

Graymont South-Western Pit – Geology and Soil Report

✦ Prepared for

Graymont (NZ) Ltd

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Limitations:

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Table of Contents

SECTION	PAGE
1.0 Introduction	1
1.1 Objective and Scope	1
1.2 Report Structure	2
2.0 Geological Description of the Existing Environment	3
2.1 Topography	3
2.2 Local Geology	3
2.3 Structural Geology	5
2.4 Hydrology and Hydrogeology	6
2.5 Geomorphology	8
3.0 Geotechnical Hazards and Effects Assessment	10
3.1 Seismic Hazards	10
3.2 Ground and Slope Stability	13
3.3 Geotechnical Design	14
3.4 Geotechnical Hazard / Effects Mitigation	16
4.0 Overburden Effects Assessment	17
4.1 Overburden Volume and Thickness	17
4.2 Topsoil Volume and Thickness	17
4.3 Earthworks and Erosion and Sediment Controls	18
4.4 Overburden Stripping	22
4.5 Overburden Disposal / Placement (ELF)	23
4.6 Topsoil Reclamation	25
5.0 Summary of Effects, Mitigation and Residual Effects	28
6.0 References	33

Table of Figures

Figure 1: Site Plan	35
Figure 2: Regional Geology	36
Figure 3: Soil Sampling Locations	37
Figure 4: Caves of Significance and Karst Features	38
Figure 5: Isopach and Slope Model of Overburden	39

Table of Tables

Table 1: South-Western Pit Site Legal Description	1
Table 2: Geological Units of South-Western Pit Project Site	4
Table 3: WDC Significant Cave Systems	10
Table 4: Peak Ground Acceleration	11
Table 5: Overburden at South-Western Pit area	18
Table 6: Soil Horizon Organic Content	26
Table 7: Topsoil Characteristics	27
Table 8: Summary of Key Geotechnical and Soil Related Effects and Mitigation Measures	30
Table 9: Karst Landforms Summary	A-7

Appendices

- Appendix A: Geology, Geomorphology and Geotechnical Background Information
- Appendix B: Site Images
- Appendix C: Soil Sampling and Analysis Results

1.0 Introduction

Graymont (NZ) Limited supply limestone products to the domestic market in New Zealand and export markets across the South Pacific islands. The limestone products are used in major industries including agriculture and animal health, roading and civil infrastructure; manufacturing (for example paper, leather, sugar refining), the steel industry, mining, water quality treatment and in wastewater treatment.

Graymont operate the Oparure limestone quarry (the existing operation), located approximately 8 km west of Te Kuiti. The Oparure Pit is a high-grade limestone quarry with onsite processing facilities (i.e. crushing, drying and bagging plant).

Graymont wish to expand the quarry operation, to recover the identified resource and maintain a nationally significant supply of limestone aggregate. PDP previously produced a geology and soils report (Graymont Pakeho Pit – Geology and Soils Report, C03870503R001, dated 14 October 2022) covering the previously proposed expansion area. A revised pit shell footprint has recently been put forward for consenting, named the South-Western Pit.

South-Western Pit is a proposed new open pit limestone quarry near the existing operation Oparure (the South-Western Pit or the site, refer to the substantive application for a description of the quarry proposal).

The new pit is located on farmland <1 km west of the existing operation. The legal description of land parcels on which the new quarry will be located are summarised below in Table 1 and shown on Figure 1.

Table 1: South-Western Pit Site Legal Description			
Address	Legal Description	Site Area (Ha)	Owner
966 Oparure Road	Lot 1 DPS 77130	21.9	Graymont
	Lot 2 DPS 33442	33.1	
	Lot 1 DPS 74022	4.0	

1.1 Objective and Scope

The objective of this report is to summarise the geology, geomorphology and soils at the site and present an effects assessment for the South-Western Pit relating to these elements, including an assessment of the potential geotechnical hazards.

The scope of work and methodology adopted to prepare this combined geology, geomorphology, geotechnical and soils assessment included:

- ✧ Background information review of published geological information.
- ✧ Desktop study of available geotechnical reports for the Oparure Pit.
- ✧ Development of the geological model and preliminary overburden isopach model / volumes assessment.
- ✧ Site visit assessments including geotechnical stability assessments, geological features and soil sampling at the site.
- ✧ Soil sampling and baseline laboratory testing and assessment of the nutrient value of the topsoil.
- ✧ Impacts assessment of overburden stripping and disposal for the South-Western Pit.

The information provided in the following sections is based on a combination of the above desktop assessments, field observations, field investigations and laboratory testing.

1.2 Report Structure

The report structure is as follows:

- ✧ A summary of the existing environment at the site, including the local topography, geology, hydrology and hydrogeology, and geomorphology (Section 2.0).
- ✧ Assessment of geotechnical effects due to the quarry pit (Section 3.0).
- ✧ Assessment of environmental effects of overburden stripping and placement at the site (Section 4.0).
- ✧ Supporting regional geological, geomorphology (with relevant karst and cave system definitions) and background geotechnical information (Appendix A).
- ✧ Site images (Appendix B).
- ✧ Soil sampling results (Appendix C).

1.2.1 Contaminated Land

Contaminated land aspects and assessments are considered separately (Oparure South-Western Pit – Contaminated Land Preliminary Site Investigation March 2026) and are, therefore, not discussed in this report.

2.0 Geological Description of the Existing Environment

The following sections summarise the existing environment in terms of topography, geology, hydrology and hydrogeology, and geomorphology. The information is based on published literature, unpublished geological theses and site observations / investigations (refer to Appendix A for additional background information).

2.1 Topography

The local terrain is dominated by undulating to rolling hills rising to approximately 260 – 265 m RL in the site area. The site contours are shown on Figure 1.

Notably within the site area, the topography is an undulating, karst landform with exposed steep ($>25^\circ$) limestone bluffs and dolines (sinkholes). The dolines merge in places to create short valley systems.

2.2 Local Geology

The geological units and key structural elements in the general area of the proposed South-Western Pit are outlined below.

2.2.1 Geological Units

Geology in the general site area comprises:

- ✧ Cover deposits comprising topsoil, volcanic ash and minor ignimbrite.
- ✧ Taumatamaire Formation (mudstone).
- ✧ Otorohanga Limestone.

2.2.1.1 Cover Deposits

The Mairoa topsoil is classified as ‘typic orthic allophanic’ and is well draining, with a permeability in the range of 4 – 72 mm/hr (Landcare Research, 2019). In the project area the Mairoa topsoil is around 50 – 200 mm thick (refer to Section 4.6.1 and Figure 3).

The near surface volcanic ash is brown to reddish brown sandy silt and inferred to be Mairoa Ash (based on colour). The volcanic ash is the parent material of the above topsoil. The Mairoa Ash may only be around 600 – 1000 mm thick (the base of this unit was not encountered during investigations). Mairoa Ash lies unconformably over Kauroa Ash at depth. Kauroa Ash was not observed during site investigations. In this report the two deposits are collectively referred to as volcanic ash.

A thin layer of pinkish red weathered ignimbrite (inferred to be the Ongatiti Formation of the Pakamanau Group) was observed on an isolated ridge in the site area. In outcrop the weathered ignimbrite overlies the Taumatamaire Formation and underlies the volcanic ash.

2.2.1.2 Mudstone

The Taumatamaire Formation (Mahoenui Group) is a weakly bedded to massive, calcareous fine to sandy mudstone. The formation was deposited in the Early Miocene and lies conformably on the Otorohanga Limestone. The contact of this unit with volcanic ash or Otorohanga Limestone was not observed during site investigations.

2.2.1.3 Limestone

Otorohanga Limestone at the site is a blue grey to white bioclastic limestone which has flaggy / blocky bedding and is jointed. Weathered units are cream coloured. There are three limestone units (members) in the Otorohanga Limestone: the basal Pakeho Limestone, intermediate Waitanguru Limestone, and upper Piopio Limestone. The economic limestone units are based on the primary units described above and CaCO₃ grade for the Oparure Pit (refer to Table 2, based on Hanson 2008).

Table 2: Geological Units of South-Western Pit Project Site	
Geological Unit	Economic Unit
Volcanic Ash	Overburden
Ongatiti Formation	Overburden
Taumatamaire Formation	Overburden
Piopio Limestone	Overburden (Caprock)
Waitanguru Limestone	Upper Steel
Pakeho Limestone	Ag Lime (AG1 + AG2)
Pakeho Limestone	High Grade
Pakeho Limestone	Lower Steel
Pakeho Limestone	Lower Ag Lime (AG3)
Notes: 1. Geological and the economic units of the Oparure Quarry, based on Hanson 2008.	

2.2.1.4 Basement

Mesozoic rocks form the basement underlying the limestone (Upper Te Kuiti Group rocks) at the site. Based on the available information, the basement rock is likely to be indurated, interbedded siltstone and sandstone (Greywacke). A review of the available Graymont borehole data indicates basement rock was not intersected during exploration drilling.

The Otorohanga Limestone can overlie the upper Te Kuiti Group rocks Waitomo Sandstone, Orahiri Limestone, basement rock and less commonly the Aotea Sandstone (Lower Te Kuiti Group). Waitomo Sandstone is not present near the site (Hanson 2008).

The limestone resource likely overlies the Orahiri Limestone which in turn overlies the basement rock. Aotea Sandstone (Lower Te Kuiti Group), Orahiri Limestone and a sandy limestone (an equivalent of the Waitomo Sandstone) are present below the existing quarry (Hanson 2008).

2.3 Structural Geology

2.3.1 Faults

The major regional faults in the site vicinity are the northerly trending Waipa Fault and the southern extension of Hikurangi Fault (refer to Figure 2).

The Waipa Fault lies around 2 km east of the site and the Hikurangi Fault is approximately 3 km to the west.

An unnamed regional inactive fault crosses the site on a southwest-northeast trend (Geology of Waikato, QMAP 1:250,000 geological map, Frosted 2004). Localised faults with similar orientations are observed at the nearby Oparure Pit and have previously been inferred to be offshoots / fault splays from the major regional faults. These northeast trending faults are inferred to be recent (Miocene / Pliocene age) and postdate the limestone deposition.

Offset limestone and mudstone (due to faulting) are observed in the nearby Oparure Pit and are exposed in the west and north of the quarry. The faults have brittle fracture zones (breccia, crush zones) of up to 3 m wide. These zones are highly permeable and have increased water content. Cave genesis is expected to align with the highly permeable zones.

The limestone resource at the Oparure Pit is downthrown to the west by around 20 m in the north of the quarry. Locally the faulting increases the bedding dip of the limestone. A zone around 50 m wide west of the fault has elevated water levels and the fault is inferred to dam the west to east subsurface flow of water. Similar fault patterns can be expected at the site.

2.3.2 Bedding

The Otorohanga Limestone and the overlying Taumatamairi Formation gently dip towards the east and northeast (Frosted 2004, Graymont MEP Exploration report). Within the nearby Oparure Pit area, the limestone beds dip gently at 3°–5° towards the east (Adams 2018) and are locally steepened near faults.

2.3.3 Joints / Fracture Network

There are three prominent sub-vertical/southeast dipping joint sets in the limestone at the Oparure Pit (Adams 2018). The dominant joints strike approximately northeast.

An assessment of the limestone outcrops on the site indicate that jointing is consistent with the offshoot fault orientations and jointing at the Oparure Pit.

The joints show preferential fracture development (large open fractures / dissolution features) trending between 050° and 110° (roughly northeast to east) (Photograph 3, Appendix B).

2.4 Hydrology and Hydrogeology

The following sections cover the site hydrology and hydrogeology.

2.4.1 Rainfall

The closest Waikato Regional Council (WRC) operated rain gauge to the site is located in Te Kuiti. The annual average rainfall near Te Kuiti is estimated to be 1478 mm (WRC 2026).

2.4.2 Surface Hydrology

For the purposes of Sections 2.4.2 and 2.4.3, the terms ‘surface hydrology’ and ‘subsurface hydrology’ have simply been used to describe the water resource above ground level and the water resources below ground level. In reality, the nature of the karst landscape is that the interaction between surface and subsurface is dynamic and changes frequently. This is reflected in the Waikato Regional Plan (WRP) glossary which provides the following definition for groundwater:

“Groundwater: *The subsurface water within the zone of saturation where the pore spaces are filled with water and the pressure of water is equal to or greater than atmospheric pressure. For the purposes of this plan groundwater excludes water flowing in karst systems which are considered to be surface water.”*

Accordingly, any water existing above ground level or within the karst system is defined as 'surface water'.¹

Surface water bodies in the vicinity of the site that are above ground include (refer to Figure 2):

- ✧ The Mangawhitikau Stream to the north.
- ✧ The Mangapu River to the south and southeast.

The above ground hydrology is controlled by short gullies and valleys that end abruptly and is discharged into the ground via dolines (sinkholes).

Above ground surface water is transmitted to the subsurface waterways (i.e. the epikarst, tomos and cave systems). The subsurface waterways will likely discharge at spring locations or stream emergences which will again form above ground surface water channels.

2.4.3 Subsurface Hydrology (Karst Landscape)

The precise level of subsurface water beneath the South-Western Pit has not yet been determined. However, the stream flowing through the Camelot Cave system beneath the SW Pit occurs at approximately 80 m below current ground level (based on cavers' estimates). In specific areas, the subsurface water level may be higher or lower due to presence of similar fault patterns described in Section 2.3.1.

The proposed base of the South-Western Pit ranges from approximately 159 to 218 m RL. Assuming a similar subsurface water level to that at the Oparure Pit:

- ✧ Localised short duration ponding may occur in the South-Western Pit, but this is likely to drain rapidly.
- ✧ Pit pumping is not expected to be required.

2.4.4 Subsurface Hydrogeology (Non-Karst Landscape)

The groundwater 'aquifer' is inferred to be in the limestone and sandstone underlying the quarry limestone resource (the Te Kuiti Limestone), based on information and boreholes in the vicinity of the existing Oparure quarry. The actual groundwater levels have not been established in the vicinity of the South-Western Pit area. The water resources (which are not within the scope of this report) are discussed in the water assessment report, 'South-Western Pit: Water Assessment', PDP 2026c.

Perched water may occur in the volcanic ash / mudstone overburden and engineered landforms. However, the existing landscape in the vicinity of the site

¹ It is noted that Graymont draws water from a subsurface water resource outside the karst system, and that is defined as groundwater in accordance with the first sentence of the WRP definition.

does not lend itself to the presence of significant perched water tables. This is due to the natural drainage characteristic in the limestone, steep slopes, rocky outcrops and ridges, thin cover deposits and presence of many subsidence and collapse dolines (the polygonal karst).

2.5 Geomorphology

The key geomorphic features identified at the site are outlined below.

2.5.1 Landslides and the Taumatamaire Formation

The main geomorphic distinction in the South-Western Pit area to the Oparure Pit area is the limited mapped Taumatamaire Formation (mudstone) cover overlying the Otorohanga Limestone. The mudstone is present in the north of the project area and localised landslide features can be observed on the larger slopes (Photograph 4, Appendix B).

2.5.2 Karst and Cave Systems

The following sections outline known karst and cave systems that are of potential geological importance or interest (and that may be affected by the future quarry) and to provide context to the site geomorphology. The potential physical impacts due to quarrying (e.g. noise and vibration) on these landforms within the South-Western Pit area are assessed in a separate report covering noise and vibration, refer to the substantive application. The natural character/landscape effects are also considered in a separate report, as part of the substantive application.

2.5.2.1 Pakeho Polygonal Karst

The proposed South-Western Pit area coincides with a geomorphic feature recognised by Geological Society of New Zealand (GSNZ) 'the Pakeho Polygonal Karst' (Figure 4). GSNZ have delineated this feature as a geopreservation area which is an area of around 3.5 km² (346 Ha).

GSNZ describe the feature as:

"the largest autogenic karst aquifer in the North Island. The area of polygonal karst has numerous dolines, with scattered limestone outcrops with patchy bush, mostly grassed farmland that is quite smooth and probably blanketed in ash"

Graymont completed a survey of the site karst landscape in 2019 (refer to inset on Figure 4). The survey included visiting and recording general observations and geomorphic features at the locations (inferred as dolines and steep limestone bluffs) from the topographic contours and aerial images within the quarry boundaries or near to the site.

The site is dominated by the polygonal karst that has developed due to many dolines in the Otorohanga Limestone (refer to overview images, Photographs 1 – 8, Appendix B). These features are inferred to be predominantly subsidence

and collapse dolines based on surface appearance. There has also been coalescence of the dolines to form short valley systems.

