Appendix D. Preliminary Geotechnical Design Report

RILEY
CONSULTANTS

PRELIMINARY GEOTECHNICAL CONCEPT ASSESSMENT ARATAPU WATER STORAGE RESERVOIR

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

PRELIMINARY GEOTECHNICAL CONCEPT ASSESSMENT ARATAPU WATER STORAGE RESERVOIR

Report prepared for:	Te Tai Tokerau Water Trust
Report prepared by:	Titus Smith, Technical Director - Geotechnical, CPEng …………………………….
Report reviewed by:	Scott Vaughan, Managing Director - CPEng …………………………….
Report approved for issue by:	Peter Lilley, Project Director …………………………….
Report reference:	200240-B
Date:	1 September 2020

Copies to:	Te Tai Tokerau Water Trust	1 electronic copy
	Williamson Water and Land Advisory	1 electronic copy
	Riley Consultants Ltd	1 copy

Issue:	Details:	Date:
1.0	Preliminary Geotechnical Concept Assessment K13 Dam and Water Storage Reservoir	1 September 2020

Contents

Appendices

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

PRELIMINARY GEOTECHNICAL CONCEPT ASSESSMENT ARATAPU WATER STORAGE RESERVOIR

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 on behalf of Northland Regional Council (NRC) to prepare documentation to support a resource consent application for construction of the Aratapu Water Storage Reservoir located approximately 12km south of Dargaville.

The site is one of several options identified by the Northland Water Storage and Use Project (NWSUP): Pre-feasibility Demand Assessment and Design Study, which form part of a distributed system of reservoirs that could collectively supply irrigable water to suitable land along the northern end of the Pouto Peninsula.

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

The primary objectives of the geotechnical and dam concept assessment are to:

- Specify the geological context of the dam site and reservoir basin, and how this influences structural 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 appurtenant structures based on geological, geotechnical, hydrological, and operational considerations.
- Gain an understanding of the potential failure modes and how defensive measures can be incorporated into the design to reduce the risk of dam safety incidents or failure.
- Evaluate the present concept design against recommended performance criteria that is commensurate with the hazard posed by the reservoir (potential impact classification).
- Outline additional recommendations for the progression of the project through design investigations and detailed design.

At the time of writing this report, additional intrusive geotechnical investigations (machine boreholes and laboratory testing) were being undertaken. 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.

This report should be read in conjunction with RILEY report 200240-D Hydrology and Hydraulic Assessment.

2.0 Site Description and Topography

The proposed reservoir site is located on the Pouto Peninsula approximately 12km south of Dargaville. The site is located to the east of a north-west to south-east orientated ridge at the western margin of the Wairoa floodplain. The site is situated within gentle valleys formed on the on the leeward side of a series of coalescing fixed parabolic dunes.

The proposed main embankment crosses a valley which is 70m wide at its base and approximately 170m wide at the proposed dam crest (RL 29m). The base of the gully contains a small spring fed watercourse which creates a swampy/wetland area.

A natural saddle is located beyond of the right abutment, within which a flood spillway could be located cut into natural ground.

Watercourses downstream generally pass through farmland. The current site is grassed and utilised for farming.

3.0 Existing Information

3.1 Regional Geology

The dunes of the North Kaipara Barrier dominating this terrane were formed during the last interglacial periods from sand transported by the dominant south-westerly winds and supply of sediment from the coast. This has formed an extensive dune complex with the major central ridge line striking generally north-west to south-east.

The Geological and Nuclear Sciences (GNS) (1:250,000) Geological Map of the Whangarei Area suggests that the site is underlain by two distinct geological units:

- Tauranga Group Alluvium: Recent alluvial, swamp and estuarine deposits comprising unconsolidated mud, sand, gravel, and peat deposits (<12k-years old).
- Awhitu Group: fixed, parabolic, and transverse dunes comprising unconsolidated dune bedded sands with intercalated paleosols, lignite and cabonanceous mudstone and some sub-horizontally bedded sandstone of Late Pliocene age (1.8M to 3.6M-years old).

The reservoir basins are bounded by moderate to steep arcuate east facing slopes, a result of the dominant south-westerly wind forming and shaping the dunes. Above the proposed reservoir, the dunes are populated by a few small lakes, typically located at the head of gullies that either drain to the west or east. The gullies and streams on the eastern side of the ridges that will feed the reservoir.

Tauranga Group deposits are mapped within the valley floors and will form the foundation for the proposed embankment dam.

3.2 Seismicity

The seismic hazard at the site is considered generally low in the New Zealand context, with no recorded large earthquakes since records began (c. 1840). There are no active faults mapped nearby (nearest is approximately 150km away). Inactive faults associated with the emplacement of the Northland Allochthon are noted to occur throughout the area, though not known to be within 10km of the proposed Aratapu Water Storage Reservoir.

Seismicity in terms of site hazard considerations are addressed in Section 6.2.

4.0 Geotechnical Site Investigations

4.1 Investigation Phases

Investigations of the dam site are evolving in three phases. Phase 1 and Phase 2 were specifically configured to provide sufficient technical detail to support advancing the project through Resource Consents and Preliminary Dam design. Phase 3 investigations are configured to allow final design and support application for building consent. The three phases consist of:

1. A high-level review of available geotechnical information across the Kaipara coast. This was undertaken as part of the Northland Water Storage and Use project: Pre-feasibility Demand Assessment and Design Study, and included an initial site visit.
2. Geological mapping and engineering geological assessment of the dam alignment and reservoir surrounds and preliminary geotechnical investigations.
3. Comprehensive geotechnical investigation to assist in detailed design are currently underway at the site and will be reported on at a later stage.

Results of the investigations are discussed within Section 5.0 of this report.

4.2 Desktop Study and Initial Site Visit

A high-level review of available geotechnical information across the Kaipara coast was undertaken as part of the Northland Water Storage and Use project: Pre-feasibility Demand Assessment and Design Study. This considered likely ground conditions and the potential variability across several reservoir sites, and was used to highlight known regional hazards to 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.
- Site Walkover assessment.
- ENGEO report for Kaipara District Council: Geotechnical Assessment – West Coast Sites Kaipara District (2019).

4.3 Preliminary Geotechnical Investigation

Preliminary geotechnical investigations were undertaken by RILEY on 30 April and 1 May 2020. The purpose of these investigations was to obtain initial information on actual ground conditions to inform a concept design for resource consenting and provide indicative construction costings (provided separately). The investigations involved:

- A site walkover and engineering geological inspection of the site and surrounding areas.

- Six excavated test pits, four at the dam embankment, one at the spillway and one in a potential borrow area.
- Five cone penetrometer tests (CPTs), three beneath the crest of the main dam embankment and two along the valley alignment at the upstream and downstream extents of the proposed dam. Two pore pressure dissipation tests were undertaken within CPT 4 (middle of dam crest).

Investigation locations and test pit logs are presented in Appendix A and C.

4.3.1 Geological Mapping

A walkover was undertaken by an engineering geologist from RILEY to undertake preliminary geological mapping. Locations of outcrops are shown on the site plan (Appendix C).

4.3.2 Test Pits

Test pits were excavated with a 15t excavator operated by a local contracting company. All samples were logged on-site by an engineering geologist in general accordance with the New Zealand Geotechnical Society (NZGS) Guidelines. Excavations were backfilled and the ground reinstated to its previous level upon completion.

Test pit logs are attached in Appendix A.

4.3.3 Cone Penetrometer Testing

CPT tests were undertaken by Ground Investigation Limited on the 1 May 2020 using a Georig 220 with screw anchors. CPT5 located beneath the proposed dam crest toward the left abutment refused at 0.5m and was discontinued. The remainder of the CPTs extended to depths between 20.0m and 27.4m.

5.0 Investigation Results

Ground conditions encountered in the valley floor (from test pits and CPT) show up to 12m of soft sediment across the middle portion of the valley which tapers to the valley sides. Valley infill material comprises very soft to soft, organic silt or silty peat. Material is described as spongey with fibrous plant matter including wood fragments and tree trunks. Shear vane tests recorded undrained shear strengths of between 6kPa and 32kPa but in many cases no reading could be obtained due to the vane sinking, i.e. very soft consistency. Test pits in these units also often collapsed at shallow depth (less than 3m) due to the saturated soft soils.

Tauranga Group deposits are underlain by sand and silty sand with minor clay (Awhitu Group) at depths of approximately 12m below ground level in the valley floor. The Awhitu Group sand is also exposed in the dam abutments. Awhitu Group deposits observed in test pits at the abutments and in borrow areas and in exposures were generally described as very loose to medium dense, fine grained sand and silty fine-grained sand with no or slight plasticity. Throughout the wider Kaipara area outcrops in road cuttings were observed as moderately weathered, very weak to extremely weak sandstone with thick bedding and occasional discontinuous cemented hard-pan layers. Occasional carbonaceous layers are noted throughout the material in various locations.

The geology and geomorphology of the valley is asymmetrical with steeper slopes on the western abutment, consistent with their orientation on the leeward side of the sand dunes. Therefore, Tauranga Group deposits are likely to from a thicker wedge at the left abutment of the dam in comparison to tapering out over a greater distance on the right.

Awhitu Group sands are generally loose to medium dense and can vary in density with depth (as is common with sand dune deposits). The level of cementation of the dune sand is also variable which is reflected in the CPT results. Abutment slopes in the Awhitu Group appear stable, although surficial failures developed in more recent active dune deposits were noted in places within the reservoir basin. Loose sands recorded nearer the surface on slopes could represent slopewash or colluvium historically washed down from the valley sides.

Awhitu Group deposits observed in borrow areas appear generally suitable for reuse in dam construction subject to further assessment. Layers containing higher proportions of silt and clay could be suitable as low permeability fill, whilst sandy silt and silty sand layers could be utilised as general fill.

Groundwater was typically encountered between 1.0m to 1.5m beneath existing ground level in the valley floor.

Comprehensive ground investigations are currently being undertaken at the site, to date investigation results are consistent with the existing geotechnical model summarised above.

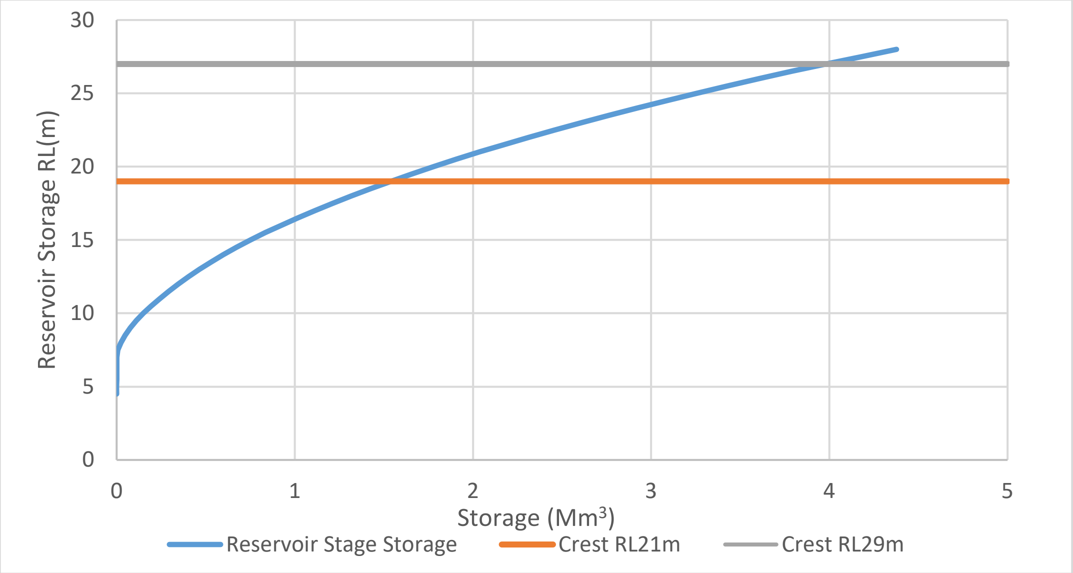
6.0 Dam Arrangement

Two dam height options are presented in this report which correspond to 1.5 or 4.0 million cubic metres of water storage. The relationship between storage volume and reservoir elevation is presented in Figure 1. To achieve the target storage volumes, dam crest elevations of RL 21m and RL 29m respectively are required. The existing ground level in the valley at the dam location is around RL 7m. Dam heights above existing ground level are therefore around 14m and 22m.

It is understood that final storage requirements will depend on demand for water and the storage size adopted for other proposed dam sites. This is why two dam options have been retained at this stage. It is understood that an intermediate dam storage/height combination could be selected for detailed design.

The 4.0 million cubic metre storage option has been used as the basis for the majority of this assessment as this represents the larger dam and associated design considerations.

Figure 1: Stage storage curve for Aratapu Water Storage Reservoir



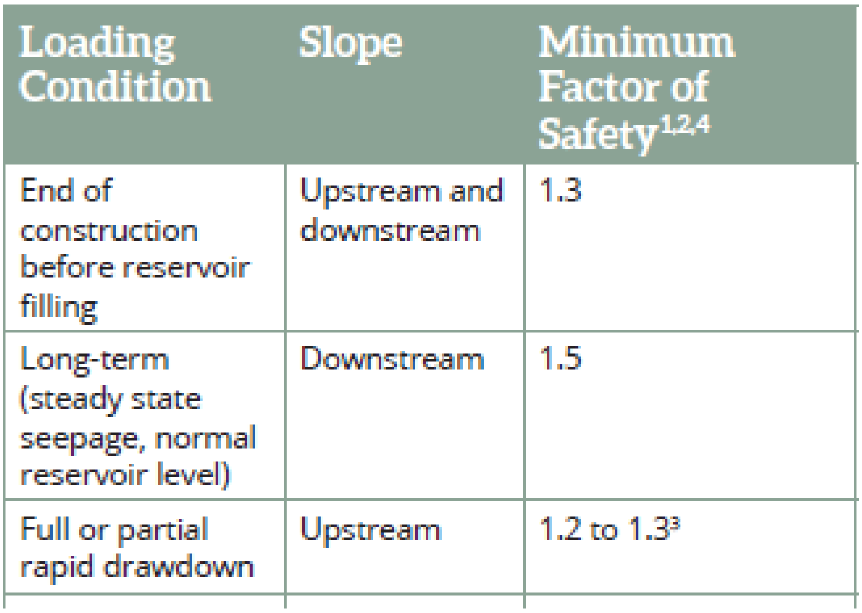
6.1 Design Standards

The 4.0Mm^3 storage dam has been assessed as having a potential impact classification (PIC) of medium (refer RILEY 200240-D). However, it is recognised that the use of the reservoir may result in intensification of development in the area, which could result in a future increase to the PIC. Design standards in keeping with the upper range of a medium PIC 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): 1:2,500 AEP ground motion developed by a probabilistic approach.
- Incremental damage flood (IDF): 1:10,000 AEP event.

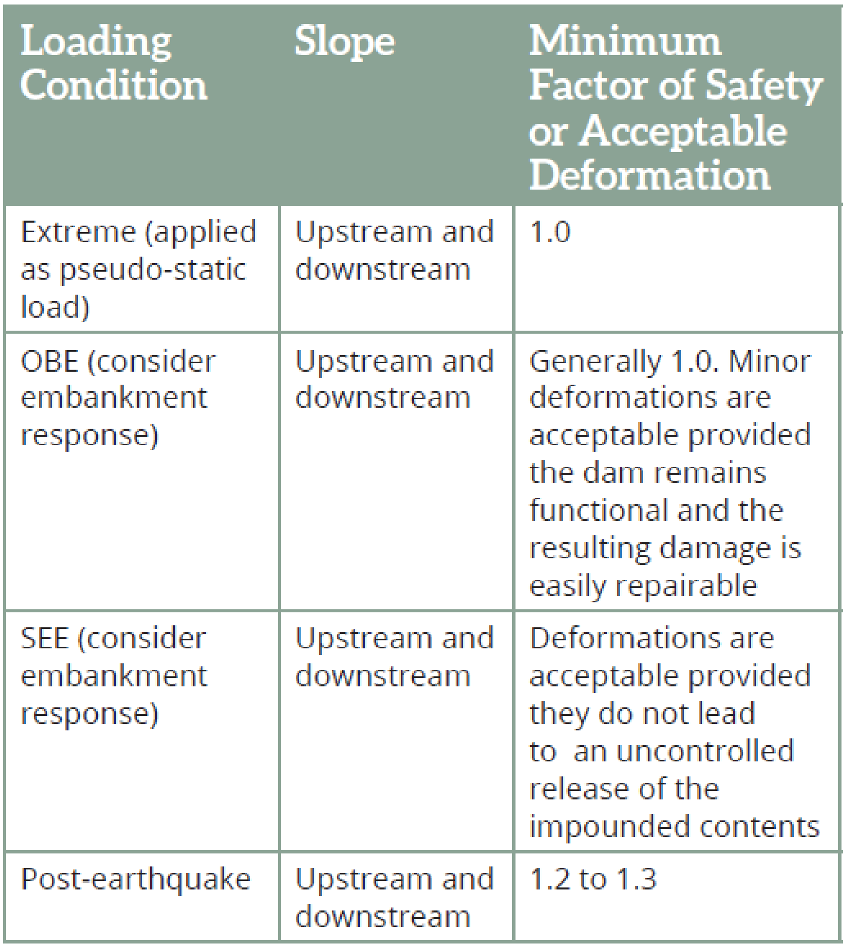
Performance standards and recommended factors of safety are nominated by the NZSOLD Guidelines for a range of operational and emergency scenarios. Minimum stability requirements adopted for design for non-seismic load cases are as set out in Table 1. Seismic performance standards are set out in Table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

6.2 Design Ground Motions

A regional seismic hazard study for the Kaipara area has been commissioned but is not available at the time of writing. For purposes of preliminary geotechnical analysis and design, design ground motions corresponding to the OBE and SEE seismic cases have been obtained from the NZ Transport Agency Bridge Manual as summarised in Table 3.

Table 3: Design ground motions for Class D/E sites from NZTA Bridge Manual

	OBE 1:150 AEP	SEE 1:2,500 AEP
Peak ground acceleration (g)	0.074	0.22
Magnitude (Mw)	5.8	6.5

6.3 Key Dimensions and Features

The adopted typical dam section is outlined in the appended drawing set and incorporates:

- A crest width of 6m.
- Freeboard above full supply level of 2m.
- A geomembrane liner applied to the upstream face of the dam and a 40m wide geomembrane apron extending upstream from the dam toe.

- A low-level irrigation inlet/outlet pipe in the right abutment which also serves as the construction diversion.
- A passive (simple overflow) spillway cut into natural at the right dam abutment.

7.0 Design Considerations

7.1 Foundations and Abutments

There are two general foundation treatment options for the portion of the dam underlain by a significant depth of soft Tauranga Group alluvium:

1. Limited undercut followed by staged construction, with allowance for settlement of the dam over time.
2. Limited undercut and mechanical stabilisation of soft soils to their full depth beneath the dam footprint.

