Appendix 10

Geotechnical Assessment
Otaika Quarry - Pegram Block Overburden Disposal
Assessment of Adverse Effects on Land Stability

1 Introduction

Tonkin and Taylor Ltd (T+T) has been providing geotechnical design advice to GBC Winstone for their proposed overburden disposal area (OBDA) on the Pegram Block adjacent to their Otaika Quarry.

The results of preliminary ground investigation and stability analyses are reported in our preliminary geotechnical assessment\(^1\) which was prepared as one of a number of technical supporting documents to GBC Winstones application for resource consent.

The purpose of this memo is to address specific requirements for land use consent under the District Plan that are geotechnical in nature and provide additional information on how the overburden fill will be placed.

The specific requirements are covered in the following objectives, policies and rules in the Whangarei District Plan:

- Objective 19.3.1:
  - The adverse effects of natural hazards on people, property and the environment are avoided, as far as practicable, or otherwise remedied or mitigated.

- Policy 19.4.1:
  - Natural Hazard Effects: To ensure that subdivision, use and development do not increase the risk from, occurrence of, or the adverse effects of natural hazards.

- Rule 64.3.1.2 & 3: Mineral Extraction – Activity Matters of control and discretion:
  - iv. The extent of any adverse effect on land stability

This memo draws heavily on our preliminary geotechnical assessment report and should be read in conjunction with that report.

\(^1\) Tonkin +Taylor report prepared for GBC Winstone. Otaika Quarry – Proposed Overburden Disposal Area, Preliminary Geotechnical Assessment, Dated March 2017, ref: 1000785v4
2 Geological context and slope stability

The Pegram Block is underlain by a combination of Whangarei Limestone, Ruatangata Sandstone and Northland Allochthon siltstones & mudstones, with local alluvium as set out in our previous reporting. Other lithologies are present in the upper part of the Pegram Block, but the performance of the Northland Allochthon is expected to control stability. In particular, the potential presence of low strength, pervasive shearing with a high level of persistence through the unit makes Northland Allochthon slopes prone to developing (or reactivating) instability, particularly during periods of prolonged or high intensity rainfall.

Earthworks cuts or fills substantially increase the risk of slope instability developing on marginally stable slopes unless engineering designs incorporate mitigation measures to improve stability. It has been our experience that modified Northland Allochthon slopes that have incorporated appropriate design measures typically can achieve a reduced risk of slope instability when compared to natural slopes in the same materials.

3 Proposed development

3.1 General

The proposed OBDA will incorporate filling a broad gully with overburden material from the adjacent Otaika Quarry. The volume of placed fill is expected to be approximately 2.4 million m$^3$ and will be undertaken over a period of 35 years. More detail on the development is set out in our earlier reporting.

Fill is expected to be placed over a number of earthworks seasons within the period of the consent. The main AEE application document defines enabling works and general works as illustrated in the concept plan (reproduced in Appendix A). The enabling works and general works incorporate different material types and placement methodologies as set out below.

3.2 Enabling works

Initial works will concentrate on the toe area, where excavation of unsuitable soils, construction of a shear key, placement of a toe buttress and placement of an initial Mattressed material that will support later placement of overburden (refer General works).

The proposed toe buttress and Shear Key will be made up of weathered greywacke rock (often referred to as brown rock) that is unsuitable for processing into aggregate. This material retains good intact strength and when placed with a degree of compaction, provides a strong, free draining toe that supports weaker fill material placed behind it.

The remaining work to be undertaken within the enabling works area is a zone of Mattressed material to be placed immediately behind the toe buttress and developed as part of the same initial landform.

The Mattressed material comprises 1-2m thick layers of general overburden fill, weathered greywacke fill and unweathered, blocky Ruatangata Sandstone. The purpose of the Mattressed material is to improve the drainage characteristics of the lower parts of the OBDA, which will improve stability and supplement the underfill drainage system that controls groundwater pressure at the contact with the previous ground surface.

---

2 Pages 8-10.
3 Pages 1-2.
4 Boffa Miskell Limited - OTAIKA QUARRY - PROPOSED OVERBURDEN DISPOSAL AREA - Application for Land Use Consent and Assessment of Environmental Effects Prepared for GBC Winstone
3.3 General works

General works comprise general overburden filling on the gently graded upper slopes and will include a mixture of overburden waste rock and residual clay soils. In general, the softest, wettest soils are typically placed towards the back of the OBDA, with firmer, drier soils placed towards the front face.

A sketch of the conceptual interrelationships of the various fill types that makeup the enabling works and general works are set out in Figure 3-1 and GBC Winstones Concept Plan reproduced in Appendix A.

Figure 3-1: Annotated cross section illustrating interrelationship of fill types (section sourced from reference 1).

4 Potential for adverse effects on land stability

Without appropriate geotechnical design the placement of fill at the volumes proposed could have significant potential for adverse effects on land stability. As such, the OBDA is being designed to incorporate:

1. Subsoil drains which are to be excavated into existing natural surface water drainage channels to manage groundwater pressure in the OBDA foundation;
2. A toe buttress of weathered rock fill. This aids stability by providing load at the toe of the constructed fill slope;
3. A shear key across the valley, which is an excavation and removal of soft or weak soils down to underlying competent rock & replacement with brown rock (a higher strength zone that disrupts continuity of shear surfaces and locks in the fill);
4. Mattressed material that improves the drainage characteristics of the toe of the overall OBDA and provides an improved foundation for later general works (overburden filling).

These geotechnical design measures are effective and commonly used to improve the stability of large earth fills for residential, commercial and quarry/mining land developments.

Our earlier report provides the detail of the analytical work undertaken to assess slope stability and presents our design recommendations. Overall, we concluded that a suitable level of long term slope stability could be achieved at the Pegram Block that is appropriate to the long term end use of the site (a return to farmland).

---

5 Pages 12-17.
5 Conclusions

Provided that the geotechnical design recommendations for the site are implemented we anticipate higher levels of stability than those which currently exist for natural slopes within the footprint of the proposed OBDA.

For the purposes of the land use consent, we therefore conclude that the proposed design is appropriate and is unlikely to have a significant adverse effect on land stability.

It is our opinion that the final OBDA landform can meet or exceed the requirements of the objectives, policies and rules related to natural hazards (specifically landslides) set out in the Whangarei District Plan (refer Section 1), based on the geotechnical recommendations and design elements set out in this memo and in our previous geotechnical assessment report.

6 Closure & Applicability

We trust that the information provided in this memo and our preliminary geotechnical assessment report clearly set out the limited potential for adverse effects on land stability. We would be pleased to discuss any aspect as required.

This report has been prepared for the exclusive use of our client GBC Winstone, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd
Environmental and Engineering Consultants

Report prepared by: Authorised for Tonkin & Taylor Ltd by:

.......................................................... ...........................................................
Cameron Lines Kevin Hind
Senior Engineering Geologist Technical Director

p:\1000785\6 geotech variation otaika obda\workingmaterial\tt pegram district council geotech v4.docx
Appendix A: GBC Winstone Concept Plan
This plan has been prepared by Boffa Miskell Limited on the specific instructions of our Client. It is solely for our Client's use and will not be reproduced in whole or in part without the Client's prior written consent. Any use or reliance by a third party is at that party's own risk. Where information has been supplied by the Client or obtained from other external sources, it has been assumed that it is accurate. No liability or responsibility is accepted for incorrect data or omissions to the extent that they arise from inaccurate information provided by the Client or any external source.

Date: 13 March 2017 | Revision: 0
Plan prepared for GBC Winstone by Boffa Miskell Limited
Drawn: Dlr | Checked: CCl

Legend
- Enabling Works
- General Works
- Pagram Block boundary

OTAIIKA QUARRY - PROPOSED OVERBURDEN DISPOSAL AREA
Concept Plan - Final Form

OTAIIKA SPORTS PARK
ACACIA PARK
SCMEATON RESIDENTIAL AREA
PEGRAM BLOCK
GBC WINSTONE

Projection: NZGD 2000 New Zealand Transverse Mercator
Distribution:

GBC Winstone  Digital
Tonkin & Taylor Ltd (FILE)  1 copy
Table of contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction</td>
</tr>
<tr>
<td>2</td>
<td>Description of proposed development</td>
</tr>
<tr>
<td>3</td>
<td>Site Description</td>
</tr>
<tr>
<td>4</td>
<td>Geology</td>
</tr>
<tr>
<td>5</td>
<td>Subsurface investigation</td>
</tr>
<tr>
<td>5.1</td>
<td>General</td>
</tr>
<tr>
<td>5.2</td>
<td>Subsurface conditions</td>
</tr>
<tr>
<td>5.3</td>
<td>Geotechnical Units</td>
</tr>
<tr>
<td>5.3.1</td>
<td>Topsoil</td>
</tr>
<tr>
<td>5.3.2</td>
<td>Recent mixed alluvium/colluvium</td>
</tr>
<tr>
<td>5.3.3</td>
<td>Northland Allochthon</td>
</tr>
<tr>
<td>5.3.4</td>
<td>Ruatangata Sandstone</td>
</tr>
<tr>
<td>5.4</td>
<td>Groundwater</td>
</tr>
<tr>
<td>6</td>
<td>Proposed OBDA feasibility slope stability assessment</td>
</tr>
<tr>
<td>6.1</td>
<td>General</td>
</tr>
<tr>
<td>6.2</td>
<td>Design Criteria</td>
</tr>
<tr>
<td>6.3</td>
<td>Material properties</td>
</tr>
<tr>
<td>6.4</td>
<td>SlopeW Preliminary Stability Assessment Results</td>
</tr>
<tr>
<td>6.4.1</td>
<td>Static case</td>
</tr>
<tr>
<td>6.4.2</td>
<td>Elevated groundwater case</td>
</tr>
<tr>
<td>6.4.3</td>
<td>Seismic case</td>
</tr>
<tr>
<td>6.4.4</td>
<td>Assessment of slope displacement under seismic load</td>
</tr>
<tr>
<td>7</td>
<td>Geotechnical design issues</td>
</tr>
<tr>
<td>7.1</td>
<td>General</td>
</tr>
<tr>
<td>7.2</td>
<td>Foundation conditions and stability</td>
</tr>
<tr>
<td>7.3</td>
<td>Assessment of void potential in OBDA foundation</td>
</tr>
<tr>
<td>7.4</td>
<td>Groundwater and Surface Water</td>
</tr>
<tr>
<td>7.5</td>
<td>Fill consistency &amp; landform geometry</td>
</tr>
<tr>
<td>8</td>
<td>Summary and Conclusions</td>
</tr>
<tr>
<td>9</td>
<td>Applicability</td>
</tr>
</tbody>
</table>

Appendix A: Figures
Appendix B: Test Pit Logs
Appendix C: Scantec Geophysical Report
Appendix D: SlopeW Analysis Results
Appendix E: Kermode Report
GBC Winstone (Winstones) are planning for long term overburden disposal at their Otaika Quarry. An overburden development area (OBDA) is planned for the Pegram Block to the East of the Quarry and GBC Winstone are in the process of preparing an application for resource consent for the site.

Tonkin & Taylor Ltd (T+T) has been engaged to review the proposed development, assess the underlying geology and geotechnical characteristics of the site, outline the geotechnical risks, and provide an assessment of the suitability of the site from a geotechnical perspective.

Overall, we consider that the proposed finished OBDA landform can achieve an appropriate level of slope stability provided the key geotechnical risk areas outlined below are mitigated appropriately in final design. A geotechnical design report to support construction should be prepared prior to site works commencing.

