ADVERTISED PLAN

Lang Lang Sand Resources Pty Ltd

5575 South Gippsland Highway, Lang Lang

Geotechnical Assessment

September 2022

Table of contents

Table index

Figure index

ADVERTISED
PLAN

1. Introduction

1.1 General

GHD Pty Ltd (GHD) understands that Lang Lang Sand Resources Pty Ltd (the Client), owned by Aurora Construction Materials (ACM), wish to develop sand resources at Work Authority 7541 (WA7541), located at 5575 South Gippsland Highway (SGH) in the Lang region of Victoria (the site; see Figure 1). It is understood that the Client's work plan application must satisfy any requirements prescribed by the Department of Jobs, Precincts and Regions (DJPR) - Earth Resources Regulation (ERR) division.

The site is currently a greenfield site and is bound by South Gippsland Highway to the south and west, private farmland to the north and the Lang Lang Gas Plant facility to the north east (Figure 1). There is no heritage overlay on the site and no European Heritage listed assets in the vicinity. Additionally, there are no named waterways on the property, however an un-named drainage line flows east to west along the northern margin of the property. The proposed site occupies an approximate area of 118 Ha.

To assist the client with this application, GHD has been engaged by Mr Kelvin Sargent of ACM to undertake a geotechnical assessment of the site (this report) and to develop a ground control management plan (GCMP) which identifies potential geotechnical risks and suitable risk treatment protocols.

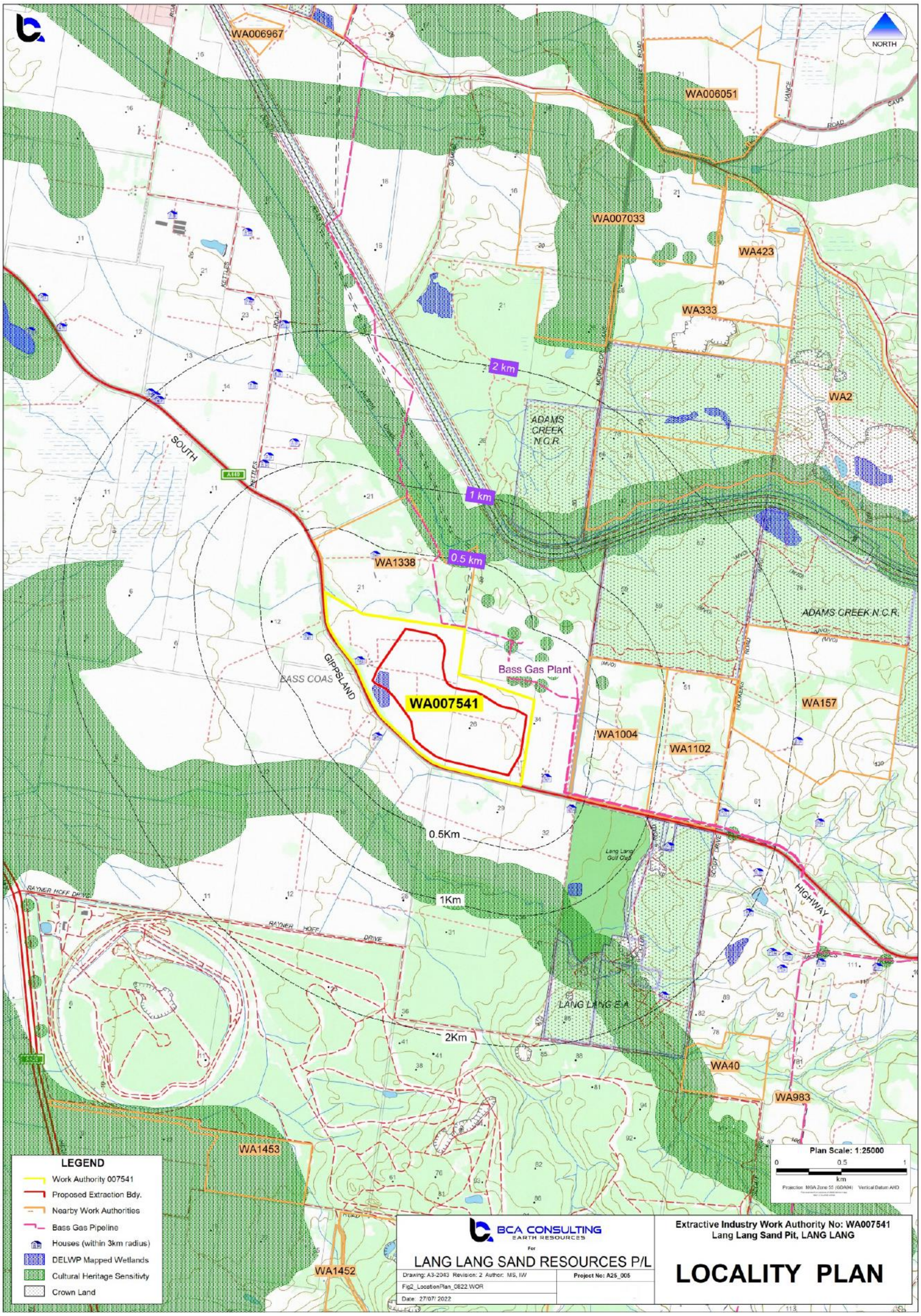


Figure 1 Site Location Plan WA7541

ADVERTISED
PLAN

1.2 Client Objectives

GHD understands that the primary objective of the Client is to develop the sand resources at WA7541 (the site). The Client proposes to extract sand resources above the standing groundwater level using truck and excavator methods, prior to extracting below groundwater level using dredge or dragline method. The total depth of extraction is expected to be approximately 30 m below current surface level, with working and rehabilitated profiles of 1V:3H (approx. 18°) above groundwater and 1V:2H (approx. 26°) below. A beaching bench will be established at the water level.

1.3 Scope of Works

As outlined in the GHD proposal titled '*5575 South Gippsland Highway, Lang Lang Proposal for Geotechnical Assessment*, dated 18 February 2021 (GHD Ref: 12527040-29852), the following scope of work was undertaken:

Site Inspection

Undertake a cursory site visit to:

- Visually assess existing conditions (including any geotechnical and or geological features at the site).
- Inspect any outcrops and nearby sand extraction sites where possible.
- Gain a visual appreciation of potential hazards at the site.

Geotechnical Assessment

Upon completion of the site inspection component of the geotechnical assessment, GHD would:

- Review available site information, including any technical reports (e.g., the drill reports) and groundwater information, if made available.
- Develop a site geological and geotechnical model based on the results of the desktop review, site inspection and the available resource definition drilling information.
- Undertake slope stability assessments using Client supplied batter geometry profiles for the proposed development at the site.
  - Limit-equilibrium modelling (LEM) analyses would be undertaken to calculate factors of safety to assess the stability of the proposed design batter geometries (for long term stability) where required.
  - Undertake sensitivity assessments for seismic and elevated phreatic conditions (surface water conditions).
- Undertake a bearing capacity assessment for an excavator pad design, as part of the planned excavation below groundwater level. This assessment would take into consideration the load of the proposed excavator for the slope stability analyses, particularly near the anticipated groundwater surface.
  - Calculate a suitable stand-off (or buffer) distance between the crest of the beaching zone bench and mobile plant for mechanical dredging.
- Based on the outcomes of the stability analyses, with regards to the proposed quarry design, we would undertake a geotechnical risk assessment which would identify, where necessary, suitable risk treatment protocols.
- GHD would undertake preliminary erodibility assessments, based on the proposed slope design, using the revised universal soil loss equation (RUSLE). The findings would assist

the Client in understanding potential long term average annual soil loss volumes. Application of the RUSLE equation considers the following factors:

- Rainfall erosivity
- Soil erodibility
- Topography
- Cropping management factors

- Prepare a geotechnical report outlining the findings and recommendations, which can be subsequently submitted to the ERR as part of the work authority application. The geotechnical assessment report would include:
  - A summary of the methodology.
  - A summary of the site observations.
  - Limit equilibrium stability analysis results.
  - The bearing capacity assessment results for the excavator loading.
  - Soil erodibility assessment results.
  - Recommendations on the safe and stable batter profiles / geometries within the overburden (if any) and resource units.
  - Outline of recommendations as applicable for any requirements in relation to slope / batter movement monitoring during profiling works to the proposed design.
  - Risk Assessment Matrix with controls outlined.

1.4 Limitations

This report: has been prepared by GHD for Lang Lang Sand Resources Pty Ltd and may only be used and relied on by Lang Lang Sand Resources Pty Ltd for the purpose agreed between GHD and the Lang Lang Sand Resources Pty Ltd as set out in this report.

GHD otherwise disclaims responsibility to any person other than Lang Lang Sand Resources Pty Ltd arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Lang Lang Sand Resources Pty Ltd and others (including BCA Consulting Pty Ltd) who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

1.5 Client Supplied Information

We have relied upon the following sources of information for the geotechnical assessment detailed in this report. Relevant information was extracted from the following documents:

- BCA Consulting – Regional Plan, dated 28 July 2020.
- BCA Consulting - Locality Plan (draft), dated 6 August 2020.
- BCA Consulting –Site Layout Plan), dated 17 March 2022.
- Borehole logs provided by BCA Consulting, on behalf of ACM for their site titled:
  – Borehole logs (.pdf) titled, ‘A25_005_Drillogger_April2020_red.pdf’, dated 25 March 2021.

2. Background

2.1 General

The proposed quarry extraction site is situated in Lang Lang, Victoria, an area containing multiple sand extraction quarries. The WA7541 site, at 5575 South Gippsland Highway, Lang Lang, is currently an undeveloped greenfield site, located approximately 7 km southeast of the Lang Lang township, and 80 km southeast of Melbourne (Figure 2). This location is bounded to the west and south by the South Gippsland Highway, to the northwest by WA1338 (Len Huxtable), to the northeast by Bass Gas Plant and to the east by private farmland. 4 other existing WA tenements can be found within 3 km of the proposed site: WA2 (Holcim), WA157 (Metro Quarry Group), WA1004 (Railway Sand Supplies) and WA1102 (Metro Quarry Group), as shown in Figure 3.

Figure 2 Site Location Map

The WA boundary covers an area of just under 118 Ha. The resource will likely be used for the production of construction materials such as concrete and road surfacing material.

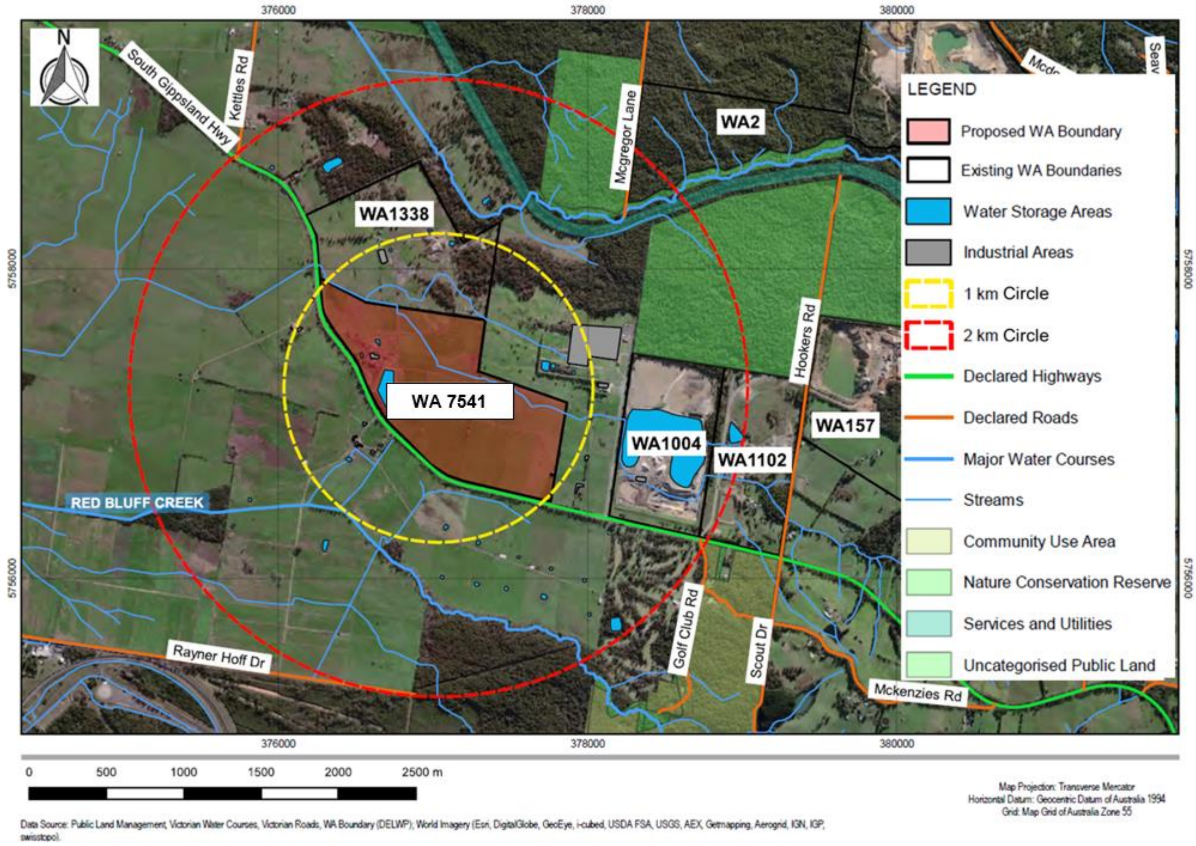


Figure 3 Plan View of the Proposed Quarry WA7541 Location Depicting Nearby Receptors

2.2 Regional and Site Geology

2.2.1 Regional Geology

The proposed quarry site lies approximately 7 km inland from the eastern shores of Western Port Bay. The area is situated within a tectonic depression, known as the Western Port Sunklands. The sunklands are bounded to the west by the Tyabb Fault, and to the east by the Bass and Heath Hill Faults (GeoVic, 2014; Geoscience Australia, 2020), forming a horst (Mornington Peninsula bedrock ridge) and graben (Port Phillip Sunkland, Western Port Sunkland) sequence (McAndrew & Marsden, 1968).

2.2.2 Regional Structural Geology

The proposed quarry site is situated on a graben (Western Port Sunklands), downthrown relative to the Mornington Peninsula bedrock to the west and the South Gippsland Highlands to the east. The extents of the sunklands are defined by the Tyabb Fault to the west, and the Heath Hill Fault to the east (GeoVic, 2014). Within the sunklands, the quarry site sits in a slightly elevated zone known as the Lang Lang Lowlands, delineated by the Lang Lang Fault as shown in Figure 4 (Carillo-Rivera, 1975).

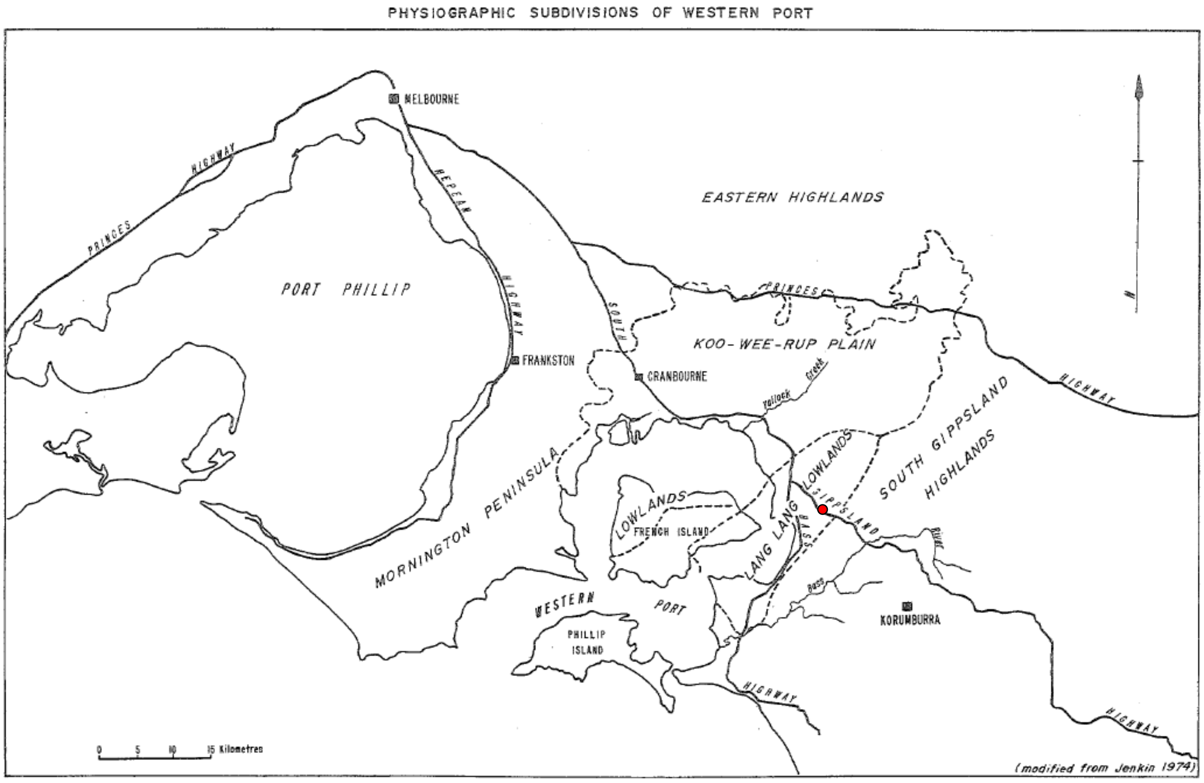


Figure 4 Physiographic Sub-Divisions of Western Port (Carillo-Rivera, 1975, modified from Jenkin, 1974). Proposed quarry WA 7541 shown in red

