



Te Whare Taonga o Te Arawa - Rotorua Museum Development

Geotechnical Seismic Assessment Report

Prepared for
Rotorua Lakes Council

Prepared by
Tonkin & Taylor Ltd

Date
April 2022

Job Number
1017126.0000.v2



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Document Control

Title: Te Whare Taonga o Te Arawa - Rotorua Museum Development - Geotechnical Seismic Assessment Report					
Date	Version	Description	Prepared by:	Reviewed by:	Authorised by:
23/07/2021	0	Stage 1 Geotechnical Assessment – Issued to the structural engineer for comment – Draft	T H Lai S Tjokro	S Palmer	C Davanna
3/03/2022	1 (interim)	Stage 2 Geotechnical Assessment – Additional factual and interpretative information from recent investigation – Interim Issue (Sections 1 to 6.2.4.2 only) – Draft	T H Lai S Tjokro	M Jacka	C Davanna
21/03/2022	1	Stage 2 Geotechnical Assessment – Additional factual and interpretative information from recent investigation – Full Report – Draft	T H Lai S Tjokro	M Jacka	C Davanna
13/04/2022	2	Stage 2 Geotechnical Assessment – Additional factual and interpretative information from recent investigation – Final Issue	T H Lai S Tjokro	M Jacka	C Davanna

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1 Introduction

Tonkin & Taylor Ltd (T+T) has been engaged by Rotorua Lakes Council (RLC) to provide geotechnical services to support the structural engineers (Dizhur Consulting) seismic strengthening assessment of the Te Whare Taonga o Te Arawa (Rotorua Museum). This report presents the findings and recommendations of the geotechnical analyses and assessments outlined in our Offer of Service¹ and Variation Order².

Additional geotechnical site investigation and laboratory testing have been undertaken since the previous version of this report. The main objective of the investigation was to obtain additional geotechnical data to better understand the static properties of the soils in relation to static settlement and to better characterise the resistance of the ground beneath the museum building to liquefaction in seismic events.

2 Site description

Rotorua Museum is bounded by Oruawhata Drive (west), Queens Drive (north), Hatupatu Drive (south) and the Energy Events Centre (east). The site is located adjacent to an active geothermal area (Sulphur Point) and ground temperatures are known to exceed 40°C at relatively shallow depth. The general layout of the site is shown below in Figure 2.1.



Figure 2.1: Overview of the site. Source: Google Maps³

¹ Tonkin & Taylor Ltd (7 May 2021) *Geotechnical and Geological Engineering Services, Te Whare Taonga o Te Arawa – Rotorua Museum Development*. Ref 1017126.0000.

² Tonkin & Taylor Ltd (1 Dec 2021) *Geotechnical and Geological Engineering Services, Te Whare Taonga o Te Arawa – Rotorua Museum Development*. Stage 2 Geotechnical Work, Variation Order (VO1), Revision 1, Ref 1017126.0000.

³ Google (2021) *Google Maps*.

The published geology of the area is shown below in Figure 3.1 and indicates that the site is underlain by Holocene Alluvial deposits, described as a mixture of gravel and sand with pumice clasts, silt and clay with local peat beds.

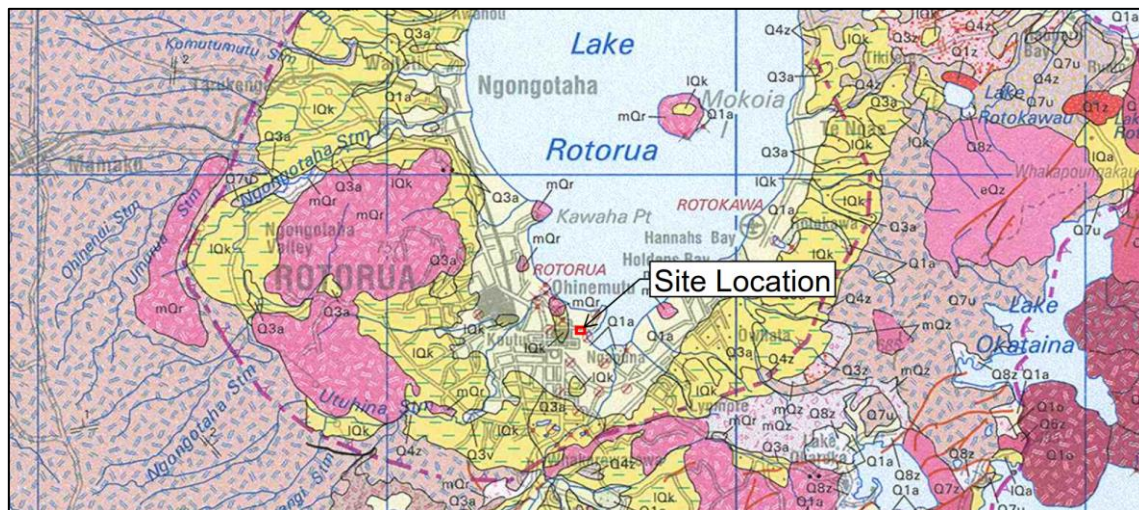


Figure 3.1: Published geological map of the area. Key: Q1a = Holocene Alluvial deposits. Source: Institute of Geological & Nuclear Sciences⁴

3.2.1 Previous investigation by others

Previous geotechnical field investigation data from various consultants was provided and used for the assessment. The locations of these investigations are shown in Figure A1 in Appendix A. The investigation logs and data are attached in Appendix B2.

Based on the publicly available survey data⁵, the ground level around the site is generally sloping towards southeast, with high point approximately at RL 285.0 m and low point at RL 282.0 m (based on Moturiki vertical datum). The site mean groundwater level is estimated to be at RL 280.0 m with a typical seasonal fluctuation of approximately 0.5 m above and below this level.

3.2.2 Recent investigation

A number of additional geotechnical investigations were undertaken between November 2021 and February 2022. These comprise:

- 6No. HQT cored machine boreholes;
- 4No. gel-push sampling machine boreholes;
- Groundwater monitoring using level loggers;
- Cross hole shear wave velocity measurements;

⁴ Leonard, G.S., Begg, J.G., Wilson, C.J.N. (2010) *Geology of the Rotorua area*. Institute of Geological & Nuclear Sciences. 1:250,000 Geological Map 5. 1 sheet + 102 p. Lower Hutt, New Zealand.

⁵ Ground level based on 2011 survey in Bay of Plenty Regional Council GIS sourced on 19 July 2021. Hyperlink: <https://gis.boprc.govt.nz/BayMaps/?appid=1a67c7dd0ccc64c28b9b35241d3478a6f/>

- Downhole shear wave velocity measurements;
- Laboratory cyclic triaxial tests (CTT); and
- 1D consolidation tests (with 24-hour load cycle).

Table 3.1 summarises the investigations undertaken at each location. The locations of these investigations are shown in Figure A2 in Appendix A.

Table 3.1: Summary of investigation undertaken

BH ID	HQTT core recovered	Groundwater monitoring piezometer	Shear wave velocity measurement	Gel-push sampling
BH1	✓	✓ (Groundwater response zone at 4.0 to 6.0 m bgl)	-	-
BH2	-	-	✓ (downhole)	✓ (3.0 to 4.08, 4.2 to 5.28, 5.4 to 6.48 m bgl)
BH3	✓	-	✓ (downhole and cross hole)	-
BH4	-	-	✓ (cross hole)	✓ (3.2 to 4.28, 4.3 to 5.38 m bgl)
BH5	✓	-	- (PVC conduit broken at 2.5m bgl, unable to obtain downhole shear wave velocity measurement)	-
BH6	✓	-	✓ (downhole and cross hole)	-
BH7	-	-	✓ (downhole and cross hole)	✓ (3.2 to 4.28, 4.28 to 5.36, 5.5 to 6.58 m bgl)
BH8 (wash drilled)	-	✓ (Groundwater response zone at 4.0 to 6.0 m bgl)	-	-
BH9	-	-	✓ (downhole)	✓ (5.0 to 6.08, 6.5 to 7.58 m bgl)
BH10	✓	-	✓ (downhole)	-
BH11	✓	-	✓ (downhole)	-

Note: bgl = below ground level

3.2.2.1 Borehole logs

6No HQTT coring was undertaken in the recent investigation. The samples were carefully recovered and were logged in accordance with NZGS guideline. These logs are provided in Appendix C1.

3.2.2.2 Gel push sampling

Gel-push sampling was undertaken at four borehole locations. Following retrieval, the samples were left to drain before being frozen and transported to the laboratory. The purpose of this is to attempt to obtain high quality undisturbed samples for the cyclic triaxial and one-dimensional consolidation testing.

3.2.2.3 Groundwater monitoring

Groundwater monitoring piezometers have been installed in BH1 and BH8. Two levelloggers and a barometer were installed on site for monitoring over the period between 22 December 2021 and 3 February 2022. The levellogger and barometer devices were removed from the piezometers as these holes are due to be decommissioned. Rotorua Welldrilling Co Ltd, who is a specialist well drilling and installation contractor in Rotorua, had advised that the type of well installation for the piezometers is suitable for temporary only (generally two months) due to the geothermal hazard presented in the area. It is also noted that the levellogger sensor in BH8 was damaged on 19 January 2022 by the aggressive soil condition and could not continue recording. Table 3.2 provides a summary of the monitoring results. The recorded groundwater levels are shown on the plot in Appendix C2.

Table 3.2: Summary of groundwater monitoring

BH ID	Level logger monitoring period	Groundwater level (m bgl)	Manual dip level (m bgl)
BH1	22/12/2021 to 3/2/2022	2.75 to 3.07	3.18 on 18/2/2022
BH8	22/12/2021 to 19/1/2022	2.96 to 3.16	3.34 on 18/2/2022

3.2.2.4 Laboratory cyclic triaxial tests

Laboratory cyclic triaxial testing was undertaken by University of Canterbury and Geotechnics Ltd on the recovered gel-push samples. The summary results are presented in Table 3.3 and the laboratory datasheet for each testing can be found in Appendix C3.

Table 3.3: Summary of cyclic triaxial test results

Sample ID	Depth (m bgl)	Indicative shear wave velocity from bender element tests at consolidation pressure (m/s)	Consolidation pressure (kPa)	Applied cyclic stress ratio, CSR_{lab}	No of cycle to 5% double amplitude axial strain
RM BH9 GPTR1 A	Between 5.0 to 6.0 m	180	80	0.315	Failure not reached after 610 cycles
RM BH9 GPTR1 B	Between 5.0 to 6.0 m	173	80	0.44	976
RM BH9 GPTR1 D	Between 5.0 to 6.0 m	194	80	0.518	15
BH2-3.81 m	3.81	192	50	0.49	212
BH7-4.94 m	4.94	121	50	0.41	65
BH7-5.14 m	5.14	117	50	0.53	4
BH7-6.26 m	6.26	153	60	0.46	3

3.2.2.5 One-dimensional consolidation test

One dimensional consolidation testing with 24-hour load cycle was undertaken by Babbage Geotechnical Laboratory. Table 3.4 below summarises the tests results with the laboratory datasheet attached in Appendix C4.

Table 3.4: Summary of one-dimensional consolidation test results

Sample ID	Soil description from the laboratory test report	Confining pressure applicable for the site (kPa)	Coefficient of volume compressibility (m^2/MN)	Coefficient of secondary compression
BH02 2.42 to 2.50 m	CLAY, silty, soft to firm, moderately plastic, blackish dark brown with white speckles, slightly moist.	31 to 247	0.46 to 0.67	0.001 to 0.006
BH09 4.13 to 4.23 m	SILT, soft, slightly plastic to non-plastic, yellowish light brown, saturated, dilatant.	50 to 201	0.34 to 0.75	0.003 to 0.004

3.2.2.6 Shear wave velocity measurements

Downhole and cross-hole shear wave velocity measurement was undertaken between 12 and 14 January 2022 by Resource Development Consultants Ltd (RDCL). The results are presented in Appendix C5. A comparison of the shear wave velocity based on measurements and CPT-correlations are discussed further in section 3.3.1.

3.3 Subsoil conditions

The geological units encountered in the investigations are generally in agreement with the description provided in the published geology for the area. The localised peat deposit as described in the literature was not encountered in any of the investigations. It is likely that some of the sediments underlying the Rotorua Museum are lacustrine sediments associated with historic lake levels of Lake Rotorua.

For this assessment, the subsoil condition has been divided into four main engineering units. The surficial layer (Unit 1 in Table 3.5) exhibits a dry and friable surficial characteristic, generally consists of fill, sinter and other miscellaneous deposit. This surficial layer overlies the lake sediments which overlies dense sand or stiff to hard silt with cemented layers at depth. Figures A3 to A7 in Appendix A provide cross sections showing the elevations of these units. The lake sediments are further divided into sub-units (Unit 2a and 2b) based on their observed engineering behaviour from the investigation data. This was undertaken by reviewing the description in the borehole logs and interpretation of the cone penetration tests (CPT) results. Underneath the surficial layer, the lake deposits (Unit 2b) appear to be cohesive and exhibit a behaviour of a fine-grained soil. This unit consist of mainly silty sand and sandy silt. Therefore, the lake sediments in the southeast area are categorised as a fine-grained dominated soil. In some areas of the site, this fine-grained dominated lake sediment overlies another unit of lake sediment that mainly consist of gravel (Unit 2a) that exhibits coarse-grained dominated soil matrix. Underlying Unit 2a and 2b is the sand and silt layer with some gravels (Unit 3). This layer is typically very stiff to hard or medium dense and contains cemented layers. The deepest ground investigation terminated in this layer, therefore the bottom

boundary is unknown. The sub-unit delineation (Unit 2a and 2b) has been considered to allow for the various soil behaviour and responses to be sufficiently captured in the engineering assessment. In reality, the ground condition is highly variable and interbedded with layers with various grain sizes.

A summary of the inferred subsurface ground conditions is provided in Table 3.5.

Table 3.5: Summary of inferred subsurface ground conditions.

Unit	Soil Layer	Description	Depth to Top of layer (m)	Range of thickness (m)	SPT Blow counts N ^(note 1)	CPT Tip Resistance, qc (MPa)
1	Dry and friable surficial layer	Topsoil, pavement, road-subgrade overlying mixture of gravel, sand and silt	0	0.5 to 2.0	No SPT undertaken in this layer	2 to 15
2a	Lake sediments - Very loose to loose GRAVEL	Fine sand to medium coarse gravel, occasional thin layers of sandy silt. Pumiceous and geothermally altered	1.0 to 1.4	3.4 to 6.0	1 to 4	2 to 10
2b	Lake sediments – Silty SAND and Sandy SILT	Silt to coarse sand. Occasionally thin layer of gravel. Very loose / soft to firm. Pumiceous and geothermally altered	0.5 to 1.5	3.7 to 6.5	No SPT undertaken in this layer	0.5 to 5
3	SAND and SILT with cemented layers	Sand and silt with some gravels, stiff to hard / medium dense, with cemented layers.	6.0 to 8.4	Not assessed	9 to 36	5 to >30
4	Compacted engineered hardfill	Compacted WHAP40 across Zone 1 building footprint.	0	0 to 2.5m	No SPT undertaken in this layer	No SPT undertaken in this layer

Note: 1. Uncorrected SPT N value.

3.3.1 Shear wave velocity

Shear wave velocity measurements were undertaken as part of the recent investigation, and the results are summarised in Figure 3.2. The raw data of the shear wave velocity measurements are included in Appendix C5. Laboratory Bender Element tests were carried out to provide indicative shear wave velocity of the samples that were tested for the cyclic triaxial tests. The indicative shear wave velocities of these sample are plotted in Figure 3.2 for comparison (shown as hollow circles). These show that the tested samples appear to be comparable to the field condition, which indicates that there is no obvious evidence of sample disturbance (loosening or densifying of the soil).

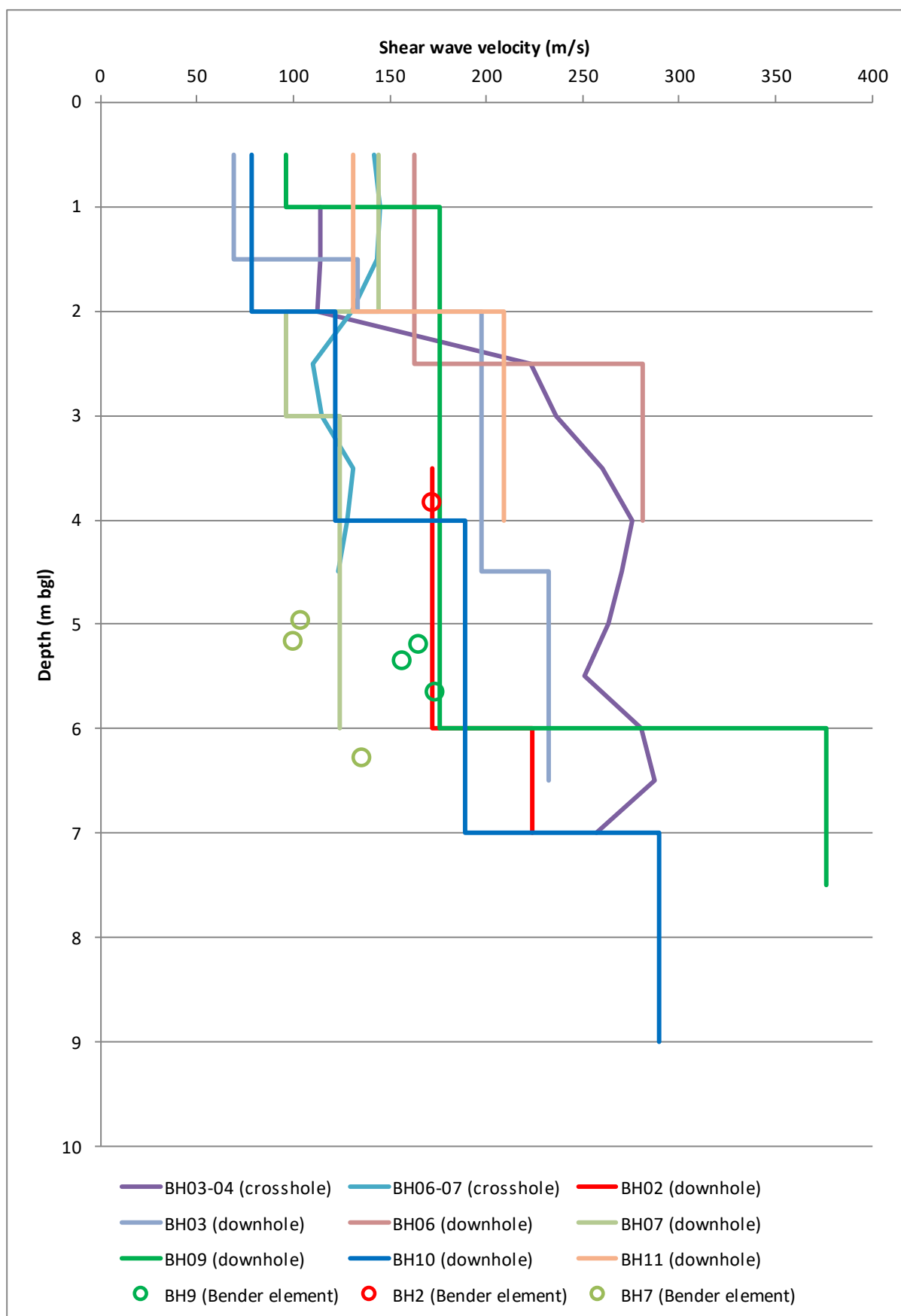


Figure 3.2: Summary of laboratory and field measured shear wave velocities

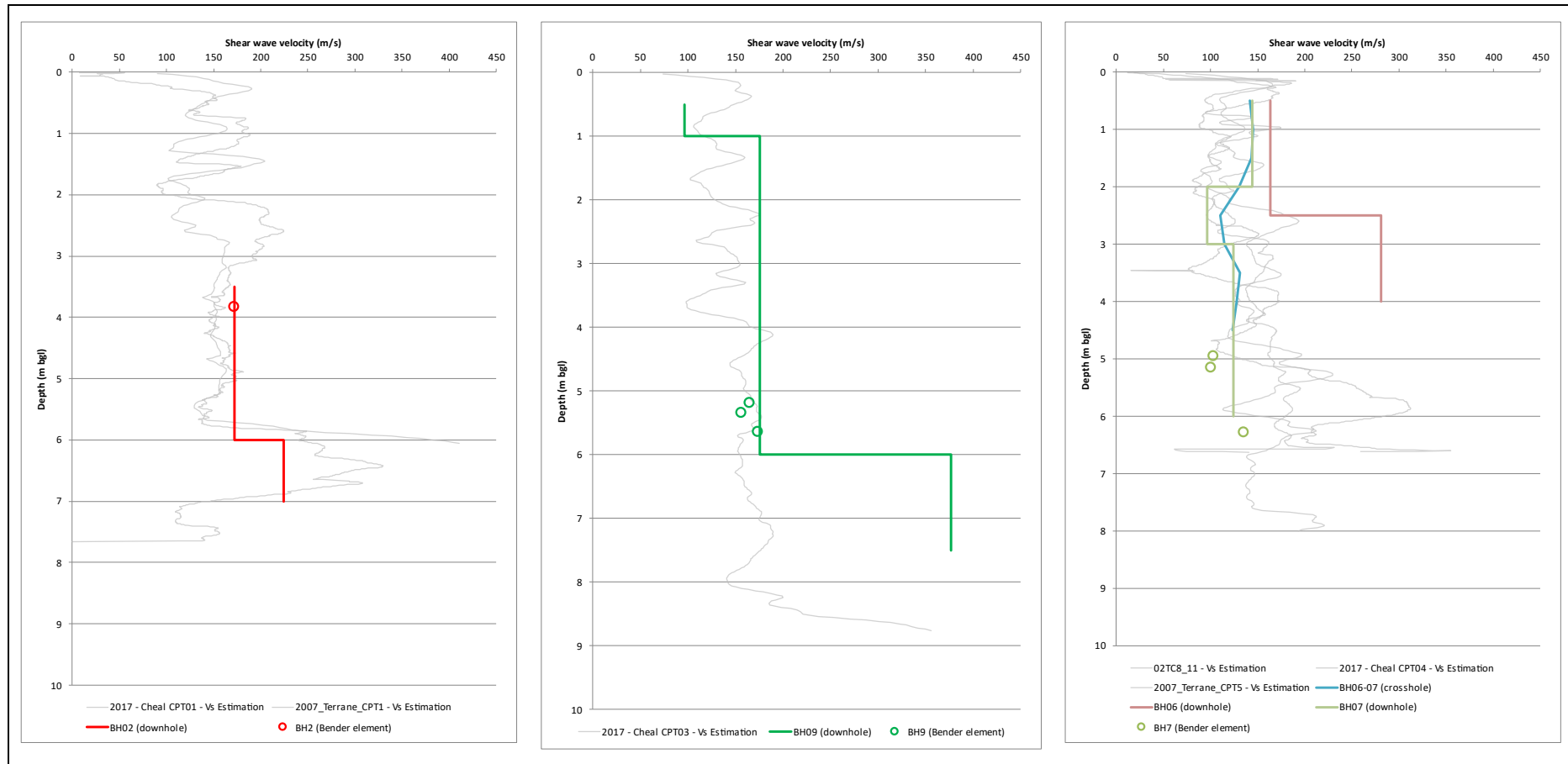


Figure 3.3: Comparison between the measured shear wave velocity value and the shear wave velocity value estimated from CPT within 15 m radius of the shear wave velocity testing location. Note, there is no CPT located within 15 m radius of shear wave velocity testing at BH3, BH4, BH10 and BH11.

The results from the downhole and cross hole shear wave velocity measurements are also compared with those correlated from the CPT results. Figure 3.3 compares the measured downhole or cross hole shear wave velocities with the correlated data obtained from CPT located within 15 m radius of the respective downhole or cross hole shear wave velocity testing locations. The coloured traces represent the measured shear wave velocity data while the grey traces represent the CPT correlated data.

From the Figure 3.3 above, the measured data generally tends to show good agreement with the correlated data, and in the case of BH9, the measured data is significantly higher from a depth of 6 m below ground level. This could potentially be explained by the CPT under-representing the density in dense crushable pumiceous soils. In dense crushable soil, the cone from the CPT crushes rather than displacing the soil particles. However, in the loose state (shear wave velocity < 200 m/s) the measured and correlated values seem to be in good agreement.

It is also noted that BH6 downhole measurement shows higher shear wave velocity than the cross-hole shear wave velocity measurement between BH6 and BH7 as well as the downhole shear wave velocity measurement in the nearby BH7. RDCL commented that the apparent high shear wave velocity reading in the BH6 downhole measurement may be due to:

- The shear wave refracting in an unexpected way down the infilled grout between the PVC and the annulus. This may occur if the annulus is large (due to hole blowout/collapse), and a large amount of grout has been used to infill; and/or
- Unexpected highly localised geological change (a gravel lens or similar) resulting in stiffer materials between the shear beam the hole on one side than another.

Based on the above comments and the cross hole BH6-BH7 and BH7 downhole measurements, the high shear wave velocity reading from the BH6 downhole measurement is likely to be an anomaly.

4 Existing building layout

The Rotorua Museum building has been categorised into six main zones shown in Figure 4.1 below for the purpose of seismic assessment. The approximate years when the various zones were built are shown in Figure 4.2.

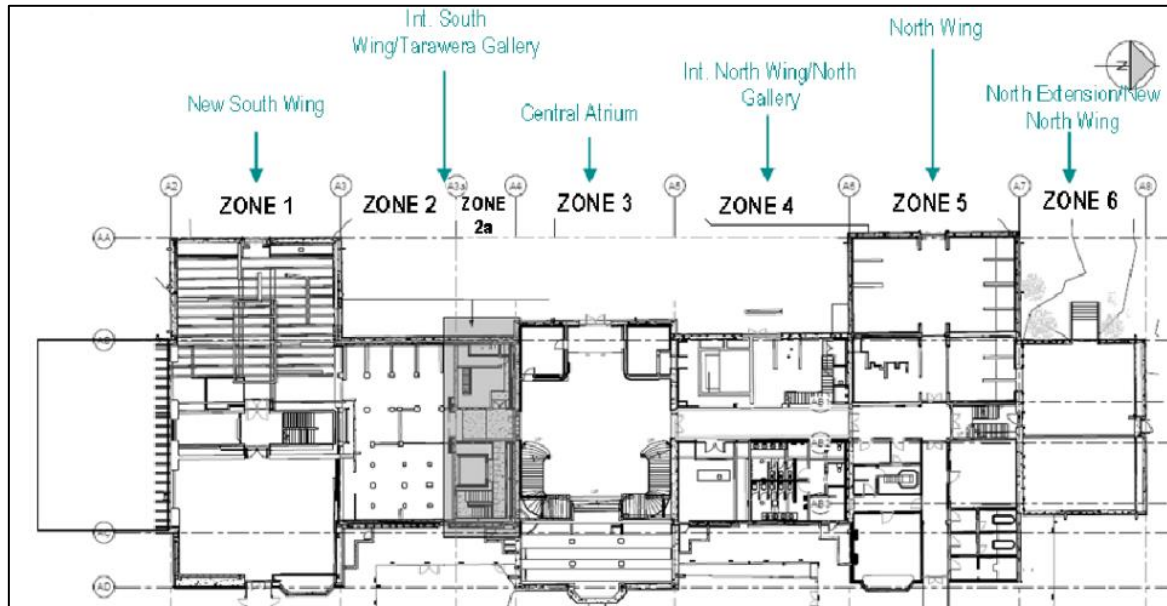


Figure 4.1: Zoning of Rotorua Museum building for the purpose of seismic assessment. Source: WSP⁶

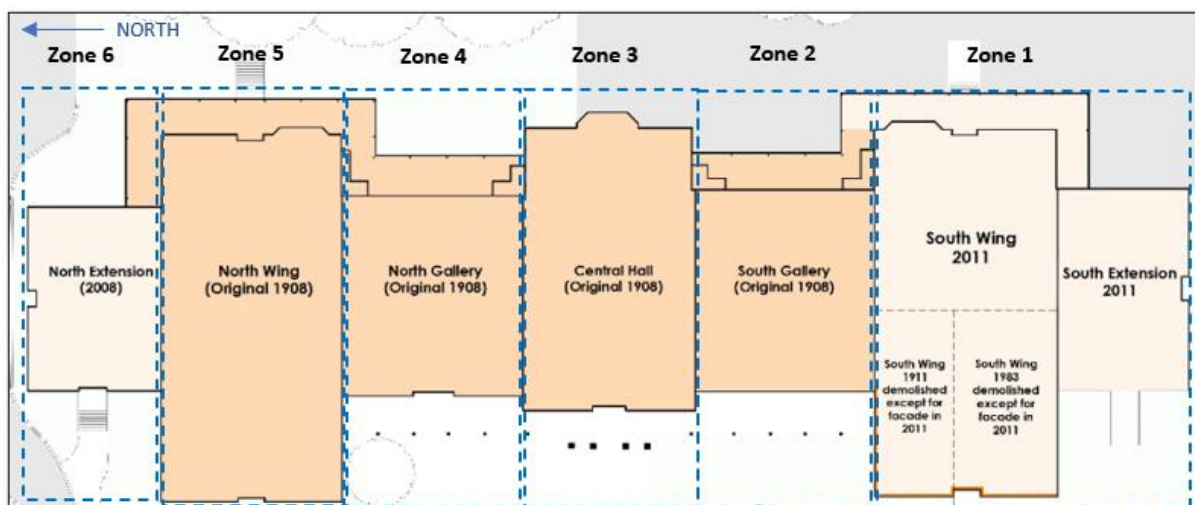


Figure 4.2: Years and stages of building of the Rotorua Museum. Source: DPA Architects⁷

4.1 South wing extension (Zone 1, constructed 2011)

The south wing extension is designated as Zone 1. The building is supported by edge-thickened slabs with varying depths and widths around the perimeter of the building and a number of shallow pad foundations. The width of strip foundation ranges from 500 mm to 2500 mm and the depth ranges

⁶ WSP (2021) *Rotorua Museum Development – Project Specific Information*.

⁷ DPA Architects (April 2019) *Rotorua Bath House (Former) Conservation Plan*.

from 300 mm to 400 mm thick. The pad foundations range from 2000 mm to 5000 mm in width and are 400 mm thick.

The basement floor of Zone 1 is partly situated below the ground level, with the basement wall retaining up to 2 m of ground on the northwest corner, decreasing to approximately 1 m high towards the southwest corner and no retention on the eastern side.

In general, the foundation level is approximately RL 281.6 m to RL282 m, with the exception of the lift shaft at 279.8 m RL. Based on the provided drawings from the 2011 building extension work (drawings 3278-G11 and G12 attached in Appendix B1) it appears that in most areas the foundations are underlain by up to 2 m thick of hardfill backfill, with the exception of the western edge where the hardfill backfill is only approximately 0.5 m thick, and approximately 1.3 m thick below the lift shaft.

4.2 South Wing to North Wing (Zone 2 to Zone 5, constructed 1908)

These zones are supported by a combination of shallow pads and strip footings. The pad foundations range from 600 mm to approximately 2400 mm wide and the width of the strip footing ranges from 450 mm to 1150 mm. Based on our observation on site, most footings appear to be sitting at ground surface level (i.e. not embedded). The bottom of the foundations is approximately at RL 283.0 m. Based on the information in the Conservation Plan⁷, these footings are made of pumice concrete.

A partial basement is also present within zones 2 to 5, with the basement wall retaining up to 2 m of ground along on the western perimeter of the building. There is no retention on the eastern side of the building.

A series of grouted columns up to 6.5 m deep underneath the zones 2 to 5 building footprint were installed in 2010 to improve the foundation soil properties, particularly relating to voids that had been observed within the ground. The as-built location of the grout columns is shown in drawing 3278.02-100 in Appendix B1. The compressive strength and diameter achieved in the ground for each grout column are unknown (not provided in the as-built information).

4.3 North wing extension (Zone 6, constructed 2008)

The north wing extension is designed with 2000 mm wide 400 mm deep edge-thickened slabs to support the perimeter and partition walls. The amount of engineered backfill underneath the founding level of the footing is approximately 150 mm. Typical detail of the footing and backfill depth is provided in drawings 5138 – S101 and S102 in Appendix B1. The basement level in Zone 6 is partially below the ground surface, with the basement wall retaining up to 1.3 m of ground.

5 Geotechnical parameters

Based on our review of the available geotechnical investigation data, the geotechnical parameters shown in Table 5.1 have been adopted for our assessment. These parameters have been derived generally from the CPT data and our experience with similar materials in the neighbouring project.

These parameters are considered appropriate for the purpose of the current seismic assessment of the existing building. It is possible that these parameters are on the conservative side and could be higher due to the pumice content within the subsoil materials as indicated in published literatures. However, additional laboratory testing (e.g. static triaxial testing) would be required to verify more favourable parameters for use in design. For the current geotechnical seismic assessment of the Rotorua Museum, the parameters in Table 5.1 are generally used for estimating the existing foundation bearing capacities and the earth pressure load on the existing basement wall. It is understood that these elements do not govern the overall outcome of the assessment, and refining

the parameters below are unlikely to materially change the outcome of the assessment. Accordingly, additional effort such as the additional laboratory testing to refine these parameters is not considered necessary at this stage.

Table 5.1: Geotechnical parameters used for assessment of existing buildings

Unit	Material description	Bulk unit weight (kN/m ³)	Effective friction angle (deg)	Effective cohesion c' (kPa)	Undrained shear strength s _u (kPa)	Liquefied strength ratio ^(Note 1) (s _{u(liq)'/σ_v'}	Young's modulus E (Mpa)	Poisson's ratio ν
1	Dry and friable surficial layer	14	30	1	-	-	30	0.1 - 0.3
2a	Very loose to loose GRAVEL	14	33	2	-	-	20	0.1 - 0.25
2b	Silty SAND and Sandy SILT	14	28	3	40	-	10	0.1 - 0.3
2c	Liquefied Lake Sediments	14	-	-	-	0.09	1.5	0.49
3	SAND and SILT with cemented layers	16	32	5	-	-	70	0.1 - 0.25
4	Compacted engineered hardfill	19	36	1	-	-	60	0.2 - 0.3

Note: 1. The post liquefaction residual strength (s_{u(liq)'/σ_v'}

Idriss & Boulanger⁸.

6 Geotechnical assessment

The following subsections outline various geotechnical considerations that are relevant for the seismic assessment of the Rotorua Museum. Particular considerations relevant for structural analysis is discussed in Section 7.

6.1 Existing static settlement experienced by the building

The structural engineer (Dizhur Consulting) carried out a building condition assessment in May 2021. During this assessment, a number of considerable sized cracks were observed in the building walls in zones 1 to 5. The structural engineer installed twenty plaster “dog-bone” gauges (Figure 6.1) in May 2021 over selected wall crack locations in zones 1 to 5 to monitor the crack width and determine whether or not the cracks are active (opening or closing). The structural engineer inspected and measured the crack width monitoring gauges in June and August 2021. Movements were observed in seven of the monitoring gauges installed in Zone 3 and one of the monitoring gauges installed in Zone 5. No movement was observed in the monitoring gauges installed in zones 1, 2 and 4.

⁸ Idriss I.M. & Boulanger R.W. (2008) *Soil liquefaction during earthquakes*. Earthquake Engineering Research Institute.

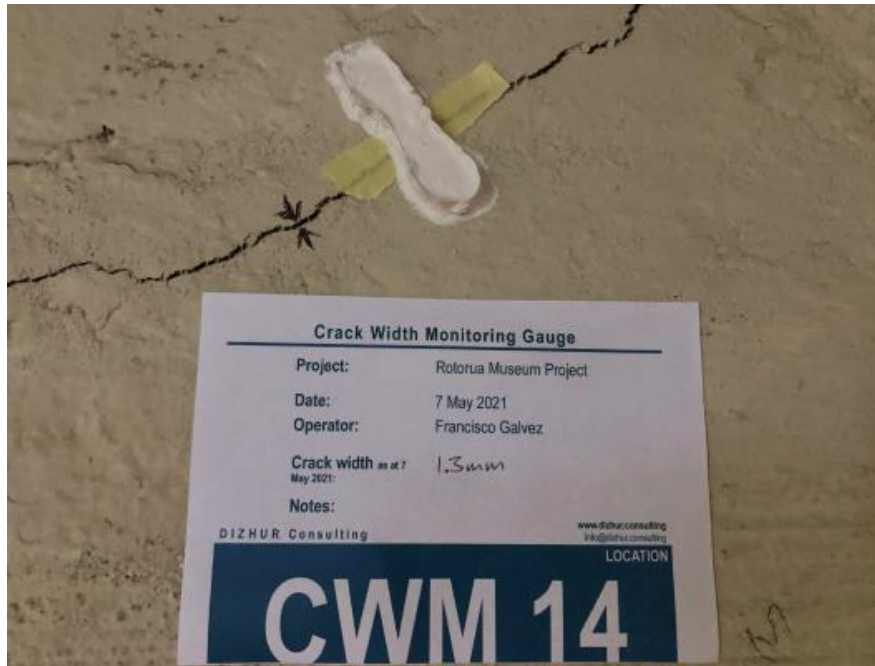


Figure 6.1: One of the plaster “dog-bone” gauges installed by the structural engineer to monitor the crack width in the wall

Following this, the structural engineer processed the information from the point cloud surveys that RLC had undertaken in the past (in 2016 and 2020) with focus on the original 1908 part of the museum building (zones 2 to 5) where recent movements have been observed to investigate further the likely cause of the crack movements. The structural engineer reported that there is no notable evidence of out-of-plane deformations observed in the walls from point cloud assessments. However, there is a considerable difference in the foundation levels observed from the point cloud data, which may indicate that the building is experiencing differential foundation settlements. The subsections below outline the assessments undertaken to further investigate the observed differential settlements.

6.1.1 Static differential settlement observations and assessment by structural engineer

The structural engineer has produced contour plots showing differential in elevations of the foundations in zones 2 to 5 relative to the reference point in Zone 3 from the point cloud data. These plots are shown in Figure 6.2 to Figure 6.4. It is understood that, in assessing the elevation differential, the structural engineer has assumed that the foundations were level at the time when they were constructed. The contour plots seem to indicate a general trend of worsening differential in the elevations towards the locations of the large gable walls, where the heaviest loads from the building are imposed.

It is also understood that the structural engineer compared the 2016 and 2020 Point Cloud survey data to assess whether or not there is any change to the relative foundation levels between 2016 and 2020. The structural engineer observed that the difference in relative foundation level at the gable walls has increased at a rate of approximately 1 mm per year over this period.

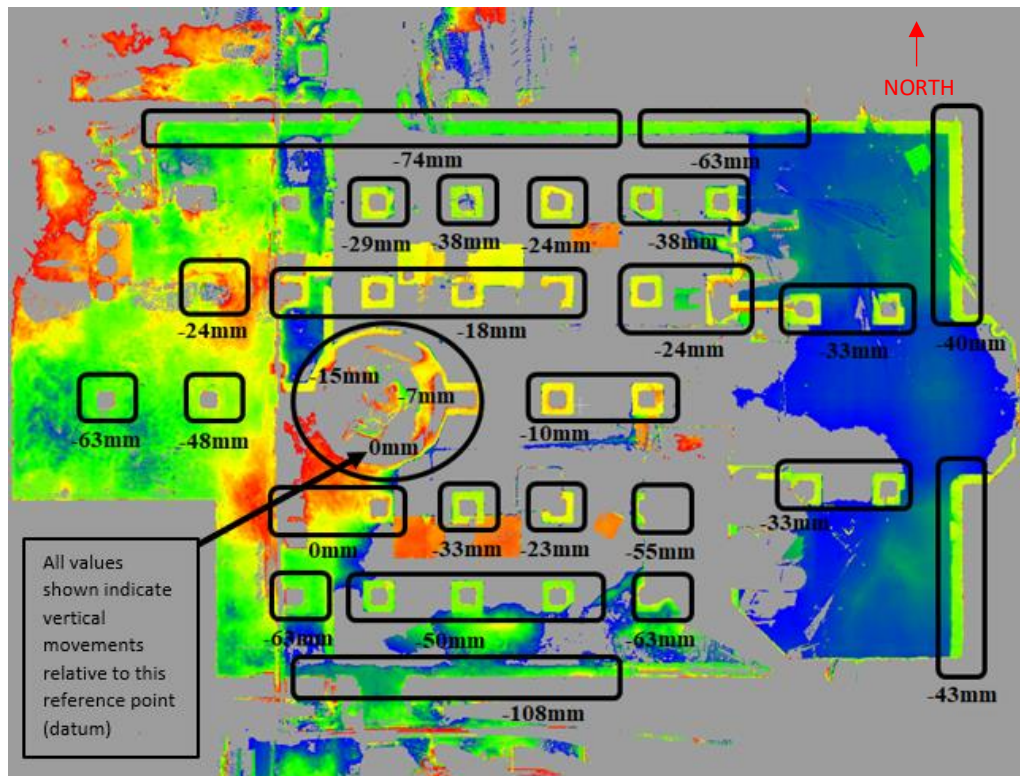


Figure 6.2: Differential in foundation elevations in Zone 3 relative to the reference point. Source: Dizhur Consulting⁹

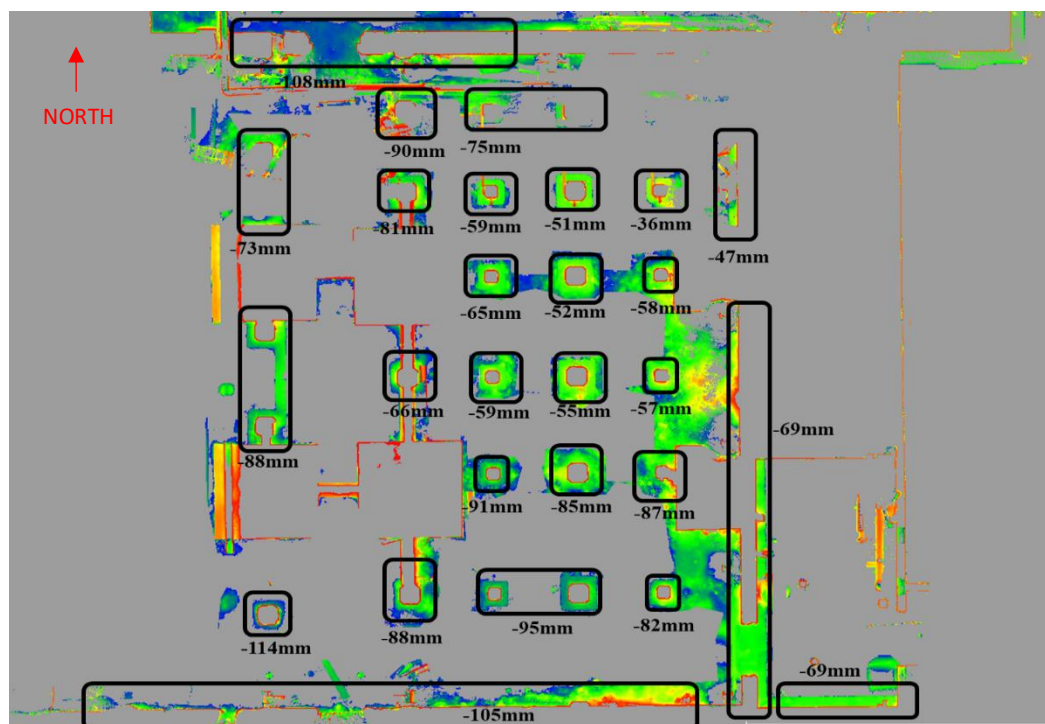


Figure 6.3: Differential in foundation elevations in Zone 2 relative to the reference point in Zone 3. Source: Dizhur Consulting⁹

⁹ Dizhur Consulting Ltd (May 2021) *Rotorua Museum – Basement Damage Investigation Report*. Government Gardens, Oruawhata Drive, Rotorua.



Figure 6.4: Differential in foundation elevations in Zone 4 & 5 relative to the reference point in Zone 3. Source: Dizhur Consulting⁹

6.1.2 Static differential settlement assessment based on recent laboratory information

From the recent laboratory one-dimensional consolidation tests undertaken in February 2022, it was observed that the soils underlying the footings are showing evidence of being prone to secondary compression. The coefficient of the secondary compression also appears to increase with increasing effective stress in the ground. In other words, soils that experience larger building loads would experience larger creep settlement. With the imposed bearing pressures being varied between the various building footings, and the differing secondary settlement property as a function of the effective stress, this is likely to have caused differential settlement to the building over the time the building has been standing on site. Based on this laboratory testing we have estimated that over the past 114 years, differential settlements of between 100 mm and 140 mm could have occurred between the footing with the heaviest load (e.g. the gable walls) and the footing with the lightest load. This estimate appears to be in a similar ballpark as the assessment made by the structural engineer outlined in Section 6.1.1 above. The secondary settlement calculation is attached in Appendix F.

6.1.3 April 2020 geothermal blow out

It is understood that the south wing (2011 build) part of the building (Zone 1) experienced a significant increase in temperature in April 2020. Temperature as high as 60°C was measured inside Zone 1, and the vent pipes around the Zone 1 perimeter were also venting out heat (over 80°C)¹⁰.

¹⁰ Email from Stewart Brown (RLC) to Leith Swinney (WSP) dated 5 May 2020.

RLC identified that a geothermal bore failure was the prime cause following testing undertaken on the nearby geothermal bores. The approximate location of the faulty bore is shown on Figure 6.5.

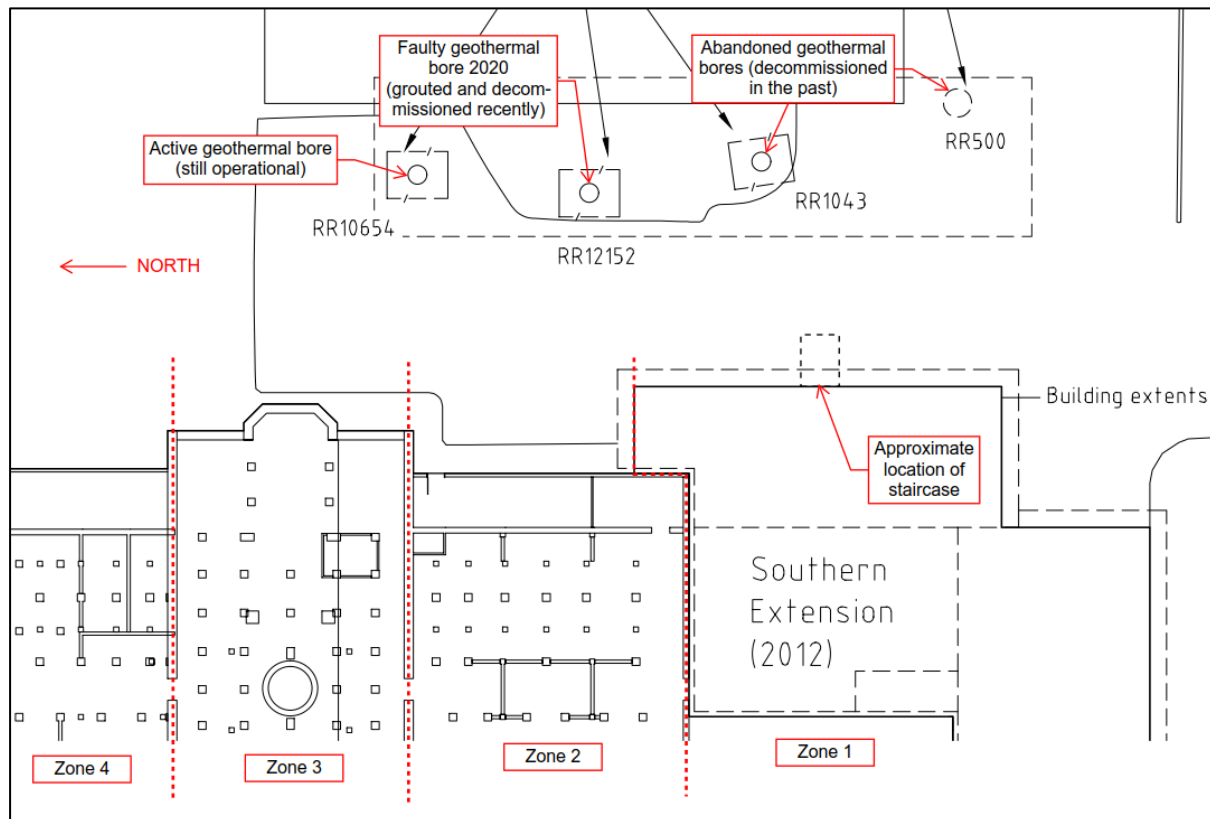


Figure 6.5: Approximate location of the faulty geothermal bore

The faulty bore was decommissioned using pressurised grout. However, an elevated temperature level remains noticeable in some areas of Zone 1 and southern end of Zone 2, albeit it is understood that it is no longer as high as prior to the decommissioning of the faulty bore.

There is, however, currently not sufficient evidence to conclusively link the geothermal blow out event and the elevated temperature experienced in Zone 1 with the differential settlement at the gable walls. We have also discussed with the structural engineer whether or not it is possible for the gable walls to be pulled down by Zone 1, if Zone 1 is settling more than the rest of the building. The structural engineer believes that such scenario has low probability as the structural connectivity in building has been “detached” by the differential settlement that had occurred in the building.

6.1.4 Estimates of potential future settlement

Based on the laboratory testing data, the secondary settlement magnitude vs time relationship is expressed in logarithmic scale. For the current pattern of building foundation load, we estimate that the differential settlement due to secondary settlement could increase by approximately 10 to 25 mm in the next 50 years (refer to Appendix F for calculation).

As noted in Section 6.1.1, the structural engineer compared the 2016 and 2020 Point Cloud survey data to estimate a rate of change in relative foundation level of 1 mm/year over this period. Based on this, the structural engineer has made the observation that differential settlements of approximately 50 mm could occur at the gable walls in the next 50 years if the settlement continues at this rate.

Additionally, we understand that the structural engineer has installed five digital crack monitoring instruments in mid-December 2021 that allow for continuous monitoring of the crack width to be carried out. They have observed that the cracks opening and closing in daily as well as weekly time scales and appear to respond to changes in groundwater level. This suggests that the building in general also moves with the change in groundwater level. This may contribute to the settlement experienced by the building. However, the extent of the influence of the groundwater fluctuation to the differential settlement observed at the gable walls is inconclusive at this stage due to insufficient groundwater monitoring data.

The above observations suggest that the estimated differential settlement in the next 50 years could be in the order of 10 to 50 mm but could possibly be larger if the groundwater also influences the differential settlement.

It is recommended that the monitoring of the building movements is continued to provide more monitoring data and allow for better understanding of the cause of the observed differential settlements. It is recommended that this is also done in conjunction with a long-term monitoring of the site groundwater level to obtain information of the seasonal fluctuation of the groundwater level and how the building responds to this.

For the purpose of seismic assessment of the building, the structural analysis should consider the differential movements that have already been experienced by the building and potential future differential settlement.

6.2 Geotechnical seismic assessment

6.2.1 Overview

Shaking during large earthquakes could cause strength loss and deformation in soils. Loose, saturated, non-plastic soils could experience liquefaction, while saturated, soft, plastic soils such as clays and plastic silts could experience cyclic softening. Liquefaction and cyclic softening could result in a substantial loss of soil strength and can potentially cause significant damage to buildings, land and infrastructure. The following aspects are considered in our liquefaction/cyclic softening assessments:

- Liquefaction and cyclic softening susceptibility assessments of the specific soil types encountered in the boreholes;
- Liquefaction triggering potential using site specific cyclic resistance ratio data from the laboratory cyclic triaxial testing, and cyclic softening triggering assessment based on published literature; and
- Liquefaction/cyclic softening consequences.

6.2.2 Seismic shaking hazard

6.2.2.1 Adopted design parameters

The seismic shaking hazard for the site has been calculated in accordance with the guidance outlined in the 2016 version of the MBIE/NZGS Earthquake Geotechnical Engineering Practice Module 1¹¹. Based on the published geology, the available existing geotechnical investigation data and our understanding of the ground conditions, the site is considered to be Subsoil Class D: 'Deep or soft soil' as per the NZS 1170.5:2004¹². Interpolation could be considered between Subsoil Class C and D

¹¹ Ministry of Business, Innovation & Employment (MBIE) & New Zealand Geotechnical Society (NZGS) (March 2016) *Earthquake Geotechnical Engineering Practice Module 1: Overview of the guidelines*. Rev 0.

¹² Standards New Zealand (2016) *Structural design actions Part 5: Earthquake actions – New Zealand*. NZS 1170.5:2004.

as per NZS 1170.5:2004 Amendment 1 with additional geotechnical investigation testing, which would reduce the seismic demand in the structural analysis. Following discussion with the structural engineer, we understand that this approach is unlikely to result in significant changes in structural design.

It is understood that the structural engineer has based the seismic strengthening design on an Importance Level 3 (IL3) structure for a 50-year design life scenario. It is also understood that RLC has set an initial building seismic performance target of 80% NBS as indicated in the RFP document¹³. Accordingly, our initial liquefaction assessment is based on 80% ULS(IL3) shaking for 50-year design life. The peak ground acceleration (PGA) and earthquake magnitude pairs for these cases are provided in Table 6.1.

Table 6.1: PGA and magnitude pair for various design seismic events

Load case	Return period	PGA	Earthquake magnitude
Serviceability limit state (SLS)	25 years	0.08	6.0
Ultimate limit state (ULS)	1,000 years	0.39	6.0
80% ULS shaking	N/A	0.31	6.0

Notes:

PGA and effective magnitude have been assessed based on 2016 version of MBIE/NZGS Guideline Module 1 with the following input parameters:

- Building importance level: Level 3 (AS/NZS 1170.0:2002¹⁴, Table 3.2), as advised by the structural engineer
- Building design life: 50 years, as advised by the structural engineer
- Return period and factor, R_u : 0.25 and 1.3 for 25 and 1,000 year return periods respectively based on NZS 1170.5:2004, Table 3.5
- Seismic site category: D (Deep or soft soil) as per NZS1170.5:2004
- PGA: $C_{0,1000} \times R_u / 1.3 \times f \times g$ (NZTA Bridge Manual¹⁵ Section 6.2)

6.2.2.2 Implications of differences in earthquake magnitude

We note that there are various tectonic domains which contribute to the seismic hazard at the site, each with different typical magnitude characteristics. The NZ active fault source model shows characteristic magnitude of typically 6.0 - 6.5 to the south of Rotorua, 6.1 – 6.8 to the north, and 7.1 - 7.5 to the east. The contributions of these different domains are aggregated together in the seismic hazard analysis to calculate the single PGA/magnitude pairs for each design event given in Table 6.1. We have given thought to whether deaggregation of the seismic hazard to separately assesses consequences from higher and lower magnitude events would have any material impact on the current engineering assessment. For the current stage of assessment this was not considered necessary, as the liquefaction resistance of the soil was found to be not highly sensitive to number of cycles (refer Section 6.2.4.1), and extensive lateral spreading is not expected (refer Section 6.2.5.3).

6.2.2.3 2021 update to seismic hazard parameters for geotechnical design of new buildings

It is noted that MBIE released an update to the MBIE/NZGS Earthquake Geotechnical Engineering Practice Module 1 in November 2021. The new guideline has identified a higher design PGA for Rotorua than the previous version. Table 6.2 compares the design PGA values between the 2016 and 2021 versions of the MBIE guideline.

¹³ WSP (23 April 2021) *Request for Price – Briefing. Rotorua Museum Development Project: Geotechnical and Geological Engineering Service Request*. Ref 2-82142.00.

¹⁴ Australian/New Zealand Standard (2011) *Structural design actions Part 0: General principles*. AS/NZS 1170.0:2002.

¹⁵ Waka Kotahi (2018) *Bridge Manual SP/M/022 Third Edition*. Amendment 3.

Table 6.2: Difference in PGA between MBIE 2016 and MBIE 2021 guidelines

	MBIE 2016	MBIE 2021
ULS design earthquake magnitude	M 6.0	M 6.0
ULS design PGA for IL3 structure for 50 years design life (1000-year return period)	0.39g	0.47g

We note that MBIE have issued an interim recommendation that at the present time, the design PGA values from the 2016 guidance can continue to be used for calculating %NBS scores for assessing whether a building is earthquake prone as defined in the 2016 Earthquake Prone Building legislation. This interim recommendation also extends to %NBS assessments for other purposes, such as Council policy for allowing occupation of its buildings, and for design of strengthening work. However, a full revision of the National Seismic Hazard model is due in August 2022, and this may trigger changes to the legislative requirements for assessment of existing buildings. In any event, design of any new building works (e.g. as part of seismic strengthening) would likely need to at least give thought to the potential implications of the updated 2021 design values.

6.2.3 Liquefaction and cyclic softening susceptibility

Liquefaction susceptibility is a fundamental physical characteristic of the soil that describes how it responds to earthquake shaking. Liquefaction typically only occurs in soils which are saturated, non-cohesive, and low to moderate permeability. This includes the following broad soil types:

- Sands and low plasticity/non-plastic silts¹⁶;
- Fine grained low to non-plastic soils with a high moisture content^{17,18};
- Young, typically Holocene-aged ($\leq 12,000$ years old) deposits; and
- Gravels (if they have a low permeability or are confined by less permeable layers or their behaviour is controlled by the fines portion in the matrix).

Based on the geological information available for the site, some underlying soil layers are considered susceptible to liquefaction. However, it should be appreciated that an accurate assessment of soil plasticity or grain size distribution is very difficult to assess from the current geological information (soil descriptions from historical logged boreholes, test pits and CPTs).

Cyclic softening is generally used in reference to strength loss and deformation in clays and plastic silts during a seismic shaking event. Typical soil that is susceptible are low strength, highly plastic and saturated. A soil type can only either be susceptible to liquefaction or cyclic softening.

6.2.4 Liquefaction resistance and triggering

Liquefaction triggering describes the strength of shaking required to liquefy susceptible soils. Denser soils require more intense and/or longer duration of shaking than those that are less dense. The level of earthquake shaking that induces liquefaction is the point at which liquefaction is triggered.

For a hard-grained quartz-based sand, the CPT test is a typically good indicator of the soil behaviour type and its relative density. Both these parameters are key inputs into the liquefaction triggering assessment. However, from the shear wave velocity measurements, it is evident that the pumiceous soils underlying the Rotorua Museum building could crush when the CPT probe was advanced

¹⁶ Bray, J. et al (2014) *Liquefaction effects on buildings in Central Business District of Christchurch*. Earthquake Spectra, 30 (1), 85-109.

¹⁷ Bray J.D. & Sancio R.B. (2006) *Assessment of the liquefaction susceptibility of fine-grained soils*. Journal of Geotechnical and Geoenvironmental Engineering, 132 (9), 1165-1177.

¹⁸ Boulanger R.W. & Idriss I.M. (2006) *Liquefaction Susceptibility Criteria for Silts and Clays*. Journal of Geotechnical and Geoenvironmental Engineering, 132 (11), 1412-1426.

(particularly for denser soil). This could result in the relative density of the ground being underpredicted using the CPT method of investigation. Therefore, the conventional method of assessing liquefaction triggering using CPT proposed by Boulanger and Idriss (2014)¹⁹ tends to underpredict the liquefaction resistance of the soils. This could potentially lead to overly conservative design where the conventional method predicted widespread liquefaction.

Section 6.2.4.1 presents the liquefaction resistance obtained from the site-specific cyclic triaxial test and its comparison with that obtained from a hard grained quartz-based sand (conventional method).

6.2.4.1 Site-specific laboratory cyclic testing

The dynamic cyclic triaxial tests were undertaken to establish a site-specific liquefaction triggering curve for the soils of greatest significance for the seismic assessment of the building. The cyclic triaxial test results are plotted in Figure 6.6 below as coloured dots. In the same plot, example resistance curves for reference hard-grained soils from published literature are plotted for comparison. For a particular curve, the higher it is plotted (high cyclic resistance ratio), the higher the liquefaction resistance.

The light blue Toyoura sand curve represents a typical cyclic resistance curve for loose hard-grained sand (relative density of 50%) while the dark blue curve represents the cyclic resistance for dense hard-grained sand (relative density of 80%). The curve for the dense line plots above the loose line, indicating that the denser the material the higher its liquefaction resistance. Similar correlation (shown in light and dark red) is observed by the University of Auckland on the reconstituted pumice-rich soil samples from other sites.

Comparing the site-specific cyclic triaxial tests results to that of a typical hard grained sand, all results indicate that the Rotorua Museum soil samples tested display higher liquefaction resistance than the example dense hard grained reference sand.

Figure 6.7 provides a similar plot to Figure 6.6, the difference being the laboratory cyclic resistance ratio (CRR) is converted to an equivalent field CRR. The conversion adopted a CRR field to laboratory ratio of 0.57, which was estimated in accordance with the methodology outlined by Orense et al (2020)²⁰.

Additionally, the CRR curve of the Rotorua Museum cyclic triaxial testing is showing a flatter line in comparison to the pumice rich soil CRR curves from the University of Auckland laboratory testing. This also suggests that the CRR is less sensitive to the number of cycles (i.e. earthquake magnitude).

The site-specific laboratory test results (corrected to equivalent field values, CRR_{field}) are plotted against the conventional CPT-based and V_s -based liquefaction triggering curves. These are shown in Figure 6.8 and Figure 6.9. The red dots represent CRR_{field} derived from the laboratory cyclic triaxial tests, and the solid black lines represent the conventional CPT-based and V_s -based liquefaction triggering curves. In a liquefaction triggering assessment, any point that falls above the liquefaction triggering curve is predicted to be liquefied and any point that falls below the curve is considered not liquefied. If the liquefaction curve shifts further up (i.e. higher liquefaction resistance), larger cyclic stress is required to liquefy the soil. The laboratory test results plot above the CPT and V_s based liquefaction triggering curves, indicating that the samples tested show higher liquefaction resistance than the conventional triggering analysis methods suggest.

¹⁹ Boulanger, R.W. & Idriss, I.M. (2014) *CPT and SPT based liquefaction triggering procedures*. Report No. UCD/CGM-14/01, Center for Geotechnical Modelling, Department of Civil and Environmental Engineering, University of California, Davis, CA, 134 pp.

²⁰ Orense, R.P., Asadi, M.B., Stringer, M.E. & Pender, M.J. (2020) *Evaluating liquefaction potential of pumiceous deposits through field testing: Case study of the 1987 Edgecumbe earthquake*. Bulletin of the New Zealand Society for Earthquake Engineering, Vol. 53, No. 2, June 2020.

In addition to the above, we also observed a rapid build-up of water pressure (which reduces ground bearing strength and causes ground settlement) occurring during the initial cycles of loading, but after this the water pressure increases only gradually up to the point of complete liquefaction. This pattern is often observed for pumice-rich soils such as the soils from the Rotorua Museum site, and is different than for hard-grained sands (where pressure increases only gradually at first, before rapidly increasing as the soil approaches the point of liquefaction). This pattern of gradual change in the ground response has implications for how the structural performance is assessed. This is discussed further in Section 6.2.4.3 below.

For the purposes of this report, for Unit 2a/2b soils we will refer to this loss of strength under cyclic loading as “liquefaction”. However, it is possible that in some cases the mechanism could be closer to “cyclic softening”. The difference between these similar phenomena is immaterial for practical purposes for the current seismic assessment purposes, as our engineering assessment of strength loss and settlement for Unit 2a/2b soils is based directly on the laboratory results rather than on published liquefaction or cyclic softening correlations. However, the potential for this alternative strength loss mechanism should be considered if relevant for future assessments. Where clay-like soils are present, a conventional cyclic softening assessment has been undertaken as outlined in Section 6.2.6.

Cyclic Resistance Ratio from Laboratory Cyclic Triaxial Tests

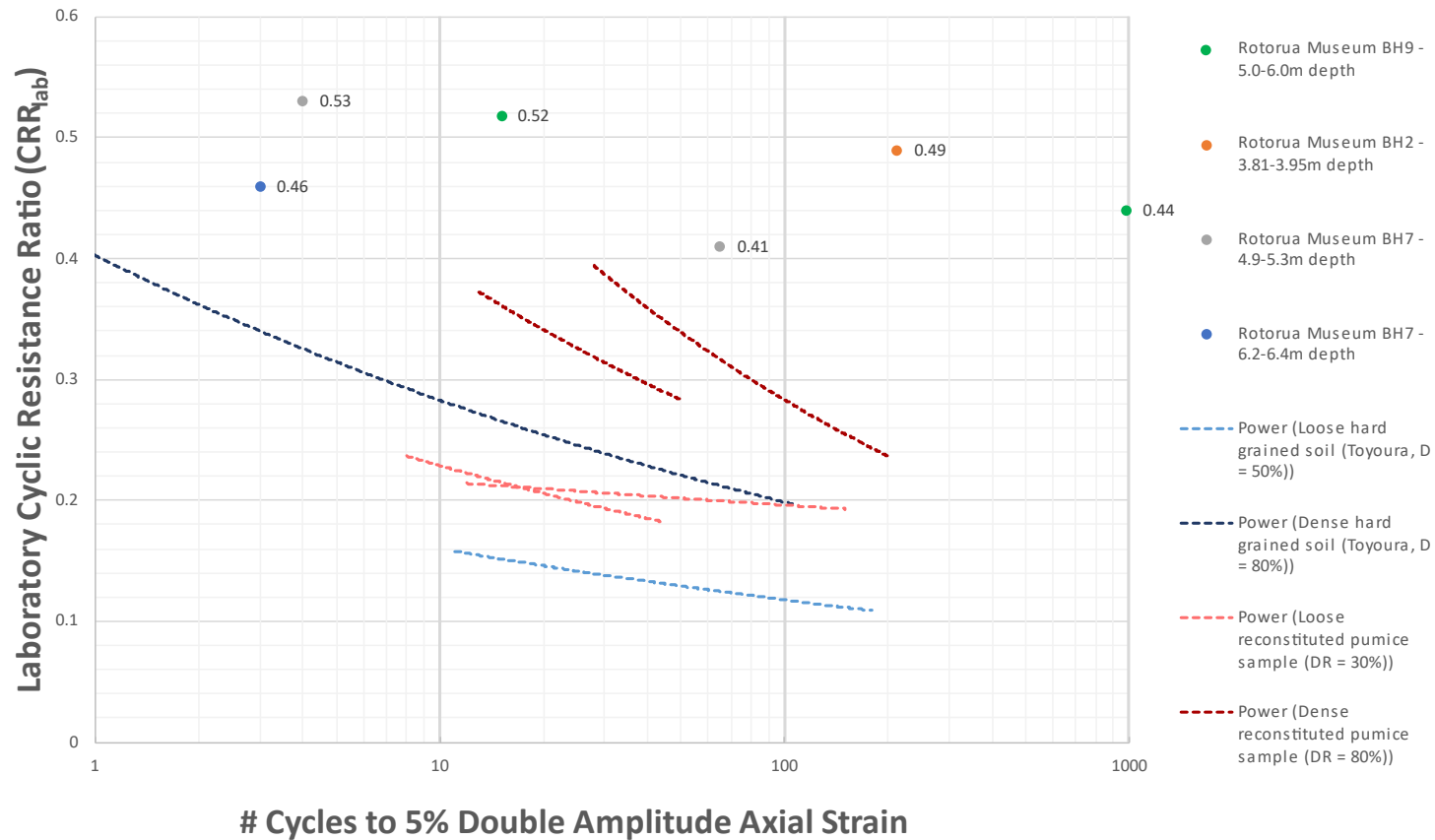


Figure 6.6: CTT results showing number of cycles required to reach 5% double amplitude axial strain (laboratory definition of liquefaction) for a given laboratory cyclic stress ratio. Other sites cyclic resistance ratio curves were obtained from Asadi et al²¹

²¹ Asadi, M.S., Asadi, M.B., Orense, R.P. & Pender, M.J. (2018) *Undrained Cyclic Behaviour of Reconstituted Natural Pumiceous Sand*. Journal of Geotechnical and Geoenvironmental Engineering 2018, 144 (8): 04018045.

Estimated Field CRR based on Laboratory Cyclic Triaxial Tests

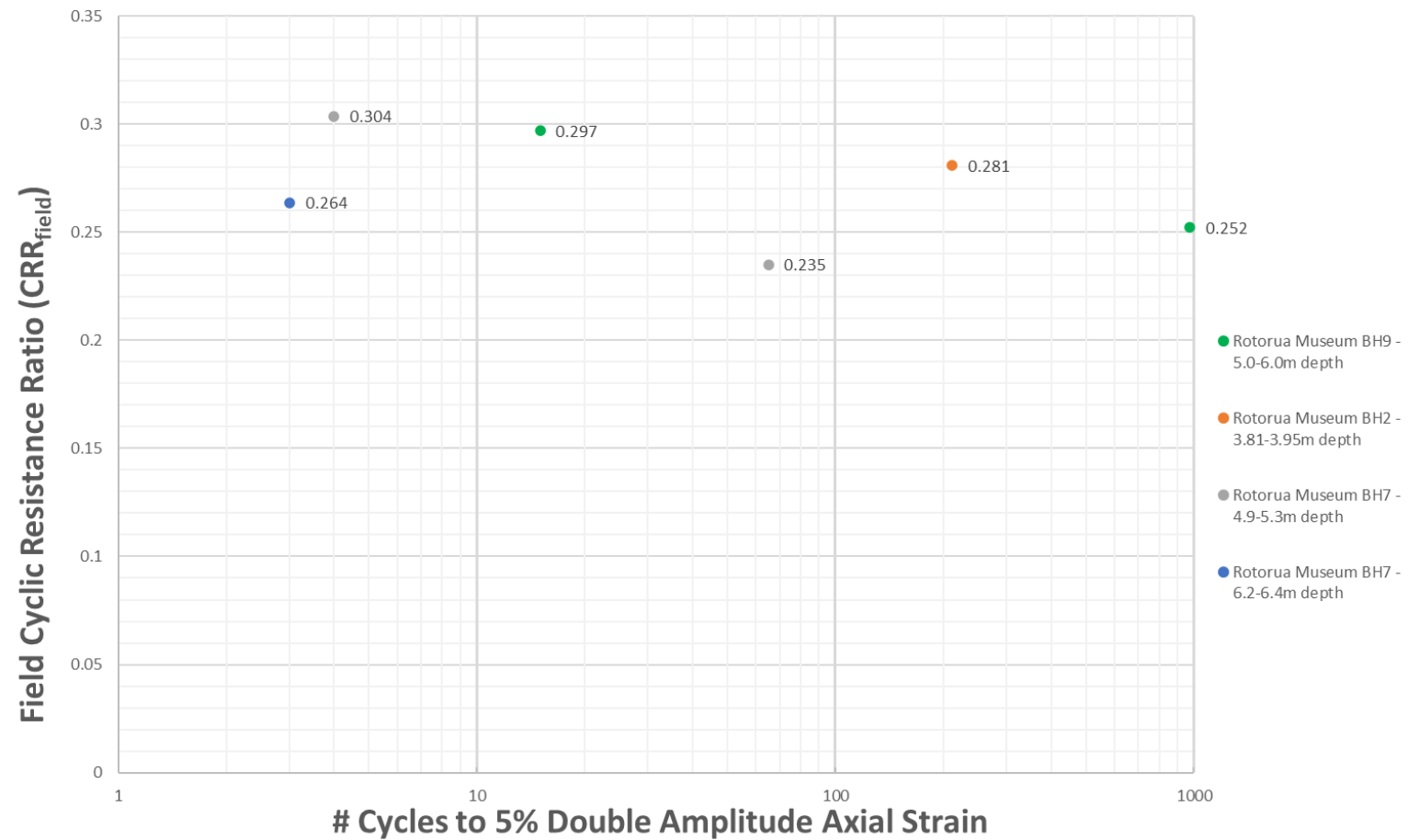


Figure 6.7: Field cyclic resistance ratio vs number of cycles required to 5% double amplitude axial strain

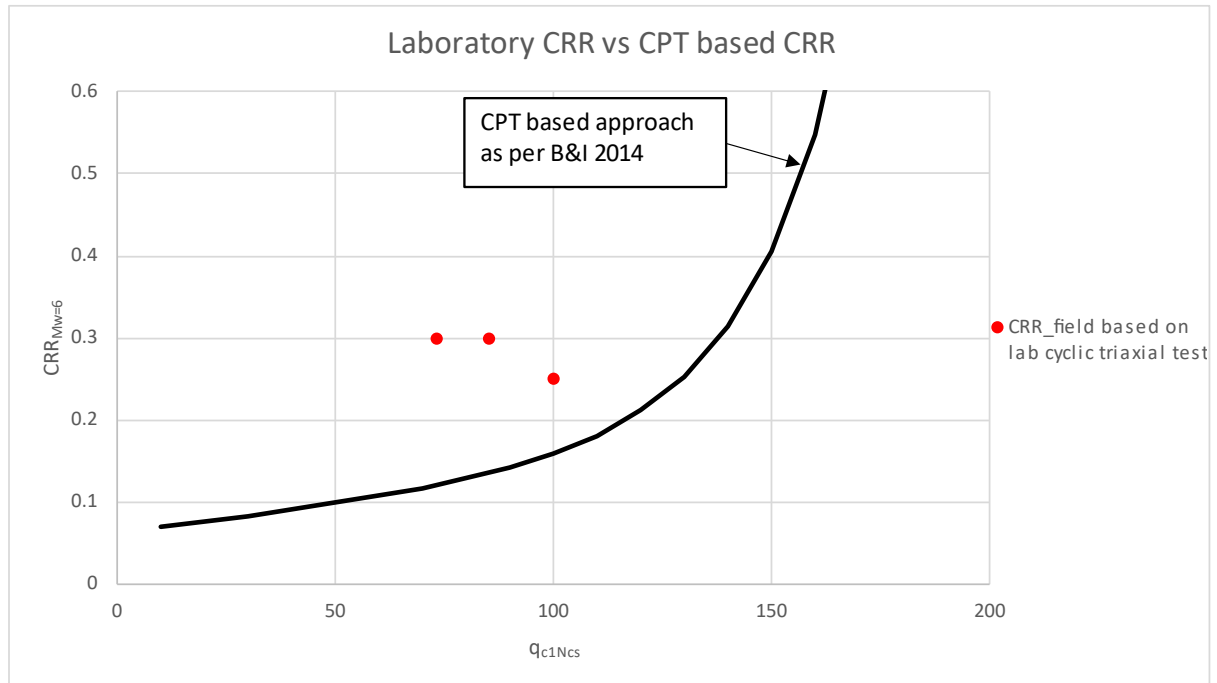


Figure 6.8: Comparison between laboratory and CPT-based estimates of cyclic resistance for a magnitude $M_w=6$ earthquake. CPT-based triggering curve is based on Boulanger & Idriss (2014)¹⁸ with a probability of liquefaction $P_L=15\%$, and lab-based results are interpolated from the cyclic resistance curves at 5 cycles.