<table>
<thead>
<tr>
<th>Key Consideration</th>
<th>Background</th>
<th>Key Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundation Conditions &amp; Slope Stability</td>
<td>The foundation is expected to be Northland Allochthon siltstone and mudstone, with the NW area on Ruatangata Sandstone and Whangarei Limestone.</td>
<td>Foundation conditions present a low stability risk of slope instability, provided that soft, weak soils are identified and excavated, and a shear key is developed to support the proposed toe buttress. Preliminary slope stability modelling indicates an acceptable level of stability can be achieved for the final OBDA landform. Recommendation: The final depth and position of the key should be confirmed during the early stages of site earthworks. [refer Section 7.2]</td>
</tr>
<tr>
<td>Groundwater and Surface Water</td>
<td>The site is poorly drained with saturated soils and small springs located under the footprint.</td>
<td>Stability risk is high unless under-fill drainage is incorporated into the construction. This risk becomes low with appropriate surface and groundwater management. Recommendation: Development of an under-fill sub-soil drainage network in the former gully floors, sidling gullies and as required to pick up spring seepages. A surface water drainage design will be required to manage flows both during construction and long term (post closure). [refer Section 7.4]</td>
</tr>
<tr>
<td>Fill consistency and landform geometry</td>
<td>The fill material is to be made up of soils, weathered greywacke and unweathered Ruatangata Sandstone and Whangarei Limestone.</td>
<td>Fill material and landform shape present a medium stability risk for general filling. This risk can be considered as low, if placement can be managed i.e. dry weather placement and zoning the fill material with the most competent material in the toe. Recommendation: The overburden placement should be developed in a zoned fashion with a free draining material used to develop the proposed toe bund and shear key. [refer Section 7.5]</td>
</tr>
<tr>
<td>Void potential in foundation</td>
<td>Void potential is limited only to small areas of Whangarei Limestone in the NW of the proposed OBDA foundation.</td>
<td>There is limited potential for a substantial void within the small extent of limestone that is anticipated beneath the NW extent of the OBDA, due to soil formation and weathering effects. The small thickness of the proposed overburden fill in this area (4 – 6 m) is unlikely to have a significant detrimental effect on any small voids that may be present. Recommendation: No further assessment required. [refer Section 7.3]</td>
</tr>
</tbody>
</table>

1 This summary presents an overview of the key outcomes and geotechnical risks at the site. It should be read in conjunction with the relevant detail included in the main body of the report.
1 Introduction

GBC Winstone is currently in the planning phase for the next stage of overburden stripping from their Otaika Quarry, which is located some 5km south of the Whangarei CBD. Soil and weathered rock will be removed from above the greywacke resource and are to be placed in an adjacent overburden disposal area (OBDA).

A broad valley to the east of the Quarry, known as the Pegram Block, has been identified as the preferred disposal location for the overburden materials and GBC Winstone are in the process of preparing a resource consent application. Tonkin & Taylor Ltd (T+T) has been engaged to undertake geotechnical assessment of the proposed OBDA.

The purpose of the assessment is to consider the feasibility of the proposal, likely engineering requirements for ongoing design and construction and potential environmental effects related to geotechnical performance.

This report presents the results of the initial suite of ground investigation and provides preliminary geotechnical recommendations on the expected long term stability of the proposed OBDA.

The geotechnical scope of works undertaken by T+T has included:

- Review of development plans for the proposed site;
- Review of relevant existing geotechnical data held in the T+T archive, provided by GBC Winstone and readily available published geological information for the area;
- Site investigation, comprising 12 test pits to depths of between 1.5 m bgl and 4.4 m bgl, with shear vane testing at regular depth intervals;
- Preparation of a geological model of the site (including two cross sections);
- Preliminary stability analyses to assess long term stability of the final OBDA landform;
- Preparation of this report presenting the results of the geotechnical investigation and providing preliminary geotechnical recommendations to support the proposed development.

2 Description of proposed development

A description of the proposed development is set out in the main AEE documentation which includes plans of the proposed development.

In summary the key geotechnical elements of the concept design include.

1 Filling of a broad gully system, with construction of a shear key and toe bund to support the overburden fill material placed behind.
2 Diversion of an unnamed tributary of Te Waiti stream over a length of approximately 500m.
3 A maximum fill thickness of approximately 30m depending on position within the final OBDA footprint.
4 The total footprint of the overburden disposal area is 16.7 hectares in area. The total of volume overburden disposal will be approximately 2.4 million m$^3$ to be placed intermittently over a period of up to 35 years.
5 Indicative slope angles for the main body of the proposed OBDA are approximately 12°. The front bunds are made up of individual 10m high fill batters sloping at approximately 32°, separated by small 3m catch benches, making up an overall slope angle of approximately 26°.
6 An 8m wide bench across the toe of the overburden, in a small section of buttress located downslope of the proposed shear key.

3 Site Description

The proposed overburden filling will occur within a broad northeast trending gully. The site is entirely within pastoral land with general slope angles of approximately 8° and gently undulating terrain. The proposed area of the OBDA is set out in Figure 3-1 and Figure 3-2.

To the northwest of the site, within the area highlighted as a limestone outcrop (orange), the topography is of a mantled karstic terrain, with swallow, open tomo features leading to cave systems, closed doline (tomo) features and of exposed limestone outcrop, some containing large vertical fissures of 15 m to 16m depth (reference Kermode Appendix E).
Figure 3-1: Aerial photo showing approximate outline of OBDA footprint (red), limestone outcrop (orange) and siltstone outcrop (light blue).
A stream channel flows through the lower third of the proposed OBDA footprint (Figure 3-3). The main parts of the proposed OBDA foundation are very wet with numerous seepage points observed and ponding of seepage flows and surface water as indicated on Figure 3-3. The drainage on the lower part of the slopes appears to have been modified with some very linear drainage channels evident (Figure 3-3).
4 Geology

The most recent geological map of the area\(^3\) indicates that the proposed overburden footprint covers an area that is expected to include:

- Whangarei Limestone – a bioclastic, weak, flaggy limestone;
- Ruatangata Sandstone – a glauconitic greenish grey, very weak sandstone;
- Undifferentiated Northland Allochthon – comprising a range of lithologies including red brown shales, siltstones, sandstones, limestones and volcanics. The nature of the emplacement of the Allochthon means that it is often significantly disturbed, with low strength pervasive shear surfaces. It can be highly variable over short distances.

A speleological study by L.O. Kermode of the limestone caves at Ruarangi A block (approximately 500 m northwest of the site) indicates that the limestone is flaggy and crystalline, and approximately 15 m thick. It grades downward into a sandy, flaky limestone of about 8 m thickness. Caves formed by solution and collapse of the limestone seem to follow a basal glauconitic sandstone, which was found to outcrop in the larger streams to the north of the Ruarangi B block.

A Senior Engineering Geologist from T+T completed a preliminary site walkover on 13 October 2016. Key observations from this walkover include:

- A grey, white limestone outcrops at ground surface along the northwest boundary of the site. This material is weak to moderately strong and has visible bedding dipping towards the north at approximately 10-15° (refer Figure 3-1 and Figure 4-1);
- A 1m deep depression adjacent to a limestone outcrop on the NW boundary was observed. This was investigated during the test pit investigation. However, no obvious voids were identified.
- Limestone rock is also apparent outcropping in a small drainage channel on the lower part of the slope (refer Figure 3-1 - photo location 18 and Figure 4-3).
- A weak, white grey siliceous, moderately to highly weathered, closely fractured Siltstone is observed in outcrop in the southeastern part of the site and in a highly weathered outcrop in the northern corner of the site (refer Figure 3-1 – photo location 22, 29, 33 and Figure 4-4);

---

\(^3\) Edbrooke, S. W., Brook, F. J., (compilers) 2009. Geology of the Whangarei Area, Institute of Geological and Nuclear Sciences 1:250,000 Geological Map 2.
Figure 4-1: Limestone outcrop on NW boundary.

Figure 4-2: Depression adjacent to limestone outcrop
Figure 4-3: Limestone outcrop in drainage channel on lower slopes

Figure 4-4: Highly weathered, siliceous siltstone outcropping in a drainage channel in the southeastern part of the site.
5 Subsurface investigation

5.1 General

T+T undertook a preliminary geotechnical investigation at the site on 27 and 28 October 2016. The work comprised 12 test pits (TP1 to TP12) to depths of between 1.5 m bgl and 4.4 m bgl. The test pits were excavated by GBC Winstone using a 10 tonne excavator. The undrained shear strength has been measured by shear vane testing at regular depth intervals in the test pits.

The test pits were positioned to provide investigation data on the ground conditions to better understand the geotechnical risks at target locations across the site.

- Test pit TP1 was undertaken in the subsidence feature to aid in assessment of potentially cavernous limestone;
- Three test pits (TP2 to TP4) were undertaken up the valley axis of the main body of the proposed OBDA to assess material types and conditions;
- Four test pits (TP5 to TP8) were undertaken across a potential shear key location, to confirm the material type and depth to competent rock;
- Three test pits (TP9, TP10 and TP12) were undertaken to assess ground conditions in the toe area downslope of the proposed shear key location; and
- One test pit (TP11) was undertaken at the top of the ridgeline to the south of the proposed main body of the OBDA to assess the material type.

Test pit locations are indicated on Figure 1 in Appendix A and the test pit logs are attached in Appendix B.

5.2 Subsurface conditions

The geological conditions presented in this report are based on our visual appraisal of the site and the results of test pits at discrete locations across the site. The nature and continuity of the subsoils away from the test locations is inferred, but it must be appreciated that actual conditions may vary from the assumed model.

The geological profile of the site is generally consistent with the published information set out in Section 4.0. The results of the recent geotechnical investigation conducted on this site indicate that:

- The area to the northwest of the site, (distinguished by the two east-west trending ridgelines and gullies) is inferred to be underlain by Whangarei Limestone, which outcrops along the northern boundary of the site and locally in a stream bank in the northern part of the site;
- The western part of the site is underlain by residual and slightly weathered Ruatangata Sandstone;
- The central part of the site in underlain by residual and completely weathered siliceous siltstone, a member of the Northland Allochthon, which locally outcrops in two of the stream banks and on the hillside in the central-northern part of the site;
- The eastern part of the site is underlain by residual soil, overlying pervasively sheared Siltstone, Mudstone and Coal Measures, collectively referred to below as weathered Northland Allochthon.

The site observations are substantiated by the results of a preliminary electromagnetic geophysical survey (refer Appendix C) which illustrates a substantial change in site conductivity between the Whangarei Limestone/Ruatangata Sandstone in the NW and the Northland Allochthon siltstone and mudstone in the NE.
Our site observations have been compiled into an Engineering Geological Map of the proposed OBDA footprint and near surrounds (Figure 2, Appendix A). Geological cross-sections are attached as Figures 3 and 4, in Appendix A. Descriptions of the geological units encountered at the site are presented in Section 5.2 to 5.6 below.

5.3 Geotechnical Units

5.3.1 Topsoil
Topsoil was encountered from ground level across the site, and found to extend to depths of between 0.1 m bgl and 0.4 m bgl. The topsoil generally comprised firm dark brown sandy silt with organic matter.

5.3.2 Recent mixed alluvium/colluvium
Recent alluvial and colluvial deposits were found at the subsidence feature in TP1, and in the gully in TP7 and TP9. These deposits have been inferred to be present through the northern gully and in the smaller stream channels that run through the centre of the site and at the toe of the proposed OBDA.