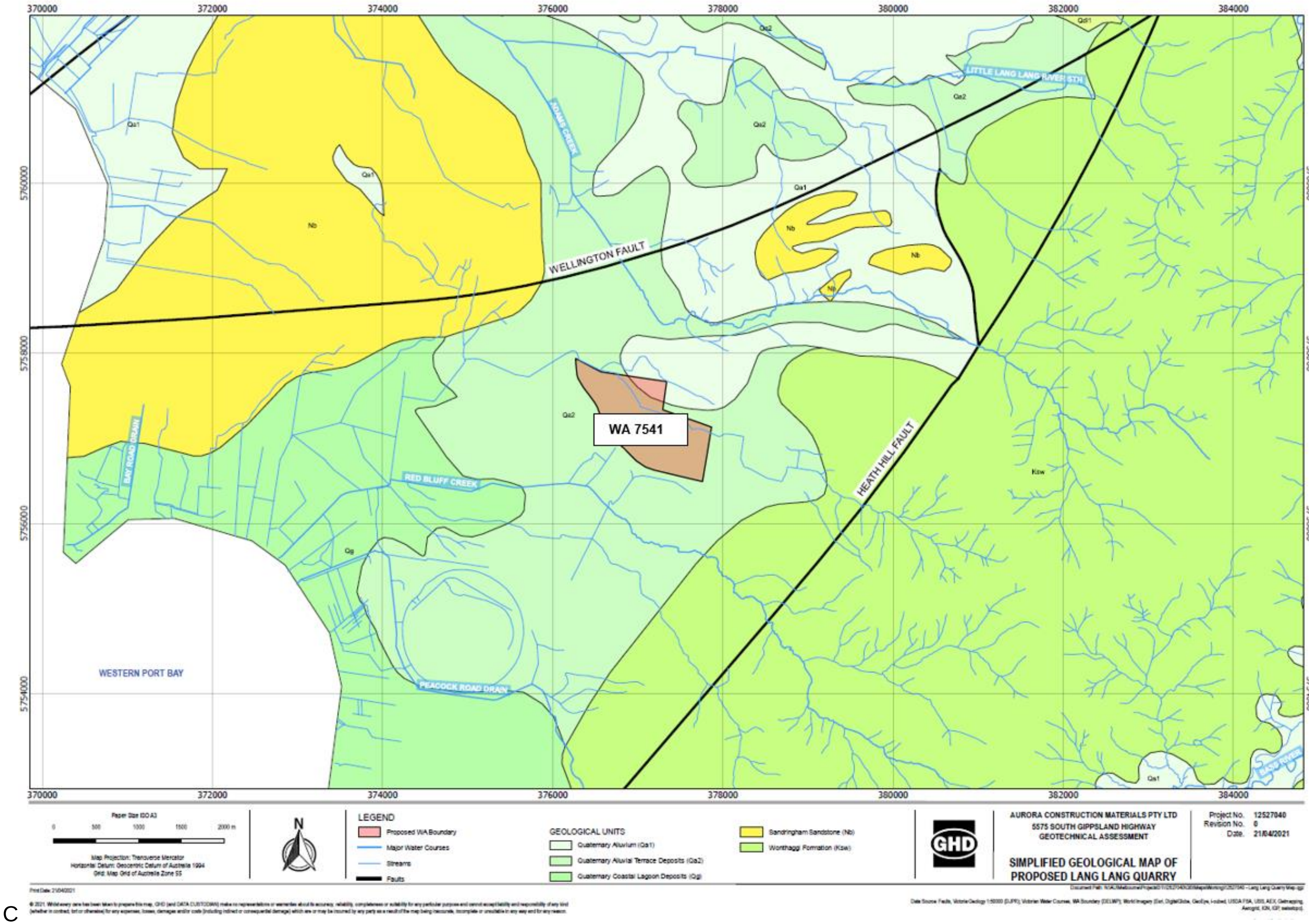
2.2.3 Stratigraphy

The area in the vicinity of the proposed quarry site consists of 3 main stratigraphic units (Figure 5), as follows (from oldest to youngest):

- Wonthaggi Formation (*Ksw*)
- Sandringham Sandstone, formerly known as Brighton Group (*Nb*)
- Unconsolidated Quaternary Deposits (Qg, *Qa2* and *Qa1*)

A geological map of the proposed quarry site and the surrounding region is presented in Figure 5.

ADVERTISED
PLAN



C

Figure 5 Simplified Geological Map of the Lang Lang Region

Wonthaggi Formation (*Ksw*)

The oldest rocks found around the proposed quarry area is the sedimentary Wonthaggi Formation (*Ksw*). The Wonthaggi Formation is part of the Strzelecki Group, which were the first sediments deposited within the Gippsland Basin (Mehin & Bock, 1998). The overall thickness of the Strzelecki Group is at least 3000 m and consists of interbedded non-marine greywackes, mudstones, sandstones, conglomerates, minor coals and volcanics deposited in lacustrine, swamp or floodplain environments (Mehin & Bock, 1998). The Wonthaggi Formation is defined by Welch *et al*. (2011) as a lithic volcaniclastic sandstone, arkose and siltstone, with minor conglomerate and coal. Bryan *et al*. (1997) assigns an age of 129.5 – 100.5 Ma for the Wonthaggi Formation.

Sandringham Sandstone, formerly known as Brighton Group (*Nb*)

The Sandringham Sandstone (*Nb*) is a newly redescribed unit, grouping together the following units: Hanson Plain Sand, Moorabool Viaduct Sands, Baxter Sandstone, Marina Cove Sand, Black Rock Sandstone, Red Bluff Sandstone, Beaumaris Sandstone and the Brighton Group (VandenBerg, 2016).

Within the Port Phillip Bay region, exposures of Neogene sandstone are widely distributed and are often of variable quality (VandenBerg, 2016). Therefore, these exposures have been studied in isolation from each other, resulting in many outcrops being given their own rock unit name. VandenBerg (2016) conducted a re-examination of the various type sections of these units and concluded that all name Neogene units in this region are shallow marine in origin and contain sedimentary structures such as planar bedding and swaley cross-stratification. As such, he interpreted that these units were deposited as a continuous sheet on an extensive strandplain, which has been subsequently eroded into the scattered exposures that we see today. Because of these similarities, VandenBerg (2016) proposes that these late-Neogene sediments be unified under the Sandringham Sandstone name.

In the Lang area, the Sandringham Sandstone is described as a paralic (interbedded marine and non-marine) silt, sand and gravel deposit. The unit is variably calcareous and ferruginised, with sections of limestone (GeoVic, 2014). Elsewhere, the Sandringham Sandstone also exists as sandy silt, fine sandstone, sandy conglomerate to pebbly sandstone and clayey sand. The sandstone also contains carbonaceous bands (with plant fossils), lag deposits, horizontal and swaley cross-lamination, and preserved burrows (VandenBerg, 2016).

The Sandringham Sandstone has been dated as Pliocene to Miocene in age, with a minimum age of 4.6 Ma constrained by the overlying basalts of the Newer Volcanic Group and a maximum age of 5.8 (±0.2) Ma determined by Sr/Sr isotope ratios within mollusc fossils (Hare *et al*., 2005; Wallace *et al*., 2005).

Due to its widespread distribution, the Sandringham Sandstone is overlain by multiple units. In the Lang Lang Lowlands area, the Sandringham Sandstone is overlain by unconsolidated Quaternary sediments.

Unconsolidated Quaternary Deposits (*Qa2, Qa1, Qg*)

The youngest units found within the proposed quarry area are a series of Quaternary aged unconsolidated sediments (GeoVic, 2014). There are two distinct phases of alluvial sedimentation (*Qa2* and *Qa1*) and a series of coastal lagoon deposits (*Qg*). Both phases of alluvial sedimentation are defined as generally unconsolidated, variably sorted silt, sand and gravel, with *Qa2* dissected to form terraces higher than *Qa1* (GeoVic, 2014). The coastal lagoon deposits can be found on the coast of Western Port Bay, to the southwest of the proposed quarry site (GeoVic, 2014). *Qg* consists of variably consolidated, dark grey to black silt and clays.

In this region, these Quaternary sediments directly overlie the Sandringham Sandstone. A stratigraphy column is presented in Figure 10.

2.2.4 Major Structures

A search of the Neotectonic Features Database (Geoscience Australia, 2020) reveals a number of faults within a 10 km radius of the proposed quarry site (Figure 6). The Wellington Fault is the closest, at a distance of approximately 1.8 km to the northwest. This is followed by the Heath Hill Fault, which can be found 2.1 km to the southeast. Other major faults within 10 km of the quarry site are the Lang Lang Fault, the Bass Fault and the Almurta Fault (Geoscience Australia, 2020). The major structure traces are presented in Figure 6.

Wellington Fault

The Wellington Fault is the closest mapped structure to the proposed quarry site, with the closest point approximately 1.8 km away. However, the lack of research on the Wellington Fault results in many questions regarding the nature and characteristics of the Wellington Fault. The 1:250 000 Warragul geological map (VandenBerg, 1997) maps the Wellington Fault as a 15 km long, a E to NE trending structure splaying off the Heath Hill Fault near Lang Lang East, extending offshore into Western Port Bay. The Wellington Fault is not listed as a neotectonic feature (Geoscience Australia, 2020), nor has any recorded earthquake greater than magnitude 3 been attributed to it.

Given the present day stress field of southeast Australia (Rajabi *et al*., 2017), the predominately east trending strike of the Wellington Fault appears unfavourable for ongoing crustal stress relief compared to the more conducive, NE-SW trending Heath Hill Fault. Therefore, the Wellington Fault is unlikely to produce a large earthquake under the current stress regime.

Heath Hill Fault

The Heath Hill Fault is a known fault in the Lang Lang area. The Heath Hill Fault is a NE-SW trending reverse fault represented as a topographical scarp, with the Cretaceous Wonthaggi Formation upthrown relative to the Western Port Sunklands. Geoscience Australia (2020) measures the Heath Hill Fault at 50.3 km, with a location precision of 250 m resulting from small-scale mapping from the 90 m resolution SRTM DEM. It is probable that the Heath Hills Fault has experienced “recent” activity, with the Neogene-aged Haunted Hills Formation displaced across the fault trace, evidence of Pliocene or younger movement.

Lang Lang Fault

The complex Lang Lang Fault is a fault which acts as the northern/western boundary of the Lang Lang Lowlands. The Lang Lang Fault is an approximately 20 km long fault splaying off the Heath Hill Fault just northeast of Heath Hill. The easternmost extent of the Lang Lang Fault has an almost E-W strike, which transitions to NE-SW from around Caldermeade (GeoVic, 2014).

Like the Wellington Fault, the Lang Lang Fault is not listed as a neotectonic feature (Geoscience Australia, 2020). However, topographical analysis of the region show that the Lang Lang Lowlands have been elevated relative to the Western Port Sunklands. Remnants of the Sandringham Sandstone have been preserved on the Lang Lang Lowlands block, in contrast to the purely Quaternary nature of the deposits within the northern sunklands. Therefore, it is likely that the Lang Lang Fault has experienced post-Neogene activity to some degree. However, a combination of the lack of surface expression, the absence of recorded earthquake activity along the fault and the less than optimal orientation of the fault trace suggest that future activity along this fault is unlikely, but not impossible.

Bass Fault/Almurta Fault

The Bass Fault is a NE-SW trending reverse fault located to the east of the Heath Hill Fault. Geoscience Australia (2020) lists the fault as 57.6 km in length, dipping to the southeast. The fault trace is mapped based on its topographic expression, with an estimated vertical displacement across the fault of 45 m. This fault is suggested to be neotectonically active based on displaced Neogene fluvial deposits across the fault scarp. One single earthquake has been recorded in proximity to the Bass Fault, with a magnitude 3.1 recorded in 1987 (discussed further in Section 2.2.5).

The Almurta Fault (located further east) is often considered as continuous with the Bass Fault, however Geoscience Australia (2020) does not consider this to be the case. The 1:250 000 geological map for Warragul (VandenBerg, 1997) also maps these two structures as separate faults.

Other than the fault trace, not much else is known about the Almurta Fault, which is not classified as a neotectonic feature on the Neotectonic Features database (Geoscience Australia, 2020).

2.2.5 Neotectonics

In a search of Geoscience Australia's Earthquakes@GA database (2021), only two earthquakes with a magnitude greater than 3.0 have been recorded in the 10 km surrounding the proposed quarry site (Figure 6). The most recent of those was a magnitude 3.3 which occurred on 20 December 1987, approximately 600 m from the proposed quarry. Another earthquake was recorded on 18 September 1980, this time 8.5 km to the southeast of the proposed site (magnitude 3.1).

Due to the age of these events, the records for these earthquakes are incomprehensive, recording only the time and location, and not attributed to a specific fault. Based on location alone, it is likely that the 1980 event occurred on the Bass Fault, while the 1987 event occurred in between the Wellington Fault and the Heath Hill Fault.

Based on the earthquake record, large earthquakes are uncommon in the area, with a magnitude 5.0 at the mouth of Western Port Bay being the largest recorded in 1971. However, the area remains seismically active in the Australian context, with smaller earthquakes recorded every few years, the majority recorded within the South Gippsland Highlands. Given the present-day stress field of Australia (Rajabi *et al*., 2017) and the strike of the mapped faults in the immediate area, the Heath Hill Fault and the Bass Fault are the most likely faults near the proposed quarry location to experience a future fault rupture.

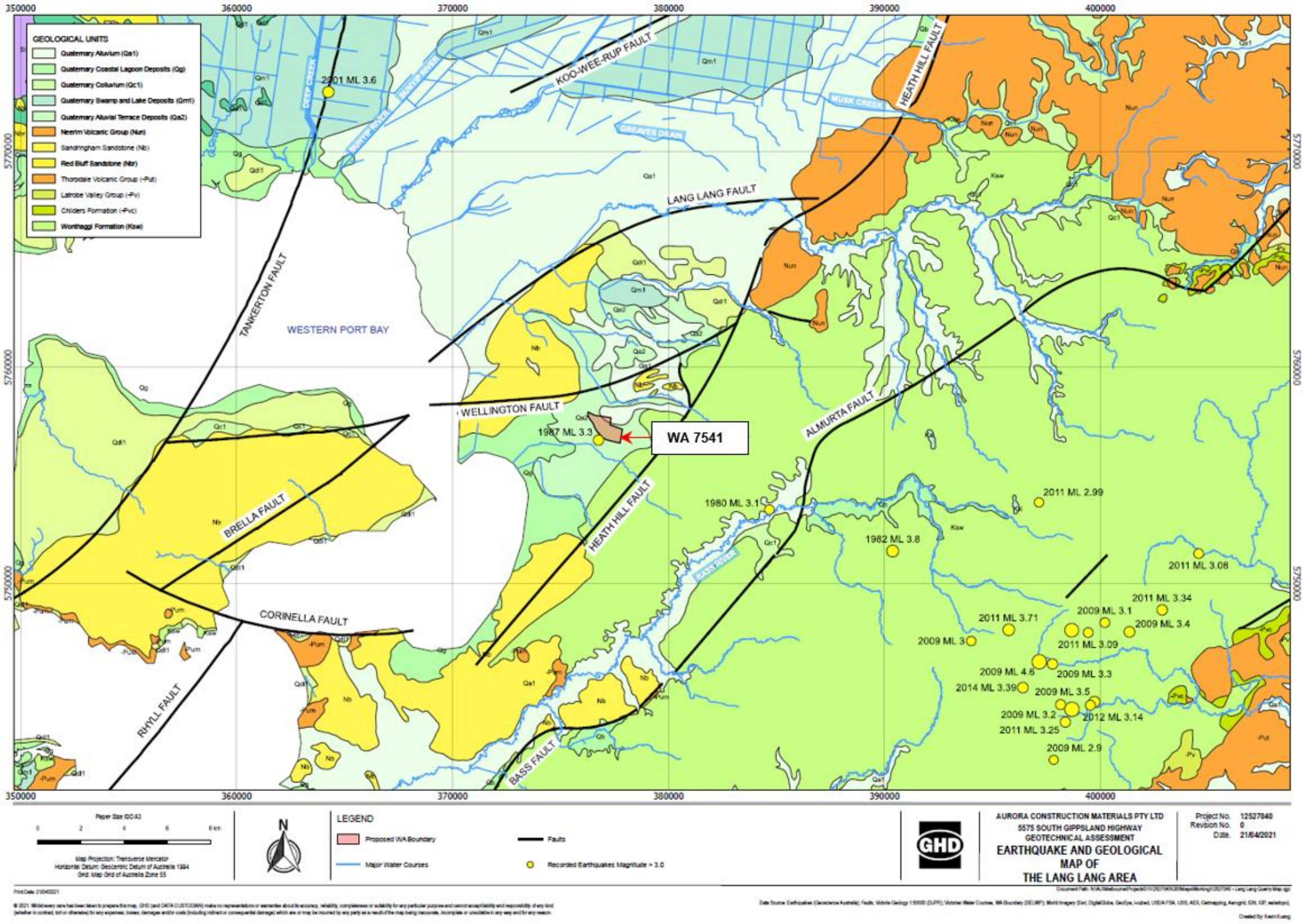


Figure 6 Geological Map of the Lang Lang Area. Earthquakes ≥ Magnitude 3.0 Shown

2.3 Hydrogeology

The groundwater table at WA7541 was interpreted using Visualising Victoria's Groundwater (VVG), a web based software that federates groundwater data from disparate sources. The depth to water table is depicted in Figure 7. It is noted that this depth to groundwater is generally consistent with the information recorded on the provided lithology logs.

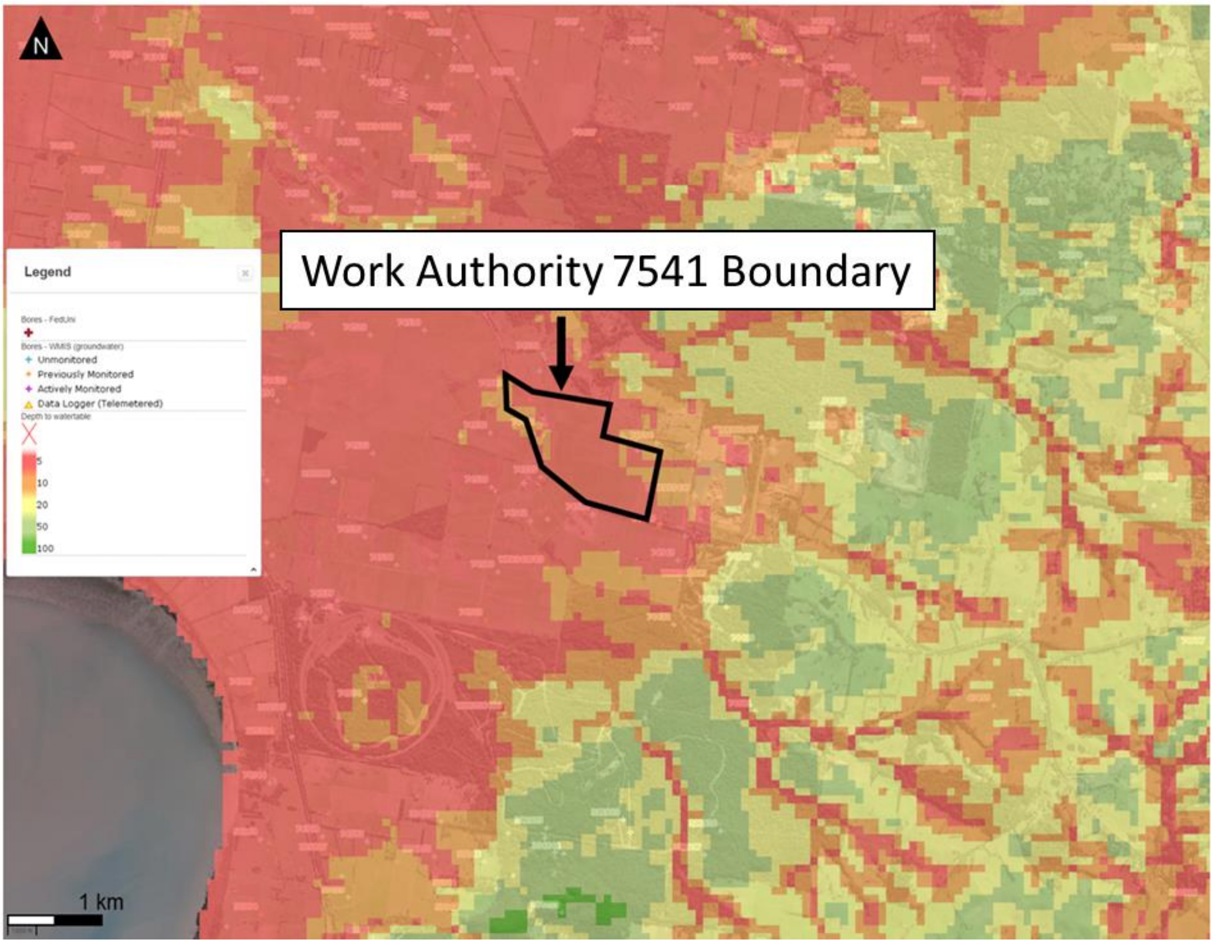


Figure 7 Depth to Groundwater at the WA 7541 Site (VVG, 2021)

3. Proposed Pit Design

3.1 General

Based on the provided information, excavation of the pit will be undertaken using a staged approach (see Figure 8) from east to west. The proposed pit geometry, based on information provided by BCA Consulting and as noted in the GHD proposal is as follows:

- Total depth of extraction is expected to be approximately 30 m below current surface level.
- Working and rehabilitated profiles of 1V:3H (approx. 18°) above groundwater and 1V:2H (approx. 26°) below.
- A 10 m wide beaching bench will be established at the water level.

