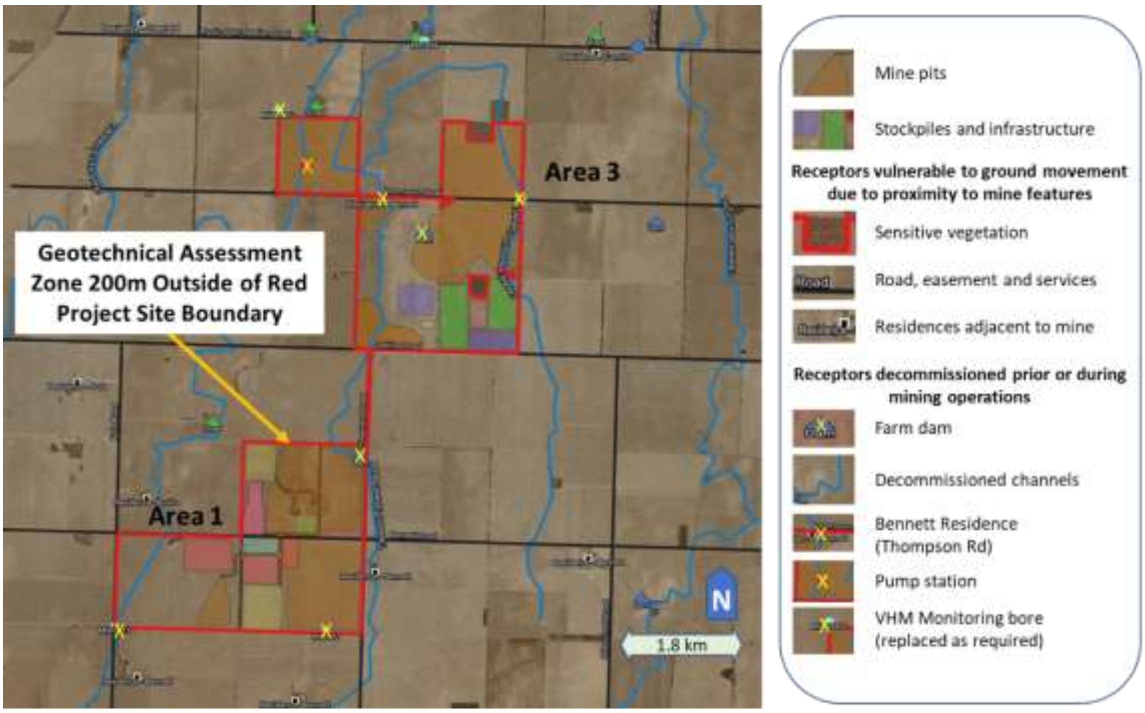

Figure 7-4: 80m buffer around Goschen Project and vulnerable receptors

Receptors outside of the proposed mine project boundary include features such as:

- Public road networks, vegetation, and infrastructure services within road easements along Bennett Road, Mystic Road, Donald Swan Road, Ultima Road and David Road.

- Various private property features including sheds and residences; and
- Land and vegetation and infrastructure services along the pipeline alignment (Figure 2-3).

There are several features that are in the proposed mine site or adjacent to it (within the 200m geotechnical assessment zone) that have not been classed as sensitive receptors. These include:

- Decommissioned drainage channels.
- Monitoring bores owned by VHM which will be relocated/reinstalled as mining impacts them.
- Decommissioned farm dams.
- Pump station (to be decommissioned prior to the mine commencing).
- The Bennett property on Thompson Rd (purchase agreement for property prior to mine commencement).

These features are highlighted in Figure 7-4 and noted in the legend and have not been further assessed (Figure 2-1).

7.5 Limitations, uncertainties, and assumptions

7.5.1 Tailings

Tailings design has been based on a number of assumptions, extrapolations and comparisons with similar materials and limited laboratory testing for analytical models.

The risk related to the co-deposited material (cdm) properties are:

- Settlement.
- Timing for overburden placement.
- Water recovery.

Variations in settlement of the tailings, the timing of overburden placement and water recovery have been considered to not contribute to ground movement that may impact sensitive receptors from geotechnical causes.

The current data on water recovery and settlement rates is considered sufficient to assess the likely order of ground movement. Further testing and analysis that refines understanding of these elements will inform the ongoing rehabilitation and tailing management

7.5.2 Offsite Infrastructure and Utilities

The following are areas where further investigations and analyses are recommended as part of the future design process:

- Location of all existing public services to confirm their proximity to the buffer zones.
- Information on the current road infrastructure and its ability to support development and operation of the mine requires further investigation, programmed to be undertaken during FEED; and
- Limited information is available on dispersive soils in the proposed pipeline alignment, and it is currently assumed they are like those identified in the mine area and appropriate dispersive soil management will be required as part of the construction specification and management.

8. Risk assessment

The potential impacts on sensitive receptors from ground movement risk and associated residual risk ratings, after implementation of recommended measures, are listed in Table 8-1 and Table 8-3. The likelihood and consequence ratings determined during the risk assessment process and the mitigation measures recommended are presented in Appendix A.

For pathway 1 to 3 the event is considered potentially feasible though with mitigation measures as described further it is considered that potential effects on sensitive receptors are not credible. For example, separation distances integrated in mine operations create too large a distance for the ground movement to feasibly impact on a receptor.

Table 8-1: Ground movement risks

Risk ID	Potential threat and effects on the environment	Residual risk rating	Phase
Pathway 1	Slope collapse or slide of above ground stockpiles releasing material to impact on sensitive receptors.	Non Credible Event	O
Pathway 2	Slope collapse or slide of below ground pit slopes directly affecting adjacent sensitive receptors or impacting stability of ground supporting the receptor.	Low	O
Pathway 3	Earthquake liquefying material which may be released and impact on sensitive receptors.	Non Credible Event	O
Pathway 4	Deformation or heave of material directly affecting sensitive receptors or impacting stability of ground supporting the receptor.	Low	R P
Pathway 5	Dispersive/sodic soil may contribute to erosion and distribution of material leading to impact on ground stability and uncontrolled movement of material affecting receptors.	Low	C O R

Legend: **C:** Construction Phase **O:** Operations Phase **R:** Rehabilitation Phase **P:** Post Closure

Risk assessment of the project, with respect to potential effects of ground movement, was undertaken to prioritise the focus of the impact assessments and development of mitigation measures. Risks were assessed for the construction, operation, and decommissioning phases of the project.

The likelihood and consequence ratings determined during the risk assessment process and the adopted mitigation measures are presented in Appendix A – Ground Movement and Tailings Storage Risk Assessment. The risk assessment has been undertaken in line with Preparation of Work Plans and Work Plan Variations Guideline for Mining Projects December 2020 (version 1.3) and in accordance with AS/NZS ISO 31000:2009.

The assessment identified potential risk pathways which link project activities (causes) to potential effects on the environmental assets, values or uses (refer to Appendix A). The risk pathways in this geotechnical assessment link several components as follows.

8.1 Ground movement types (Elements)

Potential ground movement types which may affect receptors have been grouped into three elements:

- Collapse/slide.
- Deformation/settlement/bearing failure; and
- Liquefaction.

8.2 Movement triggers (Causes)

The ground movement may be caused by a range of potential triggers described, for the purpose of this assessment, as a Cause, which include the following:

- Slope/Batter design is not adequate.
- Construction of stockpiles or process foundation including pump station and trenching exceeds ground bearing capacity.
- Earthquake.
- Slope / Batter is not formed to the required design, applies to:
  - Mine pit slopes
  - Stockpile batter slope.
  - Sedimentation pond or pit bund slope.
  - Tailings storage bund slope.
- Surface water run-off causing erosion or reduction in material strength or increase in bulk weight:
  - Management of stormwater generated on the mine site from extreme events is addressed in the technical report pitt&sherry 2023a.
- Change of groundwater levels.

8.3 Risk pathways

Combinations of the above Elements and Causes present several risk Pathways (Hazards) for which harm to the environment may arise. The likelihood of the hazard causing harm to various environmental receptors and the magnitude of the consequence (the Risk) has been considered with the assessment outcomes presented in detail in Appendix A, with summarised descriptions following.

8.3.1 Pathway 1 and 2 – Slope Collapse (above ground and subsurface respectively)

Slope collapse may occur due to the following potential hazards:

- intersection of material that is weaker than allowed for in design.
- pit walls not being constructed to design slope and bench geometry.
- encountered an area of ground softened by stormwater ponding leading substantial deformation of the bench and the drainage channels and associated system being compromised.
- increase in groundwater levels greater than allowed for in design.
- weaker and more variable material than allowed for in design of the stockpile.
- deformation of the drainage channels through ponding of stormwater or uncontrolled overland flow and erosion of the bench/batter.
- the batter slope or bench geometry not being constructed to the design geometry.
- inadequate maintenance of wall/batter drainage channels on benches and overland flow paths, allowing ponding or erosion of slopes, batter, or benches; and
- Erosion risks associated with surface water are addressed in technical report – H1 Surface Water - Water Technology

8.3.2 Pathway 3 – Liquefaction – Earthquake

- Slope collapse of pit walls and batter slopes caused by earthquake loads due to ground acceleration being greater than the design allowed for in terms of material properties and slope geometry in conjunction with a raised water table creating saturated and liquefaction prone materials.

8.3.3 Pathway 4 – Deformation/Settlement/Heave

- Substantial deformation/settlement of the rehabilitated ground surface caused by:
    - consolidation of the tailings more than assessed based on the analysis and testing.
    - over consolidation of the subgrade under stockpiles and process plant foundation hardstands.
- Substantial deformation/settlement of the subgrade under construction plant and process plant foundations caused by static or dynamic loads being higher than design allowances.

In addition to geotechnical risks within the proposed mine boundary, geotechnical risks associated with the pump station, pipeline, and road network along which the pipeline is aligned have been assessed as follows:

- The pump station site at Kangaroo Lake has geotechnical risks including bank stability, erosion potential and settlement/subsidence of the pump station foundations and the access for fuel tankers and other heavy vehicles. The geotechnical investigations and future engineering design will need to address these.
- The pipeline alignment includes several aerial (bridge) crossings of irrigation channels and trenchless crossings of channels, watercourses, and a railway. The geotechnical risks associated with these crossings include constructability and risk of settlement of the ground above the trenchless crossing – with associated impacts to the channels or railway. The geotechnical investigations and future engineering design will need to address these. The construction contractor’s specialist trenchless subcontractor will need to design the trenchless works in accordance with industry standards and their proposed methods and their own equipment.
- Soils along the alignment will be further characterised with geotechnical investigations, with risks affecting pipeline design and constructability currently expected to include unstable trench walls in sandy soils, weak bearing resistance requiring large thrust blocks, and low soil resistivity.
- Ground movement impacts on the current road network are based on desktop information. The geotechnical investigations and future engineering design will need to address pavement life, soil and subgrade strength and susceptibility to dispersive soils
- Erosion risks associated with surface water are addressed in technical report – H1 Surface Water, (Water Technology 2023)

8.3.4 Pathway 5 - Dispersive soils

Dispersion testing has been carried out in the laboratory testing from site investigations. The SLR Technical Report - M Soils and Land Resources (SLR 2023) assesses the risk and provides treatment requirements. This has been further expanded in the pitt&sherry technical report pitt&sherry 2023.

Potential dispersion of material used for the tailings bunds and ponds is addressed in Appendix B of this report.

Potential hazards include:

- Exposure of dispersive material to rainfall events:
    - to open mine pit faces during active mining operations and pre-final rehabilitation, resulting in erosion and soil loss.
    - to stockpile slopes during active mining operations and pre-final rehabilitation, resulting in erosion and soil loss.

- to detention basins or ponds during active mining operations and pre-final rehabilitation, resulting in erosion and soil loss.
- during trenching and backfilling operations as part of the pump station and pipeline construction resulting in erosion and soil loss and potential collapse; and
- during upgrade of local road networks to support the proposed mining operations, resulting in erosion and soil loss.

8.4 Risk assessment [summary of impacts]

The geotechnical risk assessment involved analysis of potential ground movement risks arising through the previous identified pathways.

The identified risks and associated residual risk ratings are listed below.

Table 8-2 list the events where the potential impacts on sensitive receptors has been assessed as non-credible. Table 8-3 list the events that have been assessed as credible events.

The likelihood and consequence ratings determined during the risk assessment process and the mitigation measures recommended are presented in further detail in the following chapters and Appendix A.

Table 8-2: Geotechnical risks Assessed as Non-Credible

Risk ID / environmental receptor	Potential threat contributing to detrimental impact on environmental receptors	Residual risk rating	Mine stage for which ground movement may contribute harm
Credible Events Potentially Impacting Sensitive Receptors – Based on Risk Assessment - Appendix A			
General ground movement pathways that may contribute to environmental harm			
1.C.A1 - Public Road/land and public services (overhead or subsurface) on undisturbed ground	Pathway 1 and 2 – Slope Collapse (above ground or subsurface). Slope collapse or slide directly affecting adjacent sensitive receptors or impacting stability of ground supporting the receptor.	Non Credible Event	O
2.C.A1 – Private property	Pathway 1 and 2 – Slope Collapse / Slide (above ground or subsurface). Slope collapse or slide directly affecting adjacent sensitive receptors or impacting stability of ground supporting the receptor.	Non Credible Event	O
1.L.A2 - Public Road/land and public services (overhead or subsurface) on undisturbed ground	Pathway 3 – Liquefaction – Earthquake Earthquake liquefying material which may be released and impact on sensitive receptors.	Non Credible Event	O
2.L.A2 - Private property	Pathway 3 – Liquefaction – Earthquake Earthquake liquefying material which may be released and impact on sensitive receptors.	Non Credible Event	O
3.L.A2 - Sensitive receptor within site or adjacent to site	Pathway 3 – Liquefaction – Earthquake Earthquake liquefying material which may be released and impact on sensitive receptors.	Non Credible Event	O

Risk ID / environmental receptor	Potential threat contributing to detrimental impact on environmental receptors	Residual risk rating	Mine stage for which ground movement may contribute harm
1.D.A3 - Public Road/land and public services (overhead or subsurface) on undisturbed ground	Pathway 4 – Deformation/Settlement/Heave Deformation or heave of material directly affecting sensitive receptors or impacting stability of ground supporting the receptor.	Non Credible Event	R P
2.D.A3 - Private property	Pathway 4 – Deformation/Settlement/Heave Deformation or heave of material directly affecting sensitive receptors or impacting stability of ground supporting the receptor.	Non Credible Event	R P
Tailings Storage Facility	Pathway 1 and 2 – Slope Collapse / Slide (subsurface). Slope collapse or slide directly affecting adjacent sensitive receptors or impacting stability of ground supporting the receptor.	Non Credible Event	O

Legend: **C:** Construction Phase **O:** Operations Phase **R:** Rehabilitation Phase **P:** Post Closure

Table 8-3 Geotechnical risks assessed as credible events

Risk ID / environmental receptor	Potential threat contributing to detrimental impact on environmental receptors	Residual risk rating	Mine stage for which ground movement may contribute harm
Credible Events Potentially Impacting Sensitive Receptors – Based on Risk Assessment - Appendix A			
General ground movement pathways that may contribute to environmental harm			
3.C.A1 – Sensitive receptor within site or adjacent to site	Pathway 1 and 2 – Slope Collapse / Slide (above ground or subsurface). Slope collapse or slide directly affecting adjacent sensitive receptors or impacting stability of ground supporting the receptor (Tree protection zone).	Low	O
3.D.A3 - Public Road/land and public services (overhead or subsurface) on undisturbed ground	Pathway 4 – Deformation/Settlement/Heave Deformation or heave of material directly affecting sensitive receptors or impacting stability of ground supporting the receptor.	Low	R P
3.C.A4 Sensitive receptor within site or adjacent to site	Pathway 5 – Sodic / Dispersive Soils Dispersive/sodic soil may contribute to erosion and distribution of material leading to impact on ground stability and uncontrolled movement of material affecting receptors.	Low	C O R
1.C.A4 Public Road/land and public services (overhead or subsurface) on undisturbed ground	Pathway 5 – Sodic / Dispersive Soils Dispersive/sodic soil may contribute to erosion and distribution of material leading to impact on ground stability and uncontrolled movement of material affecting receptors.	Low	C O R

Legend: **C:** Construction Phase **O:** Operations Phase **R:** Rehabilitation Phase **P:** Post Closure

9. Impacts assessment – General

The impact assessment process included review of numerous potential development options in design, construction, operation, and post closure stages to arrive at recommended preferred measures for avoidance and minimisation measures.

Detailed modelling and analysis have been undertaken to address general impact assessment and where appropriate recommend separation distances (buffer zones). The process undertaken to establish safe buffer zones and their applicability for use in conservatively assessing the possibility of any impact on a sensitive receptor is discussed in detail in Appendix B - Geotechnical Investigation Factual and Interpretive Report (pitt&sherry. 2022b). Considerations incorporated in the geotechnical analysis and assessment includes, but is not limited to:

- Overview of the scale and distribution of geotechnical investigation carried out within the proposed mine site.
- Process and outcome of geotechnical domaining of the materials encountered during the investigations.
- Detailed analysis of the insitu and laboratory testing to establish conservative material properties for each of the domains identified.
- Development of geotechnical models for critical pit wall slope locations adjacent to sensitive receptors.
- Development of geotechnical models for stockpile slopes adjacent to sensitive receptors.
- A detailed review of appropriate factors of safety (FoS) relating to ground movement impacts for pit walls with similar characteristics to the Goschen project pit walls.

- A detailed review of appropriate values of probability of failure (PoF) for pit walls with similar characteristics to the Goschen project pit walls.
- Consideration to the application of the selected slope geometry and FoS in operations to minimise changes and complexity in construction particularly associated with convex and concave changes of wall alignment.

Modelling and analysis and management is described in detail in the following appendices:

- Appendix B – Geotechnical Investigation Factual and Interpretive Report (pitt&sherry. 2022b).
- Appendix C – Design development of tailings storage facility; and
- Appendix D – Seismicity and earthquake risk.

Most risks identified in the impact assessment broadly cover many elements of the proposed Goschen Project. A range of design considerations or standard operational control measures have been assessed which if implemented are considered likely to reduce the residual impact to low. An outline of the GCMP is provided in Appendix E – Proposed GCMP Outline. The GCMP is in development.

The following sections summarise the potentially vulnerable receptors and general risks identified with recommended design or operational control measures.

9.1 Sensitive receptors - general

Potential vulnerable sensitive receptors within or surrounding the mine which may be affected by ground movement for which the avoidance measures apply include the following:

- Public roads - The public roads assessed were the roads that run adjacent to, but outside of the mining lease. Roads that cross the mining lease will be closed as part of the mining plan and were excluded from the risk assessment.
- Private properties – The properties near to the mining lease were assessed. The properties were considered to be any part of the cadastral boundary closest to the mining lease.
- Public services – Any public utility near the mining lease was assessed. The asset was assessed from the location data provided to VHM from the service authority.
- Process equipment and mine services which were within the mining lease were not assessed. This included the process plant and MUP locations, temporary pipelines and electrical services that could be readily moved as part of normal mining activities were ignored; and
- Pump station, pipeline and roading network are vulnerable to ground movement effects of potential deformation and subsidence including effects resultant from sodic and dispersive soil.

9.2 Impact risk pathways

Summary descriptions of the identified pathways for potential environmental harm due to ground movement and the assessed avoidance and mitigation measures are provided below. The following table summarises the stability analyses results and the applicable buffer distances for stockpile and pit wall slopes.

Table 9-1 Summary of stability analyses results and the applicable buffer distances for stockpile and pit wall slopes

Description	Pit Depth	FoS	PoF	Minimum Buffer Zone	Control
Conservative material properties selected for all geotechnical domains	N/A	N/A	N/A	N/A	Periodic review of material domains against actual pit wall exposures
Minimum FoS for slips at pit walls with a design life of 12 to 24 months	30m	1.6	5%	10m	Routine monitoring & surveillance in accordance with the GCMP refer to outline in Appendix E
	>30m <40m	1.6	5%	15m	
	>40m <47m	1.6	5%	20m	
Minimum FoS for slips on pit walls including convex and concave changes in wall alignment with a design life less than 12 months	30m	1.6	5%	10m	Routine monitoring & surveillance in accordance with the GCMP refer to outline in Appendix E
	>30m <40m	1.6	5%	15m	
	>40m <47m	1.6	5%	20m	
Stockpile Slopes	<30m	1.58	-	10m	Routine monitoring & surveillance in accordance with the GCMP refer to outline in Appendix E

9.2.1 Pathway 1- Slope collapse above ground - Stockpile locations

For stockpiles required during construction and operation application of design buffer separation distances from sensitive environmental receptors will reduce the likelihood of ground movement impact to low. For analysis associated with development of safe buffer zones refer to Appendix B. The resulting buffer distances are presented in Figure 9-1 below. A 10m buffer zone was selected as a minimum practical length, independent of stability results to allow for surface water bunds/drains and maintenance tracks around the stockpile toe.

With the buffer zones applied the risk of a slope collapse impacting on sensitive receptors is assessed as a non-credible event.

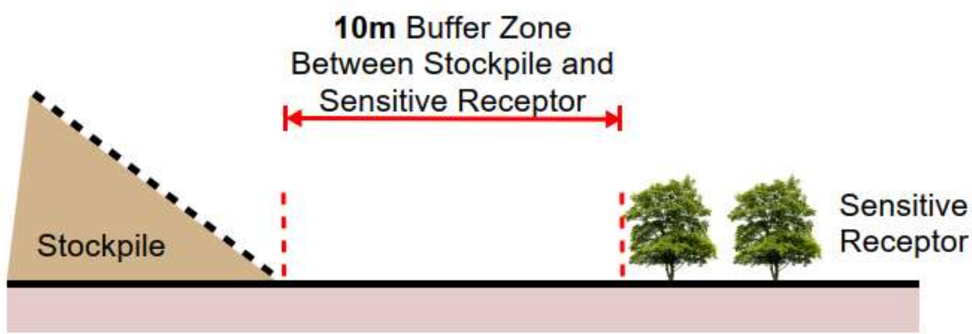

Figure 9-1 Stockpile Minimum Buffer Zone

9.2.2 Pathway 2 - Slope collapse (subsurface) – Mine pit slopes

For constructed pit slopes application of design buffer separation distances from sensitive environmental receptors is considered likely to reduce the likelihood of ground movement impact to low. For analysis associated with development of safe buffer zones refer to Appendix B. The resulting buffer distances are presented in Figure 9-2 below.

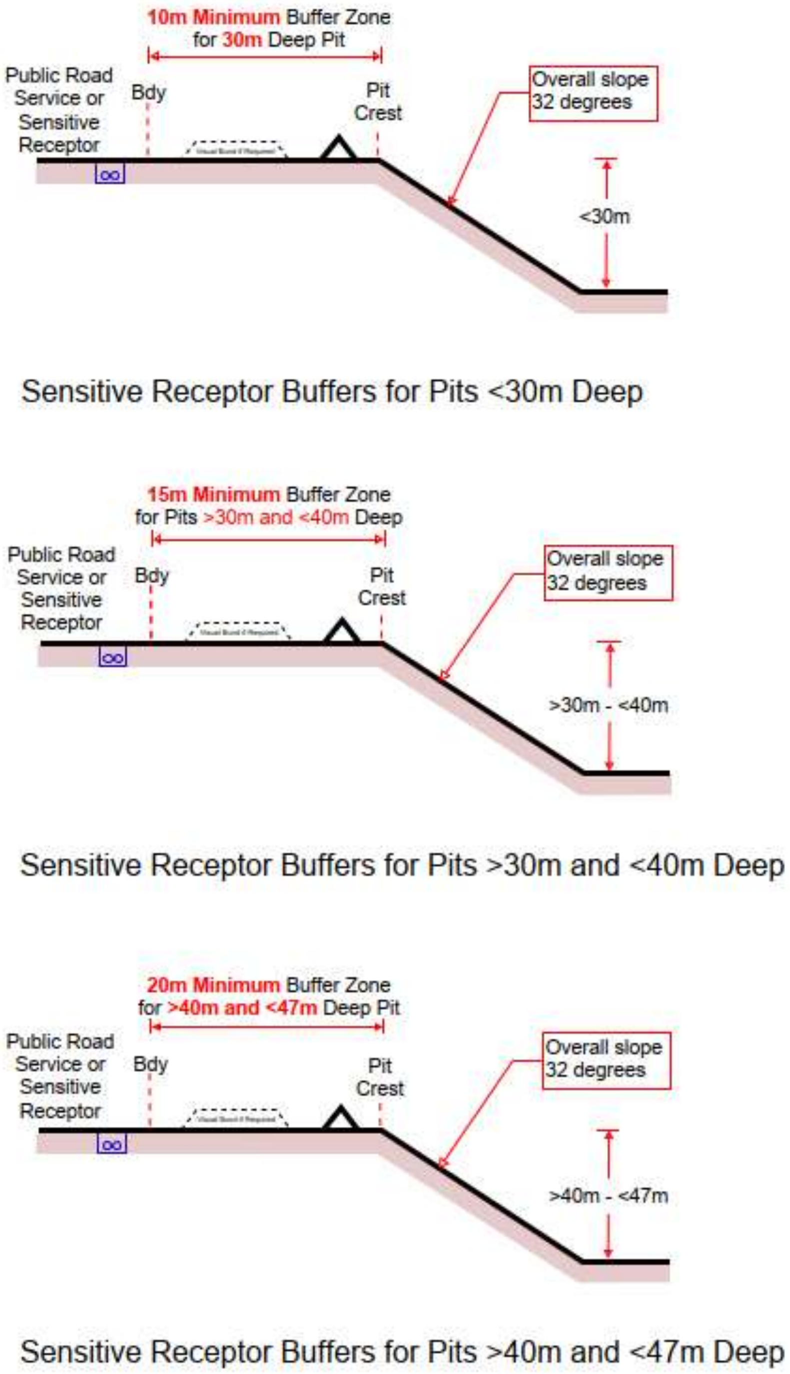

Figure 9-2 Recommended proximity buffer distances for crest of pit slope

The impact of convex (outward pointing) slopes was assessed using stability charts (ASCE 2016 - 3D Stability Charts for Convex and Concave Slopes in Plan - View with Homogeneous Soil Based on the - Strength-Reduction Method Internal Journal of Geomechanics, ASCE, 2017) assuming a homogeneous slope. The FoS will be influenced by the radius of curvature with small radius having the largest negative impact on stability.

The radius of curvature was taken as 10m as a conservative lower limit, given the size of the areas. For larger radii the 3D effects should be insignificant. This minimum dimension can readily be achieved during FEED and on site. The stability charts indicate a reduction in the FoS of less than 1% for a 30 degree to 45-degree slope with a 10m convex radius and improved factor of safety with a concave slope.

With the buffer zones applied the risk of a slope collapse impacting on sensitive receptors is assessed as a non-credible event.

9.2.3 Pathway 3 – Liquefaction – Earthquake

A comprehensive design assessment has been undertaken with a broad range of potential above and below ground storage options in conjunction with extraction restricted to depths above the existing ground water table provide the preferred below ground storage option reducing potential effects of ground movement to as low as practicable.

The seismic assessment has been carried out in accordance with AS 1170.4 - 2007 - Structural design actions Part 4: Earthquake actions in Australia (AS1170.4:2007). The investigation and assessment identified that the mine project is in region of seismic stability with low earthquake risk. The Avoca fault and the Geera Clay mentioned in Section 7.2.1 refer to regional scale structures that related to ancient periods of tectonic movement. The scale of the mine operation is not sufficient to impact on regional scale faulting.

The geological setting and existing lithologies identified to date and expected to be encountered within the mine area suggests that liquefiable material at the proposed subsurface levels of the mine operation are unlikely. Material with significantly different geotechnical parameters to those identified and considered has not been identified to date and is considered unlikely.

Seismicity considerations are included in modelling and risk determination in accordance with industry standards. The potential for the material, including tailings, to undergo liquefaction and create an increased risk of failure under the design earthquake event, with consideration of several factors included in design analysis, including:

- The particle size distribution of the tailings.
- Their density.
- The water table level.
- The pore pressure in the tailings; and
- The magnitude of the design earthquake.

The mining operations are designed to ensure that extraction is restricted to material above the ground water table with proposed management plans to include ground water and surface water to assist ensuring that materials do not become saturated and subject to altered behaviour parameters.

Assessment of the tailings as unsaturated and partially saturated states indicates that liquefaction is not a likely risk at the Goschen mine. The tailings are a draining tailing and as such a fully saturated condition is not considered likely.

The preferred option for tailings storage is subsurface providing a further level of risk avoidance and mitigation.

In pit void tailings storage avoids the risk of a tailing breach reaching a sensitive receptor with suitable bunds to separate returned tailings from open pit working.

- The pit floor and base of mining operations termination above the groundwater table with dewatering of localised ground water mounding where required minimises the risk of liquefaction; and
- In the event of a low probability earthquake occurring any tailing breach is contained subsurface.
- The assessment has identified that the impact of liquefaction from an earthquake event impacting on a sensitive receptor is considered a non-credible event. Refer to Appendix D Seismicity and earthquake risk for additional clarification.

9.2.4 Pathway 4 – Deformation/Settlement/Heave

The geotechnical modelling and analysis included assessment of potential impacts due to deformation and settlement with mitigation measures to reduce the risk to as low as practicable, include the following.

- Rehabilitated areas will be returned to the original landform as broad acre farming. Ground movement of the rehabilitated area may result in harm of the landform through settlement of the underlying replaced material.
- The Goschen mine has adopted a cyclic approach to mining. As mining advances and an area of the pit is excavated it is then prepared as tailings containment cells. Each tailings containment cell is filled with tailings over a period of months until it reaches its design capacity. During filling the tailing settles, and as more tailings are deposited it continues to settle as the water content is either decanted off for reuse or seeps into the pit floor. Once the tailings reach sufficient strength overburden is placed on the tailings as part of the rehabilitation process. The load of the overburden on the tailings continues to compress the tailings.
- The intent of the design is for the tailings to dewater through a combination of methods with no controls intended to reduce seepage into the pit floor. Under the tailings dam the seepage from the tailings will merge with the groundwater. There will be a dewatering system on the dry side of the tails bund to maintain the groundwater below the pit floor. The seepage into the pit floor will reduce the likelihood of Liquefaction.
- Based on a combination of testing and application of assessment against published data for similar materials, the results of the modelling of settlement of the tailings and overburden reduces over time as represented in Figure 9-3.

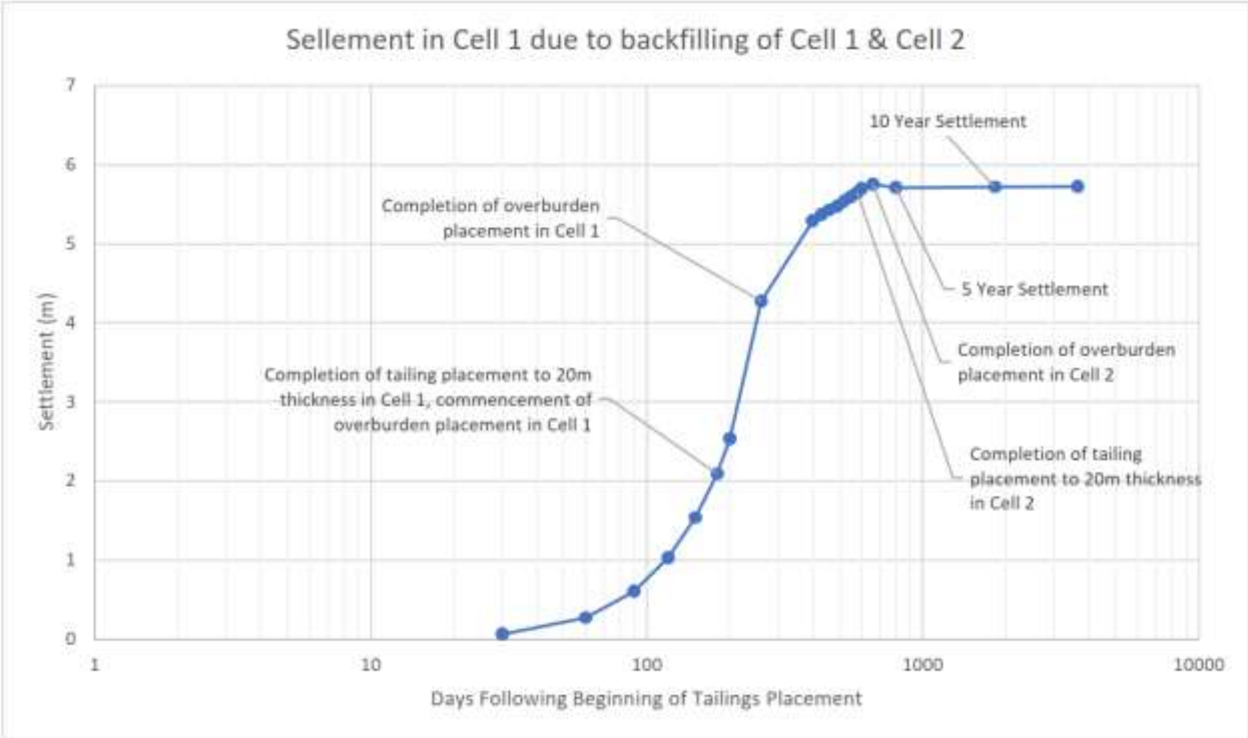

Figure 9-3: Model of settlement of tailings and overburden over time

- The tailings are more compressible than the material used to construct the tailings bund and where the overburden crosses from the tailings to the tailings bund there is a risk of differential settlement. Modelling of the settlement over time in the zone of tailings and overburden and of overburden and tailing bund indicate that differential settlement will be low, less than 100mm and that the transition will have a gradient of 1 in 500. This is less of a gradient change than is observed in the pre mining landscape (Figure 9-4)

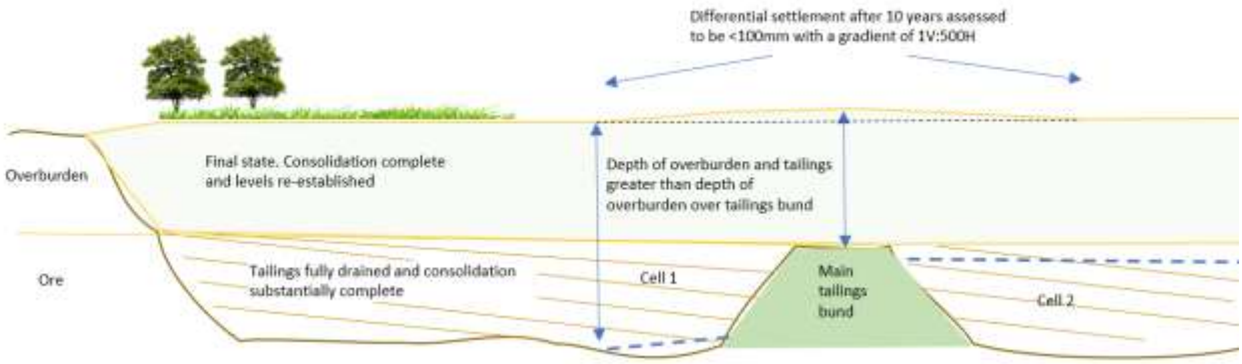

Figure 9-4: Schematic cross section of the rehabilitated landform at closure

- The severity of the differential settlement is assessed as minor. Normal preparation for cropping may reduce the actual affect. There is not expected to be any risk of harm to people or environmental harm. Land use harm is expected to be minor and manageable.
- Possible impacts could be minor impact on overland flow paths leading to minor impacts of the broad acre farming. The large scale cell size and existing site cross fall will assist in mitigation.

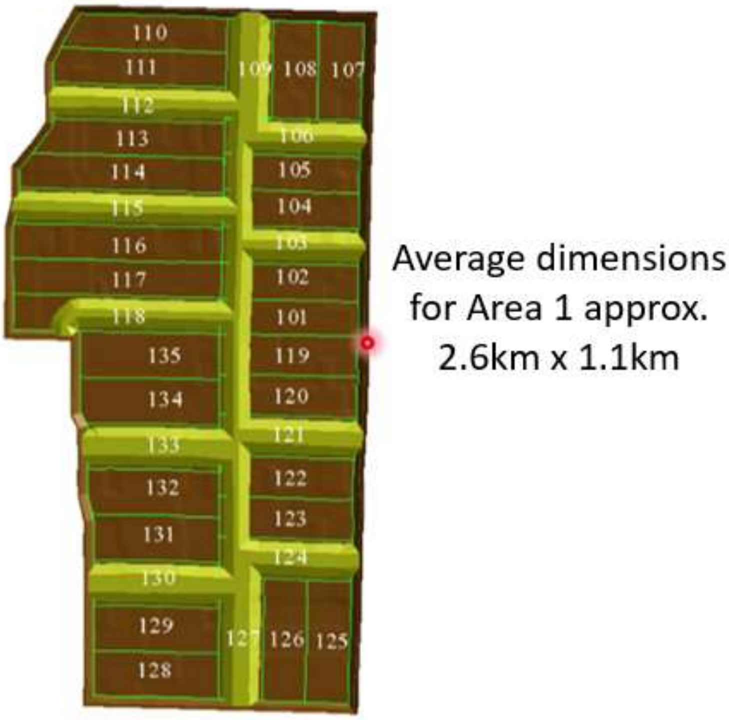

Figure 9-5: Indicative main tailings bund cell arrangement

- The mine life is in the order of 20-25 years. During this time for most cells the majority of the consolidation cycle will have occurred, and the mine will review the final landform as part of its rehabilitation plan; and
- For limited areas where settlement is likely to continue post closure the mine would maintain a monitoring program and undertake limited regrading of the final landform if required and in accordance with the rehabilitation plan.
- It is recognised that rehabilitation of the disturbed ground is a critical aspect of the project. The rate at which the tailings consolidates and increases in strength controls the commencement of overburden placement and eventual hand back of the rehabilitated site.
- The mine will adjust its mining rate and therefore its stockpiling and tailings production to manage the potential timing risk associated with the tailings consolidating sufficiently to allow overburden placement to commence.
- The mine will also vary the rate at which rehabilitated land is handed back to suite the actual rate of settlement of the tailings and the overburden.
- It is recognised that additional testing of the tailings and how it will dewater under time needs to be undertaken and this will be carried out in FEED.

The approach to managing the risk that the time associated with consolidation of the tailings and the degree of settlement experienced is described in Pitt&sherry 2023 as well as in the GCMP an outline of which is provided in Appendix E.

9.2.5 Pathway 5 - Dispersive soils

Soil and landform technical analysis identified that some sub soil material is dispersive and may cause the following ground movement risks:

- Exposure of dispersive material to rainfall events on open mine pit faces, stockpile slopes, detention basins or pond batters during mining operations resulting in erosion and soil loss and potential collapse; and

- Exposure of dispersive material to rainfall events during trenching and backfilling operations as part of the pump station, pipeline and local road upgrade construction works resulting in erosion and soil loss and potential collapse.

Dispersive soils will be exposed during construction and operation of the mine and in areas under rehabilitation. The following measures will mitigate the risk and should form part of the construction management plan (CMP) and the GCMP.

Drains and internal (cut) batters of sediment basins are particularly susceptible to erosion where dispersible soils are exposed. The increased erosion hazard is due to the erosive action of concentrated stormwater flow in drains and due to increased velocities on the steep slopes on batters.

Erosion control will be achieved using appropriate lining of dispersible soil materials with measures to be outlined in site Options include lining of internal basin batters and drains using a suitable rolled erosion control product (RECP), such as jute mesh or light weight non-woven geofabric. Use of RECPs should be considered over at least the upper part of the batters and at the main inlets and outlets to basins. RECPs would also be appropriate for lining the inverts of major drains.

Where structures such as stockpiles and sedimentation ponds will be constructed and expected to remain for extended periods the preferred surface protection is through revegetation, for example on batters of bunds and stockpiles, and otherwise where soils are temporarily disturbed but not required for ongoing operations. Topsoiling and sowing with appropriate early growth crops or local grasses is desirable and hydro mulching may be beneficial to promote early growth depending on the season that the works are carried out and where suitable irrigation water is available.

Where necessary soils can be treated with gypsum to counter the effects of sodicity during stripping and in stockpiles, as recommended by SLR (2022). Gypsum application would be undertaken during stripping, stockpiling and material spreading as detailed in Table 9-2 below.

Table 9-2 Gypsum application rates

Ameliorant	**Topsoil**	**Subsoil**
Soil stripping:		
Gypsum	5 T/ha (10 T/ha if ESP>14)	n/a
Stockpile surface:		
Gypsum	n/a	10 T/ha
Granulock 15 (or similar)	80 kg/ha	80 kg/ha
Re-spread materials:		
Gypsum	n/a	10 T/ha *
Granulock 15 (or similar)	120 kg/ha	120 kg/ha

* Gypsum only recommended if subsoil is to be left exposed for a length of time prior to topsoil respreading

In all areas disturbed by construction works or operation of the mine surface water must be controls and as far as reasonably practical the velocity of any concentrated flows managed to reduce erosion and temporary or long term drainage paths should avoid directing flows onto untreated or unrehabilitated ground.

The pit walls are to be similarly treated with drainage paths controlled and scour control structures such as energy dissipaters/flow check barriers and silt fencing used in all bench drains and down batter drains. The slope of benches should be managed to ensure they are constructed to slope inwards and overland flow from the ground surface should be managed so that it does not enter the pit. The mining process means that pit walls will be exposed to rain events for less than 18 months and in most cases less than 12 months. The site exposures in the quarry area provided in the photographic record in Section 5.3.1 of Appendix B show that while there has been deterioration of the slopes that considering that the quarry slopes have been exposed for greater than 10 years that the Goschen protect short term pit slopes, <12-18 months, are likely to be able to be maintained successfully.

Assessment of soils for dispersion is described in the EES Technical Report – SLR - M. Soils and Land Resources. (SLR 2023) and a range of avoidance and mitigation measures are recommended in Pitt&sherry 2023. With implementation of these measures the residual risk is low.

10. Impact assessment – Location specific

At a number of specific locations, the impact from potential ground movement on potentially sensitive environmental receptors cannot be completely avoided or mitigated to low without implementing additional location specific mitigation measures as summarised in Table 10-1 below. Figure 10-1 and Figure 10-2 respectively indicate the location of these potentially vulnerable receptors in Area 1 and Area 3.

Table 10-1: Summary of location specific impacts

Risk ID	Potential threat and effects on the environment	Residual risk rating	Mine stage for which ground movement may contribute harm
Area 1 - sensitive receptor No. 1 - Bennett Road which bisects the proposed mine	• The proposed mine pit shell spans across the location of Bennett Rd from Shepherds Road in the easter side for the full width of the paddock. On the western side of the paddock there will be various stockpiles and hardstands associated with the mine. operation which will impact the existing road • It is proposed that this section of Bennett Rd is closed over this period in accordance with the mine road closure strategy. • Closure of the road during this period will avoid the risk people and impact the land use and amenity of access along the road. Native vegetation within the road corridor will be removed. Any services within the road corridor will be impacted; and • Rehabilitation and restoration of the road and associated service may be affected by subsequent ground movement related to deformation and settlement. • Refer to Technical Report E. Traffic and Transport	Low	R, P
Area 1 – sensitive receptor No. 2 – Farm residence east of Shepherds Road	• The proposed pit will be located to the east of the farm residence which is located to the immediate east of Shepherds Road. • A slope failure in the pit wall might cause ground movement that could impact the road and if large enough the farm residence. • Ground movement from a slope failure in the pit wall may damage the residence and contribute a risk to the public and the property	Non-Credible Event	O

Risk ID	Potential threat and effects on the environment	Residual risk rating	Mine stage for which ground movement may contribute harm
Area 3 - sensitive receptor No. 3 - Sensitive vegetation Area 3	• There are areas of remnant vegetation along road reserves and a small number of areas of remnant vegetation within the mine site area. • A tree protection zone has been identified around these the remanent vegetation. • The mine pit wall crest is located 25m from the proposed mine site boundary for all Area 3 pit shells. • There is a risk that a pit wall slope failure could extend into the tree protection zone. • Potential ground movement may cause harm through undermining native vegetation or altering soil parameters including moisture. • Refer to Technical Report A Flora Vegetation	Low	O
Area 3 - sensitive receptor No. 4 - Thompsons Road which bisects the proposed mine	• The proposed mine pit shell spans across approximately 1km of Thompson Rd which will be affected by mining, tailings deposition and rehabilitation for approximately 12-18 months. • On completion of the mining in that vicinity it is intended to return the area to its pre mining landform in accordance with the rehabilitation plan. • Ground movement from subsidence of rehabilitated ground may damage the road, services restored within the easement and contribute risk to public. • Closure of the road during this period will avoid the risk people. Mine operations will completely remove the section of the existing road impacting the land use and amenity of access along the road. • Native vegetation within the road corridor will be removed. Any services within the road corridor will be impacted; and • Rehabilitation and restoration of the road and associated services may be affected by subsequent ground movement related to deformation and settlement. • Refer to Technical Report E. Traffic and Transport	Low	R, P

Risk ID	Potential threat and effects on the environment	Residual risk rating	Mine stage for which ground movement may contribute harm
Sensitive receptor No. 5 - Mine area as private property after rehabilitation and closure	▪ Rehabilitated areas will be returned to the original landform as broad acre farming. ▪ Ground movement of the rehabilitated area may result in harm of the landform through settlement of the underlying replaced material; and ▪ Ground movement of the rehabilitated area may alter surface water pathways and may lead to erosion and expose dispersive soil	Low	R, P

Legend: **C:** Construction Phase **O:** Operations Phase **R:** Rehabilitation Phase **P:** Post Closure

Figure 10-1: Area 1 receptors vulnerable to ground movement within current risk criteria buffer distances

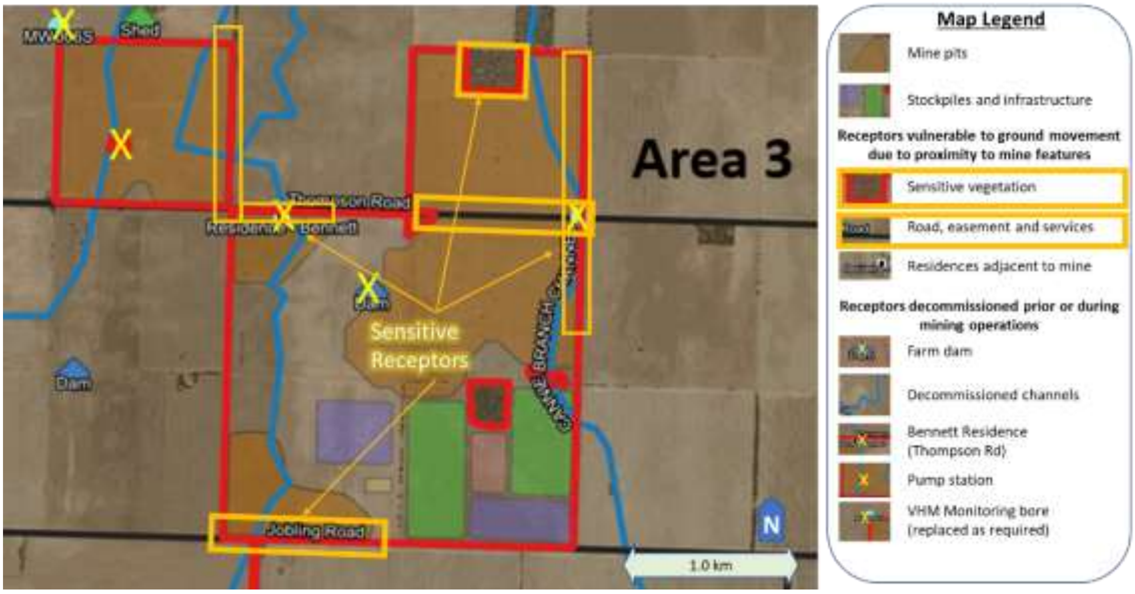

Figure 10-2: Area 3 receptors vulnerable to ground movement within current risk criteria buffer distances

Detail on the potential impacts on the sensitive receptors and mitigation measures recommended for implementation to reduce the risk as low as practicable are further described in the following sections.

10.1 Area 1 sensitive receptor No. 1 – Bennett Residence Shepherd Road - Eastern side of proposed mine operation

- The farm residence to the east of Shepherd Road (Figure 10-3) is considered a sensitive receptor which may be vulnerable to effects from ground movement.
- Potential ground movement may cause harm through altering soil material properties or failures impacting infrastructure support and foundations including access roads and residence and fam building structures.
- The proposed mine pit shell east of the residence has a proposed maximum depth of less than 25m. The modelled buffer zone for a 30m deep pit is 10m calculated for a FoS of 1.6 and a 5% PoF (Table 9-1). Refer to Appendix B section 8 Geotechnical engineering assessment (pitt&sherry 2022b) for additional information.
- The farm structures are identified to be more than 75m from the proposed mine operation boundary and in excess of ~120m from the closest point of the pit crest.
- The sensitive receptor is 110m outside of the applicable buffer zone. With implementation of the recommended buffer zones as the proposed mitigation option the consequence and likelihood of harm occurring to the sensitive receptor is considered to be a non-credible risk event and is not assessed further in this report.

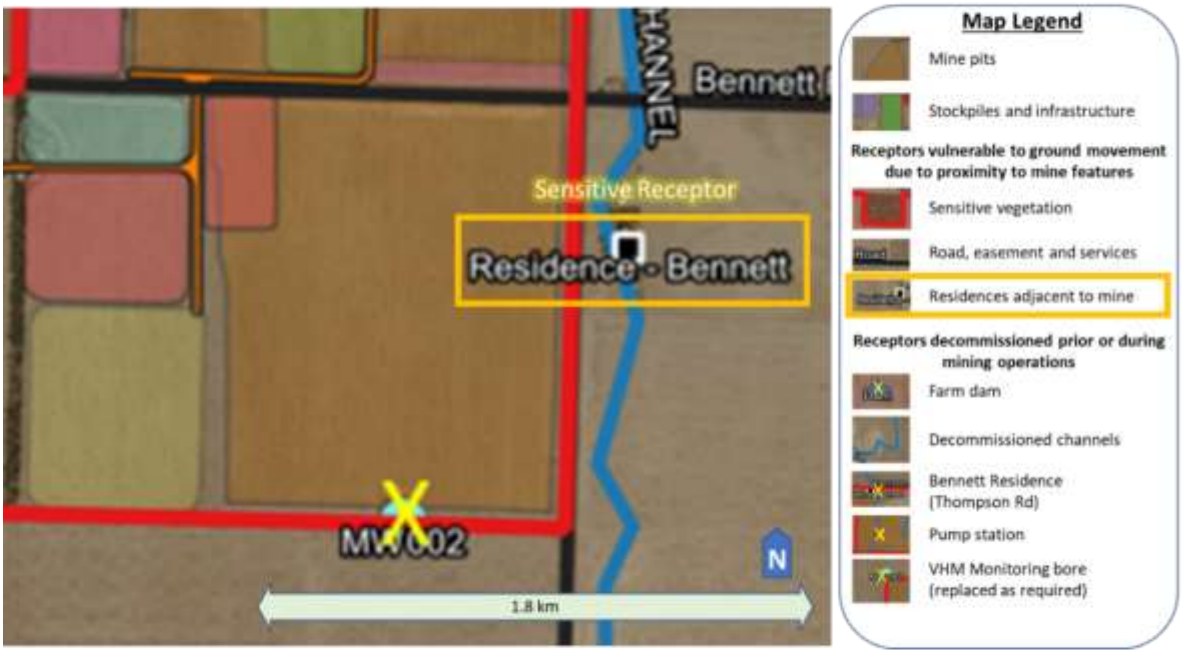

Figure 10-3: Area 1 Main Pit Bennett Residence Shepherds Rd

10.2 Area 1 sensitive receptor No. 2 - Bennett Road which bisects the proposed mine

- The proposed mine pit shell spans across the location of Bennett Road from Shepherds Road in the eastern side for the full width of the paddock. On the western side of the paddock there will be various stockpiles and hardstands associated with the mine operation which will impact the existing road and associated roadside vegetation. Refer to Figure 10-4.
- It is proposed that this section of Bennett Rd is closed over this period in accordance with the mine road closure strategy (Figure 10-4).

- Closure of the road during this period will avoid the risk to people. Given the mine operations will completely remove the section of the existing road contained within the mine pit shell impact to the land use and amenity of access along the road will occur. Native vegetation within the road corridor will be removed. Services which may exist within the road corridor will be impacted.
- The mine plan indicates that the area of the pit shell would be affected by mining, tailings deposition and rehabilitation for approximately 12-18 months at which stage it is intended to return the area to its pre mining landform in accordance with the rehabilitation plan. In addition, the stockpile, processing, and mine access areas will impact the area for 8 years before being rehabilitated to its pre mining landform.
- Closure of the road is not expected to substantially impact travel times for local and through traffic based on the traffic management planning with diversions to be established in accordance with Figure 10-5.

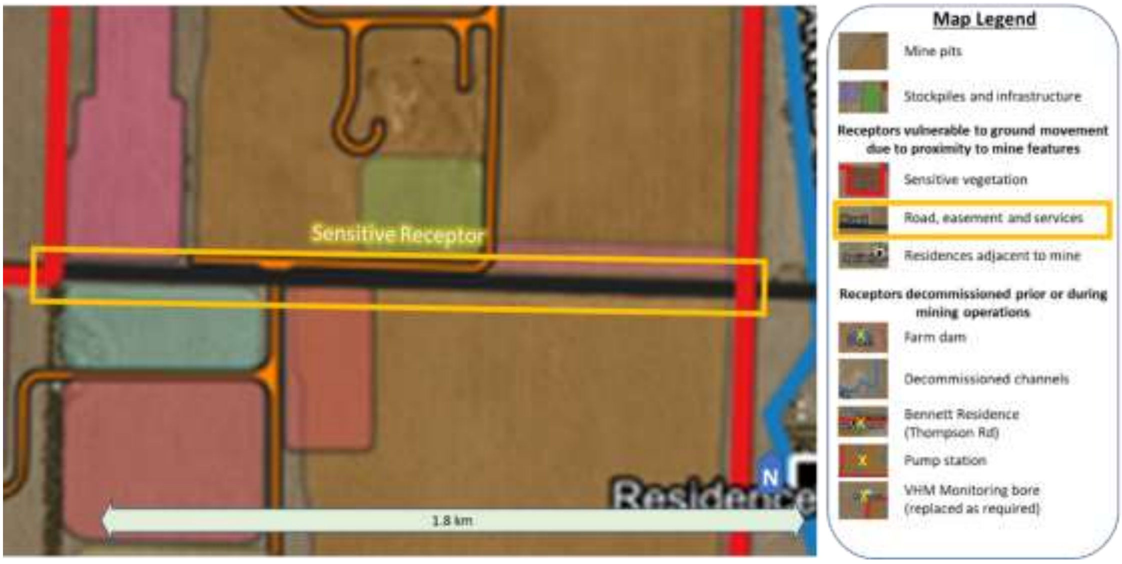

Figure 10-4: Area 1 - Bennett Road location plan of impacted section which bisects the proposed mine

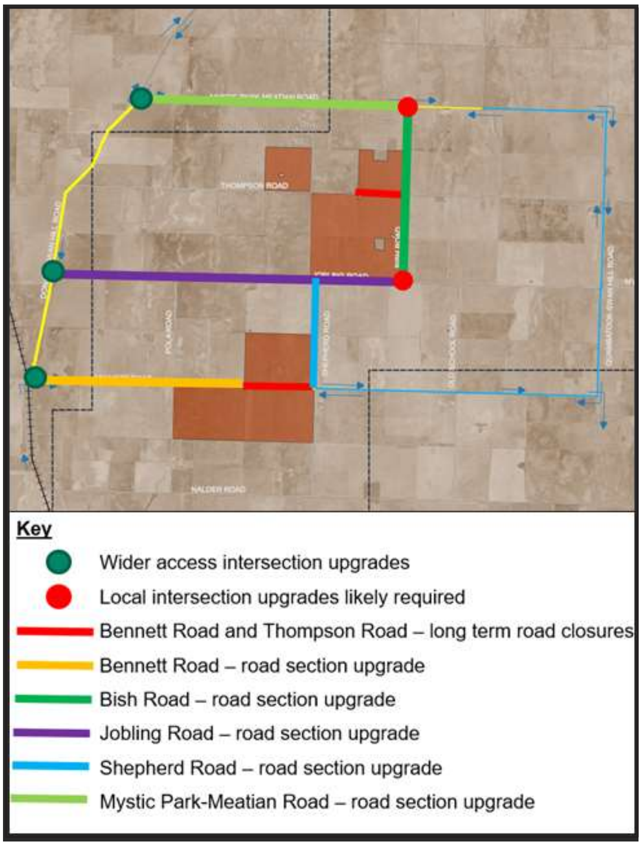

Figure 10-5: Draft Road closure and diversion plan

- On closure of the mine Bennett Road, it is anticipated that reinstatement will be undertaken to a similar road specification as existing in accordance with council standards. The corridor is expected to be rehabilitated in accordance with the rehabilitation plan.
- The potential for ground movement to contribute to environmental harm may occur following completion of rehabilitation and closure mine due to ground settlement of the rehabilitated landscape.
- The Goschen Project proposes to adopt a cyclic approach to mining. As mining advances and an area of the pit is excavated it is then prepared as tailings containment cells. Each tailings containment cell is filled with tailings over a period of months until it reaches its design capacity. During filling the tailing settles and as more tailings are deposited it continues to settle as the water content is either decanted off for reuse or seeps into the pit floor. Once the tailings reach sufficient strength overburden is placed on the tailings as part of the rehabilitation process. The load of the overburden on the tailings continues to compress the tailings.
- The tailings are more compressible than the material used to construct the tailings bund and where the overburden crosses from the tailings to the tailings bund there is a risk of differential settlement.
- The mine life is in the order of 20-25 years. During this time for most cells the majority of the consolidation cycle will have occurred prior to closure.
- Restoration of road networks across the rehabilitated landscape or reuse of the landforms for agricultural use may be exposed to risk from deformation of the surface topography.
- Following rehabilitation, the potential magnitude of differential settlement is assessed as low, less than 100mm and with a transition across the covered subsurface bund walls with differential settlement across a very shallow gradient of 1 in 500.
- The roading is currently dirt surfaced and subject to routine scheduled maintenance activities including regrading as required and consequently any minor settlement which does occur post closure is highly likely to be negligible, inconspicuous, and managed through routing maintenance activities including re-grading, drainage cleaning and maintenance.

- The mine operation methodology for overlying fill depths, placement and compaction is proposed to proceed in accordance with ground control and water management plans (GCMP, GWMP and SWMP). Refer to Appendix E for an outline of the GCMP.
- Post closure monitoring and periodic resurveys are proposed to monitor for any potential surface topographic changes with material regrading and relevelling in the event that threshold triggers for topographic deformation are exceeded.
- The risk of harm post closure is assessed as Low.

With implementation of the recommended mitigations the consequence and likelihood of potential environmental harm from the effects of ground movement is Low.

10.3 Area 3 sensitive receptor No. 3 - Sensitive vegetation Area 3

These sensitive receptors comprise areas of high value vegetation where the tree protection zone intersects or crosses the proposed mine site boundary and in some localised areas encroach on the modelled separation buffers as illustrated in Figure 10-6.

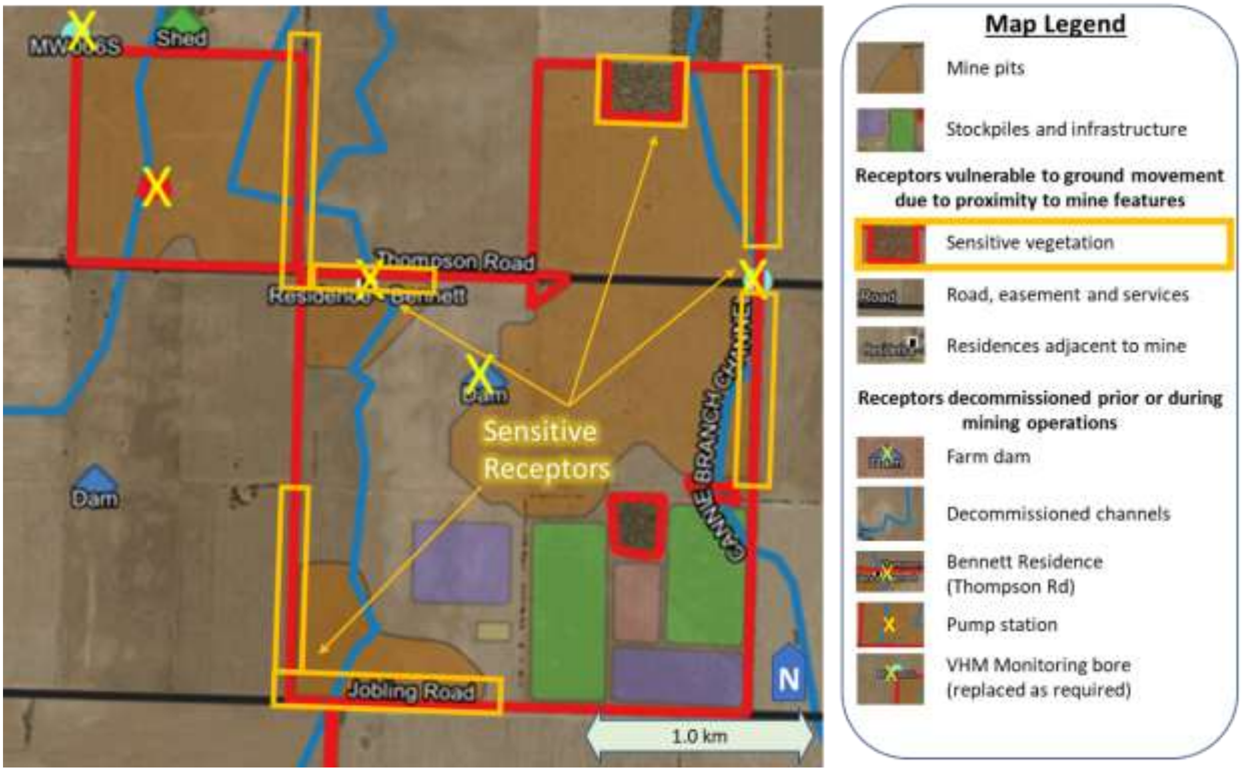

Figure 10-6: Sensitive vegetation receptors Area 3

- Potential ground movement may cause harm through undermining native vegetation or altering soil parameters including moisture.
- The proposed mine pit shell at the northern end of Area 3 main pit has a depth ranging from 37m to 42m. For a 40m deep pit a buffer distance of 15m for < 40m depth and 20m for >40m depth but <47m has been calculated for a FoS of 1.6 and a 5% PoF. Refer to Appendix B section 8 Geotechnical engineering assessment (pitt&sherry 2022b) for additional information.
- Portions of the tree protection zones occur at distances less than the recommended buffer from the crest of the proposed pit slope. Consequently, the outside extremity of the vegetated area in width may be exposed to soil movement with a factor of safety of less than 1.6.

- The pit wall in this area would be open for approximately 12 months noting that the progressive mine/fill/rehabilitation cycle means that the period until a substantial depth of tailings is placed back into the pit void is expected to occur within approximately 6 months of the ore extraction.
- It is considered unlikely that the potential environmental impact related to a slope failure impacting the sensitive receptor will occur; and
- The preferred FoS of 1.6 and the resulting buffers chosen for the Goschen mine project have been conservatively chosen. This in conjunction with monitoring on the effected slopes for the period from initial mining to the point where tailings deposition has reduced the effective pit wall height to <25m will mitigate the risk to an acceptable level.

Mitigation options that may be considered include a specific focus when implementing the ground control management plan and water management plans (GCMP, GWMP and SWMP) on the pit slope boundaries in the vicinity of the sensitive vegetation to enable observation of potential triggers and implementation of action prior to harm occurring. Refer to Appendix E for an outline of the proposed GCMP.

With implementation of the recommended mitigation options the consequence and likelihood of harm occurring to the sensitive receptor is reduced and the risk is rated as Low.

10.4 Area 3 sensitive receptor No. 4 - Thompsons Road which bisects the proposed mine

- The proposed mine pit shell spans across approximately 1km of Thompson Road.
- The mine plan indicates that the area of the pit shell would be affected by mining, tailings deposition and rehabilitation for approximately 12-18 months at which stage it is intended to return the area to its pre mining landform in accordance with the rehabilitation plan. In addition, the stockpile, processing, and mine access areas will impact the area for 8 years before being rehabilitated to its pre mining landform.

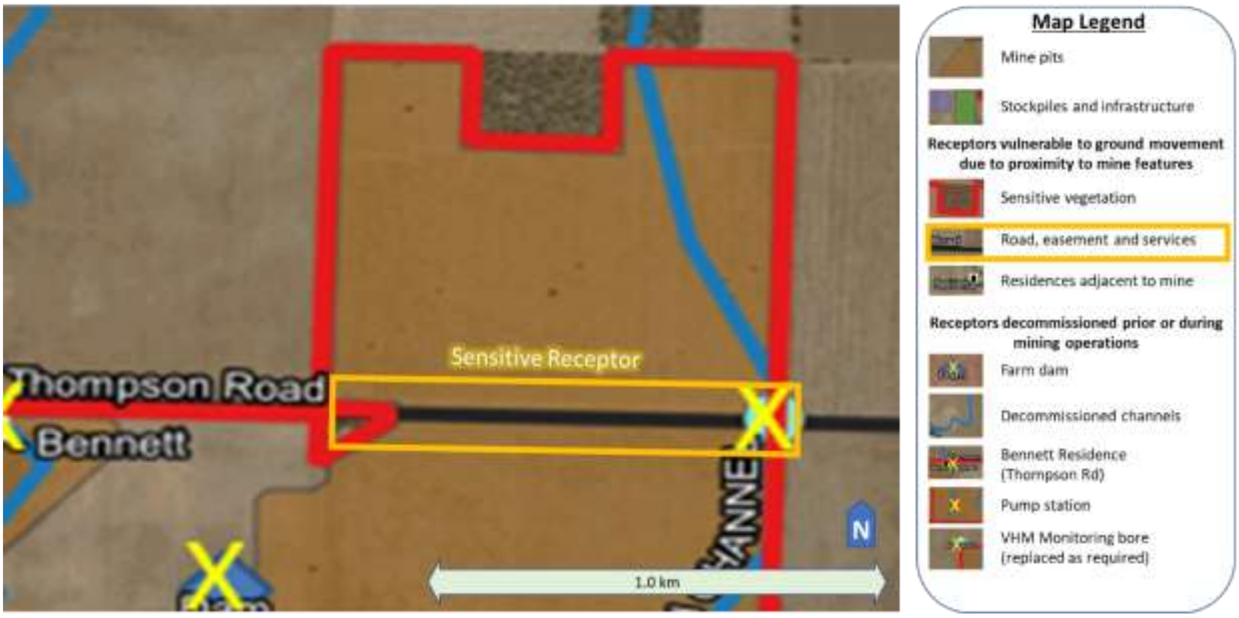

Figure 10-7: Area 3 - Thompson Road location plan of impacted section which bisects the proposed mine

- Closure of the road during this period will avoid exposing members of the public to harm. Given the mine operations will completely remove the section of the existing road contained within the mine pit shell. This will impact the land use and amenity of access along the road. Native vegetation within the road corridor will be removed. Any services within the road corridor will be impacted.

- It is proposed that this section of Thompson Road is closed over this period in accordance with the mine road closure strategy.
- Closure of the road is not expected to substantially impact travel times for local and through traffic based on the traffic management plan (refer to previous Figure 10-5).
- On closure of the mine, it is expected that Thompson Road would be reinstated to a similar specification as existing in accordance with council's standards. The overall corridor is likely to be rehabilitated in accordance with the rehabilitation plan.
- Closure of the road during this period will avoid the risk to people. Given the mine operations will completely remove the section of the existing road contained within the mine pit shell impact to the land use and amenity of access along the road will occur. Native vegetation within the road corridor will be removed. Services which may exist within the road corridor will be impacted.
- The potential for ground movement to contribute to environmental harm may occur following completion of rehabilitation and closure mine due to ground settlement of the rehabilitated landscape.
- The Goschen mine proposes to adopt a cyclic approach to mining. As mining advances and an area of the pit is excavated it is then prepared as tailings containment cells. Each tailings containment cell is filled with tailings over a period of months until it reaches its design capacity. During filling the tailing settles and as more tailings are deposited it continues to settle as the water content is either decanted off for reuse or seeps into the pit floor. Once the tailings reach sufficient strength overburden is placed on the tailings as part of the rehabilitation process. The load of the overburden on the tailings continues to compress the tailings.
- The tailings are more compressible than the material used to construct the tailings bund and where the overburden crosses from the tailings to the tailings bund there is a risk of differential settlement.
- The mine life is in the order of 20-25 years. During this time for most cells the majority of the consolidation cycle will have occurred prior to closure.
- Restoration of road networks across the rehabilitated landscape or reuse of the landforms for agricultural use may experience deformation of the surface topography.
- Following rehabilitation, the potential magnitude of differential settlement is assessed as low, less than 100mm and with a transition across the covered subsurface bund walls with differential settlement across a very shallow gradient of 1 in 500.
- The roading is currently dirt surfaced and subject to routine scheduled maintenance activities including regrading as required and consequently any minor settlement which does occur post closure is highly likely to be negligible, inconspicuous, and managed through routing maintenance activities including re-grading, drainage cleaning and maintenance.
- The mine operation methodology for overlying fill depths, placement and compaction is proposed to proceed in accordance with ground control and water management plans (GCMP, GWMP and SWMP). Refer to Appendix E for an outline of the GCMP.
- Post closure monitoring and periodic resurveys are proposed to monitor for any potential surface topographic changes with material regrading and relevelling in the event that threshold triggers for topographic deformation are exceeded.
- The risk of harm post closure is assessed as Low.

The consequence and likelihood of potential harm is likely to be further reduced with implementation of the above recommended mitigations.

10.5 Sensitive receptor No. 5 - Mine area as private property after rehabilitation and closure

It is intended that rehabilitated areas will be returned to the original landform as broad acre farming. This is described in detail in Pitt&sherry 2023.

- The potential for ground movement to contribute to environmental harm may occur following completion of rehabilitation and closure of the mine due to ground settlement of the rehabilitated landscape.
- The Goschen mine proposes to adopt a cyclic approach to mining. As mining advances and an area of the pit is excavated it is then prepared as tailings containment cells. Each tailings containment cell is filled with tailings over a period of months until it reaches its design capacity. During filling the tailing settles and as more tailings are deposited it continues to settle as the water content is either decanted off for reuse or seeps into the pit floor. Once the tailings reach sufficient strength overburden is placed on the tailings as part of the rehabilitation process. The load of the overburden on the tailings continues to compress the tailings.
- The tailings are more compressible than the material used to construct the tailings bund and where the overburden crosses from the tailings to the tailings bund there is a risk of differential settlement.
- The mine life is in the order of 20-25 years. During this time for most cells the majority of the consolidation cycle will have occurred prior to closure.
- Following rehabilitation, the potential magnitude of differential settlement is assessed as low, less than 100mm and with a transition across the covered subsurface bund walls with differential settlement across a very shallow gradient of 1 in 500.
- The mine operation methodology for overlying fill depths, placement and compaction is proposed to proceed in accordance with ground control and water management plans (GCMP, GWMP and SWMP). Refer to Appendix E for an outline of the GCMP.
- Rehabilitated areas of the mine will be handed back for broad acre farming when the rate of settlement has reduced to handback trigger levels that will form one aspect of the GCMP and after any pre-handback adjustment to the topography are carried out to ensure the handback criteria are met.
- The mine will only had back land once the handback criteria have been achieved.
- Post closure monitoring and periodic resurveys are proposed to monitor for any potential surface topographic changes with material regrading and relevelling in the event that threshold triggers for topographic deformation are exceeded.
- The risk of harm post closure is assessed as Low.

The consequence and likelihood of potential harm is likely to be further reduced with implementation of the above recommended mitigations.

11. Summary of mitigation, monitoring, and contingency measures

11.1 Mitigation measures

The mitigation measures that are proposed to avoid, mitigate, or manage potential ground movement impacts associated with the Goschen Project are summarised in Table 11-1: Mitigation measures relevant to ground movement include monitoring and contingency measures.

Table 11-1: Mitigation measures relevant to ground movement

Measure ID	Mitigation measure	Phase
MIT01	**All Pathways** Construction, Operational and Decommissioning Management Plans should be developed and implemented. Plans should be updated during the life of the project to reflect changes to site layout and risk profile. Plans to include • Ground Control Management Plan (GCMP) • Surface Water Management Plan (SWMP) • Groundwater monitoring and management plans (GWMP) An outline of the GCMP is provided in Appendix E	C O R
Slope Collapse/Slide - Pathway 1 (above ground) and Pathway 2 (sub surface) • 3.C.A1 - Sensitive Receptor within site or adjacent to site • 10.5 - Sensitive receptor No. 5 - Mine area as private property after rehabilitation and closure • 10.3 - Area 3 sensitive receptor No. 3 - Sensitive vegetation Area 3		
MIT02	Incorporate comprehensive geotechnical design methodology and review using conservative elastic parameters and incorporate sensitivity assessments - Refer to Appendix B and Section 4.2.1	O
MIT03	Implement pit and stockpile buffer zones from sensitive receptors Refer Section 9.2	O
MIT04	Mine operation planning to integrate ground and surface water monitoring in accordance with MIT01 to ensure mine pit floor is above groundwater table and surface flows are directed to minimise interaction with exposed slopes to avoid water altering material properties - Refer Section 9.2.4	O
Deformation/Settlement/Heave - Pathway 4 • 3.D.A3 - Sensitive receptor within site or adjacent to site • 10.2 - Area 1 sensitive receptor No. 2 - Bennett Road which bisects the proposed mine • 10.4 - Area 3 sensitive receptor No. 4 - Thompsons Road which bisects the proposed mine		
MIT05	Undertake comprehensive tailings material properties and assessment program - Refer 9.2.4	R
MIT06	Undertake comprehensive dewatering/settlement analysis for tailing and overburden - Refer 9.2.4	R
MIT07	Revise tailing management strategy incorporating the results of MIT05 and MIT06	R
Dispersive Soils – Pathway 5 • 1.C.A4 - Public Road/land and public services (overhead or subsurface) on undisturbed ground • 3.C.A4 - Sensitive receptor within site or adjacent to site • 10.2 - Area 1 sensitive receptor No. 2 - Bennett Road which bisects the proposed mine • 10.4 - Area 3 sensitive receptor No. 4 - Thompsons Road which bisects the proposed mine		

Measure ID	Mitigation measure	Phase
MIT08	Ensure that exposed soils are treated as soon as practical: Test material exposed on site for dispersivity and treat on a case-by-case basis in accordance with a CMP or the GCMP • Basins internal exposed upper face - use RCEP or hydro mulch/reseed if program permits • Stockpiles topsoil and reseed/hydro mulch. Treat with gypsum Refer to Section 9.2.5 and EES Technical Report – SLR - M. Soils and Land Resources. (SLR Consulting 2023)	C O R
MIT9	Ensure all surface water is managed for temporary and long term situations • Construct benches to fall away from the pit and all construct all pit wall drainage to reduce velocities and control scour • Install silt/erosion control structures such as velocity check barriers, silt fencing and energy dissipaters • Direct all surface water runoff to controlled discharges Refer to Section 9.2.5 and EES Technical Report – SLR - M. Soils and Land Resources. (SLR Consulting 2023)	C O R

Legend: **C:** Construction Phase **O:** Operations Phase **R:** Rehabilitation Phase

11.2 Monitoring measures

The monitoring measures that are proposed to assess ground movement impacts associated with the Goschen Project are summarised in Table 11-2.

