Appendix D. Geotechnical and Site Suitability Assessment Report

RILEY
CONSULTANTS

GEOTECHNICAL AND SITE SUITABILITY ASSESSMENT

TE RUAOTEHAUHAU WATER STORAGE RESERVOIR, OHAEWAI

Engineers and Geologists

RILEY CONSULTANTS LTD
New Zealand
Email: riley@riley.co.nz
Email: rileychch@riley.co.nz
Web: www.riley.co.nz

AUCKLAND
4 Fred Thomas Drive, Takapuna, Auckland 0622
PO Box 100253, North Shore, Auckland 0745
Tel: +64 9 489 7872 Fax: +64 9 489 7873

CHRISTCHURCH
22 Moorhouse Avenue, Addington, Christchurch 8011
PO Box 4355, Christchurch 8140
Tel: +64 3 379 4402 Fax: +64 3 379 4403

RILEY CONSULTANTS

GEOTECHNICAL AND SITE SUITABILITY ASSESSMENT TE RUAOTEHAUHAU WATER STORAGE RESERVOIR, OHAEWAI

Report prepared for: Te Tai Tokerau Water Trust

Report prepared by: Shael Monk-Fromont, Geotechnical Engineer

……………………………..

Report reviewed by: Eli Maynard, Senior Water Resources/Geotechnical Engineer, CPEng

Eli Maynard.

……………………………..

Report approved for issue by: Scott Vaughan, Managing Director, CPEng

……………………………..

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	Te Tai Tokerau Water Trust	Electronic copy
	Williamson Water and Land Advisory	Electronic copy

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RILEY CONSULTANTS LTD
New Zealand
Email: riley@riley.co.nz
Email: rileychch@riley.co.nz
Web: www.riley.co.nz

AUCKLAND
4 Fred Thomas Drive, Takapuna, Auckland 0622
PO Box 100253, North Shore, Auckland 0745
Tel: +64 9 489 7872 Fax: +64 9 489 7873

CHRISTCHURCH
22 Moorhouse Avenue, Addington, Christchurch 8011
PO Box 4355, Christchurch 8140
Tel: +64 3 379 4402 Fax: +64 3 379 4403

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1.0 Introduction

Riley Consultants Ltd (RILEY), along with Williamson Water and Land Advisory Ltd (WWLA) and other project partners, has been commissioned by the Te Tai Tokerau Water Trust (TTTWT) to prepare documentation to support a resource consent application to construct and operate the proposed Te Ruaotehauhau Water Storage Reservoir, located west of Ohaewai.

The purpose of the reservoir is to provide a secure source of irrigable water for horticulture and non-ruminant agricultural use within the mid-north region. It is one of several options identified by the Northland Water Storage and Use Project (NWSUP): Pre-feasibility Demand Assessment and Design Study. This site was previously referred to as MN-06.

This location was initially short-listed due to its central location within and elevated above the mid-north command area, geological setting, and proximity to Lake Omapere among other criteria. The current proposal is for a 21m high embankment dam capable of storing 1.4Mm^3 at full supply level. An initial potential impact classification (PIC) by RILEY indicates that the dam will be High PIC due primarily to its location upstream of Ohaewai.

This report outlines typical design, construction, and operational considerations for the reservoir, outlined with reference to the New Zealand Society of Large Dams (NZSOLD) Dam Safety Guidelines.

The primary objectives of the geotechnical and site suitability assessment is to:

- Assess the geological context of the dam site and reservoir basin, and how this influences dam concept options, design considerations, safety, water retention and reservoir slope integrity.
- Assess if any geological or geotechnical conditions exist that could prohibit safe and cost-effective dam construction and operation.
- Refine the most suitable dam type and conceptual arrangements for appurtenant structures based on geological, geotechnical, ecological and hydrological considerations.
- Outline recommendations for the progression of the project through detailed design investigations and detailed design.

At the time of writing this report, additional intrusive geotechnical investigations (machine boreholes and laboratory testing) were being undertaken to support future detailed design. This report, therefore, provides an assessment based on present understanding using available geotechnical information captured to-date. The findings presented will need to be reviewed and updated once machine boreholes and laboratory testing can be completed.

1.1 Supporting Documents

This report should be read in conjunction with RILEY Report Ref: 200240-F titled Hydrology and Hydraulics which covers aspects such as temporary flood diversion during construction, spillway requirements and an initial dam failure and consequence assessment.

2.0 Site Description and Topography

The proposed Dam site is located on a volcanic plateau at the confluence of Te Ruaotehauhau and Waitaia streams, approximately 2.5km upstream of Ohaewai, Northland.

Topography comprises a generally flat terrace on the left abutment and moderate slopes on the right, each formed by pre-historic lava flows (Figure 1). The catchment is predominantly in pasture, with isolated areas of wetland and forest predominantly along riparian margins.

Figure 1: View west from right abutment along main dam alignment. Te Ahuahu scoria cone partly obscured by fog in the middle background.

The stream running through the site meanders around the inferred boundary between separate volcanic lava flows. The main channel is slightly incised into weathered rock and is less than 10m wide at its base and up to about 100m wide at its highest point (RL 200m). The stream is fed by springs emanating at several locations within the reservoir basin. This stream, along with a number of others, flow eastwards to the Waitangi estuary where it joins the Bay of Islands.

Lake Omapere is located 3km to the west of the site and is 30m higher in elevation than the proposed Dam site.

3.0 Geotechnical Site Investigations and Laboratory Testing

3.1 Investigation Scope

Geotechnical investigations have been undertaken at the site, involving:

- An initial review of broad geotechnical issues across the mid-north region as part of the Northland Water Storage and Use project: Pre-feasibility Demand Assessment and Design Study.
- A site walkover assessment of the dam alignment and reservoir surrounds including detailed geomorphic field mapping.
- Excavation of eleven test pits spread across the dam embankment, borrow areas and reservoir basin. Retrieval of bulk soil samples for future laboratory testing.
- Advancement of six cone penetration tests (CPTs) to a maximum depth of 9.7m.

The above scope of investigation is deemed appropriate to support a preliminary feasibility assessment and preliminary design to support an application for resource consent. Further investigation will be required to support detailed feasibility and final design to support an application for building consent. The requirement for and scope of additional deep investigations required to support detailed design are discussed in Section 7.0.

3.2 Desktop Study and Initial Site Visit

A high-level review of available geotechnical information across the Kaipara and mid-north was undertaken as part of the wider assessment. This looked into likely ground conditions and the potential variability across several reservoir sites, and for highlighting any known regional hazards that should be considered in the context of shortlisting and concept design for the water storage and distribution scheme.

Information was obtained from the following sources:

- 1:250k Geological Map 2 – Whangarei, GNS Science 2009.
- New Zealand Geology Webmap v.2.3 https://data.gns.cri.nz/geology/.
- New Zealand Active Fault Database v3.3 https://data.gns.cri.nz/af/.
- New Zealand Landslide Database v.4.1 https://data.gns.cri.nz/landslides/.
- Geotechnical investigation information contained in the New Zealand Geotechnical Database https://www.nzgd.org.nz.
- Photoblique images captured in 2017 and 2018.
- Information relating to known recent or historic large dam projects nearby.
- Walkover of this site.

3.3 Geomorphic Field Mapping

Comprehensive geomorphic mapping of the reservoir basin and surrounds including gullies and steeper slopes was undertaken by a senior engineering geologist from RILEY during field investigations. This enabled surface exposure and subsurface information to be correlated to published geological map of the area, the results of which are summarised on RILEY Dwg: 200240-101.

3.4 Test Pits

Eleven test pits were excavated by Far North Roading using a 15t hydraulic excavator under the guidance and supervision of RILEY. Test locations were spatially distributed across the dam embankment and reservoir basin in key areas of interest.

Six test pits were excavated as part of the embankment foundation investigation (TP1 to TP6), four in the potential borrow areas within the reservoir basin (TP8 to TP10), and one near the auxiliary spillway (TP7).

All test pits were extended to a target depth of 5m or earlier refusal on competent rock. A RILEY engineering geologist inspected exposures within the test pits, logging the materials encountered, and any geological structures in general accordance with the New Zealand Geotechnical Society (NZGS) Guidelines. Bulk samples were retained for future laboratory testing.

3.5 Cone Penetration Tests

Six cone penetration tests with piezocone enhancement (CPTu) were advanced by Underground Investigation Ltd using a Georig 220 with a 10cm^2 100MPa probe.

All tests were undertaken within the dam embankment footprint, advancing to refusal at a maximum depth of 9.7m (CPT6). All CPT tests reached refusal due to failure of ground anchors that provide resisting force to the test rig.

4.0 Investigation Results

4.1 Geological Setting

Regional geology comprises Kerikeri Volcanic Group Early to Late Pleistocene basalt of the Kaikohe – Bay of Islands Volcanic Field underlain by Northland Allochthon (1:250k QMAP 2 Whangarei, GNS Science 2009).

The provisional dam location has been selected within a local gully on a volcanic plateau formed by lava flows inferred to originate from three prominent scoria cones: Tarahi Volcano to the south, Maungakawakawa to the south-west, and Te Ahuahu to the north-west. GNS Science (2009) indicates that the age of these volcanos is in the range 60ka (thousand years) to 1,400ka. Older deposits, in the order of 1,800ka to 9,700ka are indicated to the north and south of these volcanos and may underly the younger volcanic deposits at the site. Other studies of the Kaikohe – Bay of Islands Volcanic Field (e.g. Dr Bruce Hayward, 'Out of the Ocean into the Fire') suggest that all the volcanoes erupted in the last 300,000 years, and that many are likely younger than 100,000 years.

'Geology of the Whangarei Area' (GNS Science, 2009) describes the typical eruption sequence of volcanism in the Kaikohe-Bay of Islands volcanic field. Typically, there is an initial vent-opening explosion, which is followed by weakly energetic eruption of ash, scoria and bombs, fluid lava effusion follows. The volcanic deposits are constrained by topography of the time, often filling valleys, and burying deposits of alluvium.

The site is located on the lower northern slopes of the Tarahi volcano, which forms the highest scoria cone in the Kaikohe Volcanic Field, approximately 140m above the surrounding flows. The Maungakawakawa volcano to the west forms a 60m high scoria cone that breached to the north-west and formed radially running volcanic flows. The Te Ahuahu volcano forms a prominent scoria cone rising 100m above its east-west trending flows below.

Due to the eroded nature of the Tarahi and Maungakawakawa volcanoes, they are both interpreted to be older than the Te Ahuahu. Basalt lava typically has a low viscosity erupting with effusive volcanism.

The Kaikohe – Bay of Islands Volcanic Field is underlain at depth by structurally complex units of tectonically intercalated sandstone and mudstone of the Northland Allochthon. The materials of the Northland Allochthon are inferred to rest on basement rock of the Waipapa (Composite) Terraine. The basement Waipapa Group greywacke rock is indicated to be at a depth greater than 500m below ground level (bgl).

4.2 Observations from Site Walkover

The following observations were made by RILEY during the geomorphic and geologic field mapping undertaken on 6 to 7 May 2020.

The dam site is located at the boundary of three intercalated basaltic lava flows: the left abutment originating from the Te Ahuahu volcano (north), the right abutment from the Tarahi volcano (south), and west extent of the reservoir from the Maungakawakawa volcano (west). The flows formed by the Te Ahuahu volcano form a wide ridge that gently slopes east, where the flows formed by the Maungakawakawa and Tarahi volcanoes slope more moderately north-west and north.

There were no obvious signs of large-scale slope instability on the abutments of the Dam site. Observed instability is limited to localised small scale rockfall on the left abutment and shallow soil movement on the right abutment. Both these areas are adjacent to the main stream channel and assessed to be due to toe-erosion and resulting oversteepening of the slopes. The shallow soil movement is typically observed as terracettes.

Springs were observed around the reservoir basin at several locations, often found at the heads of gullies, as well as within several test pits perching at the contact between the residually weathered soils and underlying rock.

Outcrops of slightly weathered basaltic boulders are typically observed at the surface of the Tarahi lava flows, and not the Te Ahuahu and Maungakawakawa flows. This is likely due to the gentle slopes formed by the Tarahi lava flows and its younger age. The boulders typically range from 0.5m to 2.0m in diameter.

Slightly upstream of the proposed Dam site near the intersection of two stream channels, is a flat-lying area at the base of the slopes, which due to its close-proximity to the stream and geomorphology, may include deposits of alluvium.

4.3 Ground Model

4.3.1 Stratigraphy

Surficial soils observed in test pits were predominantly described as dark reddish brown with purple and orange silt and clay with minor fractions of sand, gravels and cobbles. These are interpreted as residually weathered basalt of the Kerikeri Volcanic Group.

The weathering depth was variable but generally in the order of a few metres thick, beneath which unweathered, hard basalt was encountered. Deeper weathering was generally observed on the right abutment, suggesting the deposits from Tarahi volcano are likely to be older than on Te Ahuahu Volcano on the left.

Basaltic rock is known to weather more rapidly and variably compared to other volcanic rock types. As these materials are potentially deposited by explosive volcanic episodes, potential ash, lapilli, blocks and scoria layers between flows at depth cannot be discounted. Further, being a relatively recent flow deposit means that intercalated or overlapping flows with intermediate soil deposits that have been preserved are possible. For these reasons, a range of soil and rock properties are possible beneath the dam site and these will be investigated as part of detailed design. Permeability of the intact basalt rock will be governed by the persistence, width and orientation of cooling joints and other defects, which can result in very high permeabilities.

Scoriaceous gravels, ash and lapilli were identified in the borrow area at the base of TP10 from 4.3m to 4.6m+ and extends to an unknown depth. This material may have rafted down with lava flows from the breached scoria cone of the Maungakawakawa volcano located to the west of the site and may contain materials that could have high permeability.

Beneath all units is sandstone and mudstone of the Northland Allochthon, and below that basement Waipapa Group greywacke rock at depth.

Simplified ground models have been developed based on the information captured to-date. These are summarised in the following sections. Refer to RILEY Dwgs: 200240-103 and -104.

4.3.2 Left Abutment

The ground model comprises firm to stiff, silt and clayey silt with slight to moderate plasticity interpreted as residual Kerikeri Volcanics in the upper few meters. Underlying this is weathered basalt originating from the Te Ahuahu volcano. Outcrops of rock and boulders at the surface towards the stream channel indicate that rock is at a shallow depth in this area (Figure 1). As this is one of the younger lava flows in the area, the basalt encountered by the test pits and CPTs could be underlain by older lava flows and other deposits, such as alluvium. The depth of the Northland Allochthon has not yet been confirmed here.

4.3.3 Right Abutment

The description here applies to both the right dam abutment and also to the auxiliary spillway.

The ground model comprises several meters of firm to very stiff, silt and clayey silt with non to moderate plasticity interpreted as residual Kerikeri Volcanics. Underlying this is weathered basalt originating from the Maungakawakawa volcano. This volcano is inferred to be one of the older in the area, and therefore, has a deeper weathering profile compared to the left abutment. Underlying this basalt is likely to be older lava flows and other deposits, such as alluvium. The depth of the Northland Allochthon has not yet been confirmed here.

4.3.4 Foundation

Within the main valley section, the ground profile transitions between two lava flows outlined above. At the transition between flows there is often greater variability variable. The active stream channel can also increase weathering rates and initiate erosion. Soft alluvium within or adjacent to the stream channel is also likely. The depth of the Northland Allochthon has not yet been confirmed here.

4.3.5 Groundwater

Springs were observed around the reservoir basin at several locations, often found perching at the contact between the residually weathered soils and fresh rock where there is a large permeability contrast.

Moderate seepage flows were encountered within TP1 to TP3, TP5, and TP6 at depths of between 3m to 4m bgl immediately above the soil rock interface. These seepages appear to be spring-fed and have a general downslope trend toward the nearest stream channel.

On the left abutment, groundwater is only a few meters below ground level; on the right abutment groundwater was not observed above the stream channel. Within the main valley section, groundwater is likely to be at or near the same level as the stream invert.

Groundwater located within localised basalt and scoria aquifers and is used as a source for irrigation wells and municipal supply in the area.

Defining the location, thickness and hydraulic properties of the soil and rock units, along with improving understanding of the site hydrogeology and any aquifer units present, will be a key focus of future drilling work.

4.4 Dam Fill Borrow Areas

A possible borrow area for Dam fill was identified upstream of the proposed dam site to the west of the stream channel, as indicated on the appended RILEY Dwg: 200240-101. Additionally, excavations to form the auxiliary spillway will provide material that could be reused in dam construction.

Test pits TP7, TP8, TP9, TP9A, and TP10 undertaken by RILEY were sited to provide an assessment of the suitability of the soil material within this area. These test pits encountered 3m to 4m of cohesive silt and clay with slight to moderate plasticity, which could be suitable as earthfill subject to further assessment. Recorded shear strengths were typically between 50kPa and 200kPa+ i.e. stiff to very stiff conditions.

Other potential borrow areas around the reservoir basin could be considered depending on volume requirements.

Unweathered rock, such as that observed near ground surface on the left abutment, and possibly some excavated during excavation of the auxiliary spillway, could be suitable for reuse as riprap on the upstream face subject to further assessment.

5.0 Natural Hazards

5.1 Seismicity

Seismic/earthquake risk in Northland is generally low by national standards, with no recorded large earthquakes since records began (c. 1840).

Seismicity here is dominated by distributed or background seismicity used to model historical earthquakes, rather than known active fault sources in the area. No fault sources are known to exist in the vicinity of the site, with the closest active fault being a possible northern extension of the Kerehepu Fault in the Hauraki Golf nearly 200km away. Inactive faults associated with the emplacement of the Northland Allochthon are noted to occur throughout the area, and are not considered to require specific consideration for design.

Notwithstanding that, seismic aspects will be a design consideration and being a High PIC means that specific assessment will be undertaken to inform detailed design.