ADVERTISED PLAN

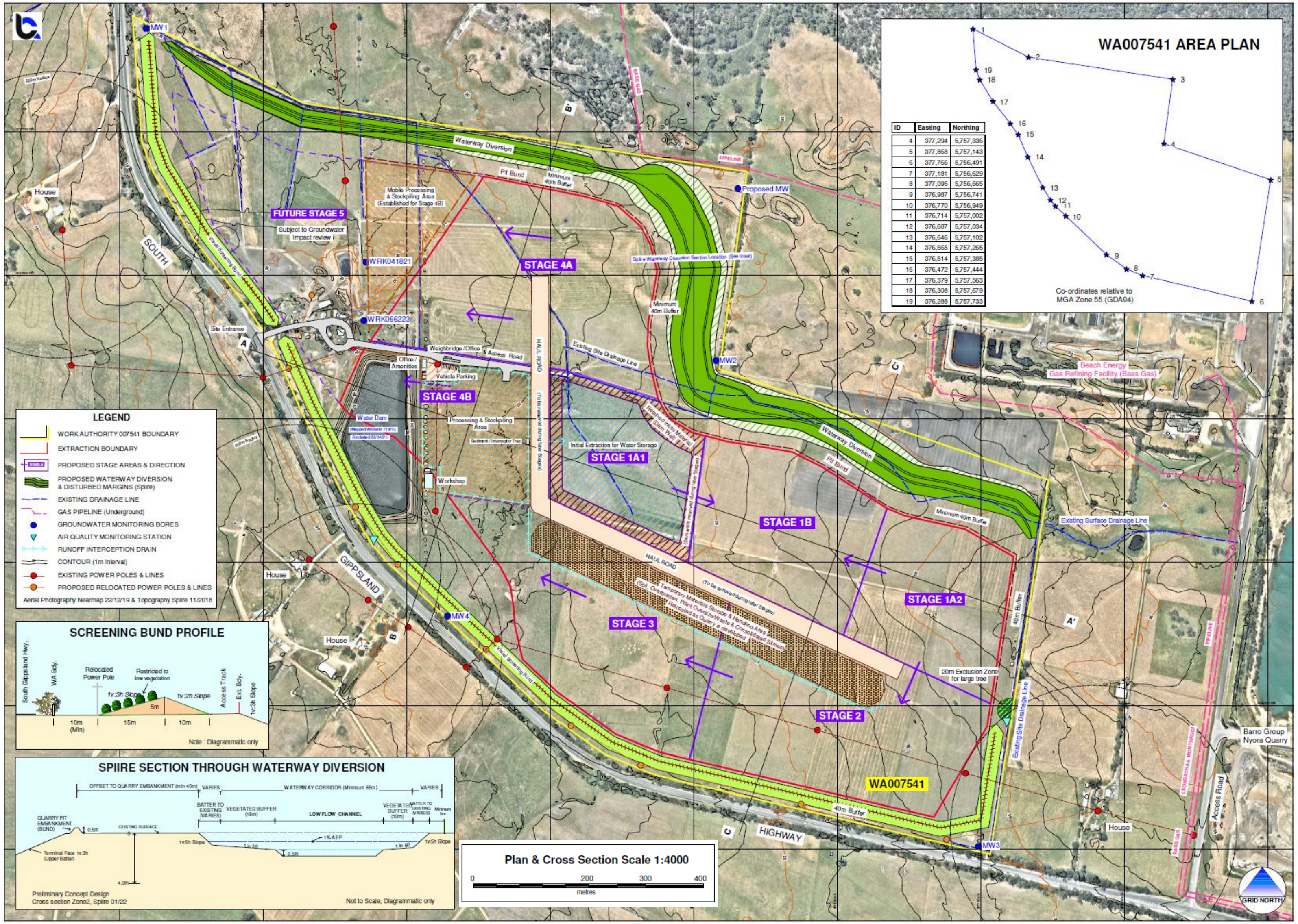


Figure 8 Pit Development Plan (BCA, 2022)

GHD understand that the client is proposing to excavate the resource using a sequenced process, as follows:

1. Removal of overburden material (varies between 2 and 6 m in thickness).
2. Dry extraction above the groundwater table.
3. Mechanical dredging to remove sand resources below the groundwater table.

3.2 Drilling

The Client's resource geologist (i.e., BCA Consulting Pty Ltd) completed a resource drilling campaign in 2013. Based on the provided information, 26 air cored (AC) boreholes were drilling at the site to between 9 m and 54 m depth below ground surface level (bgsl).

Groundwater encountered in the boreholes was recorded on the AC bore logs.

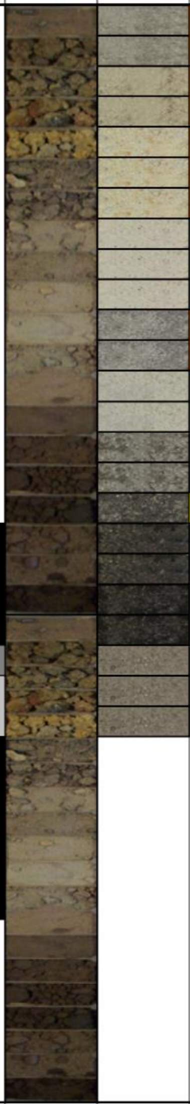
An excerpt from the provided AC bore hole logs is presented in Figure 9. The core log indicates the logged grain size of the coarser units and the percentage of fines within the soil units.

In general, the logs indicate alluvially deposited fine grained soils, overlying interbedded layers of fine to coarse grained sand (i.e., resource) and interburden (i.e. clay, organic material) to air cored hole termination depth.

Air Cored Log

Bore No.	AC13-05		
Client	Aurora	Date Drilled	2/10/2013
Project	Lang Lang	Project No.	A25-005
Logged By	Jason Larocca	Drilled By	Wallis Drilling
Drill Type	Air core	Co-ords	376901E 5757272N
GDA94, MGA Zone 55		Hole Attitude	Vertical
Collar RL	32.7m ( )	Local (Non Earth)	
Hole Size		Hole Depth	36.0m
Collar Confidence	Good	Measured Water Level	

Interval from (m)	Interval to (m)	DOMINANT MATERIAL	MINOR MATERIAL	COLOUR	BULK PROPERTIES	Organic	Silt & Clay	Sand FM	Sand %	Gravel %	Assigned Quality
0.0	4.0	CLAY/SILT	f-m. sand	Md gy	stiff-plastic		50.1	1.34	50	0	OB
				Md yw/or			62.1	0.9	38	0	
4.0	7.0	med SAND	silty, c. sand	Md gy/bn	Cohesive-sl.Cohesive		20.1	1.65	80	0	silty f-m. SD Av FM=1.48 Av S&C=16.3%
7.0	10.0	fine SAND	silty	Pl red/gy			12.6	1.32	87	0	
10.0	12.0	CLAY/SILT		Md gy	stiff-plastic		47.4	1.2	53	0	CLAY-SILT
12.0	17.0	fine SAND	silty	Md gy/bn	Cohesive		14.2	1.39	86	0	silty f. SD Av FM=1.36 Av S&C=14.9%
							14	1.43	86	0	
				Dk bn/blk	stiff-plastic		18.1	1.14	82	0	
17.0	21.0	PEAT	m. sand	Dk bn/blk	sl. Cohesive	High	3.6	1.73	96	0	PEAT
						High	4.7	1.93	94	1	
21.0	24.0	med SAND	peat	Dk bn/gy	loose	Medium / Low	2.6	1.65	97	0	m. SD Av FM=1.65 Av S&C=2.6%
24.0	27.0	PEAT		Dk bn/gy	stiff-plastic	High					PEAT
				Dk bn		High					
27.0	30.0	CLAY		Dk bn		High					CLAY-SILT
30.0	35.0	coarse SAND	f-m. sand	Dk bn	loose						c. SD
35.0	36.0	f-m SAND		Pl gy/wht	loose						



REMARKS / ABREVIATIONS
Data Reliability:- Good

LEGEND ORGANIC CONTENT
- Clean / No Organic Content
- Low Organic Content
- Medium Organic Content
- High Organic Content

Figure 9 Example Air Cored Bore Log (AC13-05)

ADVERTISED PLAN

3.3 Stratigraphic Sequencing

Based on the provided air core logs, the three main stratigraphic units encountered at the site are outlined below:

3.3.1 Unit 1 (Overburden) – Quaternary Alluvial Terrace Deposits (Qa2)

This unit belongs to the Quaternary Alluvial Terrace Deposits (Qa2) and comprises:

> ***Sandy CLAY* (CL – CH)**: *grey and brown, low to high plasticity clay, with fine to coarse grained sand, variable silt content, moist, firm to stiff, encountered natural surface to between 2 and 6 metres depth.*

Based on the provided air core logs, no overburden material was encountered at the northern areas of Stage 2 and 3 development (see Figure 8).

3.3.2 Interbedded Unit 2 (Resource Unit) and Unit 3 (Interburden) – Quaternary Coastal Lagoon Deposits (Qg)

Geological units 2 and 3 are interbedded layers of Quaternary Coastal Lagoon Deposits (Qg). These two units are outlined below

> ***Unit 2: CLAYEY SAND (SC) and SAND (SW) with Clay/Silt****: brown, grey, fine to coarse grained sand, well graded, low to high plasticity clay, variable silt content, moist to wet, loose to medium dense and is encountered from natural surface to between 6 and 30 metres depth.*
>
> *Interbedded with*
>
> ***Unit 3: CLAY (CL – CH) and Sandy CLAY (CL – CH)****: brown, grey, black, low to high plasticity clay, fine to coarse grained sand, trace gravel, variable silt content, some organic material, moist, stiff, layer thickness of up to 5m which separate the overlying and underlying sand resources.*

Based on the provided air core logs, no interburden material was encountered at the northern areas of Stage 2 and 3 development (see Figure 8).

The AC bore logs indicate that groundwater generally occurred at depths of around 5 metres below ground surface level, which is consistent with the data available on the VVG (2021) website.

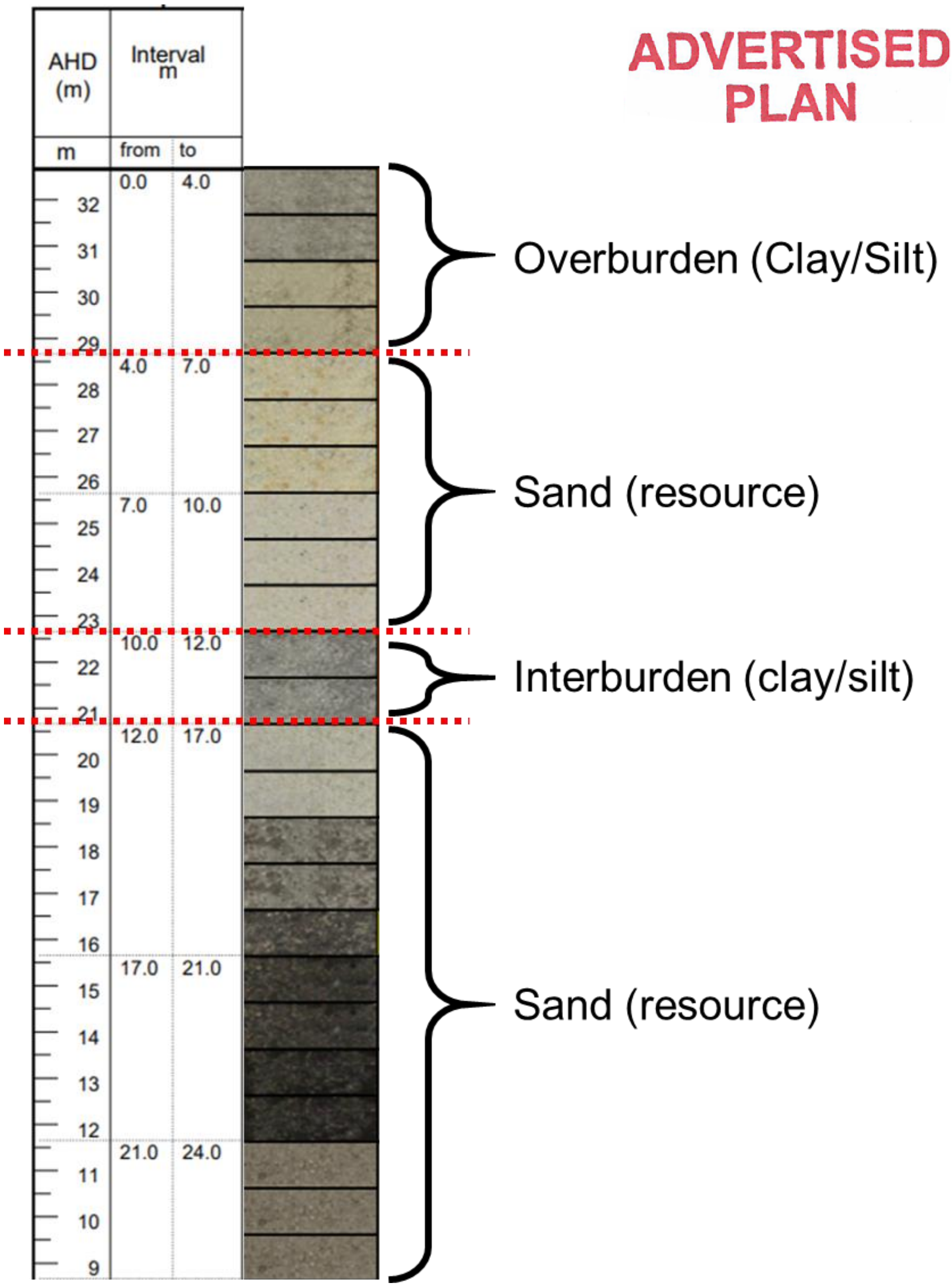


Figure 10 Typical Subsurface Profile at the Site

4. Geotechnical Domains and Models

4.1 Considerations

The geotechnical domain model forms the basis for any quarry pit slope design. The geotechnical domain model facilitates the segregation of a quarry pit into sectors or zones which have similar geological, structural and material property characteristics, thus modes of instability. In principle, the act of geotechnical domaining allows for multiple optimisation techniques to apply, where the slope design is optimised, in terms of safety and economics, for a given sector rather than applying a single slope design across the entire pit. In essence, geotechnical domaining a quarry pit can be used inform quarry owners/operators where to focus their time and effort.

The geotechnical domain model is compiled from four component models:

- Geological model
- Structural model
- Hydrogeological model, and
- Material properties model

Geotechnical domaining of the Client's site has relied upon the philosophy set out by Read and Stacey (2009). Outlined in the Figure 11 are the considerations that are taken into account when formulating site specific geotechnical domains.

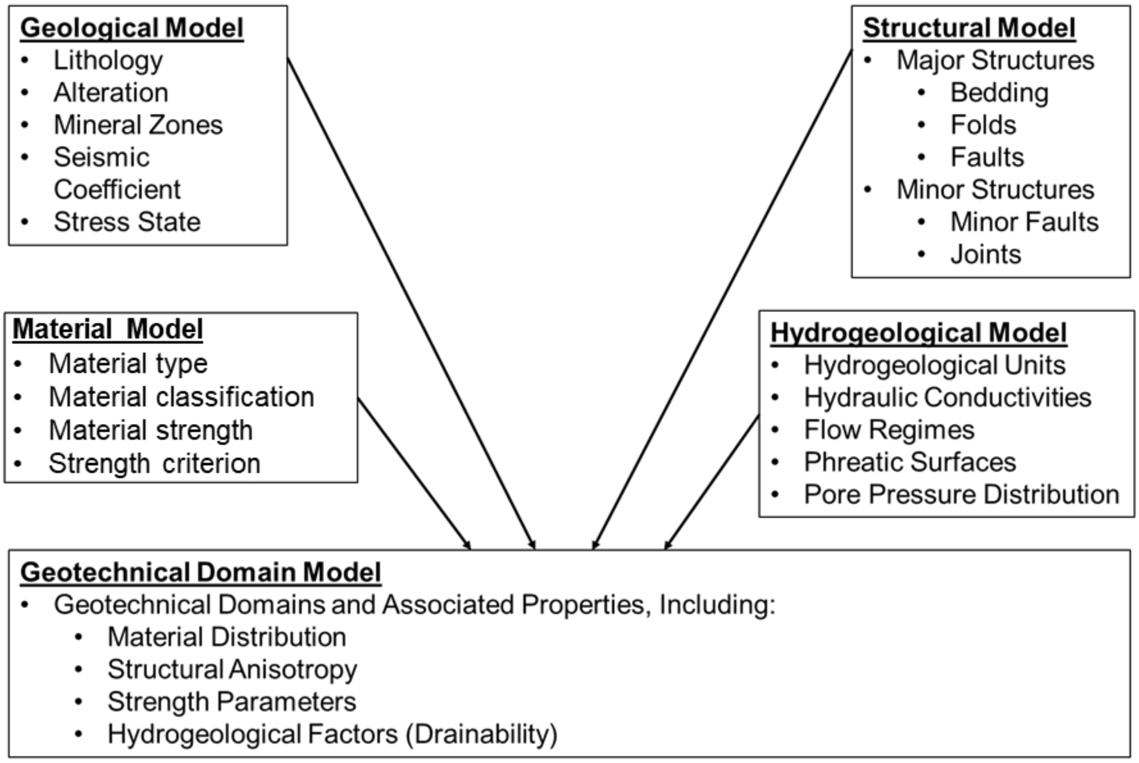


Figure 11 Development of Geotechnical Domain Model after Read and Stacey (2009)

4.2 Anticipated Pit Slope Instability Mechanisms

Based on the geological information presented above, and our understanding of the Lang Lang region, it is possible to interpret potential critical slope instability (failure) mechanisms that need to be analysed and catered for as part of the slope design process. The scale and mode of anticipated instabilities form a crucial component of the geotechnical domaining process.