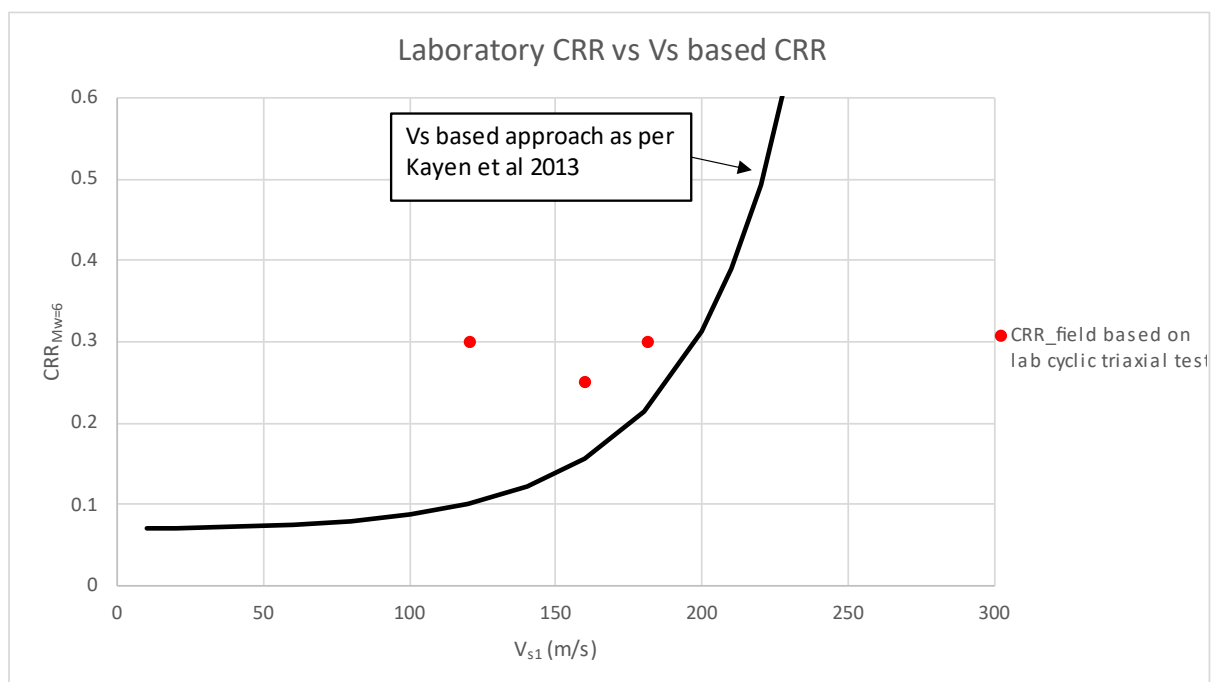


Figure 6.9: Comparison between laboratory and Vs based estimates of cyclic resistance for a magnitude $M_w=6$ earthquake. Vs-based triggering curve is based on Kayen et al (2013)²² with effective vertical overburden stress of $\sigma'_{v0}=80\text{kPa}$, fines content of $FC=30\%$ and a probability of liquefaction $P_L=15\%$.

²² Kayen, R. Moss, R.E.S., Thompson, E.M., Seed, R.B., Cetin, K.O., Der Kiureghian, A., Tanaka, Y. & Tokimatsu, K. (2013) *Shear-Wave Velocity–Based Probabilistic and Deterministic Assessment of Seismic Soil Liquefaction Potential*. Journal of Geotechnical and Geoenvironmental Engineering Vol. 139, No. 3, March 2013.

6.2.4.2 Verifying that samples from laboratory cyclic tests are representative of the range of liquefaction-susceptible soils present at the site

The laboratory cyclic testing suggests that the liquefaction-susceptible soils at the site have a higher liquefaction triggering resistance than was previously estimated from conventional CPT and shear wave velocity correlations. This result is expected given the pumiceous nature of the soils, with the cyclic laboratory testing considered to provide a more reliable assessment than CPT-based correlations which were developed predominantly using data for hard-grained soils.

It is therefore preferable to base the assessment of seismic performance of the site on the cyclic laboratory results, setting aside the previous CPT and shear wave velocity liquefaction triggering analysis. However, for completeness, before doing this it is important to verify that the samples tested in the laboratory are representative of the full range of soils present at the site. For example, if all the laboratory samples were silty, but there are significant clean sand layers present across the site, then it could be non-conservative to assume a higher cyclic resistance for the sandy soils based on the favourable results from only silty samples. This could mean that the CPT and shear wave velocity correlations would still need to be used for any soil types that were not included in the cyclic laboratory test samples.

We have therefore undertaken a simplified soil behaviour screening exercise, to compare the range of soil types inferred from the extensive CPT testing across the site to the range of soil types inferred for the cyclic laboratory samples. For this we have used the CPT soil behaviour chart developed by Robertson et. al. (1990) and updated by Robertson (2010). There are limitations in the application of the soil behaviour type chart to pumice-rich soils (due to grain crushing altering the correlation between cone resistance and sleeve friction), so there is considerable uncertainty regarding the absolute accuracy of the inferred soil type and density. However, this chart can still be of use in helping to understand the relative variability of site ground conditions encountered in the CPT tests.

The results from all CPTs across the site are plotted on the soil behaviour chart in Figure 6.10(a). The red points indicate that the CPT-based analysis would predict liquefaction triggering at 80% of ULS shaking demand, and blue points indicate liquefaction would not be predicted. Figure 6.10(b) is a similar plot, but only showing the data from CPTs closest to the locations and depth of the cyclic triaxial test samples. The purple dots correspond to samples which plotted along a similar cyclic resistance curve in Figure 6.7, while the yellow dots correspond to the one sample which indicated a noticeably lower resistance than the others.

The red dots (where the CPT-based analysis indicates liquefaction) are concentrated in Zone 5 and 6 of the soil behaviour chart (which would correlate to sandy silt to clean sand for hard-grained soils). The purple and yellow dots (cyclic triaxial sample locations) are well distributed across the area of red dots. This confirms that the samples selected for cyclic triaxial testing are reasonably representative of the full range of potentially liquefaction-susceptible soils present across the site.

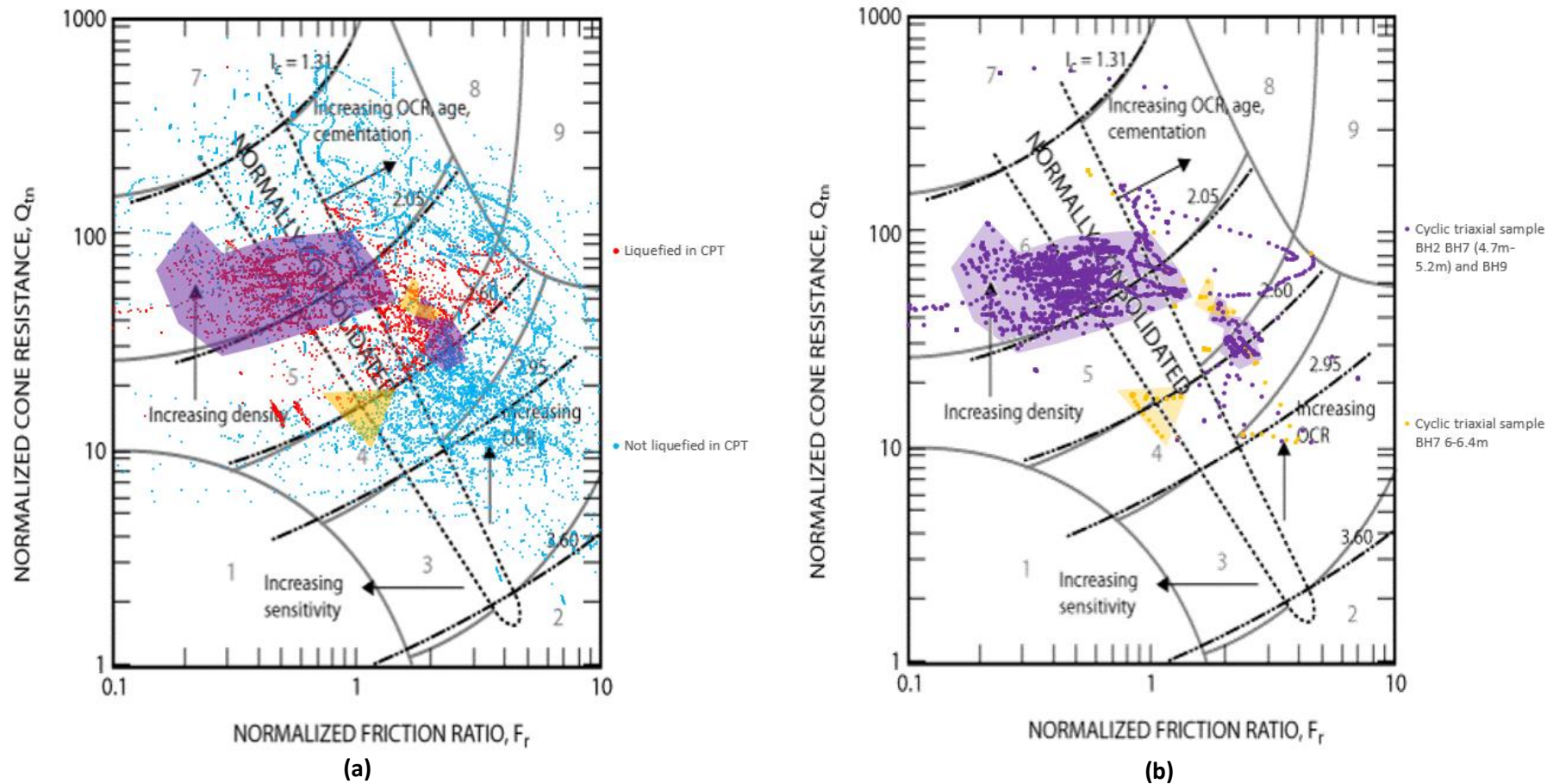


Figure 6.10:

- (a) All CPT results from across the site plotted on a soil behaviour chart. Red dots indicate soil which would be predicted to liquefy using the B&I 2014 CPT-based triggering assessment method, at 80% of ULS shaking demand. Blue dots indicate liquefaction would not be predicted. The purple and yellow shading indicates the range of soil behaviour for cyclic triaxial test samples highlighted in (b).
- (b) Purple and yellow dots represent the data from CPTs close to the locations of the gel push sampling in the depth range corresponding to the cyclic triaxial test samples. The purple and yellow shading highlights the typical range of soil behaviour covered by these dots. BH7 6-6.4m is plotted separately, as this sample indicated a lower cyclic resistance trend than the other samples tested.

6.2.4.3 Level of shaking required to trigger liquefaction

The output of the CPT-based liquefaction triggering analysis is attached in Appendix D. The CPT-based analysis indicates that under the SLS event, the strength of shaking is not sufficient to induce liquefaction. The onset of liquefaction, where the soil begins to experience substantial loss of strength resulting in potentially material effect to the building performance, is estimated by the CPT-based analysis to be at a PGA of 0.15g or greater. The liquefaction is predicted within the Holocene lakes sediments units 2a and 2b. PGA of 0.15g corresponds to 100-year return period based on the parameters outlined in Section 6.2.2, or 40% of ULS (IL3) shaking demand for 50 years design life scenario.

As noted in Section 6.2.4.1, the laboratory cyclic triaxial testing indicates that the pumiceous soil from the Rotorua Museum site has a greater resistance to liquefaction triggering than would be predicted using the CPT-based correlation. The cyclic testing also indicates that the soil experiences a gradual loss of strength as the shaking level increases before it reaches a level where the soil experiences significant strength loss and completely liquefies. This pattern is different to the hard-grained quartz-based sands that forms the basis of the CPT-based liquefaction triggering analysis described in the paragraph above, where the soil experiences little strength loss at lower level shaking up to the point of liquefaction when a geotechnical step change occurs with near-complete strength loss.

In the case of the pumiceous soil from the Rotorua Museum site, excess pore water pressure is expected to begin building up at a PGA of approximately 0.19g, gradually worsening with shaking levels up to PGA of approximately 0.27g. Above this level, the ground is expected to experience significant strength loss and completely liquefy, at which point the consequences of liquefaction are likely to be similar to those predicted using the CPT-based approach.

We recommend that the structural assessment considers gradual development of strength loss and ground settlement over the range of PGA = 0.19 – 0.27g, with a sudden step change worsening above this level. This corresponds to 50% – 70% of ULS (IL3) shaking demand for 50 years design life scenario (based on ULS PGA from the older MBIE 2016 guideline). The calculation attached in Appendix G outlines the assessment of the “geotechnical step-change” being at 70% of ULS (IL3) shaking based on the recent laboratory cyclic triaxial testing. This finding was discussed with the structural engineer in the meeting held on 22 February 2022. We understand from the discussion that the structural engineer intends to incorporate in the design of building seismic strengthening the ground effects (strength loss and settlement) associated with 70% ULS (IL3) shaking. These ground effects are discussed further in Section 6.2.5.

We have taken into consideration Cubrinovski's 'system-response' effects²³ in our liquefaction triggering assessment. Where liquefaction triggering is predicted, liquefaction is expected to occur in Unit 2a/2b which appears to be relatively “homogenous” from a liquefaction triggering point of view (albeit that this is inferred from the CPT testing, which could potentially fail to identify denser pumiceous material). This condition is similar to the “YY profile” in the Cubrinovski et al publication. Accordingly, the possible dampening with the presence of stratified layers, which may reduce the liquefaction extent, does not appear to be present in this site.

6.2.5 Liquefaction consequence

For the Rotorua Museum building, liquefaction could impact the building performance in various ways. Liquefied soils are generally low in strength and stiffness. When liquefied ground cannot

²³ Cubrinovski, M., Rhodes, A., Ntritsos, N. and Van Ballegooy, S. (2019) *System response of liquefiable deposits*. Soil Dynamics and Earthquake Engineering 124 (2019) 212-229.

sustain the stresses of its load from the foundations, the foundation sinks into the liquefied layer and possibly causes the building to deform significantly.

Even after the peak seismic shaking has passed, further settlement may continue to occur in the form of ejecta and reconsolidation settlement. Lateral spread towards Lake Rotorua could also occur. These individual mechanisms are discussed further in the following subsections. These mechanisms are relevant to Holocene lake sediments Unit 2a and 2b.

6.2.5.1 Reconsolidation and ejecta induced settlement

At the 70% ULS (IL3) shaking level, some build-up of water pressure is expected in the ground which would cause partial strength loss and development of ground settlement. We have assessed the reconsolidation settlements at the 70% ULS (IL3) shaking level based on the general approach outlined in Ishihara & Yoshimine (1992)²⁴. However, this correlation has been recalibrated using the site-specific data obtained from the cyclic triaxial laboratory testing, along with available test results for pumiceous soils from other sites.

The findings of this assessment for 70% ULS (IL3) shaking are:

- Zones 3 to 6, total seismic settlement is estimated to be in the order of 15 mm with differential of approximately 1:600 in both North-South and East-West directions.
- In Zones 1 and 2, total seismic settlement increases to approximately 65 mm. This results in a differential of 1:200 in both North-South and East-West directions.

These results suggest that there could be benefit in having each zone detailed to be structurally independent of each other, and we understand that this is the current structural seismic strengthening philosophy that is adopted by the structural engineer.

At shaking levels greater than 70% ULS (IL3) shaking, full liquefaction is expected to be triggered. The post-liquefaction one-dimensional reconsolidation settlement has been estimated using the methodology developed by Zhang, Robertson and Brachman (2002), and Idriss and Boulanger (2014) and the results of the liquefaction triggering analyses. It should be noted that this estimated settlement is the “free-field” (i.e. no building load) reconsolidation settlement estimation. This describes the liquefaction induced settlement at the ground surface, which is caused by dissipation of excess pore water pressure generated during earthquake shaking. The liquefaction could also generate ejecta which would result in soil volume loss and additional settlement. These phenomena are illustrated in Figure 6.11. The estimated settlements due to these effects are provided in Figure 6.12 below as well as in Figure E2 of Appendix E. For the purpose of structural analysis for shaking levels greater than 70% ULS (IL3) shaking, in the absence of ground improvement the structural engineer should consider a differential settlement of 100 mm over 10 m distance in the building. Further settlement could be expected due to soil strain under loading from foundations due to the triggered liquefaction. This is discussed in section 6.2.5.2.

²⁴ Ishihara, K. & Yoshimine, M. (1992) *Evaluation of Settlements in Sand Deposits Following Liquefaction During Earthquakes*. Soils and Foundations Vol. 32, No. 1, 173-188, March 1992, Japanese Society of Soil Mechanics and Foundation Engineering.

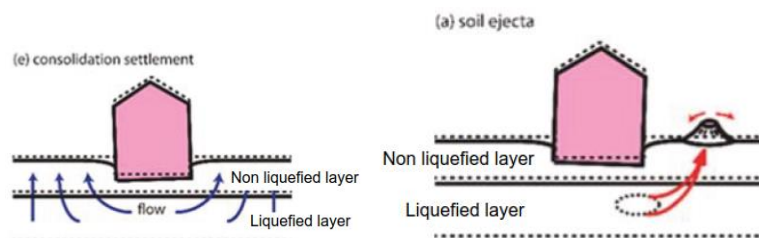


Figure 6.11: Schematic showing reconsolidation settlement (left) and ejecta (right). Source: Bray and Macedo²⁵

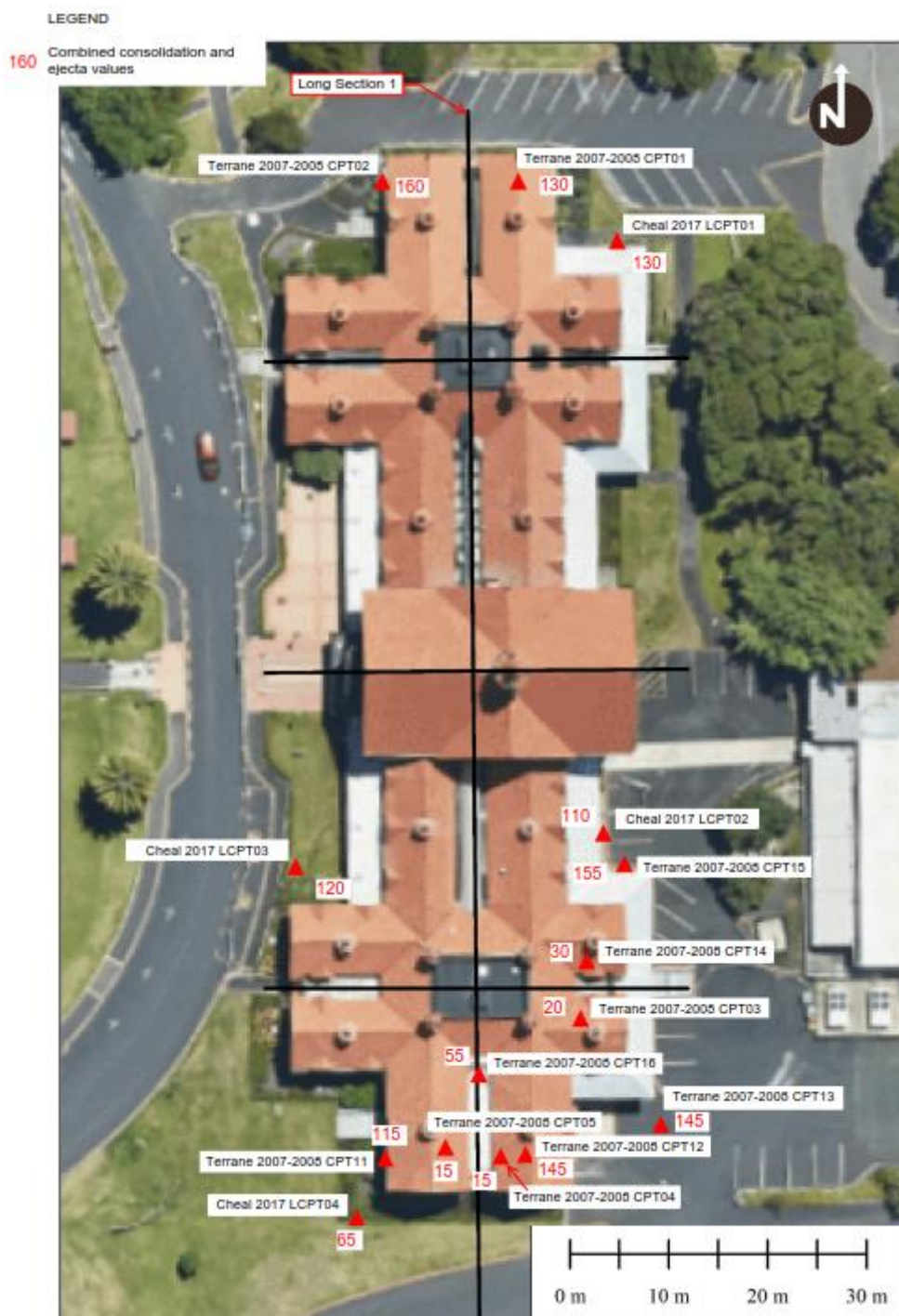


Figure 6.12: Estimated settlements (mm) due to reconsolidation and ejecta shown in red

6.2.5.2 Building induced seismic settlement

When full liquefaction is triggered at shaking level greater than the 70% ULS (IL3) shaking, the presence of a building induces settlements during seismic events, in addition to the free field seismic settlements outlined in Section 6.2.5.1. The static load of the building as well as the soil-structure interaction (SSI) induced cyclic loading on the edges of the building could result in additional settlements during strong earthquake shaking. Deformations caused by these phenomena have been assessed based on the method by Bray & Macedo²⁵. The effects of these are embedded within the seismic subgrade reaction modulus outlined in Section 7.

6.2.5.3 Lateral spread

Lateral movement occurs when earthquake shaking causes a mass of soil to lose shear strength and move relative to the surrounding soil. Lateral movement can be entirely horizontal and occur on flat ground, but it is more likely to occur on or around sloping ground, such as adjacent to hillsides and waterways (due to the presence of a free face). When lateral spreading occurs, the ground tears and stretches causing cracks and fissures to form. In most cases the land located immediately adjacent to the free face is likely to experience the most severe cracking and stretching. These effects reduce as the distance from the free face increases. A schematic sketch for lateral spread phenomenon is shown in Figure 6.13. This ground movement can induce significant lateral force to the affected foundations and structures.

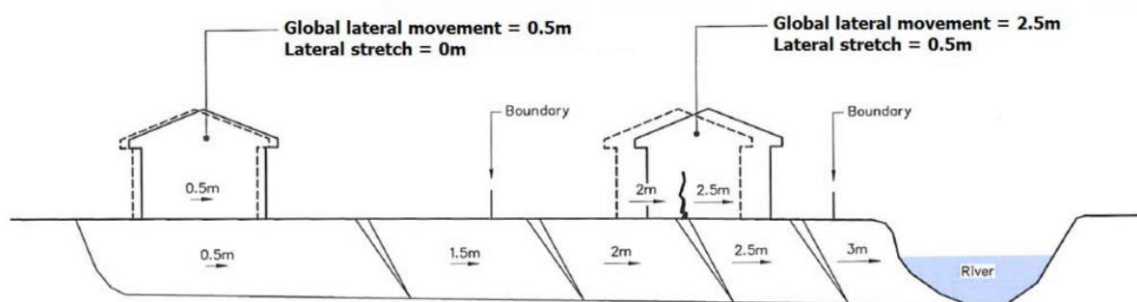


Figure 6.13: Schematic of lateral spread phenomenon (note: values of lateral movement and lateral stretch shown are illustrative only, and do not relate to the Rotorua Museum site). Source: Ministry of Business, Innovation & Employment (MBIE)²⁶

The southern side of the Rotorua Museum building is located approximately 60m away from the edge of the lake. A vertical slope of approximately 2.5 m in height is present at the lake edge.

When full liquefaction is triggered, lateral spreading could occur. We have estimated that this phenomenon could impose a lateral displacement of around 200 mm total at the building and a lateral stretch of 100 mm across the building based on the method by Zhang et al²⁷ and Youd et al²⁸. Within the building, this 100 mm lateral stretch could be expected to concentrate at location(s) where the structure is poorly tied together.

²⁵ Bray, J. and Macedo, J. (2017) *Simplified procedure for estimating liquefaction-induced building settlement*. Proceedings of the 19th International Conference on Soil Mechanics and Geotechnical Engineering.

²⁶ Ministry of Business, Innovation & Employment (April 2015) *Build it Right Canterbury – The groundwork for good decisions. Part C: Assessing, repairing and rebuilding foundations in TC3*. Version 3a.

²⁷ Zhang, G., Robertson, P.K., & Brachman, R.W.I. (2004) *Estimating Liquefaction-Induced Lateral Displacement Using the Standard Penetration Test or Cone Penetration Test*. Journal of Geotechnical and Geoenvironmental Engineering, ASCE.

²⁸ Youd, T. L., Hansen, C. M., Bartlett, S.F. (2002) *Revised Multilinear Regression Equations for Prediction of Lateral Spread Displacement*. Journal of Geotechnical and Geoenvironmental Engineering, ASCE.

At 70% of ULS (IL3) shaking demand, some lateral ground movement could occur due to partial strength loss of the soil. Based on the data from the recent investigation, it is estimated that a lateral ground stretch of approximately 20 mm could occur between the south and north boundaries of Zone 1. The lateral stretch of the foundation is likely to be concentrated at the weak link within this zone or at the boundary between zones 1 and 2, where, as we understand, a seismic gap is present at this boundary.

6.2.6 Cyclic softening

An assessment of the factor of safety of the plastic silt and clay layers, which behave as clay-like soil when subject to seismic shaking, has been assessed in accordance with Boulanger and Idriss (2007)²⁹. The factor of safety from cyclic softening is typically greater than 1.5. Therefore, the likelihood of significant cyclic softening in the clay-like soils that may have material consequential to the performance of the building is considered low. Liquefaction effects can be expected to dominate the vulnerability of the Holocene lakes sediments Unit 2a and 2b.

6.3 Bearing capacity

The bearing capacity of the soil is the point at which the soils yield and deform excessively under a constant load. The assessment has been undertaken based on the method prescribed in B1/VM4³⁰ and adopted as the bearing capacity for non-liquefied case.

The effects of the existing grout columns in zones 2 to 5 were incorporated in the bearing capacity and the soil spring stiffness analyses. The presence of grout provided a slight increase to the ground bearing capacity and soil spring stiffness. The increase was assessed based on estimated weighted average of the area and the stiffness of the grout column and the soil.

At the 70% ULS (IL3) shaking level, partial strength loss is expected and may reduce the bearing capacity. When the underlying soil fully liquefies at shaking levels greater than 70% ULS (IL3) shaking, there is a possibility of punching shear bearing failure mechanism to occur. A method developed by Hanna & Meyerhof³¹ has been used to assess the capacity of the soil under this mechanism. The governing (lower) capacity from the B1/VM4 and the Hanna-Meyerhof methods is adopted as the bearing capacity for the liquefied case.

Conclusions are reported in Section 7 and Figure E1, Figure E3 and Table E3 in Appendix E.

6.4 Lateral earth pressures

Lateral earth pressures are acting on the basement retaining wall. Static earth pressures have been estimated based on at-rest earth pressure theory, and seismic earth pressures were estimated using the method for stiff walls documented in Earthquake Geotechnical Engineering Practice Guideline Module 6³². The resulting loads on the basement wall are summarised in Table 6.3. The at-rest and seismic earth loads are to be added together for the seismic case.

²⁹ Boulanger, R.W. & Idriss, I. M. (2007) *Evaluation of Cyclic Softening in Silts and Clays*. Journal of Geotechnical and Geoenvironmental Engineering, ASCE.

³⁰ Ministry of Business, Innovation & Employment (November 2019) *Acceptable Solutions and Verification Methods For New Zealand Building Code Clause B1 structures*. 1st Edition, Amendment 19.

³¹ Hanna A.M. & Meyerhof G.G. (1980) *Design charts for ultimate bearing capacity of foundations on sand overlying soft clay*. Canadian Journal, vol 17, no 2, pp 300-303.

³² Ministry of Business, Innovation & Employment (MBIE) & New Zealand Geotechnical Society (NZGS) (May 2017) *Earthquake Geotechnical Engineering Module 6 – Earthquake resistant retaining wall design*.

Table 6.3: Loading from lateral earth pressures on basement wall

Height of retention (m)	At-rest earth load (kN per m of wall)	SLS seismic earth load (kN per m of wall)	70%ULS seismic earth load for 50-year design life (kN per m of wall)	80%ULS seismic earth load for 50-year design life (kN per m of wall)
0.5	0.9	0.2	0.8	0.9
1.0	3.7	0.8	3.1	3.5
1.5	8.4	1.9	6.9	7.8
2.0	14.9	3.4	12.2	13.9

Note: The at-rest pressure is modelled as a triangular distribution, with the overall resultant load at 1/3 of the retained height above the base. The seismic earth pressure is modelled as a uniform distribution, with the overall resultant load at half of the retained height above the base. The at-rest and seismic earth loads are to be added together for the seismic case.

7 Consideration for structural analysis

The foundations are divided into different sections shown in Figure E1 of Appendix E and the associated parameters are provided in the Table E3 within the same appendix. From a geotechnical behaviour standpoint, there are three design phases that should be considered, namely:

- 1 Phase 1 – Before seismic shaking. Static settlement and non-liquefied parameters should be considered.
- 2 Phase 2 – During shaking event. For ULS event (greater than 70% ULS shaking), liquefied parameters should be assumed for affected area as shown in Appendix E. For SLS event, liquefaction is not predicted and non-liquefied parameters are to be used. At 70% ULS shaking, the recommendation outlined in Section 7.2 below should be considered.
- 3 Phase 3 – Liquefaction induced settlement and lateral movement. Effects from liquefaction-induced consolidation, ejecta, lateral spread should be considered.

We understand that Dizhur Consulting has undertaken their structural analysis for the seismic strengthening design incorporating the ground effects at 70% ULS shaking and the geotechnical parameters presented in this report, and their results are compatible with the assumptions made in this report.

7.1 Phase 1

This analysis phase simulates the building prior to an earthquake event. The following should be adopted in the structural analysis:

- 1 Non-liquefied subgrade reaction modulus and bearing capacity (refer to Table E3); and
- 2 At-rest static earth pressures (refer to section 6.4) on section of basement acting as retaining walls.

7.2 Phase 2

In this stage, pseudo-static earthquake loads are being applied to the superstructure. The following should be adopted in the structural analysis as a continuation of Phase 1:

- 1 Liquefied subgrade reaction modulus and bearing capacity for full liquefaction scenario. For the 70% ULS (IL3) shaking level scenario, the subgrade reaction modulus and bearing capacity values associated with the 70% ULS (IL3) shaking level scenario should be used. Refer to Table E3 for bearing capacity and subgrade reaction modulus values;

- 2 Non-liquefied subgrade reaction modulus and bearing capacity for SLS scenario (refer to Table E3); and
- 3 Seismic earth pressure (refer to section 6.4) is added to section of basement acting as retaining walls.

7.3 Phase 3

This phase simulates the behaviour of the ground post peak seismic shaking (i.e. minor ground shaking is still occurring, but the strongest shaking has passed). The following should be adopted in the structural analysis as a continuation of Phase 2:

- 1 The subgrade reaction modulus and bearing capacity from Phase 2 should remain in Phase 3 (refer to Table E3);
- 2 Seismic earth load applied in Phase 2 (refer to section 6.4) on section of basement acting as retaining walls; and
- 3 In addition to the above, differential settlement values presented in Section 6.2.5.1 and lateral stretch values presented in Section 6.2.5.3 are imposed on the structure.

7.4 Sensitivity analysis

The range of subgrade reaction moduli provided in the Table E3 in Appendix E attempts to capture the inherent uncertainty of the method of analysis, actual ground conditions and the associated geotechnical parameters. The structural analysis should apply a different combination of upper and lower bound parameters across the foundation to explore potentially unfavourable scenarios due to this uncertainty.

8 Potential remedial options

From our meeting of 31 March 2022, we understand that the structural engineer (Dizhur Consulting) considers that the structural seismic strengthening scheme can be successfully designed to tolerate the assessed ground effects associated with 70% ULS (IL3) shaking that are outlined in sections 6.2.5, 6.3 and 6.4 of this report. This means that ground improvement for liquefaction mitigation is not expected to be required for this design level of shaking (or lower).

It is expected that ground improvement would only be needed to mitigate liquefaction effects if it were desired to strengthen the building to a performance target greater than 70% of ULS (IL3) shaking demand. An interconnected series of jet grout columns forming containment cells (lattice) as discussed in the earlier meeting of 19 October 2021 would be the recommended liquefaction mitigation solution. As discussed in this meeting, this solution does attract high cost and require a specialist contractor. A discussion and close collaboration with the specialist contractor and the structural engineer are also recommended during design development of the jet grout lattice.

As noted in Section 6.1, the building is currently experiencing ongoing long-term static settlement. We understand from the structural engineer that excessive ongoing settlement could compromise the structural strengthening scheme. If the lattice ground improvement solution above was adopted, then this could be designed to also address this ongoing static settlement issue.

If the lattice ground improvement solution does not proceed, building underpinning work (either using jet grout columns or micropiles) could be undertaken as an alternative solution to resolve the static settlement issue. Full underpinning of the entire building would likely attract a similar order of cost as the lattice solution discussed above, however there could be opportunities to reduce costs by targeting underpinning works only under the most critical areas to help reduce the differential settlement rate.

Further to the above, it should be noted that the inclusion of stiff columns in the ground such as the jet grout columns may change the dynamic response of the site. The presence of the stiff columns makes the ground stiffer and less likely to yield at higher accelerations, thus, may increase the shaking intensity in the building compared to the potential “natural base isolation” effect from weak unimproved ground. This would not be expected to increase the strength of building shaking above what is already assumed for design but could result in differences in the dynamic response of the building between stiffer and softer parts of the site. This effect will need to be reviewed in conjunction with the structural engineer as part of detailed design if the jet grout columns are to be implemented.

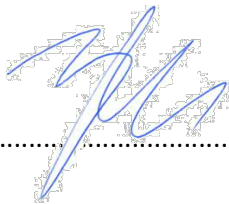
9 Applicability

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

Recommendations and opinions in this report are based on data from point investigations. The nature and continuity of subsoil away from these investigation points are inferred and it must be appreciated that actual conditions could vary from the assumed model.

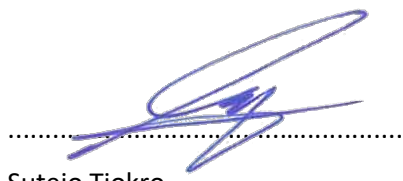
Tonkin & Taylor Ltd

Report prepared by:



Tzin Hwa Lai

Geotechnical Engineer



Sutejo Tjokro

Senior Geotechnical Engineer

Authorised for Tonkin & Taylor Ltd by:



Craig Davanna

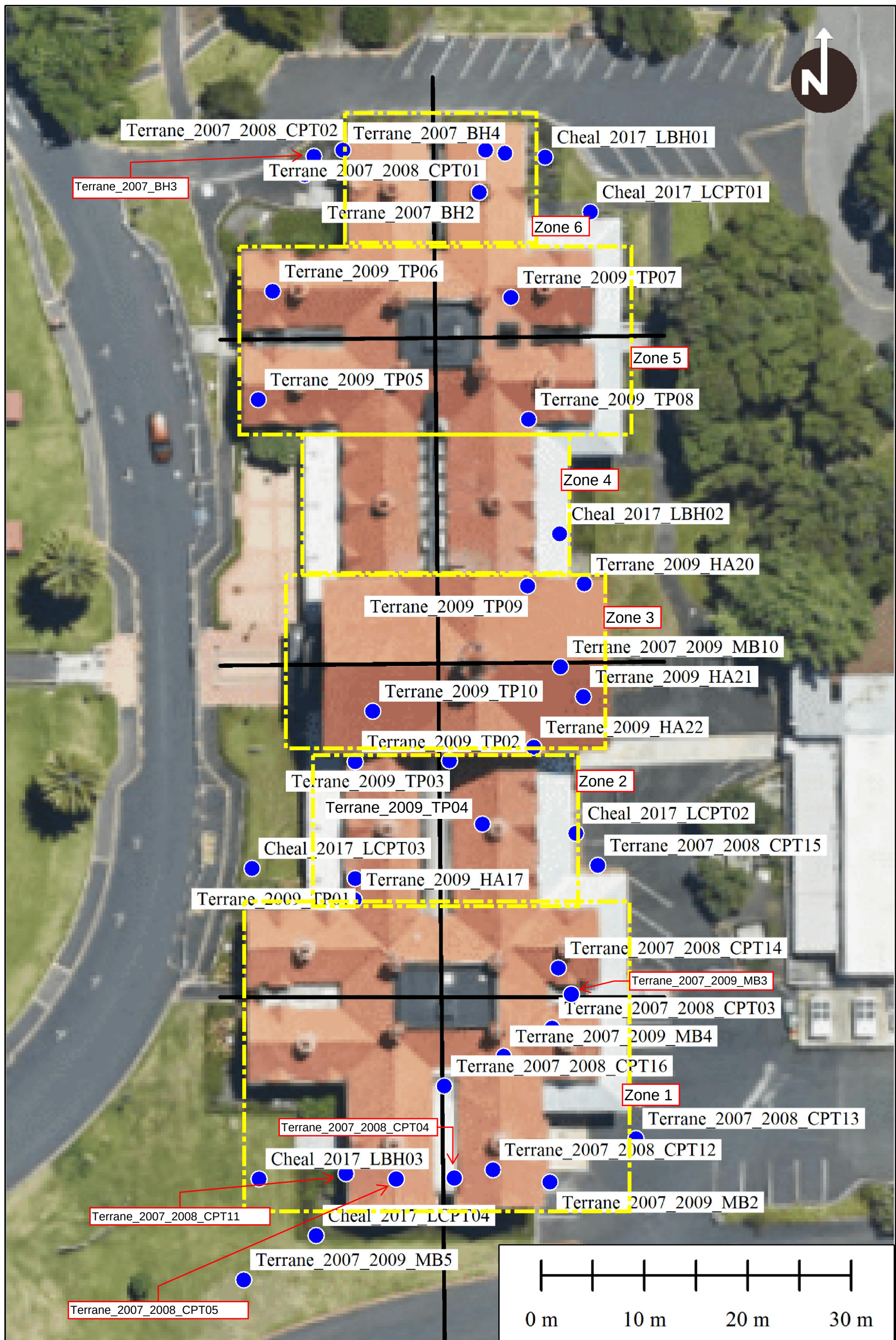
Project Director

Report reviewed by: Stuart Palmer (Technical Director, Earthquake Foundation Engineering)
 Mike Jacka (Technical Director, Earthquake Geotechnical Engineering)

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Appendix A: T+T figures

- **Figure A1 - Historical site investigation plan**
- **Figure A2 - T+T 2021 site investigation plan**
- **Figure A3 - Long section 1**
- **Figure A3a - Long section 1 - extended**
- **Figure A4 - Cross section 1**
- **Figure A5 - Cross section 2**
- **Figure A6 - Cross section 3**
- **Figure A7 - Cross section 4**



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for previous investigation

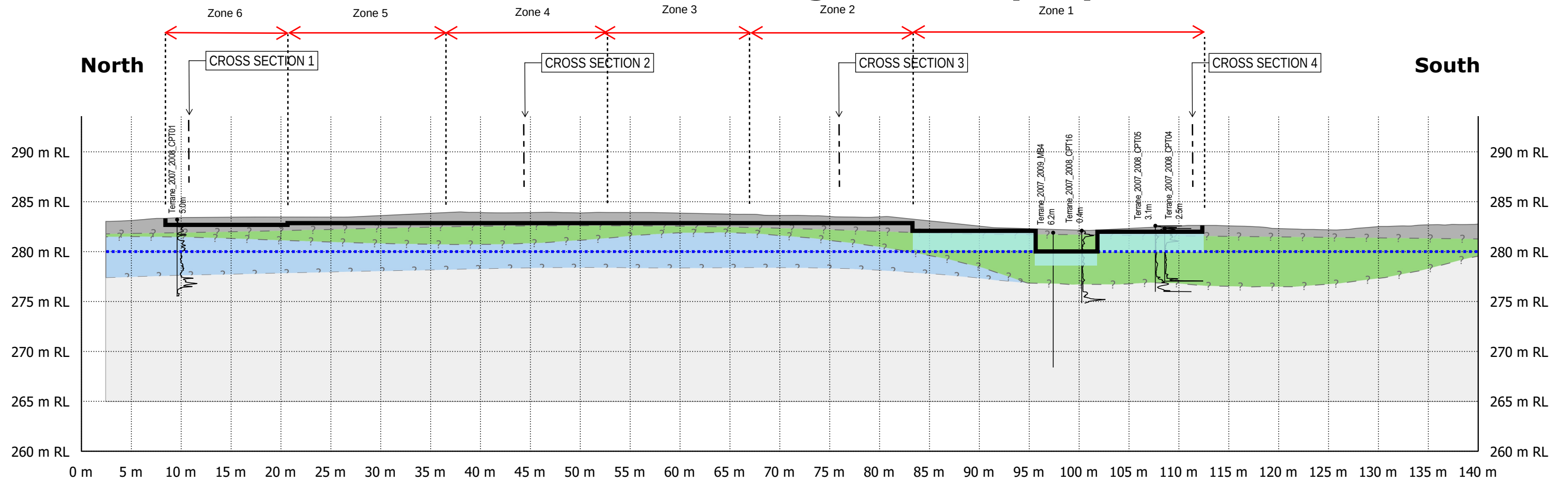
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Drawn by: CBM Date: 7/2021

Checked by: TZHL Date: 7/2021



Rotorua Museum Long Section 1 (N-S)



Note:

1. Ground model based on point historical investigation. The nature and continuity of the geology away from these locations may vary from those assumed in this figure.
2. Distance associated with investigation location represents offset from section.

Legend

- Unit 1 = Dry, friable, soft to very stiff "crust". May include fill, sinter, and other miscellaneous deposits
- Unit 2b = Saturated, very loose / soft to firm, Silty SAND and Sandy SILT
- Unit 2a = Wet, very loose to loose, GRAVEL
- Unit 3 = SAND and SILT with some gravel, very stiff to hard / med dense with cemented layers
- Unit 4 = Engineered hardfill
- Approximate underside of foundation
- Estimated mean groundwater level

Scale: 1:400



Title: Long Section 1

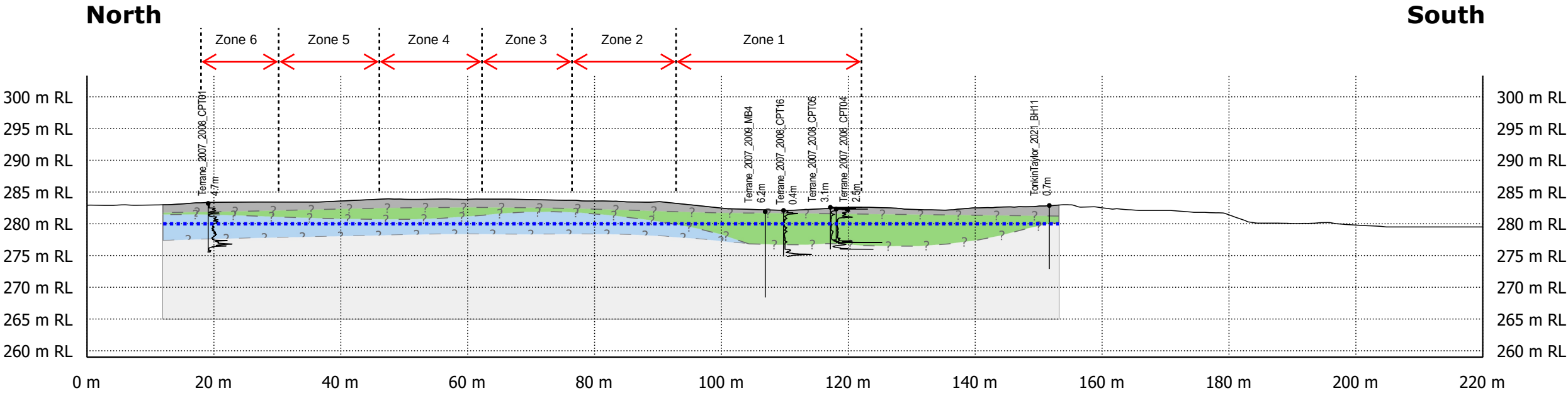
Job no: 1017126

Figure no: Figure A3

Drawn by: CBM Date: 3/2022

Checked by: JMB/DMMM Date: 3/2022

Rotorua Museum Extended Long Section 1 (N-S) - Extended



Note:

1. Ground model based on point historical investigation. The nature and continuity of the geology away from these locations may vary from those assumed in this figure.

2. Distance associated with investigation location represents offset from section.

Legend

- Unit 1 = Dry, friable, soft to very stiff "crust". May include fill, sinter, and other miscellaneous deposits
- Unit 2b = Saturated, very loose / soft to firm, Silty SAND and Sandy SILT
- Unit 2a = Wet, very loose to loose, GRAVEL
- Unit 3 = SAND and SILT with some gravel, stiff to hard / med dense with cemented layers

..... Estimated mean groundwater level

Scale: 1:750



Title: Long Section 1 - Topography extended south to the lake

Figure no: Figure A3a

Drawn by: CBM Date:3/2022

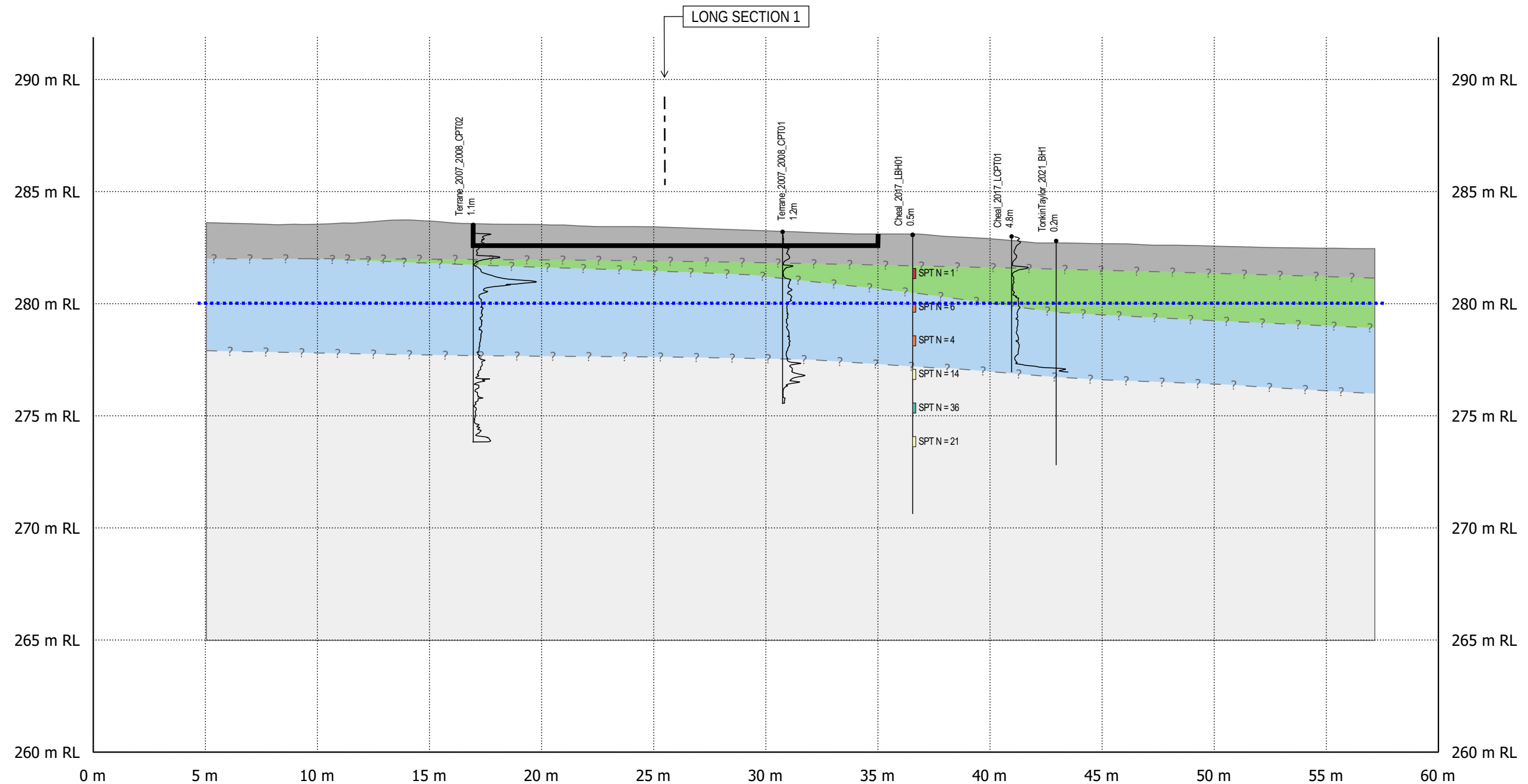
Checked by: JMB/DMMM Date:3/2022

Job no: 1017126

Rotorua Museum Cross Section 1 (W-E)

West

East



Note:

1. Ground model based on point historical investigation. The nature and continuity of the geology away from these locations may vary from those assumed in this figure.
2. Distance associated with investigation location represents offset from section.

Legend

- Unit 1 = Dry, friable, soft to very stiff "crust". May include fill, sinter, and other miscellaneous deposits
- Unit 2b = Saturated, very loose / soft-to-firm, Silty SAND and Sandy SILT
- Unit 2a = Wet, very loose to loose, GRAVEL
- Unit 3 = SAND and SILT with some gravel, stiff to hard / med dense with cemented layers
- Approximate underside of foundation
- Estimated mean groundwater level

Scale: 1:200



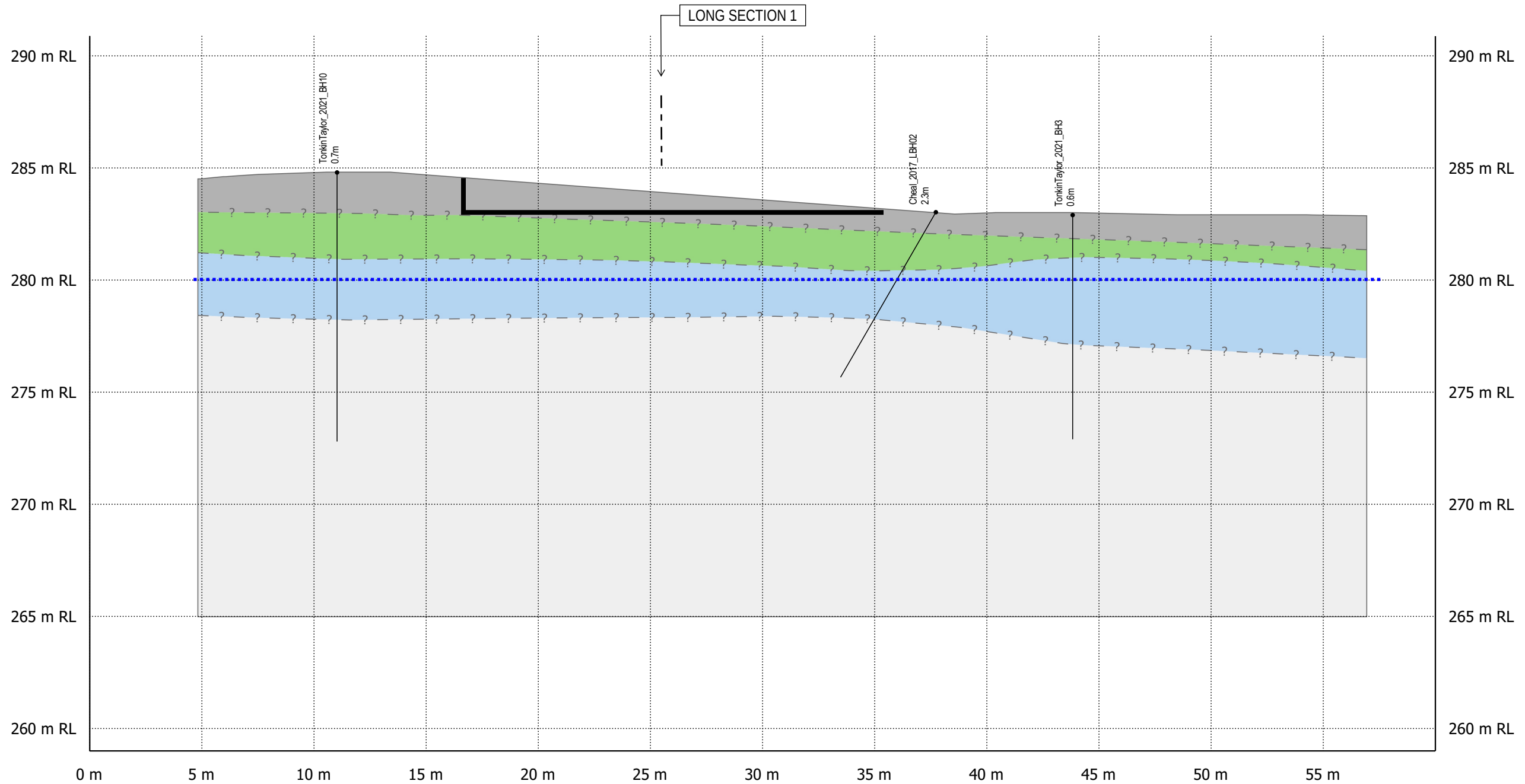
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 Drawn by: CBM Date:3/2022
 Checked by: JMB/DMMM Date:3/2022

Job no: 1017126

Rotorua Museum Cross Section 2 (W-E)

West

East



Legend

- Unit 1 = Dry, friable, soft to very stiff "crust". May include fill, sinter, and other miscellaneous deposits
- Unit 2b = Saturated, very loose / soft-to-firm, Silty SAND and Sandy SILT
- Unit 2a = Wet, very loose to loose, GRAVEL
- Unit 3 = SAND and SILT with some gravel, stiff to hard / med dense with cemented layers
- Approximate underside of foundation
- Estimated mean groundwater level

Note:

1. Ground model based on point historical investigation. The nature and continuity of the geology away from these locations may vary from those assumed in this figure.
2. Distance associated with investigation location represents offset from section.

Scale: 1:200



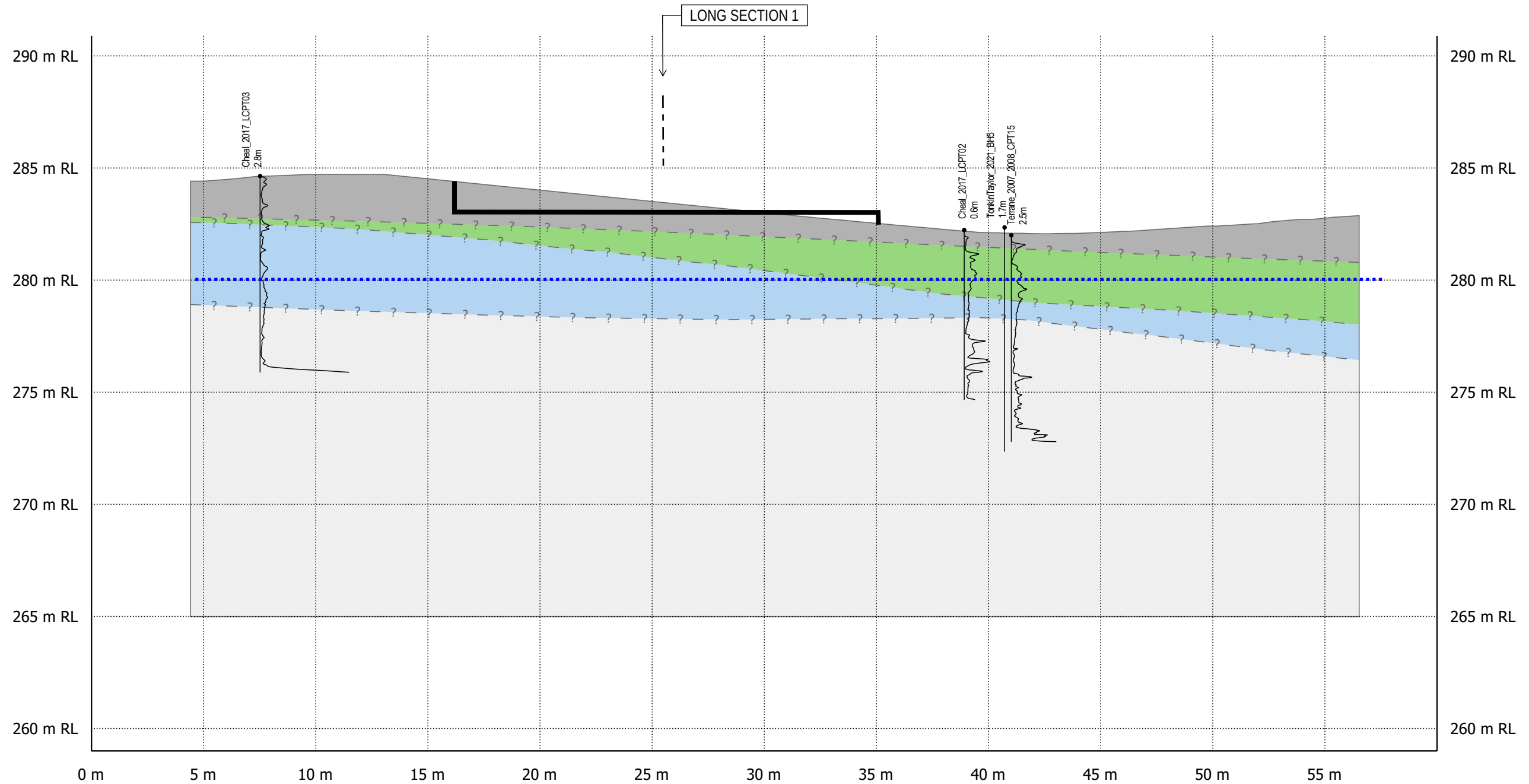
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 Drawn by: CBM Date:3/2022
 Checked by: JMB/DMMM Date:3/2022

Job no: 1017126

Rotorua Museum Cross Section 3 (W-E)

West

East



Legend

- Unit 1 = Dry, friable, soft to very stiff "crust". May include fill, sinter, and other miscellaneous deposits
- Unit 2b = Saturated, very loose / soft-to-firm, Silty SAND and Sandy SILT
- Unit 2a = Wet, very loose to loose, GRAVEL
- Unit 3 = SAND and SILT with some gravel, stiff to hard / med dense with cemented layers
- Approximate underside of foundation
- Estimated mean groundwater level

Note:

1. Ground model based on point historical investigation. The nature and continuity of the geology away from these locations may vary from those assumed in this figure.
2. Distance associated with investigation location represents offset from section.

Scale: 1:200



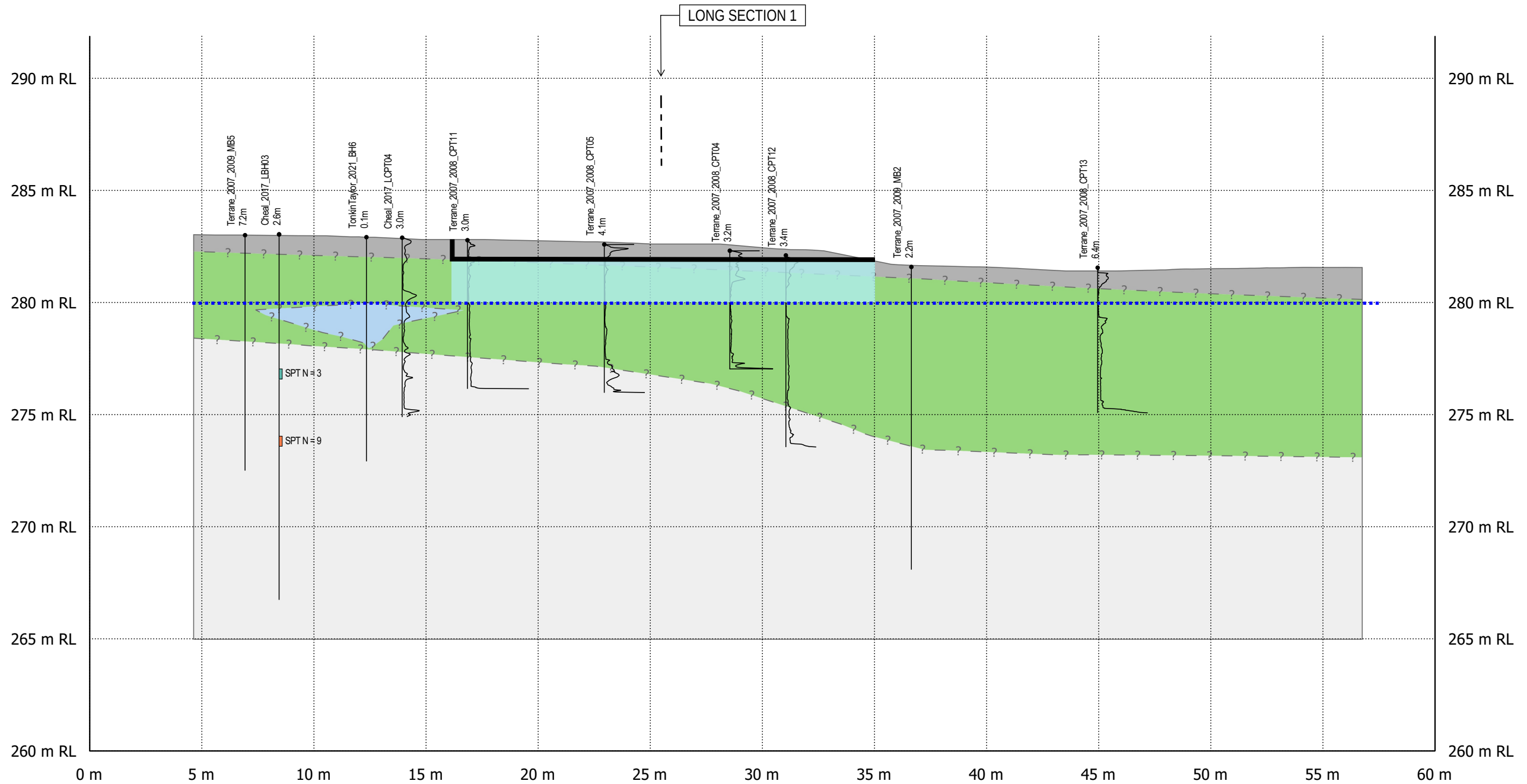
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 Figure no: Figure A6
 Drawn by: CBM Date:3/2022
 Checked by: JMB/DMMM Date:3/2022

Job no: 1017126

Rotorua Museum Cross Section 4 (W-E)

West

East



Legend

- Unit 1 = Dry, friable, soft to very stiff "crust". May include fill, sinter, and other miscellaneous deposits
- Unit 2b = Saturated, very loose / soft to firm, Silty SAND and Sandy SILT
- Unit 2a = Wet, very loose to loose, GRAVEL
- Unit 3 = SAND and SILT with some gravel, stiff to hard / med dense with cemented layers
- Unit 4 = Engineered hardfill
- Approximate underside of foundation
- Estimated mean groundwater level

Note:

1. Ground model based on point historical investigation. The nature and continuity of the geology away from these locations may vary from those assumed in this figure.
2. Distance associated with investigation location represents offset from section.

Scale: 1:200



Title: Cross Section 4

Job no: 1017126

Figure no: Figure A7

Drawn by: CBM Date:3/2022

Checked by: JMB/DMMM Date:3/2022

Appendix B: Information from others

- **B1 - Structural drawings**
- **B2 - Investigation results**

APPENDIX B1 - STRUCTURAL DRAWINGS

Zone 2 to 5

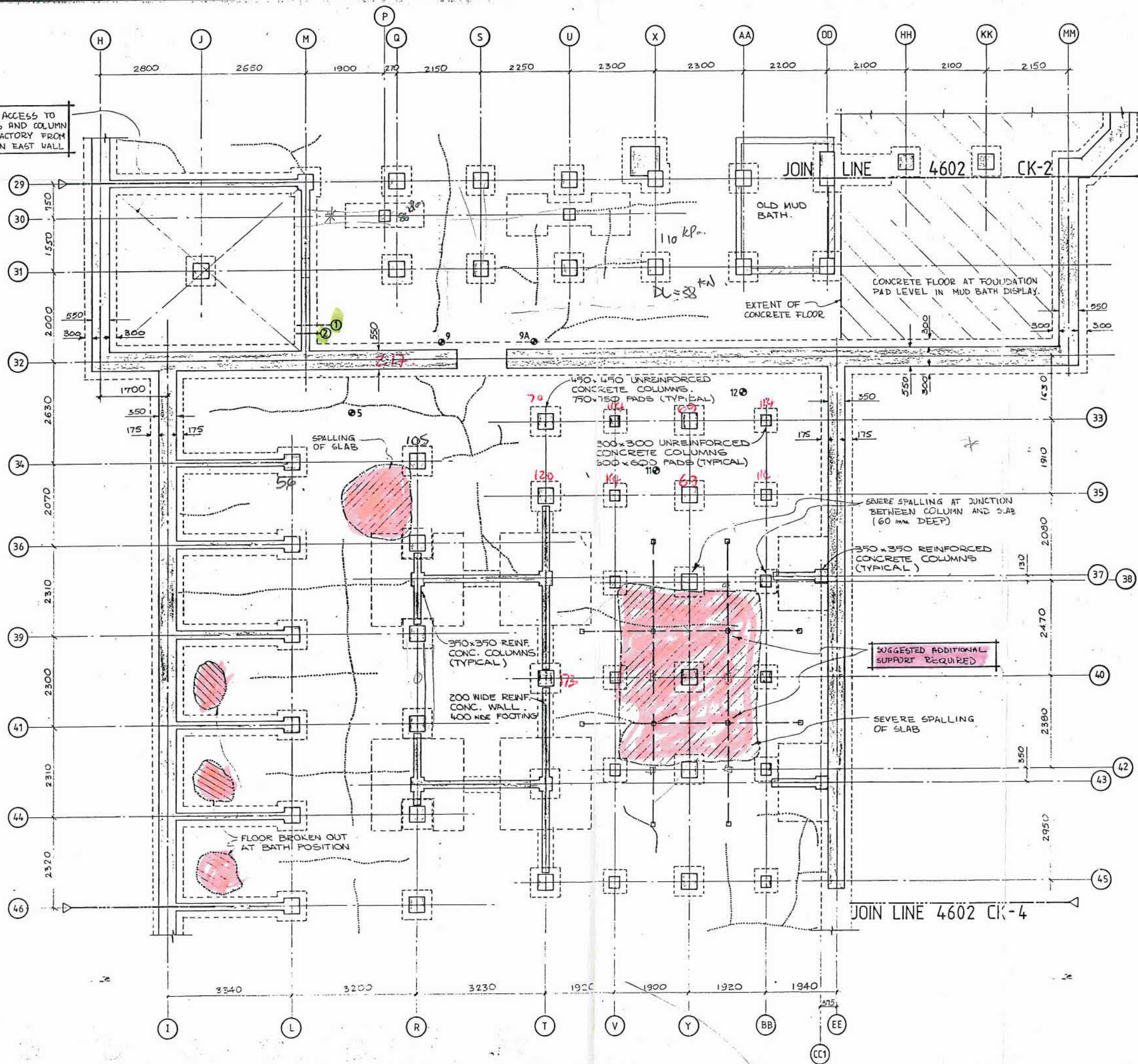
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NOTE: Metric dimensions of length where
no symbol is given -
(H) WHOLE NUMBERS = mm
(D) DECIMALISED EXPRESSIONS = m

DRAWING REFERENCES

FOR KEY TO SYMBOLS
USED, REFER DRG CK 4.

UNABLE TO GAIN ACCESS TO
THIS AREA. SLAB AND COLUMN
APPEARED SATISFACTORY FROM
VIEWING HOLE IN EAST WALL.



1	FOR REPORT	23/6/85 A.K.
0	FOR INFORMATION	5/85 G.P.
No.	ISSUE REVISIONS	Date Drawn/Co-ord
METRIC SCALE		
1:50		
Contractor must verify all dimensions on the job before commencing any work or making any shop drawings		
Designed	A.K. ; G.P.	5/85
Drawn		
Traced		
Checked		
Co-ord		
Approved		

ROTORUA DISTRICT
COUNCIL

KERSLAKE
CONSULTING REGISTERED ENGINEERS
AND PARTNERS
CIVIL STRUCTURAL ELECTRICAL MECHANICAL
ENERGY AND BUILDING SERVICES ENGINEERS

TUDOR TOWERS
FOUNDATION REPORT

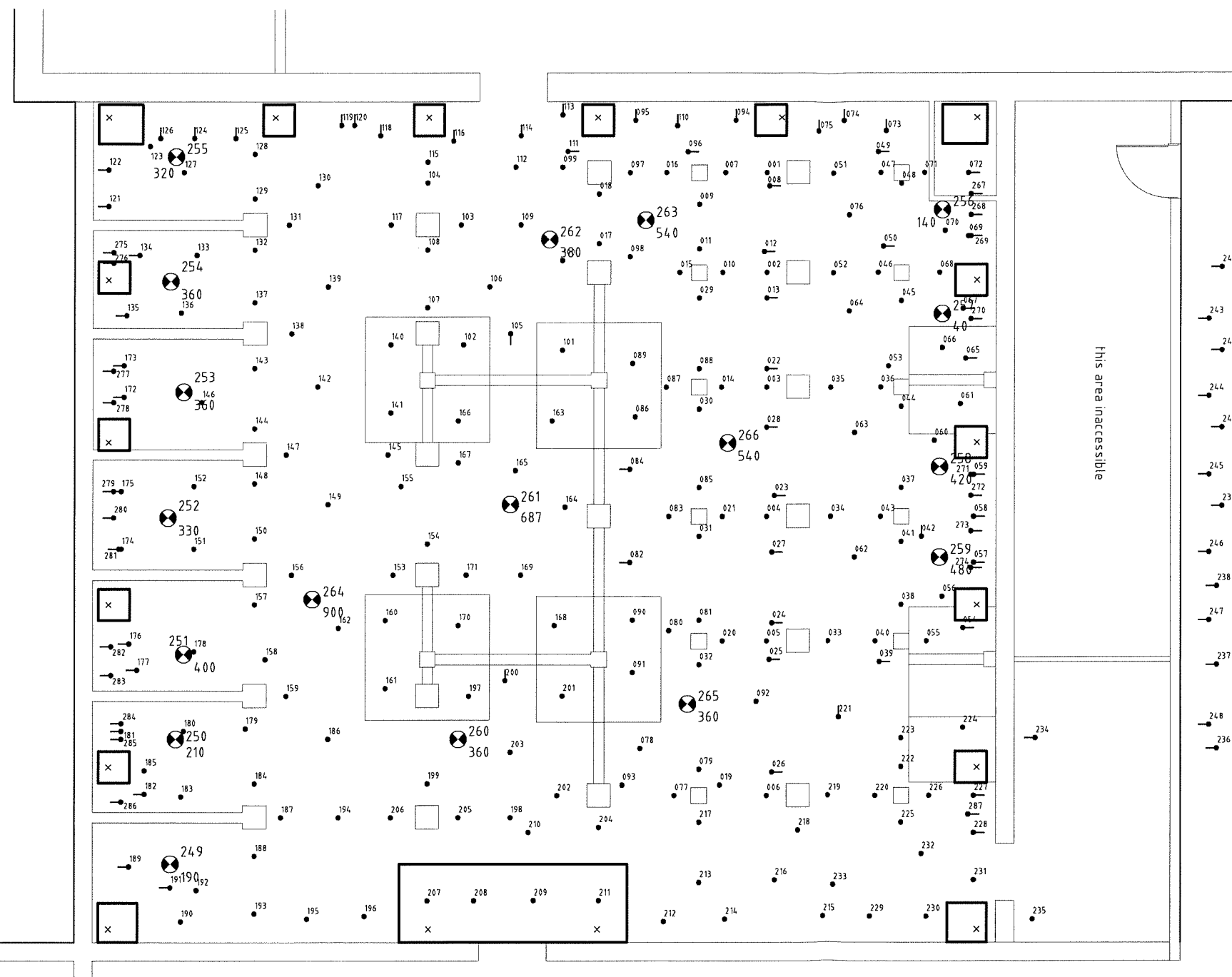
FOUNDATION LAYOUT
SHEET 3 OF 4

C/N	DWG No	Metric
4602	CK 3	
ISSUE No 1 of 1		Design

Rev no	Revision note	Date	Issued By
0	PRELIMINARY		
1	Proposed Grouting Locations ver. 2	29/04/2010	
2	Updated Grout Locations of 21 May 10	25/05/2010	
5	As-built grout locations	30/06/2010	

ENTRY OVER

CENTRAL ATRIUM OVER



KEY:

- 001 GROUT COLUMN
- 008 INCLINED GROUT COLUMN
- 249 PRESSURE GROUTED COLUMN:
TOP: BOREHOLE ID
490 BOTTOM: GROUT VOLUME (LITRES)

0 1 2 3 4 (m)
SCALE 1:100

SOUTHERN WING

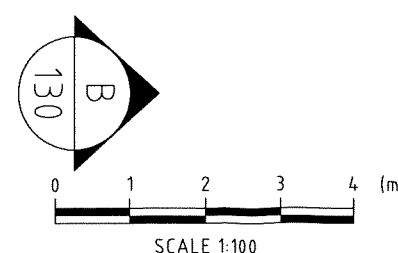
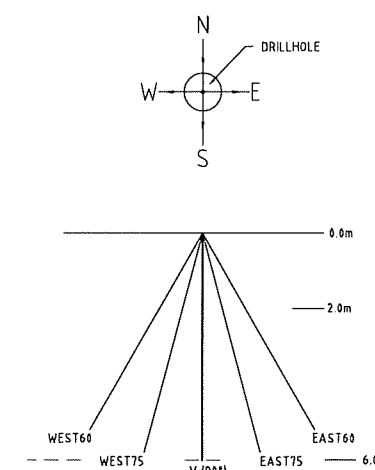
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	Chk:		Rev: S
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	Date: 30/6/10		

Rev no	Revision note	Date	Issued By
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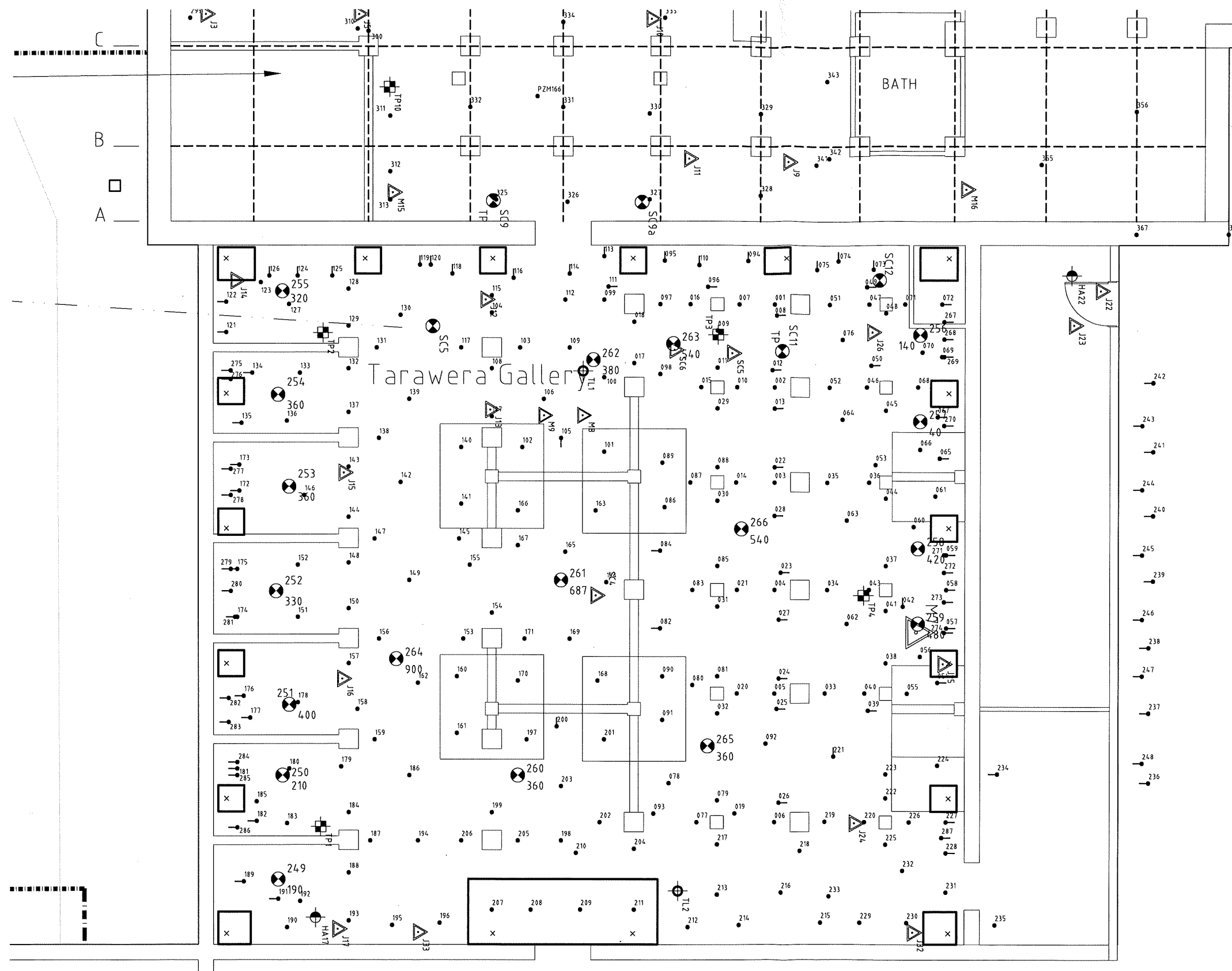


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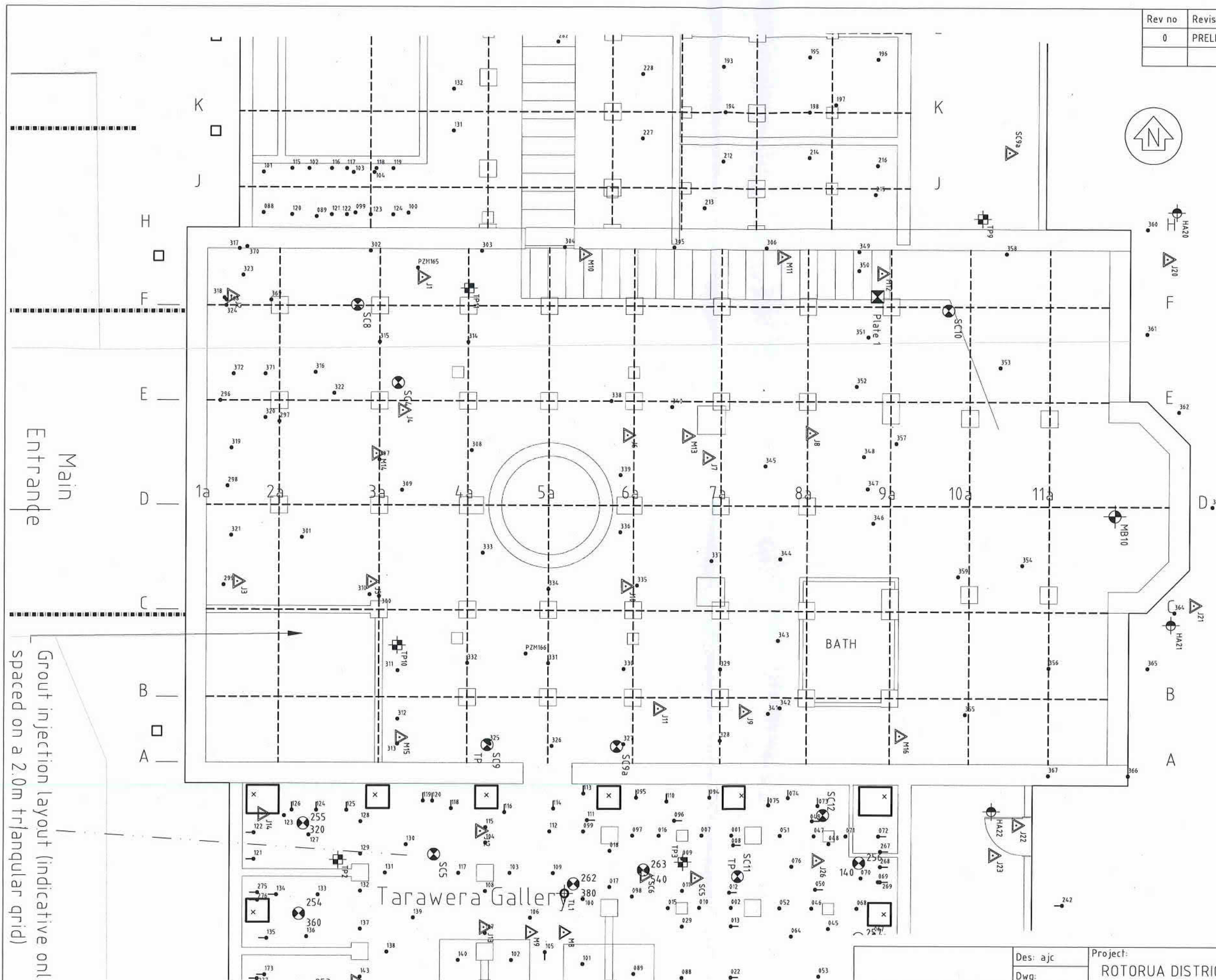
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BOTTOM: GROUT VOLUME (litres)



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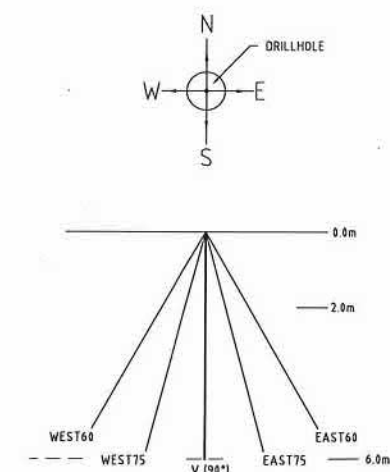


Rev no	Revision note	Date	Issued By
0	PRELIMINARY		



KEY:

- 001 GROUT COLUMN
- 008 INCLINED GROUT COLUMN
- 249 PRESSURE-GROUTED COLUMN;
490 BOREHOLE ID
GROUT VOL (litres)



0 1 2 3 4 (m)
SCALE 1:100

Main Entrance
Grout injection layout (indicative only
spaced on a 2.0m triangular grid)

Des: ajc	Project:	Scale:
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Date: 1/7/10	ATRIUM BLOCK LOCATIONS	Dwg. 3278-03-...