The Waipuna Polygonal Karst (WPK) also delineated by GSNZ (246 ha) is located approximately 3.5 km northwest of the site. GSNZ describe the feature as:

“Polygonal karst, disappearing streams and blind valleys in Oligocene limestone. Waipuna Cave is within the area, documented separately in Geopreservation Inventory”

“Under native forest therefore natural ecosystem in polygonal karst. Large areas of temperate polygonal karst uncommon nationally”

The South-Western Pit is sufficiently far enough away from the WPK, such that it is very unlikely it will have any impact on the WPK.

2.5.2.2 Significant Cave Systems

Under the proposed Waitomo District Council (WDC) - Appeals Version 1 October 2025 caves are presented in either the *“Outstanding Natural features”* or *“Significant Natural Areas”* overlays. These systems have been georeferenced (approximate locations) and are shown on Figure 4 (Caves of Significance and Karst Features). Cave systems in the vicinity of the site (<5 km) are summarised below in Table 3.

Caves of significance (with approximate distance from the South-Western Pit site), based on the proposed Waitomo District Plan – Appeals Version 1 October 2025 (WDP 2025) are as follows:

- ∴ Waitomo Glowworm Cave (9.0 km N) - National Significance
- ∴ Mangapu System (900 m SE) - Local Significance

The Waitomo Glowworm Cave and the Mangapu System (i.e. Lost World Cave Complex) are major tourist attractions in the area.

2.5.2.3 Additional Known Caves

There are caves that are also recognised by local cavers, but do not feature on the WDC Caves of Significance list. Professor Paul Williams (University of Auckland) has compiled a list of known caves in the vicinity of the South-Western Pit that includes those located between the Mangawhitakau and Mangapu catchments.

PDP has georeferenced the location of the caves that feature on the list (located between the Mangawhitakau and Mangapu catchments) provided by Professor Williams.

Table 3: WDC Significant Cave Systems			
System	WDC DP ID ¹	Geoheritage Significance ²	Distance (km)
Digme - Camelot	(KO05)	-	<1.0
Waipuna Road (Rumbling Gut, Catherwoods, Waipapa, Lembergs, Guildford, Yoyo)		National	1.0
Mangapu	(KO2-C)	National	1.5
Mangawhitikau	(KO3-C)	National	1.8
Troopers Rd (Black)	(KO4-C)	National	3.6
Waipuna (Scenic Reserve)		National	4.3
Deception Cave		Regional	4.7
Waitomo Headwaters	(KO5-C)	National	4.7
Lee's Swamp-General Ward	(KO08)	-	5+ (in map area)
Shangri La	(KO21)	-	5+ (in map area)
Notes: 1. Karst Overlay features – Schedule 12 Proposed Waitomo District Plan Appeals version 1 October 2025. 2. Geoheritage significance sourced from Waikato Regional Council Technical Report 2022/03 "Mapping significant natural areas of the Waikato region: the physical basis for the identification of karst ecosystem sites".			

3.0 Geotechnical Hazards and Effects Assessment

Geotechnical considerations for quarry operations and an assessment of the associated hazards are provided below. The hazards are not unusual for a moderate sized quarry operation in New Zealand and can be managed by health and safety hazard management, industry best practice and geotechnical design.

3.1 Seismic Hazards

3.1.1 Fault Rupture

No known active faults are located within the South-Western Pit area. The nearest active fault (Turi Fault) is offshore >40 km from the site and is a normal west dipping fault. The northern extension of this fault is unlikely to exist onshore. In addition, there is no evidence of reported / observed fault displacement at the site in the recent deposits. The risk of fault rupture is therefore considered negligible.

3.1.2 Seismicity

The South-Western Pit is located in an area with historically low seismic activity and only moderately strong earthquakes (<MM6) are expected at some time in the future.

To inform the geotechnical design, estimates of the ground motion due to earthquake activity is necessary. The determination of peak ground acceleration (PGA) for the site (refer below) is based on the method described in the MBIE/NZGS Earthquake Engineering Practice – Module 1, November 2021.

Based on Module 1 (MBIE/NZGS 2021) estimates of the hazard parameters (a_{max} and M_w) are selected using recommended values from Table A1: Peak Ground Acceleration.

The annual probability of exceedance (AEP) for the ultimate limit state (ULS) and serviceability state (SLS) events for the site is based on a 'structure' Importance Level 2 as defined in NZS 1170. Importance Level 2 is generally considered as normal risk, i.e. the consequence of failure may result in moderate risk to human life, or will have considerable risk to economic, social or environmental consequence.

Table 4 summarises the estimated PGA for the ULS and SLS events for the Class A (Rock) and Class C (natural soils) site soil classes. The estimated PGA (horizontal) due to M_w 5.9 earthquake is to be used for seismic slope stability analysis at the site (refer to Table 4).

For open pit slope design, a geotechnical professional with experience in mining and quarrying should be consulted to determine the appropriate site-specific analyses and design criteria for ground motion predictions for rock slopes.

Table 4: Peak Ground Acceleration		
Limit State	AEP	Class A and Class C
ULS	1/1000	0.36
SLS	1/25	0.07
Notes: 1. ULS and SLS for Importance Level 2 and using a design life 100+ years at Te Kuiti.		

The following measures to mitigate risks due to seismic activity will be implemented at the site:

- ✧ Engineered landform and quarry pit slope design criteria provided by a geotechnical professional with experience in mining and quarrying.
- ✧ Final pit shells are reviewed by a qualified geotechnical engineer with experience in mining and quarrying.

- ✧ Slope stability analysed using the above earthquake loadings.

The following are additional measures recommended to mitigate risks due to seismic activity that may be implemented at the site by Graymont:

- ✧ Structural design carried out using the structure importance and earthquake loadings derived from NZS1170.
- ✧ Emergency preparedness and earthquake quarry re-entry management plans implemented.

3.1.3 Liquefaction

Liquefaction hazard at the South-Western Pit area has been mapped based on an MBIE Level A desktop assessment. The South-Western Pit is generally mapped as unlikely with a section on the northern extent of the pit mapped as undetermined. Liquefaction hazard at the site is anticipated to be low due to the presence of limestone rock, low groundwater levels and presence of relatively thin, dense / stiff, Quaternary deposits overlying the limestone. A small portion of the northern South-Western Pit area is mapped as undetermined. The site area ground shaking susceptibility is a Category C (i.e. defined as not very hazardous), based on the WRC GIS hazard portal (accessed online 23 Feb 2026).

Fill materials at the site, making up the in-pit engineered landform (ELF – refer Sections 4.3 and 4.5), comprise a combination of rock fill and compacted soils (clay, silts and mudstone). A strong earthquake could potentially trigger localised liquefaction, cyclic softening and lateral spreading where fill is not engineered or is not constructed in accordance with the design / specification of an engineered fill.

Seismicity and liquefaction hazard is considered low risk due to absence of active faulting and the expected level of ground shaking/likelihood of occurrence during the life of the quarry and fill engineering design life. However, all other structures located outside of the pit shall require a geotechnical assessment confirming suitable ground conditions.

3.2 Ground and Slope Stability

3.2.1 Engineered Landform Stability

Engineered Landforms (ELFs) include any fill material placed in the overburden stockpiles, waste rock stacks, valley fills and platforms for buildings or temporary structures. All final ELFs will require geotechnical engineering design to ensure stability under static and dynamic loads (i.e. seismicity).

3.2.2 Landslides

No largescale landslides have been mapped in the site area. However, the Taumatamaire Mudstone is present and there is evidence of localised slope instability (hummocky ground) at the site (Photograph 4, Appendix B).

Landslides at the site are likely to be rainfall triggered / influenced events. However, strong earthquake shaking (MM6 or greater) could initiate larger landslides on the steeper slopes at the site particularly if weak, softer lithologies are present (i.e. the Taumatamaire Formation mudstone and the volcanic ash). Geotechnical stability of the overburden materials is assessed further in Section 4.0.

3.2.3 Rockfall

There is a rockfall hazard in undisturbed areas of the site due to the naturally occurring steep limestone slopes and bluffs and the flaggy / blocky nature of the limestone. As the site is developed into a quarry operation, this hazard can be mitigated by formation of engineered landforms (e.g. catch benches, earth bunds), controlled blasting and geotechnical management.

Landslides and rockfalls outlined above are expected to occur at times during the lifetime of the operation. These are considered normal hazards for the site that can be mitigated by appropriate geotechnical management.

3.2.4 Sinkholes

Sinkholes are a recognised geo-hazard feature at the site and are managed by site access controls, surface water control / drainage and filling where required.

The water table is expected to be below the base of the proposed quarry floor, with the exception of localised short duration ponding that is likely to drain rapidly.

Localised dewatering of cover deposits due to the quarrying may occur (where the quarry intersects any perched groundwater in these deposits). However, any dewatering of cover deposits is not expected to induce / enlarge sinkholes in the limestone because of quarry water control measures / limited influence.

3.3 Geotechnical Design

There are no permanent structures proposed for the South-Western Pit (except the pit slopes and the overburden ELF's inside the quarry pit). However, future quarry operations may require additional sediment retention ponds or water storage lagoons to operate post closure. These should be designed and operated in general accordance with the Erosion and Sediment Control Plan (ESCP).

General geotechnical design recommendations are outlined below, based on a review of existing AGL, GeoSolutions and PDP reporting for Oparure Pit.

- ✧ Pit slope design should be based on geotechnical assessments and reports, slope performance, drilling data, geological maps, topography, aerial imagery, seismic hazard information and published geological information.
- ✧ High strength rock (limestone) is expected at the site and based on the performance of the existing Oparure Pit, steep batter slopes of 50° to 76° with overall benched pit slope heights up to 60 m have been achieved without the development of large-scale slope instability. Higher pit batter slopes may be achieved by following existing design protocols in agreement with the geotechnical engineer.
- ✧ Slope instability in the limestone units is more likely to occur due to
 - Intersection of rock mass defects or geological structures such as fault planes / joints and associated steep bedding or weak / disintegrated or weathered rock near the faults.
 - Unfavourably oriented defects facilitating kinematic failure mechanisms such as toppling, wedge or block sliding.
- ✧ Slope instability in the overburden units is more likely to occur due to:
 - Unfavourably oriented bedding / rock fabric.
 - Weak or weathered rock mass.
 - Perched groundwater increasing pore water pressure within the batter slope.
 - Saturation of the overlying ash units during heavy rainfall.
- ✧ Catch bench (berm) design width is $>1/2 \times$ bench height and provides adequate capacity to arrest rockfalls (for up to 15 m bench heights).
- ✧ Rockfall management recommendations include the following:
 - Planning the pit slope aspect to reduce kinematic failures.
 - Optimising blasting to minimise over-break and damage of final pit slopes.

- Removal of rockfall hazards and use of benches / catch bunds to arrest rockfall.
- Matching the bench height to the equipment size.
- Minimising ponding of water by use of graded benches.
- ∴ Recommendations for slope design in overburden units are based on the following observations:
 - Drainage, ground and surface water management measures are required to mitigate the effects of perched groundwater formation in the overburden material. Sufficient perched groundwater drawdown within overburden cut batter slopes is required to improve stability.
 - Slopes cut into in-situ volcanic ash overburden $>15^\circ$ show signs of slumping at heights <8 m.
 - Permanent or long-term slopes cut into in-situ Taumatamairé Formation mudstone overburden are prone weathering, slaking and disintegration at the slope face resulting in batter angles of approximately 35° where bedding or discontinuities dip favourably such as the eastern batter slopes of the Oparure Pit.
 - Observations from the Oparure Pit northern batter slopes indicated that unfavourably oriented bedding and rock mass conditions in upper, weathered Taumatamairé Formation Mudstone can result in instability at slopes $<22^\circ$ and more than 20 m vertical height without appropriate surface water and groundwater management.
 - Slopes cut into fill overburden have achieved 35° slopes for heights <20 m. Above this height specific geotechnical slope design will likely be required for long-term stability.
- ∴ Overburden stockpile slope design is based on laboratory tested soil strengths, geotechnical site observations and slope stability analyses.
- ∴ Graymont undertake biennial reviews of the stability condition of quarry pit slopes and validate the slope designs against observed performance; check for potential unexpected ground conditions or the development of new instability hazards; and to modify slope designs if appropriate. Graymont engage independent geotechnical specialists to undertake the reviews.

The principles of geotechnical design and recommended management measures adopted for the Oparure Pit (outlined above) are considered to be appropriate for application to the South-Western Pit and ELFs for the current stage of the project.

Additional recommendations for the initial stages of the South-Western Pit quarry include:

- ∴ Mapping of faults and overburden thickness in the northern area of the quarry pit (refer to the overburden isopach model Section 4.0 and Figure 5).
- ∴ Temporary pit walls should be constructed / tested prior to commencing construction of the final pit walls.
- ∴ The temporary pit walls should be reviewed by a geotechnical professional and updates made to the geotechnical domains / model for the quarry before excavating final pit slopes.

3.4 Geotechnical Hazard / Effects Mitigation

Geotechnical hazards associated with the proposed quarry are managed through a combination of engineered design, construction methodology and ongoing monitoring.

The mitigation measures outlined in this report are implemented through:

- ∴ The requirement for ELF and slope design by a suitably qualified and experienced geotechnical professional, with the conditions of consent relating to overburden placement and pit slope design.
- ∴ The New Pit and Haul Road Site Management Plan (P&HMP), which requires all design, construction and operational controls not otherwise contained within certified sub plans to be defined and implemented.
- ∴ Ongoing geotechnical review, monitoring and update processes required under the consent conditions.

Specific mitigation measures include slope design based on site specific geotechnical assessment, with of groundwater and surface water controls, use of benching and buttressing, and ongoing inspection and review of slope performance.

These measures are implemented as part of the overall geotechnical design and management framework for the site and are not managed through the Erosion and Sediment Control Plan (ESCP) or ToMP. With these measures in place, the residual geotechnical effects are considered to be less than minor in RMA terms.

4.0 Overburden Effects Assessment

The overburden at the site comprises the low grade Piopio limestone (cap rock), Taumatamairi Formation mudstone, volcanic ash and topsoil (as described in Section 2.2).

4.1 Overburden Volume and Thickness

Overburden volumes and thickness are based on the Graymont geology model for the South-Western Pit, base of overburden and topographic surfaces provided by Graymont. This information is the best estimate possible at this stage.

The overburden isopach (thickness) model based on contouring of the borehole data indicates the average thickness of overburden will be around 11.0 m (range 0 – 44 m). The isopach map shows the overburden thickness variation across the pit (refer to Figure 5).

Standard practice involves refinement of geological (and overburden) models as additional information becomes available. This should be carried out as the project progresses. Particular emphasis should be put on any refinements to the geological model (and overburden volume and thickness) associated with fault oversets.

4.2 Topsoil Volume and Thickness

Topsoil in the site area has an average thickness of 150 mm (range 50 – 200 mm). Topsoil is very thin on steep slopes (>25°) and accumulates in the valleys.

According to the Topsoil Management Plan (ToMP, PDP 2026b), the recoverable topsoil area is therefore present on around 59.6 ha of the site area. The recoverable topsoil volume, based on the average thickness of 150 mm, is estimated to be approximately 89,400 m³ (Table 5).

Sufficient Horizon C (Mairoa Ash) should also be recovered to bring the combined recoverable soil (and silt) thickness to a minimum of 600 mm. This equates to 268,200 m³ (approx.) of Horizon C to be recovered.

Table 5: Overburden at South-Western Pit area

Geological Units	Average and Approximate Thickness ¹ (m)	Estimated Volume (m ³)
Topsoil	0.15 (0.05 – 0.2)	89,400
Volcanic Ash / Taumatamaire Mudstone / Limestone cap rock	11 (0 – 44 m)	6,483,591
Notes: 1. Range in brackets. 2. Topsoil thickness for the South-Western Pit Project based on site investigations to 0.5 m below ground level (max). 3. Volumes and surface areas used to calculate the above estimated volumes is based on information provided by Graymont.		

4.3 Earthworks and Erosion and Sediment Controls

The overburden related earthworks activities, with potential to impact the environment are the stripping, stockpiling and placement of topsoil, and the stripping and placement of non-topsoil overburden. These activities are likely to generate sediment and therefore controls are required. With the recommended controls in place, any adverse effects will be less than minor in magnitude.

The mitigation measures outlined in this section are implemented through:

- ✧ The ESCP and associated ESC Stage Plans, which address sediment generation and water quality effects.
- ✧ The P&HMP and detailed geotechnical design, which address construction methodology, engineered landform performance and stability.

4.3.1 Summary of Sediment and Erosion Controls

The mitigation of effects related to sediment generated at the site is discussed further in the project ESCP 'South Catchment Western Pit – Erosion and Sediment Control Plan Rev 7' report ref: C03870822 dated 01 September 2025).