The colluvial deposits were encountered below a nominal thickness of topsoil in TP1, TP7 and TP9. The colluvial deposits typically comprised stiff, moderate to high plasticity orange brown mottled grey clayey silt. Undrained shear strengths typically ranged between 40 kPa to 98 kPa.

The recent alluvial deposits were encountered below a nominal thickness of topsoil in TP1 and from below a 2.3 m to 3.0 m thick layer of colluvium in TP7 and TP9. The alluvial deposits generally comprised grey to black, soft to firm, high plasticity organic clayey silt. Lithic fragments of mudstone were encountered in TP7 from within the alluvium. Undrained shear strengths in the alluvial deposits typically ranged between 15 kPa to 101 kPa.

5.3.3 Northland Allochthon

5.3.3.1 Sheared Mudstone
Residual Northland Allochthon was encountered from below a nominal thickness of topsoil in TP10 and TP12. It generally comprised stiff to very stiff, low to moderate plasticity brown and orange brown mottled grey silt. Undrained shear strengths in this layer were typically between 64 kPa to 159 kPa.

Weathered Northland Allochthon was encountered below the residual Northland Allochthon in both TP10 and TP12.

In TP10 it comprised pervasively sheared grey stained orange brown extremely weak siltstone, recovered as fine to coarse gravel and cobble size fragments of extremely weak, highly weathered siltstone.

In TP12 it comprised dark grey, highly fissured mudstone, recovered as blocks of hard, moist, non-plastic silt with trace pockets of light grey silty fine sand. The fissure surfaces were noted to be slickensided with a slight greasy feel to the touch.

The weathered Northland Allochthon extended to the maximum depth investigated in both TP10 and TP12 of 4.0 m and 4.2 m bgl respectively.
5.3.3.2 Siliceous Siltstone

Residual siltstone was encountered from below a thin layer of topsoil in TP5, TP6, TP8 and TP11. It generally comprised stiff to very stiff orange brown silt, with minor to some fine sand and fine to coarse gravel size fragments of extremely weak grey siltstone.

The residual siltstone generally extended to depths of between 0.6 m and 3.0 m bgl. Undrained shear strengths in the residual soil generally ranged from 92 kPa to 136 kPa.

Completely weathered siltstone was encountered below the residual siltstone, and extended to the maximum depth investigated of 4.4 m bgl. It typically comprises stiff to very stiff silt with fine to coarse gravel and cobblesize fragments of extremely weak, light grey stained orange brown highly weathered siltstone. Undrained shear strengths in the completely weathered siltstone ranged between 87 kPa to 154 kPa.

5.3.4 Ruatangata Sandstone

Residual Ruatangata Sandstone soils were encountered below a nominal to moderate thickness of topsoil in test pits TP2 to TP4. It generally comprised stiff to very stiff orange brown mottled grey silt, and extended to depths of between 2.1 m and 2.2 m bgl. Undrained shear strengths in the residual sandstone ranged between 79 kPa and 130 kPa.

Ruatangata Sandstone was encountered below the residual Ruatangata Sandstone soils in test pits TP2 to TP4 and from below recent alluvium deposits in TP1. It typically comprised an upper layer of highly weathered dark grey fine to medium sandstone, overlying unweathered to slightly weathered, dark grey fine to medium sandstone with occasional cobblesized, very weak to weak, grey, calcareous concretions.

5.4 Groundwater

Groundwater was encountered in test pits TP1, TP4, TP5, TP7, TP9, TP10 and TP12 at depths of between 0.8 m and 4.4 m bgl.

Moderate to fast inflows were noted from within the sheared mudstone of the Northland Allochthon at depths of between 1.5 m and 3.0 m bgl (TP10 and TP12).

Slow to moderate inflows were noted from within the alluvium at depths of between 0.8 m and 3.0 m bgl (TP1, TP7 and TP9).

Slow inflows were noted from within the completely weathered Siltstone at a depth of 4.5 m in TP5, and from the highly weathered Ruatangata Sandstone at a depth of 2.4 m in TP4.

6 Proposed OBDA feasibility slope stability assessment

6.1 General

A preliminary stability assessment has been carried out using SlopeW to assess the long term stability of the final OBDA landform. Three analysis cases were assessed for a section through the central portion of the OBDA and through the toe of the OBDA.

The program uses limit equilibrium analysis (Morgenstern-Price method), assessing the ratio between resisting forces and driving forces. The lowest factor of safety (FoS) in the analysis was assessed by either searching through potential failure surfaces (grid and radius method), and/or analysing a fully specified failure surface.
The results of each analysis case are presented in Sections 6.2.1 to 6.2.3 below. The output from the SlopeW analysis are attached in Appendix D. The ground model on which this is based is shown on Figures 3 and 4 (Appendix A).

The upslope half of the proposed OBDA is underlain by the Ruatangata Sandstone, while the central part of the proposed OBDA is underlain by a siliceous siltstone member of the Northland Allochthon, which appears to be reasonably consistent in shear strength and consistency where encountered.

The toe of the proposed OBDA is underlain by pervasively sheared siltstones and mudstones of the Northland Allochthon. This material is well known for instability at shallow slope angles if loading and drainage are not well managed.

There is potential for significant fault disturbance at the boundary between the Ruatangata Sandstone and the siliceous siltstone of the Northland Allochthon, and possibly a fault contact between the siliceous siltstone and the sheared mudstone of the Northland Allochthon.

Given some of the remaining uncertainty in foundation conditions our model has conservatively allowed for a low strength, persistent sheared clay seam at the contact between soil and rock within both units of the Northland Allochthon (the siltstone and sheared mudstone).

The assessment also allows for a free draining, granular fill to be used as a toe bund and shear key backfill to manage water pressures within the overburden disposal area.

6.2 Design Criteria

We have assessed design criteria for slope stability on the basis of the current design profiles and site conditions. We understand that there will be no structure located above or below the proposed landform, which upon completion is expected to be rehabilitated and re-vegetated. On this basis we propose adopting a design FoS of 1.3 for static and 1.1 for drainage failure cases respectively. This is in general accordance with suggested limit equilibrium criteria accepted in other regions.4

The Wairoa South Fault is the closest active fault to the site (over 100 km to the South). Seismic design criteria have been adopted in accordance with The NZTA Bridge Manual, assuming an importance level 1. In line with this standard, it is proposed to adopt the peak ground acceleration (PGA) as the minimum PGA of 0.16g for a Class D - deep soil site.

In pseudo-static seismic analysis, where the FoS is above 1.0, the likelihood of significant slope movements at the adopted design acceleration is negligible to very small and no further analysis is typically required.

If the slope does not meet a FoS > 1.0 then an assessment of expected displacement can be adopted to better define the potential for movement. As the completed OBDA is not expected to support infrastructure that could be damaged by earthquake induced displacements, this form of analysis is appropriate. We consider that the OBDA site could be expected to tolerate up to 1m of displacement without loss of structural integrity which could result in a change in mechanism (i.e. rapid style debris flow), provided groundwater pressures can be managed. Table 6-1 summarises the adopted design criteria.

---

4 Auckland Council – Code of Practice for Land Development and Subdivision –Section 2 Earthworks and Geotechnical Requirements. Version 1.6, 24 September 2013. Table 2.C.1.
Table 6-1: Slope stability design criteria

<table>
<thead>
<tr>
<th>Design Groundwater Conditions</th>
<th>Elevated Groundwater Conditions</th>
<th>Seismic Stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwater conditions expected within design life.</td>
<td>Groundwater conditions associated with low probability high rainfall event or drainage failure.</td>
<td>Psuedo-Static Displacement Analysis (Makdisi and Seed, 1978)</td>
</tr>
<tr>
<td>FOS &gt; 1.3</td>
<td>FOS &gt; 1.1</td>
<td>FOS &gt; 1.0*</td>
</tr>
<tr>
<td>Maximum allowable Displacement = 1m</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*PGA = 0.13g (design acceleration)  
*Any movement will be negligible (overall stability maintained)

6.3 Material properties

Table 6-2 below presents the geotechnical design parameters adopted for the SlopeW analysis. These parameters are based on the site investigation results and T+T’s experience with similar materials.

Table 6-2: Geotechnical strength parameters used in SlopeW analysis

<table>
<thead>
<tr>
<th>Geological unit</th>
<th>Unit Weight (γ), kN/m³</th>
<th>Effective cohesion (c'), kPa</th>
<th>Effective friction angle (φ')</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residual soil</td>
<td>17</td>
<td>5</td>
<td>28</td>
</tr>
<tr>
<td>Colluvium/Alluvium</td>
<td>17</td>
<td>2</td>
<td>24</td>
</tr>
<tr>
<td>Ruatangata Sandstone</td>
<td>20</td>
<td>50</td>
<td>35</td>
</tr>
<tr>
<td>Completely weathered Siltstone</td>
<td>18</td>
<td>7</td>
<td>35</td>
</tr>
<tr>
<td>Pervasively sheared siltstone/mudstone</td>
<td>20</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>Overburden Fill</td>
<td>18</td>
<td>2</td>
<td>26</td>
</tr>
<tr>
<td>Shear key and bund</td>
<td>19</td>
<td>0</td>
<td>38</td>
</tr>
<tr>
<td>Shear surface at base of residual soil</td>
<td>18</td>
<td>1</td>
<td>12</td>
</tr>
</tbody>
</table>

6.4 SlopeW Preliminary Stability Assessment Results

6.4.1 Static case

A ‘static’ assessment of the proposed final OBDA landform was undertaken based on a partially saturated overburden fill, assuming a pore water pressure coefficient, Ru of 0.2, which is typical of long term conditions at other mixed fill OBDA’s on other GBC Winstone sites. Based on site observations, and the groundwater inflows into the test pits, groundwater has been modelled at
between 0.5 m and 1.0 m below current ground level for the static case. It is assumed that it will be maintained at that level by the proposed underfill drainage system.

The global stability and toe stability of the proposed OBDA was assessed based on the two cross sections attached in Appendix A, Figures 3 and 4. The analysis results are summarised in Table 6-3 with analysis outputs presented in Appendix D.

**Table 6-3: Static assessment of proposed OBDA landform**

<table>
<thead>
<tr>
<th>Section</th>
<th>Analysis</th>
<th>Factor of Safety</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-section 1</td>
<td>Global</td>
<td>2.16</td>
<td>Allows for proposed Shear key</td>
</tr>
<tr>
<td></td>
<td>Toe</td>
<td>1.45</td>
<td>Allows for proposed Shear key</td>
</tr>
<tr>
<td>Cross-section 2</td>
<td>Toe</td>
<td>1.41</td>
<td>Includes shear key at toe</td>
</tr>
</tbody>
</table>

The analysis results indicate that the proposed OBDA design can meet the adopted static stability design criteria for slope stability, provided that the proposed under fill drainage and shear keys are incorporated in construction.

**6.4.2 Elevated groundwater case**

The effects of a build-up of groundwater pressure in the fill on the proposed final OBDA landform was undertaken by considering a drainage failure case where the piezometric surface rises to $2/3$ of the height of the overburden affecting both the overburden material and underlying foundation. The toe buttress is expected to be made up of free draining weathered rock fill and therefore the elevated groundwater case and static case do not differ.

The analysis results indicate that the proposed OBDA design can meet the adopted elevated groundwater stability design criteria for slope stability, provided that the proposed under fill drainage and shear keys are incorporated in construction.