Terrane Consultants Ltd
PO Box 13-607 TAURANGA
Ph 07-579 9708 Fax 07 579 9702

SOUTH EXTENSION FOUNDATION PLAN (Zone 1)

Rev no	Revision note	Date	By
0	Preliminary/Draft Design	Feb 09	rm
1	For Approval/Consent		

Rotorua Museum, Government Gardens, Rotorua

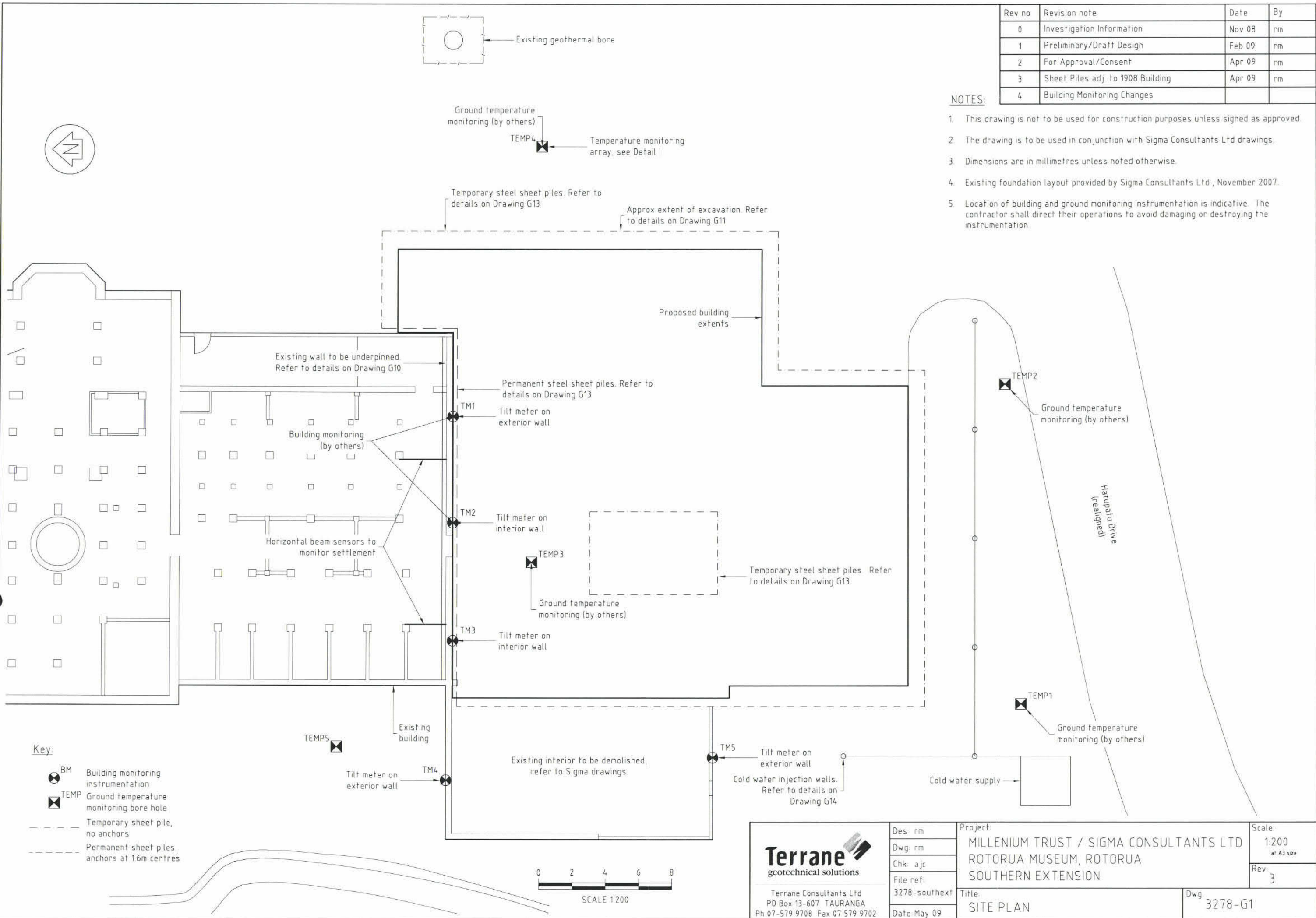
Geotechnical Design – Southern Extension

Drawing Register

Drawing Number	Drawing Title	Rev 0	Rev 1	Rev 2	Rev 3	Rev 4	Notes
3278-G0	Drawing Register	Feb 09	May 09				
3278-G1	Site Plan	Nov 08	Feb 09	Apr 09	Apr 09	May 09	
3278-G10	Underpinning Details	Apr 09	Apr 09				
3278-G11	Excavation Plan	Feb 09	Apr 09				
3278-G12	Typical Excavation Section	Feb 09	Apr 09				
3278-G13	Sheet Pile Details	Feb 09	Apr 09	Apr 09			
3278-G14	Water Injection Well Details	Feb 09	Apr 09				
3278-G15	Building Monitoring Details	May 09					
3278-G20	Footing & Sheet Pile Interface	Feb 09	Apr 09	Apr 09			
3278-G21	Footing & Sheet Pile Interface	Feb 09	Apr 09				

 Terrane Consultants Ltd PO Box 13-607 TAURANGA Ph 07-579 9708 Fax 07 579 9702	Des: rm	Project: MILLENNIUM TRUST / SIGMA CONSULTANTS LTD ROTORUA MUSEUM, ROTORUA SOUTHERN EXTENSION	Scale: at A3 size
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	Chk: ajc		
	File ref: 3278-southext	Title: DRAWING REGISTER	Rev: 1
	Date May 09	Dwg 3278-G0	

D:\JOBS\3278 Rotorua Museum\Drawings\3278-south-ext-09.dwg, 28/11/09 15:42 pm RM_A3



Rev no	Revision note	Date	By
0	Investigation Information	Nov 08	rm
1	Preliminary/Draft Design	Feb 09	rm
2	For Approval/Consent	Apr 09	rm
3	Sheet Piles adj. to 1908 Building	Apr 09	rm
4	Building Monitoring Changes		

NOTES:

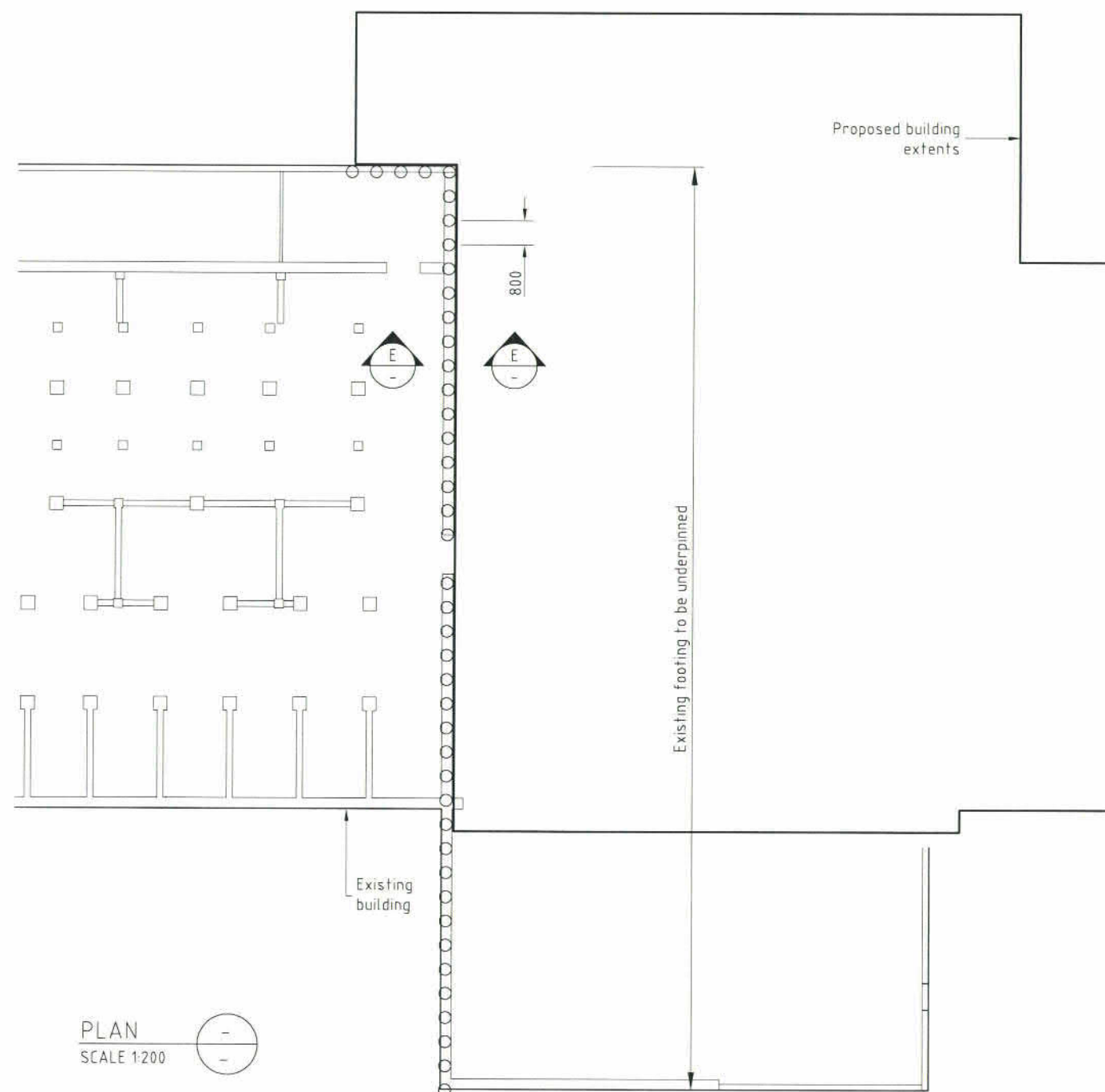
1. This drawing is not to be used for construction purposes unless signed as approved.
2. The drawing is to be used in conjunction with Sigma Consultants Ltd drawings.
3. Dimensions are in millimetres unless noted otherwise.
4. Existing foundation layout provided by Sigma Consultants Ltd, November 2007.
5. Location of building and ground monitoring instrumentation is indicative. The contractor shall direct their operations to avoid damaging or destroying the instrumentation.

Terrane geotechnical solutions Terrane Consultants Ltd PO Box 13-607 TAURANGA Ph 07-579 9708 Fax 07 579 9702	Des: rm	Project: MILLENNIUM TRUST / SIGMA CONSULTANTS LTD ROTORUA MUSEUM, ROTORUA SOUTHERN EXTENSION	Scale: 1:200 at A3 size
	Dwg: rm		
	Chk: ajc		
	File ref: 3278-southext	Title: SITE PLAN	Rev: 3
Date: May 09	Dwg: 3278-G1		

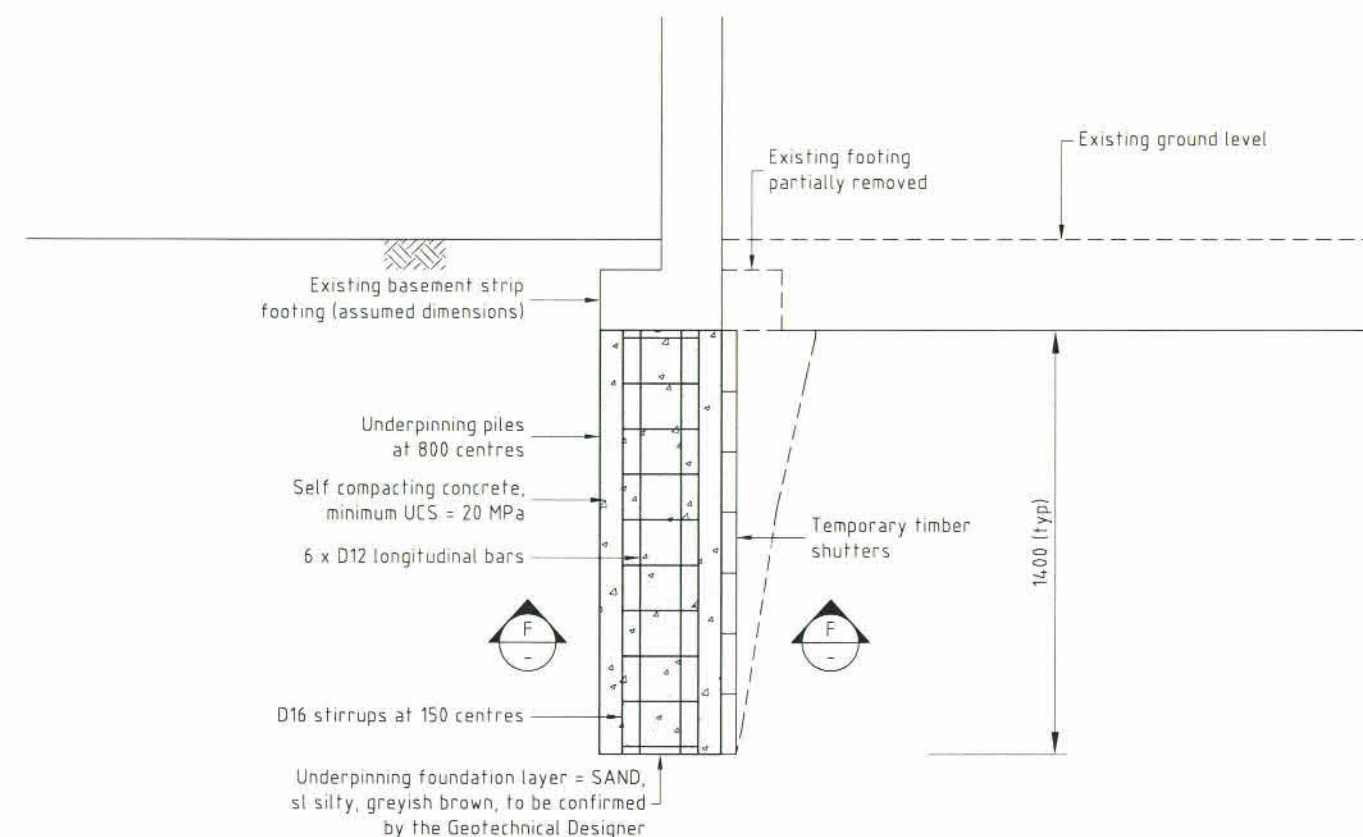
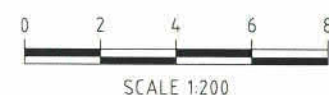
Rev no	Revision note	Date	By
0	For Approval/Consent	Apr 09	rm
1	Additional Underpinning		

NOTES:

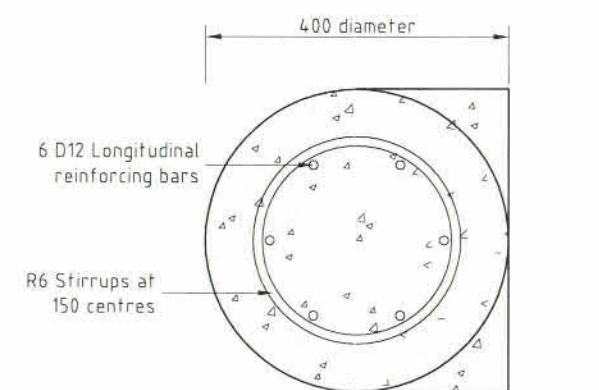
1. This drawing is not to be used for construction purposes unless signed as approved.
2. Dimensions are in millimetres unless noted otherwise.



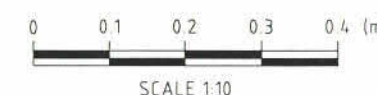
PLAN
SCALE 1:200



DETAIL E
SCALE 1:25

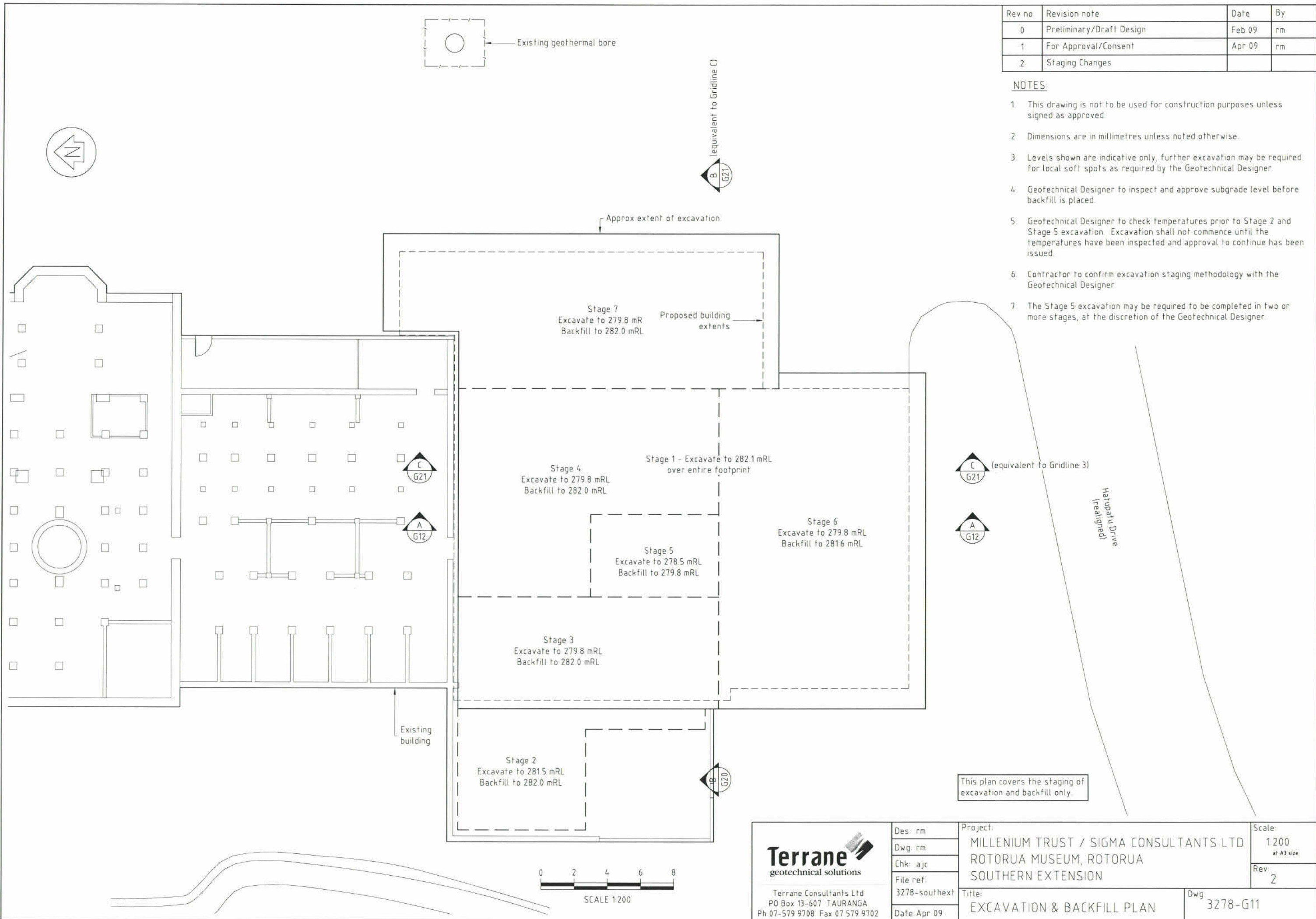


DETAIL F
SCALE 1:10



Terrane geotechnical solutions Terrane Consultants Ltd PO Box 13-607 TAURANGA Ph 07-579 9708 Fax 07 579 9702	Des: rm	Project: MILLENNIUM TRUST / SIGMA CONSULTANTS LTD ROTORUA MUSEUM, ROTORUA SOUTHERN EXTENSION	Scale: As Shown at A3 size
	Dwg: rm		
	Chk: ajc		
	File ref: 3278-southext		
Date: Apr 09	Title: UNDERPINNING DETAIL	Dwg 3278-G10	Rev: 1

U:\Jobs\3278 Rotorua Museum\Drawings\3278-south-ext-09.dwg, 28/01/2009 1:55:46 p.m., RM, A3



Rev no	Revision note	Date	By
0	Preliminary/Draft Design	Feb 09	rm
1	For Approval/Consent	Apr 09	rm
2	Staging Changes		

NOTES:

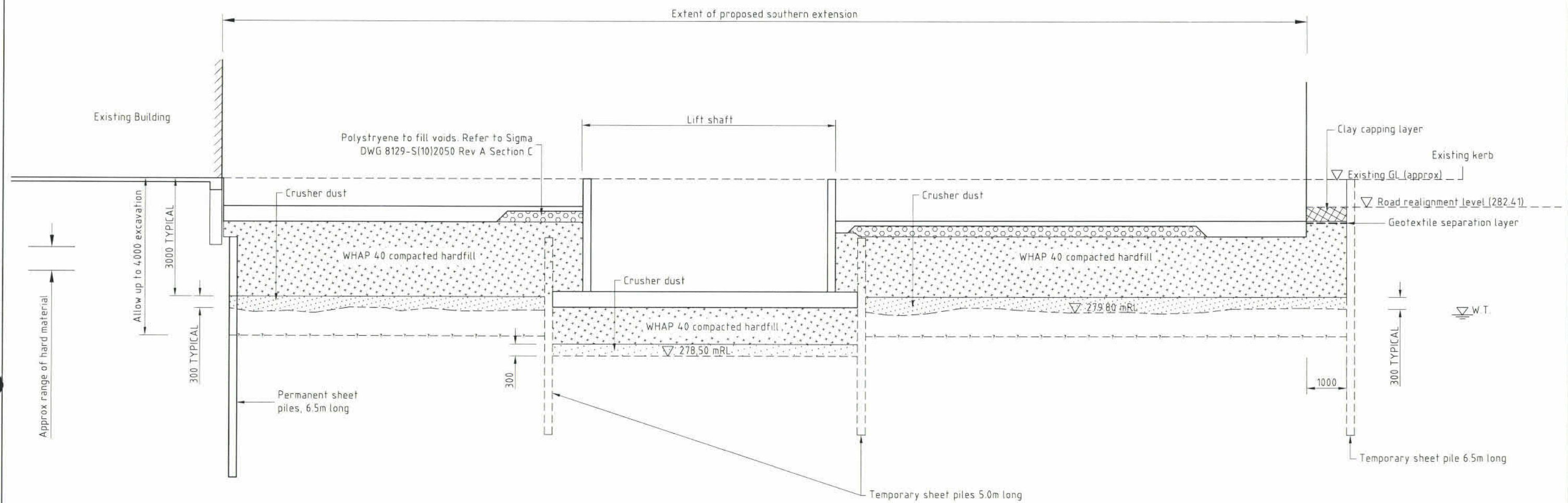
1. This drawing is not to be used for construction purposes unless signed as approved.
2. Dimensions are in millimetres unless noted otherwise.
3. Levels shown are indicative only, further excavation may be required for local soft spots as required by the Geotechnical Designer.
4. Geotechnical Designer to inspect and approve subgrade level before backfill is placed.
5. Geotechnical Designer to check temperatures prior to Stage 2 and Stage 5 excavation. Excavation shall not commence until the temperatures have been inspected and approval to continue has been issued.
6. Contractor to confirm excavation staging methodology with the Geotechnical Designer.
7. The Stage 5 excavation may be required to be completed in two or more stages, at the discretion of the Geotechnical Designer.

Terrane geotechnical solutions Terrane Consultants Ltd PO Box 13-607 TAURANGA Ph 07-579 9708 Fax 07 579 9702	Des: rm	Project: MILLENNIUM TRUST / SIGMA CONSULTANTS LTD ROTORUA MUSEUM, ROTORUA SOUTHERN EXTENSION	Scale: 1:200 at A3 size
	Dwg: rm		
	Chk: ajc		Rev: 2
	File ref: 3278-southext		
Date: Apr 09	Title: EXCAVATION & BACKFILL PLAN	Dwg: 3278-G11	

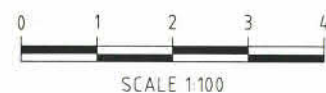
Rev no	Revision note	Date	By
0	Preliminary / Draft Design	Feb 09	rm
1	For Approval/Consent		

NOTES:

1. This drawing is not to be used for construction purposes unless signed as approved.
2. Dimensions are in millimetres unless noted otherwise.

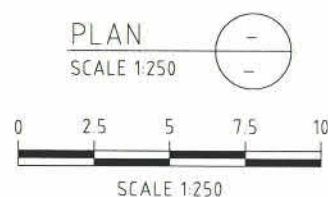
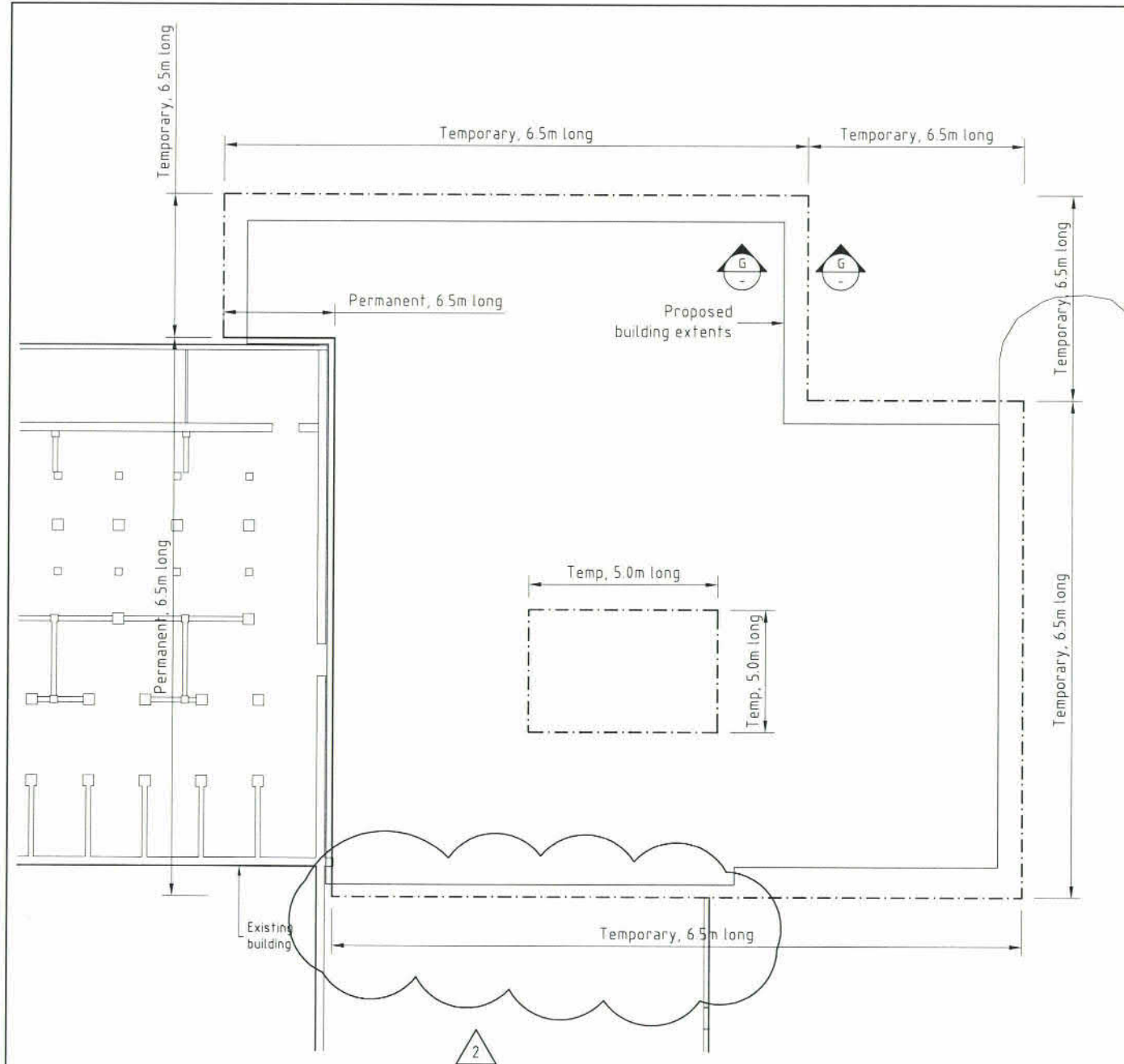


SECTION
SCALE 1:100
(GRIDLINE 4)



Terrane geotechnical solutions Terrane Consultants Ltd PO Box 13-607 TAURANGA Ph 07-579 9708 Fax 07 579 9702	Des: rm	Project: MILLENIUM TRUST / SIGMA CONSULTANTS LTD ROTORUA MUSEUM, ROTORUA SOUTHERN EXTENSION	Scale: 1:100 at A3 size
	Dwg: rm		
	Chk: ajc		Rev: 0
	File ref: 3278-southext Date: Apr 09	Title: TYPICAL EXCAVATION SECTION	Dwg 3278-G12

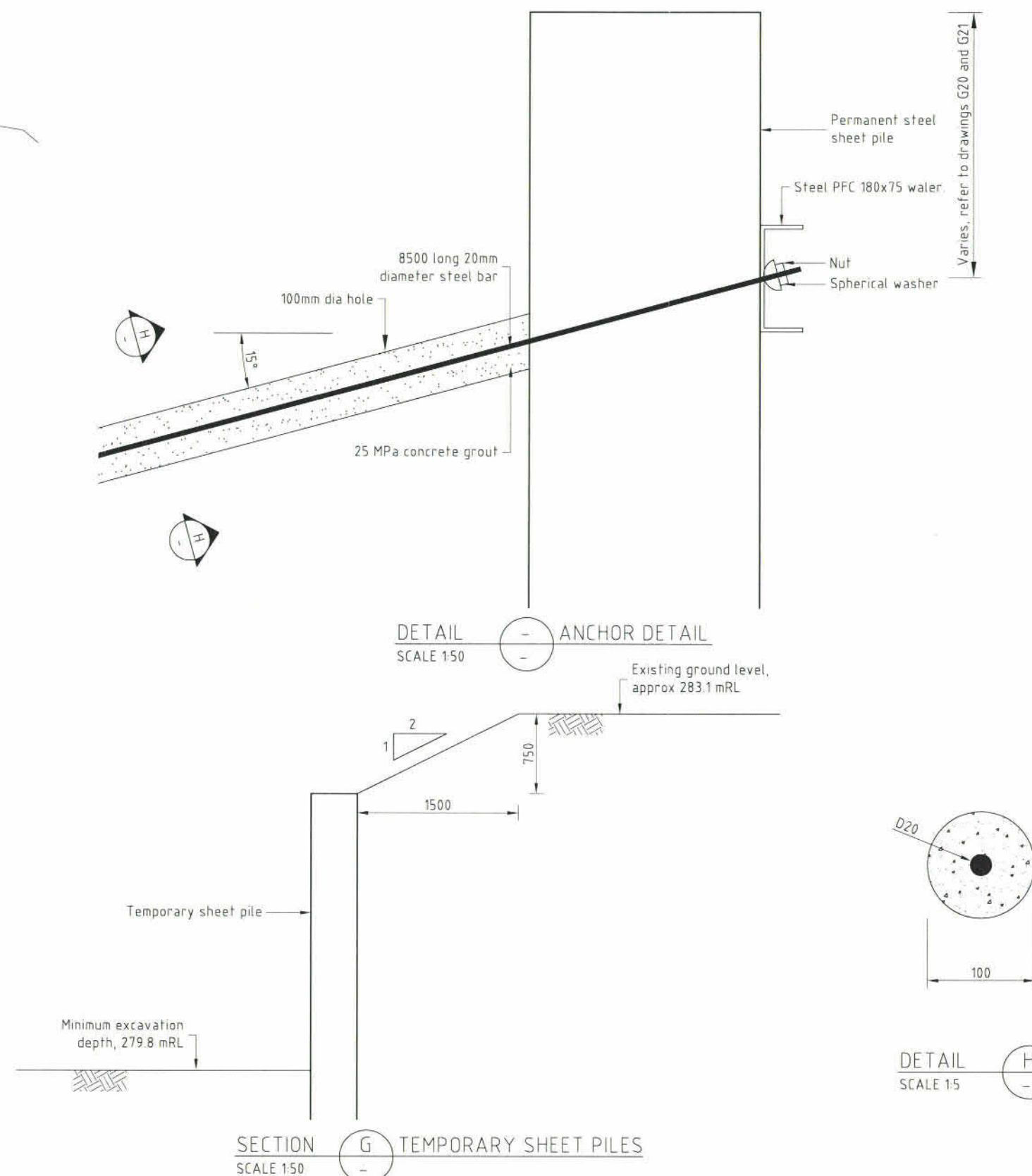
Rev no	Revision note	Date	By
0	Preliminary / Draft Design	Feb 09	rm
1	For Approval/Consent	Apr 09	rm
2	Sheet Piles adj. to 1908 Building		



- Permanent sheet piles with anchors at 1.6m centres
- Temporary sheet piles, no anchors

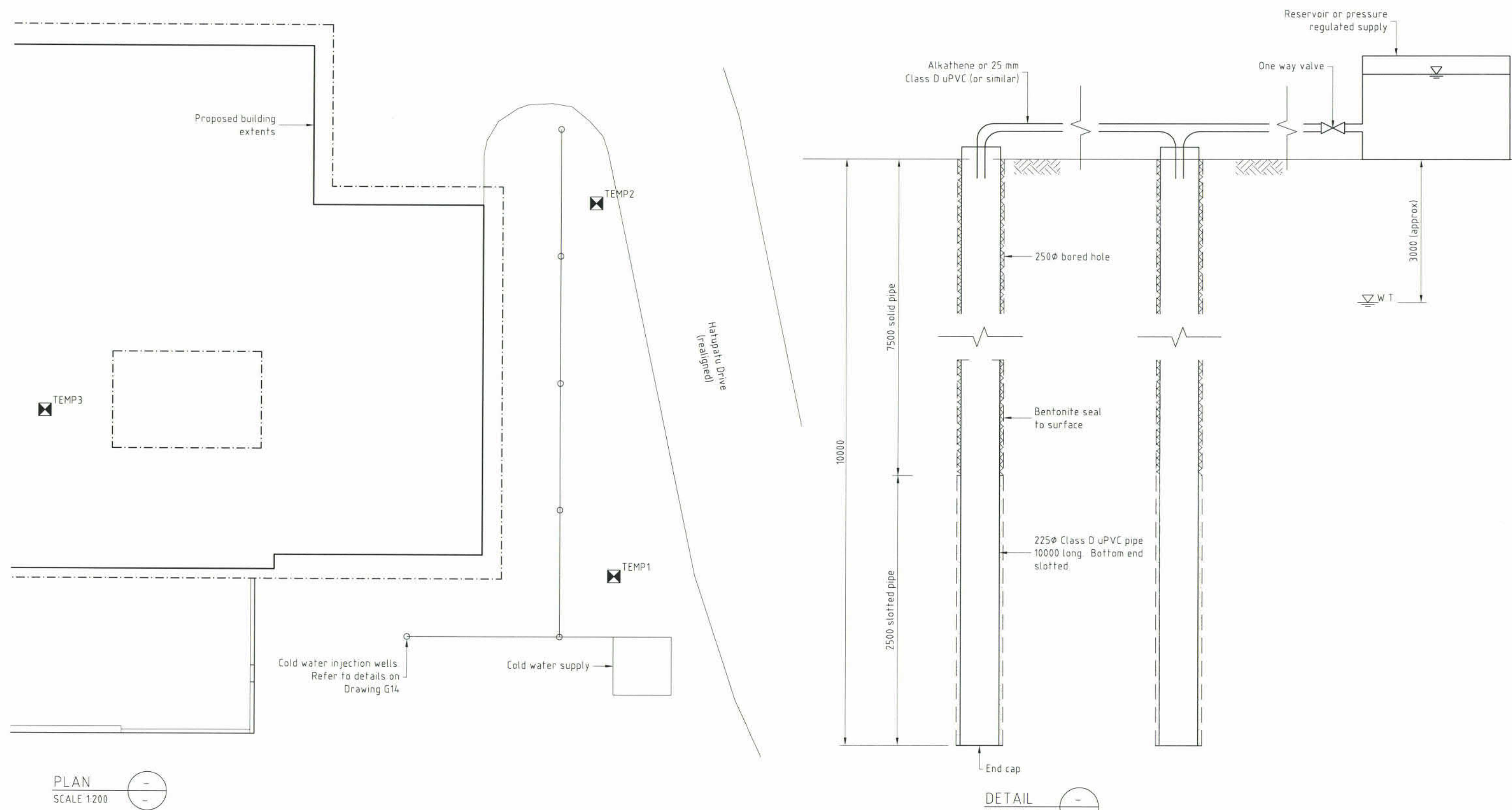
NOTES

- This drawing is not to be used for construction purposes unless signed as approved.
- Dimensions are in millimetres unless noted otherwise



Terrane geotechnical solutions Terrane Consultants Ltd PO Box 13-607 TAURANGA Ph 07-579 9708 Fax 07 579 9702	Des: rm	Project: MILLENIUM TRUST / SIGMA CONSULTANTS LTD ROTORUA MUSEUM, ROTORUA SOUTHERN EXTENSION	Scale: As Shown at A3 size
	Dwg: rm		
	Chk: ajc		Rev: 2
	File ref: 3278-southext Date: Apr 09	Title: SHEET PILE DETAILS	Dwg 3278-G13

Rev no	Revision note	Date	By
0	For Approval/Consent		



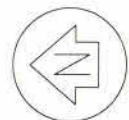
NOTES:

1. This drawing is not to be used for construction purposes unless signed as approved.
2. Dimensions are in millimetres unless noted otherwise.
3. Temperature monitoring locations are indicative only.
4. Expect low flow rates due to low permeability ground.
5. Municipal water supply would appear to be sufficient.
6. Water wells may need to be installed in two stages, if the initial set of wells does not reduce the temperatures sufficiently.



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	Dwg: rm		
	Chk: ajc		
	File ref: 3278-southext	Title: WATER INJECTION DETAIL	Rev: 0
Date: Apr 09		Dwg 3278-G14	

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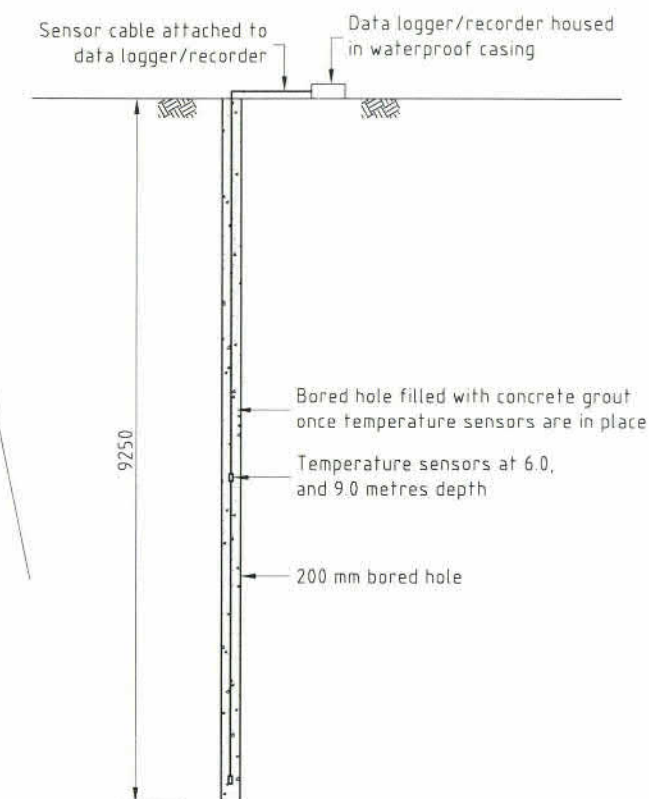
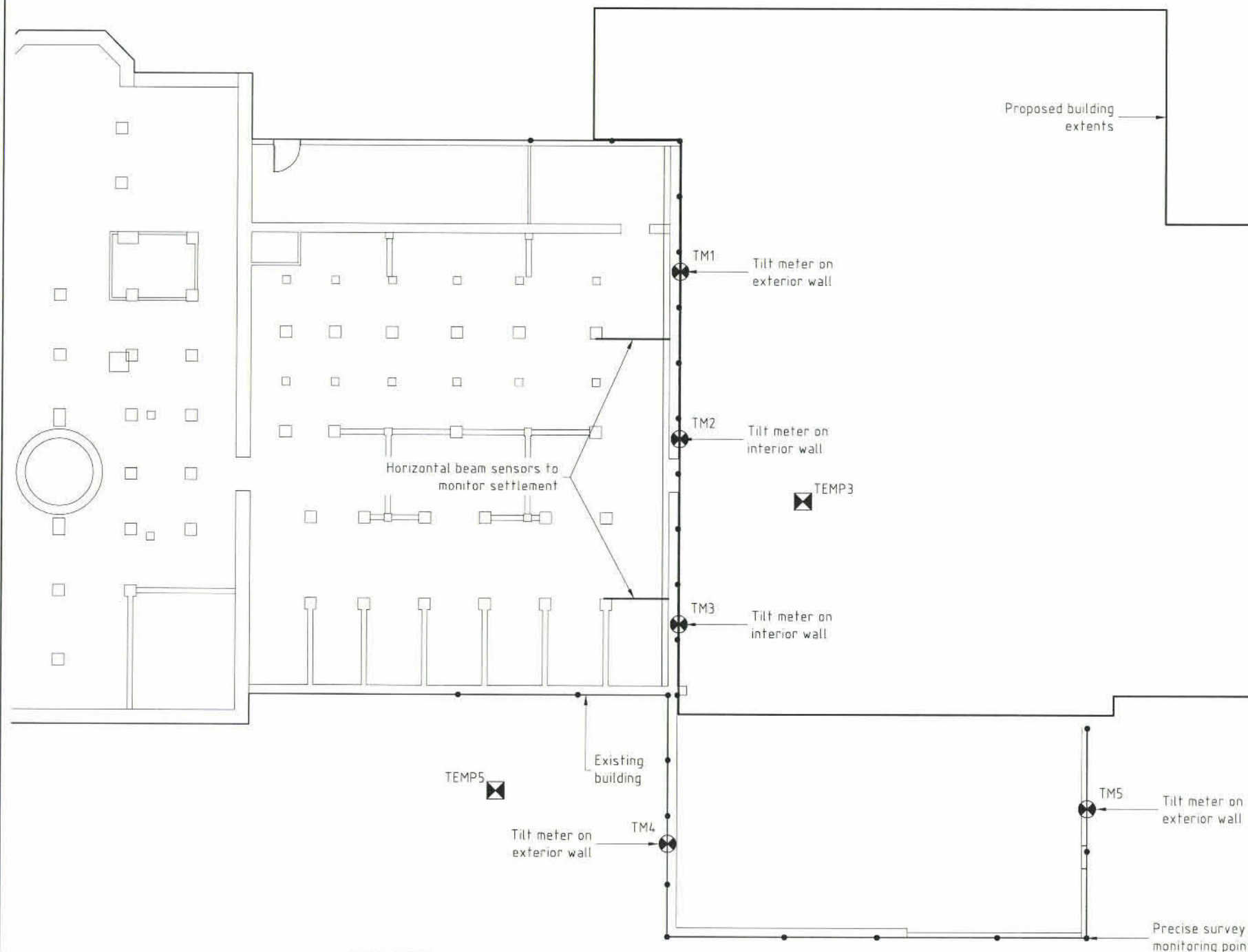


TEMP4  Temperature monitoring array, see Detail I

Rev no	Revision note	Date	By
0	First Issue		

NOTES

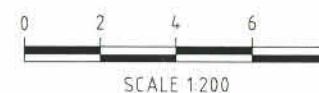
1. This drawing is not to be used for construction purposes unless signed as approved.
2. Dimensions are in millimetres unless noted otherwise.
3. Survey monitoring points and building monitoring instrumentation locations to be confirmed on site with Terrane Consultants prior to initial set out / installation.



DETAIL I
SCALE 1:100

Key

-  BM Tilt meter
-  TEMP Ground temperature monitoring bore hole
-  Precise survey monitoring point

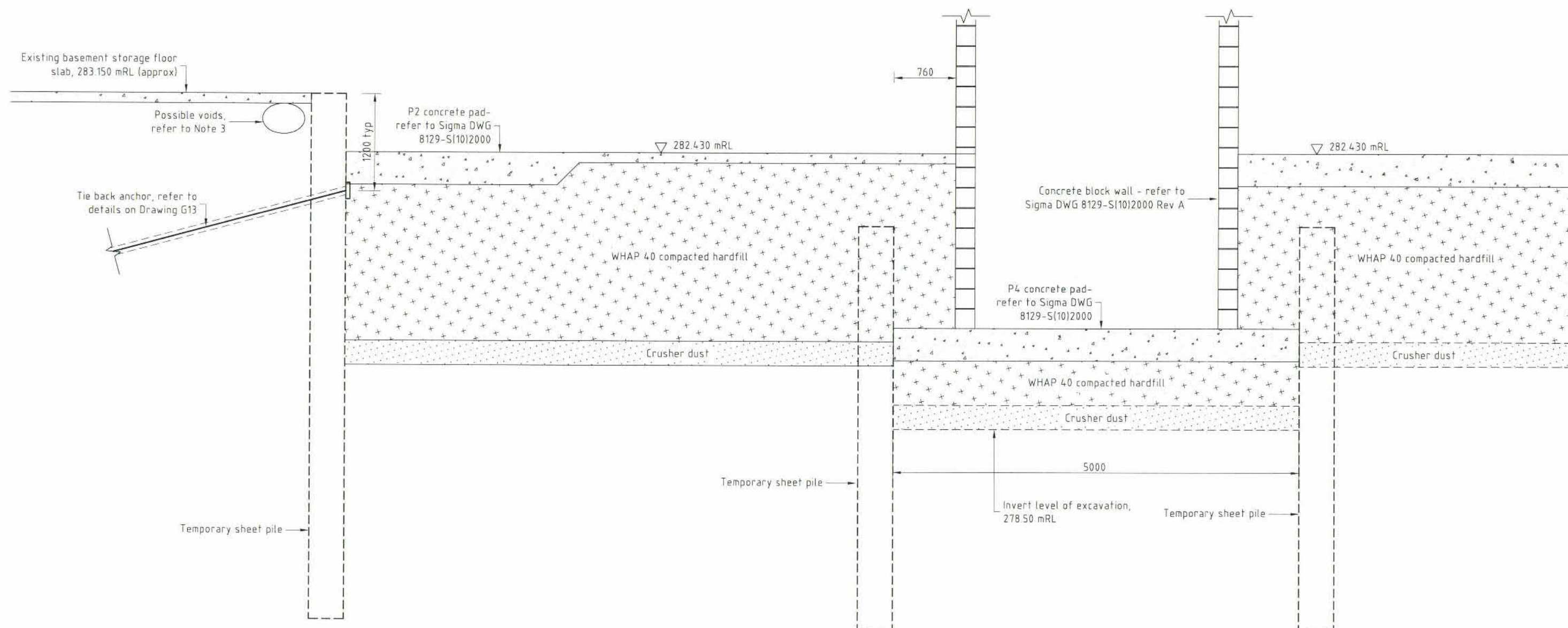


Terrane geotechnical solutions Terrane Consultants Ltd PO Box 13-607 TAURANGA Ph 07-579 9708 Fax 07 579 9702	Des: rm	Project: MILLENNIUM TRUST / SIGMA CONSULTANTS LTD ROTORUA MUSEUM, ROTORUA SOUTHERN EXTENSION	Scale: 1:200 at A3 size
	Dwg: rm		
	Chk: ajc		Rev: 0
	File ref: 3278-southext Date: May 09	Title: BUILDING MONITORING DETAILS	Dwg 3278-G15

Rev no	Revision note	Date	By
0	Preliminary/Draft Design	Feb 09	rm
1	For Approval/Consent		

NOTES:

1. This drawing is not to be used for construction purposes unless signed as approved.
2. Dimensions are in millimetres unless noted otherwise.
3. Existing footings to be checked for presence of voids. Geotechnical Designer to inspect and confirm underpinning and/or injection grouting before excavation below invert of footing.



TYPICAL
SCALE 1:50
(GRIDLINE C)

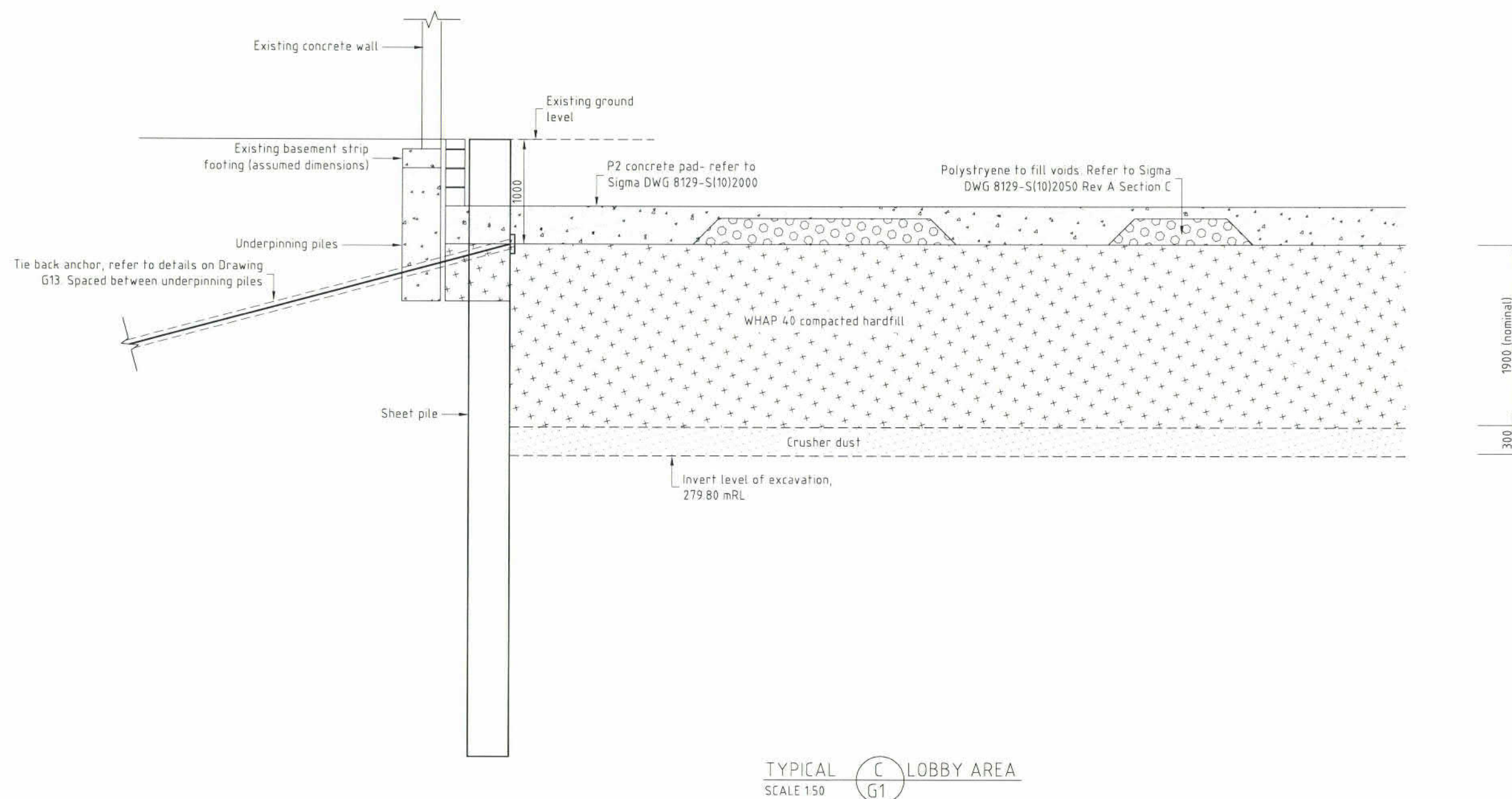


Terrane geotechnical solutions Terrane Consultants Ltd PO Box 13-607 TAURANGA Ph 07-579 9708 Fax 07 579 9702	Des: rm	Project: MILLENNIUM TRUST / SIGMA CONSULTANTS LTD ROTORUA MUSEUM, ROTORUA SOUTHERN EXTENSION	Scale: 1:50 at A3 size
	Dwg: rm		
	Chk: ajc		Rev: 0
	File ref: 3278-southext Date: Apr 09	Title: FOOTING & SHEET PILE INTERFACE	Dwg 3278-G20

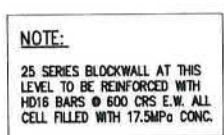
Rev no	Revision note	Date	By
0	Preliminary/Draft Design	Feb 09	rm
1	For Approval/Consent		

NOTES:

1. This drawing is not to be used for construction purposes unless signed as approved.
2. Dimensions are in millimetres unless noted otherwise.



Terrane geotechnical solutions Terrane Consultants Ltd PO Box 13-607 TAURANGA Ph 07-579 9708 Fax 07 579 9702	Des: rm	Project: MILLENIUM TRUST / SIGMA CONSULTANTS LTD ROTORUA MUSEUM, ROTORUA SOUTHERN EXTENSION	Scale: 1:50 at A3 size
	Dwg: rm		
	Chk: ajc		Rev: 0
	File ref: 3278-southext Date: Apr 09	Title: FOOTING & SHEET PILE INTERFACE	Dwg: 3278-G21



4-HD12 BARS WITH RE STIRRUPS @ 400 CRS

125

400

275

400

NOTES:

CONTRACTOR SHALL SITE CHECK AND
VERIFY ALL RELEVANT EXISTING &
PROPOSED DIMENSIONS WHERE NECESSARY.

SOIL CAPACITY TO BE 100KPa (WORKING)
OR 300KPa (ULTIMATE)

SOIL AND HARDFOLL TO BE COMPACTED
BY STATIC ROLLING ONLY, DO NOT USE
VIBRATING ROLLERS.

ALL CONCRETE TO BE 30MPa U.N.O.

ALL REINFORCING STEEL TO BE GRADE
500E MA

COVER TO STEEL:

FORMED FACES = 35mm MIN.
POURED AGAINST DPM = 50mm MIN.

ALL RE-BAR LAPS TO BE MIN. OF 60 DIA.
U.N.O.



AS BUILT PLAN

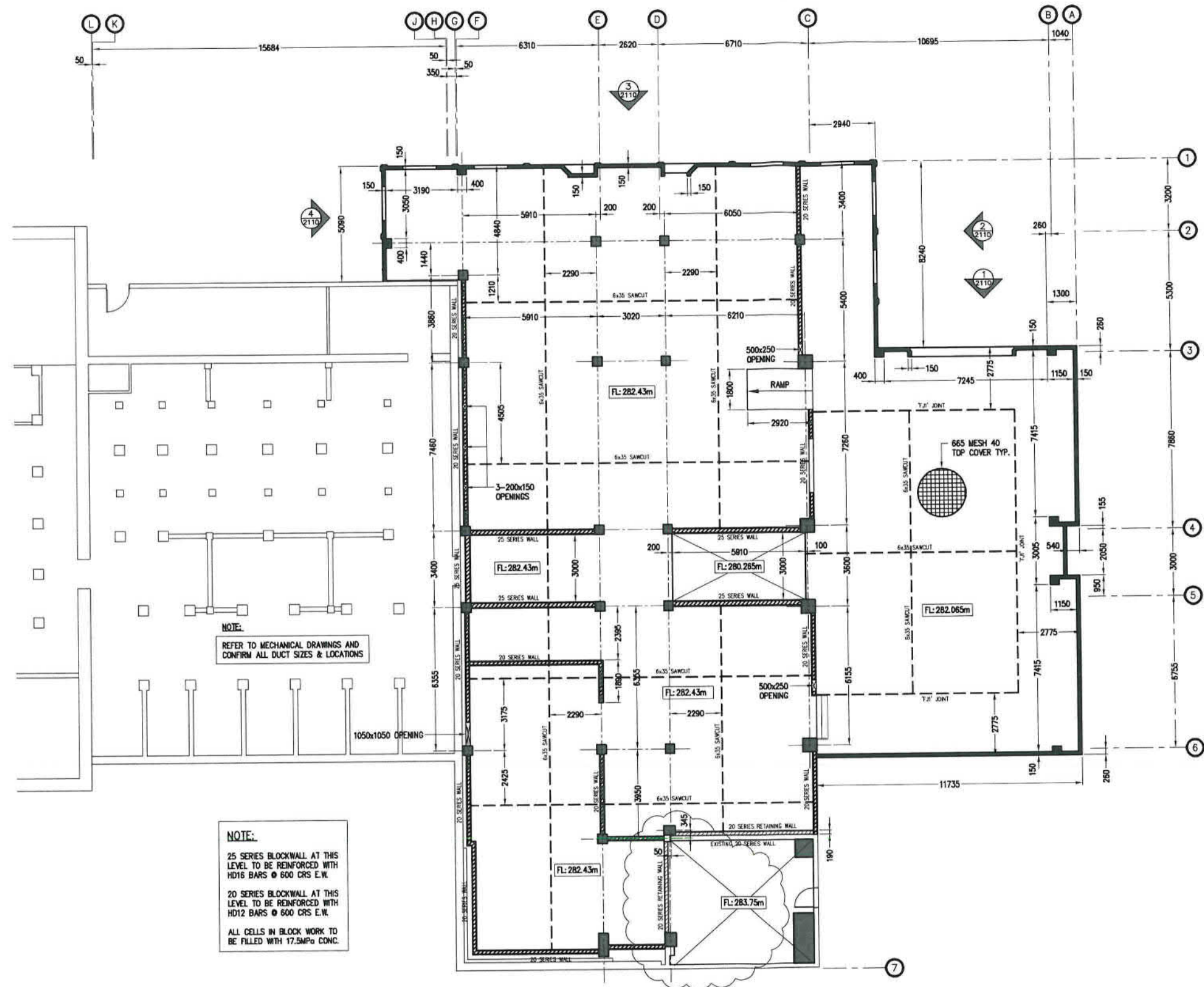
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PO Box 553, Rotorua, New Zealand
Phone 07-347 3456, Fax 07-347 3459

4	24/11/09	FOUNDATIONS REVISED	MJ	PF
3	17/9/09	SECTION D' REVISED	MJ	PF
2	19/8/09	FOR CONSTRUCTION	MJ	PF
1	28/7/09	FOR CONSTRUCTION	MJ	PF
T	31/3/09	FOR TENDER		
A	16/1/09	FOR SCHEDULING	MJ	PF
no	date	issue/revision detail	by	chk

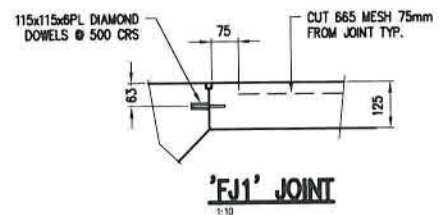
Scale
As Shown @ 'A1'

File Number
W:\8000\8129\Structure\8129-S(10)2000

drawing number rev.
8129 - S(10)2000 4



BASEMENT PLAN
1:100
(LEVEL '0')



PIM/BC
No - - 63686

**AS BUILT
PLAN**

no	date	issue/revision detail	by	chk
2	24/11/09	RETAINING WALL & COLUMN REVISED	MJ	PF
1	19/8/09	FOR CONSTRUCTION	MJ	PF
T	31/3/09	FOR TENDER		
A	16/1/09	FOR SCHEDULING	MJ	PF

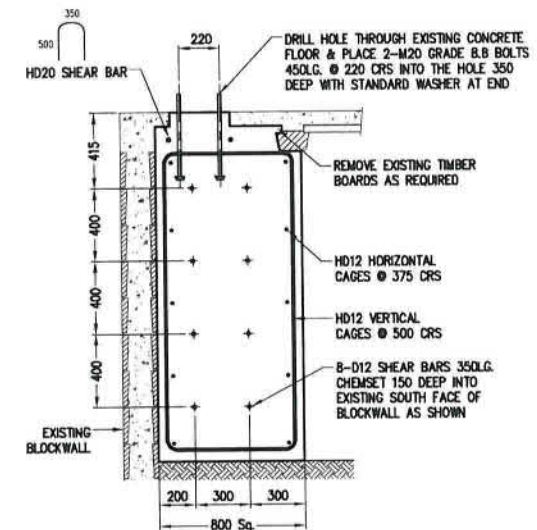
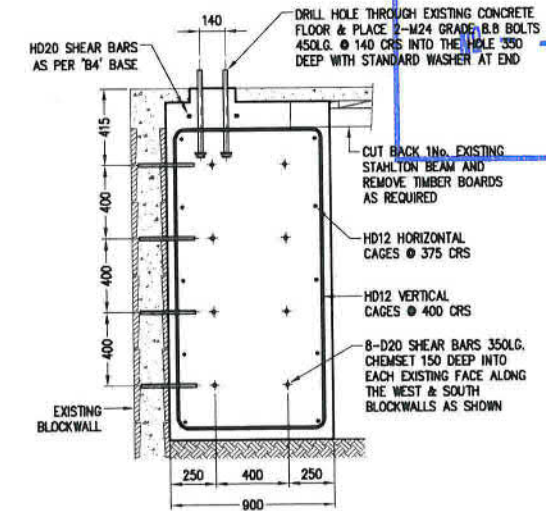
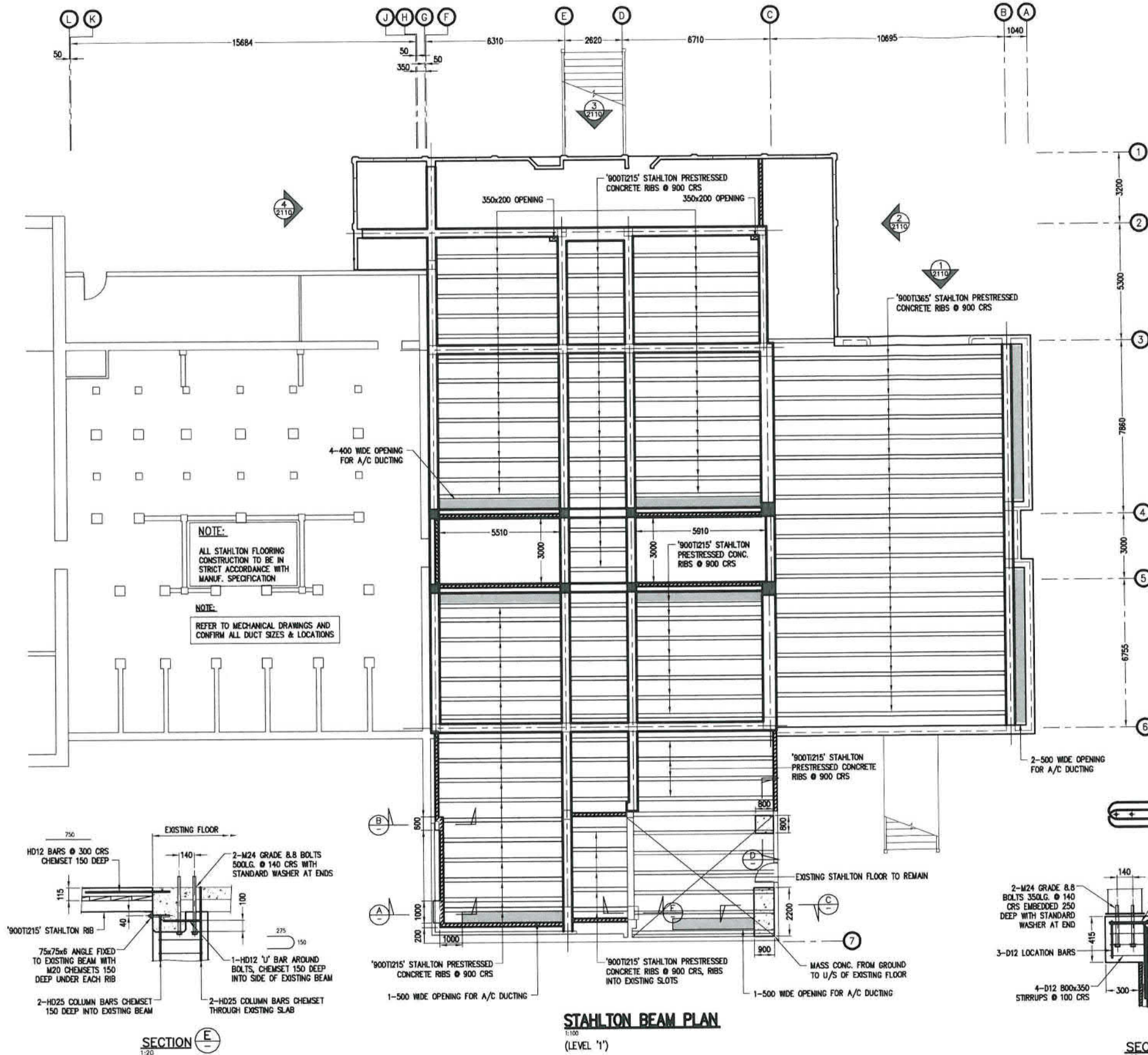
client
**ROTORUA TRUST GALLERY
CENTENNIAL DEVELOPMENT**

project
**SOUTH WING
EXTENSION**

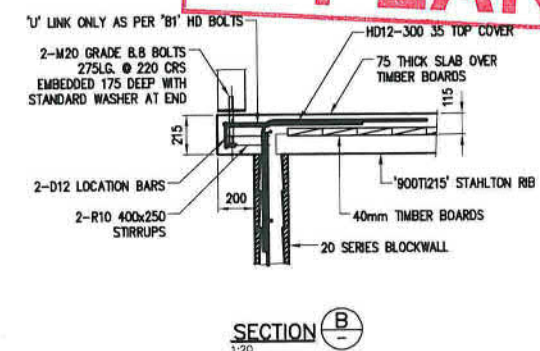
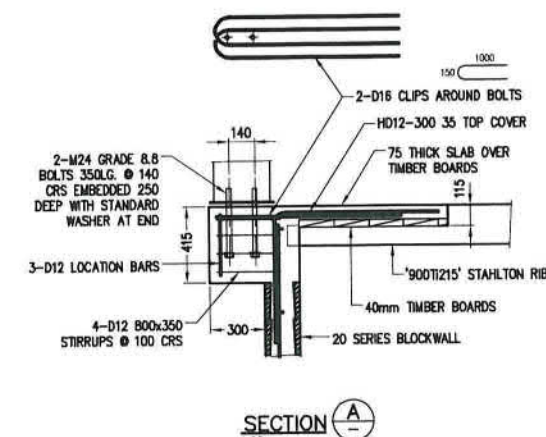
drawing title
BASEMENT PLAN

Scale
As Shown @ 'A1'
File Number
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drawing number
8129 - S(10)2001
rev. **2**

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**AS BUILT
PLAN**



3	9/2/10	SECTION E ADDED	MJ	PF
2	27/1/10	SECTIONS A to D ADDED	MJ	PF
1	15/8/09	FOR CONSTRUCTION	MJ	PF
1	31/3/09	FOR TENDER	MJ	PF
A	16/1/09	FOR SCHEDULING	MJ	PF
no	date	issue/revision detail	by	chk

client

ROTORUA TRUST GALLERY
CENTENNIAL DEVELOPMENT

project

SOUTH WING
EXTENSION

drawing title

STAHLTON BEAM PLAN
LEVEL 1

Scale

As Shown @ 'A1'

File Number

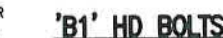
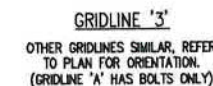
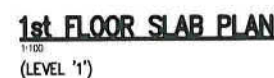
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drawing number

8129 - S(10)2002

3

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N/A AT POINTS 'C6.5' & 'F6.5', REFER
TO DWG S(10)2002 FOR DETAILS



1:20
GRIDLINES '4' & '6' SIMILAR
BUT OPPOSITE HAND



'B3' HD BOLTS



1:20
N/A AT POINTS 'C7', 'D7' & 'F7', REFER
TO DWG S(10)2002 FOR DETAILS



100 WIDE 1:20

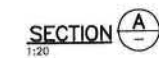
AS BUILT

HD12-300 35' TOP COVER

1500

35 THICK SLAB OVER

PLAN

client

project

drawing title

Scale

As Shown @ 'A1'