This section outlines the mechanics involved with the instability mechanisms identified at the proposed quarry site.

4.2.1 Circular Failure (Primary Mechanism)

The primary instability mechanism identified for the proposed quarry is circular failure, which typically occurs in soil materials such as the overburden, sand resources and likely within the interburden material present at the site (see Figure 12). This instability mechanism can also result in stockpiled material.

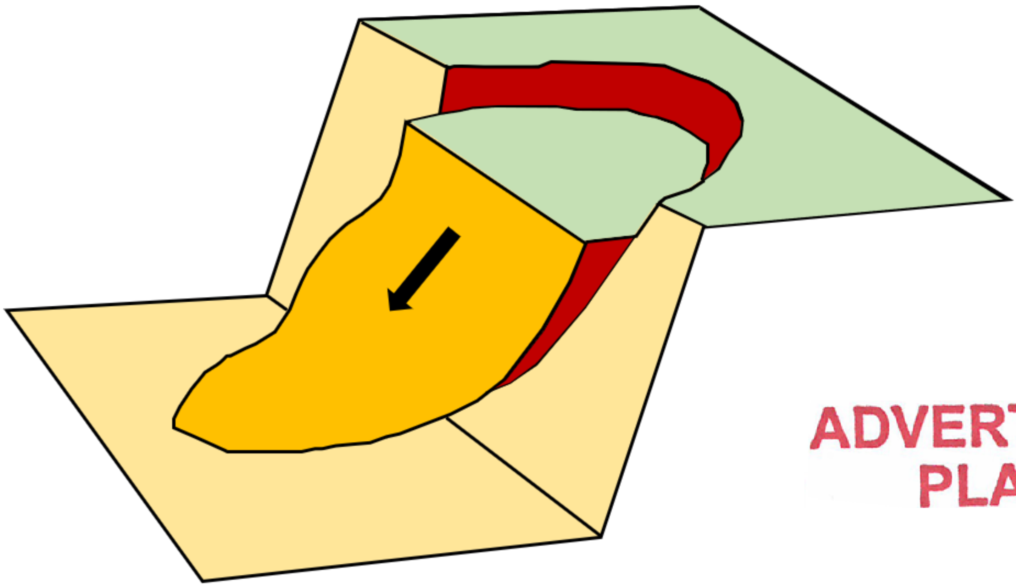


Figure 12 Schematic of a Circular Failure

Circular failure is dependent upon the shear strength characteristics of the soil materials (e.g., sand resources), the slope angle of the cut face and the phreatic conditions within the soil materials.

Circular failure occurring as a potential failure mechanism has been identified primarily for the overburden and resource units at the site. This failure mechanism is not considered to pose any significant risk, providing adequate surface water management measures are coupled with a suitable pit geometry.

A typical subsurface profile of the proposed development is shown below in Figure 16. Cohesive soils (i.e., clays and silts) overly mostly sand resources, with discontinuous and relatively thin layers of interburden (i.e., clays and silts).

4.3 Erosion and Piping (Secondary Mechanism)

Erosion of exposed batters has been identified as a secondary instability mechanism which can result as slumping and / or sloughing of operating, terminal or rehabilitated quarry batter faces and any (temporary) stockpiled materials. These potential instabilities can occur due to:

- The presence of highly disturbed material

- Weak planes encountered during excavation of sand resources
- Improper surface water and groundwater management
- Inappropriate construction geometry.

Figure 13 Example of Erosion of Exposed Sand Batters at Nearby Quarry

Piping can occur as water infiltration or perched water may drain via weak zones in the in-situ materials causing the soil to wash out and undercut overlying batters. This can potentially lead to batter instability if not suitably managed. Based on the encountered materials, it is likely that the primary mechanism of failure is circular failure. Circular failure can also result, particularly where the standing groundwater level interfaces with the exposed sand batters above pond level. Undercutting of the base/foundation could potentially increase the likelihood of circular failure of the overlying batter slope. This instability mechanism can be managed with suitable batter design (including offset from base of slope) and surface water management. The secondary mechanism of potential instability can occur from erosion of exposed batters, as the initiation of instabilities within exposed soil units are usually governed by build of pore water pressures as a result of uncontrolled / excessive surface water ingress. This can lead to a decrease in material strength and eventuate as slumping and / or sloughing of batters.

4.4 Variations to Groundwater Conditions

Variations to the groundwater conditions behind excavated batters can notably impact the slope stability performance, where nearby dewatering activities (e.g., at surrounding quarry sites) may lead to a decrease in the groundwater level and therefore reduce the stability performance of excavated slope faces, particularly for steeper batters).

4.5 Interpretation of Material Strength Properties

GHD has performed a number of geotechnical assessments, including site inspection and mapping campaigns, throughout a number of quarries in the Lang Lang and Nyora areas. This has included visual classification of site soils, performance measurements i.e., stable batter and slope angles, observations and measurements of stockpiled materials (i.e.,typically the angle of repose of material) and geological mapping of structures (where relevant).

With the benefit of these verified empirical observations of stability conditions and site borehole logs, GHD has enhanced its understanding of the geological and geotechnical conditions in the Lang Lang and Nyora extractives areas and improved the level of geotechnical confidence for those sites. GHD has also been involved in undertaking geotechnical reviews of operating conditions at the nearby sites (i.e., subsequent to commencement of quarrying), with the intent of assessing slope stability conditions and utilising visual observations and measurements to verify design assumptions. These can assist with updating design parameters, which are typically documented in a site Ground Control Management Plan.

As has been undertaken for the nearby quarries, GHD has relied upon published geological information and its growing understanding of this area of Victoria, to determine suitable material strength parameters for use in slope stability modelling for this site. When considering a greenfield site which is to be formed in a locality of known geological conditions, whereby the variability or the lack thereof is well understood, a suitable approach entails making prudently conservative interpretations of material strengths to facilitate stability analyses and appropriate sensitivity calculations.

As outlined above, three main stratigraphic units are present within the proposed quarry footprint, which are categorised according to soil type. The material strength parameters, as assessed by GHD (2022), are based on our experience with similar materials in this area of Victoria and our understanding of batter stability conditions at nearby quarry sites. It is noted that the resource and interburden units comprise variable cohesive material content and as such, a range in typical effective strengths has been outlined in Table 1, which is based on the batter stability observations including measurements of stable batter profile, slope analyses and follow-up geotechnical reviews performed for proximate sand quarries.

For the proposed 5575 South Gippsland Highway quarry, GHD is of the opinion that suitable and appropriate geotechnical information is available to reasonably undertake slope stability modelling. Accordingly, GHD considers that the material parameters (including Mohr-Coulomb strength parameters) in Table 1 are suitable for use in slope stability calculations.

4.5.1 Material Strength Variability

As noted above and for conservatism, GHD has adopted the lower bound strengths for the analyses. Accordingly, the results presented in this report are considered to be conservative. Table 1 outlines and Figure 14 and Figure 15 depict the material strengths assessed for the site. Figure 15 also presents typical friction angles for sand, sandy gravels and silty sand (after Terzaghi and Peck, 1967).

Table 1 Summary of Mohr Coulomb Parameters

Unit	Description	Unit Weight (kN/m^3)	Cohesion, c' (kPa)	Friction Angle, ϕ' (°)
1	Overburden	19.0	20 – 25	26 – 28
2	Sand (resource)	18.0	3 – 5	32 – 34
3	Interburden	18.0	5 – 10	25 – 30

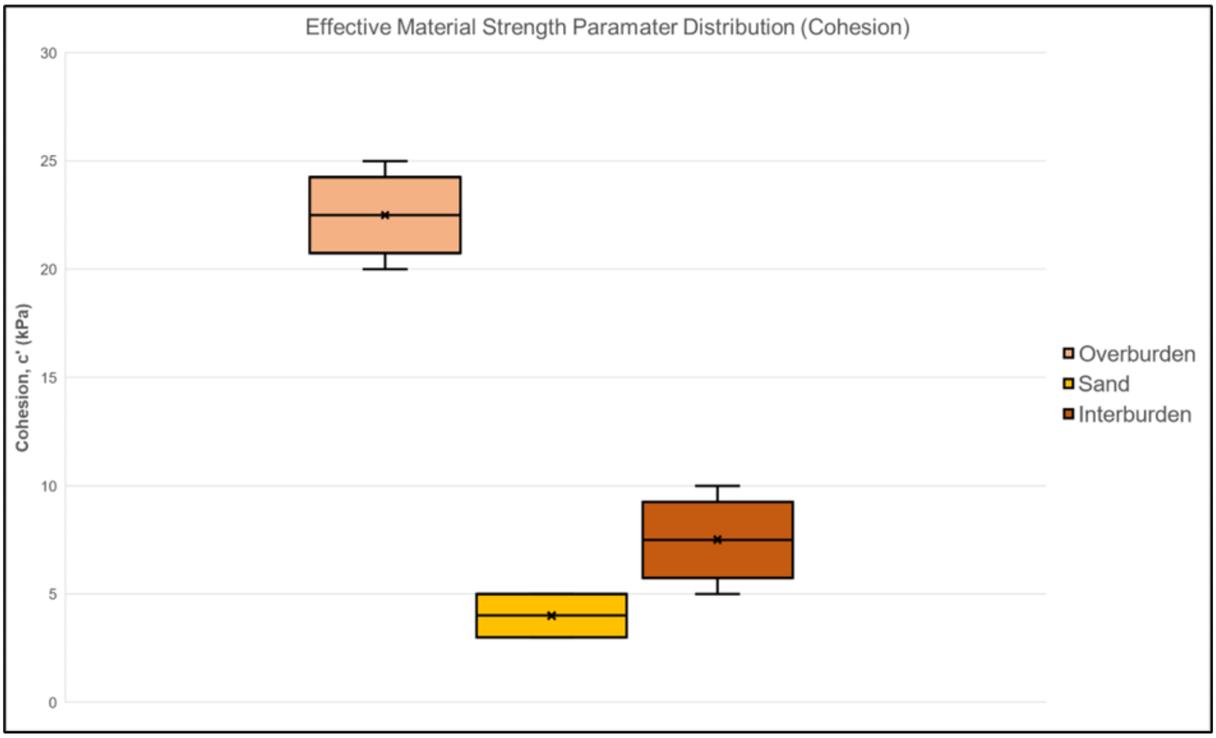


Figure 14 Summary of Effective Strength Distribution (Cohesion)

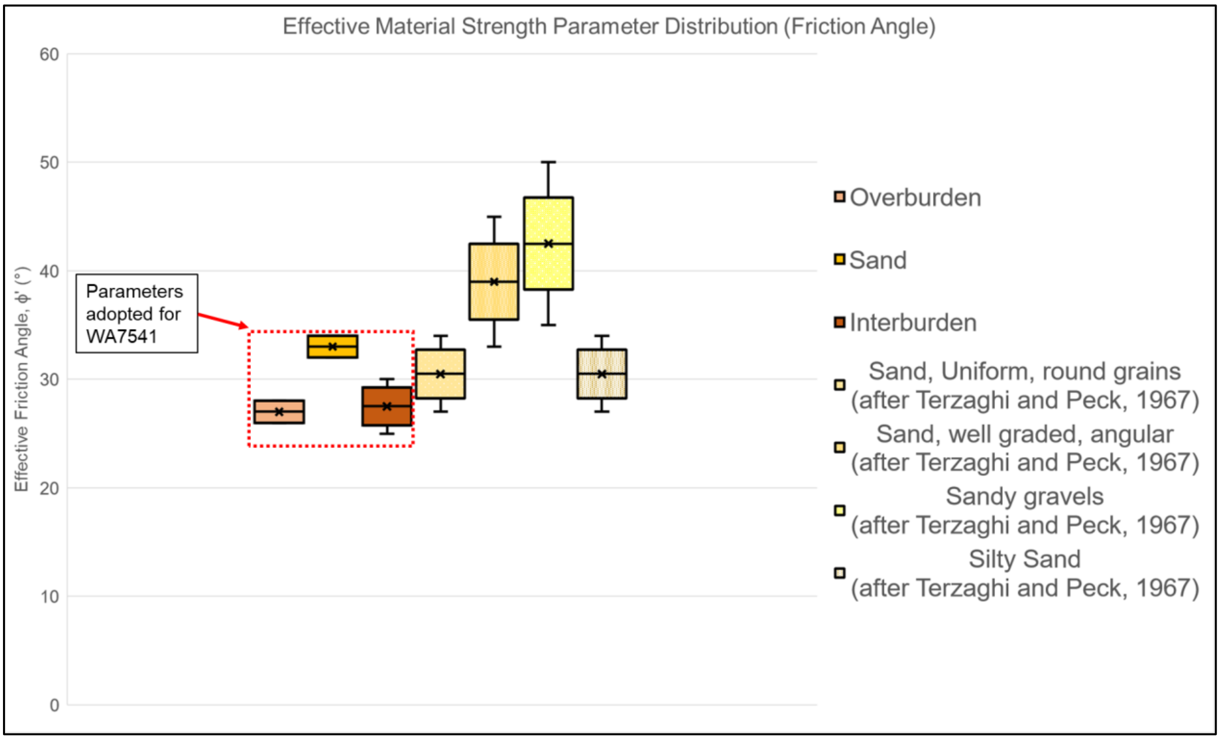


Figure 15 Summary of Effective Strength Distribution (Friction Angle)

As depicted in Figure 15, GHD notes that the material strength parameters adopted for WA7541 are conservative (lower bound) in comparison to the spectrum of typical friction angles (after Terzaghi and Peck, 1967).

4.6 Summary of Anticipated Failure Mechanisms

Table 2 Summary of Anticipated Instability Mechanisms at the Site

Anticipated Instability Mechanisms Present
Primary (Critical) Mechanism – Circular Failure
Instability controlled primarily by shear strength characteristics of the soil materials, the slope angle of the cut face and phreatic conditions within the soil materials.
Secondary Mechanism – Erosion and Piping
Slumping and / or sloughing of any operating, terminal or remediated quarry batter faces and any (temporary) stockpiles, where applicable. This mechanism can lead to the instability of overlying batters if not suitably managed.

5. Stability Assessment

5.1 Overview

Two-dimension Limit-equilibrium stability analyses have been undertaken using Rocscience's Slide 2018 modelling software to determine:

- The stability performance of the proposed design geometry for:
  - Overall slope
  - Localised slope below standing GW level.
- A suitable stand-off distance between the crest of the below water table batter and mobile plant (e.g., a mechanical dredging grab crane).

The process adopted by GHD to develop the geological model is outlined below in sequential order.

1. A review of the provided AC bore logs was undertaken to determine the geotechnical significance of the encountered soil units to batter stability with regards to the proposed pit design.
2. From the above, interpretations were undertaken to group similar geological units (e.g., sand) based on geotechnical significance, i.e., the resource sand layers were grouped together irrespective of the grain size of the unit.
3. Borehole location, material type (i.e., based on the grouped lithological units), layer thicknesses and depths and depth to groundwater table were recorded in a database.
4. This database was imported into Maptek's Vulcan software to spatially visualise and represent:

   i) the location of each bore

   ii) the grouped stratigraphy encountered at each bore location relative to the collar RL

   iii) The depth to groundwater across the site, to enable comparison against the VVG groundwater database.
5. Interpolations were made to link the 'floor' and 'roof' of the respective grouped units in a AC bore hole with the 'floor' and 'roof' of the same unit in a laterally adjacent borehole. This process was undertaken for all bores across the site, with the aim of creating a 3D surface to represent the interface of the overburden with the underlying sand resource or the sand resource and interburden interface etc.

6. Following this, the 3D subsurface model (i.e., showing the layers of the grouped units) was interrogated to identify critical geometry (i.e., strata dip) across the site, particularly in proximity to external receptors such as Bass Gas and the South Gippsland Highway.
7. Vulcan software was used to create an alignment, A-A' (see Figure 16), to then extract the 2D subsurface geometry.
8. The proposed pit geometry was overlain over the 2D subsurface profile (including groundwater) to create a section representing a 'cut' batter (Figure 17) upon which subsequent stability analyses could be undertaken.
9. A check was performed to identify the location of critical subsurface conditions (i.e. strata dip, material strengths) along alignment A-A' with due consideration of the location of external receptors.
10. The section identified as being most critical was a multi layered 2D subsurface profile (vs a single layer, e.g., sand) as depicted in Figure 17, which corresponds to a critical section perpendicular to the highway.

5.2 Material Strengths

Slope stability analyses were carried out for on nominated design sections based on geometry of the stratigraphy and thicknesses of the respective units. Material strength properties outlined in Section (4.5) were used as the strength input parameters in the slope stability models.

5.3 Design Acceptance Criteria

5.3.1 General

The nomination of suitable acceptance criteria is a key part of the design and development of stability management protocols. The basis of nomination of suitable acceptance criteria, will need to demonstrate that the deterministic Factor of Safety (FoS) for a particular batter is acceptable in light of the scale and potential instability and the associated consequences posed by it.

The design acceptance criteria (DAC) adopted for this assessment was sourced from DJPR's (2020) *Geotechnical guideline for terminal and rehabilitated slopes* for the extractives industry projects.

5.3.2 Data Uncertainty

In the context of quarry operations, data uncertainty arises from the challenges encountered when attempting to quantify the variability in properties and characteristics of the insitu materials (soil) that forms the proposed quarry batters. The uncertainty associated with the materials can be broadly categorised under three categories, which are: geological uncertainty, material strength parameter uncertainty and model (geometry) uncertainty.

In the context of most quarries, it is not uncommon for some level of data uncertainty to exist. Based on our understanding of the Lang Lang region and from the learnings of geotechnical inspections undertaken at nearby quarries, it is considered that the risk(s) associated with geotechnical data uncertainty is 'low'.

5.3.3 Nominated Design Acceptance Criteria

In nominating the design acceptance criteria for the proposed quarry and in line with the guidelines set out by DJPR (2020), consideration has been given to the data uncertainty associated with the respective geological units as well as the risk associated with potential instability.

Based on above outlined aspects, and in light of the anticipated risk of instability within the confines of the site, the following design acceptance criteria has been nominated:

- A Factor of Safety (FoS) of 2.0 is proposed for all Rehabilitated batters.
- A Factor of Safety for 1.6 is proposed for Terminal batters.
- A Factor of Safety of 1.3 is proposed for Operating batters.
- A Factor of Safety of 1.1 for seismic conditions.

5.4 Nominated Stability Section

A critical stability section (section A-A') of the proposed quarry pit has been selected for stability analyses. Figure 16 below depicts the relative cross section in relation to the proposed quarry pit. The basis of nomination was as follows:

- Subsurface conditions – The section intersects where the interbedded units are most prominent across the site (i.e., at the south-west of the quarry pit).
- External receptors – The site is bounded to the west and south by the South Gippsland Highway, Bass Gas to the north east. The section alignment is perpendicular to the highway and intersects through the proposed noise/screening bund. This section alignment was nominated to assess the potential stability implications associated with the excavation of resource sand in proximity to these features.