This will typically involve evaluation of the following scenarios during detailed design:

- Operating Basis Earthquake (OBE) – The earthquake for which a dam, appurtenant structure, and gate/valve system that fulfils a dam safety function is designed to remain operational, with any damage being minor and readily repairable following the event. It is considered that an annual exceedance probability (AEP) of 1 in 150 is appropriate for the OBE.
- Safety Evaluation Earthquake (SEE) – The earthquake that would result in the most severe ground motion, which a dam structure must be able to endure without uncontrolled release of the reservoir. It is considered that AEP of 1 in 10,000 is appropriate for the SEE based on the assessed High PIC.
- Controlling Maximum Earthquake (CME) – The maximum earthquake on a seismic source that is capable of inducing the largest seismic demand on a dam.

Due to the long recurrence interval design events, seismic parameters for use in design of a High PIC dam are normally established by a site-specific seismic hazard assessment by a technical specialist, using a probabilistic analysis. We are aware of two such studies undertaken for the following large High PIC dams in Northland:

1. Kerikeri Irrigation Dams, 10km north-east of the site (GNS Science, 2015).
2. Whau Valley Dam, west of Whangarei (GNS Science, 2012).

Both studies provide recommended ground motions for the SEE. Additionally, the Whau Valley Dam study provides estimates for a M6.5 normal faulting earthquake at a distance 20km from the site. In the absence of any nearby known active fault, this earthquake is used to develop a default minimum ultimate limit state (ULS) spectrum in NZS 1170.5 in low seismic regions, such as Northland.

Based on present information, the site would be classed as either Site Class B ‘rock’ or Class C ‘shallow soil’ in accordance with NZS 1170.5.

5.2 Liquefaction

Qualitative assessment of materials encountered during excavation of the test pits was undertaken to identity potential soil types that may be susceptible to liquefaction. All materials were described as either firm to stiff cohesive silt and clay or rock, which are not considered susceptible for liquefaction or considerable strength loss on cyclic loading.

A preliminary liquefaction assessment was also undertaken on the CPT results using updated methods (e.g. I&B 2014) and ground motions provided in the above seismic studies. Results indicate that the soils are either sufficiently plastic or dense to liquefy, and this will be confirmed once additional investigations are completed to support detailed design.

These preliminary results from the seven CPTs, together with the low regional seismicity, indicates that liquefaction is unlikely to pose a significant risk to this dam. Notwithstanding this, consideration of potential for liquefaction in deeper soil layers will be assessed once machine borehole findings are available.

As noted, fine grained soils with significant plasticity are not considered liquefiable. However, soft or sensitive cohesive sediments can be subject to cyclic softening. The mechanism for this softening is similar to liquefaction insofar as high intensity cyclic loading can cause significant shear strains to accumulate, with a corresponding increase in pore pressure and reduction in shear strength. This will be considered further during detailed design.

5.3 Volcanic Activity

The Kaikohe – Bay of Islands field is generally considered to be dormant, and many of the volcanos are thought to have erupted in the last 100ka. Geologists are continuing work to date volcanos in the field. Dr Bruce Howard refers to Te Puke and Tauanui volcanos as among the youngest centres in the field with dates of 75ka, and 45ka, respectively. Work is continuing amongst geologist to estimate the recurrence interval of volcanic eruption within the field. Kear and Thompson (1964) suggested 1ka to 2ka, but GNS Science (2009) indicate it is probably much longer than this.

Volcanos within the Kaikohe – Bay of Islands field have dominantly been identified as monogenetic, meaning each volcanic sequence forms a new volcanic vent rather than erupting from an existing volcano. For this reason, the volcanic hazard affects the entire volcanic field rather than specific volcanos, such as those surrounding the site. Bogalo (2000) estimated that a future basalt eruption within the field would directly affect by an area of up to 78km^2, including lava flows typically 5km in length and ashfall over an area up to 20km^2.

There are no practical steps that can be taken from a design perspective to mitigate the volcanic hazard. Emergency preparedness and resilience should be considered.

5.4 Landslides

Landslides can threaten the dam embankment or safe operation of the reservoir in a variety of ways. Examples include:

- Reservoir operation could result in reactivation or new landslides around the reservoir basin impacting the dam, appurtenant structures, adjacent land or increasing sedimentation.
- Landslide-generated waves impacting communities adjacent to the reservoir, or to the dam itself resulting in overtopping.
- Excavations for embankment foundation preparation, or to form the spillway channel, could initiate ground movement.

Geomorphic mapping of the dam abutments and reservoir basin did not identify any signs of large scale or deep-seated slope instability, and is generally not anticipated within this volcanic setting.

Signs of small-scale surficial landslips developed at the rock/soil contact, minor rockfalls, and shallow soil creep were observed. These features are reasonably common in the area and often manifest after periods of extended rainfall. The key features of interest were located near or below the proposed maximum reservoir line as shown on RILEY Dwg: 200240-101. As the intention is to draw down the reservoir either partially or fully across a season, reservoir operation may exacerbate or promote minor slumping or slips developing around the reservoir basin that will be need to be specifically assessed.

Long-term excavations are proposed at the borrow area and in forming the auxiliary spillway. The former will likely involve excavations in the order of 3m to 4m deep; the latter could be more significant up to 9m deep. All cut slopes will be specifically assessed as part of detailed design to ensure target factors of safety will be met, in particular where slopes will be fully or intermittently submerged, such as the borrow area.

Generally, the dam concept does not involve any long-term slope toe excavations or slope surcharging. The soils strengths indicated from the in-situ shear strength testing, do not indicate any obvious slope instability hazard in the slopes within the reservoir basin or dam abutments. Notwithstanding this, further consideration of stability for any permanent cut slopes required to form the spillway and borrow area as outlined above are necessary, as well as stability of temporary excavations required for undercutting of soft unsuitable soils in the dam footprint. Options such as battering, benching or slope retention could be considered to improve factors of safety should this be required.

Slopes across the region comprising of Northland Allochthon material are known to be prone to instability. While Northland Allochthon is present beneath the volcanic deposits, investigation at the site to-date has not encountered it at shallow depths, where it would influence the stability of the slopes.

5.5 Flooding

Detailed analyses of the site catchment, temporary flood diversion during construction, and permanent spillway facilities are provided in the Hydrology and Hydraulics Assessment (RILEY Ref: 200240-F).

6.0 Preliminary Dam Design

Whilst a number of potential geotechnical hazards have been considered, based on the investigations undertaken to-date, we have not identified any specific geotechnical hazards that indicated the possible dam site is unsuitable. The following provides comment on specific elements considered for preliminary design.

6.1 Dam Type and Spillway

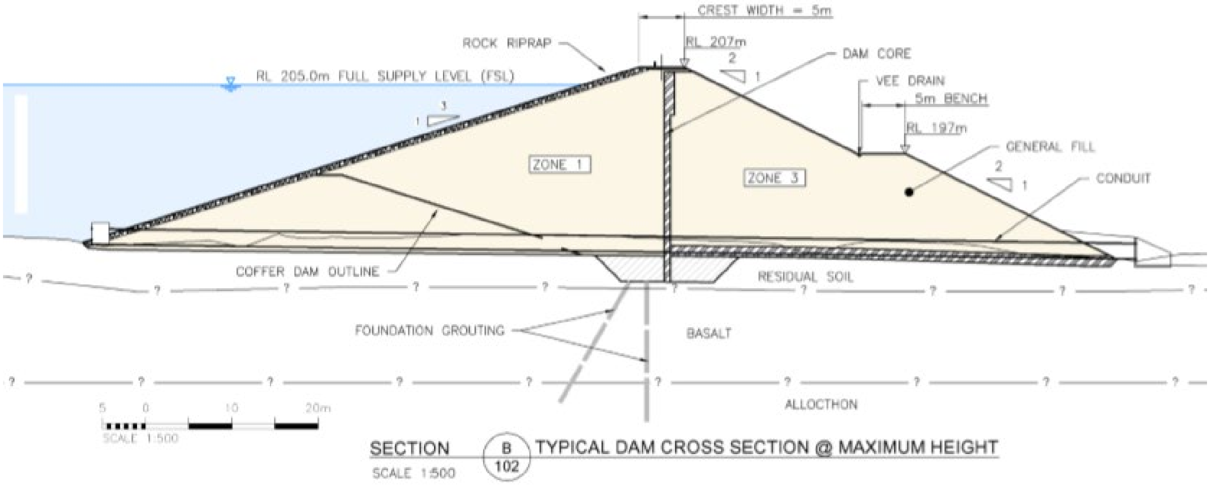
The site topography and interpreted ground model indicate conditions suitable for an embankment dam. Based on a storage requirement of 1.4Mm^3, the dam embankment would be up to approximately 21m high in the main valley section and around 400m long. Only the central portion (~50m in length) is in the order of 10m to 20m high, with majority of its length on the left abutment being generally less than 5m.

A preliminary design cross section is presented in Figure 2 and on the appended RILEY Dwg: 200240-105. The embankment has up- and down-stream slope batters of 1V:3H (horizontal : vertical) and 1V:2H with a 5m wide mid-height bench, and minimum 5m wide crest. A wider crest could be considered depending on future access requirements.

The embankment itself could be zoned, utilising selected low-permeability, cohesive silt and clay as the upstream shoulder and general earthfill (probably still cohesive material) in the downstream shoulder. The zones would be separated by a central chimney drain with blanket or finger drain outlets to control seepage and internal erosion. The embankment would be founded on stiff residual soil or weathered rock, with preparation involving grouting, dental treatment and keyways as required.

A low-level conduit installed within the valley floor at the toe of the left abutment would provide temporary flood diversion during construction, house both a residual flow pipe and supply pipes and provide emergency dewatering facilities. The current concept includes both service/primary and auxiliary spillways. The service spillway could be incorporated into either the left or right abutment; the auxiliary spillway is envisaged to be formed beyond the right abutment, discharging to the stream approximately 200m below the dam. The service spillway could also be incorporated within the auxiliary spillway. Refer to RILEY Dwg: 200240-106.

Figure 2: Preliminary Dam Cross Section



The concept design outlined above is based on the Kerikeri irrigation dams constructed in the early 1980s. The two Kerikeri dams are both higher, also High PIC, are underlain by similar Kaikohe – Bay of Islands Volcanic rock and were constructed using similar residual soil. These have largely performed well since their construction in the mid-1980's.

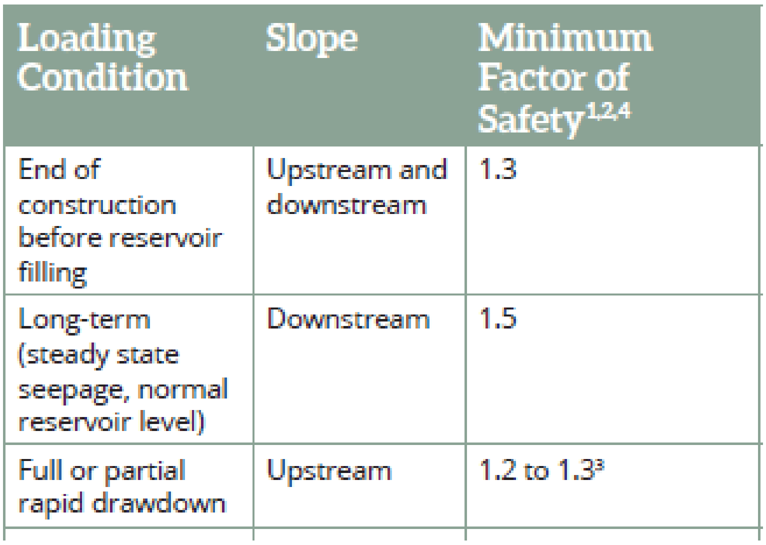
6.2 Design Standards

The Dam has been assessed as having a High PIC (refer RILEY Ref: 200240-F). Design standards in keeping with a High have, therefore, been adopted in accordance with the NZSOLD Guidelines as follows:

- Operating Basis Earthquake (OBE): 1:150 AEP ground motion.
- Seismic Evaluation Earthquake (SEE): 1:10,000 AEP ground motion developed by a probabilistic approach.
- Inflow Design Flood (IDF): 1:10,000 AEP event to Probable Maximum Flood (PMF).

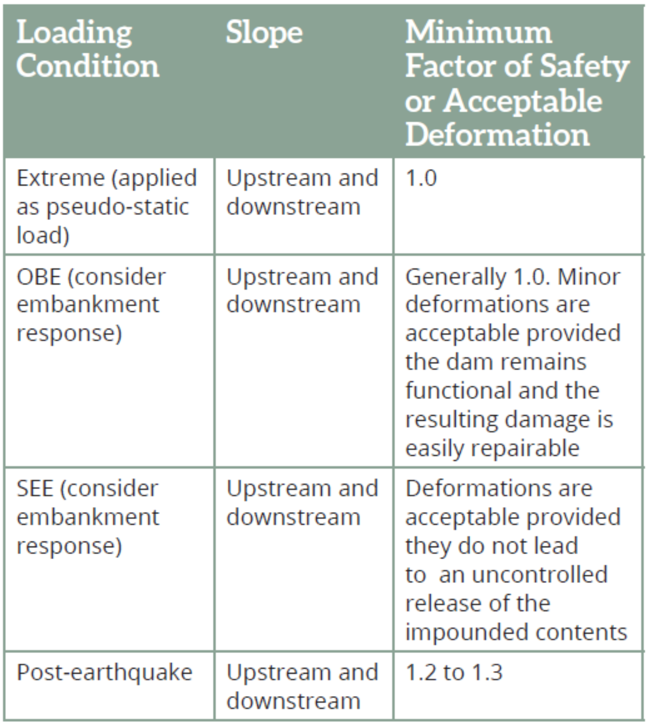
Performance standards and recommended factors of safety are nominated by the NZSOLD Guidelines for a range of operational and emergency scenarios. Minimum stability requirements adopted for design for non-seismic load cases are as set out in Table 1. Seismic performance standards are set out in Table 2.

Table 1: Minimum Factors of Safety for Slope Stability – Static Assessment (reproduced from NZSOLD, 2015)



Loading Condition	Slope	Minimum Factor of Safety[1,2,4]
End of construction before reservoir filling	Upstream and downstream	1.3
Long-term (steady state seepage, normal reservoir level)	Downstream	1.5
Full or partial rapid drawdown	Upstream	1.2 to 1.3[3]

Table 2: Minimum Requirements for Slope Stability – Seismic Assessment (reproduced from NZSOLD, 2015)



Loading Condition	Slope	Minimum Factor of Safety or Acceptable Deformation
Extreme (applied as pseudo-static load)	Upstream and downstream	1.0
OBE (consider embankment response)	Upstream and downstream	Generally 1.0. Minor deformations are acceptable provided the dam remains functional and the resulting damage is easily repairable
SEE (consider embankment response)	Upstream and downstream	Deformations are acceptable provided they do not lead to an uncontrolled release of the impounded contents
Post-earthquake	Upstream and downstream	1.2 to 1.3

6.3 Foundations and Abutments

6.3.1 Foundation Treatment

Soils observed within the embankment footprint were generally stiff, low-permeability, cohesive and are non-liquefiable. Shear vane testing at regular intervals in test pits typically recorded undrained shear strengths in the range of 50kPa to 200kPa+, i.e. stiff to very stiff consistency. Discrete zones of saturated silts had shear strengths as low as 30kPa.

Based on the above, only a nominal stripping and undercut up to a few meters appears to be needed to remove any soft zones for stability or settlement purposes, i.e. to ensure the foundation has sufficient strength and to limit consolidation settlement. Preliminary 1D settlement analyses suggest expected settlements are within manageable ranges. It is possible that a full undercut is only warranted within the main valley section where the embankment is highest, and this should be subject to further assessment.

In addition to the above, foundation grouting and dental treatment to seal any open voids or joints if these are encountered (noting that none have been identified to-date), or alternatively an upstream clay blanket, such as those constructed for the Kerikeri dams, may be required to limit foundation seepage through jointed basalt beneath the dam.

6.3.2 Abutment Treatment

The depth to unweathered rock on the left abutment is in the order of 3m to 4m, and whilst this would be relatively straightforward to excavate, such an undercut may not be required given the lower embankment height as the loads imposed on the ground are smaller and the potential leakage path is longer. This also applies to the right abutment where the depth to rock appears much deeper and may not be feasible to excavate down to.

Dam fill could then be keyed in and compacted against the abutments. If potentially dispersive or high permeability soils are encountered in the abutments, it is envisaged this will be removed completely to the underlying cohesive horizon and benched into the abutment.

6.4 Reservoir and Abutment Leakage

The site geology includes stratigraphy with the potential for high permeability layers, such as basaltic, ash, tephra and scoria. Potential leakage beneath the reservoir or beneath the dam foundation or around the abutments, with associated erosion of soil through open joints within the underlying rock, is therefore, considered as potentially the most significant geotechnical issue associated with the reservoir.

Natural springs observed within the reservoir basin, some emerging some distance downstream (200m to 300m north-east) on the true-left and slightly above stream level at the dam centreline, indicate the potential for existing flow pathways within the underlying rock. These features may require local drainage and monitoring, or upstream lining if the source can be identified.

Operation of the Kerikeri irrigation dams on similar geology indicate that seepage is not excessive but does emerge beyond a ridge in the northern dam. Similar seepage could be expected here on the around the abutments, albeit that the seepage paths are reasonably long. The strong stream flows observed on-site suggest that stream losses are not significant and may relate to the upper soils within the valley providing a low-permeability capping, i.e. natural lining.

Further work is required during detailed design to better understand the site hydrogeology and how groundwater will flow through the site as a result of the proposed reservoir. Seepage through the foundation and around the abutments should be a key focus area for this work.

If required, options such as grouting beneath the embankment and lining sections of the reservoir, or partial lining with natural clay or a geomembrane, could be considered should future investigation and assessment indicate treatment is warranted.

6.5 Borrow Area Fill Suitability

Preliminary design indicates the following earthwork quantities will be required to construct the reservoir:

- Fill for dam embankment: 143,270m^3.
- Excavation of unsuitable in dam foundation: 19,600m^3.
- Excavation for auxiliary spillway: 92,610m^3.
- Balance of excavation from borrow area: 50,660m^3 plus additional from unsuitable and topsoil strip.