File Number
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drawing number

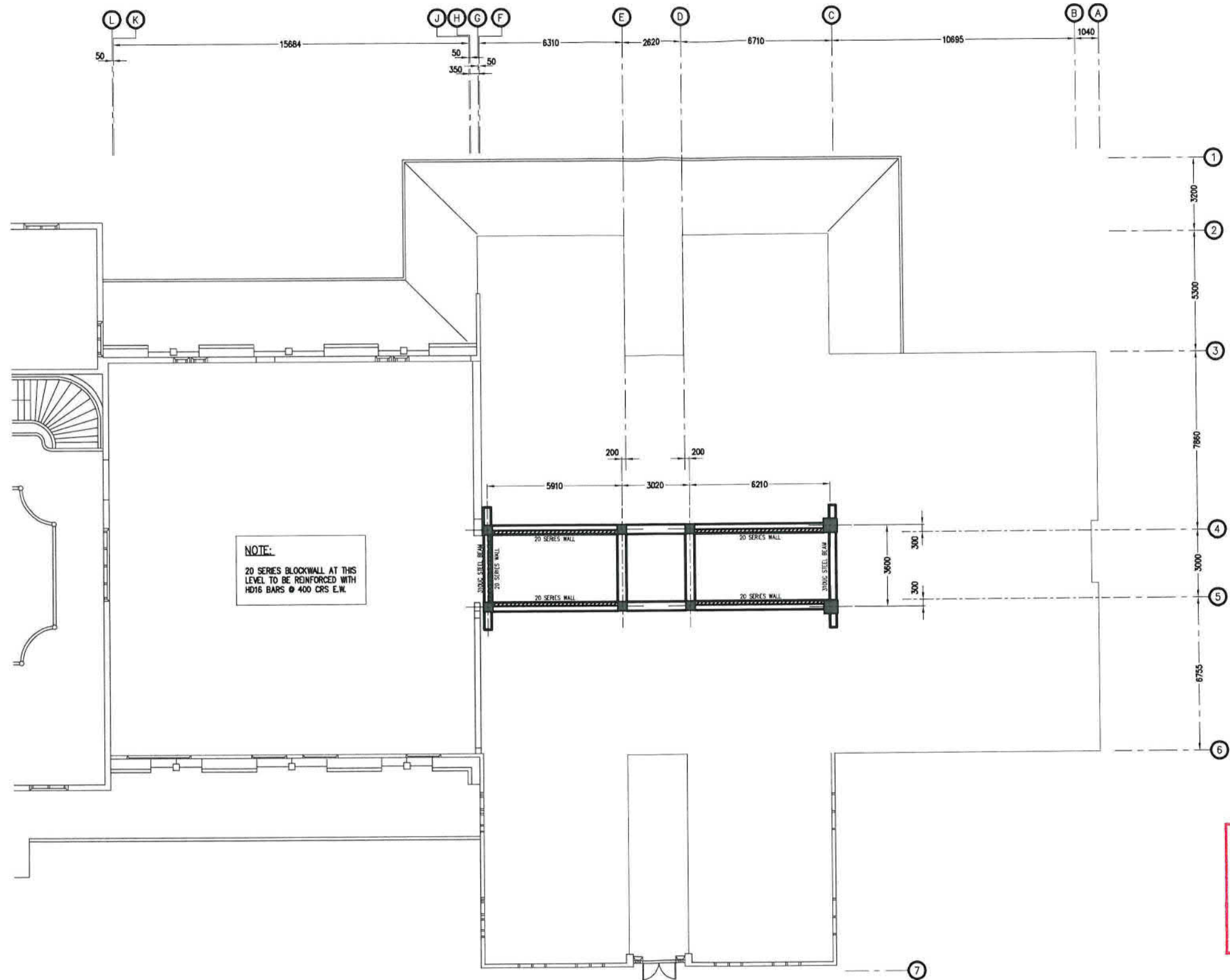
8129 - S(10)2003 3

3

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PIM/BC

№ - - 63686



AS BUILT
PLAN

no	date	issue/revision detail	by	chk
2	24/3/10	FOR CONSTRUCTION	MJ	PF
1	19/8/09	FOR CONSTRUCTION	MJ	PF
A	16/1/09	FOR SCHEDULING	MJ	PF

client
**ROTORUA TRUST GALLERY
CENTENNIAL DEVELOPMENT**

project
**SOUTH WING
EXTENSION**

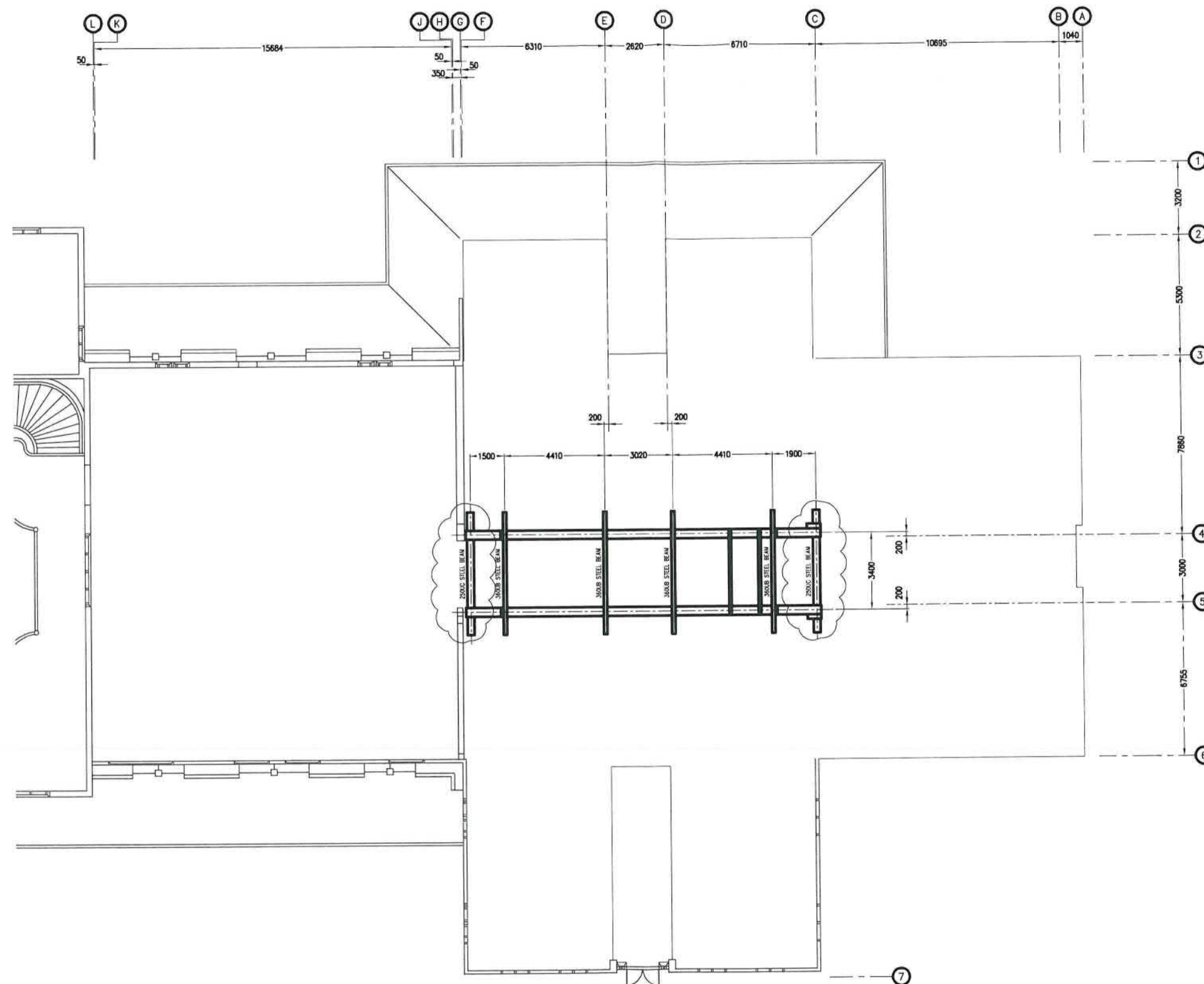
drawing title
**SHALTON BEAM PLAN
LEVEL 2**

Scale
As Shown @ 'A1'
File Number
W:\8000\8129\Structure\8129-S(10)2000
drawing number
8129 - S(10)2004
rev.
2

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PIM/BC

No - - 63686



PLANT ROOM PLAN
1:100
(LEVEL '3')

**AS BUILT
PLAN**

no	date	issue/revision detail	by	chk
2	24/3/10	FOR CONSTRUCTION	MJ	PF
1	19/8/09	FOR CONSTRUCTION	MJ	PF
A	16/1/09	FOR SCHEDULING	MJ	PF

client
**ROTORUA TRUST GALLERY
CENTENNIAL DEVELOPMENT**

project
**SOUTH WING
EXTENSION**

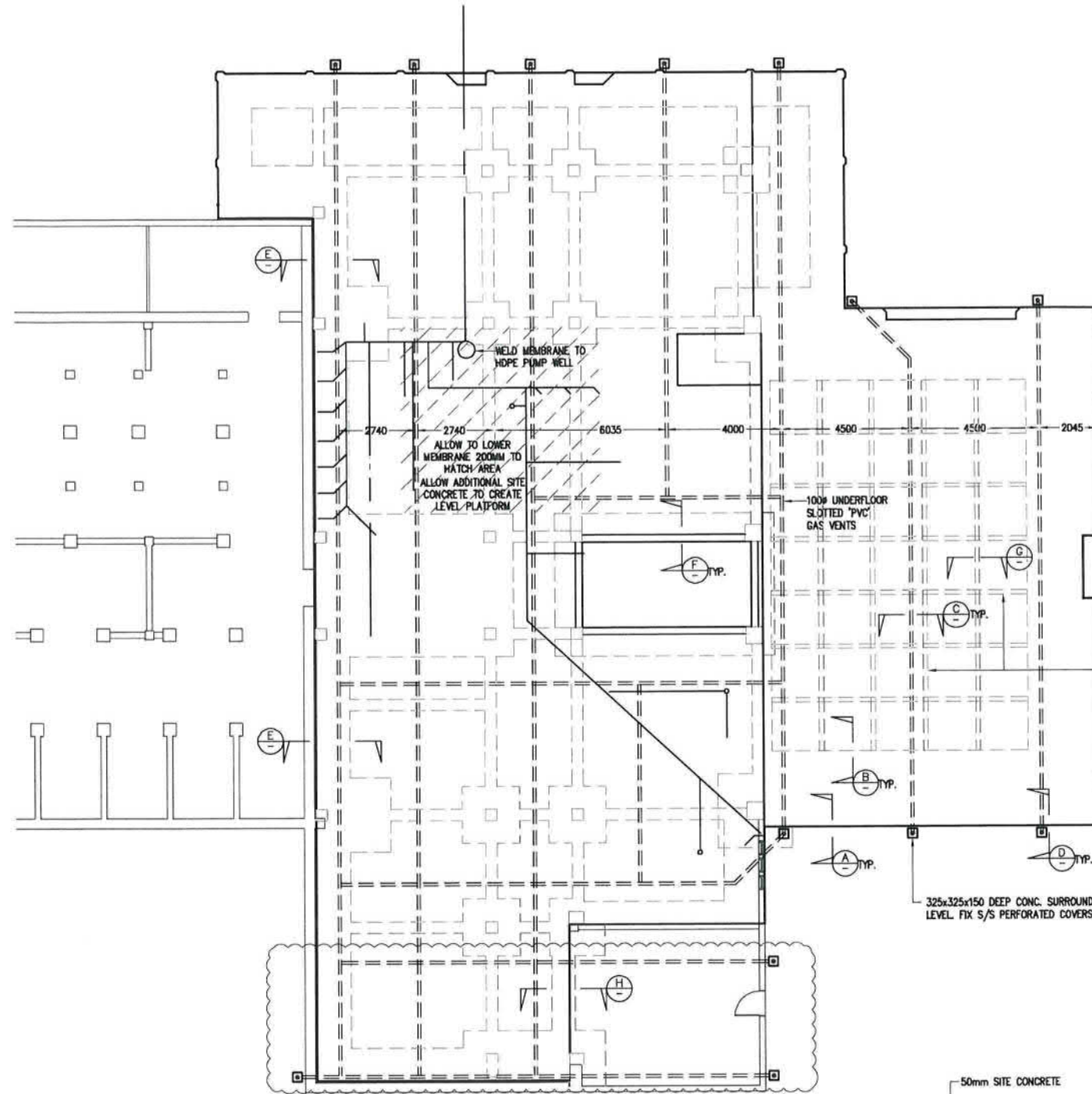
drawing title
**PLANT ROOM
FLOOR PLAN**

Scale
As Shown @ 'A1'
File Number
W:\8000\8129\Structure\8129-S(10)2000
drawing number
8129 - S(10)2005
rev.
2

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PO Box 553, Rotorua, New Zealand
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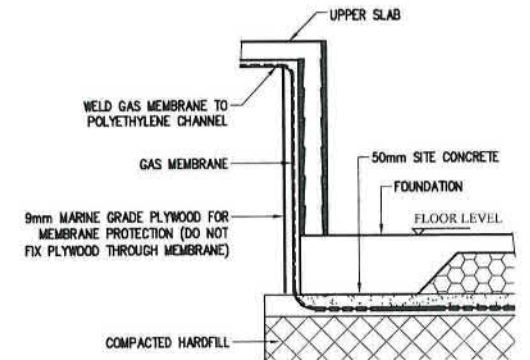
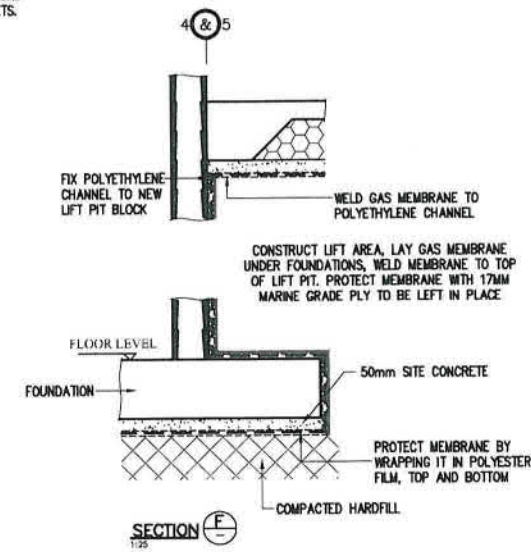
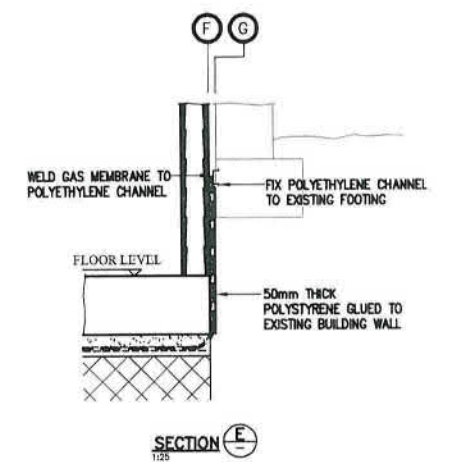
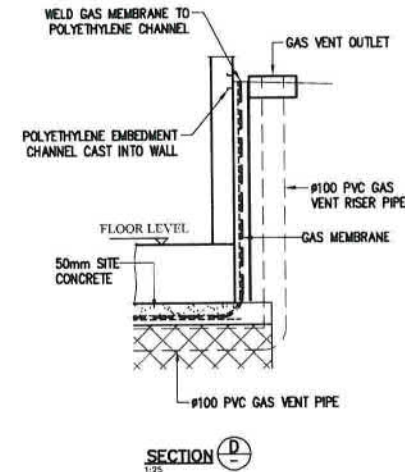
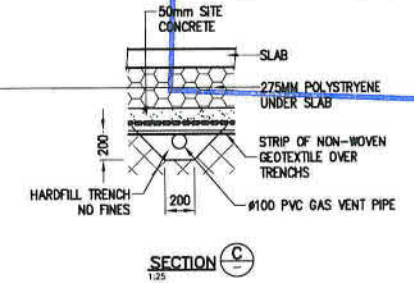
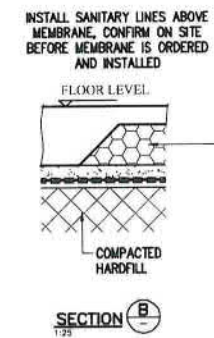
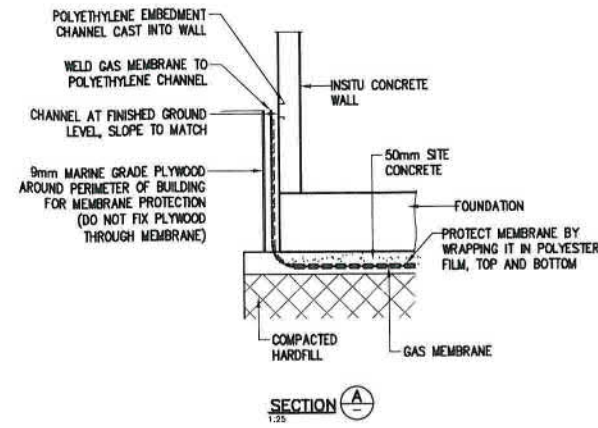
PIM/BC

No - - 63686



MEMBRANE PLAN

1:100



AS BUILT PLAN

no	date	issue/revision detail	by	chk
2	26/10/09	FOR CONSTRUCTION		
1	19/8/09	FOR CONSTRUCTION	MJ	PF
T	31/3/09	FOR TENDER		

client
ROTORUA TRUST GALLERY CENTENNIAL DEVELOPMENT

project
SOUTH WING EXTENSION

drawing title
FOUNDATION MEMBRANE PLAN

Scale
As Shown @ 'A1'

File Number
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drawing number
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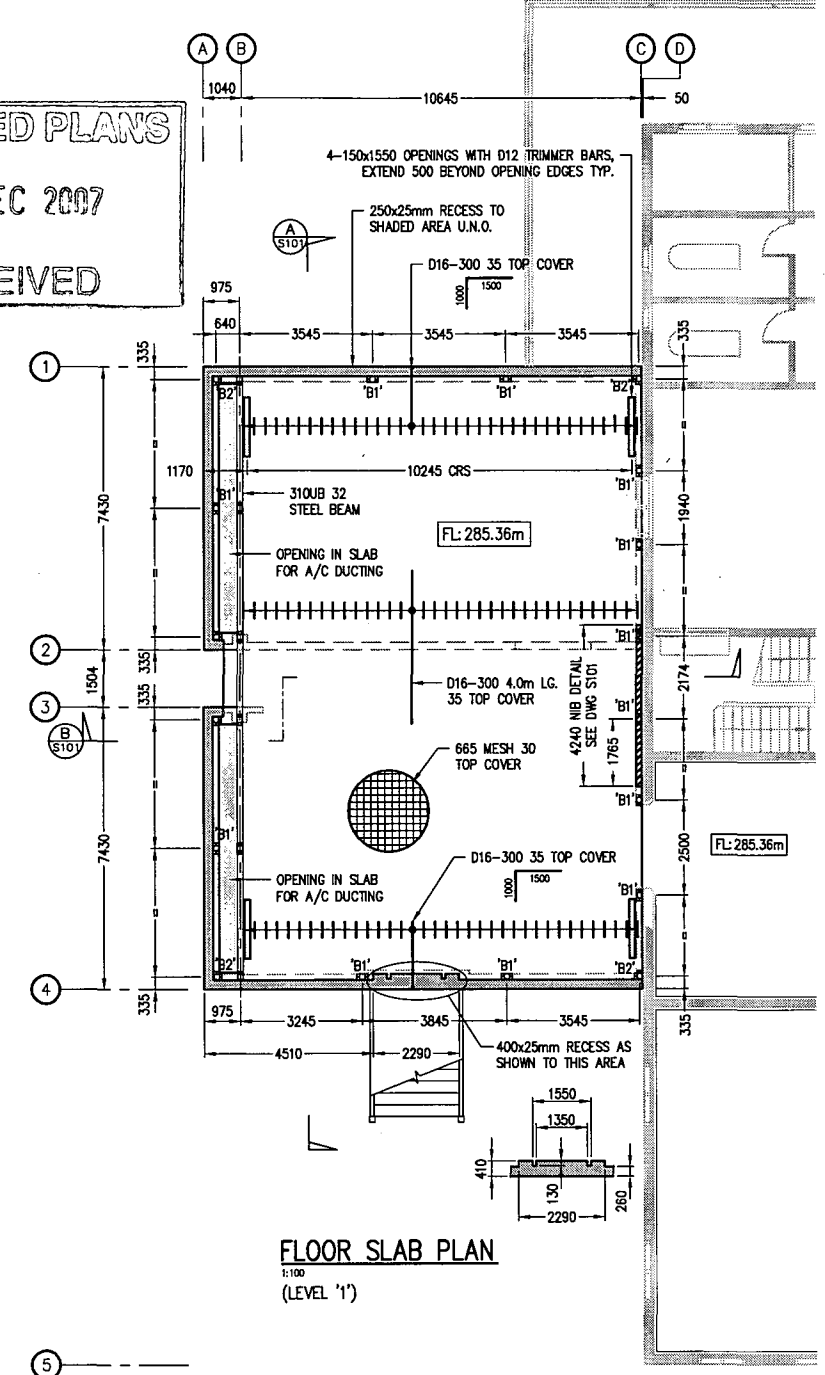
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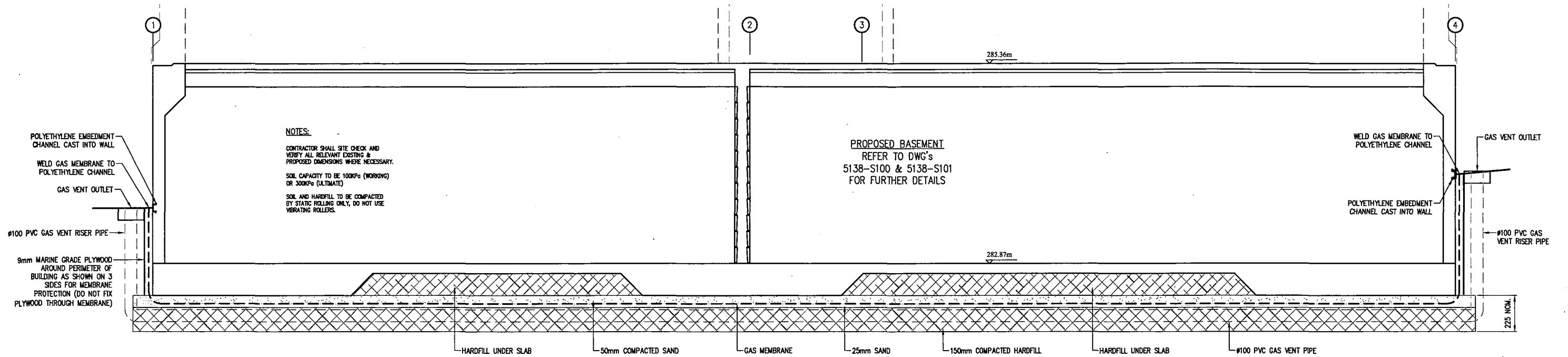
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(Zone 6)

PO0030
PS-3051

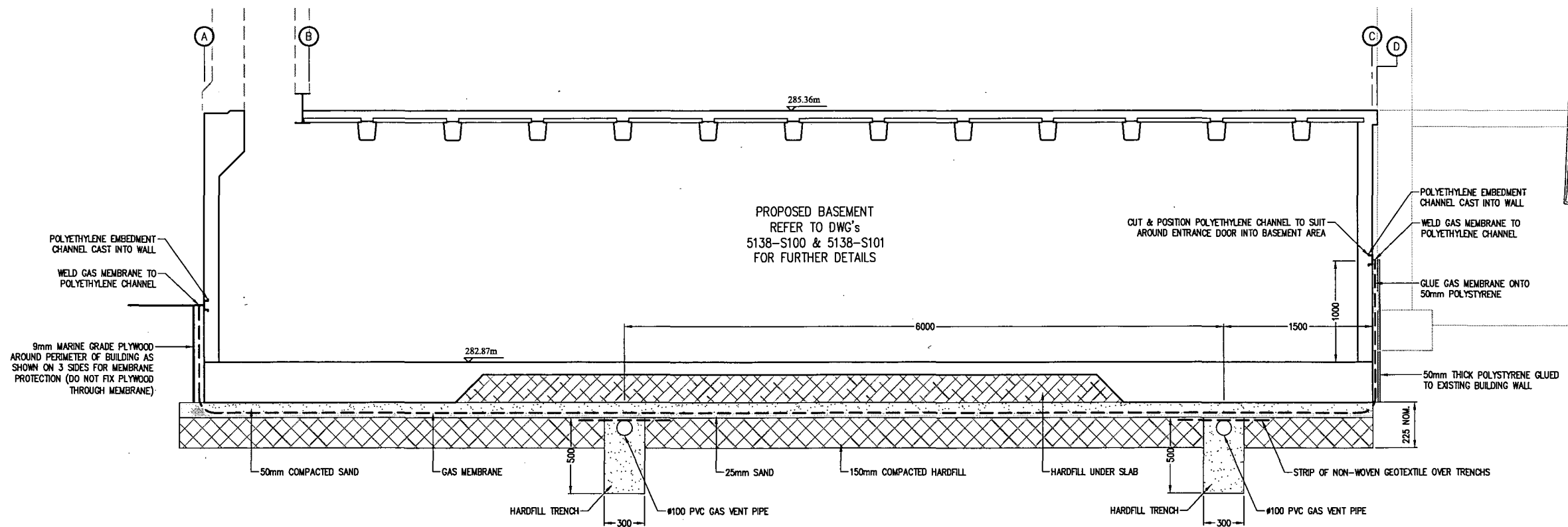


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2	20/8/07	FOR TENDER	MJ	DW

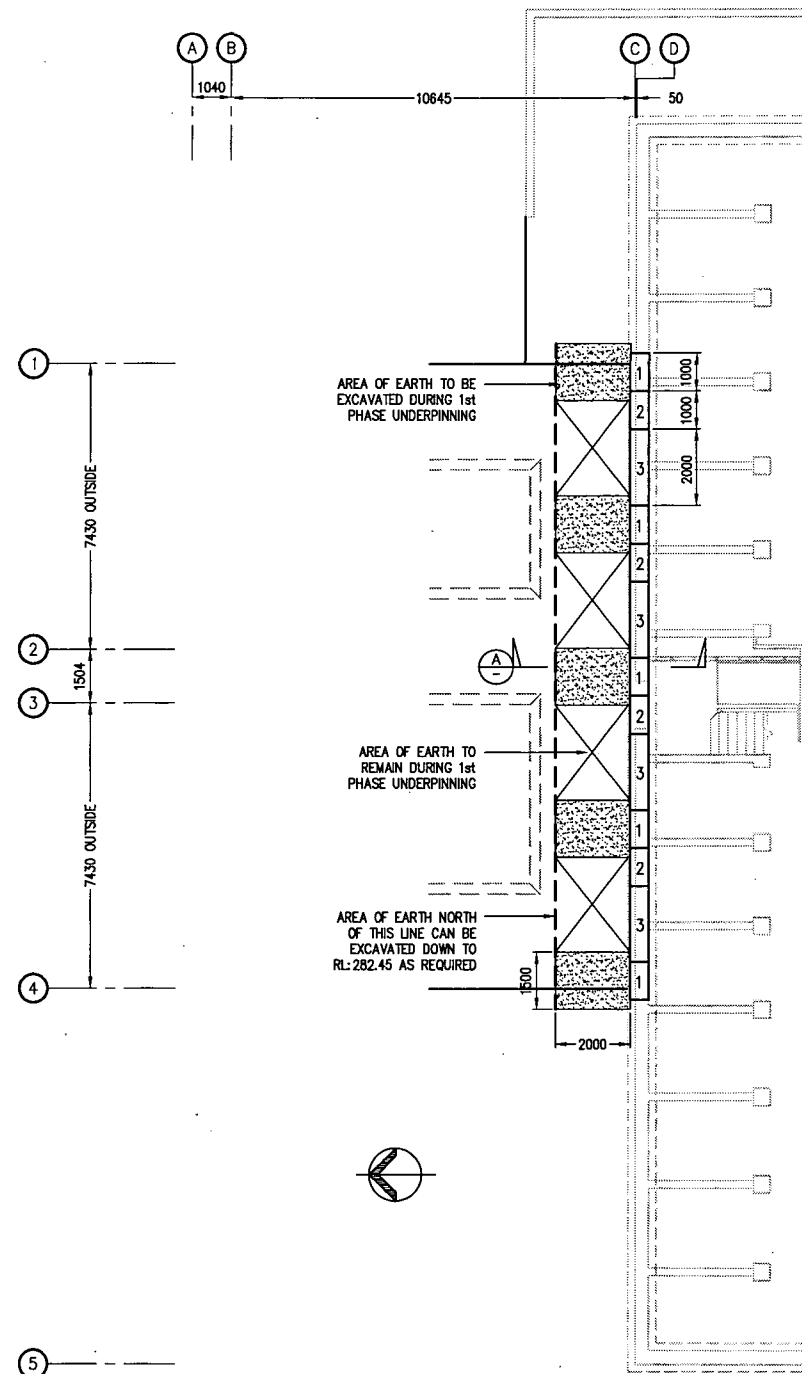
client
**ROTORUA TRUST GALLERY
 CENTENNIAL DEVELOPMENT
 NORTH WING**

project
**NORTH WING
 EXTENSION**

drawing title
**GROUNDWORKS & GAS
 COLLECTOR DRAIN DETAILS**

Scale
 N.T.S.
 File Number
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 drawing number
5138 - S102
 rev.
1

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UNDERPINNING PLAN
1:100
(LEVEL '0')

SEQUENCE

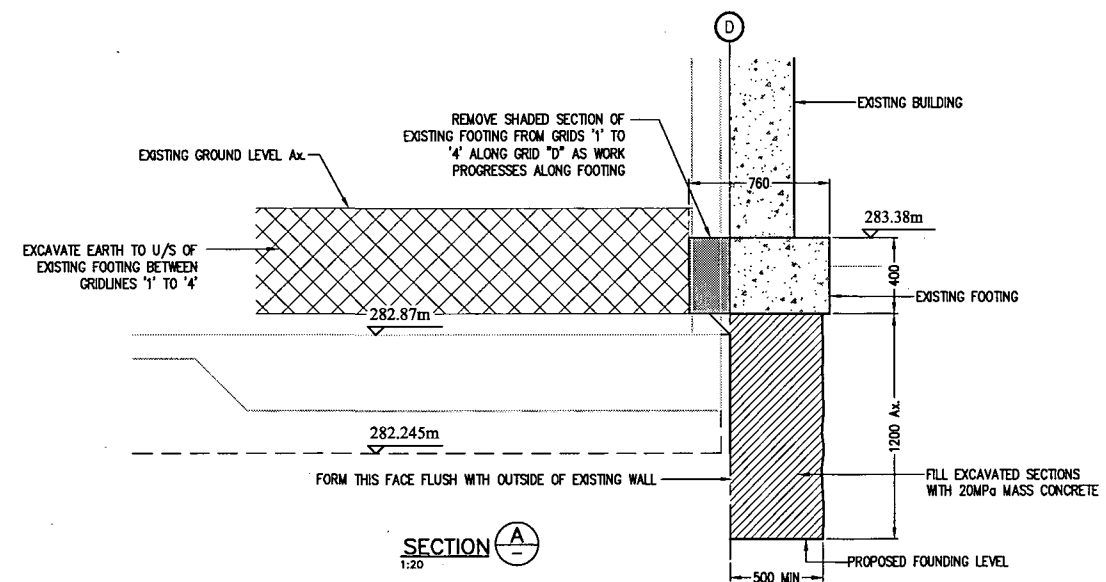
EXCAVATE EARTH DOWN TO U/S OF EXISTING FOOTING BETWEEN GRIDLINES '1' TO '4'

REMOVE EXISTING FOOTING AS SHOWN ON SECTION 'A' AS WORK PROGRESSES DURING 3 STAGES.

EXCAVATE AREAS IN FRONT OF MARK '1' DOWN TO PROPOSED EXCAVATION LEVEL, FORM FACE AND FILL VOID WITH 20MPa MASS CONCRETE.

ALLOW CONCRETE TO CURE 7 DAYS MIN BEFORE MOVING ON TO THE NEXT EXCAVATION STAGE '2'.

REPEAT THESE STEPS UNTIL ALL 3 STAGES ARE COMPLETE



SECTION A-A
1:20

no	date	issue/revision detail	by	chk
1	15/10/07	FOR CONSTRUCTION	MJ	PF
1	11/9/07	FOR TENDER	MJ	PF

client

**ROTORUA TRUST GALLERY
CENTENNIAL DEVELOPMENT
NORTH WING**

project

**NORTH WING
EXTENSION**

drawing title

UNDERPINNING PLAN

Scale

As Shown @ 'A1'

File Number

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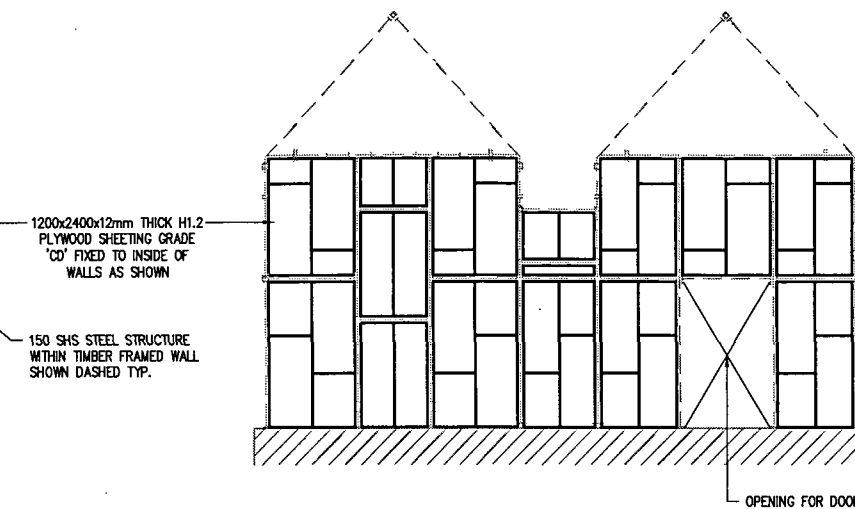
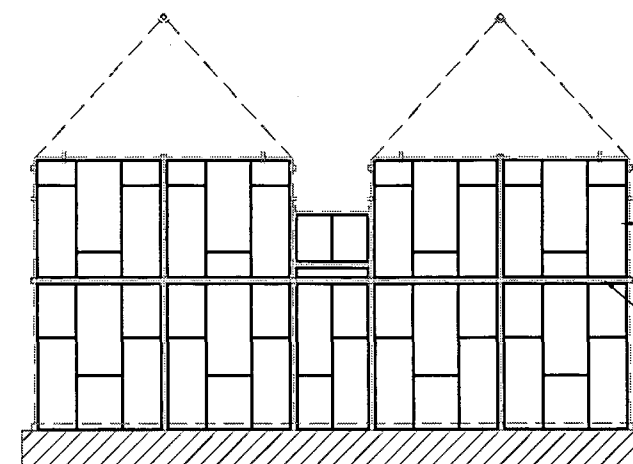
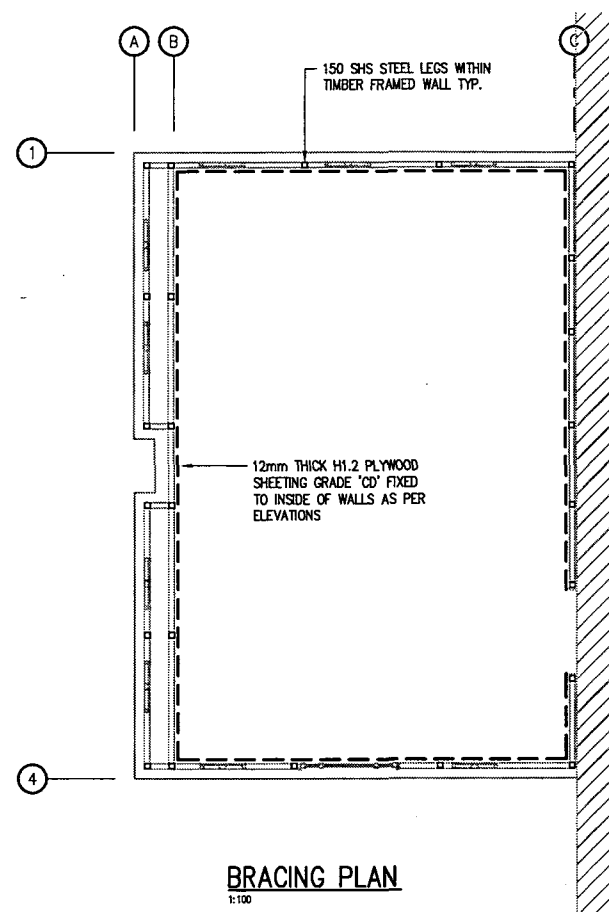
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5138 - S103

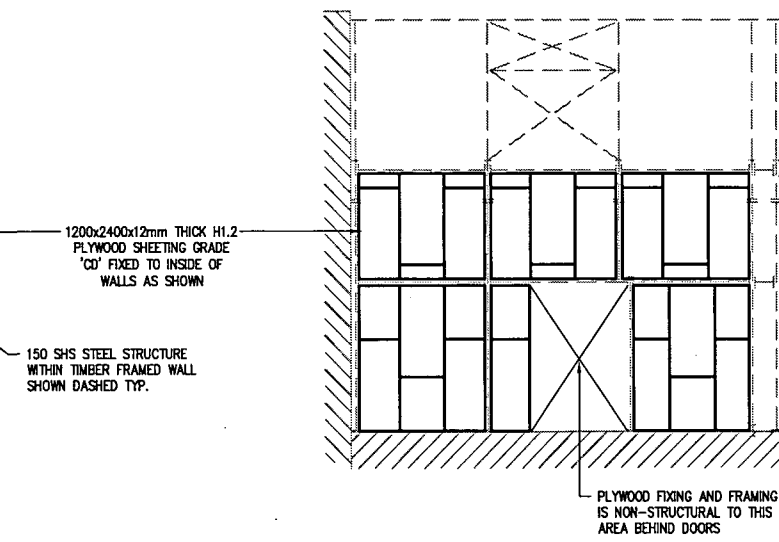
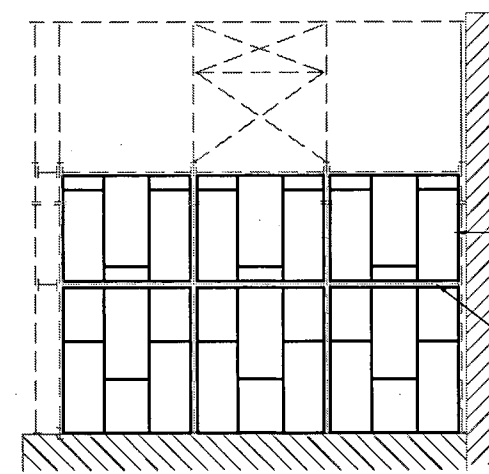
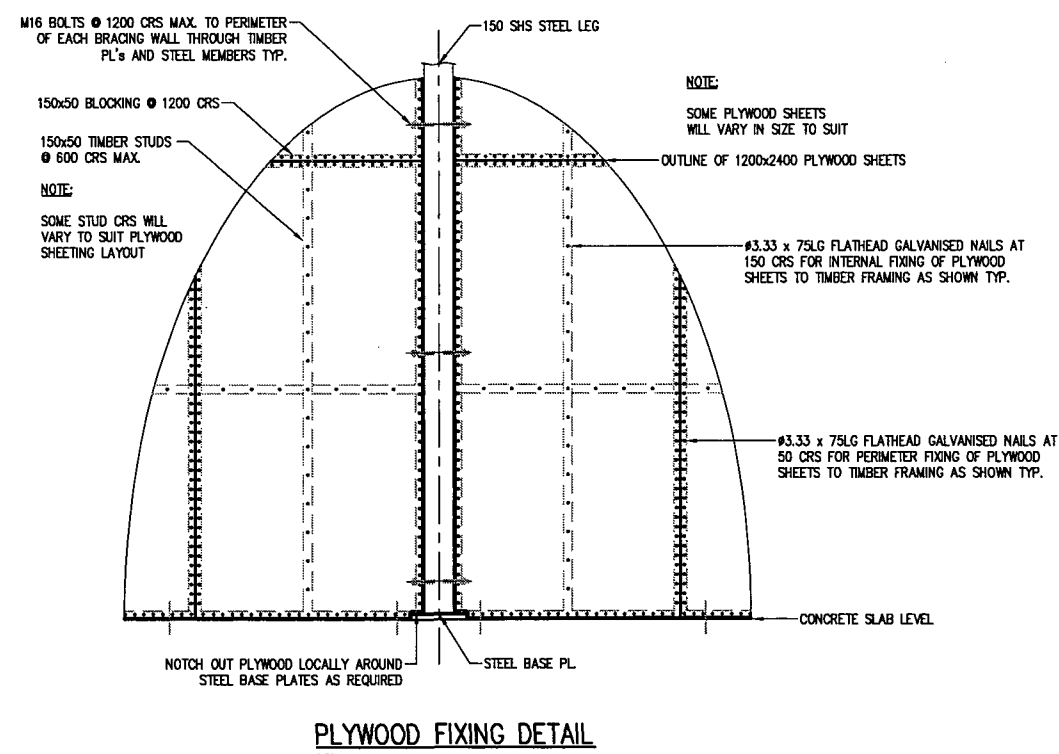
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A	18/9/07	FOR TENDER	MJ	PF

client
**ROTORUA TRUST GALLERY
CENTENNIAL DEVELOPMENT
NORTH WING**

project
**NORTH WING
EXTENSION**

drawing title
**BRACING PLAN
& DETAILS**

Scale
As Shown @ 'A1'

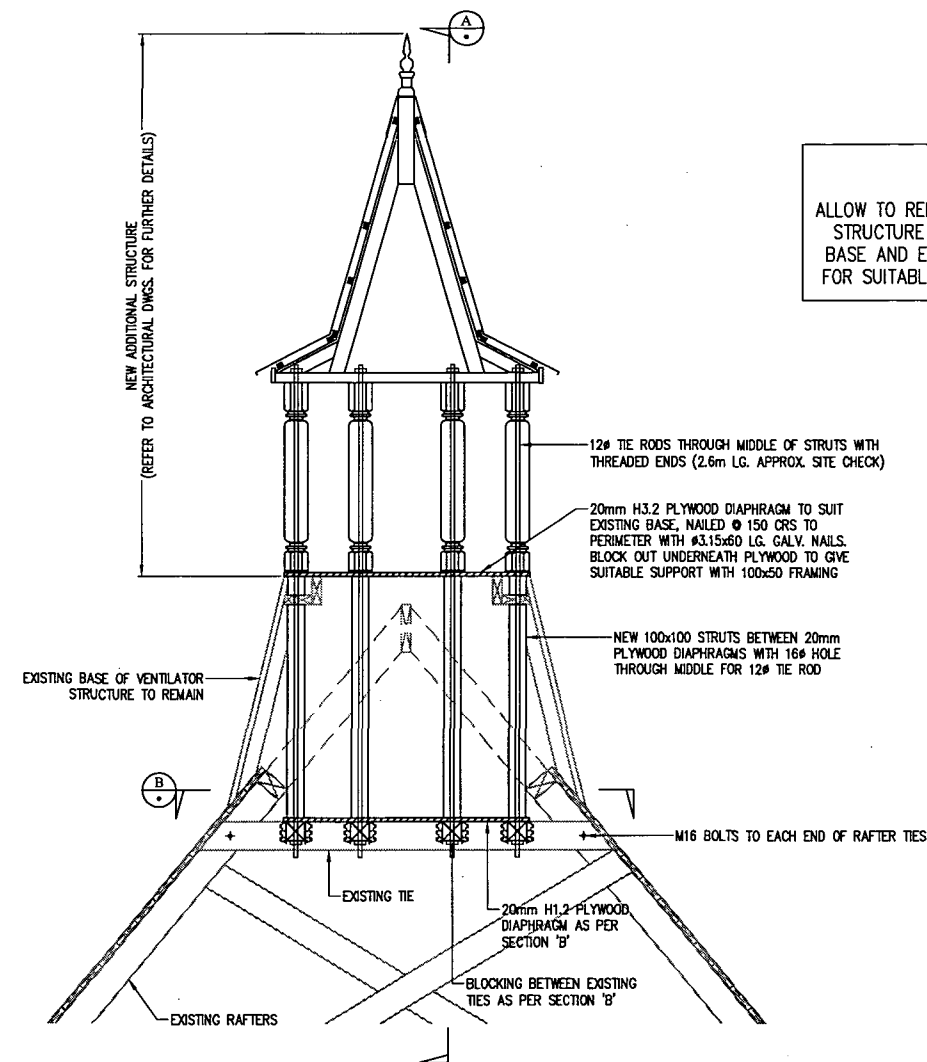
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drawing number
5138 - S104

rev.
1

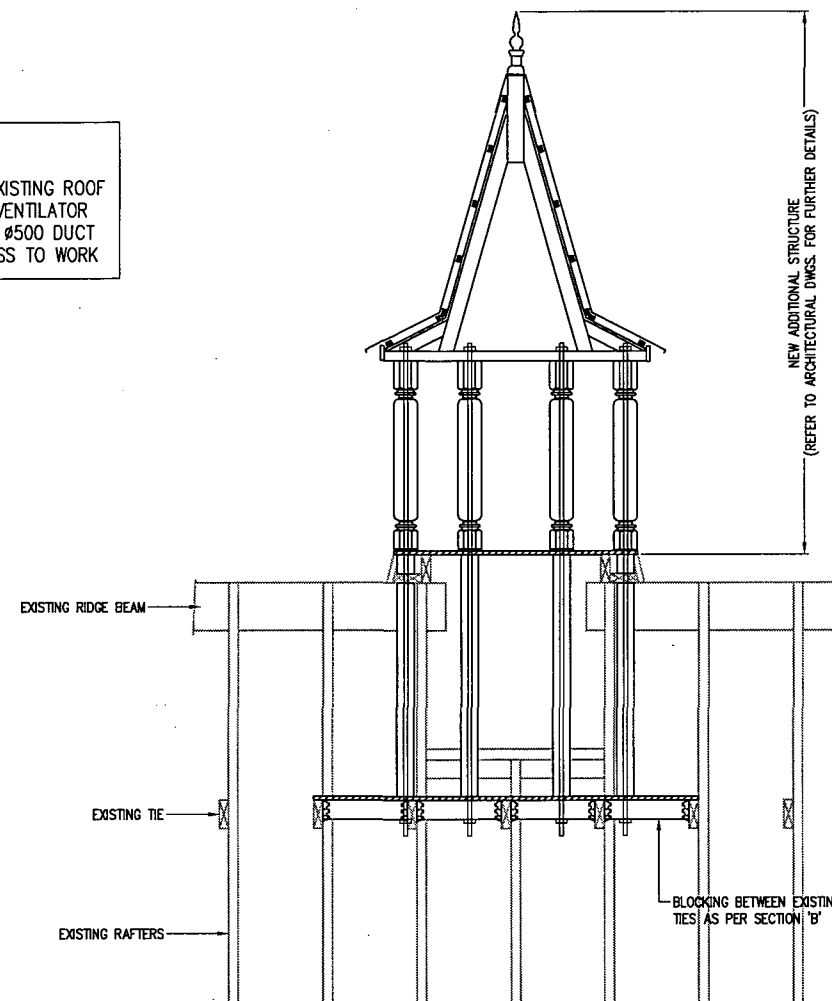
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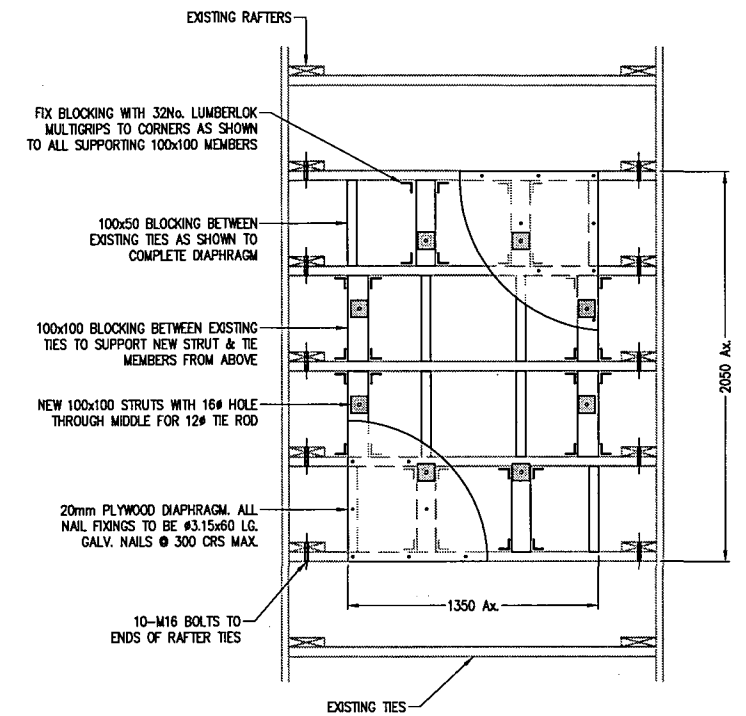


RIDGE LINE ELEVATION
1:20
6No. REQ'D

NOTE:
ALLOW TO REMOVE EXISTING ROOF
STRUCTURE FROM VENTILATOR
BASE AND EXISTING #500 DUCT
FOR SUITABLE ACCESS TO WORK



SECTION A-A
1:20



SECTION B-B
1:20

no	date	issue/revision detail	by	chk
1	15/10/07	FOR CONSTRUCTION	MJ	PF
A	20/9/07	FOR TENDER	MJ	PF

client

**ROTORUA TRUST GALLERY
CENTENNIAL DEVELOPMENT
NORTH WING**

project

**NORTH WING
EXTENSION**

drawing title

**STRENGTHENING OF
EXISTING VENTILATION
SUPPORTS**

Scale

As Shown @ 'A1'

File Number

W:\5000\5138\Structure\5138-S100

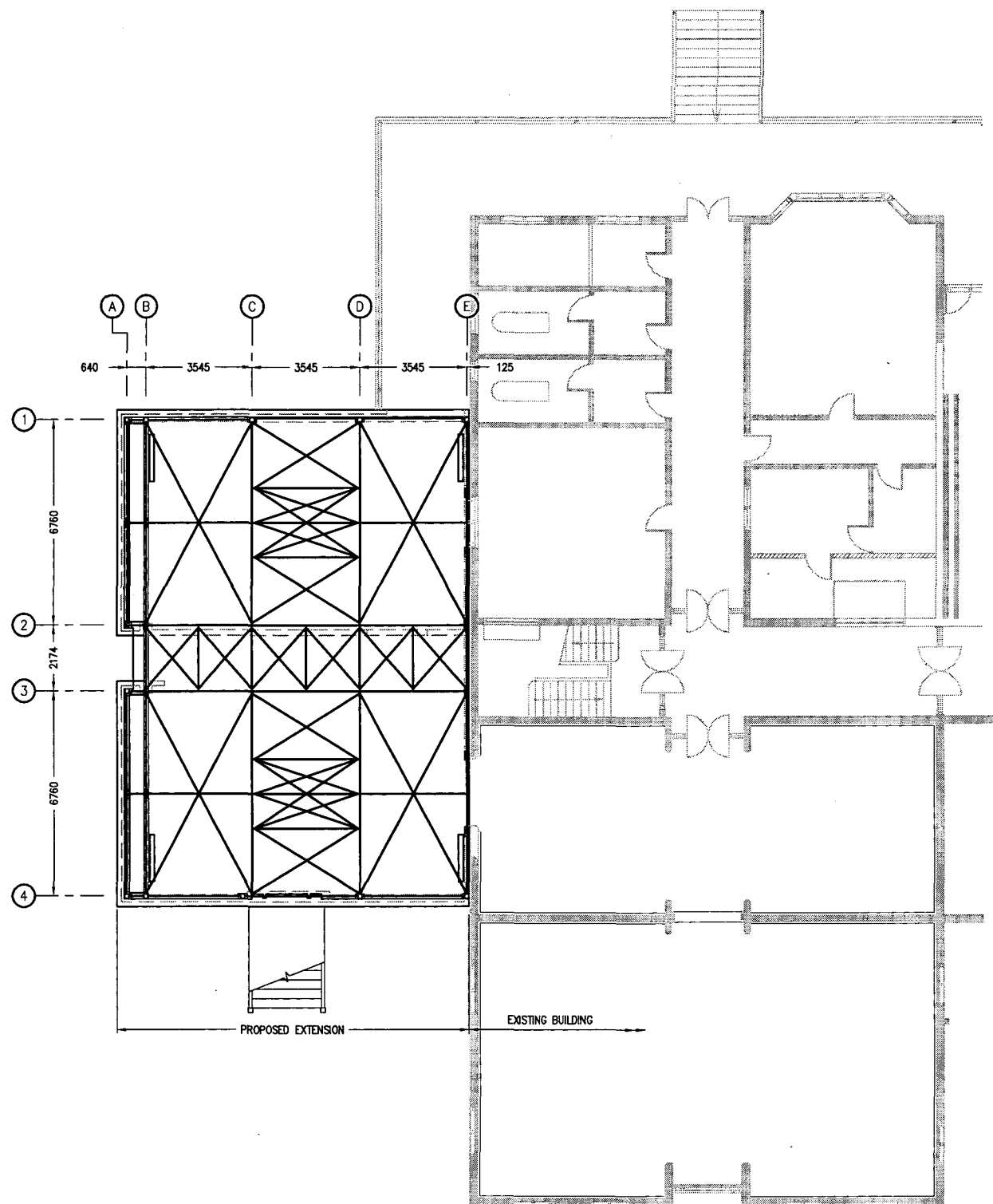
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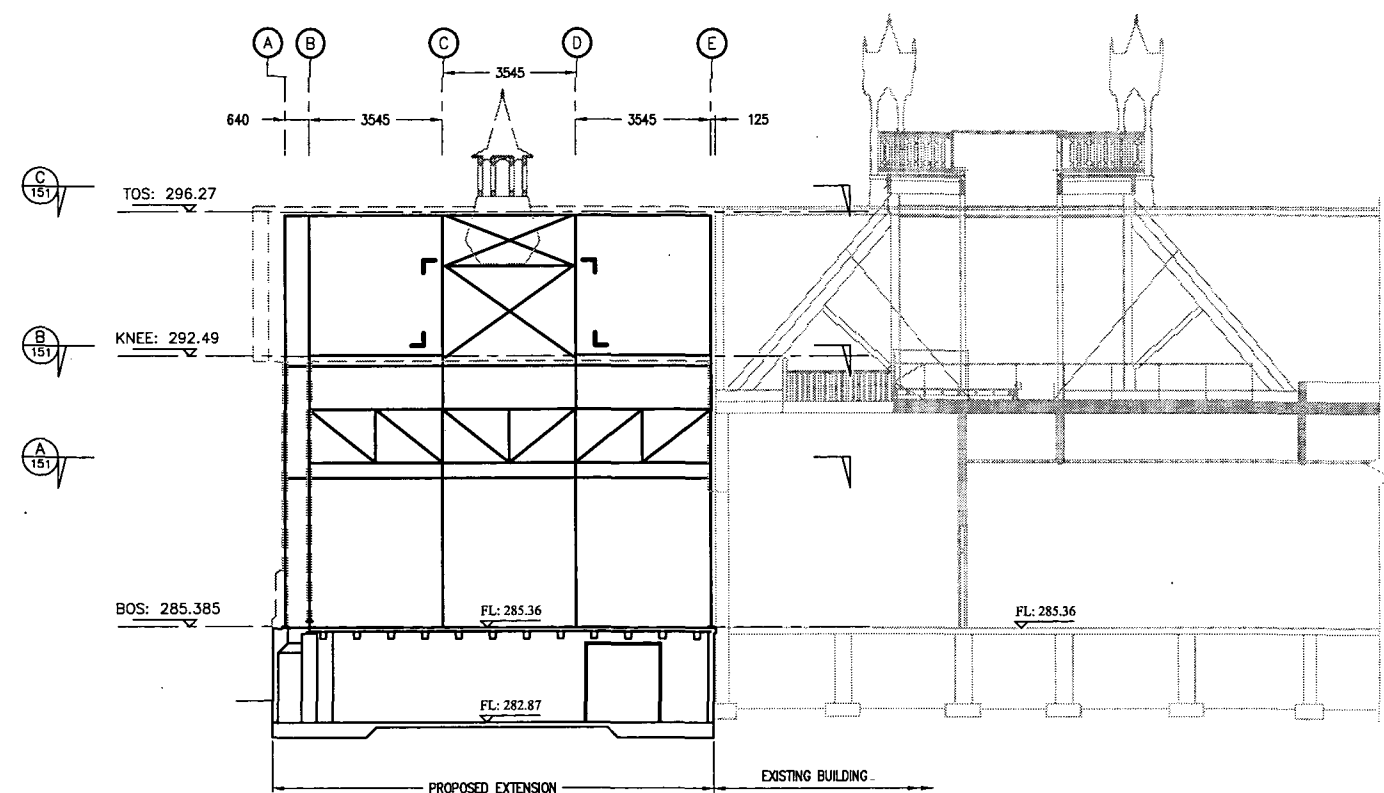
rev.

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GENERAL STRUCTURAL STEEL PLAN
1:100



GENERAL STRUCTURAL STEEL ELEVATION
1:100

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14 DEC 2007
RECEIVED

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2	6/12/07	GRIDLINES MODIFIED	MJ	PF
1	15/10/07	FOR CONSTRUCTION	MJ	PF
T	20/8/07	FOR TENDER	MJ	PF
A	3/8/07	PRELIMINARY	MJ	PF

client

ROTORUA TRUST GALLERY
CENTENNIAL DEVELOPMENT
NORTH WING

project

PROPOSED NORTH
WING EXTENSION

drawing title

STRUCTURAL STEEL
GENERAL LAYOUTS

Scale

As Shown @ 'A1'

File Number

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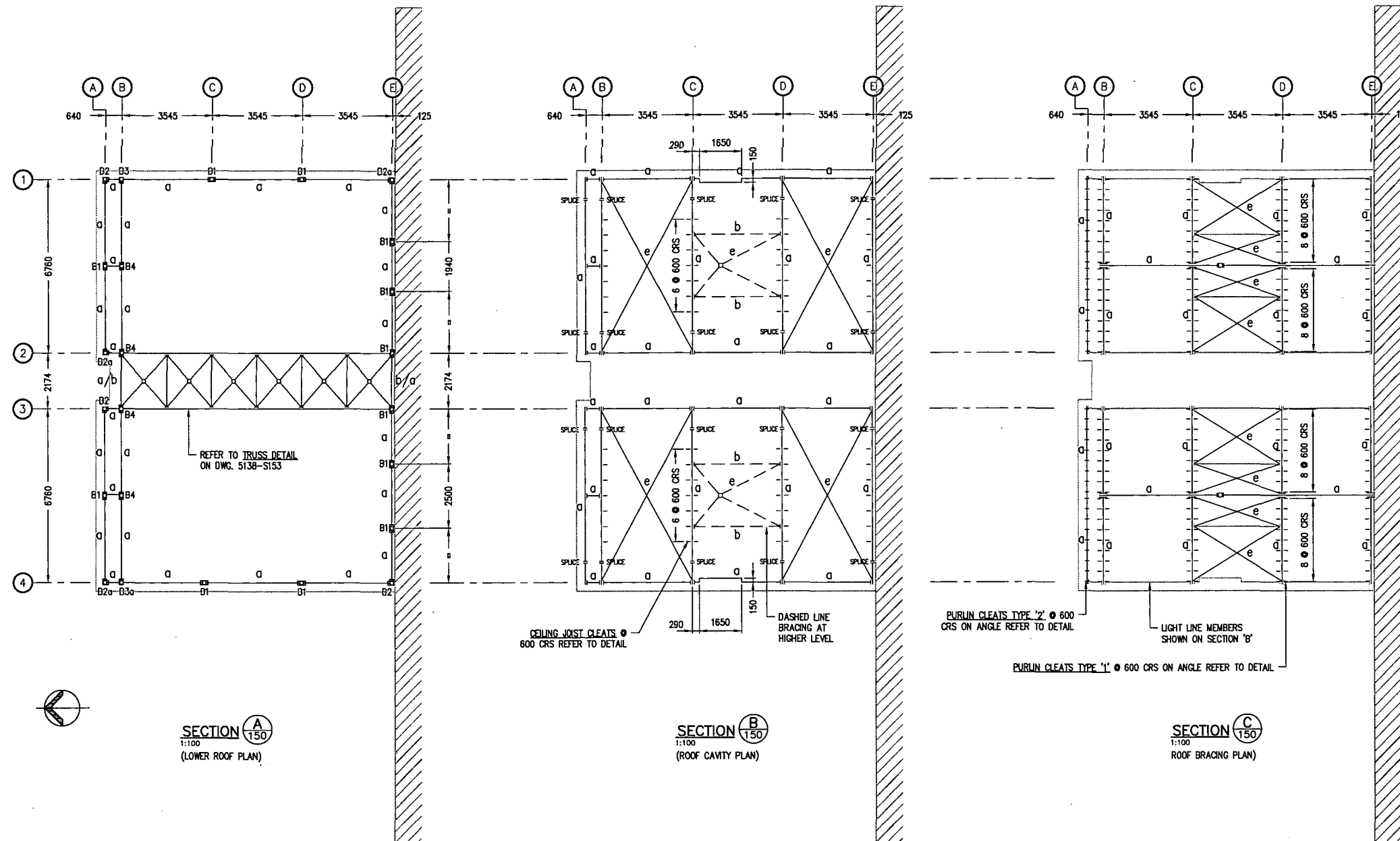
drawing number

5138 - S150

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KEY:

a	150x150x6 SHS
b	125x125x5 SHS
c	32NB SCH40 (SITE CHECK)
d	310x632
e	RB20 REDDBRACE
f	#16 M/S ROD
g	#20 M/S ROD
h	100x100x5 SHS

NOTES:

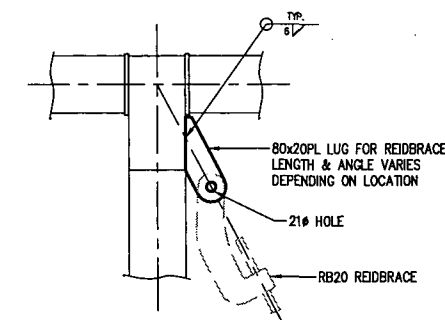
CONTRACTOR SHALL SITE CHECK AND VERIFY ALL RELEVANT EXISTING & PROPOSED DIMENSIONS WHERE NECESSARY.

ALL DIMENSIONS TO CENTRE OF STEEL UNLESS NOTED OTHERWISE.

ALL STEELWORK FABRICATION TO COMPLY WITH NZS3404:1997.

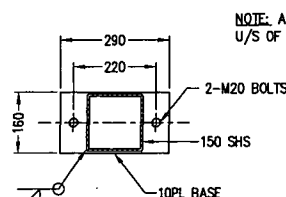
ALL WELDING SHALL COMPLY WITH NZS4701 CLASS 'A' SPEC. WELDS TO BE 6mm CONTINUOUS FILLET OR FULLY BUTT WELDED AS APPROPRIATE.

ALL INTERNAL STEELWORK TO BE ZINC RICH PRIMED. EXTERNAL TO BE HOT DIP GALV.



RB20 LUG DETAIL

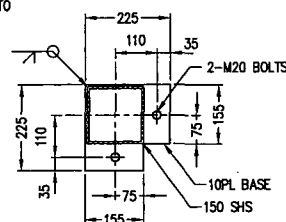
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'B1' BASE PL.

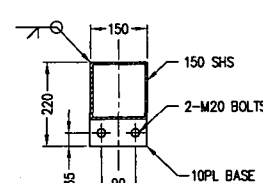
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12No. OFF

NOTE: ALLOW FOR 25mm OF GROUT TO U/S OF BASE PL's 'B1' & 'B2' ONLY



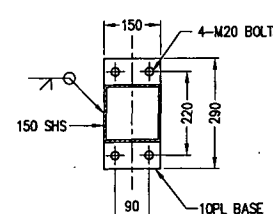
'B2' BASE PL.

1:10
3No. OFF
(B2a' OPPOSITE HAND)
3No. OFF



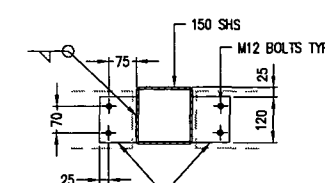
'B3' BASE PL.

1:10
1No. OFF
(B3a' OPPOSITE HAND)
1No. OFF



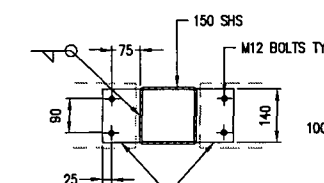
'B4' BASE PL.

1:10
4No. OFF

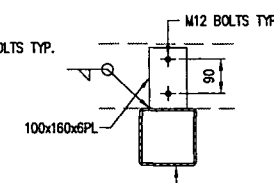


CEILING JOIST CLEAT

1:10
84No. CLEATS ONLY



TYPE '1'
252No. CLEATS ONLY
(GRIDLINES 'B','C','D','E')



TYPE '2'
36No. CLEATS ONLY
(GRIDLINES 'A' ONLY)

PURLIN CLEATS

1:10

no	date	issue/revision detail	by	chk
2	6/12/07	GRIDLINES MODIFIED	MJ	PF
1	15/10/07	FOR CONSTRUCTION	MJ	PF
T	20/8/07	FOR TENDER	MJ	PF
A	3/8/07	PRELIMINARY	MJ	PF

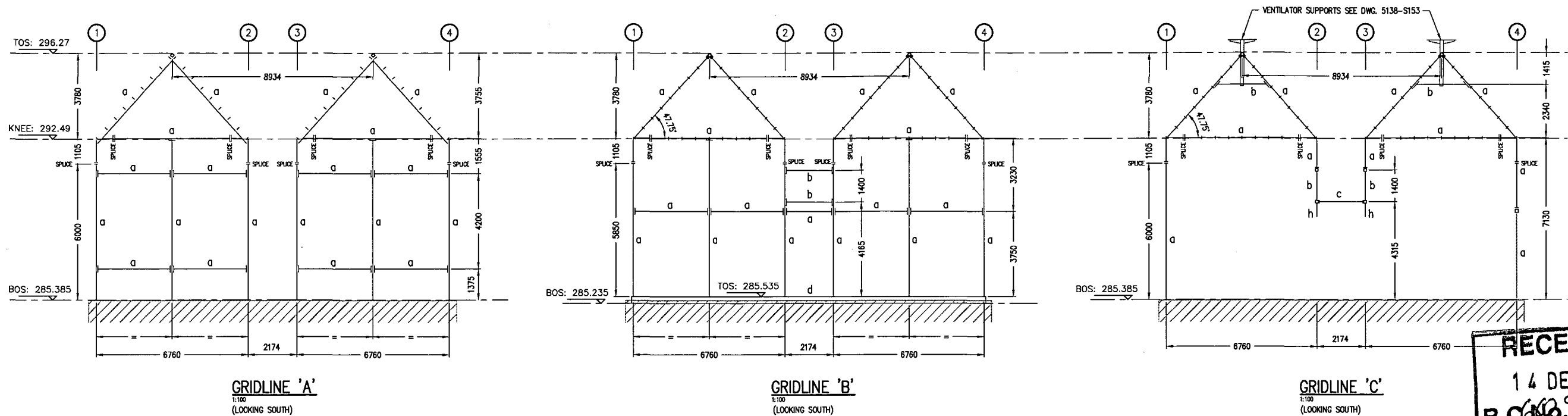
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**ROTORUA TRUST GALLERY
CENTENNIAL DEVELOPMENT
NORTH WING**

project
**PROPOSED NORTH
WING EXTENSION**

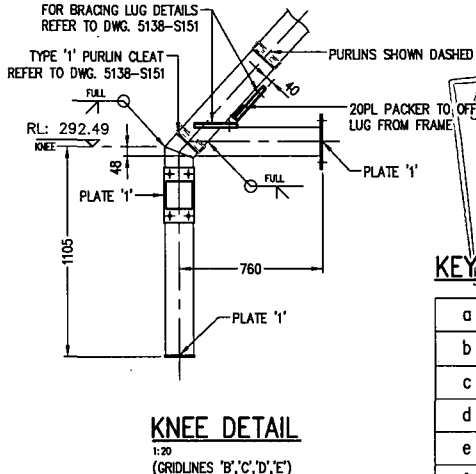
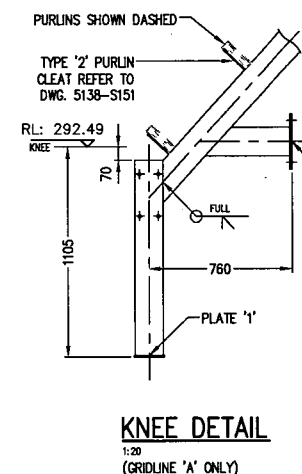
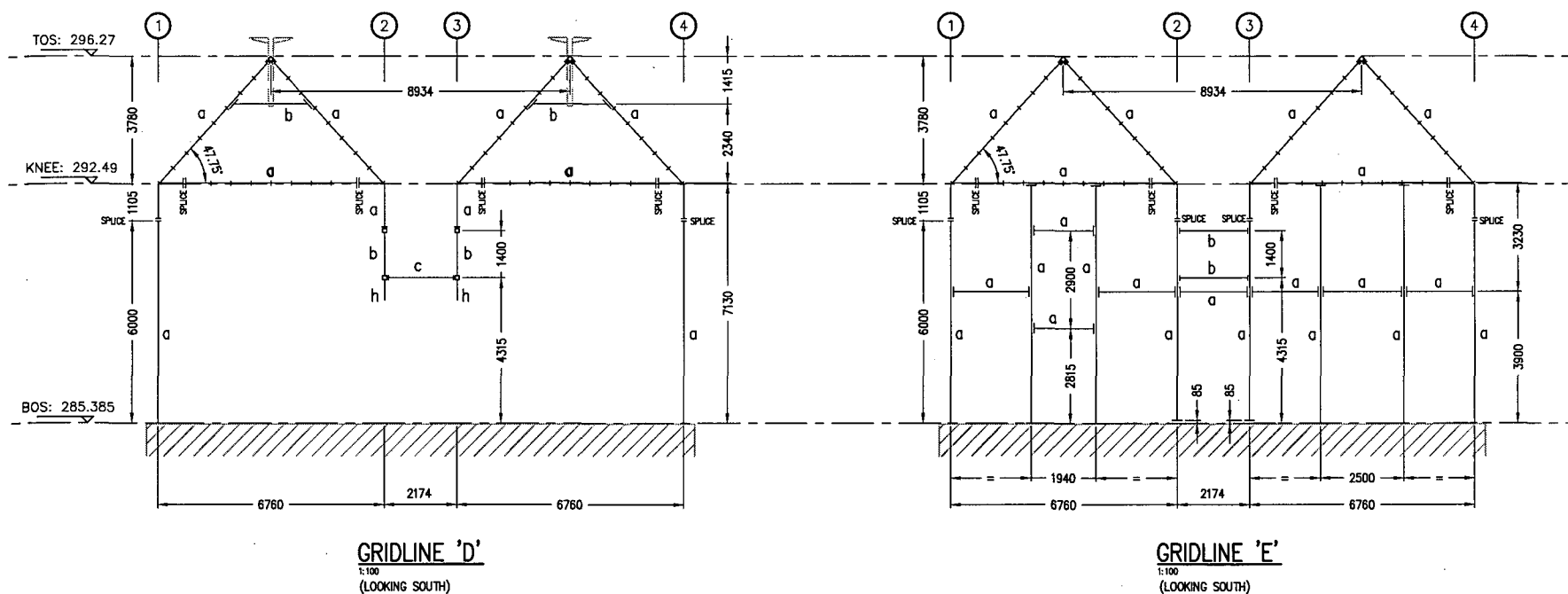
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**STRUCTURAL STEEL
PLANS**

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drawing number 5138 - S151	rev. 2

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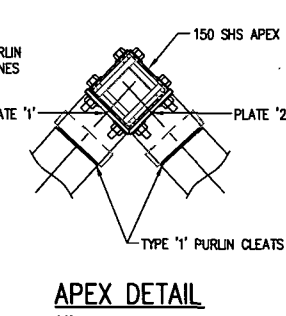
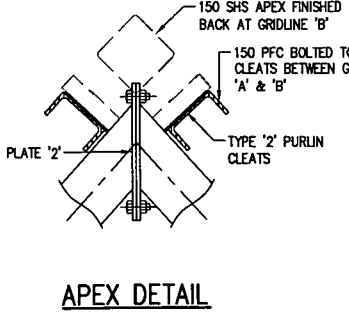
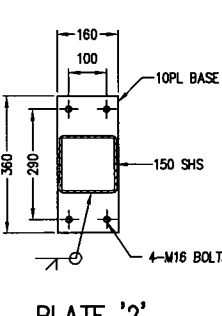
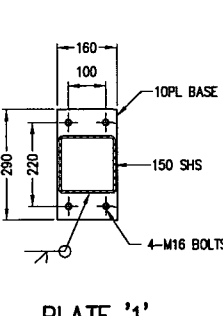
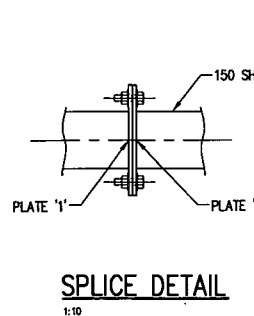
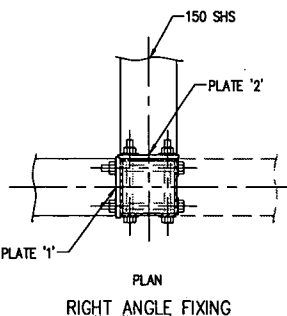
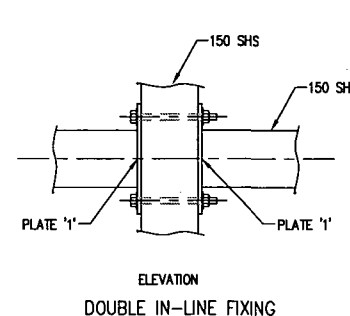
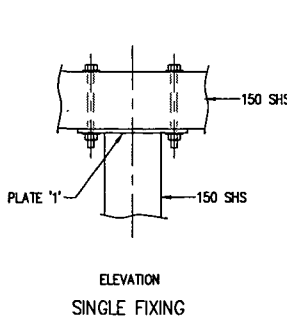
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KEY:

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b	125x125x5 SHS
c	32NB SCH40 (SITE CHECK)
d	310UB32
e	RB20 REIDBRACE
f	#16 M/S ROD
g	#20 M/S ROD
h	100x100x5 SHS



STD. 150 SHS JOINTS
1:10

no	date	issue/revision detail	by	chk
2	6/12/07	GRIDLINES MODIFIED	MJ	PF
1	15/10/07	FOR CONSTRUCTION	MJ	PF
T	20/8/07	FOR TENDER	MJ	PF
A	3/8/07	PRELIMINARY	MJ	PF