Controls implemented during overburden stripping that relate to sediment generation and erosion control are implemented through the ESCP and ESC Stage Plans. These include:

- ✧ Limit exposure and stage works:
 - Strip overburden in defined campaigns aligned with quarry stage plans.
 - Minimise the area of exposed overburden at any one time and backfill or stabilise progressively.

- ∴ Divert and separate surface water:
 - Install clean water diversion bunds and drains upslope before stripping starts.
 - Keep clean runoff separate from runoff from active stripping areas using water tables and toe drains.
- ∴ Control runoff velocity and erosion:
 - Use benching, roughening, and check dams to shorten flow paths and reduce velocities on stripped surfaces.
 - Provide drains at the toe of highwalls to intercept runoff and direct it to pit floor soakage areas.
- ∴ Stabilise exposed surfaces:
 - Apply hydroseeding, grassing, or mulching to stripped areas that will remain exposed.
 - Provide additional temporary stabilisation ahead of forecast heavy rainfall events.
- ∴ Apply weather, material, and inspection controls:
 - Restrict stripping to dry conditions, with no stripping during the winter period unless approved.
 - Strip and manage topsoil separately from other overburden materials.
 - Inspect stripping areas and controls regularly, with trigger response actions implemented if erosion or instability is observed.

The following are a summary of controls to be implemented for the overburden ELF and associated earthworks, as outlined in the ESCP:

- ∴ Toe buttressing and internal reinforcement
 - Maintain and progressively extend limestone or competent mudstone toe buttresses as fill height increases. Temporary slopes do not require engineered toe buttresses but may be monitored as ELF filling progresses.
 - Install internal rock layers at regular vertical intervals to improve stability and provide drainage pathways towards toe buttress and outer facing of the ELF and drainage benches.
- ∴ Control placement geometry and drainage:
 - Maintain and extend rockfill toe buttresses at the base of the overburden landform as height increases.

- For higher fill stages, ensure toe buttress widths are consistent with adopted design guidance, increasing buttress width with increasing fill height.
 - Use limestone cap rock preferentially for toe buttressing and basal drainage layers.
 - Where limestone supply is constrained, use competent mudstone as a secondary buttressing material, particularly to support volcanic ash units or soft / weak material.
 - Placing of internal rock layers, within the landform, to improve stability and drainage as needed and agreed with the geotechnical engineer. Monitoring of drainage performance should be included with routine inspections of the overburden ELF.
- ✧ Manage water during placement:
- Avoid directing surface water over the external faces of the landform during construction.
 - Allow runoff from internal placement areas to infiltrate into drainage layers and discharge as controlled flow through the drainage filter blanket the base of the landform to the pit floor.
 - Maintain internal drainage pathways for the fill via basal drainage, drainage layers and contact drainage zones using high permeability limestone or rockfill.
 - Prevent clean water entering the fill sites using crest diversion bunds and graded benches.
- ✧ Stage placement and minimise exposure:
- Place soft / weak materials progressively in small cells rather than large continuous lifts ensuring sufficient mudstone or rockfill on the outside of the bench.
 - Avoid leaving large areas of fine overburden exposed at any one time, particularly during wet periods.
- ✧ Stabilise and rehabilitate surfaces promptly:
- Place topsoil in stages once final landform geometry is achieved.
 - Hydroseed or grass exposed surfaces as soon as practicable to limit erosion during rainfall.
- ✧ Inspect and respond to performance issues:

- Inspect landform surfaces, benches, and drainage features regularly, with increased frequency after rainfall.
- Continue daily visual inspections for cracking, slumping, seepage, or erosion and use survey data and periodic geotechnical review to confirm performance as fill heights increase.
- Apply trigger response actions if erosion, instability, or sediment discharge is observed, including repair, regrading, or additional stabilisation measures.

These measures are described in detail within the ESCP and implemented through ESC Stage Plans prepared for each stage of earthworks, in accordance with the conditions of consent. While certain construction measures may assist in reducing erosion or sediment generation, the ESCP remains the primary control mechanism for sediment effects. Geotechnical construction measures are not relied upon as primary erosion and sediment controls.

The following measures relate to geotechnical construction methodology and engineered landform performance, rather than erosion and sediment control. These measures are implemented through geotechnical design requirements and the P&HMP. The following are a summary of additional geotechnical controls to be implemented for the overburden ELF and associated earthworks:

- ∴ Geotechnical Construction Methodology (P&HMP and design requirements):
 - Use bottom-up construction with paddock stacking on wide benches, avoiding uncontrolled end tipping and local over steepening.
 - Place fill in controlled lifts and compact each lift by dozer and haul truck trafficking before the next lift.
 - End tipping can be utilised within specific zones on the ELF, these should be designated in agreeance with the geotechnical engineer.
- ∴ Slope geometry and final landform development:
 - Keep temporary batter slopes at or below about 35 to 37 degrees during construction.
 - Adopt flatter, benched, and non-convex geometries for the final engineered landform to support long term stability and rehabilitation.
- ∴ Material segregation and placement:
 - Deliberately segregate weak materials such as volcanic ash and weathered mudstone from stronger limestone.

- Place weak materials toward the rear of benches and encapsulate them with competent mudstone or limestone to avoid continuous weak layers.

While some aspects of overburden placement also assist in reducing erosion and sediment generation, the primary purpose of the construction methodology measures outlined above is to manage geotechnical stability. As such, they are not relied on as primary erosion and sediment control measures under the ESCP.

4.4 Overburden Stripping

Stripping is undertaken in campaigns (typically annually) as already outlined above. Stripping activities are aligned with the quarry stages and includes vegetation removal, topsoil stripping / stockpiling, large scale excavation of overburden and haulage of overburden to disposal sites. Following quarrying and closure of the site, Graymont propose to return as much of the disturbed area as possible to productive farmland by filling with overburden following by topsoil and grassing.

The potential environmental effects (considered within the scope of this report) due to overburden stripping are as follows:

- ✧ Impacts on Topsoil
- ✧ Geotechnical stability of surrounding slopes.
- ✧ Sediment generation (outlined in the South-Western Pit Project - Erosion and Sediment Control Plan (PDP 2025)).

The first two aspects are discussed further below.

4.4.1 Impacts on Topsoil

Topsoil will be stripped and managed in accordance with the ToMP, which defines stripping, stockpiling, storage duration and reuse requirements. The potential effects of topsoil removal / handling are the depletion of nutrient value for future pastoral land use, poor stockpile management and over consolidation during placement. These effects are discussed further in Section 4.6 below. Topsoil stripping shall be undertaken in accordance with the ToMP.

4.4.2 Geotechnical Stability of Surrounding Slopes

The stability of cut slopes into soft / weak volcanic ash and mudstone is likely to be more critical than the stability of rock slopes (notwithstanding large-scale geological structures and rock fall hazards, as discussed in Section 3.0).

Graymont slope design is based on slope performance at the Oparure Pit. Stable slopes cut into the overburden that are <20 m vertical height have been previously achieved where bedding and rock fabric was favourably oriented.

The overburden thickness in the South-Western Pit will exceed this height in places, notably for the western pit slope (required cut of approximately 45 m vertical height). Observations of the Oparure Pit northern batter slopes indicates that cuts of these magnitudes can show signs of instability and that combinations of buttressing, benching and slope dewatering maybe required to improve batter stability. Further investigations are required to determine the nature of the surficial ash and underlying mudstone deposits and the extent of potential mitigation measures.

The investigations should be based on temporary cut slopes and assessed by a geotechnical professional prior to final slope design (as recommended in Section 3.3).

Provided that the above design and construction requirements are implemented through the P&HMP and in accordance with the conditions of consent, the effects associated with overburden placement stability are considered to be less than less than minor.

4.5 Overburden Disposal / Placement (ELF)

The design and construction parameters for overburden engineered landforms (ELFs) are required to be provided by a suitably qualified and experienced geotechnical professional in accordance with the conditions of consent. Detailed construction methodology and design controls are implemented through:

- ∴ The geotechnical design required under the consent conditions relating to overburden placement.
- ∴ The P&HMP, which incorporates the construction methodology for engineered landforms and associated drainage and stability controls.

In general, the overburden material has no economic value. The exception as dimension and landscaping stone which can be sourced from the limestone 'caprock'. However, we understand this is considered a limited market and not significant compared to the volume of waste rock that is produced.

Topsoil will be recovered separately from other overburden materials and will be used for rehabilitation and planting including for final slopes of the overburden ELFs.

Non-topsoil overburden therefore requires disposal. PDP is advised by Graymont that transporting to an alternate fill site is not economically feasible due to high transportation costs and no demand for the specific material type.

The proposed strategy for overburden disposal is placement into quarried pits (e.g. Oparure Pit and progressively the South-Western Pit after year 13 of the quarry operation) as overburden ELFs.

The methodology for construction of the in-pit overburden ELF is discussed in Section 4.3

The objective of the in-pit overburden disposal is to infill as much of the quarry pit space as possible so as to restore the landscape to a natural form and maximise reinstatement of productive farmland.

The potential environmental effects due to overburden disposal in the South-Western Pit are considered to be:

- ∴ Waste management (disposal of kiln waste and fly ash).
- ∴ Geotechnical stability of placed overburden.
- ∴ Sediment generation (discussed above, refer to ESCP).

4.5.1 Waste Management

Disposal of kiln waste and fly ash shall not be carried out at the South-Western Pit. As a consequence, the effects are not relevant to this technical assessment.

4.5.2 Geotechnical Stability of Placed Overburden

The current design of the overburden ELF shows it contained within the South-Western Pit. The ELF will fill the void in the central parts of the quarry between approximate elevations 222 m RL in the west and 188 m RL in the east (i.e. 22 – 34 m thick) at current estimated volumes from mine planning. The final volumes and therefore final height may vary in the final design. The ELF will be confined by the quarry pit slopes therefore the vertical height is not considered a constraint.

The final slopes should be designed as part of closure planning. The final slope of the ELF in the current design is flat and graded west to east at 1v:22h (4.5%) (refer to stage Plan Year 53). The slopes should be constructed using a similar construction methodology to the Oparure overburden ELF; buttressed (using 35 – 40 m wide buttress at the toe of the slope and be benched). The recommended final inter bench slopes shall not exceed 1v:2.5h (40%) to facilitate rehabilitation, grassing, planting, grazing, access and to minimise erosion.

Slope instability issues for placed overburden are considered low risk, provided construction methodology and geotechnical inputs for overburden placement similar to those outlined above are implemented. With these measures in place and appropriate level of geotechnical management, any effects due to overburden instability will be less than minor.

4.6 Topsoil Reclamation

Topsoil shall be removed prior to stripping the bulk of the overburden. The overall soil management approach is to use the recovered topsoil for ongoing remediation projects around the site immediately and only temporarily stockpile where necessary.

The potential effects on the topsoil during removal / handling are the depletion of nutrient value for future pastoral land use, due to poor stockpile management and over consolidation during placement.

Topsoil at the site is described in Section 2.2.1.1 and is referred to as Mairoa topsoil. The parent material is the immediately underlying volcanic ash (Mairoa Ash).

To assess topsoil reclamation aspects, PDP undertook sampling of the topsoil at the site. The objective of the sampling and laboratory analysis was to determine general topsoil thickness and organic content to estimate the volume to be reclaimed (depth of cut) and re-used for site rehabilitation.

A ToMP (PDP 2026b) has been developed by PDP titled '*South Catchment Western Pit - Top Soil Management Plan*' report ref. C03870822R002 Rev 5 dated 27 February 2026. Topsoil will be managed in accordance with the ToMP, which sets out the measures for stripping, stockpiling, storage duration, nutrient management and reuse for rehabilitation. The following sections provide observations and factual information on the investigations into topsoil properties. The ToMP sets out the recommended measures and controls to ensure that any potential effects on topsoil caused by development of the South-Western Pit are less than minor in magnitude.

4.6.1 Topsoil Horizons and Thickness

The soil horizons listed below are based on visual assessments of physical characteristics of the soil, including colour and organic content. The typical soil profile with depth below ground level (bgl) is as follows:

- ∴ A - Organic rich topsoil, dark brown, sandy SILT (0 – 50 mm bgl).
- ∴ B - Slightly organic, volcanic ash soil, medium brown, sandy SILT (50 – 200 mm bgl).
- ∴ C - Mairoa Ash, brownish red SILT (>200 mm bgl).

Topsoil (Horizon A) is very thin (<50 mm) or non-existent on slopes >25° at the site. This topsoil is typically thicker on less steep slopes and in the valleys (in some places >200 mm).

Example soil profiles are shown in Photographs 1 – 7 (Appendix C – Soil sampling and Analysis Results).

4.6.2 Topsoil Sampling

Soil samples were collected from hand augers (HA) and bulk samples from shallow road cuts / outcrops (OC) at a number of locations across the site on 10 October 2019. The soil sample locations are shown on Figure 3.

Samples from each soil horizon (A, B, and C) were submitted for organic tests. Samples were composited for testing nutrient values (NZTA P39) with relative proportions of Horizons A (100%), A+B (50%), A+B+C (around 33%).

4.6.3 Organic Content

The organic content of the soil horizons based on the laboratory test results is summarised in Table 6 below. Refer to Appendix C for soil test reports.

Table 6: Soil Horizon Organic Content				
Analysis	Medium Range	Soil Horizon		
		A	B	C
Potentially Available Nitrogen ¹	100 – 150 kg/ha	299	101	18
Anaerobically Mineralisable N (µg/g)	N/A	314	87	16
Anaerobically Mineralisable N/Total N Ratio	3 – 5%	2.7	1.3	<0.5
Organic Matter	7 – 17%	27.2	13.4	5.9
C/N Ratio	N/A	13.3	11.2	8.9
Total Carbon %	N/A	15.8	7.8	3.4
Total Nitrogen	0.3 – 0.6%	1.18	0.7	0.39
Volume Weight	0.6 – 1.0 g/mL	0.63	0.77	0.74
Notes: 1. Potentially available nitrogen assumes sample taken to a depth of 150 mm.				

Based on the above results, soil Horizons A and B (or a composite of A and B) will have suitable organic content for pasture growth. Potentially available N is very high in soil Horizon A. Soil Horizon C is depleted in organic content (both carbon and nitrogen).

4.6.4 Topsoil Analysis for Pasture Growth

Suitability of the topsoil for land rehabilitation has been assessed based on elements of the NZTA P39 Standard Specification for Highway Landscape Treatments (2013). The standard is used in the absence of any other known standards that provide guidance on topsoil management and testing / guidelines for topsoil quality and characteristics.

The soil sample results in Table 7 are a summary of the NZTA P39 standard test suite results (completed by R J Hill Laboratories Ltd, 30 October – 07 November 2019). Refer to Appendix C for the full test reports.

Table 7: Topsoil Characteristics				
Analysis	Criteria (optimum range for grass / pasture growth) ¹	Soil Horizon Composites		
		A	A+B	A+B+C
Texture	Sand (0.06 – 2.0 mm) 20% – 75%	31	24	26
	Silt (0.002 – 0.06 mm) 20% – 75%	45	46	46
	Clay (<0.002 mm) 20% – 75%	25	29	28
Stones / Gravel	Stone / Gravel content 2 – 50 mm <35% by dry weight, of this fraction 2 – 5 mm <20% by dry weight.	0	0	0
Organic Matter	>4% by weight	23.5	14.5	10.3
Soil Reaction	pH 5.8 – 6.3	5.3	5.5	5.6
Olsen's Phosphorus (P)	Extractable K, 20 – 30 mg/L	30	11	5
Potassium (K)	Extractable P, 0.5 – 0.8 me/100 g	1.05	0.5	0.3
Calcium (Ca)	Optimum Ca, 6 – 12 me/100 g	13.2	5.8	3.5
Magnesium (Mg)	Extractable Mg, 1 – 3 me/100 g	2.26	0.88	0.5
Sodium (Na)	Optimum Na, 0.2 – 0.5 me/100g	0.32	0.18	0.11
CEC ²	Optimum CEC, 12 – 25 me/100g	37	25	17

Table 7: Topsoil Characteristics				
Nitrogen (N)	Potentially available ³ N, 100 – 150 kg/ha	231	117	138
Sulphur (S)	Optimum S, 7 – 15 mg/kg	40	167	447
<i>Notes:</i> 1. Optimum ranges based on Hills Ltd medium ranges for crop guides, based on reference values where published. 2. CEC - Cation Exchange Capacity. 3. Potentially available nitrogen assumes sample taken to a depth of 150 mm. 4. Soil should be free of contamination including free of roots, perennial weeds, sticks, subsoil, toxic chemicals and foreign matter. 5. Topsoil structure should have a clearly defined crumb structure and not be waterlogged or over compacted.				