Table 11-2: Monitoring measures relevant to ground movement

Measure ID	Monitoring measure	Phase
Collapse ground movement scenario - Monitoring *(All receptors and pathway 1 and pathway 2)*	• Recommend that a slope monitoring system be implemented on pit wall slopes to record slope movements of >2mm and present the data to a centralised managed hub • Recommend that a daily visual monitoring process be implemented to record deterioration in pit wall and stockpile slopes, benches and drains • Recommended that material parameters used in design are verified by ongoing field inspection, laboratory testing prior construction of stockpiles and pit slopes.	O
Deformation / Settlement / Heave ground movement scenario - Monitoring *(All receptors and pathway 4)*	• Recommend that competent geotechnical expert verify ground conditions following completion of rehabilitation and prior to mine closure • Recommend that a weekly settlement monitoring system is implemented on rehabilitated areas to record settlement trends over time with an accuracy of <2mm • Recommended that material parameters used in design are verified by ongoing field inspection and laboratory testing during tailings placement and rehabilitation	O
Dispersive soil contributing to ground movement scenario - Monitoring *(All receptors and pathway 5)*	• Recommend that a daily visual monitoring process be implemented to record deterioration in the surface of areas prone to erosion • Recommend that a daily visual monitoring process be implemented to verify that surface water drainage systems operate as designed and controlled discharge is maintained	C O R

Legend: **C:** Construction Phase **O:** Operations Phase **R:** Rehabilitation Phase

This document and associated factual and interpretive report attached as Appendix B will inform the measures within the GCMP. An outline of the proposed GCMP is provided as Appendix E.

12. Summary

This study has assessed the impacts of construction and operation of the Goschen Project for potential geotechnical risks and ground movement impacts on assets and values to be protected.

The significance of the impacts has been assessed in accordance with the evaluation framework, based on applicable legislation, policy and standards and the evaluation objectives and environmental significance guidelines arising from the government terms of reference established to guide the assessments.

In relation to the evaluation objectives set out in the EES Scoping Requirements, the project would not have significant impacts due to ground movement for the following reasons:

- The underlying theme of the mine design has been to utilise the space within the mine lease efficiently and to contain potential hazards to within the mine lease
- The mine design includes comprehensive geotechnical investigations, insitu and laboratory testing for geotechnical material properties, conservative selection of material properties for design purposes and detailed design focussed on the key risk pathways of:
    - Slope Stability
    - Settlement/heave
    - Dispersive Soils
- Mine design is to maintain the pit floor above the water table to remove the risk of liquefaction of pit wall or stockpile slopes and any localised groundwater mounding will be managed through local dewatering of the active pit area.
- All tailings will be deposited in a sub-surface tailings storage facility and avoids the risk to sensitive receptors from any potential failure of tailing containment with no risks or consequences outside of the pit
- Based on the geotechnical analysis safe buffer zones have been established that provide a factor of safety of a slip exceeding the safe buffer distance of >1.6 and a PoF of 5% which given the conservative selection of the base material properties used in design is considered conservative and in many areas around the proposed mine means that potential events causing ground movement impacting sensitive receptors are non-credible events.
- All residual risks to sensitive receptors due to ground movement are assessed as Low.
- The use of the mine pit void for tailings storage and consolidation allows early rehabilitation of the disturbed area and once settlement reaches trigger levels will be returned to its original broad acre farming. This progressive rehabilitation and handback incorporate principles for sustainable.

13. Conclusion

The purpose of this technical report is to document assessment of geotechnical risks, defined as impacts from potential ground movement, associated with the Goschen Project to inform the preparation of the EES required for the project.

In accordance with the Mineral Resources (Sustainable Development) Act 1990 (MRSDA) the Goschen project is assessed as providing the following key outcomes:

- Safe – The geotechnical risk assessment has found that the Goschen project is a safe project. If the recommendations in this report are implemented the project will not pose a risk to the public or to properties adjacent to the proposed mine site, due to slope failures, settlement, or dispersive soils.
- Stable - The stockpiles and pit walls have been designed to a conservative factor of safety (FoS) of 1.6 using conservatively chosen material properties derived from geotechnical investigations of the subsurface strata and will be stable.
- Sustainable - The mine has been designed for all tailings to be managed in sub surface tailings storage facilities and these storages will be progressively rehabilitated to their former use as broad acre farming. This provides a sustainable operation benefiting the local community and the state.

14. References

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15. Important information about your ground engineering report

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Goschen Mineral Sands and Rare Earths Project - Environment Effects Statement Geotechnical Impact Assessment

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Goschen Mineral Sands and Rare Earths Project

Environmental Effects Statement
Geotechnical Assessment

Appendices A to E

Prepared for
VHM

Client representative
Bryan Chadwick

Date
15 May 2023

Draft Rev10

Appendices

1. Appendix A – Risk Assessments
2. Appendix B – Geological and Geotechnical Factual and Interpretive Report
3. Appendix C – Design Development of Tailings Storage Facility
4. Appendix D – Seismicity and Earthquake Risk
5. Appendix E – Draft Ground Control Management Plan Outline

1. Appendix A – Risk Assessments

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Ground Movement Risk Assessment

					INITIAL RISK BEFORE CONTROL											RESIDUAL RISK AFTER CONTROL						
					Consequences				Risk			Controls and Contingency				Consequences				Risk		
					Impact Areas				Impact Areas			Mitigation control by location	Mitigation - controlled by design	Monitoring - controlled by human intervention	Contingency - event recognition & response	Impact Areas				Impact Areas		
Event Status	Item Id	Receptor	Vulnerable Receptor	Ground Movement Pathway Description	People	Property	Environment	Likelihood	People	Property	Environment	Protection	Prevention	Monitoring	Detection	People	Property	Environment	Likelihood	People	Property	Environment
Credible Events																						
Credible Event	3.D.A3	3	Sensitive Receptor within site or adjacent to site	Pathway 4 - Deformation/Settlement/Heave - Substantial deformation of rehabilitated ground surface from consolidation of the tailings more than assessed in design, swelling of rehabilitated ground surface from over consolidation of the subgrade under stockpiles and foundation or due to loading from construction plant and process plant foundations caused by static or dynamic loads being higher design allowances.	1	1	3	C	Low	Low	Medium		Mine design recommended to -incorporate comprehensive geotechnical design methodology and review using conservative elastic parameters and incorporate sensitivity assessments - enable pit slopes and stockpile locations to be separated by suitable buffer distance from vulnerable receptors - ensure mine pit floor is above groundwater table - consideration force due to earthquake loading in slope/batter design where design life > 2 year. Recommendation that Ground Water Monitoring Plan (GWMP), Surface Water Monitoring Plan (SWMP) and Ground Control Management Plan (GCMP) are established	Recommend that monitoring in accordance with the GCMP, SWMP and GWMP be implemented Recommend that competent geotechnical expert verify ground conditions following completion of rehabilitation and prior to mine closure Recommend that settlement monitors be established and monitored to observe surface topographic levels	Recommend that threshold triggers of the GCMP, GWMP and SWMP are adopted and a Survey reconciliation is conducted at the end of construction as part of the construction phase handover process Recommend that abnormalities, departures for expected situations or unplanned for contingencies be managed with timely risk-based geotechnical investigation and implementation of appropriate rectification, remediation or other actions as required Recommend that post closure bond be established to include cost of regrading and releveling surfaces where settlement or deformation is unexpected and varies from planned design	1	1	1	D	Low	Low	Low
Credible Event	3.C.A1	3	Sensitive Receptor within site or adjacent to site	Pathway 1 (above ground) and Pathway 2 (sub surface) - Slope Collapse/Slide - Slope collapse of pit walls caused by intersection of weaker than expected material, construction not to design, encounters area of stormwater softened material or ground water level is higher than expected - Slope collapse of the stockpile batters caused by more variable and weaker than expected in design, construction not to design, encounters area of stormwater softened material, ground water level is higher than expected, uncontrolled overland flow causing erosion of the bench/batter - Slope collapse or substantial deformation of the slope or batter caused by inadequate maintenance of drainage system allowing uncontrolled ponding or erosion	1	1	2	D	Low	Low	Low	Geological setting and existing lithologies identified to date and expected to be encountered within the mine area suggests that significant weak structures or material with significantly different geotechnical parameters to those identified and considered to date are unlikely	Mine design recommended to -incorporate comprehensive geotechnical design methodology and review using conservative elastic parameters and incorporate sensitivity assessments - enable pit slopes and stockpile locations to be separated by suitable buffer distance from vulnerable receptors - ensure mine pit floor is above groundwater table - consideration force due to earthquake loading in slope/batter design where design life > 2 year. Recommendation that Ground Water Monitoring Plan (GWMP), Surface Water Monitoring Plan (SWMP) and Ground Control Management Plan (GCMP) are established	Recommend that monitoring in accordance with GCMP, SWMP and GWMP be implemented Recommended that material parameters used in design are verified by field inspection, laboratory testing prior construction of stockpiles, foundations and pit slopes	Recommend that threshold triggers of the GCMP, GWMP and SWMP are adopted and a Survey reconciliation is conducted at the end of construction as part of the construction phase handover process Recommend that abnormalities, departures for expected situations or unplanned for contingencies be managed with timely risk-based geotechnical investigation and implementation of appropriate rectification, remediation or other actions as required	1	1	2	D	Low	Low	Low
Credible Event	3.C.A4	3	Sensitive Receptor within site or adjacent to site	Pathway 5- Dispersive soils - Exposure of dispersive subsoil to rainfall events on open mine pit faces, stockpile slopes, detention basins or pond batters during mining operations resulting in erosion and soil loss and potential collapse. - Exposure of dispersive subsoil to rainfall events during trenching and backfilling operations as part of the pump station, pipeline and local road upgrade construction works resulting in erosion and soil loss and potential collapse.	1	2	3	C	Low	Medium	Medium		Recommendation that a Surface Water Monitoring Plan (SWMP) and Ground Control Management Plan (GCMP) are established including the recommendations of the soils specialist report to be incorporated in the construction specification and siteworks management plans.	Recommend that monitoring in accordance with the GCMP, SWMP be implemented	Recommend that threshold triggers of the GCMP and SWMP are adopted. Review performance of slopes, excavations and disturbed areas for evidence of erosion	1	2	2	D	Low	Low	Low
Credible Event	1.C.A4	1	Public Road/land and public services (overhead or subsurface) on undisturbed ground	Pathway 5- Dispersive soils - Exposure of dispersive subsoil to rainfall events on open mine pit faces, stockpile slopes, detention basins or pond batters during mining operations resulting in erosion and soil loss and potential collapse. - Exposure of dispersive subsoil to rainfall events during trenching and backfilling operations as part of the pump station, pipeline and local road upgrade construction works resulting in erosion and soil loss and potential collapse.	1	2	3	C	Low	Medium	Medium		Recommendation that a Surface Water Monitoring Plan (SWMP) and Ground Control Management Plan (GCMP) are established including the recommendations of the soils specialist report to be incorporated in the construction specification and siteworks management plans.	Recommend that monitoring in accordance with the GCMP, SWMP be implemented	Recommend that threshold triggers of the GCMP and SWMP are adopted. Review performance of slopes, excavations and disturbed areas for evidence of erosion	1	2	2	D	Low	Low	Low
Non Credible Events																						
Non Credible Event	1.C.A1	1	Public Road/land and public services (overhead or subsurface) on undisturbed ground	Pathway 1 (above ground) and Pathway 2 (sub surface) - Slope Collapse/Slide - Slope collapse of pit walls caused by intersection of weaker than expected material, construction not to design, encounters area of stormwater softened material or ground water level is higher than expected - Slope collapse of the stockpile batters caused by more variable and weaker than expected in design, construction not to design, encounters area of stormwater softened material, ground water level is higher than expected, uncontrolled overland flow causing erosion of the bench/batter - Slope collapse or substantial deformation of the slope or batter caused by inadequate maintenance of drainage system allowing uncontrolled ponding or erosion								Based on the current project design, investigations and analysys carried out this event is assessed to not create a credible risk of a slope failure impacting a sensitive receptor and has not been included in the risk assessment		Recommend that monitoring in accordance with GCMP, SWMP and GWMP be implemented Recommended that material parameters used in design are verified by field inspection, laboratory testing prior construction of stockpiles, foundations and pit slopes	Recommend that threshold triggers of the GCMP, GWMP and SWMP are adopted and a Survey reconciliation is conducted at the end of construction as part of the construction phase handover process Recommend that abnormalities, departures for expected situations or unplanned for contingencies be managed with timely risk-based geotechnical investigation and implementation of appropriate rectification, remediation or other actions as required							
Non Credible Events	3.C.A1	3	Sensitive Receptor within site or adjacent to site	Pathway 1 (above ground) and Pathway 2 (sub surface) - Slope Collapse/Slide - Slope collapse of pit walls caused by intersection of weaker than expected material, construction not to design, encounters area of stormwater softened material or ground water level is higher than expected - Slope collapse of the stockpile batters caused by more variable and weaker than expected in design, construction not to design, encounters area of stormwater softened material, ground water level is higher than expected, uncontrolled overland flow causing erosion of the bench/batter - Slope collapse or substantial deformation of the slope or batter caused by inadequate maintenance of drainage system allowing uncontrolled ponding or erosion								Based on the current project design, investigations and analysys carried out this event is assessed to not create a credible risk of a slope failure impacting a sensitive receptor and has not been included in the risk assessment		Recommend that monitoring in accordance with GCMP, SWMP and GWMP be implemented Recommended that material parameters used in design are verified by field inspection, laboratory testing prior construction of stockpiles, foundations and pit slopes	Recommend that threshold triggers of the GCMP, GWMP and SWMP are adopted and a Survey reconciliation is conducted at the end of construction as part of the construction phase handover process Recommend that abnormalities, departures for expected situations or unplanned for contingencies be managed with timely risk-based geotechnical investigation and implementation of appropriate rectification, remediation or other actions as required							
Non Credible Event	2.C.A1	2	Private property	Pathway 1 (above ground) and Pathway 2 (sub surface) - Slope Collapse/Slide - Slope collapse of pit walls caused by intersection of weaker than expected material, construction not to design, encounters area of stormwater softened material or ground water level is higher than expected - Slope collapse of the stockpile batters caused by more variable and weaker than expected in design, construction not to design, encounters area of stormwater softened material, ground water level is higher than expected, uncontrolled overland flow causing erosion of the bench/batter - Slope collapse or substantial deformation of the slope or batter caused by inadequate maintenance of drainage system allowing uncontrolled ponding or erosion								Based on the current project design, investigations and analysys carried out this event is assessed to not create a credible risk of a slope failure impacting a sensitive receptor and has not been included in the risk assessment		Recommend that monitoring in accordance with GCMP, SWMP and GWMP be implemented Recommended that material parameters used in design are verified by field inspection, laboratory testing prior construction of stockpiles, foundations and pit slopes	Recommend that threshold triggers of the GCMP, GWMP and SWMP are adopted and a Survey reconciliation is conducted at the end of construction as part of the construction phase handover process Recommend that abnormalities, departures for expected situations or unplanned for contingencies be managed with timely risk-based geotechnical investigation and implementation of appropriate rectification, remediation or other actions as required							
Non Credible Event	1.L.A2	1	Public Road/land and public services (overhead or subsurface) on undisturbed ground	Pathway 3 - Earthquake/Liquefaction - Slope collapse of pit walls and batter slopes caused by earthquake/ ground acceleration and elevated water table greater than design								Based on the current project design, investigations and analysys carried out this event is assessed to not create a credible risk of a slope failure impacting a sensitive receptor and has not been included in the risk assessment		Recommend that monitoring in accordance with GCMP, SWMP and GWMP be implemented	Recommend that any earthquake events felt by site personnel or reported locally and regionally trigger an immediate stop work. Recommend that a competent geotechnical personnel review all exposed faces and slopes. Any departure of observations or instrumentation responses from expected conditions to be managed through appropriate actions in the GCMP, SWMP or GWMP							
Non Credible Event	2.L.A2	2	Private property	Pathway 3 - Earthquake/Liquefaction - Slope collapse of pit walls and batter slopes caused by earthquake/ ground acceleration and elevated water table greater than design								Based on the current project design, investigations and analysys carried out this event is assessed to not create a credible risk of a slope failure impacting a sensitive receptor and has not been included in the risk assessment		Recommend that monitoring in accordance with GCMP, SWMP and GWMP be implemented	Recommend that any earthquake events felt by site personnel or reported locally and regionally trigger an immediate stop work. Recommend that a competent geotechnical personnel review all exposed faces and slopes. Any departure of observations or instrumentation responses from expected conditions to be managed through appropriate actions in the GCMP, SWMP or GWMP							

Ground Movement Risk Assessment

					INITIAL RISK BEFORE CONTROL											RESIDUAL RISK AFTER CONTROL						
					Consequences				Risk			Controls and Contingency				Consequences				Risk		
					Impact Areas				Impact Areas			Mitigation control by location	Mitigation - controlled by design	Monitoring - controlled by human intervention	Contingency - event recognition & response	Impact Areas				Impact Areas		
Event Status	Item Id	Receptor	Vulnerable Receptor	Ground Movement Pathway Description	People	Property	Environment	Likelihood	People	Property	Environment	Protection	Prevention	Monitoring	Detection	People	Property	Environment	Likelihood	People	Property	Environment
Non Credible Event	3.L.A2	3	Sensitive Receptor within site or adjacent to site	Pathway 3 - Earthquake/Liquefaction - Slope collapse of pit walls and batter slopes caused by earthquake/ ground acceleration and elevated water table greater than design								Based on the current project design, investigations and analysys carried out this event is assessed to not create a credible risk of a slope failure impacting a sensitive receptor and has not been included in the risk assessment		Recommend that monitoring in accordance with GCMP, SWMP and GWMP be implemented	Recommend that any earthquake events felt by site personnel or reported locally and regionally trigger an immediate stop work. Recommend that a competent geotechnical personnel review all exposed faces and slopes. Any departure of observations or instrumentation responses from expected conditions to be managed through appropriate actions in the GCMP, SWMP or GWMP							
Non Credible Event	1.D.A3	1	Public Road/land and public services (overhead or subsurface) on undisturbed ground	Pathway 4 - Deformation/Settlement/Heave - Substantial deformation of rehabilitated ground surface from consolidation of the tailings more than assessed in design, swelling of rehabilitated ground surface from over consolidation of the subgrade under stockpiles and foundation or due to loading from construction plant and process plant foundations caused by static or dynamic loads being higher design allowances.								Based on the current project design, investigations and analysys carried out this event is assessed to not create a credible risk of deformation or heave impacting on sensitive receptor and has not been included in the risk assessment		Recommend that monitoring in accordance with the GCMP, SWMP and GWMP be implemented Recommend that competent geotechnical expert verify ground conditions following completion of rehabilitation and prior to mine closure Recommend that settlement monitors be established and monitored to observe surface topographic levels	Recommend that threshold triggers of the GCMP, GWMP and SWMP are adopted and a Survey reconciliation is conducted at the end of construction as part of the construction phase handover process Recommend that abnormalities, departures for expected situations or unplanned for contingencies be managed with timely risk-based geotechnical investigation and implementation of appropriate rectification, remediation or other actions as required Recommend that post closure bond be established to include cost of regrading and releveling surfaces where settlement or deformation is unexpected and varies from planned design							
Non Credible Event	2.D.A3	2	Private property	Pathway 4 - Deformation/Settlement/Heave - Substantial deformation of rehabilitated ground surface from consolidation of the tailings more than assessed in design, swelling of rehabilitated ground surface from over consolidation of the subgrade under stockpiles and foundation or due to loading from construction plant and process plant foundations caused by static or dynamic loads being higher design allowances.								Based on the current project design, investigations and analysys carried out this event is assessed to not create a credible risk of deformation or heave impacting on sensitive receptor and has not been included in the risk assessment		Recommend that monitoring in accordance with the GCMP, SWMP and GWMP be implemented Recommend that competent geotechnical expert verify ground conditions following completion of rehabilitation and prior to mine closure Recommend that settlement monitors be established and monitored to observe surface topographic levels	Recommend that threshold triggers of the GCMP, GWMP and SWMP are adopted and a Survey reconciliation is conducted at the end of construction as part of the construction phase handover process Recommend that abnormalities, departures for expected situations or unplanned for contingencies be managed with timely risk-based geotechnical investigation and implementation of appropriate rectification, remediation or other actions as required Recommend that post closure bond be established to include cost of regrading and releveling surfaces where settlement or deformation is unexpected and varies from planned design							
Non Credible Event	1.D.A4	1	Public Road/land and public services (overhead or subsurface) on undisturbed ground	Pathway 5- Dispersive soils - Exposure of dispersive subsoil to rainfall events on open mine pit faces, stockpile slopes, detention basins or pond batters during mining operations resulting in erosion and soil loss and potential collapse. - Exposure of dispersive subsoil to rainfall events during trenching and backfilling operations as part of the pump station, pipeline and local road upgrade construction works resulting in erosion and soil loss and potential collapse.								Based on the current project design, investigations and analysys carried out this event is assessed to not create a credible risk impacting on sensitive receptor and has not been included in the risk assessment		Recommend that monitoring in accordance with the GCMP, SWMP be implemented	Recommend that where threshold triggers of the GCMP and SWMP are adopted. Review performance of slopes, excavations and disturbed areas for evidence of erosion							

Tailing Storage Risk Assessment

(Internal Infrastructure and Operations Personnel)

*** People Definition -** Mine operations personnel working in the active mine area

*** Property Definition -** Mine infrastructure working or located in the active mine area

								INITIAL RISK BEFORE CONTROL							Controls and Contingency				RESIDUAL RISK AFTER CONTROL						
								Consequences				Risk							Consequences				Risk		
								Impact Areas				Impact Areas			Mitigation control by location	Mitigation - controlled by design	Monitoring - controlled by human intervention	Contingency - event recognition & response	Impact Areas				Impact Areas		
Item Id	Receptor	Vulnerable Receptor	Element	Ground Movement	Event	Cause	Ground Movement Pathway Description	People*	Property*	Environment	Likelihood	People*	Property*	Environment	Protection	Prevention	Monitoring	Detection	People*	Property*	Environment	Likelihood	People*	Property*	Environment
1.B.A1	1	Critical mine infrastructure or Operations	B	Breach	A1	Slope Stability	Geological design does not adequately account for known geotechnical material properties Geological design does not account for construction not achieving design specification criteria. Can be controlled by additional site investigation and material property testing including sensitivity assessment and through establishment and maintenance of construction phase supervision and testing	5	2	2	B	Very High	Medium	Medium		Recommendation to undertake additional geotechnical investigation of pit wall and sensitivity analysis of pit walls adjacent to tailings bund intersections Recommendation to use conservative geometry and strength parameters, undertake geotechnical investigations into embankment material parameters and foundation parameters, design in accordance with accepted industry standards including FoS i.e. ANCOLD, detailed Technical Specification. Design to be in accordance with ANCOLD guidelines and classification system Recommend that a in pit tailings storage facility is used	Recommendation to develop a Construction Management plan, use independent QA/QC verification of the works, include construction Hold Points at key stages of the works for independent verification by an appropriately experienced Tailings Dams Engineer.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring, standpipe piezometers to monitor groundwater Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	C	Low	Low	Low
1.B.A2	1	Critical mine infrastructure or Operations	B	Breach	A2	Internal erosion through the embankment	Construction QA/QC controls to ensure that materials used in the construction of tailings bunds do not have zones of weak or higher permeability and materials used in the construction of tailings bunds are compliant with Technical Specification. Can be controlled by stability analysis incorporating additional material property testing and sensitivity analysis, and through establishment and maintenance of construction phase supervision and testing	5	2	2	B	Very High	Medium	Medium		Recommendation to use conservative geometry and strength parameters, undertake geotechnical investigations into embankment material parameters and foundation parameters, design in accordance with accepted industry standards including FoS i.e. ANCOLD, detailed Technical Specification Recommendation to ensure that foundation is covered and sealed with tailings to a nominal depth so that there is no exposed sand in foundations prior to increasing water level significantly, undertake modelling of seepage flow to demonstrate that seepage will not adversely affect the foundations. Recommend that a in pit tailings storage facility is used	Recommendation to develop a Construction Management plan, use independent QA/QC verification of the works, include construction Hold Points at key stages of the works for independent verification by an appropriately experienced Tailings Dams Engineer.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	C	Low	Low	Low
1.B.A3	1	Critical mine infrastructure or Operations	B	Breach	A3	Internal erosion through the foundations	Geological design does not adequately account for unknown geotechnical material properties in pit floor and foundations, such as lenses/ zones of silt/clay. Can be controlled by additional site investigation and material property testing and by installation of keyway to minimise potential for seepage along the embankment-foundation contact in accordance with standard industry practice.	5	3	3	B	Very High	High	High		Recommendation to use conservative geometry and strength parameters, undertake geotechnical investigations into embankment material parameters and foundation parameters. Design to be in accordance with ANCOLD guidelines and classification system Recommend that a in pit tailings storage facility is used	Recommendation to develop a Construction Management plan, use independent QA/QC verification of the works, include construction Hold Points at key stages of the works for independent verification by an appropriately experienced Tailings Dams Engineer.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	C	Low	Low	Low
1.B.A4	1	Critical mine infrastructure or Operations	B	Breach	A4	Internal erosion through the dam into the foundations	Geological/geotechnical design does not adequately account for geotechnical material properties in tailings bund construction materials and foundations and their relative compatibility. Construction QA/QC controls to ensure that materials used in the construction of tailings bunds do not have zones of weak or higher permeability and materials used in the construction of tailings bunds are compliant with Technical Specification. Can be controlled by additional site investigation and material property testing and through establishment and maintenance of construction phase supervision and testing	5	3	3	C	Very High	Medium	Medium		Recommendation to use conservative geometry and strength parameters, undertake geotechnical investigations into embankment material parameters and foundation parameters, design in accordance with accepted industry standards. Recommendation to compare gradings of embankment and foundation materials for compatibility to determine whether foundations will act as a critical filter in accordance with accepted industry standards. Design to be in accordance with ANCOLD guidelines and classification system Recommend that a in pit tailings storage facility is used	Recommendation to develop a Construction Management plan, use independent QA/QC verification of the works, include construction Hold Points at key stages of the works for independent verification by an appropriately experienced Tailings Dams Engineer.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	C	Low	Low	Low
1.B.B1	1	Critical mine infrastructure or Operations	B	Breach	B1	Flood Loading	Design flood events exceed decant pond and spillway overtopping leading to scour Excess hydrostatic loading on embankment leads to excess pore pressures, instability and/or breach.	5	3	3	C	Very High	Medium	Medium		Recommendation to design flood diversions around pit to ensure the catchment is minimised Recommendation to ensure an appropriately sized spillway is constructed or an extreme storm storage allowance is designed for and maintained for each tailings embankment, in accordance with ANCOLD Guidelines. Recommend that a in pit tailings storage facility is used	Recommendation to minimise decant pond volume via return water pump to process. Recommendation to cease tailings deposition if decant pond water level is near or exceeds the full supply level i.e. when the dam is spilling. Recommendation to cease operations when flood events are forecast.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring, standpipe piezometers to monitor groundwater Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	C	Low	Low	Low
1.B.C1	1	Critical mine infrastructure or Operations	B	Breach	C1	Seismic Loading	The design earthquake acceleration exceeds the peak ground acceleration used in the design of the tailings bund causing settlement of the bund, loss of freeboard overtopping and scour an/or breach. Can be controlled by sensitivity assessment of the bund to acceleration loads and variations in the saturation of the subgrade and ensure compaction methodology in specification maximises SDMM such that the risk of settlement is minimised.	5	3	3	E	High	Medium	Medium	Water table below pit floor. Unsaturated sands will not liquify	Recommendation to assess expected settlement in accordance with ANCOLD Guidelines, allow significant dry freeboard allowance to accommodate loss of freeboard Recommend that a in pit tailings storage facility is used	Recommendation to evacuate pit after seismic events until bund and slopes have been assessed for deformation.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring, standpipe piezometers to monitor groundwater Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	E	Low	Low	Low
1.B.D1	1	Critical mine infrastructure or Operations	B	Breach	D1	Tailing Impoundment Rim Integrity	Slope design for slumping, over saturation or undermining due to inadequate drained cases mass slump into the tailings impoundment area causing a major reduction in storage volume. A surge of saturated tailings that exceeds the tailings bund capacity to retain Can be controlled by additional site investigation and material property testing including sensitivity assessment and through establishment and maintenance of construction phase supervision and testing of the pit shell and tailings bund	4	2	1	C	High	Medium	Low	Tailings drains into pit floor and any free water decanted as the tailings is deposited. Substantial proportion of the tailings will be partially drained as the tailings reaches full depth leading to a low likelihood of a slump failure creating an overtopping event	Recommendation to use conservative geometry and strength parameters, undertake additional geotechnical investigations into pit material parameters and foundation parameters, design in accordance with accepted industry standards including FoS. Recommendation to undertake comprehensive geotechnical design methodology and review using conservative elastic parameters verified by field and laboratory testing. Recommend that sensitivity assessment is incorporated and additional investigation and testing implemented Recommend that a in pit tailings storage facility is used	Recommendation to slope condition monitoring including face mapping for comparison against design models, stability, erosion and changes in geometry for all slopes/benches as part of site operational risk management plan.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring, standpipe piezometers to monitor groundwater Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	C	Low	Low	Low
1.D.A1	1	Critical mine infrastructure or Operations	D	Deformation / Settlment / Heave	A1	Slope Stability	Geological design does not adequately account for known geotechnical material properties Geological design does not account for construction not achieving design specification criteria. Can be controlled by additional site investigation and material property testing including sensitivity assessment and through establishment and maintenance of construction phase supervision and testing	4	2	1	C	High	Medium	Low		Recommendation to undertake additional geotechnical investigation of pit wall and sensitivity analysis of pit walls adjacent to tailings bund intersections Recommendation to use conservative geometry and strength parameters, undertake additional geotechnical investigations into embankment material parameters and foundation parameters, design in accordance with accepted industry standards including FoS i.e. ANCOLD, detailed Technical Specification Recommend that a in pit tailings storage facility is used	Recommendation to use independent QA/QC verification of the works, include construction Hold Points at key stages of the works for independent verification by an appropriately experienced Tailings Dams Engineer.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring, standpipe piezometers to monitor groundwater Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	C	Low	Low	Low
1.D.A2	1	Critical mine infrastructure or Operations	D	Deformation / Settlment / Heave	A2	Internal erosion through the embankment	Construction QA/QC controls to ensure that materials used in the construction of tailings bunds do not have zones of weak or higher permeability and materials used in the construction of tailings bunds are compliant with Technical Specification. Can be controlled by stability analysis incorporating additional material property testing and sensitivity analysis, and through establishment and maintenance of construction phase supervision and testing	4	2	3	D	High	Low	Medium		Recommendation to use conservative geometry and strength parameters, undertake geotechnical investigations into embankment material parameters and foundation parameters, design in accordance with accepted industry standards including FoS i.e. ANCOLD, detailed Technical Specification Recommendation to ensure that foundation is covered and sealed with tailings to a nominal depth so that there is no exposed sand in foundations prior to increasing water level significantly Recommendation to undertake modelling of seepage flow to demonstrate that seepage will not adversely affect the foundations. Recommend that a in pit tailings storage facility is used	Recommendation to use independent QA/QC verification of the works, include construction Hold Points at key stages of the works for independent verification by an appropriately experienced Tailings Dams Engineer.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring, standpipe piezometers to monitor groundwater Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	D	Low	Low	Low

Tailing Storage Risk Assessment

(Internal Infrastructure and Operations Personnel)

*** People Definition -** Mine operations personnel working in the active mine area

*** Property Definition -** Mine infrastructure working or located in the active mine area

								INITIAL RISK BEFORE CONTROL							Controls and Contingency				RESIDUAL RISK AFTER CONTROL						
								Consequences				Risk							Consequences				Risk		
								Impact Areas				Impact Areas			Mitigation control by location	Mitigation - controlled by design	Monitoring - controlled by human intervention	Contingency - event recognition & response	Impact Areas				Impact Areas		
Item Id	Receptor	Vulnerable Receptor	Element	Ground Movement	Event	Cause	Ground Movement Pathway Description	People*	Property*	Environment	Likelihood	People*	Property*	Environment	Protection	Prevention	Monitoring	Detection	People*	Property*	Environment	Likelihood	People*	Property*	Environment
1.D.A3	1	Critical mine infrastructure or Operations	D	Deformation / Settlment / Heave	A3	Internal erosion through the foundations	Geological design does not adequately account for unknown geotechnical material properties in pit floor and foundations, such as lenses/ zones of silt/clay. Can be controlled by additional site investigation and material property testing and by installation of keyway to minimise potential for seepage along the embankment-foundation contact in accordance with standard industry practice.	4	2	3	C	High	Medium	Medium		Recommendation to use conservative geometry and strength parameters, undertake geotechnical investigations into embankment material parameters and foundation parameters, design in accordance with accepted industry standards including FoS i.e. ANCOLD, detailed Technical Specification Recommendation to compare gradings of embankment and foundation materials for compatibility to determine whether foundations will act as a critical filter in accordance with accepted industry standards. Recommend that a in pit tailings storage facility is used	Recommendation to use independent QA/QC verification of the works, include construction Hold Points at key stages of the works for independent verification by an appropriately experienced Tailings Dams Engineer.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring, standpipe piezometers to monitor groundwater Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	C	Low	Low	Low
1.D.A4	1	Critical mine infrastructure or Operations	D	Deformation / Settlment / Heave	A4	Internal erosion through the dam into the foundations	Geological/geotechnical design does not adequately account for geotechnical material properties in tailings bund construction materials and foundations and their relative compatibility. Construction QA/QC controls to ensure that materials used in the construction of tailings bunds do not have zones of weak or higher permeability and materials used in the construction of tailings bunds are compliant with Technical Specification. Can be controlled by additional site investigation and material property testing and through establishment and maintenance of construction phase supervision and testing	4	2	3	C	High	Medium	Medium		Recommendation to use conservative geometry and strength parameters, undertake geotechnical investigations into embankment material parameters and foundation parameters, design in accordance with accepted industry standards including FoS i.e. ANCOLD, detailed Technical Specification Design to be in accordance with ANCOLD guidelines and classification system Recommend that a in pit tailings storage facility is used	Recommendation to use independent QA/QC verification of the works, include construction Hold Points at key stages of the works for independent verification by an appropriately experienced Tailings Dams Engineer.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring, standpipe piezometers to monitor groundwater Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	C	Low	Low	Low
1.D.B1	1	Critical mine infrastructure or Operations	D	Deformation / Settlment / Heave	B1	Flood Loading	Design flood events exceed decant pond and spillway overtopping leading to scour Excess hydrostatic loading on embankment leads to excess pore pressures, instability and/or breach.	4	2	3	C	High	Medium	Medium		Recommendation to design flood diversions around pit to ensure the catchment is minimised Recommendation to ensure an appropriately sized spillway is constructed or an extreme storm storage allowance is designed for and maintained for each tailings embankment, in accordance with ANCOLD Guidelines. Recommend that a in pit tailings storage facility is used		Recommend monitoring of weather forecast for intense rainfall events and potential floods Recommendation to undertake surveillance – Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines. Increased surveillance during intense rainfall and/or flood events. Recommend preparation of a Dam Safety Emergency Plans to specify how to manage potential emergency situations Recommendation to establish alert hierarchy to ensure flood risk awareness and early warning	1	1	1	C	Low	Low	Low
1.D.C1	1	Critical mine infrastructure or Operations	D	Deformation / Settlment / Heave	C1	Seismic Loading	The design earthquake acceleration exceeds the peak ground acceleration used in the design of the tailings bund causing settlement of the bund, loss of freeboard overtopping and scour an/or breach. Can be controlled by sensitivity assessment of the bund to acceleration loads and variations in the saturation of the subgrade and ensure compaction methodology in specification maximises SDMM such that the risk of settlement is minimised.	5	2	3	E	High	Low	Medium	Water table below pit floor. Unsaturated sands will not liquify	Recommendation to assess expected settlement in accordance with ANCOLD Guidelines, allow significant dry freeboard allowance to accommodate loss of freeboard Design to be in accordance with ANCOLD guidelines and classification system Recommend that a in pit tailings storage facility is used		Recommend implementation of instrumentation – deformation survey targets installation and monitoring Recommend subscribing to seismological monitoring service for alerts for seismic events. Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines. Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	E	Low	Low	Low
1.D.D1	1	Critical mine infrastructure or Operations	D	Deformation / Settlment / Heave	D1	Tailing Impoundment Rim Integrity	Slope design for slumping, over saturation or undermining due to inadequate drained cases mass slump into the tailings impoundment area causing a major reduction in storage volume. A surge of saturated tailings that exceeds the tailings bund capacity to retain Can be controlled by additional site investigation and material property testing including sensitivity assessment and through establishment and maintenance of construction phase supervision and testing of the pit shell and tailings bund	4	2	3	C	High	Medium	Medium	Tailings drains into pit floor and any free water decanted as the tailings is deposited. Substantial proportion of the tailings will be partially drained as the tailings reaches full depth leading to a low likelihood of a slump failure creating an overtopping event	Recommendation to use conservative geometry and strength parameters, undertake additional geotechnical investigations into embankment material parameters and foundation parameters, design in accordance with accepted industry standards including FoS i.e. ANCOLD, detailed Technical Specification Recommendation to undertake a comprehensive geotechnical design methodology and review using conservative elastic parameters verified by field and laboratory testing. Sensitivity assessment incorporated and additional investigation and testing being implemented Design to be in accordance with ANCOLD guidelines and classification system Recommend that a in pit tailings storage facility is used	Recommendation to use independent QA/QC verification of the works, include construction Hold Points at key stages of the works for independent verification by an appropriately experienced Tailings Dams Engineer. Recommendation to undertake slope condition monitoring including face mapping for comparison against design models, stability, erosion and changes in geometry for all slopes/benches as part of site operational risk management plan.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring, standpipe piezometers to monitor groundwater Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	C	Low	Low	Low
1.L.C1	1	Critical mine infrastructure or Operations	L	Earthquake / Liquefaction	C1	Seismic Loading	The design earthquake acceleration exceeds the peak ground acceleration used in the design of the tailings bund causing settlement of the bund, loss of freeboard overtopping and scour an/or breach. Can be controlled by sensitivity assessment of the bund to acceleration loads and variations in the saturation of the subgrade and ensure compaction methodology in specification maximises SDMM such that the risk of settlement is minimised.	5	2	3	E	High	Low	Medium	Water table below pit floor. Unsaturated sands will not liquify	Recommendation to undertake geotechnical investigations to assess the liquefaction risk of the foundations, include construction Hold Points for foundation approval through independent verification by an appropriately experienced Tailings Dams Engineer. Design to be in accordance with ANCOLD guidelines and classification system Recommend that a in pit tailings storage facility is used		Recommend implementation of instrumentation – deformation survey targets installation and monitoring Recommend subscribing to seismological monitoring service for alerts for seismic events. Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines. Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	E	Low	Low	Low
1.S.A1	1	Critical mine infrastructure or Operations	S	Seepage	A1	Slope Stability	Geological design does not adequately account for known geotechnical material properties Geological design does not account for construction not achieving design specification criteria. Can be controlled by additional site investigation and material property testing including sensitivity assessment and through establishment and maintenance of construction phase supervision and testing	5	2	3	D	High	Low	Medium		Recommendation to use conservative geometry and strength parameters, undertake geotechnical investigations into embankment material parameters and foundation parameters, design in accordance with accepted industry standards. Recommendation to compare gradings of embankment and foundation materials for compatibility to determine whether foundations will act as a critical filter in accordance with accepted industry standards Design to be in accordance with ANCOLD guidelines and classification system. Recommend that a in pit tailings storage facility is used	Recommendation to develop a Construction Management plan, use independent QA/QC verification of the works, include construction Hold Points at key stages of the works for independent verification by an appropriately experienced Tailings Dams Engineer.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	D	Low	Low	Low
1.S.E1	1	Critical mine infrastructure or Operations	S	Seepage	E1	Environmental Impact on groundwater	Inadequate hydrological design of impacts of placing saturated tailings back into the pit void causes an increase in water mounding greater than allowed for causing an impact on the local aquifer	2	2	4	C	Medium	Medium	High		Recommendation to document controls to date - Groundwater modelling, testing and assessment of tails materials, Environmental Management Plan. Recommend that a in pit tailings storage facility is used		Recommend implementation of instrumentation – deformation survey targets installation and monitoring Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	2	C	Low	Low	Medium

2. Appendix B – Geological and Geotechnical Factual and Interpretive Report

pitt&sherry

Geotechnical Investigation Factual and Interpretive Report

Goschen Project

Prepared for

VHM

Client representative

Date

17 November 2022

Rev00

Table of Contents

1. Introduction.....6

2. Background.....6

3. Site and Project Overview.....7

4. Literature Review.....9

4.1 Methodology.....9
4.2 Existing Data.....9
4.3 Geology.....9
4.3.1 Regional geology.....9
4.3.2 Local Geology.....10
4.4 Topography.....11
4.5 Geohazards.....13
4.5.1 Landslides.....13
4.5.2 Acid Sulphate Soils.....13
4.5.3 Soil erosion hazard.....14
4.5.4 Potential for Soil Acidification.....14
4.5.5 Dispersive (sodic) soils.....15
4.5.6 Dispersive soils in stockpiles, drains and sediment basins.....15
4.5.7 Soil stripping, handling and stockpiling.....16
4.5.8 Amelioration with gypsum.....16
4.5.9 Drains and sediment basins.....17
4.6 Groundwater.....17

5. Site Investigation.....18

5.1 Assumptions and Limitations.....18
5.2 Methodology.....19
5.3 Observations.....19
5.3.1 Observations 2017.....19
5.3.2 Observations 2019.....22
5.4 Drilling.....23
5.5 Insitu/Field Tests.....25
5.5.1 Standard Penetration Tests.....25
5.5.2 Point Load Tests.....26
5.6 Laboratory Testing.....27

6. Ground Model.....33

6.1.1 Ground model Area 1.....33
6.1.2 Ground model area 3.....37

7. Material Properties.....39

7.1 SPTs.....39
7.1.1 Strength parameters for Cohesive (clay) soils.....39
7.1.2 Strength parameters for non-cohesive (Sand/Silty sand) soils.....39
7.1.3 Point Load Test data analysis.....39
7.1.4 Non cohesive material UCS.....40
7.1.5 Triaxial Test data.....41
7.2 Material Parameter Analysis.....41
7.2.1 Soil strength parameters: U1 - Topsoil.....42
7.2.2 Soil strength parameters: U2 - Clay/Silty Clay.....42
7.2.3 Soil strength parameters selection for U3-Sandy/Silty Clay.....43
7.2.4 Soil strength parameters selection for U4 - Sand layers/ Sandstone.....44
7.2.5 Soil strength parameters selection for U5 - Silty Sand.....45

7.2.6 Selection of Soil Unit weights 46
7.3 Design parameters....................46
8. Geotechnical engineering assessment 47
8.1 Pit depth and design life....................47
8.2 Acceptance criteria 48
8.3 Mine pit wall geometry and Setout/Buffer Zone 54
8.4 Inputs for pit stability 54
8.5 Pit wall stability analysis....................56
8.5.1 Mine pit wall stability and recommended slope profile 56
8.6 Probability of failure assessment....................58
8.7 Recommended pit batter profile 60
8.8 Comparison to RMS, AGS and First Principles Slope Risk Assessment Methodologies....................62
8.9 Topsoil....................65
8.10 Stockpile stability and recommended geometry 65
8.10.1 Topsoil stockpile 67
8.10.2 Clay and Sand overburden stockpile....................67
8.10.3 Surface water drainage bunds for stockpiles 70
8.11 Sediment ponds....................71
9. References....................72

List of figures

Figure 1: Goschen location shown in yellow 6
Figure 2: Project Area and proposed components....................8
Figure 3: Area 1 Goschen Project....................8
Figure 4: Area 3 Goschen Project....................9
Figure 5: Structural zones of Victoria and location of Goschen Project (after Willocks and Moore; 1999) 10
Figure 6 Area 1 topography photo 11
Figure 7 Area 3 topography photo 12
Figure 8: Surface topography- solid line 5m contour....................13
Figure 9: Groundwater contours from CDM Smith Technical Report I. Groundwater 18
Figure 10: Photograph of typical land use observed in 2017....................19
Figure 11: Photograph of Paddock 44 quarry (2017) 20
Figure 12: Photograph of Paddock 60 quarry, showing close to vertical cemented sand walls (2017) 21
Figure 13: Photograph of Pack 60 quarry (2017) 21
Figure 14: Photograph of representative samples retained from exploration drilling....................22
Figure 15: Photograph of paddock 40 quarry (2019)....................22
Figure 16: Photograph of paddock 40 quarry, view to the east (2019) 22
Figure 17: Photograph of paddock 40 quarry, view to the west (2019)....................22
Figure 18: Photograph of paddock 40 quarry, view to the south (2019) 23
Figure 19: Location of geotechnical boreholes in Area 1....................24
Figure 20: Location of hydrogeological boreholes in Area 1 and Area 3....................25
Figure 21 Summary of corrected SPT N value results 26
Figure 22: Bulk sample recovered for PLT test (PS003-22) 27
Figure 23 Summary of PLT value results....................27
Figure 24: Cross section locations for Area 1 34
Figure 25: Geotechnical Domain Fence Diagram - Interpretation - Area 1 North-South 35
Figure 26: Geotechnical Domain Fence Diagram - Interpretation - Area 1 South....................35

Figure 27: Geotechnical Domain Fence Diagram - Interpretation - Area 1 Mid 36
Figure 28: Geotechnical Domain Fence Diagram - Interpretation - Area 1 North....36
Figure 29: Cross section locations for Area 3. 37
Figure 30: Geotechnical Domain Fence Diagram - Interpretation - Area West 38
Figure 31 Geotechnical Domain Fence Diagram - Interpretation - Area 3 Mid 38
Figure 32: RocLab data analysis for PLT test data 40
Figure 33 GSI Chart for Sandstone Rock (Marinos & Hoek, 2000) 41
Figure 34: Soil strength parameters variation for Unit 2 (CLAY/ Silty CLAY) 42
Figure 35: Soil strength parameters variation for Unit 3 (Sandy/ Silty CLAY) 43
Figure 36: Soil strength parameters variation for Unit 4 (Silty/ Clayey SAND; Sandstone) 45
Figure 37: Soil strength parameters variation for Unit 5 (Silty SAND) 46
Figure 38: Cell arrangement and sequence for the pits in Area 1 and Area 3 – Y axis denotes north 48
Figure 39 Table 9.2 from Read and Stacey 2010 49
Figure 40 Table 9.3 from Read and Stacey 2010 49
Figure 41 Table 9.4 from Read and Stacey 2010 50
Figure 42 Table 9.5 from Read and Stacey 2010 51
Figure 43 Table 9.6 from Read and Stacey 2010 52
Figure 44 Table 9.7 from Read and Stacey 2010 53
Figure 45 Typical pit wall section terminology....55
Figure 46: Selected cross section locations for slope stability analysis 56
Figure 47: Example of Slide model output and input for A1_ShepherdRd....57
Figure 48: FoS variation with cohesion of soil unit U2....59
Figure 49: Example of PoF histogram for A3W3_JoblingRd 60
Figure 50: Locations of Area 1 pit-road geometries analysed 63
Figure 51: Locations of Area 3 pit-road geometries analysed 64
Figure 52 Waste dump and stockpile stability rating and hazard class chart (Hawley et al, 2017)....67
Figure 53: Typical stockpile arrangement 68
Figure 54 Remoulded strengths estimated based on Appendix D, AS 4678-2002 for clay soils 68
Figure 55 Example of Slope Stability Assessment for 30m high stockpiles 70
Figure 56: Cross-section of typical design for bunded surface water catch drains....70
Figure 57: Sediment Pond ('z' = depth; 'w' = water level)....71

List of tables

Table 1: Gypsum application rates 16
Table 2 Summary of laboratory test results from mining Area 1 and Area 3 boreholes 28
Table 3: Triaxial, Permeability and Emerson Test data summary for Area 1 and Area 3 boreholes....31
Table 4: Summary of laboratory test results from Combined Samples 32
Table 5: Summary of strata based on available borehole logs 33
Table 6: Ground model Area 1 33
Table 7: Ground model Area 3 37
Table 8: Parameters for in situ soils for pit slope stability....47
Table 9 Summary Table of FoS and PoF guidance based on Read and Stacey 2010 54
Table 10: Summary of results from the critical sections 57
Table 11: Material parameter variation 58

Table 12: Summary of probability of failure assessment 59
Table 13 Estimated Material Weights for failure surface with FoS > 1.6 and for failure surface with the minimum FoS 60
Table 14: Recommended pit geometry 61
Table 15 Reproduction of Table 3.12: Suggested level of effort based on waste dump and stockpile stability rating/hazard class (WSR/WHC) Hawley 2017 66
Table 16: Stockpile material parameters 68
Table 17: Subgrade parameters for the purpose of slope stability modelling 69
Table 18: Summary of the results of the long-term analysis 69
Table 19: Summary of the results of the long-term stability analysis of sediment ponds 71

Appendices

Appendix A — Explanatory Notes, disclaimer

Prepared by — Andrew Turner		**Date —** 16/11/2022
Reviewed by — Austen Easterbrook		**Date —** 16/11/2022
Authorised by — Andrew Turner		**Date —** 16/11/2022

Revision History

Rev No.	Description	Prepared by	Reviewed by	Authorised by	Date
00	Ready to issue	AT	AE	AT	16/11/2022

1. Introduction

VHM has established a Mineral Resource Estimate and ore reserve estimate on Retention licence TL6806 (Goschen Project). Mining and processing are proposed to take place on land 100% owned by VHM over a current mine life of 20years. Mining is -proposed to take place using dry- strip mining with conventional "truck and shovel" bulk earth moving equipment.

The Goschen Project site is a heavy mineral sand mining and processing operation that will produce several heavy mineral concentrates (HMC) and a range of critical rare earth minerals in Victoria, near the NSW border (Figure 1). Water for processing will be extracted from a proposed pump station east of the mine site and piped to the site. Mining is proposed to be undertaken across two defined mining areas known as Area 1 and Area 3.

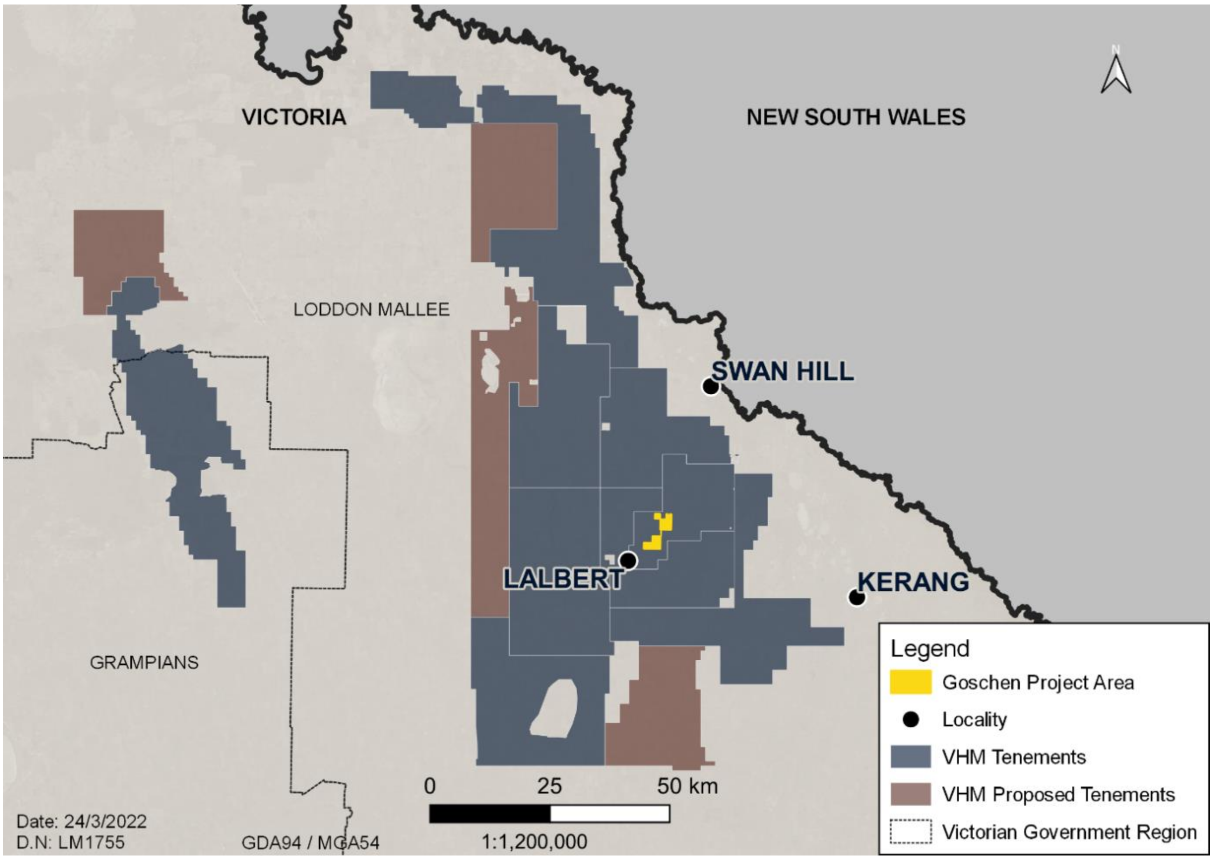

Figure 1: Goschen location shown in yellow

2. Background

The project is currently in the approvals phase. The Environmental Effects Study EES is under development while the DFS has been completed in 2021. Additional studies to support the preparation of the EES have been carried out. This Geotechnical Investigation Factual and Interpretive Report is one of these studies.

Pitt&sherry designed the geotechnical investigation and laboratory testing program, building on the 2017 limited geotechnical investigation carried out during the PFS. The new investigations have been carried out in Area 1 and Area 3 on areas of the proposed mining operation where access was permitted following consultation with the current farm operators and to minimise impact on active farming areas. The intent of the report is to characterise the materials associated with the overburden and the ore body and to establish engineering properties to refine the stability assessments associated with the pit walls, tailings bunds and stockpiles.

This report consolidates all geotechnical investigations carried out for the project to date and should be read in conjunction with:

- DFS Chapter 14 Geotechnical Engineering (Pitt&sherry 2021); and
- DFS Chapter 15 Tailings Management (Pitt&sherry 2021a).

3. Site and Project Overview

The proposed project will include:

Mining – Mining will take approximately 20 years at 5M tonnes of ore produced per year and will occur only above groundwater (no dewatering) across approximately 1,479 hectares of farmland using conventional open cut mining methods of excavation, load, and haul.

Processing – Heavy mineral sands and rare earths ore will be separated via an on-site WCP and MSP to generate a Rare Earth Mineral Concentrate (REMC). Refining of the REMC on-site is limited to hydrometallurgical extraction to produce a mixed rare earth carbonate. Tailings from the various mineral processes will be homogenised and placed back into the ore zone earlier mined.

Rehabilitation – The mined areas will be progressively backfilled in a staged manner, with tailings dewatered in-pit to allow overburden and topsoil placement in a profile that reinstates the background soil structure. This will result in the ability for a return to the current agricultural land uses within 3 years.

Power – Electrical power needed for mining and processing will be produced on-site from dual fuel diesel/LNG fired power generators, with a gradual evolution over the life of mine to renewables, hydrogen and/or battery as technologies and commercial viability increase. Heat energy for the on-site gas fired appliances shall be provided from an extension of the distribution network from the main LNG storage and regasification system.

Water - Water will be required for construction earthworks, processing, dust suppression and rehabilitation.

The Proposed mine area is broadly defined as Area 1 (in the south) and Area 3 and are shown in Figure 2 and in more detail for each site in Figure 3 (Area 1) and Figure 4 (Area 3).

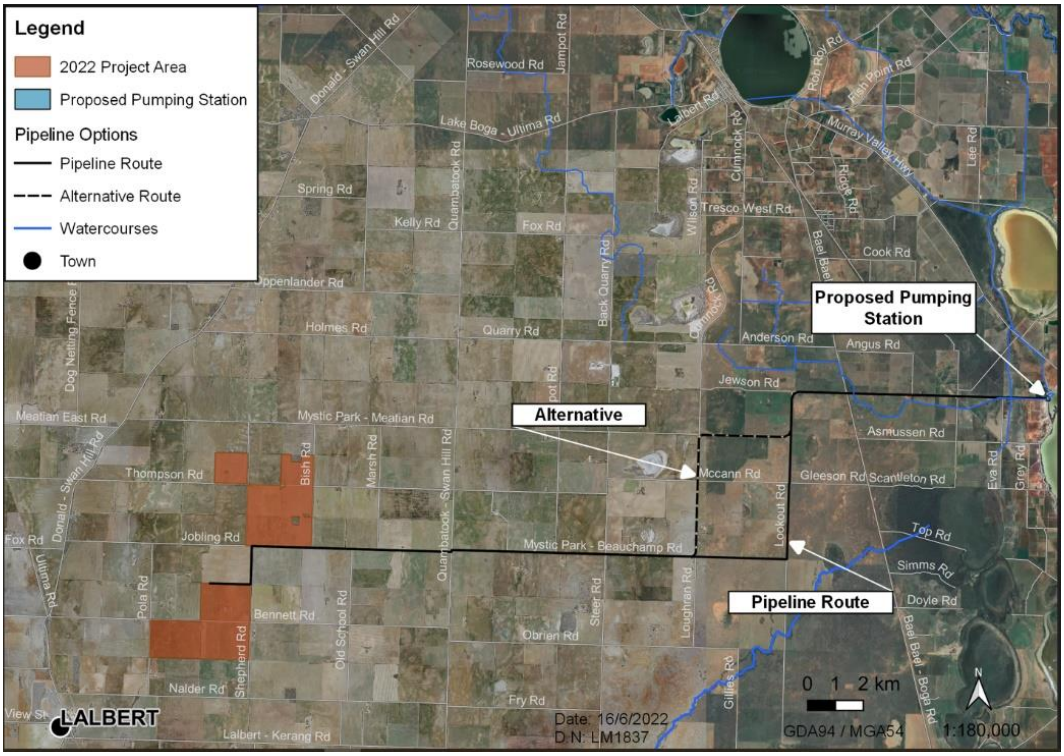

Figure 2: Project Area and proposed components

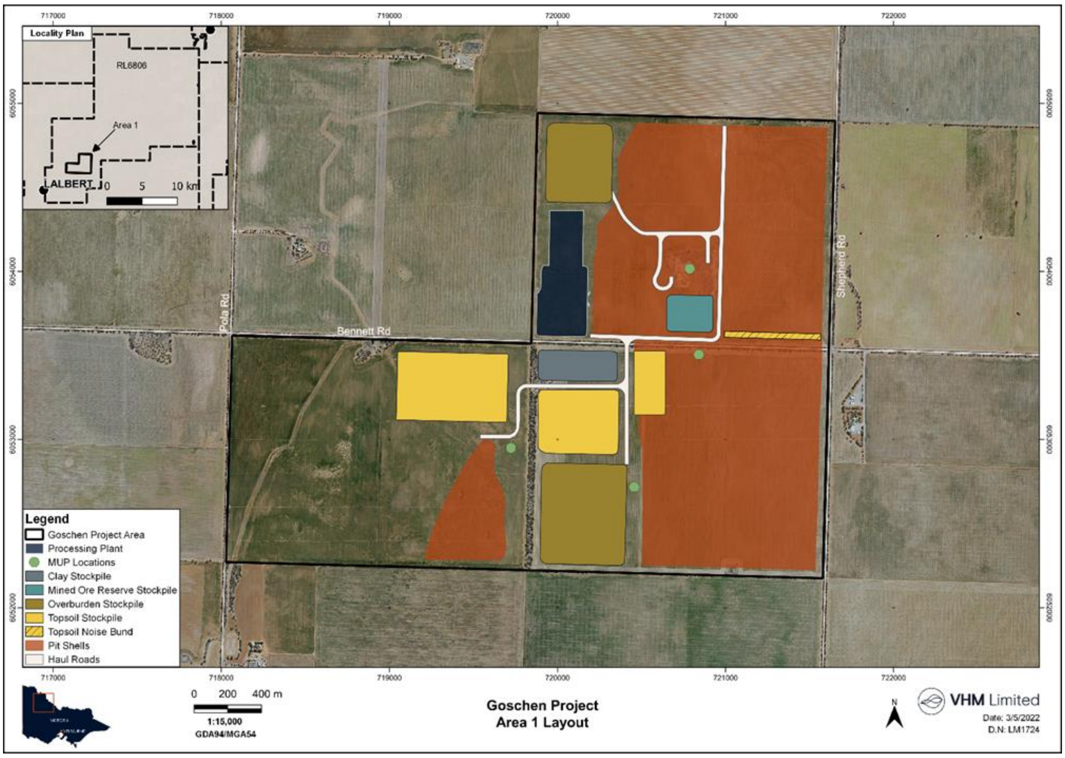

Figure 3: Area 1 Goschen Project

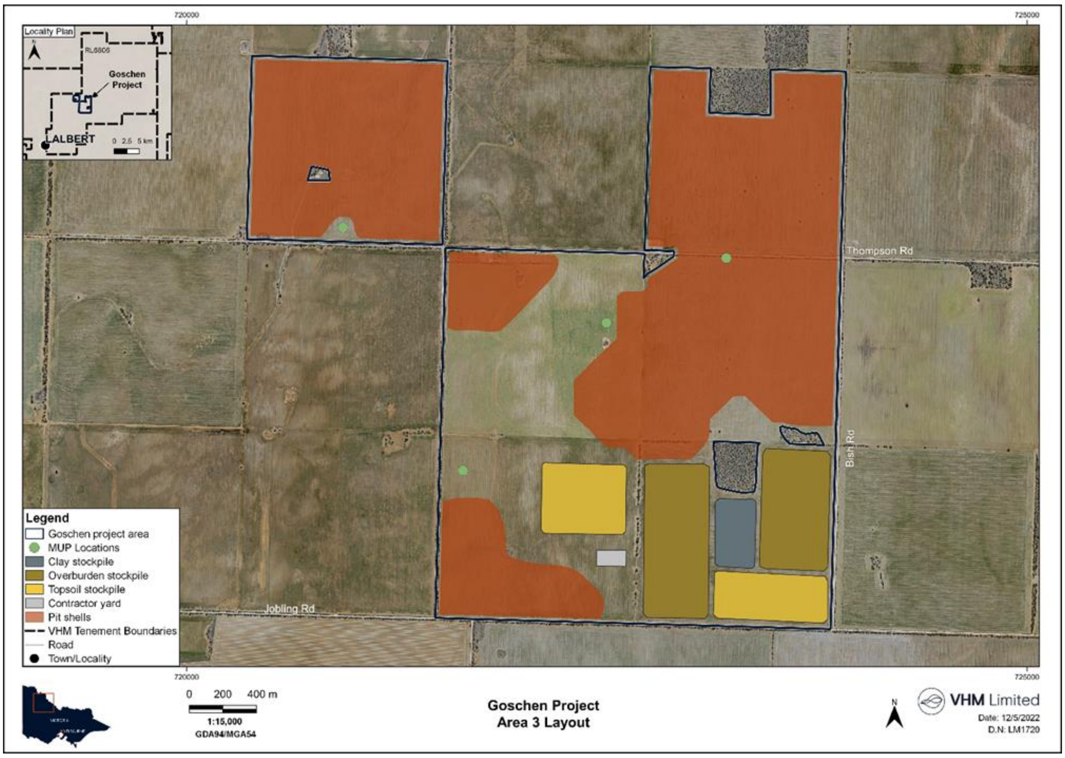

Figure 4: Area 3 Goschen Project

4. Literature Review

4.1 Methodology

An initial literature review was undertaken; including the geology, geomorphology, landslide hazards and acid sulphate soil potential of the site, plus the location and examination of relevant existing borehole and report data that was publicly available. The results of this literature review are presented in this section.

4.2 Existing Data

The Goschen site has recently had a DFS study completed, and a number of groups have carried out studies on the site. Where relevant and informative this data has been summarised in this report.

4.3 Geology

4.3.1 Regional geology

The Goschen Project is located within the Bendigo and Stawell structural zones which are separated by the Avoca Fault, as shown in Figure 5. The Goschen mineralisation is within the near-surface Tertiary Loxton Sand. The deposit has both sheet-style and strandline mineralisation within original fluvial, marginal marine and marine environments.

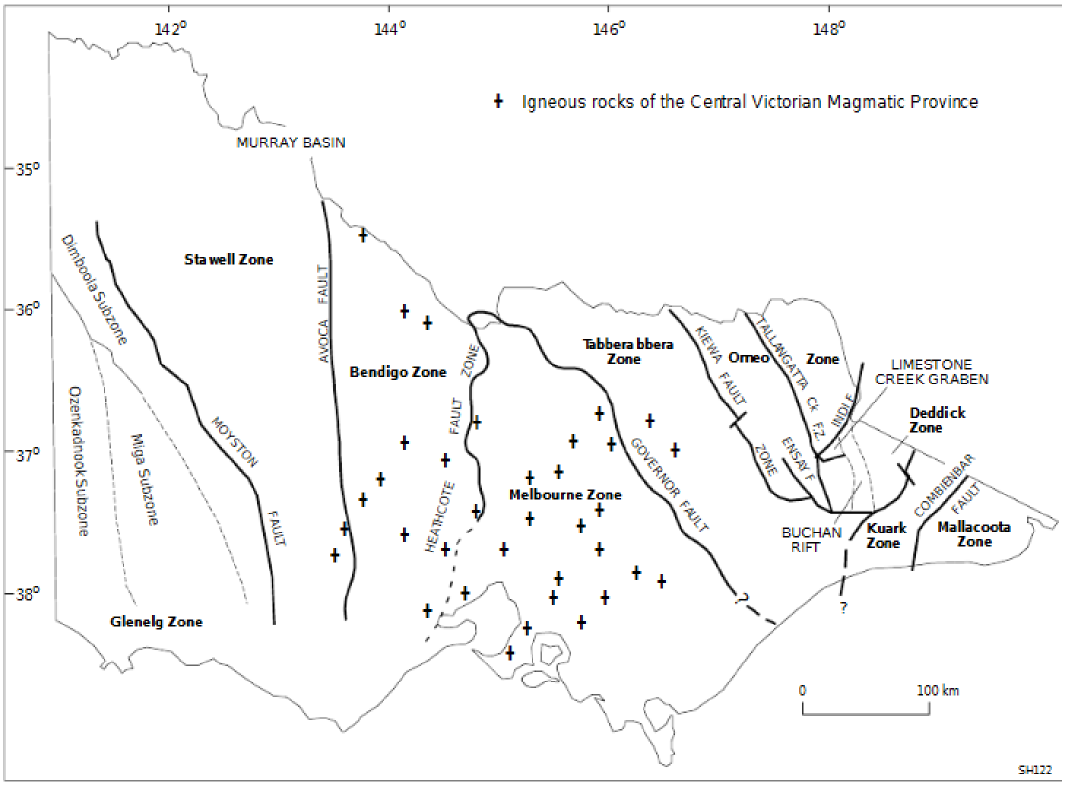

Figure 5: Structural zones of Victoria and location of Goschen Project (after Willocks and Moore; 1999)

The Tertiary sediments are generally flat-lying and unconformably overlie Proterozoic and Paleozoic basement rocks which are 88 to 175 m below the surface in the Project area and will not be intersected by current mining plans. The sediments are overlain by a thin layer of Quaternary aeolian and fluvio-lacustrine sediments.

Sheet style mineralisation extends for 14 km north–south by 15 km east–west, with each mineralised horizon (3 to 4 horizons identified) having an average thickness of between approximately 2 m to 3 m. The mineralised horizons are at a depth of 1.6 m within the central area of the tenement and dip shallowly to the west 1 m to 2 m below the surface and to the east, over 30 m below the surface (VHM Exploration, 2021). The mineralised sands have been described by Mason (2008) as yellow/brown to grey, very fine to coarse, unconsolidated to weakly cemented, well-sorted quartz sand with varying content of clay and silt.

4.3.2 Local Geology

The host sands at Area 1 and Area 3 are typically composed of very fine to fine sands deposited as sub-horizontal layers that accumulated during periods of moderate to calm wave action and contain fine-grained valuable heavy minerals predominantly zircon, rutile, ilmenite, leucoxene, monazite and xenotime, with accessory minerals, such as tourmaline, sphene and garnet.

Some coarse layers within the fine sand unit have been observed at other locations in the region in distinct horizons that is interpreted to have been transported during high-energy events that created significant erosion of the beach/barrier system and created strands of heavy minerals at the beach sites. The coarse horizons are mineralised and can range in thickness, from a few centimetres to over half a metre.

The Loxton Sand deposits of the Goschen Project comprise a sheet-like basal unit of sand which is overlain by a relatively thick mineralised horizon, enriched in zircon and rare earth minerals (REM). The mineralised layers are overlain by sand. Both Area 1 and Area 3 are across the Cannie Fault, which is a deeply buried basement structure that was active both during and after deposition of the heavy minerals. The fault movement has produced thickening of the upper sand package on the western side of the fault at both.

4.4 Topography

The Goschen Project area topography is described as containing landforms classified as either geomorphological landform described as 'Hummocky dunes dominant on the margin of the Tyrrell Depression (south-east of Lake Tyrell, north and south of Lake Hindmarsh' and 'Hummocky dunes with sub-dominant hummocky dunes and ridges (south-east of linear dune fields)', respectively Victorian Government (DEWLP 2021). These two landform types are associated with the linear dune fields that are located at a significant distance from the Project area. Both extensive site visits and a review of the surface contours (Figure 8) show Area 1 and Area 3 to be largely devoid of hummocky dunes, which may have been eroded as part of the continued formation of the Cannie Ridge.

The project area is characterised by a gently undulating topography with small depression in the landscape ranging from 60-90m on the eastern and western sies of the Cannie Ridge in the centre of the Project area. Surrounding the Project area, the main landform is a wide, flat alluvial plain with minor features, such as swamps, shallow lakes, lunettes, sand sheets and minor drainage features. The main water features near the Project area are Lake Boga to the north-east and the Kerang Wetlands 15 km to the east (Water Technology, 2018).

Figure 6 Area 1 topography photo

Figure 7 Area 3 topography photo

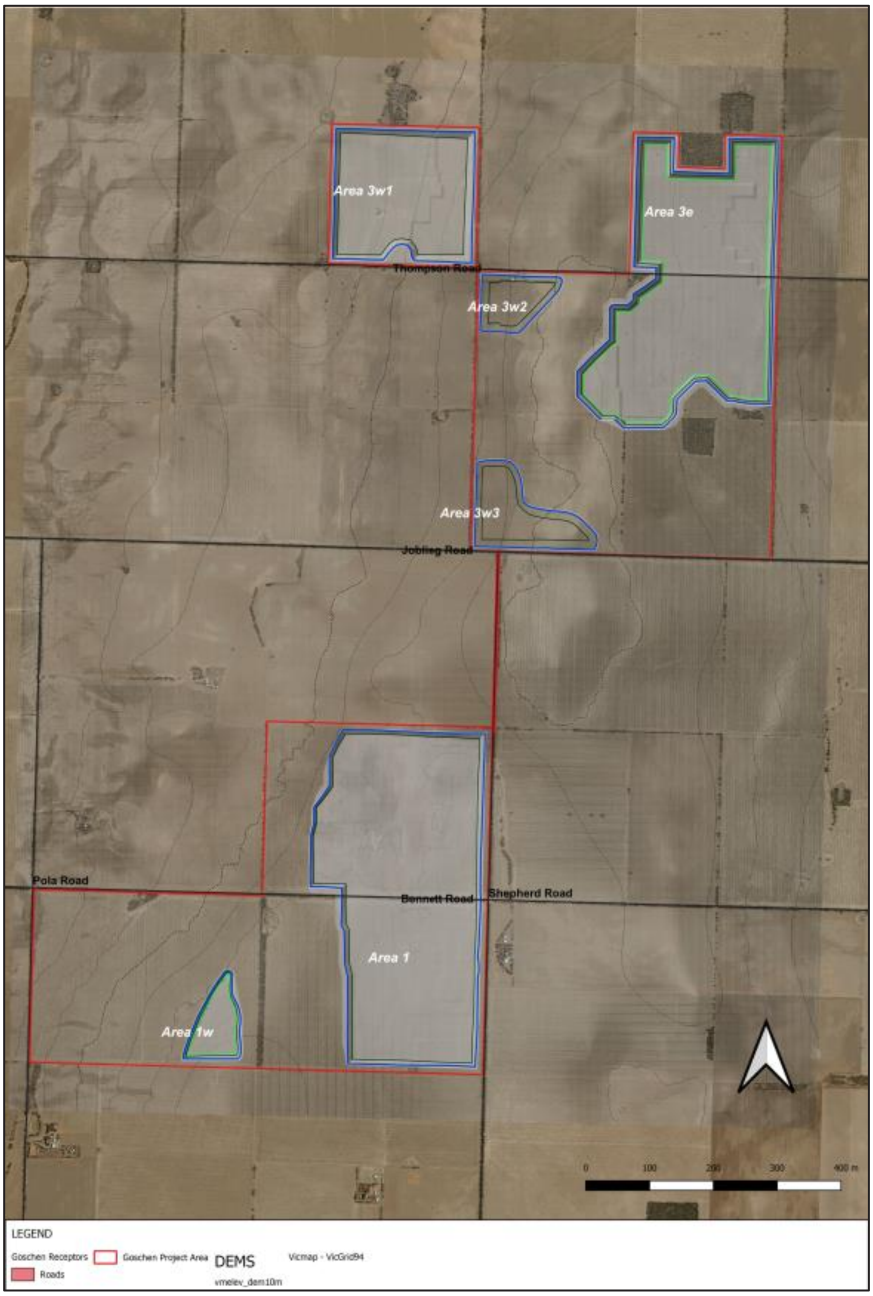

Figure 8: Surface topography- solid line 5m contour

4.5 Geohazards

4.5.1 Landslides

The Goschen site has little topographic variation and thus no mapped potential landslide locations.