5.5 Slope Stability Analyses

5.5.1 Effective Slope Formation at WA7541

Owing to the mechanical properties of the soil anticipated within the sand pit excavations at the site and broadly, the insitu subsurface conditions, suitable mechanical excavation techniques to form appropriate slope angles will be essential. The slope geometry proposed is outlined in Section 3.1 and depicted in Figure 16 and Figure 17 below. A 30 m high excavation is proposed for the development. It is noted that Figure 15 presents a possible design batter geometry for an excavation on the western portion of alignment A-A' (i.e., near the highway and the noise/screening bund).

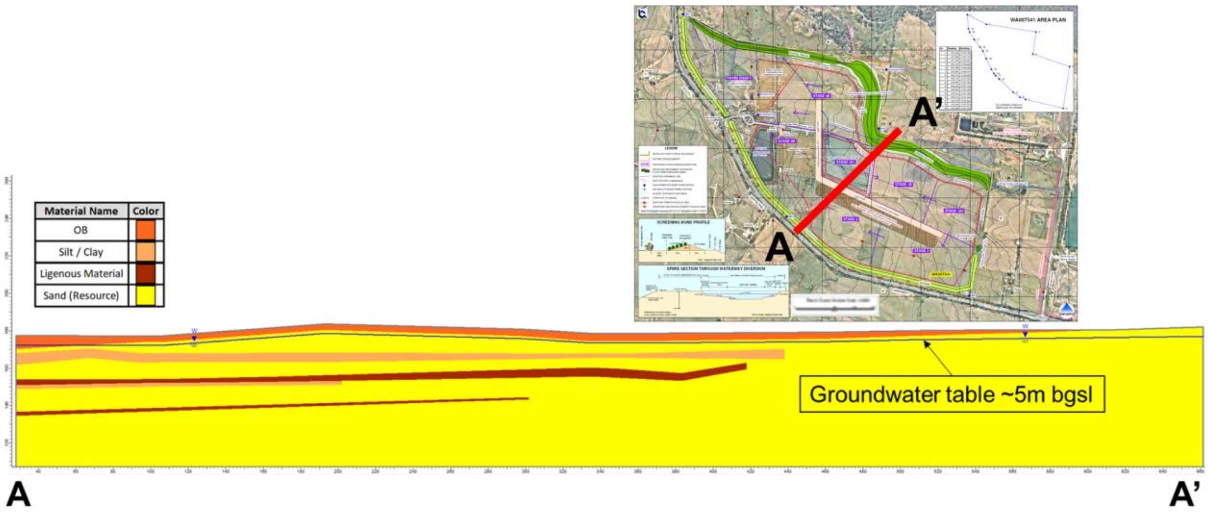


Figure 16 Subsurface Section Alignment A-A’

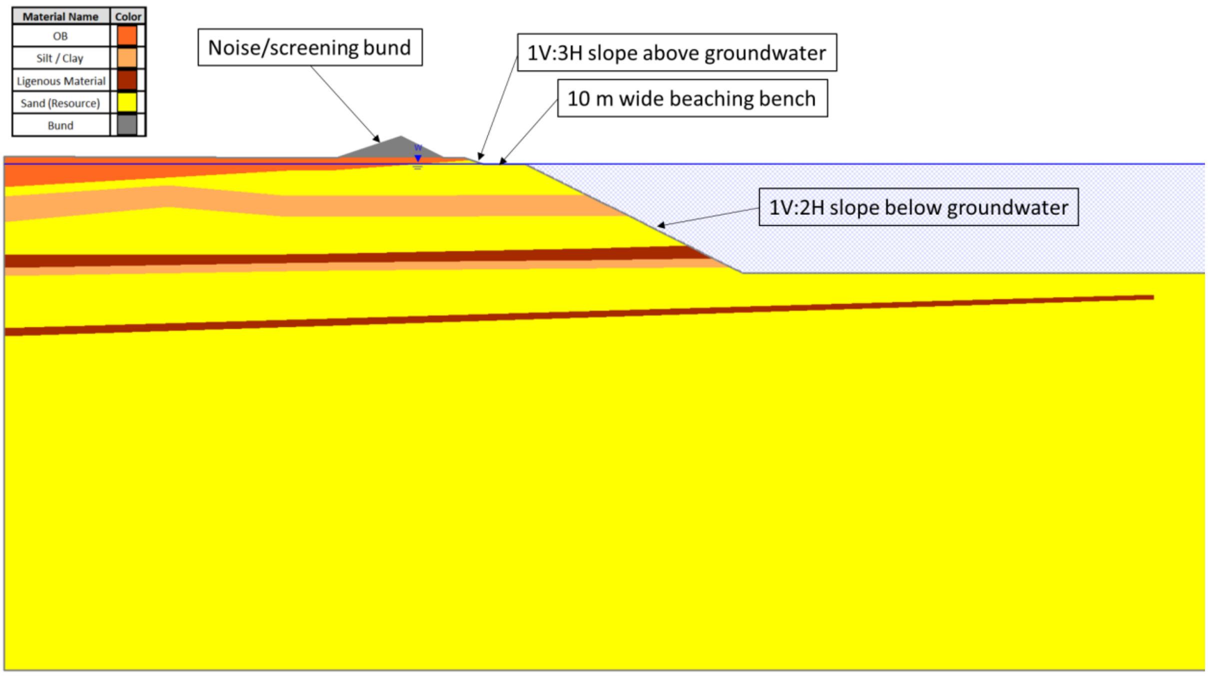


Figure 17 Section A-A’ – Proposed Pit Geometry

5.5.2 Overall Slope Analysis

Based on the proposed pit geometry, as outlined in Section 3.1, a stability assessment was undertaken on the nominated stability section. Based on the proposed design, a 30 m pit profile was assessed in this analysis. A groundwater table at approximately 5 metres below ground surface level (bgsl) was adopted based on the groundwater conditions as presented in the VVG database (2021) and the AC bore logs. The result of the stability analysis is depicted and tabulated in Figure 18 to Figure 19 and Table 3 respectively. The results presented in Figure 18 to Figure 19 indicate the minimum stand-off distance for a circular instability with a factor of safety (FoS) of 1.6 and 2.0 for the terminal and rehabilitated geometry, respectively.

Table 3 Summary of Slope Stability Analysis Results – Terminal Geometry

Stability Section	Factor of Safety	
	Terminal Slope	Rehabilitated Slope
A-A'	1.60	2.0

ADVERTISED PLAN

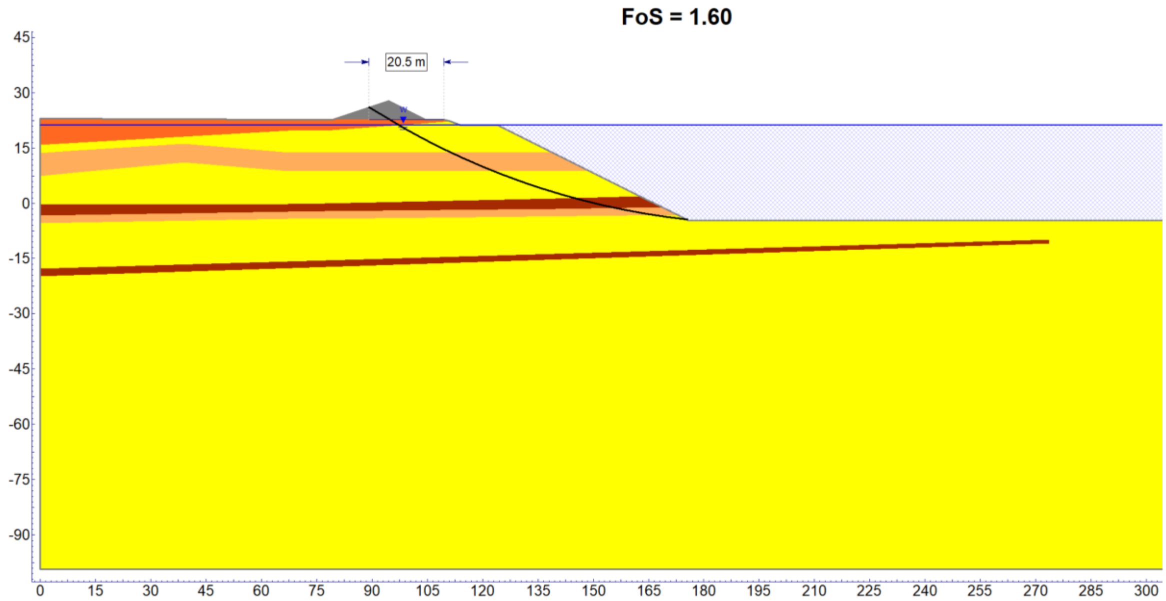


Figure 18 Section A-A' – FoS = 1.6 – Overall Slope Stability for Terminal Geometry

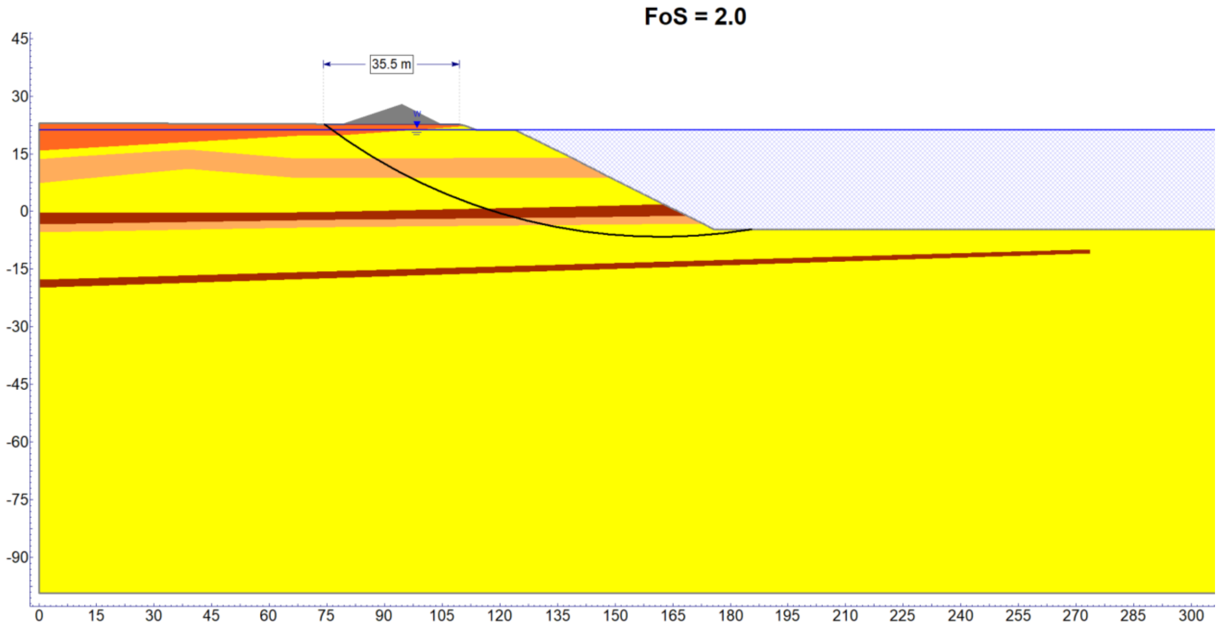


Figure 19 Section A-A' – FoS = 2.0 – Overall Slope Stability for Rehabilitation Geometry

The results of the stability analyses, which consider the presence of the noise/screening bund, indicate:

- An offset distance of approximately 20.5 m is required to achieve the nominated DAC for terminal batters (FoS > 1.6).
- For the rehabilitated DAC to be achieved (i.e., FoS > 2.0), a minimum offset distance of about 35.5 m is required. GHD understands that the eastern extraction boundary is 40 m from the Work Plan boundary, accordingly, it is unlikely for potential large scale instability to impact beyond the WA boundary.
- The minimum buffer distance of 40 m from the proposed re-alignment of the waterway, is satisfied.
- Considering the pit slope geometry including the noise/screening bund, a minimum stand-off distance of 20.5 m and 35.5 m is required to achieve the terminal and rehabilitated batter DAC, respectively.
- The above results are based on the conservative strengths (lower bound) adopted for the assessment. It should be appreciated that based on the higher strengths (i.e., cohesion), the required stand-off distances are likely to be lesser than those outlined above.
- To improve the level of geotechnical understanding of the site once quarrying has commenced, geotechnical inspections of excavated batters can be undertaken to assess stability performance and subsequently verify/refine the material characteristics.

5.6 Stability of Underwater Extraction Area

Quarrying the sand below groundwater level is proposed to be undertaken using mechanical dredging (i.e., dragline, grab crane or floating dredge). Accordingly, it should be appreciated that the proposed crane load on the beaching zone bench adds a driving force which can have an adverse impact of slope stability, specifically for the underlying batters. In the case of the proposed excavation methodology, this would impact the submerged batters. Accordingly, GHD has undertaken an analysis of the minimum stand-off distance from the crest of the beaching bench, to the nearest crawler of the crane dredge. This is presented in Section 5.6.1 below.

Whilst the crane provides a driving force, it should be noted that excavations below the waterline will always have the reinforcing effect of the quarry lake forces providing a 'counterweight' to the submerged batters. However, owing to this phenomenon there will not be a need or indeed practical basis for forming a profiled slope below the waterline. Any instability below the waterline would manifest as a surficial shear / slump at the water line interface, it will therefore be important to carefully manage this interface to ensure that it does not inadvertently undercut the 'dry' slopes above. Outlined in this section are the nominated considerations / approaches to mitigate this occurrence.

Where 'soft' ground conditions are encountered at the waterline interface a suitably qualified person should inspect the area to ensure geotechnical stability related risks are minimised. Any plant (fixed or mobile) should be located at a safe standoff distance from the crest of the interface. A field bearing capacity assessment, using dynamic cone penetrometers should be undertaken within these locations, prior to undertaking any underwater excavation.

Measures should be undertaken to operate and maintain suitably robust ground conditions at the water line interface, so as to ensure that the material beneath dry slopes are not undermined. A bearing capacity assessment should be undertaken based on the loading of the excavator proposed for extraction. Accordingly, any proposed extraction stockpiles, pads or fixed / mobile equipment should be designed to meet these requirements. Exceeding these requirements may lead to circular failure of the underlying Sand and subsequent affect the stability of the dry batters above.

Dredging should be undertaken at a safe distance from the toe of the waterline interface on which any plant or infrastructure maybe located on to ensure that this zone is not compromised from excavation of the resource.

Additionally, any stockpiling of the excavated / washed material should be undertaken at a safe standoff distance from the crest of the underwater excavation to ensure it is not adversely affected by the stockpile or from leached water. Ongoing assessments should be undertaken to determine the safe offset require for stockpiling operations.

A suitably designed surface drainage system should be implemented and maintained to prevent water from ponding in and around the toe of the dry batter above the waterline. Saturation of the toe of the dry batters may lead to a loss of strength of the pad and any associated stability risks. Regular inspections and engineering control should be undertaken and implemented in order to minimise the risk of instability of the pad, prior to and during excavation.

5.6.1 Crane Loading – Minimum Off-Set Distance

A stability assessment was undertaken to assess the minimum beaching bench width required during dredging to maintain stability of the underlying slope during excavation. For this assessment, based on the possible option of utilising a grab crane for excavation below water level, a potential load from a grab crane has been modelled. Conservatively, the loading from the grab crane has been modelled as a point load equal to 84 kN. A schematic of the loading conditions assessed in this analysis is depicted in Figure 20 below. It is noted that should a different crane be utilised, the results of this assessments would need to be updated.

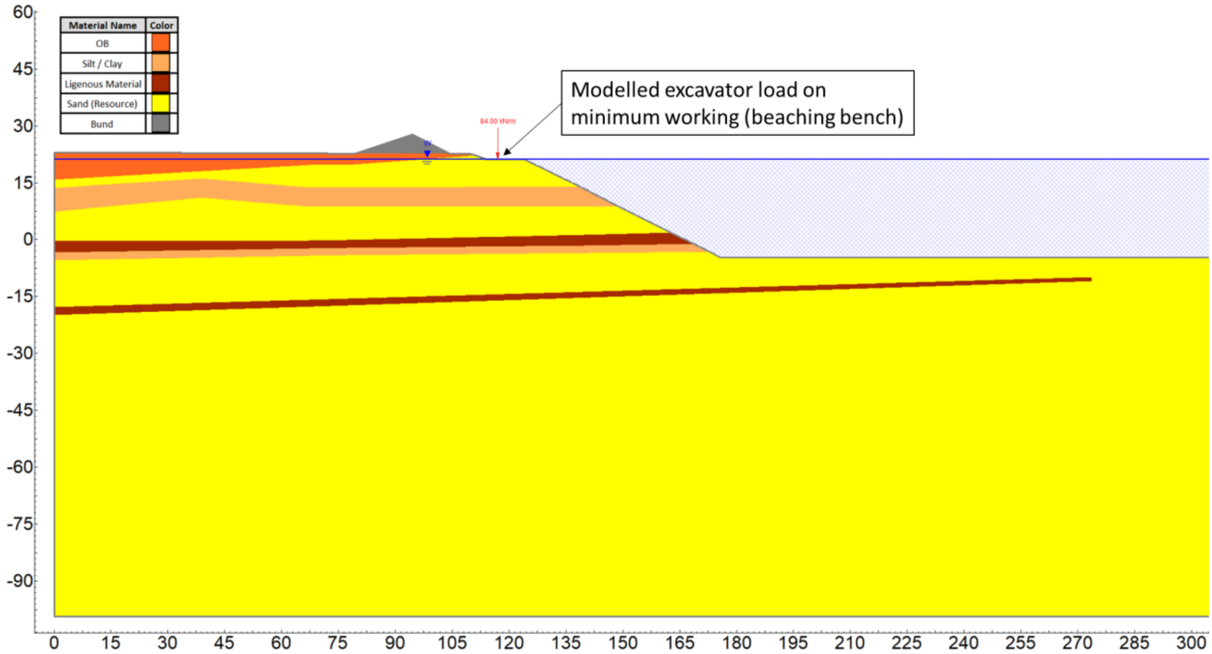


Figure 20 Schematic of Pit Geometry During Dredging

Figure 21 presents the results of the stability analyses undertaken to determine the minimum offset distance required from the crest to the nearest crawler. Based on the DAC adopted, a minimum FoS of 1.3 is required for the operating batters.