**Table 6-4: Elevated groundwater assessment on OBDA landform**

<table>
<thead>
<tr>
<th>Section</th>
<th>Analysis</th>
<th>Factor of Safety</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-section 1</td>
<td>Global</td>
<td>2.09</td>
<td>Allows for proposed Shear key</td>
</tr>
<tr>
<td></td>
<td>Toe</td>
<td>1.45</td>
<td>Allows for proposed Shear key</td>
</tr>
<tr>
<td>Cross-section 2</td>
<td>Toe</td>
<td>1.39</td>
<td>Includes shear key at toe</td>
</tr>
</tbody>
</table>

**6.4.3 Seismic case**

The effects of a seismic load have been assessed for the long term stability of the proposed OBDA. The analysis results indicate that displacements in the toe area could occur during the design earthquake (FoS < 1.0) and so an assessment of the seismic yield acceleration (the acceleration at which an FoS of 1.0 is calculated) has been undertaken for use in a displacement assessment (refer Section 6.4.4).
Table 6-5: Seismic loading effects on overall OBDA stability

<table>
<thead>
<tr>
<th>Section</th>
<th>Failure method</th>
<th>Horizontal seismic coefficient</th>
<th>Factor of Safety</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-section 1</td>
<td>Global</td>
<td>0.16g</td>
<td>0.92</td>
<td>Allows for proposed Shear key</td>
</tr>
<tr>
<td></td>
<td>Global</td>
<td>0.13g</td>
<td>1.07</td>
<td>Seismic Yield</td>
</tr>
<tr>
<td></td>
<td>Toe</td>
<td>0.16g</td>
<td>0.95</td>
<td>Allows for proposed Shear key</td>
</tr>
<tr>
<td></td>
<td>Toe (Yield)</td>
<td>0.12g</td>
<td>1.05</td>
<td>Seismic Yield</td>
</tr>
<tr>
<td>Cross-section 2</td>
<td>Toe</td>
<td>0.16g</td>
<td>0.88</td>
<td>Includes shear key at toe</td>
</tr>
<tr>
<td></td>
<td>Toe</td>
<td>0.12g</td>
<td>1.00</td>
<td>Seismic Yield</td>
</tr>
</tbody>
</table>

6.4.4 Assessment of slope displacement under seismic load

Slope displacements have been assessed in accordance with Makdisi and Seed, 1978 for the toe area using a ratio of yield acceleration and peak ground acceleration for the design earthquake.

This assessment indicates displacements in the range 10-25mm for the design earthquake for the OBDA. This level of displacement meets the adopted displacement criterion set out in Table 6-1 and the expected performance is considered to be suitable for an end use that includes a return to farmland.

7 Geotechnical design issues

7.1 General

To provide a finished OBDA landform with an acceptable level of short and long term stability, an assessment of foundation conditions, groundwater and surface water, final landform shape, fill consistency and seismic loading needs to be undertaken.

Our preliminary assessment of each of these potential design considerations is set out in the following sections.

7.2 Foundation conditions and stability

Based on the recent geotechnical investigation at the site and from our site observations, the foundation for the OBDA is expected to be a combination of Ruatangata Sandstone, a siliceous siltstone member of the Northland Allochthon and pervasively sheared siltstone / mudstone of the Northland Allochthon.

Stability issues related to the OBDA foundation would typically arise from a soft foundation or through low strength structures (i.e. bedding, shearing or faulting) beneath foundation level.

The shallow depth to rock up the valley axis under the main body of the proposed OBDA indicates that a good foundation could be achieved, however, some uncertainty remains in the foundation due to the following.

- The heavily sheared units of mudstone within the Northland Allochthon.
  - Pervasively sheared mudstone of the Allochthon was encountered at the toe of the proposed OBDA. The Northland Allochthon is known to be highly variable over short distances and includes zones of heavily sheared, softened soil and extremely weak rock (these have been allowed for in our stability models).
• The potential for faulting.
  – The Ruatangata Sandstone on site is understood to be an in-situ sedimentary sequence. The emplacement of the Allochthon material is expected to have resulted in significant fault disturbance at the boundary between the Ruatangata Sandstone, siliceous siltstone and pervasively sheared siltstone and mudstone of the Northland Allochthon. We infer these boundaries to be present beneath the proposed OBDA footprint.

• Shear key location and depth to rock
  – A shear key will be required to support the OBDA. The trial excavations across the toe of the OBDA, generally indicate that below a moderate thickness (2.5 m to greater than 4.4 m) of residual soil and/or alluvium, completely weathered siltstone is present. However, the full depth of the required shear key excavation has not been proven in proximity to the stream channel and the shear key could end up requiring a significant depth of excavation (7-8m depth) to develop sufficient embedment of the key into competent siltstone or mudstone.
  – A shear key up to 8-10m wide will be required, located between the crest of the stage 1 bund at RL 42m and the small bench in the toe bund at RL 32m. The final location of the key will depend on the depth of channel infill and condition of the rock mass identified during early stage earthworks.

Foundation/Slope Stability risk: High without mitigation works. Low with appropriate foundation preparation, including toe buttress and shear key.

Recommendation: The Shear key position should be reviewed as stage plans for construction are developed further post consenting. In particular the proposed depth of the key should be confirmed during the early stages of site earthworks.

7.3 Assessment of void potential in OBDA foundation

The proposed OBDA for the Pegram Block will be located near to an area of limestone rock that is known to include large voids and caves that have been recorded as known archaeological features.

A report on the caves located at the Ruarangi Block approximately 500m to the NW (Kermode, 1965)5 (Appendix E) provides a description of the flaggy crystalline limestone, the caves and the extent of the caves. In particular he noted:

“Caves formed by solution and collapse of the limestone seem to follow a basal glauconitic sandstone as found in the larger stream to the north of Ruarangi B.”

The flaggy limestone has subsequently been named the Whangarei Limestone and the glauconitic sandstone as the Ruatangata Sandstone6

Edbrooke & Brook, (2009)2 note that the Whangarei Limestone locally conformably overlies the Ruatangata Sandstone.

Preliminary geophysical data (Appendix C) indicates that the extent of any void formation will be limited to the high conductivity area in the northwest of the site.

When comparing the geophysical data with the outcrop location of Whangarei Limestone on the NW boundary of the Pegram Block, the identification of the Ruatangata Sandstone in trial pits TP1 to TP4, and the bedding orientations recorded from the limestone we have outlined the anticipated basal limestone contact as illustrated on Figure 2 (Appendix A). Our geological interpretation

---

indicates that only a small area of limestone is expected to underlie the north-western extent of the proposed overburden.

Overall we consider that there is limited potential for a substantial void within the small extent of limestone that may exist beneath the NW extent of the OBDA, due to soil formation and weathering effects. Further the small thickness of the proposed overburden fill in this area (4 – 6 m) is unlikely to have a significant detrimental effect on any small voids that may be present.

It is our opinion that the effect of fill placement on possible voids in this area would be less than minor. This opinion is based on the extent, and relationship between, the various lithologies, the historical descriptions of cave formation and results of subsurface investigations.

**Void collapse risk:** low to negligible due to the limited area underlain by limestone, and the expected limited thickness of limestone in this area.

**Recommendation:** No further assessment required.

### 7.4 Groundwater and Surface Water

Groundwater inflows were noted in seven of the test pits at depths of between 0.8 m and 4.4 m bgl from within the alluvium, Ruatangata Sandstone, completely weathered siltstone and pervasively sheared siltstones and mudstones of the Northland Allochthon. Fast inflows were noted in TP10 from within the pervasively sheared siltstone of the Northland Allochthon.

While the catchment for the gully is small, significant spring seepages were noted across the proposed filling area. Filling over groundwater springs can result in softening in the lower part of the overburden fill and a build-up of groundwater pressure in the fill foundation, potentially destabilising the OBDA.

Groundwater pressures are typically dealt with by provision of sub-soil drainage. This would typically include a slotted HDPE pipe, surrounded by a gravel pack and a geotextile wrap. This drainage is a standard inclusion in most earth fill designs.

Surface water from above the OBDA will need to be dealt with by way of diversion. Numerous options exist to manage surface water flows including temporary and permanent diversion across or around the developing landform. For the long term design case it is typically preferable not to pipe surface water beneath the finished landform (risk of leakage long term). In this case the main stream channel has been proposed to be diverted around the toe of the proposed OBDA.

**Groundwater risk:** High without mitigation works. Low with appropriate surface and groundwater management.

**Recommendation:** Development of an under fill sub-soil drainage network in the former gully floors, sidling gullies and as required to pick up spring seepages beneath the OBDA footprint. A surface water drainage design will be required to manage flows both during construction and long term.

Groundwater and surface hydrology are the subject of specific technical reports assessing the potential environmental effects of the OBDA.

### 7.5 Fill consistency & landform geometry

The fill material is expected to be made up of weathered greywacke soils, unsaleable weathered greywacke rock, unweathered limestone and greensand and soils that derive from them that occur in the immediate quarry surrounds. These materials will perform variably based on degree of clay content and moisture content. Handling of materials can also affect how the materials then perform when placed.
Typically adopted earthworks approaches to address this geotechnical risk around fill material performance include:

- Placement of clay rich, or high moisture soils during periods of fine weather.
- Zoning the OBDA landform with highly weathered to moderately weathered greywacke overburden in the constructed shear key and toe bunds. Use of unweathered, blocky greensand in toe bunds and placing clays further back in the developing OBDA.

The overall landform geometry has been based on guidance used for previously successfully completed OBDA sites\(^7,8\). The slope angles proposed of 12° for the main body and up to 32° for toe buttress bunds are in line with these previous recommendations and in our opinion should be achievable provided staging of overburden stripping can adequately separate the different material types, without contaminating structural fill (for bunds and shear keys) with clay overburden.

**Fill material/slope geometry risk of instability:** Medium for general filling. Low if placement can be managed.

**Recommendation:** The OBDA landform should be developed in a zoned fill fashion with weathered greywacke and unweathered, blocky greensand preferentially placed in the toe so as to provide a free draining toe bund. Any shear key construction should use free draining, granular highly or moderately weathered greywacke (brown rock) as the backfill material.

### 8 Summary and Conclusions

Tonkin & Taylor Ltd have completed a feasibility geotechnical assessment of the proposed Overburden Disposal Area on the Pegram Block at GBC Winstone’s Otaika Quarry. The purpose of the assessment is to consider the feasibility of the proposal, likely engineering requirements for ongoing design and construction and potential environmental effects related to geotechnical performance. The report is prepared as a technical report to be attached to the Assessment of Environmental Effects that will be included with an application for Resource Consent.

The site is underlain by a combination of Ruatangata Sandstone and Northland Allochthon (comprising siltstones and sheared mudstones), with a small area on the NW boundary underlain by Whangarei Limestone.

Our stability assessment of the design concept indicates that the toe area of the design is unlikely to meet typically accepted stability design criteria. However an acceptable level of stability can be achieved provided that the following engineering works are included in the overall design:

i. A robust under fill drainage network will be required to manage the extensive seepages that are presently observed at ground surface.

ii. Construction of a shear key at or near to the toe bund will be required to manage the instability risk associated with sheared Northland Allochthon and alluvium in the immediate foundation.

These are typically adopted earthworks principals that are often used to improve stability for a range of earthworks fills.

There remains a degree of uncertainty in depth to competent foundation materials immediately adjacent to the stream channel, which may necessitate a deep excavation for the shear key(s). However this is largely an operational issue and we do not anticipate this substantially affecting the geotechnical feasibility of the project.