4.5.2 Acid Sulphate Soils

ASS is a collective term for natural, waterlogged soils that contain iron sulfides formed by underwater bacterial activity. ASS mainly occur in coastal estuarine environments but are known to occur rarely in inland areas under the right conditions. Inland acid sulfate soils occur on inland waterways, wetlands and drainage channels. They develop in waterlogged, saline and anaerobic (which means living without air) conditions. Inland acid sulfate soils are often associated with salinity sites and many have not been properly identified (NSW DPE, 2022).

Once exposed to air through disturbances such as excavation or drainage, oxidation of ASS can produce sulfuric acid in large quantities. Undisturbed and unoxidized, these soils are known as potential acid sulphate soils (PASS), and soils that have been disturbed and oxidized are known as actual acid sulphate soils (AASS). ASS has the potential to cause the release of heavy metals and other toxins, with undesirable engineering and environmental impacts such as damage to structures, sensitive ecosystems and water catchments.

Available information indicates that the topsoil across the Goschen Project area predominantly consists of calcic, red Chromosols. These soils are clay loam, with weakly crumb structured 5–10 mm peds of moderate consistence, and a rough fabric. There are also areas of red-brown Calcarosols in the northern portion of the Project area (SLR Consulting, 2022). Chemical parameters of the soil from samples across the Project area are as follows:

- Soil is neutral to moderately alkaline (pH of 7.3–8.3) at surface, but very strongly alkaline (pH9.1–9.4) from approximately 15 cm depth
- Soil is sodic to strongly sodic, with sodicity increasing with depth – with an exchangeable sodium percentage (ESP) 2.2% at surface, increasing up to ESP 27.9% at 80 cm
- Moderate to high salinity occurs from depths of 10 cm, increasing with depth from 1.2 to 3.4 decisiemens per metre (dS/m) at surface, increasing to 8.8 dS/m at 80 cm (SLR Consulting, 2019); and
- The soils were considered to have moderately low inherent soil fertility (SLR Consulting, 2019).

The Australian Soil Resource Information System (CSIRO, indicates the probability of the site containing ASS is *“Extremely Low Probability of Occurrence”*.

The site does not contain waterlogged soils in drainage lines and does not possess the requisite properties for containing ASS. There is very low risk of site activities impacting on ASS. Site works are not likely to lower the watertable or cause dewatering of PASS in other locations. Detailed investigation of ASS through testing and further analysis, is not warranted.

4.5.3 Soil erosion hazard

The dispersion class and erosive potential of soils within the Study Area were determined using the Emmerson Aggregate Test (EAT). EAT gives an indicator of dispersion potential and is one indicator of how erodible a soil is likely to be when exposed to disturbance and erosion by running water.

All soil horizons within the Study Area are classed as having moderate to moderately high dispersion ratings and are therefore prone to erosion. Appropriate erosion and sediment control measures should be undertaken, including the application of gypsum, wherever surface disturbance is to be undertaken. The management of water flows over and through dispersive soils is a key tool in control of detrimental impacts. Approaches may include:

- Diversion of water flows away from areas of disturbance
- Minimising potential convergence and/or ponding of surface flows, particularly on disturbed sodic soils; and
- Development of appropriate cover/protection of dispersive soils (i.e. creation of stable linings that are resistant to rainfall erosion and runoff, or covering dispersible soils with non-dispersible materials).

4.5.4 Potential for Soil Acidification

Given the very alkaline pH and high clay content throughout the profile to a depth of 1 metre, the soil types in the Study Area have a very low potential for acidification.

4.5.5 Dispersive (sodic) soils

Sodic soils are soils with an excess of exchangeable sodium cations within the soil's cation exchange sites. Sodicity relates to the shrink-swell properties of the soil and likelihood if dispersion on wetting. Sodic soils are prone to dispersion, which has impacts on the physical and engineering properties of the soil, and due to their increased erosion hazard, can have significant impacts on waterways and water quality.

Sodic soils can have the following properties:

- Very sever surface crusting
- Very low infiltration and hydraulic conductivity
- Very hard and dense subsoils; and
- Highly susceptible to severe erosion.

Sodicity is mostly present in subsoils. When soils are in their natural undisturbed condition any adverse impacts due to sodicity may be minor to absent, as the non-sodic topsoils protect the sodic subsoils. These soils become more problematic when the topsoils are stripped or lost through accelerated erosion.

Sodicity is determined by measuring the exchangeable sodium percentage (ESP) and while general ratings of sodicity vary with region, a common rating system adopted by Hazelton & Murphy (2016) is as follows:

- ESP > 14 = strongly sodic
- ESP 6-14 = sodic
- ESP 3-6 = slightly sodic; and
- ESP <3 = Non-sodic.

SLR (2022) undertook widespread testing of soils for attributes including pH, salinity and sodicity. Materials represented in the overburden are generally dispersive in nature and this needs to be addressed, particularly with respect to management of stockpiled materials and in achieving successful rehabilitation using dispersive soils.

4.5.6 Dispersive soils in stockpiles, drains and sediment basins

It is expected that stockpile faces and sediment basins and bunds will be constructed in dispersive soils or using materials that may be dispersive. Associated risks include excessive erosion of exposed dam batters and stockpile faces, structural decline and difficulty in revegetation. Waterways conveying concentrated stormwater flow, are particularly susceptible to erosion when based in dispersible soils.

Recommendations for management of dispersive soils during stripping and stockpiling are provided in the Soil and Land Resource Assessment (SLR, 2022) and in the Mine Rehabilitation Plan (pitt&sherry, 2022). A summary is outlined below.

4.5.7 Soil stripping, handling and stockpiling

Development of the mine cells involves stripping of nominally 20 m depth of overburden including an upper soil profile comprising clay subsoils and topsoil. Overburden, clay and topsoil will be stripped then directly emplaced in rehabilitation cells as a general rule to minimise double handling and minimise potential for material decline during extended stockpiling. When stockpiling is required, materials will be separated into their respective layers and stockpiled in dedicated areas with a focus on preserving quality of the clay subsoil and topsoil material for future rehabilitation. The mine plans for Area 1 and Area 3 depict the proposed stockpile locations though this may vary during detailed mine planning. For infrastructure areas only topsoil would generally be stripped.

Based on the soil survey (SLR, 2022) the following stripping depths are recommended:

- Strip topsoil to a depth of 20 cm. Topsoil would be stripped from all disturbance areas, including haul roads, infrastructure areas and subsoil stockpile locations; and
- Strip subsoil from mining areas only to a depth of 1.0 m (80 cm thick layer). Subsoil clay would be stockpiled separately to topsoil and used to restore a rehabilitated soil profile depth at least 1.0 m thick.

A range of management and mitigation strategies are outlined in SLR (2022) for implementation as appropriate to help manage the effects of sodicity during stripping and stockpiling operations. Key measures include:

- Treating topsoils with gypsum prior to stripping, as described in Table 1;
- Where possible, replacing subsoil and topsoil directly in mine backfill (rehabilitation) areas; and otherwise minimising the time that materials are stored.
- Stripping soils under appropriate moisture conditions and using suitable equipment to minimise compaction, pulverisation and structural decline; and
- Vegetating stockpile surfaces to minimise erosion, structural decline and help maintain soil organic matter and health.

4.5.8 Amelioration with gypsum

Soils would be treated with gypsum to counter the effects of sodicity during stripping and in stockpiles, as recommended by SLR (2022). Gypsum application would be undertaken during stripping, stockpiling and material spreading as detailed in Table 1.

Table 1: Gypsum application rates

Ameliorant	**Topsoil**	**Subsoil**
Soil stripping:		
Gypsum	5 T/ha (10 T/ha if ESP>14)	n/a
Stockpile surface:		
Gypsum	n/a	10 T/ha
Granulock 15 (or similar)	80 kg/ha	80 kg/ha
Re-spread materials:		
Gypsum	n/a	10 T/ha *
Granulock 15 (or similar)	120 kg/ha	120 kg/ha

* Gypsum only recommended if subsoil is to be left exposed for a length of time prior to topsoil respreading

4.5.9 Drains and sediment basins

Drains and internal (cut) batters of sediment basins are particularly susceptible to erosion where dispersible soils are exposed. The increased erosion hazard is due to the erosive action of concentrated stormwater flow in drains and due to increased velocities on the steep slopes on batters.

Erosion control will be achieved using appropriate lining of dispersible soil materials with measures to be outlined in site specific erosion and sediment control plans. Options include lining of internal basin batters and drains using a suitable rolled erosion control product (RECP), such as jute mesh or light weight bidim. Use of RECPs should be considered over at least the upper part of the batters and at the main inlets and outlets to basins. RECPs would also be appropriate for lining the inverts of major drains.

Surface protection through revegetation would be used where appropriate, for example on batters of bunds and stockpiles, and otherwise where soils are temporarily disturbed but not required for ongoing operations.

4.6 Groundwater

CDM Smith undertook a detailed groundwater study as part of the EES CDM Smith 2022. The report provided an assessment of groundwater depth across the site. The groundwater contours prior to mining are represented in Figure 9 below. The average groundwater level across Area 1 and Area 3 in 64.5mAHD and this value has been used in design. The western side of the Area 1 and Area 3 pit shells will be less than this level ranging from 63mAHD to 64mAHD.

The surface levels across Area 1 vary from ~105mAHD to ~115mAHD and Area 3 varies from ~110mAHD to ~120mAHD. Pit depth have been set to remain well above these levels during mining.

CDM Smith 2022 identify that as the mine advances and tailings deposition increases there is a likelihood of groundwater mounding. This groundwater mounding has at this stage not been modelled at the mining block level however it is suggested that it could mean that in some areas groundwater may intersect the pit floor. It is intended that where this will occur that a system of dewatering bores will be installed to ensure that groundwater is maintained at a level of nominally 1m below pit floor. This system is currently under investigation and will be incorporated into FEED.

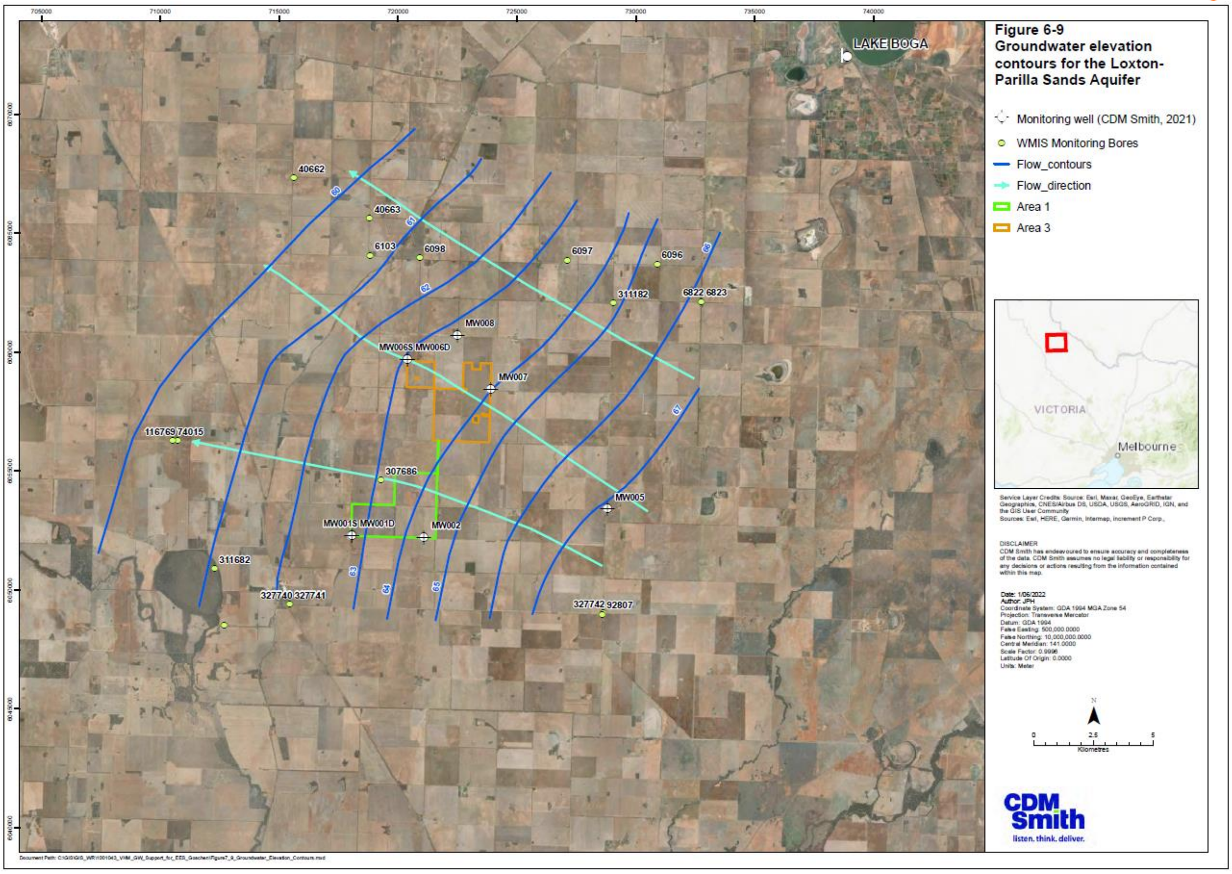

Figure 9: Groundwater contours from CDM Smith Technical Report I. Groundwater

5. Site Investigation

5.1 Assumptions and Limitations

This report is prepared generally in accordance with AS1726. Departures from AS1726 exist due primarily to the restricted scope of this investigation which has been limited to assessment of geotechnical parameters of soil and rock materials to inform geotechnical design.

A range of investigations which may be anticipated in a detailed geotechnical investigation including those relating to soils, landforms and water have been undertaken for this project by others. These investigations are not reproduced herein but when pertinent to inform geotechnical parameters are referenced within the text and in Section 9 References

Key Reliance information includes EES Technical Reports:

- Water Technology – H1. Surface Water (Water Technologies 2022)
- CDM Smith – I. Groundwater (CDM Smith 2022)
- SLR - M. Soils and Land Resources (SLR Consulting 2022); and
- Pitt&sherry – P. Rehabilitation and (Closure Pitt&sherry 2022).

5.2 Methodology

All observations and testing locations have been located using handheld GPS or equivalent applications on mobile devices / surveyed to approximately 5m accuracy. Where indicated, more precise surveying has been undertaken to locate investigation reference points, this includes drill hole collar locations collected during mine preparations.

All soil, rock and groundwater samples have been logged with unique reference numbers as indicated on the logs.

A number of programmes of work have been carried out on the proposed Goschen site including a number of resource definition drill programmes. Only those that have included geotechnical data collection are summarised in this report.

The site investigations to inform geotechnical parameters which have been carried out include:

- 2017 – site walkover
- 2019 – site visit and review of current quarrying operations; and
- 2022 – drilling and bulk sampling.

5.3 Observations

5.3.1 Observations 2017

A geotechnical site inspection was conducted on 19 December 2017, by an experienced senior geotechnical engineer from pitt&sherry. The inspection was carried out to assess site topography and any visible exposures from slopes, cuts, rivers, dams, quarries and borrow pits and review representative drill chip tray samples. It did not include a full review or relogging of any hole data. A summary of observations follows.

The proposed site is currently used as farming land and is flat with very little topographical variation. No rock outcrops were observed during the visit.

Figure 10: Photograph of typical land use observed in 2017

During the site visit, a rubbish hole, one partially filled old channel, three quarries and a series of borehole chip samples were inspected.

Three larger quarries were also inspected during the site visit in paddock 44 and paddock 60 (owned by Ian and Mark Free). The quarries were 6–10 metres deep from the paddock surface. The quarried material was used by the local council as a pavement material to build the road around the paddocks. Based on the presence of rubbish within the quarries and surface vegetation across the quarry floor and wall, it was indicated that the quarries had been inactive for several years.

Paddock 44 quarry observations included low strength rock or moderately cemented sand in the floor. A small stockpile of boulders was also present within the quarry. The quarry wall indicated the general profile as being clay overlying cemented sand (Figure 11). No subsurface water was observed.

Figure 11: Photograph of Paddock 44 quarry (2017)

Paddock 60 quarry also comprised clay overlying cemented sand; however, the cementation varied from weakly cemented to moderately cemented. Areas of moderately cemented sand can stand close to vertical over short heights (Figure 12 and Figure 13).

Figure 12: Photograph of Paddock 60 quarry, showing close to vertical cemented sand walls (2017)

Figure 13: Photograph of Pack 60 quarry (2017)

The 2017 mineral resource investigation by VHM included downhole rotary drilling which was logged by a resource geologist and representative samples (1-2cm from 1m of core retrieved) were retained in chip trays (example shown in Figure 14). Eight borehole samples were inspected during the site visit.

Figure 14: Photograph of representative samples retained from exploration drilling

5.3.2 Observations 2019

A site walkover by a civil engineer from pitt&sherry was undertaken in March 2019 to assess locations for possible stormwater detention ponds. A photographic record from the existing quarry in Area 1 is shown below (Figure 15 to Figure 18).

Figure 15: Photograph of paddock 40 quarry (2019)

Figure 16: Photograph of paddock 40 quarry, view to the east (2019)

Figure 17: Photograph of paddock 40 quarry, view to the west (2019)

Figure 18: Photograph of paddock 40 quarry, view to the south (2019)

5.4 Drilling

Four geotechnical boreholes were drilled in Area 1 in 2017 using a sonic drilling method. They were drilled to 25 m and standard penetration tests (SPT) were undertaken at selected intervals.

Four hydrogeological boreholes (MW01, MW02, MW06 and MW07) were drilled in 2021 by CDM Smith by wash boring methods. Undisturbed samples were taken at changes in soil type.

In 2022 VHM undertook a major geotechnical drilling program that included 11 boreholes advanced using a combination of sonic, push tubes and 1 triple tube rotary hole in Area 1 and 7 boreholes advanced using triple tube rotary techniques in Area 3.

The location of the boreholes is shown in Figure 19 and Figure 20. The grey areas represent the pit shells.

Figure 19: Location of geotechnical boreholes in Area 1

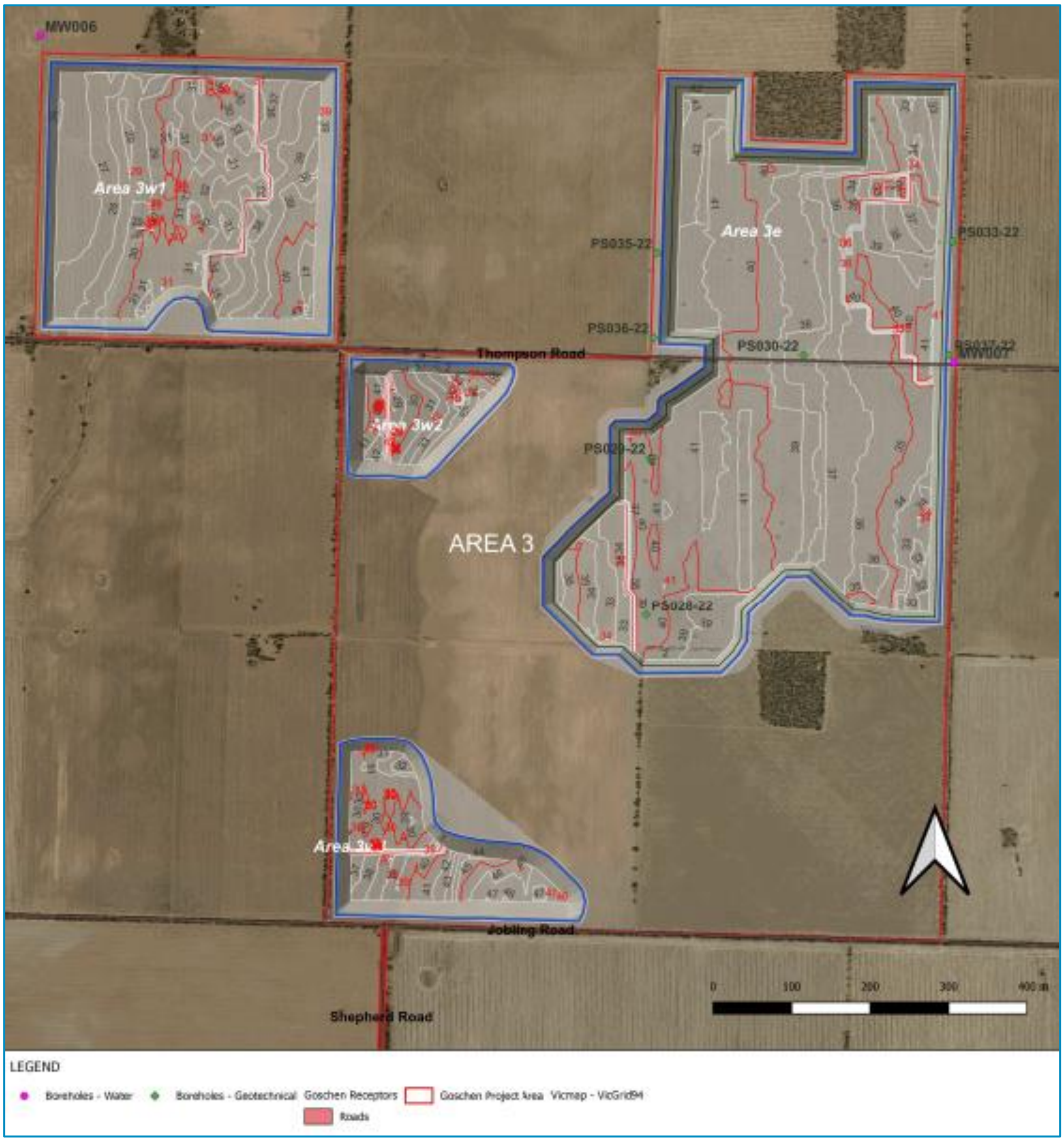

Figure 20: Location of hydrogeological boreholes in Area 1 and Area 3

5.5 Insitu/Field Tests

5.5.1 Standard Penetration Tests

86 No. Standard Penetration Tests (SPTs) were carried out in the field and are summarised in the graph presented in Figure 21 below. For the tests in Area 3 where refusal occurred, the SPT N values was conservatively set as 60 and then corrected for depth/hammer efficiency.

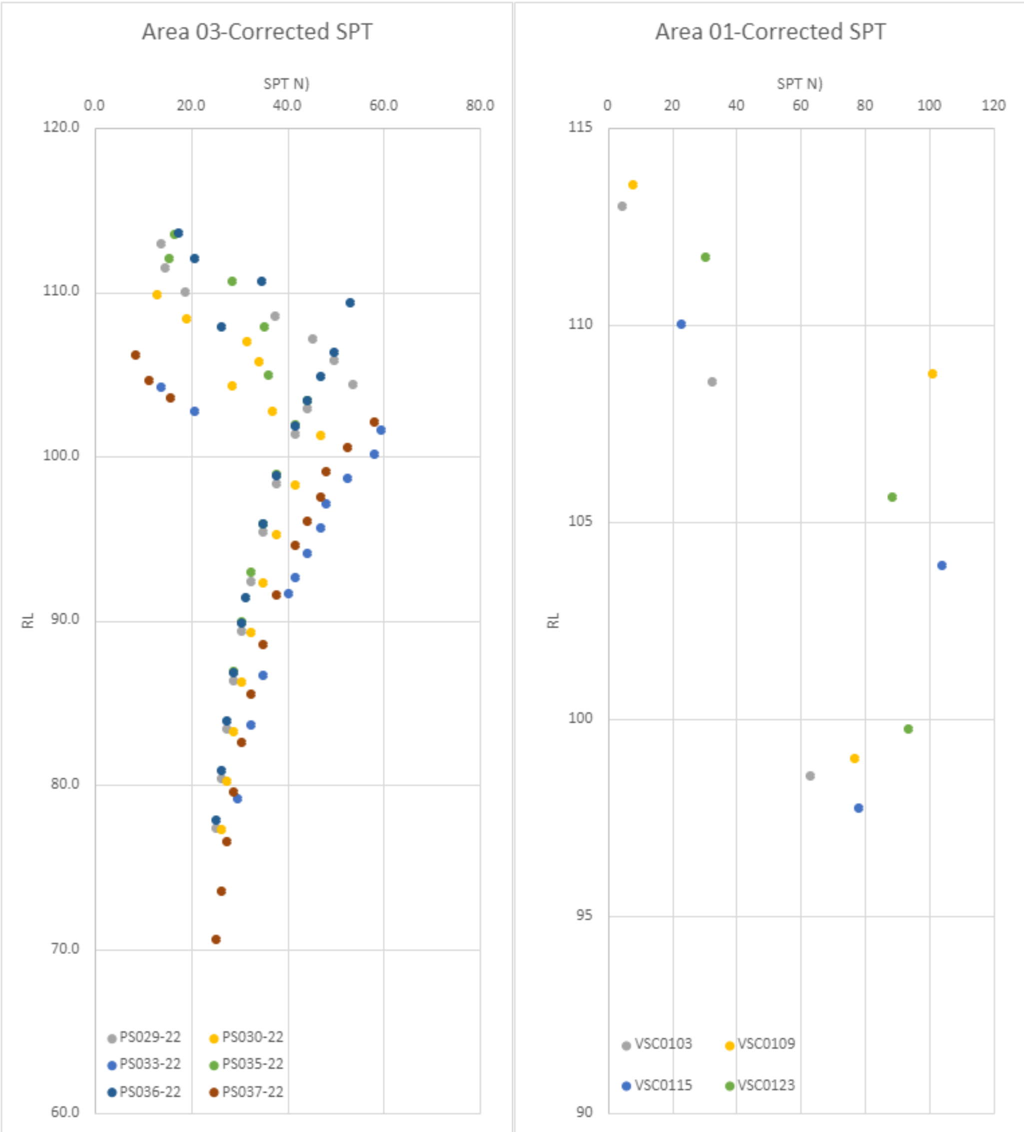

Figure 21 Summary of corrected SPT N value results

5.5.2 Point Load Tests

Point load tests (PLTs) were completed on bulk samples gathered during field investigations. A total of 102 tests were carried out. Figure 22 shows a typical bulk sample collected from Borehole PS003-22. Most of the bulk samples were collected within cemented SAND layers, in order to assess strength variation within cemented SAND layers encountered.

Point load strength index ($Is_{(50)}$) for these samples were calculated using lump dimensions and failure loads from the test (the standard 'irregular lump test' procedure (AS4133.4.3.1, 2007 Determination of Point Load Test on Rock Specimens for Engineering Purposes,) was used when calculating $Is_{(50)}$).

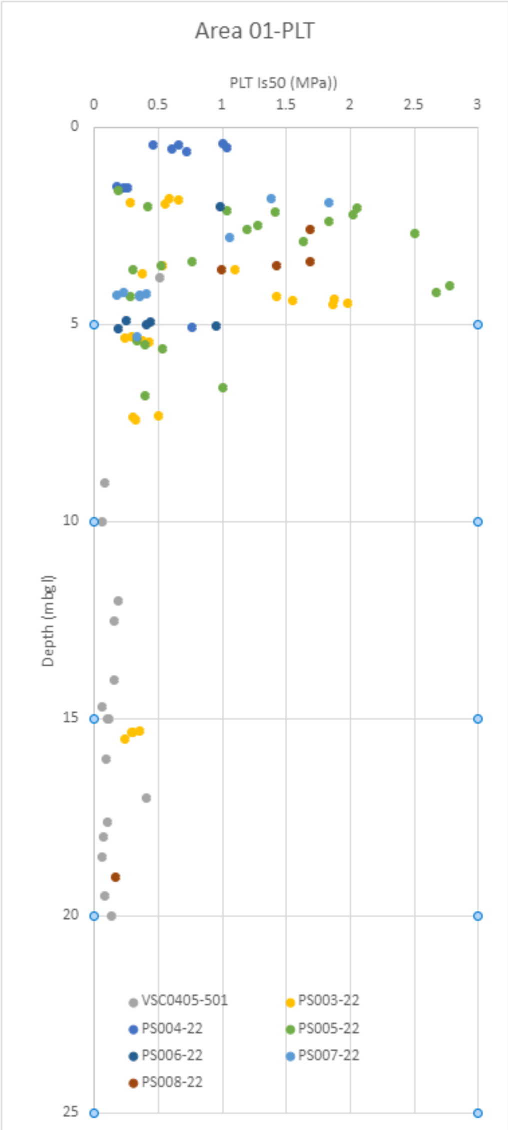

Figure 23 Summary of PLT value results

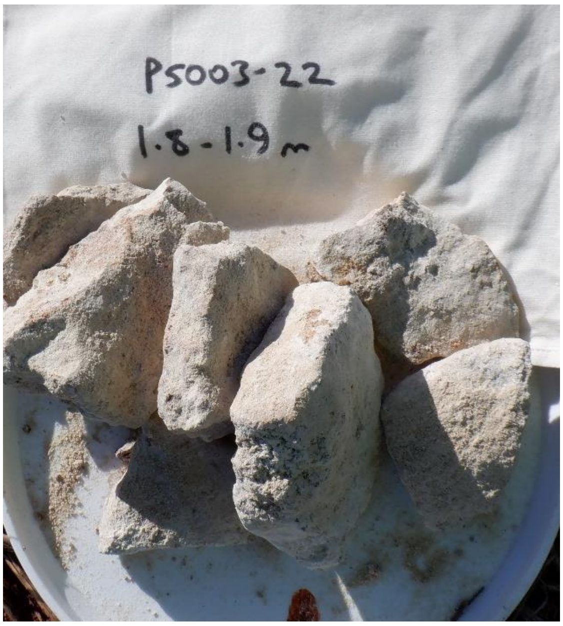

Figure 22: Bulk sample recovered for PLT test (PS003-22)

5.6 Laboratory Testing

A summary table of the laboratory test results is included in Table 2, Table 3 and Table 44.

Table 2 Summary of laboratory test results from mining Area 1 and Area 3 boreholes

Client ID	Depth (m)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)	LS (%)	Moisture (%)	Description	Plasticity	Particle density (t/m^3)
VSC 0103	1.0–1.45	0	30	21	49	77	23	54	17.5	26.6	Sandy clay with silt	High plasticity	2.65
VSC 0103	1.45–1.9	0	27	21	52	76	16	60	18.5	29.8	Silty clay with Sand	High plasticity	2.65
VSC 0103	5.0–5.45	0	83	10	7	36	18	18	8.5	8.9	Silty sand	Medium plasticity	2.52
VSC 0103	5.45–5.9	0	76	18	6	20	19	1	1	9.9	Silty sand	Low plasticity	2.65
VSC 0103	15.0–15.45	0	67	23	10	23	18	5	2.5	14.1	Silty sand	Low plasticity	2.59
VSC 0109	1.1–1.45	0	54	23	23	70	21	49	17	17.5	Clayey sand	High plasticity	2.61
VSC 0109	1.45–1.9	0	45	20	35	66	20	46	17	24	Sandy clay with silt	High plasticity	2.64
VSC 0109	5.0–5.25	0	78	14	8	35	15	20	9	11.6	Silty sand	Medium plasticity	2.62
VSC 0109	16–16.45	0	75	14	11	NO	NO	NO	NO	9.7	Silty sand	Non-plastic	–
VSC 0115	2.0–2.45	0	38	22	40	71	25	46	14.5	16.1	Sandy clay with silt	High plasticity	2.66
VSC 0115	2.45	0	51	17	32	41	17	24	11.5	16.5	Clayey sand	Medium plasticity	2.66
VSC 0115	7.7–8.12	0	75	20	5	20	14	6	2	13.8	Silty sand	Low plasticity	2.62
VSC 0115	8.12	0	77	19	4	NO	NO	NO	NO	10.2	Silty sand	Non plastic	2.66
VSC 0115	14.0–14.45	0	73	15	12	24	11	13	3.5	17.9	Silty sand/ clayey sand	Low plasticity	2.58
VSC 0115	14.25	0	77	17	6	NO	NO	NO	NO	14.8	Silty sand	Non plastic	-

Client ID	Depth (m)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)	LS (%)	Moisture (%)	Description	Plasticity	Particle density (t/m^3)
VSC 0123	2.0–2.23	0	40	8	52	63	24	39	15	14.1	Sandy clay with silt	High plastic	–
VSC 0123	2.3	0	58	9	33	--	--	--	--	--	Clayey sand	Medium plasticity	2.57
VSC 0123	8.0–8.37	0	81	13	6	40	18	22	11	15.9	Silty sand	Medium plasticity	2.52
VSC 0123	8.37	0	81	12	7	NO	NO	NO	NO	14.4	Silty sand	Non plastic	2.55
VSC 0123	14.0–14.25	0	73	19	8	NO	NO	NO	NO	14.1	Silty sand	Non plastic	2.59
VSC 0123	14.25	0	75	16	9	NO	NO	NO	NO	19.4	Silty sand	Non plastic	2.62
PS002-22	12.5-13.4	-	-	-	-	-	-	-	-	-	Clayey SAND	-	2.63
PS003-22	10.9-12.2	0	77	13	10	-	-	-	-	7.4	Silty SAND	Non Plastic	2.64
PS003-22	14.3-14.6	1	68		31	-	-	-	-	-	Silty SAND	Low to Medium plasticity	–
PS003-22	19.2-20	-	-	-	-	22	20	2	0.5	-	Silty SAND	Low to Medium plasticity	–
PS003-22	28-28.3	1	68	-	31	-	-	-	-	-	-	-	-
PS004-22	7.1-7.45	0	76		24	-	-	-	-	8.7	Silty SAND	Low to Medium plasticity	–
PS005-22	10.1-10.4	-	-	-	-	-	-	-	-	-	SAND	-	2.61
PS005-22	13.8-14.2	-	-	-	-	-	-	-	-	-	SAND	-	2.63
PS006-22	5.7-5.9	2	78		20	-	-	-	-	9.1	Silty SAND	Low to Medium plasticity	–
PS007-22	3.1-3.5	0	88		12	-	-	-	-	6.4	Silty SAND	Low to Medium plasticity	–

Client ID	Depth (m)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)	LS (%)	Moisture (%)	Description	Plasticity	Particle density (t/m^3)
PS009-22	16.8-17	-	-	-	-	NO	NO	NO	NO	-	Silty SAND	Non plastic	–
PS028-22	6.0-5.2	-	-	-	-	63	25	38	10.5	-	CLAY	High plasticity	
PS028-22	6.5-6.7	0	34	27	29	43	18	25	10		Silty Sandy CLAY	Medium plasticity	
PS028-22	17.3-17.8	0	81	19	-	-	-	-	-	-	Silty SAND	Non plastic	
PS030-22	23.6-24.1	1	72	27	-	-	-	-	-	-	Clayey Silty SAND	Non plastic	
PS033-22	6.6-7.09	5	80	-	15	-	-	-	-	-	Clayey Silty SAND	Medium plasticity	
PS033-22	38.4-38.9	0	81	19	-	-	-	-	-	-	Clayey Silty SAND	Non plastic	
PS035-22	3.5-3.9	0	29	17	54	66	21	45	8	-	Silty CLAY	Hight plasticity	
PS036-22	3.5-3.8	0	28	18	54	70	22	48	14.5	-	Silty CLAY	High plasticity	
PS036-22	5-5.2	0	58	13	29	34	10	24	4	-	Silty Sandy CLAY	Low plasticity	
PS037-22	3.5-3.9	0	18	19	63	64	23	41	9.5	-	Silty CLAY	Hight plasticity	
PS037-22	19.4-19.9	0	75	25	-	-	-	-	-	-	Silty SAND	Non plastic	

Note: LL = liquid limit; PL = plastic limit; PI = plasticity index; LS = linear shrinkage; t/m^3 = tonnes per cubic metre.

Table 3: Triaxial, Permeability and Emerson Test data summary for Area 1 and Area 3 boreholes

Client ID	Depth (m)	Description	c' (kPa)	f' (degree)	Permeability (m/s)	Emerson Class Number
VSC 0103	1.0–1.45	Sandy clay with silt	25/29/35	22.8/20.4/21.2	6.4 × 10-11	2
VSC 0103	5.0–5.45	Silty sand	2.8/1.0	35/35.3	2 × 10-10	6
VSC0103	15.0-15.45	Silty sand	-	-	-	6
VSC 0109	1.1–1.45	Clayey sand	8 / 30	27 / 34	2 × 10-10	4
VSC 0109	5.0-5.25	Clayey silty sand	-	-	-	6
VSC 0115	2.0–2.45	Sandy clay with silt	20/19/19	22.5/22.8/22.7	2.3 × 10-11	4
VSC 0115	7.7–8.12	Silty sand	8.6–14.9	34–35	–	6
VSC0115	14.0-14.45	Silty sand	-	-	-	6
VSC 0123	2.0–2.23	Sandy clay with silt	55– 57	23.5–24.3	3.3×10^{-11}	4
VSC0123	8.0-8.37	Silty sand	-	-	-	6
VSC0123	14.0-14.25	Silty sand	-	-	-	6
PS002-22	1.5-1.95	Silty clay	-	-	-	1
PS003-22	0.4-0.75	Silty clay	-	-	-	4
PS003-22	28-28.3	-	39/94/54	41/33/37	-	
PS006-22	1.4-1.6	Silty clay	-	-	-	1
PS007-22	3.1-3.5	Silty Sand	-	-	-	2

c' = drained cohesive strength; kPa = kilopascals; φ' = drained angle of friction; m/s = metres per second

Table 44: Summary of laboratory test results from Combined Samples

Combined Sample	BH Details	Depth (m)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)	LS (%)	Moisture (%)	Description	Plasticity	Particle density (t/m³)	Permeability (m/s)	Pinhole Dispersion
Combined 1	PS003-22	15.3-16.2	9	52	-	39	31	14	17	5	16.4	Clayey SAND	Low Plasticity	-	Deemed Impermeable	D1: Highly dispersive
	PS006-22	1.4-1.6														
	PS007-22	0.6-0.8														
Combined 2	PS008-22	1.3-1.5	11	56	-	33	31	17	14	3	16.1	Clayey SAND	Low Plasticity	2.59	1×10^{-9}	D1: Highly dispersive
	PS009-22	5.0-5.3														
	PS009-22	8.6-9.0														
Combined 4	PS002-22	9.0-10.5	16	71	-	13	-	-	-	-	7.2	Clayey Gravely SAND	-	-	-	
	PS003-22	4.3-4.5														
	PS003-22	5.2-5.3														
	PS004-22	1.4-1.7														
	PS004-22	2.8-3.2														
Combined 6	PS007-22	4.2-4.5	22	48	-	30	-	-	-	-	12.2	Gravely Clayey SAND	Low to Medium Plasticity	2.59	-	
	PS007-22	17.3-17.7														
	PS007-22	9.0-9.35														

Note: LL = liquid limit; PL = plastic limit; PI = plasticity index; LS = linear shrinkage; t/m³ = tonnes per cubic metre.

6. Ground Model

Ground models were developed based on the available borehole logs, field and laboratory test results. There were total of 15 boreholes completed across Area 1 and 7 boreholes completed across Area 3. Boreholes were spaced approximately 500-800m over the study areas. After analysing borehole logs, it was identified that Area 1 and Area 3 comprise of similar soil strata. Therefore, a simplified ground model using 5 main soil strata as summarised in Table 55 was adopted.

Table 55: Summary of strata based on available borehole logs

Soil Unit	Material	Material Description
U1	TOPSOIL	topsoil, sandy silt, with clay, roots, and organics
U2	CLAY; Silty CLAY	clay, variable low to medium plasticity, F to VSt strength, variable but low fine sand and silt content
U3	Sandy/Silty CLAY	sandy clay, VSt to H, low plasticity
U4	Silty/Clayey SAND; SANDSTONE	weekly cemented, MD to D, medium to coarse grained SAND
U5	Silty SAND	fine grained, cemented sands, low to medium strength

6.1.1 Ground model Area 1

Area 1 fence diagrams were developed to visualise the distribution of geotechnical strata units across the site. Figure 24 shows the location of the cross sections and fence diagrams are provided in Figure 25 to Figure 28. These indicate that cemented Sand is found beneath the overburden clay. However, the degree of cementation can be varying across the site. Most of the borehole logs recorded the cemented sand to be slightly to moderately cemented. The typical profile as shown in Table 6 has been adopted for the purposes of DFS design in Area 1.

The ground surface level in Area 1 varies from 116.06 to 106.63 m AHD (metres above Australian Height Datum) as per recorded borehole elevations. The existing groundwater level has been referenced from CDM Smith 2022 at 64.5 m AHD prior to mining and tailings deposition.

Table 6: Ground model Area 1

Soil Unit	Material	Typical depth ranges (mBGL)*	Typical depth ranges level (m AHD)	Typical layer thickness
U1	TOPSOIL	0 – 0.5	116.06 - 106.13	0.2m to 0.5m
U2	CLAY; Silty CLAY	0.2 – 8.5	115.71 – 102.28	4.5 m to 8.6 m
U3	Sandy/Silty CLAY	0.2 – 12.8	111.56 – 101.45	10 m to 16 m
U4	Silty/Clayey SAND; SANDSTONE	4.8 – 30.6	105.2 – 82.03	20 m
U5	Silty SAND	18.3 to >40	96.36 to <68.26	Not determined

* Metres Below Ground Level

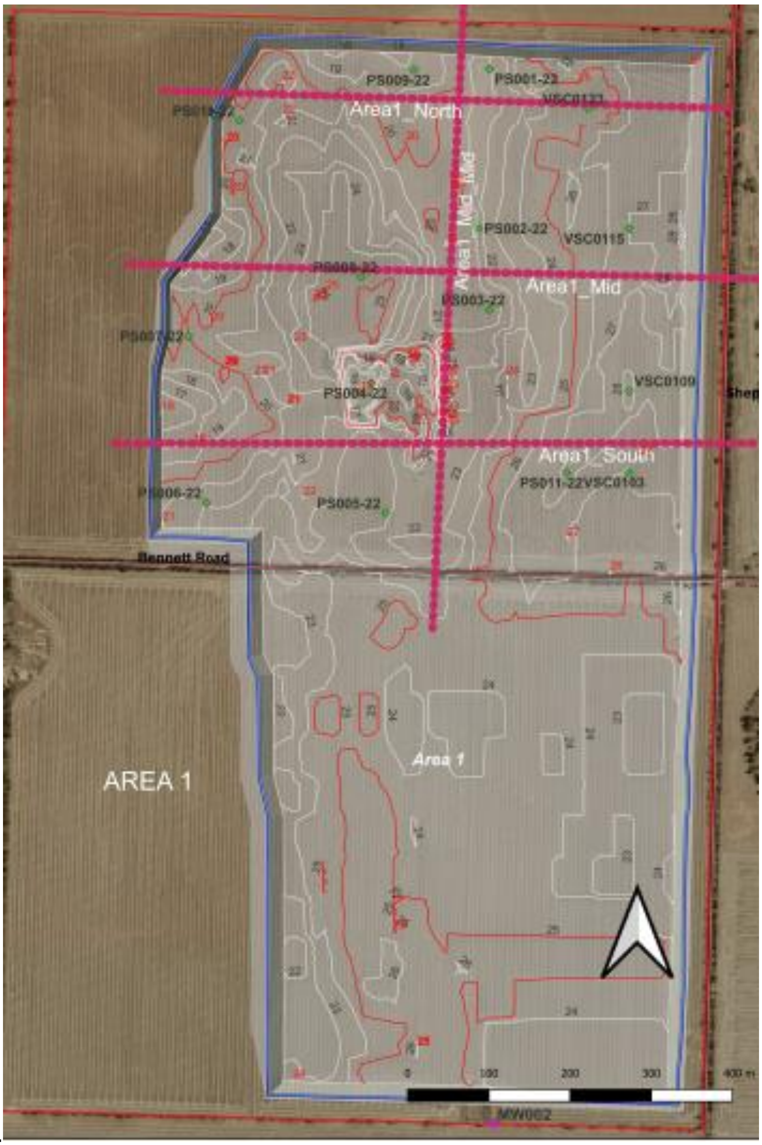

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Figure 24: Cross section locations for Area 1

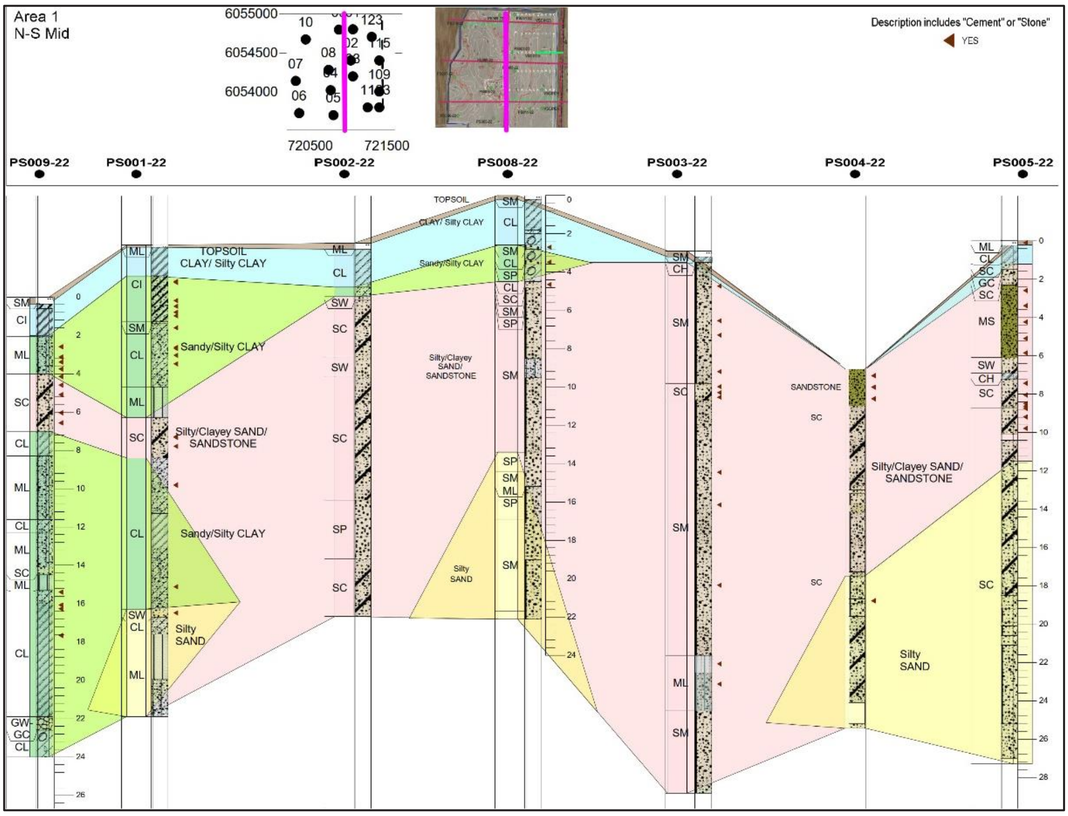


Figure 25: Geotechnical Domain Fence Diagram - Interpretation - Area 1 North-South

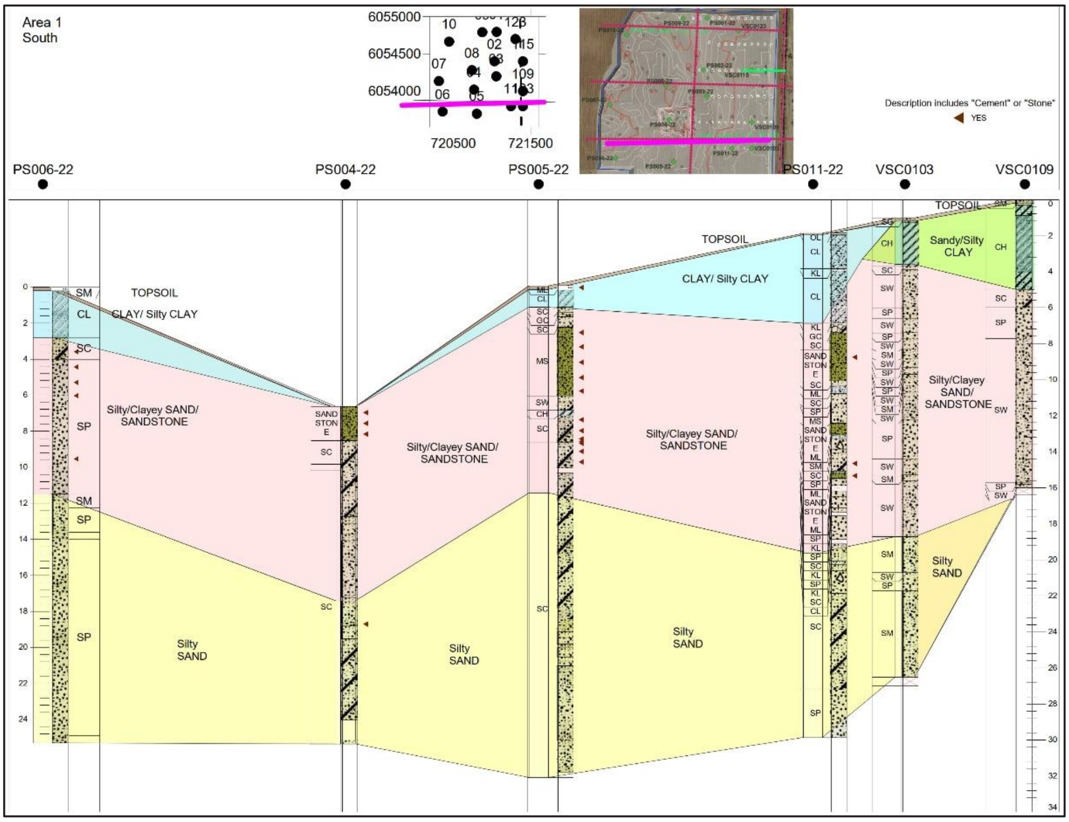


Figure 26: Geotechnical Domain Fence Diagram - Interpretation - Area 1 South

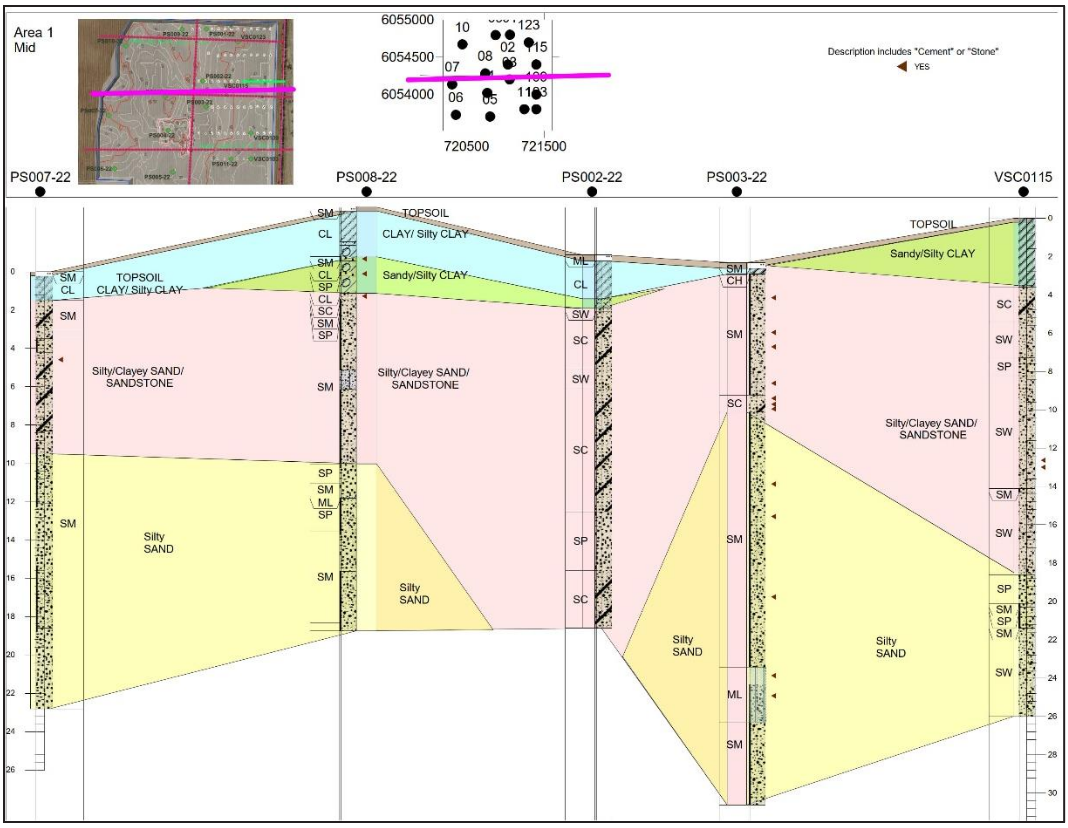


Figure 27: Geotechnical Domain Fence Diagram - Interpretation - Area 1 Mid

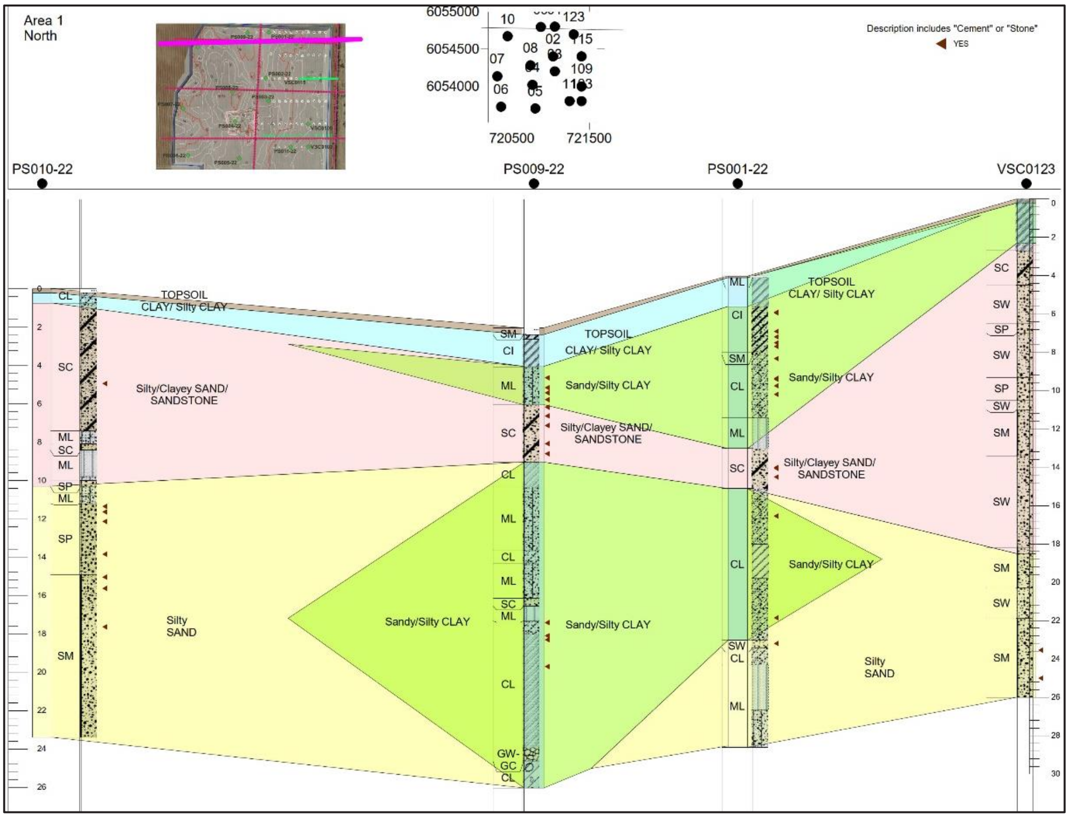


Figure 28: Geotechnical Domain Fence Diagram - Interpretation - Area 1 North

6.1.2 Ground model area 3

Area 3 fence diagrams were developed to visualise the distribution of geotechnical strata units across the site. Figure 29 shows the location of the cross sections and fence diagrams are included in Figure 25 to Figure 28. These indicate the ground model provided in Table 7 as appropriate and this model was adopted for design in Area 3. Ground conditions encountered in Area 3 are similar to the soil strata identified in Area 1. Therefore, same soil units have been adopted in the Area 3 ground model.

Table 7: Ground model Area 3

Soil Unit	Material	Typical depth ranges (mBGL)*	Typical depth ranges level (m AHD)	Typical layer thickness
U1	TOPSOIL	0 – 0.5	116.06 - 106.13	0.2m to 0.5m
U2	CLAY; Silty CLAY	0.2 – 8.5	115.71 – 102.28	4.5 m to 8.6 m
U3	Sandy/Silty CLAY	0.2 – 12.8	111.56 – 101.45	10 m to 16 m
U4	Silty/Clayey SAND; SANDSTONE	4.8 – 30.6	105.2 – 82.03	20 m
U5	Silty SAND	18.3 to >40	96.36 to <68.26	Not determined

* Metres Below Ground Level

The ground surface level in Area 3 varies from 115 to 103.52 m AHD as recorded at borehole collars. The existing groundwater level has been referenced from CDM Smith 2022. Groundwater at 64.5 m AHD

Figure 29: Cross section locations for Area 3.

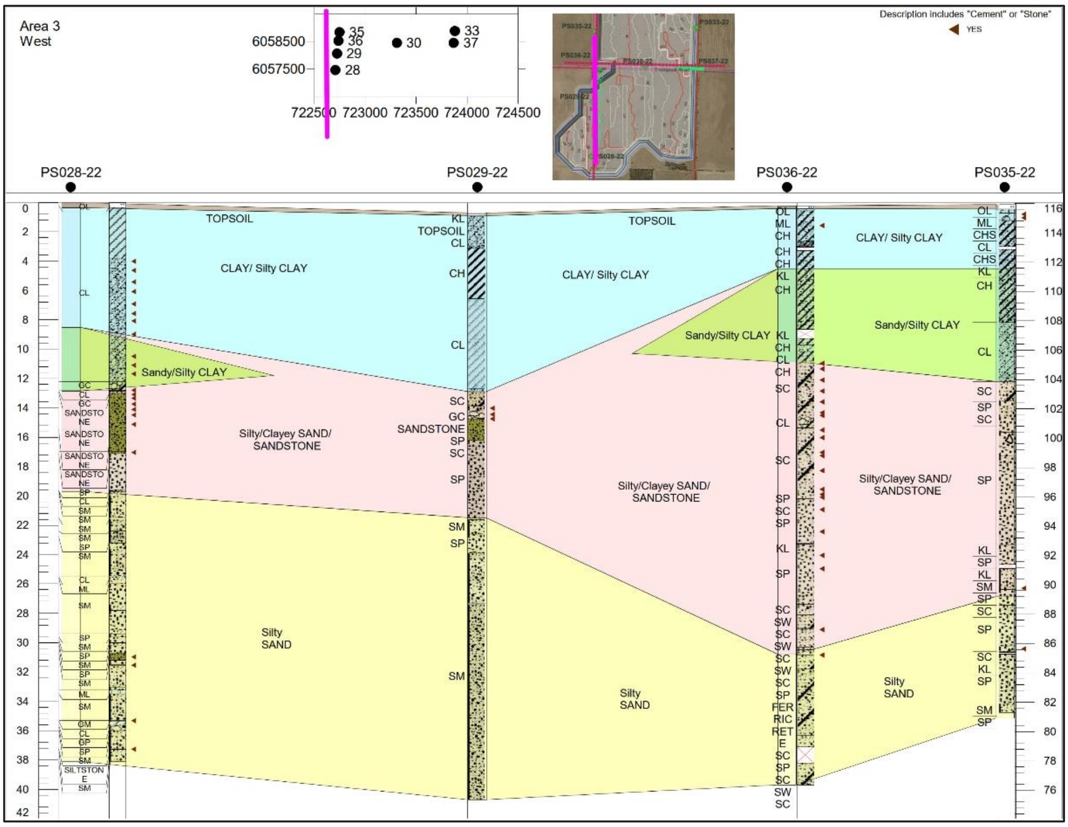


Figure 30: Geotechnical Domain Fence Diagram - Interpretation - Area West

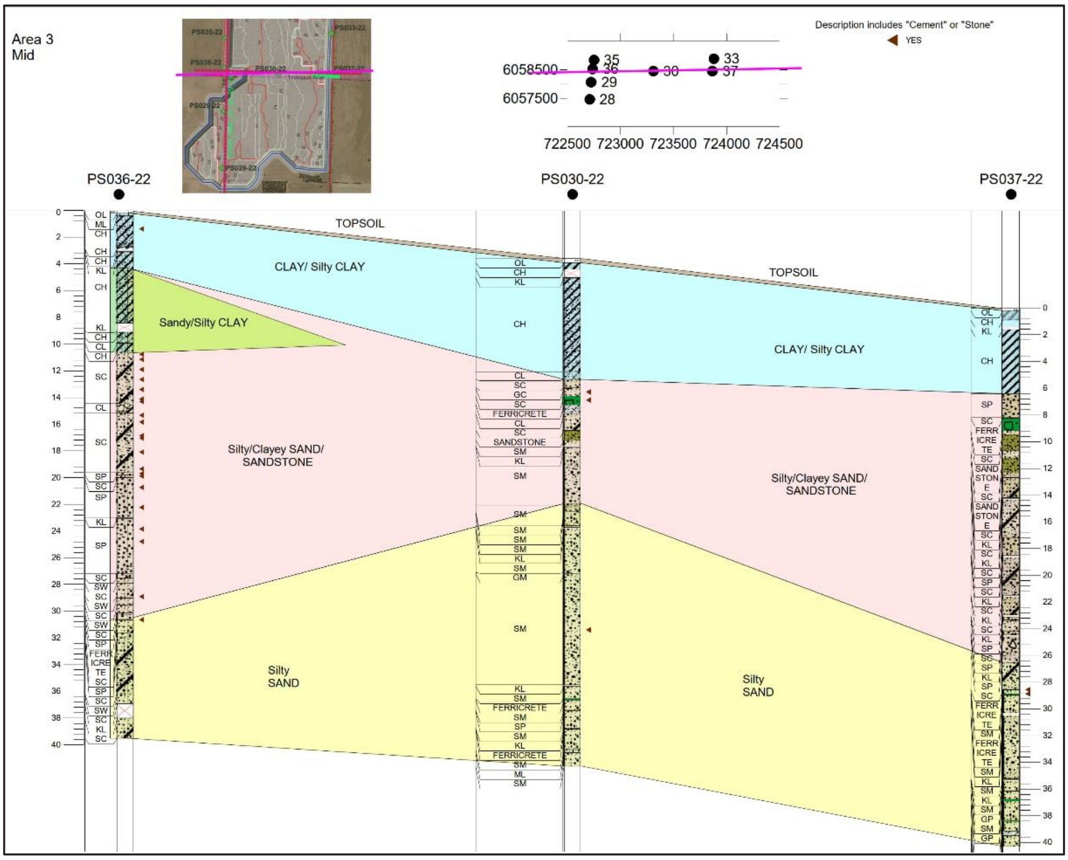


Figure 31 Geotechnical Domain Fence Diagram - Interpretation - Area 3 Mid

7. Material Properties

Material properties for the geotechnical design have been selected based on a statistical analysis and observations and experience for available field and laboratory data. Field and laboratory data for each unit has been analysed separately to define the design strength values. Field SPT data, Point Load Test (PLT) data and laboratory triaxial tests data analysis is described below.

7.1 SPTs

Field measured SPT values have been corrected using the Skempton (1986) equation prior to calculating strength parameters. For the SPT which recorded “Refusal” (which includes the majority of SPT tests in the sandy soils) the assumed N value was conservatively taken as N=60. This value was then further reduced for hammer efficiency and loss of energy in the drill rods. The following methods were then used to define strength parameters for cohesive and non-cohesive soils based on SPT data.

7.1.1 Strength parameters for Cohesive (clay) soils

Effective cohesion: This was selected based on ranges provided in Burt Look (2014). This paper assumed effective cohesion is 20% of the undrained strength. Undrained strength was conservatively taken as 5 x Corrected SPT N value.

Effective friction angle: This was selected based on ranges provided in Burt Look (2014) corresponding to the relative consistency (stiff, very stiff or hard) of the clay.

7.1.2 Strength parameters for non-cohesive (Sand/Silty sand) soils

Effective friction angle: This was calculated based on Peck et. Al (1953) equation for Sandy soils.

Effective cohesion for cemented soils was calculated using Hoek and Brown rock mass strength (Where there was no point load test data the UCS of the intact rock was taken as 10 x SPT N) and the relationship between UCS and effective cohesion was used as shown below.

$$\sigma'_{cm} = \frac{2c'Cos(\varphi')}{1 - \sin(\varphi')}$$

Where, σ'_{cm} -the UCS, c’ - the effective cohesion and φ’ - effective friction angle.

7.1.3 Point Load Test data analysis

Field PLT data was used to generate Mohr-Coulomb parameters using RocLab version 1.033, Figure 32 shows a screen capture extracted from the RocLab analysis. PLT test data was converted to UCS (Unconfined compressive rock strength) values and then the resulting UCS values inputted in to RocLab, which generated the Mohr-Coulomb parameters.

The use of lump test procedures (AS4133.4.1, 2007) provides a potential wider spread of values than would be expected from a cored sample. In addition, the lump samples had already been disturbed in their recovery method as they are intact lumps recovered from sonic core recovery

Below the upper clay layers (Unit 2 and Unit 3) the two sand strata (Unit 4 and Unit 5) contain interbedded sands with variable strengths. The layers comprise non-cemented/lightly cemented bands, between strongly cemented bands. The stronger bands have the engineering properties of a low strength rock. The non-cemented layers have a consistency of very dense sand. This layering also helps explain the wide range in point load test results with the lower values being on lightly cemented sands. Notwithstanding this, in terms of engineering behaviour, the interbedded materials are expected to behave as a single soil unit with the stronger cemented layers dominating the behaviour in terms of pit stability. The weaker layers could be subject to erosion, undermining the stronger layers. This risk will need to be managed on site.

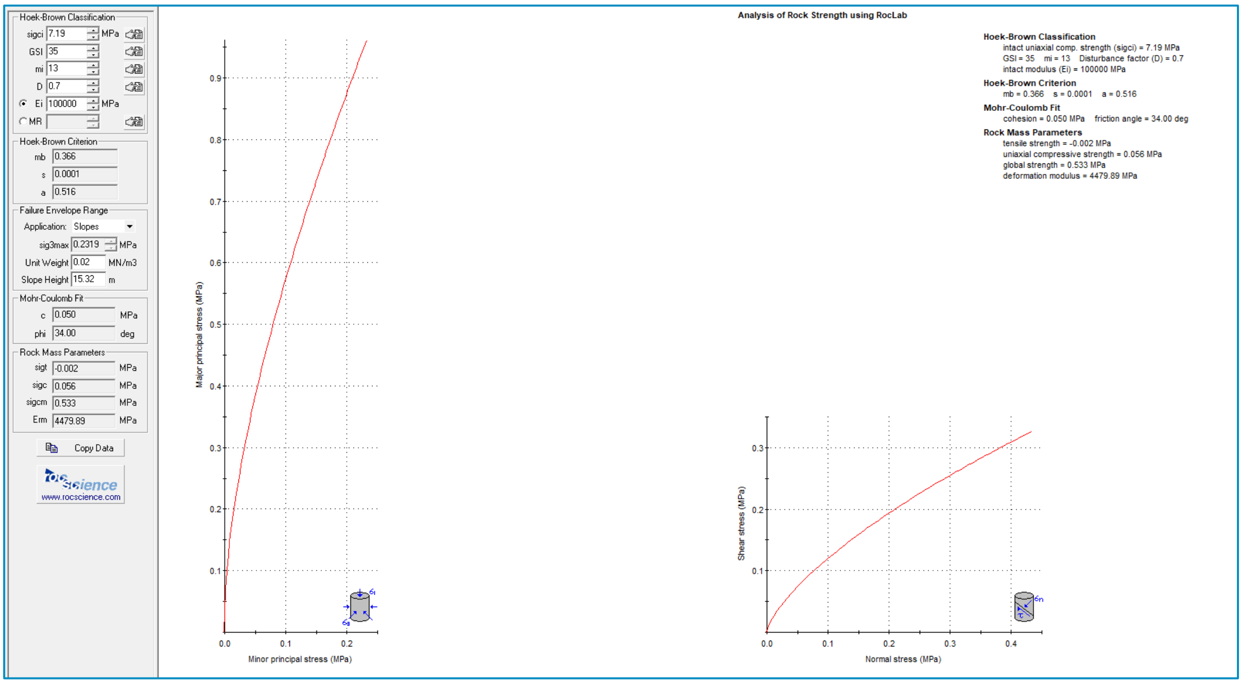


Figure 32: RocLab data analysis for PLT test data

7.1.4 Non cohesive material UCS

The non-cohesive material over the site are interbedded cemented sands and non-cemented sands. The overall engineering behaviour of these units are expected to be equivalent to a very low to low strength rock. For low strength rocks the shear strength is governed by the rock matrix. It is common practise to estimate these low strength units with a rock mass classification system, such as the Geological Strength Index (GSI) by Hoek & Brown (2018). The Hoek – Brown rock mass strength is estimated based on Unconfined Compressive Strength (UCS) of the intact rock, and an estimate of the overall rock matrix condition (GSI).

The UCS was estimated based on the Is50 point load results with the industry accepted correlated on UCS = 20 x Is50 for sedimentary rock.

The GSI for the cemented units was taken as 50%. From Figure 33 GSI Chart for Sandstone Rock (Marinos & Hoek, 2000) This value was chosen as a reasonable value for the cemented sand, which is free of clay infill, and laminations or preferential failure planes.

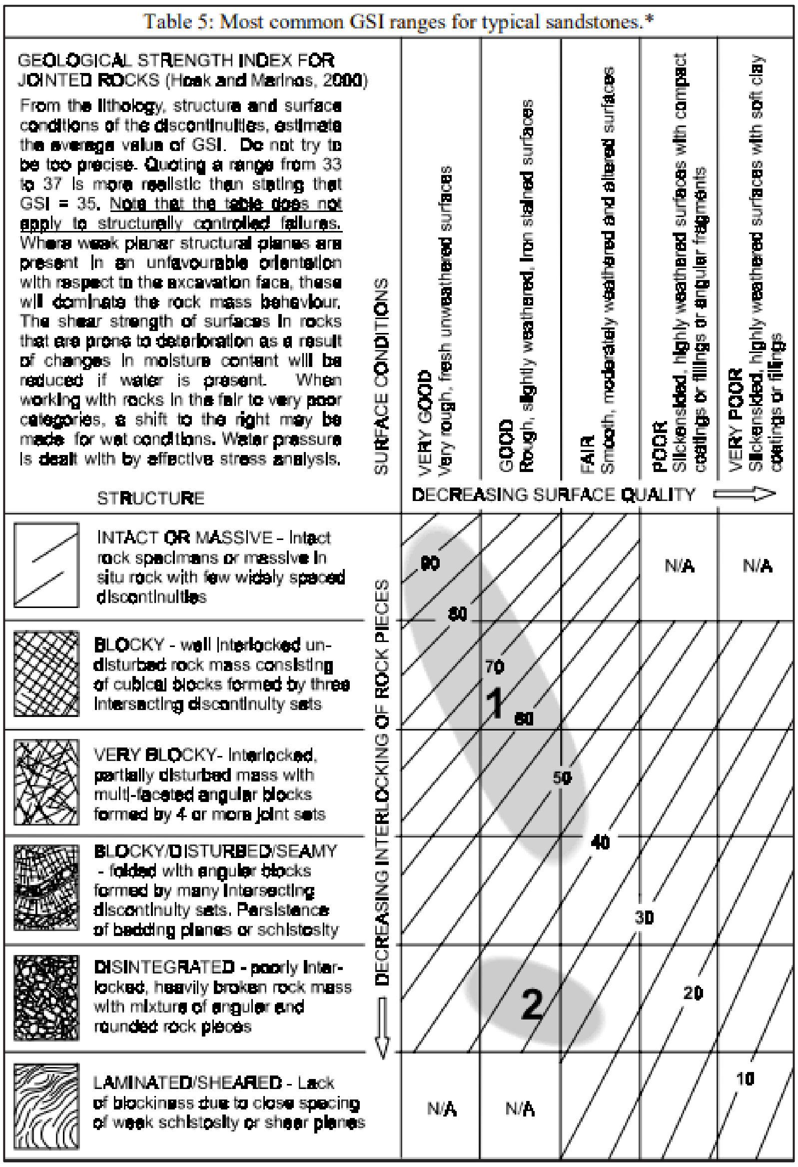


Figure 33 GSI Chart for Sandstone Rock (Marinos & Hoek, 2000)

7.1.5 Triaxial Test data

Triaxial tests were conducted on undisturbed samples recovered during the field investigation. Triaxial tests on Unit 3 and Unit 5 which contain more finer particles, provide good correlation with the other methods used for deriving shear strength parameters. For Unit 4 Triaxial tests show low values when compared to shear strengths derived from insitu tests and point load tests. This could be due to difficulties recovering undisturbed samples within the sand layers, as samples were inclined to fracture on handling and extrusion. For this reason, the triaxial tests in Unit 4 have been treated as lower confidence values.