These two options have implications both in terms of construction sequencing and the nature of works conducted on-site. This is discussed further in Section 7.2 and Section 7.3.

For the highest portion of the dam, foundation considerations include soft/compressible soils to a depth of up to 12m, underlying potentially liquefiable sands, and foundation seepage.

For the dam abutments the critical considerations are the potential for liquefaction induced slope instability in a design seismic event and foundation seepage.

7.1.1 Local Precedent for Dams with Soft Soil Foundation Conditions

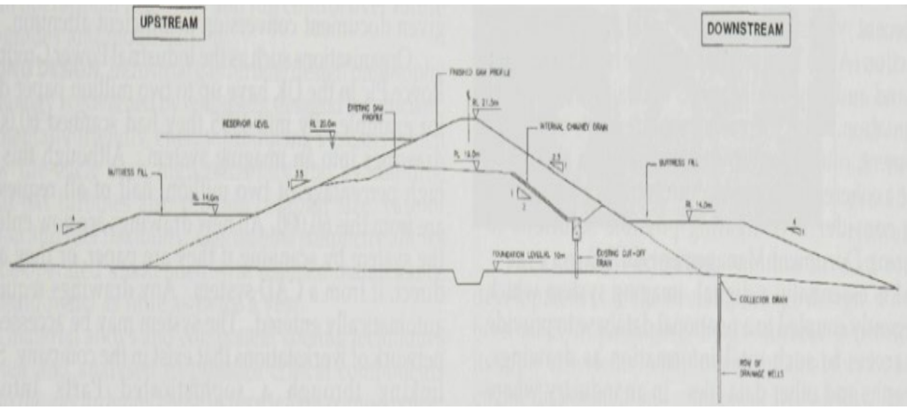
A considerable thickness of soft soil underlies the dam site in the valley section and is a key consideration for dam design. Two examples of similar reservoirs constructed in Northland are outlined below to highlight how failure can occur on similar soft soil sites, and secondly how appropriate design and construction measures can be implemented to ensure a dam can be safely constructed.

7.1.1.1 Tanekaha Dam

Tanekaha Dam is a 12m high embankment dam which initially failed during the final stages of construction in 1995. The dam is located on the fringes of the Hikurangi Swamp and is underlain by between 12m and 25m of compressible, weak alluvial sediments. Elevated pore pressures occurring within the sediments due to the embankment surcharge resulting in strength loss was suspected to be the cause of failure.

A remedial strategy involving a 4m high fill buttresses, pressure relief wells beneath the downstream shoulder, an inclined chimney drain, and careful monitoring of foundation pore pressures and settlements was implemented – Figure 2. The dam was successfully commissioned in 1996 and has been operating ever since.

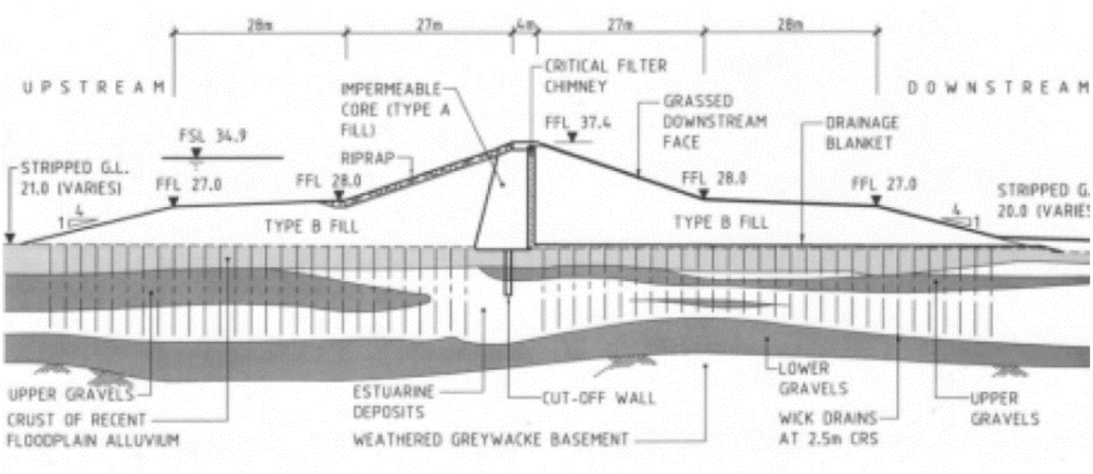
Figure 2: Cross section of Tanekaha Dam



7.1.1.2 Wilsons Dam

Wilsons Dam is an 18m high, zoned embankment dam constructed in 2002 approximately 5km north-west of Ruakaka. The dam foundation comprised 15m thick soft alluvial silts and clays interbedded with sands and gravel lenses, i.e. broadly similar soils to those identified at the subject sites. The designers applied the learnings from Tanekaha Dam, implementing specific engineering measures to address seepage, construction stability, settlement, and seismic stability. Figure 3 illustrates a typical cross section through the dam.

Figure 3: Cross section of Wilsons Dam



Key features of the successful completion of these two dams included:

- Wide berms on the upstream and downstream shoulders: to consolidate and strengthen a wide area of the foundation.
- Highly plastic core: to accommodate substantial settlements.
- Staged construction: allowing dissipation of excess pore pressure and strength gain between earthworks seasons. During construction, foundation pressures were measured by a series of vibrating wire piezometers; strength gains in the foundation were measured using 'Geonor' shear vane tests.
- Wick drains: to accelerate drainage and consolidation of soft soils.
- Cement-bentonite slurry cut-off wall: to minimise seepage through gravel lenses. Seepage losses were minimised through installation of wick drains and a cut-off wall.

7.2 Staged Construction Approach to Soft Soil

Preliminary modelling of staged construction solution similar to the Tanekaha and Wilsons Dams has been completed for the 1.5Mm³ storage option at the Aratapu site. The following comments apply to this approach:

- Peat soils encountered within the upper 2m to 4m of the soil profile are not considered suitable for inclusion in the dam foundation. This material requires excavation and disposal outside of the dam footprint.
- Limited dewatering, likely to include installation of surface drains and pumping will be required to support the foundation undercut.
- There are some indications that peat or highly organic soils could extend deeper than the upper 2m to 4m. Further investigation of the foundation is underway but not available at the time of writing. If significant peat or highly organic soil is encountered within the estimated 12m deep alluvial profile, appropriate allowances for decomposition and secondary settlement of the dam foundation will be required.
- On the basis of available data, modelling suggests that construction of the 1.5Mm³ dam could theoretically be completed within a single 12-month period following foundation preparation, though it would be prudent to assume that it may extend over two seasons.
- Due to the soft soils, to spread foundation loading, significant fill buttresses are needed at the upstream and downstream toe of the dam to enhance embankment stability.
- Initial modelling has indicated to achieve a 12-month construction period, foundation drainage acceleration via installation of wick drains across the dam foundation is required. Additionally, careful management of construction sequencing and monitoring of foundation pore pressures and settlements is required to provide for appropriate safety factors against instability.
- Dam settlements in the order of 2m to 3m are predicted by preliminary modelling, with consolidation occurring during construction and for an estimated period of 35-years following completion of the dam. This will necessitate the design of the dam, liner, and seepage interception features to accommodate ongoing settlement following construction. In addition, a comprehensive monitoring and maintenance programme following filling will be required to confirm the dam is performing appropriately.

Given the large settlements predicted for the 1.5Mm³ storage option, a similar approach for the larger 4Mm³ storage option is not currently considered feasible.

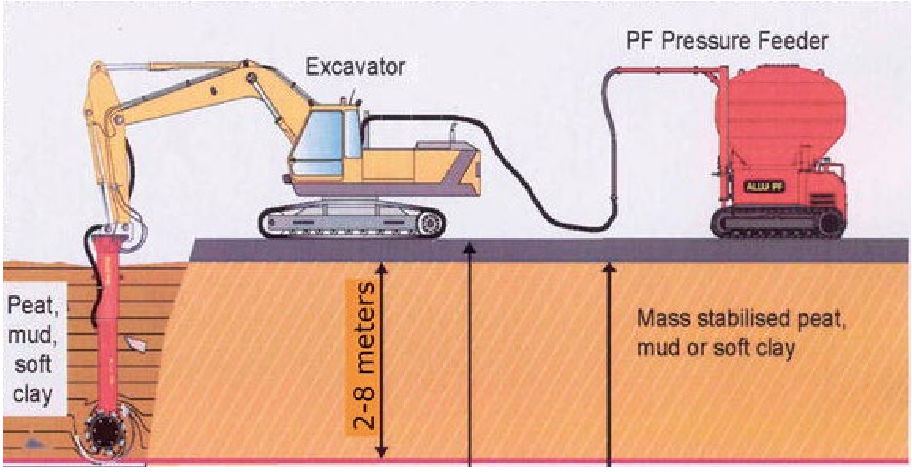
7.3 Removal/Stabilisation Approach to Soft Soil

An alternative has been considered that provides for full-depth removal or stabilisation of soft soils. Based on current information these appear to have a maximum depth of around 12m to 15m. It is proposed to excavate the upper 6m by means of temporary sheet-pile walls and well-point dewatering. Stabilisation of a variable depth of soft soil below 6m depth would then be completed to a depth of up to 8m. The following comments apply to this approach:

- Due to the very soft soils encountered to 12m to 15m depth, standard 12m long sheet piles may not have sufficient lateral capacity to allow excavation up against the sheet pile wall. The currently preferred option is to set-back the sheet pile wall from the dam toe so that a battered slope can be formed within the dewatered natural ground as shown in the appended drawing set.

- The dewatering programme applies to the entire dam footprint and will be relatively extensive is terms of the pumped water volumes and the duration.
- Once excavation and dewatering are complete, mass stabilisation of soft soils is proposed using lime or cement (or possibly a combination) by means of soil mixing with the in-situ foundation material. Excavator-mounted equipment is available in New Zealand that can stabilise to 8m depth relatively efficiently – refer to Figure 4 for an indication of the equipment involved.
- The mix design for lime or cement stabilisation is dependent on the composition of the in-situ soils, and chemical testing and dosing trials are required to support the detailed design. However, based on experience in other areas of New Zealand and published research, dosing rates are likely to be in the range 10% to 15% by mass.
- Where peat or organic soils require stabilisation at depth, there is additional complexity in the design process. Typically, organic soils do not experience the same strength gains as silt and clay soils and may still be subject to ongoing settlement. Indications of the improvement to primary and secondary consolidation coefficients for various cement dosage rates are shown in Figure 5, reproduced from a case study on Indian Peat by Paul and Hussain (2019)[1].
- Following mass stabilisation, backfill of the excavated ground would be completed using compacted earth fill. Removal of dewatering equipment and sheet piles can occur once dam fill is above natural groundwater level.

Figure 4: Mass stabilisation equipment (graphic reproduced from Juha et al 2018)



The removal and stabilisation approach removes the upper soft and compressible soils from within the dam footprint while significantly improving the strength and settlement characteristics of the underlying in-situ soils, allowing a higher embankment to be safely constructed without limitations on the rate of construction, or concerns around long-term excessive settlement. Initial indications are that this would also remove the need for the wide buttress fill required for stability in the staged approach, reducing the overall dam fill volume.

---

[1] Abhinaba Paul, Monowar Hussain. An experiential investigation on the compressibility behaviour of cement-treated Indian peat. Bulletin of Engineering Geology and the Environment, September 2019.

Figure 5: Case study showing the effect of various cement dosage rates on the consolidation parameters of peat from Paul and Hussain (2019)

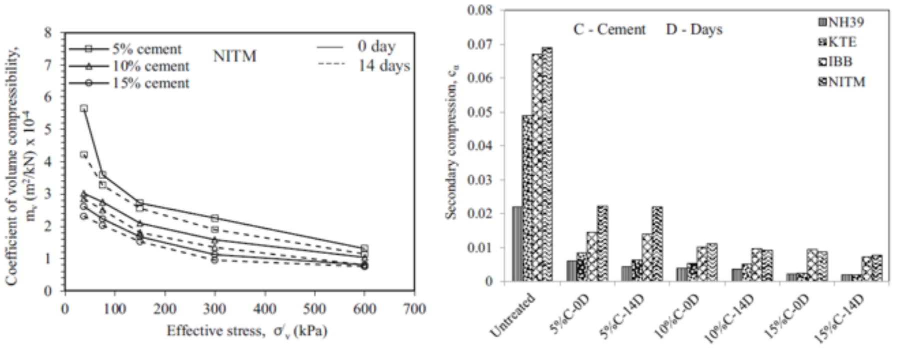


Fig. 10 Variation of coefficient of volume compressibility with effective stress at different percentages of cement and curing days (NITM)

Fig. 14 Variation of secondary compressions at different percentages of cement and curing days

The removal and stabilisation approach is considered to be appropriate for both 1.5Mm³ and 4Mm³ dam options.

7.4 Liquefaction Susceptibility

Liquefaction can occur in saturated loose to medium-dense cohesionless deposits (sands and non-plastic silts) under moderate to severe ground shaking. Geologically recent materials, or very weak manmade fills are typically the most susceptible soils.

The soft Tauranga Group sediments are not considered at risk of liquefaction due to their composition, which is dominated by peat and plastic organic soils.

Soils become more resistant to liquefaction as they become older due to densification and various weathering and chemical cementation processes. The Awhitu Group dune sand deposits are assigned to the Late Pliocene age (1.8M to 3.6M-years old). There is evidence of cementation of sand grains and "hardpan" features in weathered outcrops around the site, which have a strength consistent with "weak rock" in terms of the NZGS field description guidelines (Photo 1)

Photo 1: Weathered dune outcrop showing cemented layering

Published guidance from Youd & Perkins (1978) indicates that dune sands of this age are "very unlikely" to be susceptible to liquefaction. This conclusion is reinforced by the observation that almost all liquefaction case history data are from Holocene deposits or constructed fills (Idris & Boulanger 2008). However, soil aging effects are difficult to quantify and are not typically included in design procedures.

Against the above comments, CPT and standard penetration testing available at the time of writing indicates that the aged dune deposits forming the right-abutment ridge comprise "loose sand". Application of available empirical liquefaction assessment methods indicates that this material is likely to be subject to liquefaction to 10m to 15m depth in a SEE event if it is in a saturated state. Unsaturated sands above water table are not susceptible to liquefaction.

The potential for Awhitu Group sands to be liquefiable has been identified by others, including ENGEO in their 2019 report for the Kaipara District Council.[2] This desktop study classified similar Pleistocene-aged dunes elsewhere Pouto Peninsula as having "medium liquefaction and lateral spread potential" on the basis of their anticipated composition, whilst noting the positive effects of soil aging.

Pending the outcome of further testing at the detailed design stage together with the recommendations of the anticipated regional seismic hazard study for the Kaipara area, the Awhitu Group dunes are assumed to be susceptible to liquefaction.

7.5 Liquefaction Effects and Mitigation

Liquefaction effects on dam structures can include settlement resulting in cracking, loss of freeboard, lateral spreading of the dam shoulders, lateral spread of the abutments, and foundation bearing failure.

Within the centre portion of the dam where a significant thickness of soft soil (or improved soil) is present, preliminary modelling indicates that stability of the dam is unlikely to be affected by strength loss associated with liquefaction. Liquefaction induced settlements are predicted in the order of up to 200mm, though it is not clear that this would result in differential settlement of the dam with respect to the surrounding country.

The more critical location is near the dam abutments, where little to no capping of non-liquefiable soil is present within the dam foundation. Also, the natural dune formation of the right dam abutment is relatively narrow, and potentially at risk of liquefaction induced damage. In these locations modelling using liquefied strength parameters indicates that ground remediation is required to meet adopted stability and performance criteria.

The primary design response is the inclusion of a low permeability geomembrane liner to the dam and abutments, including a 40m apron extending upstream from the toe. This liner, together with a high-capacity upstream toe drain, is designed to limit the height to which the in-situ sand in the area can become saturated. All sand above groundwater level can be considered non-liquefiable. The effectiveness of this groundwater control system will be subject to ongoing verification and monitoring during dam filling and operation.

---

[2] ENGEO Limited. Geotechnical Assessment West Coast Sites Kaipara District (2019). Prepared for Kaipara District Council

For the portions of the dam abutments below groundwater level that remain saturated, liquefaction can still occur, and assessment of the dam performance in these areas has been completed. Modelling indicates that the stability of the downstream dam shoulder in the abutment area needs to be improved for the post-seismic liquefaction case. Buttress options have been evaluated but were found to be geometrically complex and not particularly effective. The preferred solution is to use the mass stabilisation equipment earmarked for improvement of the soft organic soils to form an 8m deep and approximately 20m wide “shear key” beneath the dam. Analysis indicates that, if appropriately positioned, this key has the potential to provide acceptable dam stability and deformation performance, even if liquefiable soils are present below the 8m treatment depth.

7.6 Cyclic Softening

As noted, in Section 7.5, 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 temporary reduction in shear strength.

A quantitative assessment of cyclic softening has not been completed and would only be of importance if a staged construction approach was adopted, with the dam being founded on the fine-grained Tauranga Group alluvium.

7.7 Seepage Design/Internal Stability

The primary water retaining element in the dam is the geomembrane liner. An HDPE or EPDM product will be specified in the detailed design phase, underlain by a non-woven geofabric.

There is the potential for a distributed or concentrated leak in the geomembrane liner on the upstream dam shoulder. In the case of leakage, flow is expected to drain through the upstream dam shoulder fill or track down the back of the geomembrane and be intercepted either by the high capacity upstream toe drain, or strip drains, and discharged at the downstream dam toe.

The upstream toe drain will be designed to be filter compatible with the surrounding materials and will include a central high capacity drainage zone. An integral sloping upstream foundation cut-off drain is also provided to intercept any foundation seepage occurring beneath the liner apron.

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 local flaws either within the soil or at the connection to the geomembrane liner.

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

- The conduit is to be founded within Awhitu Sand in the right abutment to minimise the risk of settlement induced damage as the dam is constructed.
- 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.

7.8 Reservoir Leakage

WWLA prepared a memo summarising a hydrogeological study into leakage rates for the dune lakes on the Pouto Peninsula undertaken by Jacobs NZ Ltd in 2014.

The study was based on a catchment model developed using the Soil Moisture Water Balance Model (SMWBM). The model used parameters such as daily rainfall and average monthly evaporation data combined with the local geology and vegetation to generate a daily stream flow and simulate soil moisture storage, attenuation, and losses through time. Nine lakes on the Pouto Peninsula were examined with 5.5m to 37m lake water depths. Estimated lake leakage rates ranged from 0.11mm to 1.32mm per day as a function of depth. It is not clear whether the presence of tomo or other erosional features were identified within the lakes of that study.

The reservoir for the Aratapu dam varies up to a maximum of 20m depth. Based on the findings above, we would anticipate reservoir leakage rates to be in a similar order, i.e. up to around 1mm per day or less which is considered acceptable. However, the presence of tomo features and springs within the reservoir basins would increase these leakage rates. Foundation seepages are anticipated to be minor owing to the reasonable thickness of generally low permeability soils.