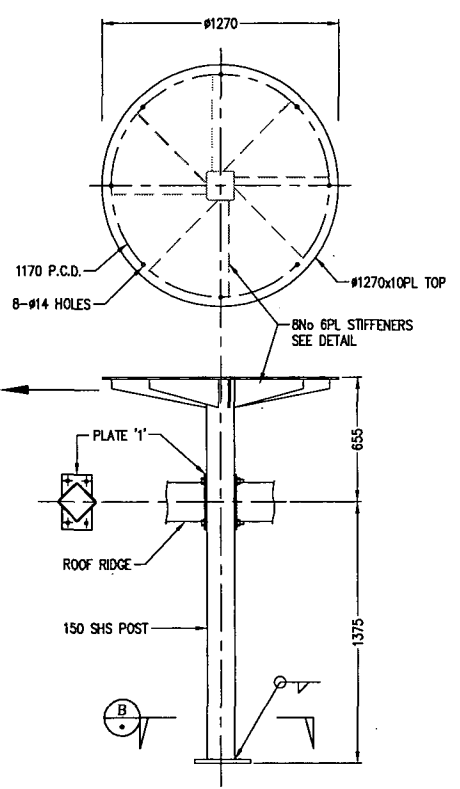
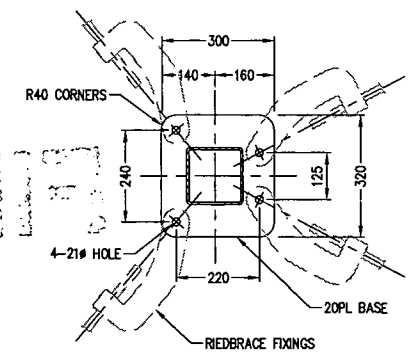
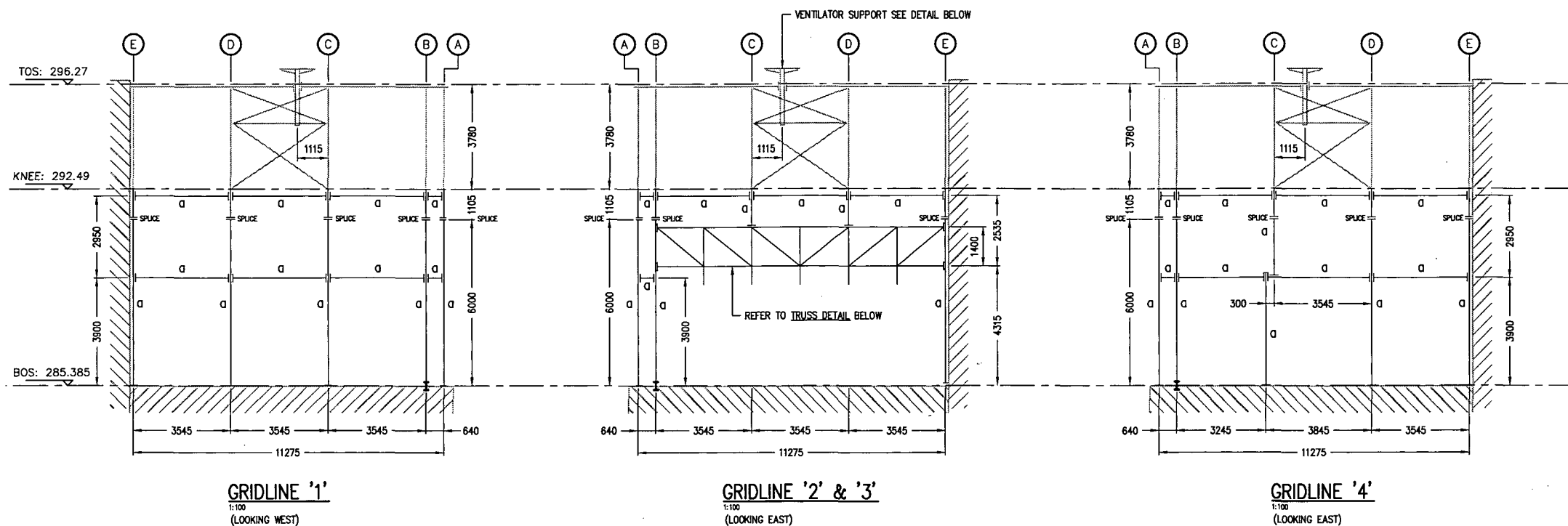
client
**ROTORUA TRUST GALLERY
CENTENNIAL DEVELOPMENT
NORTH WING**

project
**PROPOSED NORTH
WING EXTENSION**

drawing title
**STRUCTURAL STEEL
ELEVATIONS**

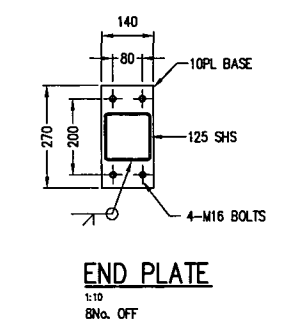
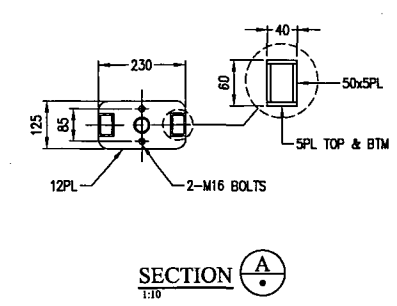
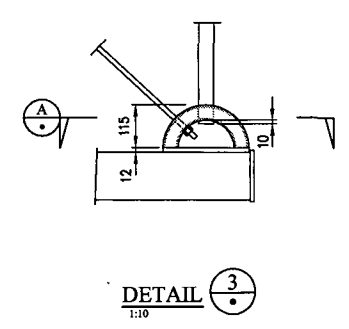
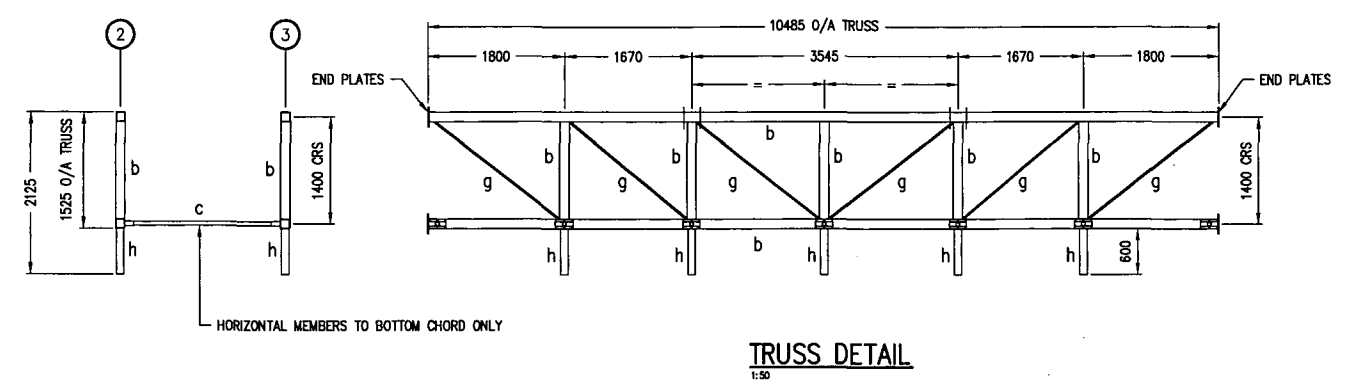
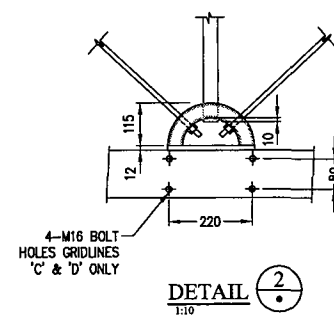
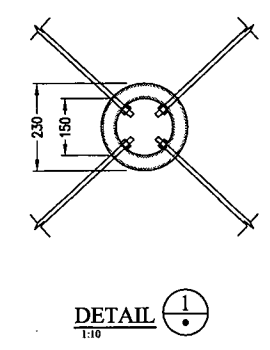
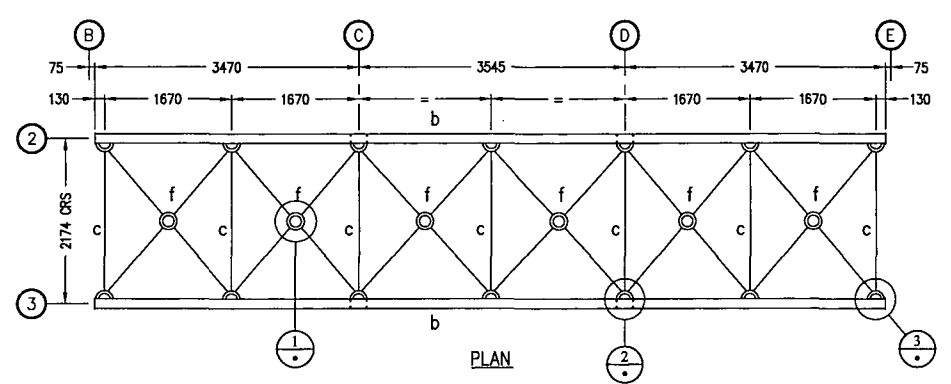
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drawing number	5138 - S152
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KEY:

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b	125x125x5 SHS
c	32NB SCH40 (SITE CHECK)
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e	RB20 REIDBRACE
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g	Ø20 M/S ROD
h	100x100x5 SHS



no	date	issue/revision detail	by	chk
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1	15/10/07	FOR CONSTRUCTION	MJ	PF
U	20/9/07	NOTICE TO TENDER	MJ	PF
T	20/8/07	FOR TENDER	MJ	PF
A	3/8/07	PRELIMINARY	MJ	PF

client
**ROTORUA TRUST GALLERY
CENTENNIAL DEVELOPMENT
NORTH WING**

project
**PROPOSED NORTH
WING EXTENSION**

drawing title
**STRUCTURAL STEEL
ELEVATIONS**

Scale
As Shown @ 'A1'

File Number
W:\5000\5138\Structure\5138-S150

drawing number
5138 - S153

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APPENDIX B2 - INVESTIGATION RESULTS

GEOLOGY Soil / Rock Type Stratigraphy	DESCRIPTION OF SOIL	GROUNDWATER	DEPTH (m)	GRAPHIC LOG	SHEAR VANE TEST RESULTS ● Peak × Residual	SCALA TEST RESULTS (blows/50mm)
FILL	Mixed SILT and GRAVEL, firm to loose, dark grey.					
TOPSOIL	SAND, gravelly, loose, brown becoming light grey, moist, pumiceous.					
LAKE SEDIMENTS	Core loss; contact not seen.					
ALTERED SEDIMENTS AND THIN TUFFS	SILT, soft, non plastic, light brown becoming black, wet, very slight sulphurous odour. - very thin sand layer					
	SAND, coarse, silty, loose, dark grey, moist, relic mucie gravel appearance, distinct sulphurous odour.					
	Core loss.					
	SAND, coarse, silty, loose, dark grey, moist, relic mucie gravel appearance, distinct sulphurous odour.					
	SILT, minor fine sand, soft, non plastic, grey with white flecks, minor sulphurous odour. - with sand, greenish grey with grey flecks. Core very soft - expanding in tube - no sand, soft to firm - grey, dries rapidly to become powdery - fine sandy, firm, greenish grey - sand becomes coarse					
	SILT, sandy, firm, non plastic, greenish grey, very slight sulphurous odour.					
SINTER	SANDSTONE, moderately weak to moderately strong, grey, with pumice gravel, cemented.					
INTERBEDDED ALTERED SEDIMENTS AND SINTER	Core loss. Driller reported softer ground from approximately 8.6m depth.					
	SAND, silty, dense, moderately well developed very thin banding, subhorizontal, grey and greenish grey, slight sulphurous odour.					
	Interbedded SANDSTONE and SILT, moderately well developed thin bedding, some sulphurous odour.					
	SANDSTONE: silty, moderately weak to moderately strong, greenish grey.					
	SILT: with fine sand, hard, non plastic, grey stained black.					
	SILT, with fine sand, hard, non plastic, grey stained black.					
	SANDSTONE, fine to coarse, moderately weak, dark grey speckled light grey, slight sulphurous odour.					
	SANDSTONE becomes moderately strong, greenish grey, speckly light grey.					
	SANDSTONE, coarse, poorly developed banding.					
	Cemented layer.					
	SILT, sandy, very stiff, greenish grey, non plastic.					
	Core loss					
	END OF HOLE at 13.5 m.					
REMARKS					DATE DRILLED 30/10/07	DRILLED BY Perry Drilling Ltd
						LOGGED BY ajc

GEOLOGY Soil / Rock Type Stratigraphy	DESCRIPTION OF SOIL	GROUNDWATER	DEPTH (m)	GRAPHIC LOG	SHEAR VANE TEST RESULTS					SCALA TEST RESULTS (blows/50mm)							
					● Peak X Residual	0	50	100	150	200	250	0	2	4	6	8	10
PAVEMENT	Pavement, top 25mm chipseal, hard fill to 0.25m.																
FILL	Mixed SILT and coarse SAND, firm, brown/grey/light brownish grey, wet, very dilatent. Contact at base not evident.																
LAKE SEDIMENTS WITH THIN TUFFS	SAND, gravelly, loose to medium dense, brown becoming brownish grey, pumiceous, slight sulphurous odour.																
	Core loss, contact not seen.																
	GRAVEL, silty, sandy, medium dense, grey, very warm.																
	SILT, gravelly, some sand, core is remoulded but appears stiff in situ, grey and light brown, slight sulphurous odour. - harder drilling																
SINTER	SANDSTONE, fine, moderately weak.																
	Core loss, jamming in core catcher.																
	SANDSTONE, fine, moderately weak.																
	Interbedded SILTSTONE and fine GRAVEL. SILTSTONE: fine sandy, moderately weak to moderately strong, dark grey. Fine GRAVEL: dense to "loose", grey, with occasional rounded pumice gravels.																
	Core loss, seems to be within soft layers. Slight sulphurous odour only.																
	Interbedded SILTSTONE and fine GRAVEL. SILTSTONE: fine sandy, moderately weak to moderately strong, dark grey. Fine GRAVEL: dense to "loose", grey, with occasional rounded pumice gravels. - gravels become cemented/weak																
	Core loss.																
	Interbedded SILTSTONE and fine GRAVEL. Hard, uncemented. SILTSTONE: fine sandy, moderately weak to moderately strong, dark grey. Fine GRAVEL: dense to "loose", grey, with occasional rounded pumice gravels.																
	Interbedded SILTSTONE and fine GRAVEL. Weak, cemented. SILTSTONE: fine sandy, moderately weak to moderately strong, dark grey. Fine GRAVEL: dense to "loose", grey, with occasional rounded pumice gravels.																
	Core loss.																
END OF HOLE at 12 m.																	
REMARKS Distinctly better ground conditions than MB2.					DATE DRILLED 30/10/07		DRILLED BY Perry Drilling Ltd		LOGGED BY ajc								

GEOLOGY Soil / Rock Type Stratigraphy	DESCRIPTION OF SOIL	GROUNDWATER	DEPTH (m)	GRAPHIC LOG	SHEAR VANE TEST RESULTS					SCALA TEST RESULTS (blows/50mm)								
					● Peak X Residual	0	50	100	150	200	250	0	2	4	6	8	10	
PAVEMENT	Chipseal; GRAVEL, sandy, dense, brown.																	
FILL	Mixed GRAVEL and SILT																	
VOLCANIC ASH	SILT, fine sandy, firm to stiff, brown, wet, sensitive.																	
ALTERED LAKE SEDIMENTS WITH TUFF LAYERS AND SINTER	Core loss.		1															
	GRAVEL, minor sand, loose, brown, becoming grey, pumiceous, slight sulphurous odour.																	
	SILT, minor fine sand, firm, grey with greenish tint, sensitive.		2															
	Core loss.																	
	SILT, minor fine sand, firm, greenish grey, sensitive. - some fine gravel, distinct sulphurous odour, greenish grey with white mottles (relic gravels)		3															
			4															
			5															
	SILT, clayey, firm to stiff, medium to high plasticity, light grey, becoming grey with greenish tint.																	
			6															
	SILT, sandy, gravelly, stiff, greenish grey.																	
	Interbedded SILT (very stiff) and SANDSTONE (moderately strong), greenish grey, sub horizontal moderately thick well developed banding, slight sulphurous odour.		7															
			8															
			9															
	Core loss.																	
	Interbedded SILT, GRAVEL and SANDSTONES. SILTS: light grey to grey, stiff, low to medium plasticity. GRAVEL and SANDSTONES: moderately strong, sub horizontal contacts, slightly sulphurous odour.		10															
	Gravelly SANDSTONE, strong, light grey, weak sulphurous odour, becomes coarse with depth up to 12m.		11															
			12															
	SILT, sandy, low plasticity, stiff, sub horizontal, moderately thick banding, greenish grey, weak to slight sulphurous odour.		13															
	END OF HOLE at 13.5 m.		14															
REMARKS					DATE DRILLED		DRILLED BY		LOGGED BY									
					31/10/07		Perry Drilling Ltd		ajc/epd									

GEOLOGY Soil / Rock Type Stratigraphy	DESCRIPTION OF SOIL	GROUNDWATER	DEPTH (m) GRAPHIC LOG	SHEAR VANE TEST RESULTS ● Peak × Residual	SCALA TEST RESULTS (blows/50mm)
FILL	Core loss.				
	SILT, sandy, some gravel, soft to firm, low plasticity, dark brown to black.				
ALTERED LAKE DEPOSITS WITH TUFF LAYERS	Mixture of black SILT with light brown, pink and white silts. Soft to firm, highly sensitive. Interlayering of altered pumice GRAVEL (moderately strong) and altered white SILT (low plasticity, soft to firm).				
ALTERED LAKE DEPOSITS	SILTS, very sensitive, firm, dark brown/brown/white/greenish white. - becomes gravelly Core sample. SILT, highly sensitive, firm, grey/brown/light brown mixed (mottled). No plasticity, strong sulphurous odour. SILT, sandy, highly sensitive, firm to stiff, blueish grey/grey mixture. Core sample.				
ALTERED LAKE DEPOSITS WITH TUFF LAYERS ALTERED LAKE DEPOSITS	SILT, sandy, highly sensitive, firm to stiff, blueish grey/grey mixture. SILT, slightly gravelly (altered gravels, weak), highly sensitive, firm to stiff, light grey. SILT, clayey, sensitive, firm to stiff, moderately strong sulphurous odour, light grey. Altered layers, stiff. Core sample.				
	SILT, clayey, sensitive, firm to stiff, moderately strong sulphurous odour, light grey.				
	SILT, clayey, high plasticity, stiff, low sensitivity, blueish grey, strong sulphurous odour.				
	SILT, clayey, extremely stiff, some hard (altered) layers, medium plasticity, crumbly, light grey.				
	END OF HOLE at 10.5 m.				
REMARKS					
				DATE DRILLED 31/10/07	DRILLED BY Perry Drilling Ltd LOGGED BY epd

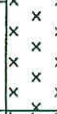
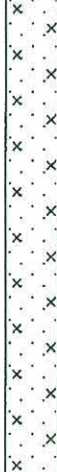
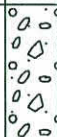
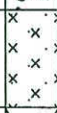
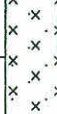
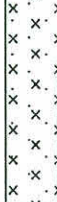
CLIENT Rotorua District Council

BOREHOLE No. MB10 Sheet 1 of 1

PROJECT Rotorua Museum - Existing Building Remedial Works

JOB NO. 3278.02

LOCATION Rotorua Museum, Government Gardens, Rotorua

STRATIGRAPHY	SOIL/ROCK DESCRIPTION	GRAPHIC LOG	DEPTH (m)	GROUNDWATER	SPT RESULT	CORE LOSS %	DRILLING METHOD	SAMPLES/ LAB TEST DETAILS
CONCRETE SINTER	CONCRETE, pumiceous, lots of small voids, small amount of orange discolouration within the pumice SINTER, lots of small voids, very strong, evidence of petrified wood at base of core SILT, slightly clayey, high plasticity, light brown, moist SINTER, cemented sand/gravel, lots of voids, very hard					5 -10 -50		
LAKE SEDIMENTS	SILT, slightly clayey, diatomaceous, no plasticity, moist		1					
	SAND, some silt, fine-medium grained sand, pumiceous, sulphurous odour, light grey, moist - becomes fine-coarse grained, no silt, brown - becomes grey - becomes fine grained, slightly silty - becomes fine-coarse grained, no silt, temperature = 32 degrees - becomes medium-coarse grained - temperature = 44 degrees		2 3					
ERUPTION BRECCIA	Sandy GRAVEL, coarse sand, subangular gravel to 30mm, pumiceous, grey		4					
HIGHLY WEATHERED SAND	Sandy SILT, some gravel, grey, saturated							
	No recovery							
	Sandy SILT, medium-coarse grained sand, some gravel, grey, saturated		5					
	SILT, some fine grained sand, stiff, no-low plasticity, massive, grey, sulphurous odour		6					
SINTER	SAND, dense, grey, becoming cemented END OF HOLE at 6.55 m.							
NOTES					STARTED 31/8/09	DRILLER Boart Longyear	LOGGED BY ajc/rm	
					FINISHED 31/8/09	PLANT USED	CHECKED BY	

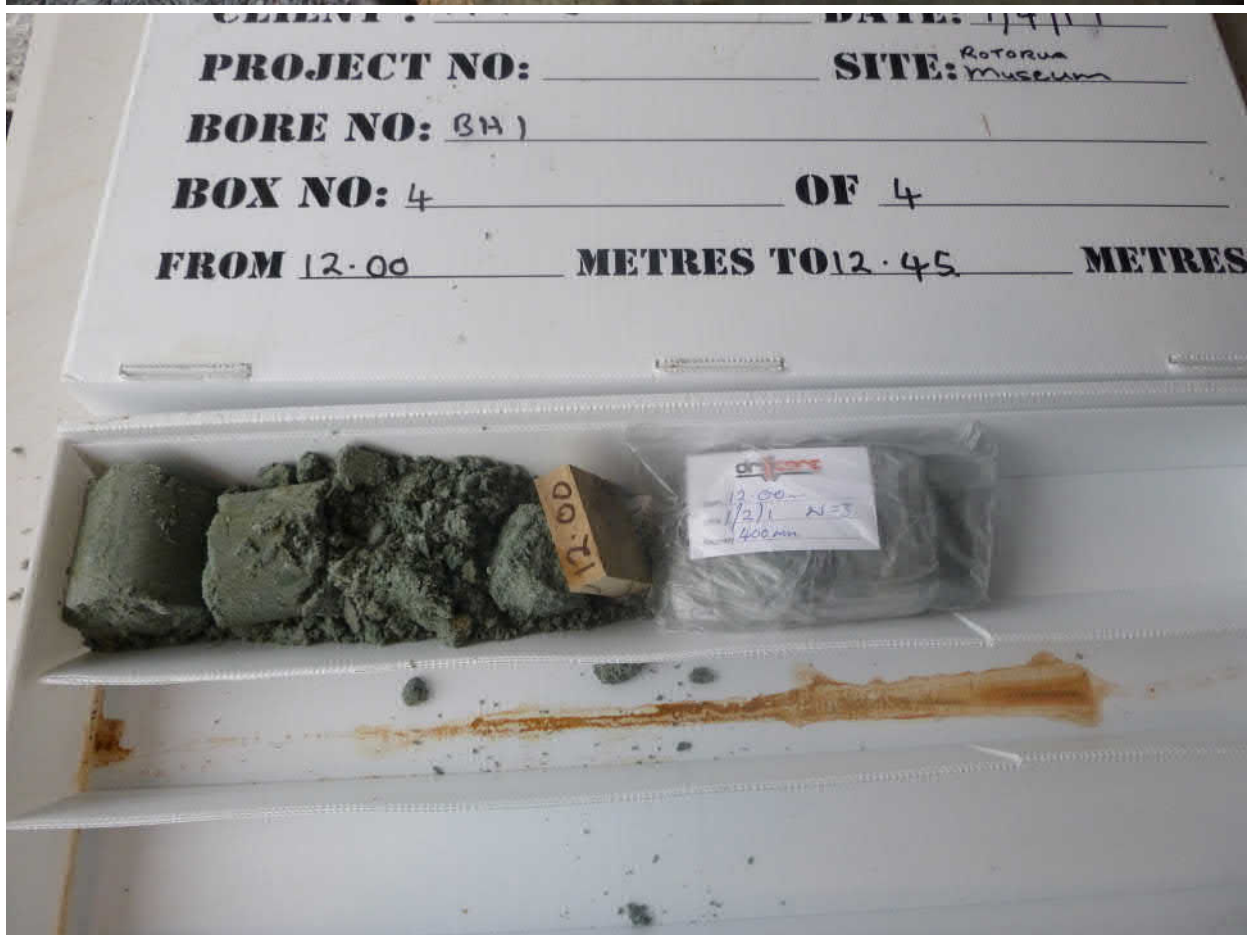
Bore: BH01		Borehole Logging Record					cheal	
Project no.: 16592			Drilling Date: 07 April 2017			Drilled Depth: 12.45 (mBGL)		
Project Name: Rotorua Lakes Council			Coordinates: 381862.4 E : 758460.8 N			Drilling Company: Drillcore		
Location: Rotorua			Ground Elevation: 283.266 (mRL)			Drilling Method: HQ		
Depth (mBGL)	R.L. (m)	Recovery (%)	Graphic Log	Soil or Rock Field Material Description	SPT (blows/300mm)	Undrained Shear Strength	In situ/ Lab Test	Geological unit
0.0	283	100		Topsoil, sandy SILT with some coarse pumice sand, dark brown, firm, moist, non plastic Sinter (siliceous), dark brown, cemented, moist				Topsoil
				Fine to medium SAND with minor fine pumice gravel, brown, moist				Sinter
1.0		99		SILT, light yellow, firm to stiff, moist, non plastic				Holocene river deposits
		100		Fine SAND, light grey, moist, uniformly graded	△		SPT (4),1,0 N=1 Push Tube	Holocene river deposits
2.0	281	100		Sandy SILT, greenish grey, firm, wet, low plastic, moderate sensitive				Holocene river deposits
		100		Coarse SAND with minor pumice gravel, greenish grey, medium dense, moist	△		SPT (4),3,3 N=6	Holocene river deposits
3.0		100		Sandy fine pumice GRAVEL, grey, medium dense, wet, well graded	△			Holocene river deposits
4.0	279	100		Sandy medium to coarse pumice GRAVEL, medium dense, wet, well graded			SPT (622),1,3 N=4	Holocene river deposits
5.0		100		Sandy SILT, grey, firm, moist, non plastic	△		SPT (5),7,7 N=14	Holocene river deposits
6.0	277	100		Cemented sandy SILT (altered pumice), light grey, very stiff to hard, wet				Holocene river deposits
		100		Sandy SILT (altered pumice), light grey, firm to stiff, saturated with strong sulphur odour				Holocene river deposits
7.0		100		Cemented sandy SILT (altered pumice), light grey, very stiff to hard, wet				Holocene river deposits
		100		Silty SAND with minor fine pumice gravel, dark greenish brown, dense, saturated Silty fine SAND, grey, dense, wet			SPT (17),23,13 N=36	Holocene river deposits
8.0	275	72.3		Cemented fine SAND with minor pumice gravel, grey, medium dense to dense, saturated				Holocene river deposits
		100		Fine SAND with some pumice gravel, dark grey, medium dense, saturated	△		SPT (6),8,13 N=21	Holocene river deposits
9.0		100						Holocene river deposits
10.0		100						Holocene river deposits

Bore: BH01		Borehole Logging Record				cheal		
Project no.: 16592		Drilling Date: 07 April 2017		Drilled Depth: 12.45 (mBGL)				
Project Name: Rotorua Lakes Council		Coordinates: 381862.4 E : 758460.8 N		Drilling Company: Drillcore				
Location: Rotorua		Ground Elevation: 283.266 (mRL)		Drilling Method: HQ				
Depth (mBGL)	R.L. (m)	Recovery (%)	Graphic Log	Soil or Rock Field Material Description	SPT (blows/300mm)	Undrained Shear Strength	In situ/ Lab Test	Geological unit
					0 10 20 30 40 50	0 50 100 150 200 250		
	273	100		Cemented fine SAND with some pumice gravel, dark grey, dense, saturated				
		100		Silty pumice SAND, greenish grey, loose, saturated	△		SPT (0),0,2 N=2	Holocene river deposits
11.0		100						Holocene river deposits
		100						
		100		Silty pumice SAND, greenish grey, loose to dense, saturated, cemented with depth				
12.0		100						
	271				△		SPT (1),2,1 N=3	Holocene river deposits
				EOB 12.45m				

BH01: Box01 (0-4.35m) and Box02 (4.35-8.05m)



BH01: Box03 (8.05-11.87m) and Box04 (11.87-12.45m)



cheat

Drilling Method: HO

Borehole was drilled inclined 30° from vertical line

BH02: Box01 (0-2.6m) and Box02 (2.6-5.5m)



BH02: Box03 (5.5-8.5m)



Bore: BH03		Borehole Logging Record					cheal		
Project no.: 16592			Drilling Date: 05 April 2017			Drilled Depth: 16.3 (mBGL)			
Project Name: Rotorua Lakes Council			Coordinates: 381830 E : 758359.2 N			Drilling Company: Drillcore			
Location: Rotorua			Ground Elevation: 283.39 (mRL)			Drilling Method: HQ			
Depth (mBGL)	R.L. (m)	Recovery (%)	Graphic Log	Soil or Rock Field Material Description	SPT (blows/300mm)	Undrained Shear Strength	In situ/ Lab Test	Geological unit	
0.0	283	100		Topsoil, silty fine SAND with some pumice, brownish black				Topsoil	
				Sandy SILT with some coarse pumice sand and some ash, dark brown to black, dense, moist, slight sulphur odour					Holocene river deposit
				Sinter (siliceous), yellowish grey, cemented, wet					
1.0	281	N/R		SILT with traces of coarse pumice sand, orange and grey, soft, moist, moderate plastic, sensitive, sulphur odour				Holocene river deposit	
		100		Core loss					Push Tube
		100		SILT with traces of coarse pumice sand, yellowish grey to grey, very soft to soft, moist to wet, high plastic, moderate sensitivity, slight sulphur odour (altered sediments)			X	Holocene river deposit	
2.0	279	100		Core loss				Push Tube	
		100		Gravelly pumice SILT, dark grey to black, soft, wet, non plastic (altered sediments)					Holocene river deposit
		100		SILT with some fine sand, dark grey, very soft to soft, saturated, non plastic, extra sensitive (altered sediments)					
3.0	277	N/R		Core loss				LL=47, PI=11, FC=82%	
		54		SILT with some fine sand, dark grey, very soft to soft, saturated, non plastic, extra sensitive (altered sediments)					Holocene river deposit
		100		SILT with traces of fine sand, grey, firm to stiff, saturated, non plastic, insensitive (altered sediments)			X		
4.0	275	100		SILT with traces of fine sand, grey, firm to stiff, saturated, non plastic, insensitive (altered sediments)				LL=59, PI=19, FC=96%	
		100		Core loss					Push Tube
		100		Silty fine to coarse pumice SAND, greenish grey, saturated, sulphur odour (altered sediments)					
5.0	273	N/R		Core loss				SPT (1),1,2 N=3	
		100		Silty fine to coarse pumice SAND, greenish grey, saturated, sulphur odour (altered sediments)					LL=50, PI=6, FC=23%
		100		Silty fine pumice SAND with traces of coarse pumice sand, greenish grey, saturated, sulphur odour (altered sediments)					
6.0	271	100		Silty fine pumice SAND with traces of coarse pumice sand, greenish grey, saturated, sulphur odour (altered sediments)				LL=78, PI=37, FC=28%	
		100		Sinter (siliceous)					Push Tube
		72.3		Silty fine pumice SAND with traces of coarse pumice sand, greenish grey, saturated, sulphur odour (altered sediments)					
7.0	275	100		Silty fine pumice SAND with traces of coarse pumice sand, greenish grey, saturated, sulphur odour (altered sediments)				SPT (3),4,5 N=9	
		100		Sinter (siliceous)					Push Tube
		100		Silty fine pumice SAND with traces of coarse pumice sand, greenish grey, saturated, sulphur odour (altered sediments)					
8.0	275	100		Silty fine pumice SAND with traces of coarse pumice sand, greenish grey, saturated, sulphur odour (altered sediments)				SPT (3),4,5 N=9	
		100		Sinter (siliceous)					Push Tube
		100		Silty fine pumice SAND with traces of coarse pumice sand, greenish grey, saturated, sulphur odour (altered sediments)					
9.0	275	100		Silty fine pumice SAND with traces of coarse pumice sand, greenish grey, saturated, sulphur odour (altered sediments)				SPT (3),4,5 N=9	
		100		Sinter (siliceous)					Push Tube
		100		Silty fine pumice SAND with traces of coarse pumice sand, greenish grey, saturated, sulphur odour (altered sediments)					
10.0	275	100		Silty fine pumice SAND with traces of coarse pumice sand, greenish grey, saturated, sulphur odour (altered sediments)				SPT (3),4,5 N=9	
		100		Sinter (siliceous)					Push Tube
		100		Silty fine pumice SAND with traces of coarse pumice sand, greenish grey, saturated, sulphur odour (altered sediments)					

Bore: BH03		Borehole Logging Record					cheal	
Project no.: 16592			Drilling Date: 05 April 2017			Drilled Depth: 16.3 (mBGL)		
Project Name: Rotorua Lakes Council			Coordinates: 381830 E : 758359.2 N			Drilling Company: Drillcore		
Location: Rotorua			Ground Elevation: 283.39 (mRL)			Drilling Method: HQ		
Depth (mBGL)	R.L. (m)	Recovery (%)	Graphic Log	Soil or Rock Field Material Description	SPT (blows/300mm)	Undrained Shear Strength	In situ/ Lab Test	Geological unit
					0 10 20 30 40 50	0 50 100 150 200 250		
		N/R	X	Core loss				
	273	100	X	Sandy SILT with minor coarse pumice sand, greenish grey, stiff, saturated, non plastic, moderately sensitive, with thin interbedded layers of medium pumice sand (altered sediments)			Push Tube	Holocene river deposit
11.0		100	X				SPT (62),0,2 N=2	
		100	X					
12.0		100	X				SPT (0),1,0 N=1	
	271	89.5	X					
13.0		100	X				SPT (0),0,2 N=2	
				Sandy SILT with minor coarse pumice sand, greenish grey, stiff, saturated, non plastic, moderately sensitive, with interbedded layers of cemented medium pumice sand (altered sediments)				Holocene river deposit
14.0		99	X					
	269	100	X					
15.0		100	X	Sandy SILT with minor coarse pumice sand, greenish grey, stiff, saturated, non plastic, moderately sensitive (altered sediments)			SPT (0),0,1 N=1	Holocene river deposit
16.0		100	X	Cemented silty pumioce SAND with some medium pumice gravel, grey, dense, saturated (altered sediments)				Holocene river deposit
	267		X	EOB 16.3m				

BH03: Box01 (0-4.8m) and Box02 (4.8-9.5m)



BH03: Box03 (9.5-13.75m) and Box04 (13.75-16.3m)



GEOTECH DRILLING CONE PENETROMETER

PROJECT: ROTORUA MUSEUM EXT.

CPT No: 1

Cone No.: 5942

CLIENT: TERRANE LTD

LOCATION: ROTORUA

JOBNO: 3278

Date: 8 Jun 2007

Cone Range: 100 kN

Groundwater:

R.L.:

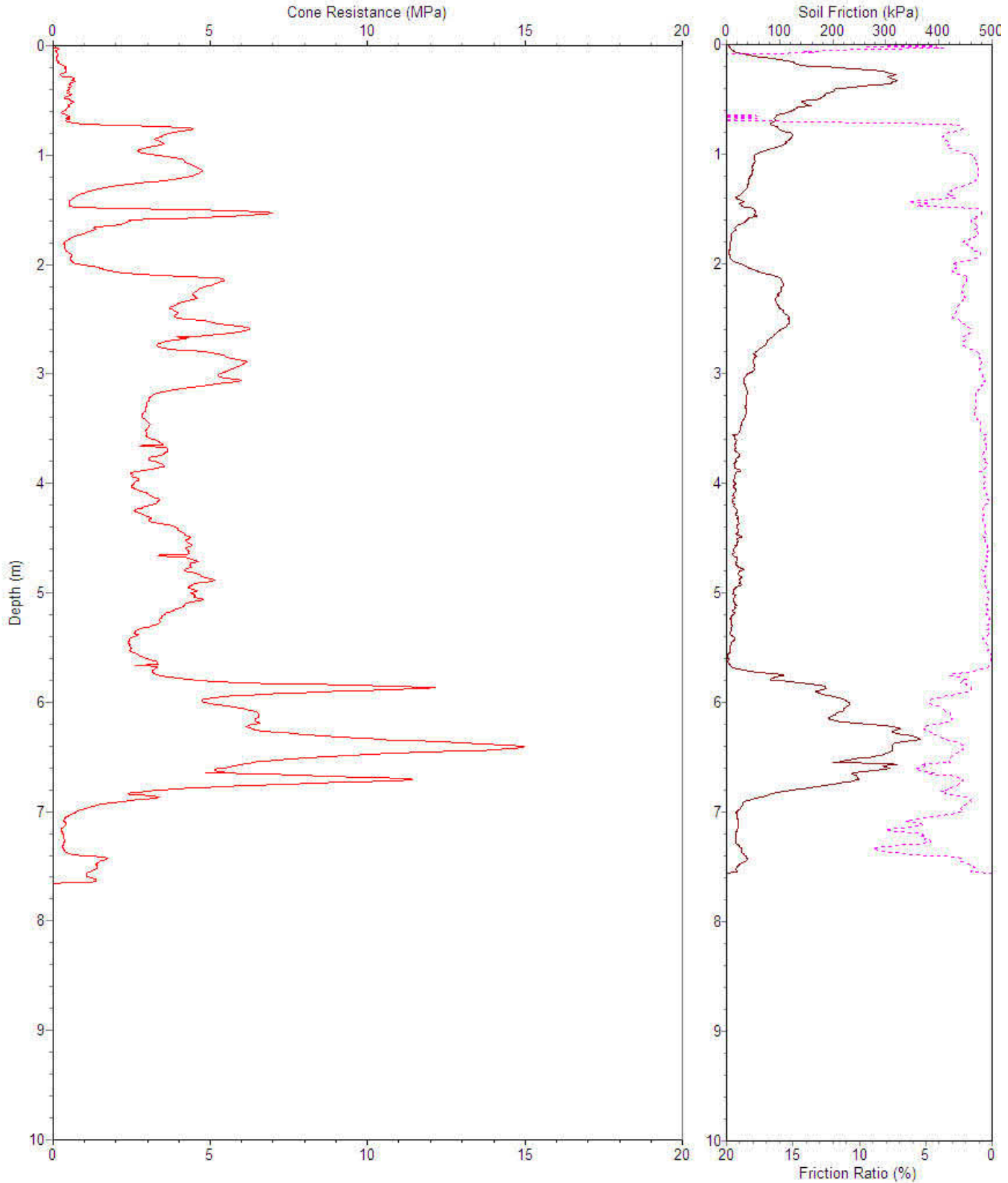
Operator: M BARNETT

Easting:

Datum:

Grid Ref:

Northing:



COMMENT:

GEOTECH DRILLING CONE PENETROMETER

PROJECT: ROTORUA MUSEUM EXT.

CPT No: 2

Cone No.: 5942

CLIENT: TERRANE LTD

LOCATION: ROTORUA

JOBNO: 3278

Date: 8 Jun 2007

Cone Range: 100 kN

Groundwater:

R.L.:

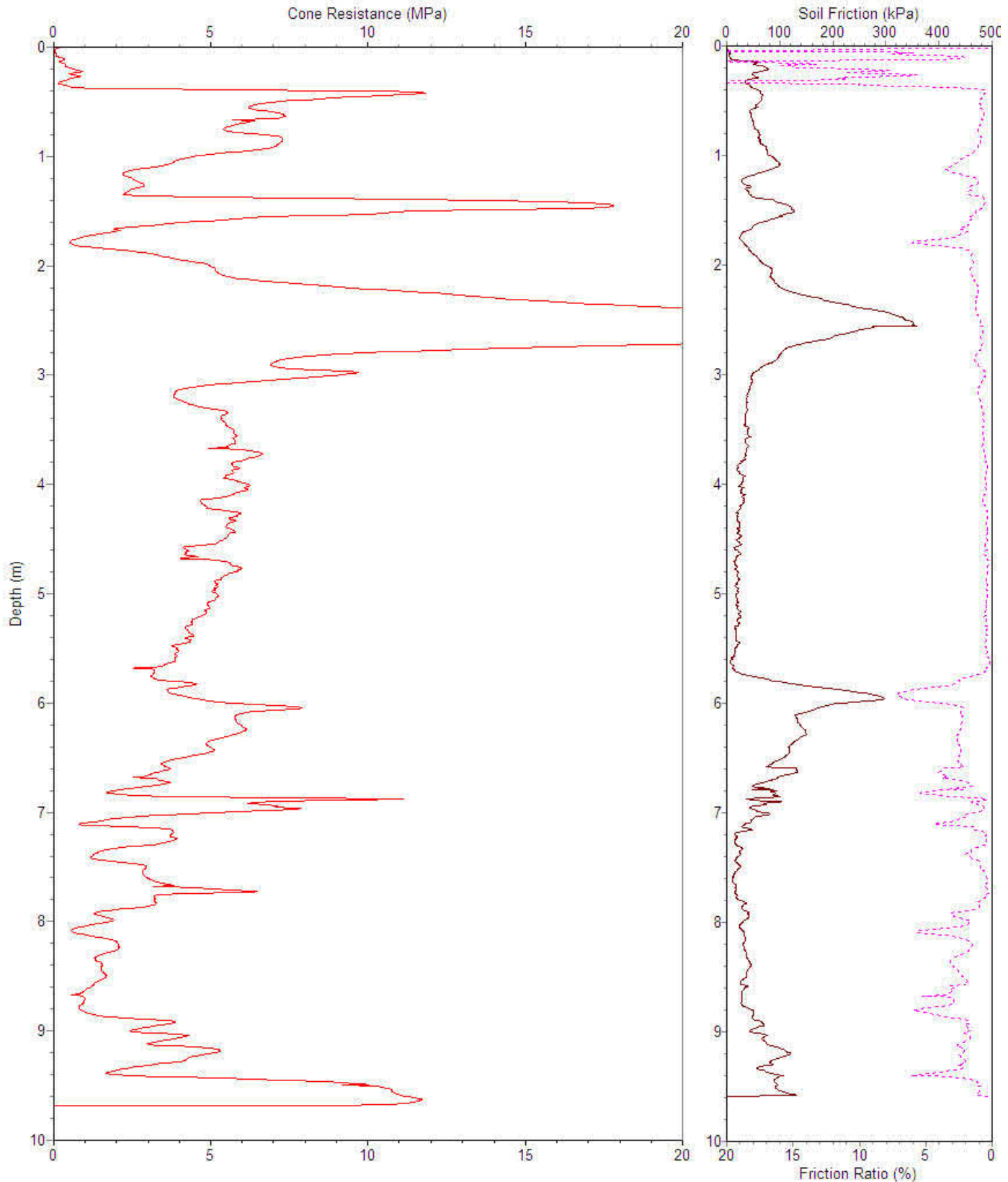
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Easting:

Datum:

Grid Ref:

Northing:



COMMENT:

GEOTECH DRILLING CONE PENETROMETER

PROJECT: ROTORUA MUSEUM EXT.

CPT No: 3

Cone No.: 5942

CLIENT: TERRANE LTD

LOCATION: ROTORUA

JOBNO: 3278

Date: 8 Jun 2007

Cone Range: 100 kN

Groundwater:

R.L.:

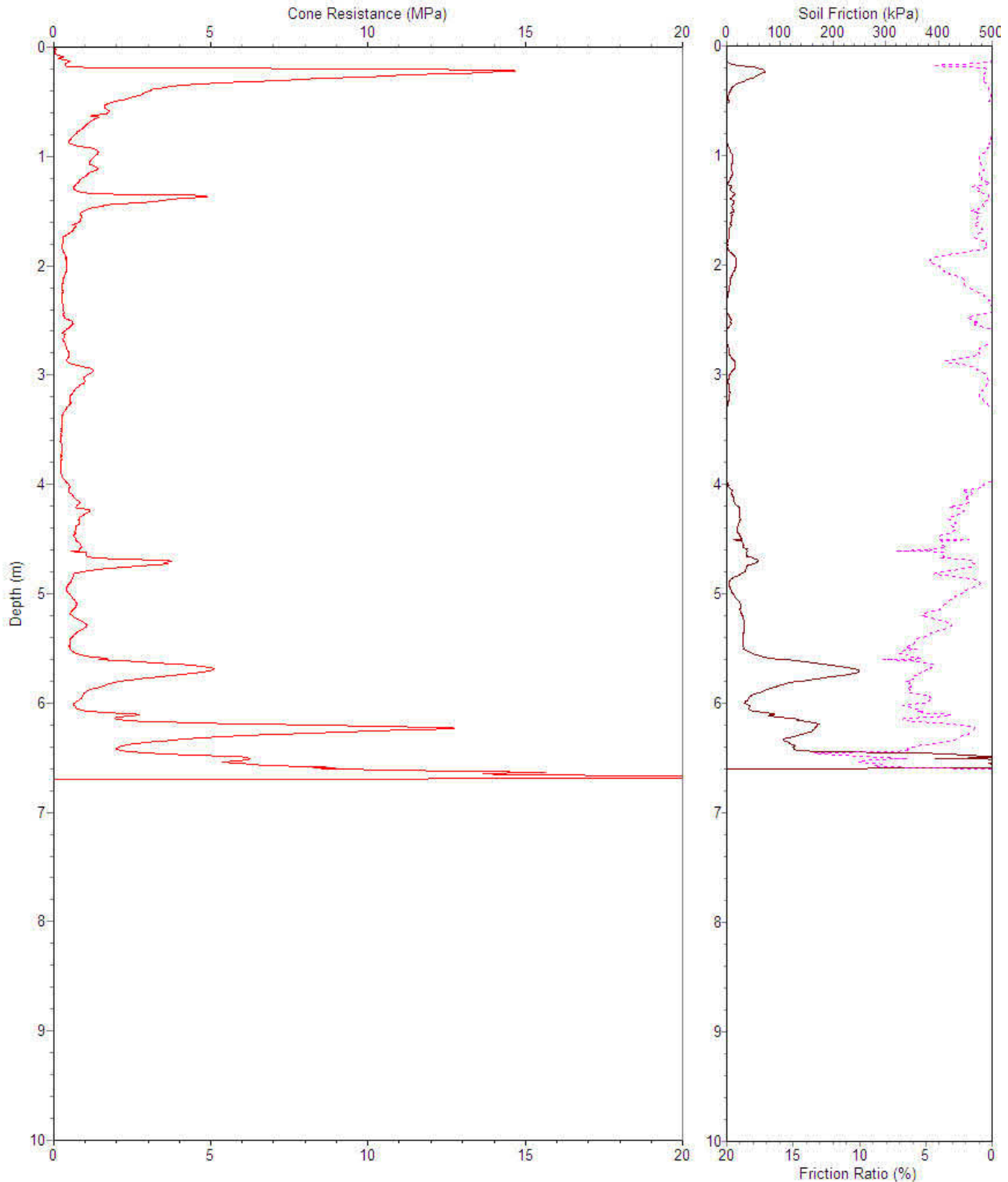
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Easting:

Datum:

Grid Ref:

Northing:



COMMENT:

GEOTECH DRILLING CONE PENETROMETER

PROJECT: ROTORUA MUSEUM EXT.

CPT No: 4

Cone No.: 5942

CLIENT: TERRANE LTD

LOCATION: ROTORUA

JOBNO: 3278

Date: 8 Jun 2007

Cone Range: 100 kN

Groundwater:

R.L.:

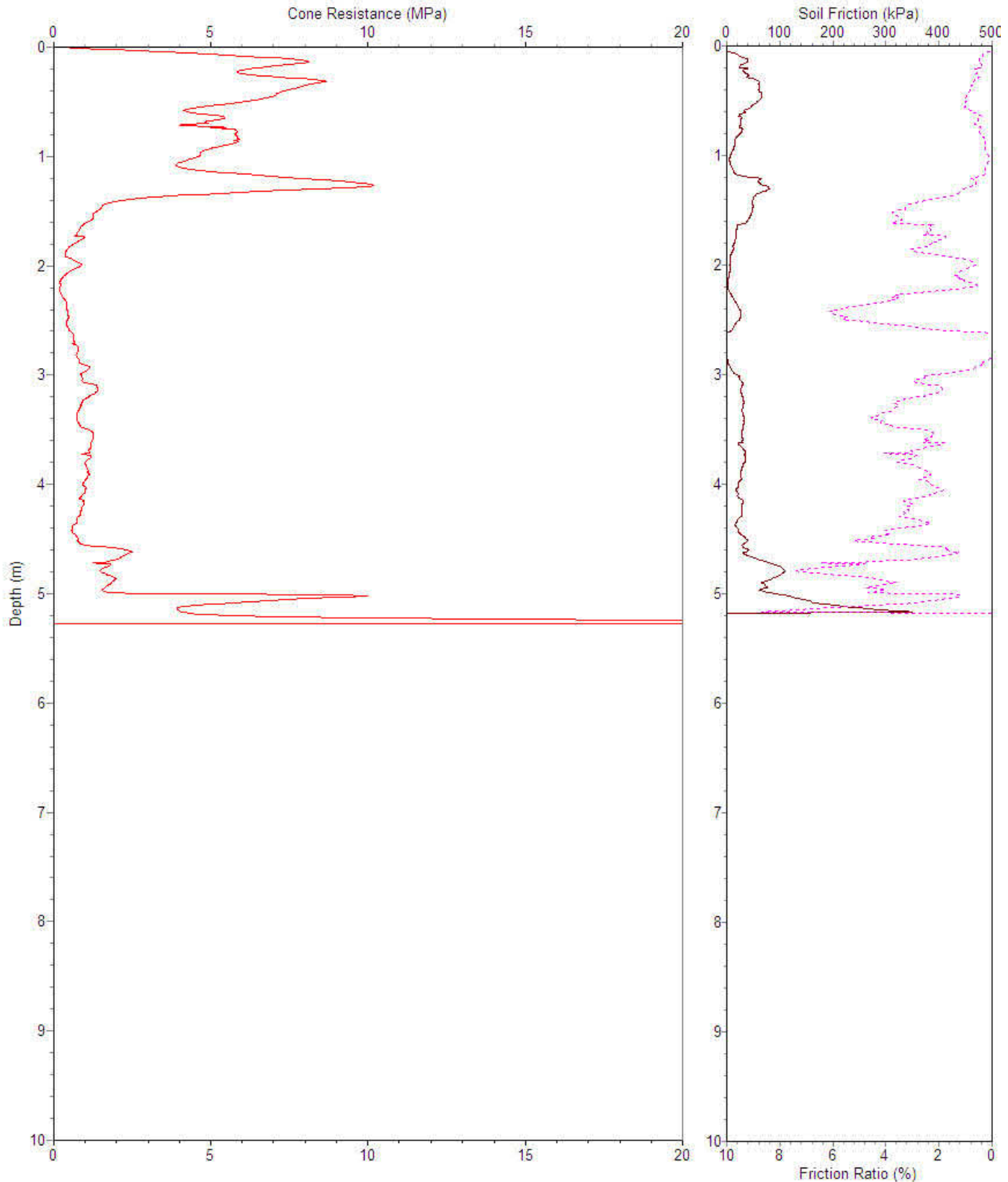
Operator: M BARNETT

Easting:

Datum:

Grid Ref:

Northing:



COMMENT:

GEOTECH DRILLING CONE PENETROMETER

PROJECT: ROTORUA MUSEUM EXT.

CPT No: 5

Cone No.: 5942

CLIENT: TERRANE LTD

LOCATION: ROTORUA

JOBNO: 3278

Date: 8 Jun 2007

Cone Range: 100 kN

Groundwater:

R.L.:

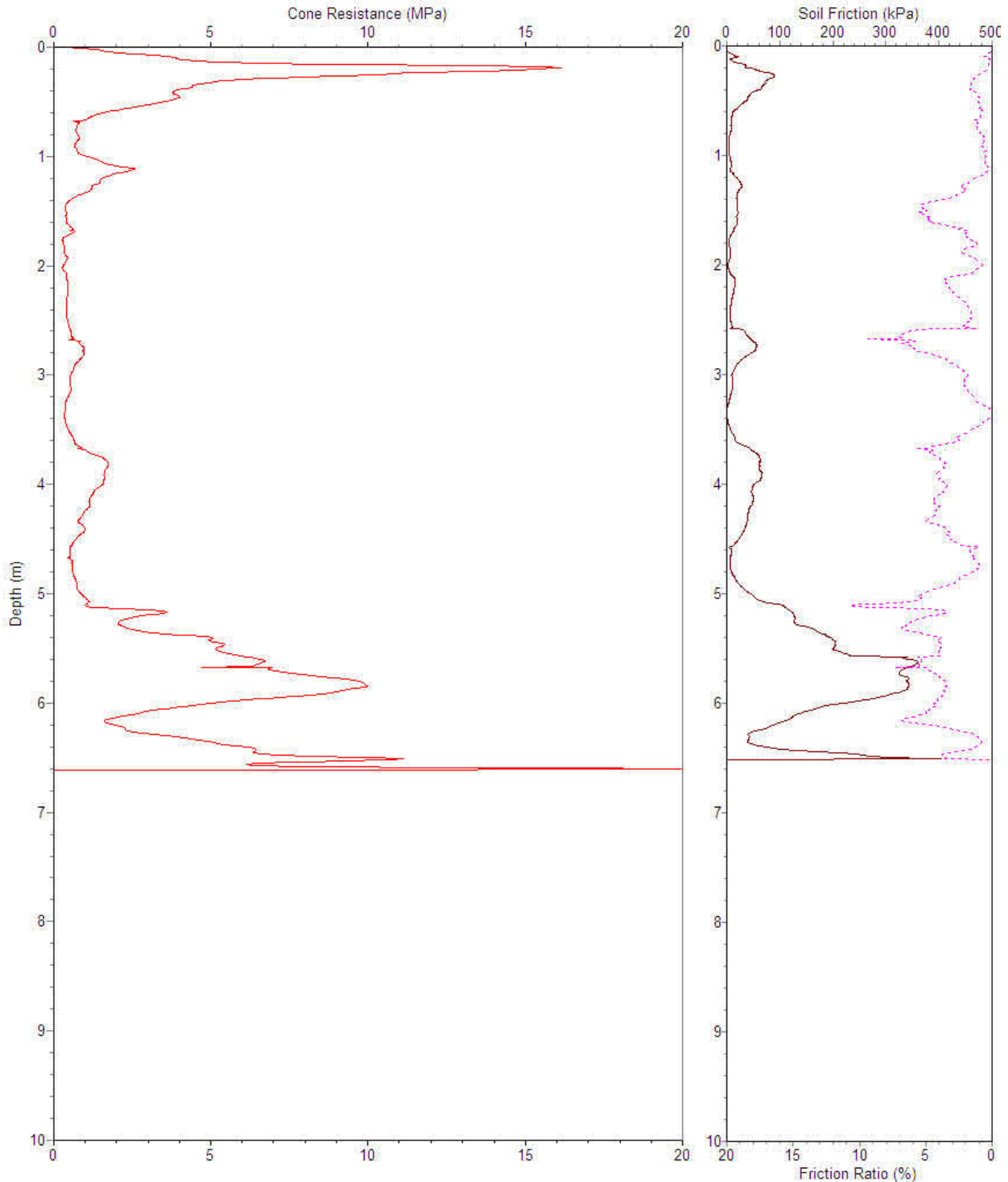
Operator: M BARNETT

Easting:

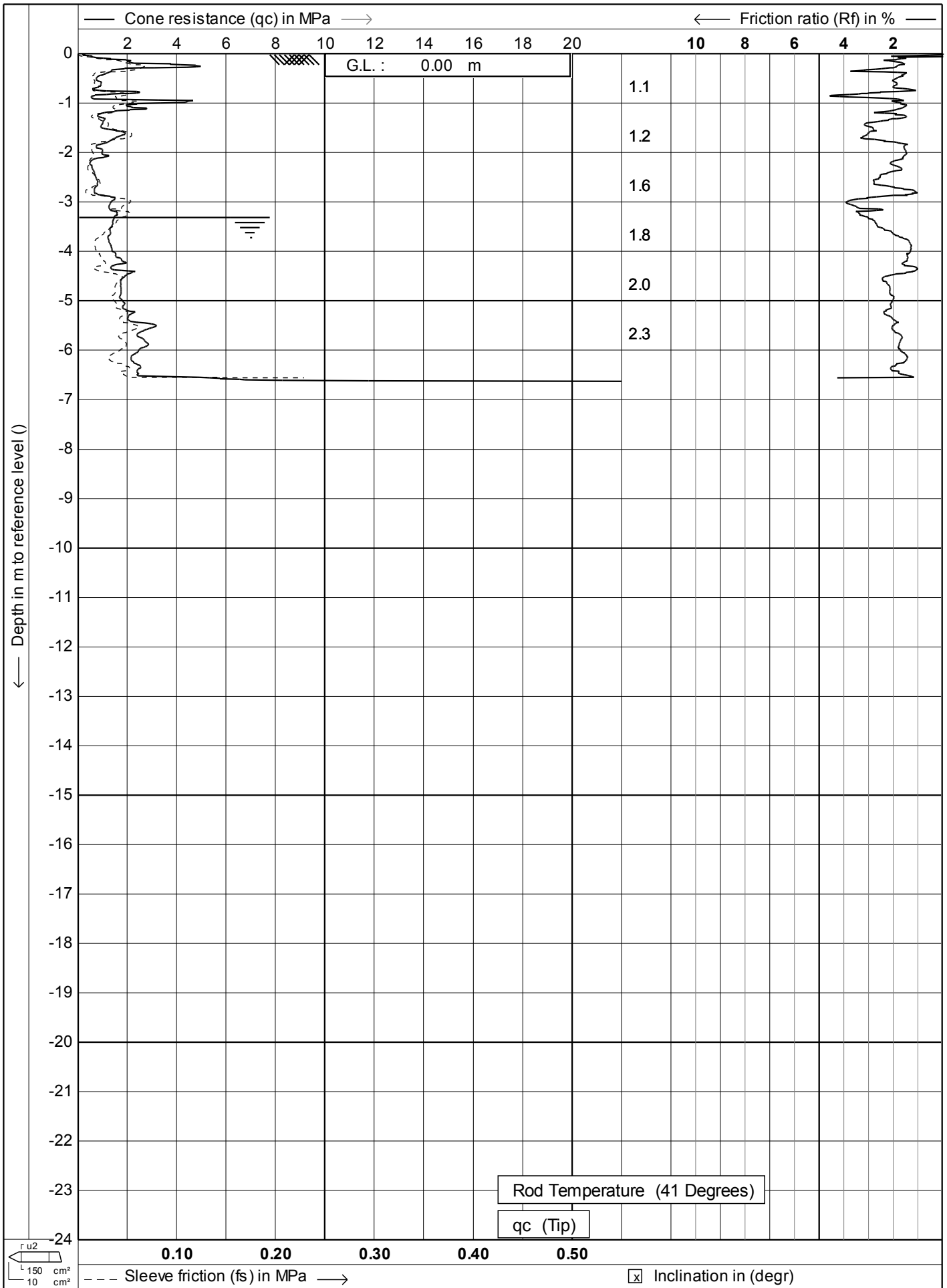
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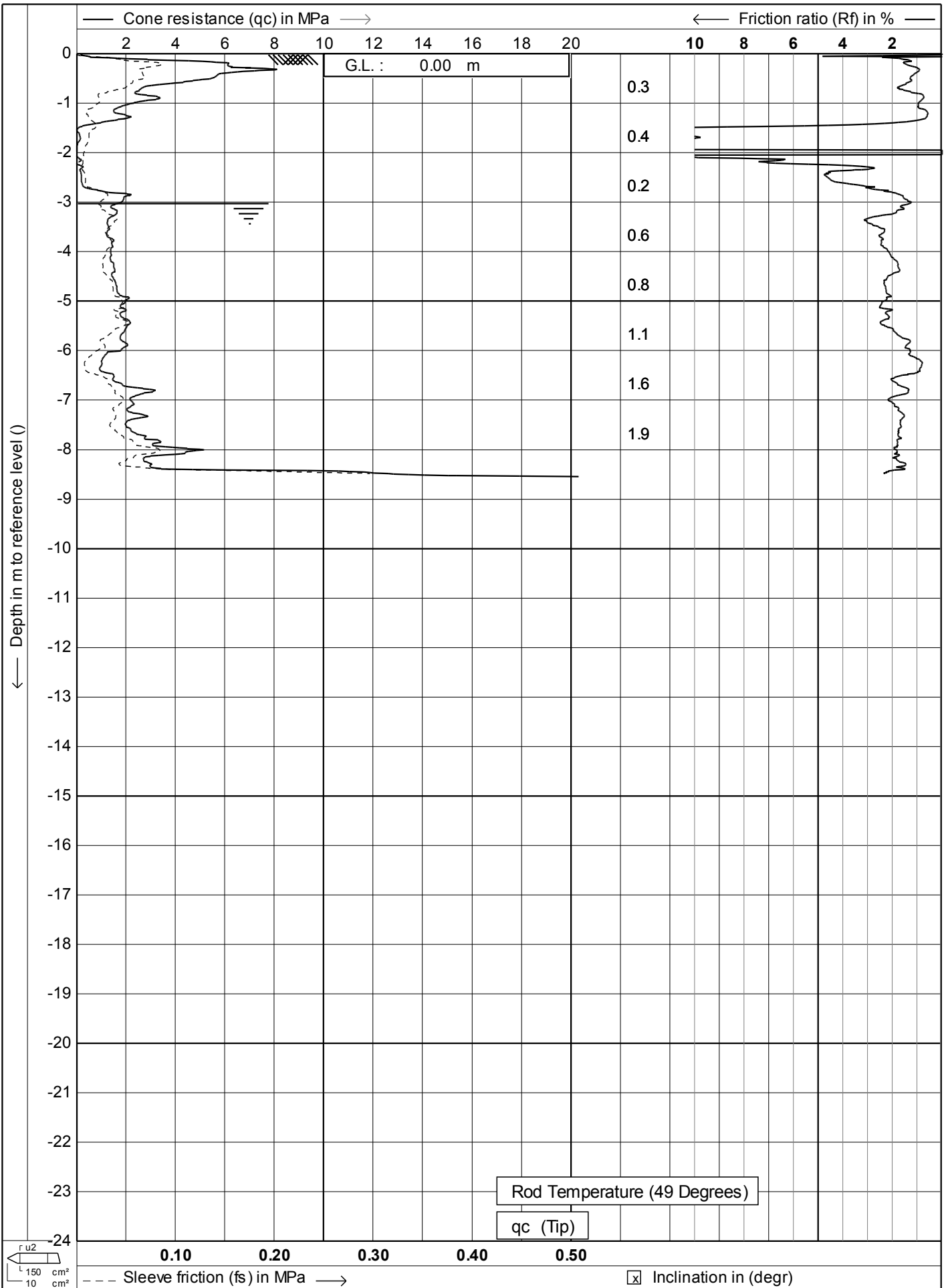
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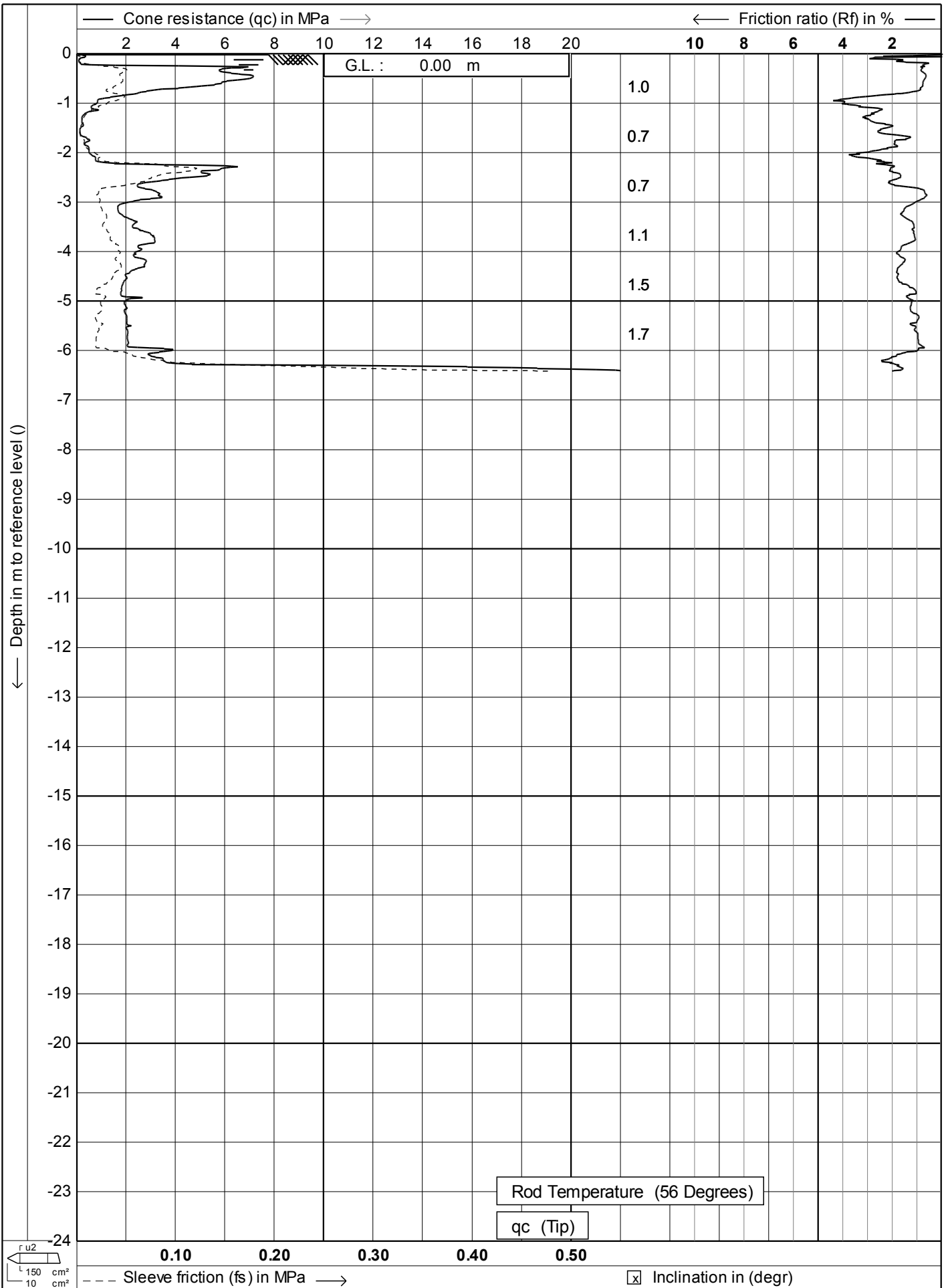
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COMMENT:

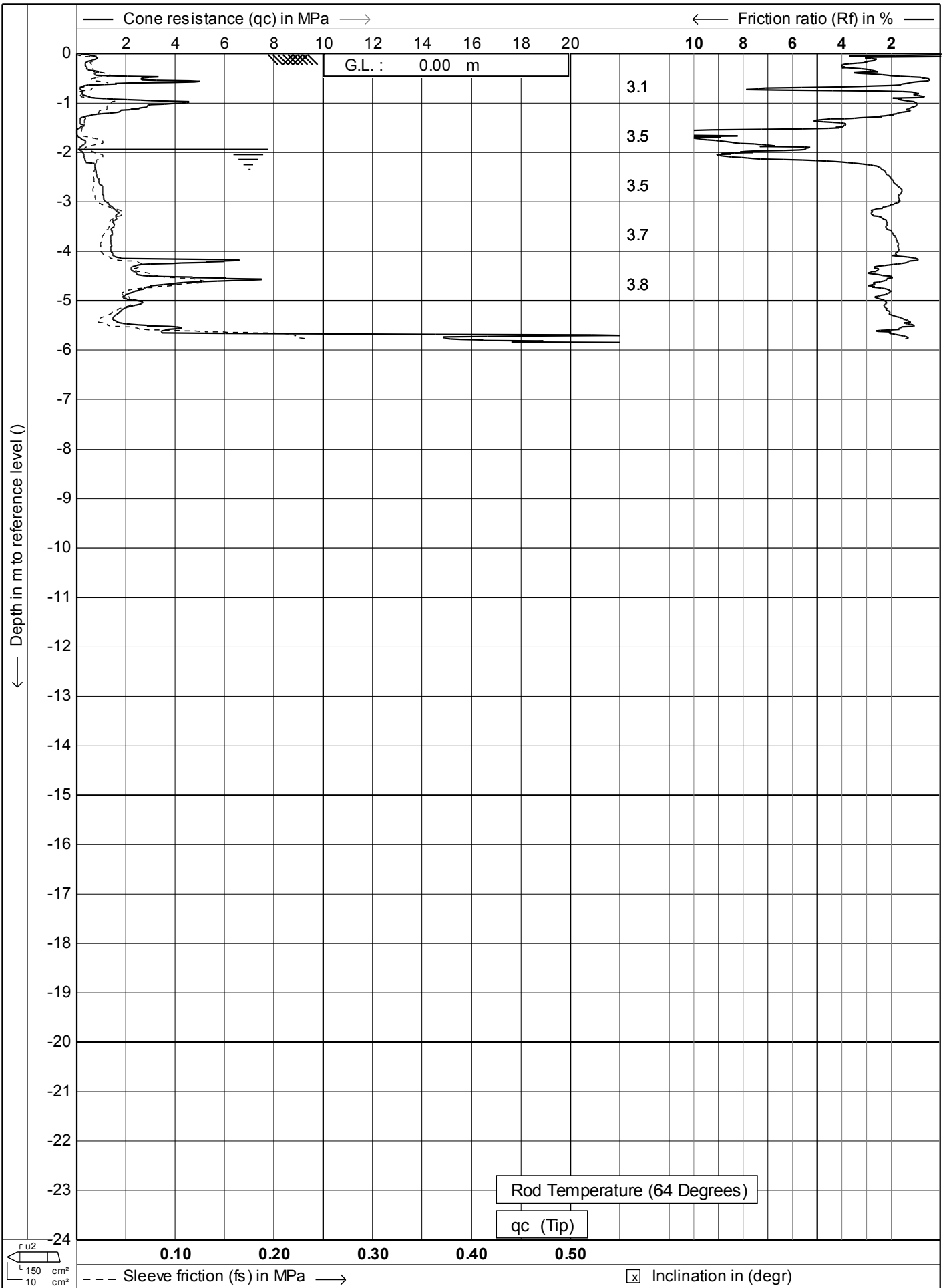


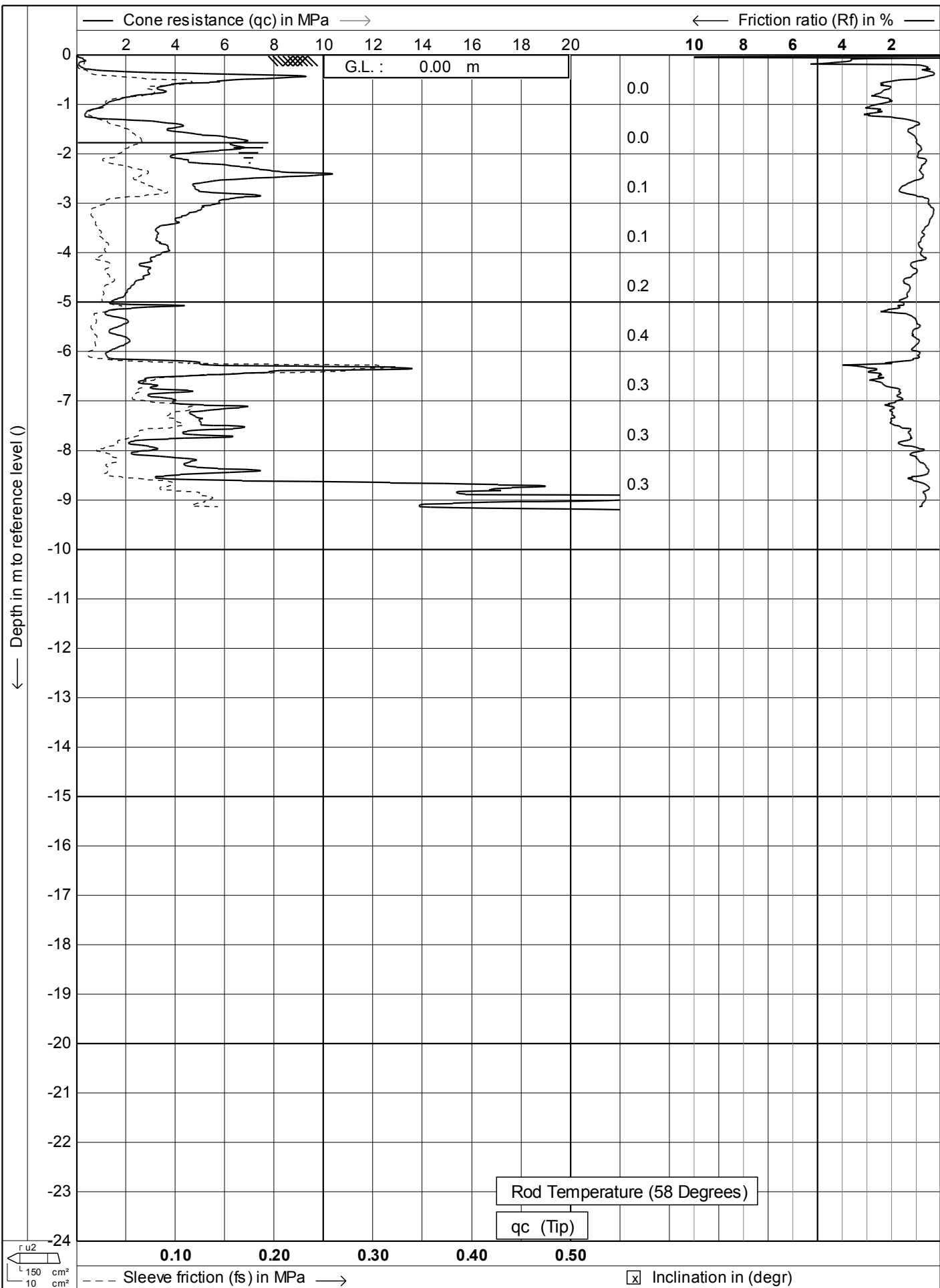




Test according A.S.T.M. Standard D 5778-95
Project : **Rotorua Museum Extensions**
Location: **Queens Drive - Rotorua**

Date : **28-10-2008**
Cone no. : **C10CFIIP.E60**
Project no. : **02TC8**
CPT no. : **13**