7.2 Material Parameter Analysis

Material strength parameters variation with depth are presented in Figure 34 to Figure 37 for the different units. Based on these variations, design parameters were selected for each unit at the lower range to minimise the risks associated with strength variations of the soil units over the site area. A summary of the details is provided below.

7.2.1 Soil strength parameters: U1 - Topsoil

Soil strength parameters for Unit 1 - Topsoil was assigned based on field borehole logs. As topsoil is expected to be stripped during mining construction the impact of the topsoil layer is negligible on pit stability and stockpile stability. Laboratory tests were not conducted over the Topsoil layer.

7.2.2 Soil strength parameters: U2 - Clay/Silty Clay

The topsoil is underlain by Clay/Silty Clay of varying thickness up to 8.6m at some of the locations. Effective cohesion (c') and friction angle for this strata has been defined using the available SPT test data and includes effective cohesion varying from 4.35 to 53.4 kPa with an average value of 22.5 kPa (Figure 34).

A value of c' = 10kPa was selected for use in design. This value was selected as it reflects a conservative value below the average value as shown on the graph.

The effective friction angle varies from 20 to 30 degrees (Figure 34). With the majority of the data points being assessed as 26 deg and only 3 points falling below this value, it is assessed as a conservative value to use in design.

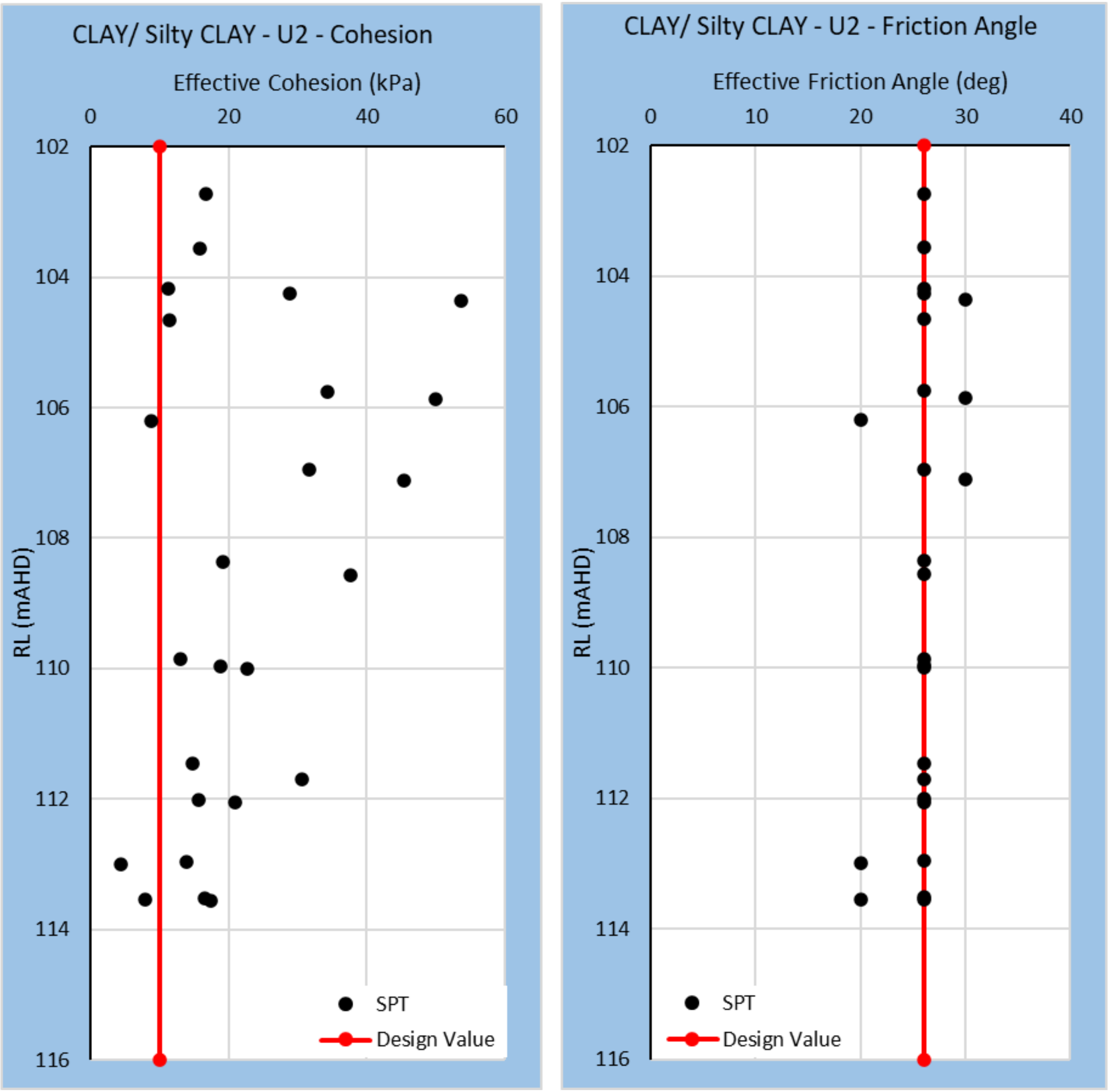


Figure 34: Soil strength parameters variation for Unit 2 (CLAY/ Silty CLAY)

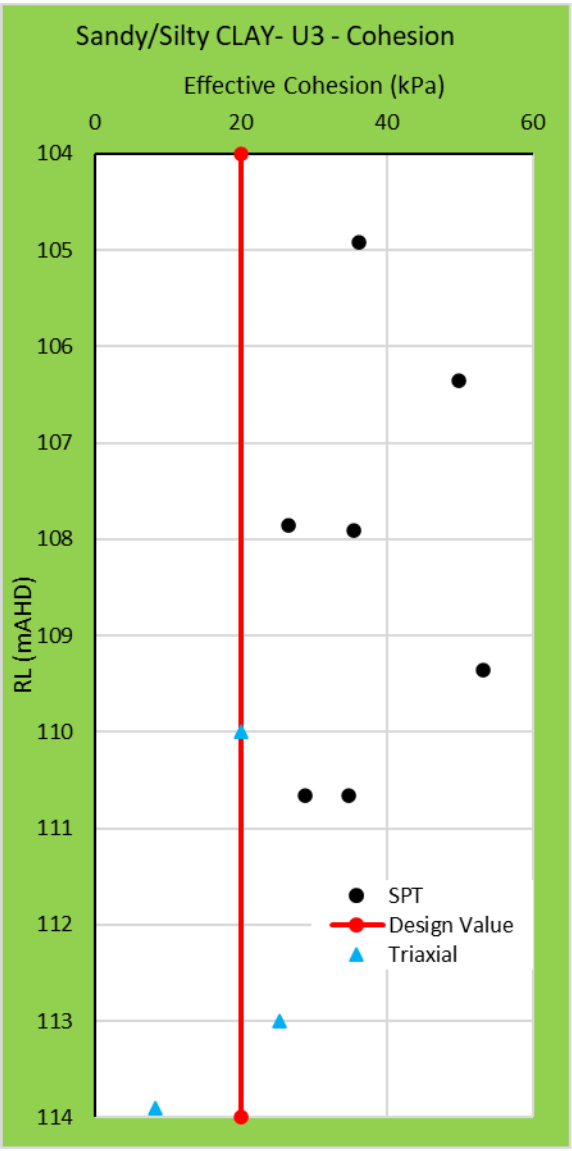
7.2.3 Soil strength parameters selection for U3-Sandy/Silty Clay

A Sandy/Silty Clay layer (U3) is present over Area 1 and Area 3 below the U2. Variations in the thickness and location of this layer can be seen in the geotechnical cross sections presented in Figure 25, Figure 28, Figure 30 and Figure 31.

Effective cohesion (c') and friction angle for this soil strata has been defined based on the available SPT data and Triaxial test results. Analysis of the test data indicates that effective cohesion varies from 8.2 to 53.2 kPa with average value of 26.9 kPa. A value of c' = 20kPa was selected for use in design. This value has been conservatively selected after review of the full set of results are shown in Figure 35.

The effective friction angle varies from 22.5 to 33.4 degrees with average value of 26.9, and 27 deg was selected as the design friction angle. The friction angle of 27 degrees in likely to be conservative given the clay material typically has about 30% sand and gravel, which would typically result in a friction angle of at least 30 degrees. For example, AS 4678-2002 (Earth Retaining Structures) suggests values of 26 degrees to 32 degrees for stiff sandy clays.

One (1) out of 3 of the triaxial test resulted has a lower effective cohesion value than the selected design value, however 2 of the triaxial test results shows higher cohesion than the selected design value. Triaxial tests were assigned lower level of confidence due to sample disturbance and very high confining pressures during testing



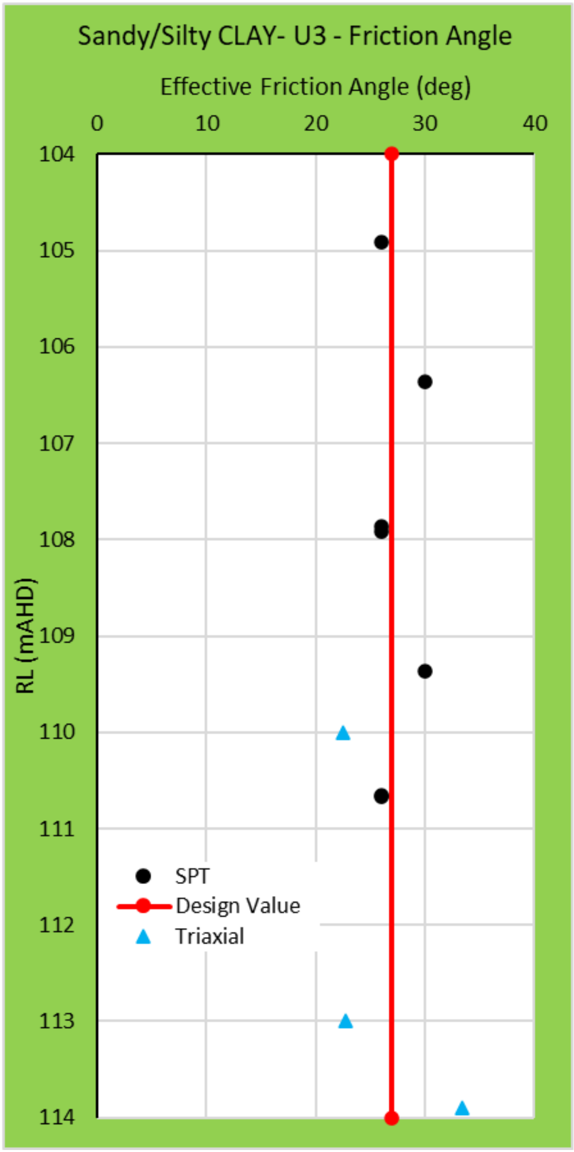


Figure 35: Soil strength parameters variation for Unit 3 (Sandy/ Silty CLAY)

7.2.4 Soil strength parameters selection for U4 - Sand layers/ Sandstone

Cemented Sand layers/ Sandstone with varying content of silt and clay were encountered below units U2 and U3. There are substantial numbers of PLT and SPT insitu test results in this unit as well as triaxial data over both Area 1 and Area 3.

Due to insitu testing constraints the SPT results are all in Area 3 while the PLT tests are concentrated in Area 1. In selecting conservative material properties for U4 a single value to cover this unit over both areas was deemed justified given the entire unit should act as a single weak rock/soil matrix as described earlier.

The results show that the effective cohesion varies from 2.8 to 148 kPa with average value of 59.4 kPa. A value of c' = 32kPa was adopted for design value.

Effective cohesion values based on PLT data resulted in lower effective cohesion values when compared to SPT values. The use of lump test procedures provides a potential wider spread of values than would be expected from a cored sample. In addition, the lump samples had already been disturbed in their recovery method as they are intact lumps recovered from sonic core recovery, while SPT results are insitu and in comparison, less disturbed. On this basis higher confidence was placed on the SPT results as the SPT is an insitu tests, widely used for sand soils.

Effective friction angle values varied between 34.3 to 63.7 degrees with average value of 47.2, however a conservative value of 35 deg was selected for design as shown in Figure 36. This cautious value was adopted to assist in addressing the lower confidence in effective cohesion.

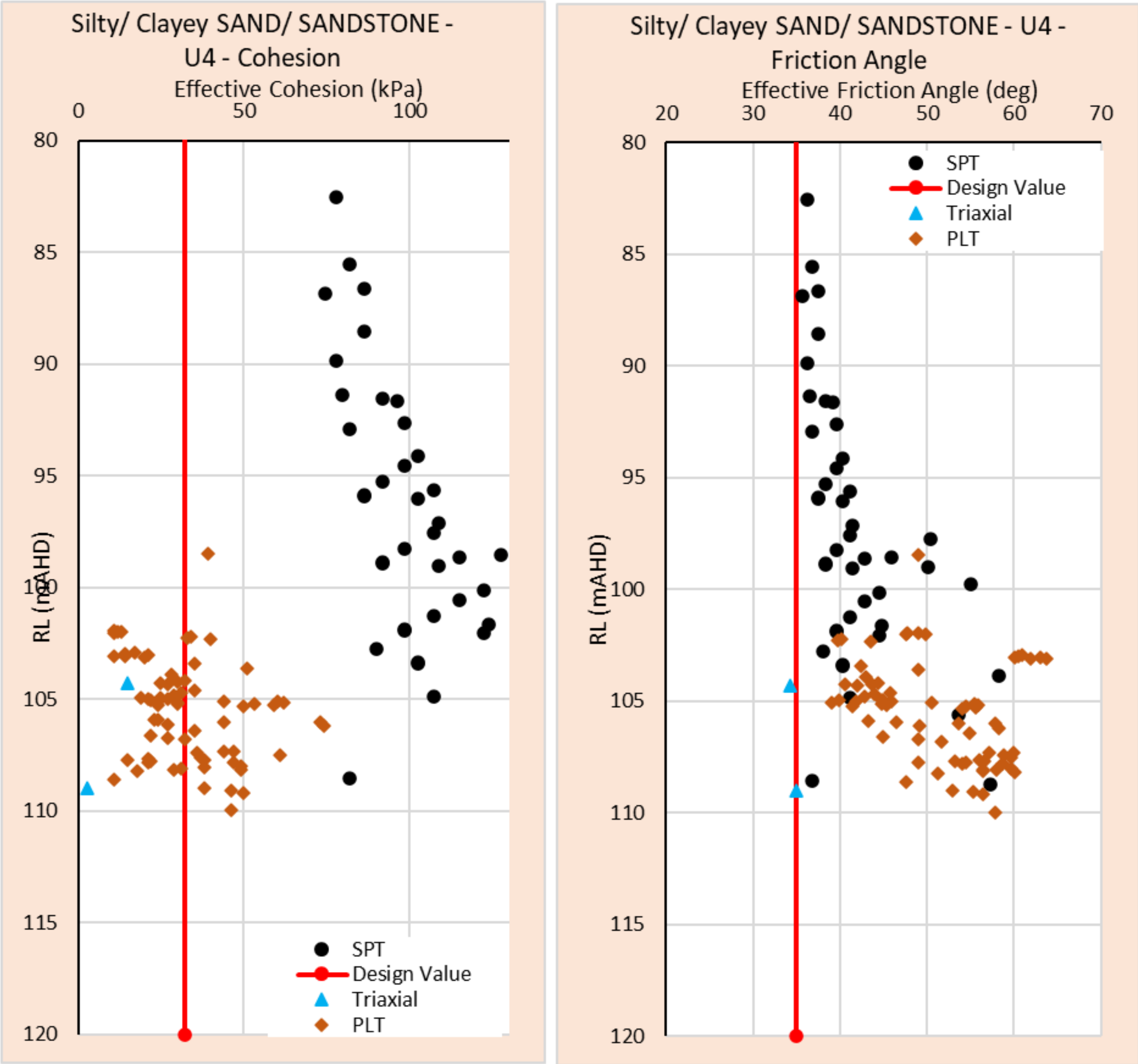


Figure 36: Soil strength parameters variation for Unit 4 (Silty/ Clayey SAND; Sandstone)

7.2.5 Soil strength parameters selection for U5 - Silty Sand

This unit presents as a Silty Sand and was usually encountered below the Sand/ Clay unit. There are PLT, SPT and triaxial data available for this soil strata across Area 1 and Area 3. Effective cohesion varies from 39 to 86 kPa with average value of 68.5 kPa. A design value of c' = 39kPa was selected, which is conservative based on the available data.

Effective friction angle varies between 28.5 to 41 degrees with average value of 35.4. For this unit a value of 35 degrees was selected as the design friction angle. As per available triaxial test data, the friction angle is 41 deg, while PLT tests showing comparatively lower values for effective friction angle. Figure 37 shows the available data plots for U5 soil strata, which shows the variation of effective cohesion and friction angle values.

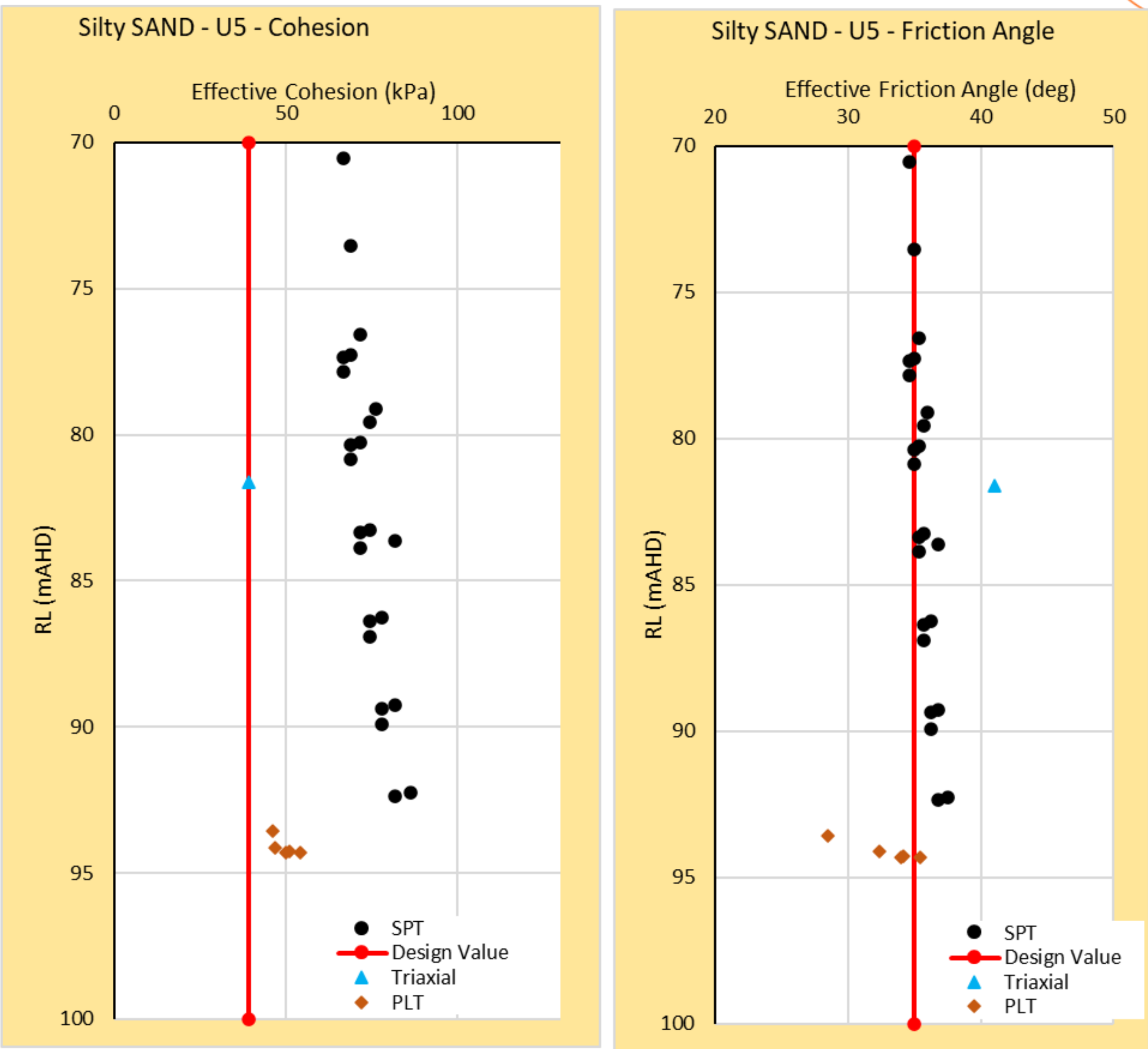


Figure 37: Soil strength parameters variation for Unit 5 (Silty SAND)

7.2.6 Selection of Soil Unit weights

Soil unit weights for different soil units have been assigned based on laboratory test data. Dry density of the topsoil layers (U2 and U3) varies between 1.65 to 1.87 t/m^3; therefore, a value of 19 kN/m^3 was adopted for these layers.

Bulk density values for U4 and U5 were selected based on the data provided in VHMs technical memo on Bulk Density for Area 1 and 3 (VHM 2022). A bulk density value of 20kN/m^3 was selected for U4 and U5 for design purposes.

7.3 Design parameters

The adopted parameters for the in-situ soils for pit slope stability, and stockpile stability are provided below in Table 8.

The top visual bund is expected to be constructed from site won materials (most likely from U2, U3 and U4), and therefore the assessed strength parameters for this material were conservative.

Table 8: Parameters for in situ soils for pit slope stability

Unit	Material	Unit weight (kN/m^3)	c' (kPa)	φ' (deg)
U1	TOPSOIL	18	5	24
U2	CLAY; Silty CLAY	19	10	26
U3	Sandy/Silty CLAY	19	20	27
U4	Silty/Clayey SAND; SANDSTONE	20	32	35
U5	Silty SAND	20	39	35
Top Bund	Compacted site won fill	18	3	26

Note: kN/m^3 = kilonewtons per cubic metre; c' = drained cohesive strength; ϕ' = drained angle of friction.

8. Geotechnical engineering assessment

8.1 Pit depth and design life

The depth of the pit is expected to vary over the two areas, depending on the mineral grade of the sand ore body, and the depth to the groundwater table. Pitt&sherry understands that all mining will be above the groundwater table. As mining advances and tailing deposition is undertaken modelling undertaken by CDM Smith (CDM Smith 2022) indicates that ground water mounding may occur. VHM have indicated that, as a component of the mining plan, localised dewatering will be installed in affected mine blocks to ensure that mining and tails bund construction is carried out nominally 1m above the lowered top of mounding.

The mining depth is generally ~25-30m deep in Area 1 and due to increased overburden Area 3 is generally 35-43m deep with on pit shell close to Jobling Rd reaching 47m deep.

Mining will occur in cells with excavation, tailings deposition and backfilling/rehabilitation undertaken progressively from cell to cell. It is expected that the pit wall in any area will only be open for a maximum of 8 to 12 months including backfilling (VHM Limited 2021). The mining period for Area 1 is expected to be 9 years.

The mine plan has been optimised to allow co-deposition of tailings into the pit cells without the requirement for an above ground temporary tailings facility. To facilitate this method, the pit will be mined in a series of cells, nominally 500 m wide by 350 m long. Cell dimensions have been optimised so they are mined in a north–south orientation for cells 1–6 (Area 1) before switching to an east–west orientation so that, as mining is completed in cells 7 to 9, subsequent cells can be mined without exposing partially consolidated tailings. This arrangement is repeated in Area 3 where cells 1-9 are mined in a north to south sequence before orienting east-west for cells 10-12. This methodology is fully outlined in Chapter 9 of the VHM DFS (Auralia Mining Consulting 20210.

The cell arrangement is shown for Area 1 and Area 3 in Figure 38 below. Notwithstanding this, it is expected that the mining and backfilling cycle will be completed in approximately 12 months.

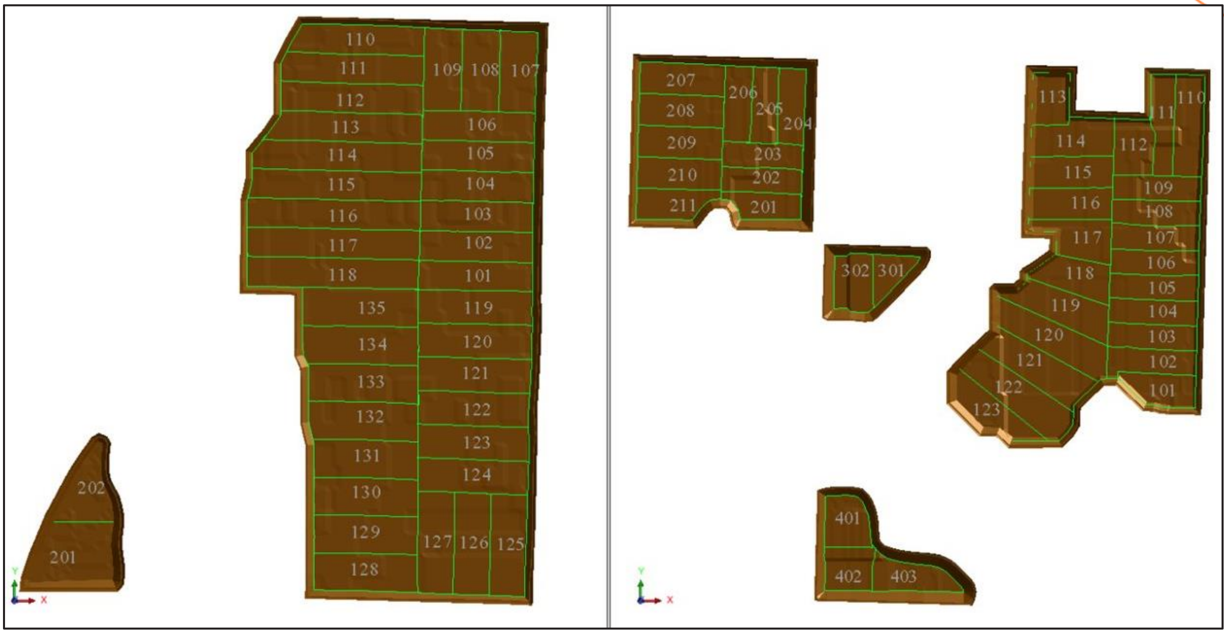


Figure 38: Cell arrangement and sequence for the pits in Area 1 and Area 3 – Y axis denotes north

8.2 Acceptance criteria

The Goschen mine pit walls have been assessed in general accordance with the process outlined in Read and Stacey 2010. The following section provides a summary of the process of establishing appropriate FoS and PoF values for the pit walls and how the general cases included in the guideline has been assessed for the specific case of the Goschen project pits with their very short life cycles which are less than 12 months compared with the guideline that considers much longer timeframes of many years for terminal pit walls

Figure 39 (Table 9.2 of Read and Stacey) outlines acceptable design FoS values recommended in the literature review carried out, as part of the development of the guideline, for civil engineering applications. For normal operating conditions and long-term stability, the guideline suggests that the FoS may vary from 1.25 to 2.

For slopes that are classed as “permanent” an FoS or 1.5 would be applicable. This is a conservative assessment given the very short life of the Goschen project pit slopes where a value of 1.25 for a “temporary” slope might be more applicable

Table 9.2: Acceptable FoS values, civil engineering applications

Material type	Conditions	Acceptance level (static)	Reference
Soil earthworks	Normal loads and service conditions	1.5	Meyerhof (1984)
	Maximum loads and worst environmental conditions	1.3	
Earth retaining structures and excavations	Normal loads and service conditions	2	
	Maximum loads and worst environmental conditions	1.5	
Slopes	Cohesionless soils	1.3	
	Cohesive soils	1.5	
	Based on field vane tests corrected for strain rate and anisotropic effects	1.3	Bjerrum (1973)
		1.25	Bowles (1979)
	Highest value for serious consequence of failure or high uncertainty	1.25–1.5	Gedney & Weber (1978)
		1.5	Hansen (1967)
		1.3–1.5	Meyerhof (1970)
		1.3–1.4	Sowers (1979)
	Lower values for temporary loading	1.5 1.25–1.3	Terzaghi (1943)
	Permanent or sustained conditions	1.5	US Navy Department (1962)
	Temporary	1.25	SAICE COP (1989)
	Permanent	1.5	SAICE COP (1989)
Dams	End of construction, no reservoir loading, pore pressure at end of construction estimates with undissipated pore pressure in foundations	1.3	Hoek (1991)
	Full reservoir, steady state seepage with undissipated pore pressure in foundation	1.3	
	Full reservoir with steady state flow and dissipated pore pressure	1.5	
	Flood level with steady state flow	1.2	
	Rapid drawdown pore pressure in dam with no reservoir loading	1.3	

Figure 39 Table 9.2 from Read and Stacey 2010

Figure 40 and Figure 41 (Table 9.2 and 9.3 of Read and Stacey 2010) provides guidance for the design FoSs and PoFs suggested by Priest and Brown (1983). In Table 9.3, Priest and Brown use three slope categories based on the consequence of failure and suggest design values for the FoS and PoF for:

- The probability of the FoS being less than 1.0 (P[FoS ≤ 1.0]); and
- The PoF being less than 1.5 (P[FoS ≤ 1.5]).

If one of these criteria is not met, the slope is deemed to be potentially unstable, as described in Table 9.4.

The guideline advises that industry experience suggests that the acceptance levels suggested by Priest and Brown in Tables 9.3 and 9.4 are conservative.

For the Goschen project based on the lifetime of the slope (less than 12 months) and the consequence of a failure being moderately serious and the slope size being less than the very serious description a mean FoS of 1.6 is suggested with a possible variance of PoF from 1% to 10%

Table 9.3: FoS and PoF guidelines

		Acceptable values		
Consequence of failure	Examples	Mean FoS	Minimum P[FoS < 1.0]	Maximum P[FoS < 1.5]
Not serious	Individual benches; small (< 50 m), temporary slopes, not adjacent to haulage roads	1.3	10%	20%
Moderately serious	Any slope of a permanent or semi-permanent nature	1.6	1%	10%
Very serious	Medium-sized (50–100 m) and high slopes (<150 m) carrying major haulage roads or underlying permanent mine installations	2.0	0.30%	5%

Source: Priest & Brown (1983)

Figure 40 Table 9.3 from Read and Stacey 2010

Based on Figure 41 (Table 9.3 of Read and Stacey 2010) the Goschen pit slopes with a consequence of moderately serious would meet the interpretation of **Operation of slope presents risk that may or may not be acceptable; level of risk can be reduced by comprehensive monitoring program.** The Goschen pit wall are managed in accordance with a comprehensive GCMP which includes requirement for monitoring

Table 9.4: Interpretation of Priest & Brown (1983) FoS and PoF guidelines

Performance of slope with respect to Table 9.3	Interpretation
Satisfies all three criteria	Stable slope
Exceeds minimum mean FoS but violates one or both probabilistic criteria	Operation of slope presents risk that may or may not be acceptable; level of risk can be reduced by comprehensive monitoring program
Falls below minimum mean FoS but satisfies both probabilistic criteria	Marginal slope: minor modifications of slope geometry required to raise mean FoS to satisfactory level
Falls below minimum mean FoS and violates one or both probabilistic criteria	Unstable slope: major modifications of slope geometry required; rock improvement and slope monitoring may be necessary

Figure 41 Table 9.4 from Read and Stacey 2010

Figure 42 (Table 9.5 from Read and Stacey 2010) incorporates the service life, public liability and type of monitoring applied. The table also provides guidance for interpreting the PoF level in terms of the frequency of failed slopes, including unstable movements. The guideline also notes that although this may sometimes be helpful, it should be used with caution as it was based on a frequency-of-event interpretation of the PoF not a degree-of-belief, subjectively assessed PoF (Vick 2003), and therefore implicitly assumes the PoF to be a property of the slope and not of the design.

Notwithstanding the above the Goschen project slopes would be assessed as:

- Having a medium-term life.
- The presence of visual bunds and a security fence around the perimeter of the mine site supports that the public are discouraged from access to the slope
- The proposed implementation of a GCMP which includes monitoring of pit wall slopes addresses the minimum surveillance requirement; and
- There are currently no exposures that suggest unstable slopes (noting that the maximum exposure in only in the order of 5m depth.

Table 9.5: PoF design acceptance guidelines

PoF (%)	Design criteria			Aspects of natural situation	
	Serviceable life	**Public liability**	**Minimum surveillance required**	**Frequency of slope failures**	**Frequency of unstable movements**
50–100	None	Public access forbidden	Serves no purpose	Slope failures generally evident	Abundant evidence of creeping valley sides
20–50	Very very short-term	Public access forcibly prevented	Continuous monitoring with intensive sophisticated instruments	Significant number of unstable slopes	Clear evidence of creeping valley sides
10–20	Very short-term	Public access actively prevented	Continuous monitoring with sophisticated instruments	Significant instability evident	Some evidence of slow creeping valley sides
5–10	Short-term	Public access prevented	Continuous monitoring with simple instruments	Odd unstable slope evident	Some evidence of very slow creeping valley sides
1.5–5	Medium-term	Public access discouraged	Conscious superficial monitoring	No ready evidence of unstable slopes	Extremely slow creeping valley sides
0.5–1.5	Long-term	Public access allowed	Incidental superficial monitoring	No unstable slopes evident	No unstable movements evidence
<0.5	Very long-term	Public access free	No monitoring required	Stable slopes	No movements

Source: Kirsten (1983)

Figure 42 Table 9.5 from Read and Stacey 2010

Based off these criteria a PoF of 1.5-5% would be applicable.

Figure 43 (Table 9.6 of Read and Stacey 2010) was developed by SRK for diamond mines which is not considered to be highly relevant to the Goschen pit wall slopes. The most applicable assessment however would be a category 2 slope and an PoF of <15% would be applicable

Table 9.6: Acceptable PoFs, mining rock slopes

Category	Description	Acceptable PoF
1	Critical slopes where failure may affect continuous operation and pit safety	<5%
2	Slopes where failure have a significant impact on costs and safety	<15%
3	Slopes where failure has no impact on costs and where minimal safety hazards exist	<30%

Source: SRK Consulting (2006)

Figure 43 Table 9.6 from Read and Stacey 2010

Figure 44 (Table 9.7 of Read and Stacey) describes the acceptance criteria for the design of the slopes specifically at the Ujina open pit in Chile. As noted above this mine example is not considered to be a closely relevant however the process combines FoSs and PoFs with the physical consequences of slope instability and their effect on the integrity of the slopes at bench, inter-ramp and overall (global) scale. On this basis it has been used as a useful general guide.

For the Goschen project:

- Bench scale final walls with a loss of 25-50% and a failure of 1000 tons/m would indicate that a PoF of less than 30 would be applicable; and
- Global final walls for failures of less than 25,000 tons/m would indicate a FoS >1.3 and a PoF <12% would be applicable (note assessed failure volumes for the Goschen pit walls have been assessed as <2000 tons/m

Table 9.7: Acceptance criteria, FoS, PoF and category of slope instability

Slope type	Case	Characteristics of instability		Acceptability Criterion		Comments
		Loss of ramp berm (%)	Material affected (ktons/m)	FoS	PoF (%)	
Bench	Expansion, not adjacent to a ramp	<25	<0.5/<1.0			Berms should have a nominal width to contain unravelling wedges whose probability of occurrence is >30%; controlled blasting will be used to minimise induced damage and presplitting on the final wall slopes
		25–50	<1.0/<2.0		<45	
		>50	>1.0/>2.0		<35	
	Expansion, adjacent to a ramp	<25	<0.5/<1.0			
		25–50	<1.0/<2.0		<40	
		>50	>1.0/>2.0		<30	
	Final wall, not adjacent to a ramp	<25	<0.5/<1.0			
		25–50	<1.0/<2.0		<35	
		>50	>1.0/>2.0		<25	
	Final wall, adjacent to a ramp	<25	<0.5/<1.0			
		25–50	<1.0/<2.0		<30	
		>50	>1.0/>2.0		<20	
Inter-ramp	Expansion	<25	<5	>1.20	<30	Stability analysis must include explicit effect of rock mass structures; two independent access ramps will be made to the pit bottom; measures will be implemented for slope drainage
			>5	>1.25	<25	
		25–50	<5	>1.25	<25	
			5–10	>1.30	<22	
			>10	>1.35	<20	
		>50	<10	>1.30	<22	
			10–20	>1.35	<20	
			>20	>1.45	<18	
	Final wall	<25	<5	>1.20	<25	
			>5	>1.25	<20	
		25–50	<5	>1.30	<22	
			5–10	>1.35	<20	
			>10	>1.45	<18	
		>50	<10	>1.35	<20	
			10–20	>1.40	<18	
			>20	>1.50	<15	
Global	Expansion		<25	>1.30	<15	Stability analysis must include mass structures; all mine infrastructure lie outside pit perimeter limits
			25–50	>1.40	<12	
			>50	>1.50	<10	
	Final wall		<25	>1.30	<12	
			25–50	>1.45	<10	
			>50	>1.60	<8	

Source: Swan & Sepulveda (2000)

Figure 44 Table 9.7 from Read and Stacey 2010

A summary of the significant variation in applicable FoS and PoF provided by interpreting Read and Stacey 2010 is provided in Table 9.

Table 9 Summary Table of FoS and PoF guidance based on Read and Stacey 2010

Reference	FoS and PoS	Goschen Project compliance
Figure 39 Table 9.2 from Read and Stacey 2010Figure 39 Table 9.2 from Read and Stacey 2010	FoS **1.5**	FoS of 1.6 Adopted
Figure 40 Table 9.3 from Read and Stacey 2010	FoS of **1.6** variance of PoF from **1%** to **10%**	FoS 1.6 however Minimum PoF exceeded noting that the Goschen project material properties have been conservatively selected and the PoF analysis varies the material properties below these conservative values (i.e. conservatism on top of conservatism outcome)
Figure 41 Table 9.4 from Read and Stacey 2010	**Potentially Unstable Monitoring required**	Goschen pit wall are managed in accordance with a comprehensive GCMP which includes requirement for monitoring.
Figure 42 Table 9.5 from Read and Stacey 2010	PoF of **1.5-5%**	PoF >1.5 Goschen project 0%-5%
Figure 43 Table 9.6 from Read and Stacey 2010	PoF of **<15%**	Goschen project 0%-5%
Figure 44 Table 9.7 from Read and Stacey 2010	FoS **>1.3** and a PoF **<12%**	Goschen project FoS 1.6 and PoF 0%-5%

8.3 Mine pit wall geometry and Setout/Buffer Zone

The depth mining in each area was defined by Auralia Mining Consulting, together with a proposed crest of pit wall set out string, toe of pit wall, as well as bench heights and berm widths. This setout was taken as the basis for assessing the pit wall stability and any requirements for a buffer zone to protect sensitive receivers.

Typically pit depths in Area 1 are around 25 to 30m deep, and in Area 3 the depths are 35m to 43m deep, and locally up to 47m deep.

The pit wall geometry and pit crest alignment have been designed such that there is no failure surface/slip which extends into the sensitive receiver areas that do not satisfy the Acceptance Criteria. The zone from the crest of the pit to the point where the stability condition is satisfied has been termed the Buffer Zone.

8.4 Inputs for pit stability

The following inputs for the pit stability assessment have been made based on pitt&sherry's experience in similar materials, guidelines from published papers and references and understanding of the works.

- For the selection of Bench Heights, consideration was given to the suggestions in Section 10.2.1.1 of Reed & Stacey (2009), where 10m to 18m is a typical bench height, and 15m is more common. For the pit walls the first bench height is 10m which was conservatively chosen to coincide with the average base of the clay layer. The second bench is typically at 25m depth (I.e. 15m high bench) and then the batter extending down to the pit floor (I.e. Second bench height and third bench height 15m each). The exception to this is Jobling Road where the pit depth is 47m and a fourth bench of 7m height is included
- The criteria adopted for the bench widths is the ability to arrest potential rock/soil falls, and to provide enough width for safe access for monitoring equipment, For bench widths the formulae in Equation 10.1 of Reed and Stacey 2009 results in a theoretical bench width of 6.5m to 7.5m. As the pit walls will be formed in soils/ weak rock where the failure volumes are expected to small when compared to large rock failure formed by jointing/bedding, berm widths were restricted to 6m wide. This is adequate to provide light and heavy vehicle access as well as a small safety berm

- A typical pit wall section with terminology defined is shown below on Figure 45

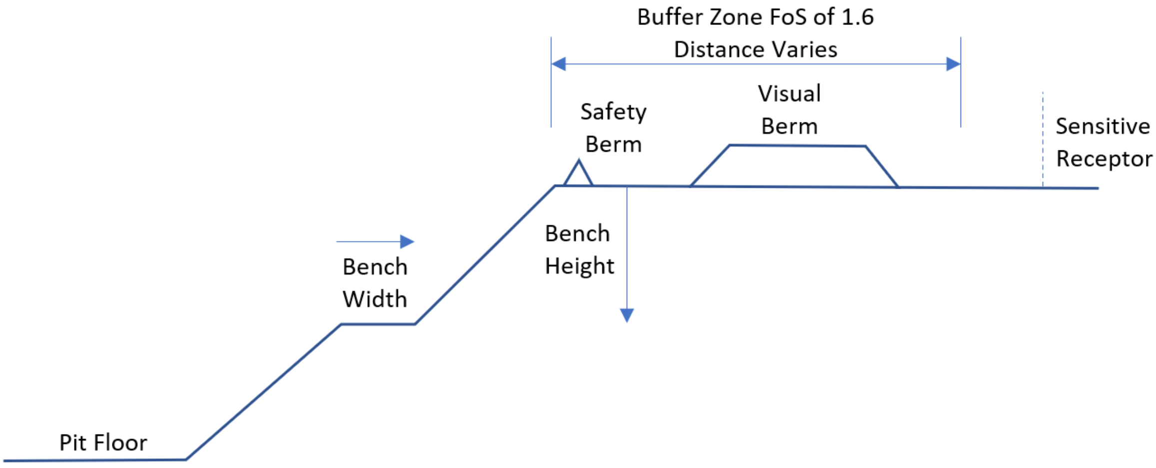


Figure 45 Typical pit wall section terminology

- Five critical pit wall sections were selected for analysis. These were sections which corresponded to the locations of sensitive receivers
- Groundwater phreatic surface will remain below the pit floor and influence zone of slopes. If mounding of the groundwater begins to occur, dewatering will be undertaken to keep the groundwater level below the pit floor. As the permeability of the soils near the pit floor is relatively high the resultant phreatic surface should remain below the pit floor to a distance well outside the influence of the pit slopes
- The soil materials within the pit wall will always remain dry without perched water tables forming during periods of heavy rainfall. In the event of flooding or during extreme wet periods, operation procedures will be in place to manage the risk of localised failures from unforeseen groundwater conditions; and
- Earthquakes are not considered to be valid design load cases for the pit walls.

8.5 Pit wall stability analysis

8.5.1 Mine pit wall stability and recommended slope profile

A pit wall stability analysis was carried out in RocScience limit equilibrium analysis software Slide 2D version 7.0 using the Morgenstern-Price method.

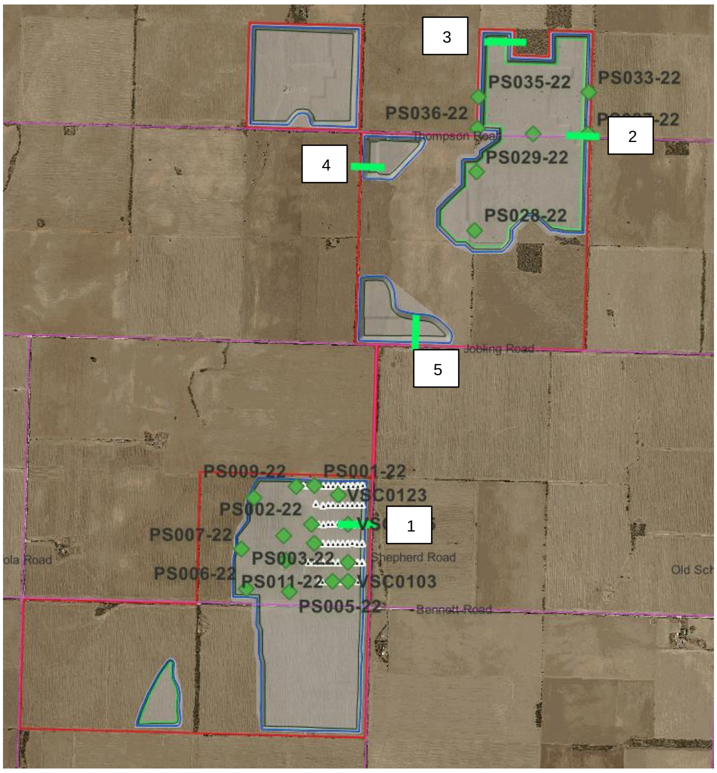


Figure 46: Selected cross section locations for slope stability analysis

Five critical sections across Area 1 and Area 3 were identified for pit wall stability analysis. A summary of analysis results are shown in Table 10. When developing the models, the following principles were included:

- All the berms were 6m wide
- Ground profile was developed based on nearest borehole log/ logs; and
- The back of the visual berm is 22m from the slope crest.

Table 10: Summary of results from the critical sections

Model number	Section	Pit depth (m)	Min FoS	Distance (m) from Crest to FoS > 1.6	Min FoS beyond visual berm	Benches arrangement	Overall batter angle (º)
1	A1_ShepherdRd	30	2.01	See Note 1	2.14	At 10m and 20m	32
2	A3E_ThompsonRd	40.5	1.84	See Note 1	1.93	At 10m and 25m	32 (See Note 2)
3	A3E_Veg	42.2	1.69	See Note 1	1.87	At 10m and 25m	32 (See Note 2)
4	A3W2_Rd	42.3	1.29	17.5	1.82	At 10m and 25m	32
5	A3W2_JoblingRd	47	1.34	15.1	1.81	At 10m, 25m and 40m	32 (See Note 2)

Note 1: For Model No. 1, 2 and 3 no buffer zone is required in terms of stability as all potential failure surfaces have a FoS > 1.6.

Note 2: Batter angle modelled at 31degrees, for assessing buffer distance. Final overall batter angle to be verified in FEED.

An example of full outputs for each Slide model is shown on Figure 47.

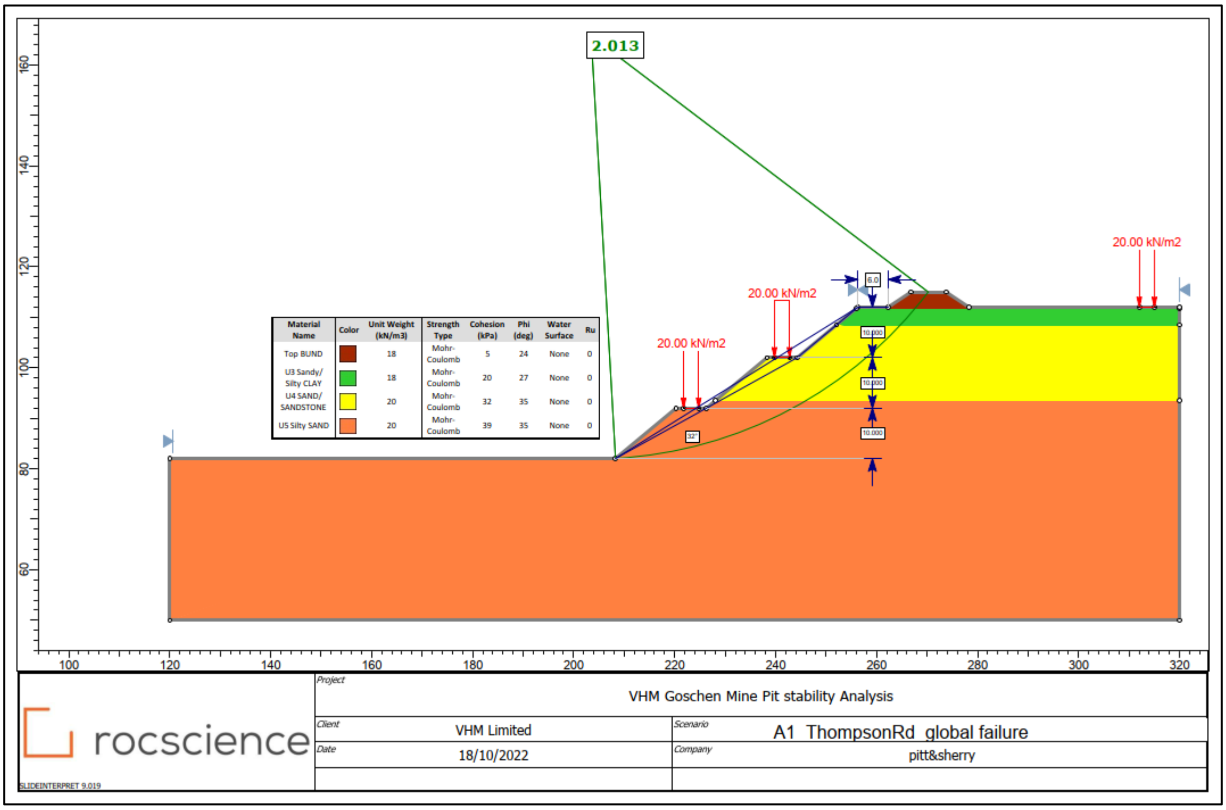


Figure 47: Example of Slide model output and input for A1_ShepherdRd

8.6 Probability of failure assessment

Probability assessment was conducted to assess the material parameters sensitivity to the factor of safety of the pit batter profile.

Mohr-Coulomb parameters (cohesion and friction angle) were considered as independent variables for the probability analysis. Standard deviation was set to be 20% of the selected design values. Sampling of the cohesion was done assuming a normal distribution to provided further distribution of the sample space. Friction angle was sampled using Lognormal distribution, which is a widely used sampling method for soil friction angle sampling as friction angle cannot be negative (and variation in friction angle for soil stratum do not usually significantly vary). Material parameters variation used in the probability assessment are summarised in Table 11.

Table 11: Material parameter variation

Soil Unit	Property	Distribution	Mean	Standard Deviation	Min	Max
U1	Cohesion	Normal	5	1	2	8
	Friction Angle	Lognormal	24	5	9	39
U2	Cohesion	Normal	10	2	4	16
	Friction Angle	Lognormal	26	5	11	41
U3	Cohesion	Normal	20	4	8	32
	Friction Angle	Lognormal	27	5	12	42
U4	Cohesion	Normal	32	6	14	50
	Friction Angle	Lognormal	35	7	14	56
U5	Cohesion	Normal	39	8	15	63
	Friction Angle	Lognormal	35	7	14	56

The sensitivity assessments were conducted for 2000 random samples selected by the Monte Carlo sampling technique as per the distribution defined in Table 11.

Figure 48 Shows a FoS variation with cohesion values (2000 points) selected based on Monte Carol sampling for Soil U2, similarly all the parameters defined in Table 11 have been sampled and then those values were used in the stability model to calculate FoS for each case.

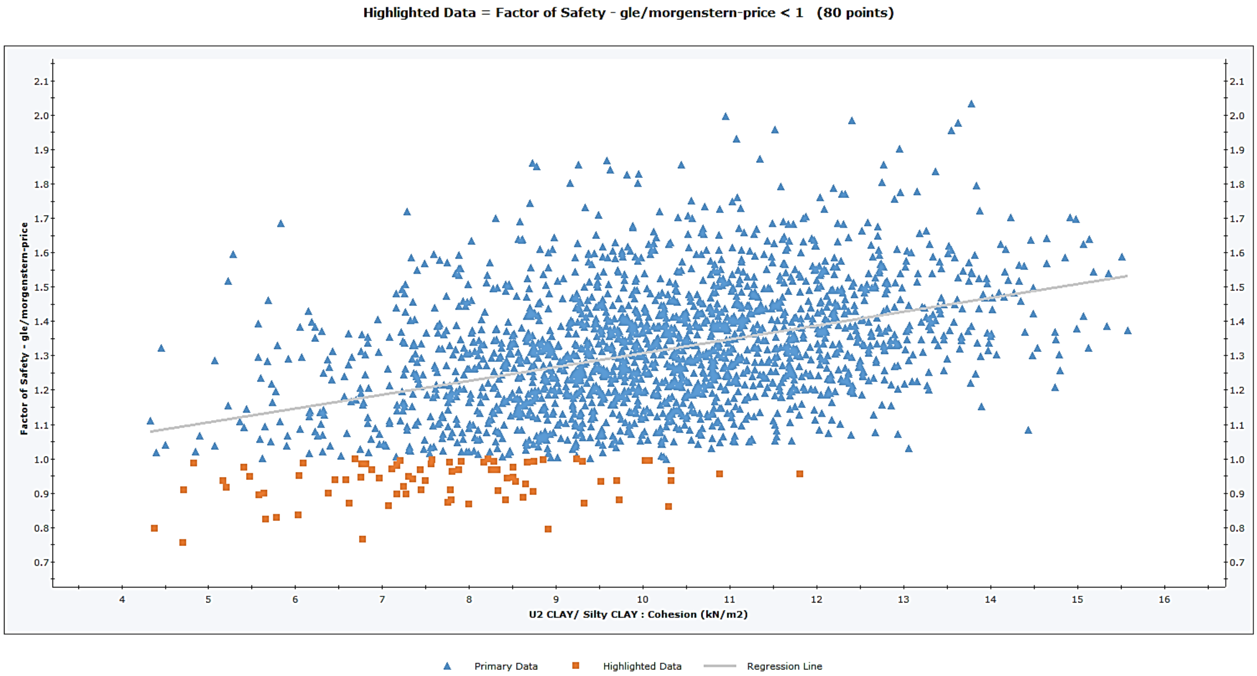


Figure 48: FoS variation with cohesion of soil unit U2

A summary of PoF values for each Scenario are summarised in Table 12. All results indicate a probability of failure with material sensitivity analysis lower than 5%.

Table 12: Summary of probability of failure assessment

Model No.	Analysis Scenario	**PoF % (FOS<1)**
1	A1_ShepherdRd	0
2	A3E_ThomsonRd	0.3
3	A3E_Veg	0.05
4	A3W2_Rd	5
5	A3W3_JoblingRd	4

An example pf PoF histograms for each Slide model is shown on Figure 49 below.

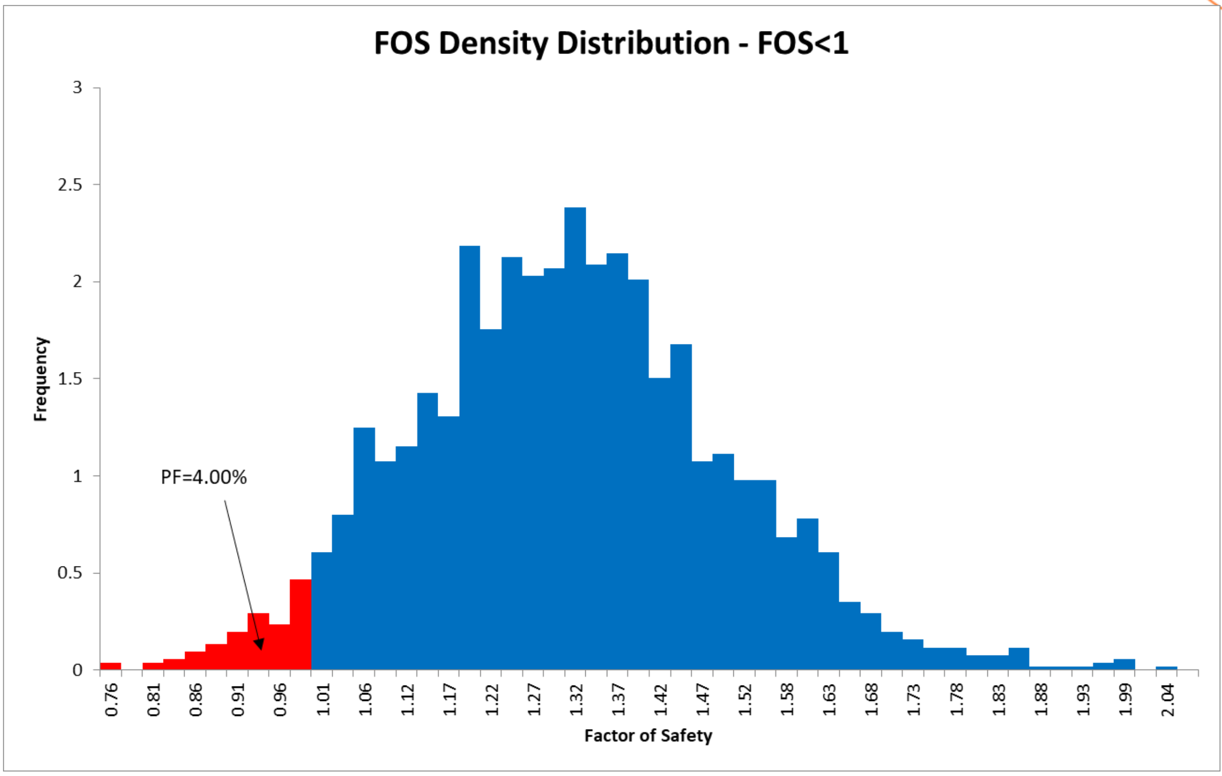


Figure 49: Example of PoF histogram for A3W3_JoblingRd

8.7 Recommended pit batter profile

The slope stability assessment shows that all potential failure surfaces have a factor of safety of at least 1.6 within calculated buffer zone of 0m to 17.5m measured from the crest of the pit wall. For Model No's 1,2 and 3 all potential failure surfaces have a FoS > 1.6 and therefore in these areas no buffer zone is required. These pit slopes therefore exceed the Acceptance Criteria for stability. The stability analysis is considered to be conservative as the strength parameters selected for the modelling are a cautious estimate of characteristic values demonstrated by testing.

The PoF (FoS has been assessed as from 0% to a maximum of 5% which satisfies the guidelines and acceptance criteria using a normal distribution of both cohesion and friction. (The PoF is calculated as the number of slip surfaces with a FoS < 1/ Total No. Of slip surfaces analysed x 100), Lower bound values in the normal distribution are well below any values represented by test results and typical values for the materials expected.

As the pit slopes are in soils, the volume of material within a theoretical failure surface is relatively low when compared to an equivalent pit wall in rock. Included in Table 13 is the slip weight for the slip surface with factor of safety less than 1.6, FoS (1.3 to 2.01). It should be noted that these slip surfaces are well within the buffer zone and will have no impact on the sensitive receptors.

Table 13 Estimated Material Weights for failure surface with FoS > 1.6 and for failure surface with the minimum FoS

Model No	Analysis Scenario	Slip Weight for failure surface with FoS of 1.6	Slip Weight for failure surface with lowest FoS
1	A1_ShepherdRd	See Note 1	See Note 1
2	A3E_ThomsonRd	See Note 1	See Note 1

3	A3E_Veg	See Note 1	See Note 1
4	A3W2_Rd	< 2 k tons/m	< 0.5k tons/m
5	A3W3_JoblingRd	< 2 k tons/m	< 0.5 k tons/m

Note 1: for Model No. 1, 2 and 3 all failure surfaces are > 1.6

Based on the results of this assessment, it is recommended that for design purposes, the pit slope should generally have the geometry shown in Table 14. The minimum buffer zone has been set at 22m to allow provision of safety berms and visual berm, however in terms of pit stability, no buffer zone is required in some areas, and the theoretical maximum buffer zone is 17.5m. Optimisation of buffer zones for various areas around the pit wall can be considered in FEED.

Table 14: Recommended pit geometry

Geometry	**Recommend limits**	
Pit depth	Up to 42 m	47 m
Bench Heights*	First bench at 10m Second Bench at 25m	First bench at 10m Second bench at 25m Third bench at 40m
Minimum berm width	6 m	6 m
Overall slope angle	Max. 32° degrees	Max. 31° degrees
Buffer Zone	22m	22m

*Bench heights has been selected based on guidelines provided in Read and Stacey (2009)

8.8 Comparison to RMS, AGS and First Principles Slope Risk Assessment Methodologies

During investigations into the feasibility of the Goschen Area 1 and Area 3 pits the question of risk to users of the nearby roads was considered. To address this issue a series of risk assessments have been undertaken using the:

- Roads and Maritime Safety NSW Slope Risk Analysis Version 4
- The RMS Slope Risk Analysis methodology (RMS 2014) was based on the AGS methodology and optimised for use in the vicinity of roads. It is becoming required for road authorities in some parts of Australia and becoming regarded as best practice in other areas.
- Practice Note guidelines for Landslide Risk Management (Australian Geomechanics Society, 2007c)
- The Australian Geomechanics Society methodology from 2007 has been the best practice method for landslide risk assessment in the general case for several years.
- First Principles Analysis; and
- The third assessment was made by "stepping back" and considering the geometry of the pit-road system and the basic soil parameters.

These assessments were made only in respect to risk to road users. The following critical cross sections were assessed.

Figure 50: Locations of Area 1 pit-road geometries analysed

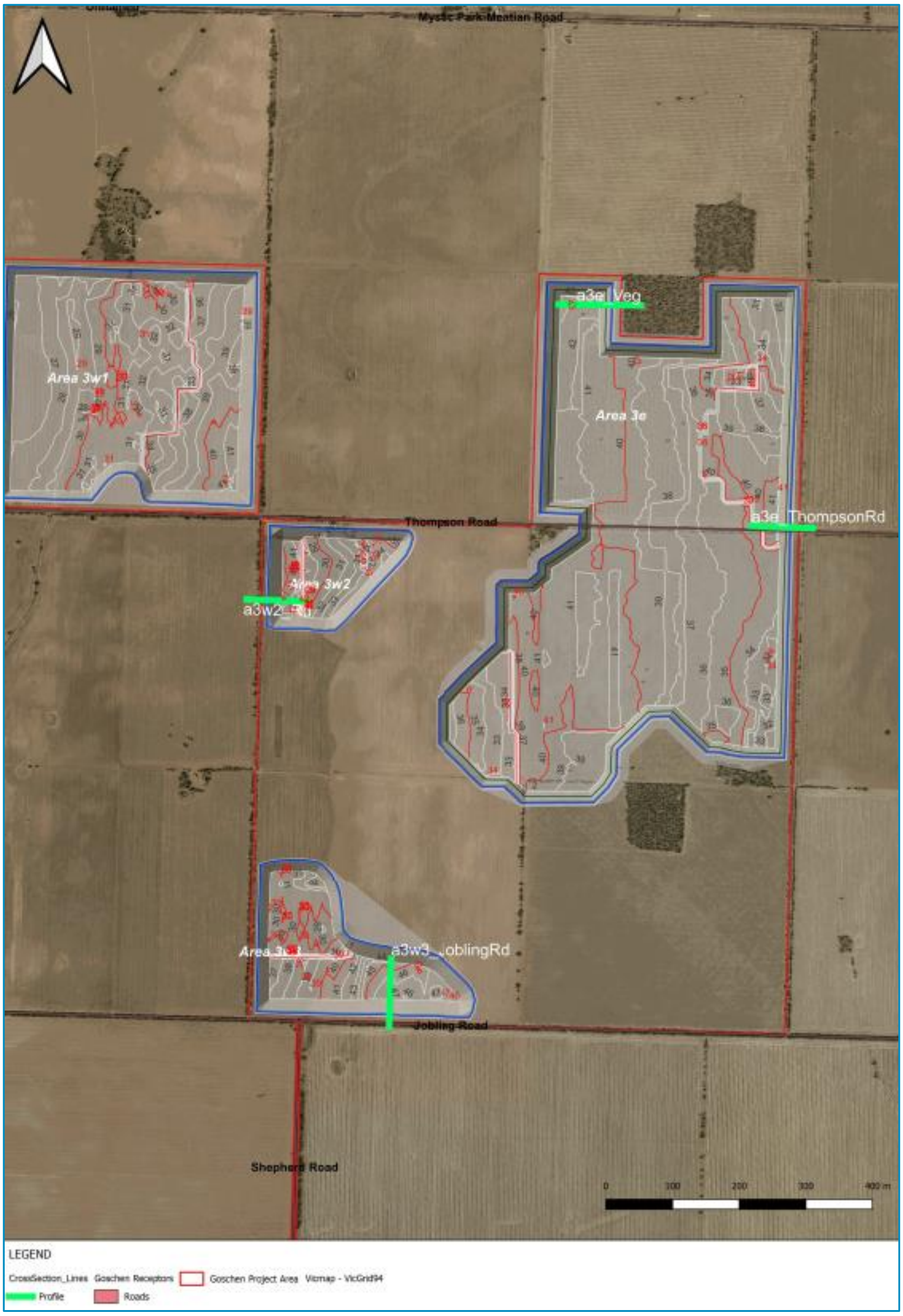


Figure 51: Locations of Area 3 pit-road geometries analysed

Summary of outcomes of the assessments

- As the key element assessed is the risk to road users the RMS methodology is considered to be the most appropriate methodology. It gives the most robust method for assessment given the uncertainties associated with likelihood of failure and has the most research behind the assessment of temporal probability and vulnerability with respect to road users. The result of this assessment is the **lowest (safest) category possible in that methodology.**
- Taking a more general view the AGS methodology has been the standard for risk assessment of slope instability in Australia since its publication in 2007. The result of this assessment is **three orders of magnitude lower (safer) than the upper limit for acceptable risk**; and

- Stepping further back, an analysis based on the basic geometry of the sites together with simple soil parameters indicate that **failure back to the road is not a credible scenario**.

Based on these assessment methodologies it is not considered probable that a road user would be likely to be impacted due to a slope failure.

8.9 Topsoil

The site investigations to date, have indicated that up to 1.5m of topsoil is present on the Goschen mining site. The topsoil in the sonic borehole logs has been recorded as a sandy clay with some silty and a clayey sand (around 30% to 50% sand).

Although the relative percentage of organic content of the topsoil was not recorded, based on pitt&sherry experience in farm paddocks and the site inspection carried out including observations of limited exposures on site the upper 300mm is expected to have a high organic content. Below this organic matter may be present but will be in low proportions compared to the overall soil matrix. Typically soils with around 5% organic matter by volume can be left in place without impacting permanent works.

Triaxial tests on the topsoil layer indicates the material below the organic layer has adequate shear strength to support construction loads and soil embankments.

For the purpose of the DFS and quantity estimates and based on pitt&sherry's experience in similar soils, the upper 300mm is recommended to be stripped and stockpiled. The remaining topsoil layer (i.e. below the 300mm organic layer), can be left in place for the areas that are designated to have road embankments and stockpiles constructed.

For mining area's, the remaining topsoil layer can be classified as "sand overburden" and placed in safety bunds, noise barriers, or stockpiled for future overburden backfilling.

Further testing of the topsoil layer to evaluate the proportion of organic matter and requirements for topsoil conditions for re-use should be undertaken during the FEED stage.

8.10 Stockpile stability and recommended geometry

A number of stockpiles will be maintained over the duration of the mine life including organic topsoil material which will be used for final mine rehabilitation. Other stockpiles include separate clay stockpiles for material used to construct tailing bunds and provide a capping layer as part of the mine rehabilitation process. The final stockpile will be mixed overburden material of poor ore grade, not suitable for processing.

As part of the stockpile design process the Goschen project stockpiles have been assessed using the Waste Dump and Stockpile Stability Rating and Hazard Classification System (WSRHC) outlined in Mark Hawley and John Cunning 2017. Guidelines for Mine Waste Dump and Stockpile Design (Mark Hawley and John Cunning 2017).

the WSRHC system can be used as a guide to the level of effort required to investigate, design and construct waste dump. Waste dumps and stockpiles with lower stability ratings, or that fall into higher hazard classes, logically ought to require more investigative and design effort, and more care and monitoring during construction and operations, than waste dumps and stockpiles with higher stability ratings, or that fall into lower hazard classes. Table 3.12 from Hawley 2017 is reproduced below and provides suggestions regarding the appropriate level of effort for the site investigation and characterisation, analysis and design, and construction and operation stages in the life cycle of a waste dump or stockpile based on WSR and WHC.

Table 15 Reproduction of Table 3.12: Suggested level of effort based on waste dump and stockpile stability rating/hazard class (WSR/WHC) Hawley 2017

Stability class		**Level of effort**		
Waste dump and stockpile hazard class (WHC)	**Instability hazard**	**Investigation and characterisation**	**Analysis and design**	**Construction and operation**
I	Very Low Hazard	Basic desktop studies to establish initial stability rating and hazard classification; basic site reconnaissance to confirm key assumptions from desktop studies and plan field investigations; limited mapping and test pitting to establish/verify subsurface conditions; material parameters based on literature/ experience and validated with limited field and laboratory index testing; initiate limited baseline environmental monitoring; condemnation drilling	Simplified stability analyses to verify that stability does not influence design and potential impacts are minor; design by geotechnical specialist with peer review	Minimal site preparation; minimal restriction on construction; periodic visual monitoring; periodic inspection by geotechnical specialist
II	Low Hazard	Desktop studies to establish initial stability rating and hazard classification; site reconnaissance to confirm key assumptions from desktop studies and plan supplementary field investigations; mapping and test pitting as required to verify subsurface conditions; material parameters based on literature/experience and validated with field and laboratory index testing; initiate environmental baseline monitoring; condemnation drilling	Stability analyses to verify that stability has limited impact on design; design by experienced geotechnical specialist with peer review	Limited site preparation, may include minor diversions; limited construction constraints; standard instrument and visual monitoring with basic trigger action response plan (TARP); periodic inspection by experienced geotechnical specialist
III	Moderate Hazard	Comprehensive desktop studies to establish initial stability rating and hazard classification; detailed site reconnaissance to confirm assumptions from desktop studies; detailed mapping and subsurface investigations likely including test pitting/trenching and limited drilling and sampling; *in situ* instrumentation and testing and laboratory testing to verify foundation and fill material properties; initiate comprehensive baseline environmental monitoring; condemnation drilling	Comprehensive stability analyses, including consideration of runout potential; qualitative risk assessment; design moderately constrained by stability and potential impacts; design optimisation and impact mitigation studies; design conducted by experienced geotechnical specialist with peer review	Moderate site preparation, may include diversions and underdrainage; limited foundation instrumentation to verify performance; runout/rollout mitigation measures, if required; moderately constrained construction sequence; control of fill quality and placement as necessary; loading/advance rate restrictions; standard instrumentation and visual monitoring with well-defined TARPs; periodic (minimum annual) inspections by experienced geotechnical specialist
IV	High Hazard	Detailed desktop studies to establish initial stability rating and hazard classification; comprehensive site reconnaissance to confirm assumptions from desktop studies; detailed, phased mapping and subsurface investigations likely including test pitting/trenching, geophysics, specialised drilling and sampling; *in situ* instrumentation and testing and laboratory index and shear strength testing to establish foundation and fill material properties to a high degree of confidence; initiate comprehensive baseline environmental monitoring; condemnation drilling	Phased design study with detailed stability analyses of interim and final stages, including runout assessments; parametric studies; design constrained by stability and potential impacts; semi-quantitative risk assessment; optimisation, trade-off and mitigation studies; design by experienced geotechnical specialist with peer review; third party specialist review at critical stages in design	Moderate to extensive site preparation, may including underdrainage and diversions; foundation and fill instrumentation; runout/rollout mitigation measures; moderately constrained construction sequence with control of fill quality and placement; moderate to severe loading/advance rate restrictions; detailed instrument and visual monitoring with redundancy; well-defined/site-specific TARPs; frequent inspections and review by experienced geotechnical specialist; annual or more frequent review by third party specialist

The EGI for both stockpiles were assessed as having a rating score of 28, and a DPI of 35. Figure 52 below shows how these values plot on a Hazard Class Chart to assign an overall hazard rating to the stockpile.

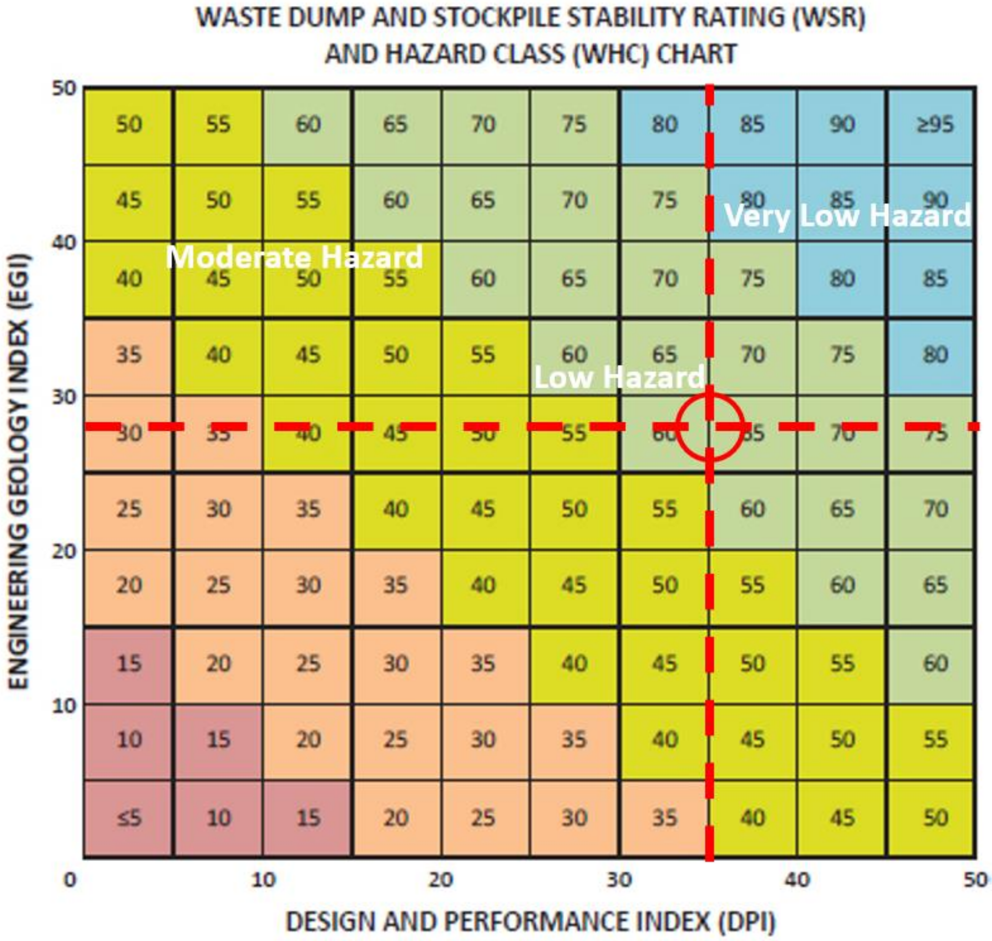


Figure 52 Waste dump and stockpile stability rating and hazard class chart (Hawley et al, 2017)

Both stockpiles were assigned an overall score of 63 and are classed as Low Hazard. The level of investigation and analysis has followed the guidelines of Table 3.12: Hawley 2017

8.10.1 Topsoil stockpile

The maximum height for individual topsoil stockpiles will be 3 m to maintain the organic material close to its original condition and, therefore, suitable for supporting regrowth. Given this low height, no modelling has been undertaken.