7.9 Reservoir Slope Stability

The dunes generally have gently rounded to flat ridge crests, flanked by moderate to steep slopes. The steeper slopes (24° to 34°) typically show signs of colluvium accumulation at their base and may be subject to soil creep. Exposed sand soils have limited resistance to erosion, and incised gully features are present where overland flow paths concentrate near the valley floor.

Tomos, or collapsed gully erosion features, are known to exist nearby and are typically located downslope of ponds and upslope of steep to very steep slopes. The depth of these can vary considerably but are often in the order of 1m to 3m deep and from 2m to 20m wide.

Generally, slope instability on the reservoir margins is expected to be minor in nature and unlikely to represent a hazard for the dam. Maintenance of grass and vegetative cover in the slopes above reservoir level is recommended to further minimise the potential for shallow slumping or erosion.

7.10 Spillway Cut

Design of the spillway cut is covered in RILEY report RILEY Ref: 200240-D. Geotechnical considerations relevant to the spillway relate largely to protection of the underlying Awhitu Group sands from erosion. If disturbed, the fine sand making up the invert and side slopes of the channel are likely to be erodible under surface flows. In addition, careful detailing for seepage control is required where hard materials are used such as concrete linings or nib walls, as water tracking beneath such interfaces could cause internal erosion.

All non-engineered spillway surfaces should have topsoil cover reinstated with grass cover following excavation.

8.0 Construction Considerations

8.1 Site Establishment and Traffic Movement

A new track and site turn-off area from West Coast Road is likely to be required to enable construction traffic and workers to safely access the site. During periods of rainfall the site can quickly become muddy and slippery. Haul roads and site access tracks will require surfacing with imported aggregate.

Construction will largely be conducted using site derived materials. Key materials to be transported to site include filter compatible drainage aggregate, geomembrane and geosythetics.

8.1.1 Site Preparation and Stream Diversion

The location of the diversion culvert in the right abutment is arranged so that work required to install the culvert can be undertaken in the dry, without accessing the soft central portion of the valley. Construction of the coffer dam located upstream from the main site works will be required prior to dewatering and excavation activities commencing in the valley floor.

A risk-based assessment of the level of flood protection provided by the diversion works is presented in RILEY report RILEY Ref: 200240-D.

A significant initial task will be the excavation of unsuitable peat-dominated soil from within the dam footprint. It is anticipated that this material can be disposed of on-site, for example by re-spreading it on land for agricultural benefit or infilling and re-contouring a gully-head outside of the immediate area of the dam. Care is required to ensure peat and organic earth fills do not generate a risk either from instability or erosion. The gully into which the spillway discharges should not be used for disposal of unsuitables.

8.2 Earthworks and Dam Fill

General dam fill will be obtained from onsite sources of Awhitu Group sand and silt mixtures. Several potential borrow sites have been identified within the reservoir area.

Sand dominated earth fills tend to require the addition of significant moisture to achieve an acceptable degree of compaction. This will necessitate access to a locally derived water source. The compacted sand fill is likely to be relatively free draining but may be subject to erosion due to water flow for example from rainfall on dam batters during construction.

8.3 Erosion and Sediment Control

Further to the potential for erosion of compacted dam fill, there is potential for open borrow areas or potions of the dam footprint that have been stripped of topsoil to erode. Construction is to be managed to minimise the area of exposed soil at any time. Completed borrow areas shall be reinstated for example by using unsuitable soils obtained from the dam foundation undercut.

Appropriate sediment control is likely to take the form of careful worksite drainage, silt fences, and collection of site runoff into sediment stilling areas as indicated in the drawings.

9.0 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 and the relevant government authorities in processing the consent. 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

Christchurch:
22 Moorhouse Ave. Addington, Christchurch 8011
PO Box 4355, Christchurch 8140
Tel. 03 379 4402 Email: rileychch@riley.co.nz

Auckland:
4 Fred Thomas Drive, Takapuna, Auckland 0622
PO Box 100253, North Shore, Auckland 0745
Tel. 09 489 7872 Email: riley@riley.co.nz

GEOTECHNICAL AND GEOLOGICAL INFORMATION

SOIL TYPES AND SYMBOLS

☒	FILL	▤	CLAY
▥	TOPSOIL	▨	PEAT
▦	SILT	▼	GROUNDWATER LEVEL
▩	SAND	⊥ 10,11,10	SCALA PENETROMETER LAST 3 NUMBER OF BLOWS PER 50mm INCREMENT
▩	GRAVEL		

ROCK TYPES AND SYMBOLS

▤	SANDSTONE	▨	BASALT
▦	SILTSTONE	▨	TUFF
▤	MUDSTONE	▨	IGNIMBRITE
▦	LIMESTONE	▨	GREYWACKE

SOIL STRENGTH CLASSIFICATION

FINE GRAINED COHESIVE SOILS

TERM	FIELD IDENTIFICATION	UNDRAINED SHEAR STRENGTH (KPa)
Very Soft (Vs)	Exudes between fingers when squeezed.	<12
Soft (S)	Easily indented by fingers.	12 – 25
Firm (F)	Indented only by strong finger pressure.	25 – 50
Stiff (St)	Indented by thumb pressure.	50 – 100
Very Stiff (VSt)	Indented by thumbnail.	100 – 200
Hard (H)	Difficult to indent by thumbnail.	200+

SPT & SCALA PENETROMETER RESULTS

TERM	SPT VALUE No. of BLOWS/300mm	SCALA PENETROMETER No. of BLOWS/100mm
very dense	>50	17+
dense	30 – 50	7 – 17
medium dense	10 – 30	3 – 7
loose	4 – 10	1 – 3
very loose	0 – 4	0 – 2

ROCK STRENGTH CLASSIFICATION

TERM		FIELD IDENTIFICATION	UNCONFINED UNIAXIAL COMPRESSIVE STRENGTH (MPa)
Extremely weak	(EW)	Indented by thumbnail.	< 1
Very weak	(VW)	Crumbles under firm blows with point of geological hammer. Can be peeled with pocket knife.	1 – 5
Weak	(W)	Difficult to peel with pocket knife.	5 – 20
Moderately strong	(MS)	Cannot be scraped or peeled with pocket knife.	20 – 50
Strong	(S)	More than one blow of geological hammer to fracture.	50 – 100
Very strong	(VS)	Many blows of geological hammer to break.	100 – 250
Extremely strong	(ES)	Can only be chipped with geological hammer.	250+

MOISTURE CONDITION

Dry (D)	Looks and feels dry; powdery and friable.
Moist (M)	Feels cool; darkened in colour; no free water when remoulded.
Wet (W)	Feels cool; darkened in colour; free water forms on hands.
Saturated (S)	Free water is present on sample.

SAMPLE TYPES

■	UNDISTURBED
☒	MACHINE AUGER DISTURBED
D	HAND AUGER DISTURBED
▼	STANDARD PENETRATION TEST (solid cone)
▽	STANDARD PENETRATION TEST (hollow cone)

DRILLING METHOD

OB	OPEN BARREL
TT	TRIPLE TUBE
WB	WASH BORE
SH	UNDISTURBED SHELBY TUBE
RC	ROCK CORE
SPT	STANDARD PENETRATION TEST

FIELD TESTS

V	SHEAR VANE (corrected to BS:1377)
R	REMOULDED STRENGTH
P	POCKET PENETROMETER
CH	CLEGG HAMMER

INFORMATION BASED ON THE NZ GEOTECHNICAL SOCIETY INC. GUIDELINES FOR THE CLASSIFICATION AND DESCRIPTION OF SOIL AND ROCK FOR ENGINEERING PURPOSES

GEOLOGICALINFO.DWG REV. 3

Riley Consultants Limited
Level 1, 4 Fred Thomas Drive
Auckland 0622
Tel: 09 489 7872

TEST PIT LOG

Project: Northland Irrigation Pre-Feasibility	Location: K13, Te Kopuru, Kaipara Coast	Hole position: K13 Spillway, W of ridgetop.	No.: **TP01**
Job No.: 190272	Start Date: 30-04-20 Finish Date: 30-04-20	Ground Level (m):	Co-Ordinates (Mt Eden 2000):
Client: Northland Regional Council	Hole Depth: 5.70 m		Sheet: 1 of 1

Depth (m)	Geological Unit	Geological Description (refer to separate Geotechnical and Geological Information sheet for further information)	Soil Moisture	Tests
0.15	Awhitu Group	TOPSOIL	D	V= 41 R= 23
0.70		Silty SAND; light grey. Stiff/very loose; dry; non plastic; sand, very fine [AWHITU FIXED DUNE DEPOSITS]. 0.50 m Becomes very stiff to hard.		V= 203+
1.00		Moderately weathered; light orange brown closely fractured silty SANDSTONE. Very weak to extremely weak; weakly cemented; closely spaced, narrow, sub horizontal fractures filled with rootlets [HARD PAN].	M	V= 203+
2.20		Silty SAND, some clay; light brown, speckled black. Hard; moist; slightly plastic with 1m long, closely spaced, very thin lenses of organic silt. 1.40 m Becomes stiff.		V= 98 R= 49
2.80		SILT, some organics, trace to some clay; dark brown. Stiff to very stiff; moist; slightly plastic; organics, amorphous.		V= 203+
3.00		SAND; light orange to light yellow. Medium dense; sand, fine; limonite staining.		V= 203+
5.70		Silty SAND, trace clay; light yellow to light orange. Loose/very stiff; moist to wet; non plastic; sand, fine to medium.	MW	V= 139 R= 75 V= 203+
		EOH @ 5.70 m		

Elevation (m) | Depth (m) 1 2 3 4 5 | Legend | Unified Symbol | Soil Shear Strength (kPa) 50 100 150 200 | Scala Penetrometer (blows / 50 mm) 3 6 9 12 15 | Groundwater | Samples

Explanations:
Rock Mass Weathering - unweathered, slightly weathered, moderately weathered, highly weathered, completely weathered, residually weathered
Relative soil Strength - very soft/very loose, soft/loose, firm/medium dense, stiff/dense, very stiff/very dense

- ● Small Disturbed Sample
- Large Disturbed Sample
- ■ U100 Undisturbed Sample
- ▼ Scala Penetrometer - blows/50mm
- Permeability Test
- ▼ Schmidt Hammer
- ∨ Insitu Vane Shear Strength (kPa) V=Peak, R=Residual, UTP=Unable to penetrate
- ▼ Water Strike (1st, 2nd ...)
- Water Rise (1st, 2nd ...) and Rise Time (minutes)

GROUNDWATER
☒ None
☐ Slow Seep (depth)
☐ Rapid Inflow (depth)

HOLE TERMINATED DUE TO:
Target Depth

Remarks

All dimensions in metres Scale 1:34	Rig Type: CAT 313F	Shear Vane No. 1706	Logged by: AWT	Checked by: SRO

Riley Consultants Limited
Level 1, 4 Fred Thomas Drive
Auckland 0622
Tel: 09 489 7872

TEST PIT LOG

Project: Northland Irrigation Pre-Feasibility

Location: K13, Te Kopuru, Kaipara Coast

Hole position: K13 True Right Abutment

No.: **TP02**

Job No.: 190272

Start Date: 30-04-20
Finish Date: 30-04-20

Ground Level (m):

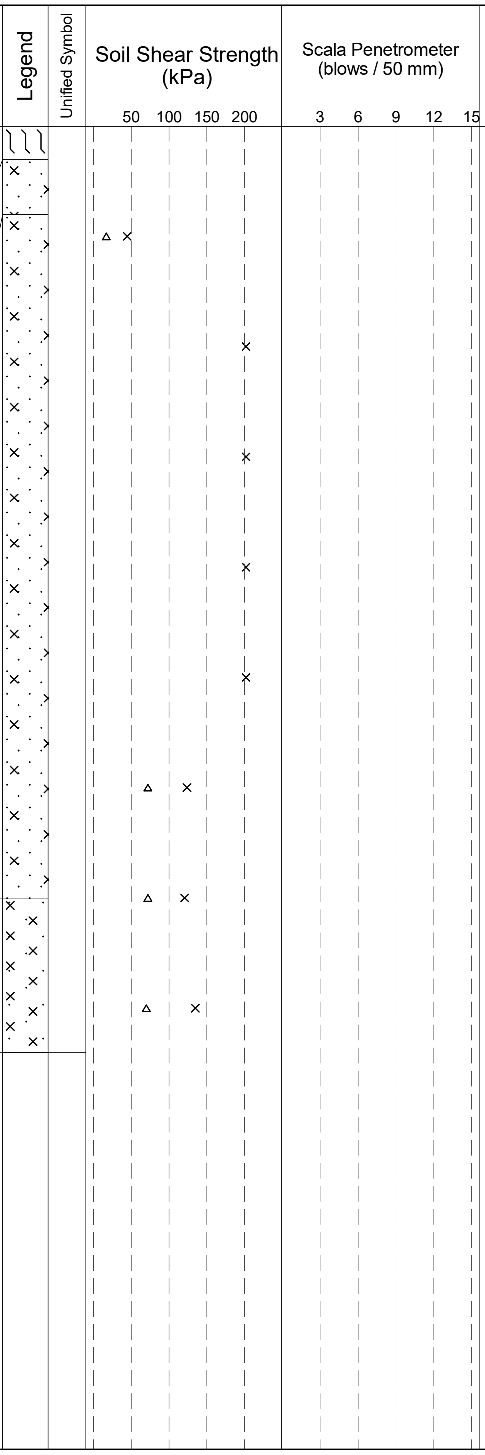
Co-Ordinates (Mt Eden 2000):

Client: Northland Regional Council

Hole Depth: 4.20 m

Sheet: 1 of 1

Elevation (m)	Depth (m)	Geological Unit	Geological Description (refer to separate Geotechnical and Geological Information sheet for further information)	Groundwater	Soil Moisture	Samples	Tests
	0.15		TOPSOIL		D		
	0.40	Awhitu Group	Silty SAND; orange brown. Hard/medium dense; non plastic; sand, fine [AWHITU FIXED DUNE DEPOSITS].				
	3.50		Silty SAND, some clay; light grey to light yellow. Very stiff/loose; dry; slightly plastic; sand, fine. 0.90 m Grades to light brown to orange brown. 2.00 m - 2.50 m Minor amorphous organics; dark orange brown; slightly plastic.				V= 46 R= 17 V= 203+ V= 203+ V= 203+ V= 203+ V= 125 R= 72 V= 122 R= 72
	4.20		Sandy SILT, minor clay; dark orange brown. Very stiff to stiff; moist to wet; non plastic; sand, fine; trace amorphous organics.		MW		V= 136 R= 70
			EOH @ 4.20 m				



Explanations:

Rock Mass Weathering - unweathered, slightly weathered, moderately weathered, highly weathered, completely weathered, residually weathered
Relative soil Strength - very soft/very loose, soft/loose, firm/medium dense, stiff/dense, very stiff/very dense

- ● Small Disturbed Sample
- Large Disturbed Sample
- ■ U100 Undisturbed Sample
- ▼ Scala Penetrometer - blows/50mm
- Permeability Test
- ▼ Schmidt Hammer
- ✓ Insitu Vane Shear Strength (kPa) V=Peak, R=Residual, UTP=Unable to penetrate
- ▼ Water Strike (1st, 2nd ...)
- ▽ Water Rise (1st, 2nd ...) and Rise Time (minutes)

GROUNDWATER

☒ None

☐ Slow Seep (depth)

☐ Rapid Inflow (depth)

HOLE TERMINATED DUE TO:
Target Depth

Remarks

1. Material @0.15mbgl extended down to 2.0mbgl in E. cnr. - Tree mould/erosion channel?

All dimensions in metres
Scale 1:34

Rig Type: CAT 313F

Shear Vane No. 1706

Logged by: AWT

Checked by: SRO

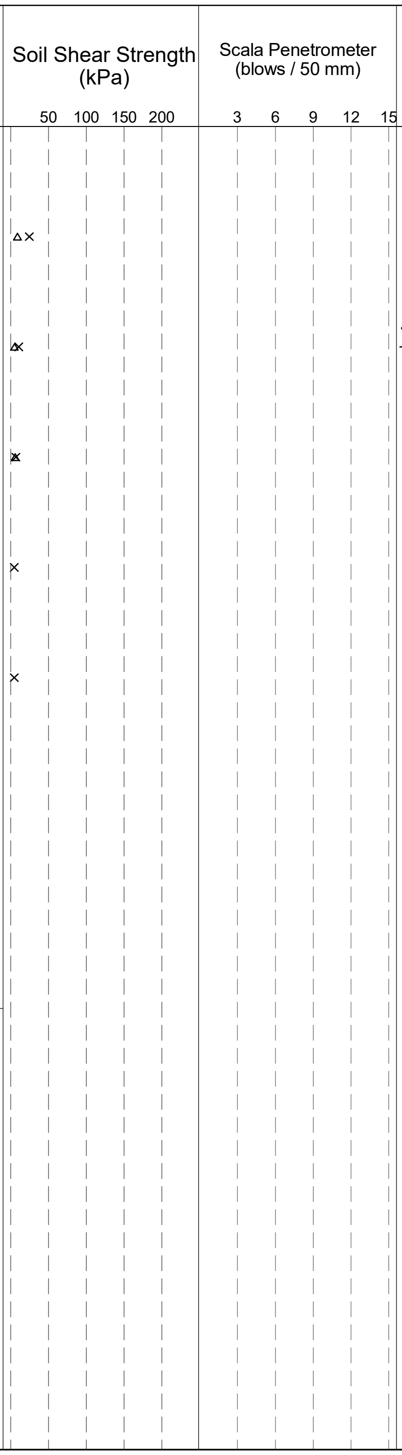
RILEY CONSULTANTS Engineers and Geologists

Riley Consultants Limited
Level 1, 4 Fred Thomas Drive
Auckland 0622
Tel: 09 489 7872

TEST PIT LOG

Project: Northland Irrigation Pre-Feasibility	Location: K13, Te Kopuru, Kaipara Coast	Hole position: Middle of embankment	No.: **TP03**
Job No.: 190272	Start Date: 30-04-20 Finish Date: 30-04-20	Ground Level (m):	Co-Ordinates (Mt Eden 2000):
Client: Northland Regional Council	Hole Depth: 4.00 m		Sheet: 1 of 1

Elevation (m)	Depth (m)	Geological Unit	Geological Description (refer to separate Geotechnical and Geological Information sheet for further information)	Unified Symbol	Groundwater	Soil Moisture	Samples	Tests
	0.15	Tauranga Group (0.00–4.00)	TOPSOIL			DM		
			Organic SILT; dark brown, mottled dark grey. Spongy; firm; wet; organics, fibrous plant remains [TAURANGA GROUP ALLUVIUM].			M W		V= 26 R= 9 rootlets
	1		1.00 m Minor wood inclusions. Soft; saturated.		30/04/2020	S		V= 12 R= 5 rootlets
	1.40		Organic clayey SILT; dark reddish brown. Soft; saturated; liquid limit exceeded; organics, fibrous plant remains, strong hydrogen sulfide odour.					V= 8 R= 6
	2							V= 6 R= - sank on remould
								V= 6 R= - sank on remould
	3							-
	4.00		Collapsed from 4mbgl to 3mbgl. EOH @ 4.00 m					-
	5							



Explanations:
Rock Mass Weathering - unweathered, slightly weathered, moderately weathered, highly weathered, completely weathered, residually weathered
Relative soil Strength - very soft/very loose, soft/loose, firm/medium dense, stiff/dense, very stiff/very dense

- ● Small Disturbed Sample
- ↕ Large Disturbed Sample
- ■ U100 Undisturbed Sample

- ▼ Scala Penetrometer - blows/50mm
- Permeability Test
- ▼ Schmidt Hammer
- ✓ Insitu Vane Shear Strength (kPa) V=Peak, R=Residual, UTP=Unable to penetrate
- ▼ Water Strike (1st, 2nd ...)
- ▽ Water Rise (1st, 2nd ...) and Rise Time (minutes)

GROUNDWATER
☐ None
☒ Slow Seep (depth 1.0 m)
☐ Rapid Inflow (depth)

HOLE TERMINATED DUE TO:
Collapse

Remarks
1. 33mm shearvane blade was used - undrained shearstrengths are estimates only and conditional on results of calibration.