---


\(^8\) Applied Geology Associates Limited – Waste Dump Stability, Otaika Quarry, Whangarei Ref 1251, August 1985
The potential risk of void collapse in the limestone is considered to be low to negligible, based on the small area of limestone that is expected to underlie the proposed OBDA footprint, the likely small thickness of limestone, and limited overburden thickness (4-6m) in that area.

Overall we consider that the proposed OBDA is geotechnically feasible and that the environmental effects related to geotechnical performance can be managed by good design and construction practices and are therefore expected to be less than minor.

9 Applicability

This report has been prepared for the exclusive use of our client GBC Winstone, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

We trust that this letter report meets your present requirements. If you have any queries or wish to discuss any aspect please contact the undersigned.

Tonkin & Taylor Ltd

Report prepared by: 

PP: 

.......................................................... ...........................…...............

Douglas Atkinson
Engineering Geologist

Report reviewed by: 

..........................................................

..........................................................

Cameron Lines
Senior Engineering Geologist

Authorised for Tonkin & Taylor Ltd by:

..........................................................

..........................................................

Kevin Hind
Project Director
Appendix A: Figures

- Figure 1: Site Plan
- Figure 2: Geological Map
- Figure 3: Geological Cross Section 1
- Figure 4: Geological Cross Section 2
Appendix B: Test Pit Logs

- T+T Engineering Log Terminology
- Test Pit logs (TP1 to TP12)
EXCAVATION LOG

PROJECT: Otaika Quarry
LOCATION: Otaika
JOB No.: 1000785

CO-ORDINATES: 6042030.25 mN (NZTM 2000)
1717425.39 mE
R.L.: 68.60m
DATUM: NZVD2009

EXCAVATION Tests

<table>
<thead>
<tr>
<th>PENETRATION</th>
<th>SUPPORT</th>
<th>WATER</th>
<th>SAMPLES, TESTS</th>
<th>RL (m)</th>
<th>DEPTH (m)</th>
<th>GRAPHIC LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1 @ 0.5m</td>
<td>25/12 kPa</td>
<td>Sample 2 @ 1.3m</td>
<td>36/9 kPa</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ENGINEERING DESCRIPTION

<table>
<thead>
<tr>
<th>PENETRATION</th>
<th>SUPPORT</th>
<th>WATER</th>
<th>SAMPLES, TESTS</th>
<th>RL (m)</th>
<th>DEPTH (m)</th>
<th>GRAPHIC LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1 @ 0.5m</td>
<td>25/12 kPa</td>
<td>Sample 2 @ 1.3m</td>
<td>36/9 kPa</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SOIL NAME, PLASTICITY OR PARTICLE SIZE CHARACTERISTICS, COLOUR, SECONDARY AND MINOR COMPONENTS

<table>
<thead>
<tr>
<th>PENETRATION</th>
<th>SUPPORT</th>
<th>WATER</th>
<th>SAMPLES, TESTS</th>
<th>RL (m)</th>
<th>DEPTH (m)</th>
<th>GRAPHIC LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1 @ 0.5m</td>
<td>25/12 kPa</td>
<td>Sample 2 @ 1.3m</td>
<td>36/9 kPa</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SUPPORT

<table>
<thead>
<tr>
<th>PENETRATION</th>
<th>SUPPORT</th>
<th>WATER</th>
<th>SAMPLES, TESTS</th>
<th>RL (m)</th>
<th>DEPTH (m)</th>
<th>GRAPHIC LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1 @ 0.5m</td>
<td>25/12 kPa</td>
<td>Sample 2 @ 1.3m</td>
<td>36/9 kPa</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

COMMENTS: Sides of pit unstable. Collapsing from GL to 1.2 m. KEY: TS = Topsoil, RSst=Ruatangata Sandstone
**EXCAVATION LOG**

**PROJECT:** Otaika Quarry  
**LOCATION:** Otaika  
**JOB No.:** 1000785

<table>
<thead>
<tr>
<th>CO-ORDINATES: 6641935.40 mN (NZTM 2000)</th>
<th>1717490.70 mE</th>
<th>EXPOSURE METHOD: TP</th>
<th>EXCAV. STARTED: 27/10/2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>R.L.: 67.30m</td>
<td></td>
<td>EQUIPMENT: 10 Tonne Excavator</td>
<td>EXCAV. FINISHED: 27/10/2016</td>
</tr>
<tr>
<td>DATUM: NZVD2009</td>
<td></td>
<td>OPERATOR: GBC Winstone</td>
<td>LOGGED BY: DSA</td>
</tr>
</tbody>
</table>

**DIMENSIONS:** 2.3m by 1m  
**CHECKED BY:** CJL

---

**EXCAVATION TESTS**

<table>
<thead>
<tr>
<th>PENETRATION</th>
<th>SUPPORT</th>
<th>WATER</th>
<th>SAMPLES, TESTS</th>
<th>PENETRATION</th>
<th>SUPPORT</th>
<th>WATER</th>
<th>SAMPLES, TESTS</th>
<th>PENETRATION</th>
<th>SUPPORT</th>
<th>WATER</th>
<th>SAMPLES, TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**ENGINEERING DESCRIPTION**

<table>
<thead>
<tr>
<th>PENETRATION</th>
<th>SUPPORT</th>
<th>WATER</th>
<th>SAMPLES, TESTS</th>
<th>PENETRATION</th>
<th>SUPPORT</th>
<th>WATER</th>
<th>SAMPLES, TESTS</th>
<th>PENETRATION</th>
<th>SUPPORT</th>
<th>WATER</th>
<th>SAMPLES, TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**GEOLOGICAL**

<table>
<thead>
<tr>
<th>PENETRATION</th>
<th>SUPPORT</th>
<th>WATER</th>
<th>SAMPLES, TESTS</th>
<th>PENETRATION</th>
<th>SUPPORT</th>
<th>WATER</th>
<th>SAMPLES, TESTS</th>
<th>PENETRATION</th>
<th>SUPPORT</th>
<th>WATER</th>
<th>SAMPLES, TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**SKETCH / PHOTO:**

**Comments:** KEY: TS = Topsoil; ResS = Residual Soil; RSst = Ruatangata Sandstone

---

**EXCAVATION TESTS**

- **Sandy SILT:** dark brown. Firm, wet, low plasticity.
- **SILT:** orange brown mottled grey. Very stiff, wet, low plasticity.
- **Highly weathered, dark grey SANDSTONE.** Extremely weak. [Silty, fine to medium SAND; dark grey mottled dark brown. Tightly packed, moist. Fissile]

**Sample 1 @ 1.0m:** Retrieved as fine sand/small (10cm-30cm) blocks.

**Sample 2 @ 2.4m:** 1.5m: grading light brown mottled grey.

**2.6m:** Hard to excavate. **2.6m: END OF INVESTIGATION**
### EXCAVATION TESTS

<table>
<thead>
<tr>
<th>PENETRATION</th>
<th>SUPPORT</th>
<th>WATER</th>
<th>SAMPLES, TESTS</th>
<th>PENETRATION</th>
<th>SUPPORT</th>
<th>WATER</th>
<th>SAMPLES, TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>115/51 kPa</td>
<td></td>
<td></td>
<td>Sample B @ 2.0m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>79/36 kPa</td>
<td></td>
<td></td>
<td>Sample S @ 2.2m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sample S @ 2.3m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sample S @ 2.4m</td>
</tr>
</tbody>
</table>

### GEOLOGICAL

- **Sandy SILT**: dark brown. Firm, moist, low plasticity.
- **SILT**: trace rootlets; orange brown mottled grey. Very stiff, wet, low plasticity.
- **SILT, minor clay**: trace rootlets; brown. Stiff, saturated, moderate plasticity.
- **Highly weathered**: dark grey fine to medium grained SANDSTONE. Extremely weak. [Silty, fine to medium SAND; dark grey mottled dark brown. Tightly packed, moist, fissile.]
- **Unweathered to slightly weathered**: dark grey to medium grained SANDSTONE with very weak to weak, well cemented, 10 cm to 30 cm ovoid calcareous concretions. Very weak, moderately cemented.

**2.4m: Difficult to excavate**

2.4m: END OF INVESTIGATION

**COMMENTS: KEY:**
- **TS**: Topsoil
- **ResS**: Residual Soil
- **RSst**: Ruatangata Sandstone
EXCAVATION LOG

EXCAVATION TESTS
SAMPLES
- SILT, some roots; dark brown. Firm, wet, non-plastic to low plasticity.
- SILT, minor roots; orange brown. Very stiff, wet, low plasticity.
- SILT, trace roots; orange brown mottled white. Very stiff, wet, low plasticity.
- SILT, trace roots; orange brown. Very stiff, wet, low plasticity.

ENGINEERING DESCRIPTION
- Highly weathered, dark greyish brown fine to medium grained SANDSTONE. Extremely weak. Weakly cemented [Fine to coarse SAND, some silt; dark greyish brown]
- Unweathered to slightly weathered dark grey, fine to medium grained SANDSTONE. Very weak. With weak, well cemented, 10 cm to 30 cm ovoid calcareous concretions.

GEOLOGICAL
- 2.6m: Difficult to excavate

COMMENTs: KEY: TS = Topsoil; ResS = Residual Soil; RSst = Ruatangata Sandstone
EXCAVATION LOG

PROJECT: Otaika Quarry
LOCATION: Otaika
JOB No.: 1000785

CO-ORDINATES: 6042137.20 mN (NZTM 2000)
R.L.: 37.70m
DATUM: NZVD2009

EXCAVATION TESTS

WATER

SAMPLES

SOIL NAME, PLASTICITY OR PARTICLE SIZE CHARACTERISTICS, COLOUR,
SECONDARY AND MINOR COMPONENTS

SAMPLES

SUPPORT

WEATHERING

W

STRENGTH/DENSITY

111/64 kPa

CLASSIFICATION

SILT

ESTIMATED
SHEAR

SANDY SILT, with roots; dark brown.

STRENGTH (kPa)

1.5

1.0

0.5

VSt

SILT, trace fine sand; orange brown. Very stiff, wet, low plasticity.

124/17 kPa

101/12 kPa

4.4m: Terminated at reach of excavator.

SILT, minor fine sand; light brown mottled orange brown. Very stiff, wet, low plasticity.

SILT, minor fine sand, some fine to coarse gravel sized fragments of extremely weak grey mottled orange brown siltstone, trace rootlets; grey mottled orange brown. Very stiff, moist, low plasticity.

4.4m: END OF INVESTIGATION

4.4m: Terminated at reach of excavator.

SKETCH / PHOTO:

COMMENTS: KEY: TS = Topsoil; ResS = Residual Soil
**EXCAVATION TESTS**

<table>
<thead>
<tr>
<th>PENETRATION</th>
<th>SUPPORT</th>
<th>WATER</th>
<th>SAMPLES, TESTS</th>
<th>RL (m)</th>
<th>DEPTH (m)</th>
<th>SPECIAL LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sample 1 @ 0.4m</td>
<td>32</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>52/33 kPa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sample 2 @ 1.5m</td>
<td>31</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>154/46 kPa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sample 3 @ 3.5m</td>
<td>29</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>87/20 kPa</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**SOIL NAME, PLASTICITY OR PARTICLE SIZE CHARACTERISTICS, COLOUR, SECONDARY AND MINOR COMPONENTS**

- Sandy SILT, minor roots; dark brown. Firm, moist, non-plastic.
- SILT, minor fine to coarse gravel sized fragments of extremely weak orange brown and grey siltstone. Stiff, moist to wet, low plasticity; gravel has manganese and orange brown iron oxide staining.
- SILT, minor to some fine sand; light brown mottled orange brown and grey. Very stiff, moist, non-plastic to low plasticity. Minor fragments of extremely to very weak, highly weathered, grey siltstone. Manganese and iron staining on surfaces is prevalent.