The test results indicate:

- ✧ Horizon A and composited soil horizons are slightly acidic with pH slightly below optimum (pH 5.8 – 6.3).
- ✧ Phosphorus (P) in composites of Horizons A+B will be optimum. Composites with Horizon C included will have less than optimum P.
- ✧ Composites of A+B will likely have close to optimum K, Ca, Mg, Na levels.
- ✧ Composites of A+B+C will be depleted in K, Ca, Mg, Na.
- ✧ Composites of A+B+C will have optimum N levels.
- ✧ Horizon A will have high and composited horizons will have very high S levels, respectively.
- ✧ Composites of A+B+C will have suitable organic content. However, levels of nutrients are likely to be out of the optimum range.

5.0 Summary of Effects, Mitigation and Residual Effects

All mitigation measures described in this report are implemented through the conditions of consent and the certified management plans prepared under those conditions, including the P&HMP, ESCP, ToMP and others. Where detailed construction or design measures are described, these shall be incorporated into the P&HMP and supporting geotechnical design documentation rather than being standalone measures.

Table 8 summarises the key potential geotechnical hazard; and the geology, geomorphology and soils related effects identified in this report. Broad measures are proposed to avoid, remedy or mitigate those effects, and the resulting level of effect after mitigation.

Generally, the residual effects are anticipated to be less than minor provided the mitigation measures and recommendations in this report are followed.

Table 8: Summary of Key Geotechnical and Soil Related Effects and Mitigation Measures

Effect	Nature of Effect	Mitigation Measures	Residual Effect
Seismic hazard and ground shaking	Potential for earthquake shaking to affect stability of pit slopes and engineered landforms	- Geotechnical design parameters provided by a suitably qualified and experienced professional, incorporating MBIE/NZGS seismic parameters and slope stability assessment. - Design and management requirements are captured through consent conditions and implemented via the P&HMP.	Less than minor
Liquefaction and cyclic softening	Localised susceptibility of fill materials to cyclic softening or liquefaction if not properly engineered	- Managed through engineered fill design and controlled placement, including compaction and material selection. - Geotechnical design and P&HMP requirements.	Less than minor
Pit slope and overburden slope instability	Instability of cut slopes in rock and overburden due to geological structure, groundwater and rainfall	- Managed through site specific geotechnical design, slope geometry control, drainage, benching and buttressing. - Ongoing monitoring and review. - Implemented through consent conditions and P&HMP.	Less than minor
Rockfall hazards	Localised rockfall from steep limestone faces and quarry batters	- Managed through catch benches, bunds, scaling and controlled blasting. - Geotechnical design and operational procedures within the P&HMP.	Less than minor

Table 8: Summary of Key Geotechnical and Soil Related Effects and Mitigation Measures

Effect	Nature of Effect	Mitigation Measures	Residual Effect
Landslides in overburden soils	Localised slope instability in volcanic ash and mudstone, particularly during rainfall events	- Managed through slope design, drainage control, staged excavation and monitoring. - Geotechnical design and P&HMP.	Less than minor
Sinkholes and karst features	Potential for subsidence or collapse associated with karst terrain	- Managed through surface water control, access restrictions and localised infilling where required. - Site management controls under the P&HMP.	Less than minor
Sediment generation during earthworks	Sediment discharge from stripping, stockpiling and placement of overburden	- Managed through the certified ESCP and ESC Stage Plans. - Includes staging, runoff diversion, sediment retention, stabilisation and inspection regimes required under consent conditions.	Less than minor
Overburden stripping effects on topsoil	Loss of soil structure, nutrient depletion and potential erosion during handling	Managed through the ToMP, which defines stripping, stockpiling, storage duration, and reuse requirements.	Less than minor
Topsoil loss (erosion or handling)	Reduction in recoverable topsoil volume due to erosion or mismanagement	Managed through ToMP and ESCP controls, including staged stripping, stockpile management and stabilisation of exposed areas.	Less than minor
Geotechnical stability of engineered landforms (ELFs)	Instability of placed overburden if not constructed appropriately	- Managed through engineered landform design, including in pit filling, controlled placement, lift thickness, material segregation, drainage layers and buttressing. - Consent conditions and the P&HMP.	Less than minor

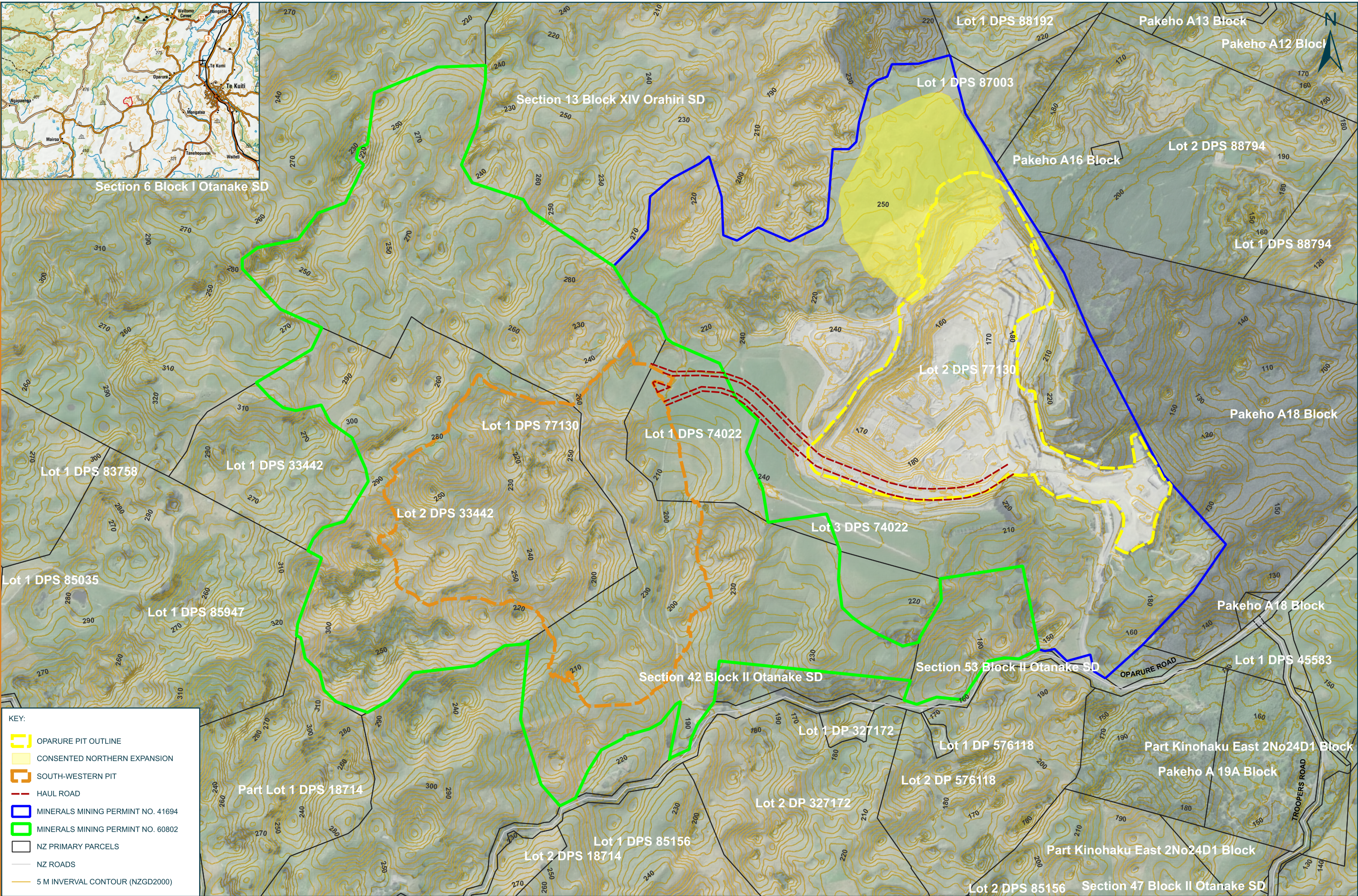
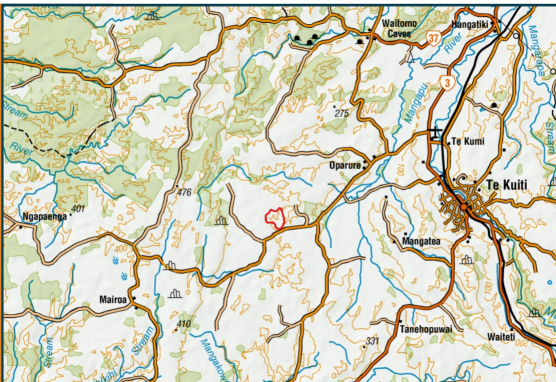
Table 8: Summary of Key Geotechnical and Soil Related Effects and Mitigation Measures

Effect	Nature of Effect	Mitigation Measures	Residual Effect
Sediment from overburden placement	Sediment generation during placement and shaping of ELF's	Managed through ESCP and ESC Stage Plans, with water management, erosion control and progressive stabilisation.	Less than minor
Effects of overburden stripping on surrounding slopes	Temporary instability of adjacent slopes during excavation	- Managed through staged excavation, temporary slope assessment and incorporation of findings into final design. - Geotechnical design and P&HMP.	Less than minor
Long term rehabilitation and soil productivity	Potential reduction in post quarry land productivity if soils are not managed correctly	- Managed through ToMP and rehabilitation requirements, including soil reinstatement and amendment if required. - Consent conditions and P&HMP.	Less than minor

6.0 References

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KEY:

- OPARURE PIT OUTLINE
- CONSENTED NORTHERN EXPANSION
- SOUTH-WESTERN PIT
- HAUL ROAD
- MINERALS MINING PERMIT NO. 41694
- MINERALS MINING PERMIT NO. 60802
- NZ PRIMARY PARCELS
- NZ ROADS
- 5 M INTERVAL CONTOUR (NZGD2000)



0 100 200 300 m

SCALE 1:10,000 (A3)

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A	IFR	MAR 25
NO.	REVISION	DATE
		BY

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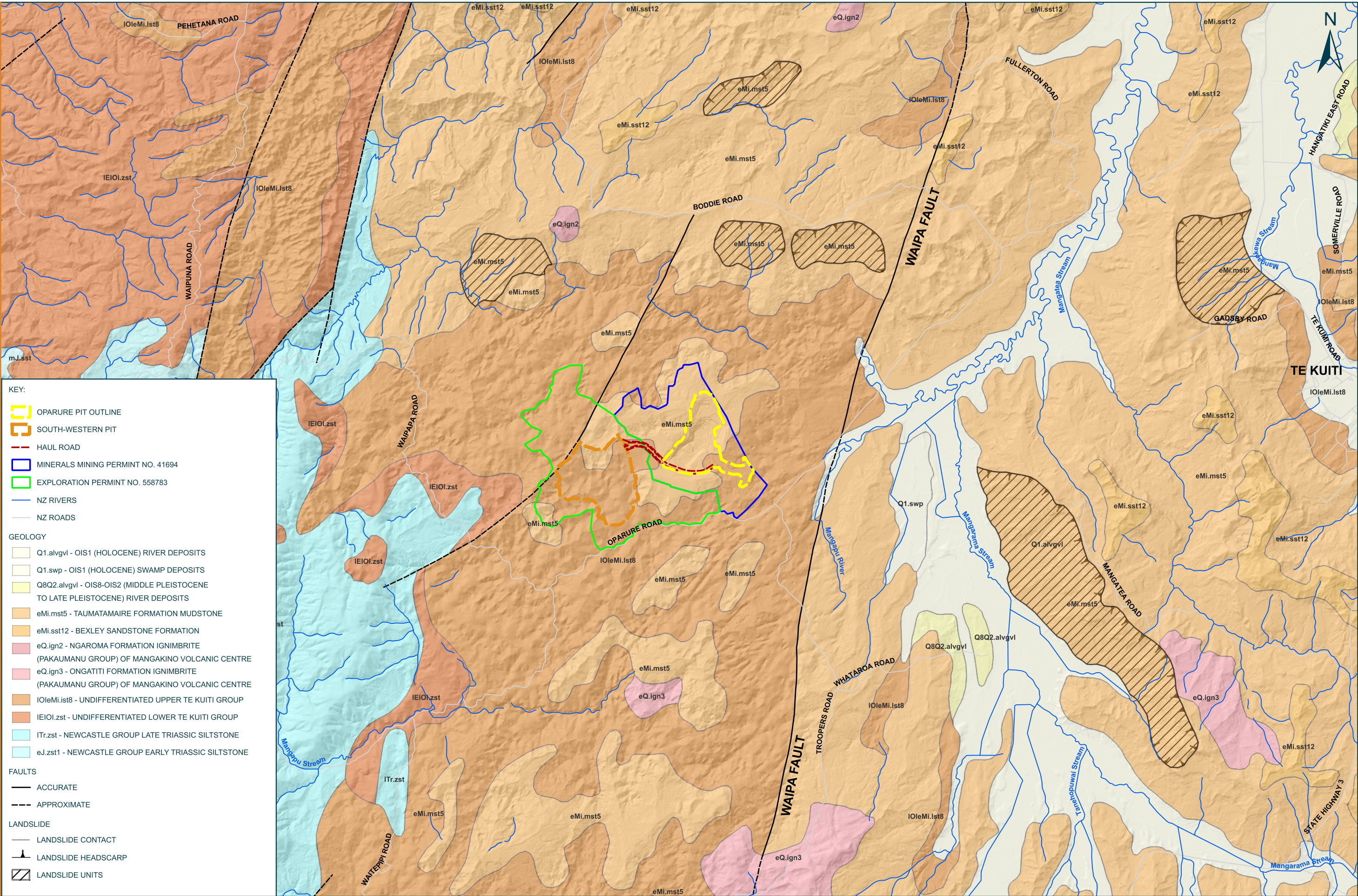
2. CONTOURS DERIVED FROM WAIKATO REGIONAL LIDAR SOURCED FROM THE LINZ DATA SERVICE, REPROJECTED TO NZGD2000 ELLIPSOID USING LINZ NZ2016 QUASIGEOID CONVERSION.



FIGURE 1: SITE PLAN

PROJECT

C038700004 SOUTH-WESTERN PIT GEOLOGY AND SOIL REPORT



KEY:

- OPARURE PIT OUTLINE
- SOUTH-WESTERN PIT
- HAUL ROAD
- MINERALS MINING PERMIT NO. 41694
- EXPLORATION PERMIT NO. 558783
- NZ RIVERS
- NZ ROADS

GEOLOGY

- Q1.alvgvl - OIS1 (HOLOCENE) RIVER DEPOSITS
- Q1.swp - OIS1 (HOLOCENE) SWAMP DEPOSITS
- Q8Q2.alvgvl - OIS8-OIS2 (MIDDLE PLEISTOCENE TO LATE PLEISTOCENE) RIVER DEPOSITS
- eMi.mst5 - TAUMATAMAI FORMATION MUDSTONE
- eMi.sst12 - BEXLEY SANDSTONE FORMATION
- eQ.ign2 - NGAROMA FORMATION IGNIMBRITE (PAKAUMANU GROUP) OF MANGAKINO VOLCANIC CENTRE
- eQ.ign3 - ONGATITI FORMATION IGNIMBRITE (PAKAUMANU GROUP) OF MANGAKINO VOLCANIC CENTRE
- IOleMi.lst8 - UNDIFFERENTIATED UPPER TE KUITI GROUP
- IEIOI.zst - UNDIFFERENTIATED LOWER TE KUITI GROUP
- ITr.zst - NEWCASTLE GROUP LATE TRIASSIC SILTSTONE
- eJ.zst1 - NEWCASTLE GROUP EARLY TRIASSIC SILTSTONE

FAULTS

- ACCURATE
- APPROXIMATE

LANDSLIDE

- LANDSLIDE CONTACT
- LANDSLIDE HEADSCARP
- LANDSLIDE UNITS



PATTLE DELAMORE PARTNERS

0 250 500 750 1,000 1,250 m
SCALE 1:40,000 (A3)

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2. GEOLOGY, FAULTS AND LANDSLIDE BOUNDARIES SOURCED FROM THE GNS ONLINE GEOLOGICAL WEBMAPS.