All dimensions in metres Scale 1:34	Rig Type: CAT 313F	Shear Vane No. 1706	Logged by: AWT	Checked by: SRO

RILEYAKL.GLB Log RILEY TP (AKL) 190272 K13.GPJ <<DrawingFile>> 10/05/2020 16:52 Produced by gINT Professional

RILEY CONSULTANTS Engineers and Geologists

Riley Consultants Limited
Level 1, 4 Fred Thomas Drive
Auckland 0622
Tel: 09 489 7872

TEST PIT LOG

Project: Northland Irrigation Pre-Feasibility	Location: K13, Te Kopuru, Kaipara Coast	Hole position: True Left abutment	No.: **TP04**
Job No.: 190272	Start Date: 30-04-20 Finish Date: 30-04-20	Ground Level (m):	Co-Ordinates (Mt Eden 2000):
Client: Northland Regional Council	Hole Depth: 3.70 m		Sheet: 1 of 1

Elevation (m)	Depth (m)	Geological Unit	Geological Description (refer to separate Geotechnical and Geological Information sheet for further information)	Legend	Unified Symbol	Soil Shear Strength (kPa) 50 100 150 200	Scala Penetrometer (blows / 50 mm) 3 6 9 12 15	Groundwater	Soil Moisture	Samples	Tests
	0.15	Colluvium	TOPSOIL						DM		V= 46 R= 12
	0.40		Silty SAND, minor clay; light yellow, mottled dark brown, orange. Firm; moist to wet; non plastic; sand, fine [COLLUVIUM].						MW		V= 41 R= 6
	1.20		Silty SAND; dark brown to black. Firm/very loose; wet; slightly plastic; sand, fine; organics, amorphous and rootlets.					1/05/2020	S		
	2.20	Tauranga Group	Silty PEAT; black, mottled dark grey. Spongy; soft; saturated; non plastic; organics, large tree trunk, wood inclusions and plant remains; no shearvane test due to tree trunk [TAURANGA GROUP ALLUVIUM].								
	2.80		Sandy Clayey SILT, trace organics; greyish brown. Soft; saturated; moderately plastic; sand, fine; strong hydrogen sulfide odour.								V= 26 R= 0
	3.70		2.80 m Collapse above 2.8m, bulging. Silty sandy CLAY; light greyish brown. Very soft; saturated, highly plastic; sand, fine. 3.20 m Becomes light grey with black specks.								V= 32 R= 04 V= 32 R= 04
			Collapsed EOH @ 3.70 m								

Explanations:
Rock Mass Weathering - unweathered, slightly weathered, moderately weathered, highly weathered, completely weathered, residually weathered
Relative soil Strength - very soft/very loose, soft/loose, firm/medium dense, stiff/dense, very stiff/very dense

● Small Disturbed Sample
↕ Large Disturbed Sample
■ U100 Undisturbed Sample

▼ Scala Penetrometer - blows/50mm
Permeability Test
Schmidt Hammer
✓ Insitu Vane Shear Strength (kPa) V=Peak, R=Residual, UTP=Unable to penetrate
▼ Water Strike (1st, 2nd ...)
Water Rise (1st, 2nd ...) and Rise Time (minutes)

GROUNDWATER
☐ None
☒ Slow Seep (depth 1.2 m)
☐ Rapid Inflow (depth)

HOLE TERMINATED DUE TO:
Collapse

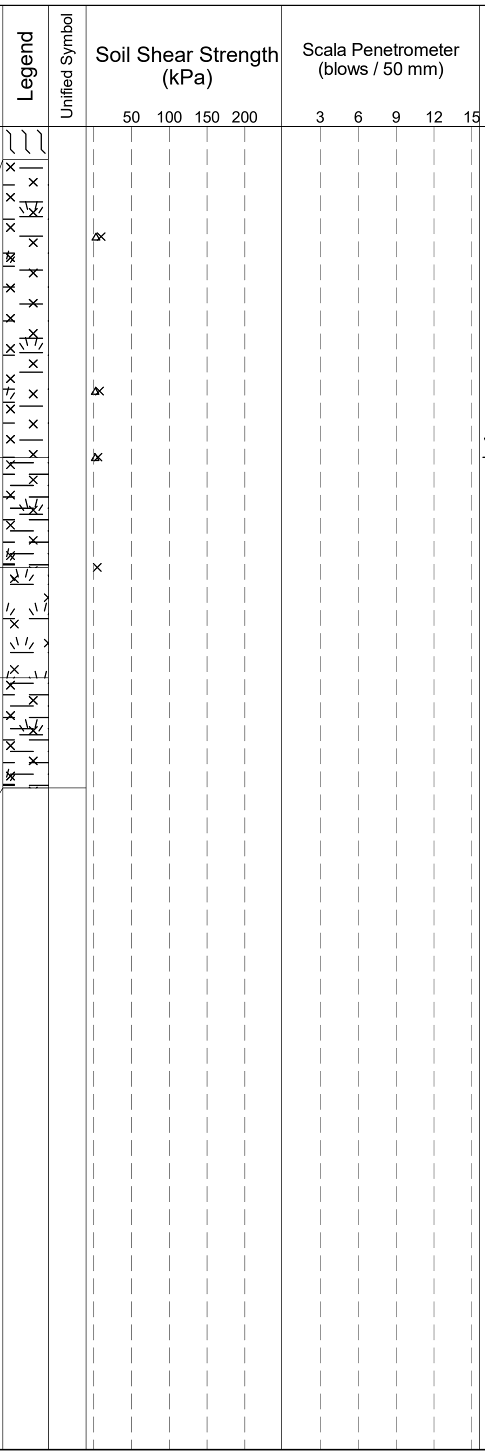
Remarks
1. Moved 10m downslope for safe digger access. Slope was a bit boggy and steep; possibly located on slip debris.

All dimensions in metres Scale 1:34	Rig Type: CAT 313F	Shear Vane No. 1706	Logged by: AWT	Checked by: SRO

Riley Consultants Limited
Level 1, 4 Fred Thomas Drive
Auckland 0622
Tel: 09 489 7872

TEST PIT LOG

Project: Northland Irrigation Pre-Feasibility	Location: K13, Te Kopuru, Kaipara Coast	Hole position: K13 Upstream toe of embankment, centre.	No.: **TP06**
Job No.: 190272	Start Date: 30-04-20 Finish Date: 30-04-20	Ground Level (m):	Co-Ordinates (Mt Eden 2000):
Client: Northland Regional Council	Hole Depth: 3.00 m		Sheet: 1 of 1



Depth (m)	Geological Unit	Geological Description (refer to separate Geotechnical and Geological Information sheet for further information)	Soil Moisture	Tests
0.15	Tauranga Group	TOPSOIL	DM	
1.50	Tauranga Group	Organic clayey SILT; dark brown. Soft to firm; wet to saturated; moderately plastic; organics, fibrous plant remains, tree trunks etc [TAURANGA GROUP ALLUVIUM]. 0.70 m Tree trunk, ~500mm dia. firm, fibrous.	WS	V= 11 R= 3 V= 9 R= 2
2.00	Tauranga Group	Organic silty CLAY; dark orange brown, Soft; saturated; liquid limit exceeded; organics, fibrous wood.	S	V= 7 R= 2
2.50	Tauranga Group	Silty PEAT; dark orange brown. Soft; Spongy; fibrous; saturated; organics, wood, and plant remains; strong hydrogen sulfide odour.		V= 6 R= - Sank on remould
3.00	Tauranga Group	2.50 m Collapsing due to slow groundwater ingress from above. Material saturated. Organic clayey SILT; dark reddish brown. Very soft; saturated; liquid limit exceeded; organics, fibrous plant remains and tree trunks/roots up to~300mm.		- -
		EOH @ 3.00 m		

Explanations:
Rock Mass Weathering - unweathered, slightly weathered, moderately weathered, highly weathered, completely weathered, residually weathered
Relative soil Strength - very soft/very loose, soft/loose, firm/medium dense, stiff/dense, very stiff/very dense

● Small Disturbed Sample
↕ Large Disturbed Sample
■ U100 Undisturbed Sample

▼ Scala Penetrometer - blows/50mm
Permeability Test
Schmidt Hammer
✓ Insitu Vane Shear Strength (kPa) V=Peak, R=Residual, UTP=Unable to penetrate
Water Strike (1st, 2nd ...)
Water Rise (1st, 2nd ...) and Rise Time (minutes)

GROUNDWATER
☐ None
☒ Slow Seep (depth 1.5 m)
☐ Rapid Inflow (depth)

HOLE TERMINATED DUE TO:
Collapse

Remarks
1. 33mm shearvane blade was used - undrained shearstrengths are estimates only and conditional on results of calibration.

All dimensions in metres Scale 1:34	Rig Type: CAT 313F	Shear Vane No. 1706	Logged by: AWT	Checked by: SRO

Riley Consultants Limited
Level 1, 4 Fred Thomas Drive
Auckland 0622
Tel: 09 489 7872

TEST PIT LOG

Project: Northland Irrigation Pre-Feasibility	Location: K13, Te Kopuru, Kaipara Coast	Hole position: K13 Borrow Area	No.: **TP07**
Job No.: 190272	Start Date: 30-04-20 Finish Date: 30-04-20	Ground Level (m):	Co-Ordinates (Mt Eden 2000):
Client: Northland Regional Council	Hole Depth: 4.20 m		Sheet: 1 of 1

Depth (m)	Geological Unit	Geological Description (refer to separate Geotechnical and Geological Information sheet for further information)	Soil Moisture	Tests
0.15		TOPSOIL	D	
0.35	Awhitu Group	Silty SAND; light grey. Loose/very stiff; dry; non plastic; sand, fine [AWHITU GROUP FIXED DUNE DEPOSITS].		V= 41 R= 12 V= 203+
0.90		Sandy SILT; dark brown to light orange. Hard; dry; non plastic; sand, fine.		V= 203+
2.00		Sandy SILT, some clay; light grey. Very stiff; moist; slightly to moderately plastic; sand, fine. 1.20 m Becomes slightly plastic.	M	V= 203+ V= 203+
2.20		SILT, some clay, trace sand, trace to minor rootlets; light grey. Very stiff; moist; slightly plastic; sand, fine; rootlets, fibrous.		V= 92 R= 14
3.00		Silty SAND; light grey to dark brown. Very stiff; moist, non plastic; sand, fine. 2.60 m Minor clay, trace organics. Slightly plastic; organics, amorphous.		V= 203+
4.20		SILT, some clay, some sand, trace to organics; dark brown. Very stiff; moist; slightly plastic; sand, fine; organics, amorphous.		V= 203+ V= 203+
		EOH @ 4.20 m		

Explanations:
Rock Mass Weathering - unweathered, slightly weathered, moderately weathered, highly weathered, completely weathered, residually weathered
Relative soil Strength - very soft/very loose, soft/loose, firm/medium dense, stiff/dense, very stiff/very dense

● Small Disturbed Sample
Large Disturbed Sample
■ U100 Undisturbed Sample

Scala Penetrometer - blows/50mm
Permeability Test
Schmidt Hammer
Insitu Vane Shear Strength (kPa) V=Peak, R=Residual, UTP=Unable to penetrate
Water Strike (1st, 2nd ...)
Water Rise (1st, 2nd ...) and Rise Time (minutes)

GROUNDWATER
☒ None
☐ Slow Seep (depth)
☐ Rapid Inflow (depth)

HOLE TERMINATED DUE TO:
Target Depth

Remarks

All dimensions in metres Scale 1:34	Rig Type: CAT 313F	Shear Vane No. 1706	Logged by: AWT	Checked by: SRO

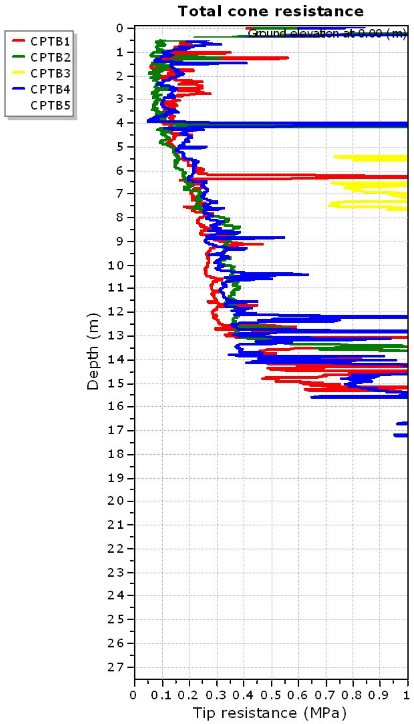
APPENDIX B

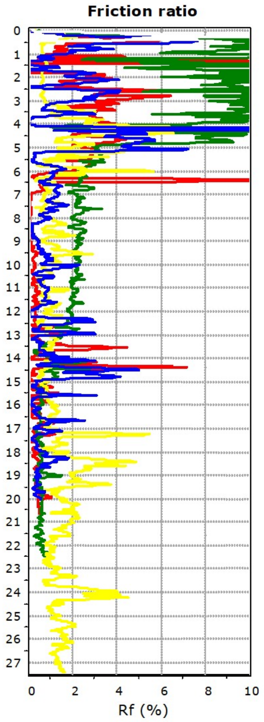
CPT Results

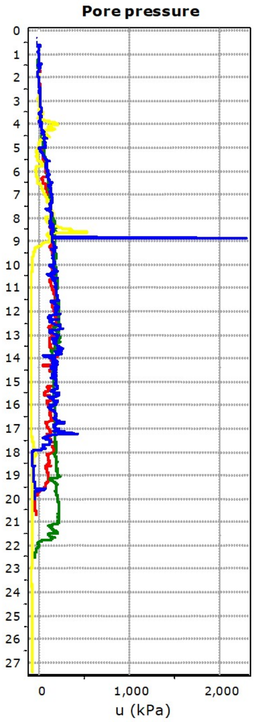
Project:

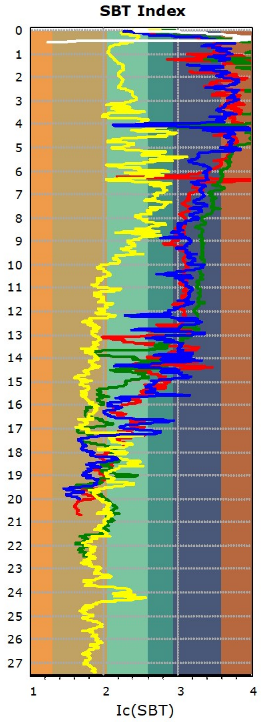
Location:

Overlay basic interpretation plots

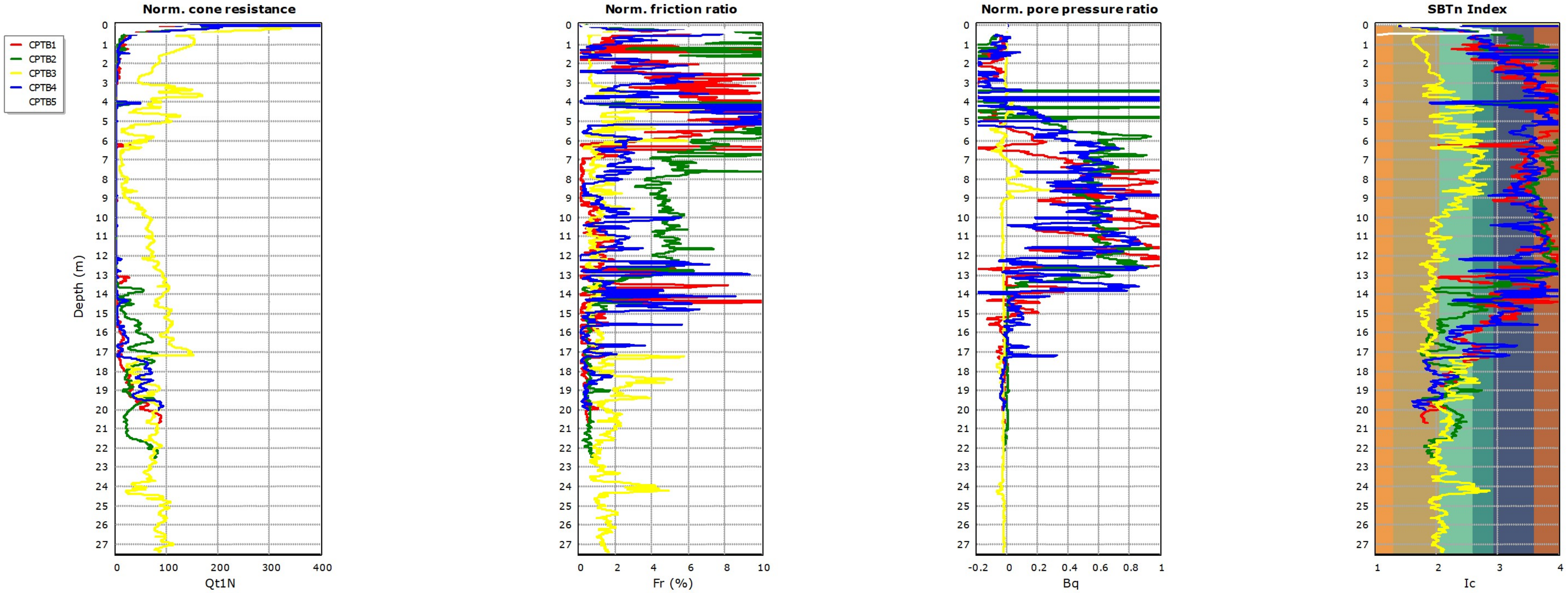








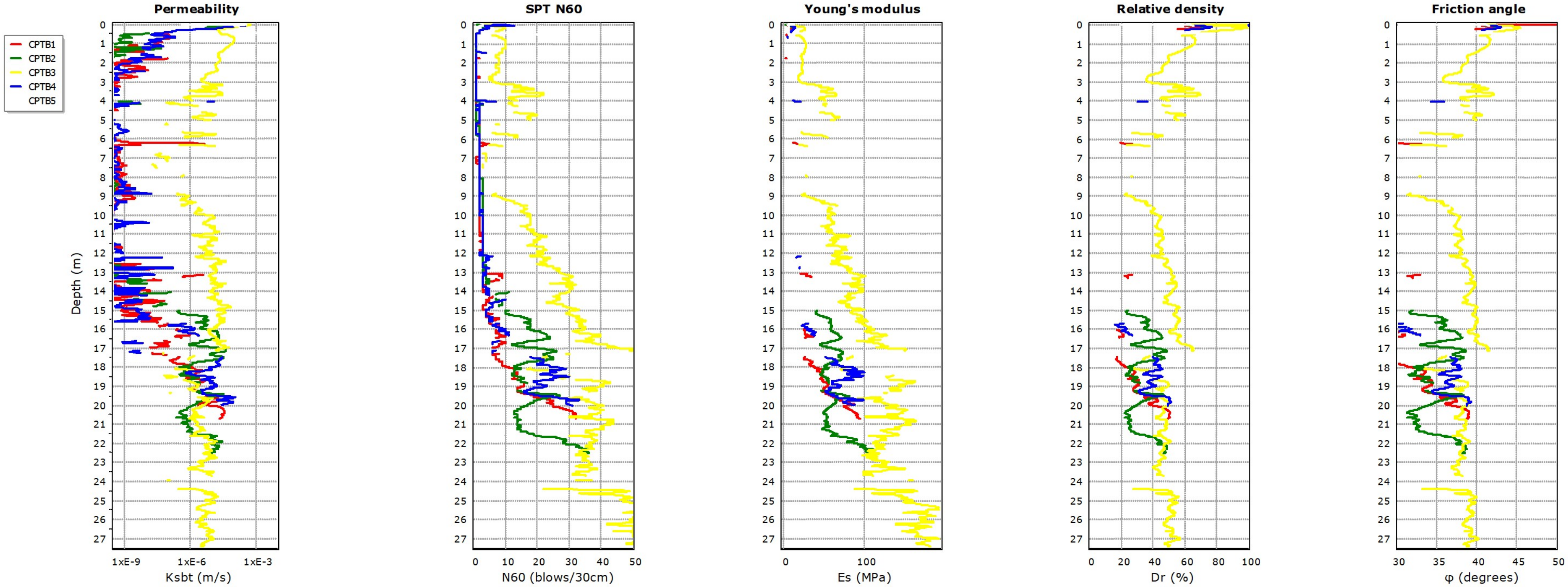
Normalized basic plots



Project:

Location:

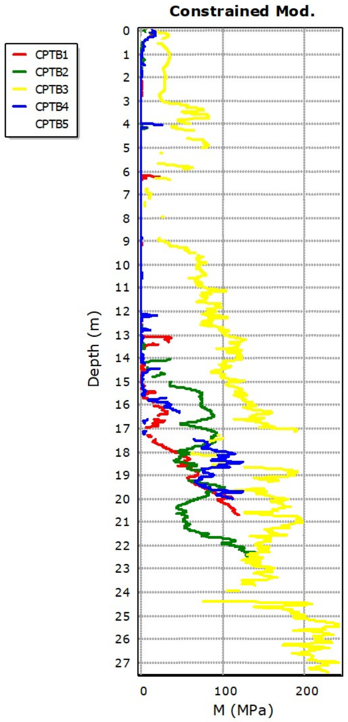
Overlay estimation plots (1)

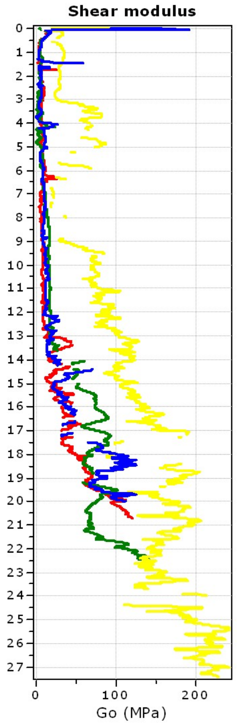


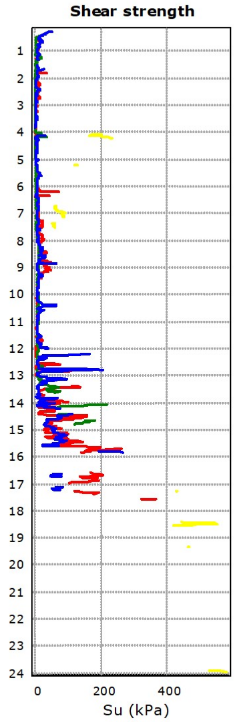
Project:

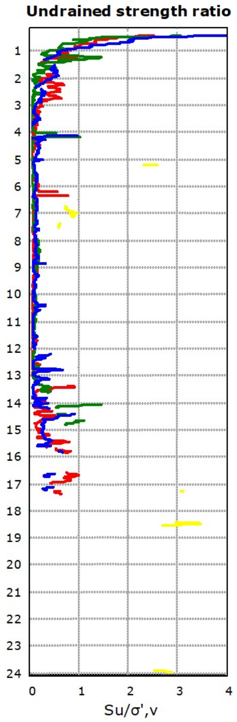
Location:

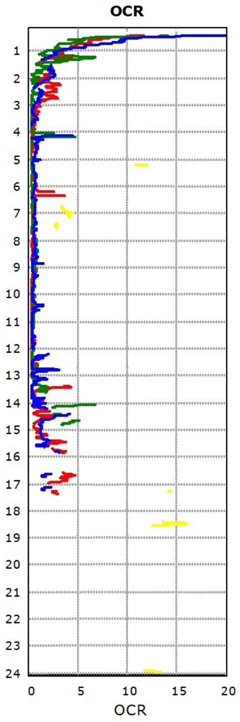
Overlay estimation plots (2)







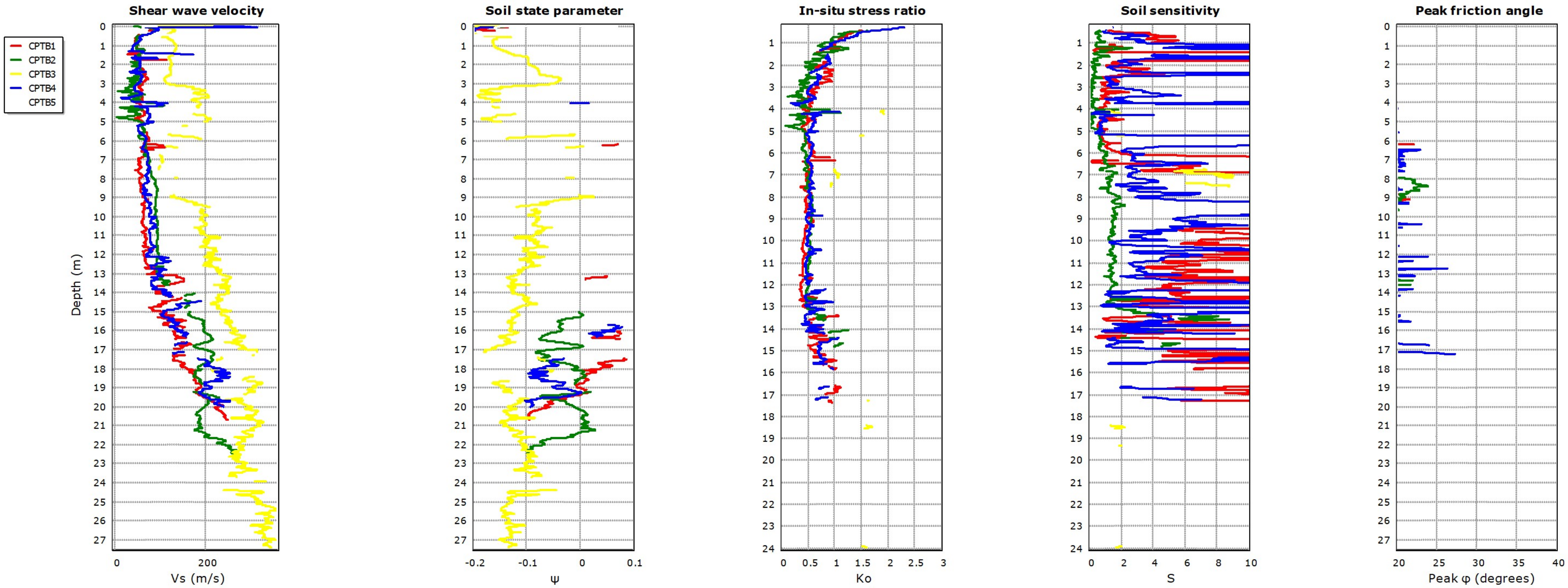




Project:

Location:

Overlay estimation plots (3)



APPENDIX C

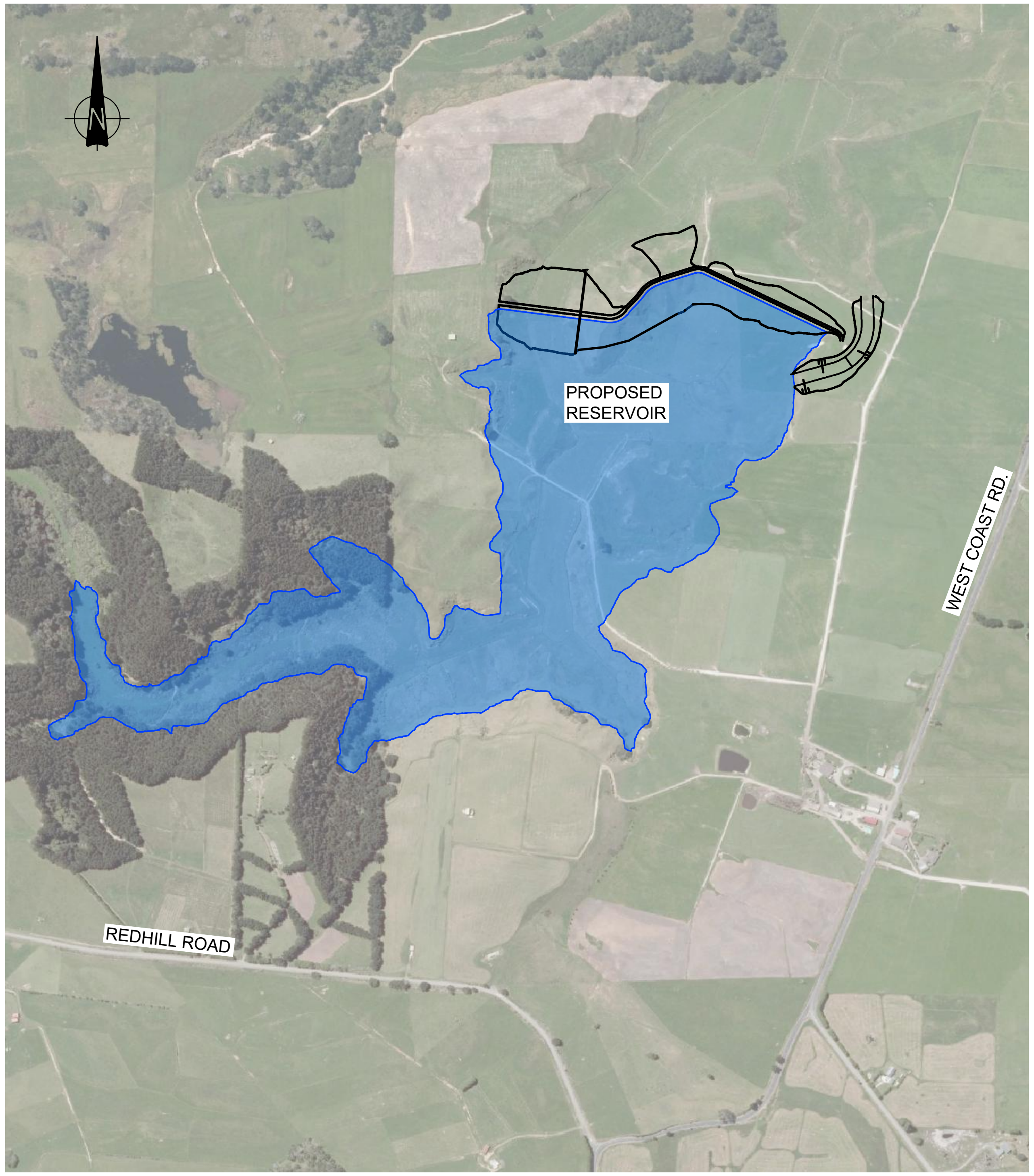
RILEY Dwgs:
200240/2-0 to -3,
-101 to -109

TE TAI TOKERAU WATER TRUST

ARATAPU WATER STORAGE RESERVOIR

DRAWING LIST - AUGUST 2020

DWG. No.	TITLE	REV.
200240/1-0	DRAWING LIST & LOCATION PLAN	1
200240/1-1	DAM SITE AND INVESTIGATION PLAN	1
200240/1-2	DAM GEOTECHNICAL SECTION A	1
200240/1-3	DAM GEOTECHNICAL CROSS SECTION B	1
200240/1-101	DAM AND RESERVOIR LAYOUT - 4 Mm³ OPTION	1
200240/1-102	DAM EMBANKMENT LAYOUT - 4 Mm³ OPTION	1
200240/1-103	SPILLWAY DETAILS - 4 Mm³ OPTION	1
200240/1-104	DAM EMBANKMENT DETAILS - 4 Mm³ OPTION	1
200240/1-105	TYPICAL CONDUIT DETAILS	1
200240/1-106	SEDIMENT CONTROL WORKS - 4 Mm³ OPTION	1
200240/1-107	DAM SITE AND INVESTIGATION LAYOUT - 1.5 Mm³ OPTION	1
200240/1-108	DAM TYPICAL CROSS SECTION - 1.5 Mm³ OPTION	1
200240/1-109	SPILLWAY DETAILS - 1.5 Mm³ OPTION	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
200240/2-210	CATCHMENT PLAN - AERIAL BACKGROUND	1
200240/1-211	CATCHMENT PLAN - GEOLOGY BACKGROUND	1
200240/2-220	10,000 YEAR DESIGN FLOOD - PEAK LEVELS	1
200240/2-221	10,000 YEAR DESIGN FLOOD - PEAK DEPTHS	1
200240/1-222	10,000 YEAR DESIGN FLOOD - PEAK VELOCITIES	1



NOTE: MAP SOURCED FROM LINZ

SITE LOCATION

SCALE 1: 10 000

SCALE 1:10,000

0 100 200 300 400 600 (m)

FOR CONSENT

1		FOR CONSENT	MP
REV	DATE	ISSUE	BY

DESIGN EM	DES CHECK TS	APPROVED FOR ISSUE S.A. Vaughan
DRAWN MP	CAD CHECK JM	
DATE DRAWN AUG. 2020		ISSUE DATE 01 / 09 / 20

RILEY CONSULTANTS
www.riley.co.nz

WILLIAMSON WATER & LAND ADVISORY

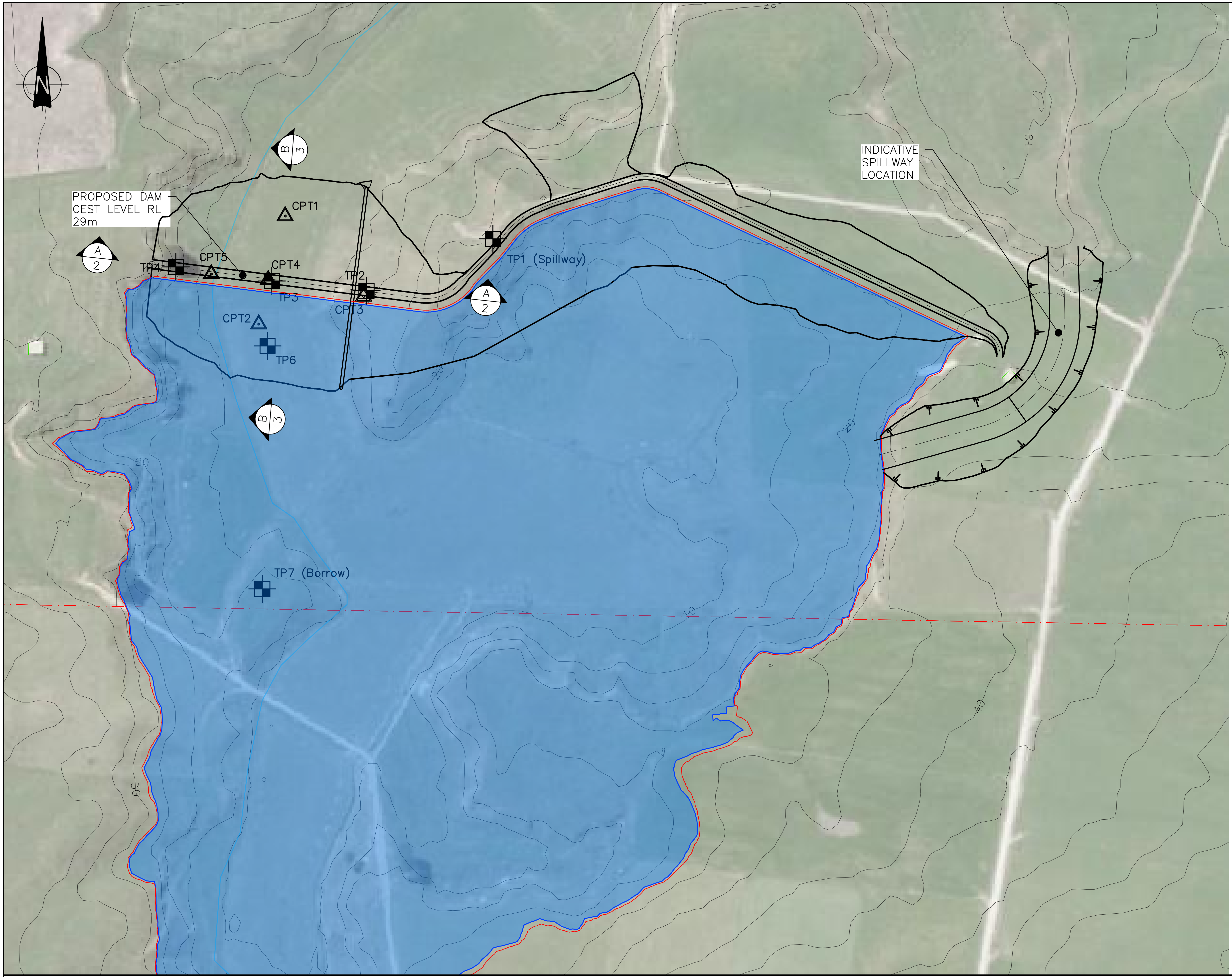
TE TAI TOKERAU WATER TRUST
Ngā Puna Wai: He koha Oranga Tangata He koha Oranga Whenua
The Springs of Water: A gift of life to our people. A gift of life to our land

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

ACENZ

ISO CERTIFIED GCS

CADFILE 200240_2–0.dwg	
SCALE (A3) 1:10,000	ORIG. SHEET SIZE A3
DRAWING No. 200240/2-0	REV. 1



LEGEND

5m CONTOURS

PROPERTY BOUNDARY

STREAM CHANNELS

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.