8.10.2 Clay and Sand overburden stockpile

The clay and sand overburden stockpiles have been nominated as being around 30 m high, measured above existing ground level (VHM Limited 2021). The stockpile was modelled with 4 m berm and 6 m lift, with a 1V:2.5H batter, it is assumed that the natural ground slopes away at the stockpile toe at five degrees from the horizontal (worst case). The typical geometry is as shown in Figure 53.

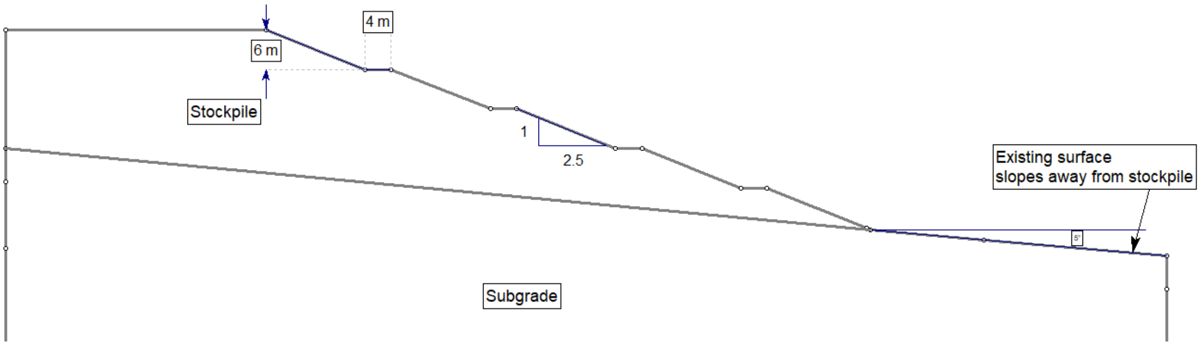


Figure 53: Typical stockpile arrangement

The stockpile material parameters which were adopted for this analysis have been summarised in Table 16 below. Remoulded strengths were used for the stockpile material. The remoulded strengths were estimated using the Figure 54 Remoulded strengths estimated based on Appendix D, AS 4678-2002 for clay soils below (AS 4678-2002) for the clay soils and based on loose sands for the sand stockpile. Cohesion has been conservatively ignored for the remoulded sand.

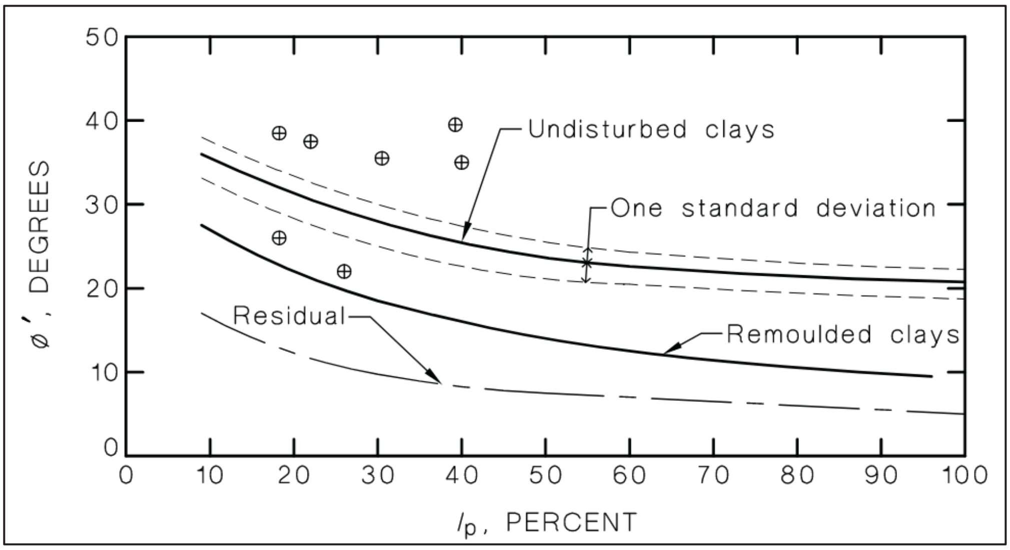


Figure 54 Remoulded strengths estimated based on Appendix D, AS 4678-2002 for clay soils

Table 16: Stockpile material parameters

Description	Maximum height above existing ground level	Unit weight of stockpile material (kN/m)	Overall Stockpile angle (β) degree	c' (kPa)	f' (degree)
Clay (Unit 2 and Unit 3)	30 m	19	17.5	5	23°
Sand stockpile (Unit 4 and Unit 5)	30 m	19	17.5	0	32°

The subgrade was modelled as a stiff to very stiff clay, following topsoil striping. The following parameters were used for the subgrade. By inspection the cemented sand layers below will have very high bearing capacity and will not be critical for the model.

Table 17: Subgrade parameters for the purpose of slope stability modelling

Unit	Material	Unit weight (kN/m^3)	Cu (kPa)	c' (kPa)	f' (deg)	Thickness
U2	CLAY; Silty CLAY	19	100	10	26	5m
U3	Sandy/Silty CLAY	19	200	20	27	10m

The analysis was carried out using the commercially available RocScience limit equilibrium analysis software Slide 2D version 9.023 using the Morgenstern-Price method. The following assessments were completed for both sand and clay stockpiles: A minimum factor of safety of 1.5 has been adopted for the stockpile stability under static load, and 1.1 under earthquake load. These values are typically used for permanent works designs in civil works projects and are considered conservative for stockpile design.

- Short term assessment: using the undrained strength parameters
- Long term assessment (stockpiles will be in place for ~10years): using the drained strength parameters; and
- Earthquake loading assessment: a Hazard Factor Z (AS 1170.4) equivalent to the effective peak ground acceleration with a return period of 500 years has been assessed. The code states the Z value for Melbourne is 0.08g. For the bund design a horizontal ground acceleration (Z) of 0.1g was adopted.

Results from the eight different scenarios are summarised in Table 18 below.

Table 18: Summary of the results of the long-term analysis

	Long term		Short term	
Scenario	**Scenario ID**	**FoS**	**Scenario ID**	**FoS**
Clay Stockpile Assessment	VHM_SA_1	1.591	VHM_SA_2	1.560
Sand Stockpile Assessment	VHM_SA_3	1.582	VHM_SA_4	1.587
Clay Stockpile Seismic Assessment	VHM_SA_5	1.175	VHM_SA_6 (Earthquake)	1.127
Sand Stockpile Seismic Assessment	VHM_SA_7	1.209	VHM_SA_8 (Earthquake)	1.209

From this assessment it is concluded that 30 m high stockpiles should be stable and meet minimum stability requirements, without special subgrade treatment.

The slip surfaces are confined within the stockpile perimeter bund, as shown in Figure 55 stockpiles are not expected to have any impact on sensitive receivers. Notwithstanding this a maintenance and drainage spacing of about 20m is recommended to allow adequate access.

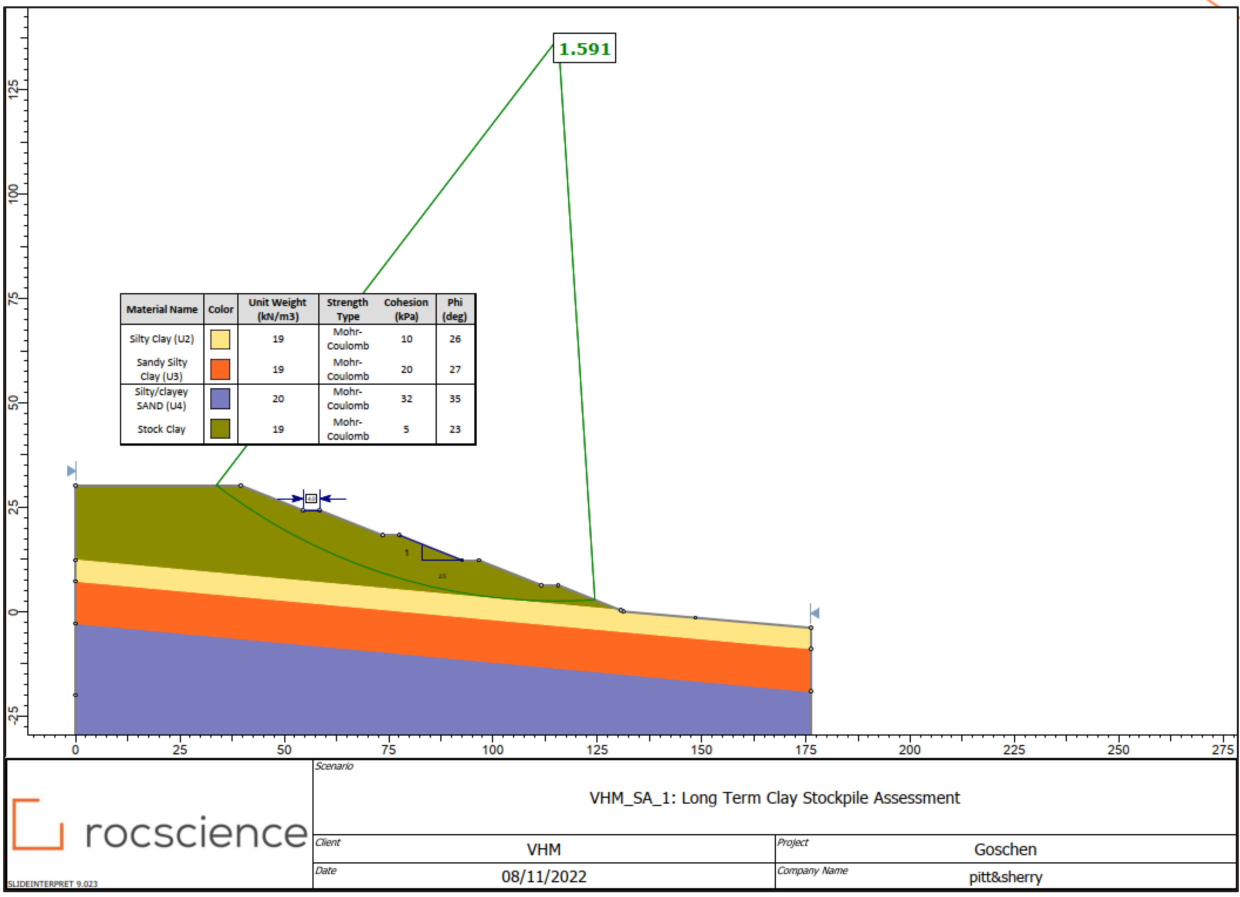


Figure 55 Example of Slope Stability Assessment for 30m high stockpiles

8.10.3 Surface water drainage bunds for stockpiles

In order to capture surface water runoff from stockpiles and prevent it entering bunded areas, catch drains with bunds, formed by using clay overburden material to prevent erosion and scour, will be constructed where required. The catch drains will be about 600 mm deep and their bunds will be approximately 2 m high with grass-lined batters. A typical arrangement is shown in Figure 56 below. The crest will be nominally 1 m wide, and all batters will be 1V:2H.

Due to their low height, no stability assessment has been undertaken as, by inspection, the 1V:2H batters should be stable.

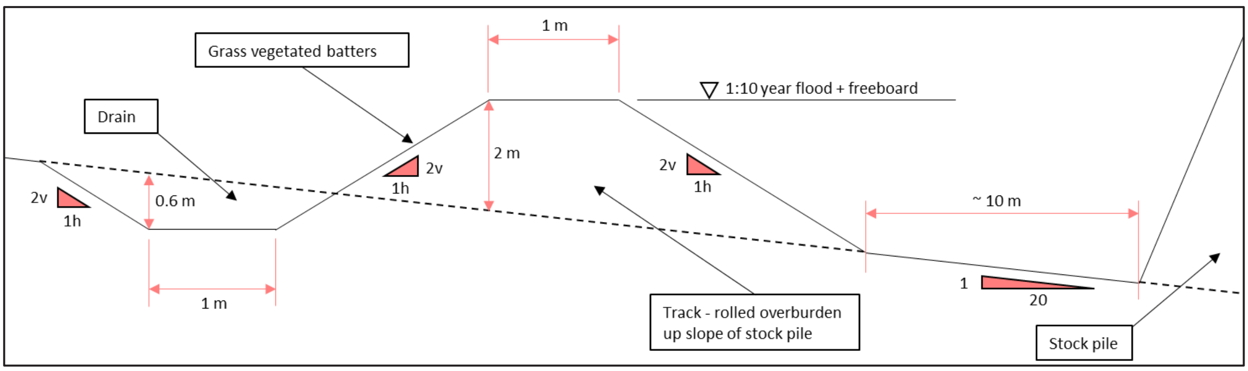


Figure 56: Cross-section of typical design for bunded surface water catch drains

8.11 Sediment ponds

The mine will include a number of sediment ponds for storage of surface water runoff and removal of sediments before overland discharge or decanting off. A stability assessment has been undertaken for storage ponds that are 5 m and 7 m deep.

As a worst-case scenario, the pond was assumed to be drained, in a rapid drawdown situation, with the phreatic surface above the pond floor level. With pond batters of 1V:2.5H, the slopes are stable without treatment. A typical detail is shown in Figure 57. No liner is considered necessary from a geotechnical engineering point of view. After repeated drawdown cycles, the surface of the ponds become uneven with surface rills or tidelines on the batters. This should be considered normal and periodic regrading and clean-out should be allowed for during dry periods.

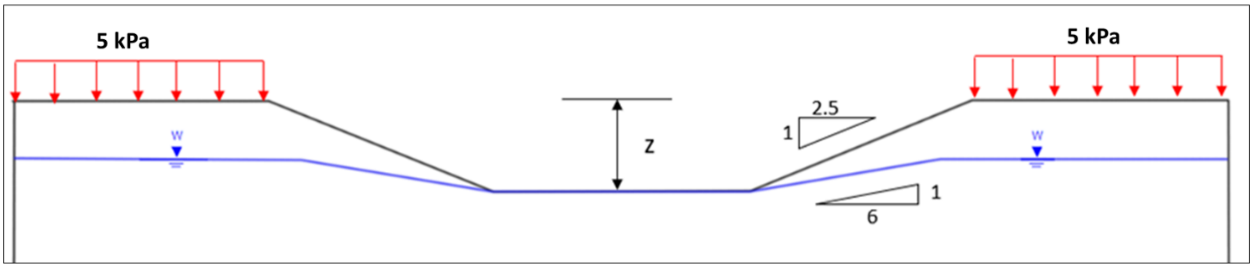


Figure 57: Sediment Pond ('z' = depth; 'w' = water level)

The analysis was carried out on two different scenarios as summarised in Table 19.

Table 19: Summary of the results of the long-term stability analysis of sediment ponds

Scenario ID	Pond depth (m)	FoS
VHM_SPA_GMA3_1	5	2.430
VHM_SPA_GMA3_2	7	2.217

9. References

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- Auralia Mining Consulting 2021 Section 9 – Mining and Ore Reserve of this DFS
- VHM 2017. Sonic Boreholes drilled in Area 1 in 2017 as logged by VHM
- VHM 2021. Goschen 5Mtpa Project Description (Doc Ref RPP960) Revision 2.0 August 2021.
- VHM 2021a Lithology records for Area 1 and in Area 3 as supplied by VHM
- VHM DFS 2021b - Section 9 – Mining and Ore Reserve
- VHM 2022 - VHM technical memo 'Bulk Density – Area 1 and 3 (dated 22 August 2022)
- Water Technology. 2018. Surface Water Assessment, Goschen Mineral Sands and Rare Earths Project (Goschen Project). Unpublished report prepared for VHM Limited. Victoria
- Water Technologies 2022 - EES Technical Report - Water Technologies – H1. Surface Water
- CDM Smith. 2021a. Groundwater Borehole logs drilled in July and August 2021 in Area 1 × 2 No and Area 3 × 2 No
- CDM Smith 2022 EES Technical Report - CDM Smith – I. Groundwater
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- SLR Consulting 2022 - EES Technical Report – SLR - M. Soils and Land Resources
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- Pitt&sherry 2021a – DFS Chapter 15 Tailings Management
- Pitt&sherry 2022 - EES Technical Report - Pitt&sherry – P. Rehabilitation and Closure
- John Read, Peter Stacey 2010 - Guidelines for Open Pit Slope Design
- Mark Hawley and John Cunning 2017 - Guidelines for Mine Waste Dump and Stockpile Design
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- Hoek Brown 2018 - The Hoeke Brown failure criterion and GSI 2018 edition
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- AS4133.4.1- 2007 Methods of testing rocks for engineering purposes Rock strength tests - Determination of point load strength index
- AS 1170.4 - 2007 - Structural design actions Part 4: Earthquake actions in Australia
- Water Technology. 2018. Surface Water Assessment, Goschen Mineral Sands and Rare Earths Project (Goschen Project). Unpublished report prepared for VHM Limited. Victoria
- Hazelton, P.A. and Murphy, B.W. (2016). Third Edition. 'What Do All the Numbers Mean? - A Guide to the Interpretation of Soil Test Results'. (CSIRO Publishing, Melbourne)
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- RMS 2014 - Roads and Maritime Safety NSW Slope Risk Analysis Version 4 2014

- Skempton 1986 - Geotchnique 36, No3 425-447 Standard penetration test procedures and the effects in sands of overburden pressure, relative density, particle size of ageing and over consolidation; and
- Lambe, W. and Whitman, R. 1979. Soil Mechanics, SI Version, John Wiley & Sons, 1979.

Important information about your ground engineering report

These notes are additional to any limitations noted within the report. They have been provided by pitt&sherry to clarify the limitations of the report, and to clearly identify the individual responsibilities of all parties involved. It is important that all documents from pitt&sherry are read thoroughly and that clarification is sought when necessary.

Specificity

Your report has been developed based on pitt&sherry's understanding of your project requirements and applies only to that project. If there are subsequent changes to the proposed project, pitt&sherry should be consulted to assess how the changes impact on the report's recommendations. If pitt&sherry are not consulted, they do not accept responsibility for issues that may occur due to project changes. No responsibility is accepted for the use of this report, in whole or in part, in other contexts or for any other purpose.

Report integrity

This report is presented as a whole; with conclusions and recommendations reliant upon data presented in other sections. Reading parts of the report in isolation may lead to misinterpretations, and as such the report should not be copied in part or altered in any way.

Where information contained within this report is to be used for tendering purposes it is recommended that the entire report be made available. In situations where this is not appropriate, pitt&sherry can assist in preparing a specially edited document to provide the information within an appropriate context.

Site variability

The results presented in this report represent the conditions at the specific sampling and testing locations. They also represent the conditions at the time that the work was carried out. Variations in conditions may occur between or beyond assessment locations, either due to natural variability or previous excavations.

It is recognised that conditions may change over time. This can be due to natural processes (landslides, water content change) or driven by human activities (cutting or filling in the vicinity).

The advice presented in this report is based on the data gathered during the investigation, and the accuracy may be impacted by undetected variations in ground conditions or later changes to the site. Retaining pitt&sherry throughout development stages can assist in reducing the impact of these issues by identifying variances, conducting additional testing if required, and recommending solutions to problems encountered on site.

Goschen Mineral Sands and Rare Earths Project

Environmental Effects Statement
Geotechnical Assessment

Appendices A to E

Prepared for
VHM

Client representative
Bryan Chadwick

Date
15 May 2023

Draft Rev10

Appendices

1. Appendix A – Risk Assessments
2. Appendix B – Geological and Geotechnical Factual and Interpretive Report
3. Appendix C – Design Development of Tailings Storage Facility
4. Appendix D – Seismicity and Earthquake Risk
5. Appendix E – Draft Ground Control Management Plan Outline

1. Appendix A – Risk Assessments

pitt&sherry

Ground Movement Risk Assessment

					INITIAL RISK BEFORE CONTROL											RESIDUAL RISK AFTER CONTROL						
					Consequences				Risk			Controls and Contingency				Consequences				Risk		
					Impact Areas				Impact Areas			Mitigation control by location	Mitigation - controlled by design	Monitoring - controlled by human intervention	Contingency - event recognition & response	Impact Areas				Impact Areas		
Event Status	Item Id	Receptor	Vulnerable Receptor	Ground Movement Pathway Description	People	Property	Environment	Likelihood	People	Property	Environment	Protection	Prevention	Monitoring	Detection	People	Property	Environment	Likelihood	People	Property	Environment
Credible Events																						
Credible Event	3.D.A3	3	Sensitive Receptor within site or adjacent to site	Pathway 4 - Deformation/Settlement/Heave - Substantial deformation of rehabilitated ground surface from consolidation of the tailings more than assessed in design, swelling of rehabilitated ground surface from over consolidation of the subgrade under stockpiles and foundation or due to loading from construction plant and process plant foundations caused by static or dynamic loads being higher design allowances.	1	1	3	C	Low	Low	Medium		Mine design recommended to -incorporate comprehensive geotechnical design methodology and review using conservative elastic parameters and incorporate sensitivity assessments - enable pit slopes and stockpile locations to be separated by suitable buffer distance from vulnerable receptors - ensure mine pit floor is above groundwater table - consideration force due to earthquake loading in slope/batter design where design life > 2 year. Recommendation that Ground Water Monitoring Plan (GWMP), Surface Water Monitoring Plan (SWMP) and Ground Control Management Plan (GCMP) are established	Recommend that monitoring in accordance with the GCMP, SWMP and GWMP be implemented Recommend that competent geotechnical expert verify ground conditions following completion of rehabilitation and prior to mine closure Recommend that settlement monitors be established and monitored to observe surface topographic levels	Recommend that threshold triggers of the GCMP, GWMP and SWMP are adopted and a Survey reconciliation is conducted at the end of construction as part of the construction phase handover process Recommend that abnormalities, departures for expected situations or unplanned for contingencies be managed with timely risk-based geotechnical investigation and implementation of appropriate rectification, remediation or other actions as required Recommend that post closure bond be established to include cost of regrading and releveling surfaces where settlement or deformation is unexpected and varies from planned design	1	1	1	D	Low	Low	Low
Credible Event	3.C.A1	3	Sensitive Receptor within site or adjacent to site	Pathway 1 (above ground) and Pathway 2 (sub surface) - Slope Collapse/Slide - Slope collapse of pit walls caused by intersection of weaker than expected material, construction not to design, encounters area of stormwater softened material or ground water level is higher than expected - Slope collapse of the stockpile batters caused by more variable and weaker than expected in design, construction not to design, encounters area of stormwater softened material, ground water level is higher than expected, uncontrolled overland flow causing erosion of the bench/batter - Slope collapse or substantial deformation of the slope or batter caused by inadequate maintenance of drainage system allowing uncontrolled ponding or erosion	1	1	2	D	Low	Low	Low	Geological setting and existing lithologies identified to date and expected to be encountered within the mine area suggests that significant weak structures or material with significantly different geotechnical parameters to those identified and considered to date are unlikely	Mine design recommended to -incorporate comprehensive geotechnical design methodology and review using conservative elastic parameters and incorporate sensitivity assessments - enable pit slopes and stockpile locations to be separated by suitable buffer distance from vulnerable receptors - ensure mine pit floor is above groundwater table - consideration force due to earthquake loading in slope/batter design where design life > 2 year. Recommendation that Ground Water Monitoring Plan (GWMP), Surface Water Monitoring Plan (SWMP) and Ground Control Management Plan (GCMP) are established	Recommend that monitoring in accordance with GCMP, SWMP and GWMP be implemented Recommended that material parameters used in design are verified by field inspection, laboratory testing prior construction of stockpiles, foundations and pit slopes	Recommend that threshold triggers of the GCMP, GWMP and SWMP are adopted and a Survey reconciliation is conducted at the end of construction as part of the construction phase handover process Recommend that abnormalities, departures for expected situations or unplanned for contingencies be managed with timely risk-based geotechnical investigation and implementation of appropriate rectification, remediation or other actions as required	1	1	2	D	Low	Low	Low
Credible Event	3.C.A4	3	Sensitive Receptor within site or adjacent to site	Pathway 5- Dispersive soils - Exposure of dispersive subsoil to rainfall events on open mine pit faces, stockpile slopes, detention basins or pond batters during mining operations resulting in erosion and soil loss and potential collapse. - Exposure of dispersive subsoil to rainfall events during trenching and backfilling operations as part of the pump station, pipeline and local road upgrade construction works resulting in erosion and soil loss and potential collapse.	1	2	3	C	Low	Medium	Medium		Recommendation that a Surface Water Monitoring Plan (SWMP) and Ground Control Management Plan (GCMP) are established including the recommendations of the soils specialist report to be incorporated in the construction specification and siteworks management plans.	Recommend that monitoring in accordance with the GCMP, SWMP be implemented	Recommend that threshold triggers of the GCMP and SWMP are adopted. Review performance of slopes, excavations and disturbed areas for evidence of erosion	1	2	2	D	Low	Low	Low
Credible Event	1.C.A4	1	Public Road/land and public services (overhead or subsurface) on undisturbed ground	Pathway 5- Dispersive soils - Exposure of dispersive subsoil to rainfall events on open mine pit faces, stockpile slopes, detention basins or pond batters during mining operations resulting in erosion and soil loss and potential collapse. - Exposure of dispersive subsoil to rainfall events during trenching and backfilling operations as part of the pump station, pipeline and local road upgrade construction works resulting in erosion and soil loss and potential collapse.	1	2	3	C	Low	Medium	Medium		Recommendation that a Surface Water Monitoring Plan (SWMP) and Ground Control Management Plan (GCMP) are established including the recommendations of the soils specialist report to be incorporated in the construction specification and siteworks management plans.	Recommend that monitoring in accordance with the GCMP, SWMP be implemented	Recommend that threshold triggers of the GCMP and SWMP are adopted. Review performance of slopes, excavations and disturbed areas for evidence of erosion	1	2	2	D	Low	Low	Low
Non Credible Events																						
Non Credible Event	1.C.A1	1	Public Road/land and public services (overhead or subsurface) on undisturbed ground	Pathway 1 (above ground) and Pathway 2 (sub surface) - Slope Collapse/Slide - Slope collapse of pit walls caused by intersection of weaker than expected material, construction not to design, encounters area of stormwater softened material or ground water level is higher than expected - Slope collapse of the stockpile batters caused by more variable and weaker than expected in design, construction not to design, encounters area of stormwater softened material, ground water level is higher than expected, uncontrolled overland flow causing erosion of the bench/batter - Slope collapse or substantial deformation of the slope or batter caused by inadequate maintenance of drainage system allowing uncontrolled ponding or erosion								Based on the current project design, investigations and analysys carried out this event is assessed to not create a credible risk of a slope failure impacting a sensitive receptor and has not been included in the risk assessment		Recommend that monitoring in accordance with GCMP, SWMP and GWMP be implemented Recommended that material parameters used in design are verified by field inspection, laboratory testing prior construction of stockpiles, foundations and pit slopes	Recommend that threshold triggers of the GCMP, GWMP and SWMP are adopted and a Survey reconciliation is conducted at the end of construction as part of the construction phase handover process Recommend that abnormalities, departures for expected situations or unplanned for contingencies be managed with timely risk-based geotechnical investigation and implementation of appropriate rectification, remediation or other actions as required							
Non Credible Events	3.C.A1	3	Sensitive Receptor within site or adjacent to site	Pathway 1 (above ground) and Pathway 2 (sub surface) - Slope Collapse/Slide - Slope collapse of pit walls caused by intersection of weaker than expected material, construction not to design, encounters area of stormwater softened material or ground water level is higher than expected - Slope collapse of the stockpile batters caused by more variable and weaker than expected in design, construction not to design, encounters area of stormwater softened material, ground water level is higher than expected, uncontrolled overland flow causing erosion of the bench/batter - Slope collapse or substantial deformation of the slope or batter caused by inadequate maintenance of drainage system allowing uncontrolled ponding or erosion								Based on the current project design, investigations and analysys carried out this event is assessed to not create a credible risk of a slope failure impacting a sensitive receptor and has not been included in the risk assessment		Recommend that monitoring in accordance with GCMP, SWMP and GWMP be implemented Recommended that material parameters used in design are verified by field inspection, laboratory testing prior construction of stockpiles, foundations and pit slopes	Recommend that threshold triggers of the GCMP, GWMP and SWMP are adopted and a Survey reconciliation is conducted at the end of construction as part of the construction phase handover process Recommend that abnormalities, departures for expected situations or unplanned for contingencies be managed with timely risk-based geotechnical investigation and implementation of appropriate rectification, remediation or other actions as required							
Non Credible Event	2.C.A1	2	Private property	Pathway 1 (above ground) and Pathway 2 (sub surface) - Slope Collapse/Slide - Slope collapse of pit walls caused by intersection of weaker than expected material, construction not to design, encounters area of stormwater softened material or ground water level is higher than expected - Slope collapse of the stockpile batters caused by more variable and weaker than expected in design, construction not to design, encounters area of stormwater softened material, ground water level is higher than expected, uncontrolled overland flow causing erosion of the bench/batter - Slope collapse or substantial deformation of the slope or batter caused by inadequate maintenance of drainage system allowing uncontrolled ponding or erosion								Based on the current project design, investigations and analysys carried out this event is assessed to not create a credible risk of a slope failure impacting a sensitive receptor and has not been included in the risk assessment		Recommend that monitoring in accordance with GCMP, SWMP and GWMP be implemented Recommended that material parameters used in design are verified by field inspection, laboratory testing prior construction of stockpiles, foundations and pit slopes	Recommend that threshold triggers of the GCMP, GWMP and SWMP are adopted and a Survey reconciliation is conducted at the end of construction as part of the construction phase handover process Recommend that abnormalities, departures for expected situations or unplanned for contingencies be managed with timely risk-based geotechnical investigation and implementation of appropriate rectification, remediation or other actions as required							
Non Credible Event	1.L.A2	1	Public Road/land and public services (overhead or subsurface) on undisturbed ground	Pathway 3 - Earthquake/Liquefaction - Slope collapse of pit walls and batter slopes caused by earthquake/ ground acceleration and elevated water table greater than design								Based on the current project design, investigations and analysys carried out this event is assessed to not create a credible risk of a slope failure impacting a sensitive receptor and has not been included in the risk assessment		Recommend that monitoring in accordance with GCMP, SWMP and GWMP be implemented	Recommend that any earthquake events felt by site personnel or reported locally and regionally trigger an immediate stop work. Recommend that a competent geotechnical personnel review all exposed faces and slopes. Any departure of observations or instrumentation responses from expected conditions to be managed through appropriate actions in the GCMP, SWMP or GWMP							
Non Credible Event	2.L.A2	2	Private property	Pathway 3 - Earthquake/Liquefaction - Slope collapse of pit walls and batter slopes caused by earthquake/ ground acceleration and elevated water table greater than design								Based on the current project design, investigations and analysys carried out this event is assessed to not create a credible risk of a slope failure impacting a sensitive receptor and has not been included in the risk assessment		Recommend that monitoring in accordance with GCMP, SWMP and GWMP be implemented	Recommend that any earthquake events felt by site personnel or reported locally and regionally trigger an immediate stop work. Recommend that a competent geotechnical personnel review all exposed faces and slopes. Any departure of observations or instrumentation responses from expected conditions to be managed through appropriate actions in the GCMP, SWMP or GWMP							

Ground Movement Risk Assessment

					INITIAL RISK BEFORE CONTROL											RESIDUAL RISK AFTER CONTROL						
					Consequences				Risk			Controls and Contingency				Consequences				Risk		
					Impact Areas				Impact Areas			Mitigation control by location	Mitigation - controlled by design	Monitoring - controlled by human intervention	Contingency - event recognition & response	Impact Areas				Impact Areas		
Event Status	Item Id	Receptor	Vulnerable Receptor	Ground Movement Pathway Description	People	Property	Environment	Likelihood	People	Property	Environment	Protection	Prevention	Monitoring	Detection	People	Property	Environment	Likelihood	People	Property	Environment
Non Credible Event	3.L.A2	3	Sensitive Receptor within site or adjacent to site	Pathway 3 - Earthquake/Liquefaction - Slope collapse of pit walls and batter slopes caused by earthquake/ ground acceleration and elevated water table greater than design								Based on the current project design, investigations and analysys carried out this event is assessed to not create a credible risk of a slope failure impacting a sensitive receptor and has not been included in the risk assessment		Recommend that monitoring in accordance with GCMP, SWMP and GWMP be implemented	Recommend that any earthquake events felt by site personnel or reported locally and regionally trigger an immediate stop work. Recommend that a competent geotechnical personnel review all exposed faces and slopes. Any departure of observations or instrumentation responses from expected conditions to be managed through appropriate actions in the GCMP, SWMP or GWMP							
Non Credible Event	1.D.A3	1	Public Road/land and public services (overhead or subsurface) on undisturbed ground	Pathway 4 - Deformation/Settlement/Heave - Substantial deformation of rehabilitated ground surface from consolidation of the tailings more than assessed in design, swelling of rehabilitated ground surface from over consolidation of the subgrade under stockpiles and foundation or due to loading from construction plant and process plant foundations caused by static or dynamic loads being higher design allowances.								Based on the current project design, investigations and analysys carried out this event is assessed to not create a credible risk of deformation or heave impacting on sensitive receptor and has not been included in the risk assessment		Recommend that monitoring in accordance with the GCMP, SWMP and GWMP be implemented Recommend that competent geotechnical expert verify ground conditions following completion of rehabilitation and prior to mine closure Recommend that settlement monitors be established and monitored to observe surface topographic levels	Recommend that threshold triggers of the GCMP, GWMP and SWMP are adopted and a Survey reconciliation is conducted at the end of construction as part of the construction phase handover process Recommend that abnormalities, departures for expected situations or unplanned for contingencies be managed with timely risk-based geotechnical investigation and implementation of appropriate rectification, remediation or other actions as required Recommend that post closure bond be established to include cost of regrading and releveling surfaces where settlement or deformation is unexpected and varies from planned design							
Non Credible Event	2.D.A3	2	Private property	Pathway 4 - Deformation/Settlement/Heave - Substantial deformation of rehabilitated ground surface from consolidation of the tailings more than assessed in design, swelling of rehabilitated ground surface from over consolidation of the subgrade under stockpiles and foundation or due to loading from construction plant and process plant foundations caused by static or dynamic loads being higher design allowances.								Based on the current project design, investigations and analysys carried out this event is assessed to not create a credible risk of deformation or heave impacting on sensitive receptor and has not been included in the risk assessment		Recommend that monitoring in accordance with the GCMP, SWMP and GWMP be implemented Recommend that competent geotechnical expert verify ground conditions following completion of rehabilitation and prior to mine closure Recommend that settlement monitors be established and monitored to observe surface topographic levels	Recommend that threshold triggers of the GCMP, GWMP and SWMP are adopted and a Survey reconciliation is conducted at the end of construction as part of the construction phase handover process Recommend that abnormalities, departures for expected situations or unplanned for contingencies be managed with timely risk-based geotechnical investigation and implementation of appropriate rectification, remediation or other actions as required Recommend that post closure bond be established to include cost of regrading and releveling surfaces where settlement or deformation is unexpected and varies from planned design							
Non Credible Event	1.D.A4	1	Public Road/land and public services (overhead or subsurface) on undisturbed ground	Pathway 5- Dispersive soils - Exposure of dispersive subsoil to rainfall events on open mine pit faces, stockpile slopes, detention basins or pond batters during mining operations resulting in erosion and soil loss and potential collapse. - Exposure of dispersive subsoil to rainfall events during trenching and backfilling operations as part of the pump station, pipeline and local road upgrade construction works resulting in erosion and soil loss and potential collapse.								Based on the current project design, investigations and analysys carried out this event is assessed to not create a credible risk impacting on sensitive receptor and has not been included in the risk assessment		Recommend that monitoring in accordance with the GCMP, SWMP be implemented	Recommend that where threshold triggers of the GCMP and SWMP are adopted. Review performance of slopes, excavations and disturbed areas for evidence of erosion							

Tailing Storage Risk Assessment

(Internal Infrastructure and Operations Personnel)

*** People Definition -** Mine operations personnel working in the active mine area

*** Property Definition -** Mine infrastructure working or located in the active mine area

								INITIAL RISK BEFORE CONTROL – Consequences (Impact Areas)				Risk (Impact Areas)			Controls and Contingency – Mitigation control by location	Mitigation - controlled by design	Monitoring - controlled by human intervention	Contingency - event recognition & response	RESIDUAL RISK AFTER CONTROL – Consequences (Impact Areas)				Risk (Impact Areas)		
Item Id	Receptor	Vulnerable Receptor	Element	Ground Movement	Event	Cause	Ground Movement Pathway Description	People*	Property*	Environment	Likelihood	People*	Property*	Environment	Protection	Prevention	Monitoring	Detection	People*	Property*	Environment	Likelihood	People*	Property*	Environment
1.B.A1	1	Critical mine infrastructure or Operations	B	Breach	A1	Slope Stability	Geological design does not adequately account for known geotechnical material properties Geological design does not account for construction not achieving design specification criteria. Can be controlled by additional site investigation and material property testing including sensitivity assessment and through establishment and maintenance of construction phase supervision and testing	5	2	2	B	Very High	Medium	Medium		Recommendation to undertake additional geotechnical investigation of pit wall and sensitivity analysis of pit walls adjacent to tailings bund intersections Recommendation to use conservative geometry and strength parameters, undertake geotechnical investigations into embankment material parameters and foundation parameters, design in accordance with accepted industry standards including FoS i.e. ANCOLD, detailed Technical Specification. Design to be in accordance with ANCOLD guidelines and classification system Recommend that a in pit tailings storage facility is used	Recommendation to develop a Construction Management plan, use independent QA/QC verification of the works, include construction Hold Points at key stages of the works for independent verification by an appropriately experienced Tailings Dams Engineer.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring, standpipe piezometers to monitor groundwater Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	C	Low	Low	Low
1.B.A2	1	Critical mine infrastructure or Operations	B	Breach	A2	Internal erosion through the embankment	Construction QA/QC controls to ensure that materials used in the construction of tailings bunds do not have zones of weak or higher permeability and materials used in the construction of tailings bunds are compliant with Technical Specification. Can be controlled by stability analysis incorporating additional material property testing and sensitivity analysis, and through establishment and maintenance of construction phase supervision and testing	5	2	2	B	Very High	Medium	Medium		Recommendation to use conservative geometry and strength parameters, undertake geotechnical investigations into embankment material parameters and foundation parameters, design in accordance with accepted industry standards including FoS i.e. ANCOLD, detailed Technical Specification Recommendation to ensure that foundation is covered and sealed with tailings to a nominal depth so that there is no exposed sand in foundations prior to increasing water level significantly, undertake modelling of seepage flow to demonstrate that seepage will not adversely affect the foundations. Recommend that a in pit tailings storage facility is used	Recommendation to develop a Construction Management plan, use independent QA/QC verification of the works, include construction Hold Points at key stages of the works for independent verification by an appropriately experienced Tailings Dams Engineer.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	C	Low	Low	Low
1.B.A3	1	Critical mine infrastructure or Operations	B	Breach	A3	Internal erosion through the foundations	Geological design does not adequately account for unknown geotechnical material properties in pit floor and foundations, such as lenses/ zones of silt/clay. Can be controlled by additional site investigation and material property testing and by installation of keyway to minimise potential for seepage along the embankment-foundation contact in accordance with standard industry practice.	5	3	3	B	Very High	High	High		Recommendation to use conservative geometry and strength parameters, undertake geotechnical investigations into embankment material parameters and foundation parameters. Design to be in accordance with ANCOLD guidelines and classification system Recommend that a in pit tailings storage facility is used	Recommendation to develop a Construction Management plan, use independent QA/QC verification of the works, include construction Hold Points at key stages of the works for independent verification by an appropriately experienced Tailings Dams Engineer.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	C	Low	Low	Low
1.B.A4	1	Critical mine infrastructure or Operations	B	Breach	A4	Internal erosion through the dam into the foundations	Geological/geotechnical design does not adequately account for geotechnical material properties in tailings bund construction materials and foundations and their relative compatibility. Construction QA/QC controls to ensure that materials used in the construction of tailings bunds do not have zones of weak or higher permeability and materials used in the construction of tailings bunds are compliant with Technical Specification. Can be controlled by additional site investigation and material property testing and through establishment and maintenance of construction phase supervision and testing	5	3	3	C	Very High	Medium	Medium		Recommendation to use conservative geometry and strength parameters, undertake geotechnical investigations into embankment material parameters and foundation parameters, design in accordance with accepted industry standards. Recommendation to compare gradings of embankment and foundation materials for compatibility to determine whether foundations will act as a critical filter in accordance with accepted industry standards. Design to be in accordance with ANCOLD guidelines and classification system Recommend that a in pit tailings storage facility is used	Recommendation to develop a Construction Management plan, use independent QA/QC verification of the works, include construction Hold Points at key stages of the works for independent verification by an appropriately experienced Tailings Dams Engineer.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	C	Low	Low	Low
1.B.B1	1	Critical mine infrastructure or Operations	B	Breach	B1	Flood Loading	Design flood events exceed decant pond and spillway overtopping leading to scour Excess hydrostatic loading on embankment leads to excess pore pressures, instability and/or breach.	5	3	3	C	Very High	Medium	Medium		Recommendation to design flood diversions around pit to ensure the catchment is minimised Recommendation to ensure an appropriately sized spillway is constructed or an extreme storm storage allowance is designed for and maintained for each tailings embankment, in accordance with ANCOLD Guidelines. Recommend that a in pit tailings storage facility is used	Recommendation to minimise decant pond volume via return water pump to process. Recommendation to cease tailings deposition if decant pond water level is near or exceeds the full supply level i.e. when the dam is spilling. Recommendation to cease operations when flood events are forecast.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring, standpipe piezometers to monitor groundwater Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	C	Low	Low	Low
1.B.C1	1	Critical mine infrastructure or Operations	B	Breach	C1	Seismic Loading	The design earthquake acceleration exceeds the peak ground acceleration used in the design of the tailings bund causing settlement of the bund, loss of freeboard overtopping and scour an/or breach. Can be controlled by sensitivity assessment of the bund to acceleration loads and variations in the saturation of the subgrade and ensure compaction methodology in specification maximises SDMM such that the risk of settlement is minimised.	5	3	3	E	High	Medium	Medium	Water table below pit floor. Unsaturated sands will not liquify	Recommendation to assess expected settlement in accordance with ANCOLD Guidelines, allow significant dry freeboard allowance to accommodate loss of freeboard Recommend that a in pit tailings storage facility is used	Recommendation to evacuate pit after seismic events until bund and slopes have been assessed for deformation.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring, standpipe piezometers to monitor groundwater Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	E	Low	Low	Low
1.B.D1	1	Critical mine infrastructure or Operations	B	Breach	D1	Tailing Impoundment Rim Integrity	Slope design for slumping, over saturation or undermining due to inadequate drained cases mass slump into the tailings impoundment area causing a major reduction in storage volume. A surge of saturated tailings that exceeds the tailings bund capacity to retain Can be controlled by additional site investigation and material property testing including sensitivity assessment and through establishment and maintenance of construction phase supervision and testing of the pit shell and tailings bund	4	2	1	C	High	Medium	Low	Tailings drains into pit floor and any free water decanted as the tailings is deposited. Substantial proportion of the tailings will be partially drained as the tailings reaches full depth leading to a low likelihood of a slump failure creating an overtopping event	Recommendation to use conservative geometry and strength parameters, undertake additional geotechnical investigations into pit material parameters and foundation parameters, design in accordance with accepted industry standards including FoS. Recommendation to undertake comprehensive geotechnical design methodology and review using conservative elastic parameters verified by field and laboratory testing. Recommend that sensitivity assessment is incorporated and additional investigation and testing implemented Recommend that a in pit tailings storage facility is used	Recommendation to slope condition monitoring including face mapping for comparison against design models, stability, erosion and changes in geometry for all slopes/benches as part of site operational risk management plan.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring, standpipe piezometers to monitor groundwater Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	C	Low	Low	Low
1.D.A1	1	Critical mine infrastructure or Operations	D	Deformation / Settlment / Heave	A1	Slope Stability	Geological design does not adequately account for known geotechnical material properties Geological design does not account for construction not achieving design specification criteria. Can be controlled by additional site investigation and material property testing including sensitivity assessment and through establishment and maintenance of construction phase supervision and testing	4	2	1	C	High	Medium	Low		Recommendation to undertake additional geotechnical investigation of pit wall and sensitivity analysis of pit walls adjacent to tailings bund intersections Recommendation to use conservative geometry and strength parameters, undertake additional geotechnical investigations into embankment material parameters and foundation parameters, design in accordance with accepted industry standards including FoS i.e. ANCOLD, detailed Technical Specification Recommend that a in pit tailings storage facility is used	Recommendation to use independent QA/QC verification of the works, include construction Hold Points at key stages of the works for independent verification by an appropriately experienced Tailings Dams Engineer.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring, standpipe piezometers to monitor groundwater Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	C	Low	Low	Low
1.D.A2	1	Critical mine infrastructure or Operations	D	Deformation / Settlment / Heave	A2	Internal erosion through the embankment	Construction QA/QC controls to ensure that materials used in the construction of tailings bunds do not have zones of weak or higher permeability and materials used in the construction of tailings bunds are compliant with Technical Specification. Can be controlled by stability analysis incorporating additional material property testing and sensitivity analysis, and through establishment and maintenance of construction phase supervision and testing	4	2	3	D	High	Low	Medium		Recommendation to use conservative geometry and strength parameters, undertake geotechnical investigations into embankment material parameters and foundation parameters, design in accordance with accepted industry standards including FoS i.e. ANCOLD, detailed Technical Specification Recommendation to ensure that foundation is covered and sealed with tailings to a nominal depth so that there is no exposed sand in foundations prior to increasing water level significantly Recommendation to undertake modelling of seepage flow to demonstrate that seepage will not adversely affect the foundations. Recommend that a in pit tailings storage facility is used	Recommendation to use independent QA/QC verification of the works, include construction Hold Points at key stages of the works for independent verification by an appropriately experienced Tailings Dams Engineer.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring, standpipe piezometers to monitor groundwater Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	D	Low	Low	Low

Tailing Storage Risk Assessment
(Internal Infrastructure and Operations Personnel)

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								INITIAL RISK BEFORE CONTROL							Controls and Contingency				RESIDUAL RISK AFTER CONTROL						
								Consequences				Risk							Consequences				Risk		
								Impact Areas				Impact Areas			Mitigation control by location	Mitigation - controlled by design	Monitoring - controlled by human intervention	Contingency - event recognition & response	Impact Areas				Impact Areas		
Item Id	Receptor	Vulnerable Receptor	Element	Ground Movement	Event	Cause	Ground Movement Pathway Description	People*	Property*	Environment	Likelihood	People*	Property*	Environment	Protection	Prevention	Monitoring	Detection	People*	Property*	Environment	Likelihood	People*	Property*	Environment
1.D.A3	1	Critical mine infrastructure or Operations	D	Deformation / Settlment / Heave	A3	Internal erosion through the foundations	Geological design does not adequately account for unknown geotechnical material properties in pit floor and foundations, such as lenses/ zones of silt/clay. Can be controlled by additional site investigation and material property testing and by installation of keyway to minimise potential for seepage along the embankment-foundation contact in accordance with standard industry practice.	4	2	3	C	High	Medium	Medium		Recommendation to use conservative geometry and strength parameters, undertake geotechnical investigations into embankment material parameters and foundation parameters, design in accordance with accepted industry standards including FoS i.e. ANCOLD, detailed Technical Specification Recommendation to compare gradings of embankment and foundation materials for compatibility to determine whether foundations will act as a critical filter in accordance with accepted industry standards. Recommend that a in pit tailings storage facility is used	Recommendation to use independent QA/QC verification of the works, include construction Hold Points at key stages of the works for independent verification by an appropriately experienced Tailings Dams Engineer.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring, standpipe piezometers to monitor groundwater Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	C	Low	Low	Low
1.D.A4	1	Critical mine infrastructure or Operations	D	Deformation / Settlment / Heave	A4	Internal erosion through the dam into the foundations	Geological/geotechnical design does not adequately account for geotechnical material properties in tailings bund construction materials and foundations and their relative compatibility. Construction QA/QC controls to ensure that materials used in the construction of tailings bunds do not have zones of weak or higher permeability and materials used in the construction of tailings bunds are compliant with Technical Specification. Can be controlled by additional site investigation and material property testing and through establishment and maintenance of construction phase supervision and testing	4	2	3	C	High	Medium	Medium		Recommendation to use conservative geometry and strength parameters, undertake geotechnical investigations into embankment material parameters and foundation parameters, design in accordance with accepted industry standards including FoS i.e. ANCOLD, detailed Technical Specification Design to be in accordance with ANCOLD guidelines and classification system Recommend that a in pit tailings storage facility is used	Recommendation to use independent QA/QC verification of the works, include construction Hold Points at key stages of the works for independent verification by an appropriately experienced Tailings Dams Engineer.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring, standpipe piezometers to monitor groundwater Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	C	Low	Low	Low
1.D.B1	1	Critical mine infrastructure or Operations	D	Deformation / Settlment / Heave	B1	Flood Loading	Design flood events exceed decant pond and spillway overtopping leading to scour Excess hydrostatic loading on embankment leads to excess pore pressures, instability and/or breach.	4	2	3	C	High	Medium	Medium		Recommendation to design flood diversions around pit to ensure the catchment is minimised Recommendation to ensure an appropriately sized spillway is constructed or an extreme storm storage allowance is designed for and maintained for each tailings embankment, in accordance with ANCOLD Guidelines. Recommend that a in pit tailings storage facility is used		Recommend monitoring of weather forecast for intense rainfall events and potential floods Recommendation to undertake surveillance – Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines. Increased surveillance during intense rainfall and/or flood events. Recommend preparation of a Dam Safety Emergency Plans to specify how to manage potential emergency situations Recommendation to establish alert hierarchy to ensure flood risk awareness and early warning	1	1	1	C	Low	Low	Low
1.D.C1	1	Critical mine infrastructure or Operations	D	Deformation / Settlment / Heave	C1	Seismic Loading	The design earthquake acceleration exceeds the peak ground acceleration used in the design of the tailings bund causing settlement of the bund, loss of freeboard overtopping and scour an/or breach. Can be controlled by sensitivity assessment of the bund to acceleration loads and variations in the saturation of the subgrade and ensure compaction methodology in specification maximises SDMM such that the risk of settlement is minimised.	5	2	3	E	High	Low	Medium	Water table below pit floor. Unsaturated sands will not liquify	Recommendation to assess expected settlement in accordance with ANCOLD Guidelines, allow significant dry freeboard allowance to accommodate loss of freeboard Design to be in accordance with ANCOLD guidelines and classification system Recommend that a in pit tailings storage facility is used		Recommend implementation of instrumentation – deformation survey targets installation and monitoring Recommend subscribing to seismological monitoring service for alerts for seismic events. Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines. Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	E	Low	Low	Low
1.D.D1	1	Critical mine infrastructure or Operations	D	Deformation / Settlment / Heave	D1	Tailing Impoundment Rim Integrity	Slope design for slumping, over saturation or undermining due to inadequate drained cases mass slump into the tailings impoundment area causing a major reduction in storage volume. A surge of saturated tailings that exceeds the tailings bund capacity to retain Can be controlled by additional site investigation and material property testing including sensitivity assessment and through establishment and maintenance of construction phase supervision and testing of the pit shell and tailings bund	4	2	3	C	High	Medium	Medium	Tailings drains into pit floor and any free water decanted as the tailings is deposited. Substantial proportion of the tailings will be partially drained as the tailings reaches full depth leading to a low likelihood of a slump failure creating an overtopping event	Recommendation to use conservative geometry and strength parameters, undertake additional geotechnical investigations into embankment material parameters and foundation parameters, design in accordance with accepted industry standards including FoS i.e. ANCOLD, detailed Technical Specification Recommendation to undertake a comprehensive geotechnical design methodology and review using conservative elastic parameters verified by field and laboratory testing. Sensitivity assessment incorporated and additional investigation and testing being implemented Design to be in accordance with ANCOLD guidelines and classification system Recommend that a in pit tailings storage facility is used	Recommendation to use independent QA/QC verification of the works, include construction Hold Points at key stages of the works for independent verification by an appropriately experienced Tailings Dams Engineer. Recommendation to undertake slope condition monitoring including face mapping for comparison against design models, stability, erosion and changes in geometry for all slopes/benches as part of site operational risk management plan.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring, standpipe piezometers to monitor groundwater Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	C	Low	Low	Low
1.L.C1	1	Critical mine infrastructure or Operations	L	Earthquake / Liquefaction	C1	Seismic Loading	The design earthquake acceleration exceeds the peak ground acceleration used in the design of the tailings bund causing settlement of the bund, loss of freeboard overtopping and scour an/or breach. Can be controlled by sensitivity assessment of the bund to acceleration loads and variations in the saturation of the subgrade and ensure compaction methodology in specification maximises SDMM such that the risk of settlement is minimised.	5	2	3	E	High	Low	Medium	Water table below pit floor. Unsaturated sands will not liquify	Recommendation to undertake geotechnical investigations to assess the liquefaction risk of the foundations, include construction Hold Points for foundation approval through independent verification by an appropriately experienced Tailings Dams Engineer. Design to be in accordance with ANCOLD guidelines and classification system Recommend that a in pit tailings storage facility is used		Recommend implementation of instrumentation – deformation survey targets installation and monitoring Recommend subscribing to seismological monitoring service for alerts for seismic events. Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines. Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	E	Low	Low	Low
1.S.A1	1	Critical mine infrastructure or Operations	S	Seepage	A1	Slope Stability	Geological design does not adequately account for known geotechnical material properties Geological design does not account for construction not achieving design specification criteria. Can be controlled by additional site investigation and material property testing including sensitivity assessment and through establishment and maintenance of construction phase supervision and testing	5	2	3	D	High	Low	Medium		Recommendation to use conservative geometry and strength parameters, undertake geotechnical investigations into embankment material parameters and foundation parameters, design in accordance with accepted industry standards. Recommendation to compare gradings of embankment and foundation materials for compatibility to determine whether foundations will act as a critical filter in accordance with accepted industry standards Design to be in accordance with ANCOLD guidelines and classification system. Recommend that a in pit tailings storage facility is used	Recommendation to develop a Construction Management plan, use independent QA/QC verification of the works, include construction Hold Points at key stages of the works for independent verification by an appropriately experienced Tailings Dams Engineer.	Recommend implementation of instrumentation – deformation survey targets installation and monitoring Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	1	D	Low	Low	Low
1.S.E1	1	Critical mine infrastructure or Operations	S	Seepage	E1	Environmental Impact on groundwater	Inadequate hydrological design of impacts of placing saturated tailings back into the pit void causes an increase in water mounding greater than allowed for causing an impact on the local aquifer	2	2	4	C	Medium	Medium	High		Recommendation to document controls to date - Groundwater modelling, testing and assessment of tails materials, Environmental Management Plan. Recommend that a in pit tailings storage facility is used		Recommend implementation of instrumentation – deformation survey targets installation and monitoring Recommend implementation of Formal Routine Visual Inspections undertaken in accordance with ANCOLD Guidelines Recommend preparation of Dam Safety Emergency Plans to specify how to manage potential emergency situations	1	1	2	C	Low	Low	Medium

2. Appendix B – Geological and Geotechnical Factual and Interpretive Report

pitt&sherry

pitt&sherry

Geotechnical Investigation Factual and Interpretive Report

Goschen Project

Prepared for

VHM

Client representative

Date

17 November 2022

Rev00

Table of Contents

1. Introduction ... 6

2. Background ... 6

3. Site and Project Overview ... 7

4. Literature Review ... 9

4.1 Methodology ... 9
4.2 Existing Data ... 9
4.3 Geology ... 9
4.3.1 Regional geology ... 9
4.3.2 Local Geology ... 10
4.4 Topography ... 11
4.5 Geohazards ... 13
4.5.1 Landslides ... 13
4.5.2 Acid Sulphate Soils ... 13
4.5.3 Soil erosion hazard ... 14
4.5.4 Potential for Soil Acidification ... 14
4.5.5 Dispersive (sodic) soils ... 15
4.5.6 Dispersive soils in stockpiles, drains and sediment basins ... 15
4.5.7 Soil stripping, handling and stockpiling ... 16
4.5.8 Amelioration with gypsum ... 16
4.5.9 Drains and sediment basins ... 17
4.6 Groundwater ... 17

5. Site Investigation ... 18

5.1 Assumptions and Limitations ... 18
5.2 Methodology ... 19
5.3 Observations ... 19
5.3.1 Observations 2017 ... 19
5.3.2 Observations 2019 ... 22
5.4 Drilling ... 23
5.5 Insitu/Field Tests ... 25
5.5.1 Standard Penetration Tests ... 25
5.5.2 Point Load Tests ... 26
5.6 Laboratory Testing ... 27

6. Ground Model ... 33

6.1.1 Ground model Area 1 ... 33
6.1.2 Ground model area 3 ... 37

7. Material Properties ... 39

7.1 SPTs ... 39
7.1.1 Strength parameters for Cohesive (clay) soils ... 39
7.1.2 Strength parameters for non-cohesive (Sand/Silty sand) soils ... 39
7.1.3 Point Load Test data analysis ... 39
7.1.4 Non cohesive material UCS ... 40
7.1.5 Triaxial Test data ... 41
7.2 Material Parameter Analysis ... 41
7.2.1 Soil strength parameters: U1 - Topsoil ... 42
7.2.2 Soil strength parameters: U2 - Clay/Silty Clay ... 42
7.2.3 Soil strength parameters selection for U3-Sandy/Silty Clay ... 43
7.2.4 Soil strength parameters selection for U4 - Sand layers/ Sandstone ... 44
7.2.5 Soil strength parameters selection for U5 - Silty Sand ... 45

7.2.6 Selection of Soil Unit weights 46
7.3 Design parameters......46
8. Geotechnical engineering assessment 47
8.1 Pit depth and design life......47
8.2 Acceptance criteria 48
8.3 Mine pit wall geometry and Setout/Buffer Zone 54
8.4 Inputs for pit stability 54
8.5 Pit wall stability analysis......56
8.5.1 Mine pit wall stability and recommended slope profile 56
8.6 Probability of failure assessment......58
8.7 Recommended pit batter profile 60
8.8 Comparison to RMS, AGS and First Principles Slope Risk Assessment Methodologies......62
8.9 Topsoil......65
8.10 Stockpile stability and recommended geometry 65
8.10.1 Topsoil stockpile 67
8.10.2 Clay and Sand overburden stockpile......67
8.10.3 Surface water drainage bunds for stockpiles......70
8.11 Sediment ponds......71
9. References......72

List of figures

Figure 1: Goschen location shown in yellow 6
Figure 2: Project Area and proposed components......8
Figure 3: Area 1 Goschen Project......8
Figure 4: Area 3 Goschen Project......9
Figure 5: Structural zones of Victoria and location of Goschen Project (after Willocks and Moore; 1999) 10
Figure 6 Area 1 topography photo 11
Figure 7 Area 3 topography photo 12
Figure 8: Surface topography- solid line 5m contour......13
Figure 9: Groundwater contours from CDM Smith Technical Report I. Groundwater 18
Figure 10: Photograph of typical land use observed in 2017......19
Figure 11: Photograph of Paddock 44 quarry (2017) 20
Figure 12: Photograph of Paddock 60 quarry, showing close to vertical cemented sand walls (2017) 21
Figure 13: Photograph of Pack 60 quarry (2017) 21
Figure 14: Photograph of representative samples retained from exploration drilling......22
Figure 15: Photograph of paddock 40 quarry (2019)......22
Figure 16: Photograph of paddock 40 quarry, view to the east (2019) 22
Figure 17: Photograph of paddock 40 quarry, view to the west (2019)......22
Figure 18: Photograph of paddock 40 quarry, view to the south (2019) 23
Figure 19: Location of geotechnical boreholes in Area 1......24
Figure 20: Location of hydrogeological boreholes in Area 1 and Area 3......25
Figure 21 Summary of corrected SPT N value results 26
Figure 22: Bulk sample recovered for PLT test (PS003-22) 27
Figure 23 Summary of PLT value results......27
Figure 24: Cross section locations for Area 1 34
Figure 25: Geotechnical Domain Fence Diagram - Interpretation - Area 1 North-South......35
Figure 26: Geotechnical Domain Fence Diagram - Interpretation - Area 1 South......35

Figure 27: Geotechnical Domain Fence Diagram - Interpretation - Area 1 Mid 36
Figure 28: Geotechnical Domain Fence Diagram - Interpretation - Area 1 North....36
Figure 29: Cross section locations for Area 3. 37
Figure 30: Geotechnical Domain Fence Diagram - Interpretation - Area West 38
Figure 31 Geotechnical Domain Fence Diagram - Interpretation - Area 3 Mid 38
Figure 32: RocLab data analysis for PLT test data 40
Figure 33 GSI Chart for Sandstone Rock (Marinos & Hoek, 2000) 41
Figure 34: Soil strength parameters variation for Unit 2 (CLAY/ Silty CLAY) 42
Figure 35: Soil strength parameters variation for Unit 3 (Sandy/ Silty CLAY) 43
Figure 36: Soil strength parameters variation for Unit 4 (Silty/ Clayey SAND; Sandstone) 45
Figure 37: Soil strength parameters variation for Unit 5 (Silty SAND) 46
Figure 38: Cell arrangement and sequence for the pits in Area 1 and Area 3 – Y axis denotes north 48
Figure 39 Table 9.2 from Read and Stacey 2010 49
Figure 40 Table 9.3 from Read and Stacey 2010 49
Figure 41 Table 9.4 from Read and Stacey 2010 50
Figure 42 Table 9.5 from Read and Stacey 2010 51
Figure 43 Table 9.6 from Read and Stacey 2010 52
Figure 44 Table 9.7 from Read and Stacey 2010 53
Figure 45 Typical pit wall section terminology....55
Figure 46: Selected cross section locations for slope stability analysis 56
Figure 47: Example of Slide model output and input for A1_ShepherdRd....57
Figure 48: FoS variation with cohesion of soil unit U2....59
Figure 49: Example of PoF histogram for A3W3_JoblingRd 60
Figure 50: Locations of Area 1 pit-road geometries analysed 63
Figure 51: Locations of Area 3 pit-road geometries analysed 64
Figure 52 Waste dump and stockpile stability rating and hazard class chart (Hawley et al, 2017)....67
Figure 53: Typical stockpile arrangement 68
Figure 54 Remoulded strengths estimated based on Appendix D, AS 4678-2002 for clay soils 68
Figure 55 Example of Slope Stability Assessment for 30m high stockpiles 70
Figure 56: Cross-section of typical design for bunded surface water catch drains....70
Figure 57: Sediment Pond (‘z’ = depth; ‘w’ = water level)....71

List of tables

Table 1: Gypsum application rates 16
Table 2 Summary of laboratory test results from mining Area 1 and Area 3 boreholes 28
Table 3: Triaxial, Permeability and Emerson Test data summary for Area 1 and Area 3 boreholes....31
Table 4: Summary of laboratory test results from Combined Samples 32
Table 5: Summary of strata based on available borehole logs 33
Table 6: Ground model Area 1 33
Table 7: Ground model Area 3 37
Table 8: Parameters for in situ soils for pit slope stability....47
Table 9 Summary Table of FoS and PoF guidance based on Read and Stacey 2010 54
Table 10: Summary of results from the critical sections 57
Table 11: Material parameter variation 58

Table 12: Summary of probability of failure assessment 59
Table 13 Estimated Material Weights for failure surface with FoS > 1.6 and for failure surface with the minimum FoS 60
Table 14: Recommended pit geometry 61
Table 15 Reproduction of Table 3.12: Suggested level of effort based on waste dump and stockpile stability rating/hazard class (WSR/WHC) Hawley 2017 66
Table 16: Stockpile material parameters 68
Table 17: Subgrade parameters for the purpose of slope stability modelling 69
Table 18: Summary of the results of the long-term analysis 69
Table 19: Summary of the results of the long-term stability analysis of sediment ponds 71

Appendices

Appendix A — Explanatory Notes, disclaimer

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Revision History

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00	Ready to issue	AT	AE	AT	16/11/2022

1. Introduction

VHM has established a Mineral Resource Estimate and ore reserve estimate on Retention licence TL6806 (Goschen Project). Mining and processing are proposed to take place on land 100% owned by VHM over a current mine life of 20years. Mining is -proposed to take place using dry- strip mining with conventional "truck and shovel" bulk earth moving equipment.

The Goschen Project site is a heavy mineral sand mining and processing operation that will produce several heavy mineral concentrates (HMC) and a range of critical rare earth minerals in Victoria, near the NSW border (Figure 1). Water for processing will be extracted from a proposed pump station east of the mine site and piped to the site. Mining is proposed to be undertaken across two defined mining areas known as Area 1 and Area 3.

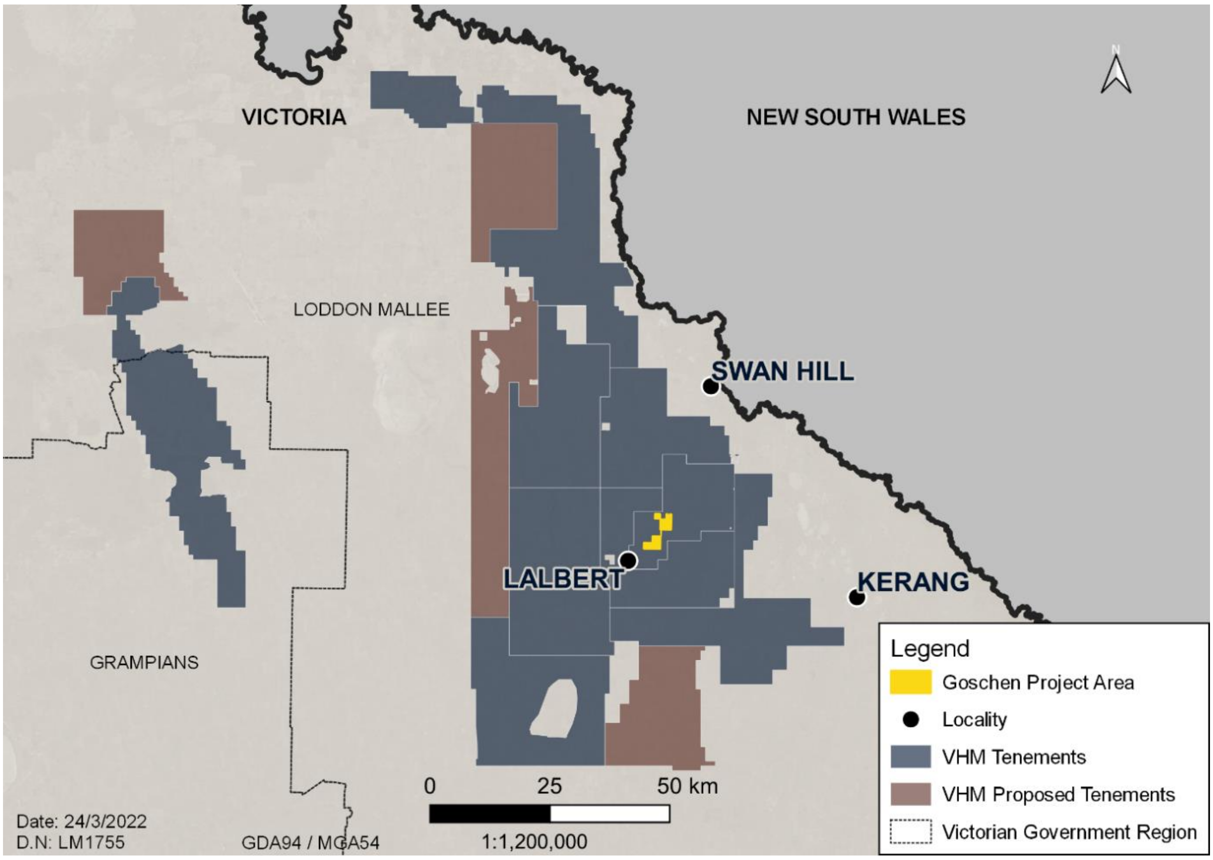

Figure 1: Goschen location shown in yellow

2. Background

The project is currently in the approvals phase. The Environmental Effects Study EES is under development while the DFS has been completed in 2021. Additional studies to support the preparation of the EES have been carried out. This Geotechnical Investigation Factual and Interpretive Report is one of these studies.

Pitt&sherry designed the geotechnical investigation and laboratory testing program, building on the 2017 limited geotechnical investigation carried out during the PFS. The new investigations have been carried out in Area 1 and Area 3 on areas of the proposed mining operation where access was permitted following consultation with the current farm operators and to minimise impact on active farming areas. The intent of the report is to characterise the materials associated with the overburden and the ore body and to establish engineering properties to refine the stability assessments associated with the pit walls, tailings bunds and stockpiles.

This report consolidates all geotechnical investigations carried out for the project to date and should be read in conjunction with:

- DFS Chapter 14 Geotechnical Engineering (Pitt&sherry 2021); and
- DFS Chapter 15 Tailings Management (Pitt&sherry 2021a).

3. Site and Project Overview

The proposed project will include:

Mining – Mining will take approximately 20 years at 5M tonnes of ore produced per year and will occur only above groundwater (no dewatering) across approximately 1,479 hectares of farmland using conventional open cut mining methods of excavation, load, and haul.

Processing – Heavy mineral sands and rare earths ore will be separated via an on-site WCP and MSP to generate a Rare Earth Mineral Concentrate (REMC). Refining of the REMC on-site is limited to hydrometallurgical extraction to produce a mixed rare earth carbonate. Tailings from the various mineral processes will be homogenised and placed back into the ore zone earlier mined.

Rehabilitation – The mined areas will be progressively backfilled in a staged manner, with tailings dewatered in-pit to allow overburden and topsoil placement in a profile that reinstates the background soil structure. This will result in the ability for a return to the current agricultural land uses within 3 years.

Power – Electrical power needed for mining and processing will be produced on-site from dual fuel diesel/LNG fired power generators, with a gradual evolution over the life of mine to renewables, hydrogen and/or battery as technologies and commercial viability increase. Heat energy for the on-site gas fired appliances shall be provided from an extension of the distribution network from the main LNG storage and regasification system.

Water - Water will be required for construction earthworks, processing, dust suppression and rehabilitation.

The Proposed mine area is broadly defined as Area 1 (in the south) and Area 3 and are shown in Figure 2 and in more detail for each site in Figure 3 (Area 1) and Figure 4 (Area 3).