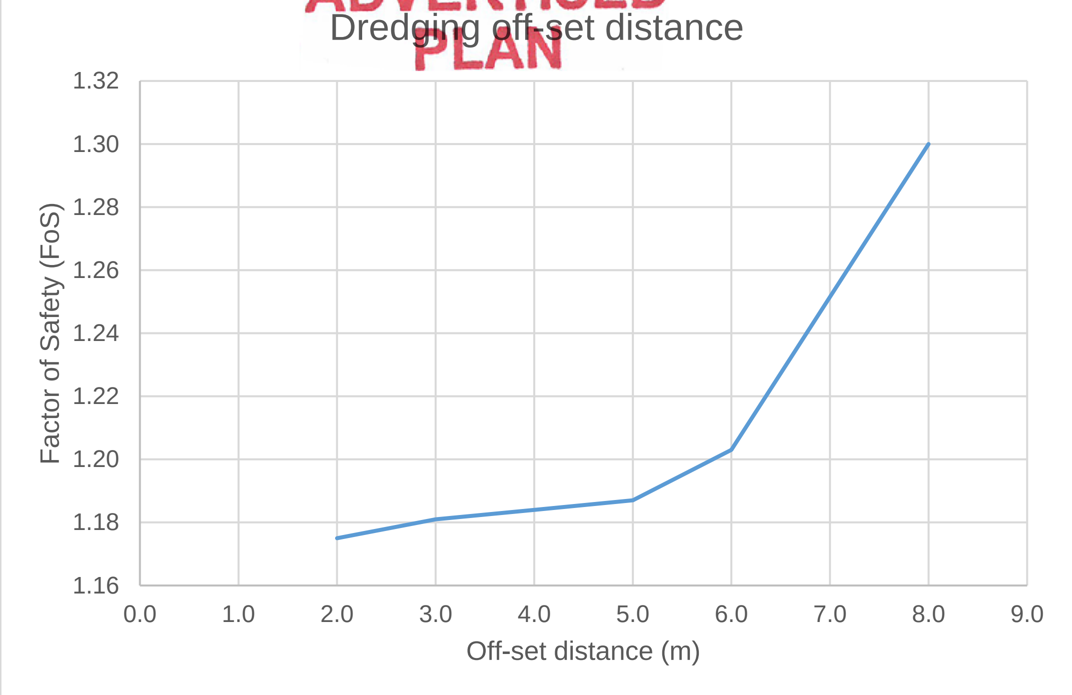


Figure 21 Crane Offset Distance

The results presented in Figure 21 indicate that a minimum offset distance of between 6 and 8 m from the crest is required to achieve the minimum operational FoS of between 1.2 to 1.3, respectively. It is considered that based on the duration of loading (e.g., short term: sustained crane loading for a duration of 1 month; a FoS of 1.2 can be adopted). This is depicted in Figure 22 for a FoS 1.3.

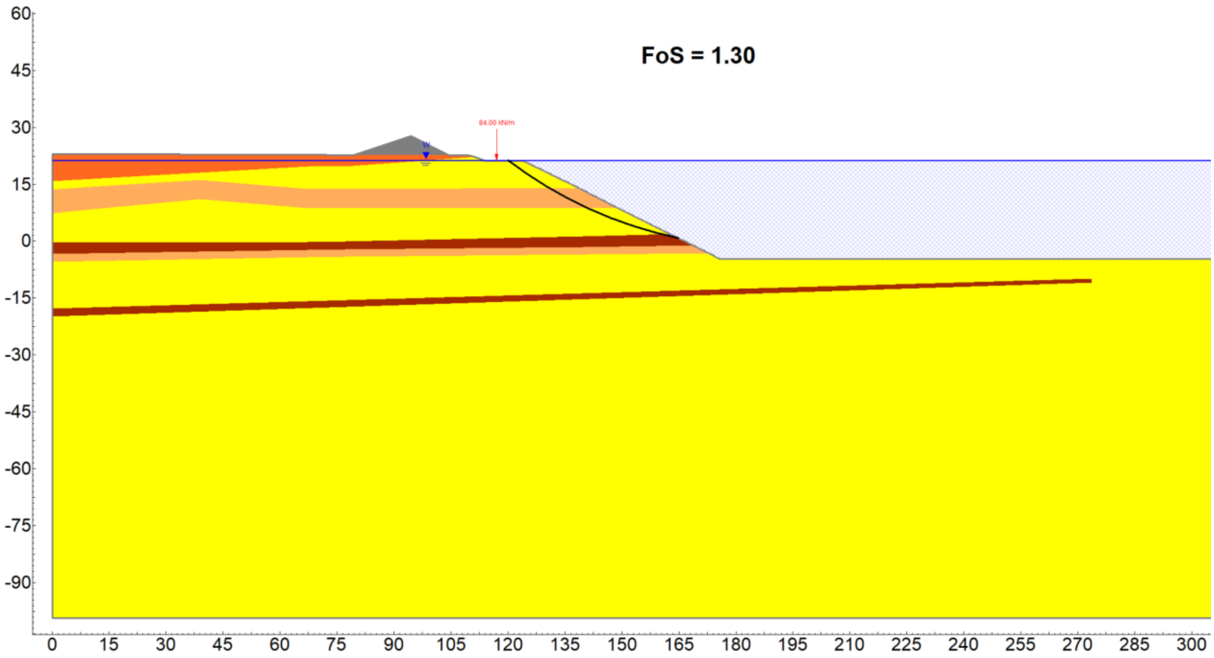


Figure 22 Section A-A' – Operational Slope Stability

5.7 Seismicity

The Melbourne area inclusive of the proposed WA7541 site is within a relatively intermediate to high risk seismic zone. GHD has undertaken additional stability assessments on the critical slope profiles to determine the sensitivity of the proposed pit to seismic events.

According to the 'Atlas of Seismic Hazard Maps of Australia' 2013, Melbourne and surrounding areas have among the highest Peak Ground Acceleration (PGA) compared to the rest of the nation. The Spectral Acceleration (SA) hazard value at 500 and 2500 year return periods (ARI) are PGA 0.0627 g (refer to Figure 23) and PGA 0.1704 g respectively. Stability assessments have been done in accordance with the CSIRO (2009) guidelines for a 1 in 500 ARI. The results of the seismic stability analysis are presented in Table 4.

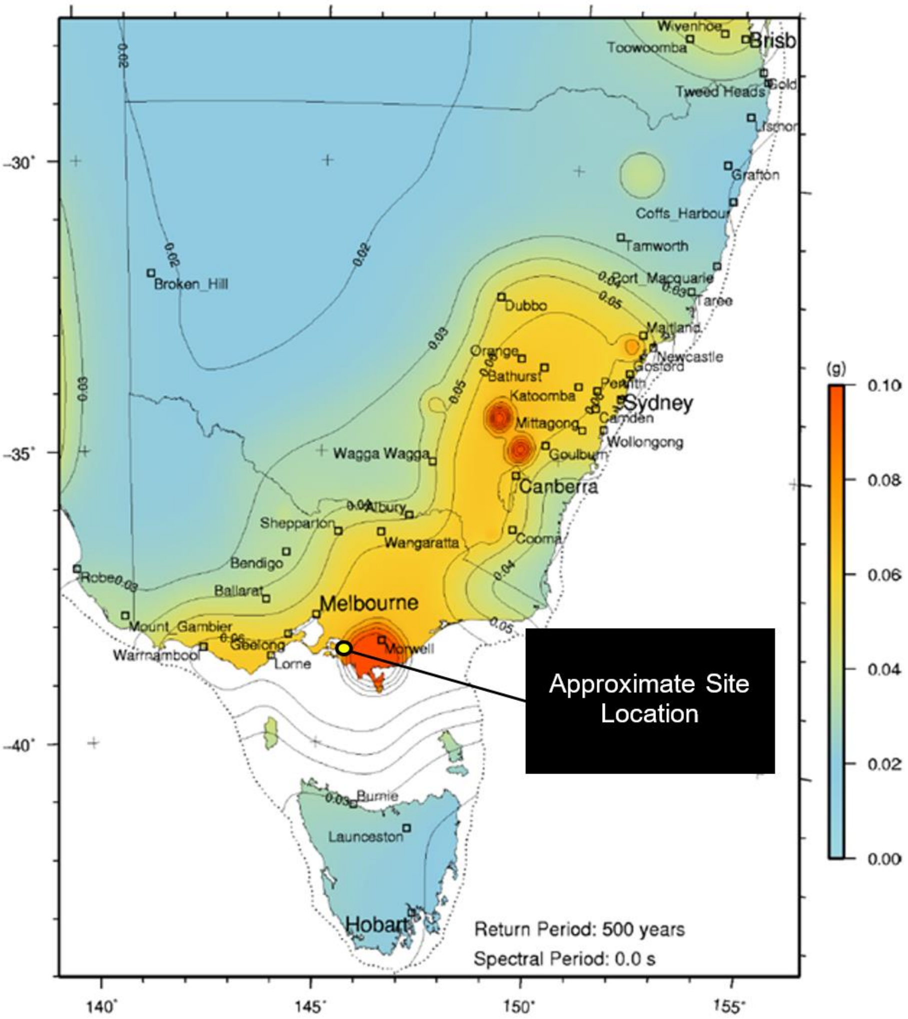


Figure 23 Seismic Hazard Map after Geosciences Australia for a 1 : 500 year ARI

Table 4 Summary of Sensitivity Analysis Results – Seismic Loading 1 : 500 year ARI

Scenario	Minimum FoS
Seismic	1.22

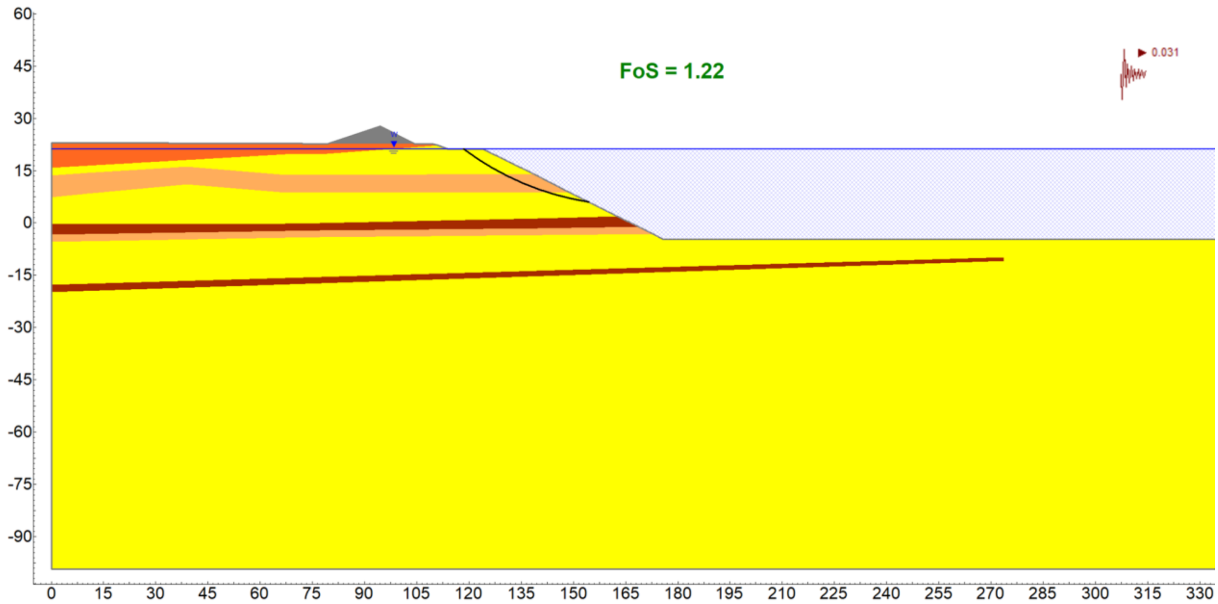


Figure 24 Section A-A' – Slope Stability Under Seismic Loading (1 in 500 ARI)

The results presented in Table 4 indicate:

- The slope stability performance under seismic loading conditions for a 1 in 500 ARI achieves a FoS of 1.22, which exceeds the nominated DAC of FoS > 1.1.

5.8 Sensitivity Analysis – Lower Pond Level

As noted above, quarry lake forces provide a reinforcing effect and suitable 'counterweight' to the submerged batters. However, variance in water level may occur during and beyond dredging operations within the proposed quarry pit. Under extreme conditions, a rapid drawdown condition within the slope batters may occur. A sensitivity assessment has been undertaken to assess the stability implications as a result in the reduction of external water levels (i.e., by 1 to 2 m), this is presented in Table 5 and depicted in Figure 25. It should be noted that the calculated critical plane of instability is on a localised scale.

Table 5 Summary of Sensitivity Analysis Results – Lower Pond Level

Scenario for Reduction in Lake/External Water Level by	Minimum FoS
1 m	1.37
2 m	1.29

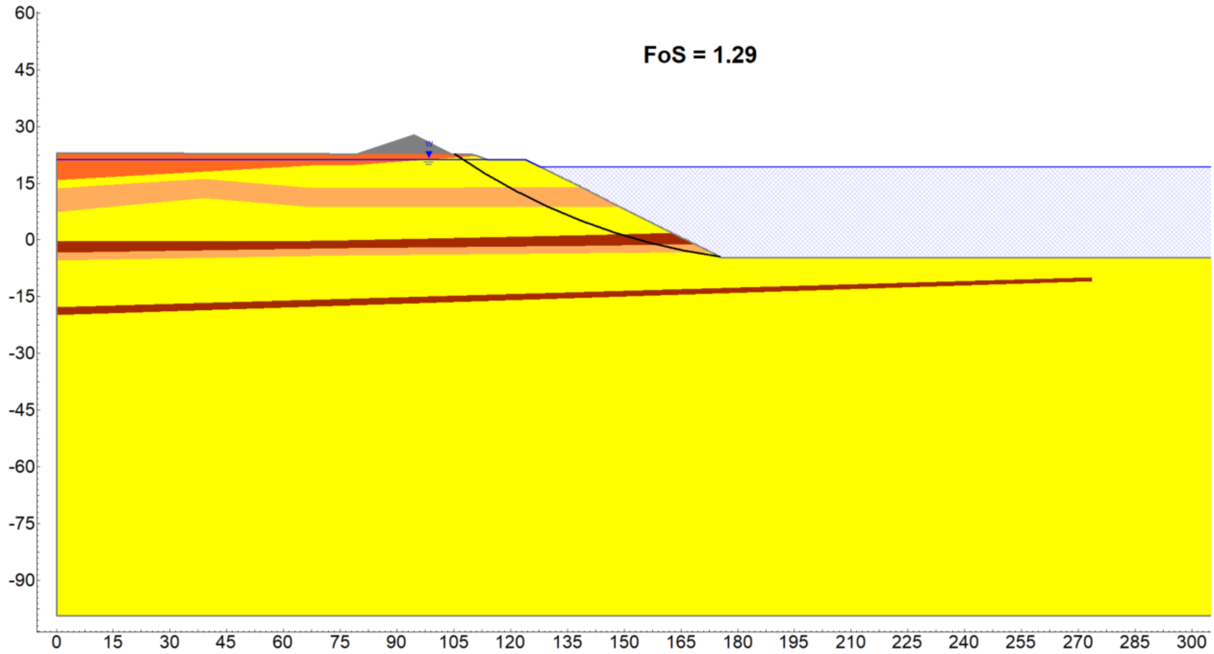


Figure 25 Section A-A' – Sensitivity Analyses – 2 m Reduction in External Water Level

The results from the sensitivity analyses indicate:

- The FoS reduces with a decrease in quarry lake level (i.e., due to the temporarily elevated gradient and lesser resistive lake forces), with the FoS falling below 1.3 as a result of a 2 m reduction in pond level.
  - Whilst the results of the sensitivity analyses indicates that the batter is sensitive to a reduction in lake level, it is important to note that the pit wall is largely formed by granular materials, where an elevated potential head within the slope batter is considered unlikely.

5.9 Discussion of Stability Analyses Results

Based on the stability assessment of the proposed quarry pit, the results of this assessment indicate the following:

- Considering the pit slope geometry including the noise/screening bund, a minimum stand-off distance of 20.5 m and 35.5 m is required to achieve the terminal and rehabilitated batter DAC, respectively.
  - The above results are based on the conservative strengths (lower bound) adopted for the assessment. It should be appreciated that based on the higher strengths (i.e., cohesion), the required stand-off distances are likely to be lesser than those outlined above.
  - To improve the level of geotechnical understanding of the site once quarrying has commenced, geotechnical inspections of excavated batters can be undertaken to assess stability performance and subsequently verify/refine the material characteristics.
- A minimum offset / beaching bench between 6.0 and 8.0 m (i.e., depending on the duration of crane loading) from the crest, is required during dredging to meet the operational design acceptance criteria.

- The proposed realignment of the waterway to the north / northeast of the proposed WA boundary has a minimum buffer of 40 m to the extraction boundary as stipulated by the water authority, which is greater than the minimum 35.5 m offset distance calculated in the stability analyses. Accordingly, the proposed waterway re-alignment is not likely to adversely impact batter stability.
- GHD understands that the eastern extraction boundary is 40 m from the Work Plan boundary, accordingly, it is unlikely for potential large scale instability to impact beyond the WA boundary.
- It is considered alternative methods of extraction, e.g., floating cutter suction dredging would eliminate the potential localised scale instabilities on the beaching bench induced by plant such as a dragline/grab crane.

6. Erosion Potential Analysis

6.1 General

The Revised Universal Soil Loss Equation (RUSLE) is a tool used to estimate the potential soil loss due to direct rainfall on an exposed slope and can provide an indication of the general erosion risk of the surface. It is useful for quantifying the impact of various factors that contribute to erosion when designing batters under long term (rehabilitated) conditions. The RUSLE equation is not applicable for concentrated flows that may result from localised catchments flowing onto the slope.

6.2 Nominated Erosion Potential Criteria

Two widely adopted erodibility potential criterions have been adopted for this erosion assessment. These design acceptance criterions, as suggested by the Commonwealth of Australia (2016) and by Morse and Rosewell (1996) and Landcom (2004) are commonly adopted to assess the potential volume of soil loss at a site against tolerance levels. This may assist with identifying suitable treatment options to minimise potential soil loss in order to satisfy the nominated design acceptance criteria.

For this assessment, GHD has adopted the two following design acceptance criterions to assess potential soil loss for the rehabilitation batter geometries outlined in this letter:

Criterion 1

Based on the Erosion Hazard Guidelines (after Morse and Rosewell (1996) and Landcom (2004), which are summarised in Table 6.

Table 6 Soil Loss Classes (after Morse and Rosewell 1996 and Landcom, 2004)

Soil Loss Class	Calculated Soil Loss (t/ha/yr.)	Erosion Hazard
1	0 to 150	Very Low
2	151 to 225	Low
3	226 to 350	Low-moderate
4	351 to 550	Moderate
5	501 to 750	High

6	751 to 1500	Very High
7	> 1500	Extremely High

Criterion 2

Criterion 2 is based on the tolerable soil loss tolerances which are cited in 'Mine Rehabilitation, Leading Practice Sustainable Development Program for the Mining Industry' (Commonwealth of Australia, 2016). This design acceptance criteria indicates that the soil loss should not exceed 4.5 tonnes per hectare per year (i.e., 4.5 t/ha/yr.).

6.3 Potential Erodibility of Terminal and Rehabilitated Batters

The RUSLE equation calculates an annual erosion rate based on the multiplication of five factors, and is expressed as:

$$\boldsymbol{A = R \cdot K \cdot LS \cdot C \cdot P}$$

Where:

A = Estimated average soil loss in tonnes per acre per year

R = Rainfall erosivity factor

K = Soil erodibility factor

LS = Topographic factor that accounts for slope length and slope gradient

C = Erosion practice control

P = Ground cover factor

A discussion of RUSLE factors in the relation to the proposed batter design scenarios is included in the following sections.