CLIENT



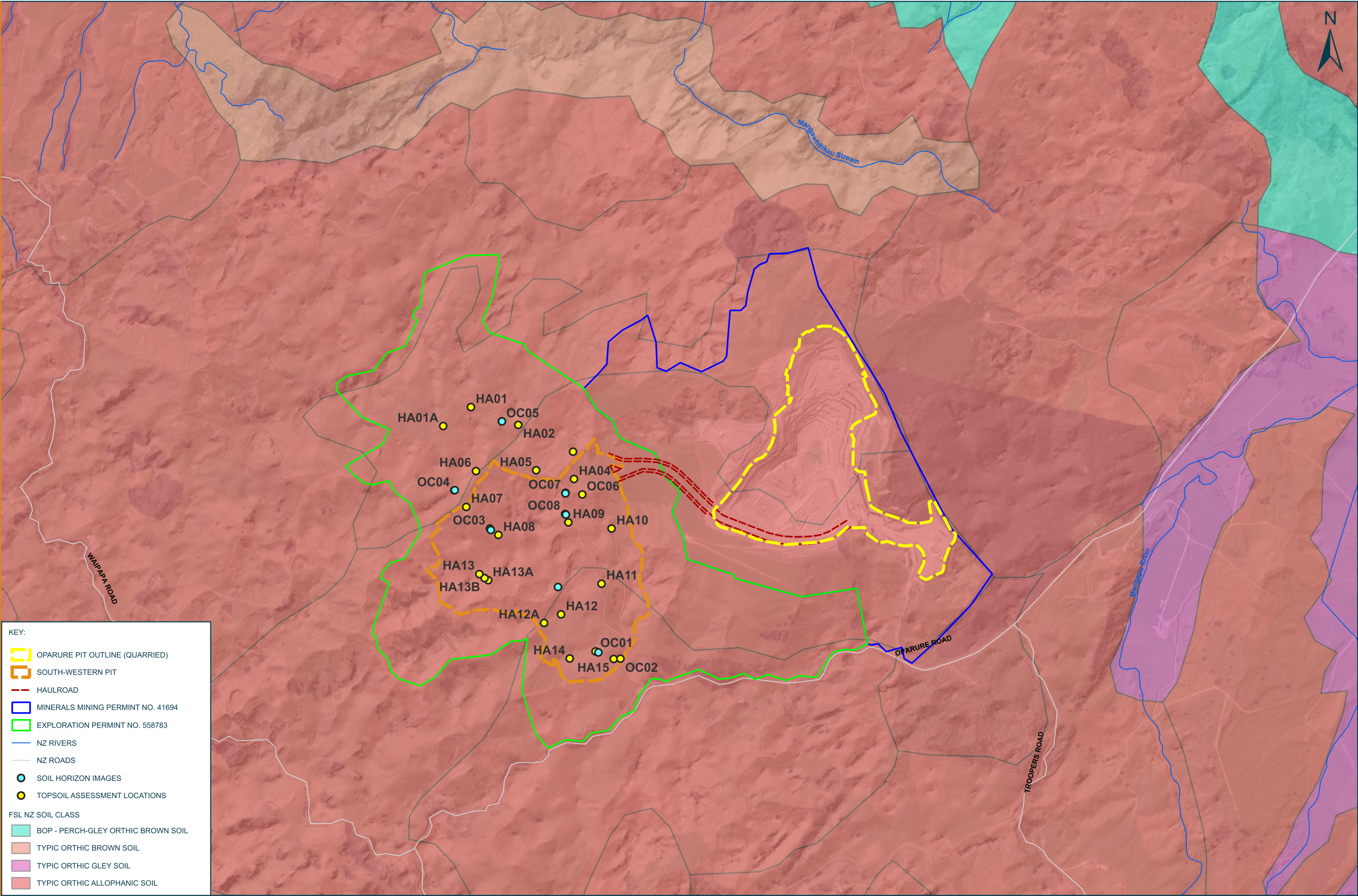
GRAYMONT

FIGURE

FIGURE 2: REGIONAL GEOLOGY

PROJECT

C038700004 SOUTH-WESTERN PIT GEOLOGY AND SOIL REPORT



KEY:

OPARURE PIT OUTLINE (QUARRIED)

SOUTH-WESTERN PIT

HAULROAD

MINERALS MINING PERMIT NO. 41694

EXPLORATION PERMIT NO. 558783

NZ RIVERS

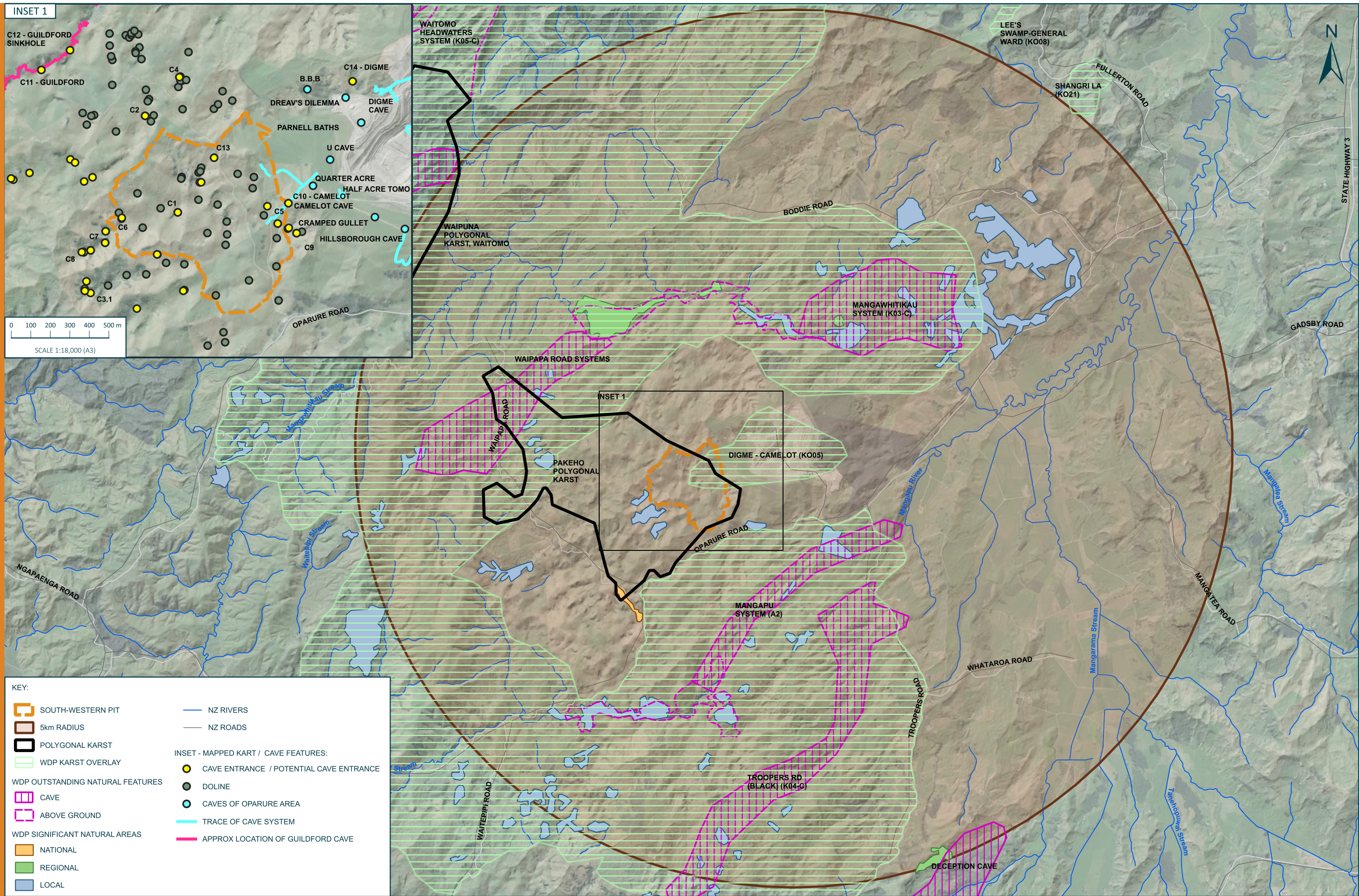
NZ ROADS

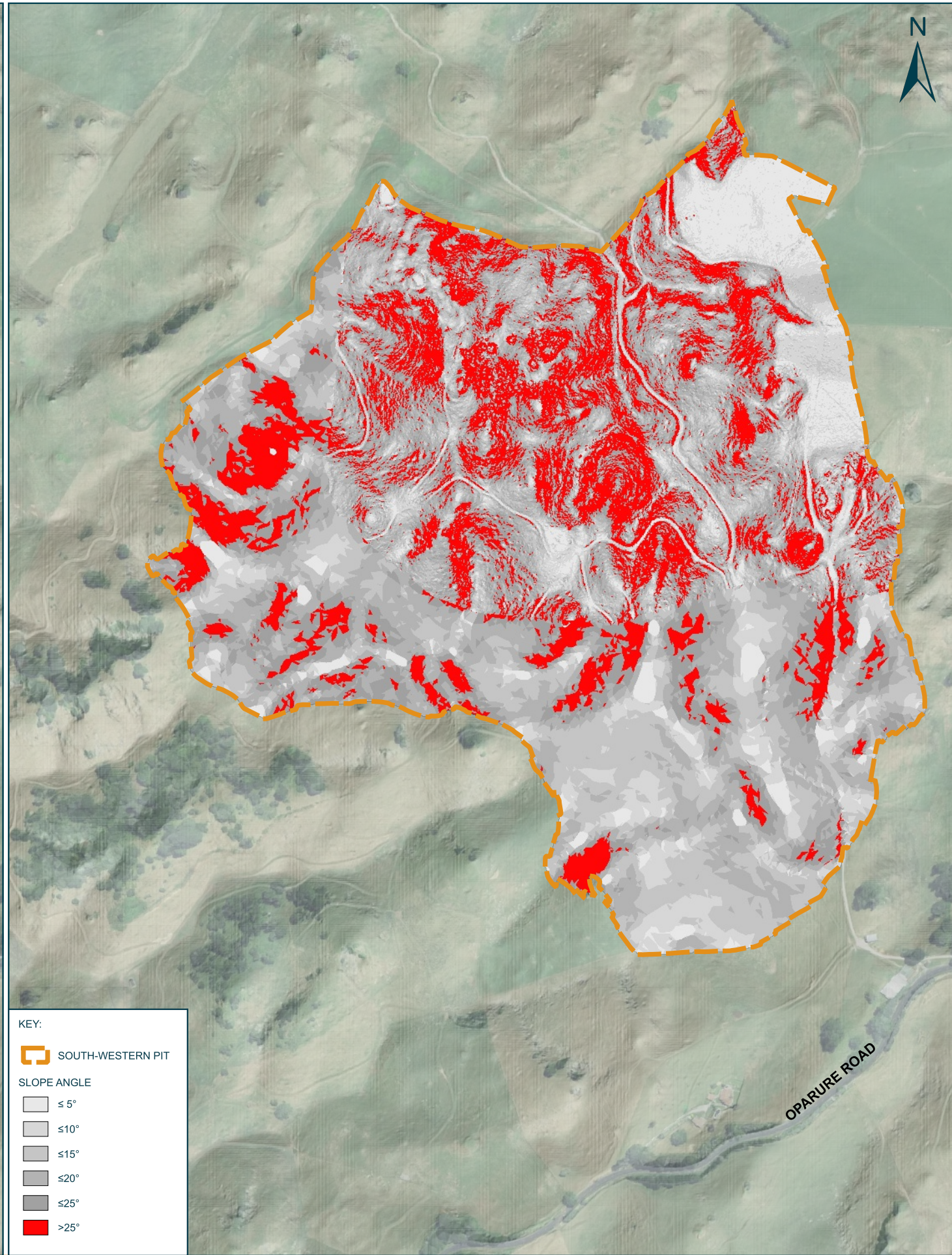
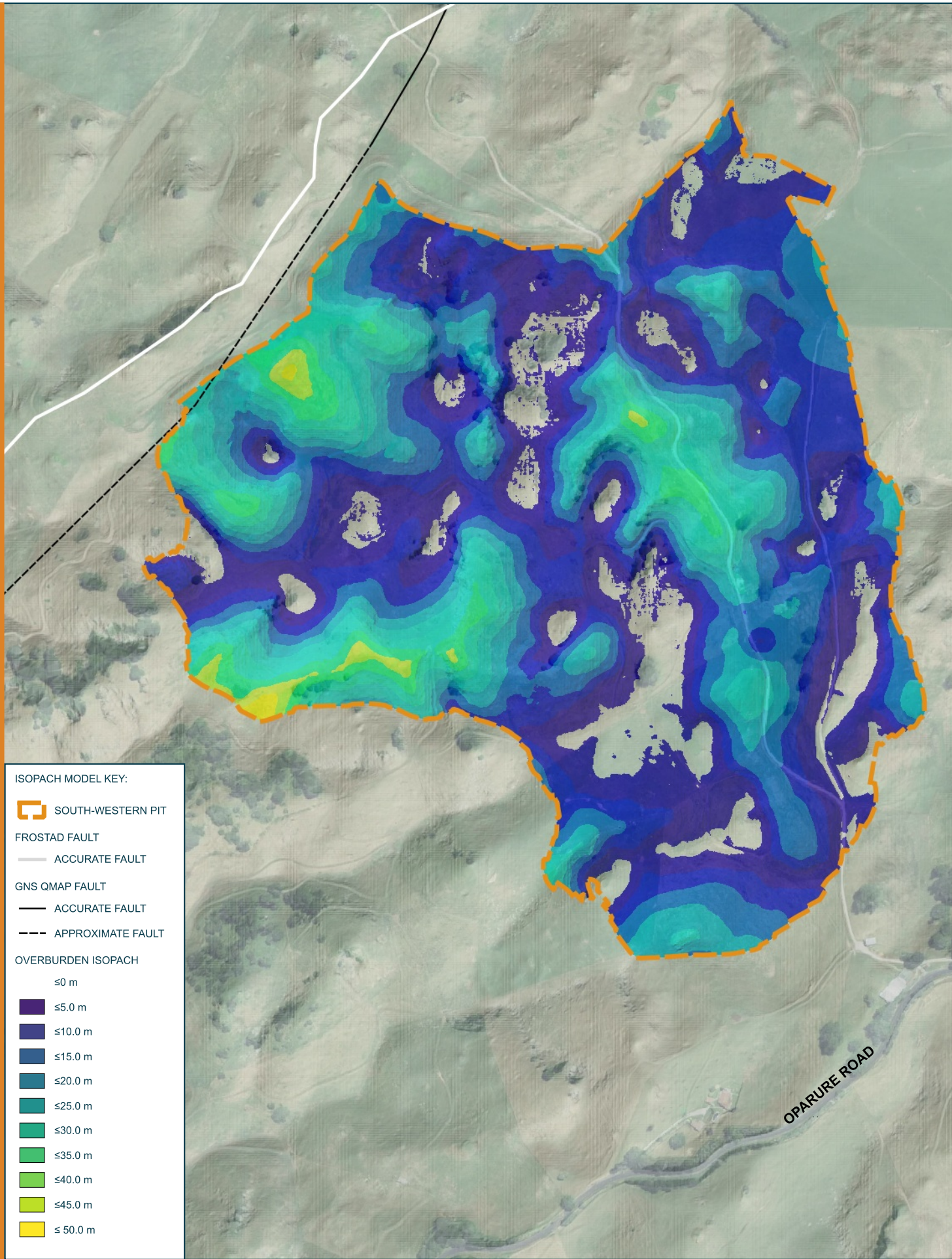
SOIL HORIZON IMAGES

TOPSOIL ASSESSMENT LOCATIONS

FSL NZ SOIL CLASS

BOP - PERCH-GLEY ORTHIC BROWN SOILTYPIC ORTHIC BROWN SOILTYPIC ORTHIC GLEY SOILTYPIC ORTHIC ALLOPHANIC SOIL





ISOPACH MODEL KEY:

SOUTH-WESTERN PIT

FROSTAD FAULT

ACCURATE FAULT

GNS QMAP FAULT

ACCURATE FAULT

APPROXIMATE FAULT

OVERBURDEN ISOPACH

≤0 m

≤5.0 m

≤10.0 m

≤15.0 m

≤20.0 m

≤25.0 m

≤30.0 m

≤35.0 m

≤40.0 m

≤45.0 m

≤50.0 m

KEY:

SOUTH-WESTERN PIT

SLOPE ANGLE

≤5°

≤10°

≤15°

≤20°

≤25°

>25°

Appendix A: Geology, Geomorphology and Geotechnical Background Information

Regional Geology (Te Kuiti – Waitomo – Oparure)

The following summary of the regional geological features (in the site vicinity) is based on the GNS Science geological web map and published geological map; Geology of Waikato (GNS QMAP 1:250000 geological map series), Edbrooke 2005 (refer to Figure 2); Volcanic Ash Beds of the Lower Waikato Basin, North Island, Ward 1965; and the Geology of the Te Kuiti Subdivision, Marwick 1946.

Regional Faults

Regional faults provide useful rock mass domains for describing the basement rock. The faults trend north – south and include the Waipa Fault in the east and the Hikurangi Fault in the west (Figure 2).