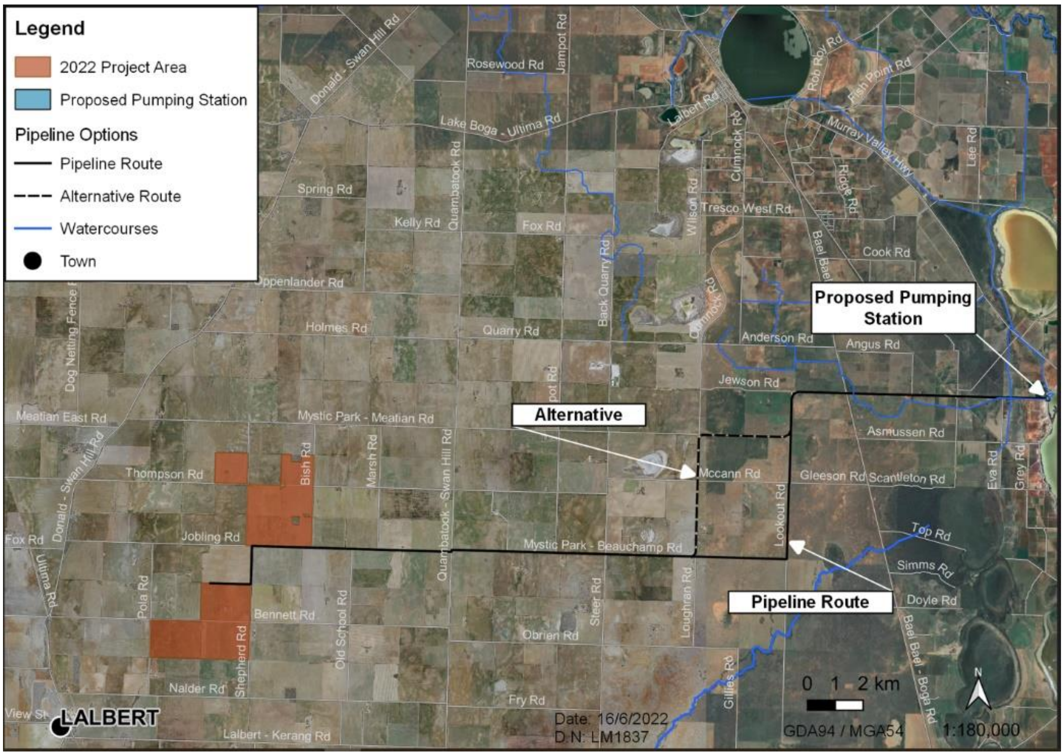

Figure 2: Project Area and proposed components

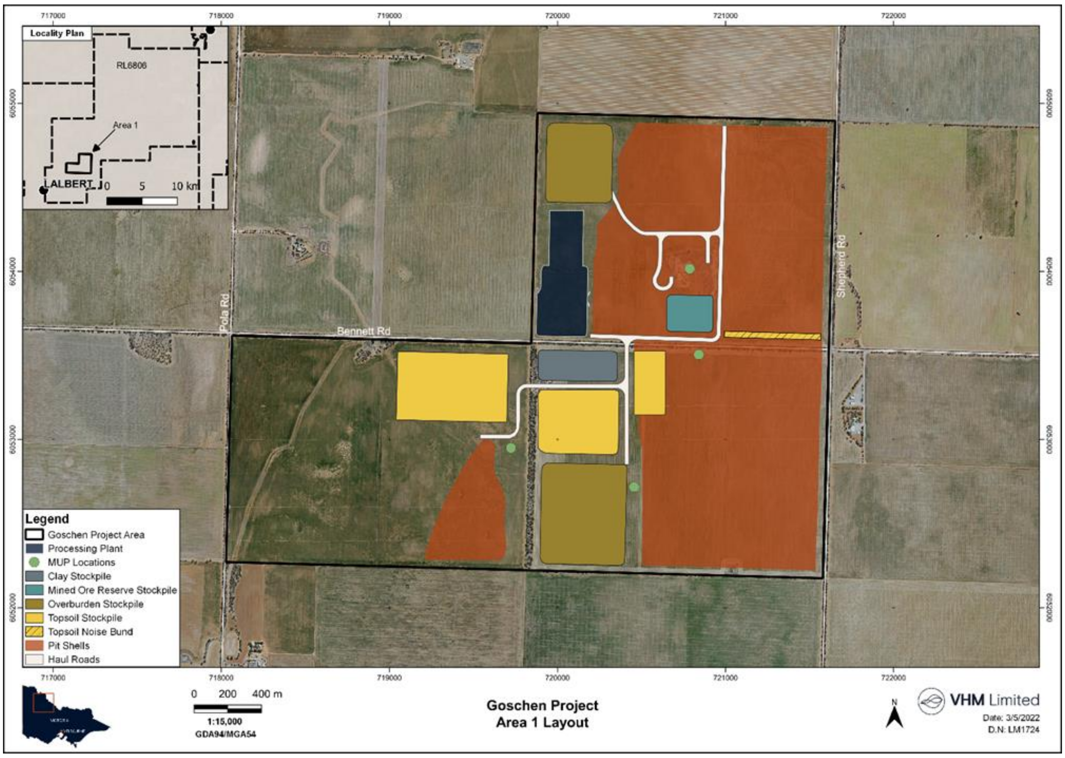

Figure 3: Area 1 Goschen Project

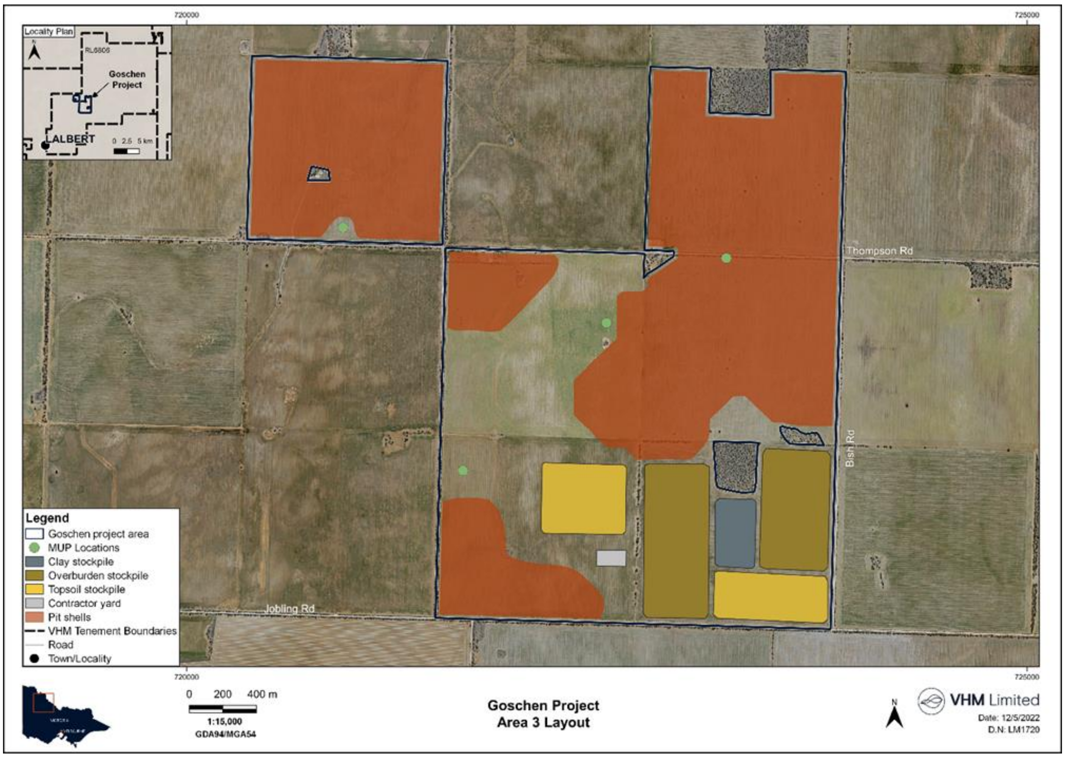

Figure 4: Area 3 Goschen Project

4. Literature Review

4.1 Methodology

An initial literature review was undertaken; including the geology, geomorphology, landslide hazards and acid sulphate soil potential of the site, plus the location and examination of relevant existing borehole and report data that was publicly available. The results of this literature review are presented in this section.

4.2 Existing Data

The Goschen site has recently had a DFS study completed, and a number of groups have carried out studies on the site. Where relevant and informative this data has been summarised in this report.

4.3 Geology

4.3.1 Regional geology

The Goschen Project is located within the Bendigo and Stawell structural zones which are separated by the Avoca Fault, as shown in Figure 5. The Goschen mineralisation is within the near-surface Tertiary Loxton Sand. The deposit has both sheet-style and strandline mineralisation within original fluvial, marginal marine and marine environments.

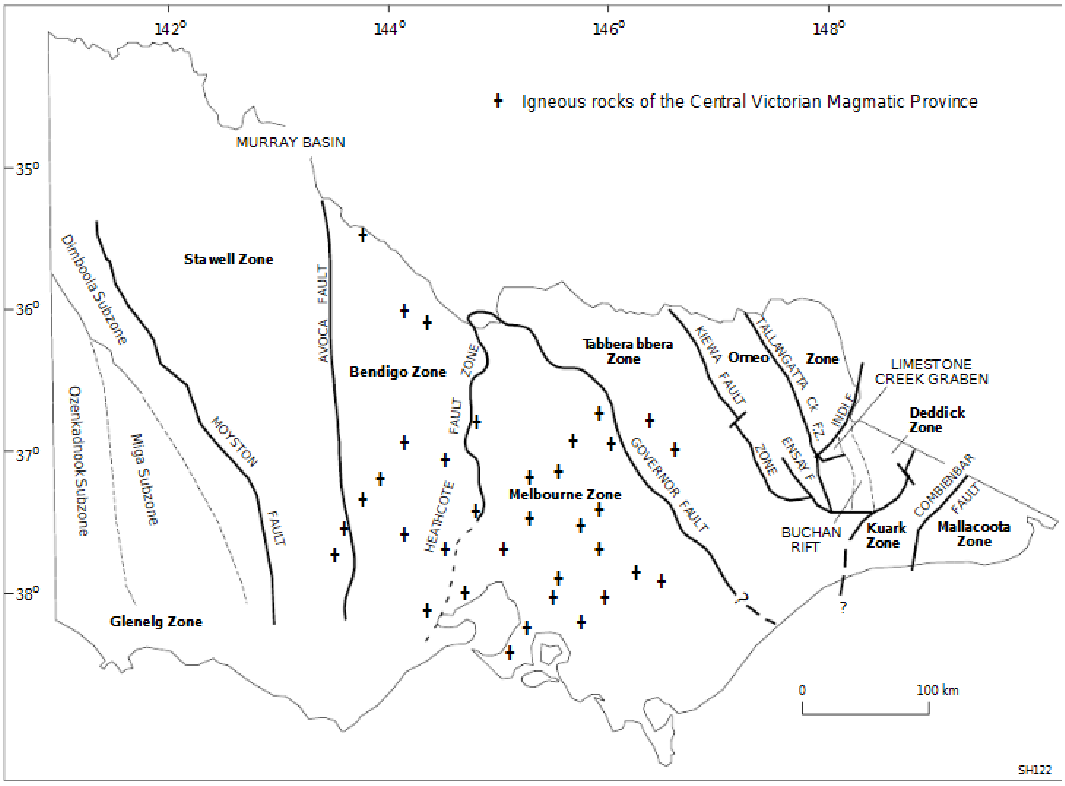

Figure 5: Structural zones of Victoria and location of Goschen Project (after Willocks and Moore; 1999)

The Tertiary sediments are generally flat-lying and unconformably overlie Proterozoic and Paleozoic basement rocks which are 88 to 175 m below the surface in the Project area and will not be intersected by current mining plans. The sediments are overlain by a thin layer of Quaternary aeolian and fluvio-lacustrine sediments.

Sheet style mineralisation extends for 14 km north–south by 15 km east–west, with each mineralised horizon (3 to 4 horizons identified) having an average thickness of between approximately 2 m to 3 m. The mineralised horizons are at a depth of 1.6 m within the central area of the tenement and dip shallowly to the west 1 m to 2 m below the surface and to the east, over 30 m below the surface (VHM Exploration, 2021). The mineralised sands have been described by Mason (2008) as yellow/brown to grey, very fine to coarse, unconsolidated to weakly cemented, well-sorted quartz sand with varying content of clay and silt.

4.3.2 Local Geology

The host sands at Area 1 and Area 3 are typically composed of very fine to fine sands deposited as sub-horizontal layers that accumulated during periods of moderate to calm wave action and contain fine-grained valuable heavy minerals predominantly zircon, rutile, ilmenite, leucoxene, monazite and xenotime, with accessory minerals, such as tourmaline, sphene and garnet.

Some coarse layers within the fine sand unit have been observed at other locations in the region in distinct horizons that is interpreted to have been transported during high-energy events that created significant erosion of the beach/barrier system and created strands of heavy minerals at the beach sites. The coarse horizons are mineralised and can range in thickness, from a few centimetres to over half a metre.

The Loxton Sand deposits of the Goschen Project comprise a sheet-like basal unit of sand which is overlain by a relatively thick mineralised horizon, enriched in zircon and rare earth minerals (REM). The mineralised layers are overlain by sand. Both Area 1 and Area 3 are across the Cannie Fault, which is a deeply buried basement structure that was active both during and after deposition of the heavy minerals. The fault movement has produced thickening of the upper sand package on the western side of the fault at both.

4.4 Topography

The Goschen Project area topography is described as containing landforms classified as either geomorphological landform described as 'Hummocky dunes dominant on the margin of the Tyrrell Depression (south-east of Lake Tyrell, north and south of Lake Hindmarsh' and 'Hummocky dunes with sub-dominant hummocky dunes and ridges (south-east of linear dune fields)', respectively Victorian Government (DEWLP 2021). These two landform types are associated with the linear dune fields that are located at a significant distance from the Project area. Both extensive site visits and a review of the surface contours (Figure 8) show Area 1 and Area 3 to be largely devoid of hummocky dunes, which may have been eroded as part of the continued formation of the Cannie Ridge.

The project area is characterised by a gently undulating topography with small depression in the landscape ranging from 60-90m on the eastern and western sies of the Cannie Ridge in the centre of the Project area. Surrounding the Project area, the main landform is a wide, flat alluvial plain with minor features, such as swamps, shallow lakes, lunettes, sand sheets and minor drainage features. The main water features near the Project area are Lake Boga to the north-east and the Kerang Wetlands 15 km to the east (Water Technology, 2018).

Figure 6 Area 1 topography photo


Figure 7 Area 3 topography photo

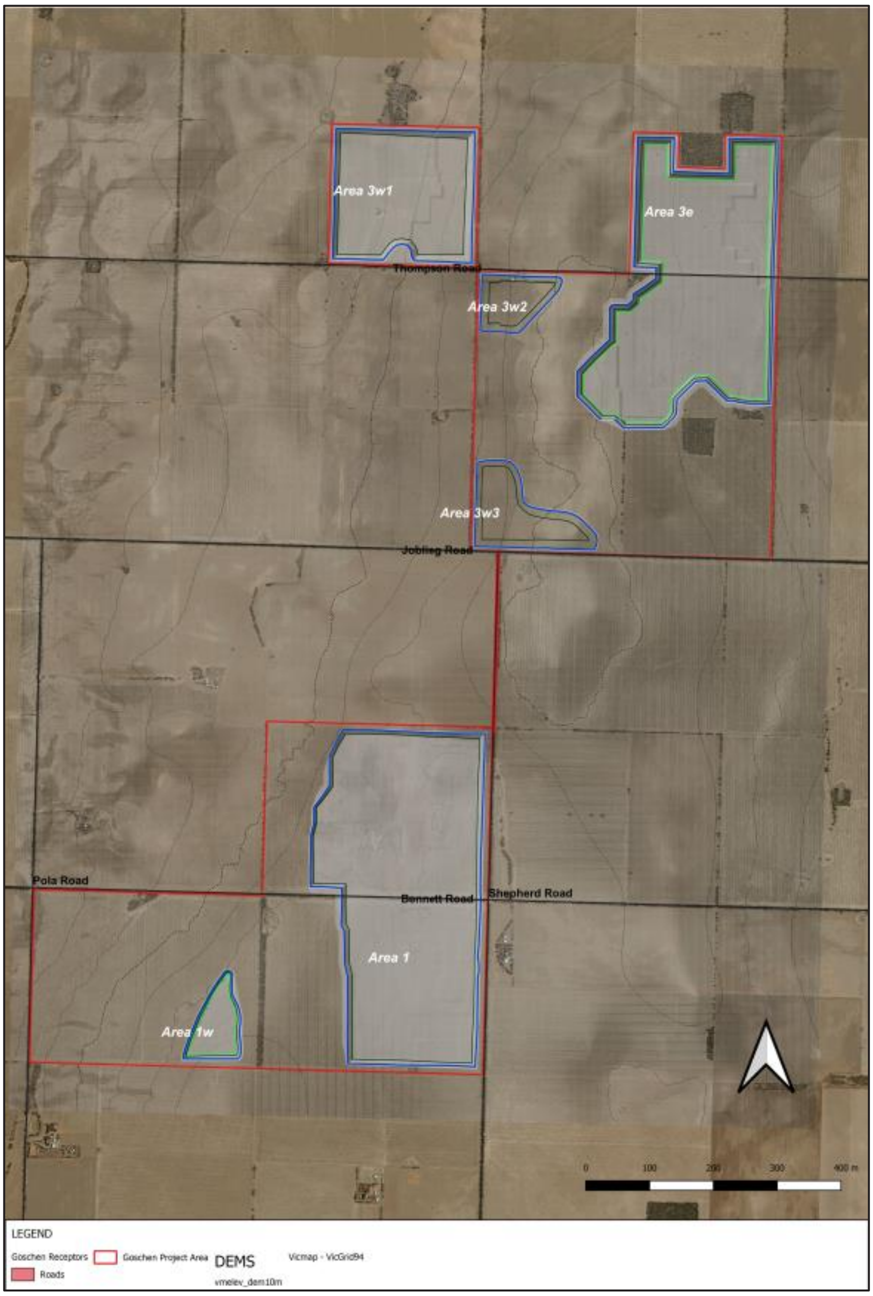

Figure 8: Surface topography- solid line 5m contour

4.5 Geohazards

4.5.1 Landslides

The Goschen site has little topographic variation and thus no mapped potential landslide locations.

4.5.2 Acid Sulphate Soils

ASS is a collective term for natural, waterlogged soils that contain iron sulfides formed by underwater bacterial activity. ASS mainly occur in coastal estuarine environments but are known to occur rarely in inland areas under the right conditions. Inland acid sulfate soils occur on inland waterways, wetlands and drainage channels. They develop in waterlogged, saline and anaerobic (which means living without air) conditions. Inland acid sulfate soils are often associated with salinity sites and many have not been properly identified (NSW DPE, 2022).

Once exposed to air through disturbances such as excavation or drainage, oxidation of ASS can produce sulfuric acid in large quantities. Undisturbed and unoxidized, these soils are known as potential acid sulphate soils (PASS), and soils that have been disturbed and oxidized are known as actual acid sulphate soils (AASS). ASS has the potential to cause the release of heavy metals and other toxins, with undesirable engineering and environmental impacts such as damage to structures, sensitive ecosystems and water catchments.

Available information indicates that the topsoil across the Goschen Project area predominantly consists of calcic, red Chromosols. These soils are clay loam, with weakly crumb structured 5–10 mm peds of moderate consistence, and a rough fabric. There are also areas of red-brown Calcarosols in the northern portion of the Project area (SLR Consulting, 2022). Chemical parameters of the soil from samples across the Project area are as follows:

- Soil is neutral to moderately alkaline (pH of 7.3–8.3) at surface, but very strongly alkaline (pH9.1–9.4) from approximately 15 cm depth
- Soil is sodic to strongly sodic, with sodicity increasing with depth – with an exchangeable sodium percentage (ESP) 2.2% at surface, increasing up to ESP 27.9% at 80 cm
- Moderate to high salinity occurs from depths of 10 cm, increasing with depth from 1.2 to 3.4 decisiemens per metre (dS/m) at surface, increasing to 8.8 dS/m at 80 cm (SLR Consulting, 2019); and
- The soils were considered to have moderately low inherent soil fertility (SLR Consulting, 2019).

The Australian Soil Resource Information System (CSIRO, indicates the probability of the site containing ASS is *"Extremely Low Probability of Occurrence"*.

The site does not contain waterlogged soils in drainage lines and does not possess the requisite properties for containing ASS. There is very low risk of site activities impacting on ASS. Site works are not likely to lower the watertable or cause dewatering of PASS in other locations. Detailed investigation of ASS through testing and further analysis, is not warranted.

4.5.3 Soil erosion hazard

The dispersion class and erosive potential of soils within the Study Area were determined using the Emmerson Aggregate Test (EAT). EAT gives an indicator of dispersion potential and is one indicator of how erodible a soil is likely to be when exposed to disturbance and erosion by running water.

All soil horizons within the Study Area are classed as having moderate to moderately high dispersion ratings and are therefore prone to erosion. Appropriate erosion and sediment control measures should be undertaken, including the application of gypsum, wherever surface disturbance is to be undertaken. The management of water flows over and through dispersive soils is a key tool in control of detrimental impacts. Approaches may include:

- Diversion of water flows away from areas of disturbance
- Minimising potential convergence and/or ponding of surface flows, particularly on disturbed sodic soils; and
- Development of appropriate cover/protection of dispersive soils (i.e. creation of stable linings that are resistant to rainfall erosion and runoff, or covering dispersible soils with non-dispersible materials).

4.5.4 Potential for Soil Acidification

Given the very alkaline pH and high clay content throughout the profile to a depth of 1 metre, the soil types in the Study Area have a very low potential for acidification.

4.5.5 Dispersive (sodic) soils

Sodic soils are soils with an excess of exchangeable sodium cations within the soil's cation exchange sites. Sodicity relates to the shrink-swell properties of the soil and likelihood if dispersion on wetting. Sodic soils are prone to dispersion, which has impacts on the physical and engineering properties of the soil, and due to their increased erosion hazard, can have significant impacts on waterways and water quality.

Sodic soils can have the following properties:

- Very sever surface crusting
- Very low infiltration and hydraulic conductivity
- Very hard and dense subsoils; and
- Highly susceptible to severe erosion.

Sodicity is mostly present in subsoils. When soils are in their natural undisturbed condition any adverse impacts due to sodicity may be minor to absent, as the non-sodic topsoils protect the sodic subsoils. These soils become more problematic when the topsoils are stripped or lost through accelerated erosion.

Sodicity is determined by measuring the exchangeable sodium percentage (ESP) and while general ratings of sodicity vary with region, a common rating system adopted by Hazelton & Murphy (2016) is as follows:

- ESP > 14 = strongly sodic
- ESP 6-14 = sodic
- ESP 3-6 = slightly sodic; and
- ESP <3 = Non-sodic.

SLR (2022) undertook widespread testing of soils for attributes including pH, salinity and sodicity. Materials represented in the overburden are generally dispersive in nature and this needs to be addressed, particularly with respect to management of stockpiled materials and in achieving successful rehabilitation using dispersive soils.

4.5.6 Dispersive soils in stockpiles, drains and sediment basins

It is expected that stockpile faces and sediment basins and bunds will be constructed in dispersive soils or using materials that may be dispersive. Associated risks include excessive erosion of exposed dam batters and stockpile faces, structural decline and difficulty in revegetation. Waterways conveying concentrated stormwater flow, are particularly susceptible to erosion when based in dispersible soils.

Recommendations for management of dispersive soils during stripping and stockpiling are provided in the Soil and Land Resource Assessment (SLR, 2022) and in the Mine Rehabilitation Plan (pitt&sherry, 2022). A summary is outlined below.

4.5.7 Soil stripping, handling and stockpiling

Development of the mine cells involves stripping of nominally 20 m depth of overburden including an upper soil profile comprising clay subsoils and topsoil. Overburden, clay and topsoil will be stripped then directly emplaced in rehabilitation cells as a general rule to minimise double handling and minimise potential for material decline during extended stockpiling. When stockpiling is required, materials will be separated into their respective layers and stockpiled in dedicated areas with a focus on preserving quality of the clay subsoil and topsoil material for future rehabilitation. The mine plans for Area 1 and Area 3 depict the proposed stockpile locations though this may vary during detailed mine planning. For infrastructure areas only topsoil would generally be stripped.

Based on the soil survey (SLR, 2022) the following stripping depths are recommended:

- Strip topsoil to a depth of 20 cm. Topsoil would be stripped from all disturbance areas, including haul roads, infrastructure areas and subsoil stockpile locations; and
- Strip subsoil from mining areas only to a depth of 1.0 m (80 cm thick layer). Subsoil clay would be stockpiled separately to topsoil and used to restore a rehabilitated soil profile depth at least 1.0 m thick.

A range of management and mitigation strategies are outlined in SLR (2022) for implementation as appropriate to help manage the effects of sodicity during stripping and stockpiling operations. Key measures include:

- Treating topsoils with gypsum prior to stripping, as described in Table 1;
- Where possible, replacing subsoil and topsoil directly in mine backfill (rehabilitation) areas; and otherwise minimising the time that materials are stored.
- Stripping soils under appropriate moisture conditions and using suitable equipment to minimise compaction, pulverisation and structural decline; and
- Vegetating stockpile surfaces to minimise erosion, structural decline and help maintain soil organic matter and health.

4.5.8 Amelioration with gypsum

Soils would be treated with gypsum to counter the effects of sodicity during stripping and in stockpiles, as recommended by SLR (2022). Gypsum application would be undertaken during stripping, stockpiling and material spreading as detailed in Table 1.

Table 1: Gypsum application rates

Ameliorant	Topsoil	Subsoil
Soil stripping:		
Gypsum	5 T/ha (10 T/ha if ESP>14)	n/a
Stockpile surface:		
Gypsum	n/a	10 T/ha
Granulock 15 (or similar)	80 kg/ha	80 kg/ha
Re-spread materials:		
Gypsum	n/a	10 T/ha *
Granulock 15 (or similar)	120 kg/ha	120 kg/ha

* Gypsum only recommended if subsoil is to be left exposed for a length of time prior to topsoil respreading

4.5.9 Drains and sediment basins

Drains and internal (cut) batters of sediment basins are particularly susceptible to erosion where dispersible soils are exposed. The increased erosion hazard is due to the erosive action of concentrated stormwater flow in drains and due to increased velocities on the steep slopes on batters.

Erosion control will be achieved using appropriate lining of dispersible soil materials with measures to be outlined in site specific erosion and sediment control plans. Options include lining of internal basin batters and drains using a suitable rolled erosion control product (RECP), such as jute mesh or light weight bidim. Use of RECPs should be considered over at least the upper part of the batters and at the main inlets and outlets to basins. RECPs would also be appropriate for lining the inverts of major drains.

Surface protection through revegetation would be used where appropriate, for example on batters of bunds and stockpiles, and otherwise where soils are temporarily disturbed but not required for ongoing operations.

4.6 Groundwater

CDM Smith undertook a detailed groundwater study as part of the EES CDM Smith 2022. The report provided an assessment of groundwater depth across the site. The groundwater contours prior to mining are represented in Figure 9 below. The average groundwater level across Area 1 and Area 3 in 64.5mAHD and this value has been used in design. The western side of the Area 1 and Area 3 pit shells will be less than this level ranging from 63mAHD to 64mAHD.

The surface levels across Area 1 vary from ~105mAHD to ~115mAHD and Area 3 varies from ~110mAHD to ~120mAHD. Pit depth have been set to remain well above these levels during mining.

CDM Smith 2022 identify that as the mine advances and tailings deposition increases there is a likelihood of groundwater mounding. This groundwater mounding has at this stage not been modelled at the mining block level however it is suggested that it could mean that in some areas groundwater may intersect the pit floor. It is intended that where this will occur that a system of dewatering bores will be installed to ensure that groundwater is maintained at a level of nominally 1m below pit floor. This system is currently under investigation and will be incorporated into FEED.

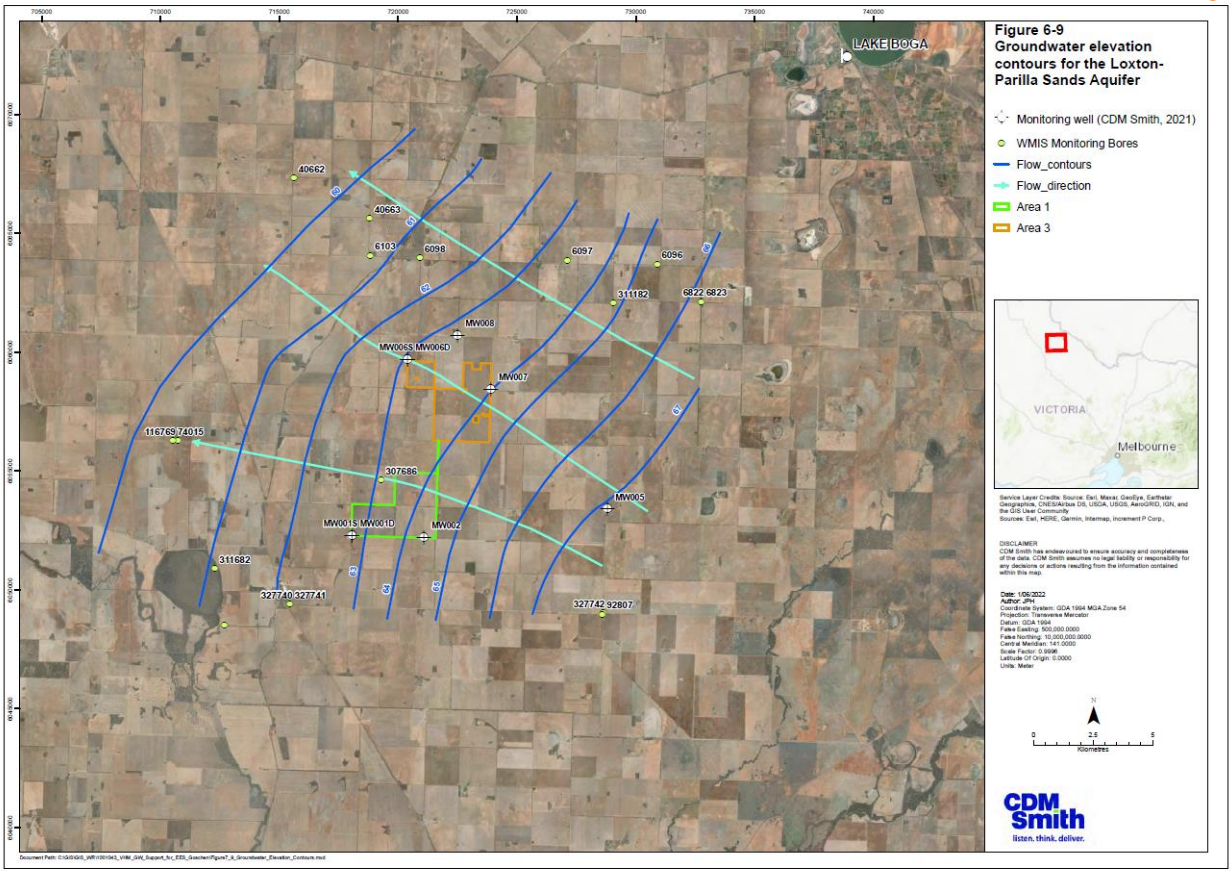

Figure 9: Groundwater contours from CDM Smith Technical Report I. Groundwater

5. Site Investigation

5.1 Assumptions and Limitations

This report is prepared generally in accordance with AS1726. Departures from AS1726 exist due primarily to the restricted scope of this investigation which has been limited to assessment of geotechnical parameters of soil and rock materials to inform geotechnical design.

A range of investigations which may be anticipated in a detailed geotechnical investigation including those relating to soils, landforms and water have been undertaken for this project by others. These investigations are not reproduced herein but when pertinent to inform geotechnical parameters are referenced within the text and in Section 9 References

Key Reliance information includes EES Technical Reports:

- Water Technology – H1. Surface Water (Water Technologies 2022)
- CDM Smith – I. Groundwater (CDM Smith 2022)
- SLR - M. Soils and Land Resources (SLR Consulting 2022); and
- Pitt&sherry – P. Rehabilitation and (Closure Pitt&sherry 2022).

5.2 Methodology

All observations and testing locations have been located using handheld GPS or equivalent applications on mobile devices / surveyed to approximately 5m accuracy. Where indicated, more precise surveying has been undertaken to locate investigation reference points, this includes drill hole collar locations collected during mine preparations.

All soil, rock and groundwater samples have been logged with unique reference numbers as indicated on the logs.

A number of programmes of work have been carried out on the proposed Goschen site including a number of resource definition drill programmes. Only those that have included geotechnical data collection are summarised in this report.

The site investigations to inform geotechnical parameters which have been carried out include:

- 2017 – site walkover
- 2019 – site visit and review of current quarrying operations; and
- 2022 – drilling and bulk sampling.

5.3 Observations

5.3.1 Observations 2017

A geotechnical site inspection was conducted on 19 December 2017, by an experienced senior geotechnical engineer from pitt&sherry. The inspection was carried out to assess site topography and any visible exposures from slopes, cuts, rivers, dams, quarries and borrow pits and review representative drill chip tray samples. It did not include a full review or relogging of any hole data. A summary of observations follows.

The proposed site is currently used as farming land and is flat with very little topographical variation. No rock outcrops were observed during the visit.

Figure 10: Photograph of typical land use observed in 2017

During the site visit, a rubbish hole, one partially filled old channel, three quarries and a series of borehole chip samples were inspected.

Three larger quarries were also inspected during the site visit in paddock 44 and paddock 60 (owned by Ian and Mark Free). The quarries were 6–10 metres deep from the paddock surface. The quarried material was used by the local council as a pavement material to build the road around the paddocks. Based on the presence of rubbish within the quarries and surface vegetation across the quarry floor and wall, it was indicated that the quarries had been inactive for several years.

Paddock 44 quarry observations included low strength rock or moderately cemented sand in the floor. A small stockpile of boulders was also present within the quarry. The quarry wall indicated the general profile as being clay overlying cemented sand (Figure 11). No subsurface water was observed.

Figure 11: Photograph of Paddock 44 quarry (2017)

Paddock 60 quarry also comprised clay overlying cemented sand; however, the cementation varied from weakly cemented to moderately cemented. Areas of moderately cemented sand can stand close to vertical over short heights (Figure 12 and Figure 13).

Figure 12: Photograph of Paddock 60 quarry, showing close to vertical cemented sand walls (2017)

Figure 13: Photograph of Pack 60 quarry (2017)

The 2017 mineral resource investigation by VHM included downhole rotary drilling which was logged by a resource geologist and representative samples (1-2cm from 1m of core retrieved) were retained in chip trays (example shown in Figure 14). Eight borehole samples were inspected during the site visit.

Figure 14: Photograph of representative samples retained from exploration drilling

5.3.2 Observations 2019

A site walkover by a civil engineer from pitt&sherry was undertaken in March 2019 to assess locations for possible stormwater detention ponds. A photographic record from the existing quarry in Area 1 is shown below (Figure 15 to Figure 18).

Figure 15: Photograph of paddock 40 quarry (2019)

Figure 16: Photograph of paddock 40 quarry, view to the east (2019)

Figure 17: Photograph of paddock 40 quarry, view to the west (2019)

Figure 18: Photograph of paddock 40 quarry, view to the south (2019)

5.4 Drilling

Four geotechnical boreholes were drilled in Area 1 in 2017 using a sonic drilling method. They were drilled to 25 m and standard penetration tests (SPT) were undertaken at selected intervals.

Four hydrogeological boreholes (MW01, MW02, MW06 and MW07) were drilled in 2021 by CDM Smith by wash boring methods. Undisturbed samples were taken at changes in soil type.

In 2022 VHM undertook a major geotechnical drilling program that included 11 boreholes advanced using a combination of sonic, push tubes and 1 triple tube rotary hole in Area 1 and 7 boreholes advanced using triple tube rotary techniques in Area 3.

The location of the boreholes is shown in Figure 19 and Figure 20. The grey areas represent the pit shells.

Figure 19: Location of geotechnical boreholes in Area 1

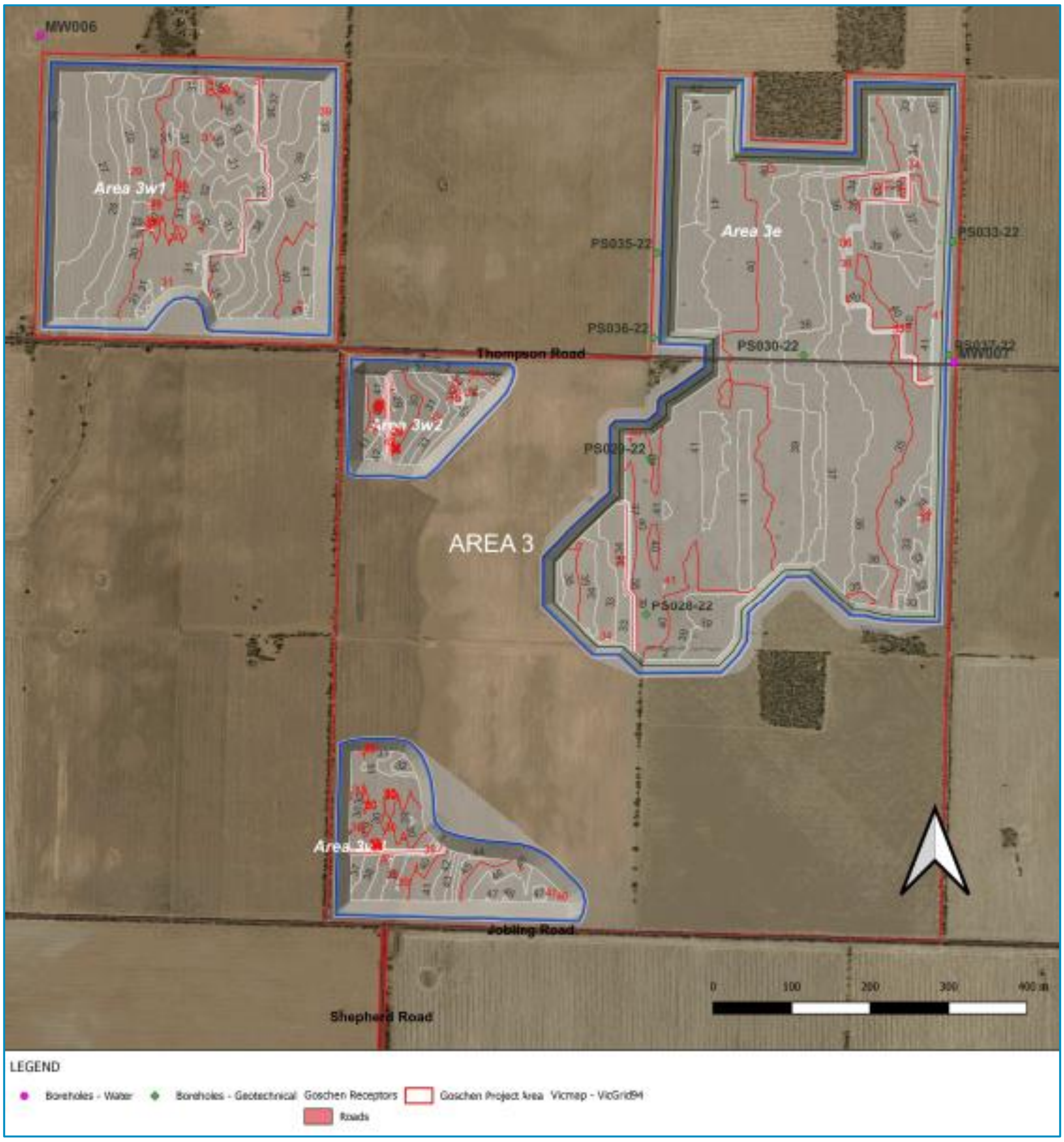

Figure 20: Location of hydrogeological boreholes in Area 1 and Area 3

5.5 Insitu/Field Tests

5.5.1 Standard Penetration Tests

86 No. Standard Penetration Tests (SPTs) were carried out in the field and are summarised in the graph presented in Figure 21 below. For the tests in Area 3 where refusal occurred, the SPT N values was conservatively set as 60 and then corrected for depth/hammer efficiency.

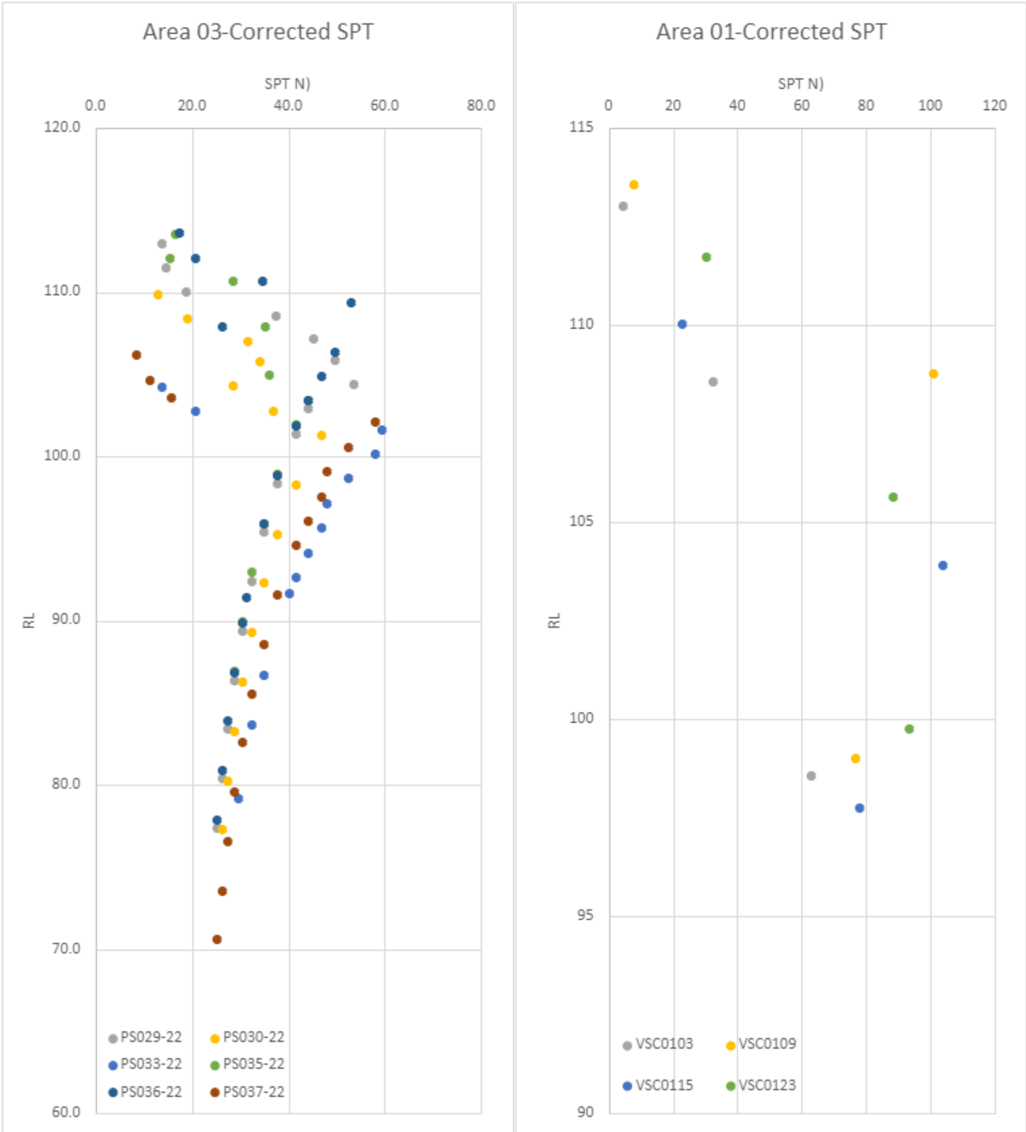

Figure 21 Summary of corrected SPT N value results

5.5.2 Point Load Tests

Point load tests (PLTs) were completed on bulk samples gathered during field investigations. A total of 102 tests were carried out. Figure 22 shows a typical bulk sample collected from Borehole PS003-22. Most of the bulk samples were collected within cemented SAND layers, in order to assess strength variation within cemented SAND layers encountered.

Point load strength index ($Is_{(50)}$) for these samples were calculated using lump dimensions and failure loads from the test (the standard 'irregular lump test' procedure (AS4133.4.3.1, 2007 Determination of Point Load Test on Rock Specimens for Engineering Purposes,) was used when calculating $Is_{(50)}$).

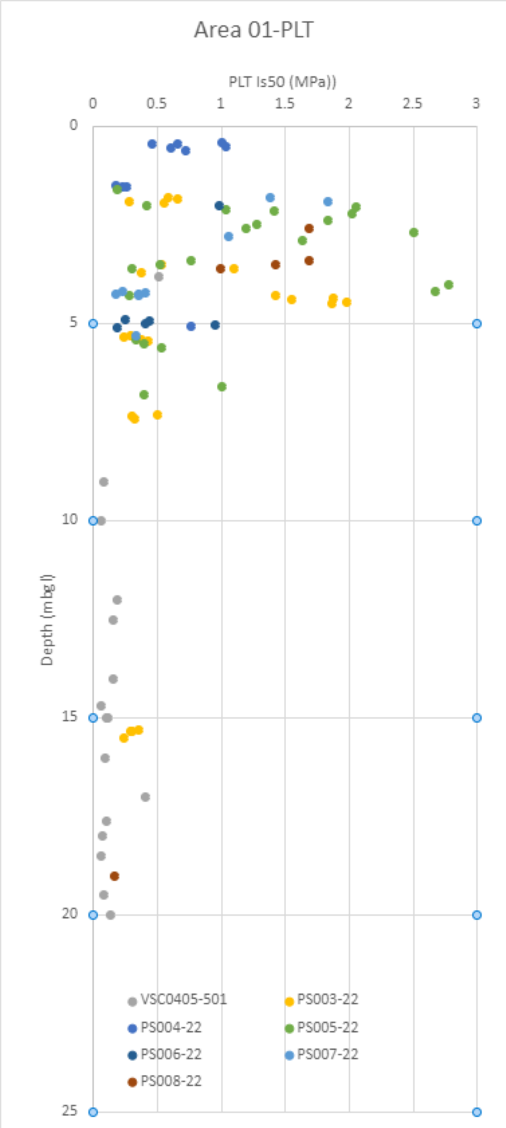

Figure 23 Summary of PLT value results

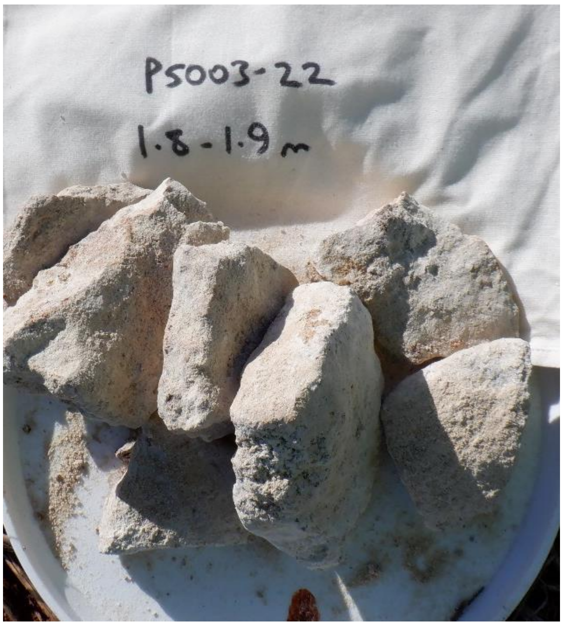

Figure 22: Bulk sample recovered for PLT test (PS003-22)

5.6 Laboratory Testing

A summary table of the laboratory test results is included in Table 2, Table 3 and Table 44.

Table 2 Summary of laboratory test results from mining Area 1 and Area 3 boreholes

Client ID	Depth (m)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)	LS (%)	Moisture (%)	Description	Plasticity	Particle density (t/m^3)
VSC 0103	1.0–1.45	0	30	21	49	77	23	54	17.5	26.6	Sandy clay with silt	High plasticity	2.65
VSC 0103	1.45–1.9	0	27	21	52	76	16	60	18.5	29.8	Silty clay with Sand	High plasticity	2.65
VSC 0103	5.0–5.45	0	83	10	7	36	18	18	8.5	8.9	Silty sand	Medium plasticity	2.52
VSC 0103	5.45–5.9	0	76	18	6	20	19	1	1	9.9	Silty sand	Low plasticity	2.65
VSC 0103	15.0–15.45	0	67	23	10	23	18	5	2.5	14.1	Silty sand	Low plasticity	2.59
VSC 0109	1.1–1.45	0	54	23	23	70	21	49	17	17.5	Clayey sand	High plasticity	2.61
VSC 0109	1.45–1.9	0	45	20	35	66	20	46	17	24	Sandy clay with silt	High plasticity	2.64
VSC 0109	5.0–5.25	0	78	14	8	35	15	20	9	11.6	Silty sand	Medium plasticity	2.62
VSC 0109	16–16.45	0	75	14	11	NO	NO	NO	NO	9.7	Silty sand	Non-plastic	–
VSC 0115	2.0–2.45	0	38	22	40	71	25	46	14.5	16.1	Sandy clay with silt	High plasticity	2.66
VSC 0115	2.45	0	51	17	32	41	17	24	11.5	16.5	Clayey sand	Medium plasticity	2.66
VSC 0115	7.7–8.12	0	75	20	5	20	14	6	2	13.8	Silty sand	Low plasticity	2.62
VSC 0115	8.12	0	77	19	4	NO	NO	NO	NO	10.2	Silty sand	Non plastic	2.66
VSC 0115	14.0–14.45	0	73	15	12	24	11	13	3.5	17.9	Silty sand/ clayey sand	Low plasticity	2.58
VSC 0115	14.25	0	77	17	6	NO	NO	NO	NO	14.8	Silty sand	Non plastic	-

Client ID	Depth (m)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)	LS (%)	Moisture (%)	Description	Plasticity	Particle density (t/m³)
VSC 0123	2.0–2.23	0	40	8	52	63	24	39	15	14.1	Sandy clay with silt	High plastic	–
VSC 0123	2.3	0	58	9	33	--	--	--	--	--	Clayey sand	Medium plasticity	2.57
VSC 0123	8.0–8.37	0	81	13	6	40	18	22	11	15.9	Silty sand	Medium plasticity	2.52
VSC 0123	8.37	0	81	12	7	NO	NO	NO	NO	14.4	Silty sand	Non plastic	2.55
VSC 0123	14.0–14.25	0	73	19	8	NO	NO	NO	NO	14.1	Silty sand	Non plastic	2.59
VSC 0123	14.25	0	75	16	9	NO	NO	NO	NO	19.4	Silty sand	Non plastic	2.62
PS002-22	12.5-13.4	-	-	-	-	-	-	-	-	-	Clayey SAND	-	2.63
PS003-22	10.9-12.2	0	77	13	10	-	-	-	-	7.4	Silty SAND	Non Plastic	2.64
PS003-22	14.3-14.6	1	68		31	-	-	-	-	-	Silty SAND	Low to Medium plasticity	–
PS003-22	19.2-20	-	-	-	-	22	20	2	0.5	-	Silty SAND	Low to Medium plasticity	–
PS003-22	28-28.3	1	68	-	31	-	-	-	-	-	-	-	-
PS004-22	7.1-7.45	0	76		24	-	-	-	-	8.7	Silty SAND	Low to Medium plasticity	–
PS005-22	10.1-10.4	-	-	-	-	-	-	-	-	-	SAND	-	2.61
PS005-22	13.8-14.2	-	-	-	-	-	-	-	-	-	SAND	-	2.63
PS006-22	5.7-5.9	2	78		20	-	-	-	-	9.1	Silty SAND	Low to Medium plasticity	–
PS007-22	3.1-3.5	0	88		12	-	-	-	-	6.4	Silty SAND	Low to Medium plasticity	–

Client ID	Depth (m)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)	LS (%)	Moisture (%)	Description	Plasticity	Particle density (t/m^3)
PS009-22	16.8-17	-	-	-	-	NO	NO	NO	NO	-	Silty SAND	Non plastic	–
PS028-22	6.0-5.2	-	-	-	-	63	25	38	10.5	-	CLAY	High plasticity	
PS028-22	6.5-6.7	0	34	27	29	43	18	25	10		Silty Sandy CLAY	Medium plasticity	
PS028-22	17.3-17.8	0	81	19	-	-	-	-	-	-	Silty SAND	Non plastic	
PS030-22	23.6-24.1	1	72	27	-	-	-	-	-	-	Clayey Silty SAND	Non plastic	
PS033-22	6.6-7.09	5	80	-	15	-	-	-	-	-	Clayey Silty SAND	Medium plasticity	
PS033-22	38.4-38.9	0	81	19	-	-	-	-	-	-	Clayey Silty SAND	Non plastic	
PS035-22	3.5-3.9	0	29	17	54	66	21	45	8	-	Silty CLAY	Hight plasticity	
PS036-22	3.5-3.8	0	28	18	54	70	22	48	14.5	-	Silty CLAY	High plasticity	
PS036-22	5-5.2	0	58	13	29	34	10	24	4	-	Silty Sandy CLAY	Low plasticity	
PS037-22	3.5-3.9	0	18	19	63	64	23	41	9.5	-	Silty CLAY	Hight plasticity	
PS037-22	19.4-19.9	0	75	25	-	-	-	-	-	-	Silty SAND	Non plastic	

Note: LL = liquid limit; PL = plastic limit; PI = plasticity index; LS = linear shrinkage; t/m^3 = tonnes per cubic metre.

Table 3: Triaxial, Permeability and Emerson Test data summary for Area 1 and Area 3 boreholes

Client ID	Depth (m)	Description	c' (kPa)	f' (degree)	Permeability (m/s)	Emerson Class Number
VSC 0103	1.0–1.45	Sandy clay with silt	25/29/35	22.8/20.4/21.2	6.4 × 10-11	2
VSC 0103	5.0–5.45	Silty sand	2.8/1.0	35/35.3	2 × 10-10	6
VSC0103	15.0-15.45	Silty sand	-	-	-	6
VSC 0109	1.1–1.45	Clayey sand	8 / 30	27 / 34	2 × 10-10	4
VSC 0109	5.0-5.25	Clayey silty sand	-	-	-	6
VSC 0115	2.0–2.45	Sandy clay with silt	20/19/19	22.5/22.8/22.7	2.3 × 10-11	4
VSC 0115	7.7–8.12	Silty sand	8.6–14.9	34–35	–	6
VSC0115	14.0-14.45	Silty sand	-	-	-	6
VSC 0123	2.0–2.23	Sandy clay with silt	55– 57	23.5–24.3	3.3×10^{-11}	4
VSC0123	8.0-8.37	Silty sand	-	-	-	6
VSC0123	14.0-14.25	Silty sand	-	-	-	6
PS002-22	1.5-1.95	Silty clay	-	-	-	1
PS003-22	0.4-0.75	Silty clay	-	-	-	4
PS003-22	28-28.3	-	39/94/54	41/33/37	-	
PS006-22	1.4-1.6	Silty clay	-	-	-	1
PS007-22	3.1-3.5	Silty Sand	-	-	-	2

c' = drained cohesive strength; kPa = kilopascals; φ' = drained angle of friction; m/s = metres per second

Table 44: Summary of laboratory test results from Combined Samples

Combined Sample	BH Details	Depth (m)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)	LS (%)	Moisture (%)	Description	Plasticity	Particle density (t/m^3)	Permeability (m/s)	Pinhole Dispersion
Combined 1	PS003-22	15.3-16.2	9	52	-	39	31	14	17	5	16.4	Clayey SAND	Low Plasticity	-	Deemed Impermeable	D1: Highly dispersive
	PS006-22	1.4-1.6														
	PS007-22	0.6-0.8														
Combined 2	PS008-22	1.3-1.5	11	56	-	33	31	17	14	3	16.1	Clayey SAND	Low Plasticity	2.59	1×10^{-9}	D1: Highly dispersive
	PS009-22	5.0-5.3														
	PS009-22	8.6-9.0														
Combined 4	PS002-22	9.0-10.5	16	71	-	13	-	-	-	-	7.2	Clayey Gravely SAND	-	-	-	
	PS003-22	4.3-4.5														
	PS003-22	5.2-5.3														
	PS004-22	1.4-1.7														
	PS004-22	2.8-3.2														
Combined 6	PS007-22	4.2-4.5	22	48	-	30	-	-	-	-	12.2	Gravely Clayey SAND	Low to Medium Plasticity	2.59	-	
	PS007-22	17.3-17.7														
	PS007-22	9.0-9.35														

Note: LL = liquid limit; PL = plastic limit; PI = plasticity index; LS = linear shrinkage; t/m^3 = tonnes per cubic metre.

6. Ground Model

Ground models were developed based on the available borehole logs, field and laboratory test results. There were total of 15 boreholes completed across Area 1 and 7 boreholes completed across Area 3. Boreholes were spaced approximately 500-800m over the study areas. After analysing borehole logs, it was identified that Area 1 and Area 3 comprise of similar soil strata. Therefore, a simplified ground model using 5 main soil strata as summarised in Table 55 was adopted.

Table 55: Summary of strata based on available borehole logs

Soil Unit	Material	Material Description
U1	TOPSOIL	topsoil, sandy silt, with clay, roots, and organics
U2	CLAY; Silty CLAY	clay, variable low to medium plasticity, F to VSt strength, variable but low fine sand and silt content
U3	Sandy/Silty CLAY	sandy clay, VSt to H, low plasticity
U4	Silty/Clayey SAND; SANDSTONE	weekly cemented, MD to D, medium to coarse grained SAND
U5	Silty SAND	fine grained, cemented sands, low to medium strength

6.1.1 Ground model Area 1

Area 1 fence diagrams were developed to visualise the distribution of geotechnical strata units across the site. Figure 24 shows the location of the cross sections and fence diagrams are provided in Figure 25 to Figure 28. These indicate that cemented Sand is found beneath the overburden clay. However, the degree of cementation can be varying across the site. Most of the borehole logs recorded the cemented sand to be slightly to moderately cemented. The typical profile as shown in Table 6 has been adopted for the purposes of DFS design in Area 1.

The ground surface level in Area 1 varies from 116.06 to 106.63 m AHD (metres above Australian Height Datum) as per recorded borehole elevations. The existing groundwater level has been referenced from CDM Smith 2022 at 64.5 m AHD prior to mining and tailings deposition.

Table 6: Ground model Area 1

Soil Unit	Material	Typical depth ranges (mBGL)*	Typical depth ranges level (m AHD)	Typical layer thickness
U1	TOPSOIL	0 – 0.5	116.06 - 106.13	0.2m to 0.5m
U2	CLAY; Silty CLAY	0.2 – 8.5	115.71 – 102.28	4.5 m to 8.6 m
U3	Sandy/Silty CLAY	0.2 – 12.8	111.56 – 101.45	10 m to 16 m
U4	Silty/Clayey SAND; SANDSTONE	4.8 – 30.6	105.2 – 82.03	20 m
U5	Silty SAND	18.3 to >40	96.36 to <68.26	Not determined

* Metres Below Ground Level

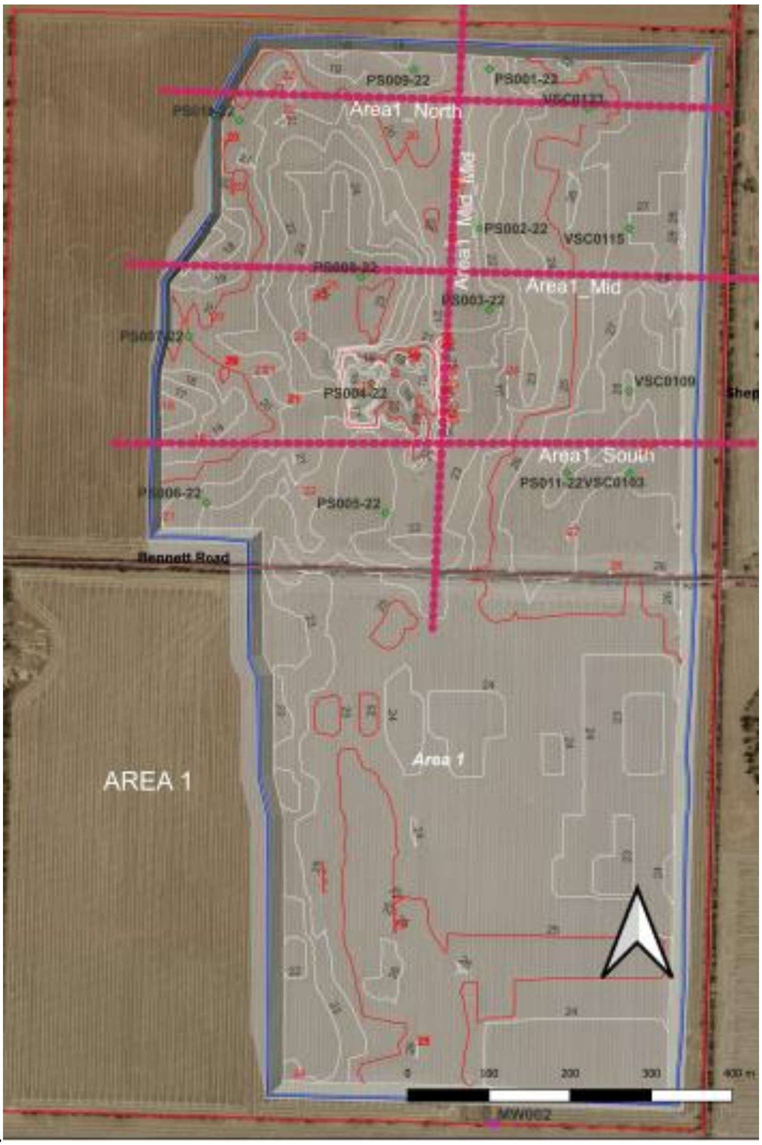

Figure 24: Cross section locations for Area 1

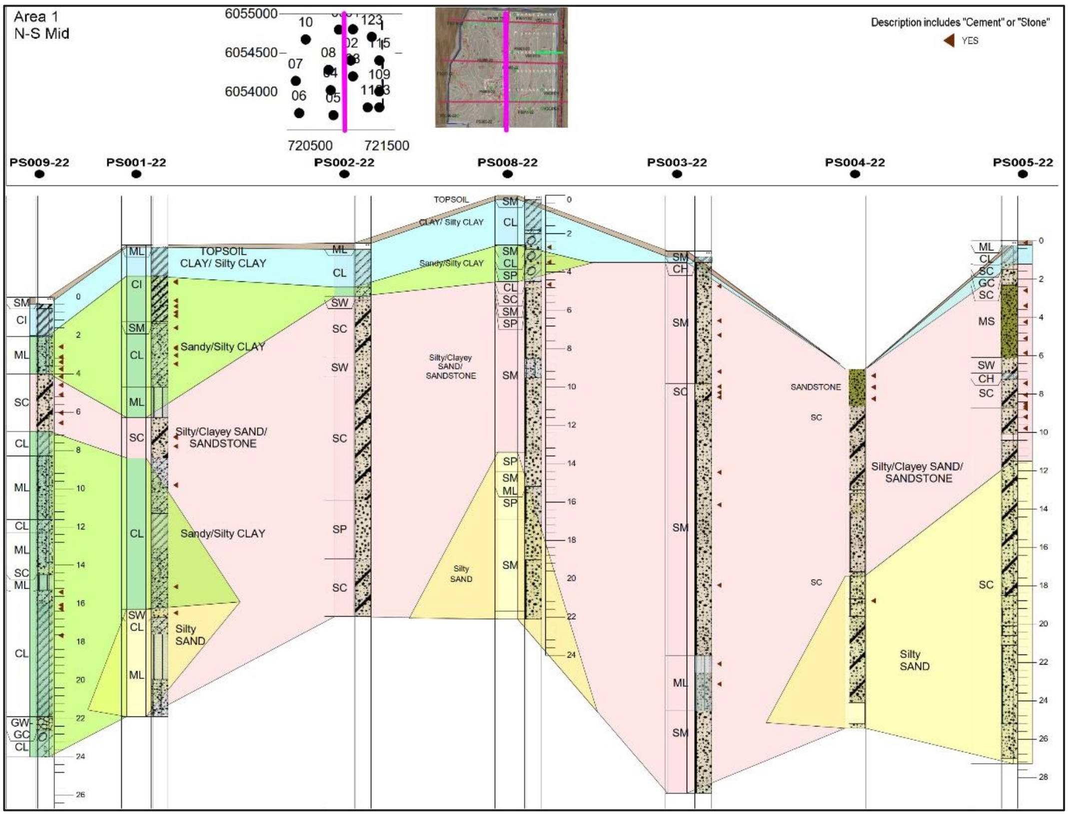

Figure 25: Geotechnical Domain Fence Diagram - Interpretation - Area 1 North-South

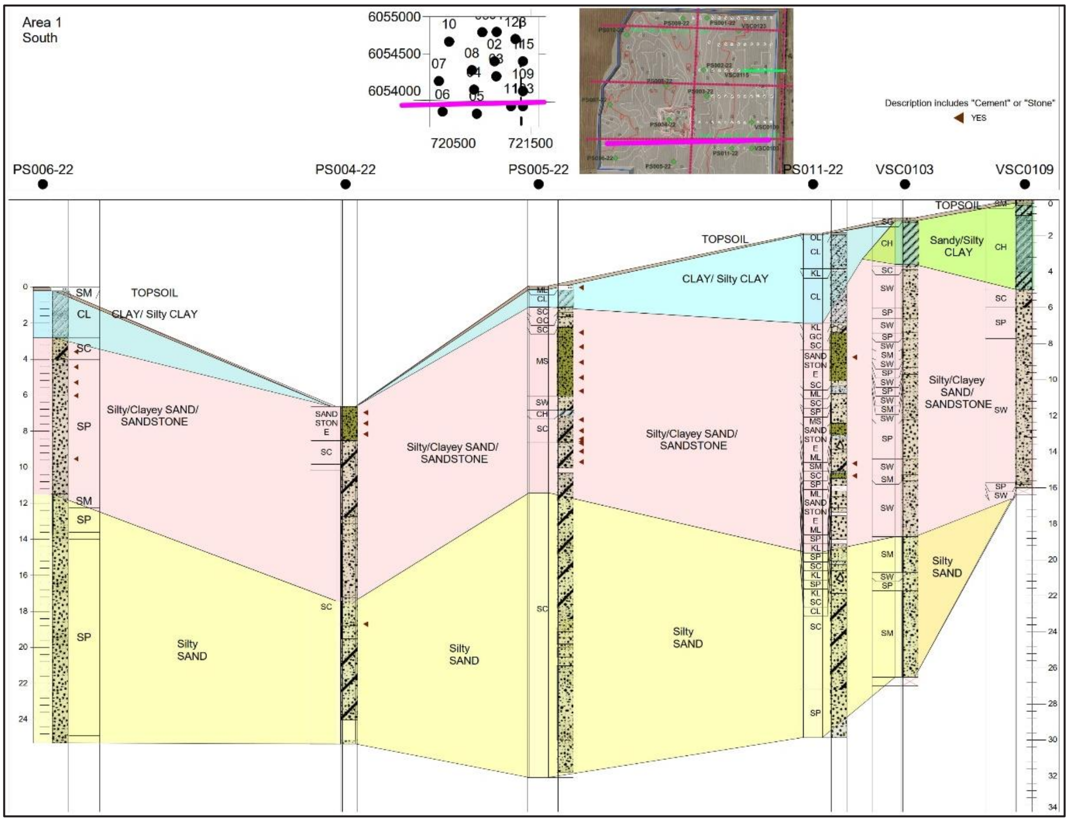

Figure 26: Geotechnical Domain Fence Diagram - Interpretation - Area 1 South

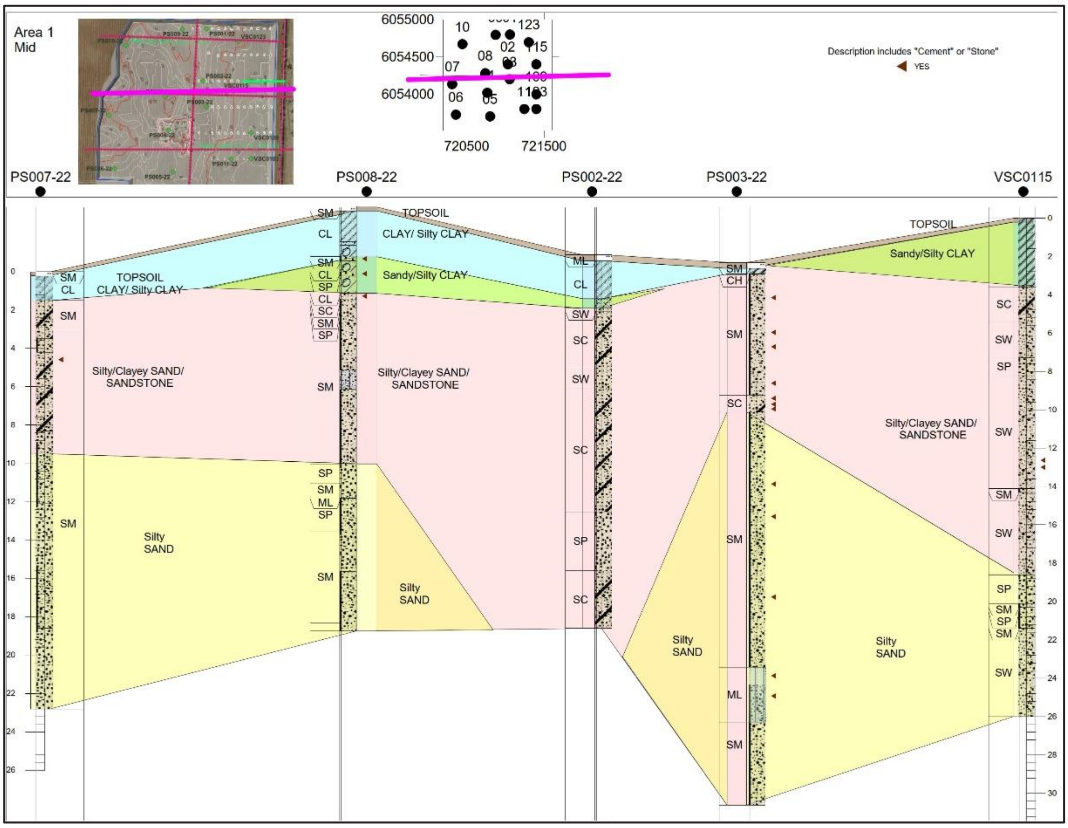

Figure 27: Geotechnical Domain Fence Diagram - Interpretation - Area 1 Mid

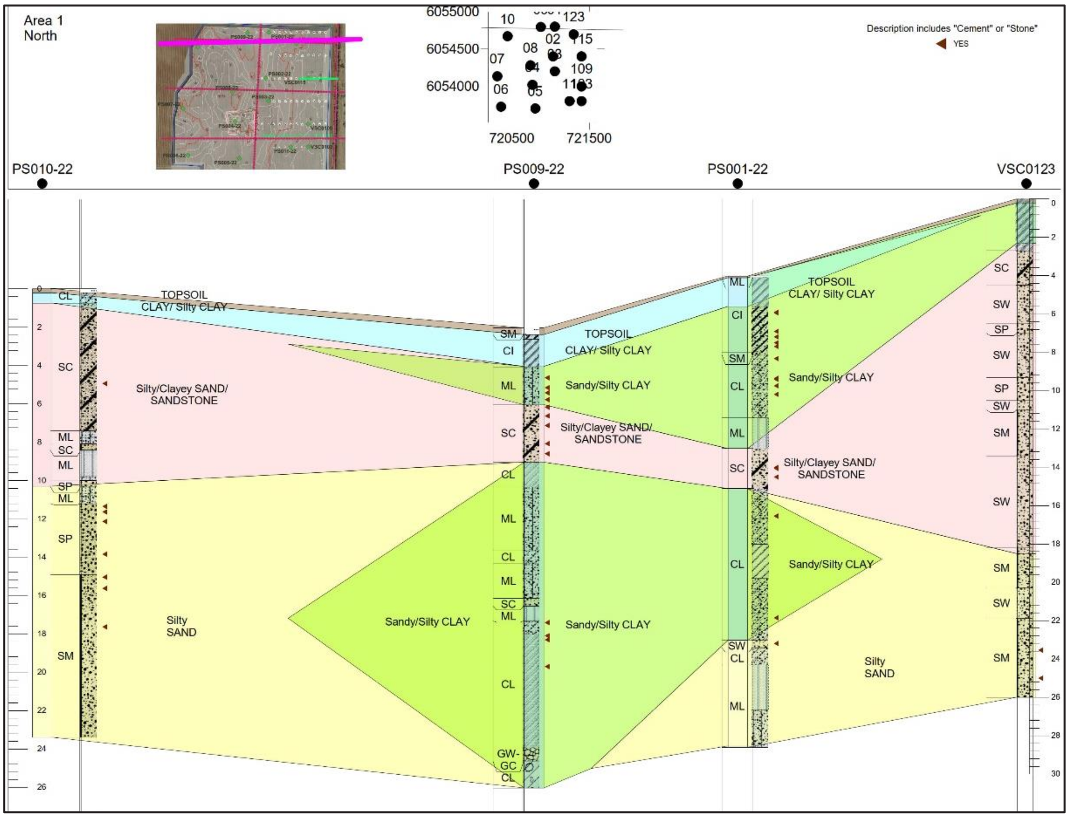

Figure 28: Geotechnical Domain Fence Diagram - Interpretation - Area 1 North

6.1.2 Ground model area 3

Area 3 fence diagrams were developed to visualise the distribution of geotechnical strata units across the site. Figure 29 shows the location of the cross sections and fence diagrams are included in Figure 25 to Figure 28. These indicate the ground model provided in Table 7 as appropriate and this model was adopted for design in Area 3. Ground conditions encountered in Area 3 are similar to the soil strata identified in Area 1. Therefore, same soil units have been adopted in the Area 3 ground model.

Table 7: Ground model Area 3

Soil Unit	Material	Typical depth ranges (mBGL)*	Typical depth ranges level (m AHD)	Typical layer thickness
U1	TOPSOIL	0 – 0.5	116.06 - 106.13	0.2m to 0.5m
U2	CLAY; Silty CLAY	0.2 – 8.5	115.71 – 102.28	4.5 m to 8.6 m
U3	Sandy/Silty CLAY	0.2 – 12.8	111.56 – 101.45	10 m to 16 m
U4	Silty/Clayey SAND; SANDSTONE	4.8 – 30.6	105.2 – 82.03	20 m
U5	Silty SAND	18.3 to >40	96.36 to <68.26	Not determined

* Metres Below Ground Level

The ground surface level in Area 3 varies from 115 to 103.52 m AHD as recorded at borehole collars. The existing groundwater level has been referenced from CDM Smith 2022. Groundwater at 64.5 m AHD

Figure 29: Cross section locations for Area 3.