The earthworks quantities were estimated with following assumptions:

- Excavations for the dam foundation assume a nominal 0.5m strip plus 3m deep keyway within the main valley.
- No material from the foundation excavation is reused as dam fill.
- Volume of topsoil from auxiliary spillway excavation is ignored.
- No bulking or compaction factors applied.

Based on inspection of materials encountered within test pits and by the CPTs, and experience working with similar residual volcanics, the silt and clay in the potential borrow area and spillway excavation appear generally suitable for use earthfill in dam construction as it has a high fines content and plasticity, is not known to be dispersive, generally has good strength properties and will result in a low-permeability material once recompacted. This should be subject to laboratory testing during detailed design to confirm. The soils may be sensitive to moisture changes during placement and compaction that will require an experienced contractor to achieve design requirements. Gravel and boulder-sized inclusions, such as those identified in some of the test pits a few meters below ground level, will also need to be considered.

Bulk fill should be constructed from cohesive material with a compacted permeability no greater than 10^{-7}m/s and likely orders of magnitude less. Once compacted, the earthfill should perform well in terms of low-permeability and shear strength as outlined above. Earthworks consent is likely to be required for sourcing fill from on-site sources.

Specialist filter material for internal chimney and blanket drains, may need to be specifically processed and imported from a nearby quarry to suit the dam fill grading. Riprap for upstream wave protection should be able to be sourced from within the reservoir or nearby.

6.6 Seepage and Internal Erosion

Seepage flow through the embankment itself is anticipated to be minor owing to the low-permeability silt and clay fill proposed. As outlined above, defensive measures such as chimney, blanket and toe drains, and abutment drains beneath the downstream fill shoulder flanking the abutments designed to comply with no-erosion filter criteria will be incorporated into the design.

A critical element for seepage design is the low-level outlet pipe penetration. The stiffness contrast between the pipe and the surrounding soil leads to the potential for differential movement, and the challenges associated with recompacting fill adjacent to pipe haunch zones.

A number of defensive design features are provided for the outlet pipe including:

- Concrete encasement of the conduit, to eliminate the potential for un-compacted fill within the pipe haunch zone.
- Sloped sides to the concrete encasement, to minimise the potential for cracking in the event of dam fill settlement.
- Inclusion of a filter compatible drainage surround to the culvert.
- De-pressurisation of the culvert once it has finished functioning as the construction diversion. Filling and emptying the reservoir will be by means of a smaller pressurised pipe suspended within the main concrete pipe.

6.7 Spillway

The preliminary design incorporates both a service and auxiliary spillway as shown on RILEY Dwg: 200240-102. During detailed design, consideration will be given to located the service spillway on either the left or right abutments, or potentially incorporating this function within the auxiliary spillway.

The service spillway will be designed to have a very low-risk of erosion for the more frequent flood events; the auxiliary spillway, potentially in conjunction with the service spillway, will be designed to accommodate the probable maximum flood (PMF) events possible at the site.

We note that some erosion repair work may be required after extreme flood events when the auxiliary spillway operates, but not such that would allow the uncontrolled release of the reservoir. Both spillways would discharge into the stream downstream of the dam.

The concept design shows the auxiliary spillway excavated into natural ground beyond the right abutment. TP7 located within the proposed auxiliary spillway encountered very stiff silt and clay to the target depth of 5m. The requirement for and extent of erosion protection measures, such as energy dissipation structures or riprap will be considered as part of detailed design.

7.0 Further Assessment

Information retrieved from the geotechnical investigations to-date have provided information on the shallow geology within the dam embankment footprint, borrow area and across the site generally.

Six machine boreholes are proposed, along the dam footprint, to investigate the continuity of materials to a much greater depth. In-situ permeability (Lugeon/packer) testing will be undertaken within these boreholes. Following completion of these, the ground model will be reviewed and updated to inform detailed design.

Bulk soil samples have been retained from the test pits. These, in combination with selected samples from the machine boreholes, will be delivered to an IANZ soil laboratory for them to perform a suite of tests to better understand material characteristics and behaviour. Such information will be used to inform detailed design of the reservoir including material suitability for dam construction, strength parameters, and construction processes. A suite of laboratory testing will be confirmed following a review of the ground model after the completion of the boreholes. Testing will include Atterberg limits, hydrometer grading curves, compaction testing and other tests required for design of the dam.

8.0 Limitation

This report has been prepared solely for the benefit of the Te Tai Tokerau Water Trust as our client with respect to the brief. The reliance by other parties on the information or opinions contained in the report shall, without our prior review and agreement in writing, be at such parties' sole risk.

Recommendations and opinions in this report are based on data from limited test positions. The nature and continuity of subsoil conditions away from the test positions are inferred, and it must be appreciated that actual conditions could vary considerably from the assumed model.

APPENDIX A

Test Pit Logs

RILEY CONSULTANTS
Engineers and Geologists

RILEY Consultants Ltd
Level 2, 22 Moorhouse Ave
Addington, Christchurch, 8024
Tel: +64 3 379 4402
Fax:

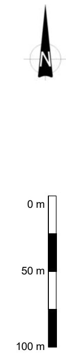
INSPECTION PIT LOG

Project: Northland Irrigation Scheme	Location: MN06 - Ohaeawai	Hole position: RILEY Dwg: 200249-102	No.: **TP01**
Job No.: 200240	Start Date: 07-05-20 Finish Date: 07-05-20	Ground Level (LINZ): 204.2m	Co-Ordinates (NZTM2000): E 1,677,373.0 N 6,087,757.0
Client: Te Tai Tokerau Water Trust	Hole Depth: 4.00 m		Sheet: 1 of 1

Elevation (m LINZ) +204.20	Depth (m)	Geological Description (refer to separate Geotechnical and Geological Information sheet for further information)	Legend	Weathering RS CW HW MW SW UW	Field Strength Soil | Rock VS/VL S/L F/MD St/D VSt/VD H/EW VW W MS S VS ES	Defect Description (type, orientation, spacing, roughness, persistence aperture, infilling etc)	Groundwater	Samples	In-situ / Lab Testing
+204.00	0.20	TOPSOIL							
+202.60	1.60	SILT with minor clay; dark reddish brown. Stiff, moist, slightly plastic [RESIDUALLY WEATHERED BASALT] 0.50m Grades to trace cobbles to boulders, highly weathered basalt, angular to subrounded 1.00m Grades to some clay, slightly to moderately plastic							P= 66 kPa R= 13 kPa P= 59 kPa R= 19 kPa P= 219 kPa
+202.20	2.00	Clayey SILT, brown with red and pink inclusions. Firm, wet, moderately plastic							
+200.20	4.00	SILT with minor clay; dark pink with white and orange inclusions. Firm to stiff, wet, slightly plastic 3.00m Grades to trace clay, trace cobbles to boulders, highly weathered basalt, angular; purple, orange, brown and pink.					▼		P= 63 kPa R= 31 kPa P= 31 kPa R= 32.5 kPa
		Sharp rock interface. Basalt lava flow EOH @ 4.00 m							

SKETCH/PHOTOS:

SITE MAP



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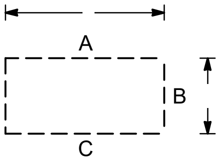
Shoring/Support:
Stability:



SAMPLES AND TESTING
- ● Grab Sample (Disturbed)
- Bulk Sample (Disturbed)
- ▼ Scala Penetrometer (blows/50mm)
- ∨ Insitu Vane Shear Strength (kPa): P: Peak; R: Residual; UTP: Unable to penetrate
- Lab Testing: PSD: particle size dist. OMC: optimum moisture cont.; MDD: max dry density; Disp: dispersivity

GROUNDWATER
- ☐ None
- ☐ Slow Seep
- ☒ Rapid Inflow
- ▼ Water Strike
- Water Rise
- ▽ Time (minutes)

TERMINATION DUE TO
- ☐ Target depth
- ☐ Collapse
- ☒ Refusal
- ☐ Machine limit

Remarks

All dimensions in metres Scale 1:50	Contractor: Far North Roading Ltd	Rig/Plant Used: Machine Excavator (15 tonne)	Logged by: AHL	Checked by: SRO

RILEY CONSULTANTS Engineers and Geologists

RILEY Consultants Ltd
Level 2, 22 Moorhouse Ave
Addington, Christchurch, 8024
Tel: +64 3 379 4402
Fax:

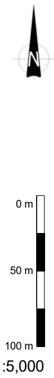
INSPECTION PIT LOG

Project: Northland Irrigation Scheme	Location: MN06 - Ohaeawai	Hole position: RILEY Dwg: 200249-102		No.: **TP02**
Job No.: 200240	Start Date: 07-05-20 Finish Date: 07-05-20	Ground Level (LINZ): 203.2m	Co-Ordinates (NZTM2000): E 1,677,666.2 N 6,087,912.9	
Client: Te Tai Tokerau Water Trust	Hole Depth: 3.90 m			Sheet: 1 of 1

Elevation (m LINZ)	Depth (m)	Geological Description (refer to separate Geotechnical and Geological Information sheet for further information)	Legend	Weathering RS CW HW MW SW UW	Field Strength Soil | Rock VS/VL S/L F/MD St/D VSt/VD H/EW VW W MS S VS ES	Defect Description (type, orientation, spacing, roughness, persistence aperture, infilling etc)	Groundwater	Samples	In-situ / Lab Testing
+203.20									
+203.10	0.10	TOPSOIL							
+202.40	0.80	SILT with minor clay and trace cobbles to boulders; dark reddish brown. Very stiff, moist, slightly plastic; cobbles to boulders, highly weathered basalt, angular to subrounded [RESIDUALLY WEATHERED BASALT]							P= 219 kPa
+199.30	3.90	SILT with minor clay; pinkish grey with white inclusions. Very stiff, moist, slightly plastic 1.50m Grades to some clay 2.50m Grades to minor clay, trace coarse sand; pinkish grey with light orange inclusions					▼		P= 172 kPa R= 63 kPa P= 113 kPa R= 16 kPa P= 63 kPa R= 19 kPa P= 75 kPa R= 19 kPa P= UTP kPa
		Sharp rock interface. Basalt lava flow. EOH @ 3.90 m							

SKETCH/PHOTOS:

SITE MAP



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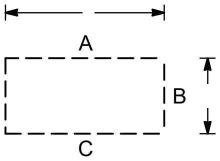
Shoring/Support:
Stability:



SAMPLES AND TESTING
- ● Grab Sample (Disturbed)
- Bulk Sample (Disturbed)
- ▼ Scala Penetrometer (blows/50mm)
- ∨ Insitu Vane Shear Strength (kPa): P: Peak; R: Residual; UTP: Unable to penetrate
- Lab Testing: PSD: particle size dist. OMC: optimum moisture cont.; MDD: max dry density; Disp: dispersivity

GROUNDWATER
- ☐ None
- ☐ Slow Seep
- ☒ Rapid Inflow
- ▼ Water Strike
- Water Rise
- Time (minutes)

TERMINATION DUE TO
- ☐ Target depth
- ☐ Collapse
- ☒ Refusal
- ☐ Machine limit

Remarks

All dimensions in metres Scale 1:50	Contractor: Far North Roading Ltd	Rig/Plant Used: Machine Excavator (15 tonne)	Logged by: AHL	Checked by: SRO

RILEY AGS 3_1 NZ LIB 13.GLB Log RILEY CHCH TP 200240 MN06 TPS.GPJ <<DrawingFile>> 13/08/2020 15:51 Produced by gINT Professional

RILEY Consultants Ltd
Level 2, 22 Moorhouse Ave
Addington, Christchurch, 8024
Tel: +64 3 379 4402
Fax:

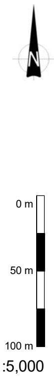
INSPECTION PIT LOG

Project: Northland Irrigation Scheme	Location: MN06 - Ohaeawai		Hole position: RILEY Dwg: 200249-102	No.: **TP03**
Job No.: 200240	Start Date: 07-05-20 Finish Date: 07-05-20	Ground Level (LINZ): 203.1m	Co-Ordinates (NZTM2000): E 1,677,733.0 N 6,087,876.0	
Client: Te Tai Tokerau Water Trust	Hole Depth: 5.50 m			Sheet: 1 of 1

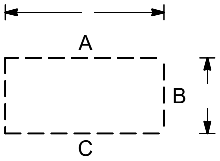
Elevation (m LINZ)	Depth (m)	Geological Description (refer to separate Geotechnical and Geological Information sheet for further information)	Legend	Weathering RS CW HW MW SW UW	Field Strength Soil | Rock VS/VL S/L F/MD St/D VSt/VD H/EW VW W MS S VS ES	Defect Description (type, orientation, spacing, roughness, persistence aperture, infilling etc)	Groundwater	Samples	In-situ / Lab Testing
+203.10									
+203.00	0.10	TOPSOIL							
+202.50	0.60	SILT with minor clay, minor gravel to cobbles; reddish brown. Very stiff moist, slightly plastic; gravel and cobbles, highly weathered basalt, angular to subrounded [RESIDUALLY WEATHERED BASALT]							P= 219 kPa
	1								P= 97 kPa R= 22 kPa
		Clayey SILT; purplish grey with brown and orange mixed. Firm; moist to wet; slightly to moderately plastic 1.00m Grades to purplish grey brown							
	2								P= 94 kPa R= 16 kPa
+200.60	2.50								P= UTP kPa
	3	SILT, trace sand, trace cobbles and boulders; pink and orange mixed. Very stiff, wet, non plastic; sand, coarse, cobbles and boulders, highly to completely weathered basalt, angular to subround							P= 172 kPa R= 56 kPa
	4	4.00m Grades to minor sand, trace clay; pink, orange and light yellow mixed. Wet to saturated, non to slightly plastic					▼		
	5								
+197.60	5.50	Highly weathered basalt. Can still be excavated. EOH @ 5.50 m							

SKETCH/PHOTO

SITE MAP



Shoring/Support:
Stability:



SAMPLES AND TESTING
- ● Grab Sample (Disturbed)
- Bulk Sample (Disturbed)
- ▼ Scala Penetrometer (blows/50mm)
- ∨ Insitu Vane Shear Strength (kPa): P: Peak; R: Residual; UTP: Unable to penetrate
- Lab Testing: PSD: particle size dist. OMC: optimum moisture cont.; MDD: max dry density; Disp: dispersivity

GROUNDWATER
- ☐ None
- ☒ Slow Seep
- ☐ Rapid Inflow
- ▼ Water Strike
- Water Rise
- ▽ Time (minutes)

TERMINATION DUE TO
- ☒ Target depth
- ☐ Collapse
- ☐ Refusal
- ☐ Machine limit

Remarks

All dimensions in metres Scale 1:50	Contractor: Far North Roading Ltd	Rig/Plant Used: Machine Excavator (15 tonne)	Logged by: AHL	Checked by: SRO

RILEY CONSULTANTS
Engineers and Geologists

RILEY Consultants Ltd
Level 2, 22 Moorhouse Ave
Addington, Christchurch, 8024
Tel: +64 3 379 4402
Fax:

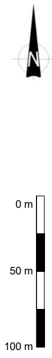
INSPECTION PIT LOG

Project: Northland Irrigation Scheme	Location: MN06 - Ohaeawai	Hole position: RILEY Dwg: 200249-102	No.: **TP04**
Job No.: 200240	Start Date: 07-05-20 Finish Date: 07-05-20	Ground Level (LINZ): 200.4m	Co-Ordinates (NZTM2000): E 1,677,793.0 N 6,087,833.0
Client: Te Tai Tokerau Water Trust	Hole Depth: 2.00 m		Sheet: 1 of 1

Elevation (m LINZ)	Depth (m)	Geological Description (refer to separate Geotechnical and Geological Information sheet for further information)	Legend	Weathering RS CW HW MW SW UW	Field Strength Soil | Rock VS/VL S/L F/MD St/D VSt/VD H/EW VW W MS S VS ES	Defect Description (type, orientation, spacing, roughness, persistence aperture, infilling etc)	Groundwater	Samples	In-situ / Lab Testing
+200.40									
+200.20	0.20	TOPSOIL							
+200.00	0.40								
		SILT, minor clay; dark reddish brown. Stiff, moist, slightly plastic [RESIDUALLY WEATHERED BASALT]							P= 219 kPa
	1	SILT with clay and minor gravels to boulders; pinkish red with orange inclusions. Very stiff, moist, non to slightly plastic; gravels, coarse, boulders, highly weathered basalt, angular to subangular							P= 219 kPa
+199.20	1.20								
		COBBLES with silty matrix; red, brown and pink. Dense; cobbles, angular to subangular							P= UTP kPa
+198.40	2.00	Sharp rock interface. Basalt Lava Flow EOH @ 2.00 m							
	3								
	4								
	5								

SKETCH/PHOTOS:

SITE MAP



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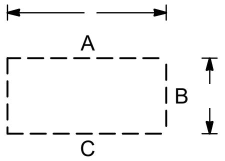
Shoring/Support:
Stability:



SAMPLES AND TESTING
● Grab Sample (Disturbed)
Bulk Sample (Disturbed)
▼ Scala Penetrometer (blows/50mm)
∨ Insitu Vane Shear Strength (kPa):
P: Peak; R: Residual;
UTP: Unable to penetrate
Lab Testing: PSD: particle size dist.
OMC: optimum moisture cont.; MDD: max dry density; Disp: dispersivity

GROUNDWATER
☒ None
☐ Slow Seep
☐ Rapid Inflow
Water Strike
Water Rise
Time (minutes)

TERMINATION DUE TO
☐ Target depth ☐ Collapse
☒ Refusal ☐ Machine limit

Remarks

All dimensions in metres Scale 1:50	Contractor: Far North Roading Ltd	Rig/Plant Used: Machine Excavator (15 tonne)	Logged by: AHL	Checked by: SRO

RILEY AGS 3_1 NZ LIB 13.GLB Log RILEY CHCH TP 200240 MN06 TPS.GPJ <<DrawingFile>> 13/08/2020 15:51 Produced by gINT Professional

RILEY Consultants Ltd
Level 2, 22 Moorhouse Ave
Addington, Christchurch, 8024
Tel: +64 3 379 4402
Fax:

INSPECTION PIT LOG

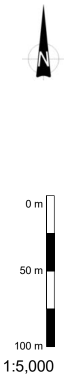
Project: Northland Irrigation Scheme	Location: MN06 - Ohaeawai	Hole position: RILEY Dwg: 200249-102	No.: **TP05**
Job No.: 200240	Start Date: 07-05-20 Finish Date: 07-05-20	Ground Level (LINZ): 188.7m	Co-Ordinates (NZTM2000): E 1,677,840.0 N 6,087,772.0
Client: Te Tai Tokerau Water Trust	Hole Depth: 5.50 m		Sheet: 1 of 1

Elevation (m LINZ)	Depth (m)	Geological Description (refer to separate Geotechnical and Geological Information sheet for further information)	Legend	Weathering	Field Strength Soil | Rock	Defect Description (type, orientation, spacing, roughness, persistence aperture, infilling etc)	Groundwater	Samples	In-situ / Lab Testing
+188.70									
+188.60	0.10	TOPSOIL							
		SILT; minor clay; dark reddish brown. Very stiff; moist; slightly plastic [RESIDUALLY WEATHERED BASALT]							P= 172 kPa R= 50 kPa
+187.90	0.80	0.50m Grades to trace cobbles to boulders, highly weathered basalt, subangular to subrounded							
	1	Clayey SILT; reddish brown with grey and pinkish white inclusions. Very stiff, moist, moderately plastic							P= 94 kPa R= 16 kPa
+187.20	1.50	1.30m Grades to orangish brown with light yellow specks							
	2	SILT with trace clay; light orange. Firm, wet, slightly plastic							P= 50 kPa R= 16 kPa
+186.20	2.50								P= 38 kPa R= 16 kPa
	3	SILT with trace clay and trace sand; pale pinkish grey with orange and white inclusions. Firm to stiff; wet to saturated, non to slightly plastic							P= 75 kPa R= 13 kPa
									P= 91 kPa R= 25 kPa
	4	4.00m Grades to purplish grey, saturated					▼		
+183.70	5 5.00	Highly weathered, black with orange staining, BASALT; strong. Recovered as cobbles and boulders, angular [BASALT LAVA FLOW]							
+183.20	5.50	EOH @ 5.50 m							

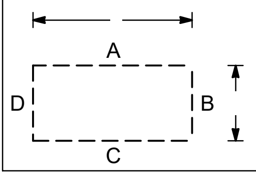
Weathering: RS CW HW MW SW UW
Field Strength: VS/VL S/L F/MD St/D VSt/VD H/EW VW W MS S VS ES

SKETCH/PHOTO

SITE MAP



Shoring/Support:
Stability:



SAMPLES AND TESTING
- ● Grab Sample (Disturbed)
- Bulk Sample (Disturbed)
- ▼ Scala Penetrometer (blows/50mm)
- ∨ Insitu Vane Shear Strength (kPa): P: Peak; R: Residual; UTP: Unable to penetrate
- Lab Testing: PSD: particle size dist. OMC: optimum moisture cont.; MDD: max dry density; Disp: dispersivity

GROUNDWATER
- ☐ None
- ☒ Slow Seep
- ☐ Rapid Inflow
- ▼ Water Strike
- Water Rise
- ▽ Time (minutes)

TERMINATION DUE TO
- ☐ Target depth
- ☐ Collapse
- ☒ Refusal
- ☐ Machine limit

Remarks

All dimensions in metres Scale 1:50	Contractor: Far North Roading Ltd	Rig/Plant Used: Machine Excavator (15 tonne)	Logged by: AHL	Checked by: SRO

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RILEY Consultants Ltd
Level 2, 22 Moorhouse Ave
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Tel: +64 3 379 4402
Fax:

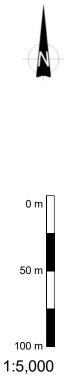
INSPECTION PIT LOG

Project: Northland Irrigation Scheme		Location: MN06 - Ohaeawai	Hole position: RILEY Dwg: 200249-102	No.: **TP06**
Job No.: 200240	Start Date: 07-05-20 Finish Date: 07-05-20	Ground Level (LINZ): 186.6m	Co-Ordinates (NZTM2000): E 1,677,875.0 N 6,087,771.0	
Client: Te Tai Tokerau Water Trust		Hole Depth: 4.00 m		Sheet: 1 of 1

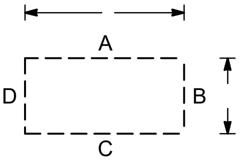
Elevation (m LINZ) +186.60	Depth (m)	Geological Description (refer to separate Geotechnical and Geological Information sheet for further information)	Legend	Weathering RS CW HW MW SW UW	Field Strength Soil / Rock VS/VL S/L F/MD St/D VSt/VD H/EW VW W MS S VS ES	Defect Description (type, orientation, spacing, roughness, persistence aperture, infilling etc)	Groundwater	Samples	In-situ / Lab Testing
+186.40	0.20	TOPSOIL							
+185.40	1.20	SILT, minor clay; dark reddish brown. Very stiff, moist, slightly plastic [RESIDUALLY WEATHERED BASALT]	×						P= 175 kPa R= 63 kPa
+184.20	2.40	SILT with some clay; pinkish grey with light yellow specks. Firm to stiff, wet, slightly to moderately plastic	×						P= 56 kPa R= 34 kPa P= 159 kPa R= 9 kPa
+183.10	3.50	SILT with minor clay and minor cobbles to boulders, trace sand; pinksih grey with orange and black staining. Very stiff, wet, non to slightly plastic; cobbles and boulders, highly to completely weathered basalt; sand, coarse	×				▼		P= UTP kPa
+182.60	4.00	Highly weathered BASALT; strong. Recovered as cobbles and boulders, angular to subangular; orange, black and brown [BASALT LAVA FLOW]							
		EOH @ 4.00 m							

SKETCH/PHOTOS:

SITE MAP



Shoring/Support:
Stability:



SAMPLES AND TESTING
- ● Grab Sample (Disturbed)
- Bulk Sample (Disturbed)
- ▼ Scala Penetrometer (blows/50mm)
- ✓ Insitu Vane Shear Strength (kPa): P: Peak; R: Residual; UTP: Unable to penetrate
- Lab Testing: PSD: particle size dist. OMC: optimum moisture cont.; MDD: max dry density; Disp: dispersivity

GROUNDWATER
- ☐ None
- ☒ Slow Seep
- ☐ Rapid Inflow
- ▼ Water Strike
- Water Rise
- ▽ Time (minutes)

TERMINATION DUE TO
- ☐ Target depth
- ☐ Collapse
- ☒ Refusal
- ☐ Machine limit

Remarks

All dimensions in metres Scale 1:50	Contractor: Far North Roading Ltd	Rig/Plant Used: Machine Excavator (15 tonne)	Logged by: AHL	Checked by: SRO

RILEY Consultants Ltd
Level 2, 22 Moorhouse Ave
Addington, Christchurch, 8024
Tel: +64 3 379 4402
Fax:

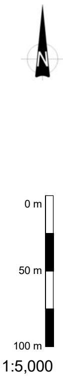
INSPECTION PIT LOG

Project: Northland Irrigation Scheme	Location: MN06 - Ohaeawai		Hole position: RILEY Dwg: 200249-102	No.: **TP07**
Job No.: 200240	Start Date: 07-05-20 Finish Date: 07-05-20	Ground Level (LINZ): 201.4m	Co-Ordinates (NZTM2000): E 1,677,961.8 N 6,087,790.2	
Client: Te Tai Tokerau Water Trust	Hole Depth: 4.50 m			Sheet: 1 of 1

Elevation (m LINZ)	Depth (m)	Geological Description (refer to separate Geotechnical and Geological Information sheet for further information)	Legend	Weathering RS CW HW MW SW UW	Field Strength Soil VS/VL S/L F/MD St/D VSt/VD H/EW VW W MS S VS ES Rock	Defect Description (type, orientation, spacing, roughness, persistence aperture, infilling etc)	Groundwater	Samples	In-situ / Lab Testing
+201.40									
+201.30	0.10	TOPSOIL							
+200.90	0.50	SILT with minor clay; brown. Stiff, moist, slightly plastic [RESIDUALLY WEATHERED BASALT]							⌄ P= 125 kPa R= 22 kPa
	1	Clayey SILT; light pinkish grey. Very stiff; moist; moderately plastic							⌄ P= 219 kPa
+199.90	1.50	Silty CLAY; light pinkish grey. Very stiff, moist, moderately plastic							⌄ P= 219 kPa
+199.40	2.00	SILT with some clay; light pinkish orange. Very stiff, moist, slightly plastic							⌄ P= 188 kPa R= 63 kPa
	3	3.00m Grades to minor clay, pinkish grey with white specks, moist to wet							⌄ P= 219 kPa
	4	4.00m Grades to trace gravel, fine to coarse, angular to subangular, highly weathered basalt							
+196.90	4.50	EOH @ 4.50 m							
	5								

SKETCH/PHOTOS:

SITE MAP



Shoring/Support:
Stability:

A
B
C
D

SAMPLES AND TESTING
● Grab Sample (Disturbed)
Bulk Sample (Disturbed)
▼ Scala Penetrometer (blows/50mm)
⌄ Insitu Vane Shear Strength (kPa): P: Peak; R: Residual; UTP: Unable to penetrate
Lab Testing: PSD: particle size dist. OMC: optimum moisture cont.; MDD: max dry density; Disp: dispersivity

GROUNDWATER
☒ None
☐ Slow Seep
☐ Rapid Inflow
Water Strike
Water Rise
Time (minutes)

TERMINATION DUE TO
☐ Target depth
☐ Collapse
☐ Refusal
☒ Machine limit

Remarks

All dimensions in metres Scale 1:50	Contractor: Far North Roading Ltd	Rig/Plant Used: Machine Excavator (15 tonne)	Logged by: AHL	Checked by: SRO

RILEY CONSULTANTS
Engineers and Geologists

RILEY Consultants Ltd
Level 2, 22 Moorhouse Ave
Addington, Christchurch, 8024
Tel: +64 3 379 4402
Fax:

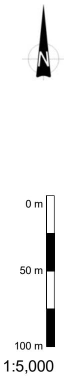
INSPECTION PIT LOG

Project: Northland Irrigation Scheme
Location: MN06 - Ohaeawai
Hole position: RILEY Dwg: 200249-102
No.: **TP08**
Job No.: 200240
Start Date: 08-05-20
Finish Date: 08-05-20
Ground Level (LINZ): 197.9m
Co-Ordinates (NZTM2000): E 1,677,852.0 N 6,087,631.0
Client: Te Tai Tokerau Water Trust
Hole Depth: 5.50 m
Sheet: 1 of 1

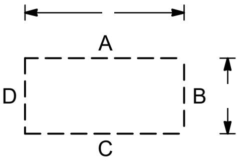
Elevation (m LINZ) +197.90	Depth (m)	Geological Description (refer to separate Geotechnical and Geological Information sheet for further information)	Legend	Weathering RS CW HW MW SW UW	Field Strength Soil | Rock VS/VL S/L F/MD St/D VSt/VD H/EW VW W MS S VS ES	Defect Description (type, orientation, spacing, roughness, persistence aperture, infilling etc)	Groundwater	Samples	In-situ / Lab Testing
+197.70	0.20	TOPSOIL							
+195.40	2.50	Clayey SILT; dark reddish brown. Very stiff, moist; moderately plastic [RESIDUALLY WEATHERED BASALT]							P= 219 kPa P= 172 kPa R= 44 kPa P= 141 kPa R= 56 kPa P= 134 kPa R= 63 kPa
+194.90	3.00	SILT with minor clay; dark orangish reddish brown. Very stiff, moist, slightly plastic							
+192.40	5.50	SILT with minor clay and cobbles to boulders; dark reddish brown with black inclusions. Very stiff, moist, slightly plastic; cobbles to boulders, highly weathered basalt, angular to sub rounded 3.50m Grades to wet							
		EOH @ 5.50 m							

SKETCH/PHOTO

SITE MAP



Shoring/Support:
Stability:



SAMPLES AND TESTING
● Grab Sample (Disturbed)
Bulk Sample (Disturbed)
▼ Scala Penetrometer (blows/50mm)
﹀ Insitu Vane Shear Strength (kPa):
P: Peak; R: Residual;
UTP: Unable to penetrate
Lab Testing: PSD: particle size dist.
OMC: optimum moisture cont.; MDD: max dry density; Disp: dispersivity

GROUNDWATER
☒ None
☐ Slow Seep
☐ Rapid Inflow
Water Strike
Water Rise
Time (minutes)

TERMINATION DUE TO
☐ Target depth
☐ Collapse
☐ Refusal
☒ Machine limit

Remarks

All dimensions in metres
Scale 1:50
Contractor: Far North Roading Ltd
Rig/Plant Used: Machine Excavator (15 tonne)
Logged by: AHL
Checked by: SRO

RILEY CONSULTANTS
Engineers and Geologists

RILEY Consultants Ltd
Level 2, 22 Moorhouse Ave
Addington, Christchurch, 8024
Tel: +64 3 379 4402
Fax:

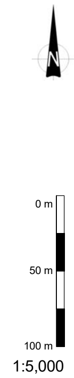
INSPECTION PIT LOG

Project: Northland Irrigation Scheme		Location: MN06 - Ohaeawai	Hole position: RILEY Dwg: 200249-102	No.: **TP09**
Job No.: 200240	Start Date: 08-05-20 Finish Date: 08-05-20	Ground Level (LINZ): 202.7m	Co-Ordinates (NZTM2000): E 1,677,664.7 N 6,087,685.3	
Client: Te Tai Tokerau Water Trust		Hole Depth: 4.10 m		Sheet: 1 of 1

Elevation (m LINZ) +202.70	Depth (m)	Geological Description (refer to separate Geotechnical and Geological Information sheet for further information)	Legend	Weathering RS CW HW MW SW UW	Field Strength Soil | Rock VS/VL S/L F/MD St/D VSt/VD H/E/W VW W MS S VS ES	Defect Description (type, orientation, spacing, roughness, persistence aperture, infilling etc)	Groundwater	Samples	In-situ / Lab Testing
+202.50	0.20	TOPSOIL							
+202.20	0.50	SILT, minor clay; light greyish brown. Very stiff, moist, slightly plastic [RESIDUALLY WEATHERED BASALT]							P= 219 kPa
+201.20	1.50	Silty CLAY; puple grey with white inclusions. Very stiff, moist, moderately plastic 1.20m Grades to some silt, moderately to highly plastic							P= 172 kPa R= 63 kPa
+199.70	3.00	SILT with some clay; dark purple grey with white inclusions. Very stiff, moist slightly plastic							P= 219 kPa P= 188 kPa R= 50 kPa P= 53 kPa R= 28 kPa
+198.90	3.80	SILT with minor clay; dark purple grey with white inclusions. Firm, moist to wet, slightly plastic							
+198.60	4.10	Completely to highly weathered, puplish grey BASALT. Very weak to weak. [BASALT LAVA FLOW]							P= UTP kPa
		EOH @ 4.10 m							

SKETCH/PHOTO

SITE MAP



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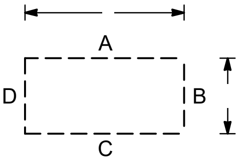
Shoring/Support:
Stability:



SAMPLES AND TESTING
- ● Grab Sample (Disturbed)
- Bulk Sample (Disturbed)
- ▼ Scala Penetrometer (blows/50mm)
- ∨ Insitu Vane Shear Strength (kPa): P: Peak; R: Residual; UTP: Unable to penetrate
- Lab Testing: PSD: particle size dist. OMC: optimum moisture cont.; MDD: max dry density; Disp: dispersivity

GROUNDWATER
- ☒ None
- ☐ Slow Seep
- ☐ Rapid Inflow
- Water Strike
- Water Rise
- Time (minutes)

TERMINATION DUE TO
- ☐ Target depth
- ☐ Collapse
- ☒ Refusal
- ☐ Machine limit

Remarks

All dimensions in metres Scale 1:50	Contractor: Far North Roading Ltd	Rig/Plant Used: Machine Excavator (15 tonne)	Logged by: AHL	Checked by: SRO

RILEY CONSULTANTS
Engineers and Geologists

RILEY Consultants Ltd
Level 2, 22 Moorhouse Ave
Addington, Christchurch, 8024
Tel: +64 3 379 4402
Fax:

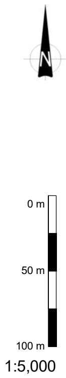
INSPECTION PIT LOG

Project: Northland Irrigation Scheme	Location: MN06 - Ohaeawai	Hole position: RILEY Dwg: 200249-102	No.: **TP09A**
Job No.: 200240	Start Date: 08-05-20 Finish Date: 08-05-20	Ground Level (LINZ): 194.2m	Co-Ordinates (NZTM2000): E 1,677,681.5 N 6,087,726.1
Client: Te Tai Tokerau Water Trust	Hole Depth: 4.10 m		Sheet: 1 of 1

Elevation (m LINZ) +194.20	Depth (m)	Geological Description (refer to separate Geotechnical and Geological Information sheet for further information)	Legend	Weathering RS CW HW MW SW UW	Field Strength Soil | Rock VS/VL S/L F/MD St/D VSt/VD H/EW VW W MS S VS ES	Defect Description (type, orientation, spacing, roughness, persistence aperture, infilling etc)	Groundwater	Samples	In-situ / Lab Testing
+194.00	0.20	TOPSOIL							
+193.70	0.50	SILT with minor clay; light brown grey. Very stiff, moist, slightly plastic [RESIDUALLY WEATHERED BASALT]							P= 172 kPa R= 50 kPa
+192.60	1.60	Silty CLAY; light brown and purple grey mixed. Very stiff, moist, moderately plastic							P= 97 kPa R= 63 kPa P= 50 kPa R= 38 kPa
+191.70	2.50	SILT with trace clay, trace gravels and trace cobbles; light brown with dark orange inclusions. Very stiff, moist to wet, non plastic; gravel and boulders, completely to highly weathered basalt							P= 100 kPa R= 20 kPa
+190.10	4.10	SILT with trace gravel and trace clay; orangish, pinkish grey with white inclusions. Very stiff, to hard, wet, non plastic [COMPLETELY WEATHERED BASALT]							P= UTP kPa
		Rock interface at 4.1m. Difficult to excavate. Recovered as completely to highly weathered basalt cobbles to boulders. EOH @ 4.10 m							