Greywacke Basement Rock (Late Triassic to Late Jurassic)

Basement rocks include the Murihiku Terrane rocks (the Newcastle Group near the site), an interbedded siltstone and fine to coarse grained sandstone (Greywacke). The basement rocks are broadly folded in the regional Kawhai syncline and underlie the map area west of the Waipa Fault. East of the Waipa Fault the Waipapa terrane forms the basement rock.

The basement Greywacke strata is overlain by Tertiary age marine sedimentary rocks as outlined below.

Tertiary Limestone (Te Kuiti Group)

The Te Kuiti Group was deposited during a period of regional subsidence during the Oligocene, around 23 – 34 million years ago (mya). The lower Te Kuiti Group in the wider area comprises coal measures, sandstone and limestone.

The upper Te Kuiti Group includes the Orahiri Limestone, Waitomo Sandstone and the Otorohanga Limestone. The Otorohanga Limestone formation overlies the Orahiri and Waitomo formations and basement rock (and less frequently the lower Te Kuiti Group). The Otorohanga limestone was formed in shallow seas in the Late Oligocene adjacent to a low-lying landscape.

Otorohanga Limestone is a light grey to white flaggy bioclastic limestone. It forms the characteristic Karst topography with near vertical cliffs, bluffs and caves in the area. The limestone has a blocky appearance and is generally <30 m thick, except in the Waitomo area where it is up to 70 m thick. The Otorohanga Limestone is the high-grade limestone resource quarried at the Oparure Pit.

Tertiary Mudstone (Mahoenui Group)

Mahoenui Group mudstone are marine sediments deposited in the Early Miocene (24 mya).

The mudstone is thick (up to 1300 m in the Waikato map area) and outcrops extensively south of Otorohanga. The Mahoenui Group generally lies conformably on the Otorohanga Limestone and unconformably over the Newcastle Group rocks (Greywacke) near the Hikurangi Fault in the West.

There are two main formations in the Mahoenui Group mudstone. The Taumatamaire Formation is a massive to weakly bedded calcareous mudstone to a fine sandy mudstone. This formation is conformably overlain by the Taumarunui Formation which is an interbedded massive fine to very fine-grained sandstone and mudstone sequence. In some places the Taumatamaire Formation mudstone is unconformably overlain by the Bexley Formation of the Mokau Group (a massive to thickly bedded grey brown, medium to fine grained sandstone).

Ignimbrites

Pakaumanu Group ignimbrites are mapped in the site vicinity. The ignimbrites originated from the Mangakino Volcanic Centre of the Taupo Volcanic Zone (TVZ) and include the Ongatiti and the earlier Ngaroma Formation ignimbrites. The ignimbrites are generally thin near the site which is consistent with it being located close to the distal margin (edge) of the pyroclastic flow that formed the ignimbrites.

Volcanic Ash

Volcanic ash (tephra) is not shown on the QMAP 1:250,000 geological map area near the site as it is a surficial deposit. In hill country volcanic ash ranges in thickness around 1.0 m thick and up to 10 m in places and is present on slopes $<25^\circ$ (being stripped from steeper slopes $>25^\circ$). Only thicker sequences are shown on the Q map area west of Hamilton and north of Otorohanga.

Volcanic ash generally forms a blanket that mantles the surface and forms the parent material of the modern soils on the hill slopes. Sources of volcanic ash include:

- ✧ Kauroa Ash Formation: A sequence of extremely weathered, clay rich rhyolitic tephra deposits and associated paleosols which is mapped in the north near Kawhia Harbour. Sources of Kauroa Ash are the younger volcanoes of the Coromandel Volcanic Zone and the older TVZ.
- ✧ Hamilton Ash Formation: Up to 6 m of weathered, clay rich multiple rhyolitic tephra deposits and associated paleosols. The source of Hamilton Ash is reportedly the Whakamaru caldera and younger centres of the TVZ.

The volcanic ash layers were deposited between 2.3 – 0.1 mya. The Kauroa ash is older and underlies the Hamilton ash layer following a notable time interval (unconformity) between deposition (Ward 1965). The unconformity is marked by distinct colour change (due to leaching of Kauroa Ash) and a fossil topsoil (paleosol) may be present. The Hamilton ash layers weather to reddish brown clays (Hanson 2008).

Mairoa ash is the youngest member of the Hamilton ash formation. Mairoa ash is mixture of andesite and rhyolite ash (potential source includes Mount Taranaki) and forms the topmost layer and the parent material of the modern soils. Mairoa ash is thin, brown and friable. The Mairoa ash has a uniform thickness (around 600 mm) in the Waikato area (Ward 1965).

Recent Sediments

Recent sediments in the general site vicinity include the Tauranga Group (Piako Subgroup) of Late Pleistocene to Holocene age. The Piako Subgroup alluvial / colluvial deposits consist of pumiceous clay, sandy clay, silt, gravels and muddy peat which occur as unconsolidated deposits in stream valleys east of the site.

Geomorphology: Karst and Caves

The South-Western Pit area is typified by karst topography that includes features such as caves, dolines, stream sinks, arches and springs. The following sections provide description and definitions for these features to provide consistency for the project.

In addition, understanding the karst and cave system development is important to the hydrological and geomorphic interpretation for the project.

The definitions in Table 9 for karst landforms is based on Ford and Williams 2009; and Kenny and Hayward 2010.

Karst Landforms

Karst is the description of a geomorphological landscape formed by the dissolution of carbonate rocks (e.g. limestone). In general terms, water typically mechanically erodes rock, however in karst landscapes the rock is also ‘corroded’ (dissolved) by water.

Water flows down / along the natural fractures in the limestone and together with carbon dioxide reacts with the limestone to form carbonic acid and calcium carbonate as well as calcium bicarbonate. The bicarbonate in solution flows to a discharge zone and may precipitate out as limestone.

Approximately 3% of surface rock cover in New Zealand has a karst geomorphic landscape.

Karst typically develops under the following conditions:

- ✧ Hard dense limestones with high percentage of calcium carbonate, with joints / cracks with higher permeability zones in the rock mass.
- ✧ High rainfall and warm temperature (i.e. humid and temperate).
- ✧ Subsurface flowing water.

Karst development can be close to surface or can occur at depth along the following lines:

- ✧ Active Karst – landscape with distinctive landforms and hydrology <15 m to land surface.
- ✧ Transition Karst – areas underlain by carbonate rock below 15 – 30 m of sediment cover.
- ✧ Covered Karst – defined as areas underlain by carbonate rock >30 m sediment cover.

In New Zealand well-developed karst typically occurs in the first 10 m below the surface. With depth the cracks taper out and water accumulates. Chalky, muddy limestone with minor sand and mud do not develop karst as voids become clogged with insoluble residues (Hayward 2009).

Epikarst is located in the vadose zone (unsaturated) between the ground surface and the water table. Epikarst is often weathered, unsaturated limestone, where water can percolate downwards through the joints and fractures in the rock to reach the groundwater surface.

Karst geomorphological features include caves and cave systems. Karst surface landforms are divided into four main systems as outlined below (with examples):

- ✧ Input – dolines, stream sinks
- ✧ Throughput – caves, arches
- ✧ Output – resurgence or springs
- ✧ Residual – relict karsts

Karst landforms are in a state of permanent flux and can be described as 'modified' (e.g. pavements, pillars and solutions runnels). The continued modification of the karst landform system can lower the permanent water table forcing the developing karst system to lower levels.

Table 9: Karst Landforms Summary		
Type	Name	Description
Input	Doline	Collapse dolines formed by mechanical collapse of existing cavities (tomo)
		Solution dolines formed by the dissolution of surface rock
		Subsidence doline form by suffusion / subsidence from down washing of overlying superficial deposits unto conduits in the underlying karst (dimpled surface)
	Stream sink	Enclosed basin, where water disappears into subterranean drainage
	Blind valley	Abruptly terminating valley
	Poljes	Large scale coalescence of blind valleys leading to elongate, flat floored, closed depressions with steep valley sides. The floor corresponds to the permanent groundwater level. Possible intermittent streams that drains into stream sinks, prone to flooding and referred to as semi-blind if can overflow
Modified	Solution runnels	Fluting, lapies, karren. Millimetre to metre sized vertical furrows or fish like skeletons on horizontal outcrops. Formed by rain corroding susceptible rocks (sharp flutes) or chemical interaction beneath soil and vegetation cover (rounded flutes) rounded flutes. Fluting is not unique to carbonated rocks.
	Pavements	Jointed surface akin to paving. Pavement slabs are called clints and fissures called grikes. Best developed (exposed) by glaciation which removes loose rubble.
	Pillars and pinnacles	Dissected landscape, with isolated clints. Bogaz are extreme grike features like a corridor in the landscape.

Table 9: Karst Landforms Summary		
Throughput	Caves	Caves are conduits for the subterranean drainage system, not as exposed to extreme conditions. Stalactites, stalagmites
	Arches, natural bridges, overhangs	Arches formed by wind, rain, ice erosion where surface cracks and softer zones in limestone ridges gradually erode out. Arches continue to be enlarged by wind. Bridges are formed by running water, creating tunnels. Bridges develop along subterranean stream where intact sections of limestone left behind by two adjacent collapse dolines. Overhangs are formed by water and mechanical erosion.
	Gorges	Roof of subterranean stream collapse.
Output	Resurgence	Natural springs.
	Precipitation	Percolating water reaches cave overhang, CaCO ₃ precipitation out to form speleotherms (stalactites, stalagmites, columns and helictites). Precipitation examples are flowstone, rimstone pools and travertine.
Residual	Relict karst hills	Solution has removed most of the of limestone leaving isolated hills and towers, surrounded by plains formed on the underlying non karst rock.
Notes: 1. Karst landform descriptions based on Kenny and Hayward 2009.		

Cave Systems

Caves and cave systems are subsurface karst landforms, where large voids have developed over time due to underground water flow and dissolution of the bedrock. Cave development continues when water (that is undersaturated with carbonate) remains in contact with the limestone of cave walls. The definition of a cave (in this report) is a natural underground opening in rock that is large enough for human entry.

The above definition of cave does not include the hydrological sense of 'break through' where diameter of a conduit is around 5 - 15 mm, where turbulent flow of water can occur.

The WRC regional plan defines a cave as:

"A natural cavity, fissure or canyon in a rock large enough to be entered by a human and which acts as a conduit for water flow, seepage water, or ground water between input points such as stream sinks, and output points such as springs or seeps"

Caves are frequently inaccessible, unexplored or unknown. They can be dry or filled with water. The internal environment may have high, moderate and low energy (water flow). Cave development, to the extent that they are traversable is estimated to be in the order of 10,000 – 100,000 years (Palmer 1991). The development of some of the major karst features seen at the surface (e.g. gorges, collapse dolines), is due to the internal drainage, subsidence and collapse of caves systems over time.

Cave systems contain features (speleothems and biology) that may be sensitive to changes in the flows of air, water and sediment through the cave or disturbance by caving activities, quarry blasting and vibrations. Land disturbance, such as earthworks and vegetation clearance (especially around cave entrances) can affect the processes that create / maintain the cave system features.

Caves can be a very complex array of interconnected cavities. The description of caves and cave systems includes the following:

- ✧ Cave patterns
 - Branchwork, network, anastomotic, ramiform or spongework
- ✧ Cave passages
 - Linear, i.e. straight and no elevation change
 - Angulate, i.e. 90° up and down
 - Sinuous, i.e. curved path and smooth changes in elevation
- ✧ Presence of speleothems

- Structures formed in a cave from mineral deposition such as stalactites or stalagmites.

Regional Geotechnical Hazards

The following is a summary of the regional geotechnical and natural hazards relevant to the site and is based on published geological information (Edbrooke 2005).

Earthquake

The Waikato map area (QMAP 1:250,000 geological map) has experienced low to moderate seismicity when compared to the rest of New Zealand. Localised damage has occurred due to moderate magnitude earthquakes, however structural damage is limited. Since around 1840, there have been eight shallow moment magnitude (M_w), $M_w > 5$ earthquakes ranging from M_w 5.1 – 6.5, with shaking intensity on the Modified Mercalli (MM) scale MM6 – MM8 that have originated near the Waikato area.

The two nearest known active faults to the site and the predicted earthquake magnitude and recurrence interval are:

- ∴ Turi Fault - M_w 7.2, located offshore around 40 km west of the site, recurrence interval 1600 years.
- ∴ Kerepehi Fault - M_w 6.7, Okoroire south section, onshore 78 km northeast of the site, recurrence interval 5000 years.

It is not known if the $M_w > 5$ earthquakes outlined above occurred on the recognised active faults in the region. Earthquakes $M_w > 6.5$ are expected to be rare.

Landslides

The weak, soft Mahoenui Group mudstones (e.g. Taumatamairi Formation) are susceptible to both large and small scale instability.

The GNS Landslide Inventory map (accessed online 10 December 2019) shows selected larger landslides are located >1.5 km north of the quarry (south of Waitomo Road) and >2 km southeast of the quarry.

Volcanic Hazard

The volcanic hazard threat in the Waikato region is due to potential future volcanic activity at the relatively remote Taupo Volcanic Zone, Mayor Island and Mt Taranaki. Eruptions at the TVZ have been frequent throughout the last 2.5 mya and are violent and likely to occur with very little warning.

Eruption of Taupo Volcanic Centre is likely to be extremely violent and lead to large pyroclastic flows. Pyroclastic flows are more likely to affect the southeast

of the Waikato region. Ash falls from a major eruption have potential to significantly affect the environment and human activity.

The volcanic hazard threat is due to potential future volcanic activity at the TVZ, Mt Taranaki, Mt Ngauruhoe and Mt Ruapehu and potentially from Mayor Island.

Ash fall is potentially a relevant natural hazard for the South-Western Pit area. However, predicting the timing and the actual effects is difficult.

Tsunami

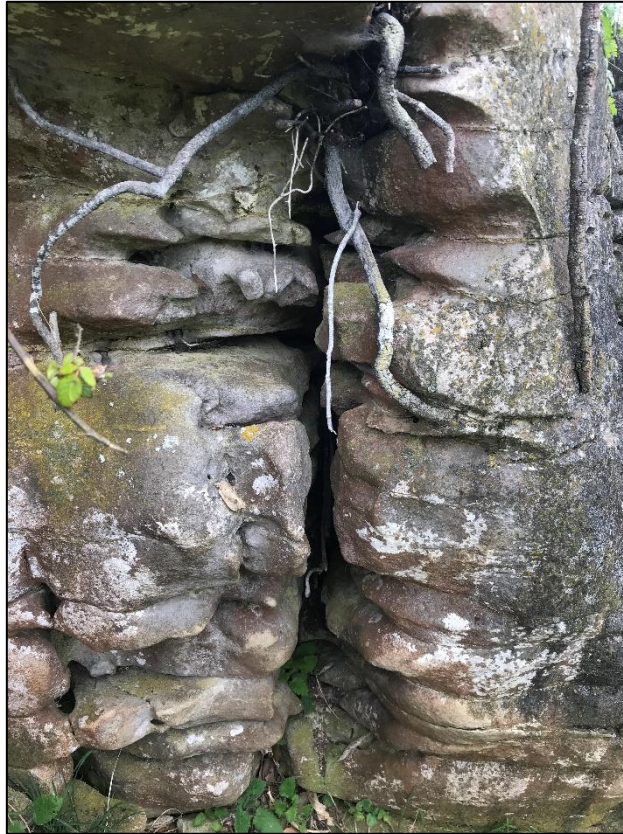
The site is not near to the coast, natural or manmade lakes. Therefore, there is no risk due to Tsunami to consider.