Test according A.S.T.M. Standard D 5778-95

Project : **Rotorua Museum Extensions**

Location: **Queens Drive - Rotorua**

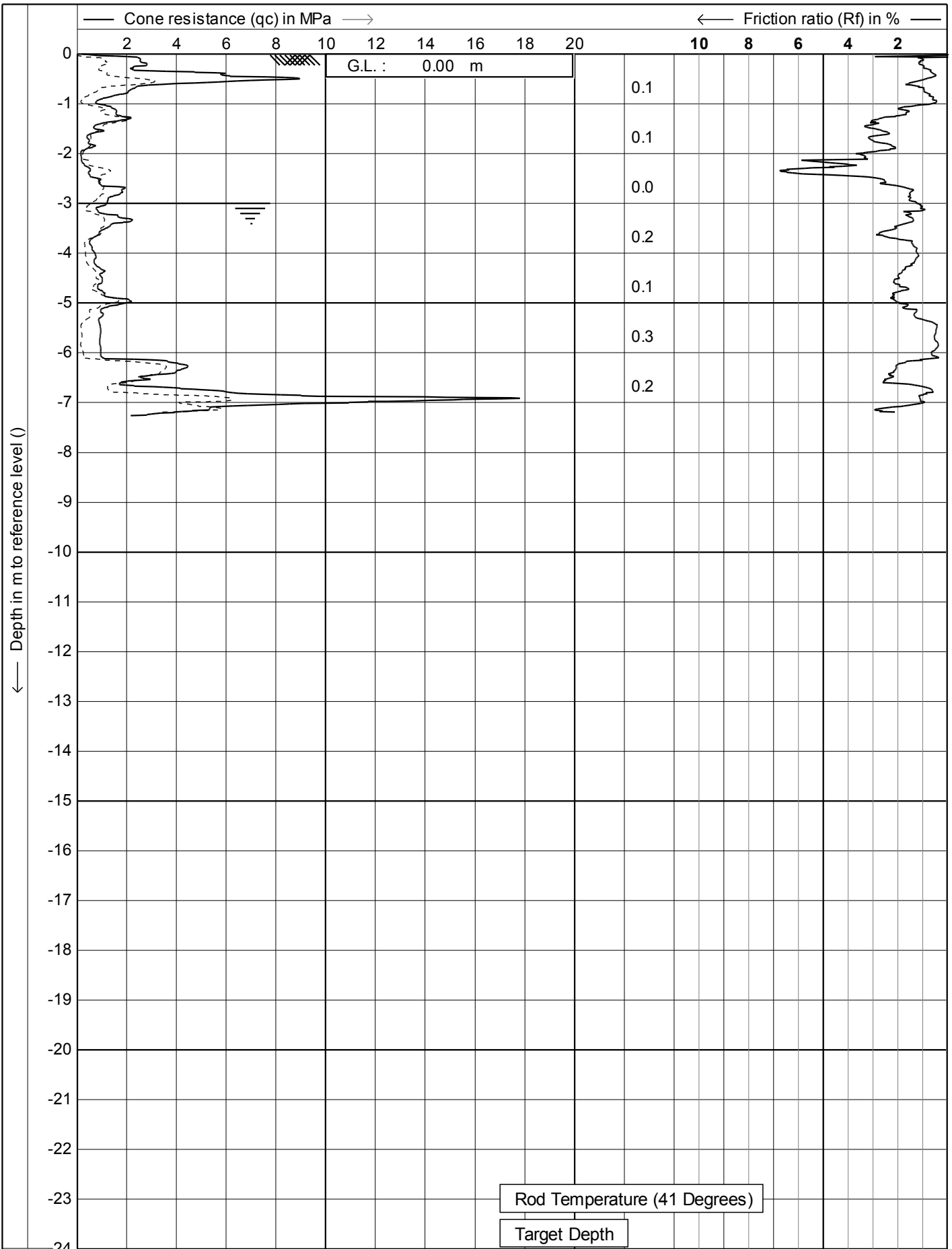
Date : **28-10-2008**

Cone no. : **C10CFIP.D88**

Project no. : **02TC8**

CPT no. : **15**

1/14



Test according A.S.T.M. Standard D 5778-95

Project : **Rotorua Museum Extensions**

Location: **Queens Drive - Rotorua**

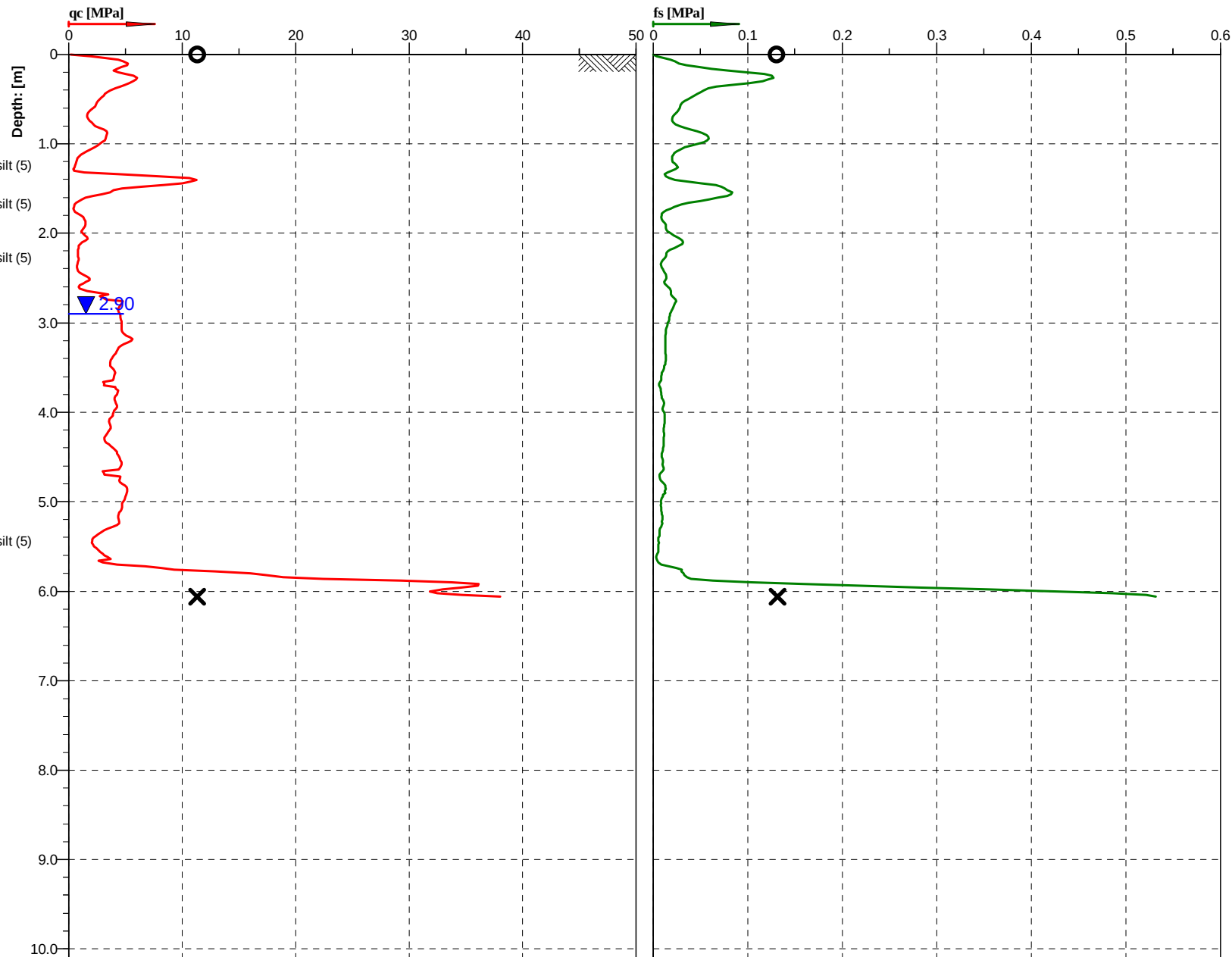
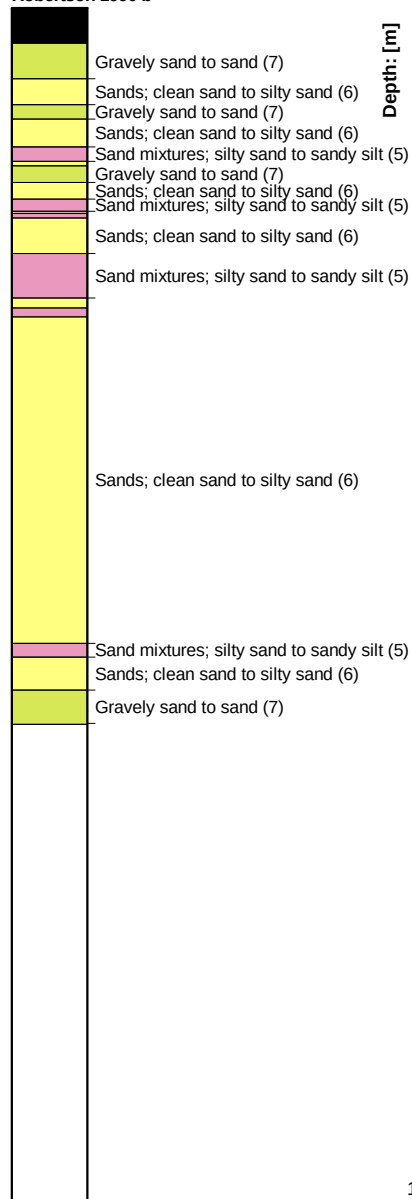
Date : **28-10-2008**

Cone no. : **C10CFIP.D88**

Project no. : **02TC8**

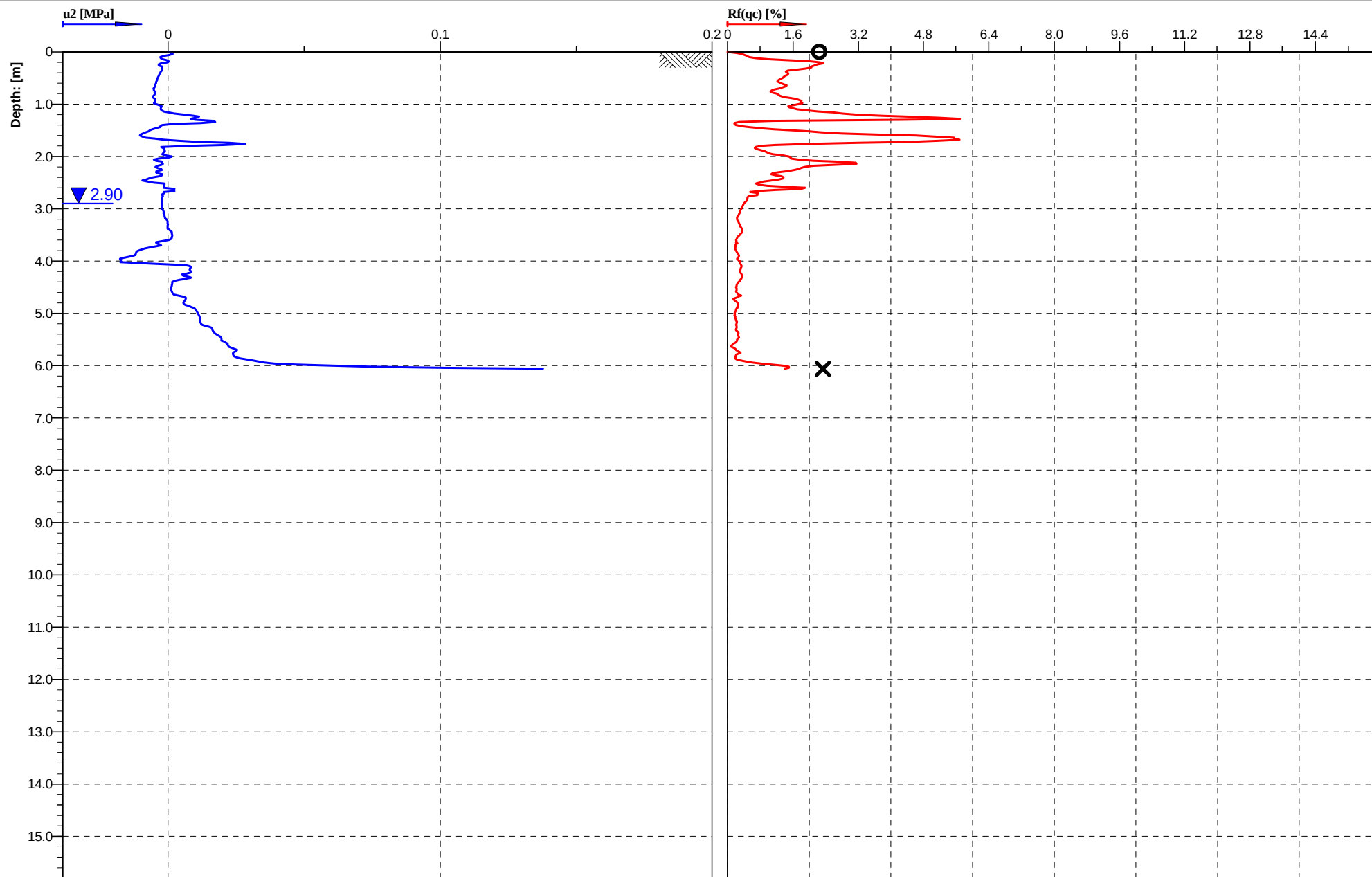
CPT no. : **16**

Classification by
Robertson 1990 b



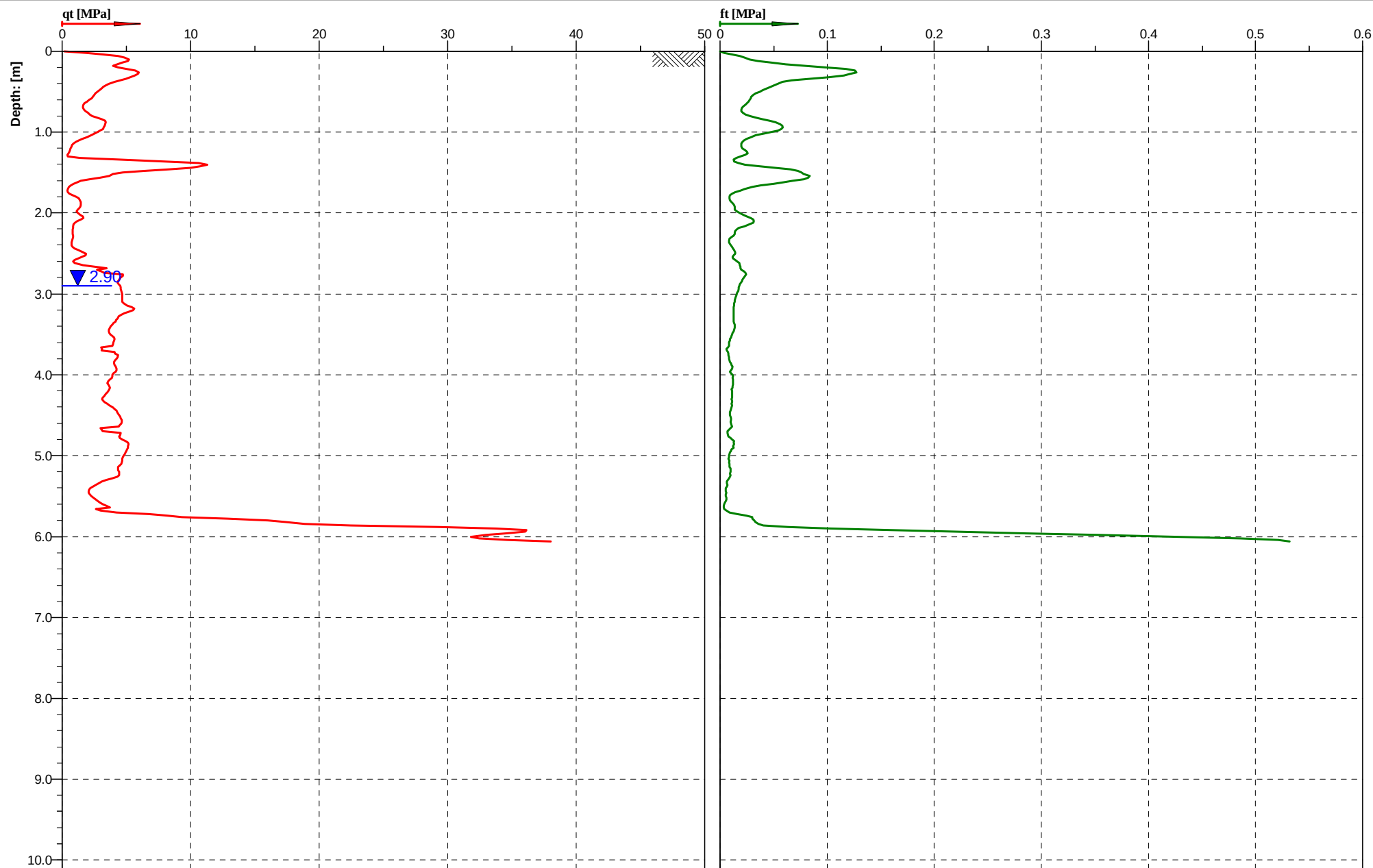
Cone No: 4756
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location:	Rotorua Museum	Position:	X: 0.00 m, Y: 0.00 m	Ground level:	0.00	Test No.:	CPT01
Project ID:		Client:	Rotorua Lakes Council	Date:	3/04/2017	Scale:	1 : 64
Project:	ROTORUA MUSEUM			Page:	1/4	Fig.:	
Refusal at 6.06m				File:	CPT01 (004).cpt		



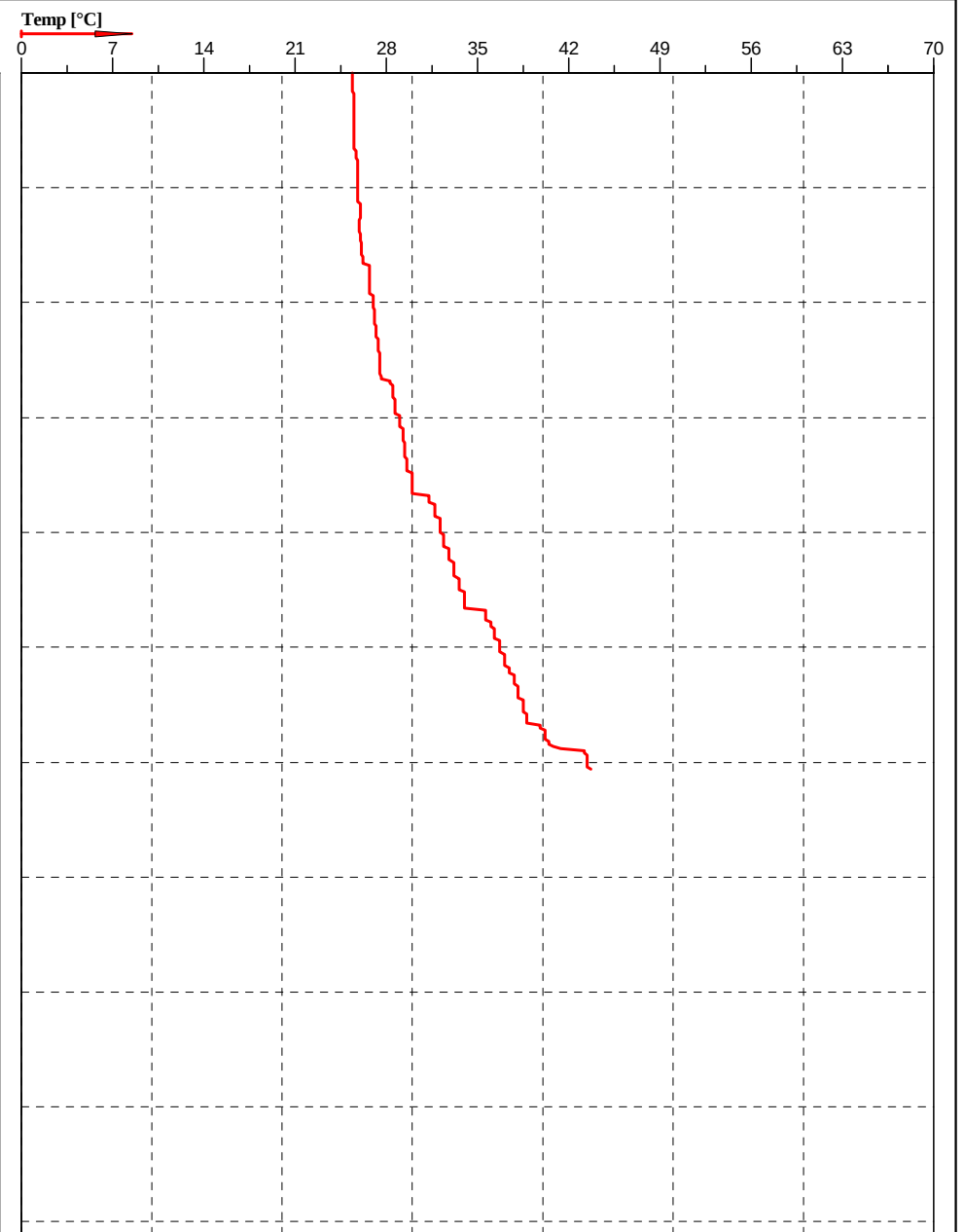
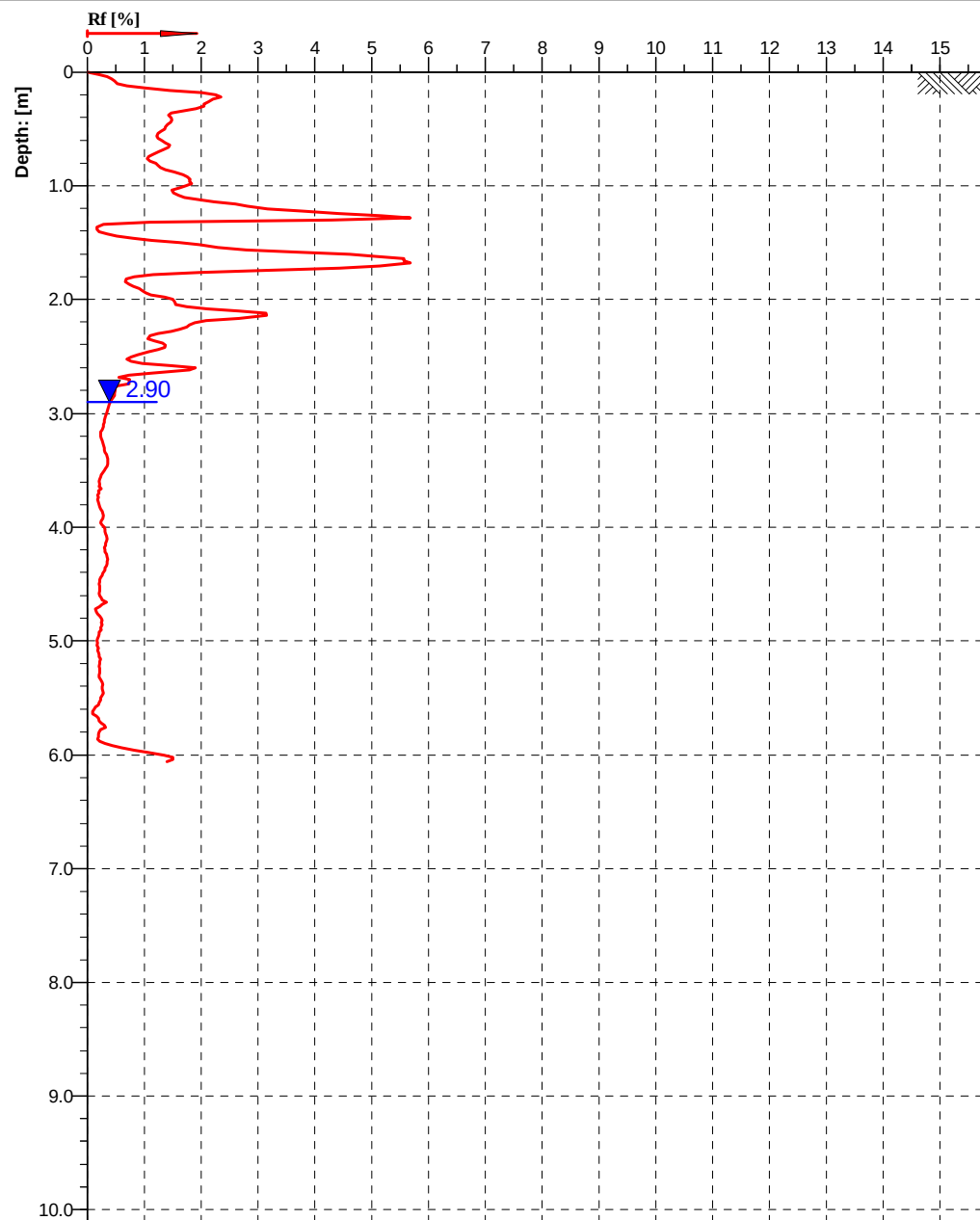
Cone No: 4756
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location:	Rotorua Museum	Position:	X: 0.00 m, Y: 0.00 m	Ground level:	0.00	Test No.:	CPT01
Project ID:		Client:	Rotorua Lakes Council	Date:	3/04/2017	Scale:	1 : 100
Project:	ROTORUA MUSEUM			Page:	2/4	Fig.:	
Refusal at 6.06m				File:	CPT01 (004).cpt		



Cone No: 4756
Tip area [cm2]: 10
Sleeve area [cm2]: 150

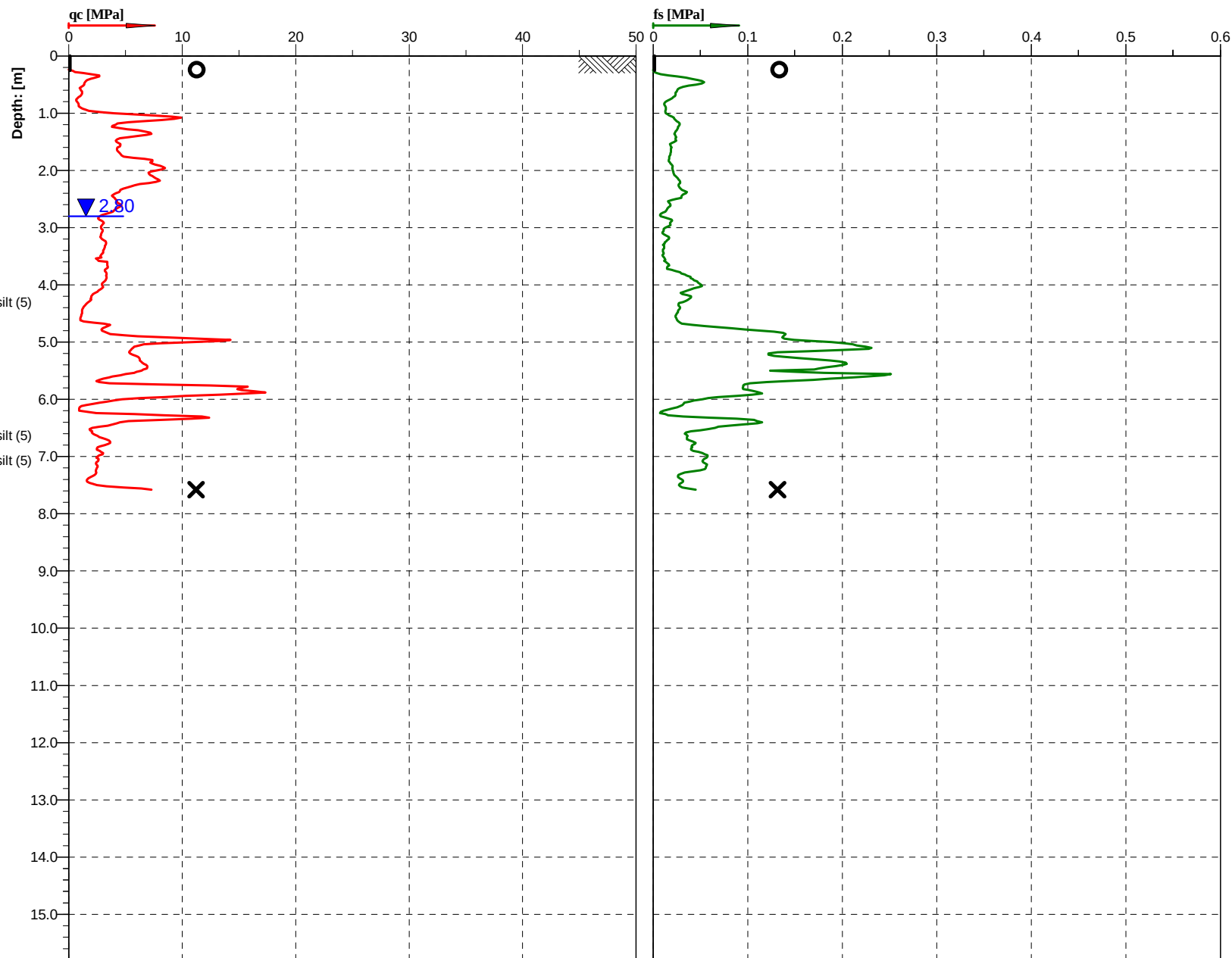
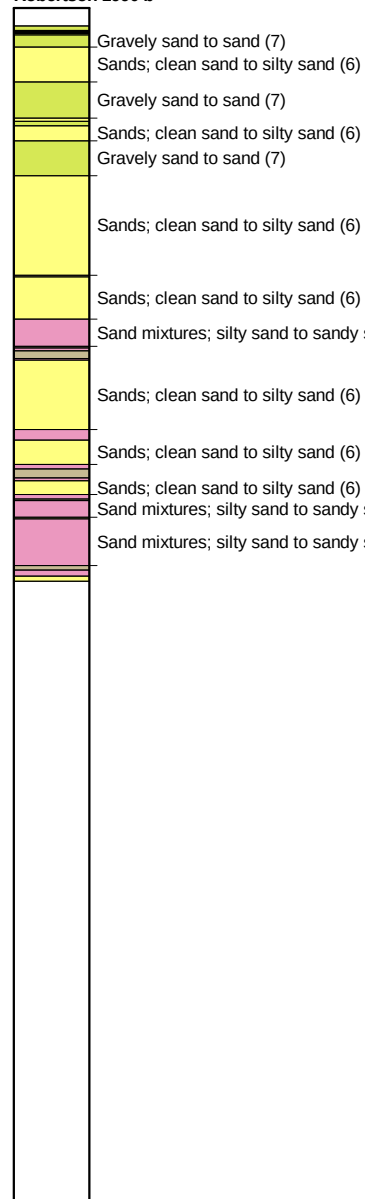
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Project ID:		Client:	Rotorua Lakes Council	Date:	3/04/2017	Scale:	1 : 64
Project:	ROTORUA MUSEUM			Page:	3/4	Fig.:	
Refusal at 6.06m				File:	CPT01 (004).cpt		



Cone No: 4756
Tip area [cm²]: 10
Sleeve area [cm²]: 150

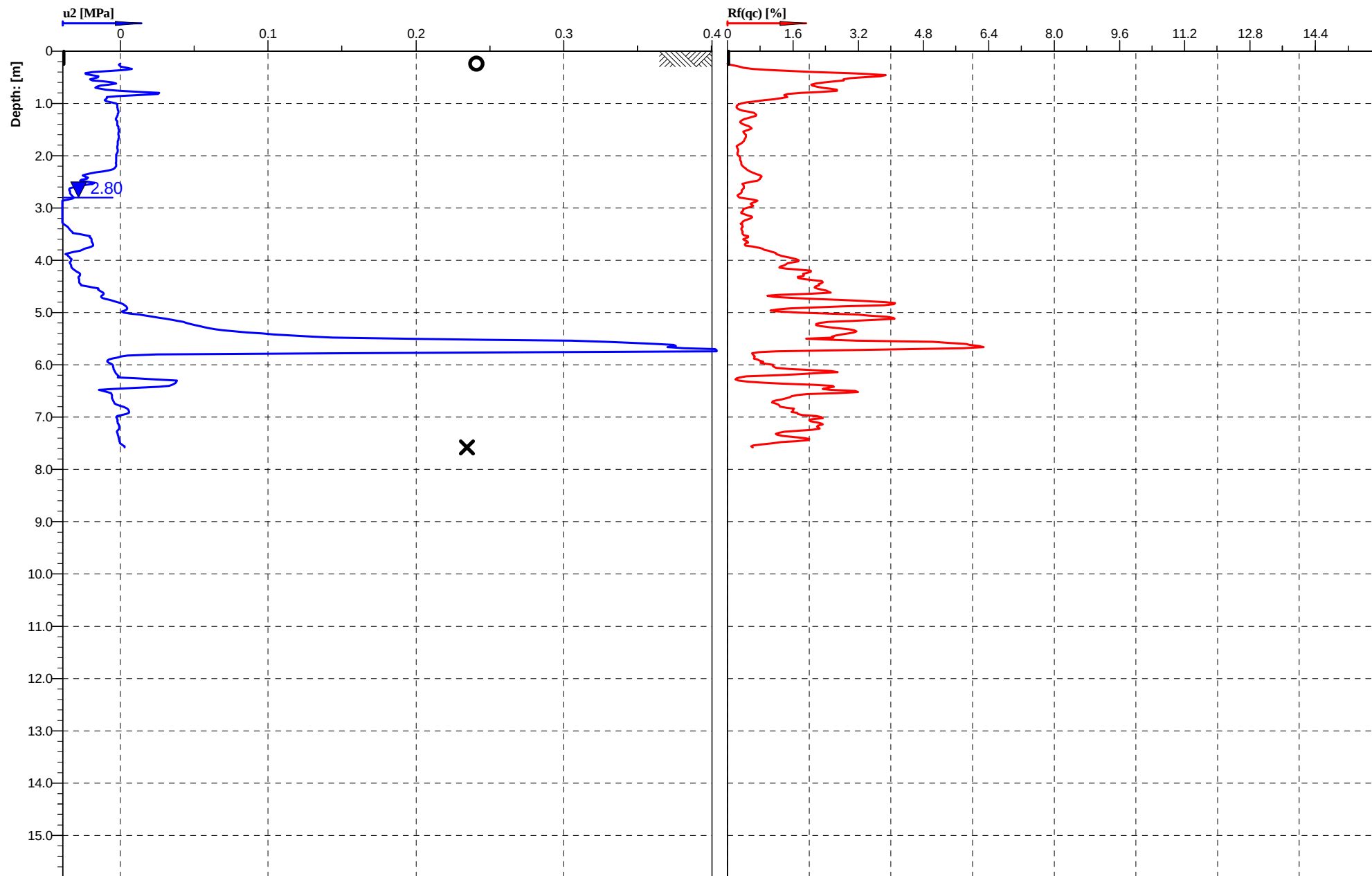
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Project ID:		Client:	Rotorua Lakes Council	Date:	3/04/2017	Scale:	1 : 64
Project:	ROTORUA MUSEUM			Page:	4/4	Fig.:	
Refusal at 6.06m				File:	CPT01 (004).cpt		

Classification by
Robertson 1990 b



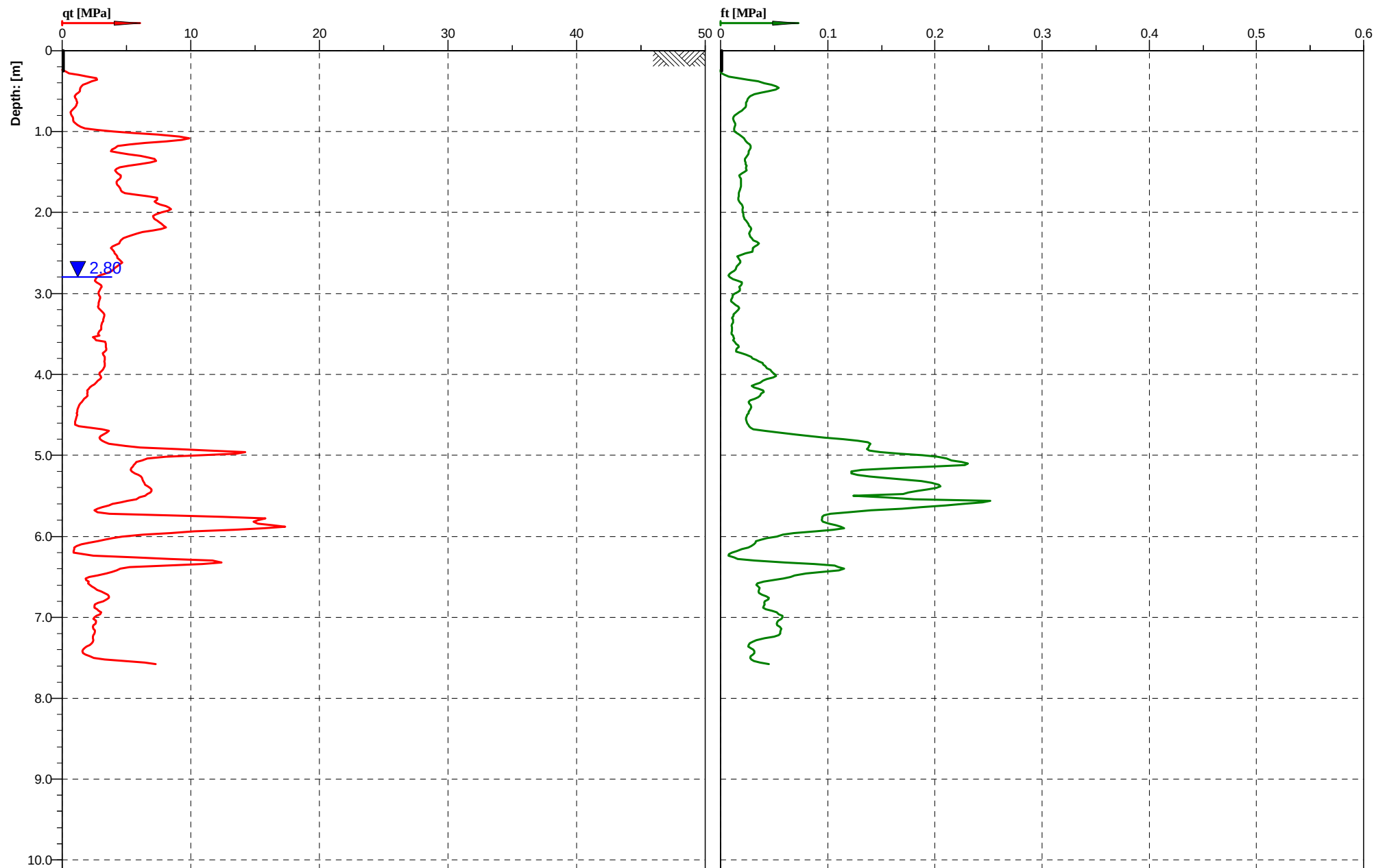
Cone No: 4756
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location:	ROTORUA MUSEUM	Position:	X: 0.00 m, Y: 0.00 m	Ground level:	0.00	Test No.:	CPT02
Project ID:		Client:	Rotorua Lakes Council	Date:	3/04/2017	Scale:	1 : 100
Project:	ROTORUA MUSEUM			Page:	1/4	Fig.:	
Pre drill 250mm, temperature exceeding 62 degrees				File:	CPT02 (005).cpt		



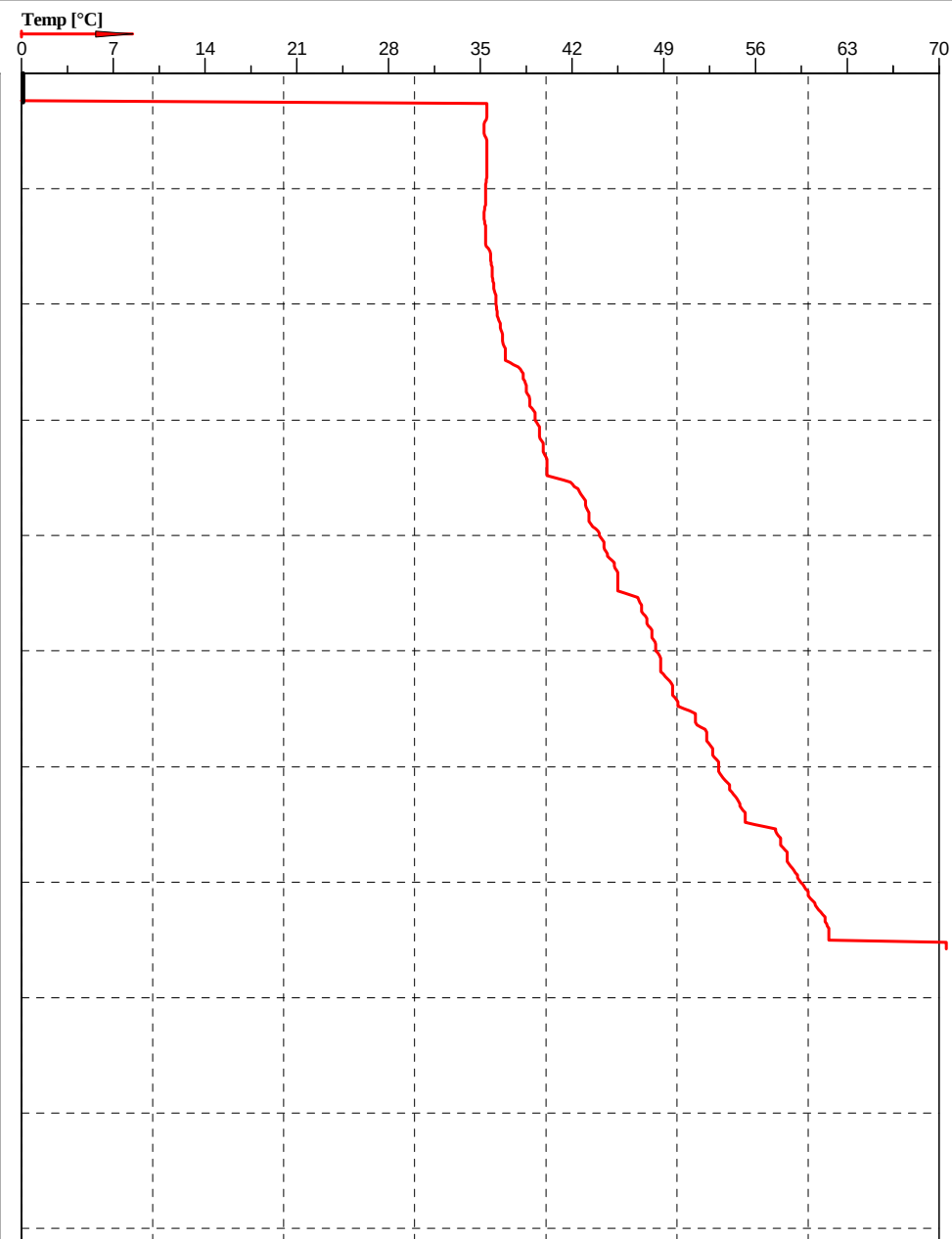
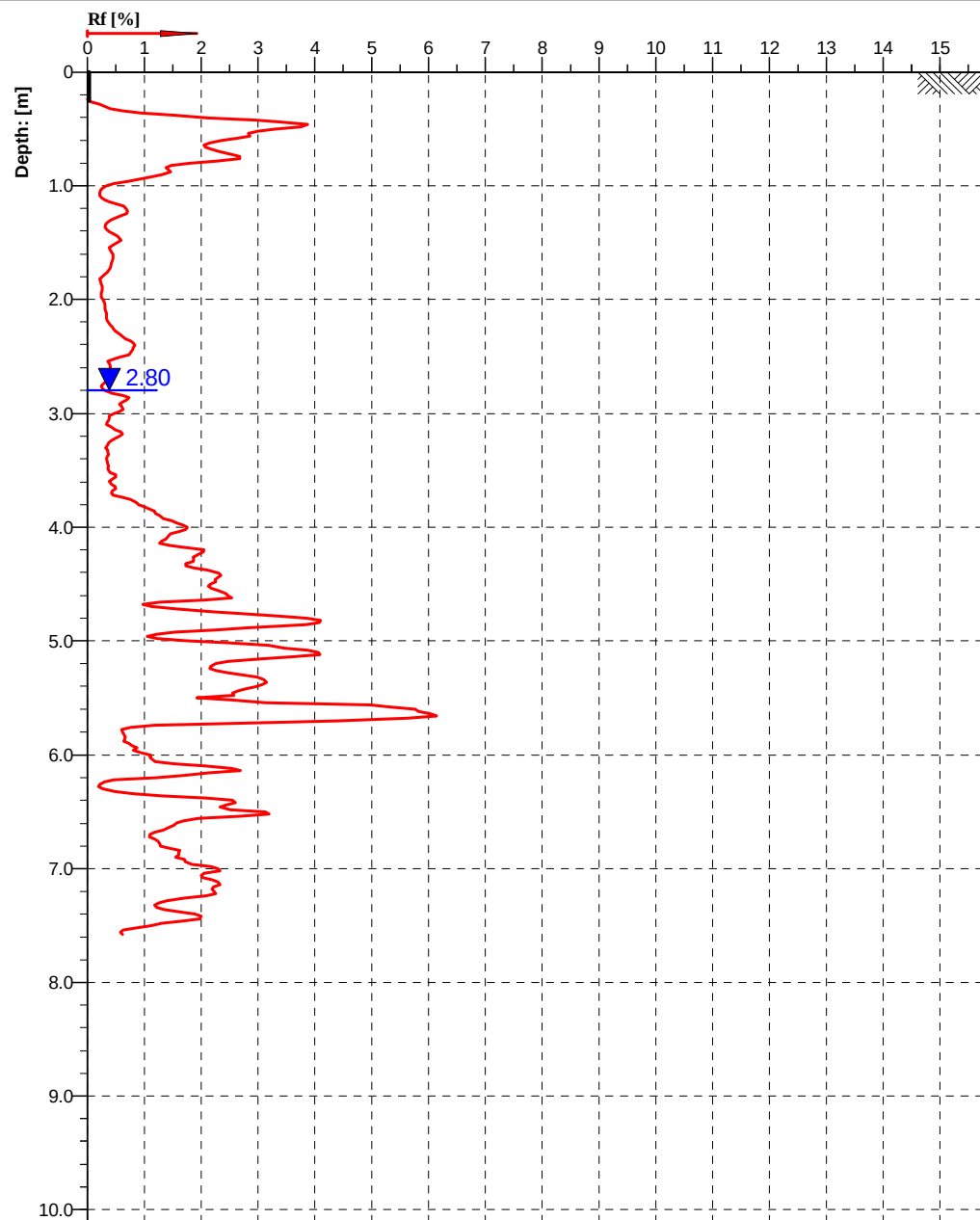
Cone No: 4756
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location:	ROTORUA MUSEUM	Position:	X: 0.00 m, Y: 0.00 m	Ground level:	0.00	Test No.:	CPT02
Project ID:		Client:	Rotorua Lakes Council	Date:	3/04/2017	Scale:	1 : 100
Project:	ROTORUA MUSEUM			Page:	2/4	Fig.:	
Pre drill 250mm, temperature exceeding 62 degrees				File:	CPT02 (005).cpt		



Cone No: 4756
Tip area [cm²]: 10
Sleeve area [cm²]: 150

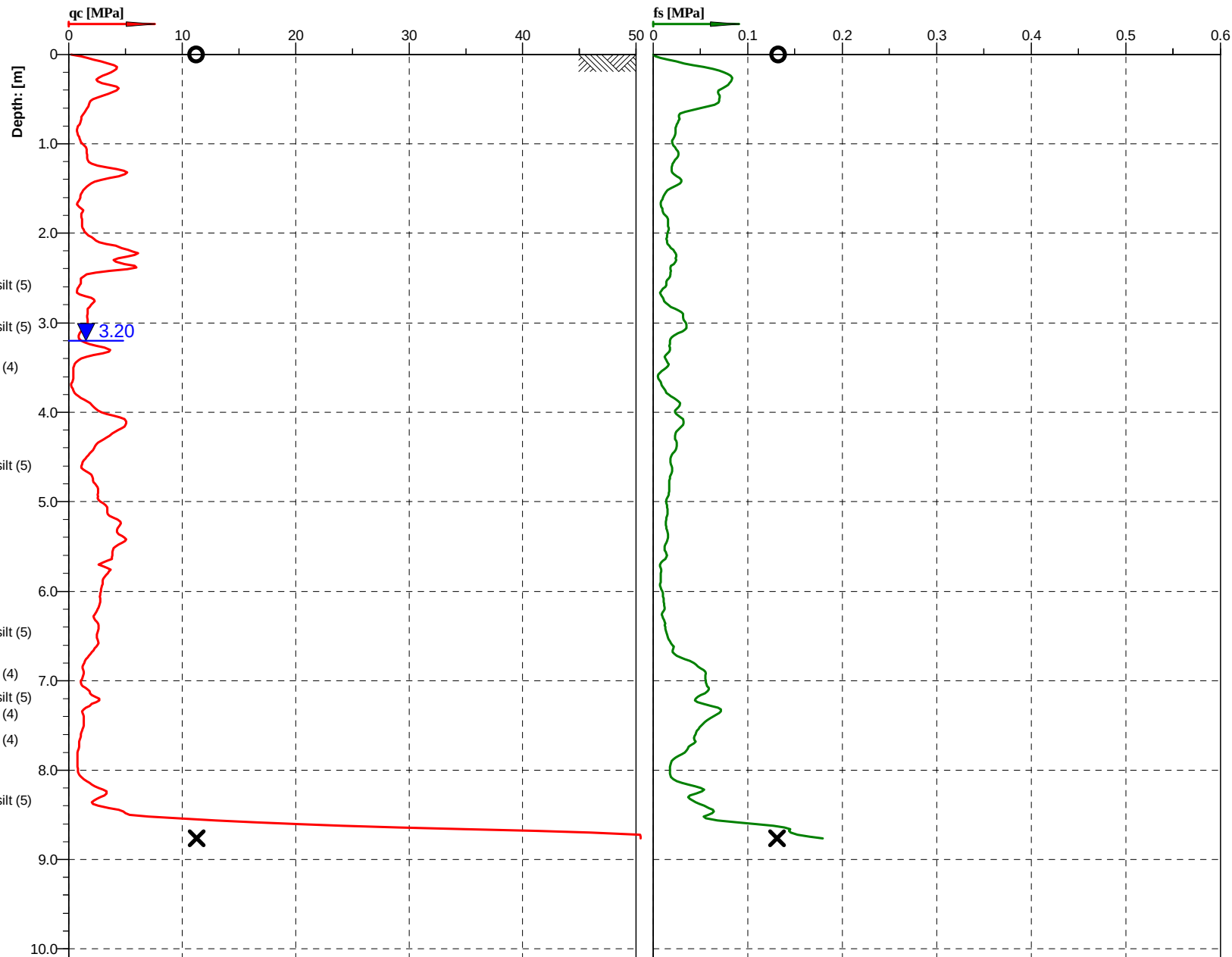
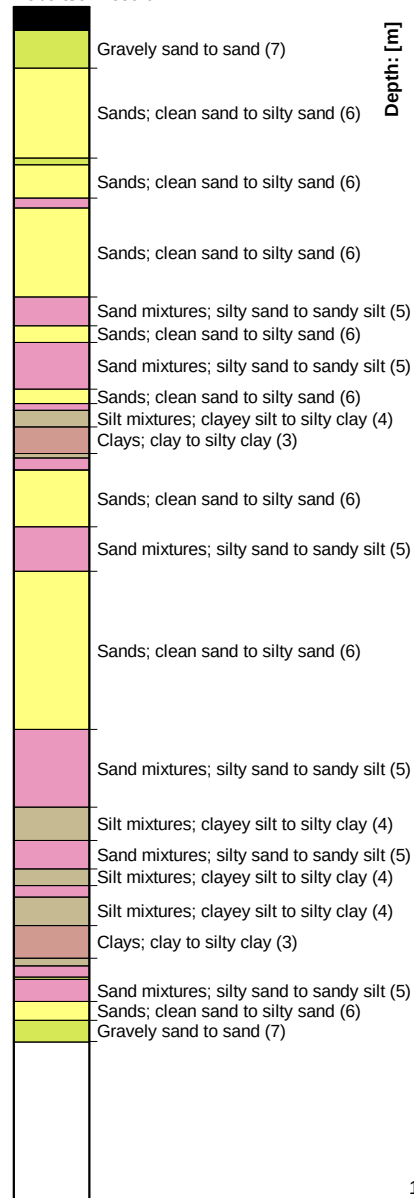
Location:	ROTORUA MUSEUM	Position:	X: 0.00 m, Y: 0.00 m	Ground level:	0.00	Test No.:	CPT02
Project ID:		Client:	Rotorua Lakes Council	Date:	3/04/2017	Scale:	1 : 64
Project:	ROTORUA MUSEUM			Page:	1/1	Fig.:	
Pre drill 250mm, temperature exceeding 62 degrees				File:	CPT02 (005).cpt		



Cone No: 4756
Tip area [cm²]: 10
Sleeve area [cm²]: 150

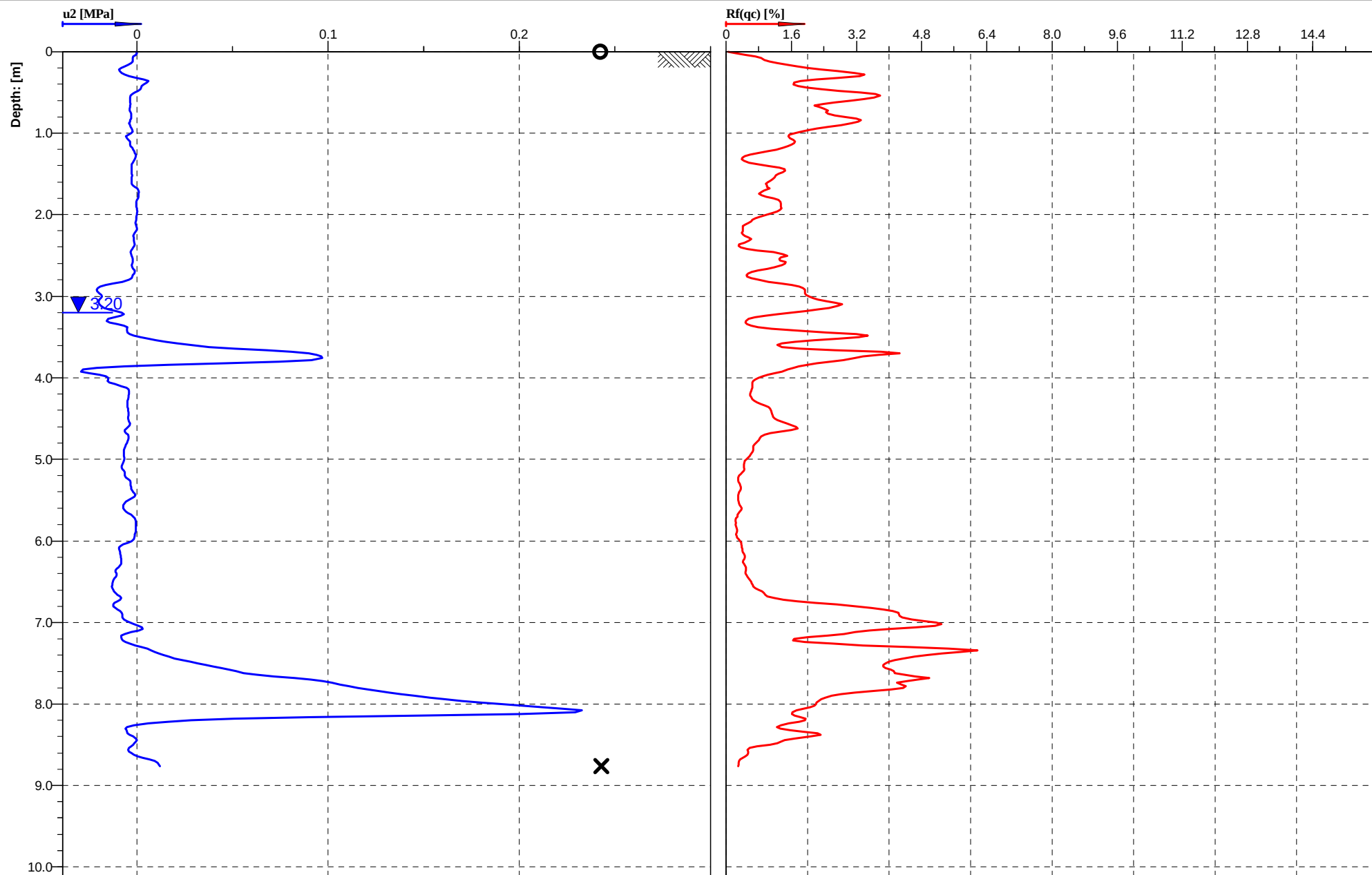
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Project ID:		Client:	Rotorua Lakes Council	Date:	3/04/2017	Scale:	1 : 64
Project:	ROTORUA MUSEUM			Page:	4/4	Fig.:	
Pre drill 250mm, temperature exceeding 62 degrees				File:	CPT02 (005).cpt		

Classification by
Robertson 1990 b



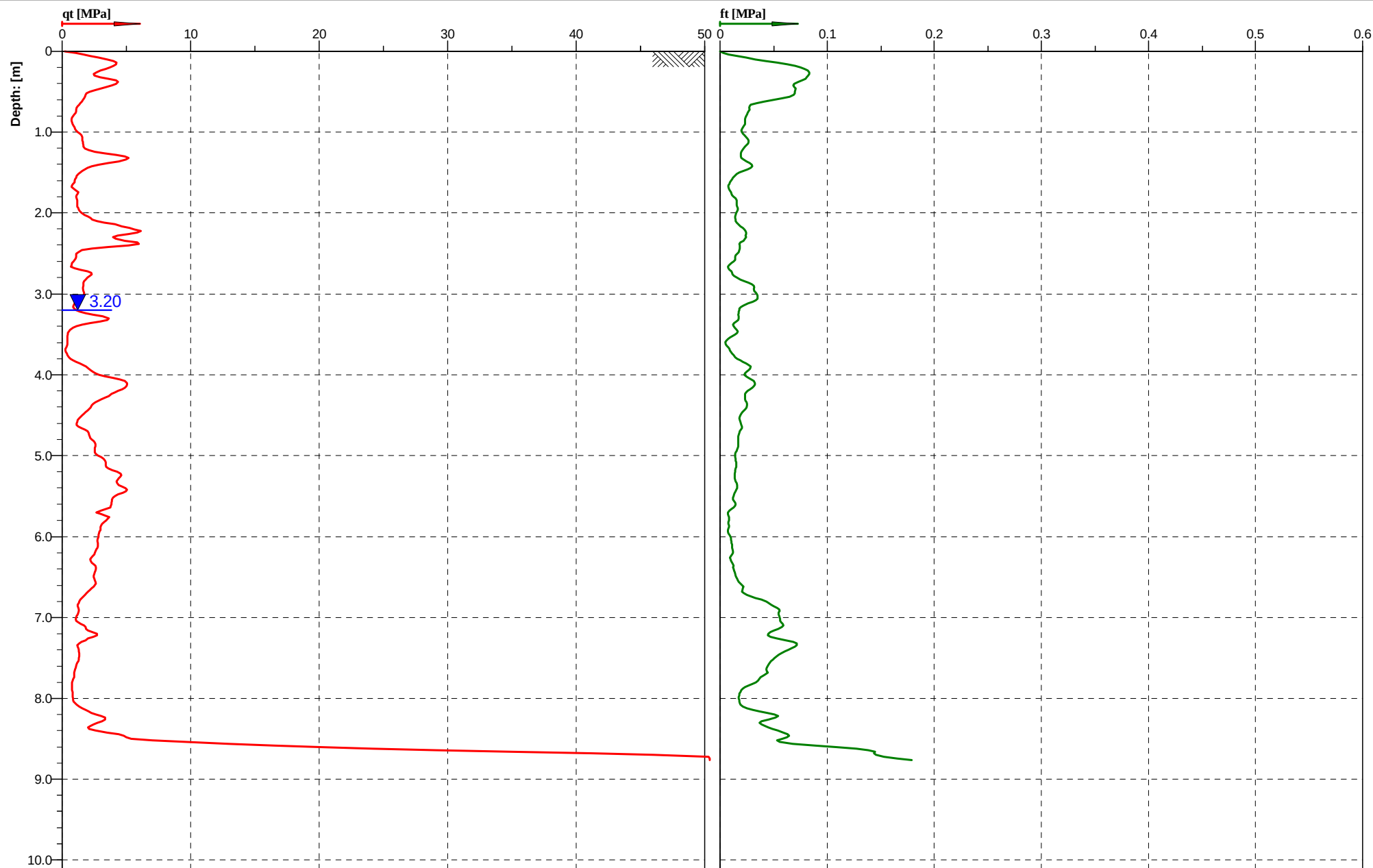
Cone No: 4756
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location:	ROTORUA MUSEUM	Position:	X: 0.00 m, Y: 0.00 m	Ground level:	0.00	Test No.:	CPT03
Project ID:		Client:	Rotorua Lakes Council	Date:	3/04/2017	Scale:	1 : 64
Project:	ROTORUA MUSEUM			Page:	1/4	Fig.:	
Refusal at 8.76m				File:	CPT03 (003).cpt		



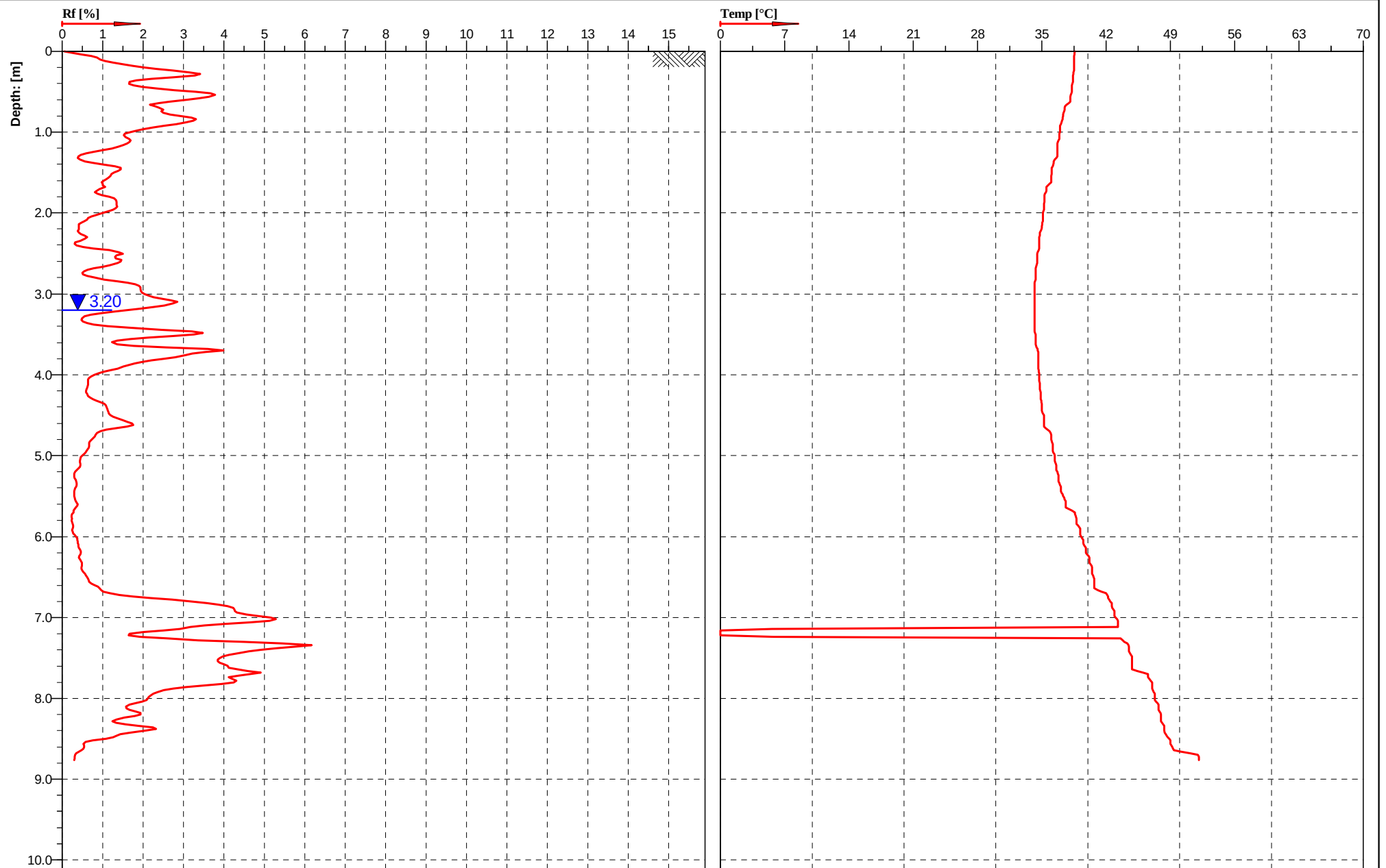
Cone No: 4756
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location:	ROTORUA MUSEUM	Position:	X: 0.00 m, Y: 0.00 m	Ground level:	0.00	Test No.:	CPT03
Project ID:		Client:	Rotorua Lakes Council	Date:	3/04/2017	Scale:	1 : 64
Project:	ROTORUA MUSEUM			Page:	2/4	Fig.:	
Refusal at 8.76m				File:	CPT03 (003).cpt		



Cone No: 4756
Tip area [cm²]: 10
Sleeve area [cm²]: 150

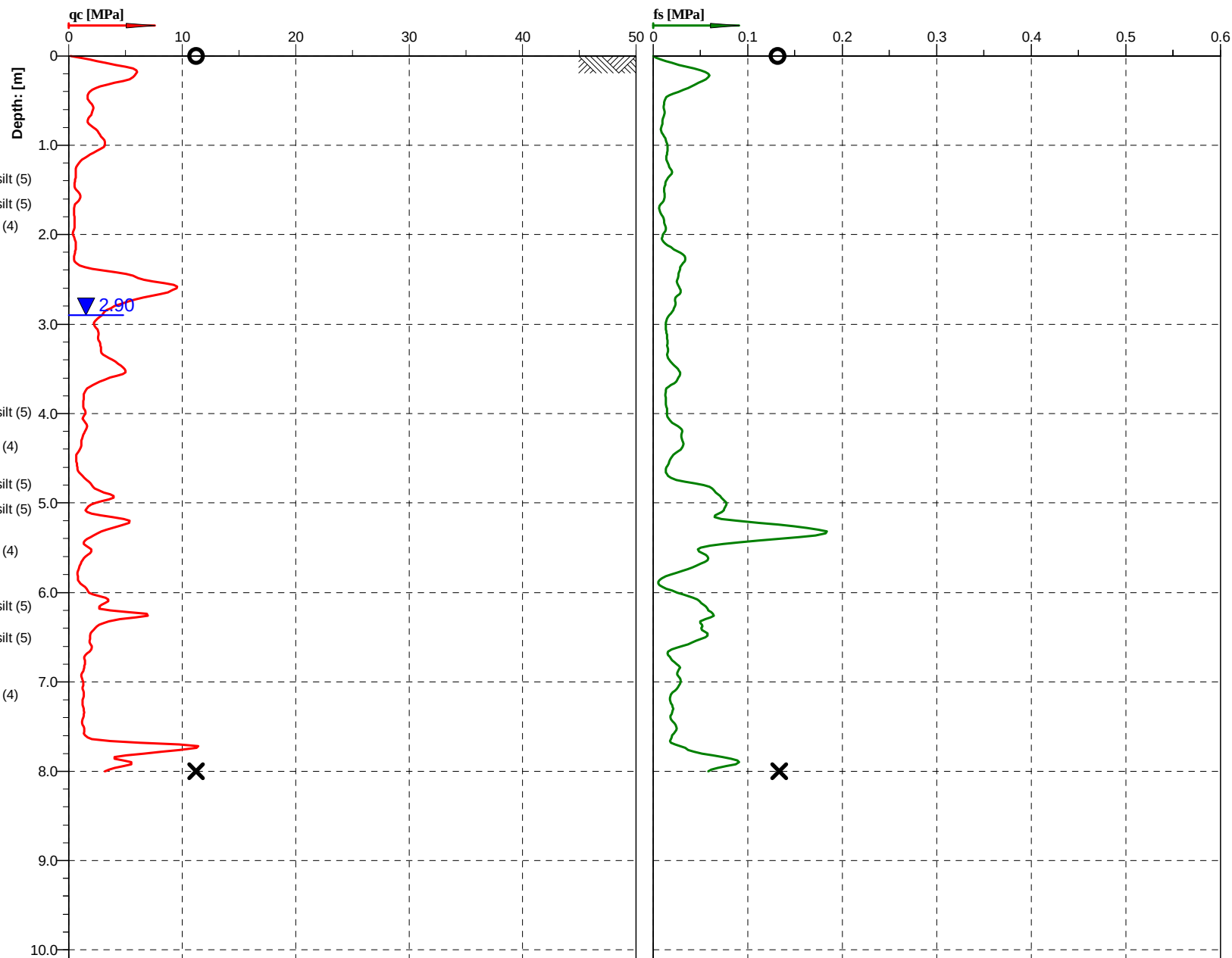
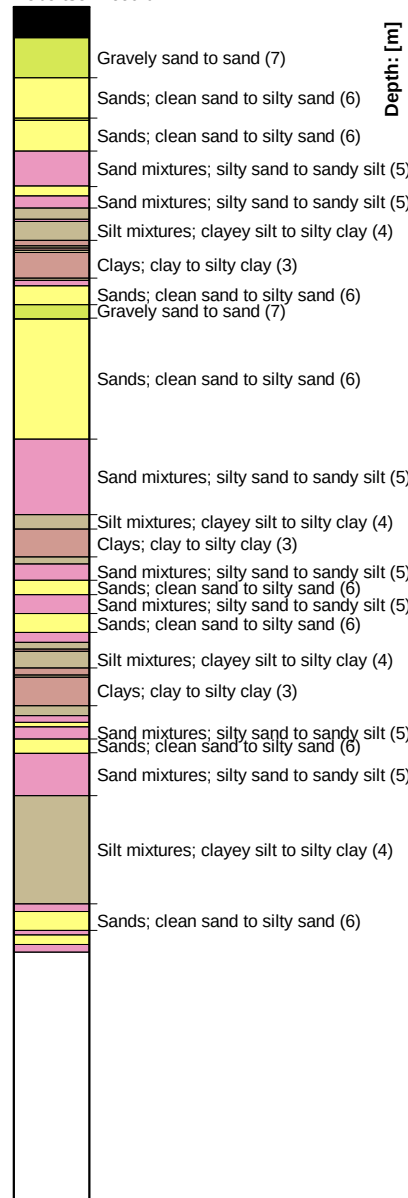
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Project ID:		Client:	Rotorua Lakes Council	Date:	3/04/2017	Scale:	1 : 64
Project:	ROTORUA MUSEUM			Page:	3/4	Fig.:	
Refusal at 8.76m				File:	CPT03 (003).cpt		



Cone No: 4756
Tip area [cm²]: 10
Sleeve area [cm²]: 150

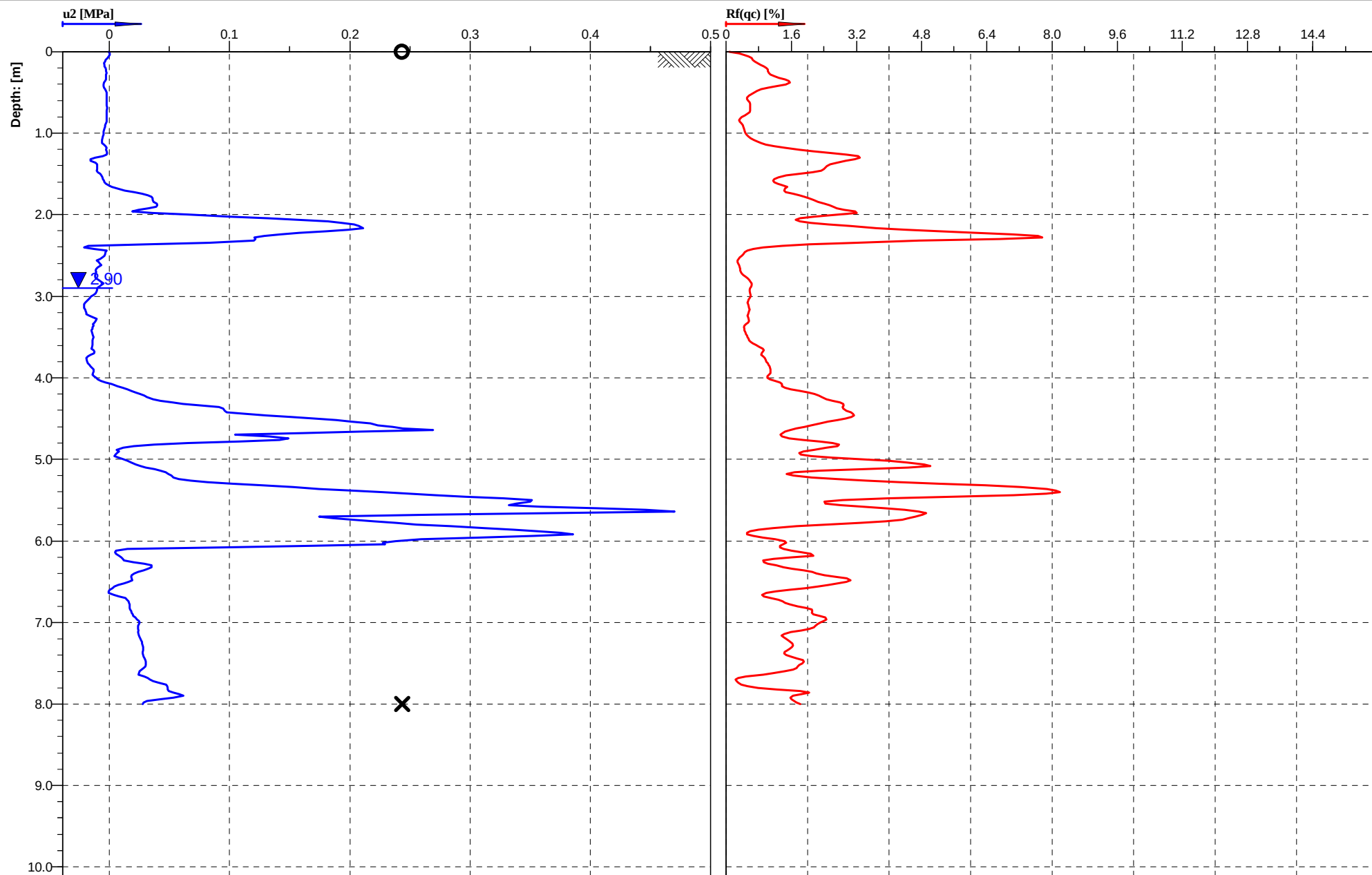
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Project ID:		Client:	Rotorua Lakes Council	Date:	3/04/2017	Scale:	1 : 64
Project:	ROTORUA MUSEUM			Page:	4/4	Fig.:	
Refusal at 8.76m				File:	CPT03 (003).cpt		

Classification by
Robertson 1990 b



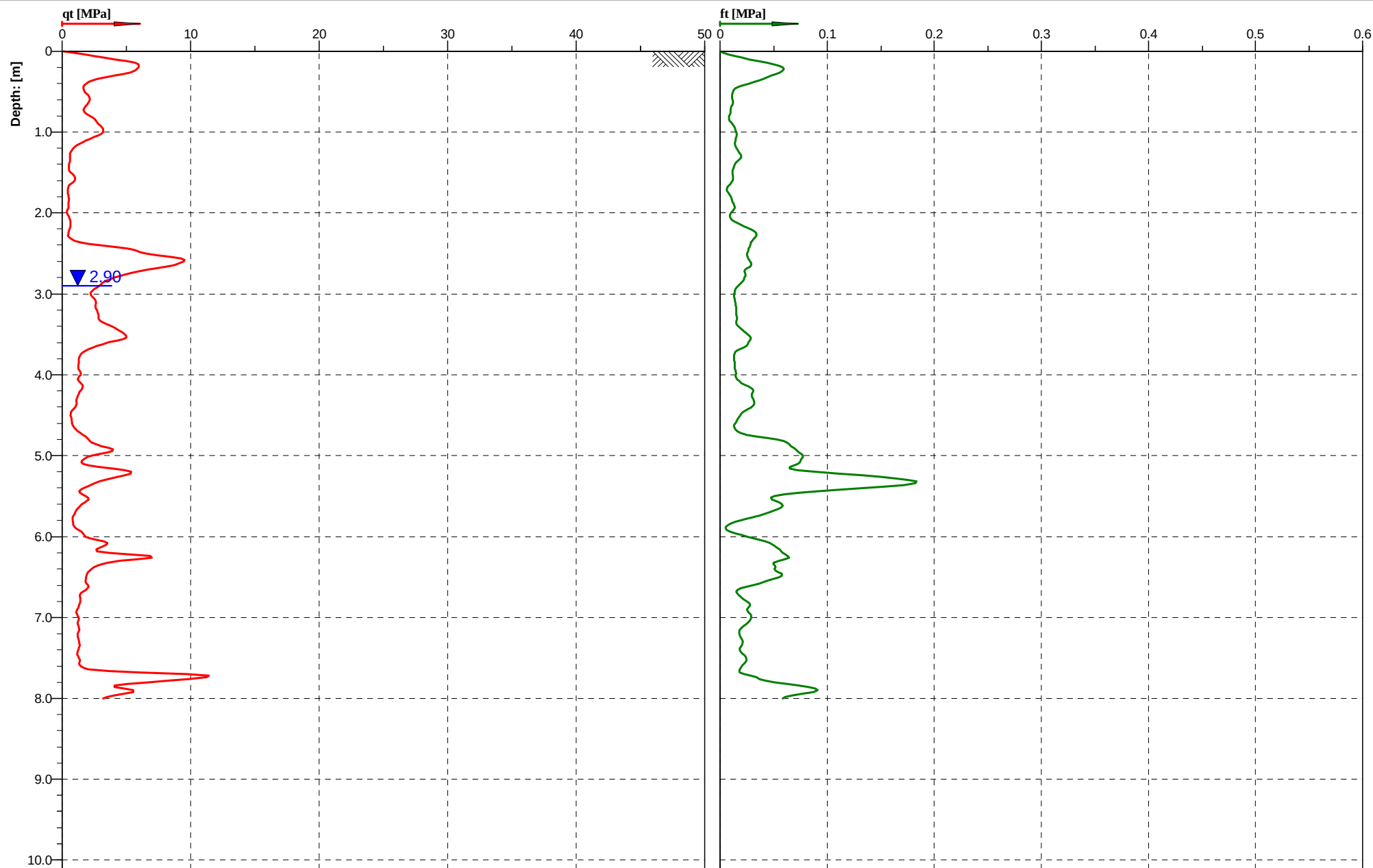
Cone No: 4756
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location:	ROTORUA MUSEUM	Position:	X: 0.00 m, Y: 0.00 m	Ground level:	0.00	Test No.:	CPT04
Project ID:		Client:	Rotorua Lakes Council	Date:	3/04/2017	Scale:	1 : 64
Project:	ROTORUA MUSEUM			Page:	1/4	Fig.:	
Temperature exceeding 62 degrees				File:	CPT04.cpt		