3.0m: - fragments of siltstone increase in size up to 10-20cm.

3.8m: END OF INVESTIGATION

3.8m: Terminated at reach of excavator.

**SKETCH / PHOTO:**

![Image of the excavation site]

**COMMENTS:** KEY: TS = Topsoil; ResS = Residual Soil
**EXCAVATION LOG**

**PROJECT:** Otaika Quarry  
**LOCATION:** Otaika  
**JOB No.:** 1000785

**CO-ORDINATES:** 6042075.28 mN (NZTM 2000)  
**R.L.:** 27.90m  
**DATUM:** NZVD2009

**EXCAVATION TESTS**

<table>
<thead>
<tr>
<th>PENETRATION</th>
<th>SUPPORT</th>
<th>SAMPLES, TESTS</th>
<th>SAMPLES</th>
<th>RL (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>28/10/2016</td>
<td>TP</td>
<td>0.5</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>26/17 kPa</td>
<td></td>
<td></td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>35/15 kPa</td>
<td></td>
<td></td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>43/108 kPa</td>
<td>Sample 1</td>
<td>3.7 m</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>101/15 kPa</td>
<td>Sample 2</td>
<td>4.0 m</td>
<td>4.0</td>
<td></td>
</tr>
</tbody>
</table>

**ENGINEERING DESCRIPTION**

<table>
<thead>
<tr>
<th>PENETRATION</th>
<th>SAMPLES</th>
<th>RL (m)</th>
<th>PENETRATION</th>
<th>SUPPORT</th>
<th>SAMPLES</th>
<th>RL (m)</th>
<th>PENETRATION</th>
<th>SUPPORT</th>
<th>SAMPLES</th>
<th>RL (m)</th>
</tr>
</thead>
</table>
| 4.4m        | END OF INVESTIGATION | 4.4m Terminated at reach of excavator.

**SOL NAME, PLASTICITY OR PARTICLE SIZE CHARACTERISTICS, COLOUR, SECONDARY AND MINOR COMPONENTS**

- Sandy SILT, roots; dark brown. Firm, moist, low plasticity.
- Sandy SILT; grey mottled dark grey and trace orange brown. Very stiff, moist, non-plastic to low plasticity.
- SILT, minor clay; grey mottled orange brown. Very stiff, moist, moderate plasticity.
- firm, saturated.
- Organic Silty CLAY, with some organics, with roots and coarse fragments of extremely weak, highly weathered siltstone/sandstone; grey mottled brown. Firm, saturated.
- Organic SILT, minor fine sand; dark grey mottled grey, trace blue grey and trace green. Very stiff, moist to dry, low plasticity, fissile. Pockets and blocks (10cm to 30cm) of silty fine sand and pockets of grey mottled brown silty clay with roots, firm, saturated, high plasticity. Tightly packed, moist.

**DEFECTS, STRUCTURE, COMMENTS**

- 4.4m: Terminated at reach of excavator.

**MOISTURE CONDITION, STRENGTH/DENSITY CLASSIFICATION, ESTIMATED SHEAR STRENGTH (kPa)**

- 98/51 kPa
- 104/51 kPa
- 40/26 kPa
- 26/17 kPa
- 36/15 kPa
- 43/108 kPa
- 101/15 kPa

**GEOPHYSICAL**

- Alluvium

**COMMENTS:** KEY: TS = Topsoil
### EXCAVATION LOG

**EXCAVATION TESTS**

<table>
<thead>
<tr>
<th>PENETRATION SUPPORT</th>
<th>WATER</th>
<th>SAMPLES, TESTS</th>
<th>SOL NAME, PLASTICITY OR SECONDARY AND MINOR COMPONENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>Sandy SILT; dark brown. Firm, moist, low plasticity.</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>SILT, minor sand, minor roots, grey mottled orange brown. Very stiff, moist, low to moderate plasticity.</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>SILT; orange brown mottled grey.</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>SILT, trace clay; light grey mottled orange brown. Stiff, wet, moderate plasticity.</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><em>SILT, trace to minor fine sand, some fine to coarse gravel and cobble sized fragments of extremely weak, highly weathered grey siltstone; orange brown surface staining. Stiff, wet, low plasticity, fissured.</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>4.3m: END OF INVESTIGATION</strong></td>
</tr>
</tbody>
</table>

**ENGINEERING DESCRIPTION**

<table>
<thead>
<tr>
<th>PENETRATION SUPPORT</th>
<th>WATER</th>
<th>SAMPLES, TESTS</th>
<th>PENETRATION DEPTH (m)</th>
<th>RL (m)</th>
<th>GRAPHIC LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>30</strong></td>
<td><strong>4.3m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>29</strong></td>
<td><strong>4.2m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>28</strong></td>
<td><strong>4.1m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>27</strong></td>
<td><strong>4.0m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>26</strong></td>
<td><strong>3.9m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>25</strong></td>
<td><strong>3.8m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>24</strong></td>
<td><strong>3.7m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>23</strong></td>
<td><strong>3.6m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>22</strong></td>
<td><strong>3.5m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>21</strong></td>
<td><strong>3.4m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>20</strong></td>
<td><strong>3.3m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>19</strong></td>
<td><strong>3.2m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>18</strong></td>
<td><strong>3.1m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>17</strong></td>
<td><strong>3.0m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>16</strong></td>
<td><strong>2.9m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>15</strong></td>
<td><strong>2.8m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>14</strong></td>
<td><strong>2.7m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>13</strong></td>
<td><strong>2.6m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>12</strong></td>
<td><strong>2.5m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>11</strong></td>
<td><strong>2.4m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>10</strong></td>
<td><strong>2.3m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>9</strong></td>
<td><strong>2.2m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>8</strong></td>
<td><strong>2.1m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>7</strong></td>
<td><strong>2.0m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>6</strong></td>
<td><strong>1.9m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>5</strong></td>
<td><strong>1.8m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>4</strong></td>
<td><strong>1.7m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>3</strong></td>
<td><strong>1.6m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>2</strong></td>
<td><strong>1.5m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>1</strong></td>
<td><strong>1.4m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>0.5</strong></td>
<td><strong>1.3m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>0.4</strong></td>
<td><strong>1.2m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>0.3</strong></td>
<td><strong>1.1m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>0.2</strong></td>
<td><strong>1.0m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>0.1</strong></td>
<td><strong>0.9m</strong></td>
<td><strong>TS</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>0</strong></td>
<td><strong>0.8m</strong></td>
<td><strong>TS</strong></td>
</tr>
</tbody>
</table>

**GEOLOGICAL**

- **TS** = Topsoil
- **ResS** = Residual Soil
- **NAll** = Northland Allochthon

**COMMENTS: KEY:**
- **TS** = Topsoil
- **ResS** = Residual Soil
- **NAll** = Northland Allochthon

**Hole Location:** Refer site plan.

**Excavation Id.: TP8**

**Dimensions:** 2.2m by 1m

**Excavation Tests:**
- Samples
- Tests
- Depth (m)
- Penetration
- RL (m)

**Engineering Description:**
- Penetration
- Support
- Water
- Samples, Tests
- Depth (m)
- Graphic Log

**地质描述：**
- **TS** = 表土
- **ResS** = 剩余土
- **NAll** = 北陆异体

**备注：**
- **TS** = 表土
- **ResS** = 剩余土
- **NAll** = 北陆异体
**EXCAVATION LOG**

**PROJECT:** Otaika Quarry  
**LOCATION:** Otaika  
**JOB No.:** 1000785

- **CO-ORDINATES:** 6642098.31 mN (NZTM 2000)  
  1717939.71 mE  
- **R.L.:** 24.90m  
- **DATUM:** NZVD2009

**EXCAVATION TESTS**

<table>
<thead>
<tr>
<th>PENETRATION</th>
<th>SUPPORT</th>
<th>WATER</th>
<th>SAMPLES, TESTS</th>
<th>SAMPLES</th>
<th>RL (m)</th>
<th>PENETRATION DEFECTS</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.5</td>
<td>Sandy Silt, with roots; dark brown. Firm, moist, low plasticity.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sample 1 @ 1.8m</td>
<td></td>
<td>23</td>
<td></td>
<td>Silt, minor to some inclusions of topsoil, light grey mottled orange brown. Stiff, moist to wet, non-plastic to low plasticity.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sample 2 @ 3.4m</td>
<td></td>
<td>21</td>
<td></td>
<td>Clayey Silt, trace rootlets; orange brown, minor grey mottles and streaks of purplish-grey decomposing rootlets. Stiff, wet, moderate to high plasticity.</td>
</tr>
</tbody>
</table>

**ENGINEERING DESCRIPTION**

- **EQUIPMENT:** 10 Tonne Excavator  
- **OPERATOR:** GBC Winstone  
- **LOGGED BY:** DSA  
- **CHECKED BY:** CJL  
- **EXCAV. FINISHED:** 28/10/2016  
- **EXCAV. STARTED:** 28/10/2016  
- **DIMENSIONS:** 2.1m by 1m

**GEOLOGICAL**

- **SKETCH / PHOTO:**

**COMMENTS:** KEY: TS = Topsoil

- **4m END OF INVESTIGATION**

**SUPPORT**

- **WATER**
  - **SAMPLES, TESTS**
    - **SAMPLES**
      - **RL (m)**
        - 0.5
      - **PENETRATION DEFECTS**
        - **COMMENTS**
          - Sandy Silt, with roots; dark brown. Firm, moist, low plasticity.
          - Silt, minor to some inclusions of topsoil, light grey mottled orange brown. Stiff, moist to wet, non-plastic to low plasticity.
          - Clayey Silt, trace rootlets; orange brown, minor grey mottles and streaks of purplish-grey decomposing rootlets. Stiff, wet, moderate to high plasticity.

- **SKETCH / PHOTO:**
**EXCAVATION LOG**

**PROJECT:** Otaika Quarry  
**LOCATION:** Otaika  
**CO-ORDINATES:** 6042030.73 mN (NZTM 2000)  
**R.L.:** 24.30m  
**DATUM:** NZVD2009  
**EXCAVATION TESTS**

<table>
<thead>
<tr>
<th>PENETRATION</th>
<th>SUPPORT</th>
<th>WATER</th>
<th>SAMPLES, TESTS</th>
<th>SAMPLES (m)</th>
<th>RL (m)</th>
<th>GRAPHIC LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sample 1 @ 2.0m</td>
<td></td>
<td>24.30</td>
<td></td>
</tr>
</tbody>
</table>

**ENGINEERING DESCRIPTION**

<table>
<thead>
<tr>
<th>PENETRATION</th>
<th>SUPPORT</th>
<th>WATER</th>
<th>SAMPLES, TESTS</th>
<th>SAMPLES (m)</th>
<th>RL (m)</th>
<th>GRAPHIC LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sample 1 @ 2.0m</td>
<td></td>
<td>24.30</td>
<td></td>
</tr>
</tbody>
</table>

**GEOLICAL**

- Sandy SILT; dark brown. Firm, moist, low plasticity.
- SILT, minor fine sand, trace roots; brown, minor orange brown and grey mottles. Stiff, moist, low plasticity.
- SILT, trace fine sand; brown motiled orange brown. Stiff, moist, low plasticity.
- SILT; grey, minor orange brown mottles. Stiff, saturated, low plasticity. Recovered as fine to coarse gravel and cobble sized fragments of extremely weak, highly weathered, grey SILTSTONE, with minor orange brown staining.