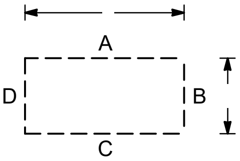
SKETCH/PHOTOS:

SITE MAP



1:5,000

Shoring/Support:
Stability:



SAMPLES AND TESTING
- ● Grab Sample (Disturbed)
- Bulk Sample (Disturbed)
- ▼ Scala Penetrometer (blows/50mm)
- ⌵ Insitu Vane Shear Strength (kPa): P: Peak; R: Residual; UTP: Unable to penetrate
- Lab Testing: PSD: particle size dist. OMC: optimum moisture cont.; MDD: max dry density; Disp: dispersivity

GROUNDWATER
- ☒ None
- ☐ Slow Seep
- ☐ Rapid Inflow
- Water Strike
- Water Rise
- Time (minutes)

TERMINATION DUE TO
- ☐ Target depth
- ☐ Collapse
- ☒ Refusal
- ☐ Machine limit

Remarks

All dimensions in metres Scale 1:50	Contractor: Far North Roading Ltd	Rig/Plant Used: Machine Excavator (15 tonne)	Logged by: AHL	Checked by: SRO

RILEY CONSULTANTS Engineers and Geologists

RILEY Consultants Ltd
Level 2, 22 Moorhouse Ave
Addington, Christchurch, 8024
Tel: +64 3 379 4402
Fax:

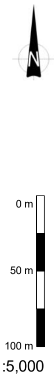
INSPECTION PIT LOG

Project: Northland Irrigation Scheme	Location: MN06 - Ohaeawai	Hole position: RILEY Dwg: 200249-102
Job No.: 200240	Start Date: 08-05-20 Finish Date: 08-05-20	Ground Level (LINZ): 202.9m
Co-Ordinates (NZTM2000): E 1,677,373.0 N 6,087,757.0	No.: **TP10**	
Client: Te Tai Tokerau Water Trust	Hole Depth: 4.60 m	Sheet: 1 of 1

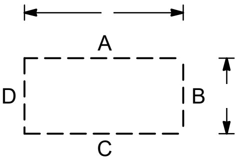
Elevation (m LINZ)	Depth (m)	Geological Description (refer to separate Geotechnical and Geological Information sheet for further information)	Legend	Weathering (RS CW HW MW SW UW)	Field Strength Soil | Rock (VS/VL S/L F/MD St/D VSt/VD H/EW VW W MS S VS ES)	Defect Description (type, orientation, spacing, roughness, persistence aperture, infilling etc)	Groundwater	Samples	In-situ / Lab Testing
+202.90									
+202.70	0.20	TOPSOIL							
+201.70	1.20	SILT with some clay; orangish brown. Very stiff to hard, moist, slightly plastic [ASH]							P= 219 kPa P= 219 kPa
+200.60	2.30	SILT with minor clay; light brown. Stiff, moist, slightly plastic							P= 97 kPa R= 50 kPa
+199.70	3.20	Clayey SILT; whitish brown. Firm, moist to wet, moderately plastic							P= 50 kPa R= 38 kPa P= 69 kPa R= 50 kPa
+198.60	4.30	SILT with trace clay and trace sand; light bluish grey with orange inclusions. Stiff, wet, non to slightly plastic 4.00m Grades to light purplish grey							P= UTP kPa
+198.30	4.60	Slightly weathered, reddish brown TUFF. Very weak to weak. Recovered as sandy GRAVEL, scoria, ash and lapilli [WELDED TUFF]							P= UTP kPa
		EOH @ 4.60 m							

SKETCH/PHOTO

SITE MAP



Shoring/Support:
Stability:



SAMPLES AND TESTING
- ● Grab Sample (Disturbed)
- Bulk Sample (Disturbed)
- ▼ Scala Penetrometer (blows/50mm)
- ﹀ Insitu Vane Shear Strength (kPa): P: Peak; R: Residual; UTP: Unable to penetrate
- Lab Testing: PSD: particle size dist. OMC: optimum moisture cont.; MDD: max dry density; Disp: dispersivity

GROUNDWATER
- ☒ None
- ☐ Slow Seep
- ☐ Rapid Inflow
- Water Strike
- Water Rise
- Time (minutes)

TERMINATION DUE TO
- ☐ Target depth
- ☐ Collapse
- ☐ Refusal
- ☒ Machine limit

Remarks

All dimensions in metres Scale 1:50	Contractor: Far North Roading Ltd	Rig/Plant Used: Machine Excavator (15 tonne)	Logged by: AHL	Checked by: SRO

RILEY AGS 3_1 NZ LIB 13.GLB Log RILEY CHCH TP 200240 MN06 TPS.GPJ <<DrawingFile>> 13/08/2020 15:52 Produced by gINT Professional

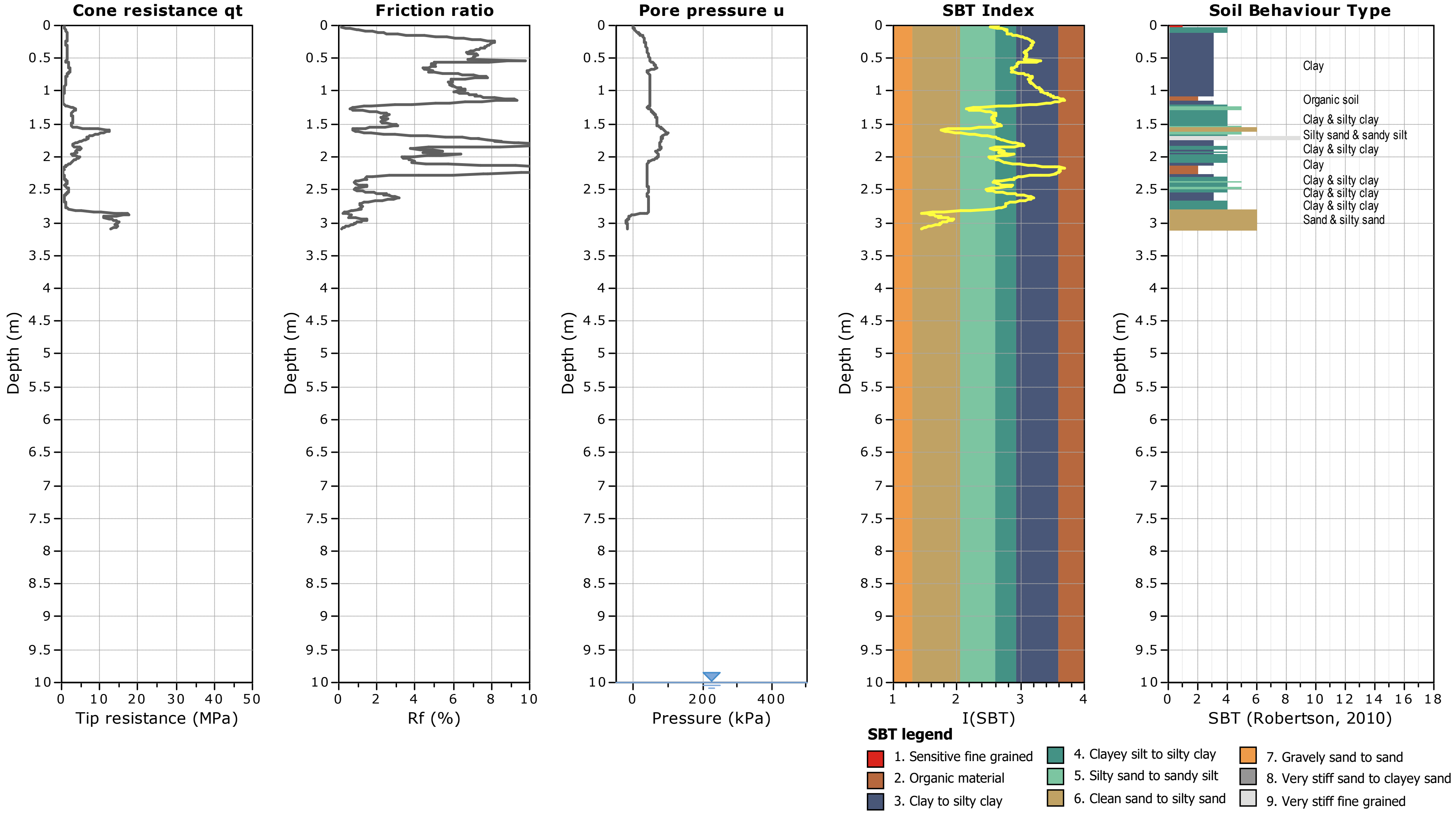
APPENDIX B

CPT Data

Riley Consultants Ltd
4 Fred Thomas Drive, Takapuna
www.riley.co.nz

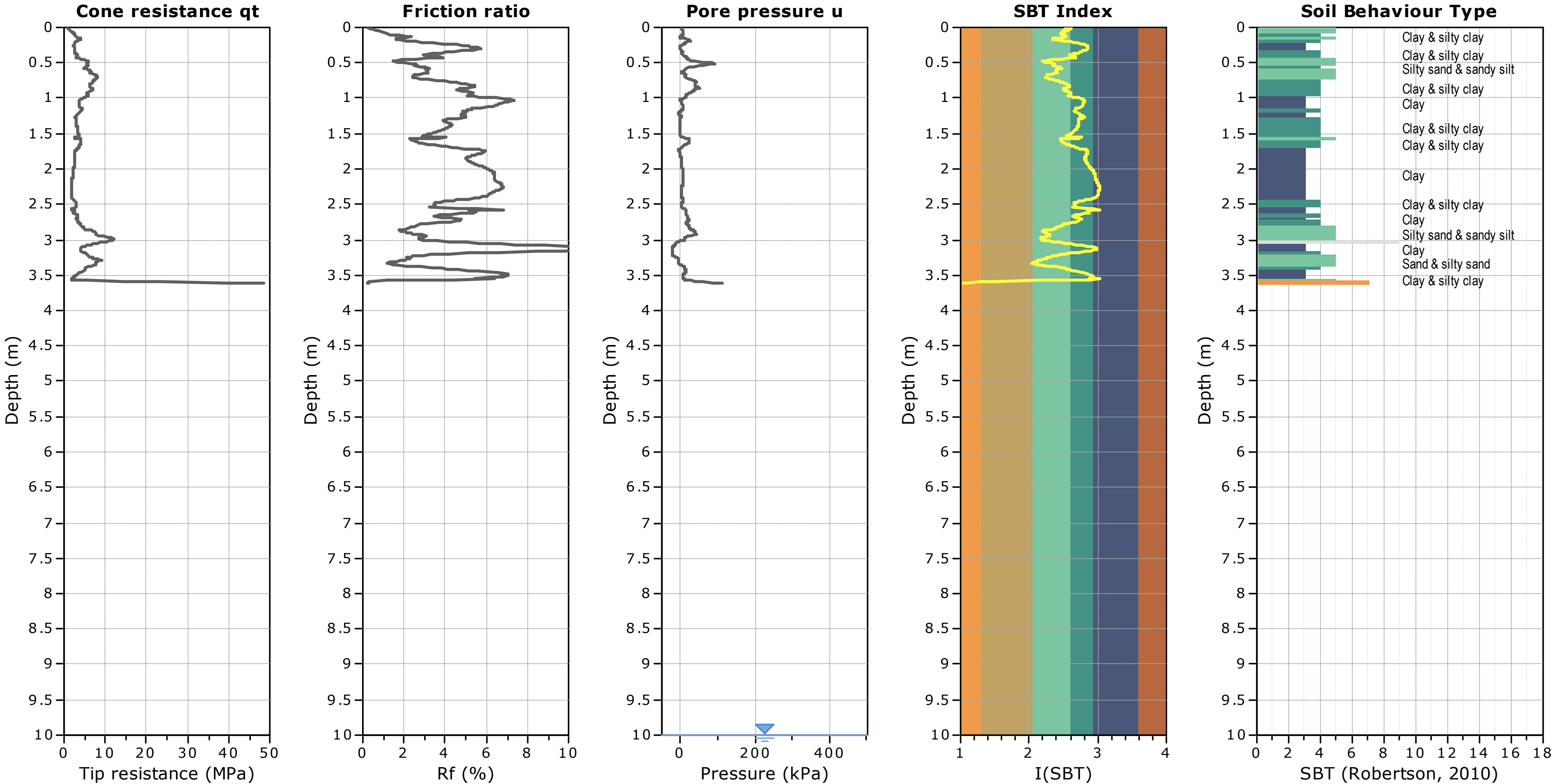
CPT: CPT01
Total depth: 3.09 m, Date: 7/05/2020
Surface Elevation: 202.20 m
Coords: X:1677545.90, Y:6087963.70
Cone Type: Nova Cone 100MPa
Cone Operator: Underground Investigation Ltd

Project: **RILEY Ref - 200240**
Location: **MN06**



Project: **RILEY Ref - 200240**
Location: **MN06**

CPT: CPT02
Total depth: 3.62 m, Date: 7/05/2020
Surface Elevation: 201.30 m
Coords: X:1677786.20, Y:6087831.90
Cone Type: Nova Cone 100MPa
Cone Operator: Underground Investigation Ltd



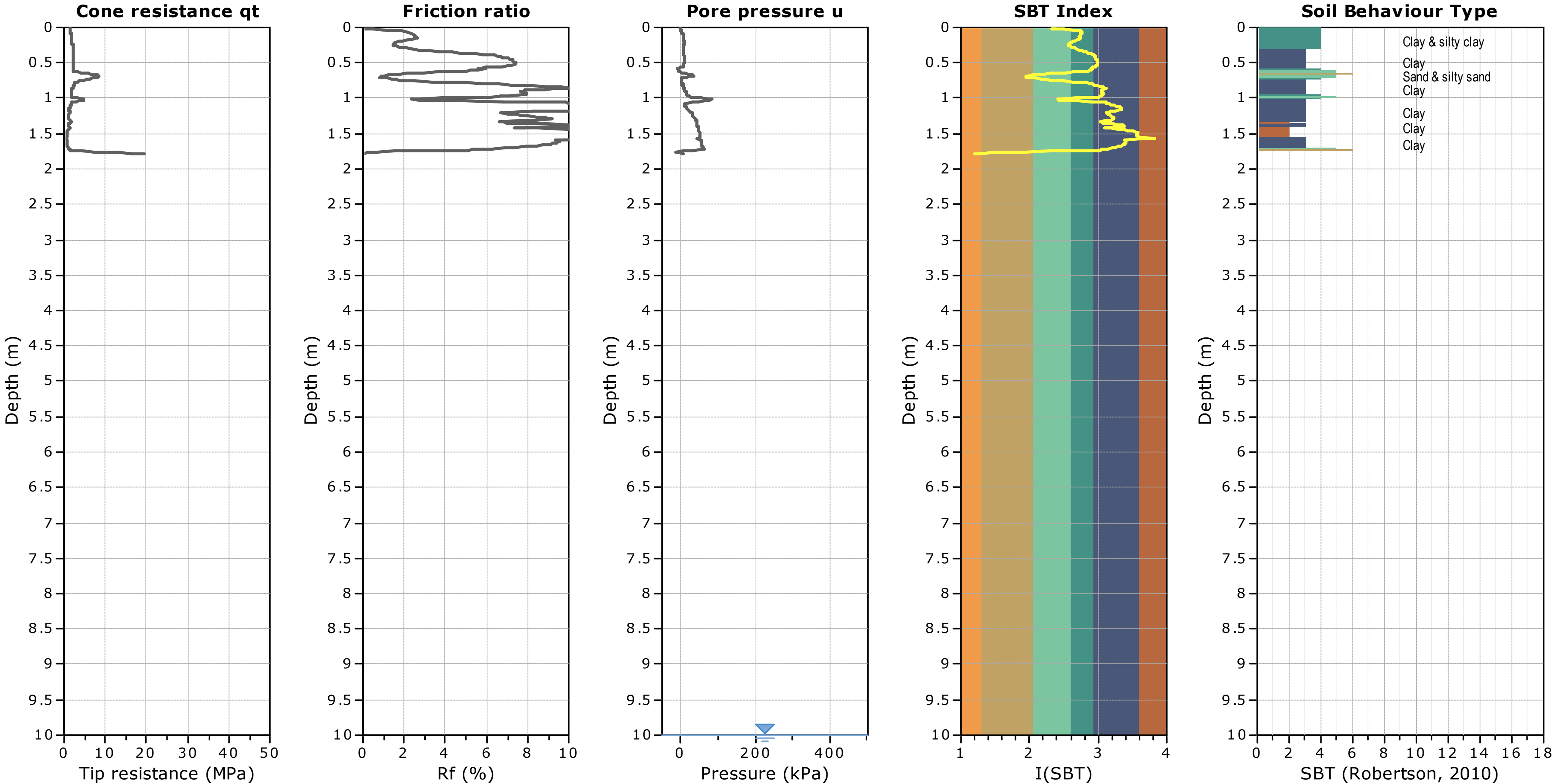
SBT legend

🟥 1. Sensitive fine grained
🟫 2. Organic material
🟦 3. Clay to silty clay
🟩 4. Clayey silt to silty clay
🟩 5. Silty sand to sandy silt
🟨 6. Clean sand to silty sand
🟧 7. Gravely sand to sand
⬜ 8. Very stiff sand to clayey sand
⬜ 9. Very stiff fine grained

Riley Consultants Ltd
4 Fred Thomas Drive, Takapuna
www.riley.co.nz

Project: **RILEY Ref - 200240**
Location: **MN06**

CPT: CPT03
Total depth: 1.79 m, Date: 7/05/2020
Surface Elevation: 187.10 m
Coords: X:1677852.60, Y:6087795.10
Cone Type: Nova Cone 100MPa
Cone Operator: Underground Investigation Ltd