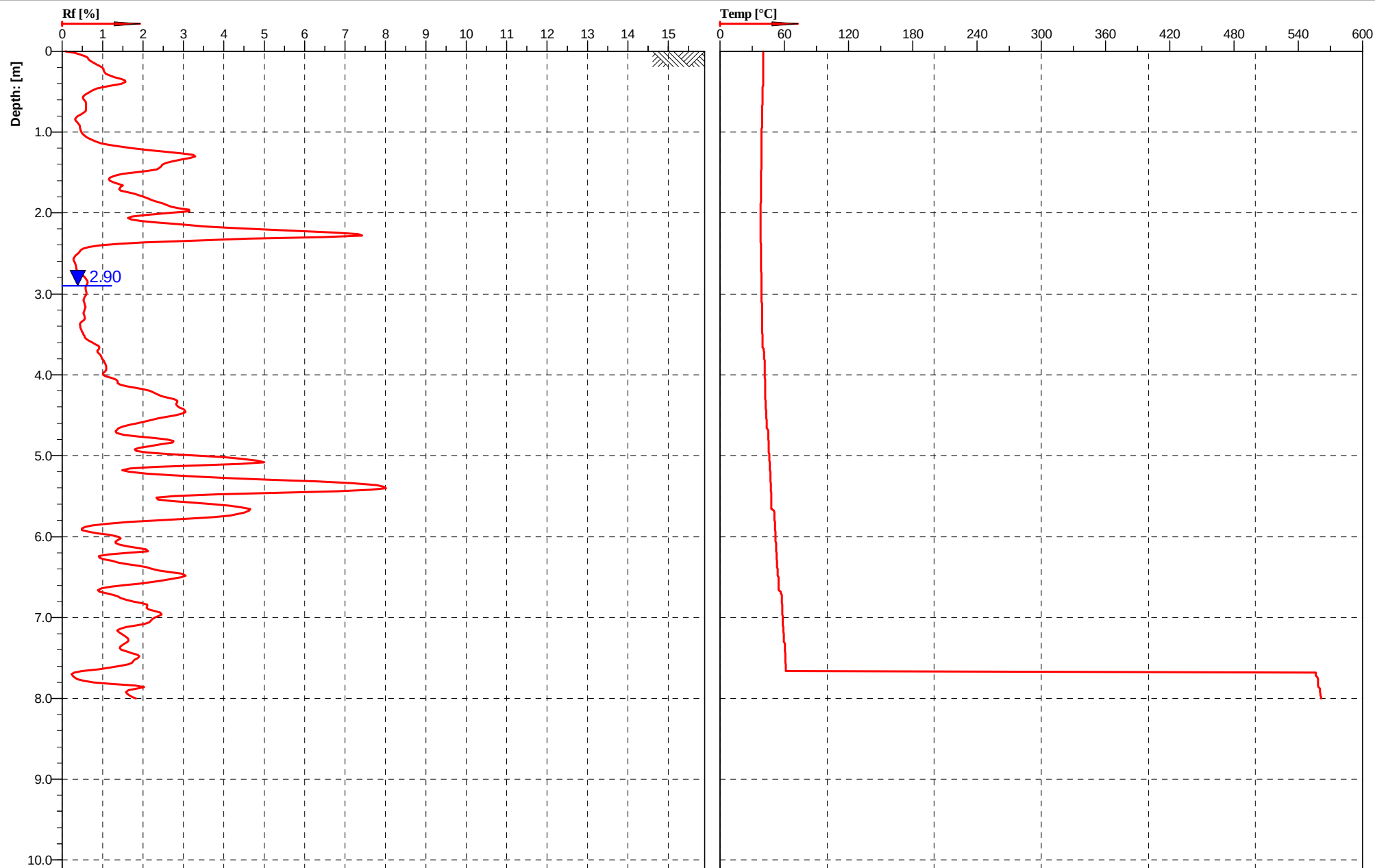
Cone No: 4756
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location:	ROTORUA MUSEUM	Position:	X: 0.00 m, Y: 0.00 m	Ground level:	0.00	Test No.:	CPT04
Project ID:		Client:	Rotorua Lakes Council	Date:	3/04/2017	Scale:	1 : 64
Project:	ROTORUA MUSEUM			Page:	2/4	Fig.:	
Temperature exceeding 62 degrees				File:	CPT04.cpt		



Cone No: 4756
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location:	ROTORUA MUSEUM	Position:	X: 0.00 m, Y: 0.00 m	Ground level:	0.00	Test No.:	CPT04
Project ID:		Client:	Rotorua Lakes Council	Date:	3/04/2017	Scale:	1 : 64
Project:	ROTORUA MUSEUM			Page:	1/1	Fig.:	
Temperature exceeding 62 degrees				File:	CPT04.cpt		



Cone No: 4756
Tip area [cm2]: 10
Sleeve area [cm2]: 150

Location:	ROTORUA MUSEUM	Position:	X: 0.00 m, Y: 0.00 m	Ground level:	0.00	Test No.:	CPT04
Project ID:		Client:	Rotorua Lakes Council	Date:	3/04/2017	Scale:	1 : 64
Project:	ROTORUA MUSEUM			Page:	4/4	Fig.:	
Temperature exceeding 62 degrees				File:	CPT04.cpt		

Client	Sigma Consultants Ltd			Borehole No.	BH3			
Site address	Rotorua Museum							
Drill method	Hand Auger			Terrane Job Ref.	3278			
Drilled by	jwc							
Logged by	jwc			Date drilled	14/05/2007			
Notes: 1.				Soil Symbol	Testing	Soil Strength	Moisture Condition	KEY • Undrained shear strength (kPa) x Residual shear strength (kPa)
Stratigraphy	Soil Description	Depth						
ROAD SUB-GRADE	Mixed gravel and sand, very dense, brownish grey, dry					VD	D	
FILL	SILT, stiff, no plasticity, brownish grey, dry	0.5m				St		
LAKE SEDIMENTS	Clayey SILT, soft, medium to high plasticity, white, moist to wet, powdery, Diatomaceous Lake Silts	1.0m				S	M-W	
	Clayey SILT, soft, medium to high plasticity, brownish white, moist to wet, Diatomaceous Lake Silts	1.5m						
		2.0m						
	End of Bore at 2.0m							
		2.5m						
		3.0m						
		3.5m						
		4.0m						
		4.5m						
		5.0m						

Client	Sigma Consultants Ltd	Borehole No.	BH4
Site address	Rotorua Museum		
Drill method	Hand Auger	Terrane Job Ref.	3278
Drilled by	jwc		
Logged by	jwc	Date drilled	14/05/2007
Notes:			
1.			
Stratigraphy	Soil Description	Depth	
ROAD SUB-GRADE	Mixed gravel and sand, very dense, brownish grey, dry		
FILL	SILT, stiff, no plasticity, brownish grey, dry	0.5m	
LAKE SEDIMENTS	Clayey SILT, soft, medium to high plasticity, white, moist to wet, powdery, Diatomaceous Lake Silts	1.0m	
	Clayey SILT, soft, medium to high plasticity, brownish white, moist to wet, Diatomaceous Lake Silts	1.5m	
		2.0m	
	End of Bore at 2.0m		
		2.5m	
		3.0m	
		3.5m	
		4.0m	
		4.5m	
		5.0m	

GEOLOGY Soil / Rock Type Stratigraphy	DESCRIPTION OF SOIL	GROUNDWATER	DEPTH (m)	GRAPHIC LOG	SHEAR VANE TEST RESULTS				
	SAND with silt, brown with red stains, medium dense, moist, non plastic, pumiceous								
	SAND with some silt, pink, medium dense, moist, non plastic								
	SILT, white, dense (cemental), moist, non plastic, lightweight, pumiceous - becomes pink								
	SILT, pinkish light brown, soft, moist to wet, low plasticity, sensitive, warm, scattering of pumiceous sand - encountered gravel sized pumiceous fragments								
	SILT, white to light brown, wet, low plasticity, sensitive, warm - becomes white pinkish brown, very soft, moderately plastic, sensitive								
	Clayey SILT, pinkish brown, wet, moderately plastic, highly sensitive, yellow / black discolouration								
	Silty CLAY, grey with dark green stains, highly plastic, highly sensitive, warm to hot, sulphurous odour - grades to black								
	SILT with some clay and trace sand, dark grey, loose to medium dense, low plasticity, sensitive, warm to hot, pumiceous - becomes hot, increased pumiceous sand								
	END OF HOLE at 2.6 m.								
REMARKS			DATE DRILLED	DRILLED BY	LOGGED BY				
			9/7/09	iar	wno				

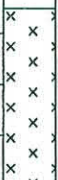
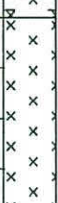
GEOLOGY Soil / Rock Type Stratigraphy	DESCRIPTION OF SOIL	GROUNDWATER	DEPTH (m)	GRAPHIC LOG	SHEAR VANE TEST RESULTS			
	SILT, dark brown, loose, moist, some rootlets							
	Gravelly SAND, mixed light grey and brown, medium dense, moist							
	SILT, mixed black and brown, very loose, moist to wet, organic							
	Sandy SILT, light brown, loose, moist, pumiceous gravel sized rock fragments, non plastic							
	SILT with some clay and minor sand, pinkish brown, soft, wet, pumiceous gravel sized rock fragments							
	SILT with minor clay, pinkish brown, soft, wet, low plasticity							
	SILT with trace clay, white, soft, moist, low plasticity, moderately sensitive							
	Fine SAND, trace silt, light brown, loose, moist to wet, non plastic, alternating layers of white clayey silt							
	Sandy SILT, dark brown, loose, wet, non plastic,							
	SAND with some silt, brown, loose, wet, non plastic, sensitive, pumiceous							
	SAND, light brown to white, loose, moist, non plastic, pumiceous, warm							
	END OF HOLE at 2.2 m.							
REMARKS			DATE DRILLED		DRILLED BY		LOGGED BY	
			9/7/09		iar		wno	

Sheet 1 of 1

JOB NO. 3278

LOCATION Southern Extension

GEOLOGY Soil / Rock Type Stratigraphy		DESCRIPTION OF SOIL	GROUNDWATER	DEPTH (m)	GRAPHIC LOG	SHEAR VANE TEST RESULTS						
						● Peak X Residual	0	50	100	150	200	250
		Topsoil / Planter material										
		SILT with trace clay, pinkish white, soft, moist to wet, non plastic, sensitive, pumiceous, alterantive layers of pinkish white sandy silt										
		SILT, white, soft, wet, sensitive, pumiceous (ash), intermixed with light brown sand										
		Silty SAND, brown, loose, wet to saturated, non plastic, sensitive, pumiceous, scattered gravel sized rock fragments (chemically altered, sub angular)										
		SAND, light brown, loose, moist, non plastic, sensitive, pumiceous										
		END OF HOLE at 2 m.										
REMARKS			DATE DRILLED		DRILLED BY		LOGGED BY					
			9/7/09		iar		wno					

GEOLOGY Soil / Rock Type Stratigraphy	DESCRIPTION OF SOIL	GROUNDWATER	DEPTH (m)	GRAPHIC LOG	SHEAR VANE TEST RESULTS		
	Concrete						
	Gravelly SAND						
	SILT with trace clay, light brown, moist, loose, low plasticity, alternate silt and sand, light brown						
	SILT with clay, white, soft, moist to wet, low plasticity, sensitive						
	Clayey SILT, light pinkish brown, wet to saturated, low plasticity, sensitive						
	SILT with minor sand, brown, loose, wet, non plastic, sensitive, pumiceous		1				
	SAND with minor silt, light brown, medium dense to dense, non plastic						
	END OF HOLE at 1.7 m.						
			2				
REMARKS			DATE DRILLED		DRILLED BY	LOGGED BY	
			9/7/09		iar	wno	

CLIENT Rotorua District Council

HOLE No. TP1

Sheet 1 of 1

PROJECT Rotorua Museum - Existing Building Remedial Works

JOB NO. 3278.02

LOCATION Rotorua Musuem, Government Gardens, Rotorua

GEOLOGY Soil / Rock Type Stratigraphy	DESCRIPTION OF SOIL	GROUNDWATER	REDUCED LEVEL (RL)	DEPTH (m)	GRAPHIC LOG	SHEAR VANE TEST RESULTS			
						● Peak × Residual 0 50 100 150 200 250			
CONCRETE	CONCRETE								
SINTER	SILT, very soft, brown, crumbly, petrified wood, banded, voids								
	SILT, varies from extremely soft to hard, white, crumbly								
LAKE SEDIMENTS	SILT, some fine sand, soft - firm, moist, sensitive, grey								
	SILT, soft - firm, moist, white, dilatant								
	END OF HOLE at 1.05 m.								
REMARKS 1. Testpit adjacent to existing strip footing						DATE DRILLED 1/9/09	DRILLED BY W&H	LOGGED BY ajc	

CLIENT Rotorua District Council

HOLE No. TP2

Sheet 1 of 1

PROJECT Rotorua Museum - Existing Building Remedial Works

JOB NO. 3278.02

LOCATION Rotorua Musuem, Government Gardens, Rotorua

GEOLOGY Soil / Rock Type Stratigraphy	DESCRIPTION OF SOIL	GROUNDWATER	REDUCED LEVEL (RL)	DEPTH (m)	GRAPHIC LOG	SHEAR VANE TEST RESULTS				
						● Peak X Residual 0 50 100 150 200 250				
CONCRETE	CONCRETE, slightly altered along underside of footing									
SINTER	SILT, very soft to hard, voids, crystalline structure, petrified wood, crumbly, white with some brown, dry									
LAKE SEDIMENTS	Sandy SILT, fine grained sand, firm, grey									
	SILT, soft, white, moist, diatomaceous									
	END OF HOLE at 1.05 m.									
REMARKS 1. Testpit adjacent to existing strip footing						DATE DRILLED	DRILLED BY	LOGGED BY		
						1/9/09	W&H	ajc		

Terrane Consultants Ltd
32 Willow Street, PO Box 13607
Tauranga
07 579 9708 Fax: 07 579 9702

CLIENT Rotorua District Council

HOLE No. TP3

Sheet 1 of 1

PROJECT Rotorua Museum - Existing Building Remedial Works

JOB NO. 3278.02

LOCATION Rotorua Museum, Government Gardens, Rotorua

GEOLOGY Soil / Rock Type Stratigraphy	DESCRIPTION OF SOIL	GROUNDWATER	REDUCED LEVEL (RL)	DEPTH (m)	GRAPHIC LOG	SHEAR VANE TEST RESULTS					
						● Peak ✕ Residual 0 50 100 150 200 250					
FILL	Gravelly SAND, medium dense, gravel is lithics and pumice, mixed yellowish orange and grey										
SINTER	SILT, extremely soft to very hard, lots of voids, voids up to 250mm wide, crystalline structure, some banding, petrified wood, white - becomes mixed white and light brown										
LAKE SEDIMENTS	SILT, soft, wet, some voids, voids are subvertical, random cracks to 20 mm and contain sulphurous precipitate, light brown, diatomaceous - becomes white										
	END OF HOLE at 1.05 m.										
REMARKS 1. Testpit adjacent to existing pad foundation 2. Strong gas smell (4.2 ppm)				DATE DRILLED 1/9/09	DRILLED BY W&H	LOGGED BY ajc					

Terrane Consultants Ltd
32 Willow Street, PO Box 13607
Tauranga
07 579 9708 Fax: 07 579 9702

CLIENT Rotorua District Council

HOLE No. TP4

Sheet 1 of 1

PROJECT Rotorua Museum - Existing Building Remedial Works

JOB NO. 3278.02

LOCATION Rotorua Museum, Government Gardens, Rotorua

[illegible]

CLIENT Rotorua District Council

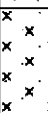
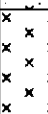
HOLE No. TP5

Sheet 1 of 1

PROJECT Rotorua Museum - Existing Building Remedial Works

JOB NO. 3278.02

LOCATION Rotorua Musuem, Government Gardens, Rotorua

GEOLOGY Soil / Rock Type Stratigraphy	DESCRIPTION OF SOIL	GROUNDWATER	REDUCED LEVEL (RL)	DEPTH (m)	GRAPHIC LOG	SHEAR VANE TEST RESULTS						
						● Peak X Residual	0	50	100	150	200	250
CONCRETE	CONCRETE, thin band of orange discolouration											
FILL	SAND, slightly silty, slightly gravelly, fine-coarse grained sand, loose to medium dense, pumiceous, dark brown, dry											
	GRAVEL, gravel to 35mm, pumiceous, loose, very dark orange, dry											
LAKE SEDIMENTS	SAND, trace of silt, minor gravel, fine-coarse grained sand (mostly fine), pumiceous gravel, light brown, dry											
	SILT, soft, no plasticity, white with some orange discolouration, moist - mixed with SAND, trace of silt, grey, moist											
	SILT, slightly clayey, white moist											
	END OF HOLE at 0.85 m.											
REMARKS 1. Testpit adjacent to existing strip footing					DATE DRILLED	DRILLED BY	LOGGED BY					
					1/9/09	W&H	rm					

GEOLOGY Soil / Rock Type Stratigraphy		DESCRIPTION OF SOIL	GROUNDWATER	REDUCED LEVEL (RL)	DEPTH (m)	GRAPHIC LOG	SHEAR VANE TEST RESULTS						
							● Peak X Residual	0	50	100	150	200	250
CONCRETE		CONCRETE											
FILL		Silty SAND, dense, white, dry, pumiceous - becomes brown Sandy GRAVEL, gravel to 30 mm, subrounded, loose, pumiceous, mixed brown and light grey											
LAKE SEDIMENTS		SAND, trace of silt, fine grained sand, medium dense, pumiceous, light brown, moist SILT, soft, no plasticity, white with some orange discolouration, moist - mixed with SAND, trace of silt, grey, moist SILT, slightly clayey, no plasticity, white, moist											
		END OF HOLE at 0.9 m.											

CLIENT Rotorua District Council

HOLE No. TP7

Sheet 1 of 1

PROJECT Rotorua Museum - Existing Building Remedial Works

JOB NO. 3278.02

LOCATION Rotorua Musuem, Government Gardens, Rotorua

GEOLOGY Soil / Rock Type Stratigraphy	DESCRIPTION OF SOIL	GROUNDWATER	REDUCED LEVEL (RL)	DEPTH (m)	GRAPHIC LOG	SHEAR VANE TEST RESULTS				
CONCRETE	CONCRETE									
LAKE SEDIMENTS	SILT, stiff, no plasticity, light brown with dark orange stains, moist									
	Silty SAND, fine grained sand, dense, pumiceous, light brown, moist									
	SAND, trade of silt, fine grained sand, medium dense, pumiceous, light grey, moist - becomes light brown									
	- becomes grey									
	SILT, stiff, no plasticity, white with orange banding, moist									
	END OF HOLE at 0.9 m.			1						
REMARKS 1. Testpit adjacent to existing strip footing				DATE DRILLED 1/9/09	DRILLED BY W&H	LOGGED BY mm				

CLIENT Rotorua District Council

HOLE No. TP8

Sheet 1 of 1

PROJECT Rotorua Museum - Existing Building Remedial Works

JOB NO. 3278.02

LOCATION Rotorua Musuem, Government Gardens, Rotorua

GEOLOGY Soil / Rock Type Stratigraphy	DESCRIPTION OF SOIL	GROUNDWATER	REDUCED LEVEL (RL)	DEPTH (m)	GRAPHIC LOG	SHEAR VANE TEST RESULTS						
						● Peak X Residual	0	50	100	150	200	250
CONCRETE	CONCRETE, orange to dark orange discolouration along underside of footing											
TOPSOIL	Gravelly SILT, soft, pumice gravel, subangular, dark brown, moist											
SINTER	SILT, hard to very hard, small amount of petrified wood, small voids, white with brown stains, dry											
LAKE SEDIMENTS	SILT, soft, no plasticity, light brown, moist											
	SILT, some fine grained sand, soft, light brown, moist											
	SILT, slightly clayey, stiff, no plasticity, white, moist											
	END OF HOLE at 0.9 m.											
REMARKS 1. Testpit adjacent to existing strip footing				DATE DRILLED	DRILLED BY		LOGGED BY					
				1/9/09	W&H		rm					

CLIENT Rotorua District Council

HOLE No. TP9

Sheet 1 of 1

PROJECT Rotorua Museum - Existing Building Remedial Works

JOB NO. 3278.02

LOCATION Rotorua Musuem, Government Gardens, Rotorua

GEOLOGY Soil / Rock Type Stratigraphy	DESCRIPTION OF SOIL	GROUNDWATER	REDUCED LEVEL (RL)	DEPTH (m)	GRAPHIC LOG	SHEAR VANE TEST RESULTS			
						● Peak X Residual 0 50 100 150 200 250			
CONCRETE	CONCRETE								
FILL	Gravelly SAND, coarse grained sand, subangular gravel to 30mm, dark grey, moist								
SINTER	SILT, hard but crumbly in places, easily fractured, lots of small voids, brown, moist								
LAKE SEDIMENT (??)	SILT, slightly clayey, firm to stiff, no plasticity, white, moist, dries very quickly when reworked								
CONCRETE	CONCRETE, slightly altered, pumiceous, dry								
SINTER	SILT, very hard, white, moist - becomes fractured								
LAKE SEDIMENTS	Sandy SILT, hard, petrified wood, small voids, mixed light/dark brown and white, moist SILT, slightly clayey, minor sand, medium grained sand, dilatent, no plasticity, very light brown, moist END OF HOLE at 0.95 m.								
REMARKS 1. Testpit adjacent to existing strip footing						DATE DRILLED 1/9/09	DRILLED BY W&H	LOGGED BY mm	

CLIENT Rotorua District Council

HOLE No. TP10

Sheet 1 of 1

PROJECT Rotorua Museum - Existing Building Remedial Works

JOB NO. 3278.02

LOCATION Rotorua Musuem, Government Gardens, Rotorua

GEOLOGY Soil / Rock Type Stratigraphy	DESCRIPTION OF SOIL	GROUNDWATER	REDUCED LEVEL (RL)	DEPTH (m)	GRAPHIC LOG	SHEAR VANE TEST RESULTS			
						● Peak X Residual 0 50 100 150 200 250			
CONCRETE	CONCRETE, slight orange discolouration								
FILL	Sandy SILT, firm to stiff, fine to medium grained sand, grey with orange discolouration, dry								
SINTER	Sandy GRAVEL, medium dense, subangular gravel to 35mm, pumiceous, orange discolouration, dry								
	SILT, very soft to very hard, crumbly in places, very few small voids, easily fractured, banded, light brown, dry								
	Sandy SILT, very crumbly, lots of small to very large voids, petrified wood, dry								
LAKE SEDIMENTS	SILT, slightly clayey, soft, dilatant, light brown to brown, moist								
	Sandy SILT, firm, fine to coarse grained sand, pumiceous, grey, moist								
	SILT, slightly clayey, dilatant, diatomaceous, very light pinkish brown, moist								
	END OF HOLE at 0.85 m.								
REMARKS 1. Testpit adjacent to existing strip footing						DATE DRILLED	DRILLED BY	LOGGED BY	
						1/9/09	W&H	rm	

Terrane Consultants Ltd
32 Willow Street, PO Box 13607
Tauranga
07 579 9708 Fax: 07 579 9702

CLIENT Rotorua District Council

HOLE No. TP11

Sheet 1 of 1

PROJECT Rotorua Museum - Existing Building Remedial Works

JOB NO. 3278.02

LOCATION Rotorua Museum, Government Gardens, Rotorua

GEOLOGY		DESCRIPTION OF SOIL	GROUNDWATER	REDUCED LEVEL (RL)	DEPTH (m)	GRAPHIC LOG	SHEAR VANE TEST RESULTS				
Soil / Rock Type Stratigraphy							● Peak × Residual				
CONCRETE		CONCRETE									
FILL		Silty SAND, fine-coarse grained sand, dense, pumiceous, mixed orange dark brown and light grey, dry									
LAKE SEDIMENTS SINTER		Clayey SILT, soft, brown, moist adjacent to 150mm thick of petrified wood, stained greenish yellow and dark orange SILT, hard, slightly crumbly, very small voids, minor petrified wood, greenish yellow stained, moist									
LAKE SEDIMENTS		SILT, slightly clayey, firm, white, moist, bedded with sandy SILT, fine grained sand, firm, grey, moist									
		SILT, slightly clayey, stiff, dilatant, very light brown, moist									
		END OF HOLE at 0.85 m.									
REMARKS		1. Testpit adjacent to existing pad foundation			DATE DRILLED	DRILLED BY	LOGGED BY				
					1/9/09	W&H	rm				



Our Ref: 1002982.0.1000.0/Rep1
Customer Ref: 16592
9 May 2017

Rotorua Lakes Council c/- Cheal Consultants
Level 1, 318 Grey Street
Hamilton East 3216

Attention: Dr Frank Havel

Dear Frank

Rotorua Museum Geotech Investigation Laboratory Test Report

Samples from the above mentioned site have been tested as received and according to your instructions. Test results are included in this report.

One-dimensional consolidation testing for BH03 (5.60 – 5.65m) was performed at our Auckland Laboratory. Test results are included as a separate report at the end of this report.

Samples not destroyed during testing will be retained for one month from the date of this report before being discarded.

Descriptions are enclosed for your information, but are not covered under the IANZ endorsement of this report.

If we can be of any further assistance, feel free to get in touch. Contact details are provided at the bottom of this page.

GEOTECHNICS LTD

Report prepared by:

.....
Brendon Kingham
Laboratory Technician

Authorised for Geotechnics by:

Paul Burton
I have reviewed this
document
2017.05.10 11:07:29 +12'00'

.....
Paul Burton
Project Director

Report checked by:

.....
David Boston
Laboratory Manager
Approved Signatory



All tests reported
herein have been
performed in accordance
with the laboratory's
scope of accreditation

This document consists of 12 pages.

10-May-17

T:\geotechnicsgroup\projects\1002982\1 tauranga laboratory testing\workingmaterial\20170509.rotorua museum.rep1.docx



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Geotechnics Project ID 1002982.0.1.0
Customer Project ID 16592
Customer Project Name Rotorua museum, Geotech invest

DETERMINATION OF LIQUID & PLASTIC LIMIT, PLASTICITY INDEX - ASTM Test D4318-10 (Method A)

TEST DETAILS				
LOCATION	ID	BH03		
	Description	Rotorua Museum		
	Data	N/A		
SAMPLE	Geotechnics ID	GEOT201704280	Date Received	Unknown
	Reference	N/A	Depth	4.50m - 4.80m
	Description	SILT, minor sand, trace gravel; grey. Wet.		
SPECIMEN	Reference	1	Depth	N/A
	Description	N/A		

TEST RESULTS	
Liquid Limit	47
Plastic Limit	36
Plasticity Index	11

Plasticity Chart - D2487-06

Soil Type
M - Silt
C - Clay
O - Organic

Plasticity
L - Low
H - High

The plasticity chart is provided for your inference only and is not covered under our scope of IANZ accreditation. Due to the nature of classifications it is possible to have discrepancies between observational behaviour descriptions and measured parameters

TEST REMARKS	
- The material used for testing was natural, whole soil. - The liquid limit was done with a manual device. The plastic limit was mechanically rolled. A plastic grooving tool was used. - The maximum grain size was approximately 4.75mm.	
This test result is IANZ accredited.	
Approved By	DFB
Date	8/05/2017

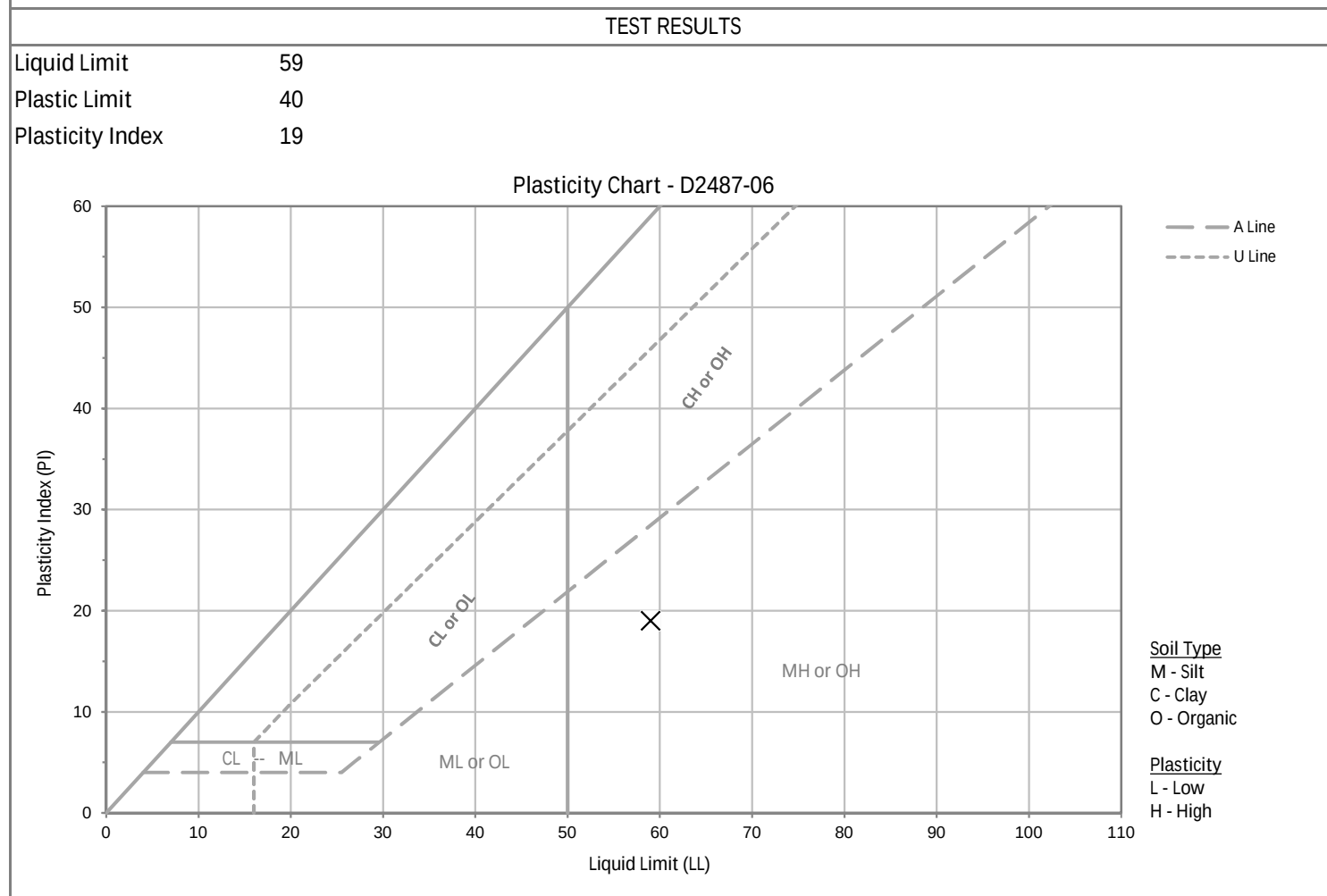


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Geotechnics Project ID 1002982.0.1.0
Customer Project ID 16592
Customer Project Name Rotorua museum, Geotech invest

DETERMINATION OF LIQUID & PLASTIC LIMIT, PLASTICITY INDEX - ASTM Test D4318-10 (Method A)

TEST DETAILS				
LOCATION	ID	BH03		
	Description	Rotorua Museum		
	Data	N/A		
SAMPLE	Geotechnics ID	GEOT201704281	Date Received	Unknown
	Reference	N/A	Depth	5.00m - 5.30m
	Description	SILT, trace sand; light grey with grey mottling. Wet.		
SPECIMEN	Reference	1	Depth	N/A
	Description	N/A		



The plasticity chart is provided for your inference only and is not covered under our scope of IANZ accreditation. Due to the nature of classifications it is possible to have discrepancies between observational behaviour descriptions and measured parameters

TEST REMARKS	
- The material used for testing was natural, whole soil. - The liquid limit was done with a manual device. The plastic limit was mechanically rolled. A plastic grooving tool was used. - The maximum grain size was approximately <2mm.	
This test result is IANZ accredited.	
Approved By	DFB
Date	8/05/2017

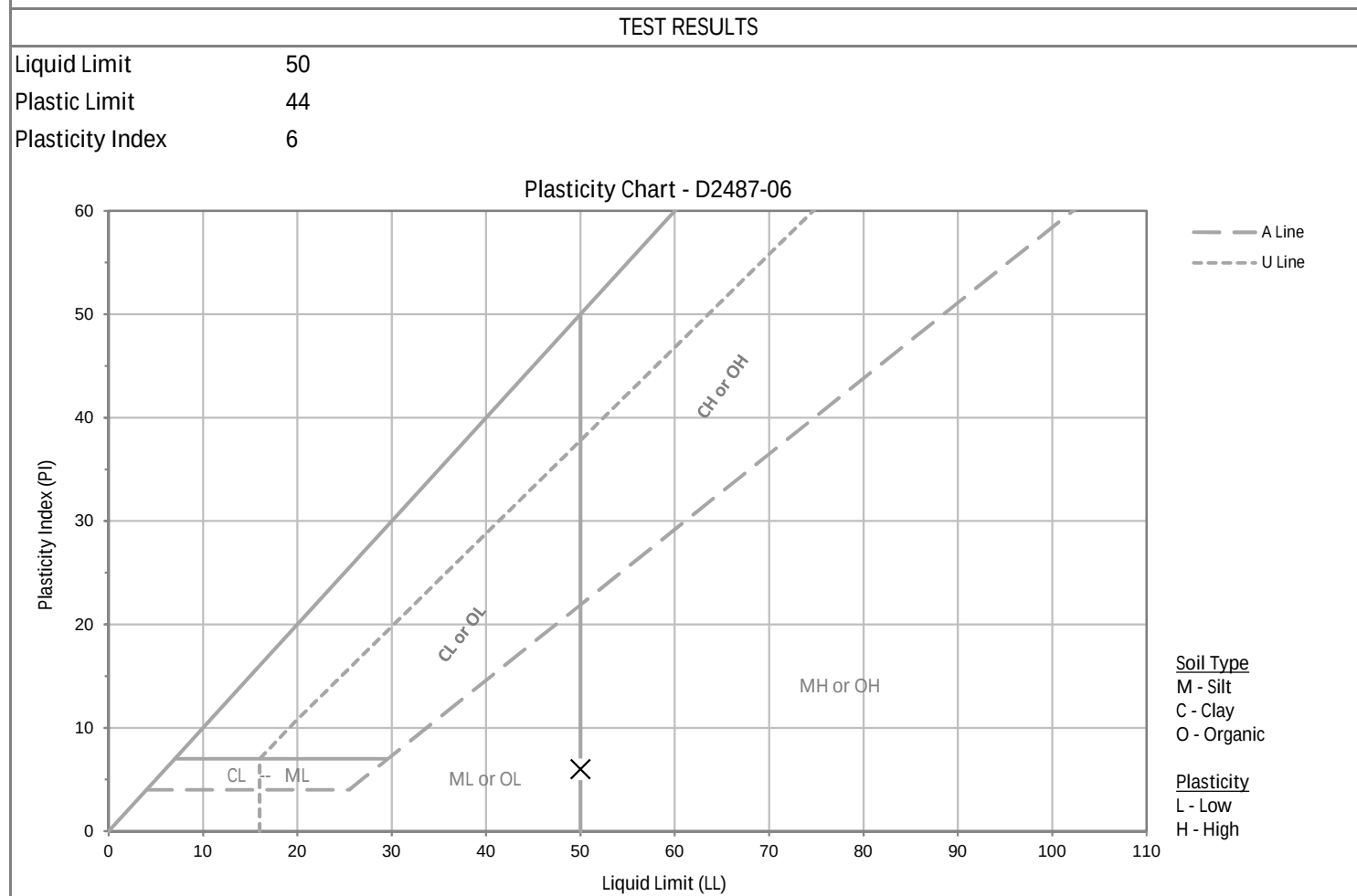


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Geotechnics Project ID 1002982.0.1.0
Customer Project ID 16592
Customer Project Name Rotorua museum, Geotech invest

DETERMINATION OF LIQUID & PLASTIC LIMIT, PLASTICITY INDEX - ASTM Test D4318-10 (Method A)

TEST DETAILS				
LOCATION	ID	BH03		
	Description	Rotorua Museum		
	Data	N/A		
SAMPLE	Geotechnics ID	GEOT201704282	Date Received	Unknown
	Reference	N/A	Depth	6.80m - 7.00m
	Description	Silty, SAND, with minor gravel; dark blueish grey. Wet.		
SPECIMEN	Reference	1	Depth	N/A
	Description	N/A		



The plasticity chart is provided for your inference only and is not covered under our scope of IANZ accreditation. Due to the nature of classifications it is possible to have discrepancies between observational behaviour descriptions and measured parameters

TEST REMARKS			
- The material used for testing was natural, whole soil. - The liquid limit was done with a manual device. The plastic limit was mechanically rolled. A plastic grooving tool was used. - The maximum grain size was approximately 4.75mm.			
This test result is IANZ accredited.			
Approved By	DFB	Date	9/05/2017

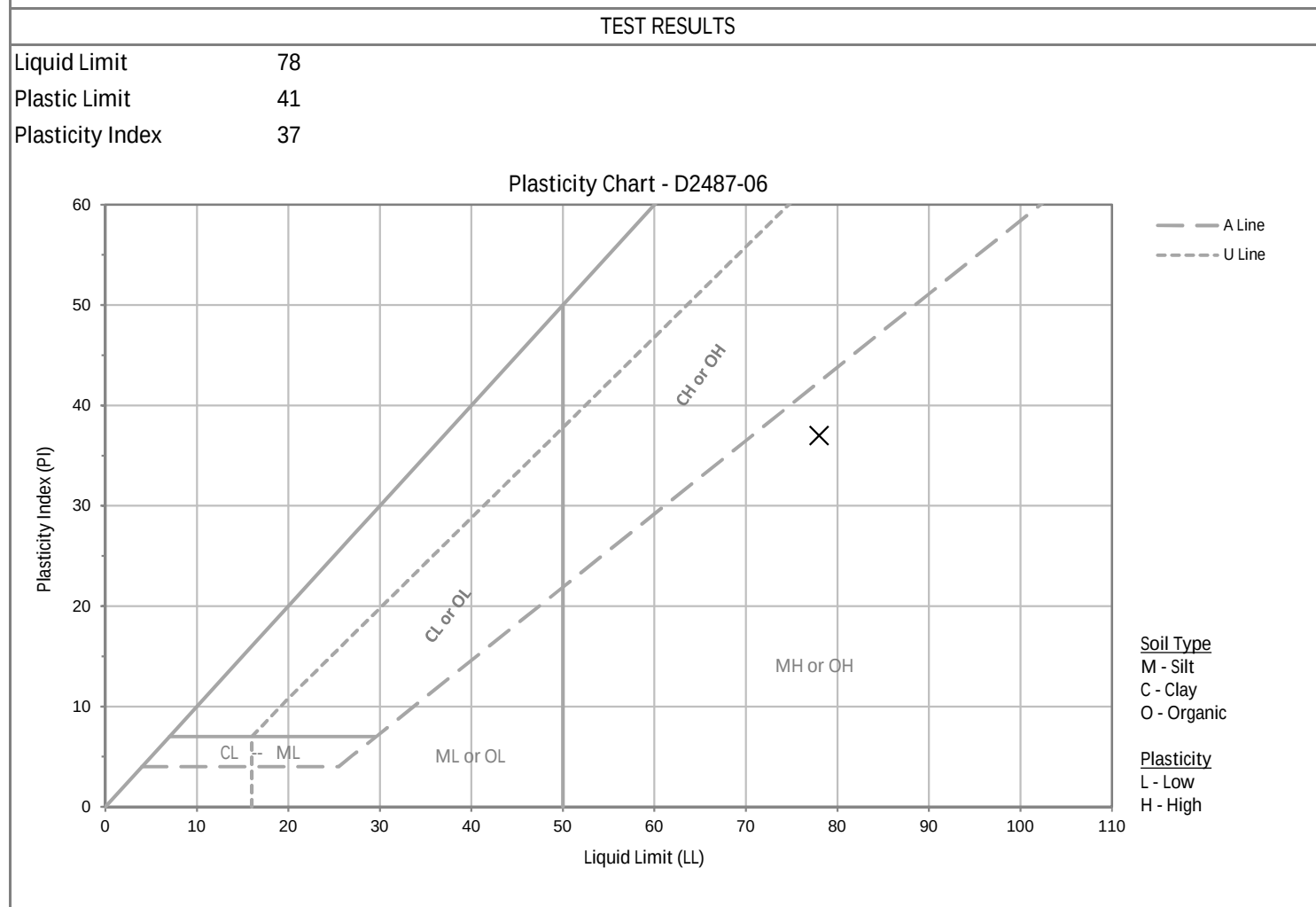


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Geotechnics Project ID 1002982.0.1.0
Customer Project ID 16592
Customer Project Name Rotorua museum, Geotech invest

DETERMINATION OF LIQUID & PLASTIC LIMIT, PLASTICITY INDEX - ASTM Test D4318-10 (Method A)

TEST DETAILS				
LOCATION	ID	BH03		
	Description	Rotorua Museum		
	Data	N/A		
SAMPLE	Geotechnics ID	GEOT201704283	Date Received	Unknown
	Reference	Push Tube	Depth	7.50m - 7.90m
	Description	Silty SAND, minor gravel; greenish blue with brownish orange mottling. Wet.		
SPECIMEN	Reference	1	Depth	N/A
	Description	N/A		



The plasticity chart is provided for your inference only and is not covered under our scope of IANZ accreditation. Due to the nature of classifications it is possible to have discrepancies between observational behaviour descriptions and measured parameters

TEST REMARKS	
- The material used for testing was natural, fraction passing 425um sieve. - The liquid limit was done with a manual device. The plastic limit was mechanically rolled. A plastic grooving tool was used. - The soil was washed over a 425um sieve. The maximum grain size was approximately 9.5mm.	
This test result is IANZ accredited.	
Approved By	DFB
Date	8/05/2017



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Geotechnics Project ID 1002982.0.1.0
Customer Project ID 16592
Customer Project Name Rotorua museum, Geotech invest

DETERMINATION OF THE WATER CONTENT & FINES CONTENT - GEO190-13

TEST DETAILS				
LOCATION	ID	BH03		
	Description	Rotorua Museum		
	Data	N/A		
SAMPLE	Geotechnics ID	GEOT201704280	Date Received	Unknown
	Reference	N/A	Depth	4.50m - 4.80m
	Description	SILT, minor sand, trace gravel; grey. Wet.		
SPECIMEN	Reference	2	Depth	N/A
	Description	N/A		
TEST RESULT				
Natural Water Content		92.5%		
Fines Content Passing 75µm Sieve		82.8%		
Fines Content Passing 63µm Sieve		81.6%		
TEST REMARKS				
The material used for testing was natural, whole soil.				
This test result is IANZ accredited.				
Approved By	DFB	Date	8/05/2017	



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Geotechnics Project ID 1002982.0.1.0
Customer Project ID 16592
Customer Project Name Rotorua museum, Geotech invest

DETERMINATION OF THE WATER CONTENT & FINES CONTENT - GEO190-13

TEST DETAILS				
LOCATION	ID	BH03		
	Description	Rotorua Museum		
	Data	N/A		
SAMPLE	Geotechnics ID	GEOT201704281	Date Received	Unknown
	Reference	N/A	Depth	5.00m - 5.30m
	Description	SILT, trace sand; light grey with grey mottling. Wet.		
SPECIMEN	Reference	2	Depth	N/A
	Description	N/A		
TEST RESULT				
Natural Water Content		71.9%		
Fines Content Passing 75µm Sieve		96.4%		
Fines Content Passing 63µm Sieve		95.9%		
TEST REMARKS				
The material used for testing was natural, whole soil.				
This test result is IANZ accredited.				
Approved By	DFB	Date	8/05/2017	



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Geotechnics Project ID 1002982.0.1.0
Customer Project ID 16592
Customer Project Name Rotorua museum, Geotech invest

DETERMINATION OF THE WATER CONTENT & FINES CONTENT - GEO190-13

TEST DETAILS				
LOCATION	ID	BH03		
	Description	Rotorua Museum		
	Data	N/A		
SAMPLE	Geotechnics ID	GEOT201704282	Date Received	Unknown
	Reference	N/A	Depth	6.80m - 7.00m
	Description	Silty, SAND, with minor gravel; dark blueish grey. Wet.		
SPECIMEN	Reference	2	Depth	N/A
	Description	N/A		
TEST RESULT				
Natural Water Content		74.4%		
Fines Content Passing 75µm Sieve		26.8%		
Fines Content Passing 63µm Sieve		23.5%		
TEST REMARKS				
The material used for testing was natural, whole soil.				
This test result is IANZ accredited.				
Approved By	DFB	Date	8/05/2017	



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Geotechnics Project ID 1002982.0.1.0
Customer Project ID 16592
Customer Project Name Rotorua museum, Geotech invest

DETERMINATION OF THE WATER CONTENT & FINES CONTENT - GEO190-13

TEST DETAILS				
LOCATION	ID	BH03		
	Description	Rotorua Museum		
	Data	N/A		
SAMPLE	Geotechnics ID	GEOT201704283	Date Received	Unknown
	Reference	Push Tube	Depth	7.50m - 7.90m
	Description	Silty SAND, minor gravel; greenish blue with brownish orange mottling. Wet.		
SPECIMEN	Reference	2	Depth	N/A
	Description	N/A		
TEST RESULT				
Natural Water Content		66.7%		
Fines Content Passing 75µm Sieve		30.4%		
Fines Content Passing 63µm Sieve		28.5%		
TEST REMARKS				
The material used for testing was natural, whole soil.				
This test result is IANZ accredited.				
Approved By	DFB	Date	8/05/2017	



Our Ref: 1002982.0.2000.0
Customer Ref: 16592
8 May 2017

Rotorua Lake Council c/- Cheal Consultants
Level 1, 318 Grey Street,
Hamilton East 3216

Attention: Mr Frank Havel

Dear Frank

Rotorua Museum Laboratory Test Report

Introduction

Geotechnics was engaged to carry out laboratory testing on samples from the above mentioned location.

Sampling Procedure

Samples have been tested as received from the customer.

Sample Location Plan

Not applicable.

Samples

One push tube sample was delivered to our laboratory.

Date of Sample Receipt

19 April 2017.

Customer's Instructions

We were instructed to perform a one-dimensional consolidation on push tube sample.

Test Method(s)

NZS 4402:1986 Test 7.1 – One-dimensional consolidation.

Test Results

Test results are attached.

Test Remarks

See page 3.

General Remarks

Sample was destroyed during testing.

Descriptions are enclosed for your information, are not covered under the IANZ endorsement of this report.

Please reproduce this report in full when transmitting to others or including in internal reports.

If we can be of any further assistance, feel free to get in touch. Contact details are provided at the bottom of the letterhead page.

GEOTECHNICS LTD

Report prepared by:



Sim Tirunahari
I am the author of this
document
2017.05.08 16:43:06 +12'00'

.....
Sim Tirunahari
Soils Laboratory Manager

Authorised for Geotechnics by:



Steven Anderson
I am approving this
document
2017.05.08 17:01:38 +12'00'

.....
Steven Anderson
Project Director
Approved Signatory

Report checked by:



Steven Anderson
I have reviewed this
document
2017.05.08 17:01:53 +12'00'

.....
Steven Anderson
Regional Manager
Approved Signatory

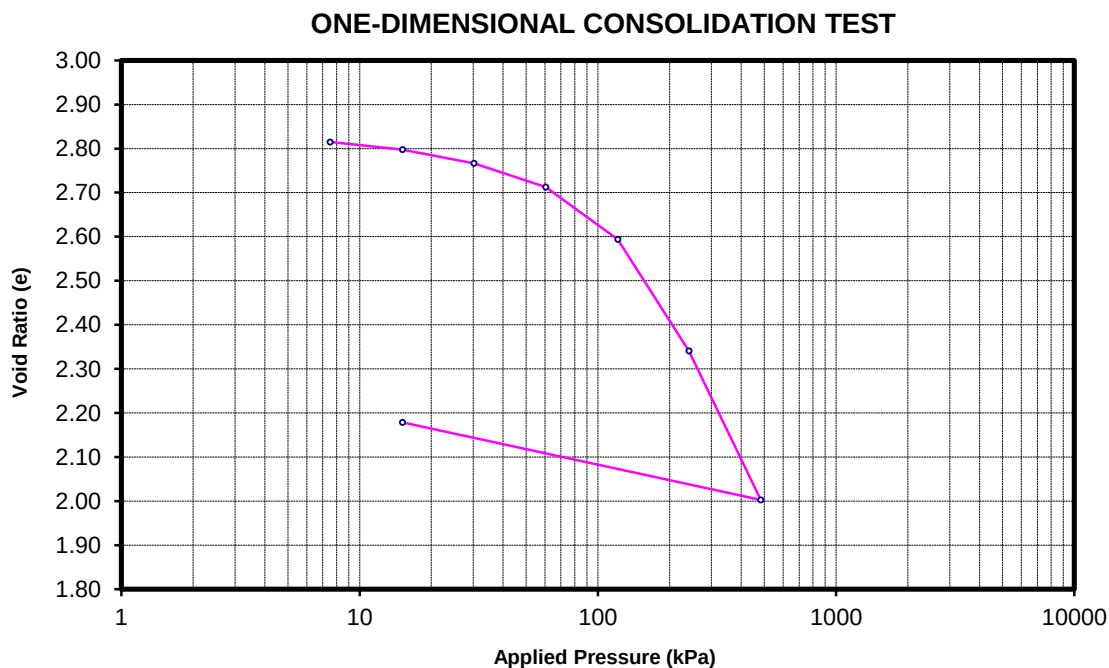


All tests reported
herein have been
performed in accordance
with the laboratory's
scope of accreditation

This report consists of 3 pages.

8-May-17

t:\geotechnicsgroup\projects\1002982\2 auckland laboratory testing\issueddocuments\20170508.st.rotorua museum.docx



Pressure (kPa)	Void Ratio (e)	Pressure Increment (kPa)	Coefficient of Consolidation Cv (m ² /yr)	Coefficient of Volume Compressibility Mv (m ² /MN)
As received 0	2.834			
Preload 7.5	2.815	0 to 7.5	NA	0.64
15.1	2.798	7.5 to 15.1	50	0.60
30.2	2.766	15.1 to 30.2	42	0.54
60.3	2.713	30.2 to 60.3	32	0.47
121	2.594	60.3 to 121	28	0.53
241	2.341	121 to 241	22	0.59
483	2.003	241 to 483	18	0.42
Unload 15.1	2.179	483 to 15.1	NA	NA

Appendix C: Investigation supervised by T+T

- **C1 - Borehole logs**
- **C2 - Groundwater monitoring results**
- **C3 - Cyclic triaxial test results**
- **C4 - One-dimensional consolidation test results**
- **C5 - Shear wave velocity report**

C1 - Borehole logs



Tonkin+Taylor

BOREHOLE LOG

BOREHOLE No.:

BH1

SHEET: 1 OF 2

DRILLED BY: Ben & Unga

LOGGED BY: JMB

CHECKED: DMMM

START DATE: 20/12/2021

FINISH DATE: 20/12/2021

CONTRACTOR: McMillan Drilling

PROJECT: Rotorua Museum Seismic Strengthening
JOB No.: 1017126.0000.4
LOCATION: Rotorua Museum

CO-ORDINATES: 5774168.00 mN
(NZTM2000) 1885665.00 mE

DIRECTION:
ANGLE FROM HORIZ.: -90°

R.L. GROUND: 283.00m
R.L. COLLAR: 283.00m
DATUM: NZVD2016
SURVEY: Handheld GPS

GEOLOGICAL UNIT	DESCRIPTION OF CORE		Rock Weathering	Rock Strength	Sampling Method	Core Recovery (%)	Testing	RL (m)	Depth (m)	Graphic Log	ROCK DEFECTS					Fluid Loss (%)	Water Level	Casing	Installation	Core Box No																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
	SOIL: Classification, colour, consistency / density, moisture, plasticity ROCK: Weathering, colour, fabric, name, strength, cementation										Defect Log	Fracture Spacing (mm)	RQD (%)	Description & Additional Observations																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
Alluvial Deposits	0.00m: NOT LOGGED - Hydrovac excavation.		W1 W2 W3 W4 W5 W6 W7 W8 W9 W10 W11 W12 W13 W14 W15 W16 W17 W18 W19 W20 W21 W22 W23 W24 W25 W26 W27 W28 W29 W30 W31 W32 W33 W34 W35 W36 W37 W38 W39 W40 W41 W42 W43 W44 W45 W46 W47 W48 W49 W50 W51 W52 W53 W54 W55 W56 W57 W58 W59 W60 W61 W62 W63 W64 W65 W66 W67 W68 W69 W70 W71 W72 W73 W74 W75 W76 W77 W78 W79 W80 W81 W82 W83 W84 W85 W86 W87 W88 W89 W90 W91 W92 W93 W94 W95 W96 W97 W98 W99 W100	W1 W2 W3 W4 W5 W6 W7 W8 W9 W10 W11 W12 W13 W14 W15 W16 W17 W18 W19 W20 W21 W22 W23 W24 W25 W26 W27 W28 W29 W30 W31 W32 W33 W34 W35 W36 W37 W38 W39 W40 W41 W42 W43 W44 W45 W46 W47 W48 W49 W50 W51 W52 W53 W54 W55 W56 W57 W58 W59 W60 W61 W62 W63 W64 W65 W66 W67 W68 W69 W70 W71 W72 W73 W74 W75 W76 W77 W78 W79 W80 W81 W82 W83 W84 W85 W86 W87 W88 W89 W90 W91 W92 W93 W94 W95 W96 W97 W98 W99 W100	HWT	0																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										</

COMMENTS: 5.5 m deep 32 mm ID standpipe piezometer installed in borehole.

Hole Depth
10m

Scale 1:35

Rev.: A

CORE PHOTOS

BOREHOLE No.: **BH1**

SHEET: 1 OF 2

PROJECT: Rotorua Museum Seismic Strengthening		LOCATION: Rotorua Museum	JOB No.: 1017126.0000.4
CO-ORDINATES: (NZTM2000)	5774168.00 mN 1885665.00 mE	DRILL TYPE: HQ3	HOLE STARTED: 20/12/2021
R.L.:	283.00m	DRILL METHOD: Rotary Cored	HOLE FINISHED: 20/12/2021
DATUM:	NZVD2016	LOGGED BY: JMB	CHECKED: DMMM



0.00-4.25m



4.25-6.80m

CORE PHOTOS

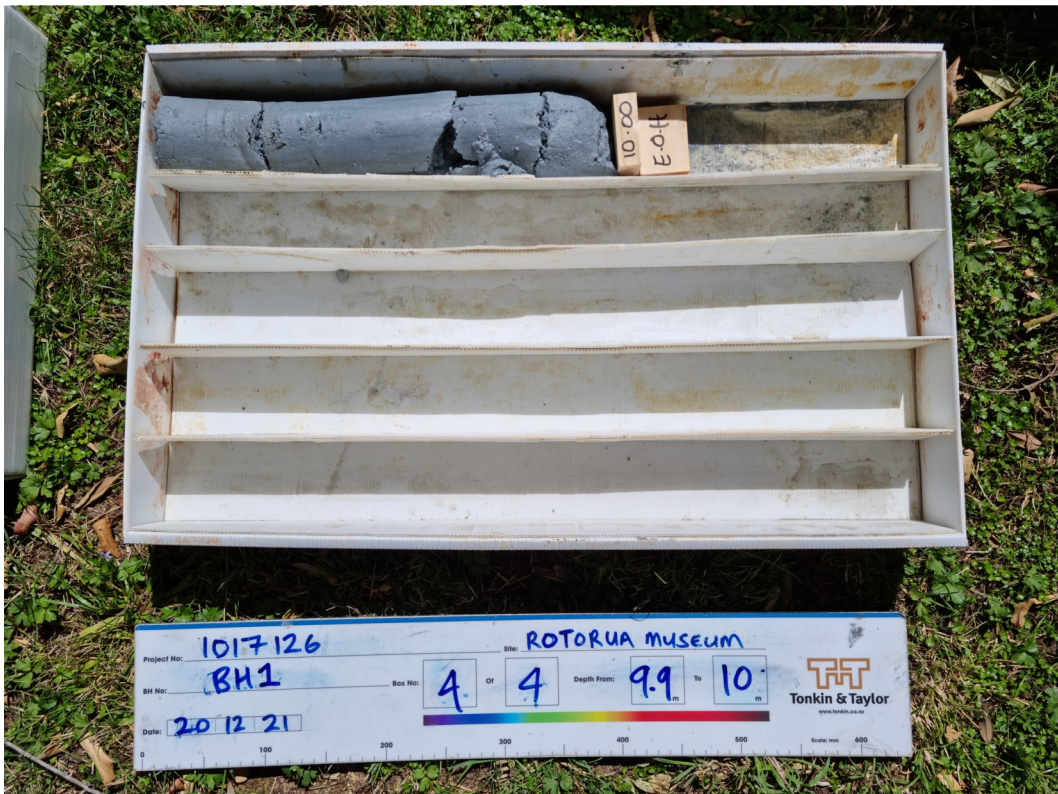
BOREHOLE No.: **BH1**

SHEET: 2 OF 2

PROJECT: Rotorua Museum Seismic Strengthening		LOCATION: Rotorua Museum	JOB No.: 1017126.0000.4
CO-ORDINATES: 5774168.00 mN (NZTM2000) 1885665.00 mE		DRILL TYPE: HQ3	HOLE STARTED: 20/12/2021
R.L.: 283.00m		DRILL METHOD: Rotary Cored	HOLE FINISHED: 20/12/2021
DATUM: NZVD2016		LOGGED BY: JMB	CHECKED: DMMM



6.80-9.90m



9.90-10.00m



Tonkin+Taylor

BOREHOLE LOG

BOREHOLE No.:

BH3

SHEET: 1 OF 2

DRILLED BY: Ben & Unga

LOGGED BY: JMB

CHECKED: DMMM

START DATE: 21/12/2021

FINISH DATE: 21/12/2021

CONTRACTOR: McMillan Drilling

PROJECT: Rotorua Museum Seismic Strengthening
JOB No.: 1017126.0000.4
LOCATION: Rotorua Museum

CO-ORDINATES: 5774133.00 mN
(NZTM2000) 1885665.00 mE

DIRECTION:

ANGLE FROM HORIZ.: -90°

R.L. GROUND: 283.00m

R.L. COLLAR: 283.00m

DATUM: NZVD2016

SURVEY: Handheld GPS

GEOLOGICAL UNIT	DESCRIPTION OF CORE	Rock Weathering	Rock Strength	Sampling Method	Core Recovery (%)	Testing	RL (m)	Depth (m)	Graphic Log	ROCK DEFECTS				Fluid Loss (%)	Water Level	Casing	Installation	Core Box No
										Defect Log	Fracture Spacing (mm)	RQD (%)	Description & Additional Observations					
Alluvial Deposits	0.00m: NOT LOGGED - Hydrovac excavation. Some sediment returned from drill run. Mixture of dark grey well graded SAND and brownish white silty pumiceous sand.																	
	1.50m: CORE LOSS.																	
	1.60m: Sandy fine GRAVEL, some silt; brownish white. Loosely packed, wet, well graded. Gravel, pumice; sand, fine to coarse, pumiceous.																	
	1.70m: Silty gravelly fine to coarse SAND; brownish white. Tightly packed, moist, well graded. Gravel, fine. Cemented layer, can't break with hands.																	
	1.85m: Sandy fine GRAVEL, some silt; brownish white. Loosely packed, wet, well graded. Gravel, sub-rounded to sub-angular, unweathered to slightly weathered, pumice; sand, fine to coarse, pumiceous. Yellow sulphur crystals present throughout layer.																	
	2.00m: Sandy fine to coarse GRAVEL, some silt; whitish brown. Loosely packed, wet, well graded. Gravel, sub-angular to angular, slightly to moderately weathered, pumice; sand, fine to coarse, pumiceous. Sulphur crystals present.																	
	2.40m: Sandy medium to coarse GRAVEL; greyish white. Poorly graded. Gravel, sub-angular to angular, unweathered to slightly weathered, pumice; sand, coarse, pumiceous. Sulphur crystals not present.																	
Alluvial Deposits	2.70m: Medium to coarse GRAVEL, some sand, minor silt; greyish white mixed with some black. Loosely packed, moist to wet, poorly graded. Gravel, sub-angular to angular, moderately to highly weathered, pumice; sand, coarse, pumiceous. Sulphur crystals present. 50 mm thick cemented layer at base of unit.																	
	3.60m: Sandy fine to medium GRAVEL, minor silt; greyish white mixed with some black. Loosely packed, moist to wet, well graded. Gravel, sub-angular to angular, moderately to highly weathered, pumice; sand, coarse, pumiceous. Sulphur crystals present.																	
Alluvial Deposits	4.50m: Fine to medium GRAVEL, some silt and some sand; grey. Tightly packed, wet to saturated, well graded. Gravel, sub-angular to angular, unweathered to slightly weathered, pumice; sand, coarse, pumiceous. Bottom 100 mm of unit changes to gravelly sandy SILT, non-plastic.																	

COMMENTS: 8 m deep 80 mm ID PVC conduit installed in borehole for cross-hole seismic test.

Hole Depth
10m

Scale 1:25

Box 1, 0.00-4.00m

Rev.: A

BOREHOLE LOG

BOREHOLE No.:

BH3

SHEET: 2 OF 2

DRILLED BY: Ben & Unga

LOGGED BY: JMB

CHECKED: DMMM

START DATE: 21/12/2021

FINISH DATE: 21/12/2021

CONTRACTOR: McMillan Drilling

PROJECT: Rotorua Museum Seismic Strengthening
JOB No.: 1017126.0000.4
LOCATION: Rotorua Museum

CO-ORDINATES: 5774133.00 mN
(NZTM2000) 1885665.00 mE

DIRECTION:

ANGLE FROM HORIZ.: -90°

R.L. GROUND: 283.00m
R.L. COLLAR: 283.00m

DATUM: NZVD2016

SURVEY: Handheld GPS

GEOLOGICAL UNIT	DESCRIPTION OF CORE	Rock Weathering	Rock Strength	Sampling Method	Core Recovery (%)	Testing	RL (m)	Depth (m)	Graphic Log	ROCK DEFECTS				Fluid Loss (%)	Water Level	Casing	Installation	Core Box No
										Defect Log	Fracture Spacing (mm)	RQD (%)	Description & Additional Observations					
Alluvial Deposits	SOIL: Classification, colour, consistency / density, moisture, plasticity ROCK: Weathering, colour, fabric, name, strength, cementation	UW MS MC CW	US MS MC CW	US MS MC CW	US MS MC CW	US MS MC CW				2000 1000 500 200 100 50 20			25 50 75					
	5.00m: Fine to medium GRAVEL, some silt and some sand; grey. Tightly packed, wet to saturated, well graded. Gravel, sub-angular to angular, unweathered to slightly weathered, pumice; sand, coarse, pumiceous. Bottom 100 mm of unit changes to gravelly sandy SILT, non-plastic.			HQ3	100			5.5										
Lake Deposits	5.80m: SILT, minor sand; dark grey. Stiff to very stiff, moist, non-plastic to low plasticity. Sand, fine. Thinly bedded.			HQ3	100		277	6.0				5.80 - 6.85m: Thin 10 - 30 mm horizons of sandy SILT.						
	6.85m: Fine SAND, some silt, minor gravel; grey. Loosely packed, wet, poorly graded. Gravel, fine, sub-rounded to sub-angular, pumice.			HQ3	100			6.5										
	7.00 - 7.10m: Grey low plasticity SILT horizon.																	
	7.40 - 7.50m: Grey sandy SILT, low plasticity horizon, trace fine gravel.																	
	7.50m: CORE LOSS.							7.5										
	7.80m: Silty fine SAND, minor gravel, trace clay; dark grey. Loosely packed, moist to wet. Gravel, fine, sub-rounded to sub-angular, pumice.			HQ3	80		275	8.0										
	8.30m: Silty fine and coarse SAND, trace gravel; dark grey, bedded. Loosely packed, moist, well graded. Gravel, fine, pumice.							8.5				8.30 - 9.10m: Thin (less than 20mm), medium to coarse silty sandy horizons throughout layer						
	9.10m: Cemented fine SAND, some gravel; light grey. Tightly packed. Gravel, fine to medium. Hydrothermally altered.						274	9.0										
	9.30m: Silty fine SAND; greyish green. Tightly packed, moist, poorly graded.			HQ3	100			9.5										
	10m: END OF BOREHOLE. Target depth.																	

Box 3, 7.10-10.00m

Box 2, 4.00-7.10m

COMMENTS: 8 m deep 80 mm ID PVC conduit installed in borehole for cross-hole seismic test.

Hole Depth
10m

Scale 1:25

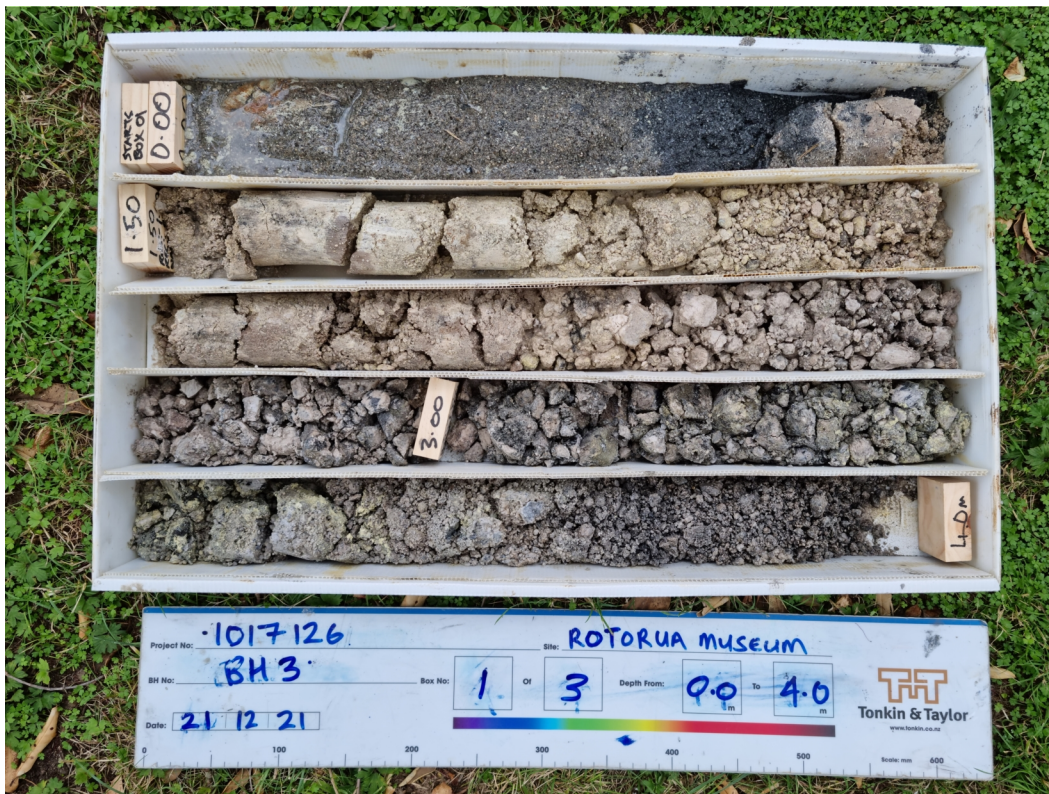
Rev.: A

CORE PHOTOS

BOREHOLE No.: **BH3**

SHEET: 1 OF 2

PROJECT: Rotorua Museum Seismic Strengthening		LOCATION: Rotorua Museum	JOB No.: 1017126.0000.4
CO-ORDINATES: (NZTM2000)	5774133.00 mN 1885665.00 mE	DRILL TYPE: HQ3	HOLE STARTED: 21/12/2021
R.L.:	283.00m	DRILL METHOD: Rotary Cored	HOLE FINISHED: 21/12/2021
DATUM:	NZVD2016	LOGGED BY: JMB	CHECKED: DMMM



0.00-4.00m



4.00-7.10m

CORE PHOTOS

PROJECT: Rotorua Museum Seismic Strengthening		LOCATION: Rotorua Museum	JOB No.: 1017126.0000.4
CO-ORDINATES: (NZTM2000)	5774133.00 mN 1885665.00 mE	DRILL TYPE: HQ3	HOLE STARTED: 21/12/2021
R.L.:	283.00m	DRILL METHOD: Rotary Cored	HOLE FINISHED: 21/12/2021
DATUM:	NZVD2016		DRILLED BY: McMillan Drilling
			LOGGED BY: JMB CHECKED: DMMM



7.10-10.00m

BOREHOLE LOG

BOREHOLE No.:

BH5

SHEET: 1 OF 2

DRILLED BY: Ben & Unga

LOGGED BY: JMB

CHECKED: DMMM

START DATE: 20/12/2021

FINISH DATE: 21/12/2021

CONTRACTOR: McMillan Drilling

PROJECT: Rotorua Museum Seismic Strengthening
JOB No.: 1017126.0000.4
LOCATION: Rotorua Museum

CO-ORDINATES: 5774101.00 mN
(NZTM2000) 1885661.00 mE

DIRECTION:

ANGLE FROM HORIZ.: -90°

R.L. GROUND: 282.00m

R.L. COLLAR: 282.00m

DATUM: NZVD2016

SURVEY: Handheld GPS

GEOLOGICAL UNIT	DESCRIPTION OF CORE		Rock Weathering	Rock Strength	Sampling Method	Core Recovery (%)	Testing	RL (m)	Depth (m)	Graphic Log	ROCK DEFECTS				Description & Additional Observations	Fluid Loss (%)	Water Level	Casing	Installation	Core Box No
	SOIL: Classification, colour, consistency / density, moisture, plasticity ROCK: Weathering, colour, fabric, name, strength, cementation										Defect Log	Fracture Spacing (mm)	RQD (%)							
Alluvial Deposits	0.00m: NOT LOGGED - Hydrovac excavation.		SW MW																	

6.40 - 7.50m: Thin (less than 100mm), cemented sandy SILT layers throughout layer, approximately spaced 200mm, very dense. Trace coarse gravel at base of unit above 50 mm thick cemented layer. Bedding visible in cemented layers

20/12/2021

Box 1, 0.00-5.80m

96mm HQTT

COMMENTS: 8 m deep 65 mm ID PVC conduit installed in borehole for cross-hole seismic test.

Hole Depth 10m

Scale 1:35

Rev.: A



Tonkin+Taylor

BOREHOLE LOG

BOREHOLE No.:

BH5

SHEET: 2 OF 2

DRILLED BY: Ben & Unga

LOGGED BY: JMB

CHECKED: DMMM

START DATE: 20/12/2021

FINISH DATE: 21/12/2021

CONTRACTOR: McMillan Drilling

PROJECT: Rotorua Museum Seismic Strengthening
JOB No.: 1017126.0000.4
LOCATION: Rotorua Museum

CO-ORDINATES: 5774101.00 mN
(NZTM2000) 1885661.00 mE

DIRECTION:

ANGLE FROM HORIZ.: -90°

R.L. GROUND: 282.00m

R.L. COLLAR: 282.00m

DATUM: NZVD2016

SURVEY: Handheld GPS

GEOLOGICAL UNIT		DESCRIPTION OF CORE		Rock Weathering	Rock Strength	Sampling Method	Core Recovery (%)	Testing	RL (m)	Depth (m)	Graphic Log	ROCK DEFECTS				Description & Additional Observations	Fluid Loss (%)	Water Level	Casing	Installation	Core Box No
		SOIL: Classification, colour, consistency / density, moisture, plasticity ROCK: Weathering, colour, fabric, name, strength, cementation	Defect Log									Fracture Spacing (mm)	RQD (%)								
Lake Deposits	7.00m: SILT, some sand, trace clay; greenish grey, bedded. Firm to stiff, moist to wet, low plasticity.					HQ3	100														
	7.50m: CORE LOSS.					HQ3	0														
	8.30m: Fine to coarse SAND, some silt, minor gravel; grey. Loosely packed, moist to wet, well graded. Gravel, fine to medium, sub-rounded to sub-angular, pumice.					HQ3	40														
	9.00m: CORE LOSS.					HQ3	100														
	9.20m: SILT, some sand, trace gravel; bluish grey. Firm to stiff, moist to wet, low plasticity. Gravel, fine, pumice.					HQ3	60														
	9.80m: Fine to coarse SAND, some silt, minor gravel; grey. Loosely packed, moist to wet, well graded. Gravel, fine to medium, sub-rounded to sub-angular, pumice.					HQ3	100														
10m: END OF BOREHOLE. Target depth.																					

COMMENTS: 8 m deep 65 mm ID PVC conduit installed in borehole for cross-hole seismic test.

Hole Depth
10m

Scale 1:35

Rev.: A

CORE PHOTOS

PROJECT: Rotorua Museum Seismic Strengthening		LOCATION: Rotorua Museum	JOB No.: 1017126.0000.4
CO-ORDINATES:	5774101.00 mN (NZTM2000) 1885661.00 mE	DRILL TYPE: HQ3	HOLE STARTED: 20/12/2021
R.L.:	282.00m	DRILL METHOD: Rotary Cored	HOLE FINISHED: 21/12/2021
DATUM:	NZVD2016		DRILLED BY: McMillan Drilling
			LOGGED BY: JMB
			CHECKED: DMMM





Tonkin+Taylor

BOREHOLE LOG

BOREHOLE No.:

BH6

SHEET: 1 OF 2

DRILLED BY: Ben & Unga

LOGGED BY: JMB

CHECKED: DMMM

START DATE: 16/12/2021

FINISH DATE: 17/12/2021

CONTRACTOR: McMillan Drilling

PROJECT: Rotorua Museum Seismic Strengthening
JOB No.: 1017126.0000.4
LOCATION: Rotorua Museum

CO-ORDINATES: 5774068.00 mN
(NZTM2000) 1885631.00 mE

DIRECTION:

ANGLE FROM HORIZ.: -90°

R.L. GROUND: 283.00m
R.L. COLLAR: 283.00m

DATUM: NZVD2016

SURVEY: Handheld GPS

GEOLOGICAL UNIT	DESCRIPTION OF CORE		Rock Weathering	Rock Strength	Sampling Method	Core Recovery (%)	Testing	RL (m)	Depth (m)	Graphic Log	ROCK DEFECTS				Fluid Loss (%)	Water Level	Casing	Installation	Core Box No
	SOIL: Classification, colour, consistency / density, moisture, plasticity	ROCK: Weathering, colour, fabric, name, strength, cementation									Defect Log	Fracture Spacing (mm)	RQD (%)	Description & Additional Observations					
Alluvial Deposits	0.00m: NOT LOGGED - Hydrovac excavation.					100													
	1.50m: CORE LOSS.				HQ3	0													
	2.10m: Fine to coarse SAND, minor silt, trace gravel; dark grey mottled with some white. Loosely packed, wet to saturated, well graded. Gravel, fine, sub-rounded to sub-angular, pumice.				HQ3	80													
	2.30m: SILT, minor sand; brownish white. Stiff, wet, rapid dilatancy, quick. Sand, fine. Grades into sandy SILT at base of unit.				HQ3	100													
	2.60m: SILT, some clay; grey. Firm to stiff, wet, medium to high plasticity.				HQ3	100													
	2.95m: Silty sandy fine to medium GRAVEL; dark grey. Loosely packed, wet, well graded. Gravel, sub-rounded to angular, unweathered to slightly weathered, Pumice. Grades into gravelly sandy SILT from 4.5 m, silt and fine sand controlling behavior, slow dilatancy.				HQ3	100													
					HQ3	100													
					HQ3	100													
					HQ3	100													
					HQ3	100													
Lake Deposits	5.00m: SILT, minor sand; light grey. Stiff to very stiff, wet, low plasticity, slow dilatancy, moderately sensitive. Sand, fine.				HQ3	100													
	6.00m: SILT, minor sand; greyish blue. Stiff to very stiff, wet, slow dilatancy. Sand, fine.				HQ3	100													
	6.60m: Sandy SILT, minor gravel; greyish blue, bedded. Loosely packed, wet, non-plastic, dilatant. Sand, fine to coarse; gravel, fine to coarse, unweathered to slightly weathered, pumice and				HQ3	100													
					HQ3	100													

2.60 - 2.95m: Upper 50 mm of unit sandy SILT with some fine pumice gravel, sub-angular.

2.95 - 5.00m: Gravel content and grain size variable throughout unit, some horizons silty than others. Some silt horizons sensitive/dilatative.