25 0 50 100m

SCALE 1:2500

FOR CONSENT

REV	DATE	ISSUE	BY

DESIGN	DES CHECK	APPROVED FOR ISSUE
TS	TS	S.A. Vaughan
DRAWN	CAD CHECK	
MP	JM	
DATE DRAWN		ISSUE DATE
AUG. 2020		01 / 09 / 20

RILEY CONSULTANTS
www.riley.co.nz

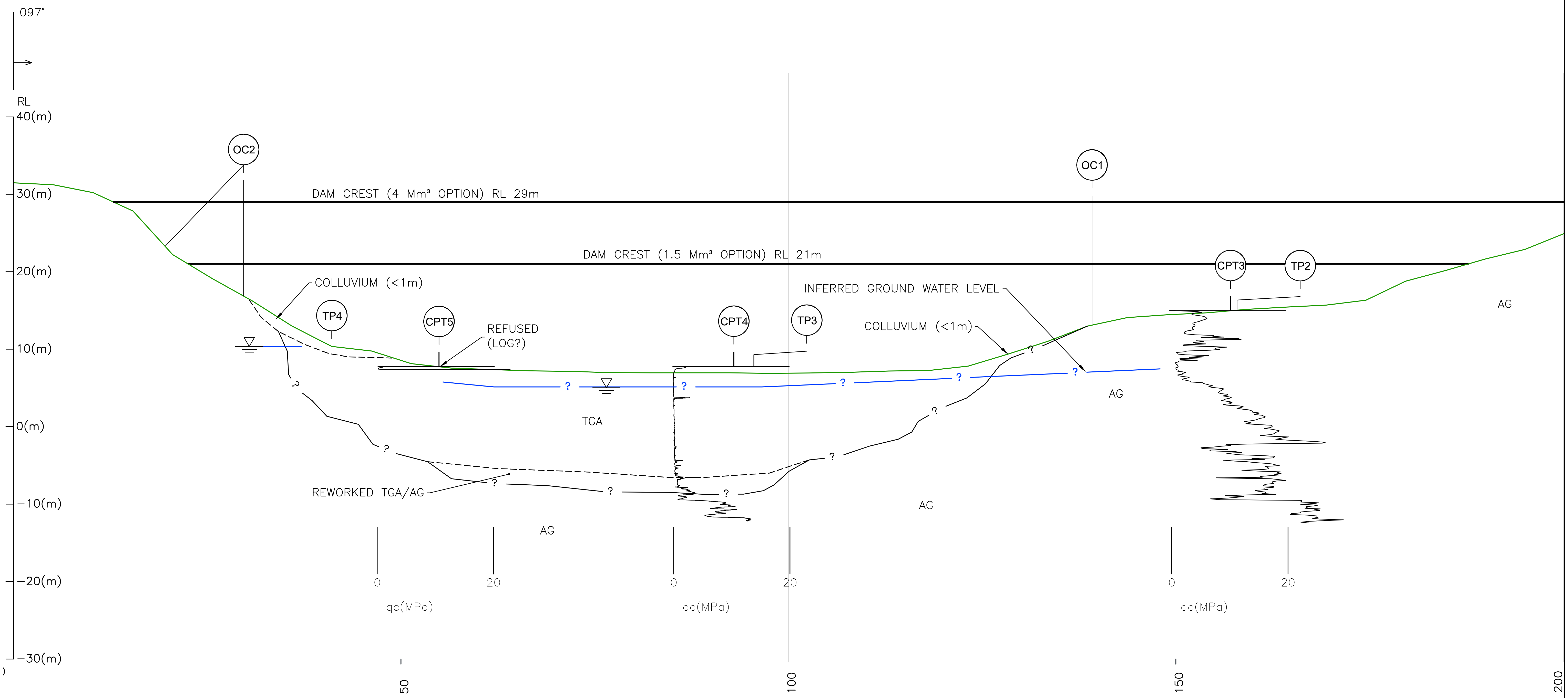
WILLIAMSON WATER & LAND ADVISORY

TE TAI TOKERAU WATER TRUST
Ngā Puna Wai He koha Oranga Tangata He koha Oranga Whenua
The Springs of Water. A gift of life to our people. A gift of life to our land

CLIENT TE TAI TOKERAU WATER TRUST
ADDRESS NORTHLAND WATER STORAGE AND USE PROJECT
PROJECT ARATAPU WATER STORAGE RESERVOIR SITE
SHEET TITLE DAM SITE & INVESTIGATION PLAN

ACENZ
ISO CERTIFIED GCS

CADFILE	
200240_2-1.dwg	
SCALE (A3)	ORIG. SHEET SIZE
1:2500	A3
DRAWING No.	REV.
200240/2-1	1



SECTION A 1

SCALE 1:500

TGA: TAURANGA GROUP ALLUVIUM
- ALLUVIAL, SWAMP AND ESTUARINE DEPOSITS
- SOFT TO VERY SOFT ORGANIC SILT AND SILT
- RECENT DEPOSITS (<12,000 YEARS OLD)

REWORKED TGA/AG
- REDEPOSITED AWHITU GROUP DEPOSITS MIXED WITH RECENT ALLUVIUM

AG: AWHITU GROUP SAND DUNES
- LOOSE TO MODERATE DENSE SAND OR
- EXTREMELY WEAK TO VERY WEAK SANDSTONE (WEAKLY CEMENTED)
- LOCALISED CARBONACEOUS LENSES
- LATE PLIOCENE (1.8M TO 3.6M YEARS OLD)

5 0 10 20m
SCALE 1:500

FOR CONSENT

1		FOR CONSENT	MP
REV	DATE	ISSUE	BY

DESIGN TS	DES CHECK TS	APPROVED FOR ISSUE S.A. Vaughan
DRAWN MP	CAD CHECK JM	
DATE DRAWN AUG. 2020		ISSUE DATE 01 / 09 / 20

RILEY CONSULTANTS
www.riley.co.nz

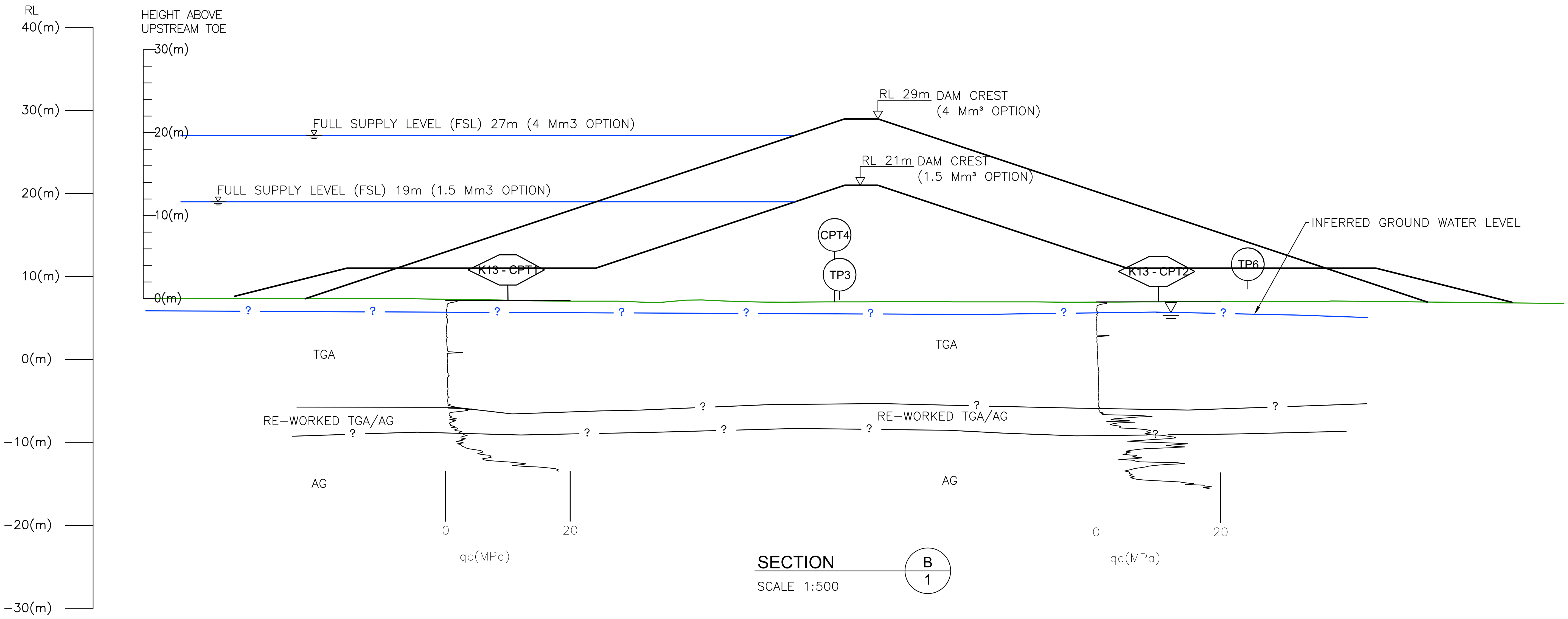
WILLIAMSON WATER & LAND ADVISORY

TE TAI TOKERAU WATER TRUST
Nga Puna Wai He koha Oranga Tangata He koha Oranga Whenua
The Springs of Water. A gift of life to our people. A gift of life to our land

CLIENT TE TAI TOKERAU WATER TRUST
ADDRESS NORTHLAND WATER STORAGE AND USE PROJECT
PROJECT ARATAPU WATER STORAGE RESERVOIR SITE
SHEET TITLE DAM GEOTECHNICAL SECTION A

ACENZ
ISO CERTIFIED 9001 GCS

CADFILE 200240_2−2&3.dwg	
SCALE (A3) 1:500	ORIG. SHEET SIZE A3
DRAWING No. 200240/2-2	REV. 1



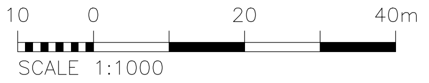
SECTION B 1

SCALE 1:500

TGA: TAURANGA GROUP ALLUVIUM
- ALLUVIAL, SWAMP AND ESTUARINE DEPOSITS
- SOFT TO VERY SOFT ORGANIC SILT AND SILT
- RECENT DEPOSITS (<12,000 YEARS OLD)

REWORKED TGA/AG
- REDEPOSITED AWHITU GROUP DEPOSITS MIXED WITH RECENT ALLUVIUM

AG: AWHITU GROUP SAND DUNES
- LOOSE TO MODERATE DENSE SAND OR
- EXTREMELY WEAK TO VERY WEAK SANDSTONE (WEAKLY CEMENTED)
- LOCALISED CARBONACEOUS LENSES
- LATE PLIOCENE (1.8M TO 3.6M YEARS OLD)



SCALE 1:1000

FOR CONSENT

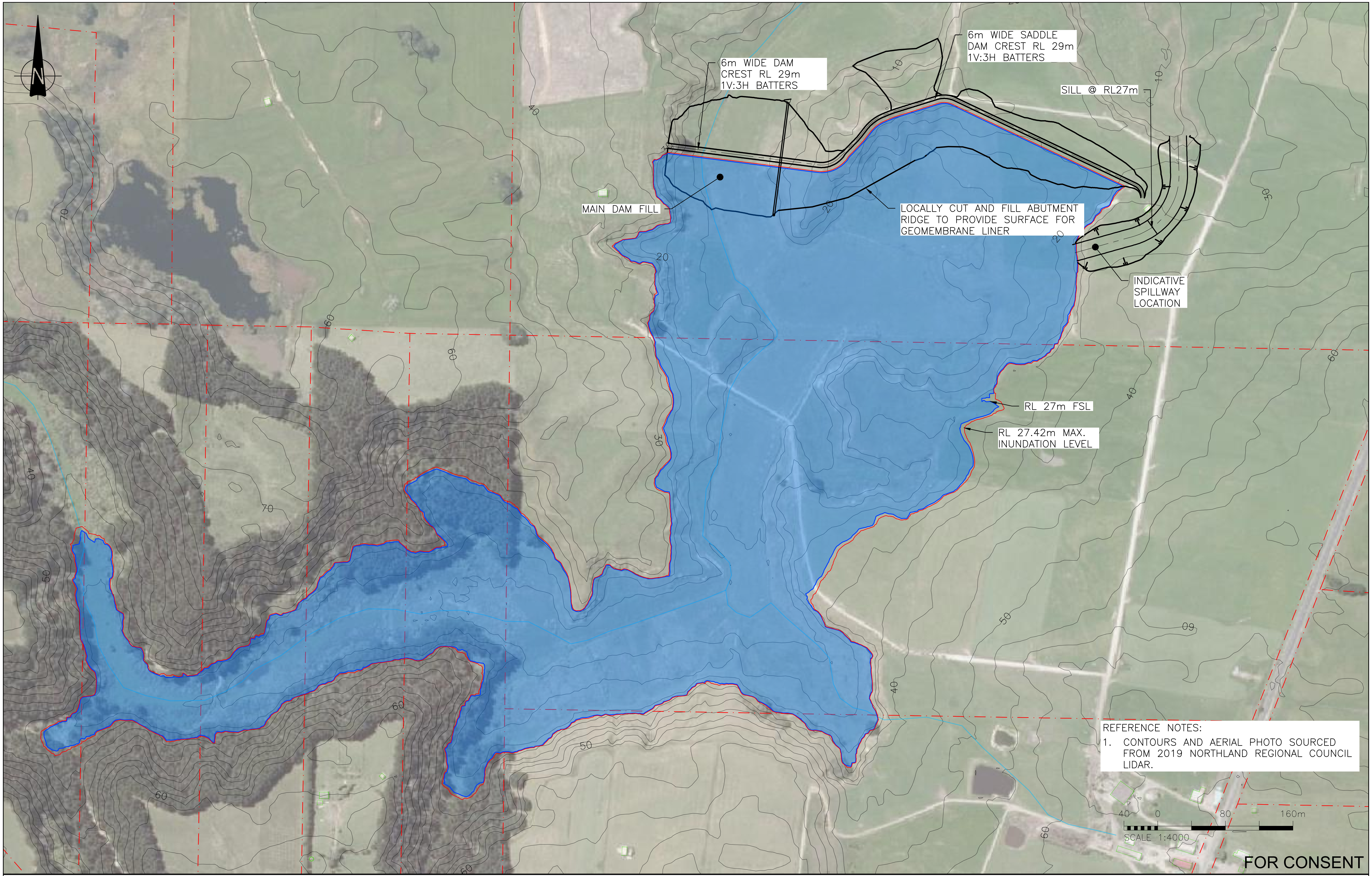
REV	DATE	ISSUE	BY
1		FOR CONSENT	MP

DESIGN: TS
DES CHECK: TS
DRAWN: MP
CAD CHECK: JM
APPROVED FOR ISSUE: S.A. Vaughan
DATE DRAWN: AUG. 2020
ISSUE DATE: 01 / 09 / 20

RILEY CONSULTANTS
www.riley.co.nz

CLIENT: TE TAI TOKERAU WATER TRUST
ADDRESS: NORTHLAND WATER STORAGE AND USE PROJECT
PROJECT: ARATAPU WATER STORAGE RESERVOIR SITE
SHEET TITLE: DAM GEOTECHNICAL CROSS SECTION B

CADFILE: 200240_2-2&3.dwg
SCALE (A3): 1:4000
ORIG. SHEET SIZE: A3
DRAWING No.: 200240/2-3
REV.: 1



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

FOR CONSENT

REV	DATE	ISSUE	BY
1		FOR CONSENT	MP

DESIGN: TS
DES CHECK: TS
DRAWN: MP
CAD CHECK: JM
APPROVED FOR ISSUE: S.A. Vaughan
DATE DRAWN: AUG. 2020
ISSUE DATE: 01 / 09 / 20

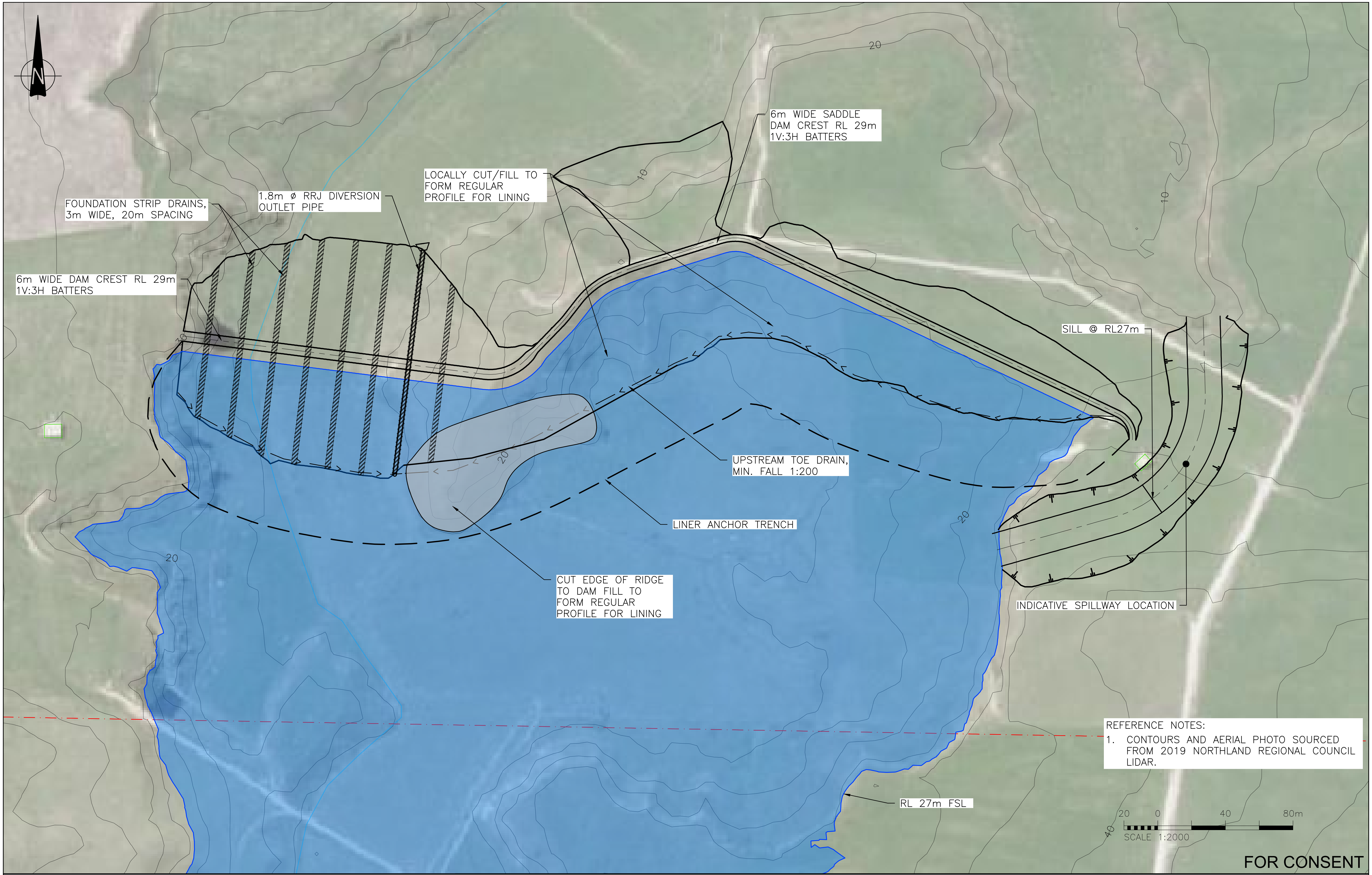
RILEY CONSULTANTS
www.riley.co.nz
WILLIAMSON WATER & LAND ADVISORY