**SKETCH / PHOTO:**

4.0m: Collapsed to 3.5m.  
4m: END OF INVESTIGATION
**EXCAVATION LOG**

**PROJECT:** Otaika Quarry  
**LOCATION:** Otaika  
**JOB No.:** 1000785

---

<table>
<thead>
<tr>
<th>PENETRATION</th>
<th>SUPPORT</th>
<th>WATER</th>
<th>SAMPLES, TESTS</th>
<th>GRAPHIC LOG</th>
<th>CONTOUR</th>
<th>RL (m)</th>
<th>PENETRATION DEPTH (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sample 1 @ 2.0m</td>
<td></td>
<td>M</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**SAMPLES**

1. **Sandy SILT**, some roots; dark brown. Firm, dry to moist, low plasticity.
2. **Sandy SILT**, minor rootlets; brown. Stiff, moist, non-plastic to low plasticity. Trace inclusions of topsoil.
3. **SILT** with fine to coarse gravel sized fragments of extremely weak, grey sandstone with orange brown staining. Very stiff, moist, non-plastic to low plasticity.
4. **SILT**, with fine to coarse gravel and cobble sized fragments of extremely to very weak, grey siltstone, with orange brown staining. Very stiff.

**DEFECTS, STRUCTURE, COMMENTS**

- **4.1m:** Terminated at reach of excavator.

**EXCAVATION TESTS**

- **Penetration:** 4.1m END OF INVESTIGATION
- **Water:** No water encountered
- **Samples:** Sample 1 @ 2.0m

**ENGINEERING DESCRIPTION**

- **Penetration:** 4.1m: Terminated at reach of excavator.
- **Water:** No water encountered
- **Samples:** Sample 1 @ 2.0m

---

**GEOLOGICAL**

**Units:**

- **TS = Topsoil**

---

**SKETCH / PHOTO:**

- **Depth:** 4.1m

**COMMENTS:** KEY: **TS** = Topsoil
**EXCAVATION LOG**

**PROJECT:** Otaika Quarry  
**LOCATION:** Otaika  
**JOB No.:** 1000785

<table>
<thead>
<tr>
<th>PENETRATION</th>
<th>SUPPORT</th>
<th>WATER</th>
<th>SAMPLES, TESTS</th>
<th>SAMPLE</th>
<th>RL (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>1.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.0</td>
</tr>
<tr>
<td>2.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.5</td>
</tr>
<tr>
<td>3.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.0</td>
</tr>
<tr>
<td>3.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.5</td>
</tr>
<tr>
<td>4.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.0</td>
</tr>
<tr>
<td>4.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.5</td>
</tr>
<tr>
<td>5.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.0</td>
</tr>
</tbody>
</table>

**EXCAVATION TESTS**

<table>
<thead>
<tr>
<th>PENETRATION</th>
<th>SUPPORT</th>
<th>WATER</th>
<th>SAMPLES, TESTS</th>
<th>SAMPLE</th>
<th>RL (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>26/10/16</td>
<td>2m x 1m</td>
<td></td>
<td></td>
<td></td>
<td>2.0</td>
</tr>
<tr>
<td>27/10/16</td>
<td>2m x 1m</td>
<td></td>
<td></td>
<td></td>
<td>3.5</td>
</tr>
</tbody>
</table>

**ENGINEERING DESCRIPTION**

- **Sample 1 @ 2.0m**: Sandy SILT; dark brown. Firm, moist, low plasticity.
- **Sample 2 @ 3.5m**: SILT, trace rootlets; orange brown mottled grey. Stiff, moist to wet, low plasticity.

**GEOLOGICAL**

- **TS = Topsoil**
- **ResS = Residual Soil**

**COMMENTS:** KEY: TS = Topsoil; ResS = Residual Soil
Appendix C: Scantec Geophysical Report
Technical Report

Geophysical Survey
Otaika Quarry
Overburden Disposal Area

Project: GBC834
Client: Golden Bay Cement
Location: Otaika Quarry
          Whangarei
Date: December 2016
Technical Staff: Matt Watson
                Tom Andrews
CONTENTS

1.0 Introduction
   1.1 Scope of Survey

2.0 Survey Methodology
   2.1 Electromagnetic Induction (EM-34)
   2.2 Ground Penetrating Radar (GPR)

3.0 Results and Interpretation
   3.1 Electromagnetic Induction (EM-34)
   3.2 Ground Penetrating Radar (GPR)

4.0 Summary

LIST OF FIGURES

Figure 1   Location of Measurements
Figure 2   EM-34 Results
Figure 3   GPR Results
1.0 Introduction

ScanTec Ltd was requested by Golden Bay Cement to carry out a geophysical survey to assist in the geotechnical assessment of the proposed overburden storage area at Otaika Quarry, Whangarei.

Geophysical techniques used included electromagnetic induction (EM) and Ground Penetrating Radar (GPR). The specific aims of the survey were to test the effectiveness of the techniques and their ability to identify cavities / tomos. Additional information would be gained on the geological structure. The work carried out consisted of a one-day trial survey.

Field work was carried out on November 17th, 2016 in fine weather and dry ground conditions by Matt Watson (Geophysicist) and Tom Andrews (Field Technician). Data processing and analysis was carried out by Matt Watson during November 2016.
2.0 Survey methodology

2.1 Electromagnetic Induction Survey

The Geonics EM-34-XL used for this survey is an electromagnetic induction system commonly used for mineral exploration, groundwater and geological investigations. Electromagnetic induction is a technique used to estimate the subsurface conductivity. This is achieved by inducing (transmitting) an electromagnetic field in the ground and measuring the response of the ground with a receiver.

The result is a reading of the bulk apparent conductivity for the material between the transmitter and receiver coils, down to the depth of induction (skin depth). The absolute depth of penetration is dependent on the conductivity of the material (low conductivity = higher penetration).

The equipment consists of two coils 1m and 0.8m diameter, which are positioned at a separation of 10, 20 or 40m and using progressively lower frequencies with increased spacings. Horizontal dipoles were used as this limits the effect near-surface conductivity variation. The operating frequencies generated by the EM-34 transmitter are 6.4kHz, 1.6kHz and 0.4kHz for 10m, 20m and 40m setting respectively.

The EM34 equipment is regularly calibrated at our test site in Whangarei and serviced in Mississauga, Canada. Calibration involves a series of measurements along a test line to monitor signal amplitude levels, instrument drift and check for variations due to cable continuity.

Measurements were collected across the site in a series of transects aimed at provided broad coverage.

All EM data was processed used customised software. GPS and survey tapes were used for positional control of measurements.
2.2 Ground Penetrating Radar (GPR) Survey

Ground penetrating radar (GPR) measurements were carried out using a GSSI SIR-3000 system with 200MHz frequency antennae. A combination of Differential GPS, digital survey wheel and survey tapes were used for positional control. Measurements were recorded at 24-bit resolution and a sampling density of 100scans per metre.

Measurements were recorded in a series of 2D profiles, towed manually.

GPR Data Processing

GPR data was processed in RADAN 6.6 software. Processing involved bandpass HP/LP filtering, predictive deconvolution, stacking, gain adjustments and background removal.

3.0 Results and interpretation

3.1 EM-34 Results

Electromagnetic measurements were recorded over quite a large area, but at sparse intervals, using a Geonics EM34 system at 10m coil separation. This provides an indication of the bulk conductivity of the ground to a depth of about 10m. Noise levels were low, and data quality/repeatability was very good. Measurement intervals are very coarse, and would need to be more closely spaced for adequate geological interpretation.

Figure 2 shows the EM results (attached jpg). The colour scale is shown, and this indicates the electrical conductivity (EC) of the ground in mS/m.

Observations on processed EM results:

- A N-S fault is interpreted.
- Higher conductivity formations on the western side, lower conductivity on the eastern side.
- Very high conductivity zone are observed in the vicinity of the interpreted fault, which is common EM response over fault lines. This also may be partly due to elevated soil moisture levels.
- No anomalies were observed that could be interpreted as showing evidence of cavities or tomos, however the data coverage over this site was very sparse and primarily aimed at indicating geological variation.
- The variation of EC levels in the eastern part of the coverage area are likely to be due to localised variation in groundwater, possibly associated with natural springs.
3.2 Ground Penetrating Radar (GPR) Results

A total of sixteen GPR transects were measured across the site with a total of 2 km of survey data (Figure 1).

Observations on processed GPR results:

- Maximum depth of signal reflections observed was about 3-4m. GPR does not have sufficient signal penetration on this site due to the conductive sediments and high soil moisture content.

- Some shallow sedimentary boundary reflections are visible corresponding to changes in lithology.

- No cavities or tomos were identified in the coverage extent and range of the GPR.

Example of typical response from GPR at this site. Signal penetration approx. 3m with weak reflection energy.
4.0 Summary and Recommendations

The trial measurements carried out at this site indicate that EM-34 is capable of operating effectively at this site and showing variation in electrical conductivity due to lithology and also groundwater.

Ground Penetrating Radar (GPR) is considered to be an unsuitable technique, providing limited data to a depth of 3-4 metres only. This is due to the conductivity of sediments and high dielectric permittivity which results in signal attenuation.

Electromagnetic induction measurements indicated the presence of a fault line running in a North-South orientation. This interpreted fault line clearly divides formation of high electrical conductivity in the West from lower conductivity formations in the East. Further geological interpretation of the EM data could be made in conjunction with borehole logs, test pits and field mapping.

Please let us know if you have any questions relating to this survey.

Matt Watson  B.Sc. M.Sc.
Geophysicist / Director

ScanTec Ltd
matt@scantec.co.nz
ph 021-376-644
Figure 1
Apparent Electrical Conductivity
Electromagnetic Induction (EM34)
10m depth range
Appendix D: SlopeW Analysis Results

- SlopeW analysis – static
- SlopeW analysis – elevated groundwater
- SlopeW analysis – seismic
Name: 3.0 Whole Slope - Seismic Case
Method: Morgenstern-Price
Slip Surface Option: Fully-Specified
Tension Crack Option: (none)
File Name: SlopeW section 1 - rev 4 (thick
**then write:**
Elevation

-128
-118
-108
-98
-88
-78
-68
-58
-48
-38
-28
-18
-8
2
12
22
32
42
52
62
72
82
92

Completely Weathered Siltstone
Sheared Mudstone
Overburden Fill

Piezometric Line: 1

Name: Ruatangata Sandstone
Model: Mohr-Coulomb
Unit Weight: 20 kN/m³
Cohesion': 50 kPa
Phi': 35 °

Name: Residual Soil
Model: Mohr-Coulomb
Unit Weight: 17 kN/m³
Cohesion': 5 kPa
Phi': 28 °

Name: Sheared Mudstone
Model: Mohr-Coulomb
Unit Weight: 20 kN/m³
Cohesion': 15 kPa
Phi': 20 °

Name: Completely Weathered Siltstone
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 7 kPa
Phi': 35 °

Name: Colluvium / Alluvium
Model: Mohr-Coulomb
Unit Weight: 17 kN/m³
Cohesion': 2 kPa
Phi': 24 °

Name: Overburden Fill
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 2 kPa
Phi': 26 °

Name: Toe Buttress
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion': 0 kPa
Phi': 38 °