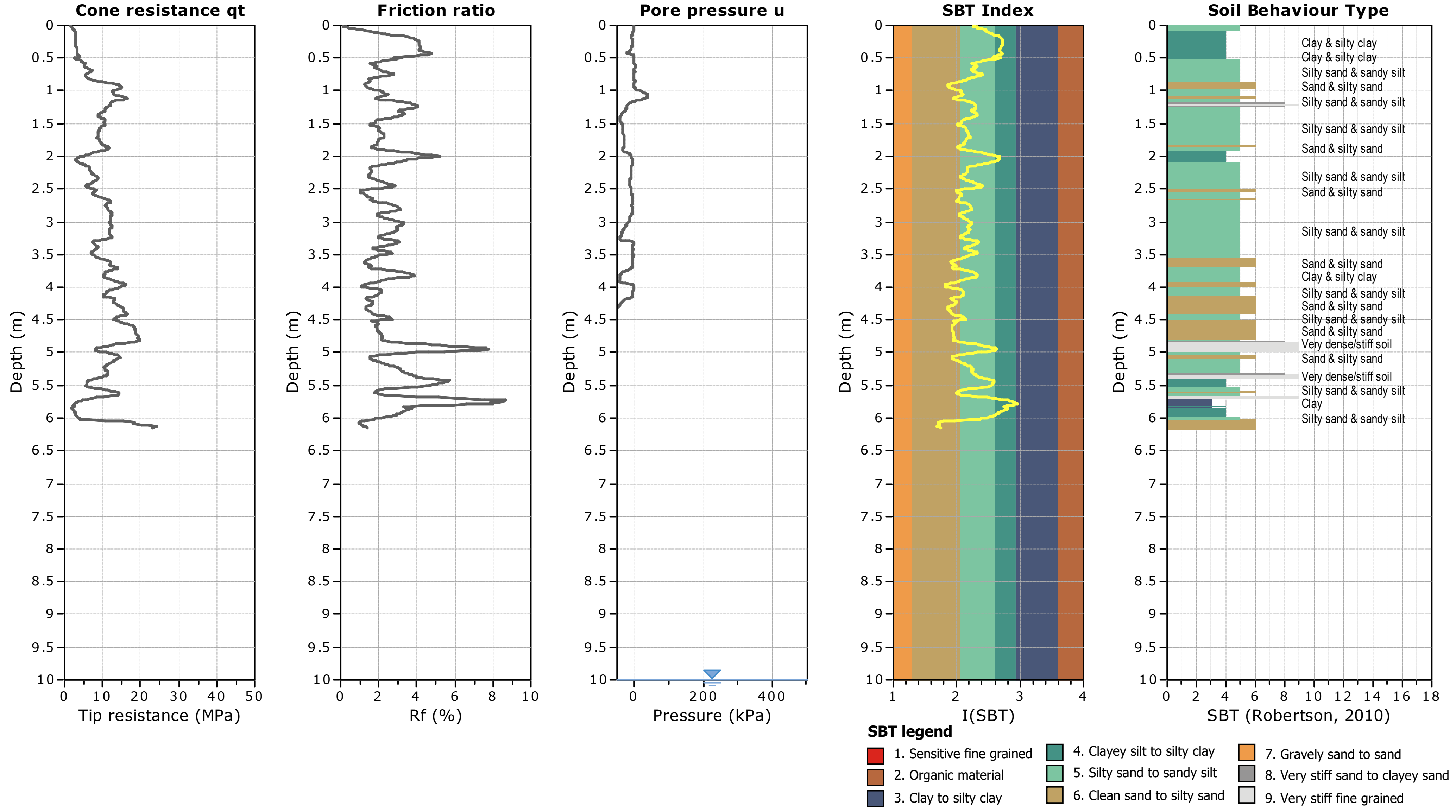
SBT legend

- 🟥 1. Sensitive fine grained
- 🟫 2. Organic material
- 🟦 3. Clay to silty clay
- 🟩 4. Clayey silt to silty clay
- 🟩 5. Silty sand to sandy silt
- 🟨 6. Clean sand to silty sand
- 🟧 7. Gravely sand to sand
- ⬜ 8. Very stiff sand to clayey sand
- ⬜ 9. Very stiff fine grained

Riley Consultants Ltd
4 Fred Thomas Drive, Takapuna
www.riley.co.nz

CPT: CPT04
Total depth: 6.14 m, Date: 7/05/2020
Surface Elevation: 192.40 m
Coords: X:1677898.80, Y:6087763.50
Cone Type: Nova Cone 100MPa
Cone Operator: Underground Investigation Ltd

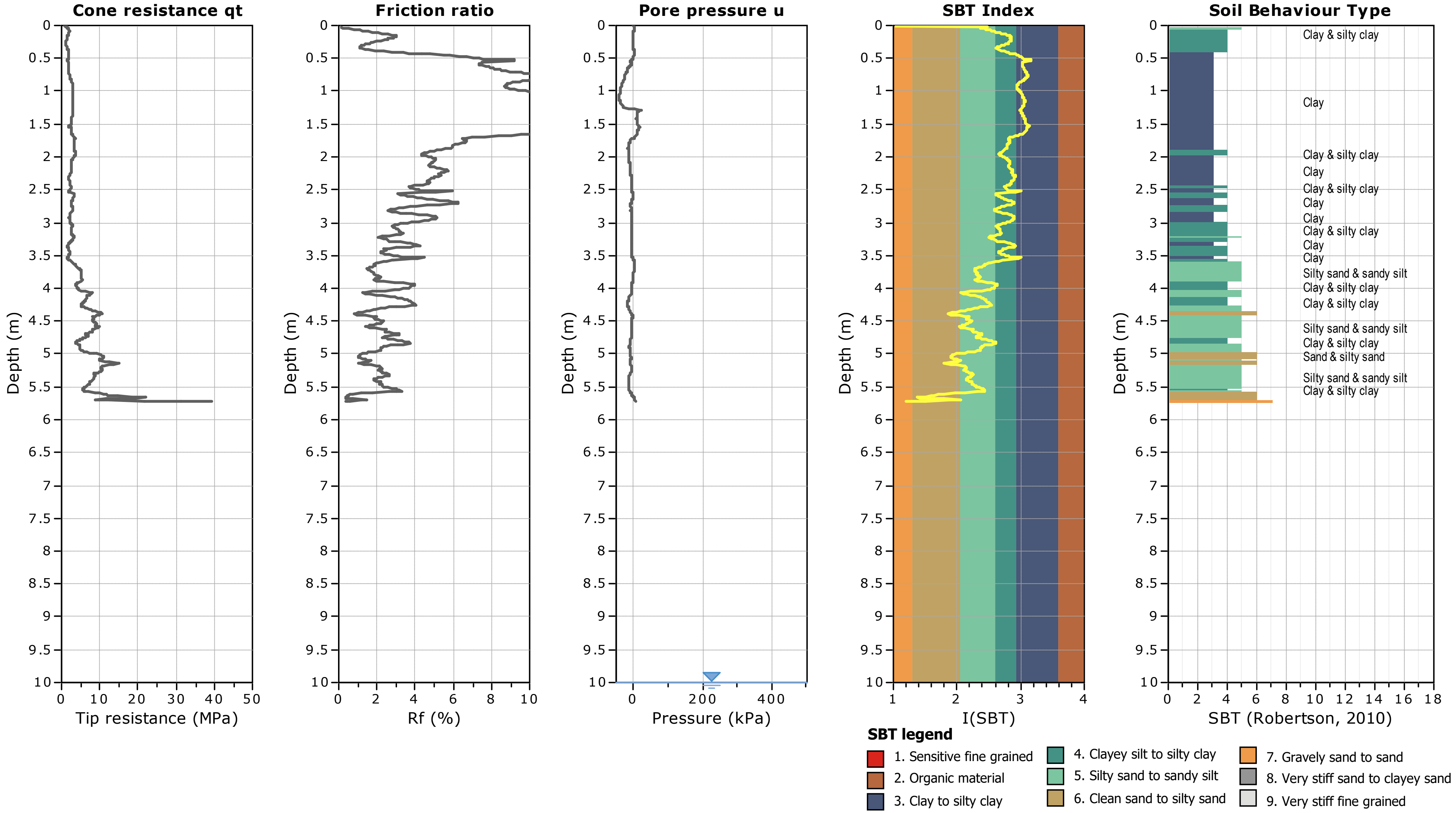
Project: **RILEY Ref - 200240**
Location: **MN06**



Riley Consultants Ltd
4 Fred Thomas Drive, Takapuna
www.riley.co.nz

Project: **RILEY Ref - 200240**
Location: **MN06**

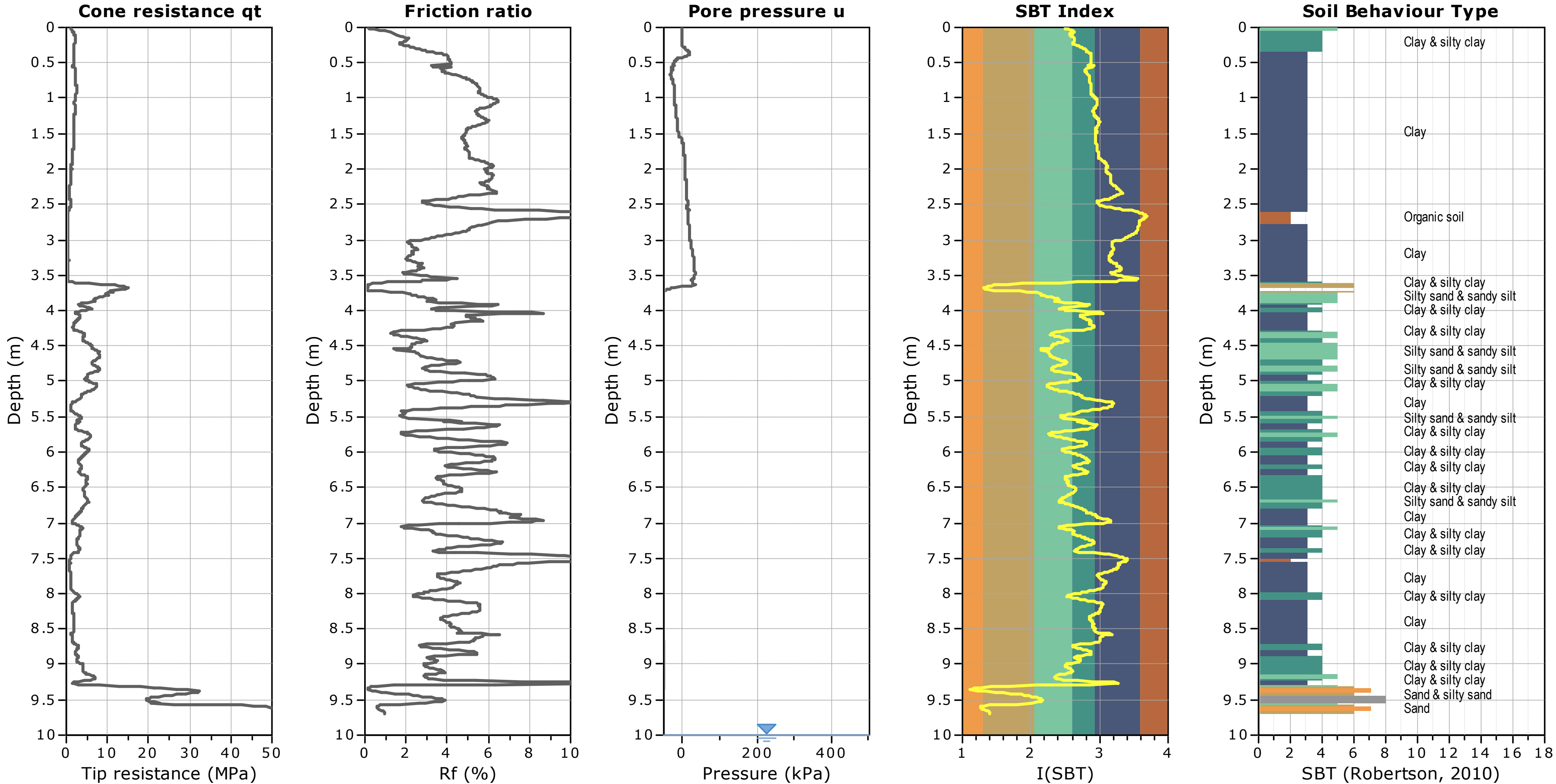
CPT: CPT05
Total depth: 5.73 m, Date: 7/05/2020
Surface Elevation: 197.90 m
Coords: X:1677895.60, Y:6087732.20
Cone Type: Nova Cone 100MPa
Cone Operator: Underground Investigation Ltd



CPT: CPT06

Total depth: 9.70 m, Date: 7/05/2020
Surface Elevation: 202.90 m
Coords: X:1677890.70, Y:6087816.60
Cone Type: Nova Cone 100MPa
Cone Operator: Underground Investigation Ltd

Project: **RILEY Ref - 200240**
Location: **MN06**



SBT legend

🟥 1. Sensitive fine grained
🟫 2. Organic material
🟦 3. Clay to silty clay
🟩 4. Clayey silt to silty clay
🟩 5. Silty sand to sandy silt
🟨 6. Clean sand to silty sand
🟧 7. Gravely sand to sand
⬜ 8. Very stiff sand to clayey sand
⬜ 9. Very stiff fine grained

APPENDIX C

*RILEY Dwgs:
200240-0 and
200240-101 to -108*

TE TAI TOKERAU WATER TRUST

TE RUAOTEHAUHAU WATER STORAGE RESERVOIR SITE

DRAWING LIST - SEPTEMBER 2020

DWG. No.	TITLE	REV.
200240/3-0	DRAWING LIST & LOCATION PLAN	1
200240/3-101	GEOMORPHIC AND GEOLOGIC MAP	1
200240/3-102	SITE PLAN AND INVESTIGATIONS	1
200240/3-103	GEOTECHNICAL CROSS SECTION B	1
200240/3-104	GEOTECHNICAL LONG SECTION A	1
200240/3-105	DAM CROSS SECTION AND LONG SECTION	1
200240/3-106	CONDUIT DETAILS	1
200240/3-107	SPILLWAY DETAILS	1
200240/3-108	TEMPORARY FLOOD CONTROL WORKS DURING CONSTRUCTION	1
200240/2-200	DOWNSTREAM FLOODPLAIN OVERVIEW	1
200240/2-201	SUNNY DAY BREACH - PEAK LEVELS (AREA 1)	1
200240/2-202	SUNNY DAY BREACH - PEAK LEVELS (AREA 2)	1
200240/2-203	SUNNY DAY BREACH - PEAK DEPTHS (AREA 1)	1
200240/2-204	SUNNY DAY BREACH - PEAK DEPTHS (AREA 2)	1
200240/2-205	SUNNY DAY BREACH - PEAK DEPTH VELOCITY PRODUCT (AREA 1)	1
200240/2-206	SUNNY DAY BREACH - PEAK DEPTH VELOCITY PRODUCT (AREA 2)	1
200240/3-210	CATCHMENT PLAN - AERIAL BACKGROUND	1
200240/3-211	CATCHMENT PLAN - GEOLOGY BACKGROUND	1

NOTE: MAP SOURCED FROM LINZ

SITE LOCATION

SCALE 1: 15 000

SCALE 1: 15000

0 150 300 450 600 900 (m)

FOR CONSENT

1		FOR CONSENT	MP
REV	DATE	ISSUE	BY

DESIGN: EM
DES CHECK: SMM
DRAWN: MP
CAD CHECK: JM
APPROVED FOR ISSUE: S VAUGHAN
DATE DRAWN: AUG. 2020
ISSUE DATE: 01 / 09 / 20

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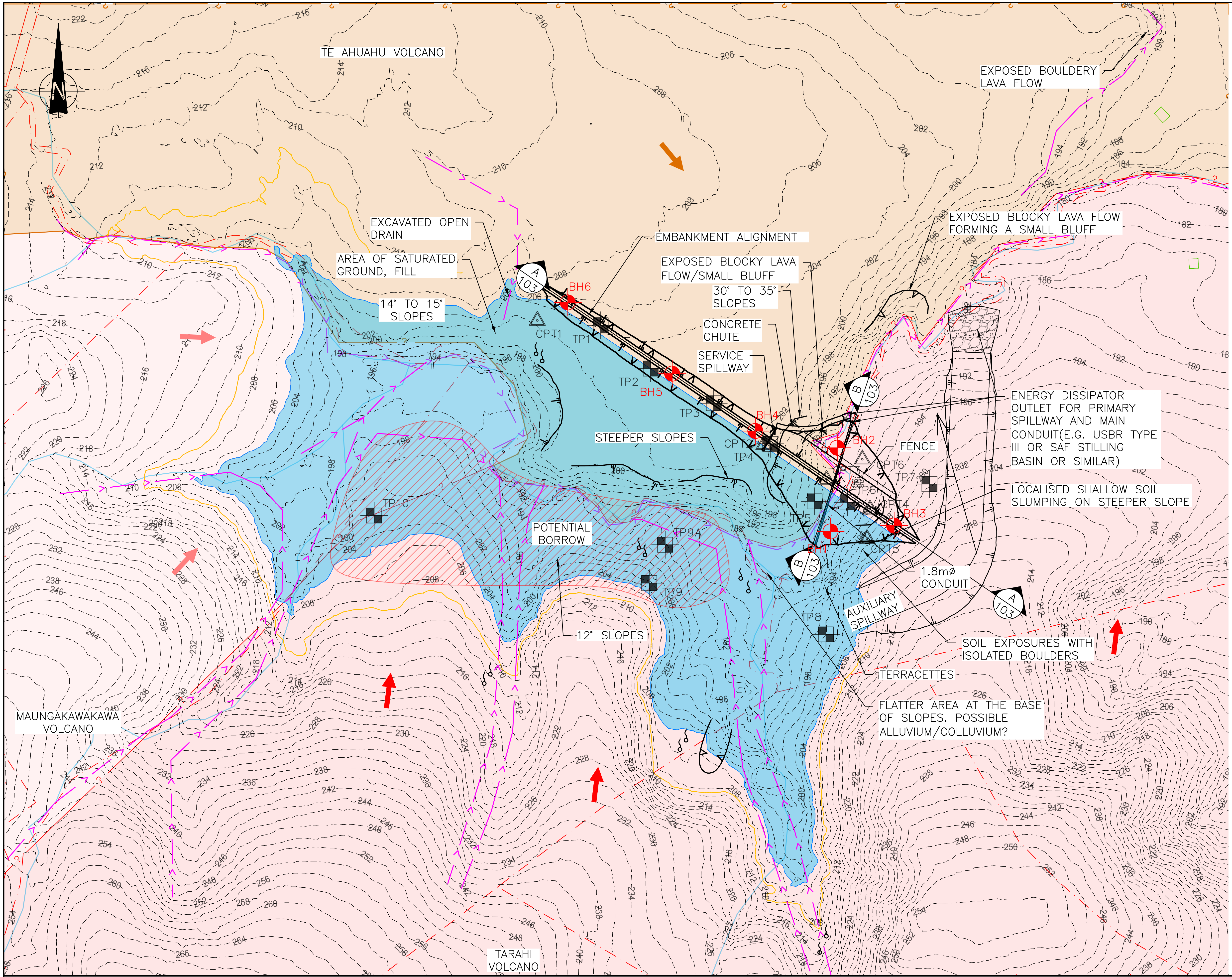
CLIENT: TE TAI TOKERAU WATER TRUST
ADDRESS: NORTHLAND WATER STORAGE AND USE PROJECT
PROJECT: TE RUAOTEHAUHAU WATER STORAGE RESERVOIR SITE
SHEET TITLE: DRAWING LIST & LOCATION PLAN