Photograph 1: Karst and Doline (Sample location 6329, Figure 3)



Photograph 2: Karst (Sample location 6349, Figure 3)



Photograph 3: Jointing trends 050° - 110°N, preferential development of fracture network (overview image)



Photograph 4: Landslide – Hummocky Ground and Dolines (Sample location 6383, Figure 3)



Photograph 5: Pakeho Polygonal Karst (overview image)



Photograph 6: Pakeho Polygonal Karst (overview image)



Photograph 7: Pakeho Polygonal Karst (overview image)



Photograph 8: Pakeho Polygonal Karst (overview image)



Photograph 1: Soil profile (sample location 6324, Figure 3)



Photograph 2: Soil profile (sample location 6350, Figure 3)



Photograph 3: Soil profile (sample location 6353, Figure 3)



Photograph 4: Soil profile (sample location 6378, Figure 3)



Photograph 5: Taumatamaire Formation mudstone (sample location 6386, Figure 3)



Photograph 6: Taumatamaire Formation mudstone (sample location 6386, Figure 3)



Photograph 7: Weathered ignimbrite (sample location 6388, Figure 3)



Certificate of Analysis

Page 1 of 3

Client:	Pattle Delamore Partners Limited	Lab No:	2266156	SUPv1
Contact:	Chris Foote	Date Received:	30-Oct-2019	
	C/- Pattle Delamore Partners Limited	Date Reported:	07-Nov-2019	
	PO Box 9528	Quote No:	83649	
	Newmarket	Order No:		
	Auckland 1149	Client Reference:	CO2870503	
		Submitted By:	Chris Foote	

Sample Type: Soil

Sample Name:		1	1+2	1+2+3	
Lab Number:		2266156.1	2266156.2	2266156.3	
Soil Texture analysis*		See attached report	See attached report	See attached report	-
pH	pH Units	5.3 ± 0.2	5.5 ± 0.2	5.6 ± 0.2	-
Olsen Phosphorus	mg/L	30 ± 4	11 ± 2	5 ± 1	-
Sulphate Sulphur	mg/kg	40 ± 8	167 ± 31	447 ± 83	-
Potassium	MAF units	13 ± 2	6 ± 1	4 ± 1	-
Calcium	MAF units	10 ± 2	5 ± 1	3 ± 1	-
Magnesium	MAF units	30 ± 3	13 ± 2	8 ± 1	-
Sodium	MAF units	8 ± 2	5 ± 2	4 ± 1	-
Potentially Available Nitrogen (15cm Depth)*	kg/ha	231 ± 85	117 ± 43	138 ± 51	-
Anaerobically Mineralisable N*	µg/g	264 ± 99	122 ± 46	134 ± 51	-
Anaerobically Mineralisable N/Total N Ratio*	%	2.2	1.6	2.5	-
Organic Matter*	%	23.5 ± 3.7	14.5 ± 2.3	10.3 ± 1.6	-
C/N Ratio*		11.4 ± 3.2	11.0 ± 3.1	11.2 ± 3.2	-
Soluble Salts (Field)	%	0.17 ± 0.05	< 0.05 ± 0.04	< 0.05 ± 0.04	-
EC (in 1:5 Extract)	mS/cm	0.48 ± 0.14	0.13 ± 0.10	0.05 ± 0.10	-
Total Carbon*	%	13.6 ± 2.2	8.4 ± 1.4	5.9 ± 1.0	-
Total Nitrogen*	%	1.20 ± 0.28	0.76 ± 0.18	0.53 ± 0.13	-
Potassium	me/100g	1.05 ± 0.15	0.50 ± 0.08	0.30 ± 0.05	-
Calcium	me/100g	13.2 ± 1.9	5.8 ± 0.9	3.5 ± 0.6	-
Magnesium	me/100g	2.26 ± 0.29	0.88 ± 0.12	0.50 ± 0.08	-
Sodium	me/100g	0.32 ± 0.06	0.18 ± 0.04	0.11 ± 0.03	-
Potassium	%BS	2.9 ± 0.5	2.0 ± 0.4	1.8 ± 0.4	-
Calcium	%BS	36 ± 7	23 ± 5	21 ± 4	-
Magnesium	%BS	6.1 ± 1.0	3.5 ± 0.7	3.0 ± 0.6	-
Sodium	%BS	0.9 ± 0.2	0.7 ± 0.2	0.7 ± 0.2	-
CEC	me/100g	37 ± 4	25 ± 3	17 ± 2	-
Total Base Saturation	%	46 ± 7	29 ± 5	26 ± 4	-
Volume Weight	g/mL	0.58 ± 0.05	0.64 ± 0.06	0.69 ± 0.06	-

The reported uncertainty is an expanded uncertainty with a level of confidence of approximately 95 percent (i.e. two standard deviations, calculated using a coverage factor of 2). Reported uncertainties are calculated from the performance of typical matrices, and do not include variation due to sampling.

For further information on uncertainty of measurement at Hill Laboratories, refer to the technical note on our website: www.hill-laboratories.com/files/Intro_To_UOM.pdf, or contact the laboratory.



Analyst's Comments

Samples 1-3 Comment:

The medium or optimum range guidelines shown in the histogram report relate to sampling protocols as per Hill Laboratories' crop guides and are based on reference values where these are published. Results for samples collected to different depths than those described in the crop guide should be interpreted with caution. For pastoral soils, the medium ranges are specific for a 75mm sample depth, but if a 150mm sampling depth is used the nutrient levels measured may appear low against these ranges, as nutrients are typically more concentrated in the top of the soil profile. These soil profile differences are altered upon cultivation or contouring.

Sample 1 Comment:

The high CEC level found in this soil indicates that it has a high capacity to retain cation nutrients (potassium, calcium, magnesium and sodium). For crop and horticulture soil sample type codes, the normal ranges and the derived histograms are based on a typical soil with a CEC level between 12 and 25 me/100g, unless otherwise denoted.

Samples 1-3 Comment:

The Potentially Available Nitrogen (kg/ha) test above assumes the sample is taken to a 15 cm depth. If the depth is 7.5 cm, then the result reported above should be divided by two.

To calculate Potentially Available Nitrogen (as kgN/ha) for other sample depths use the reported Anaerobic Mineralisable Nitrogen (AMN) result in the following equation:

$$AN \text{ (kg/ha)} = AMN \text{ (}\mu\text{g/g)} \times VW \text{ (g/ml)} \times \text{sample depth (cm)} \times 0.1$$

Note that the AN and AMN results reported include the readily available Mineral N (NH₄-N and NO₃-N) fraction, which is typically quite low.

Appendix No.1 - Eurofins report

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Soil			
Test	Method Description	Default Detection Limit	Sample No
Soil Texture analysis*	Analysis of % sand, silt, clay. Subcontracted to; Eurofins NZ Laboratory Services Ltd - Penrose, Auckland.	-	1-3
Sample Registration*	Samples were registered according to instructions received.	-	1-3
Soil Prep (Dry & Grind)*	Air dried at 35 - 40°C overnight (residual moisture typically 4%) and crushed to pass through a 2mm screen.	-	1-3
pH	1:2 (v/v) soil:water slurry followed by potentiometric determination of pH. In-house.	0.1 pH Units	1-3
Olsen Phosphorus	Olsen extraction followed by Molybdenum Blue colorimetry. In-house method.	1 mg/L	1-3
Sulphate Sulphur	0.02M Potassium phosphate extraction followed by Ion Chromatography. In-house.	1 mg/kg	1-3
Potassium (MAF)	1M Neutral ammonium acetate extraction followed by ICP-OES. In-house.	1 MAF units	1-3
Calcium (MAF)	1M Neutral ammonium acetate extraction followed by ICP-OES. In-house.	1 MAF units	1-3
Magnesium (MAF)	1M Neutral ammonium acetate extraction followed by ICP-OES. In-house.	1 MAF units	1-3
Sodium (MAF)	1M Neutral ammonium acetate extraction followed by ICP-OES. In-house.	2 MAF units	1-3
Potentially Available Nitrogen*	Determined by NIR, calibration based on Available N by Anaerobic incubation followed by extraction using 2M KCl followed by Berthelot colorimetry. (Calculation based on 15cm depth sample). Note that any Mineral N present is included in the AN/AMN result reported.	1 mg/L	1-3
Anaerobically Mineralisable N*	As for Potentially Available Nitrogen but reported as $\mu\text{g/g}$.	5 $\mu\text{g/g}$	1-3
Organic Matter*	Organic Matter is $1.72 \times$ Total Carbon.	0.2 %	1-3
Soluble Salts (Field)	1:5 soil:water extraction followed by potentiometric determination of conductivity. Calculated by $\text{EC (mS/cm)} \times 0.35$. In-house.	0.05 %	1-3
Electrical Conductivity (EC)	Electrical Conductivity measured in 1:5 Soil:Water extract.	0.01 mS/cm	1-3
Total Carbon*	Determined by NIR, calibration based on Total Carbon by Dumas combustion.	0.1 %	1-3
Total Nitrogen*	Determined by NIR, calibration based on Total N by Dumas combustion.	0.04 %	1-3
Potassium	1M Neutral ammonium acetate extraction followed by ICP-OES. In-house.	0.01 me/100g	1-3
Calcium	1M Neutral ammonium acetate extraction followed by ICP-OES. In-house.	0.5 me/100g	1-3

Sample Type: Soil			
Test	Method Description	Default Detection Limit	Sample No
Magnesium	1M Neutral ammonium acetate extraction followed by ICP-OES. In-house.	0.04 me/100g	1-3
Sodium	1M Neutral ammonium acetate extraction followed by ICP-OES. In-house.	0.05 me/100g	1-3
Potassium (Sat)	1M Neutral ammonium acetate extraction followed by ICP-OES. In-house.	0.1 %BS	1-3
Calcium (Sat)	1M Neutral ammonium acetate extraction followed by ICP-OES. In-house.	1 %BS	1-3
Magnesium (Sat)	1M Neutral ammonium acetate extraction followed by ICP-OES. In-house.	0.2 %BS	1-3
Sodium (Sat)	1M Neutral ammonium acetate extraction followed by ICP-OES. In-house.	0.1 %BS	1-3
CEC	Summation of extractable cations (K, Ca, Mg, Na) and extractable acidity. May be overestimated if soil contains high levels of soluble salts or carbonates. In-house.	2 me/100g	1-3
Total Base Saturation	Calculated from Extractable Cations and Cation Exchange Capacity.	5 %	1-3
Volume Weight	The weight/volume ratio of dried, ground soil. In-house.	0.01 g/mL	1-3

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

This certificate of analysis must not be reproduced, except in full, without the written consent of the signatory.



Karen Lim BSc
Client Services Manager - Agriculture

ANALYTICAL REPORT

REPORT CODE

AR-19-NU-090371-01

REPORT DATE

06/11/2019

For the attention of

Hill Laboratories Ltd

Enviro Reports

28 Duke Street

Frankton

3204 Hamilton

NEW ZEALAND

Phone 6478582000

Email envjobenquiry@hill-labs.co.nz

Contact for your orders:

Hanin Khan

Order code:

EUNZAU-00221642

Submission Reference:

agSubEurofinsAuck 170

Purchase Order Number:

152726

SAMPLE CODE

816-2019-00284152

Client reference:

Sample described as: 2266156.1

Reception Date & Time: 31/10/2019 16:07

Analysis starting date: 31/10/2019

Analysis ending date:

06/11/2019

SOIL PHYSICAL MEASUREMENT

RESULTS

LOQ

◆ NU092 Coarse Sand (0.6-2mm)

Coarse Sand

2 %

1

◆ NU199 Medium Sand (0.2-0.6mm)

Medium Sand

7 %

1

◆ NU134 Fine Sand (0.06-0.2mm)

Fine Sand

22 %

1

◆ NU318 Silt (0.002-0.06mm)

Silt

45 %

1

◆ NU091 Clay (<0.002mm)

Clay

25 %

1

SAMPLE CODE

816-2019-00284153

Client reference:

Sample described as: 2266156.2

Reception Date & Time: 31/10/2019 16:07

Analysis starting date: 31/10/2019

Analysis ending date:

06/11/2019

SOIL PHYSICAL MEASUREMENT

RESULTS

LOQ

◆ NU092 Coarse Sand (0.6-2mm)

Coarse Sand

1 %

1

◆ NU199 Medium Sand (0.2-0.6mm)

Medium Sand

4 %

1

◆ NU134 Fine Sand (0.06-0.2mm)

Fine Sand

19 %

1

◆ NU318 Silt (0.002-0.06mm)

Silt

46 %

1

◆ NU091 Clay (<0.002mm)

Clay

29 %

1

SAMPLE CODE

816-2019-00284154

Client reference:

Sample described as: 2266156.3

Reception Date & Time: 31/10/2019 16:07

Analysis starting date: 31/10/2019

Analysis ending date: 06/11/2019

SOIL PHYSICAL MEASUREMENT	RESULTS	LOQ
◆ NU092 Coarse Sand (0.6-2mm)		
Coarse Sand	2 %	1
◆ NU199 Medium Sand (0.2-0.6mm)		
Medium Sand	5 %	1
◆ NU134 Fine Sand (0.06-0.2mm)		
Fine Sand	19 %	1
◆ NU318 Silt (0.002-0.06mm)		
Silt	46 %	1
◆ NU091 Clay (<0.002mm)		
Clay	28 %	1

REPORT INFORMATION

Texture results reported as % of inorganic fraction

LIST OF METHODS

NU091 Clay (<0.002mm) : Sedimentation procedure by hydrometer. < 0.002mm	NU092 Coarse Sand (0.6-2mm) : Sieve analysis. 0.6-2.0mm
NU134 Fine Sand (0.06-0.2mm) : Sieve analysis. 0.06-0.2mm	NU199 Medium Sand (0.2-0.6mm) : Sieve analysis. 0.2-0.6mm
NU318 Silt (0.002-0.06mm) : Sedimentation procedure by hydrometer. 0.002-0.06mm	

Signature



Brent Miller Team Leader Agri Testing

EXPLANATORY NOTE

- ◆ test is not accredited
- test is subcontracted within Eurofins group and is accredited
- test is subcontracted within Eurofins group and is not accredited
- test is subcontracted outside Eurofins group and is accredited
- test is subcontracted outside Eurofins group and is not accredited

N/A means Not applicable

Not Detected means not detected at or above the Limit of Quantification (LOQ)

Accreditation does not apply to comments or graphical representations. Eurofins General Terms and Conditions apply.

This document can only be reproduced in full; it only concerns the submitted sample. Results have been obtained and reported in accordance with our general sales conditions available on request.

The tests are identified by a five-digit code, their description is available on request.

Unless otherwise stated, all tests in this analytical report (except for subcontracted tests) are performed at 35 O'Rorke Road, Penrose, Auckland, NEW ZEALAND.

END OF REPORT



Certificate of Analysis

Page 1 of 7

Client:	Pattle Delamore Partners Limited	Lab No:	2266156	shvpv1
Address:	PO Box 9528 Newmarket Auckland 1149	Date Received:	30-Oct-2019	
		Date Reported:	07-Nov-2019	
		Quote No:	83649	
		Order No:		
Phone:	09 523 6900	Client Reference:	CO3870503	
		Submitted By:	Chris Foote	

Sample Name: 1

Lab Number: 2266156.1

Sample Type: SOIL General, Outdoor (S10)

Analysis	Level Found	Medium Range	Low	Medium	High
pH	pH Units	5.3	5.8 - 6.3		
Olsen Phosphorus	mg/L	30	20 - 30		
Potassium	me/100g	1.05	0.50 - 0.80		
Calcium	me/100g	13.2	6.0 - 12.0		
Magnesium	me/100g	2.26	1.00 - 3.00		
Sodium	me/100g	0.32	0.20 - 0.50		
CEC	me/100g	37	12 - 25		
Total Base Saturation	%	46	50 - 85		
Volume Weight	g/mL	0.58	0.60 - 1.00		
Sulphate Sulphur	mg/kg	40	7 - 15		
Soluble Salts (Field)	%	0.17	0.05 - 0.30		
EC (in 1:5 Extract)	mS/cm	0.48			
Potentially Available Nitrogen (15cm Depth)*	kg/ha	231	100 - 150		
Anaerobically Mineralisable N*	µg/g	264			
Organic Matter*	%	23.5	7.0 - 17.0		
Total Carbon*	%	13.6			
Total Nitrogen*	%	1.20	0.30 - 0.60		
C/N Ratio*		11.4			
Anaerobically Mineralisable N/Total N Ratio*	%	2.2	3.0 - 5.0		
Soil Texture analysis*	See attached report				
Base Saturation %	K 2.9	Ca 36	Mg 6.1	Na 0.9	
MAF Units	K 13	Ca 10	Mg 30	Na 8	

The above nutrient graph compares the levels found with reference interpretation levels. NOTE: It is important that the correct sample type be assigned, and that the recommended sampling procedure has been followed. R J Hill Laboratories Limited does not accept any responsibility for the resulting use of this information. IANZ Accreditation does not apply to comments and interpretations, i.e. the 'Range Levels' and subsequent graphs.