Name: Shear surface at top of mudstone
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion': 1 kPa
Phi': 12 °
Piezometric Line: 1

Ru: 0.2

Project: Otaika Quarry - Proposed Overburden Disposal Area
Location: 92 Quarry Road, Otaika
Analysis Case: 3.0 Whole Slope - Seismic Case

Analysed by: DSA
Checked by: CJL
Job Number: 1000785
Date: 24/02/2017
Time: 4:29:38 p.m.
Figure: WS 3.0
Project: Otaika Quarry - Proposed Overburden Disposal Area
Location: 92 Quarry Road, Otaika
Analysis Case: 2.0 Whole Slope - Elevated Groundwater

Name: 2.0 Whole Slope - Elevated Groundwater
Method: Morgenstern-Price
Slip Surface Option: Fully-Specified
Tension Crack Option: (none)

File Name: SlopeW section 1 - rev 4 (thick)
Height of Water: 9.807 kN/m²
Horizontal Scale: 500 @ A4
Vertical Scale: 500 @ A4
Horz Seismic Load: 0g

Analysed by: DSA
Checked by: CJL
Job Number: 1000785
Date: 24/02/2017
Time: 4:29:38 p.m.
Figure: WS 2.0
Project: Otaika Quarry - Proposed Overburden Disposal Area
Location: 92 Quarry Road, Otaika
Analysis Case: 1.0 Whole Slope - Static

Name: 1.0 Whole Slope - Static
Method: Morgenstern-Price
Slip Surface Option: Fully-Specified
Tension Crack Option: (none)
File Name: SlopeW section 1 - rev 4 (thick)
Height of Water: 9.807 kN/m³
Horizontal Scale: 500 @ A4
Vertical Scale: 500 @ A4
Horz. Seismic Load: 0g

Analysed by: DSA
Checked by: CJL
Job Number: 1000785
Date: 24/02/2017
Time: 4:29:38 p.m.
Figure: WS 1.0
Name: 3.3 Toe - Yield Seismic Case - Additional Shear Key
Method: Morgenstern-Price
Slip Surface Option: Fully-Specified
Tension Crack Option: (none)
File Name: SlopeW section 1 - rev 3 (toe).gsz
Unit Weight of Water: 9.807 kN/m³
Horizontal Scale: 1,000 @ A4
Vertical Scale: 1,000 @ A4
Horz Seismic Load: 0.12g

Name: Residual Soil
Model: Mohr-Coulomb
Unit Weight: 17 kN/m³
Cohesion: 5 kPa
Phi: 28 °
Piezometric Line: 1

Name: Sheared Mudstone
Model: Mohr-Coulomb
Unit Weight: 20 kN/m³
Cohesion: 15 kPa
Phi: 20 °

Name: Completely Weathered Siltstone
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 7 kPa
Phi: 35 °

Name: Colluvium / Alluvium
Model: Mohr-Coulomb
Unit Weight: 17 kN/m³
Cohesion: 2 kPa
Phi: 24 °
Piezometric Line: 1

Name: Overburden Fill
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 2 kPa
Phi: 26 °
Ru: 0.2

Name: Toe Buttress
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Phi: 38 °

Name: Shear surface at top of mudstone
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 1 kPa
Phi: 12 °
Piezometric Line: 1

Project: Otaika Quarry - Proposed Overburden Disposal Area
Location: 92 Quarry Road, Otaika
Analysis Case: 3.3 Toe - Yield Seismic Case - Additional Shear Key

Analysed by: DSA
Checked by: CJL
Job Number: 1000785
Date: 24/02/2017
Figure: T-3.3
Project: Otaika Quarry - Proposed Overburden Disposal Area
Location: 92 Quarry Road, Otaika
Analysis Case: 1.1.3 Toe - Static Case - Additional Shear Key V3

Analysed by: DSA
Checked by: CJL
Job Number: 1000785
Date: 24/02/2017
Figure: T-1.1.3

Name: Residual Soil
Model: Mohr-Coulomb
Unit Weight: 17 kN/m³
Cohesion': 5 kPa
Phi': 28 °
Piezometric Line: 1

Name: Sheared Mudstone
Model: Mohr-Coulomb
Unit Weight: 20 kN/m³
Cohesion: 15 kPa
Phi: 20 °

Name: Completely Weathered Siltstone
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 7 kPa
Phi: 35 °

Name: Colluvium / Alluvium
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 2 kPa
Phi: 24 °

Name: Overburden Fill
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 2 kPa
Phi: 26 °
Ru: 0.2

Name: Toe Buttress
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Phi: 38 °

Name: Shear surface at top of mudstone
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 1 kPa
Phi: 12 °
Piezometric Line: 1

Method: Morgenstern-Price
Slip Surface Option: Fully-Specified
Tension Crack Option: (none)
File Name: SlopeW section 1 - rev 3 (toe).gsz
Unit Weight of Water: 9.807 kN/m³
Horizontal Scale: 1,000 @ A4
Vertical Scale: 1,000 @ A4
Horz Seismic Load: 0g
Project: Otaika Quarry - Proposed Overburden Disposal Area
Location: 92 Quarry Road, Otaika
Analysis Case: 3.2.3 Toe - Design Seismic Case - Additional Shear Key V3

Analysed by: DSA
Checked by: CJL
Job Number: 1000785
Date: 24/02/2017
Figure: T-3.2.3
Distance

Elevation

Name: Residual Soil
Model: Mohr-Coulomb
Unit Weight: 17 kN/m³
Cohesion: 5 kPa
Phi: 28°
Piezometric Line: 1

Name: Sheared Mudstone
Model: Mohr-Coulomb
Unit Weight: 20 kN/m³
Cohesion: 15 kPa
Phi: 20°

Name: Completely Weathered Siltstone
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 7 kPa
Phi: 35°

Name: Colluvium / Alluvium
Model: Mohr-Coulomb
Unit Weight: 17 kN/m³
Cohesion: 2 kPa
Phi: 24°
Piezometric Line: 1

Name: Overburden Fill
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 2 kPa
Phi: 26°
Ru: 0.2

Name: Toe Buttress
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Phi: 36°

Name: Shear at base of residual soil
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 1 kPa
Phi: 12°
Piezometric Line: 1

---

Project: Otaika Quarry - Proposed Overburden Disposal Area
Location: 92 Quarry Road, Otaika
Analysis Case: 3.0 Section 2 - Seismic

Analysed by: DSA
Checked by: CJL
Job Number: 1000785
Date: 24/02/2017
Time: 4:55:14 p.m.
Figure: S2 - Seismic

---

P:\1000785\Investigation\Otaika-OEBA\Work\Report\Material\SLOPEW\SlopeW section 2 - rev 3.gsz
Name: 3.1 Section 2 - Seismic Yield
Method: Morgenstern-Price
Slip Surface Option: Entry and Exit
Tension Crack Option: (none)
File Name: SlopeW section 2 - rev 3.gsz
Unit Weight of Water: 9.807 kN/m³
Horizontal Scale: 500 @ A4
Vertical Scale: 500 @ A4
Horz Seismic Load: 0.12g

Project: Otaika Quarry - Proposed Overburden Disposal Area
Location: 92 Quarry Road, Otaika
Analysis Case: 3.1 Section 2 - Seismic Yield

Analysed by: DSA
Checked by: CJL
Job Number: 1000785
Date: 24/02/2017
Time: 5:20:07 p.m.
Figure: S2 - Seismic Yield
Appendix E: Kermode Report
General Geology

The basement rock in this district is grey wacke. It forms a series of northward tilted blocks up-faulted on the southern side. Within the fault angle valleys lie younger marine sandstones and limestones. The bedding of these sediments is approximately parallel to the old erosion surface of the greywacke, i.e. they dip at 100° NNE.

Detailed Geology

The gentle northerly slope of the terrain south-west of the old farmhouse is probably the tilted erosion surface of the greywacke which is exposed in the quarry on the access road to the south-east. The streams west of Ruarangi A are eroded and basement material is not exposed.

The limestone on Ruarangi A is an archeological remnant of a once more extensive deposit. It is flaggy and crystalline, containing about 90% calcium carbonate and forms prominent bluffs on the southern side. At the site the limestone appears to be overlaid by a younger weathered sandstone which probably forms most of the scrub-covered hill just to the north. The flaggy crystalline limestone is approximately 50 ft. thick, and grades downward into a sandy, flaky limestone of about 70% calcium carbonate, and about 25 ft. in thickness.

Caves formed by solution and collapse of the limestone seem to follow a basal glauconitic sandstone as found in the larger stream to the north of Ruarangi B.

Speleology

Cave orientation is approximately down-dip, as indicated by the preliminary survey map. Fluorescein, added to the stream just upstream from Ruarangi A Burial Cave, was observed some 24 hours later at a resurgence about 1 mile NNE. The large chamber of McQueen's Cave has a similar NNE orientation. A number of sinkholes, sub-surgence and resurgence occur in an east-west alignment, but they must be investigated further before their true relationships can be determined.

The two (shafts) of Ruakore and McQueen's cave demonstrate verticality of development in crystalline limestone. The average depth of these two is 45 ft.

In the caves so far explored, horizontality of development is found within the lower sandy limestone, and major roof collapses of large, thick slab are a common feature.

On the surface upstanding remnants of flaggy limestone have been decapitated for Maori burials, and the artificial heaping of the flaggy against the sides of the rock towers is a useful guide to the archaeologist.

Speleotherm (Calcite Ornaments)

Almost every one of the few stalactites and stalagmites in the Burial Cave has been smashed by vandals. (Wall signatures date back to 1895). The difficulty of access has protected Ruakore, and a line of short columns, disjointed by natural
on the outer surface and somewhat amorphous.

Geology
Cave insects are present but none was collected.

Recommendations:
1. Whether the final fate of the area is preservation or destruction, the area is peculiar enough to warrant making a full speleological record — possibly requiring up to the end of summer, 1965-66.

2. If the national economy demands the limestone as a "sweetener" for the cement industry, could Ruarangi A be extended to include Rukidore (which includes most of the variety of speleological points of interest), and allow the remainder of Ruarangi B to be quarried, provided suitable access be left?

3. Maori burials could be re-interred elsewhere, or sealed behind a grating or solid wall in the Burial Cave. This would require a great deal of specialised effort.

4. The bush and limestone outcrops of "Extended Ruarangi A" have character and pleasantness that are unusual in New Zealand reserves close to residential areas.

MAPS AND APPENDICES

MAP 1 — General Plan showing Cave features and recommended extension

MAP 2 — Pa site.
Recommendations:

That the area be used for any purpose that would destroy the surface features, further provision be made for archaeological work to be carried out prior to the destruction of the area. At a minimum, a period of excavation and circumstances of excavation similar to that which has been the subject of the present report, would be of great value, while more extensive activities would be more desirable. A stay of bulldozing activities over a period of two years from now would provide an adequate time for further investigations to be carried out, in one or two season's excavations.

That, although there is no proof that this area is archaeologically unique, the features on the reserve are such that from an archaeological point of view, preservation would be desired. The close proximity of sites of a varying nature, the findings of the excavation, the probability that the area demonstrates local cultural variations differing from other areas of New Zealand, and, very importantly, the very good state of preservation and lack of interference that these sites exhibit, are the factors that are considered in the making of this recommendation. Should the area remain a reserve, provision for further limited excavation, under the strict control of the Archaeology lecturer of the Auckland University, and the members of the council of the New Zealand Archaeological Association, is suggested.