ACENZ

ISO CERTIFIED GCS

CADFILE: 200240_3-0.dwg
SCALE (A3): 1:10,000
ORIG. SHEET SIZE: A3
DRAWING No.: 200240/3-0
REV.: 1



LEGEND

- - - -	2m CONTOURS
— — —	PROPERTY BOUNDARY
— < —	STREAM CHANNEL
—V—	SCARP
○~	SPRING
△ CPT1	CPT LOCATION
▞ TP1	TEST PIT LOCATION
⊕ BH1	PROPOSED BOREHOLE LOCATION
→	INFERRED BASALTIC LAVA FLOW FROM MAUNGAKAWAKAWA VOLCANO
→	INFERRED BASALTIC LAVA FLOW FROM TARAHI VOLCANO
→	INFERRED BASALTIC LAVA FLOW FROM TE AHUAHU VOLCANO
🟦	RESERVOIR FULL SUPPLY LEVEL
——	MAXIMUM INUNDATION LEVEL
⬭	DAM EMBANKMENT

REFERENCE NOTES:

1. CONTOURS AND AERIAL PHOTO SOURCED FROM 2019 NORTHLAND REGIONAL COUNCIL LIDAR.
2. MAXIMUM INUNDATION AREA ILLUSTRATES THE AREA LIKEY TO BE INUNDATED ASSUMING A NOMINAL 20m BUFFER.

40 0 80 160m

SCALE 1:4000

FOR CONSENT

REV	DATE	ISSUE	BY
1		FOR CONSENT	MP

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DRAWN MP	CAD CHECK JM	
DATE DRAWN AUG. 2020		ISSUE DATE 01 / 09 / 20

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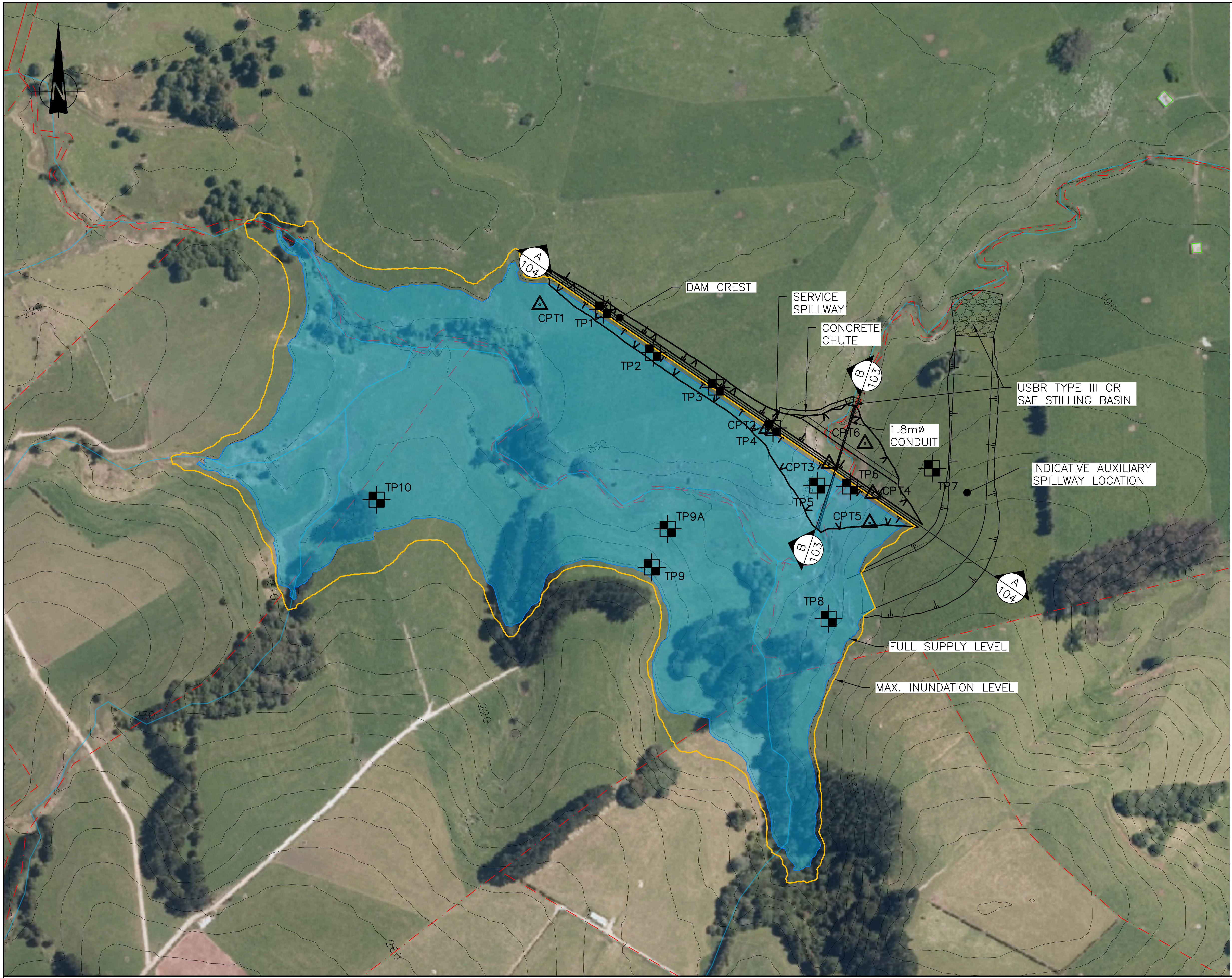
ADDRESS	NORTHLAND WATER STORAGE AND USE PROJECT
PROJECT	TE RUAOTEHAUHAU WATER STORAGE RESERVOIR SITE
SHEET TITLE	GEOMORPHIC AND GEOLOGIC MAP

CADFILE 200240_3–101.dwg		
SCALE (A3) 1:4000	ORIG. SHEET SIZE A3	
DRAWING No. 200240/3-101		REV. 1



LEGEND

—	5m CONTOURS
— · —	PROPERTY BOUNDARY
—	STREAM CHANNELS
—	MAXIMUM INUNDATION LEVEL
🟦	INUNDATION TO FULL SUPPLY LEVEL (FSL)
TP1 ▣	TEST PIT
CPT1 △	CONE PENETROMETER TEST

REFERENCE NOTES:

1. CONTOURS AND AERIAL PHOTO SOURCED FROM 2019 NORTHLAND REGIONAL COUNCIL LIDAR.
2. MAXIMUM INUNDATION AREA ILLUSTRATES THE AREA LIKEY TO BE INNUNDATED ASSUMING A NOMINAL 20m BUFFER.

40 0 80 160m

SCALE 1:4000

FOR CONSENT

REV	DATE	ISSUE	BY
1		FOR CONSENT	MP

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DES CHECK SMM
DRAWN MP
CAD CHECK JM
APPROVED FOR ISSUE S VAUGHAN
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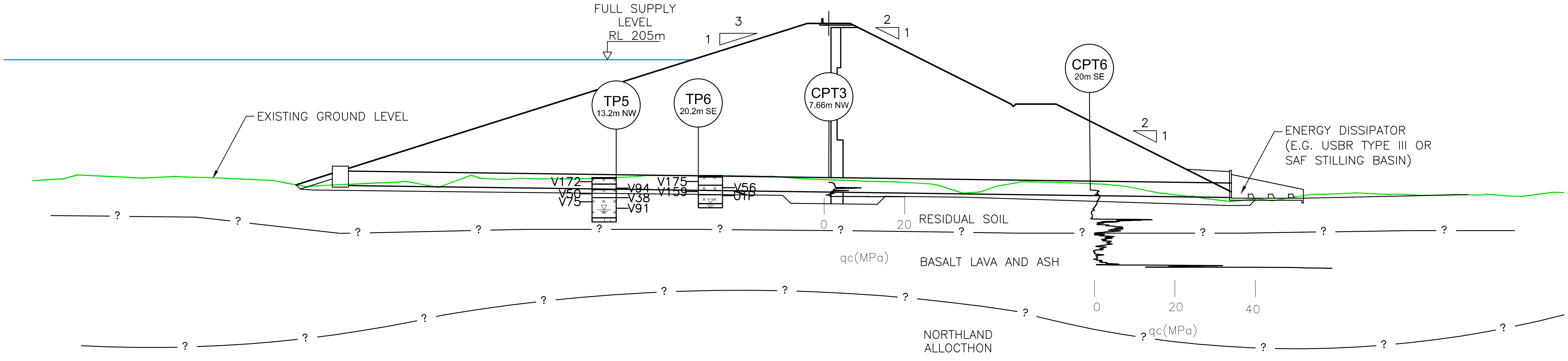
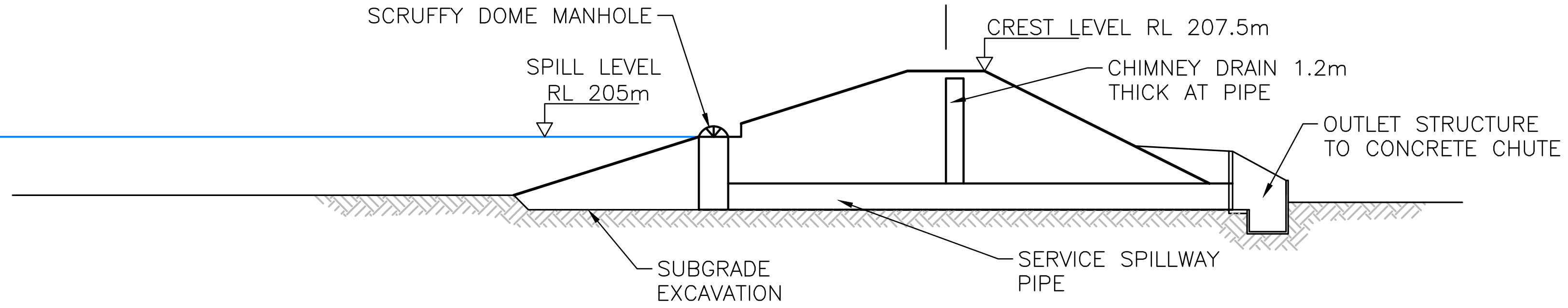
PROJECT TE RUAOTEHAUHAU WATER STORAGE RESERVOIR SITE
SHEET TITLE SITE PLAN AND INVESTIGATIONS

CADFILE 200240_3–102.dwg
SCALE (A3) 1:4000
ORIG. SHEET SIZE A3
DRAWING No. 200240/3-102
REV. 1



SECTION B 102 DAM SECTION AT MAXIMUM HEIGHT

SCALE 1:500



INDICATIVE SERVICE SPILLWAY DETAILS

SCALE 1: 500

5 0 10 20m

SCALE 1:500

FOR CONSENT

REV	DATE	ISSUE	BY
1		FOR CONSENT	MD

DESIGN: EM
DES CHECK: SMM
DRAWN: MP
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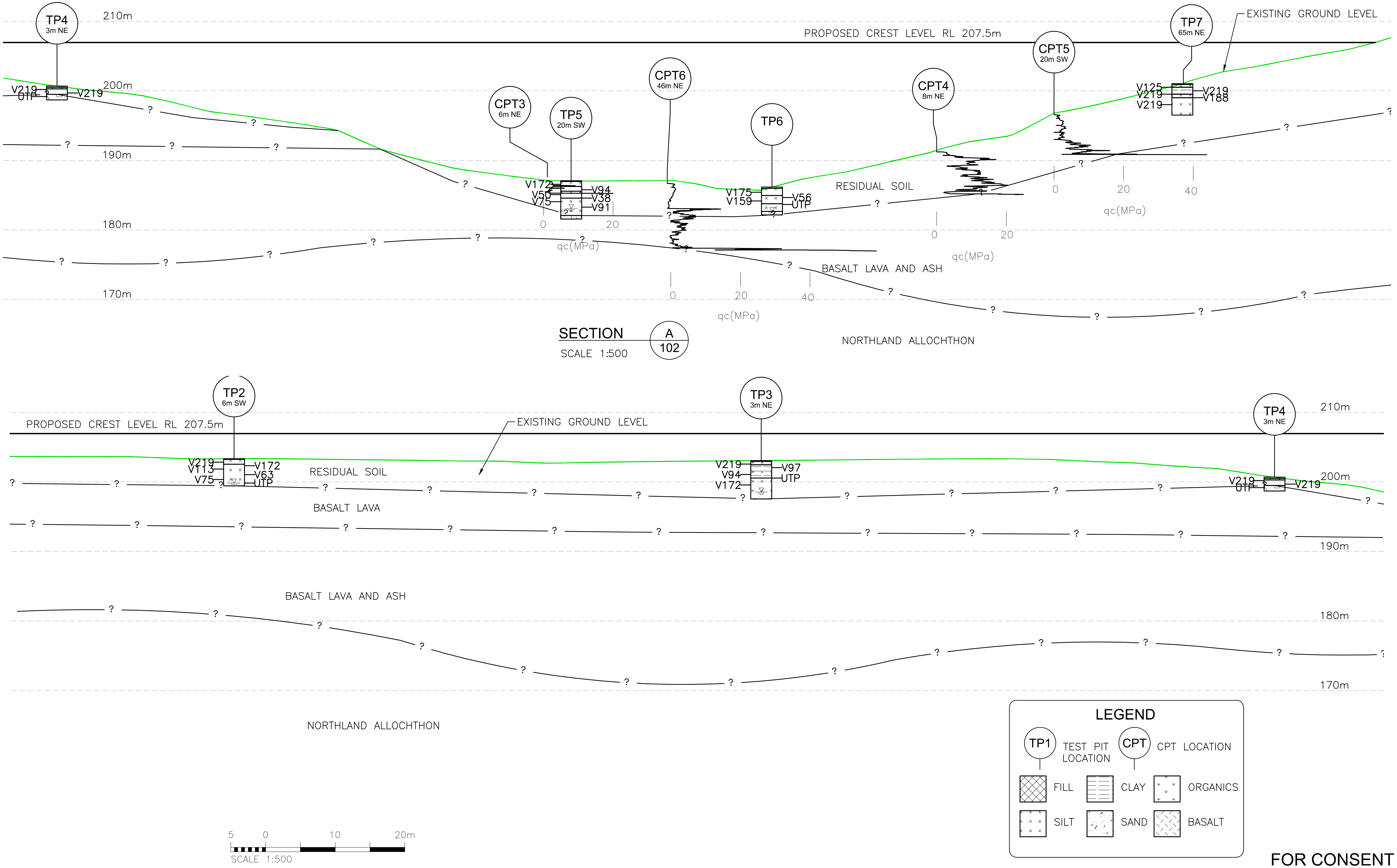
ADDRESS: NORTHLAND WATER STORAGE AND USE PROJECT
PROJECT: TE RUAOTEHAUHAU WATER STORAGE RESERVOIR SITE
SHEET TITLE: GEOTECHNICAL CROSS SECTION B & SERVICE SPILLWAY

ACENZ

CADFILE: 200240_3-103&104.dwg
SCALE (A3): AS SHOWN
ORIG. SHEET SIZE: A3
DRAWING No.: 200240/3-103
REV.: 1



SECTION A 102

SCALE 1:500

FOR CONSENT

REV	DATE	ISSUE	BY
1		FOR CONSENT	MD

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DES CHECK: SMM
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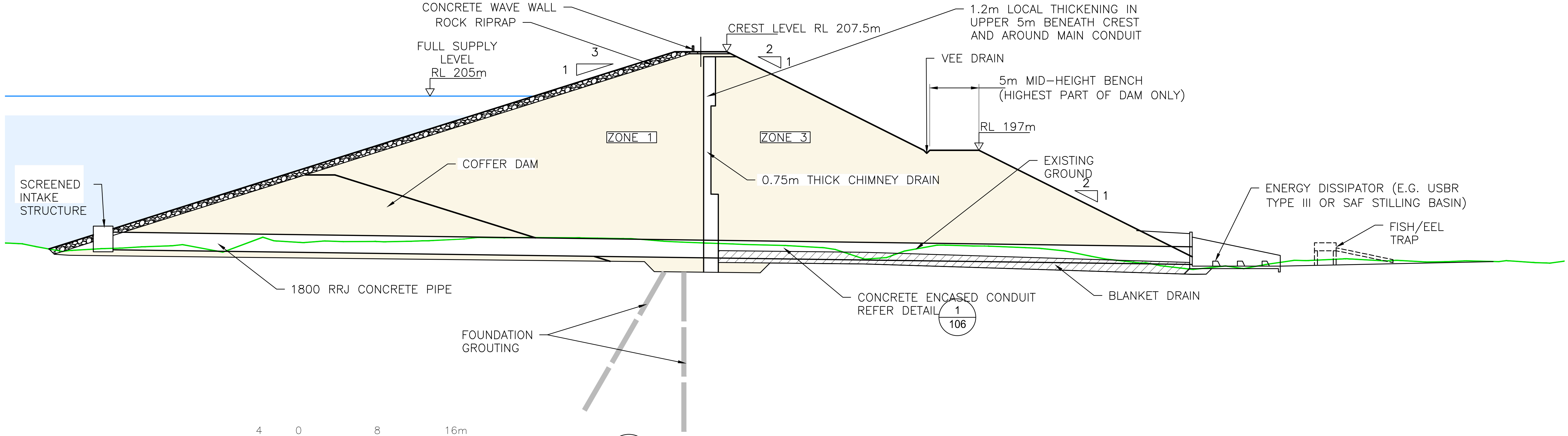
PROJECT: TE RUAOTEHAUHAU WATER STORAGE RESERVOIR SITE
SHEET TITLE: GEOTECHNICAL LONG SECTION A