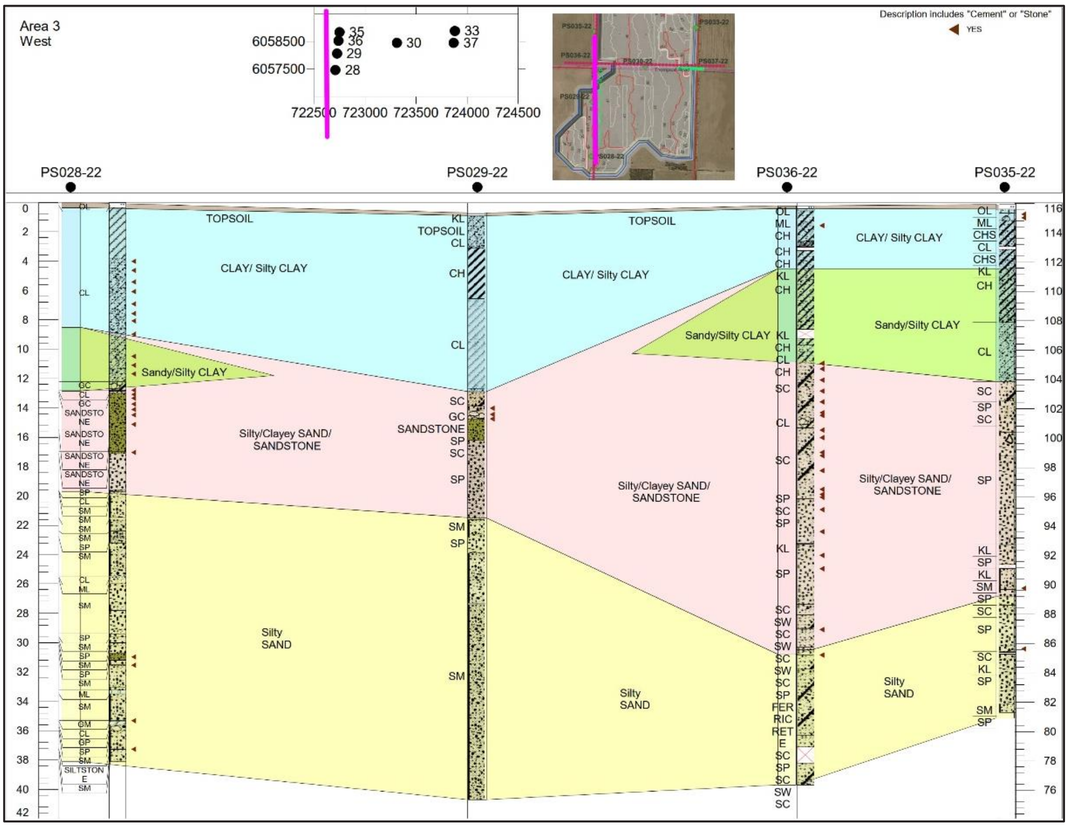

Figure 30: Geotechnical Domain Fence Diagram - Interpretation - Area West

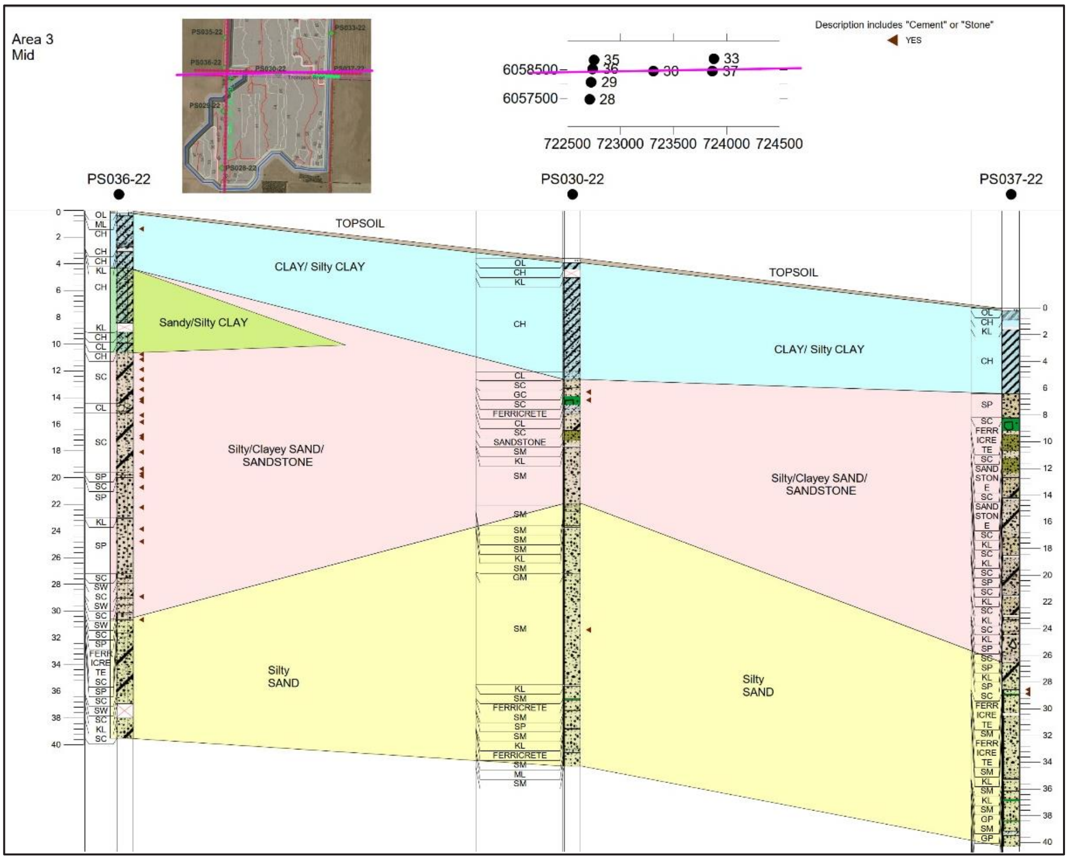

Figure 31 Geotechnical Domain Fence Diagram - Interpretation - Area 3 Mid

7. Material Properties

Material properties for the geotechnical design have been selected based on a statistical analysis and observations and experience for available field and laboratory data. Field and laboratory data for each unit has been analysed separately to define the design strength values. Field SPT data, Point Load Test (PLT) data and laboratory triaxial tests data analysis is described below.

7.1 SPTs

Field measured SPT values have been corrected using the Skempton (1986) equation prior to calculating strength parameters. For the SPT which recorded “Refusal” (which includes the majority of SPT tests in the sandy soils) the assumed N value was conservatively taken as N=60. This value was then further reduced for hammer efficiency and loss of energy in the drill rods. The following methods were then used to define strength parameters for cohesive and non-cohesive soils based on SPT data.

7.1.1 Strength parameters for Cohesive (clay) soils

Effective cohesion: This was selected based on ranges provided in Burt Look (2014). This paper assumed effective cohesion is 20% of the undrained strength. Undrained strength was conservatively taken as 5 x Corrected SPT N value.

Effective friction angle: This was selected based on ranges provided in Burt Look (2014) corresponding to the relative consistency (stiff, very stiff or hard) of the clay.

7.1.2 Strength parameters for non-cohesive (Sand/Silty sand) soils

Effective friction angle: This was calculated based on Peck et. Al (1953) equation for Sandy soils.

Effective cohesion for cemented soils was calculated using Hoek and Brown rock mass strength (Where there was no point load test data the UCS of the intact rock was taken as 10 x SPT N) and the relationship between UCS and effective cohesion was used as shown below.

$$\sigma'_{cm} = \frac{2c'Cos(\varphi')}{1 - \sin(\varphi')}$$

Where, σ'_{cm} -the UCS, c’ - the effective cohesion and φ’ - effective friction angle.

7.1.3 Point Load Test data analysis

Field PLT data was used to generate Mohr-Coulomb parameters using RocLab version 1.033, Figure 32 shows a screen capture extracted from the RocLab analysis. PLT test data was converted to UCS (Unconfined compressive rock strength) values and then the resulting UCS values inputted in to RocLab, which generated the Mohr-Coulomb parameters.

The use of lump test procedures (AS4133.4.1, 2007) provides a potential wider spread of values than would be expected from a cored sample. In addition, the lump samples had already been disturbed in their recovery method as they are intact lumps recovered from sonic core recovery

Below the upper clay layers (Unit 2 and Unit 3) the two sand strata (Unit 4 and Unit 5) contain interbedded sands with variable strengths. The layers comprise non-cemented/lightly cemented bands, between strongly cemented bands. The stronger bands have the engineering properties of a low strength rock. The non-cemented layers have a consistency of very dense sand. This layering also helps explain the wide range in point load test results with the lower values being on lightly cemented sands. Notwithstanding this, in terms of engineering behaviour, the interbedded materials are expected to behave as a single soil unit with the stronger cemented layers dominating the behaviour in terms of pit stability. The weaker layers could be subject to erosion, undermining the stronger layers. This risk will need to be managed on site.

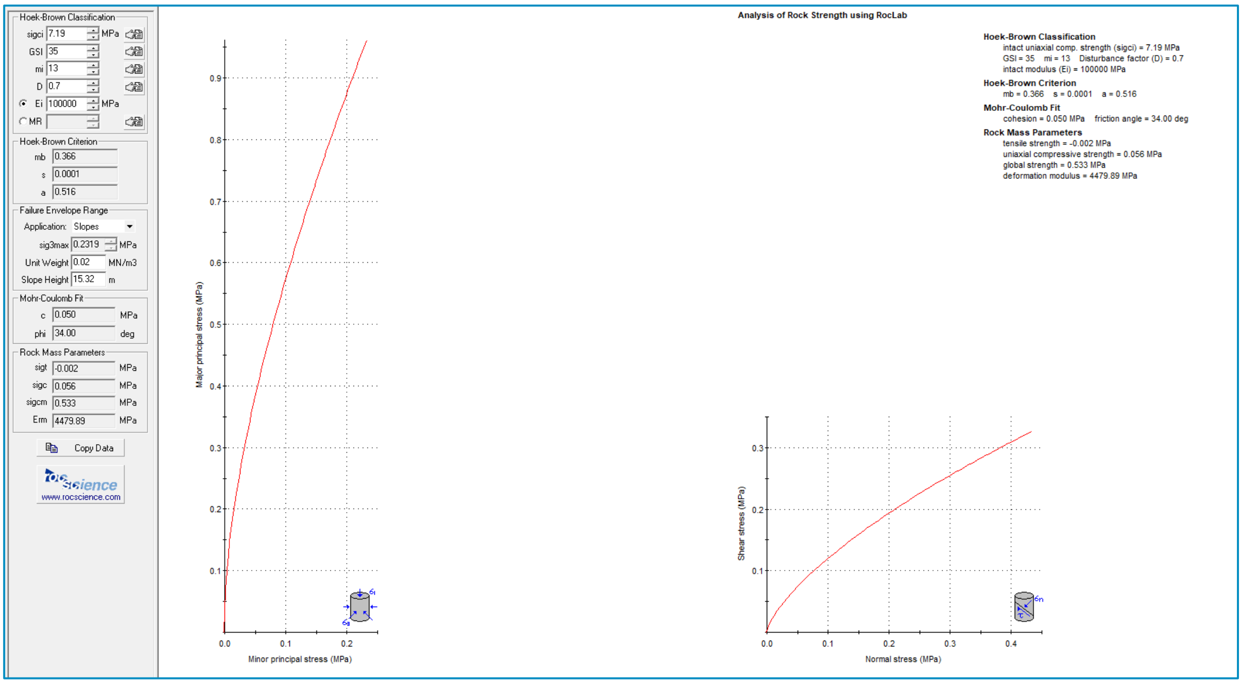

Figure 32: RocLab data analysis for PLT test data

7.1.4 Non cohesive material UCS

The non-cohesive material over the site are interbedded cemented sands and non-cemented sands. The overall engineering behaviour of these units are expected to be equivalent to a very low to low strength rock. For low strength rocks the shear strength is governed by the rock matrix. It is common practise to estimate these low strength units with a rock mass classification system, such as the Geological Strength Index (GSI) by Hoek & Brown (2018). The Hoek – Brown rock mass strength is estimated based on Unconfined Compressive Strength (UCS) of the intact rock, and an estimate of the overall rock matrix condition (GSI).

The UCS was estimated based on the Is50 point load results with the industry accepted correlated on UCS = 20 x Is50 for sedimentary rock.

The GSI for the cemented units was taken as 50%. From Figure 33 GSI Chart for Sandstone Rock (Marinos & Hoek, 2000) This value was chosen as a reasonable value for the cemented sand, which is free of clay infill, and laminations or preferential failure planes.

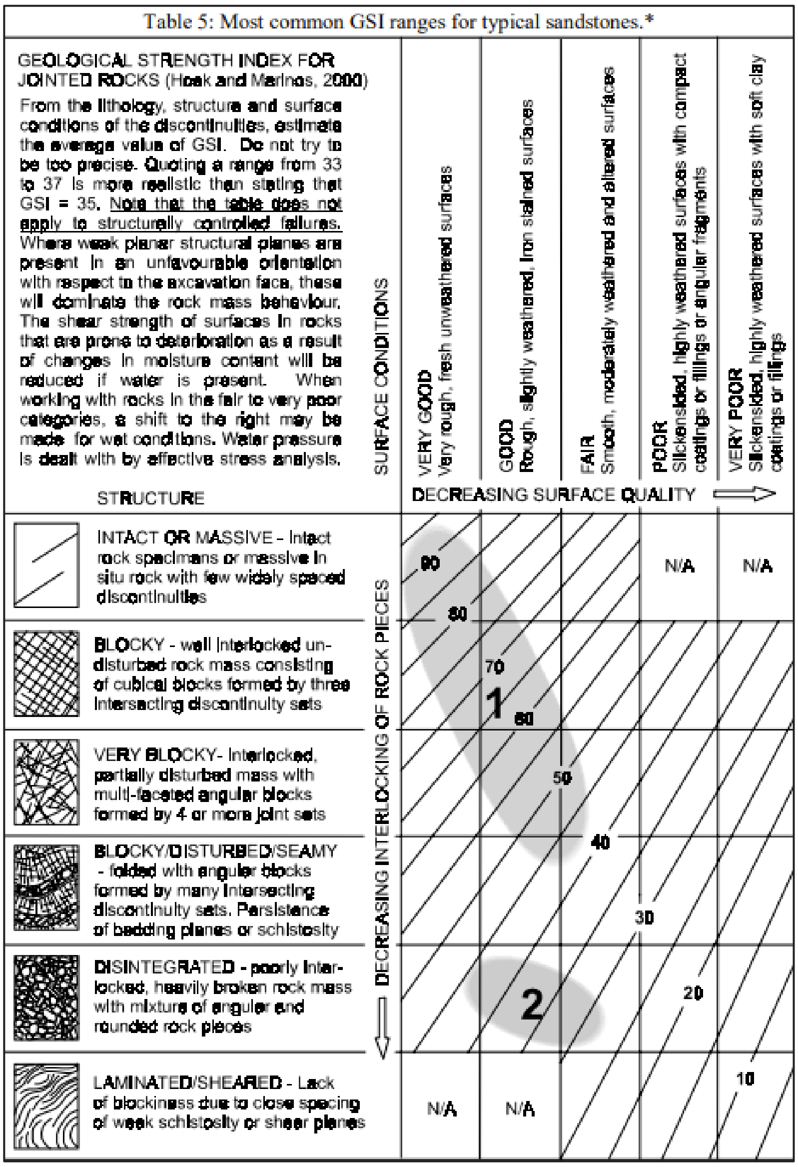

Figure 33 GSI Chart for Sandstone Rock (Marinos & Hoek, 2000)

7.1.5 Triaxial Test data

Triaxial tests were conducted on undisturbed samples recovered during the field investigation. Triaxial tests on Unit 3 and Unit 5 which contain more finer particles, provide good correlation with the other methods used for deriving shear strength parameters. For Unit 4 Triaxial tests show low values when compared to shear strengths derived from insitu tests and point load tests. This could be due to difficulties recovering undisturbed samples within the sand layers, as samples were inclined to fracture on handling and extrusion. For this reason, the triaxial tests in Unit 4 have been treated as lower confidence values.

7.2 Material Parameter Analysis

Material strength parameters variation with depth are presented in Figure 34 to Figure 37 for the different units. Based on these variations, design parameters were selected for each unit at the lower range to minimise the risks associated with strength variations of the soil units over the site area. A summary of the details is provided below.

7.2.1 Soil strength parameters: U1 - Topsoil

Soil strength parameters for Unit 1 - Topsoil was assigned based on field borehole logs. As topsoil is expected to be stripped during mining construction the impact of the topsoil layer is negligible on pit stability and stockpile stability. Laboratory tests were not conducted over the Topsoil layer.

7.2.2 Soil strength parameters: U2 - Clay/Silty Clay

The topsoil is underlain by Clay/Silty Clay of varying thickness up to 8.6m at some of the locations. Effective cohesion (c') and friction angle for this strata has been defined using the available SPT test data and includes effective cohesion varying from 4.35 to 53.4 kPa with an average value of 22.5 kPa (Figure 34).

A value of c' = 10kPa was selected for use in design. This value was selected as it reflects a conservative value below the average value as shown on the graph.

The effective friction angle varies from 20 to 30 degrees (Figure 34). With the majority of the data points being assessed as 26 deg and only 3 points falling below this value, it is assessed as a conservative value to use in design.

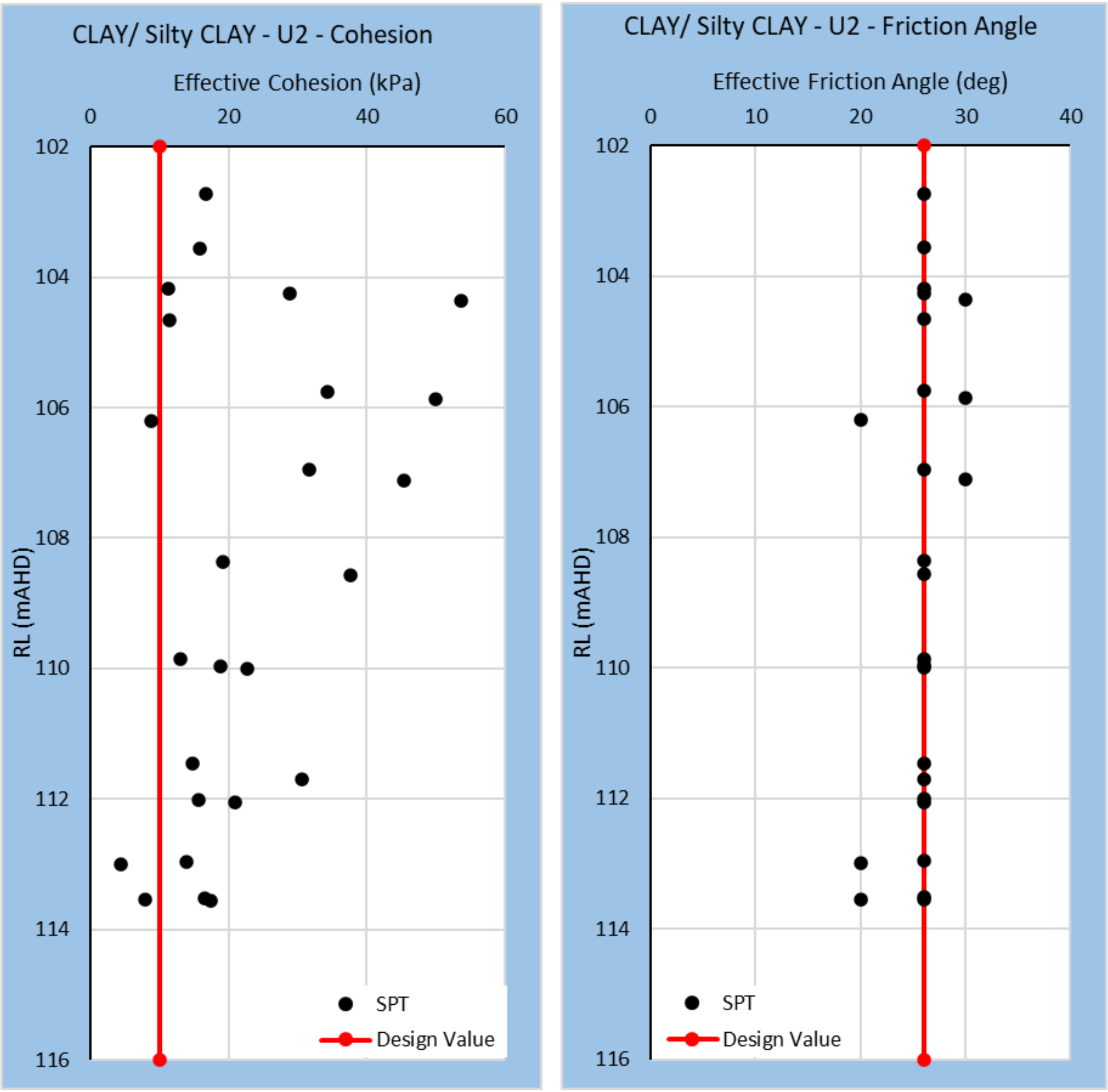

Figure 34: Soil strength parameters variation for Unit 2 (CLAY/ Silty CLAY)

7.2.3 Soil strength parameters selection for U3-Sandy/Silty Clay

A Sandy/Silty Clay layer (U3) is present over Area 1 and Area 3 below the U2. Variations in the thickness and location of this layer can be seen in the geotechnical cross sections presented in Figure 25, Figure 28, Figure 30 and Figure 31.

Effective cohesion (c') and friction angle for this soil strata has been defined based on the available SPT data and Triaxial test results. Analysis of the test data indicates that effective cohesion varies from 8.2 to 53.2 kPa with average value of 26.9 kPa. A value of c' = 20kPa was selected for use in design. This value has been conservatively selected after review of the full set of results are shown in Figure 35.

The effective friction angle varies from 22.5 to 33.4 degrees with average value of 26.9, and 27 deg was selected as the design friction angle. The friction angle of 27 degrees in likely to be conservative given the clay material typically has about 30% sand and gravel, which would typically result in a friction angle of at least 30 degrees. For example, AS 4678-2002 (Earth Retaining Structures) suggests values of 26 degrees to 32 degrees for stiff sandy clays.

One (1) out of 3 of the triaxial test resulted has a lower effective cohesion value than the selected design value, however 2 of the triaxial test results shows higher cohesion than the selected design value. Triaxial tests were assigned lower level of confidence due to sample disturbance and very high confining pressures during testing

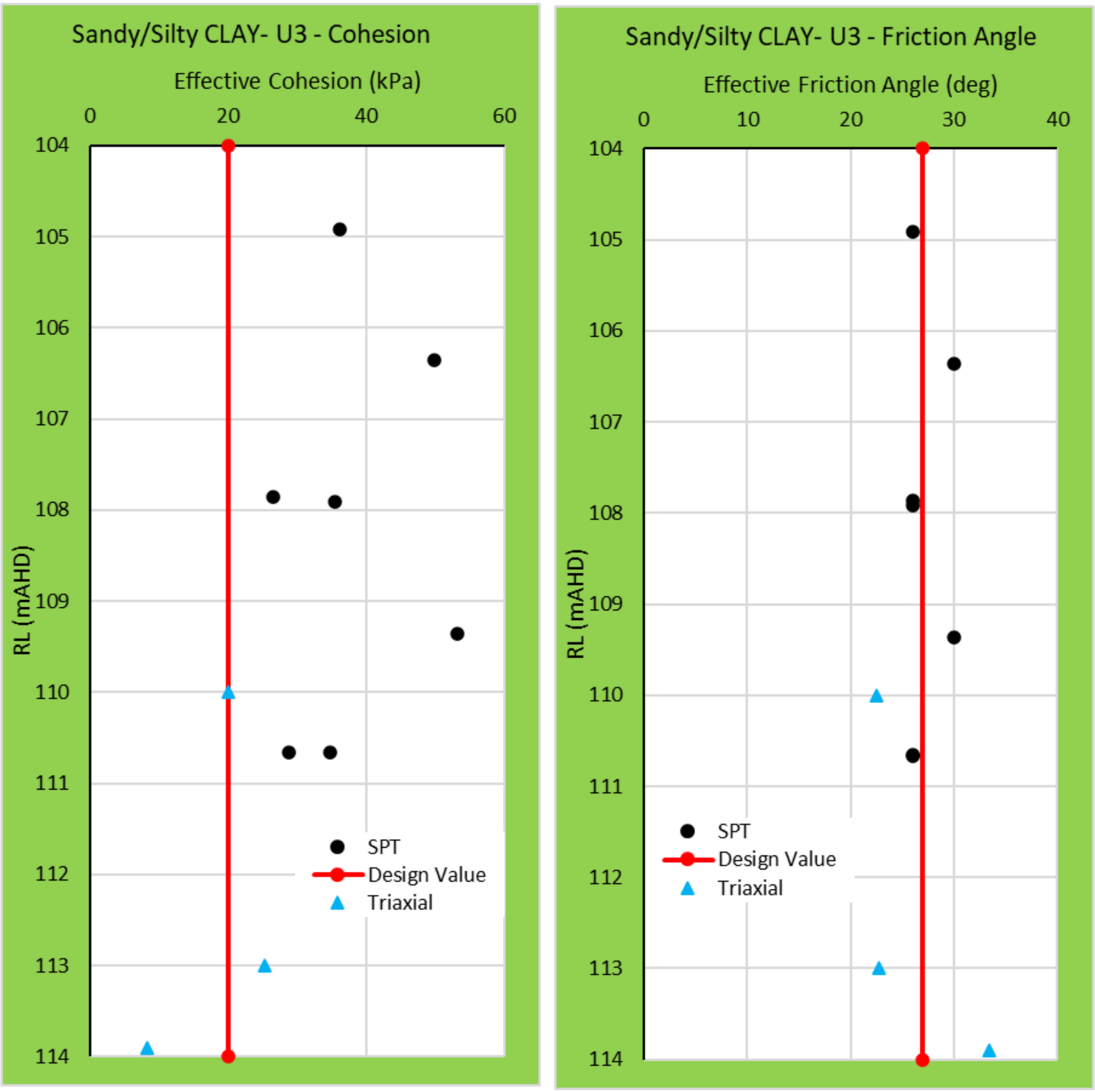

Figure 35: Soil strength parameters variation for Unit 3 (Sandy/ Silty CLAY)

7.2.4 Soil strength parameters selection for U4 - Sand layers/ Sandstone

Cemented Sand layers/ Sandstone with varying content of silt and clay were encountered below units U2 and U3. There are substantial numbers of PLT and SPT insitu test results in this unit as well as triaxial data over both Area 1 and Area 3.

Due to insitu testing constraints the SPT results are all in Area 3 while the PLT tests are concentrated in Area 1. In selecting conservative material properties for U4 a single value to cover this unit over both areas was deemed justified given the entire unit should act as a single weak rock/soil matrix as described earlier.

The results show that the effective cohesion varies from 2.8 to 148 kPa with average value of 59.4 kPa. A value of c' = 32kPa was adopted for design value.

Effective cohesion values based on PLT data resulted in lower effective cohesion values when compared to SPT values. The use of lump test procedures provides a potential wider spread of values than would be expected from a cored sample. In addition, the lump samples had already been disturbed in their recovery method as they are intact lumps recovered from sonic core recovery, while SPT results are insitu and in comparison, less disturbed. On this basis higher confidence was placed on the SPT results as the SPT is an insitu tests, widely used for sand soils.

Effective friction angle values varied between 34.3 to 63.7 degrees with average value of 47.2, however a conservative value of 35 deg was selected for design as shown in Figure 36. This cautious value was adopted to assist in addressing the lower confidence in effective cohesion.

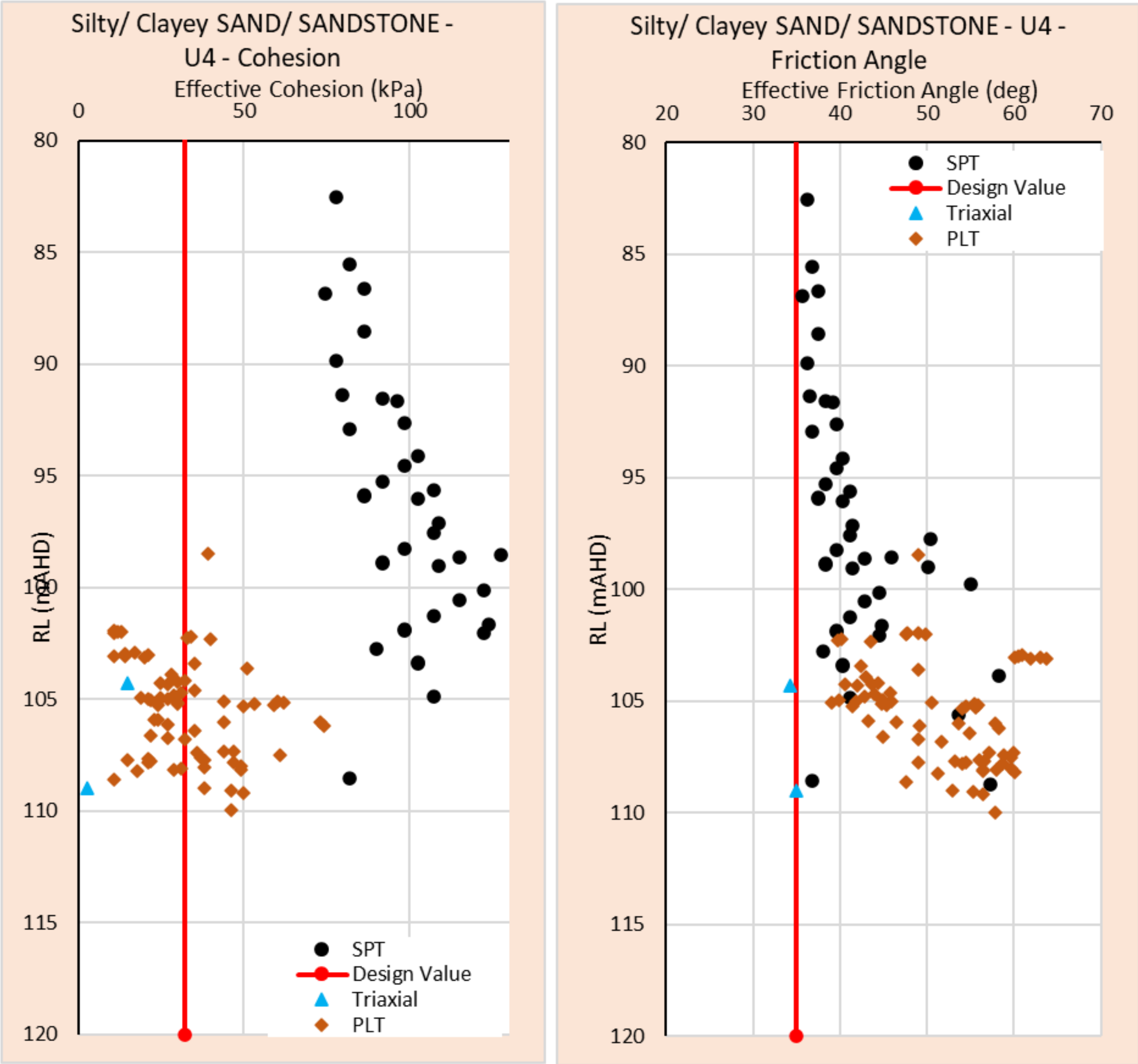

Figure 36: Soil strength parameters variation for Unit 4 (Silty/ Clayey SAND; Sandstone)

7.2.5 Soil strength parameters selection for U5 - Silty Sand

This unit presents as a Silty Sand and was usually encountered below the Sand/ Clay unit. There are PLT, SPT and triaxial data available for this soil strata across Area 1 and Area 3. Effective cohesion varies from 39 to 86 kPa with average value of 68.5 kPa. A design value of c' = 39kPa was selected, which is conservative based on the available data.

Effective friction angle varies between 28.5 to 41 degrees with average value of 35.4. For this unit a value of 35 degrees was selected as the design friction angle. As per available triaxial test data, the friction angle is 41 deg, while PLT tests showing comparatively lower values for effective friction angle. Figure 37 shows the available data plots for U5 soil strata, which shows the variation of effective cohesion and friction angle values.

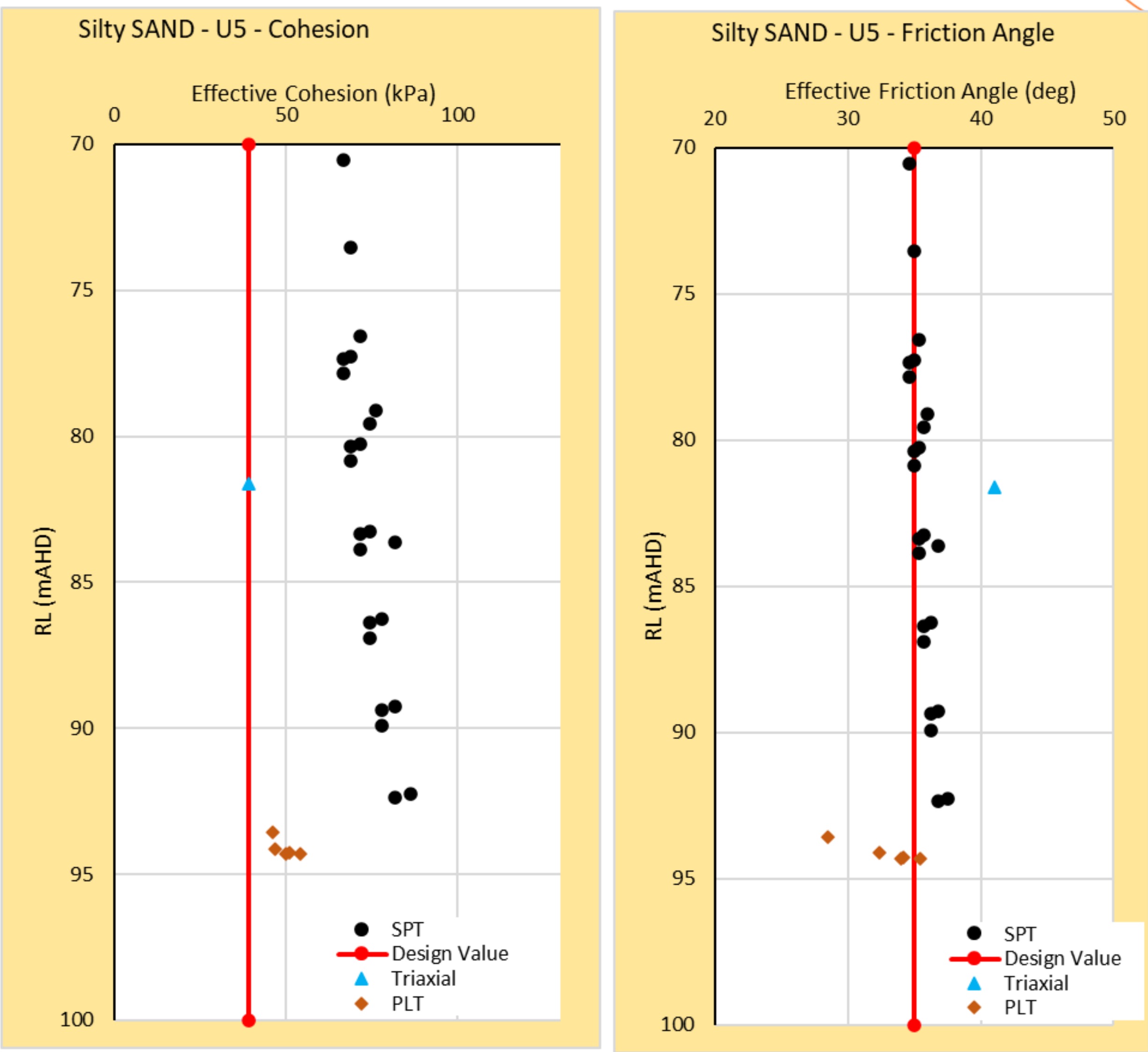

Figure 37: Soil strength parameters variation for Unit 5 (Silty SAND)

7.2.6 Selection of Soil Unit weights

Soil unit weights for different soil units have been assigned based on laboratory test data. Dry density of the topsoil layers (U2 and U3) varies between 1.65 to 1.87 t/m^3; therefore, a value of 19 kN/m^3 was adopted for these layers.

Bulk density values for U4 and U5 were selected based on the data provided in VHMs technical memo on Bulk Density for Area 1 and 3 (VHM 2022). A bulk density value of 20kN/m^3 was selected for U4 and U5 for design purposes.

7.3 Design parameters

The adopted parameters for the in-situ soils for pit slope stability, and stockpile stability are provided below in Table 8.

The top visual bund is expected to be constructed from site won materials (most likely from U2, U3 and U4), and therefore the assessed strength parameters for this material were conservative.

Table 8: Parameters for in situ soils for pit slope stability

Unit	Material	Unit weight (kN/m^3)	c' (kPa)	φ' (deg)
U1	TOPSOIL	18	5	24
U2	CLAY; Silty CLAY	19	10	26
U3	Sandy/Silty CLAY	19	20	27
U4	Silty/Clayey SAND; SANDSTONE	20	32	35
U5	Silty SAND	20	39	35
Top Bund	Compacted site won fill	18	3	26

Note: kN/m^3 = kilonewtons per cubic metre; c' = drained cohesive strength; ϕ' = drained angle of friction.

8. Geotechnical engineering assessment

8.1 Pit depth and design life

The depth of the pit is expected to vary over the two areas, depending on the mineral grade of the sand ore body, and the depth to the groundwater table. Pitt&sherry understands that all mining will be above the groundwater table. As mining advances and tailing deposition is undertaken modelling undertaken by CDM Smith (CDM Smith 2022) indicates that ground water mounding may occur. VHM have indicated that, as a component of the mining plan, localised dewatering will be installed in affected mine blocks to ensure that mining and tails bund construction is carried out nominally 1m above the lowered top of mounding.

The mining depth is generally ~25-30m deep in Area 1 and due to increased overburden Area 3 is generally 35-43m deep with on pit shell close to Jobling Rd reaching 47m deep.

Mining will occur in cells with excavation, tailings deposition and backfilling/rehabilitation undertaken progressively from cell to cell. It is expected that the pit wall in any area will only be open for a maximum of 8 to 12 months including backfilling (VHM Limited 2021). The mining period for Area 1 is expected to be 9 years.

The mine plan has been optimised to allow co-deposition of tailings into the pit cells without the requirement for an above ground temporary tailings facility. To facilitate this method, the pit will be mined in a series of cells, nominally 500 m wide by 350 m long. Cell dimensions have been optimised so they are mined in a north–south orientation for cells 1–6 (Area 1) before switching to an east–west orientation so that, as mining is completed in cells 7 to 9, subsequent cells can be mined without exposing partially consolidated tailings. This arrangement is repeated in Area 3 where cells 1-9 are mined in a north to south sequence before orienting east-west for cells 10-12. This methodology is fully outlined in Chapter 9 of the VHM DFS (Auralia Mining Consulting 20210.

The cell arrangement is shown for Area 1 and Area 3 in Figure 38 below. Notwithstanding this, it is expected that the mining and backfilling cycle will be completed in approximately 12 months.

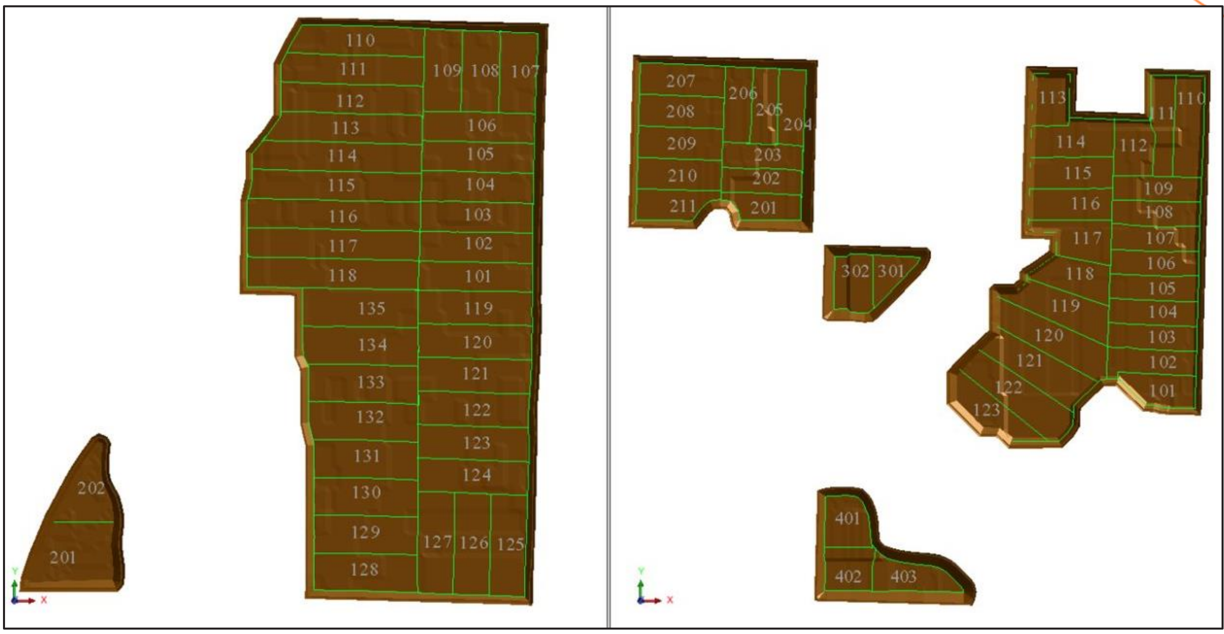

Figure 38: Cell arrangement and sequence for the pits in Area 1 and Area 3 – Y axis denotes north

8.2 Acceptance criteria

The Goschen mine pit walls have been assessed in general accordance with the process outlined in Read and Stacey 2010. The following section provides a summary of the process of establishing appropriate FoS and PoF values for the pit walls and how the general cases included in the guideline has been assessed for the specific case of the Goschen project pits with their very short life cycles which are less than 12 months compared with the guideline that considers much longer timeframes of many years for terminal pit walls

Figure 39 (Table 9.2 of Read and Stacey) outlines acceptable design FoS values recommended in the literature review carried out, as part of the development of the guideline, for civil engineering applications. For normal operating conditions and long-term stability, the guideline suggests that the FoS may vary from 1.25 to 2.

For slopes that are classed as “permanent” an FoS or 1.5 would be applicable. This is a conservative assessment given the very short life of the Goschen project pit slopes where a value of 1.25 for a “temporary” slope might be more applicable

Table 9.2: Acceptable FoS values, civil engineering applications

Material type	Conditions	Acceptance level (static)	Reference
Soil earthworks	Normal loads and service conditions	1.5	Meyerhof (1984)
	Maximum loads and worst environmental conditions	1.3	
Earth retaining structures and excavations	Normal loads and service conditions	2	
	Maximum loads and worst environmental conditions	1.5	
Slopes	Cohesionless soils	1.3	
	Cohesive soils	1.5	
	Based on field vane tests corrected for strain rate and anisotropic effects	1.3	Bjerrum (1973)
		1.25	Bowles (1979)
	Highest value for serious consequence of failure or high uncertainty	1.25–1.5	Gedney & Weber (1978)
		1.5	Hansen (1967)
		1.3–1.5	Meyerhof (1970)
		1.3–1.4	Sowers (1979)
	Lower values for temporary loading	1.5 1.25–1.3	Terzaghi (1943)
	Permanent or sustained conditions	1.5	US Navy Department (1962)
	Temporary	1.25	SAICE COP (1989)
	Permanent	1.5	SAICE COP (1989)
Dams	End of construction, no reservoir loading, pore pressure at end of construction estimates with undissipated pore pressure in foundations	1.3	Hoek (1991)
	Full reservoir, steady state seepage with undissipated pore pressure in foundation	1.3	
	Full reservoir with steady state flow and dissipated pore pressure	1.5	
	Flood level with steady state flow	1.2	
	Rapid drawdown pore pressure in dam with no reservoir loading	1.3	

Figure 39 Table 9.2 from Read and Stacey 2010

Figure 40 and Figure 41 (Table 9.2 and 9.3 of Read and Stacey 2010) provides guidance for the design FoSs and PoFs suggested by Priest and Brown (1983). In Table 9.3, Priest and Brown use three slope categories based on the consequence of failure and suggest design values for the FoS and PoF for:

- The probability of the FoS being less than 1.0 (P[FoS ≤ 1.0]); and
- The PoF being less than 1.5 (P[FoS ≤ 1.5]).

If one of these criteria is not met, the slope is deemed to be potentially unstable, as described in Table 9.4.

The guideline advises that industry experience suggests that the acceptance levels suggested by Priest and Brown in Tables 9.3 and 9.4 are conservative.

For the Goschen project based on the lifetime of the slope (less than 12 months) and the consequence of a failure being moderately serious and the slope size being less than the very serious description a mean FoS of 1.6 is suggested with a possible variance of PoF from 1% to 10%

Table 9.3: FoS and PoF guidelines

Consequence of failure	Examples	Acceptable values: Mean FoS	Acceptable values: Minimum P[FoS < 1.0]	Acceptable values: Maximum P[FoS < 1.5]
Not serious	Individual benches; small (< 50 m), temporary slopes, not adjacent to haulage roads	1.3	10%	20%
Moderately serious	Any slope of a permanent or semi-permanent nature	1.6	1%	10%
Very serious	Medium-sized (50–100 m) and high slopes (<150 m) carrying major haulage roads or underlying permanent mine installations	2.0	0.30%	5%

Source: Priest & Brown (1983)

Figure 40 Table 9.3 from Read and Stacey 2010

Based on Figure 41 (Table 9.3 of Read and Stacey 2010) the Goschen pit slopes with a consequence of moderately serious would meet the interpretation of **Operation of slope presents risk that may or may not be acceptable; level of risk can be reduced by comprehensive monitoring program.** The Goschen pit wall are managed in accordance with a comprehensive GCMP which includes requirement for monitoring

Table 9.4: Interpretation of Priest & Brown (1983) FoS and PoF guidelines

Performance of slope with respect to Table 9.3	Interpretation
Satisfies all three criteria	Stable slope
Exceeds minimum mean FoS but violates one or both probabilistic criteria	Operation of slope presents risk that may or may not be acceptable; level of risk can be reduced by comprehensive monitoring program
Falls below minimum mean FoS but satisfies both probabilistic criteria	Marginal slope: minor modifications of slope geometry required to raise mean FoS to satisfactory level
Falls below minimum mean FoS and violates one or both probabilistic criteria	Unstable slope: major modifications of slope geometry required; rock improvement and slope monitoring may be necessary

Figure 41 Table 9.4 from Read and Stacey 2010

Figure 42 (Table 9.5 from Read and Stacey 2010) incorporates the service life, public liability and type of monitoring applied. The table also provides guidance for interpreting the PoF level in terms of the frequency of failed slopes, including unstable movements. The guideline also notes that although this may sometimes be helpful, it should be used with caution as it was based on a frequency-of-event interpretation of the PoF not a degree-of-belief, subjectively assessed PoF (Vick 2003), and therefore implicitly assumes the PoF to be a property of the slope and not of the design.

Notwithstanding the above the Goschen project slopes would be assessed as:

- Having a medium-term life.
- The presence of visual bunds and a security fence around the perimeter of the mine site supports that the public are discouraged from access to the slope
- The proposed implementation of a GCMP which includes monitoring of pit wall slopes addresses the minimum surveillance requirement; and
- There are currently no exposures that suggest unstable slopes (noting that the maximum exposure in only in the order of 5m depth.

Table 9.5: PoF design acceptance guidelines

	Design criteria			Aspects of natural situation	
PoF (%)	**Serviceable life**	**Public liability**	**Minimum surveillance required**	**Frequency of slope failures**	**Frequency of unstable movements**
50–100	None	Public access forbidden	Serves no purpose	Slope failures generally evident	Abundant evidence of creeping valley sides
20–50	Very very short-term	Public access forcibly prevented	Continuous monitoring with intensive sophisticated instruments	Significant number of unstable slopes	Clear evidence of creeping valley sides
10–20	Very short-term	Public access actively prevented	Continuous monitoring with sophisticated instruments	Significant instability evident	Some evidence of slow creeping valley sides
5–10	Short-term	Public access prevented	Continuous monitoring with simple instruments	Odd unstable slope evident	Some evidence of very slow creeping valley sides
1.5–5	Medium-term	Public access discouraged	Conscious superficial monitoring	No ready evidence of unstable slopes	Extremely slow creeping valley sides
0.5–1.5	Long-term	Public access allowed	Incidental superficial monitoring	No unstable slopes evident	No unstable movements evidence
<0.5	Very long-term	Public access free	No monitoring required	Stable slopes	No movements

Source: Kirsten (1983)

Figure 42 Table 9.5 from Read and Stacey 2010

Based off these criteria a PoF of 1.5-5% would be applicable.

Figure 43 (Table 9.6 of Read and Stacey 2010) was developed by SRK for diamond mines which is not considered to be highly relevant to the Goschen pit wall slopes. The most applicable assessment however would be a category 2 slope and an PoF of <15% would be applicable

Table 9.6: Acceptable PoFs, mining rock slopes

Category	Description	Acceptable PoF
1	Critical slopes where failure may affect continuous operation and pit safety	<5%
2	Slopes where failure have a significant impact on costs and safety	<15%
3	Slopes where failure has no impact on costs and where minimal safety hazards exist	<30%

Source: SRK Consulting (2006)

Figure 43 Table 9.6 from Read and Stacey 2010

Figure 44 (Table 9.7 of Read and Stacey) describes the acceptance criteria for the design of the slopes specifically at the Ujina open pit in Chile. As noted above this mine example is not considered to be a closely relevant however the process combines FoSs and PoFs with the physical consequences of slope instability and their effect on the integrity of the slopes at bench, inter-ramp and overall (global) scale. On this basis it has been used as a useful general guide.

For the Goschen project:

- Bench scale final walls with a loss of 25-50% and a failure of 1000 tons/m would indicate that a PoF of less than 30 would be applicable; and
- Global final walls for failures of less than 25,000 tons/m would indicate a FoS >1.3 and a PoF <12% would be applicable (note assessed failure volumes for the Goschen pit walls have been assessed as <2000 tons/m

Table 9.7: Acceptance criteria, FoS, PoF and category of slope instability

		Characteristics of instability		Acceptability Criterion		
Slope type	**Case**	**Loss of ramp berm (%)**	**Material affected (ktons/m)**	**FoS**	**PoF (%)**	**Comments**
Bench	Expansion, not adjacent to a ramp	<25	<0.5/<1.0			Berms should have a nominal width to contain unravelling wedges whose probability of occurrence is >30%; controlled blasting will be used to minimise induced damage and presplitting on the final wall slopes
		25–50	<1.0/<2.0		<45	
		>50	>1.0/>2.0		<35	
	Expansion, adjacent to a ramp	<25	<0.5/<1.0			
		25–50	<1.0/<2.0		<40	
		>50	>1.0/>2.0		<30	
	Final wall, not adjacent to a ramp	<25	<0.5/<1.0			
		25–50	<1.0/<2.0		<35	
		>50	>1.0/>2.0		<25	
	Final wall, adjacent to a ramp	<25	<0.5/<1.0			
		25–50	<1.0/<2.0		<30	
		>50	>1.0/>2.0		<20	
Inter-ramp	Expansion	<25	<5	>1.20	<30	Stability analysis must include explicit effect of rock mass structures; two independent access ramps will be made to the pit bottom; measures will be implemented for slope drainage
			>5	>1.25	<25	
		25–50	<5	>1.25	<25	
			5–10	>1.30	<22	
			>10	>1.35	<20	
		>50	<10	>1.30	<22	
			10–20	>1.35	<20	
			>20	>1.45	<18	
	Final wall	<25	<5	>1.20	<25	
			>5	>1.25	<20	
		25–50	<5	>1.30	<22	
			5–10	>1.35	<20	
			>10	>1.45	<18	
		>50	<10	>1.35	<20	
			10–20	>1.40	<18	
			>20	>1.50	<15	
Global	Expansion		<25	>1.30	<15	Stability analysis must include mass structures; all mine infrastructure lie outside pit perimeter limits
			25–50	>1.40	<12	
			>50	>1.50	<10	
	Final wall		<25	>1.30	<12	
			25–50	>1.45	<10	
			>50	>1.60	<8	

Source: Swan & Sepulveda (2000)

Figure 44 Table 9.7 from Read and Stacey 2010

A summary of the significant variation in applicable FoS and PoF provided by interpreting Read and Stacey 2010 is provided in Table 9.

Table 9 Summary Table of FoS and PoF guidance based on Read and Stacey 2010

Reference	FoS and PoS	Goschen Project compliance
Figure 39 Table 9.2 from Read and Stacey 2010Figure 39 Table 9.2 from Read and Stacey 2010	FoS **1.5**	FoS of 1.6 Adopted
Figure 40 Table 9.3 from Read and Stacey 2010	FoS of **1.6** variance of PoF from **1%** to **10%**	FoS 1.6 however Minimum PoF exceeded noting that the Goschen project material properties have been conservatively selected and the PoF analysis varies the material properties below these conservative values (i.e. conservatism on top of conservatism outcome)
Figure 41 Table 9.4 from Read and Stacey 2010	**Potentially Unstable Monitoring required**	Goschen pit wall are managed in accordance with a comprehensive GCMP which includes requirement for monitoring.
Figure 42 Table 9.5 from Read and Stacey 2010	PoF of **1.5-5%**	PoF >1.5 Goschen project 0%-5%
Figure 43 Table 9.6 from Read and Stacey 2010	PoF of **<15%**	Goschen project 0%-5%
Figure 44 Table 9.7 from Read and Stacey 2010	FoS **>1.3** and a PoF **<12%**	Goschen project FoS 1.6 and PoF 0%-5%

8.3 Mine pit wall geometry and Setout/Buffer Zone

The depth mining in each area was defined by Auralia Mining Consulting, together with a proposed crest of pit wall set out string, toe of pit wall, as well as bench heights and berm widths. This setout was taken as the basis for assessing the pit wall stability and any requirements for a buffer zone to protect sensitive receivers.

Typically pit depths in Area 1 are around 25 to 30m deep, and in Area 3 the depths are 35m to 43m deep, and locally up to 47m deep.

The pit wall geometry and pit crest alignment have been designed such that there is no failure surface/slip which extends into the sensitive receiver areas that do not satisfy the Acceptance Criteria. The zone from the crest of the pit to the point where the stability condition is satisfied has been termed the Buffer Zone.

8.4 Inputs for pit stability

The following inputs for the pit stability assessment have been made based on pitt&sherry's experience in similar materials, guidelines from published papers and references and understanding of the works.

- For the selection of Bench Heights, consideration was given to the suggestions in Section 10.2.1.1 of Reed & Stacey (2009), where 10m to 18m is a typical bench height, and 15m is more common. For the pit walls the first bench height is 10m which was conservatively chosen to coincide with the average base of the clay layer. The second bench is typically at 25m depth (I.e. 15m high bench) and then the batter extending down to the pit floor (I.e. Second bench height and third bench height 15m each). The exception to this is Jobling Road where the pit depth is 47m and a fourth bench of 7m height is included
- The criteria adopted for the bench widths is the ability to arrest potential rock/soil falls, and to provide enough width for safe access for monitoring equipment, For bench widths the formulae in Equation 10.1 of Reed and Stacey 2009 results in a theoretical bench width of 6.5m to 7.5m. As the pit walls will be formed in soils/ weak rock where the failure volumes are expected to small when compared to large rock failure formed by jointing/bedding, berm widths were restricted to 6m wide. This is adequate to provide light and heavy vehicle access as well as a small safety berm

- A typical pit wall section with terminology defined is shown below on Figure 45

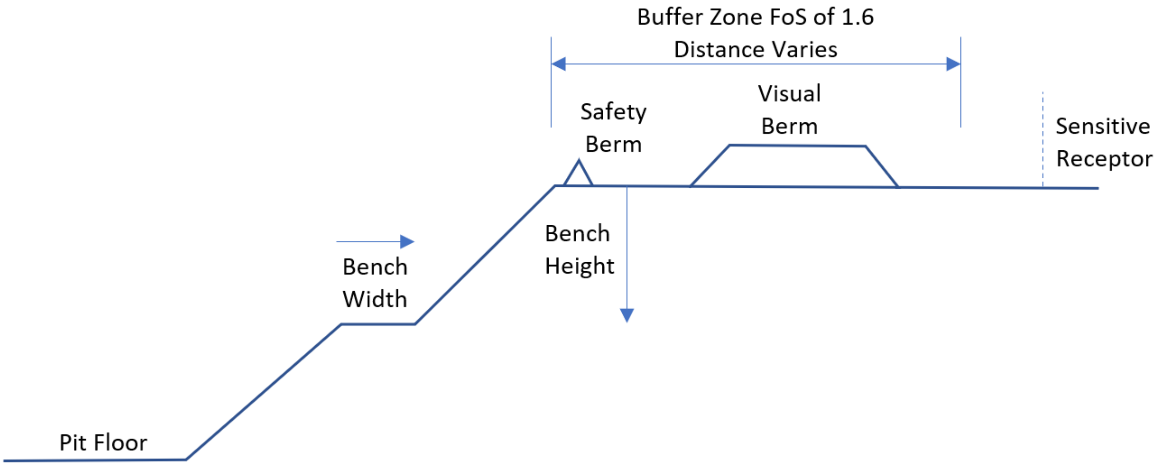

Figure 45 Typical pit wall section terminology

- Five critical pit wall sections were selected for analysis. These were sections which corresponded to the locations of sensitive receivers
- Groundwater phreatic surface will remain below the pit floor and influence zone of slopes. If mounding of the groundwater begins to occur, dewatering will be undertaken to keep the groundwater level below the pit floor. As the permeability of the soils near the pit floor is relatively high the resultant phreatic surface should remain below the pit floor to a distance well outside the influence of the pit slopes
- The soil materials within the pit wall will always remain dry without perched water tables forming during periods of heavy rainfall. In the event of flooding or during extreme wet periods, operation procedures will be in place to manage the risk of localised failures from unforeseen groundwater conditions; and
- Earthquakes are not considered to be valid design load cases for the pit walls.

8.5 Pit wall stability analysis

8.5.1 Mine pit wall stability and recommended slope profile

A pit wall stability analysis was carried out in RocScience limit equilibrium analysis software Slide 2D version 7.0 using the Morgenstern-Price method.

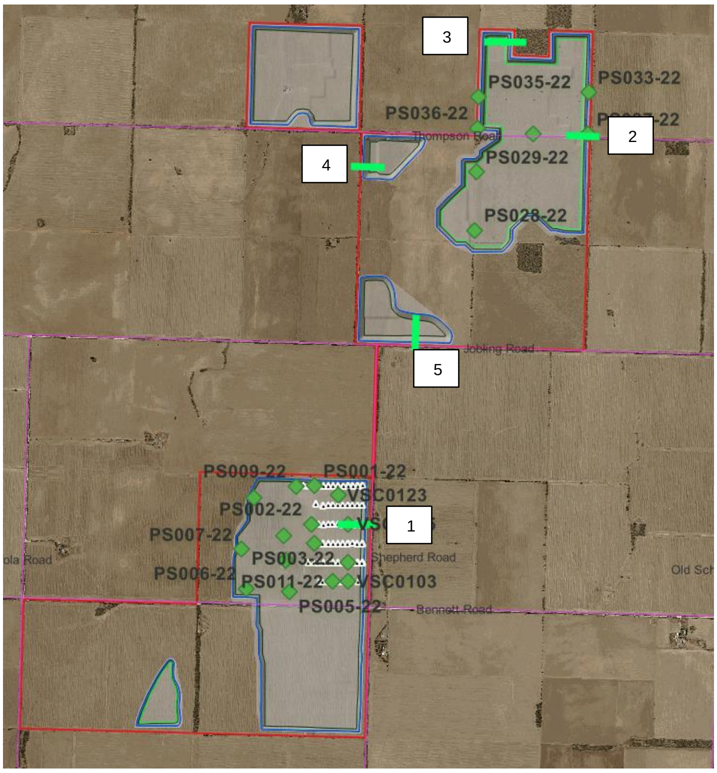

Figure 46: Selected cross section locations for slope stability analysis

Five critical sections across Area 1 and Area 3 were identified for pit wall stability analysis. A summary of analysis results are shown in Table 10. When developing the models, the following principles were included:

- All the berms were 6m wide
- Ground profile was developed based on nearest borehole log/ logs; and
- The back of the visual berm is 22m from the slope crest.

Table 10: Summary of results from the critical sections

Model number	Section	Pit depth (m)	Min FoS	Distance (m) from Crest to FoS > 1.6	Min FoS beyond visual berm	Benches arrangement	Overall batter angle (º)
1	A1_ShepherdRd	30	2.01	See Note 1	2.14	At 10m and 20m	32
2	A3E_ThompsonRd	40.5	1.84	See Note 1	1.93	At 10m and 25m	32 (See Note 2)
3	A3E_Veg	42.2	1.69	See Note 1	1.87	At 10m and 25m	32 (See Note 2)
4	A3W2_Rd	42.3	1.29	17.5	1.82	At 10m and 25m	32
5	A3W2_JoblingRd	47	1.34	15.1	1.81	At 10m, 25m and 40m	32 (See Note 2)

Note 1: For Model No. 1, 2 and 3 no buffer zone is required in terms of stability as all potential failure surfaces have a FoS > 1.6.

Note 2: Batter angle modelled at 31degrees, for assessing buffer distance. Final overall batter angle to be verified in FEED.

An example of full outputs for each Slide model is shown on Figure 47.

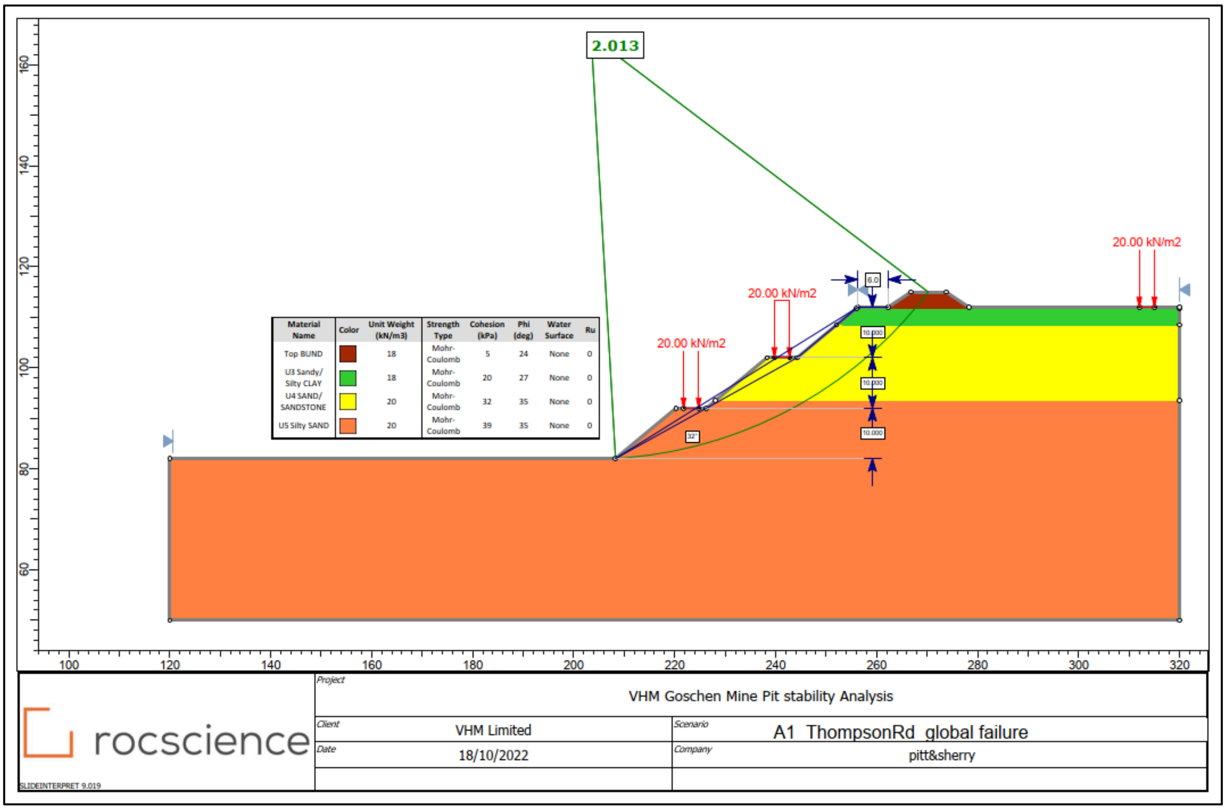

Figure 47: Example of Slide model output and input for A1_ShepherdRd

8.6 Probability of failure assessment

Probability assessment was conducted to assess the material parameters sensitivity to the factor of safety of the pit batter profile.

Mohr-Coulomb parameters (cohesion and friction angle) were considered as independent variables for the probability analysis. Standard deviation was set to be 20% of the selected design values. Sampling of the cohesion was done assuming a normal distribution to provided further distribution of the sample space. Friction angle was sampled using Lognormal distribution, which is a widely used sampling method for soil friction angle sampling as friction angle cannot be negative (and variation in friction angle for soil stratum do not usually significantly vary). Material parameters variation used in the probability assessment are summarised in Table 11.

Table 11: Material parameter variation

Soil Unit	Property	Distribution	Mean	Standard Deviation	Min	Max
U1	Cohesion	Normal	5	1	2	8
	Friction Angle	Lognormal	24	5	9	39
U2	Cohesion	Normal	10	2	4	16
	Friction Angle	Lognormal	26	5	11	41
U3	Cohesion	Normal	20	4	8	32
	Friction Angle	Lognormal	27	5	12	42
U4	Cohesion	Normal	32	6	14	50
	Friction Angle	Lognormal	35	7	14	56
U5	Cohesion	Normal	39	8	15	63
	Friction Angle	Lognormal	35	7	14	56

The sensitivity assessments were conducted for 2000 random samples selected by the Monte Carlo sampling technique as per the distribution defined in Table 11.

Figure 48 Shows a FoS variation with cohesion values (2000 points) selected based on Monte Carol sampling for Soil U2, similarly all the parameters defined in Table 11 have been sampled and then those values were used in the stability model to calculate FoS for each case.

Highlighted Data = Factor of Safety - gle/morgenstern-price < 1 (80 points)

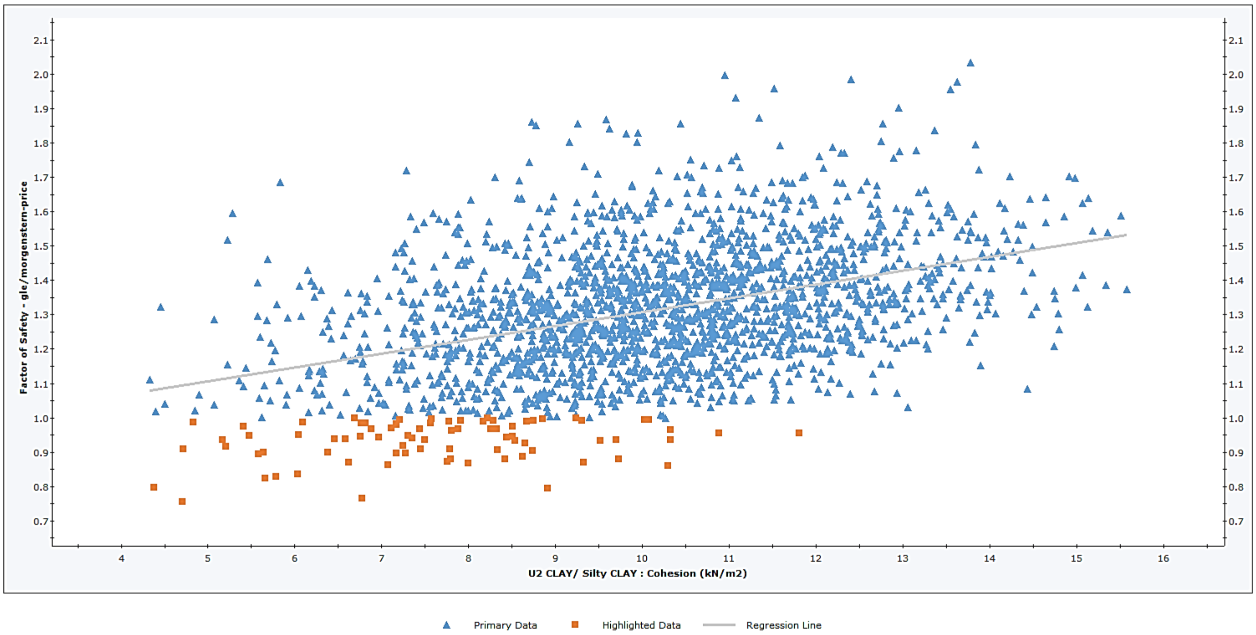

Figure 48: FoS variation with cohesion of soil unit U2

A summary of PoF values for each Scenario are summarised in Table 12. All results indicate a probability of failure with material sensitivity analysis lower than 5%.

Table 12: Summary of probability of failure assessment

Model No.	Analysis Scenario	**PoF % (FOS<1)**
1	A1_ShepherdRd	0
2	A3E_ThomsonRd	0.3
3	A3E_Veg	0.05
4	A3W2_Rd	5
5	A3W3_JoblingRd	4

An example pf PoF histograms for each Slide model is shown on Figure 49 below.

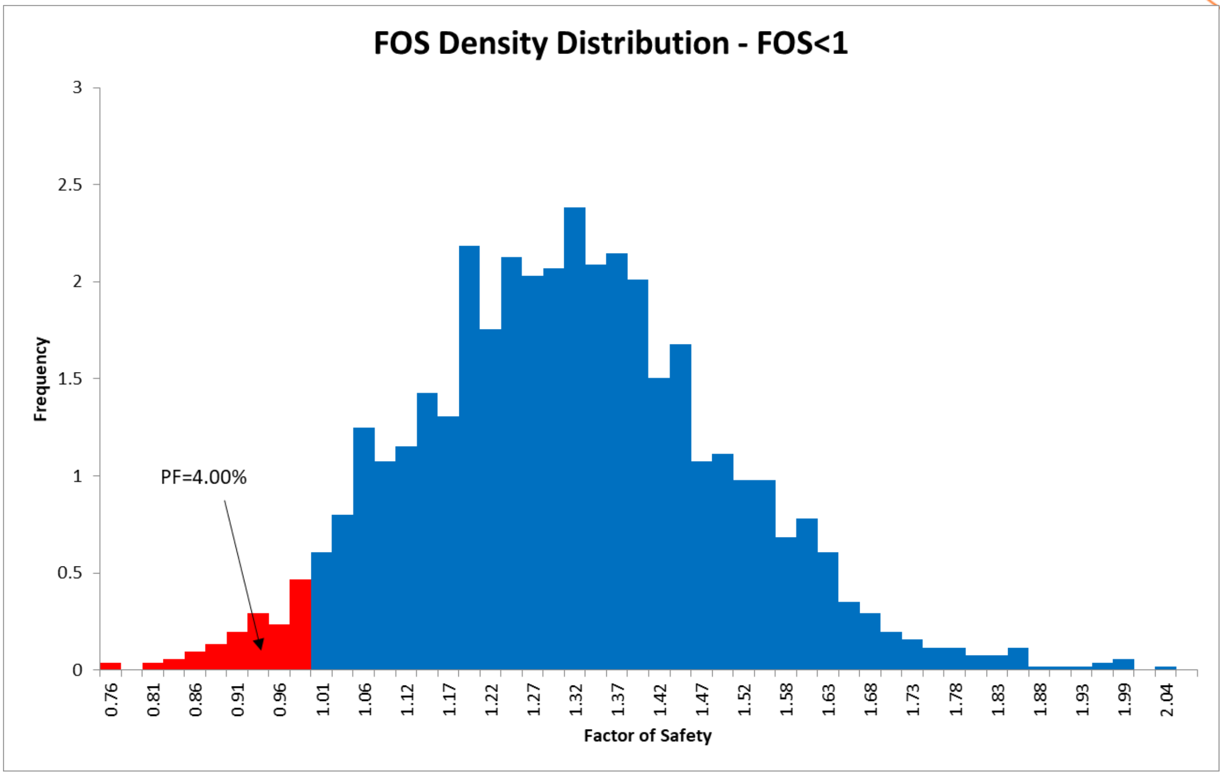

Figure 49: Example of PoF histogram for A3W3_JoblingRd

8.7 Recommended pit batter profile

The slope stability assessment shows that all potential failure surfaces have a factor of safety of at least 1.6 within calculated buffer zone of 0m to 17.5m measured from the crest of the pit wall. For Model No's 1,2 and 3 all potential failure surfaces have a FoS > 1.6 and therefore in these areas no buffer zone is required. These pit slopes therefore exceed the Acceptance Criteria for stability. The stability analysis is considered to be conservative as the strength parameters selected for the modelling are a cautious estimate of characteristic values demonstrated by testing.

The PoF (FoS has been assessed as from 0% to a maximum of 5% which satisfies the guidelines and acceptance criteria using a normal distribution of both cohesion and friction. (The PoF is calculated as the number of slip surfaces with a FoS < 1/ Total No. Of slip surfaces analysed x 100), Lower bound values in the normal distribution are well below any values represented by test results and typical values for the materials expected.

As the pit slopes are in soils, the volume of material within a theoretical failure surface is relatively low when compared to an equivalent pit wall in rock. Included in Table 13 is the slip weight for the slip surface with factor of safety less than 1.6, FoS (1.3 to 2.01). It should be noted that these slip surfaces are well within the buffer zone and will have no impact on the sensitive receptors.

Table 13 Estimated Material Weights for failure surface with FoS > 1.6 and for failure surface with the minimum FoS

Model No	Analysis Scenario	Slip Weight for failure surface with FoS of 1.6	Slip Weight for failure surface with lowest FoS
1	A1_ShepherdRd	See Note 1	See Note 1
2	A3E_ThomsonRd	See Note 1	See Note 1

3	A3E_Veg	See Note 1	See Note 1
4	A3W2_Rd	< 2 k tons/m	< 0.5k tons/m
5	A3W3_JoblingRd	< 2 k tons/m	< 0.5 k tons/m

Note 1: for Model No. 1, 2 and 3 all failure surfaces are > 1.6

Based on the results of this assessment, it is recommended that for design purposes, the pit slope should generally have the geometry shown in Table 14. The minimum buffer zone has been set at 22m to allow provision of safety berms and visual berm, however in terms of pit stability, no buffer zone is required in some areas, and the theoretical maximum buffer zone is 17.5m. Optimisation of buffer zones for various areas around the pit wall can be considered in FEED.

Table 14: Recommended pit geometry

Geometry	**Recommend limits**	
Pit depth	Up to 42 m	47 m
Bench Heights*	First bench at 10m Second Bench at 25m	First bench at 10m Second bench at 25m Third bench at 40m
Minimum berm width	6 m	6 m
Overall slope angle	Max. 32° degrees	Max. 31° degrees
Buffer Zone	22m	22m

*Bench heights has been selected based on guidelines provided in Read and Stacey (2009)

8.8 Comparison to RMS, AGS and First Principles Slope Risk Assessment Methodologies

During investigations into the feasibility of the Goschen Area 1 and Area 3 pits the question of risk to users of the nearby roads was considered. To address this issue a series of risk assessments have been undertaken using the:

- Roads and Maritime Safety NSW Slope Risk Analysis Version 4
- The RMS Slope Risk Analysis methodology (RMS 2014) was based on the AGS methodology and optimised for use in the vicinity of roads. It is becoming required for road authorities in some parts of Australia and becoming regarded as best practice in other areas.
- Practice Note guidelines for Landslide Risk Management (Australian Geomechanics Society, 2007c)
- The Australian Geomechanics Society methodology from 2007 has been the best practice method for landslide risk assessment in the general case for several years.
- First Principles Analysis; and
- The third assessment was made by “stepping back” and considering the geometry of the pit-road system and the basic soil parameters.