Certificate of Analysis

Page 2 of 7

Client:	Pattle Delamore Partners Limited	Lab No:	2266156	shvpv1
Address:	PO Box 9528 Newmarket Auckland 1149	Date Received:	30-Oct-2019	
		Date Reported:	07-Nov-2019	
		Quote No:	83649	
		Order No:		
Phone:	09 523 6900	Client Reference:	CO3870503	
		Submitted By:	Chris Foote	

Sample Name: 1+2

Lab Number: 2266156.2

Sample Type: SOIL General, Outdoor (S10)

Analysis	Level Found	Medium Range	Low	Medium	High
pH	pH Units	5.5	5.8 - 6.3		
Olsen Phosphorus	mg/L	11	20 - 30		
Potassium	me/100g	0.50	0.50 - 0.80		
Calcium	me/100g	5.8	6.0 - 12.0		
Magnesium	me/100g	0.88	1.00 - 3.00		
Sodium	me/100g	0.18	0.20 - 0.50		
CEC	me/100g	25	12 - 25		
Total Base Saturation	%	29	50 - 85		
Volume Weight	g/mL	0.64	0.60 - 1.00		
Sulphate Sulphur	mg/kg	167	7 - 15		
Soluble Salts (Field)	%	< 0.05	0.05 - 0.30		
EC (in 1:5 Extract)	mS/cm	0.13			
Potentially Available Nitrogen (15cm Depth)*	kg/ha	117	100 - 150		
Anaerobically Mineralisable N*	µg/g	122			
Organic Matter*	%	14.5	7.0 - 17.0		
Total Carbon*	%	8.4			
Total Nitrogen*	%	0.76	0.30 - 0.60		
C/N Ratio*		11.0			
Anaerobically Mineralisable N/Total N Ratio*	%	1.6	3.0 - 5.0		
Soil Texture analysis*	See attached report				
Base Saturation %	K 2.0	Ca 23	Mg 3.5	Na 0.7	
MAF Units	K 6	Ca 5	Mg 13	Na 5	

The above nutrient graph compares the levels found with reference interpretation levels. NOTE: It is important that the correct sample type be assigned, and that the recommended sampling procedure has been followed. R J Hill Laboratories Limited does not accept any responsibility for the resulting use of this information. IANZ Accreditation does not apply to comments and interpretations, i.e. the 'Range Levels' and subsequent graphs.



Certificate of Analysis

Page 3 of 7

Client:	Pattle Delamore Partners Limited	Lab No:	2266156	shvpv1
Address:	PO Box 9528 Newmarket Auckland 1149	Date Received:	30-Oct-2019	
		Date Reported:	07-Nov-2019	
		Quote No:	83649	
		Order No:		
Phone:	09 523 6900	Client Reference:	CO3870503	
		Submitted By:	Chris Foote	

Sample Name: 1+2+3

Lab Number: 2266156.3

Sample Type: SOIL General, Outdoor (S10)

Analysis	Level Found	Medium Range	Low	Medium	High
pH	pH Units	5.6	5.8 - 6.3		
Olsen Phosphorus	mg/L	5	20 - 30		
Potassium	me/100g	0.30	0.50 - 0.80		
Calcium	me/100g	3.5	6.0 - 12.0		
Magnesium	me/100g	0.50	1.00 - 3.00		
Sodium	me/100g	0.11	0.20 - 0.50		
CEC	me/100g	17	12 - 25		
Total Base Saturation	%	26	50 - 85		
Volume Weight	g/mL	0.69	0.60 - 1.00		
Sulphate Sulphur	mg/kg	447	7 - 15		
Soluble Salts (Field)	%	< 0.05	0.05 - 0.30		
EC (in 1:5 Extract)	mS/cm	0.05			
Potentially Available Nitrogen (15cm Depth)*	kg/ha	138	100 - 150		
Anaerobically Mineralisable N*	µg/g	134			
Organic Matter*	%	10.3	7.0 - 17.0		
Total Carbon*	%	5.9			
Total Nitrogen*	%	0.53	0.30 - 0.60		
C/N Ratio*		11.2			
Anaerobically Mineralisable N/Total N Ratio*	%	2.5	3.0 - 5.0		
Soil Texture analysis*	See attached report				
Base Saturation %	K 1.8	Ca 21	Mg 3.0	Na 0.7	
MAF Units	K 4	Ca 3	Mg 8	Na 4	

The above nutrient graph compares the levels found with reference interpretation levels. NOTE: It is important that the correct sample type be assigned, and that the recommended sampling procedure has been followed. R J Hill Laboratories Limited does not accept any responsibility for the resulting use of this information. IANZ Accreditation does not apply to comments and interpretations, i.e. the 'Range Levels' and subsequent graphs.



Certificate of Analysis

Page 4 of 7

Client:	Pattle Delamore Partners Limited	Lab No:	2266156	shvpv1
Address:	PO Box 9528 Newmarket Auckland 1149	Date Received:	30-Oct-2019	
		Date Reported:	07-Nov-2019	
		Quote No:	83649	
		Order No:		
Phone:	09 523 6900	Client Reference:	CO3870503	
		Submitted By:	Chris Foote	

Soil Analysis Results						
Sample Name:		1	1+2	1+2+3		
Lab Number:		2266156.1	2266156.2	2266156.3		
Sample Type:		SOIL General, Outdoor	SOIL General, Outdoor	SOIL General, Outdoor		
Sample Type Code:		S10	S10	S10		
pH	pH Units	5.3	5.5	5.6	-	-
Olsen Phosphorus	mg/L	30	11	5	-	-
Potassium	me/100g	1.05	0.50	0.30	-	-
Potassium	%BS	2.9	2.0	1.8	-	-
Potassium	MAF units	13	6	4	-	-
Calcium	me/100g	13.2	5.8	3.5	-	-
Calcium	%BS	36	23	21	-	-
Calcium	MAF units	10	5	3	-	-
Magnesium	me/100g	2.26	0.88	0.50	-	-
Magnesium	%BS	6.1	3.5	3.0	-	-
Magnesium	MAF units	30	13	8	-	-
Sodium	me/100g	0.32	0.18	0.11	-	-
Sodium	%BS	0.9	0.7	0.7	-	-
Sodium	MAF units	8	5	4	-	-
CEC	me/100g	37	25	17	-	-
Total Base Saturation	%	46	29	26	-	-
Volume Weight	g/mL	0.58	0.64	0.69	-	-
Sulphate Sulphur	mg/kg	40	167	447	-	-
Soluble Salts (Field)	%	0.17	< 0.05	< 0.05	-	-
EC (in 1:5 Extract)	mS/cm	0.48	0.13	0.05	-	-
Potentially Available Nitrogen (15cm Depth)*	kg/ha	231	117	138	-	-
Anaerobically Mineralisable N*	µg/g	264	122	134	-	-
Organic Matter*	%	23.5	14.5	10.3	-	-
Total Carbon*	%	13.6	8.4	5.9	-	-
Total Nitrogen*	%	1.20	0.76	0.53	-	-
C/N Ratio*		11.4	11.0	11.2	-	-
Anaerobically Mineralisable N/Total% N Ratio*		2.2	1.6	2.5	-	-



Hill Laboratories
TRIED, TESTED AND TRUSTED

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

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T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis

Page 5 of 7

Client:	Pattle Delamore Partners Limited	Lab No:	2266156	shvpv1
Address:	PO Box 9528 Newmarket Auckland 1149	Date Received:	30-Oct-2019	
		Date Reported:	07-Nov-2019	
		Quote No:	83649	
		Order No:		
Phone:	09 523 6900	Client Reference:	CO3870503	
		Submitted By:	Chris Foote	

Soil Analysis Results						
Sample Name:	1	1+2	1+2+3			
Lab Number:	2266156.1	2266156.2	2266156.3			
Sample Type:	SOIL General, Outdoor	SOIL General, Outdoor	SOIL General, Outdoor			
Sample Type Code:	S10	S10	S10			
Soil Texture analysis*	See attached report	See attached report	See attached report	-	-	-



Certificate of Analysis

Page 6 of 7

Client:	Pattle Delamore Partners Limited	Lab No:	2266156	shvpv1
Address:	PO Box 9528 Newmarket Auckland 1149	Date Received:	30-Oct-2019	
		Date Reported:	07-Nov-2019	
		Quote No:	83649	
		Order No:		
Phone:	09 523 6900	Client Reference:	CO3870503	
		Submitted By:	Chris Foote	

Analyst's Comments

Samples 1-3 Comment:

The medium or optimum range guidelines shown in the histogram report relate to sampling protocols as per Hill Laboratories' crop guides and are based on reference values where these are published. Results for samples collected to different depths than those described in the crop guide should be interpreted with caution. For pastoral soils, the medium ranges are specific for a 75mm sample depth, but if a 150mm sampling depth is used the nutrient levels measured may appear low against these ranges, as nutrients are typically more concentrated in the top of the soil profile. These soil profile differences are altered upon cultivation or contouring.

Sample 1 Comment:

The high CEC level found in this soil indicates that it has a high capacity to retain cation nutrients (potassium, calcium, magnesium and sodium). For crop and horticulture soil sample type codes, the normal ranges and the derived histograms are based on a typical soil with a CEC level between 12 and 25 me/100g, unless otherwise denoted.

Samples 1-3 Comment:

The Potentially Available Nitrogen (kg/ha) test above assumes the sample is taken to a 15 cm depth. If the depth is 7.5 cm, then the result reported above should be divided by two.

To calculate Potentially Available Nitrogen (as kgN/ha) for other sample depths use the reported Anaerobic Mineralisable Nitrogen (AMN) result in the following equation:

$$AN \text{ (kg/ha)} = AMN \text{ (}\mu\text{g/g)} \times VW \text{ (g/ml)} \times \text{sample depth (cm)} \times 0.1$$

Note that the AN and AMN results reported include the readily available Mineral N (NH₄-N and NO₃-N) fraction, which is typically quite low.

Appendix No.1 - Eurofins report

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Soil			
Test	Method Description	Default Detection Limit	Sample No
Soil Texture analysis*	Analysis of % sand, silt, clay. Subcontracted to; Eurofins NZ Laboratory Services Ltd - Penrose, Auckland.	-	1-3
Sample Registration*	Samples were registered according to instructions received.	-	1-3
Soil Prep (Dry & Grind)*	Air dried at 35 - 40°C overnight (residual moisture typically 4%) and crushed to pass through a 2mm screen.	-	1-3
pH	1:2 (v/v) soil:water slurry followed by potentiometric determination of pH. In-house.	0.1 pH Units	1-3
Olsen Phosphorus	Olsen extraction followed by Molybdenum Blue colorimetry. In-house method.	1 mg/L	1-3
Sulphate Sulphur	0.02M Potassium phosphate extraction followed by Ion Chromatography. In-house.	1 mg/kg	1-3
Potentially Available Nitrogen*	Determined by NIR, calibration based on Available N by Anaerobic incubation followed by extraction using 2M KCl followed by Berthelot colorimetry. (Calculation based on 15cm depth sample). Note that any Mineral N present is included in the AN/AMN result reported.	1 mg/L	1-3
Anaerobically Mineralisable N*	As for Potentially Available Nitrogen but reported as $\mu\text{g/g}$.	5 $\mu\text{g/g}$	1-3
Organic Matter*	Organic Matter is 1.72 x Total Carbon.	0.2 %	1-3
Soluble Salts (Field)	1:5 soil:water extraction followed by potentiometric determination of conductivity. Calculated by EC (mS/cm) x 0.35. In-house.	0.05 %	1-3
Electrical Conductivity (EC)	Electrical Conductivity measured in 1:5 Soil:Water extract.	0.01 mS/cm	1-3



Certificate of Analysis

Page 7 of 7

Client:	Pattle Delamore Partners Limited	Lab No:	2266156	shvpv1
Address:	PO Box 9528 Newmarket Auckland 1149	Date Received:	30-Oct-2019	
		Date Reported:	07-Nov-2019	
		Quote No:	83649	
		Order No:		
Phone:	09 523 6900	Client Reference:	CO3870503	
		Submitted By:	Chris Foote	

Sample Type: Soil			
Test	Method Description	Default Detection Limit	Sample No
Total Carbon*	Determined by NIR, calibration based on Total Carbon by Dumas combustion.	0.1 %	1-3
Total Nitrogen*	Determined by NIR, calibration based on Total N by Dumas combustion.	0.04 %	1-3
Potassium	1M Neutral ammonium acetate extraction followed by ICP-OES. In-house.	0.01 me/100g	1-3
Calcium	1M Neutral ammonium acetate extraction followed by ICP-OES. In-house.	0.5 me/100g	1-3
Magnesium	1M Neutral ammonium acetate extraction followed by ICP-OES. In-house.	0.04 me/100g	1-3
Sodium	1M Neutral ammonium acetate extraction followed by ICP-OES. In-house.	0.05 me/100g	1-3
CEC	Summation of extractable cations (K, Ca, Mg, Na) and extractable acidity. May be overestimated if soil contains high levels of soluble salts or carbonates. In-house.	2 me/100g	1-3
Total Base Saturation	Calculated from Extractable Cations and Cation Exchange Capacity.	5 %	1-3
Volume Weight	The weight/volume ratio of dried, ground soil. In-house.	0.01 g/mL	1-3

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

This certificate of analysis must not be reproduced, except in full, without the written consent of the signatory.

Karen Lim BSc
Client Services Manager - Agriculture

ANALYTICAL REPORT

REPORT CODE

AR-19-NU-090371-01

REPORT DATE

06/11/2019

For the attention of

Hill Laboratories Ltd

Enviro Reports

28 Duke Street

Frankton

3204 Hamilton

NEW ZEALAND

Phone 6478582000

Email envjobenquiry@hill-labs.co.nz

Contact for your orders:

Hanin Khan

Order code:

EUNZAU-00221642

Submission Reference:

agSubEurofinsAuck 170

Purchase Order Number:

152726

SAMPLE CODE

816-2019-00284152

Client reference:

Sample described as:

2266156.1

Reception Date & Time:

31/10/2019 16:07

Analysis starting date:

31/10/2019

Analysis ending date:

06/11/2019

SOIL PHYSICAL MEASUREMENT

RESULTS

LOQ

◆ NU092 Coarse Sand (0.6-2mm)

Coarse Sand

2 %

1

◆ NU199 Medium Sand (0.2-0.6mm)

Medium Sand

7 %

1

◆ NU134 Fine Sand (0.06-0.2mm)

Fine Sand

22 %

1

◆ NU318 Silt (0.002-0.06mm)

Silt

45 %

1

◆ NU091 Clay (<0.002mm)

Clay

25 %

1

SAMPLE CODE

816-2019-00284153

Client reference:

Sample described as:

2266156.2

Reception Date & Time:

31/10/2019 16:07

Analysis starting date:

31/10/2019

Analysis ending date:

06/11/2019

SOIL PHYSICAL MEASUREMENT

RESULTS

LOQ

◆ NU092 Coarse Sand (0.6-2mm)

Coarse Sand

1 %

1

◆ NU199 Medium Sand (0.2-0.6mm)

Medium Sand

4 %

1

◆ NU134 Fine Sand (0.06-0.2mm)

Fine Sand

19 %

1

◆ NU318 Silt (0.002-0.06mm)

Silt

46 %

1

◆ NU091 Clay (<0.002mm)

Clay

29 %

1

SAMPLE CODE

816-2019-00284154

Client reference:

Sample described as: 2266156.3

Reception Date & Time: 31/10/2019 16:07

Analysis starting date: 31/10/2019

Analysis ending date: 06/11/2019

SOIL PHYSICAL MEASUREMENT	RESULTS	LOQ
◆ NU092 Coarse Sand (0.6-2mm)		
Coarse Sand	2 %	1
◆ NU199 Medium Sand (0.2-0.6mm)		
Medium Sand	5 %	1
◆ NU134 Fine Sand (0.06-0.2mm)		
Fine Sand	19 %	1
◆ NU318 Silt (0.002-0.06mm)		
Silt	46 %	1
◆ NU091 Clay (<0.002mm)		
Clay	28 %	1

REPORT INFORMATION

Texture results reported as % of inorganic fraction

LIST OF METHODS

NU091 Clay (<0.002mm) : Sedimentation procedure by hydrometer. < 0.002mm	NU092 Coarse Sand (0.6-2mm) : Sieve analysis. 0.6-2.0mm
NU134 Fine Sand (0.06-0.2mm) : Sieve analysis. 0.06-0.2mm	NU199 Medium Sand (0.2-0.6mm) : Sieve analysis. 0.2-0.6mm
NU318 Silt (0.002-0.06mm) : Sedimentation procedure by hydrometer. 0.002-0.06mm	

Signature



Brent Miller Team Leader Agri Testing

EXPLANATORY NOTE

- ◆ test is not accredited
- test is subcontracted within Eurofins group and is accredited
- test is subcontracted within Eurofins group and is not accredited
- test is subcontracted outside Eurofins group and is accredited
- test is subcontracted outside Eurofins group and is not accredited

N/A means Not applicable

Not Detected means not detected at or above the Limit of Quantification (LOQ)

Accreditation does not apply to comments or graphical representations. Eurofins General Terms and Conditions apply.

This document can only be reproduced in full; it only concerns the submitted sample. Results have been obtained and reported in accordance with our general sales conditions available on request.

The tests are identified by a five-digit code, their description is available on request.

Unless otherwise stated, all tests in this analytical report (except for subcontracted tests) are performed at 35 O'Rorke Road, Penrose, Auckland, NEW ZEALAND.

END OF REPORT