TE TAI TOKERAU WATER TRUST
Ngā Puna Wai He koha Oranga Tangata He koha Oranga Whenua
The Springs of Water A gift of life to our people A gift of life to our land

CLIENT: TE TAI TOKERAU WATER TRUST
ADDRESS: NORTHLAND WATER STORAGE AND USE PROJECT
PROJECT: ARATAPU WATER STORAGE RESERVOIR SITE
SHEET TITLE: DAM & RESERVIOR LAYOUT - 4 Mm3 OPTION

ACENZ
ISO CERTIFIED GCS

CADFILE: 200240_2–101.dwg
SCALE (A3): 1:4000
ORIG. SHEET SIZE: A3
DRAWING No.: 200240/2-101
REV.: 1



REFERENCE NOTES:

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

FOR CONSENT

REV	DATE	ISSUE	BY
1		FOR CONSENT	MP

DESIGN	DES CHECK	APPROVED FOR ISSUE
TS	TS	S.A. Vaughan
DRAWN	CAD CHECK	
MP	JM	
DATE DRAWN		ISSUE DATE
AUG. 2020		01 / 09 / 20

RILEY CONSULTANTS
www.riley.co.nz

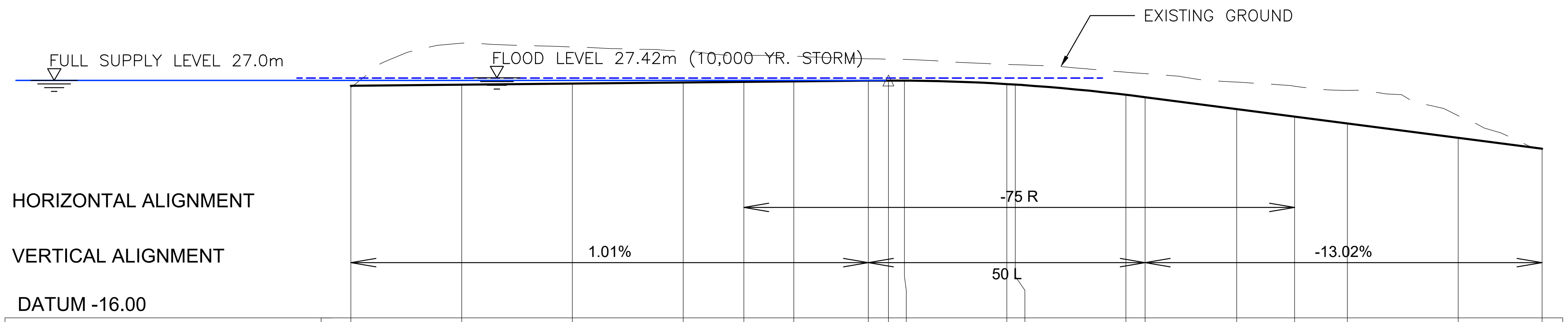
WILLIAMSON WATER & LAND ADVISORY

TE TAI TOKERAU WATER TRUST
Nga Puna Wai He koha Oranga Tangata He koha Oranga Whenua
The Springs of Water. A gift of life to our people. A gift of life to our land

CLIENT	TE TAI TOKERAU WATER TRUST
ADDRESS	NORTHLAND WATER STORAGE AND USE PROJECT
PROJECT	ARATAPU WATER STORAGE RESERVOIR SITE
SHEET TITLE	DAM EMANKMENT LAYOUT - 4 Mm3 OPTION

ACENZ
ISO CERTIFIED GCS

CADFILE	
200240_2–102.dwg	
SCALE (A3)	ORIG. SHEET SIZE
1:2000	A3
DRAWING No.	REV.
200240/2-102	1

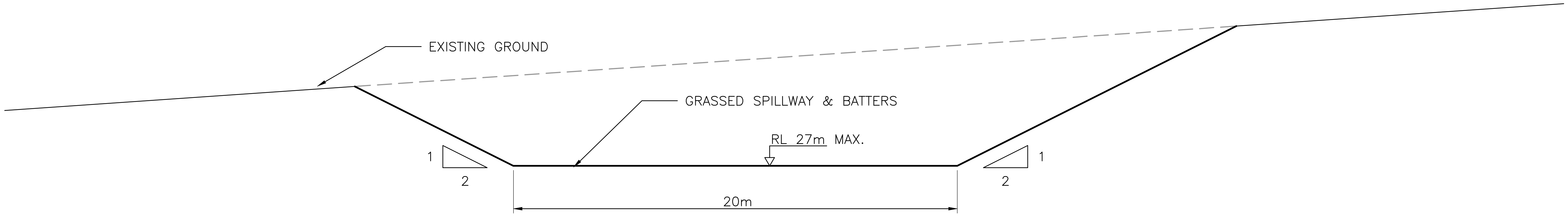


DESIGN SURFACE LEVELS	26.00	26.20	26.41	26.61	26.72	26.81	26.95	27.00	26.95	26.32	26.23	24.38	23.95	21.80	20.43	19.19	16.59	14.62
EXISTING SURFACE LEVELS	25.78	33.71	33.03	32.27	31.54	31.39	30.91	30.83	30.78	29.89	29.84	28.46	28.19	26.68	25.94	25.18	20.61	14.64
CUT - / FILL +	0.22	-7.51	-6.63	-5.66	-4.82	-4.58	-3.96	-3.86	-3.83	-3.57	-3.61	-4.08	-4.25	-4.88	-5.51	-5.99	-4.02	-0.03
CHAINAGE	0.00	20.00	40.00	60.00	70.99	80.00	93.48	97.09	100.00	118.48	120.00	140.00	143.48	160.00	170.46	180.00	200.00	215.16

SPILLWAY LONG SECTION

SCALE 1: 1000 HOR & VERT

SCALE 1:1000



TYPICAL SPILLWAY CROSS SECTION

SCALE 1:200

SCALE 1:200

FOR CONSENT

REV	DATE	ISSUE	BY
1		FOR CONSENT	MP

DESIGN: TS
DES CHECK: TS
DRAWN: MP
CAD CHECK: JM
APPROVED FOR ISSUE: S.A. Vaughan
DATE DRAWN: AUG. 2020
ISSUE DATE: 01 / 09 / 20

RILEY CONSULTANTS
www.riley.co.nz

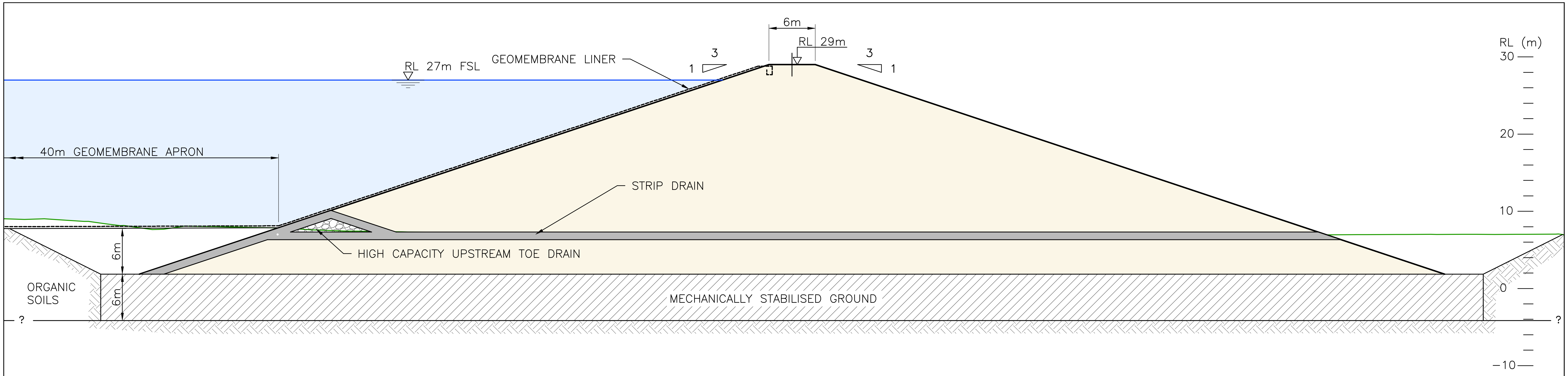
WILLIAMSON WATER & LAND ADVISORY

TE TAI TOKERAU WATER TRUST
Ngā Puna Wai He koha Oranga Tangata He koha Oranga Whenua
The Springs of Water. A gift of life to our people. A gift of life to our land

CLIENT: TE TAI TOKERAU WATER TRUST
ADDRESS: NORTHLAND WATER STORAGE AND USE PROJECT
PROJECT: ARATAPU WATER STORAGE RESERVOIR SITE
SHEET TITLE: SPILLWAY DETAILS - 4 Mm3 OPTION

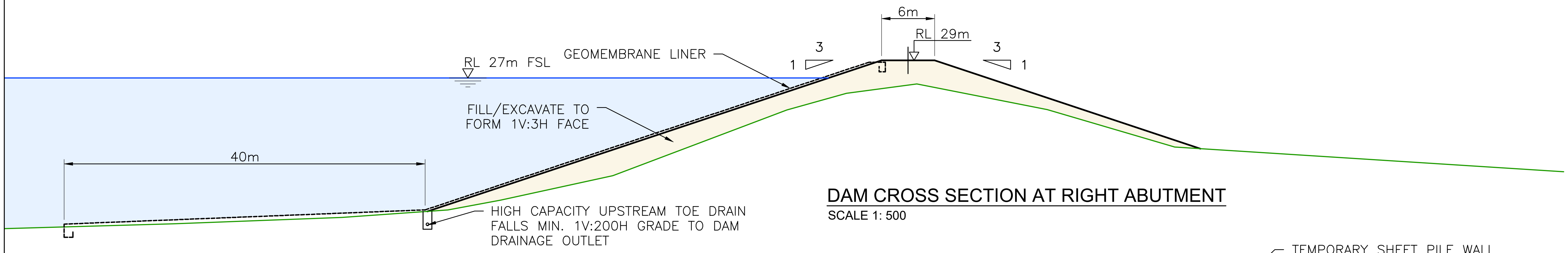
ACENZ

CADFILE: 200240_2-103.dwg
SCALE (A3): AS SHOWN
ORIG. SHEET SIZE: A3
DRAWING No.: 200240/2-103
REV.: 1



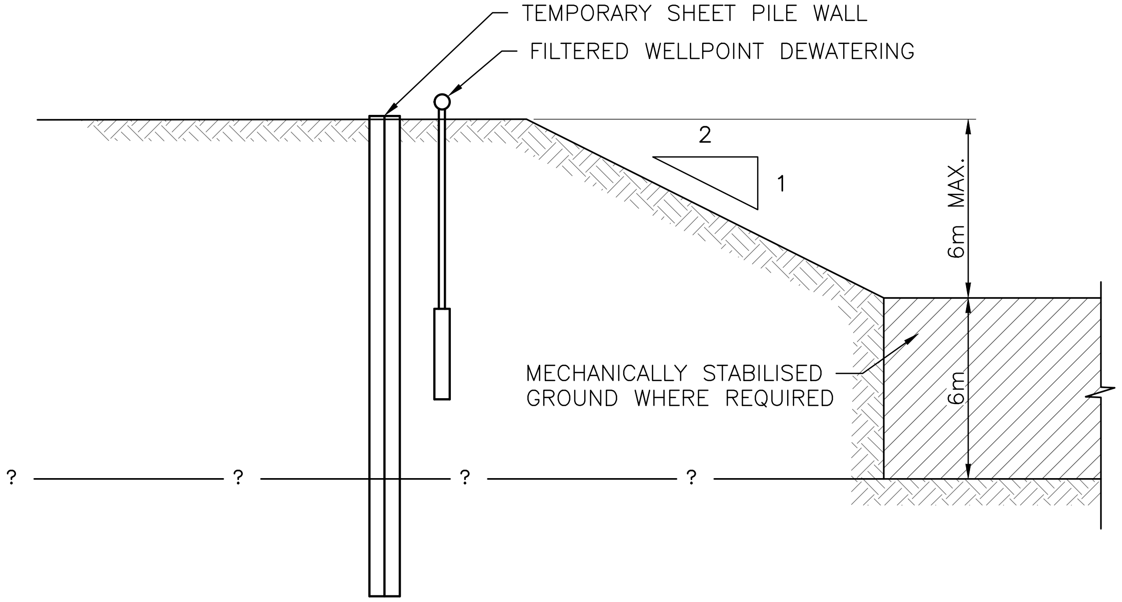
HIGH DAM TYPICAL CROSS SECTION

SCALE 1: 500



DAM CROSS SECTION AT RIGHT ABUTMENT

SCALE 1: 500



INDICATIVE TEMPORARY WORKS (U/S & D/S OF DAM)

SCALE 1: 250

5 0 10 20m

SCALE 1:500

FOR CONSENT

1		FOR CONSENT	MP
REV	DATE	ISSUE	BY

DESIGN	DES CHECK	APPROVED FOR ISSUE
TS	TS	S.A. Vaughan
DRAWN	CAD CHECK	
MP	JM	
DATE DRAWN		ISSUE DATE
AUG. 2020		01 / 09 / 20

RILEY CONSULTANTS
www.riley.co.nz

WILLIAMSON WATER & LAND ADVISORY

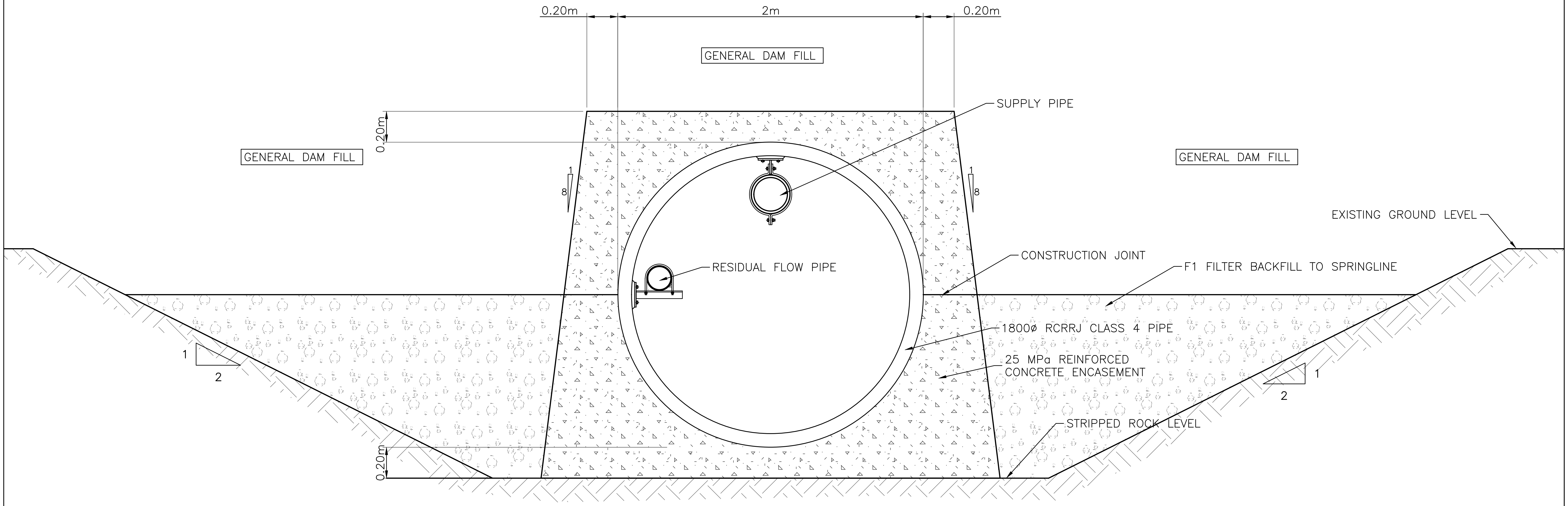
TE TAI TOKERAU WATER TRUST
Nga Puna Wai He koha Oranga Tangata He koha Oranga Whenua
The Springs of Water. A gift of life to our people. A gift of life to our land

CLIENT	TE TAI TOKERAU WATER TRUST
ADDRESS	NORTHLAND WATER STORAGE AND USE PROJECT
PROJECT	ARATAPU WATER STORAGE RESERVOIR SITE
SHEET TITLE	DAM EMBANKMENT DETAILS - 4 Mm3 OPTION

ACENZ

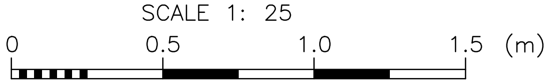
ISO CERTIFIED GCS

CADFILE 200240_2–104.dwg	
SCALE (A3) 1:4000	ORIG. SHEET SIZE A3
DRAWING No. 200240/2-104	REV. 1



DETAIL A - CONDUIT & ENCASEMENT DETAIL

SCALE 1:25



FOR CONSENT

REV	DATE	ISSUE	BY
1		FOR CONSENT	MD

DESIGN	DES CHECK	APPROVED FOR ISSUE
TS	TS	S.A. Vaughan
DRAWN	CAD CHECK	
MP	JM	
DATE DRAWN		ISSUE DATE
JULY 2020		01 / 09 / 20