These assessments were made only in respect to risk to road users. The following critical cross sections were assessed.

Figure 50: Locations of Area 1 pit-road geometries analysed

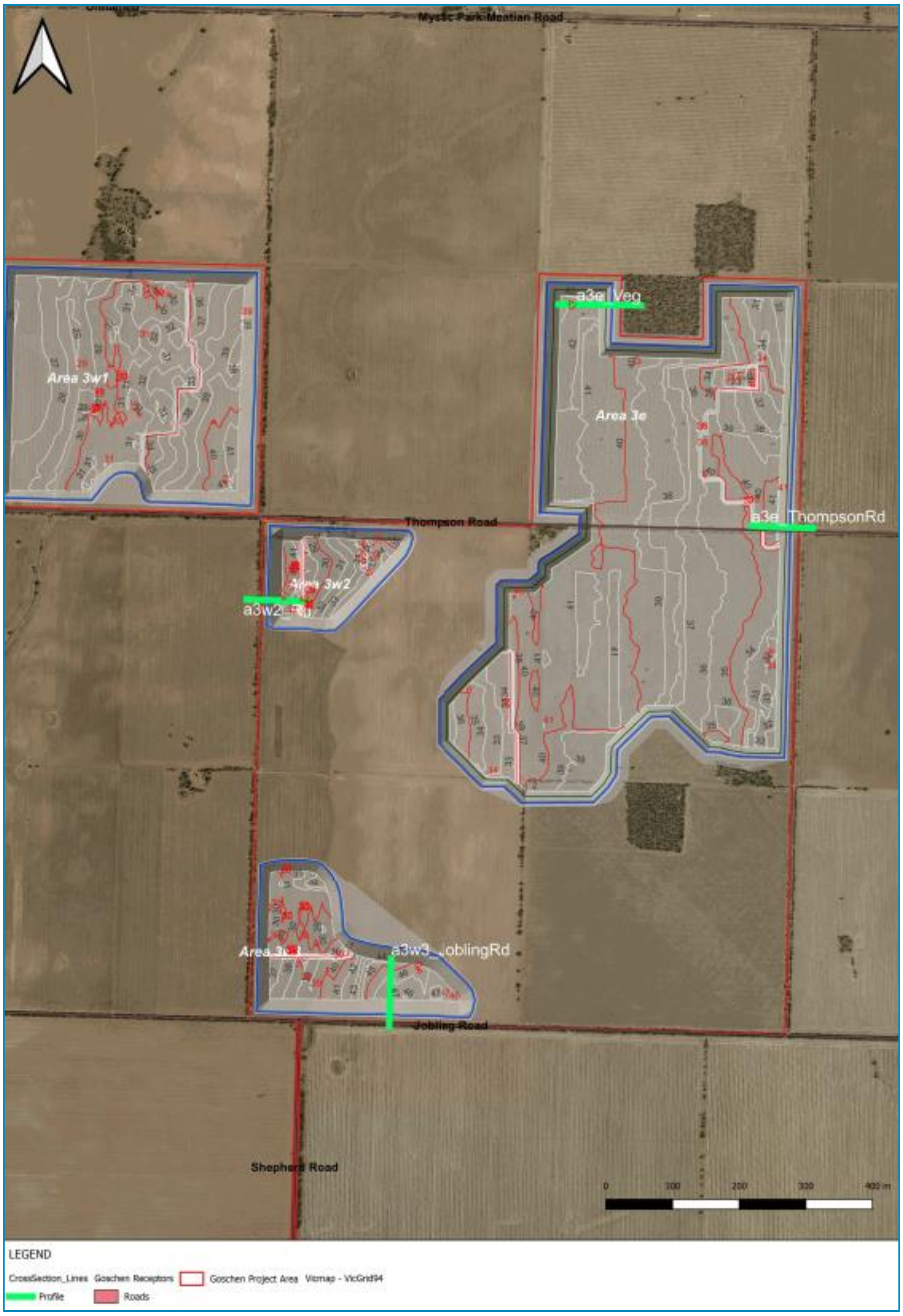

Figure 51: Locations of Area 3 pit-road geometries analysed

Summary of outcomes of the assessments

- As the key element assessed is the risk to road users the RMS methodology is considered to be the most appropriate methodology. It gives the most robust method for assessment given the uncertainties associated with likelihood of failure and has the most research behind the assessment of temporal probability and vulnerability with respect to road users. The result of this assessment is the **lowest (safest) category possible in that methodology.**
- Taking a more general view the AGS methodology has been the standard for risk assessment of slope instability in Australia since its publication in 2007. The result of this assessment is **three orders of magnitude lower (safer) than the upper limit for acceptable risk**; and

- Stepping further back, an analysis based on the basic geometry of the sites together with simple soil parameters indicate that **failure back to the road is not a credible scenario**.

Based on these assessment methodologies it is not considered probable that a road user would be likely to be impacted due to a slope failure.

8.9 Topsoil

The site investigations to date, have indicated that up to 1.5m of topsoil is present on the Goschen mining site. The topsoil in the sonic borehole logs has been recorded as a sandy clay with some silty and a clayey sand (around 30% to 50% sand).

Although the relative percentage of organic content of the topsoil was not recorded, based on pitt&sherry experience in farm paddocks and the site inspection carried out including observations of limited exposures on site the upper 300mm is expected to have a high organic content. Below this organic matter may be present but will be in low proportions compared to the overall soil matrix. Typically soils with around 5% organic matter by volume can be left in place without impacting permanent works.

Triaxial tests on the topsoil layer indicates the material below the organic layer has adequate shear strength to support construction loads and soil embankments.

For the purpose of the DFS and quantity estimates and based on pitt&sherry's experience in similar soils, the upper 300mm is recommended to be stripped and stockpiled. The remaining topsoil layer (i.e. below the 300mm organic layer), can be left in place for the areas that are designated to have road embankments and stockpiles constructed.

For mining area's, the remaining topsoil layer can be classified as "sand overburden" and placed in safety bunds, noise barriers, or stockpiled for future overburden backfilling.

Further testing of the topsoil layer to evaluate the proportion of organic matter and requirements for topsoil conditions for re-use should be undertaken during the FEED stage.

8.10 Stockpile stability and recommended geometry

A number of stockpiles will be maintained over the duration of the mine life including organic topsoil material which will be used for final mine rehabilitation. Other stockpiles include separate clay stockpiles for material used to construct tailing bunds and provide a capping layer as part of the mine rehabilitation process. The final stockpile will be mixed overburden material of poor ore grade, not suitable for processing.

As part of the stockpile design process the Goschen project stockpiles have been assessed using the Waste Dump and Stockpile Stability Rating and Hazard Classification System (WSRHC) outlined in Mark Hawley and John Cunning 2017. Guidelines for Mine Waste Dump and Stockpile Design (Mark Hawley and John Cunning 2017).

the WSRHC system can be used as a guide to the level of effort required to investigate, design and construct waste dump. Waste dumps and stockpiles with lower stability ratings, or that fall into higher hazard classes, logically ought to require more investigative and design effort, and more care and monitoring during construction and operations, than waste dumps and stockpiles with higher stability ratings, or that fall into lower hazard classes. Table 3.12 from Hawley 2017 is reproduced below and provides suggestions regarding the appropriate level of effort for the site investigation and characterisation, analysis and design, and construction and operation stages in the life cycle of a waste dump or stockpile based on WSR and WHC.

Table 15 Reproduction of Table 3.12: Suggested level of effort based on waste dump and stockpile stability rating/hazard class (WSR/WHC) Hawley 2017

Stability class Waste dump and stockpile hazard class (WHC)	Instability hazard	Level of effort Investigation and characterisation	Analysis and design	Construction and operation
I	Very Low Hazard	Basic desktop studies to establish initial stability rating and hazard classification; basic site reconnaissance to confirm key assumptions from desktop studies and plan field investigations; limited mapping and test pitting to establish/verify subsurface conditions; material parameters based on literature/ experience and validated with limited field and laboratory index testing; initiate limited baseline environmental monitoring; condemnation drilling	Simplified stability analyses to verify that stability does not influence design and potential impacts are minor; design by geotechnical specialist with peer review	Minimal site preparation; minimal restriction on construction; periodic visual monitoring; periodic inspection by geotechnical specialist
II	Low Hazard	Desktop studies to establish initial stability rating and hazard classification; site reconnaissance to confirm key assumptions from desktop studies and plan supplementary field investigations; mapping and test pitting as required to verify subsurface conditions; material parameters based on literature/experience and validated with field and laboratory index testing; initiate environmental baseline monitoring; condemnation drilling	Stability analyses to verify that stability has limited impact on design; design by experienced geotechnical specialist with peer review	Limited site preparation, may include minor diversions; limited construction constraints; standard instrument and visual monitoring with basic trigger action response plan (TARP); periodic inspection by experienced geotechnical specialist
III	Moderate Hazard	Comprehensive desktop studies to establish initial stability rating and hazard classification; detailed site reconnaissance to confirm assumptions from desktop studies; detailed mapping and subsurface investigations likely including test pitting/trenching and limited drilling and sampling; *in situ* instrumentation and testing and laboratory testing to verify foundation and fill material properties; initiate comprehensive baseline environmental monitoring; condemnation drilling	Comprehensive stability analyses, including consideration of runout potential; qualitative risk assessment; design moderately constrained by stability and potential impacts; design optimisation and impact mitigation studies; design conducted by experienced geotechnical specialist with peer review	Moderate site preparation, may include diversions and underdrainage; limited foundation instrumentation to verify performance; runout/rollout mitigation measures, if required; moderately constrained construction sequence; control of fill quality and placement as necessary; loading/advance rate restrictions; standard instrumentation and visual monitoring with well-defined TARPs; periodic (minimum annual) inspections by experienced geotechnical specialist
IV	High Hazard	Detailed desktop studies to establish initial stability rating and hazard classification; comprehensive site reconnaissance to confirm assumptions from desktop studies; detailed, phased mapping and subsurface investigations likely including test pitting/trenching, geophysics, specialised drilling and sampling; *in situ* instrumentation and testing and laboratory index and shear strength testing to establish foundation and fill material properties to a high degree of confidence; initiate comprehensive baseline environmental monitoring; condemnation drilling	Phased design study with detailed stability analyses of interim and final stages, including runout assessments; parametric studies; design constrained by stability and potential impacts; semi-quantitative risk assessment; optimisation, trade-off and mitigation studies; design by experienced geotechnical specialist with peer review; third party specialist review at critical stages in design	Moderate to extensive site preparation, may including underdrainage and diversions; foundation and fill instrumentation; runout/rollout mitigation measures; moderately constrained construction sequence with control of fill quality and placement; moderate to severe loading/advance rate restrictions; detailed instrument and visual monitoring with redundancy; well-defined/site-specific TARPs; frequent inspections and review by experienced geotechnical specialist; annual or more frequent review by third party specialist

The EGI for both stockpiles were assessed as having a rating score of 28, and a DPI of 35. Figure 52 below shows how these values plot on a Hazard Class Chart to assign an overall hazard rating to the stockpile.

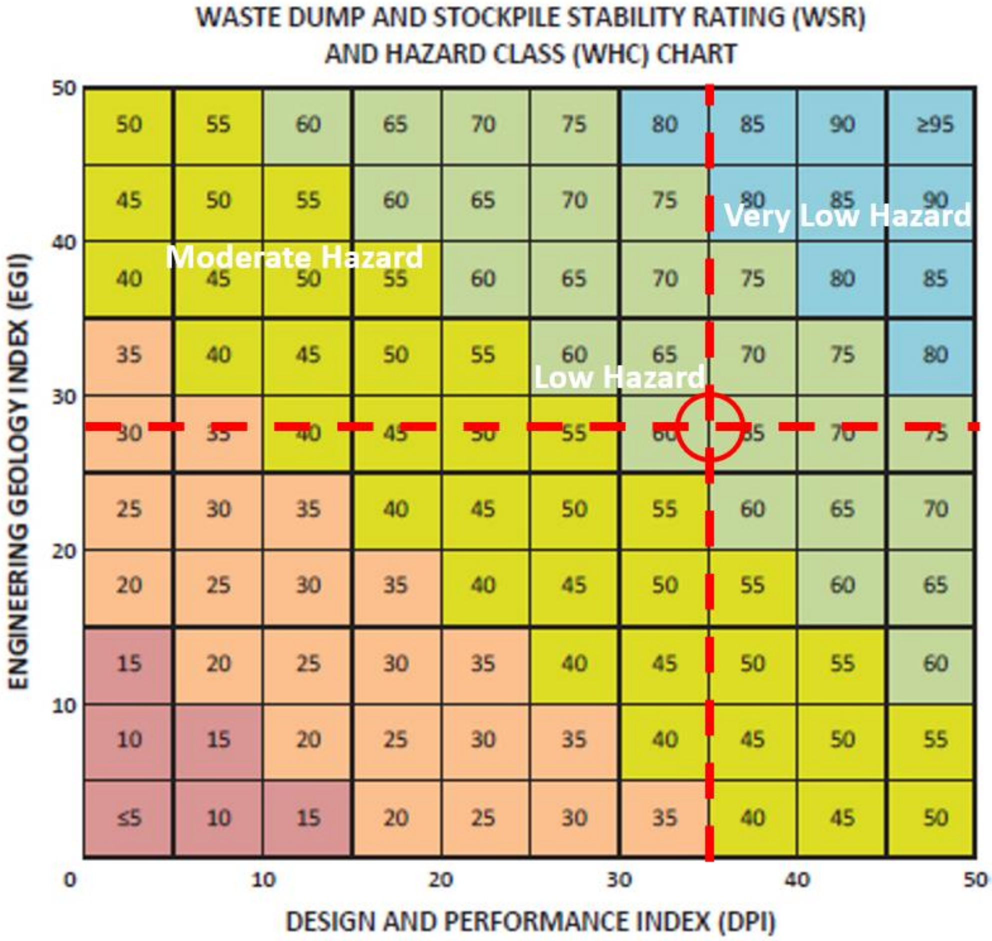

Figure 52 Waste dump and stockpile stability rating and hazard class chart (Hawley et al, 2017)

Both stockpiles were assigned an overall score of 63 and are classed as Low Hazard. The level of investigation and analysis has followed the guidelines of Table 3.12: Hawley 2017

8.10.1 Topsoil stockpile

The maximum height for individual topsoil stockpiles will be 3 m to maintain the organic material close to its original condition and, therefore, suitable for supporting regrowth. Given this low height, no modelling has been undertaken.

8.10.2 Clay and Sand overburden stockpile

The clay and sand overburden stockpiles have been nominated as being around 30 m high, measured above existing ground level (VHM Limited 2021). The stockpile was modelled with 4 m berm and 6 m lift, with a 1V:2.5H batter, it is assumed that the natural ground slopes away at the stockpile toe at five degrees from the horizontal (worst case). The typical geometry is as shown in Figure 53.

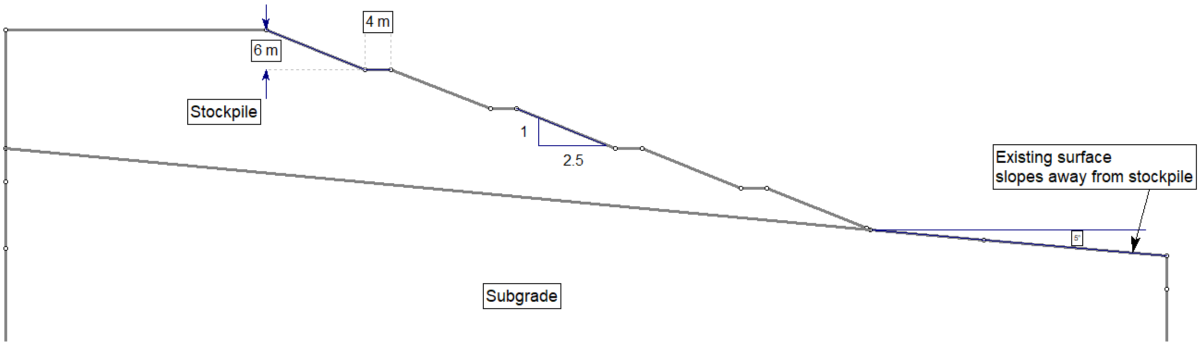

Figure 53: Typical stockpile arrangement

The stockpile material parameters which were adopted for this analysis have been summarised in Table 16 below. Remoulded strengths were used for the stockpile material. The remoulded strengths were estimated using the Figure 54 Remoulded strengths estimated based on Appendix D, AS 4678-2002 for clay soils below (AS 4678-2002) for the clay soils and based on loose sands for the sand stockpile. Cohesion has been conservatively ignored for the remoulded sand.

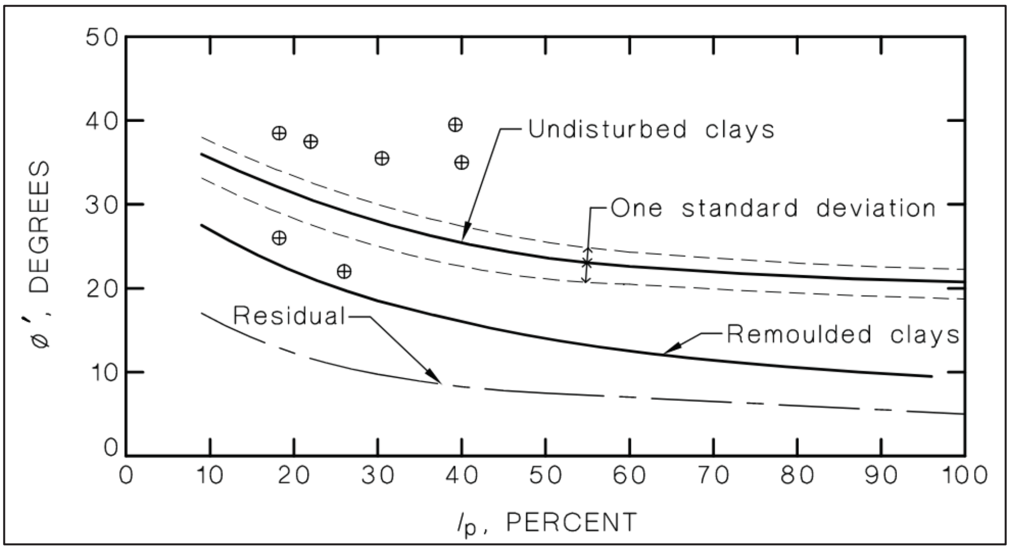

Figure 54 Remoulded strengths estimated based on Appendix D, AS 4678-2002 for clay soils

Table 16: Stockpile material parameters

Description	Maximum height above existing ground level	Unit weight of stockpile material (kN/m)	Overall Stockpile angle (β) degree	c' (kPa)	f' (degree)
Clay (Unit 2 and Unit 3)	30 m	19	17.5	5	23°
Sand stockpile (Unit 4 and Unit 5)	30 m	19	17.5	0	32°

The subgrade was modelled as a stiff to very stiff clay, following topsoil striping. The following parameters were used for the subgrade. By inspection the cemented sand layers below will have very high bearing capacity and will not be critical for the model.

Table 17: Subgrade parameters for the purpose of slope stability modelling

Unit	Material	Unit weight (kN/m^3)	Cu (kPa)	c' (kPa)	f' (deg)	Thickness
U2	CLAY; Silty CLAY	19	100	10	26	5m
U3	Sandy/Silty CLAY	19	200	20	27	10m

The analysis was carried out using the commercially available RocScience limit equilibrium analysis software Slide 2D version 9.023 using the Morgenstern-Price method. The following assessments were completed for both sand and clay stockpiles: A minimum factor of safety of 1.5 has been adopted for the stockpile stability under static load, and 1.1 under earthquake load. These values are typically used for permanent works designs in civil works projects and are considered conservative for stockpile design.

- Short term assessment: using the undrained strength parameters
- Long term assessment (stockpiles will be in place for ~10years): using the drained strength parameters; and
- Earthquake loading assessment: a Hazard Factor Z (AS 1170.4) equivalent to the effective peak ground acceleration with a return period of 500 years has been assessed. The code states the Z value for Melbourne is 0.08g. For the bund design a horizontal ground acceleration (Z) of 0.1g was adopted.

Results from the eight different scenarios are summarised in Table 18 below.

Table 18: Summary of the results of the long-term analysis

	Long term		Short term	
Scenario	**Scenario ID**	**FoS**	**Scenario ID**	**FoS**
Clay Stockpile Assessment	VHM_SA_1	1.591	VHM_SA_2	1.560
Sand Stockpile Assessment	VHM_SA_3	1.582	VHM_SA_4	1.587
Clay Stockpile Seismic Assessment	VHM_SA_5	1.175	VHM_SA_6 (Earthquake)	1.127
Sand Stockpile Seismic Assessment	VHM_SA_7	1.209	VHM_SA_8 (Earthquake)	1.209

From this assessment it is concluded that 30 m high stockpiles should be stable and meet minimum stability requirements, without special subgrade treatment.

The slip surfaces are confined within the stockpile perimeter bund, as shown in Figure 55 stockpiles are not expected to have any impact on sensitive receivers. Notwithstanding this a maintenance and drainage spacing of about 20m is recommended to allow adequate access.

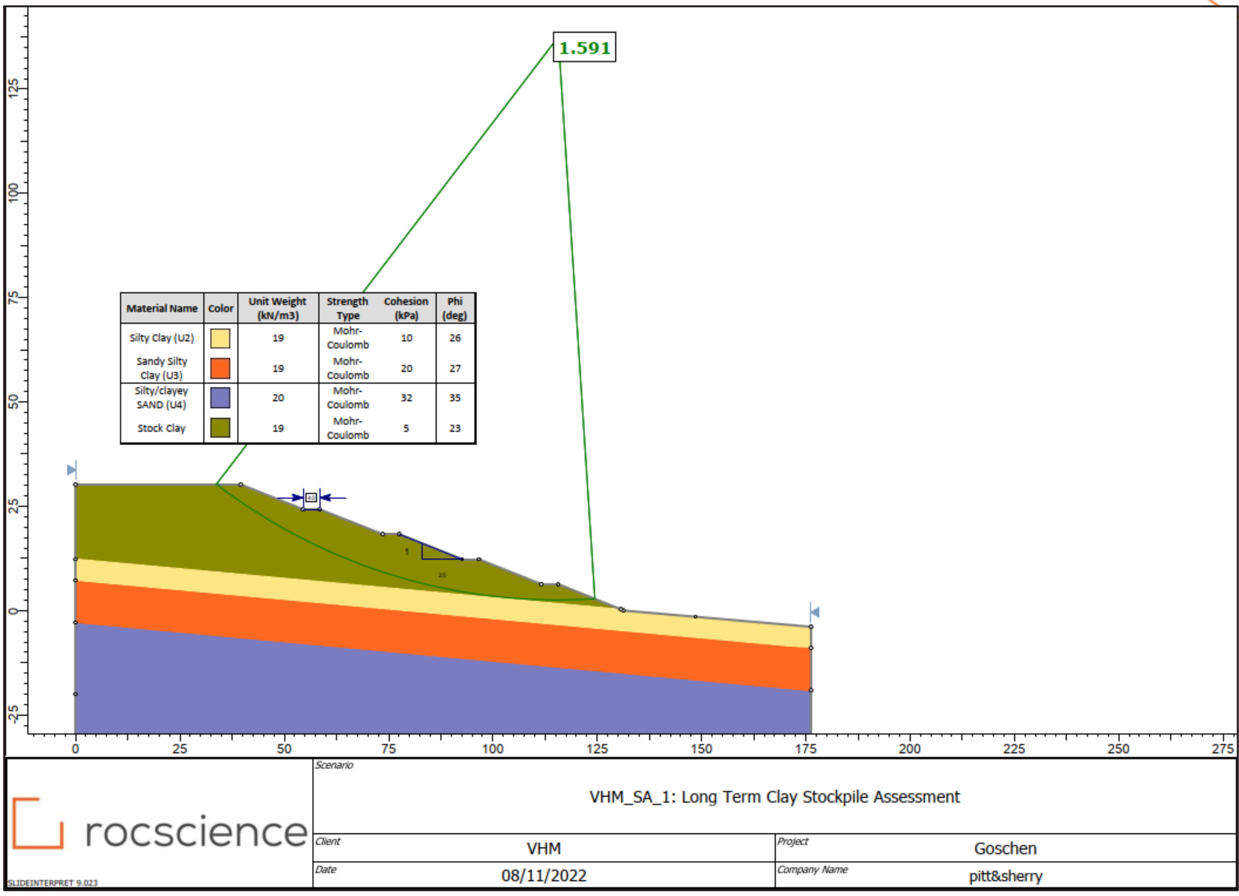

Figure 55 Example of Slope Stability Assessment for 30m high stockpiles

8.10.3 Surface water drainage bunds for stockpiles

In order to capture surface water runoff from stockpiles and prevent it entering bunded areas, catch drains with bunds, formed by using clay overburden material to prevent erosion and scour, will be constructed where required. The catch drains will be about 600 mm deep and their bunds will be approximately 2 m high with grass-lined batters. A typical arrangement is shown in Figure 56 below. The crest will be nominally 1 m wide, and all batters will be 1V:2H.

Due to their low height, no stability assessment has been undertaken as, by inspection, the 1V:2H batters should be stable.

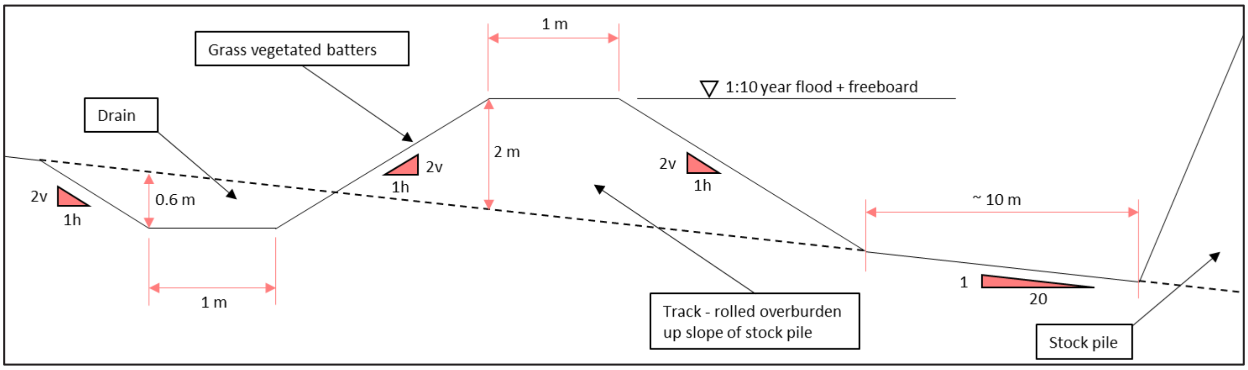

Figure 56: Cross-section of typical design for bunded surface water catch drains

8.11 Sediment ponds

The mine will include a number of sediment ponds for storage of surface water runoff and removal of sediments before overland discharge or decanting off. A stability assessment has been undertaken for storage ponds that are 5 m and 7 m deep.

As a worst-case scenario, the pond was assumed to be drained, in a rapid drawdown situation, with the phreatic surface above the pond floor level. With pond batters of 1V:2.5H, the slopes are stable without treatment. A typical detail is shown in Figure 57. No liner is considered necessary from a geotechnical engineering point of view. After repeated drawdown cycles, the surface of the ponds become uneven with surface rills or tidelines on the batters. This should be considered normal and periodic regrading and clean-out should be allowed for during dry periods.

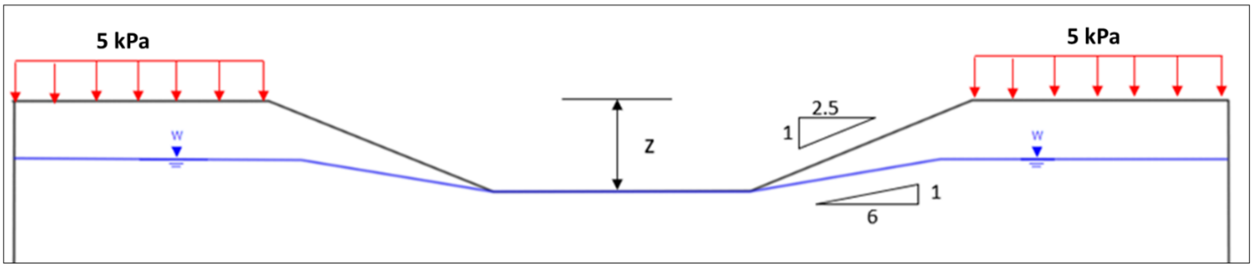

Figure 57: Sediment Pond ('z' = depth; 'w' = water level)

The analysis was carried out on two different scenarios as summarised in Table 19.

Table 19: Summary of the results of the long-term stability analysis of sediment ponds

Scenario ID	Pond depth (m)	FoS
VHM_SPA_GMA3_1	5	2.430
VHM_SPA_GMA3_2	7	2.217

9. References

- CDM Smith 2021b. Groundwater Modelling and Mounding Report (Document No. 1001043-WHM-MEMO-GW Model Rev 2 dated 29/11/2021
- Auralia Mining Consulting. 2021. Memo No. 05 dated 12th November 2021 providing data on stockpiles.
- Auralia Mining Consulting 2021 Section 9 – Mining and Ore Reserve of this DFS
- VHM 2017. Sonic Boreholes drilled in Area 1 in 2017 as logged by VHM
- VHM 2021. Goschen 5Mtpa Project Description (Doc Ref RPP960) Revision 2.0 August 2021.
- VHM 2021a Lithology records for Area 1 and in Area 3 as supplied by VHM
- VHM DFS 2021b - Section 9 – Mining and Ore Reserve
- VHM 2022 - VHM technical memo 'Bulk Density – Area 1 and 3 (dated 22 August 2022)
- Water Technology. 2018. Surface Water Assessment, Goschen Mineral Sands and Rare Earths Project (Goschen Project). Unpublished report prepared for VHM Limited. Victoria
- Water Technologies 2022 - EES Technical Report - Water Technologies – H1. Surface Water
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- AS 1170.4 - 2007 - Structural design actions Part 4: Earthquake actions in Australia
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- RMS 2014 - Roads and Maritime Safety NSW Slope Risk Analysis Version 4 2014

- Skempton 1986 - Geotchnique 36, No3 425-447 Standard penetration test procedures and the effects in sands of overburden pressure, relative density, particle size of ageing and over consolidation; and
- Lambe, W. and Whitman, R. 1979. Soil Mechanics, SI Version, John Wiley & Sons, 1979.

Important information about your ground engineering report

These notes are additional to any limitations noted within the report. They have been provided by pitt&sherry to clarify the limitations of the report, and to clearly identify the individual responsibilities of all parties involved. It is important that all documents from pitt&sherry are read thoroughly and that clarification is sought when necessary.

Specificity

Your report has been developed based on pitt&sherry's understanding of your project requirements and applies only to that project. If there are subsequent changes to the proposed project, pitt&sherry should be consulted to assess how the changes impact on the report's recommendations. If pitt&sherry are not consulted, they do not accept responsibility for issues that may occur due to project changes. No responsibility is accepted for the use of this report, in whole or in part, in other contexts or for any other purpose.

Report integrity

This report is presented as a whole; with conclusions and recommendations reliant upon data presented in other sections. Reading parts of the report in isolation may lead to misinterpretations, and as such the report should not be copied in part or altered in any way.

Where information contained within this report is to be used for tendering purposes it is recommended that the entire report be made available. In situations where this is not appropriate, pitt&sherry can assist in preparing a specially edited document to provide the information within an appropriate context.

Site variability

The results presented in this report represent the conditions at the specific sampling and testing locations. They also represent the conditions at the time that the work was carried out. Variations in conditions may occur between or beyond assessment locations, either due to natural variability or previous excavations.

It is recognised that conditions may change over time. This can be due to natural processes (landslides, water content change) or driven by human activities (cutting or filling in the vicinity).

The advice presented in this report is based on the data gathered during the investigation, and the accuracy may be impacted by undetected variations in ground conditions or later changes to the site. Retaining pitt&sherry throughout development stages can assist in reducing the impact of these issues by identifying variances, conducting additional testing if required, and recommending solutions to problems encountered on site.

Explanatory Notes, disclaimer

Appendix A

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Geotechnical Investigation Factual and Interpretive Report - Goschen Project

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3. Appendix C – Design Development of Tailings Storage Facility

pitt&sherry

Tail Management General

VHM undertook a process of evaluation of a series of possible tailings management systems. The initial intent of the investigations was to provide storage for sufficient tailings until the void created by mining was sufficient to allow in pit disposal of the tailings stream.

Tailings storage facility

VHM undertook a process of evaluation of a series of tailings management systems. The initial intent was to provide storage for sufficient tailings until the void created by mining was sufficient to allow in pit disposal of the tailings stream.

The volume of tailings to be stored evolved as the process and mining design advanced. Early assessments of above ground storage ranging from 6 months to 12 months of mining throughput i.e. 2.5Mt - 5Mt respectively. Ultimately for safety and operational efficiency VHM adopted in pit storage from the commencement of processing operations.

A key aspect of the selection assessment was managing the risks associated with an above ground tailing storage facility such as a turkey nest dam. Such a facility would have been constructed prior to any processing of ore and would have needed to remain in operation for the entire life of the mine, only being able to be rehabilitated into the final pit void and would have required an extended timeframe to rehabilitate the associated pit void. The above ground facility would have also created a dam burst risk leading to a risk to the public on the adjacent road network and environmental harm from the uncontrolled discharge across adjacent paddocks.

The decision to move to an in-pit tails storage facility from the commencement of processing has removed these risks from being able to occur. The in-pit storage facility provides storage which at its maximum fill height is more than 10m below the level of the existing paddock surface. In the remote event that there was a breach in the containment bund the tailings would discharge into the adjacent pit void and there would be no possibility of it rising sufficiently to reach the ground surface level and therefore avoid environmental harm.

Similarly, the return of tailings to the in-pit void allows the tailings to begin to consolidate and dewater both through direct decanting but importantly into the pit floor. The assessment and investigation carried out indicate that the tailings will dewater and consolidate under self-weight and as overburden is placed without excessive mounding and as part of the mine process. As the tailings consolidates and drains in place and is part of the ongoing mine process there is no requirement to rehabilitate an above ground facility at the end of the mine. As there is no above ground storage facility it is assessed that there will be no harm to the public.

The progressive rehabilitation of the tailings storage areas means that the potential requirement at the end of the mine life to move partially saturated tailings across the mine site through heavy haulage equipment or transport of the tailings in the above ground storage facility in a slurry pipeline is avoided. The possibility of environmental harm from the transfer is avoided and timeframes are minimised for the rehabilitation of the landform before it can be handed back for agricultural use. The type of tailings storage facilities considered in the design process included:

- Turkey nest sand tailings storage with smaller turkey's nest slimes storage
- Turkey nest co-disposal tailings storage with layered deposition
- Turkey nest co-disposal tailings storage with mixed deposition
- Turkey nest sand tailings storage with solar pond slimes management facility
- Dry stockpiling of sand fraction of the tailings with farmed management of slimes
- In pit tailings storage with slimes and sand deposited in separate streams from process plant initiation; and
- In pit tailings storage with slimes and sand deposited in a mixed stream from process plant initiation (preferred Option).
- A summary of the dam types together with advantages and disadvantages is provided in tabular form below:

Option Ref	Initial Tailings Storage	Life of Initial Tailings Storage Period of Operation	Final Tailings storage	Advantages	Disadvantages
1	Turkey nest sand tailings storage with smaller turkeys nest slimes storage	Full life of mine - in pit void at end of mine operation	In pit void storage	Mining of mineral sands and processing can commence at same time. Traditional tailing management process. Construction by tailings dam contractor prior to mining contractor commencement possible.	Construction of two tailings dams required prior to commencement of mining. Large volume of dam construction material required before mining commences. Dams need to be sized for maximum likely tails volume from outset. Dam must be maintained until end of mine life before rehabilitation back to pit void. Slimes dam will be unlikely to dry out to a level that can be easily transported back to pit void without reprocessing. Risk of dam breach requires dam to be located away from operational areas to minimise possible impacts
2	Turkey nest co-disposal tailings storage with layered deposition	Full life of mine - in pit void at end of mine operation	In pit void storage	Mining of mineral sands and processing can commence at same time. Traditional tailing management process. Construction by tailings dam contractor prior to mining contractor commencement possible. Single dam to construct and manage. Dewatering of slimes likely to benefit from sand layer drainage paths.	Construction of tailings dam required prior to commencement of mining. Large volume of dam construction material required before mining commences. Dam needs to be sized for maximum likely tails volume from outset. Dam must be maintained until end of mine life before rehabilitation back to pit void. Slime layers in dam create preferential shear planes and retard dewatering. Rehabilitation of tailing to pit void at end of mine life likely to require extended consolidation time before land can be handed back Risk of dam breach requires dam to be located away from operational areas to minimise possible impacts

Option Ref	Initial Tailings Storage	Life of Initial Tailings Storage Period of Operation	Final Tailings storage	Advantages	Disadvantages
3	Turkey nest co-disposal tailings storage with mixed deposition	Full life of mine - in pit void at end of mine operation	In pit void storage	Mining of mineral sands and processing can commence at same time. Traditional tailing management process. Construction by tailings dam contractor prior to mining contractor commencement possible. Single dam to construct and manage. Dewatering of slimes likely to benefit from sand layer drainage paths.	Construction of tailings dam required prior to commencement of mining. Large volume of dam construction material required before mining commences. Dam needs to be sized for maximum likely tails volume from outset. Dam must be maintained until end of mine life before rehabilitation back to pit void. Rehabilitation of tailing to pit void at end of mine life likely to require extended consolidation time before land can be handed back Risk of dam breach requires dam to be located away from operational areas to minimise possible impacts
4	Turkey nest sand tailings storage with solar pond slimes management facility	2-3 years	In pit void storage	Mining of mineral sands and processing can commence at same time. Untraditional tailing management process. Construction by tailings dam contractor prior to mining contractor commencement possible. Single dam to construct and manage.	Construction of tailings dam required prior to commencement of mining. Large volume of dam construction material required before mining commences. Dam needs to be sized for maximum likely tails volume from outset. Dam must be maintained until end of mine life before rehabilitation back to pit void. Rehabilitation of tailing to pit void at end of mine life likely to require extended consolidation time before land can be handed back. Solar ponds require large areas of the tenement to be utilised over the initial mine life and will increase the disturbance and impact. Dewatering of slimes likely to be able to be achieved in dry periods but management of rain fall critical. Requirement to manage solar ponds over large areas requires

Option Ref	Initial Tailings Storage	Life of Initial Tailings Storage Period of Operation	Final Tailings storage	Advantages	Disadvantages
					significant management time and specialised equipment Risk of dam breach requires dam to be located away from operational areas to minimise possible impacts
5	Dry stockpiling of sand fraction of the tailings with farmed management of slimes	2-3 years	In pit void storage	Mining of mineral sands and processing can commence at same time. Untraditional tailing management process. Construction by tailings dam contractor prior to mining contractor commencement possible. Single dam to construct and manage.	Construction of tailings dam required prior to commencement of mining. Large volume of dam construction material required before mining commences. Dam needs to be sized for maximum likely tails volume from outset. Dam must be maintained until end of mine life before rehabilitation back to pit void. Rehabilitation of tailing to pit void at end of mine life likely to require extended consolidation time before land can be handed back. Slimes farming requires large areas of the tenement to be utilised over the initial mine life and will increase the disturbance and impact. Dewatering of slimes likely to be able to be achieved in dry periods but management of rain fall critical. Requirement to manage slime farming on existing paddocks requires significant management time and specialised equipment

Option Ref	Initial Tailings Storage	Life of Initial Tailings Storage Period of Operation	Final Tailings storage	Advantages	Disadvantages
6	In pit tailings storage with slimes and sand deposited in separate streams from process plant initiation	Immediate return of tailings to pit void	In pit void storage	No surface tailings storage facility required Risk of dam break contained to in pit void Reduction in overall complexity of in pit tailings bunds Rehabilitation of mine commences early and there is no end of mine life rehabilitation of above ground tailings facility required	Mining operations need to commence prior to processing with ore required to be stockpiled until pit void sufficient to allow direct tailing deposition Mining rate needs to be aligned with processing and tailings storage rates In pit tailings bunds need to be constructed over the full mine life Slime layers likely to create preferential failure planes and retard dewatering In pit tailings bund construction needs a contractor with appropriate skills and engineering oversite for life of mine Working platform to allow backfilling over tailings with overburden maybe required if tailing don’t dry and form a crust Rehabilitation of deep tailings and in pit tailings bunds will create differential settlement over paddocks requiring regrading before hand back

Option Ref	Initial Tailings Storage	Life of Initial Tailings Storage Period of Operation	Final Tailings storage	Advantages	Disadvantages
7 (Preferred Option)	In pit tailings storage with slimes and sand deposited in a mixed stream from process plant initiation	Immediate return of tailings to pit void	In pit void storage	No surface tailings storage facility required Risk of dam break contained to in pit void Reduction in overall complexity of in pit tailings bunds Rehabilitation of mine commences early and there is no end of mine life rehabilitation of above ground tailings facility required Tailings will be more homogeneous than other options Improved water recovery outcomes	Mining operations need to commence prior to processing with ore required to be stockpiled until pit void sufficient to allow direct tailing deposition Mining rate needs to be aligned with processing and tailings storage rates In pit tailings bunds need to be constructed over the full mine life Co-mixed tailings will require flocculant to promote dewatering In pit tailings bund construction needs a contractor with appropriate skills and engineering oversite for life of mine Working platform to allow backfilling over tailings with overburden maybe required if tailing does not dry and form a crust Rehabilitation of deep tailings and in pit tailings bunds will create differential settlement over paddocks requiring regrading before hand back

4. Appendix D – Seismicity and Earthquake Risk

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1. Seismicity and earthquake risk

The investigation and assessment identified that the mine project is in region of seismic stability with low earthquake risk. The geological setting and existing lithologies identified to date and expected to be encountered within the mine area suggests that liquefiable material at the proposed subsurface levels of the mine operation are unlikely.

Material with significantly different geotechnical parameters to those identified and considered have not been identified to date and based on the geotechnical and geological drilling logs is considered unlikely.

Seismicity considerations are included in modelling and risk determination in accordance with industry standards and further detailed in the VHM DFS VHM. 2022a and 2022b).

2. Regional history

No large (magnitude 6 or above) earthquakes have occurred in Victoria since European settlement in the early 1800s but geographers such as Hills (1963), Bowler and Harford (1966) and Twidale and Stehbens (1978) identified Recent fault scarps in the state left by large earthquakes in prehistoric times, some of which have subsequently been dated (McPherson and others, 2012). The most destructive Victorian earthquakes to date were the two near Warrnambool in April and July 1903 (McCue, 1978 & 1996).

By good fortune no lives were lost, as there was significant damage to unreinforced masonry buildings. Foundation failure (lateral spreading) and liquefaction led to the disturbance of tombstones in the local cemetery. The two earthquakes were obviously shallow and close to the city but relatively small at magnitudes 4.9 and 5.3. These events were a classic doublet with few if any foreshocks or aftershocks.

Design earthquake for slope stability

Figure 1: Earthquake hazard design factor (Z) for New South Wales, Victoria and Tasmania

Table 1: Hazard design factor tables for Australian locations

HAZARD DESIGN FACTOR (Z) FOR SPECIFIC AUSTRALIAN LOCATIONS

Location	Z	Location	Z	Location	Z
Adelaide Albury/Wodonga Bendigo	0.10 0.09 0.09	Gladstone Gosford Gippsland	0.09 0.09 0.10	Port Augusta Port Lincoln Port Hedland	0.11 0.10 0.12
Broome Bundaberg Camden	0.12 0.11 0.09	Goulburn Karratha Katoomba	0.09 0.12 0.09	Port Pirie Robe Shepparton	0.10 0.10 0.09
Carnarvon Dampier Darwin	0.09 0.12 0.09	Latrobe Valley Lorne Maitland	0.10 0.10 0.10	Tennant Creek Wagga Wagga Wangaratta	0.13 0.09 0.09
Derby Esperance Geelong	0.09 0.09 0.10	Mittagong Morisset Newcastle	0.09 0.10 0.11	Whyalla Wollongong Wyndham	0.09 0.09 0.09
Geraldton	0.09	Perth	0.09	Wyong	0.10
Meckering region				**Islands**	
Ballidu Corrigin Cunderdin	0.15 0.14 0.22	Meckering Northam Wongan Hills	0.20 0.14 0.15	Christmas Island Heard Island	0.15 0.10
Dowerin Goomalling Kellerberrin	0.20 0.16 0.14	Wickepin York	0.15 0.14	Macquarie Island	0.60

The minimum value of the product $k_p Z$ shall be in accordance with Table 3.3.

TABLE 3.3

MINIMUM $k_p Z$ VALUES FOR AUSTRALIA

Annual probability of exceedance	Minimum value of $k_p Z$
1/500	0.08
1/1000	0.10
1/1500	0.12
1/2000	0.14
1/2500	0.15

For the bund design, a hazard factor Z (taken from Australian Standard AS1170.4:2007 – Structural design actions, Part 4 Earthquake actions in Australia) equivalent to the effective peak ground acceleration with a return period of 500 years has been assessed. The code states the Z-value for Melbourne is 0.08 g. For the bund design, a horizontal ground acceleration (Z-value) of 0.1 g was adopted.

3. Liquefaction

The potential for the tailings to undergo liquefaction and the likelihood of not achieving the acceptance criteria FoS under the design earthquake event, will depend on number of factors including:

- The particle size distribution (PSD) of the CDM tailings
- Their density
- The water table level
- The pore pressure in the tailings; and
- The magnitude of the design earthquake.

4. Localised Ground water Mounding

Modelling work by CDM Smith (CDM Smith. 2022) indicates that as the mine advances and tailings deposition increases there is a likelihood of groundwater mounding. This groundwater mounding has at this stage not been modelled at the mining block level however it is suggested that it could mean that in some areas groundwater might, if not addressed, intersect the pit floor.

To address this, it is intended that in the localised areas where this will occur that a system of dewatering bores will be installed to ensure that groundwater is maintained at a level of nominally 1m below the pit floor. This system is currently under investigation and will be incorporated into FEED.

The area of open pit floor that could be impacted would be present for less than 6 months based on the current mine plan before tailings would be deposited. The deposition of the tailings provides toe weighting of the pit walls improving the stability of the walls. This also further reduces the likelihood that Liquefaction will occur with increased confinement.

As the tailings was deposited the need for the dewatering pump system would alter to a tailings dewatering system as described in the Geotechnical Investigation Factual and Interpretive Report (pitt&sherry. 2022b)

5. Outcome of seismicity assessment for ground movement

The investigation and assessment identified that the mine project is in region of seismic stability with low earthquake risk.

The geological setting and existing lithologies identified to date and expected to be encountered within the mine area suggests that liquefiable material at the proposed subsurface levels of the mine operation are unlikely.

Material with significantly different geotechnical parameters to those identified and considered has not been identified to date and is considered unlikely.

Seismicity considerations are included in modelling and risk determination in accordance with industry standards.

The potential likelihood and impact of liquefaction is described below

The potential for the material, including tailings, to undergo liquefaction and create an increased risk of failure under the design earthquake event, with consideration of several factors included in design analysis, including:

- The particle size distribution of the -tailings
- Their density
- The water table level
- The pore pressure in the tailings; and
- The magnitude of the design earthquake.

The mining operations are designed to ensure that extraction is restricted to material above the ground water table with proposed management plans to include ground water and surface water to assist ensuring that materials do not become saturated and subject to altered behaviour parameters.

Assessment of the tailings as unsaturated and partially saturated states indicates that liquefaction is not a likely risk at the Goschen mine. The tailings are a draining tailing and as such a fully saturated condition is not considered likely.

5. Appendix E – Draft Ground Control Management Plan Outline

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The GCMP aims to provide a safe workplace for personnel and preserve VHM assets from loss due to uncontrolled ground movement within their operations.

The types of uncontrolled ground movements will be described, as will the systems in place which apply control measures (preventive and reactionary), how the control measures interrelate and how they are implemented, managed and monitored for effectiveness. This will include where and how data is stored, role descriptions and responsibility cards for mining team members.

The GCMP is a comprehensive and live document which develops over time as proposed works are more clearly defined, mine planning determined, and equipment selected. It is essential that this document is developed with the input from operational team members and includes the identification of Principal Mine Hazards and a Risk assessment.

In compliance Victorian State Government Earth Resources Department Guidelines for the assessment of geotechnical risks in open pit mines, the GCMP includes:

- Identification of the major geotechnical hazards
- Identification of the ground control risks related to geotechnical, hydrogeological and mining impacts
- Definition of the Geotechnical Risk Zone (GRZ)
- Site geology and hydrology
- Identification of all current and planned assets (public access, infrastructure, land, property and environments) within the GRZ.
- Determination of any impacts from the GRZ applicable to each asset.
- Function, operation and design principles and capacity of main components of works.
- Approach to be taken regarding mine site rehabilitation, including progressive rehabilitation and mine-closure.
- Assessment of geotechnical risks of rehabilitated areas.
- Outlines the preventative and reactionary controls required to mitigate the geotechnical hazards.
- Systems that apply the control measures identified in the Risk Assessment.

The location of this information within the GCMP is outlined in Table 1.

Note –

Appendix F and F1 of this report present background work undertaken post the Goschen project DFS which outlines possible mitigations and monitoring. This is presented as reference information allowing the reader of this outline to understand the breadth of mitigations and monitoring. The wording and presentation is not in the form that it will be as its moved into the draft GCMP which is currently under development.

Table 1: Required information location within GCMP

Aspect	Scoping requirement	Section addressed
Key issues	Identify the major geotechnical hazards	Section 5
	Identify the ground control risks related to geotechnical, hydrogeological and mining impacts	Section 6, 7 and 12
	Definition of the Geotechnical Risk Zone (GRZ)	Section 5
Existing and Future Environment	Site geology and hydrology	Section 4
	Identification of all current and planned assets (public access, infrastructure, land, property and environments) within the GRZ.	Section 5.3 and 7.1
Assessment of likely effects	Identify movement triggers; Design criteria and Assessment Criteria; Rehab/Post Closure Criteria	Section 5, 7 and 9
	Determination of any impacts from the GRZ applicable to each asset.	Section 5 and 6
Design and mitigation measures	Function, operation and design principles and capacity of main components of works	Section 7
	Approach to be taken regarding mine site rehabilitation, including progressive rehabilitation and mine-closure.	Section 9
	Assessment of geotechnical risks of rehabilitated areas.	Section 9
	Outlines the preventative and reactionary controls required to mitigate the geotechnical hazards	Section 7
	For all significant impacts posing significant risks- a statement detailing the method to be used to monitor and evaluate ground movements and their impact on the asset during operation and rehabilitation of the site.	Section 10 and
Approach to manage performance	Systems that apply the control measures identified in the Risk Assessment	Section 10, 11, 12 and 13
	Describes how the controls will be implemented, managed and monitored for effectiveness	Section 10, 11, 12, and 13
	Defines the responsibilities of management, technical and operations personnel under the GCMP	Sections 12 and 13

1. PROPOSED GCMP CONTENTS

Below is the proposed outline that will establish the Ground Control Management Plan content. Each major heading is followed by a descriptor of the sections contents, and subheadings contained within each.

This framework may be altered during the site wide risk assessment process to capture additions and changes as risks are more clearly defined and control measures (TARPS/Roles and Responsibility Cards etc.) established.

1.1 Introduction

This section describes the connection between the GCMP and the Work Plan, Regulations and Guidelines. It establishes definitions of common terms through use of a glossary.

- Glossary

1.2 Context

The items that must be addressed within the GCMP are dictated by the Victorian State Government Earth Resources Department Guidelines for the assessment of geotechnical risks in open pit mines. These items are outlined in this section with a table identifying where in the document each item is addressed is provided. Disclaimers, Limitations and Assumptions are detailed, along with triggers for review of the GCMP.

- Disclaimer for Document Version 1
- Limitations, uncertainties, and assumptions
- Triggers for Document Review
- Exclusions
- Related Documents
- Consultation and engagement

1.3 Statutory and Regulatory Requirements

The assessment of geotechnical risks to public safety, infrastructure, the environment, land and property is required by the department's Earth Resources Regulation (ERR) unit as part of the submission of a work plan. In compliance with the Mineral Resources Regulations 2019, S.R. No. 48/2019, Schedule 12—Stability requirements and processes for declared mines, the risks and controls contained in this document will consider legislation, policy, and standards relevant with assessment criteria that have been derived for the purposes of the Work Plan Risk Assessment.

- Acts and Regulations
- Standards and Guidelines

1.4 Site components

This section introduces the site location and its environmental features. It outlines the operational plan, key aspects and mining sequence, connecting physical and operational aspects to provide an overview of site conditions. Physical properties of site are linked back to geotechnical risks and design and operational mitigation measures.

- General Information
- Climate
- Topography
- Hydrology
- Geology
- Operational Aspects
- Mining Sequence
- Mined Void and Tailings Plan

1.5 Surface conditions

This section contains critical information relating to ground movement definitions and criteria, and areas at risk of and from ground movement. It outlines the risk pathways and establishes the potential scenarios detailed in the risk assessment in section 6. Risks and pathways are distinguished by phase: construction, operational and decommissioning/rehabilitation.

- 3D Geological Model
- Risk Events
- Ground movement types (Elements)
- Movement Triggers
- Potential Risks from Groundwater
- Sensitive Receptors
- Geotechnical Risk Zone
- Potential Impact Scenarios
- Risk pathways
- Pathway 1 and 2 – Slope Collapse (above ground and subsurface respectively)
- Pathway 3 – Liquefaction - Earthquake
- Pathway 4 – Deformation/Settlement/Heave
- Pathway 5 - Dispersive soils

1.6 Risk Assessment

This section lists the risk receptors compared to potential threat and prescribes both a risk rating and identifies which mining stage this risk could occur in (ie. Construction, Operation, Decommission/Rehab). This information is then aligned with sensitive receptor areas to give a clear depiction of risks as they apply to this site.

- Impact Assessment- Location Specific

1.7 Controls

This section contains the criteria for each element, as well as any benching or slope requirements prescribed within the Geotech EES. It identifies existing, design and operational stage controls for each area of risk, providing Factor of Safety justification and minimum parameters for safe conditions.

- Recommendations for front-end engineering design (FEED)

- Design Stage Acceptance Criteria
- Mitigation and Contingency Measures in Project Design
- Prescribed Measures
- Assessment Criteria for Construction and Operation
- Construction Stage Acceptance Criteria
- Operation Stage Acceptance Criteria
- Mine Pit Wall Stability and Recommended Slope Profile
- Pit Depth and Design Life
- Criteria and Qualifications for Pit Stability
- Tailings Management
- Geomechanics
- Settlement Design Parameters
- Pit Slopes
- Stockpile Stability and Recommended Geometry
- Surface Water Drainage Bunds for Stockpiles
- Sediment Ponds

1.8 Excavation Management

This section of the document relates to operational management of excavation methodology and equipment. It includes the process flow of design through management over the planned lifespan of the excavation. Input requirements, design guidelines and support/management guidelines are referenced, and operational guidelines are included. Condition assessments, QAQC processes are referenced as are the procedures of rectifying Not to Standard.

- Design
- Excavations

1.9 Rehabilitation / Post operation criteria

This section contains Rehabilitation requirements and criteria for completion. It also describes the required final landform design criteria. This section is supported by information contained within the Environment Effects Statement –Mine Rehabilitation Plan.

- Final Landform Design

1.10 Monitoring

This section outlines all areas requiring monitoring and triggers for change, action, review or TARP implementation. It lists information that must be recorded, details of monitoring methodology and identifies potential issues that may be observed. Tolerances for changes in site features and characteristics are listed to enable operational inspections to effectively identify risks before they arise.

- Monitoring - Pit Slopes
- Monitoring - Stockpile Batters
- Monitoring - Deformation

- Monitoring Construction – Geometrical
- Monitoring Construction - Material Specification
- Monitoring Construction – Public Access
- Condition Inspections
- Monitoring- Visual Assessments

1.11 Hazard and risk control

This section contains all control measures used and required by site to identify, mitigate, control, rectify and report on ground control events. It outlines the systems and controls in place to assess and respond to events. Site responses to mitigate risk during all stages of mining including QA/QC and TARPs are provided.

- TARPS
- Training and Competency
- Monitoring Responsibility
- Reporting
- Assurance Framework
- Residual Risk
- Quality Assurance and Quality Control
- Unintended Conditions or Events
- Identification of Unintended Conditions or Events
- Risk Assessment of Unintended Conditions
- Response to Unintended Conditions or Events

1.12 Operator's reference documents

A list of operational documents required by personnel on site to conduct both routine and non-routine checks and inspections including procedures, standards, SWMS, checklists etc. that relate to ground control.

1.13 GCMP Responsibility Cards

This section outlines, role by role, the responsibilities of personnel on site regarding ground control design, operational controls, and monitoring.

- Line Supervisor (Shift Boss)
- Foreman/Superintendent Mining
- Surveyor
- Senior Surveyor
- Geotechnical Practitioner
- Mining Engineer
- Superintendent Mining

1.13.1 References

Ground Control Criteria Considerations – Appendix F-1

F1.1: Draft Construction stage geotechnical criteria

During the construction phase of the mine the following geotechnical criteria are provided as possible input for use in implementation. It should be noted that this is provided as a guide to the actual GCMP and the criteria in the GCMP may vary as it is developed and reviewed.

Construction is defined as including:

- Process plant construction
- Containment ponds and water storages
- Stockpile construction
- Tailings bund construction
- Internal haul road construction; and
- Diversion drains.

F.1.1.1 Construction of process plant construction, containment ponds and water storages, and diversion drains (Draft Criteria) (Draft Criteria)

- Bearing capacity - Factor of safety of 2.5
- Settlement criteria - Generally, less than 20mm
- CBR minimum of 5
- Compaction standards - Generally, 98% to 100% standard compaction
- Slope Stability - FoS 1.5
- Geometrical Control
  - Tolerances for fill batters – steeper than design no greater than 0.5 degrees
  - Tolerances for drainage basins, and channels – steeper than design no greater than 1.25 degrees
  - Tolerance for channel/drain widths not less than 95% of design width

F1.1.2 Stockpile construction (Draft Criteria)

- Slope stability
  - 1.3 FoS for short term stockpiles
  - 1.5 FoS or permanent or long-term stockpiles
  - Stockpile toe offset to pit wall crest
    - (30m pit) – 22m
    - (40m pit) – 31m
- Stockpile toe offset to sensitive receptor (30m Stockpile height) – 20m
- Geometric Control
  - Tolerances for cut slopes – steeper than design no greater than 1 degree
  - Tolerances for stockpile batters – steeper than design no greater than 0.5 degrees
  - Tolerances for bunds, basins, and channels – steeper than design no greater than 1.25 degrees
  - Tolerance for bench width -0.0m to +0.5m width

- Tolerance for channel/drain widths not less than 95% of design width
- Maximum height 30m above existing ground level.

- Erosion and sediment control plans in accordance with IECA best Practice guidelines to be developed and implemented prior to construction commencement.
- Bearing capacity -Clay and sand stockpiles - Topsoil stockpiles not trafficked after placement
- Height control
  - Clay and Overburden piles to be less than 30m
  - Topsoil stockpiles to 2m maximum

F1.1.3 Tailing bund construction (Draft Criteria)

- Slope stability
  - FoS 1.3
  - FoS 1.1 for earthquake
- Geometrical Control
  - Tolerances for fill batters – steeper than design no greater than 0.5 degrees
  - Tolerances for drainage basins, and channels – steeper than design no greater than 1.25 degrees
  - Tolerance for crest width -0.0m to +0.5m width
  - Tolerance for channel/drain widths not less than 95% of design width
- Bearing capacity - FoS 2.5
- Compaction - 98% at OMC
- Material type - Silty Clay / Sandy Clay or Clay
- Permeability - Maximum permeability 1 x 10-9 m/s
- Erodibility Emerson class 5 or 6 in outer zones
- Shrink swell
  - Do not permit earthwork to dry out to the point where excessive shrinkage occurs
  - Linear shrinkage to be no more than 3%
- Sliding - FoS 1.5

F1.2 Operation criteria

During mine operations the following geotechnical criteria are provided as possible input for operations.

- Pit excavation and wall establishment
- Tailing placement and ongoing tailings containment bund developments (noting that the placement and process is designed to contain risks to within the mine boundaries and avoid potential ground movement impacts on public and private property or other sensitive receptors); and
- Rehabilitation / replacement of overburden and restoration of overlying material while active mining resources available.

During the operating phase of the mine the following criteria have been adopted for use in implementation.

F.1.2.1 Pit wall establishment (Draft Criteria)

- Slope stability

- 1.5 factor of safety and PoF 10% for general areas.
    - 1.25 factor of safety and PoF of 10% for localised areas with increased monitoring.
- Pit wall crest location from sensitive receptor
    - (30m pit adjacent to public infrastructure) – 22m
    - (40m pit adjacent to public infrastructure) – 29m
    - (30m pit adjacent to stockpile) – 22m
    - (40m pit adjacent to stockpile) - 31m
- Erosion and sediment control plans in accordance with IECA best Practice guidelines to be developed and implemented for ongoing operation
- Geometric Control
    - Tolerances for cut slopes – no steeper than design
    - Tolerances for channels – steeper than design no greater than 1.25 degrees
    - Tolerance for bench width -0.0m to +0.5m
    - Tolerance for channel/drain widths not less than 95% of design width

F.1.2.2 Pit wall establishment (Draft Criteria)

- Slope stability
    - 1.3 factor of safety for short term stockpiles
    - 1.5 factor of safety or permanent or long-term stockpiles
- Geometric Control
    - Tolerances for cut slopes – steeper than design no greater than 1 degree
    - Tolerances for stockpile batters – steeper than design no greater than 0.5 degrees
    - Tolerances for bunds, basins, and channels – steeper than design no greater than 1.25 degrees
    - Tolerance for bench width -0.00 to 0.5m width
    - Tolerance for channel/drain widths not less than 95% of design width
- Erosion and sediment control plans in accordance with IECA best Practice guidelines to be developed and implemented for ongoing operation
- Bearing capacity
    - Clay and sand stockpiles
    - Topsoil stockpiles not trafficked after placement
- Height control
    - Fill to be less than bund freeboard

F.1.2.3 Rehabilitation / replacement of overburden and restoration of overlying material (Draft Criteria)

- Slope stability
    - No permanent slopes steeper than the existing terrain
    - No more than 1 in 100 gradient over rehabilitated surface
- Settlement
    - No more than 100mm settlement over ten years after hand over
- Geometric Control (height and topography)

- Graded to allow natural drainage to pre-existing drainage paths
- Topographic surface no less than 1m lower than adjacent
- As flat as possible
- Can be lower than adjacent but flat
- topographic profile reflecting preconstruction landform ie low slope paddocks

- Erosion and sediment control plans in accordance with IECA best Practice guidelines to be developed and implemented for ongoing operation
- Remnant slopes to be vegetated to minimise erosion opportunities

F.1.3 Rehabilitation / Post operation criteria

During rehabilitation and following post mining closure phases of the mine the following geotechnical criteria are provided for reference and consideration.

F.1.3.1 Removal of process plant and other infrastructure (Draft Criteria)

- Demolition and removal of concrete footings - full removal of all structure and associated services coverage 100% of area of process plant or MUP
- Removal of haul road 100% removal of pavement and fill above natural ground. 100% removal of any subgrade modification not suitable for reuse to 1m.
- Voids filled to -0.5m with site one fill to 98% standard compaction and prepared for rehabilitation in accordance with Rehabilitation plan
- All areas returned to natural surface levels in accordance with the rehabilitation plan 100% coverage
- Slope stability 1.5 factor of safety and PoF 10%
- Erosion and sediment control plans in accordance with IECA best Practice guidelines to be developed and implemented for ongoing operation
- Geometric Control
  - Tolerances for cut slopes – no steeper than design
  - Tolerances for channels – steeper than design no greater than 1.25 degrees
  - Tolerance for bench width -0.0m to +0.5m
  - Tolerance for channel/drain widths not less than 95% of design width

Controls, Monitoring and Contingency considerations – Appendix F-2

The following sections outlines possible risk treatment options and controls which are considered as appropriate to be incorporated into the final GCMP. The items are however indicative and are expected to change in terms of content and presentation to ensure they align with the guidelines and the overall GCMP document.

F.2.1 Controls That Already Exist

There are some risks that have been identified and resulted in the project being modified to engineer a control. This includes, but is not limited to the following:

- The proposed maximum mining depth has been restricted to at least 3m above the water table. This has been confirmed by specific studies and through the extensive drilling program across the mine lease. There have also been no identified perched water tables encountered in the drilling programs. Based on this ground water will not influence the pore pressures in the slopes and liquefaction of the pit slopes will therefore not occur
- The presence of significantly weaker material strengths is considered unlikely. The extensive drilling program has not encountered any very weak structures and the geological age, and the formation and historical performance of the area suggests that this is unlikely to significantly impact the mine; and
- The mine area is located in an area of relative seismic stability and consequently the risk of ground movement due to liquefaction triggered by earthquake is considered Low.

F.2.1.1 Controls by Design

Control of risks by design is a key part of the risk assessment and mitigation actions. Good design methodologies and rigorous analysis and sensitivity assessments have been employed as mitigation actions. The current design work has relied on investigations and testing carried out primarily in Area 1 of the proposed mine which is the initial mining area. This combined with assessment of the comprehensive exploration drilling program results has indicated that the cover sequence and ore body have material properties that lie within the expected range of values for this and other sites in the vicinity with similar lithology. VHM have commenced a major infill geotechnical investigation over all proposed mining areas which includes sufficient coverage and material property testing to further reduce any uncertainty in the analyse carried out for pit slopes, stockpiles, foundation capacity and the construction of sedimentation basins. The investigation and testing program includes

geotechnical Investigation holes and laboratory testing of key properties including permeability.

F.2.1.2 Controls by Human Intervention

Controls by human intervention will be a key mitigation action which will continue over the life of the mine. It is likely that at stages through the mine life that pit slopes and material properties will vary requiring limited alteration to the original designs. This is likely as the mining team will gain significant experience in how the cover sequence and ore body perform in full scale slopes over time. A key part of gaining this knowledge and being able to use it centres around monitoring and assessment in accordance with risk management plans.

F.2.2 Monitoring

F.2.2.1 Monitoring- Pit Slopes

The pit slopes originally designed for the project will be nominally 40m high with a bench at about 10m depth. These slopes will be short term slopes with an expected life of 12 months from initial strip of the overburden to remediation back to pre-mined surface levels. The lower part of the slope which is the mineral sand is nominally 20m thick and is expected to be open for 6-9 months before tailings will be deposited against the slope face.

It is recommended that the pit slopes be monitored by remote surveying using survey targets installed at key locations along the pit wall both on the cover sequence and the lower mineral sand slopes. Survey would be by reflectorless total station units to minimise access requirement to cut slopes. It is expected that current improvements in laser scanning systems and increasing accuracy of drone surveys may replace traditional monitoring systems over the life of the mine further improving the safe collection of accurate survey data and the frequency that it can be collected.

It is recommended that slopes be monitored shall including the pit slopes adjacent to the MUP locations, at access ramp locations due to the persistent vibrations of the mining fleet and close to the interfaces between the in pit tailings bunds and the pit walls.

It is recommended that the frequency of monitoring be more frequent in the early stages of the mine reducing as the mining team gain experience in the performance of the slopes. It is suggested that daily monitoring is undertake in the early stages and that it is carried out as a similar time each day to improve the consistency of the results. Initial survey points should be at 30-50m spacing.

It is recommended that monitoring should occur after major rain events that cause any uncontrolled inundation of the bench drainage systems.

F.2.2.2 Monitoring - Stockpile Batters

The stockpiles created by the initial strip process will remain for the full life of the mine as they are cut to form the initial voids but remain in the stockpile as the fresh stripped overburden is used for rehabilitation. These stockpile batters will remain in place for nominally 20 years, The stockpiles vary in height depending on material type with the topsoil stockpiles being only 3m high an representing an insignificant risk due to slope stability and the clay and non-clay overburden being up to 30m high.

Stockpile monitoring should occur using a similar methodology to the pit slope monitoring. using remote surveying utilising fixed survey targets installed at key locations along the top of benches. Survey would be by reflectorless total station units to minimise access requirement to benches. It is expected that current improvements in laser scanning systems and increasing accuracy of drone surveys may replace traditional monitoring systems over the life of the mine further improving the safe collection of accurate survey data and the frequency that it can be collected.
All stockpiles are to be monitored including the low topsoil stockpiles and the bulk clay and waste overburden stockpiles.

The frequency of monitoring should be more frequent in the early stages of the mine reducing as the mining team gain experience in the performance of the stability of the stockpiles. It is suggested that daily monitoring is undertake in the early stages and that it is carried out as a similar time each day to improve the consistency of the results. Initial survey points should be at 50m spacing.

Surveys of the 3m topsoil stockpiles would be reduced to monthly once fully revegetated as well as after major rain events that cause any uncontrolled inundation of the bench drainage systems.

Surveys of the 30m bulk clay and waste overburden stockpiles would be weekly once fully revegetated as well as after major rain events that cause any uncontrolled inundation of the bench drainage systems.

Surveys of any ore stockpiles should be included in the monitoring program where the stockpiles will remain in place for greater than 3 months with the frequency being weekly as well as after major rain events that cause any uncontrolled inundation of the bench drainage systems.

F.2.2.3 Monitoring - Deformation

Deformation is not expected to be a significant failure mode for the VHM mine. Assessment of the materials contained in the overburden, their material properties and the ground water levels present across the site suggest that large scale ground softening is unlikely, and that local ponding or overland flow will only have transient impact on the local area of the ponding and not reduce material strengths more globally.

Observations on the site over the past 5 years support this assessment in that there has been no evidence of ground bearing failures on the roads or farm paddocks that has affected normal operations in the area. There will however by more heavily loaded areas of the mine. These will include the MUP locations, the Haul Road ramps, and the clay stockpile benches. There may also be some deformation along the pit perimeter however this is likely to be more readily observed by visual assessment given the flat ground surface and long site lines that will be available.

Deformation monitoring can be undertaken using remote surveying using survey targets installed at key locations along the Haul Road ramps, on the MUP structure at easily visible locations and on the top face of the lower benches of the stockpiles where the surcharge load will be the greatest. Survey would be by reflectorless total station units to minimise access requirement to undertake surveys.

F.2.2.4 Monitoring - Visual Assessments

Visual assessments/condition assessments will provide a significant tool in identifying changes that may indicate a possible issue requiring intervention.

Visual surveys should be carried out daily as part of the site operational management plan. The surveys should include coverage of all pit slopes, stockpiles, haul roads and access ramps and drainage structures. Surveys should include:

- Line of site assessment for depressions
- Cracking of process plant pavements and haul roads - Use of Austroads visual pavement guide as a basic tool to
- provide consistency
- Safety berm condition identification of edge creep and deviations, gaps and impact damage
- Deviations in slope faces
- Scour in drains
- Scour on pit and stockpile faces
- Alterations in vegetation on stockpile batters indicating seepages or variations in material properties; and
- Excessive revegetation that may cause damage to benches and drains.

F.2.2.4 Monitoring Construction - Geometrical

It is critical that the pit and stockpile slopes and benches are constructed to design geometry or that any departures are identified and recorded with the reasons for the changes. This data should be provided by the construction contractor to the mine as part of the As Built record. These records should include:

- Post construction hand over surveys
- As constructed records using drone surveys including comparisons with design models
- Provision of terrain models to mine after construction
- Verification of bench and drainage geometry to manage minor “rock falls” of loose clay or cemented sand blocks
- and ensure correct slopes achieved to manage drainage
- Tolerances for cut slopes
- Tolerances for stockpile batters
- Tolerances for bunds, basins, and channels
- Tolerance for bench width; and
- Tolerance for channel/drain widths

F.2.2.5 Monitoring Construction - Material Specification

It is critical that the materials used in construction of safety bunds, berms and pavements is in accordance with the design specification or that any departures are identified and assessed for conformance with the design intent and that the departure doesn't compromise the performance of the bund, berm or pavement

This data should be provided by the construction contractor to the mine as part of the As Built record. These records should include:

- Field lot testing
- Proof roll records
- ND test results
- Permeability and Emerson crumb testing for water retaining bunds
- Quarry dockets; and
- Records/engineers hold point releases.

F.2.2.6 Monitoring Construction - Storm water and surface water Monitoring

Management of surface runoff and storm water will be critical to the long term stability of pit slopes, stockpile batters and the performance of haul road pavements. Uncontrolled discharges will cause erosion and, in some cases, could undermine slopes or cause softening of materials if allowed to pond.

- All drainage structures, channels and basins should be monitored weekly as part of the visual monitoring program as well as after any major storm event
- Culverts, and channels shall be monitored weekly for siltation and blockage and excessive weed build up causing potential deviation in flow paths leading to uncontrolled discharges and scour
- Defects in the drainage systems should be rectified immediately and particular attention paid to the maintenance of the system prior to expected wet periods to ensure optimum performance; and
- Ponding water adjacent to safety berms along pit crests, along haul roads should be identified immediately post rain events and local drainage adjusted to allow the area to drain and to avoid future ponding.

F.2.2.7 Monitoring Construction - Public Assess

The most significant risk for any failure of the pit slopes is one that places people at risk. The public will access roads, paddocks, and a small number of properties adjacent to the mine lease. Where possible and where the locations are unavoidably close to existing public roads the roads will be closed which will eliminate the risk.

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Goschen Mineral Sands and Rare Earths Project

Environmental Effects Statement Geotechnical Assessment

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