6.3.1 Rainfall Erosivity Factor 'R'

This factor is determined by the intensity of rainfall in the area and is therefore not a design parameter. Using the aforementioned principal empirical relationships have been established to correlate mean annual precipitation with the Rainfall Erosivity Factor (R). Yu and Roswell (1996) established a relationship to estimate the R-factor based on studies conducted in south-eastern Australia. The relationship had a very good correlation with $R^2 = 0.91$. The R-Factor and mean annual relationship is expressed as:

$$\boldsymbol{R = 0.0438 \cdot P^{1.61}}$$

Where:

P = Mean annual precipitation (mm)

Mean annual precipitation for the proposed WA7541 quarry site was obtained from the Bureau of Meteorology (BOM) for the nearby station at Rhyll (Site number 086373). The mean annual precipitation at Rhyll is 699.8 mm. The maximum recorded since 1984 is 896.4 mm.

6.3.2 Soil Erodibility Factor (K)

The soil erodibility factor (K) accounts for the erodibility of the soil based on its composition (e.g., sandy clay). Nomograph equations (and visual representations) are frequently relied upon for deriving suitable K-factors, which is a simple method that makes use of basic soil properties (e.g., particle size distributions). According to the CSIRO publication after Yang et al. (2017) most of the models used to determine suitable K-factors (e.g., Wishmeier et al., 1971) have been developed for American soils and may not be representative of Australian Soils. According to Yang et al. (2017) the nomograph developed by Rosewell (1993) referred to as ‘K_SOILOSS’ yielded comparative results to field measurements and is a preferred method for deriving a suitable K-factor for Australian soils, which contain less than 68% silt content).

The K_SOILOSS nomograph equation is expressed as:

$$K_{SOILOSS} = \left(2.77 \cdot M^{1.14} \cdot 10^{-7} \cdot (12 - OM)\right) + \left(4.28 \cdot 10^{-3} \cdot (SS - 2)\right) + ((3.29 \cdot 10^{-3} \cdot (PP - 3))$$

Where: M = Particle Size Parameter = (%Silt + %Very Fine Sand) x (100 – %Clay)

OM = Organic Matter (%)

SS = Soil Structure (ranging from; 1-very fine granular; 2-fine granular; 3-medium to coarse grained; and 4-blocky, platy or massive.

PP = Soil Permeability (ranging from; 1-rapid; 2- moderate to rapid; 3-moderate; 4-slow to moderate; 5-slow; and 6-very slow).

Available soil data required for the input into the above nomograph equation was obtained from the air cored logs and checked against the publicly available Soil and Landscape Grid of Australia (SGLA, 2017) database. This data access platform enables the user to query soil data based on the site location with a 95% confidence interval and provides the necessary information to estimate a K-factor. Summarised in below in Table 7 are the adopted overburden soil index parameters (obtained from the air core logs) used to calculate the particle size parameter ‘M’.

Table 7 Summary of Overburden Soil Properties (after SGLA, 2017)

%Sand (0.05-0.1 mm)	%Silt (0.002-0.05 mm)	%Clay (< 0.002 mm)	M – Particle Size Parameter
70	10	20	800

Summarised below in Table 8 are the parameters obtained from the air core logs used to calculate the K-factor for the site.

Table 8 Summary of K-Factor Parameters (after Rosewell, 1993)

‘M’	% Organic Matter (OM)	Soil Structure (SS)	Permeability (PP)	K-Factor (Rosewell, 1993)
800	≈0	2 Fine granular	2 Moderate to rapid	0.0034

Based on the above, a K-factor of 0.02 has been adopted for this erosion assessment.

6.3.3 Topographic Factor (LS)

The topographic factor (LS) accounts for a slopes height (L) and gradient (S) and is used to represent the effect of topography on erosion rates. The equations for calculating the LS in RUSLE are:

$$LS = L \cdot S$$

$$L = \left(\frac{\lambda}{22.13}\right)^m$$

$$m = \frac{\beta}{(1+\beta)}$$

$$\beta = \frac{\sin(\theta)}{[3 \cdot \sin(\theta)^{0.8} + 0.56]}$$

ADVERTISED PLAN

$$S = 16.8 \cdot \sin(\theta) = 0.5\,; \quad \theta \geq 9\%$$

Where:

λ= Slope length (m)

m = Variable length-slope component

β = Variable slope gradient component

θ = Slope angle

Table 9 Summary of Topographic Factors

Geometry	Gradient (V:H)	Slope Length (m)	Topographic Factor, LS
Proposed Rehabilitation Design	1 in 3 (18.4°)	19	5.61

6.3.4 Erosion Control Factor (C)

The erosion control (C) factor is used to measure the effect of vegetation and management practices on erosion rates. This includes the effects of vegetation, soil cover, soil biomass and soil disturbing activities. For 'Scenario 1' where no cover management practice is applied, a C-factor of 1 was adopted, which corresponds to a bare ground condition. For 'Scenario 2' where battered slopes and areas of disturbed land are covered with topsoil and vegetation, a temporal C-factor was adopted, which is reflects a reduction in erosion potential commensurate with increased grass coverage.

C-factor reductions that result from increased grass coverage were adopted after Landcom (2004), which have been broadly correlated to C-Factor reductions after Sprague (1999) which correlates C-factor reductions to different grass (perennial seeding) periods. The C-factors used to assess the erosion potential of the site are summarised in Table 10. It should be noted that the correlated C-factors present a conservative approach to reducing soil erosion over time, i.e., C-factor reductions may be quicker than those tabulated. It is also assumed that the ongoing and active maintenance is employed until grass covers reach the desired level and have become 'fully' established (i.e., can maintain grass coverage without active maintenance).

Table 10 Summary of 'C' Factors

Treatment	Time after application (months)	Assumed Grass Coverage (%)	C-Factor after Landcom (2004)	C-Factor after Sprague, (1999)
Untreated	Undefined	0	1.0	1.0
Topsoiled and Vegetated	0	0	1.0	0.7
	1 – 3	15	0.55	0.1
	3 – 6	30	0.32	
	6 – 12	45	0.18	0.05
	12 – 18	60	0.09	0.01
	18 – 24	75	0.04	0.01
	> 24	80	0.02	0.01

6.3.5 Ground Cover Factor (P)

The erosion control practice factor (P) measures the effect of practices that reduce flow velocity and the tendency for water to flow directly downhill (e.g., track-walking or punching straw into the ground). Table 11 presents a summary of typical erosion control practices and the respective P-factor.

Table 11 Summary of Typical Erosion Control Practice Factors (after Goldman et al. 1986)

Surface condition	Erosion Control Practice Factor, P
Compacted and smooth	1.3
Track-walked along contour	1.2
Track-walked up and down the slope	0.9
Punched straw	0.9
Loose to 0.3 m depth	0.8

The typical ‘C’ and ‘P’ factors presented in Table 10 and Table 11 above have been adopted from various sources, including Meyer and Ports (1976), Israelson et al. (1980), Goldman et al. (1980), URS Greiner Woodward Clyde (1999), the North American Green website and Sprague (1999).

For this assessment and based on our understanding of the Client’s objective, GHD has adopted a ground cover factor of P = 0.8 for this analysis.

6.3.6 Results and Discussion

The results of this erodibility potential analysis are based on the assumptions outlined above for the respective input factors. Figure 26 presents the calculated soil loss rate for both the proposed treatment option and an untreated scenario, relative to the ‘Leading Practice Sustainable Development Program for the Mining Industry’ (Commonwealth of Australia, 2016) guidelines.

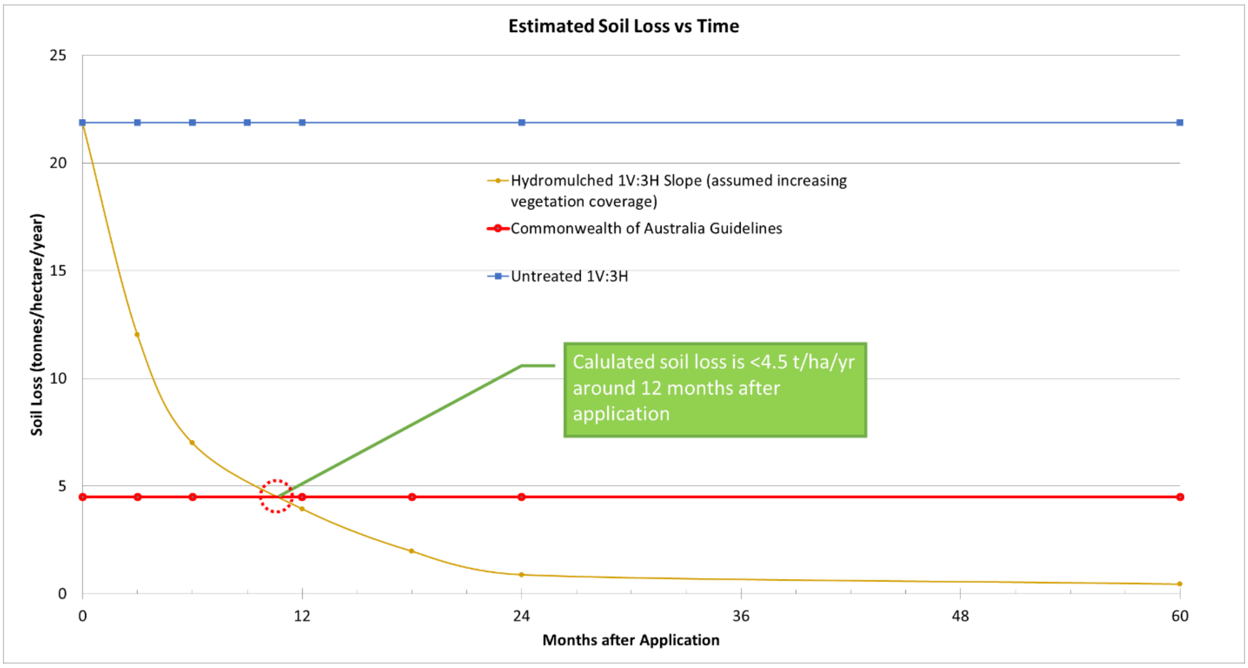


Figure 26 Results of Erosion Potential Analysis

Erosion Hazard categories after Morse and Rosewell (1966) and Landcom (2004) provide a metric for comparing the calculated soil loss rate with tolerable ranges (Table 6). The results of the erosion assessment are summarised in Table 12 with respect to the Erosion Hazard categories.

Table 12 Summary of Calculated Soil Loss Rates

Geometry	At 12 Months	
	Soil Loss Rate (t/ha/yr.)	Erosion Hazard
Rehabilitated slope (treated)	4.24	Very Low
Untreated 1V:3H slope	22	Very Low

The results of the erosion analysis indicate that:

- After 12 months, the estimated soil loss for topsoiled, pre-vegetated batters is ‘Very Low’ based on the Erosion Hazard guidelines put forward by Morse and Rosewell (1996) and also satisfies the criteria set out by Commonwealth of Australia (2016) (i.e., less than 4.5 t/ha/yr.).
  - However, in accordance with section 89E of the Miner Resources (Sustainable Development) Act 1990, quarry owners are required (requirement no. 42) to rehabilitate the site to a state which is suitable for the planned final use, where vegetation is consistent with the final land use.
- The erosion assessment indicates that through the establishment of vegetation, the long-term erosion rate for rehabilitated batters satisfies the Commonwealth of Australia (2016) guidelines (i.e., <4.5 t/ha/yr.) after 12 months.

It should be noted that the erosion assessment presented above requires ongoing maintenance to ensure that a minimum of 80% grass coverage is achieved. Selection of suitable grasses for the site (in line with the final landform use) must be considered along with its applicability to the site specific soil type(s). It is recommended that work is undertaken to verify the suitability of the erosion input parameters presented within this report. Additionally, the monitoring criteria outlined in Table 13 is recommended.

Table 13 Proposed Erosion Monitoring Criteria

Item	Rehabilitation / Closure Criteria	Elements to be Monitored	Frequency
Erosion	**Operationally** No erosion channels greater than 200 mm deep and/or wide: remedial action initiated immediately. No more than 5 erosion channels greater than 150 mm deep and/or wide within a 20 m wide area: remedial action initiated immediately. **Post Closure** No erosion channels greater than 50 mm deep and/or wide: remedial action initiated immediately. No more than 5 erosion channels greater than 20 mm deep and/or wide within a 20 m wide area: remedial action initiated immediately.	**Operationally** Erosion channels less than 150 mm deep or wide recorded & photographed for follow up. **Post Closure** Any visible erosion channel recorded & photographed for follow up.	**Operationally** - 6 Monthly - Additional inspections after significant rainfall events. **Post Closure** - Y1 - 2 Monthly - Y2 – 3 Monthly - Y3 - 6 Monthly - Y4: 12 Monthly Additional inspections after significant rainfall events.

Based on the proposed erosion monitoring schedule outlined in Table 13 above, GHD considers that the criteria is reasonable. Additionally, GHD considers that the proposed vegetated rehabilitation profile would be in line with the findings of this erodibility potential analysis.

Erosion management practices such as hydromulching or vegetation growth (minimum of 80% coverage) would greatly reduce the calculated soil loss rates to meet Commonwealth of Australia (2016) guidelines (i.e., less than 4.5 t/ha/yr.).

7. Geotechnical Risk Assessment

7.1 General

The geotechnical risk assessment is a quantitative assessment based on the ‘likelihood’ and ‘consequence’ of a major geotechnical hazard occurring.

The qualitative risk assessment process has been utilised, as outlined in the risk assessment matrix presented in Table 15, which aligns with the Australian Standard for Risk Management AS/NZ Standard 4360 (Standards Australia 2004). Table 35 outlines the risk rating acceptability.

7.2 Geotechnical Hazards

Table 14 detailed the findings of this geotechnical assessment and identified geotechnical hazards relating to the proposed quarry design at 5575 SGH:

Table 14 Geotechnical Hazards at WA7541 Quarry

Mechanism	Description
Hazard 1 Slumping/erosion of sand batters, slumping of internal stockpiles (including any stacked consolidated slimes stockpiles)	Potential for small scale circular instability, as a result of slumping and / or sloughing of the any operating, terminal or remediated sand batter faces and any (temporary) stockpiles, where applicable. Potential causes for slumping include, but are not limited to: • Highly disturbed materials and/or weak planes encountered during excavation of sand resources. • Improper surface and groundwater management during underwater extraction around the batter faces or periphery of stockpiles • Inappropriate construction geometry. • Could occur due to groundwater drawdown in the region surrounding the quarry. Suitable construction of the lower slopes would be required if groundwater levels drop below current levels (i.e., 5m bgsl).
Hazard 2 Deep seated circular instability	Larger scale slope volume movements that are governed by the soil shear strength characteristics. • Slope instability occurs when the driving forces are greater than the resisting forces. • Movement of this hazard occurs in a circular/rotational manner and is dependent upon the slope geometry, material strength and groundwater conditions. • Consequences of this type of hazard can include partial or full loss of pit crests and impacting working benches / crane pads. • Could occur due to groundwater drawdown in the region surrounding the quarry. Suitable construction of the lower slopes would be required if groundwater levels drop below current levels (i.e., 5m bgsl). • In extreme cases the failure zone may migrate some distance from the pit crest which may exceed the work authority boundary.
Hazard 3 Erosion or piping between nearby quarries.	Represented by small to large volumes of inflow into the excavation. • The failure mechanism (i.e., erosion or piping) could manifest from water flow in the sand between nearby quarries. • The consequence of this may range from a minor to full loss of the overlying pit crest but is dependent on volume of flow between the two pits.
Hazard 4a Slumping of sand batters above beaching zone.	Potential for small scale circular instability to occur above the water line (or beaching point). • This mechanism may be exacerbated due to undercutting of the submerged slopes, highly disturbed (very loose) materials, weak planes encountered during excavation of sand resources. • This mechanism may also result due to improper surface and groundwater management during underwater extraction or inappropriate construction geometry.
Hazard 4b Slumping of sand batters above beaching zone.	Potential for medium to large scale circular instability to occur due to slumping of batter below the water line, leading to propagation of a failure above the water line.

Mechanism	Description
	• This mechanism may be exacerbated due to undercutting of the submerged slopes, highly disturbed (very loose) materials, weak planes encountered during excavation of sand resources. This mechanism may also result due to improper surface and groundwater management during underwater extraction or inappropriate construction geometry.

7.3 Risk Assessment Process

Risk analysis involves the consideration of the source risks, their consequences and the likelihood of those consequences occurring. Risks are typically analysed by combining the likelihood and consequence to determine a category or level for each risk event (Table 15 and Table 16).

Table 15 Risk Assessment Matrix (DJPR, 2018)

Likelihood	Insignificant	Minor	Moderate	Major	Critical
Almost Certain	Medium	High	Very High	Very High	Very High
Likely	Medium	Medium	High	Very High	Very High
Possible	Low	Medium	Medium	High	Very High
Unlikely	Low	Low	Medium	High	High
Rare	Low	Low	Medium	Medium	High
	Consequence				

Table 16 Risk Rating Acceptability (DJPR, 2018)

Risk level	Description
Very High	Totally unacceptable level of risk. Controls must be put in place to reduce the risk to lower levels.
High	Generally unacceptable level of risk. Controls must be put in place to reduce the risk to lower levels or seek specific guidance from ERR.
Medium	May be acceptable provided the risk has been minimised as far as reasonably practicable.
Low	Acceptable level of risk provided the risk cannot be eliminated risk.

The geotechnical risk assessment for the proposed WA7541 quarry is summarised in Table 17.

Based on the risk assessment presented below, the residual risk to external receptors has been assessed to be “Low”.