RILEY CONSULTANTS
www.riley.co.nz

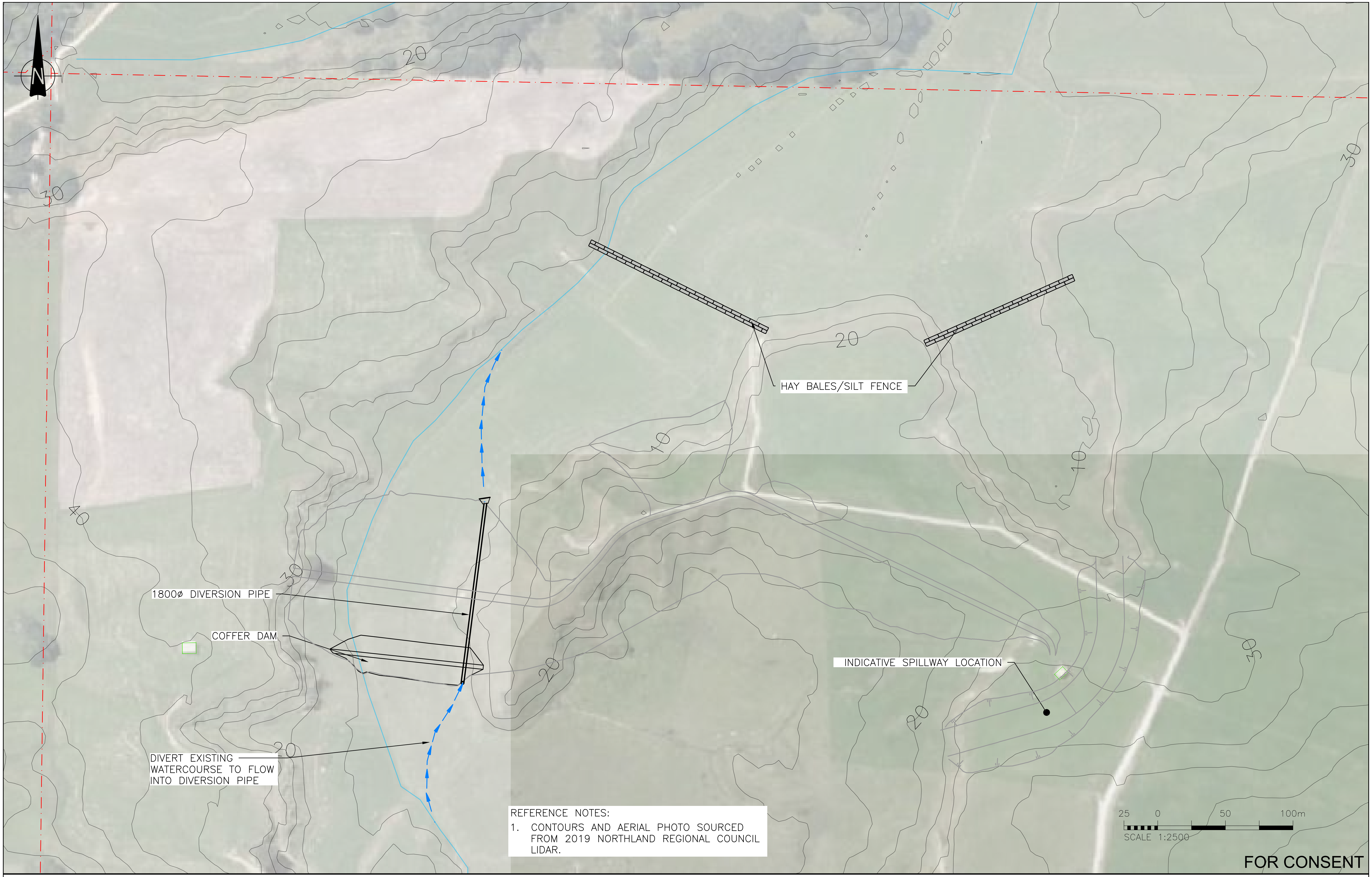
WILLIAMSON
WATER & LAND ADVISORY

TE TAI TOKERAU WATER TRUST
Nga Puna Wai He koha Oranga Tangata He koha Oranga Whenua!
The Springs of Water. A gift of life to our people. A gift of life to our land!

CLIENT	TE TAI TOKERAU WATER TRUST
ADDRESS	NORTHLAND WATER STORAGE AND USE PROJECT
PROJECT	ARATAPU WATER STORAGE RESERVOIR SITE
SHEET TITLE	TYPICAL CONDUIT DETAILS

ACENZ
ISO CERTIFIED GCS

CADFILE	200240_2–105.dwg
SCALE (A3)	ORIG. SHEET SIZE
AS SHOWN	A3
DRAWING No.	REV.
200240/2-105	1



REFERENCE NOTES:

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

FOR CONSENT

REV	DATE	ISSUE	BY
1		FOR CONSENT	MP

DESIGN	DES CHECK	APPROVED FOR ISSUE
TS	TS	
DRAWN	CAD CHECK	S.A. Vaughan
MP	JM	
DATE DRAWN		ISSUE DATE
AUG. 2020		01 / 09 / 20

RILEY CONSULTANTS
www.riley.co.nz

WILLIAMSON
WATER & LAND ADVISORY

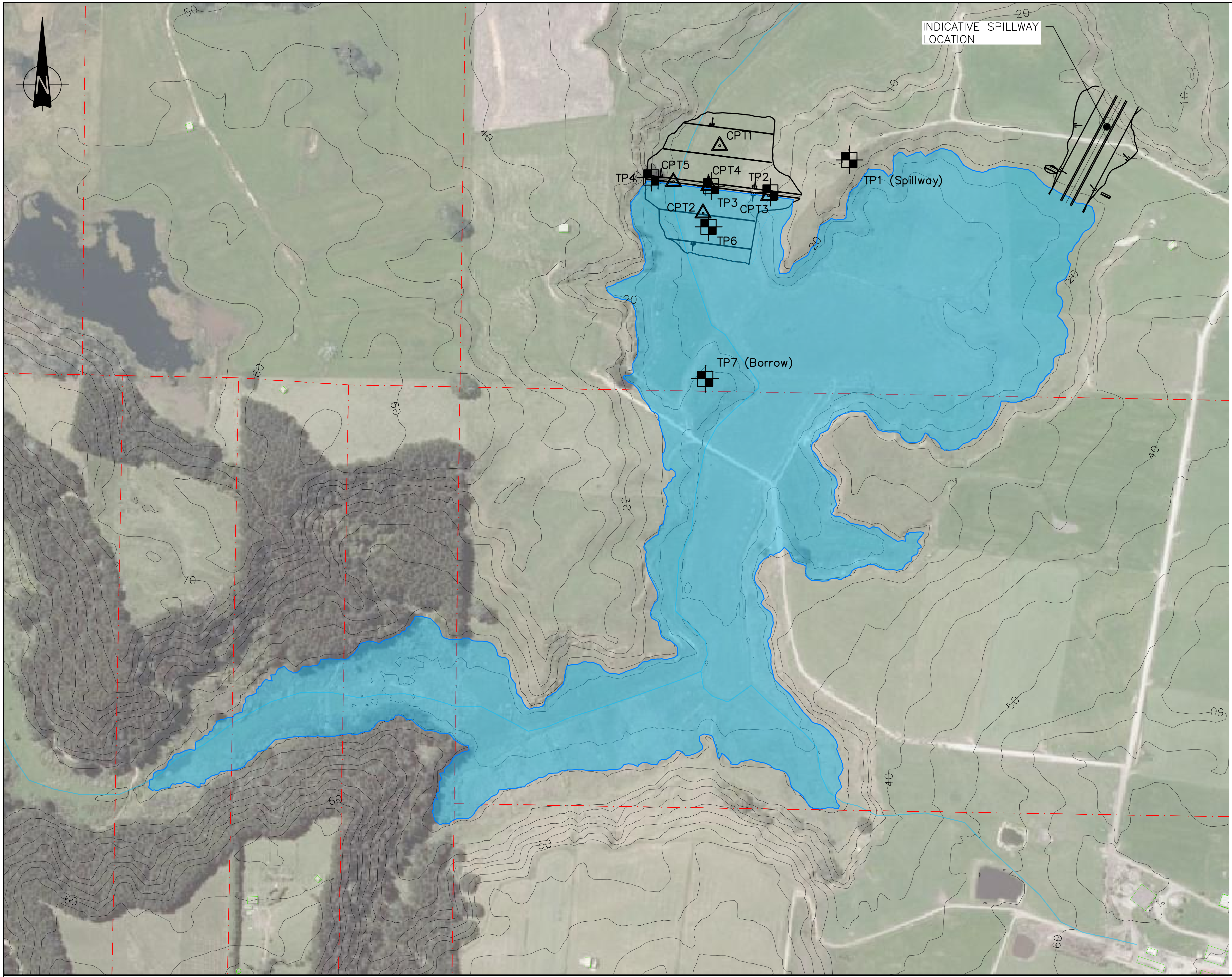
TE TAI TOKERAU WATER TRUST
Ngā Puna Wai He koha Oranga Tangata He koha Oranga Whenua
The Springs of Water. A gift of life to our people. A gift of life to our land

CLIENT	TE TAI TOKERAU WATER TRUST
ADDRESS	NORTHLAND WATER STORAGE AND USE PROJECT
PROJECT	ARATAPU WATER STORAGE RESERVOIR SITE
SHEET TITLE	SEDIMENT CONTROL LAYOUT - 4 Mm3 OPTION

ACENZ

ISO CERTIFIED GCS

CADFILE	
200240_2–106.dwg	
SCALE (A3)	ORIG. SHEET SIZE
1:2500	A3
DRAWING No.	REV.
200240/2-106	1



LEGEND

—	5m CONTOURS
— — —	PROPERTY BOUNDARY
—	STREAM CHANNELS
🟦	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.

40 0 80 160m

SCALE 1:4000

FOR CONSENT

REV	DATE	ISSUE	BY
1		FOR CONSENT	MP

DESIGN TS	DES CHECK TS	APPROVED FOR ISSUE S.A. Vaughan
DRAWN MP	CAD CHECK JM	
DATE DRAWN AUG. 2020		ISSUE DATE 01 / 09 / 20

RILEY CONSULTANTS
www.riley.co.nz

WILLIAMSON WATER & LAND ADVISORY

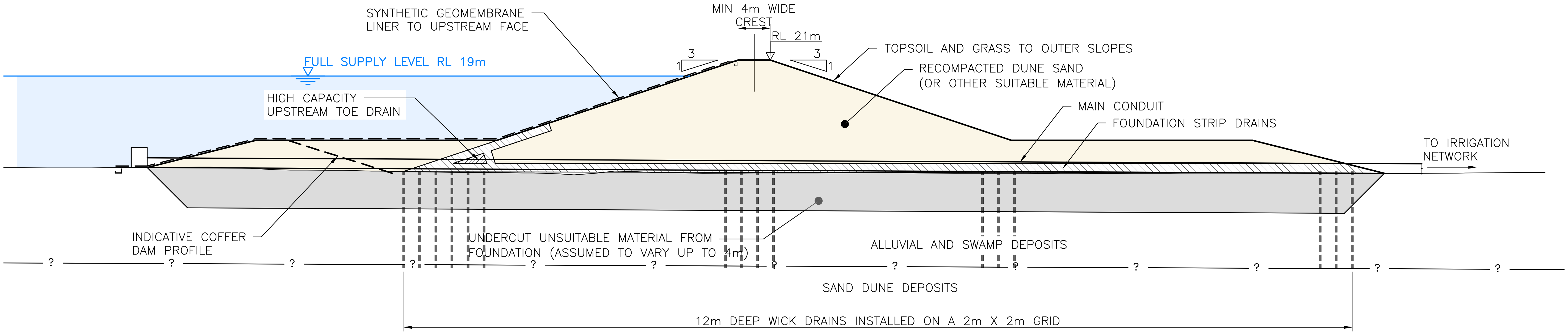
TE TAI TOKERAU WATER TRUST
Nga Puna Wai He koha Oranga Tangata He koha Oranga Whenua
The Springs of Water. A gift of life to our people. A gift of life to our land

CLIENT	TE TAI TOKERAU WATER TRUST
ADDRESS	NORTHLAND WATER STORAGE AND USE PROJECT
PROJECT	ARATAPU WATER STORAGE RESERVOIR SITE
SHEET TITLE	DAM SITE & INVESTIGATION PLAN - 1.5 Mm3 OPTION

ACENZ

ISO CERTIFIED GCS

CADFILE 200240_2–107.dwg	
SCALE (A3) 1:4000	ORIG. SHEET SIZE A3
DRAWING No. 200240/2-107	REV. 1



DAM TYPICAL CROSS SECTION

SCALE 1: 500

10 0 20 40mm

SCALE 1:1

FOR CONSENT

REV	DATE	ISSUE	BY
1		FOR CONSENT	MP

DESIGN	DES CHECK	APPROVED FOR ISSUE
TS	TS	S.A. Vaughan
DRAWN	CAD CHECK	
MP	JM	
DATE DRAWN		ISSUE DATE
AUG. 2020		01 / 09 / 20

RILEY CONSULTANTS
www.riley.co.nz

WILLIAMSON WATER & LAND ADVISORY

TE TAI TOKERAU WATER TRUST
Nga Puna Wai He koha Oranga Tangata He koha Oranga Whenua!
The Springs of Water. A gift of life to our people. A gift of life to our land!

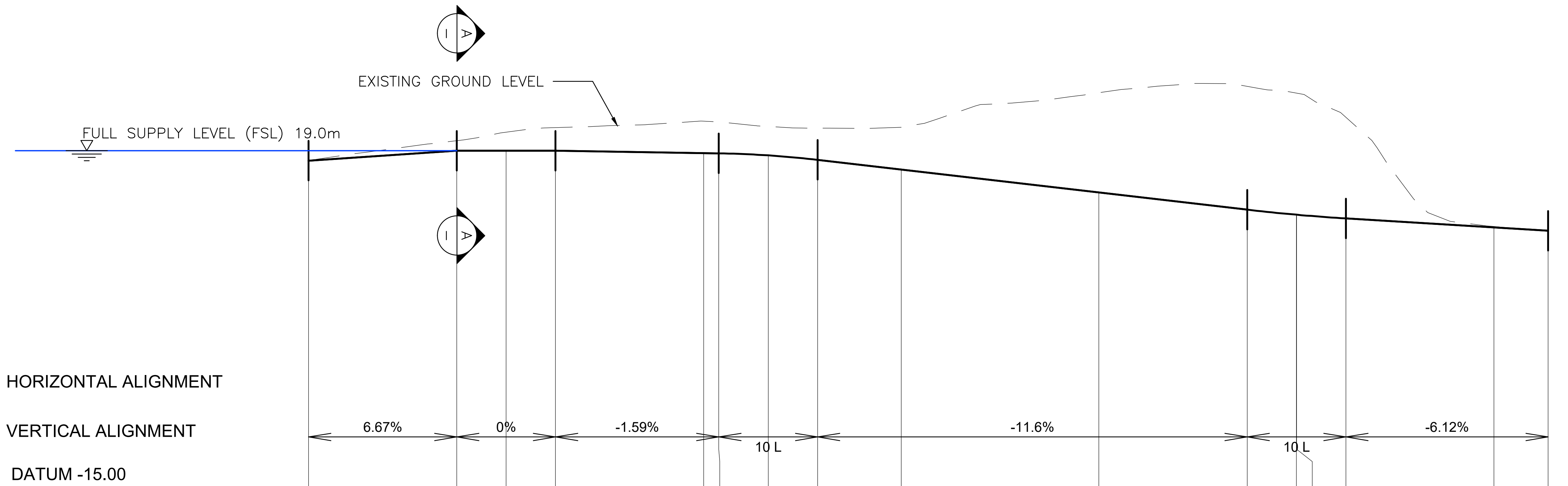
CLIENT TE TAI TOKERAU WATER TRUST
ADDRESS NORTHLAND WATER STORAGE AND USE PROJECT
PROJECT ARATAPU WATER STORAGE RESERVOIR SITE
SHEET TITLE DAM TYPICAL CROSS SECTION - 1.5 Mm3 OPTION

ACENZ
ISO 9001 CERTIFIED GCS

CADFILE
200240_2–108.dwg

SCALE (A3)	ORIG. SHEET SIZE
AS SHOWN	A3

DRAWING No.	REV.
200240/2-108	1



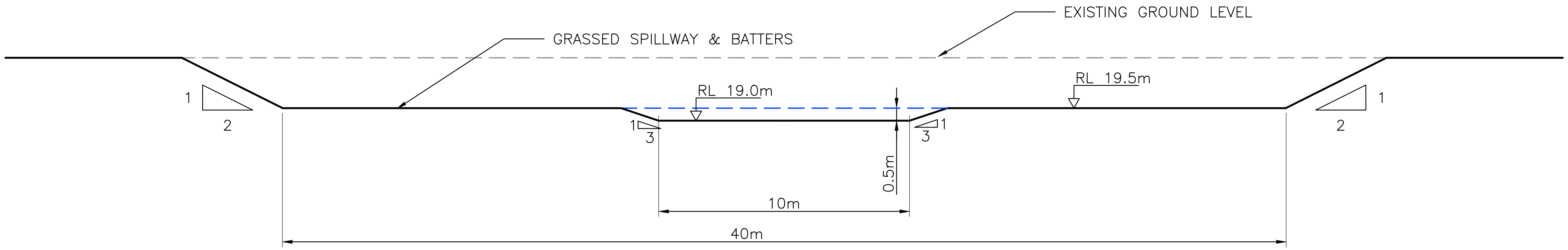
DATUM -15.00

DESIGN SURFACE LEVELS	18.00	19.00	19.00	19.00	18.76	18.74	18.53	18.08	17.10	14.77	13.03	12.52	12.52	12.15	11.23	10.89
EXISTING SURFACE LEVELS	18.02	20.03	20.87	21.34	21.99	21.92	21.46	21.30	21.39	24.87	25.53	24.84	24.84	22.39	11.32	10.89
CUT - / FILL +	-0.02	-1.03	-1.87	-2.34	-3.23	-3.18	-2.93	-3.22	-4.29	-10.10	-12.49	-12.32	-12.32	-10.25	-0.09	0.00
CHAINAGE	0.00	15.00	20.00	25.00	40.00	41.53	46.53	51.53	60.00	80.00	95.02	100.00	100.02	105.02	120.00	125.50

5 0 10 20m
SCALE 1:500

SPILLWAY LONG SECTION

SCALE 1: 500 HOR & VERT



SECTION A SPILLWAY CROSS SECTION

SCALE 1:200

2 0 4 8m
SCALE 1:200

FOR CONSENT

REV	DATE	ISSUE	BY
1		FOR CONSENT	MP

DESIGN TS
DES CHECK TS
DRAWN MP
CAD CHECK JM
APPROVED FOR ISSUE S.A. Vaughan
DATE DRAWN AUG. 2020
ISSUE DATE 01 / 09 / 20

RILEY CONSULTANTS
www.riley.co.nz

CLIENT TE TAI TOKERAU WATER TRUST
ADDRESS NORTHLAND WATER SUPPLY AND USE PROJECT
PROJECT ARATAPU WATER STORAGE RESERVOIR SITE
SHEET TITLE SPILLWAY DETAILS - 1.5Mm3 OPTION

CADFILE 200240_2–109.dwg
SCALE (A3) AS SHOWN
ORIG. SHEET SIZE A3
DRAWING No. 200240/2-109
REV. 1