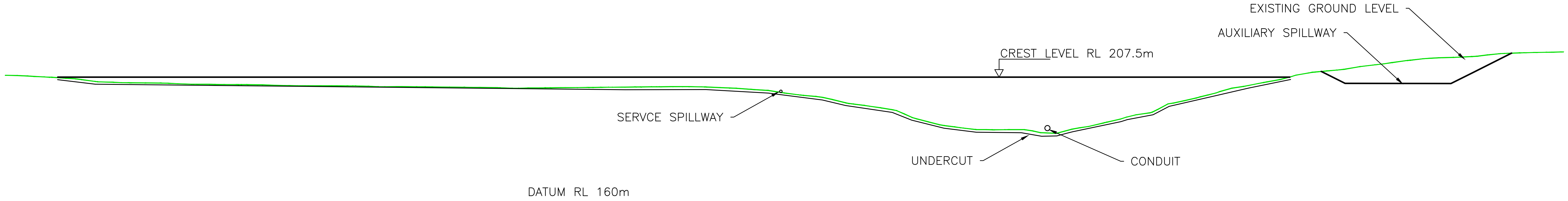
ACENZ
ISO CERTIFIED GCS

CADFILE: 200240_3–103&104.dwg
SCALE (A3): AS SHOWN
ORIG. SHEET SIZE: A3
DRAWING No.: 200240/3-104
REV.: 1



SECTION B 102 TYPICAL DAM CROSS SECTION @ MAXIMUM HEIGHT

SCALE 1:400



DAM LONG SECTION @ CENTRELINE

SCALE 1:1500

15 0 30 60m
SCALE 1:1500

FOR CONSENT

REV	DATE	ISSUE	BY
1		FOR CONSENT	MP

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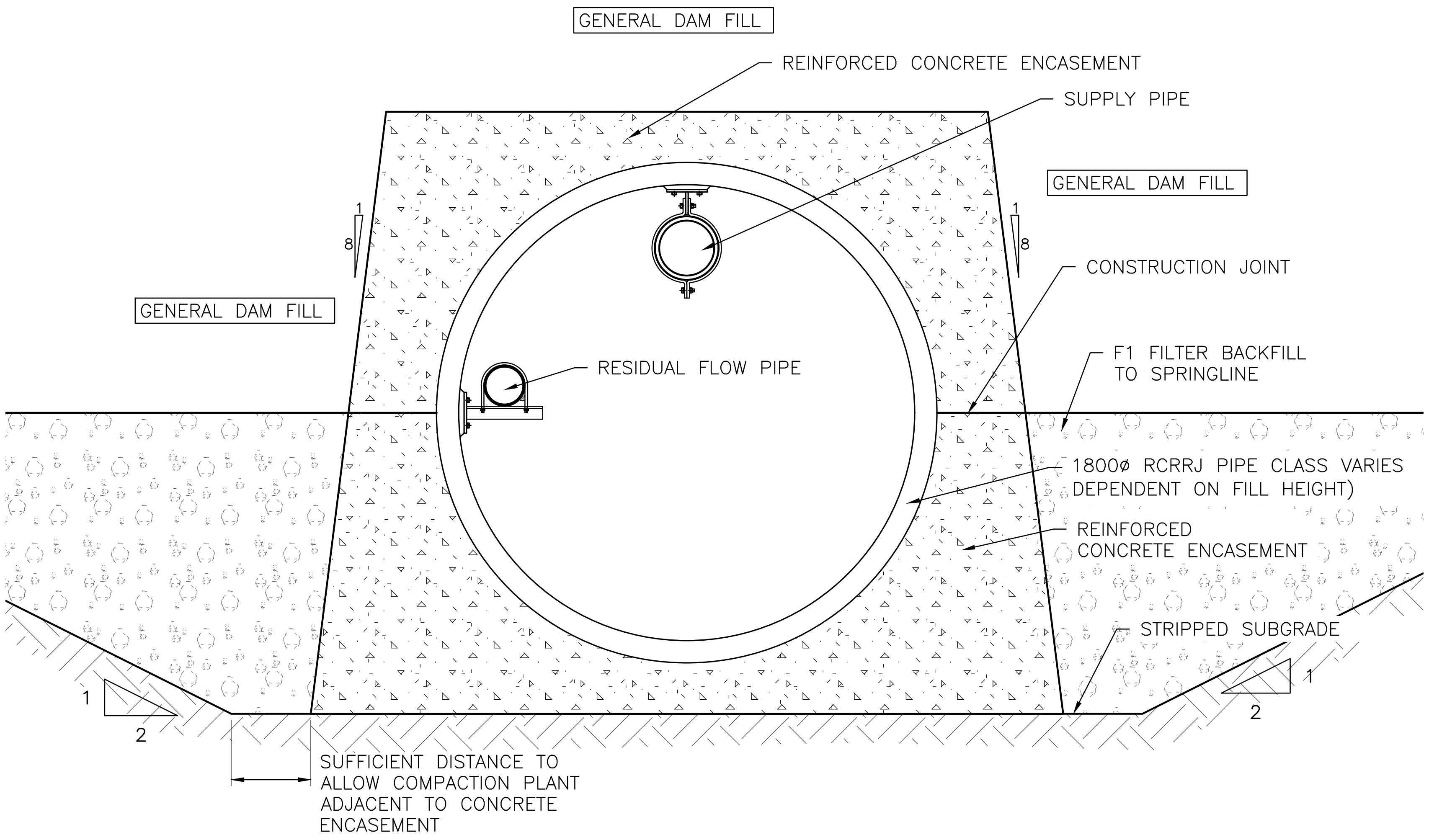
PROJECT: TE RUAOTEHAUHAU WATER STORAGE RESERVOIR SITE
SHEET TITLE: DAM CROSS AND LONG SECTIONS

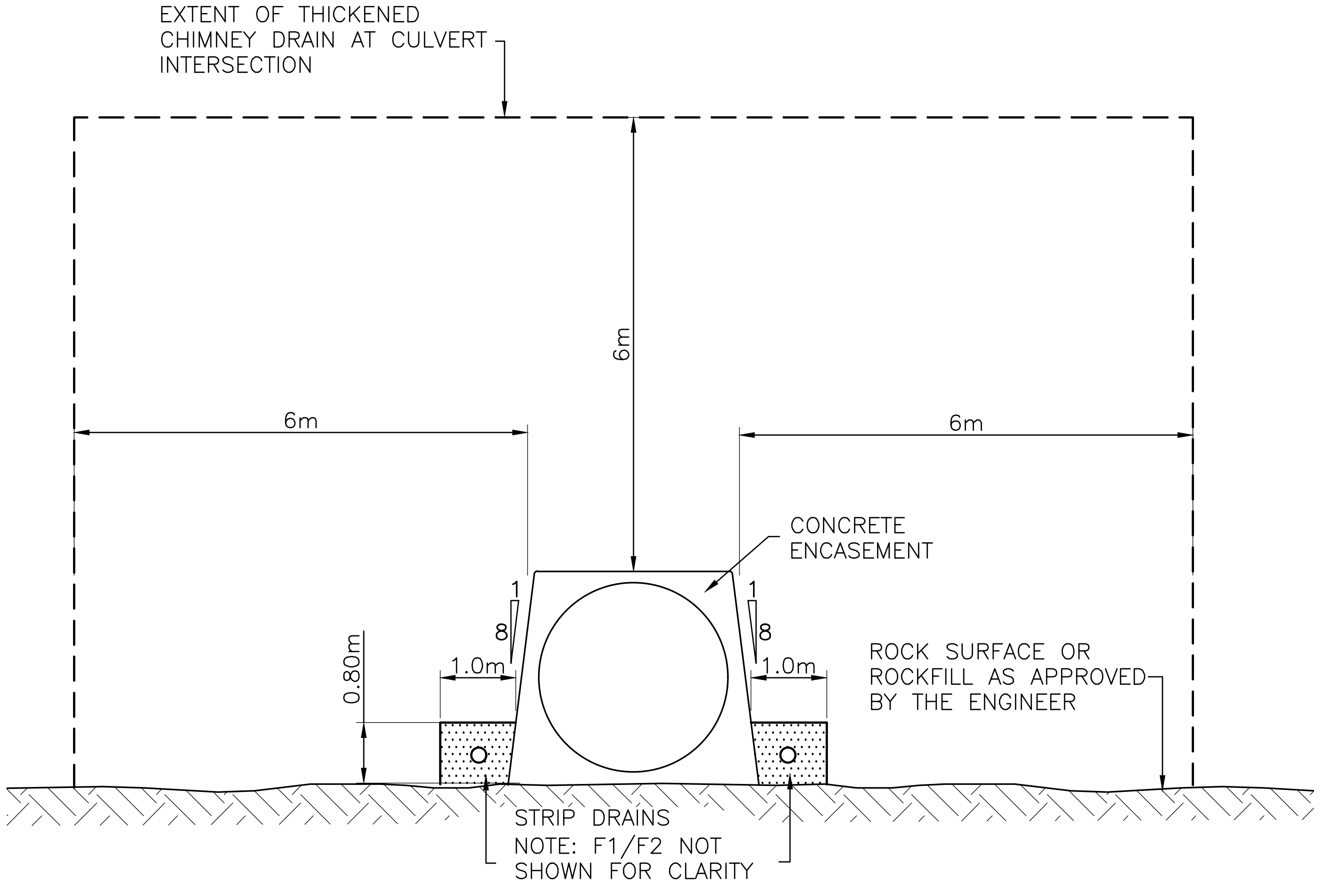
ACENZ

CADFILE: 200240_3-105&106.dwg
SCALE (A3): AS SHOWN
ORIG. SHEET SIZE: A3
DRAWING No.: 200240/3-105
REV.: 1



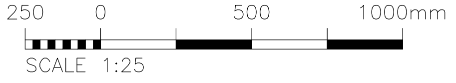
DETAIL 1/105 TYPICAL CONDUIT CROSS SECTION

SCALE 1:25



ELEVATION 1/- CHIMNEY DRAIN THICKENING AT CONDUIT

SCALE 1:100



SCALE 1:25

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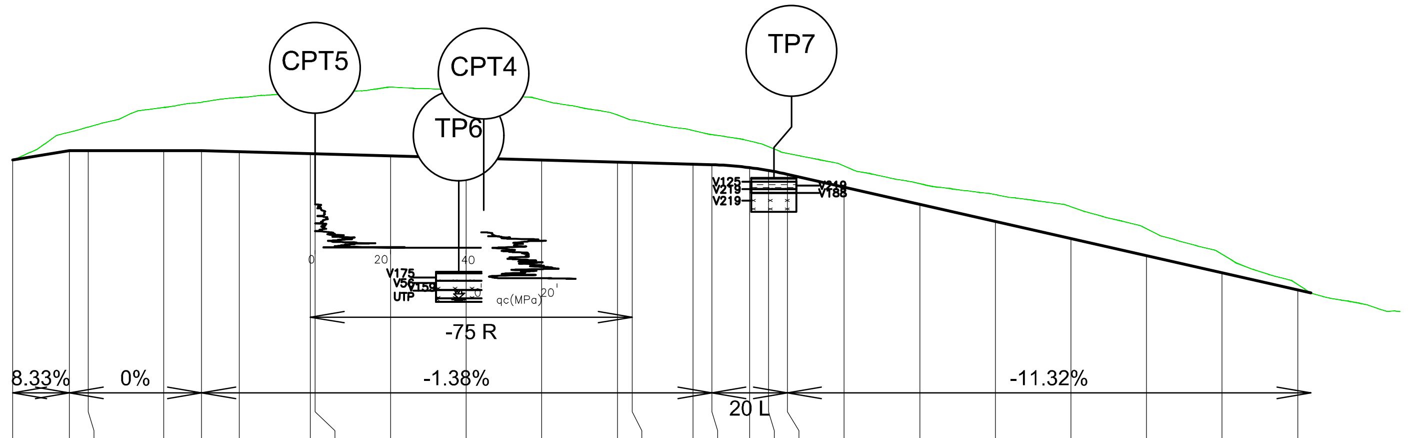
PROJECT: TE RUAOTEHAUHAU WATER STORAGE RESERVOIR SITE
SHEET TITLE: CONDUIT DETAILS

ACENZ
ISO
GCS

CADFILE: 200240_3-105&106.dwg
SCALE (A3): AS SHOWN
ORIG. SHEET SIZE: A3
DRAWING No.: 200240/3-106
REV.: 1



HORIZONTAL ALIGNMENT

VERTICAL ALIGNMENT

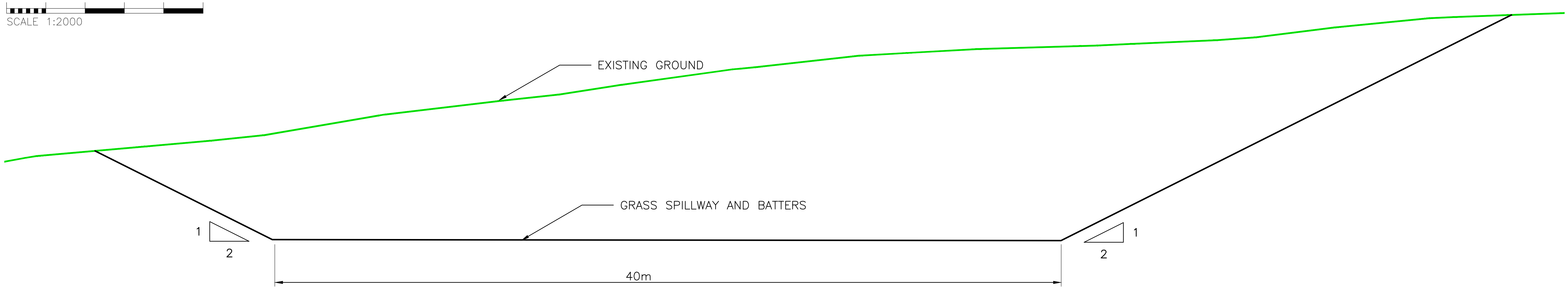
DATUM 184.00

DESIGN SURFACE LEVELS	203.75	205.00	205.00	205.00	205.00	204.86	204.60	204.59	204.31	204.03	203.76	203.48	203.43	203.21	203.14	202.75	202.37	201.87	200.17	197.91	195.64	193.38	191.12	188.85	186.59		
EXISTING SURFACE LEVELS	203.75	207.43	208.12	210.69	211.37	212.00	213.05	213.04	213.38	212.43	211.69	209.71	209.05	207.66	207.12	206.27	205.51	204.64	202.98	200.62	199.18	197.58	194.67	191.31	187.31	184.34	183.74
CUT - / FILL +	-0.00	-2.43	-3.12	-5.69	-6.37	-7.14	-8.44	-8.46	-9.07	-8.39	-7.93	-6.23	-5.62	-4.45	-3.98	-3.52	-3.14	-2.77	-2.81	-2.72	-3.54	-4.20	-3.56	-2.45	-0.72		
CHAINAGE	0.00	15.00	20.00	40.00	50.00	60.00	78.76	80.00	100.00	120.00	140.00	160.00	163.93	180.00	185.00	195.00	200.00	205.00	220.00	240.00	260.00	280.00	300.00	320.00	340.00	360.00	367.07

AUXILIARY SPILLWAY LONG SECTION

SCALE 1: 2000 HOR 1:1000 VERT

20 0 40 80m
SCALE 1:2000



2 0 4 8m
SCALE 1:200

AUXILIARY SPILLWAY TYPICAL CROSS SECTION

SCALE 1: 200

FOR CONSENT

1		FOR CONSENT	MP
REV	DATE	ISSUE	BY

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PROJECT TE RUAOTEHAUHAU WATER STORAGE RESERVOIR SITE
SHEET TITLE SPILLWAY DETAILS

CADFILE 200240_3–107.dwg
SCALE (A3) AS SHOWN
ORIG. SHEET SIZE A3
DRAWING No. 200240/3-107
REV. 1

REFERENCE NOTES:
1. CONTOURS AND AERIAL PHOTO SOURCED FROM 2019 NORTHLAND REGIONAL COUNCIL LIDAR.

SCALE 1:2500

FOR CONSENT

1		FOR CONSENT	MP
REV	DATE	ISSUE	BY

DESIGN	DES CHECK	APPROVED FOR ISSUE
EM	SMM	S VAUGHAN
DRAWN	CAD CHECK	
MP	JM	
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PROJECT TE RUAOTEHAUHAU WATER STORAGE RESERVOIR SITE

TEMPORARY FLOOD CONTROL WORKS DURING CONSTRUCTION

ACENZ
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CADFILE
200240_3–108.dwg

SCALE (A3)	ORIG. SHEET SIZE
1:4000	A3
DRAWING No.	REV.
200240/3-108	1