ADVERTISED PLAN

Table 17 Proposed WA7541 Quarry Pit Risk Rating

Element at risk	Quarry Boundary	Hazard type	Likelihood	Consequence Category[1]	Risk Rating	Corrective / Management Action(s)	Likelihood	Consequence Category[1]	Residual Risk Rating	Comments
Internal Batters - Personnel safety and Quarry Mobile Plant	All batters	*Hazard Type 1 – Small scale slumping/erosion of sand batters*	Possible	Moderate	Medium	GPS monitoring (movement); Regular inspections for signs of instability; Monitoring of groundwater; Geotechnical excavation control; Surface water managed in accordance with site instituted management plan.	Unlikely	Moderate	Medium	– Establish exclusion zone(s) for pedestrian i.e., on-site personnel – Regular visual observations/monitoring undertaken – Avoid quarry activities that would knowingly decrease the stability of batters and stockpiles, i.e., undercutting. These stockpiles (including any temporary stacked consolidated slimes stockpiles) will be maintained in accordance with the ACT EPA (2019) guidelines. – Ensure surface water drainage systems are adequately maintained to reduce water ingress into slope material. – Pond water levels should be maintained to minimise the potential for instability of submerged batters, as lowering of the pond may result in instabilities occurring in previously submerged batters. – Suitable stand-off distances for haul trucks and vehicles will be maintained from the crest of the underside batter and from the toe of excavated batters. – Bunding will be constructed to reduce the risk of vehicle roll-overs.
		Hazard Type 2 – Deep seated circular instability	Rare	Major	Medium	GPS monitoring (movement); Regular inspections for signs of instability; Monitoring of groundwater; Geotechnical excavation control; Surface water managed in accordance with site instituted management plan.	Rare	Moderate	Medium	– Establish exclusion zone(s) for pedestrian, i.e., on-site personnel. – Regular visual observations/monitoring undertaken. – Avoid quarry activities that would knowingly decrease the stability of batters and stockpiles, i.e., undercutting. These stockpiles (including any temporary stacked consolidated slimes stockpiles) will be maintained in accordance with the ACT EPA (2019) guidelines. – Ensure surface water drainage systems are adequately maintained to reduce water ingress into slope material. – Pond water levels should be maintained to minimise the potential for instability of submerged batters, as lowering of the pond may result in instabilities occurring in previously submerged batters. – Groundwater monitoring data will be collected regularly to identify any adverse trends (if any).
		Hazard Type 3 – Erosion or piping between nearby quarries.	Rare	Moderate	Medium	GPS monitoring (movement); Regular inspections for signs of instability; Monitoring of groundwater and pond levels; Geotechnical excavation control; Surface water managed in accordance with site instituted management plan	Rare	Minor	Low	– Regular visual observations/monitoring undertaken – Ensure surface water drainage systems are adequately maintained to reduce water ingress into slope material. – Pond water levels should be maintained to minimise the potential for instability of submerged batters, as lowering of the pond may result in instabilities occurring in previously submerged batters.
		Hazard Type 4a– Slumping of sand batters above beaching zone. *Hazard Type 4b– Slumping of sand batters water level leading to instability of above water level batters.*	Possible	Minor	Medium	Daily inspections; Suitable as-constructed geometry; Erosion control measures; Dedicated site surface water management plans will be implemented; GPS monitoring and / or	Unlikely	Minor	Low	– Establish exclusion zone(s) for pedestrian, i.e., on-site personnel – Regular visual observations/monitoring undertaken – Avoid quarry activities that would knowingly decrease the stability of batters and stockpiles, i.e., undercutting. These stockpiles (including any temporary stacked consolidated slimes stockpiles) will be maintained in accordance with the ACT EPA (2019) guidelines. – Ensure surface water drainage systems are adequately maintained. – Where 'soft' ground conditions are encountered at the waterline interface, a geotechnical engineer should inspect the area to ensure stability related risks are minimised.

[1] Determined on the basis of the critical credible or reasonable outcome, which takes into consideration the temporal exposure of at-risk elements.

Element at risk	Quarry Boundary	Hazard type	Likelihood	Consequence Category[1]	Risk Rating	Corrective / Management Action(s)	Likelihood	Consequence Category[1]	Residual Risk Rating	Comments
						prisms and pins should be installed.				– Any plant (fixed or mobile) should be located at a safe standoff distance from the crest of the interface. A field bearing capacity assessment, using Dynamic Cone Penetrometers, should be undertaken within these locations, prior to undertaking any underwater extraction (min blow count 6 per 100 mm of penetration).
Quarry infrastructure	Internal	*Hazard Type 1 – Small scale slumping/erosion of sand batters*	Possible	Moderate	Medium	GPS monitoring (movement); Regular inspections for signs of instability; Monitoring of groundwater; Geotechnical excavation control; Surface water managed in accordance with site instituted management plan.	Unlikely	Minor	Low	– Establish exclusion zone(s) for pedestrian, i.e., on-site personnel. – Regular visual observations/monitoring undertaken – Avoid quarry activities that would knowingly decrease the stability of batters and stockpiles, i.e., undercutting. These stockpiles (including any temporary stacked consolidated slimes stockpiles) will be maintained in accordance with the ACT EPA (2019) guidelines. – Ensure surface water drainage systems are adequately maintained to reduce water ingress into slope material. – Pond water levels should be maintained to minimise the potential for instability of submerged batters, as lowering of the pond may result in instabilities occurring in previously submerged batters. – Suitable stand-off distances for haul trucks and vehicles will be maintained from the crest of the underside batter and from the toe of excavated batters. – Bunding will be constructed to reduce the risk of vehicle roll-overs.
		Hazard Type 2 – Deep seated circular instability	Possible	Minor	Medium	GPS monitoring (movement); Regular inspections for signs of instability; Monitoring of groundwater; Geotechnical excavation control; Surface water managed in accordance with site instituted management plan.	Unlikely	Minor	Low	– Establish exclusion zone(s) for pedestrian, i.e., on-site personnel. – Regular visual observations/monitoring undertaken. – Avoid quarry activities that would knowingly decrease the stability of batters and stockpiles, i.e., undercutting. These stockpiles (including any temporary stacked consolidated slimes stockpiles) will be maintained in accordance with the ACT EPA (2019) guidelines. – Ensure surface water drainage systems are adequately maintained to reduce water ingress into slope material. – Pond water levels should be maintained to minimise the potential for instability of submerged batters, as lowering of the pond may result in instabilities occurring in previously submerged batters. – Groundwater monitoring data will be collected regularly to identify any adverse trends (if any).
		Hazard Type 4a – Slumping of sand batters above beaching zone. *Hazard Type 4b– Slumping of sand batters water level leading to instability of above water level batters.*	Possible	Moderate	Moderate	Daily inspections; Suitable as-constructed geometry; Erosion control measures; Dedicated site surface water management plans will be implemented; GPS monitoring and / or prisms and pins should be installed.	Unlikely	Minor	Low	– Establish exclusion zone(s) for pedestrian, i.e., on-site personnel – Regular visual observations/monitoring undertaken – Avoid quarry activities that would knowingly decrease the stability of batters and stockpiles, i.e., undercutting. These stockpiles (including any temporary stacked consolidated slimes stockpiles) will be maintained in accordance with the ACT EPA (2019) guidelines. – Ensure surface water drainage systems are adequately maintained. – Where ‘soft’ ground conditions are encountered at the waterline interface, a geotechnical engineer should inspect the area to ensure stability related risks are minimised. – Any plant (fixed or mobile) should be located at a safe standoff distance from the crest of the interface. A field bearing capacity assessment, using Dynamic Cone Penetrometers, should be undertaken within these locations, prior to undertaking any underwater extraction (min blow count 6 per 100 mm of penetration).
Stockpiles	Internal	*Hazard Type 4a*: Slumping of stockpiles	Unlikely	Minor	Low	Stockpiles designed in accordance with DPI (2010); Surface water managed in accordance with site instituted surface water management plan; Avoid saturation of the stockpiled material.	Unlikely	Minor	Low	– Establish exclusion zone(s) for pedestrian i.e., on-site personnel – Regular visual observations/monitoring undertaken – Avoid quarry activities that would knowingly decrease the stability of stockpiles, i.e., undercutting. These stockpiles (including any temporary stacked consolidated slimes stockpiles) will be maintained in accordance with the ACT EPA (2019) guidelines. – Ensure surface water drainage systems are adequately maintained. – Ensure that foundation area of stockpiles is suitable prior to placement. – Suitable stand-off distances for haul trucks and vehicles will be maintained from the toe of any stockpiled material.

Element at risk	Quarry Boundary	Hazard type	Likelihood	Consequence Category[1]	Risk Rating	Corrective / Management Action(s)	Likelihood	Consequence Category[1]	Residual Risk Rating	Comments
South Gippsland Highway	West and South	*Hazard Type 2 – Deep seated circular instability*	Rare	Moderate	Medium	GPS monitoring (movement); Regular inspections for signs of instability; Monitoring of groundwater; Geotechnical excavation control; Surface water managed in accordance with site instituted management plan.	Rare	Moderate	Medium	– Establish exclusion zone(s) for pedestrian, i.e., on-site personnel. – Regular visual observations/monitoring undertaken. – Avoid quarry activities that would knowingly decrease the stability of batters and stockpiles, i.e., undercutting. These stockpiles (including any temporary stacked consolidated slimes stockpiles) will be maintained in accordance with the ACT EPA (2019) guidelines. – Ensure surface water drainage systems are adequately maintained to reduce water ingress into slope material. – Pond water levels should be maintained to minimise the potential for instability of submerged batters, as lowering of the pond may result in instabilities occurring in previously submerged batters. – Groundwater monitoring data will be collected regularly to identify any adverse trends (if any).
Noise/ screening bund	West and South	Hazard Type 2 – Deep seated circular instability	Unlikely	Moderate	Medium	Regular inspections for signs of instability; Monitoring of groundwater; Geotechnical excavation control; Surface water managed in accordance with site instituted management plan.	Unlikely	Minor	Low	– Establish exclusion zone(s) for pedestrian, i.e., on-site personnel. – Regular visual observations/monitoring undertaken. – Avoid quarry activities that would knowingly decrease the stability of batters and stockpiles, i.e., undercutting. These stockpiles (including any temporary stacked consolidated slimes stockpiles) will be maintained in accordance with the ACT EPA (2019) guidelines. – Ensure surface water drainage systems are adequately maintained to reduce water ingress into slope material. – Pond water levels should be maintained to minimise the potential for instability of submerged batters, as lowering of the pond may result in instabilities occurring in previously submerged batters. – Groundwater monitoring data will be collected regularly to identify any adverse trends (if any).
Beach Energy (Bass Gas) Plant	East / North Eastern	*Hazard Type 2 – Deep seated circular instability*	Rare	Major	Medium	GPS monitoring (movement); Regular inspections for signs of instability; Monitoring of groundwater; Geotechnical excavation control; Surface water managed in accordance with site instituted management plan.	Rare	Moderate	Medium	– Establish exclusion zone(s) for pedestrian, i.e., on-site personnel. – Regular visual observations/monitoring undertaken. – Ensure surface water drainage systems are adequately maintained to reduce water ingress into slope material. – Pond water levels should be maintained to minimise the potential for instability of submerged batters, as lowering of the pond may result in instabilities occurring in previously submerged batters. – Groundwater monitoring data will be collected regularly to identify any adverse trends (if any).
Residential Property	West, East and South	*Hazard Type 2 – Deep seated circular instability*	Rare	Moderate	Medium	GPS monitoring (movement); Regular inspections for signs of instability; Monitoring of groundwater; Geotechnical excavation control; Surface water managed in accordance with site instituted management plan.	Unlikely	Minor	Low	– Establish exclusion zone(s) for pedestrian, i.e., on-site personnel. – Regular visual observations/monitoring undertaken. – Ensure surface water drainage systems are adequately maintained to reduce water ingress into slope material. – Pond water levels should be maintained to minimise the potential for instability of submerged batters, as lowering of the pond may result in instabilities occurring in previously submerged batters. – Groundwater monitoring data will be collected regularly to identify any adverse trends (if any).
Realigned waterway	North and North East	*Hazard Type 2 – Deep seated circular instability*	Rare	Major	Medium	GPS monitoring (movement); Regular inspections	Rare	Moderate	Medium	– Establish exclusion zone(s) for pedestrian, i.e., on-site personnel. – Regular visual observations/monitoring undertaken.

Element at risk	Quarry Boundary	Hazard type	Likelihood	Consequence Category[1]	Risk Rating	Corrective / Management Action(s)	Likelihood	Consequence Category[1]	Residual Risk Rating	Comments
(MW asset RD2504)						for signs of instability; Monitoring of groundwater; Geotechnical excavation control; Surface water managed in accordance with site instituted management plan.				– Avoid quarry activities that would knowingly decrease the stability of batters and stockpiles, i.e., undercutting. These stockpiles (including any temporary stacked consolidated slimes stockpiles) will be maintained in accordance with the ACT EPA (2019) guidelines. – Ensure surface water drainage systems are adequately maintained to reduce water ingress into slope material. – Pond water levels should be maintained to minimise the potential for instability of submerged batters, as lowering of the pond may result in instabilities occurring in previously submerged batters. – Groundwater monitoring data will be collected regularly to identify any adverse trends (if any).
Access Road	East	*Hazard Type 2 – Deep seated circular instability*	Rare	Major	Medium	GPS monitoring (movement); Regular inspections for signs of instability; Monitoring of groundwater; Geotechnical excavation control; Surface water managed in accordance with site instituted management plan.	Rare	Minor	Low	– Establish exclusion zone(s) for pedestrian, i.e., on-site personnel. – Regular visual observations/monitoring undertaken. – Ensure surface water drainage systems are adequately maintained to reduce water ingress into slope material. – Pond water levels should be maintained to minimise the potential for instability of submerged batters, as lowering of the pond may result in instabilities occurring in previously submerged batters. – Groundwater monitoring data will be collected regularly to identify any adverse trends (if any).

8. Recommendations

Based on the above findings, the following recommendations are made:

- It is considered alternative methods of extraction, e.g., floating cutter suction dredging would eliminate the potential localised scale instabilities on the beaching bench and submerged slopes induced by plant such as a dragline/grab crane.
- A ground control management plan (GCMP) should be developed, including suitable trigger action response plans (TARPs), instrument monitoring requirements, inspection frequency etc., to adequately control the ongoing geotechnical risk to operations. Additionally, a site surface and groundwater management plan should be developed.
  - In addition to the above, the GCMP should include a bearing capacity evaluation for the beaching bench based on the loading of the excavator to be used for underwater extraction.
- Regular inspection (by a geotechnical engineer) should be undertaken during the course of quarry operations, particularly near terminal batters and where the geological and geotechnical conditions differ from those assumed in this assessment. This will assist with identification of potential failure mechanisms and any engineering control which may need to be implemented. This is also applicable to the working batters and areas where a change in geotechnical conditions occurs.
  - The outcomes of the geotechnical inspections undertaken of the excavated batters can assist with assessing stability performance and subsequently verify/refine the material characteristics as adopted in this assessment. This observational approach is considered suitable for the site and the outcomes of which can be utilised to update the GCMP, as required.

9. References

Bryan, S. E., Constantine, A. E. & Stephens, C. J. (1997). Early Cretaceous volcano – sedimentary successions along the eastern Australian continental margin. Implications for the break-up of eastern Gondwana, *Eastern and Planetary Science Letters*, *153*, 85-102.

Carillo-Rivera, J. J. (1975). Hydrogeology of Western Port, *Geological Survey of Victoria Survey Report*, *1*.

Commonwealth of Australia (2020). Climate Data Online, Bureau of Meteorology, URL: http://www.bom.gov.au/climate/data/index.shtml, accessed on 27 August 2020.

Department of Jobs Precincts and Regions (2018). Guidance Material for the Assessment of Geotechnical Risks in Open Pit Mines and Quarries. Retrieved from Earth Resources: http://earthresources.vic.gov.au/earth-resources-regulation.

Department of Jobs Precincts and Regions (2020), Geotechnical Guidelines for Terminal and Rehabilitated Slopes, draft.

Geoscience Australia (2020). *Australian Neotectonics Database*, Geoscience Australia, accessed 30 November 2020.

Geoscience Australia (2021). *Earthquakes@GA Database*, Geoscience Australia, Canberra, accessed 15 February 2021.

GeoVic (2014). Victorian Surface Geology (Seamless Geology 2007-2014) database. Retrieved from: http://er-info.dpi.vic.gov.au/sd_weave/anonymous.html on 19 August 2020.

Hare, A. G., Cas, R. A. F., Musgrave, G. & Phillips, D. (2005). Magnetic and chemical stratigraphy for the Werribee Plains basaltic lava flow-field, Newer Volcanics Province, Victoria, Australia, *Australian Journal of Earth Sciences*, *52*, 59-78.

Institute of Water (2002). RUSLE Online Soil Erosion Assessment Tool, Michigan State University, URL: http://www.iwr.msu.edu/rusle/factors.htm, accessed on 27 August 2020.

Jenkin, J. J. (1974). The Geology of the Mornington Peninsula and Western Port. *Geological Survey of Victoria Survey Report*, *3*.

Landcom, (2004). Soils and Construction: managing urban stormwater, Sydney.

Maptek (2018), Vulcan Version 11, 3D Mine Planning, Mine Design, Geology & Scheduling in Vulcan, https://www.maptek.com/.

Mark. L., Burbidge, D. R., Edwards, M., 2013. Atlas of Seismic Hazard Maps of Australia: Seismic Hazard Maps and Hazard Spectra. *Record 2013/41:* Geoscience Australia: Canberra.

McAndrew, J. & Marsden, M. A. H. (1973). *Regional guide to Victorian geology*. [Melbourne] School of Geology, University of Melbourne

Mehin, K. & Bock, M. P. (1998). Cretaceous source rocks of the onshore Gippsland Basin, Victoria, *VIMP Report*, *54*.

Morse, R.J and Rosewell, C.J. (1996). Use of the Universal Soil Loss Equation as a tool in the Management of Urban Lands, *Proceedings of the Annual International Erosion Association (Australasia) and Stormwater Industry Association Conference on Soil and Water Management for Urban Development*, 9 - 13th September 1996, Sydney.

Rajabi, M., Tingay, M., Heidbach, O., Hillis, R. & Reynolds, S. (2017). The Present-Day Stress Field of Australia, *Earth-Science Reviews*, *168*, 165-189.

Rocscience 2018, Slide Version 2018 – 2D Limit Equilibrium Slope Stability Analysis, Rocscience Inc., Toronto, www.rocscience.com.

Terzaghi, K., Peck, R.B., (1967). Soil Mechanics in Engineering Practice, John Wiley & Sons, New York, 729 p.

VandenBerg, A. H. M. (1997). Warragul SJ 55-10 Edition 2, 1:250 000 Geological Map Series. *Geological Survey of Victoria*.

VandenBerg, A. H. M. (2016). Depositional Facies and Extent of the Late Neogene Sandringham Sandstone in Southern Victoria, Australia, *Proceedings of the Royal Society of Victoria*, *128*, 7-24.

Wallace, M. W., Dickinson, J. A., Moore, D. H. & Sandiford, M. (2005). Late Neogene strandlines of southern Victoria: a unique record of eustasy and tectonics in southeast Australia, *Australian Journal of Earth Sciences*, *52*, 279-297.

Welch, S. I., Higgins, D. V. & Gallaway, G. A. (2011) eds. Surface Geology of Victoria 1:250 000, Geological Survey of Victoria, Department of Primary Industries.

ADVERTISED
PLAN

ADVERTISED
PLAN

GHD

Level 9 180 Lonsdale Street
Melbourne VIC 3000
T: 61 3 8687 8000   F: 61 3 8732 7046   E: melmail@ghd.com

12527040-55182-8/https://projectsportal.ghd.com/sites/pp17_04/5575southgippslandhi/ProjectDocs/12527040-RPT_5575 South Gippsland Hwy Geotechnical Assessment.docx

Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
A						04/05/2021
B						10/06/2021
C						25/06/2021
D						30/03/2022
0	N. Patel	S. Narendranathan		S. Narendranathan		30/03/2022
E						31/05/2022
F						10/06/2022
1	N. Patel	S. Narendranathan	N.A	S. Narendranathan	N.A	13/09/2022

ADVERTISED
PLAN

www.ghd.com