6.60 - 7.00m: Some silty SAND (less than 100 mm) horizons throughout layer. Dominant SILT horizons have dilatative properties. Coarse gravel horizon at 6.6 m.

16/12/2021

96mm HQ

Box 1, 0.00-4.50m

Box 2, 4.50-7.00m

COMMENTS: 8 m deep 65 mm ID PVC conduit installed in borehole for cross-hole seismic test.

Hole Depth
10m

Scale 1:35

Rev.: A



BH6

CONTRACTOR: McMillan Drilling

ANGLE FROM HORIZ.: -90°

SURVEY: Handheld GPS

COMMENTS: 8 m deep 65 mm ID PVC conduit installed in borehole for cross-hole seismic test.

Scale 1:35

Rev.: A

CORE PHOTOS

BOREHOLE No.: **BH6**

SHEET: 1 OF 2

PROJECT: Rotorua Museum Seismic Strengthening		LOCATION: Rotorua Museum	JOB No.: 1017126.0000.4
CO-ORDINATES: (NZTM2000)	5774068.00 mN 1885631.00 mE	DRILL TYPE: HQ3	HOLE STARTED: 16/12/2021
R.L.:	283.00m	DRILL METHOD: Rotary Cored	HOLE FINISHED: 17/12/2021
DATUM:	NZVD2016	LOGGED BY: JMB	CHECKED: DMMM



0.00-4.50m



4.50-7.00m

CORE PHOTOS

BOREHOLE No.: **BH6**

SHEET: 2 OF 2

PROJECT: Rotorua Museum Seismic Strengthening		LOCATION: Rotorua Museum	JOB No.: 1017126.0000.4
CO-ORDINATES: (NZTM2000)	5774068.00 mN 1885631.00 mE	DRILL TYPE: HQ3	HOLE STARTED: 16/12/2021
R.L.:	283.00m	DRILL METHOD: Rotary Cored	HOLE FINISHED: 17/12/2021
DATUM:	NZVD2016		DRILLED BY: McMillan Drilling
			LOGGED BY: JMB
			CHECKED: DMMM



7.00-10.00m



Tonkin+Taylor

BOREHOLE LOG

BOREHOLE No.:

BH10

SHEET: 1 OF 2

DRILLED BY: Ben & Unga

LOGGED BY: JMB

CHECKED: DMMM

START DATE: 18/12/2021

FINISH DATE: 18/12/2021

CONTRACTOR: McMillan Drilling

PROJECT: Rotorua Museum Seismic Strengthening
JOB No.: 1017126.0000.4
LOCATION: Rotorua Museum

CO-ORDINATES: 5774136.00 mN
(NZTM2000) 1885632.00 mE

DIRECTION:

ANGLE FROM HORIZ.: -90°

R.L. GROUND: 285.00m
R.L. COLLAR: 285.00m

DATUM: NZVD2016

SURVEY: Handheld GPS

GEOLOGICAL UNIT	DESCRIPTION OF CORE	Rock Weathering	Rock Strength	Sampling Method	Core Recovery (%)	Testing	RL (m)	Depth (m)	Graphic Log	ROCK DEFECTS				Fluid Loss (%)	Water Level	Casing	Installation	Core Box No
										Defect Log	Fracture Spacing (mm)	RQD (%)	Description & Additional Observations					
	SOIL: Classification, colour, consistency / density, moisture, plasticity ROCK: Weathering, colour, fabric, name, strength, cementation	UW MS MC CW	US MS MC CW	US MS MC CW	US MS MC CW	US MS MC CW					2000 1000 500 200 100 50 20			25 50 75				
Alluvial Deposits	0.00m: NOT LOGGED - Hydrovac excavation.			HVAC	0			284	1									
	1.50m: CORE LOSS.																	
	1.90m: Sandy SILT, some organics and some gravel; dark brown. Loosely packed, moist to wet, non-plastic. Sand, fine to medium; gravel, fine to medium, pumice. Difficult to determine if historic fill material.			HQ3	73			283	2									
	2.30m: Silty fine to medium SAND, minor gravel; brownish white. Loosely packed, moist to wet, well graded, non-plastic. Gravel, fine to medium, rounded to sub-angular, pumice.																	
	2.45m: SILT, some sand; greyish white. Stiff to very stiff, moist to wet, non-plastic, slow dilatancy. Sand, fine.																	
	2.90m: Sandy SILT; grey. Loosely packed, moist to wet, non-plastic, dilatant.							282	3									
	3.10m: SILT, some sand; greyish brown. Loosely packed, moist to wet, non-plastic, slow dilatancy. Sand, fine. Thin silty SAND horizons between 3.6 m and 3.7 m.																	
	3.55m: SILT, some sand and some gravel; greyish white. Loosely packed, moist to wet, non-plastic. Sand, fine to coarse, pumiceous; gravel, fine, sub-rounded to sub-angular, pumice.			HQ3	100													
	3.90m: Sandy fine to medium GRAVEL; greyish white. Loosely packed, moist to wet, well graded. Gravel, unweathered to slightly weathered, pumice; sand, fine to coarse, pumiceous.							281	4									
	5.00 - 5.30m: Gravel changes to medium to coarse grained and poorly graded, sub-angular to angular.							280	5									
Lake Deposits	5.30m: Fine to coarse GRAVEL, some silt and some sand; dark grey. Loosely packed, wet, well graded. Gravel, moderately to highly weathered, pumice; sand, pumiceous. Pumice easily crushable in fingers, highly weathered/alterd, gravel covered in fine grained black film.			HQ3	100													
	6.60m: SILT, some sand and some gravel; grey mixed white. Soft to firm, moist to wet, slow dilatancy. Gravel, fine to medium, sub-rounded to sub-angular, moderately to highly weathered, pumice.							279	6									

3.90 - 5.30m: 100 mm Thick cemented gravel layer at top of unit. Very dense, cannot break with hands.

Box 1, 0.00-4.70m

96mm HQ

COMMENTS: 10 m deep 60 mm ID PVC conduit installed in borehole for cross-hole seismic test.

Hole Depth
12m

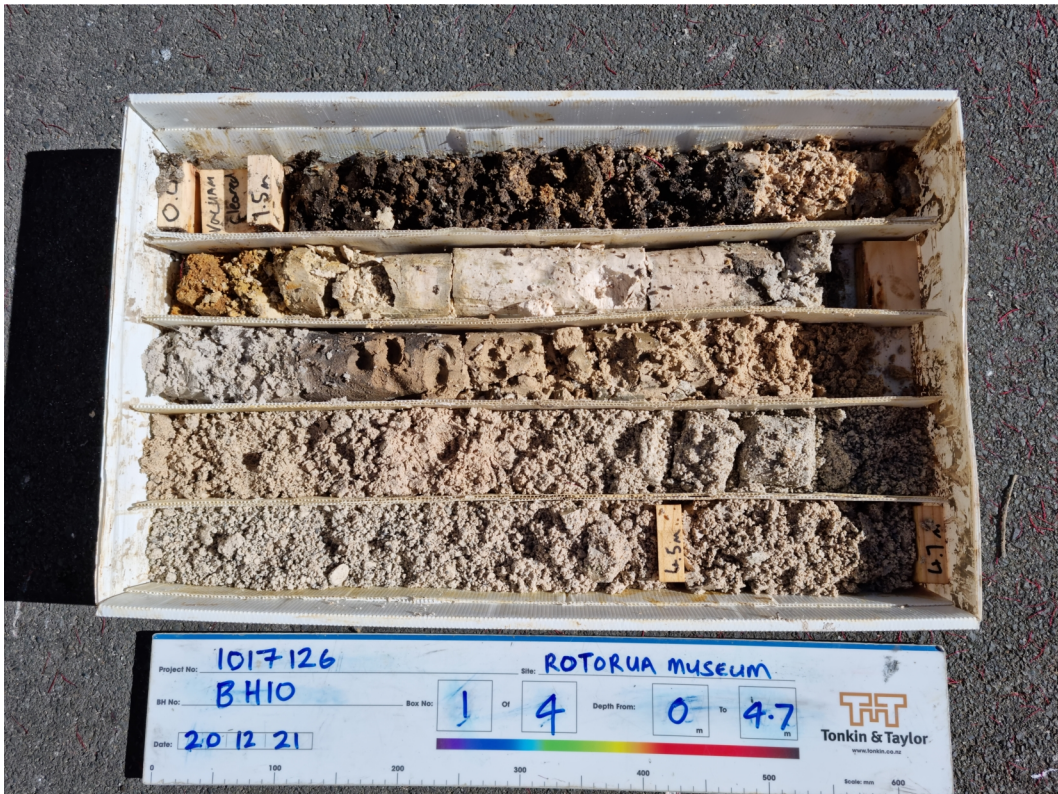
Scale 1:35

Rev.: A

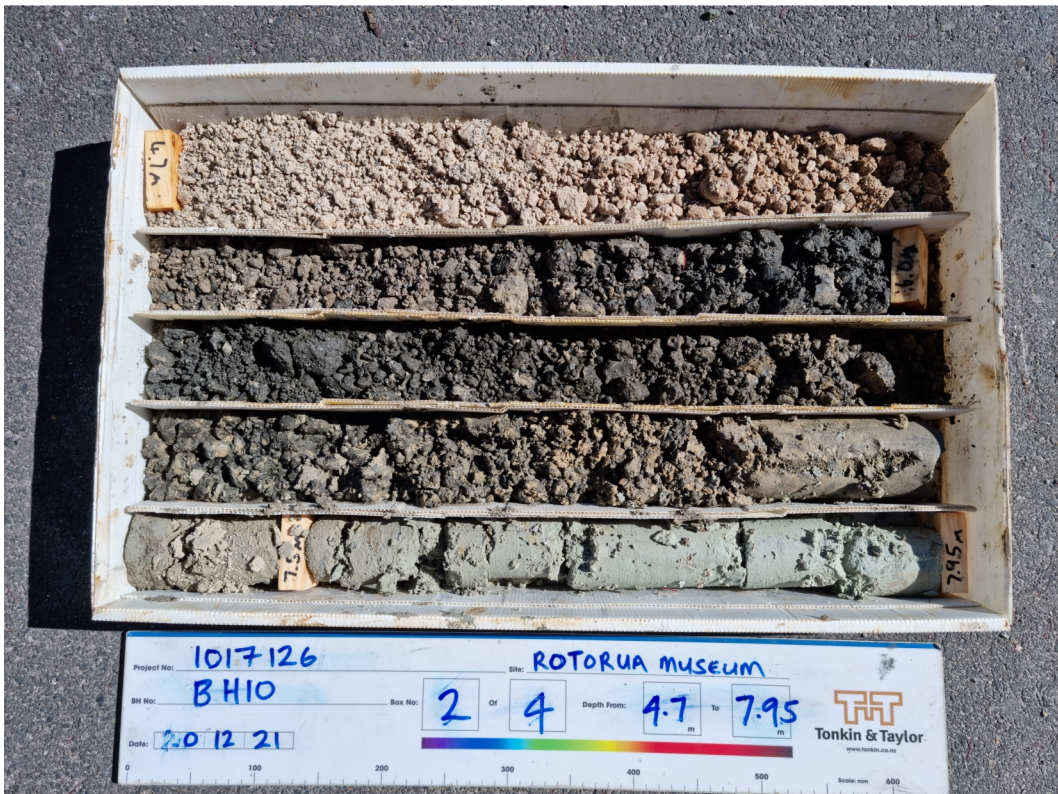
BOREHOLE LOG

CORE PHOTOS

PROJECT: Rotorua Museum Seismic Strengthening		LOCATION: Rotorua Museum	JOB No.: 1017126.0000.4
CO-ORDINATES: 5774136.00 mN (NZTM2000) 1885632.00 mE		DRILL TYPE: HQ3	HOLE STARTED: 18/12/2021
R.L.: 285.00m		DRILL METHOD: Rotary Cored	HOLE FINISHED: 18/12/2021
DATUM: NZVD2016		LOGGED BY: JMB	CHECKED: DMMM



0.00-4.70m



4.70-7.95m

CORE PHOTOS

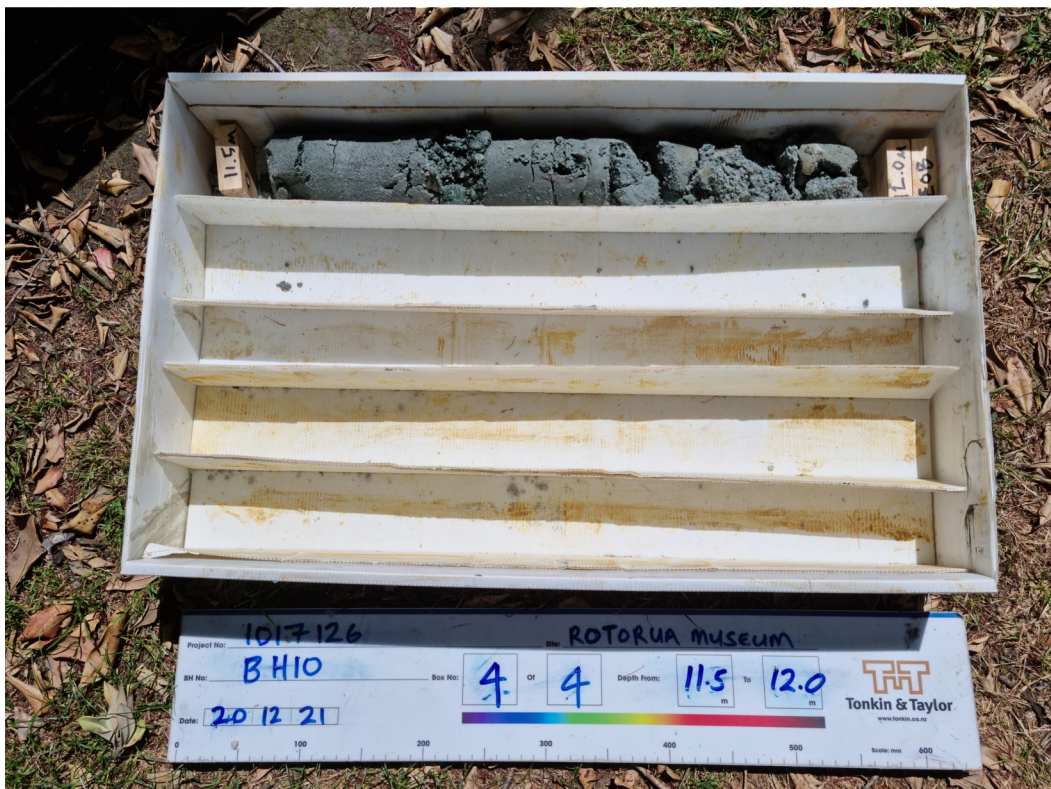
BOREHOLE No.: **BH10**

SHEET: 2 OF 2

PROJECT: Rotorua Museum Seismic Strengthening		LOCATION: Rotorua Museum	JOB No.: 1017126.0000.4
CO-ORDINATES: (NZTM2000)	5774136.00 mN 1885632.00 mE	DRILL TYPE: HQ3	HOLE STARTED: 18/12/2021
R.L.:	285.00m	DRILL METHOD: Rotary Cored	HOLE FINISHED: 18/12/2021
DATUM:	NZVD2016	LOGGED BY: JMB	CHECKED: DMMM



7.95-11.50m



11.50-12.00m



Tonkin+Taylor

BOREHOLE LOG

BOREHOLE No.:

BH11

SHEET: 1 OF 2

DRILLED BY: Ben & Unga

LOGGED BY: JMB

CHECKED: DMMM

START DATE: 16/12/2021

FINISH DATE: 17/12/2021

CONTRACTOR: McMillan Drilling

PROJECT: Rotorua Museum Seismic Strengthening
JOB No.: 1017126.0000.4
LOCATION: Rotorua Museum

CO-ORDINATES: 5774037.00 mN
(NZTM2000) 1885643.00 mE

DIRECTION:

ANGLE FROM HORIZ.: -90°

R.L. GROUND: 283.00m

R.L. COLLAR: 283.00m

DATUM: NZVD2016

SURVEY: Handheld GPS

GEOLOGICAL UNIT	DESCRIPTION OF CORE		Rock Weathering	Rock Strength	Sampling Method	Core Recovery (%)	Testing	RL (m)	Depth (m)	Graphic Log	ROCK DEFECTS				Fluid Loss (%)	Water Level	Casing	Installation	Core Box No
	SOIL: Classification, colour, consistency / density, moisture, plasticity ROCK: Weathering, colour, fabric, name, strength, cementation										Defect Log	Fracture Spacing (mm)	RQD (%)	Description & Additional Observations					
Lake Deposits	0.00m: NOT LOGGED - Hydrovac excavation.					0		282	1										
	1.50m: CORE LOSS.																		
	1.60m: Fine to coarse SAND; grey with black speckling. Loosely packed, moist, well graded. Sand, quartz.				HQ3	80													
	1.95m: Gravelly fine to coarse SAND; brownish white. Loosely packed, moist, well graded. Gravel, fine, pumice.				HQ3	0		281	2										
	2.00m: CORE LOSS.																		
	2.70m: SILT, trace sand and trace gravel; brownish white. Firm to stiff, wet to saturated, non-plastic, rapid dilatancy. Sand, fine; gravel, fine, sub-angular to angular, pumice.				HQ3	60		280	3										
	2.80m: SILT, minor clay and minor gravel; light grey. Firm to stiff, moist to wet, low plasticity, sensitive. Gravel, fine to medium, sub-angular to angular, unweathered to slightly weathered, pumice and rhyolite. Slow dilatancy.				HQ3	100													
	3.00m: SILT, minor clay and minor gravel; light grey. Stiff to very stiff, moist to wet, low plasticity, slow dilatancy, sensitive. Gravel, fine to medium, sub-angular to angular, unweathered to slightly weathered, pumice and rhyolite.				HQ3	80													
	3.50m: CORE LOSS.																		
	3.60m: SILT, minor clay and minor gravel; light grey. Stiff to very stiff, moist to wet, low plasticity, sensitive. Gravel, fine to medium, sub-angular to angular, unweathered to slightly weathered, pumice and rhyolite.				HQ3	80		279	4										
	4.00m: CORE LOSS.																		
	4.10m: SILT, minor clay and minor gravel; grey. Stiff to very stiff, moist to wet, low plasticity, slow dilatancy, sensitive. Gravel, fine to medium, sub-angular to angular, unweathered to slightly weathered, pumice and rhyolite.				HQ3	100													
	4.50m: SILT, some clay; light grey. Firm, wet, low plasticity. Very slow dilatancy.							278	5										
	5.00m: SILT, minor clay and minor gravel; light grey. Tightly packed, moist to wet, non-plastic. Gravel, fine, sub-angular to angular.				HQ3	100													
	5.50m: SILT, minor clay and minor gravel; light grey. Tightly packed, moist to wet, non-plastic. Gravel, fine, sub-angular to angular. Grades into clayey SILT with some sand at base of unit (5.9 m to 6.0 m).				HQ3	100								5.40 - 5.50m: Very dense/cemented layer (30 mm thick at 5.4 m). Drilling broken up cemented layer into angular fragments. Layer hydrothermally altered.					
	6.00m: CORE LOSS.																		
	6.40m: Silty fine to coarse GRAVEL; grey. Tightly packed, moist, well graded. Gravel, angular, cemented silt.																		
	6.50m: SILT, minor clay and minor gravel; light grey. Stiff to very stiff, moist to wet, non-plastic. Gravel, fine to medium, sub-angular to angular.				HQ3	100		277	6					6.40 - 6.50m: Very dense material. Bedding visible in some horizons. Dense cemented layer from upper unit could have caused poor recovery of unit.					

16/12/2021

Box 1, 1.50-5.00m

96mm HQ

COMMENTS: 8 m deep 65 mm ID PVC conduit installed in borehole for cross-hole seismic test.

Hole Depth
10m

Scale 1:35

Rev.: A

BOREHOLE LOG

BOREHOLE No.:

BH11

SHEET: 2 OF 2

DRILLED BY: Ben & Unga

LOGGED BY: JMB

CHECKED: DMMM

START DATE: 16/12/2021

FINISH DATE: 17/12/2021

CONTRACTOR: McMillan Drilling

PROJECT: Rotorua Museum Seismic Strengthening
JOB No.: 1017126.0000.4
LOCATION: Rotorua Museum

CO-ORDINATES: 5774037.00 mN
(NZTM2000) 1885643.00 mE

DIRECTION:
ANGLE FROM HORIZ.: -90°

R.L. GROUND: 283.00m
R.L. COLLAR: 283.00m
DATUM: NZVD2016
SURVEY: Handheld GPS

GEOLOGICAL UNIT	DESCRIPTION OF CORE		Rock Weathering	Rock Strength	Sampling Method	Core Recovery (%)	Testing	RL (m)	Depth (m)	Graphic Log	ROCK DEFECTS				Fluid Loss (%)	Water Level	Casing	Installation	Core Box No
	SOIL: Classification, colour, consistency / density, moisture, plasticity ROCK: Weathering, colour, fabric, name, strength, cementation										Defect Log	Fracture Spacing (mm)	RQD (%)	Description & Additional Observations					
Lake Deposits	7.00m: SILT, minor clay and minor gravel; light grey. Stiff to very stiff, moist to wet, non-plastic. Gravel, fine to medium, sub-angular to angular.		HQ3	100	HQ3	100		275	8		2000 1000 500 200 100 50 20		7.50 - 8.50m: Minor fine to medium pumice gravel horizons (~10 mm, 150 - 200 mm spacing) throughout layer.	25 50 75				Box 2, 5.00-7.50m	
	7.50m: SILT, minor clay and minor sand and minor gravel; light grey. Tightly packed, moist to wet, non-plastic. Gravel, fine, sub-angular to angular.																		
	8.50m: SILT, some sand, minor gravel, trace clay; greenish grey. Tightly packed, wet to saturated, non-plastic. Gravel, fine to coarse, sub-rounded to sub-angular, pumice. Cemented SILT from 9.7 m, Grades to gravelly SILT.																		
	10m: END OF BOREHOLE. Target depth.							273	10							96mm HQ		Box 3, 7.50-10.00m	
								272	11										
								271	12										
								270	13										

COMMENTS: 8 m deep 65 mm ID PVC conduit installed in borehole for cross-hole seismic test.

Hole Depth
10m

Scale 1:35

Rev.: A

CORE PHOTOS

BOREHOLE No.: **BH11**

SHEET: 1 OF 2

PROJECT: Rotorua Museum Seismic Strengthening		LOCATION: Rotorua Museum	JOB No.: 1017126.0000.4
CO-ORDINATES:	5774037.00 mN (NZTM2000) 1885643.00 mE	DRILL TYPE: HQ3	HOLE STARTED: 16/12/2021
R.L.:	283.00m	DRILL METHOD: Rotary Cored	HOLE FINISHED: 17/12/2021
DATUM:	NZVD2016	LOGGED BY: JMB	CHECKED: DMMM



1.50-5.00m



5.00-7.50m

CORE PHOTOS

BOREHOLE No.: **BH11**

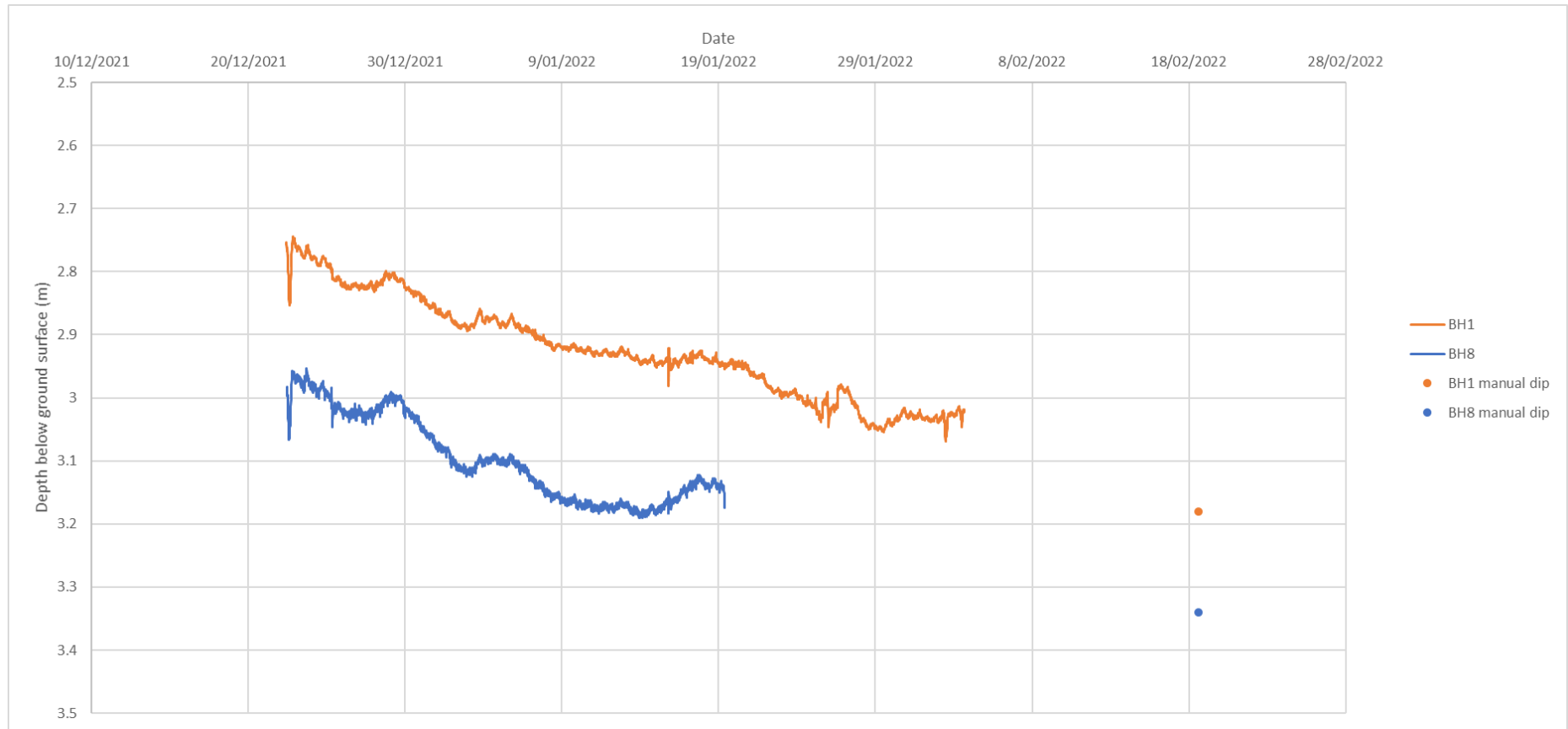
SHEET: 2 OF 2

PROJECT: Rotorua Museum Seismic Strengthening		LOCATION: Rotorua Museum	JOB No.: 1017126.0000.4
CO-ORDINATES: (NZTM2000)	5774037.00 mN 1885643.00 mE	DRILL TYPE: HQ3	HOLE STARTED: 16/12/2021
R.L.:	283.00m	DRILL METHOD: Rotary Cored	HOLE FINISHED: 17/12/2021
DATUM:	NZVD2016		DRILLED BY: McMillan Drilling
			LOGGED BY: JMB
			CHECKED: DMMM



7.50-10.00m

C2 - Groundwater monitoring results



C3 - Cyclic triaxial test results

Testing of Undisturbed Specimens from Rotorua Museum : Test Data

Report Number: RM22-01

Prepared for: Sutejo Tjokro, Tonkin+Taylor
Helen Wang, Geotechnics Ltd.

Prepared by: Mark Stringer, University of Canterbury

Date: 15/02/22

Version: 1.0

Note: While the report is believed to be correct at the time of its preparation, the authors and agents involved in its preparation and publication do not accept any liability for use of the report and its output. Questions about this report maybe directed by email to mark.stringer@canterbury.ac.nz. Users are advised that there may be later versions of this report.

1 Description of Cyclic Triaxial Device (CTX)

A DTC-367 triaxial testing system, manufactured by Seiken Ltd, was used for the testing described in this report. Key elements of this system are shown in Figure 1.

During testing the triaxial cell is filled with water above the level of the top platen, but leaving an air gap at the top of the cell. The cell is pneumatically pressurised using the central compressed air supply, and cell pressure is measured at the base of the cell. Back pressures can be applied to the specimen through either of the top or bottom drainage lines, with pressures being measured on the bottom drainage line, at the same elevation as the cell pressure transducer.

Axial displacements are measured using a linear variable displacement transducer (LVDT), which measures the vertical displacement of the loading ram, external to the cell. The drainage from the specimen is monitored using a volume meter, which can accept drainage from both the top and bottom drainage lines.

Axial loads are measured inside the triaxial cell, using a pressure compensated 2 kN load cell. Placement of the axial load cell within the triaxial cell provides a direct measurement of the loading on the specimen. The axial loading during cyclic loading is servo-controlled with closed-loop feedback. During a triaxial compression test, the position of the loading ram is locked in place, and the triaxial cell jacked vertically under displacement control.

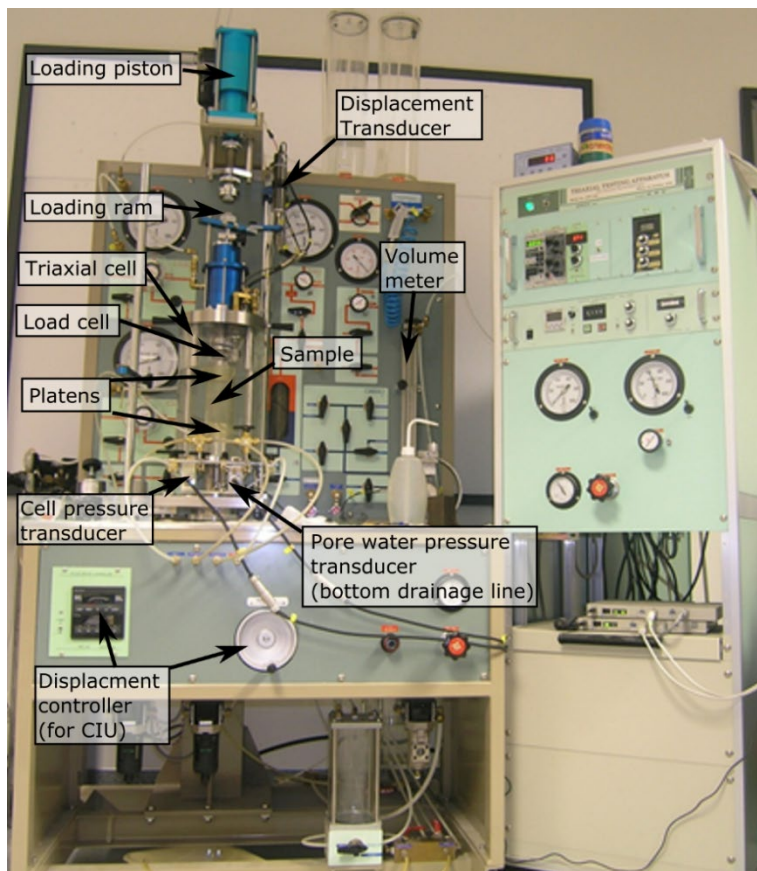


Figure 1: Main components of the cyclic triaxial device.

2 Laboratory Handling and Testing Procedures

2.1 Specimen preparation

Two soil sample tubes (BH9 GPTR1 and BH9 GPTR2) were received from Tonkin + Taylor in a frozen condition, and were subsequently stored in freezers at the University of Canterbury until the time of testing.

Soil sample BH9 GPTR 1 was selected for sub-sampling and cyclic triaxial testing.

Specimens for triaxial testing were obtained by first cutting sub-samples of length 15cm from the main soil sample using a circular saw. The top 10cm and bottom 10 cm were discarded since it is likely to be disturbed. Test specimens were cored from the sub samples using a 50 mm core barrel, and trimmed to an axial length of approximately 100 mm using a circular saw.

To enable the measurement of shear wave velocities, small rectangular slots were carved into the top and bottom of the test specimens using a hand held drill.

The specimens remained frozen during all of the preparation processes.

2.2 Specimen mounting

Specimens were carefully mounted in the CTX device while still in a frozen state, and allowed to defrost under the action of an external cell pressure of 20kPa, a small seating load (typically less than 5N) and with the drainage lines open to allow any mobile pore fluid to drain from the specimen.

Once the specimen had defrosted, measurements of specimen height were inferred from the difference in the displacement transducer reading relative to that of a spacer of known height previously placed between the CTX platens, while specimen diameter was measured using a pi-tape.

Following specimen measurement, the triaxial cell was filled with water, and the vacuum reduced while increasing the cell pressure so that the effective stress remained constant.

2.3 Specimen saturation

Test specimens were saturated using the following process:

- CO₂ was percolated through the specimen at a slow rate
- Approximately 400 ml (≈ 2 specimen volumes) of deaired water was percolated at low rate through the specimen
- Increasing degrees of vacuum were applied to the specimen, while maintaining the effective stress between 15 and 20 kPa by also applying a vacuum to the main triaxial cell. After a period of around 2 hours had elapsed with the inside of the specimen at maximum vacuum, the vacuums were gradually reduced to reestablish the cell pressure of 20kPa and zero back pressure.
- An additional 400ml of deaired water was percolated through the specimen.
- Back pressures were increased while the 20 kPa isotropic effective stress state was maintained.

Saturation was deemed complete once the B-value (Skempton, 1954 and defined in Equation 1) in excess of 0.95 was recorded.

$$B = \frac{\Delta u}{\Delta p} \quad (1)$$

2.4 Specimen consolidation

Fully saturated test specimens were isotropically consolidated to a target mean effective stress which is approximately 10% greater than the estimated in-situ vertical effective stress. For this project, this was equivalent to 80kPa based on the estimated vertical effective stresses being in the range of 70-74kPa as estimated by Tonkin+Taylor.

Consolidation was conducted such that drainage was permitted through the top of the specimen only, while pore water pressures were measured at the base of the specimen. This arrangement meant that the largest excess pore water pressures present in the specimen could be accurately monitored (i.e., primary consolidation for each stress increment was expected to have been completed when the measured excess pore water pressures returned to zero). Shear wave velocity testing (see following sub-section of this report) was performed at mean effective stresses of 20 kPa, 40 kPa and 80kPa.

For the specimens tested, it was possible to increase the cell pressures slowly enough that the excess pore water pressures were close to zero throughout the consolidation process. An additional consolidation period of approximately 10minutes was observed prior to the measurement of shear wave velocity at $p' = 40\text{kPa}$, and 30 minutes prior to the measurement at $p' = 80\text{kPa}$.

The B-value of the specimen was measured immediately prior to the commencement of cyclic loading. These values would typically reduce during the consolidation phase.

2.5 Shear wave velocity testing

Shear wave velocity testing was performed on all specimens. When undertaking this testing, a sinusoid voltage pulse is sent to the 'source' bender element (mounted in a platen as shown in Figure 2b), which deflects under the voltage applied. This generates a horizontally-orientated shear wave which propagates vertically through the specimen. When the shear wave arrives at the 'receiver' bender element, it causes a small deflection of the bender element, which in turn generates a small voltage, which is monitored using an oscilloscope. This system arrangement is shown schematically in Figure 2a, along with a photo of one of the bender elements used in the CTX device. By considering the height of the specimen and the time difference between sending the voltage pulse and the first arrival of the shear wave, it is possible to estimate the shear wave velocity (Equation 2, where l_{tt} is the distance between the tips of the bender elements). It should be noted that the source wave is not directly measured, but is assumed to be the same shape and occur at the same time as the output from the signal generator. In practice, there is a delay between the output of the signal generator and the displacement of the source bender element. The 'system delay' is measured by holding the tips of the source and receiver elements together and measuring the time lag between the source signal and the received signal. For the testing presented in this report, the time delay is 10 μs . This time delay was subtracted from the receiver signal prior to picking the arrival time.

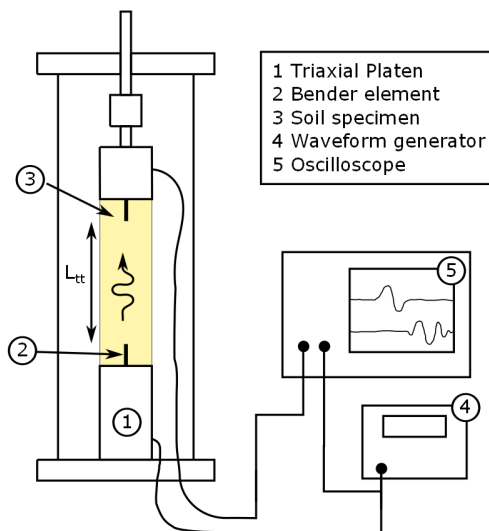
$$v_s = \frac{l_{tt}}{t_{arr}} \quad (2)$$

$$v_{s1} = v_s \left(\frac{p_a}{p'} \right)^{0.25} \quad (3)$$

The interpretation of the shear wave arrival time remains subject to some debate in the literature. Figure 3 shows outputs from a typical bender element test. Marked on the figure are typical points which have been used by researchers to define the arrival time of the shear wave. Points SA and SB refer to points on the source wave, while points RA, RB, RC and RD refer to points on the received waveform. Interpretations of the arrival time based on first arrival of the shear wave include the

difference between SA and RA, RB, RC. An estimate of shear wave velocity can also be made using the time difference between the zero crossings linking the major peaks (SB and RD).

In this report, the 'first arrival' time of the shear wave has been determined manually, using the point where the receiver signal appears to begin its major departure (i.e., point RB) in the positive direction (the direction expected based on the polarity of the bender elements). In some cases, the arrival time has been picked later than the point where the received signal begins to deviate in the positive direction due to apparent changes in the gradient of the received signal. Source and receiver bender element signals from each test are shown within the attached appendices, along with vertical line markers indicating the picked arrival times.

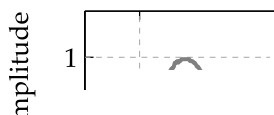


(a) Typical set-up for bender elements

Figure 2: Bender element test system arrangement.



(b) Bender element platen



BE source

Figure 3: Interpretation of shear wave arrival time.

2.6 Undrained cyclic loading

Cycles of load with constant amplitude and frequency were applied to the test specimens in an undrained condition.

Cyclic loading was typically halted once the peak-to-peak axial strain exceeded 5 % (a relatively common failure criterion used when performed undrained cyclic strength testing within the laboratory).

$$CSR = \frac{q}{2p_{0'}} \quad (4)$$

Following the undrained cyclic loading phase, the specimen was either reconsolidated (top drainage only) back to the final consolidation stress level to obtain an estimate for post-cyclic volumetric strain, or subjected to an undrained monotonic compression test. Compression tests were conducted at a rate of 1 mm/min.

A summary of the undrained cyclic loading test data is presented in Table 1.

Table 1: Undrained cyclic loading test data summary

Test specimen I.D.	Mid depth ¹ (m)	Loading date	B-value	Back pressure (kPa)	p' _{test} (kPa)	p _{d, test} (g/cm ³)	f (Hz)	CSR _{TX} ²	N _{cf} ³
RM BH9 GPTR1 A		06/02/22	0.96	301.3	80.7	580.7	0.1	0.315	FNR ⁴
RM BH9 GPTR1 B		08/02/22	0.97	200.5	79.4	571.1	0.1	0.44	976
RM BH9 GPTR1 D		10/02/22	0.97	200.9	79.1	542.4	0.1	0.518	15

Note 1: Specimen mid depths are estimated based on sampling information.

Note 2: Cyclic Stress Ratio, CSR_{TX}, corresponds to the triaxial test condition. Correction(s) should be made to adjust these values to estimated in-situ conditions.

Note 3: Number of cycles to failure, N_{cf}, is defined as the loading cycle number at which the test specimen reached a double-amplitude axial strain equal to 5 %.

Note 4: Specimen had not reached 5% double amplitude strain after 610 cycles of loading, and the test was terminated.

Table 2: Summary of post-cyclic test data

Test Specimen ID	Max Cyclic Shear Strain (%)	Volumetric Strain (%)	Reconsol.	Peak post-cyc deviator stress (kPa)
RM BH9 GPTR1 A	0.6	0.5	-	-
RM BH9 GPTR1 B	4.7	2.7	-	-
RM BH9 GPTR1 D	7.6	-	-	208

2.7 Post-test specimen handling

Post-test specimens were weighed, photographed, and then split in half to enable observation of the internal specimen structure where possible. Post-test water contents were measured on the full specimen and the measurements were used to determine the dry specimen mass.

3 Test Data

3.1 RM BH9 GPTR1 A

Test date: 06/02/22

End of Saturation			End of consolidation				Post test
Height	Diameter	Dry Density	Height	Diameter	Dry Density	Water Content	Water content
(mm)	(mm)	(kg/m ³)	(mm)	(mm)	(kg/m ³)	(%)	(%)
106.00	49.88	572.5	105.37	49.67	580.1	1.281	1.272

Back pressure (kPa)	p' _c (kPa)	B-Value	CSR ¹	N _{failure} ²	γ _{max} (%)	ε _{vol, reconsol} (%)
301.3	80.7	0.96	0.315	FNR	0.6	0.5

Note 1: Cyclic Stress Ratio, CSR_{TX}, corresponds to the triaxial test condition. Correction(s) should be made to adjust these values to estimated in-situ conditions.

Note 2: Number of cycles to failure, N_{cf}, is defined as the loading cycle number at which the test specimen reached a double-amplitude axial strain equal to 5 %.

Shear Wave Velocity Data (consolidation):

Excitation Freq	4kHz	6kHz	8kHz	Average
p'	Measured Shear Wave Velocities (m/s)			
20.5	130.5	134	137.5	134
39.6	148.3	153.3	154.5	152
80	173.7	183.9	184.9	180.8

Best fit curve: $v_s = A p'^B$

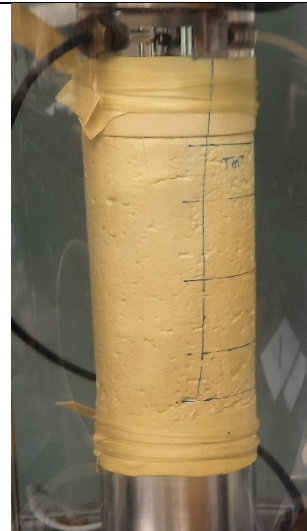
A = 68.44 B = 0.2203

Additional test notes:

- Noticeable smell (Sulphur?) present on specimens
- Gel present all through the specimens



Pre-test



After consolidation

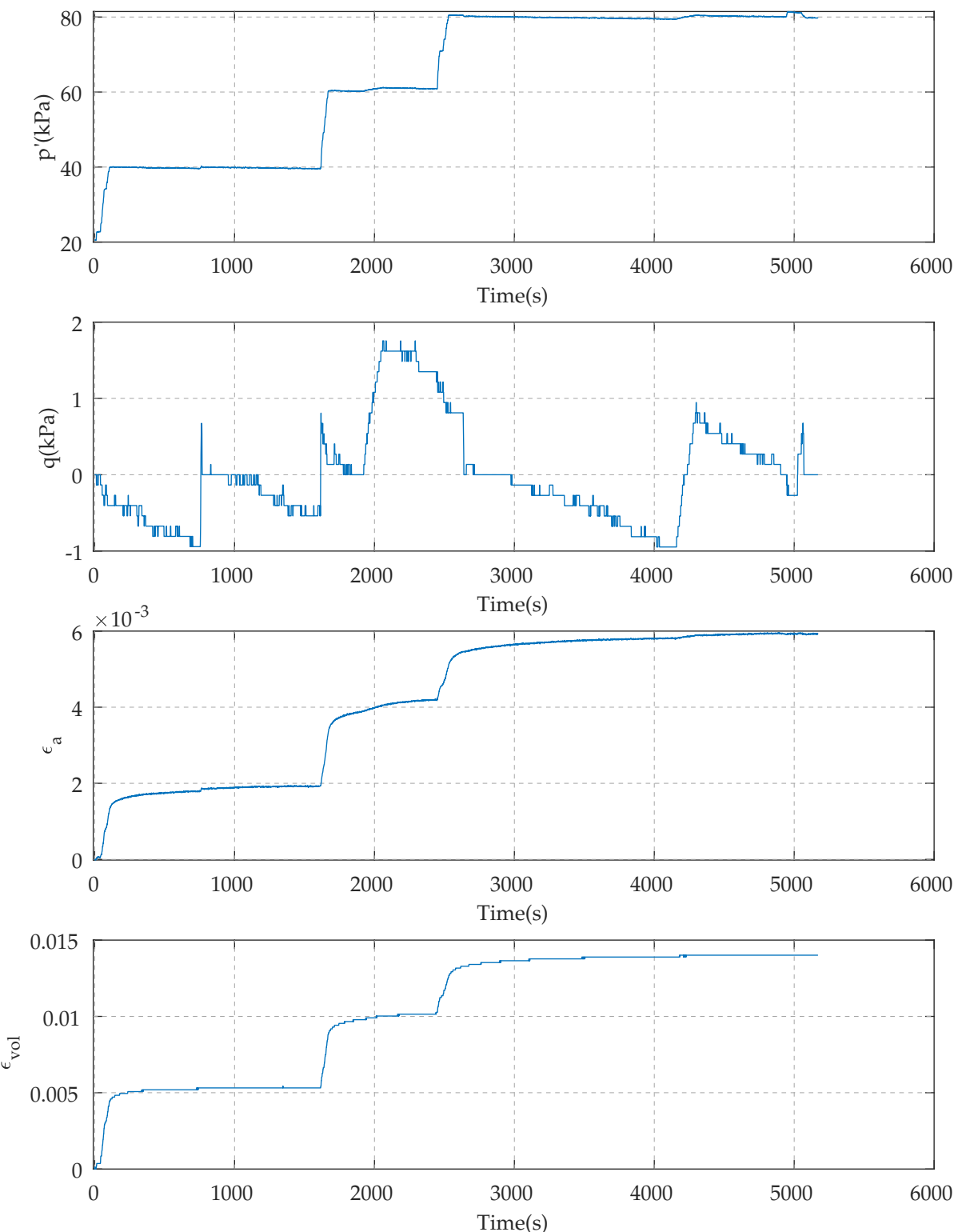


Post-test



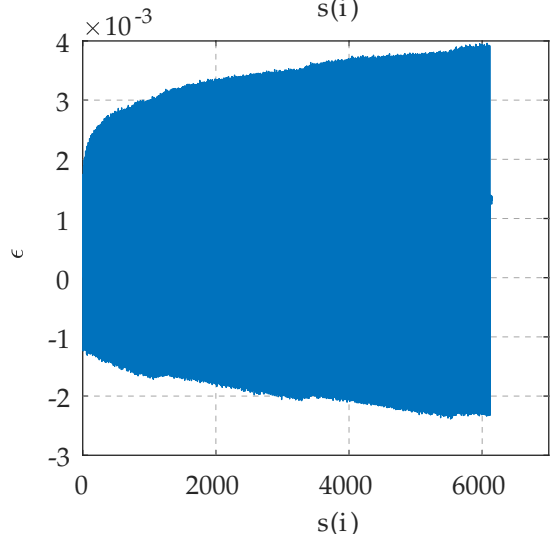
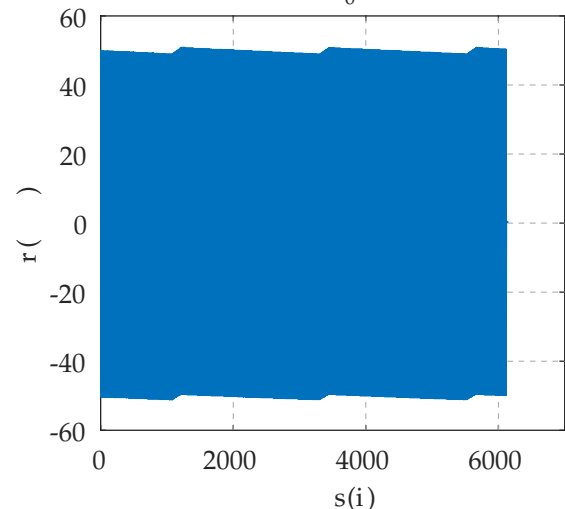
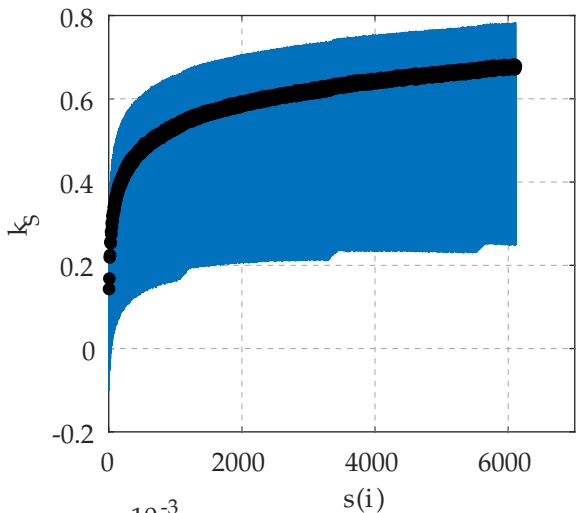
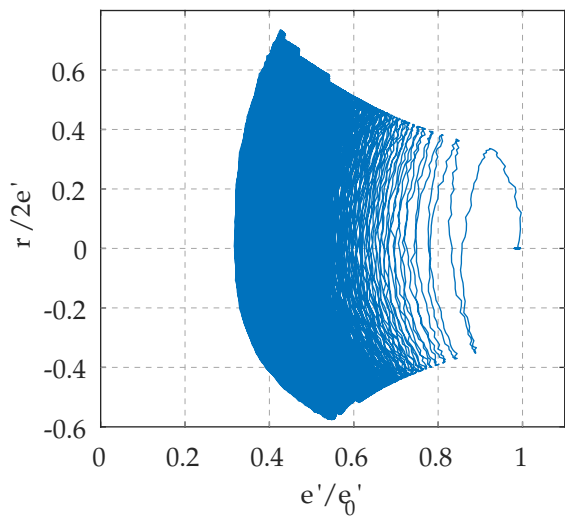
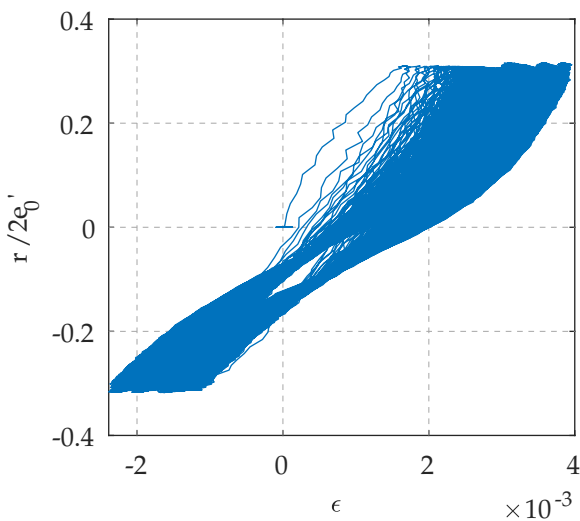
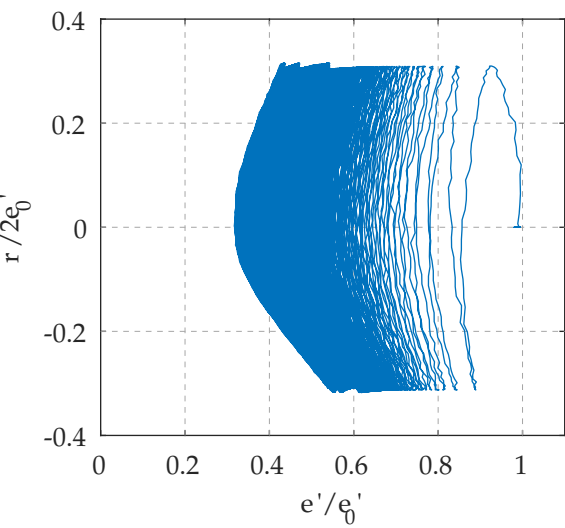
View of inside of specimen

RM-BH9-GPTR1 A - Consolidation

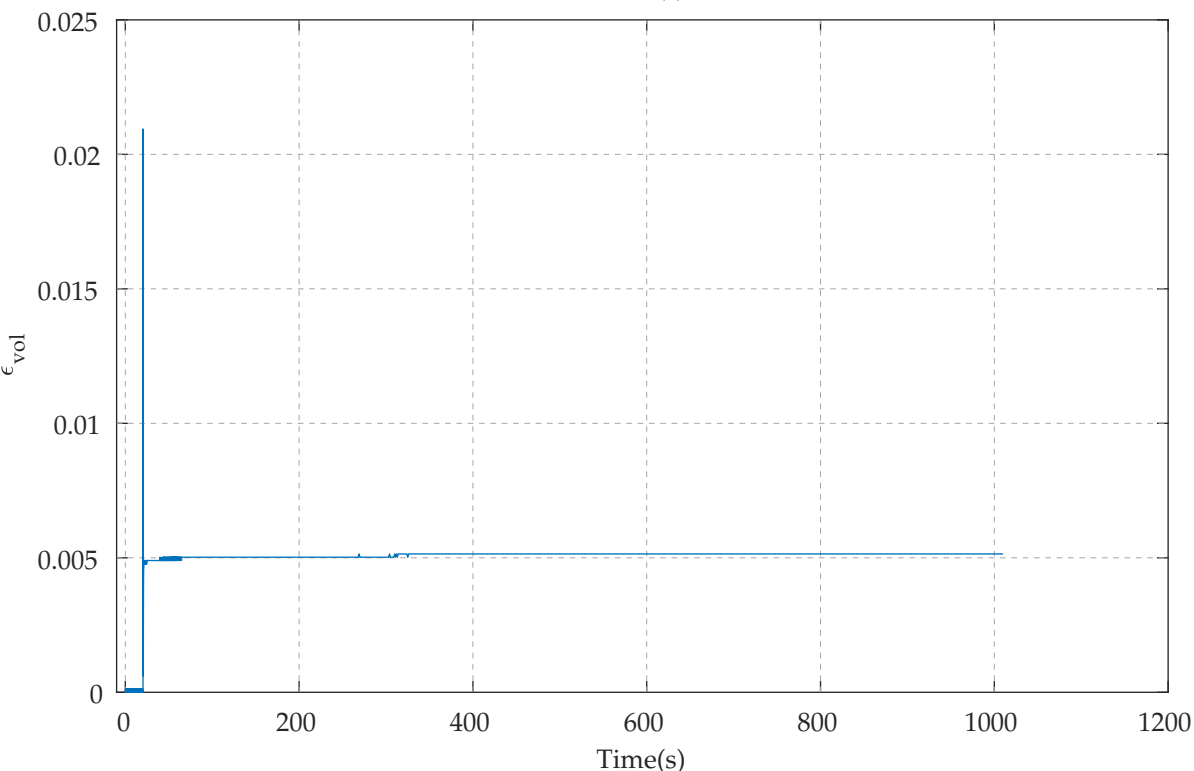
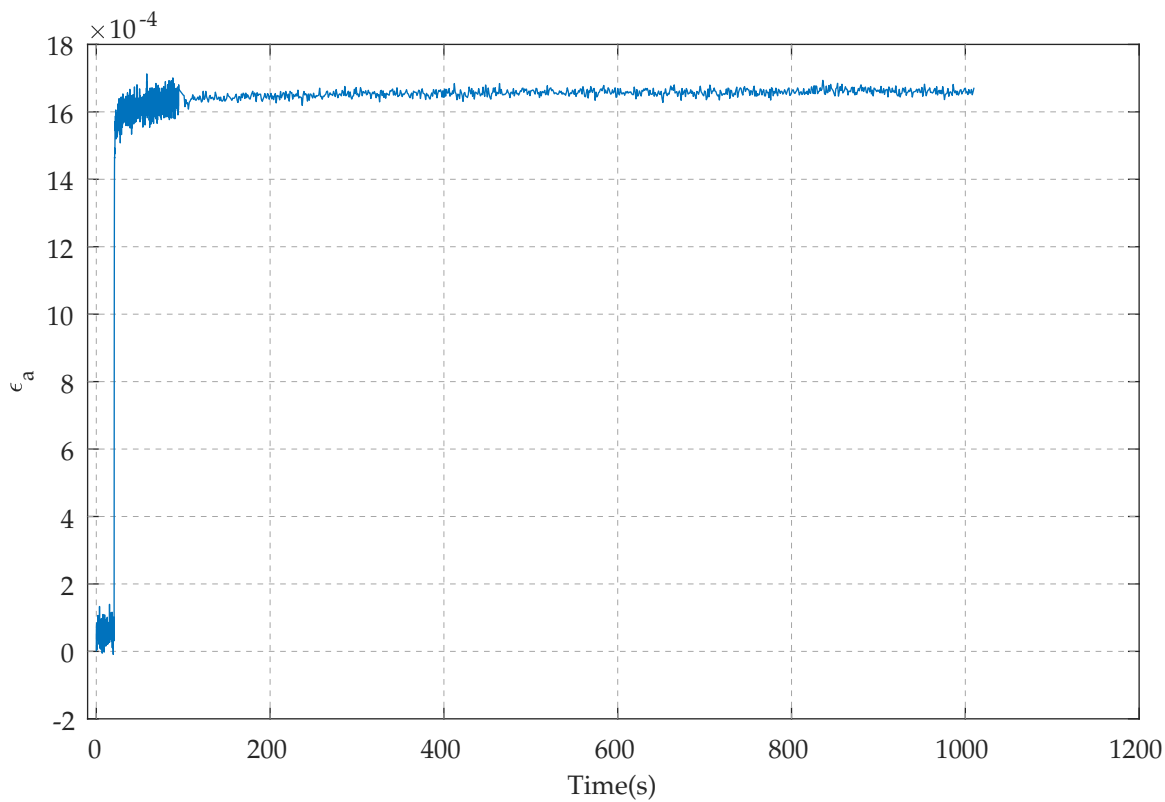


ii - l 9-o i 1n - S i

$\mathcal{M}_{\text{sk}} = 0.315$
 $e_0' = 80.6$

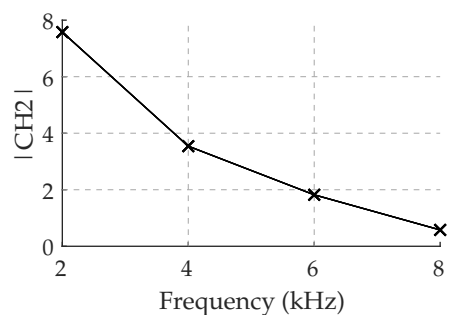
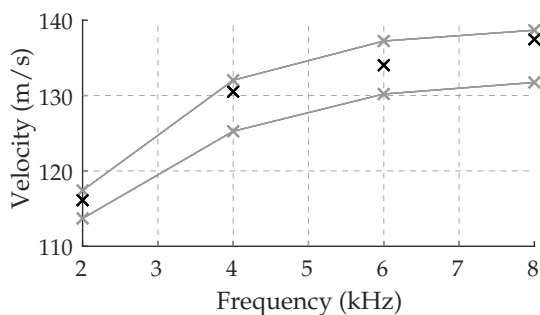
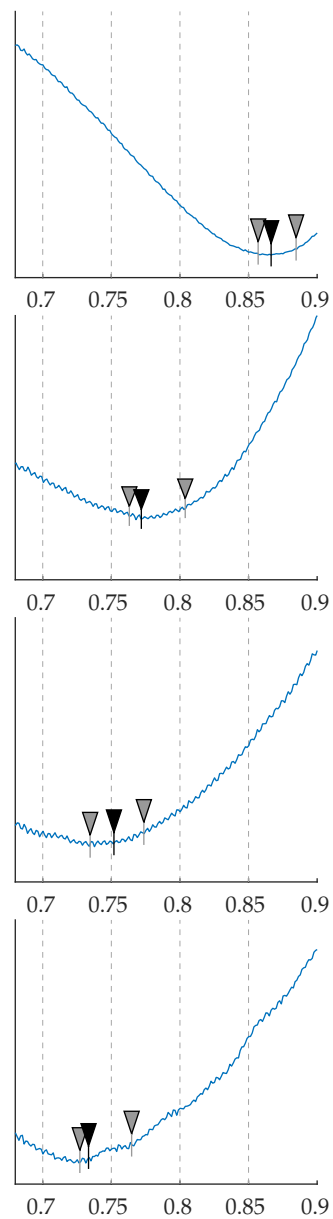
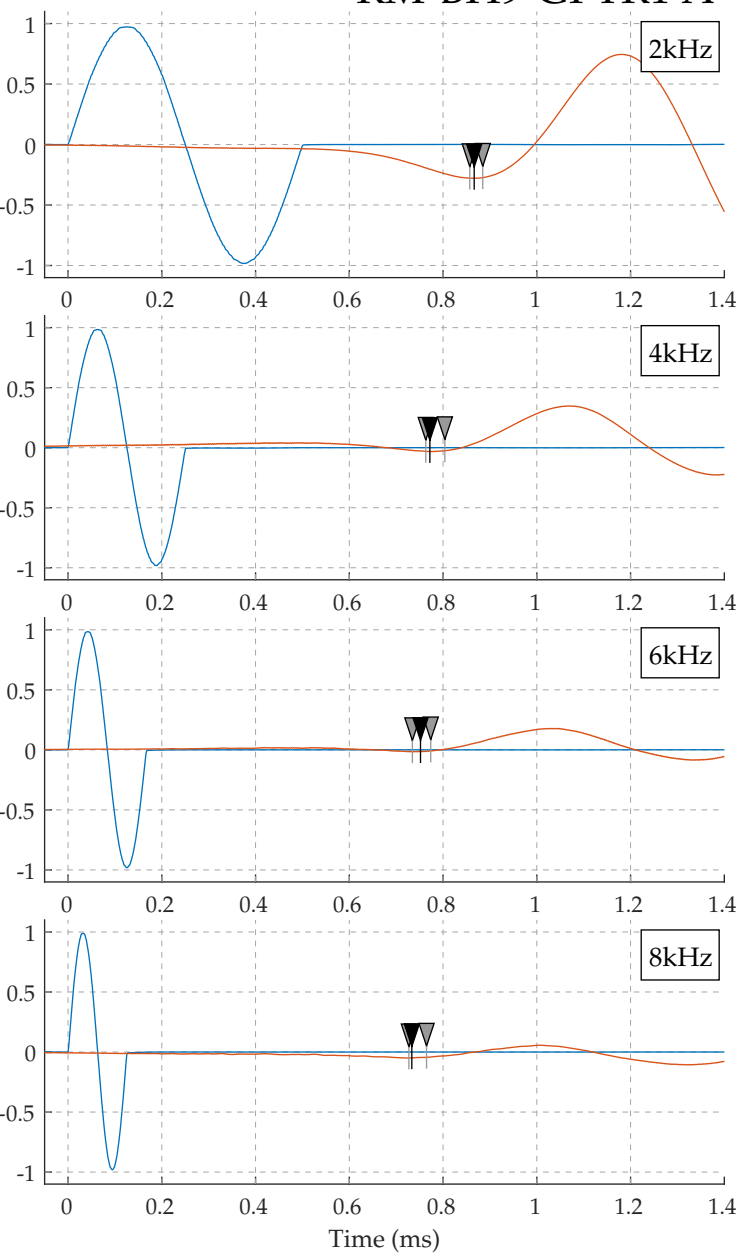


RM-BH9-GPTR1 A - Reconsolidation



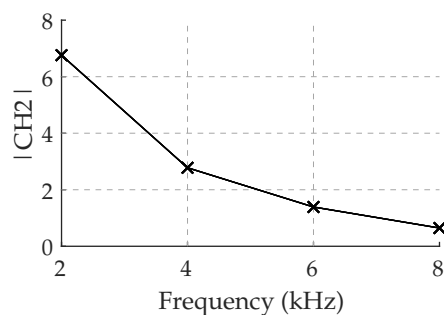
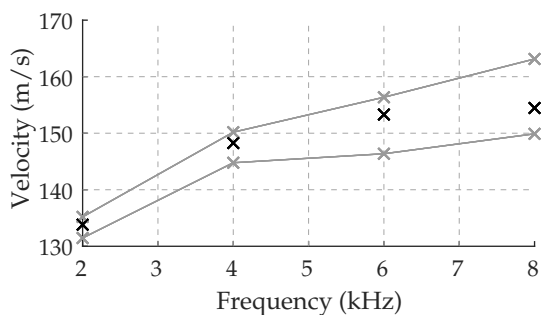
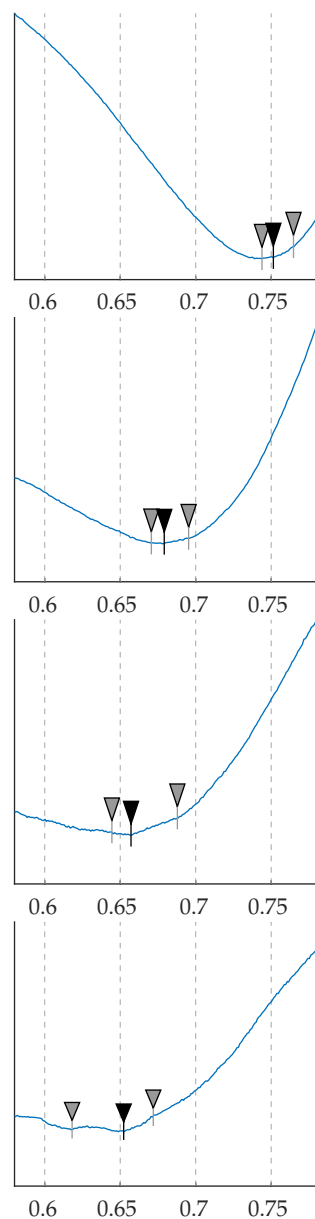
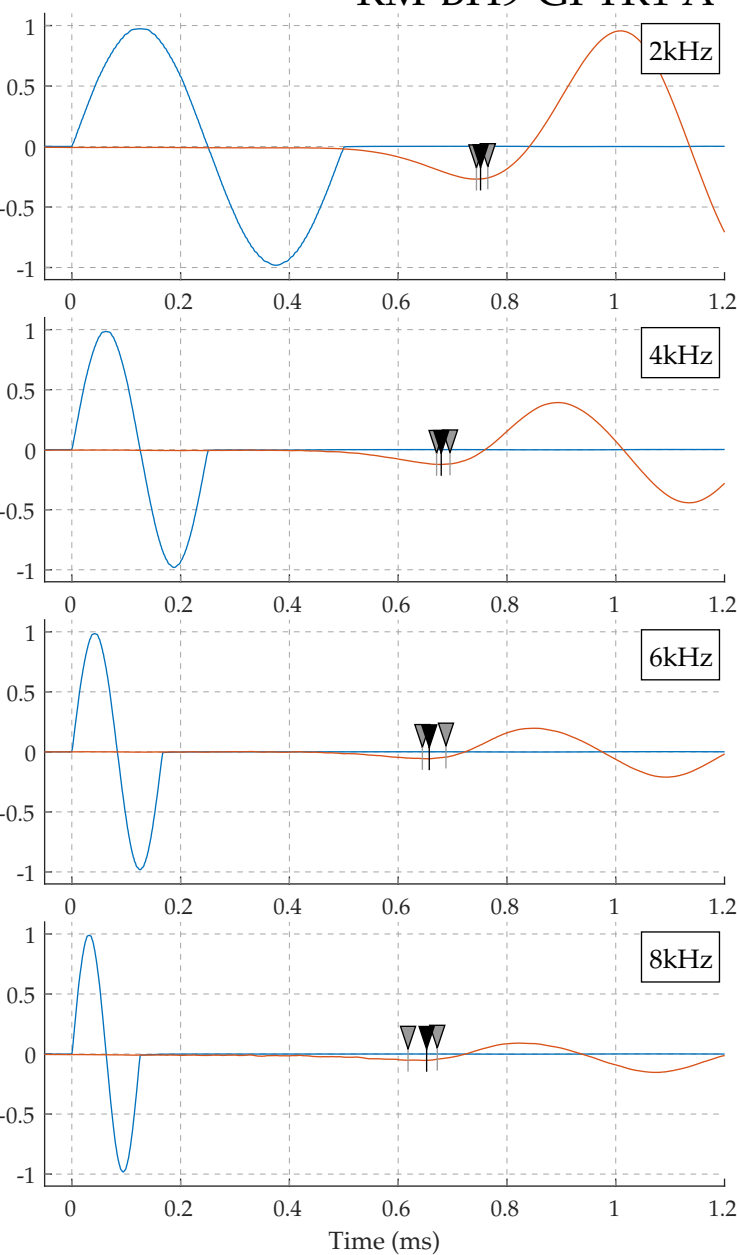
RM-BH9-GPTR1 A

$p' = 21\text{kPa}$



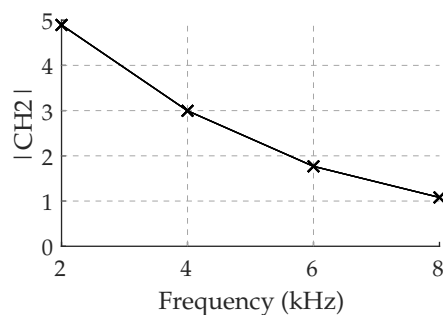
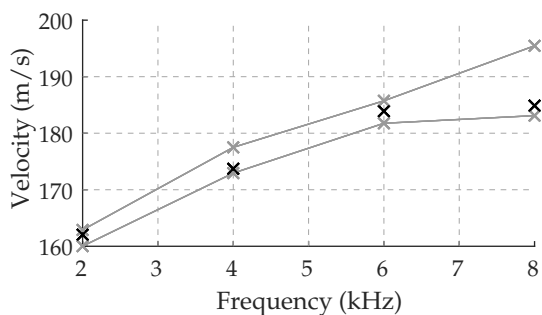
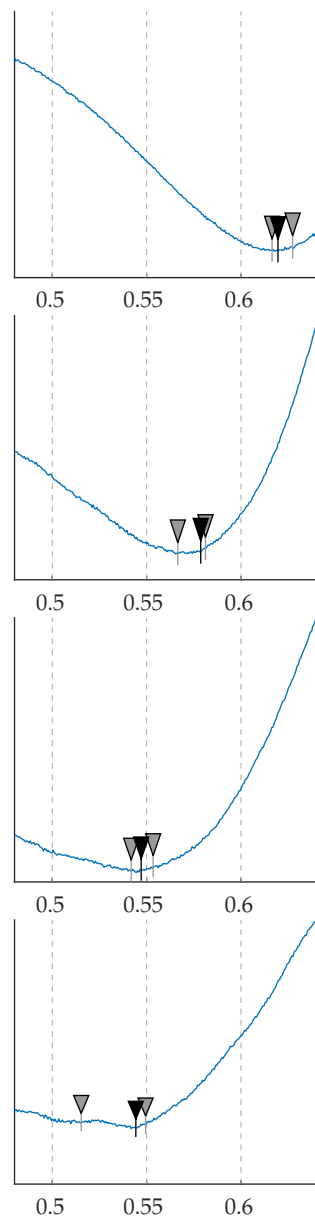
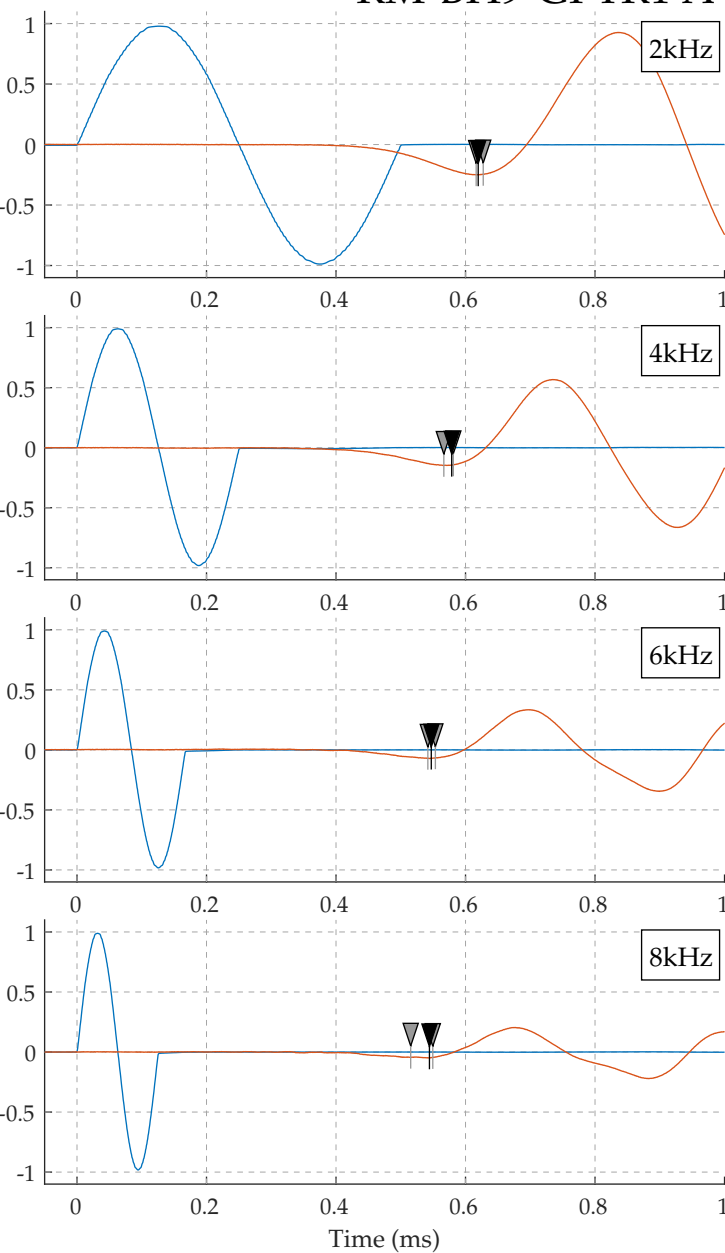
RM-BH9-GPTR1 A

$p = 40\text{kPa}$



RM-BH9-GPTR1 A

$p^* = 80\text{kPa}$



3.2 RM BH9 GPTR1 B

Test date: 08/02/22

End of Saturation			End of consolidation				Post test
Height	Diameter	Dry Density	Height	Diameter	Dry Density	Water Content	Water content
(mm)	(mm)	(kg/m ³)	(mm)	(mm)	(kg/m ³)	(%)	(%)
103.20	48.86	565.8	102.90	48.71	571.1	1.354	1.306

Back pressure (kPa)	p' _c (kPa)	B-Value	CSR ¹	N _{failure} ²	γ _{max} (%)	ε _{vol, reconsol} (%)
200.5	79.4	0.97	0.44	976	4.7	2.7

Note 1: Cyclic Stress Ratio, CSR_{TX}, corresponds to the triaxial test condition. Correction(s) should be made to adjust these values to estimated in-situ conditions.

Note 2: Number of cycles to failure, N_{cf}, is defined as the loading cycle number at which the test specimen reached a double-amplitude axial strain equal to 5 %.

Shear Wave Velocity Data (consolidation):

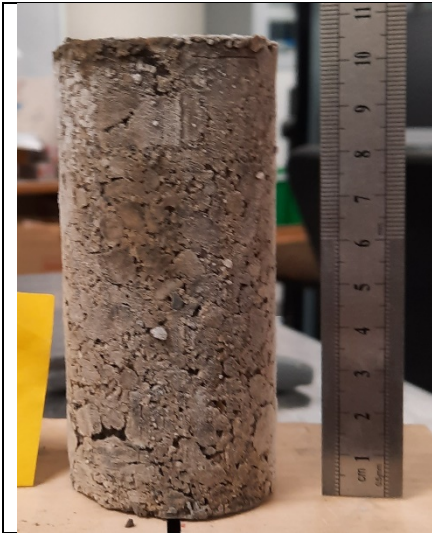
Excitation Freq	4kHz	6kHz	8kHz	Average
p'	Measured Shear Wave Velocities (m/s)			
20	121.5	125.8	124.7	124
39.5	141.4	147.2	150.5	146.4
80	168.2	172.6	178.2	173

Best fit curve: $v_s = A p'^B$

A = 60.44 B = 0.2402

Additional test notes:

- Noticeable smell (Sulphur?) present on specimens
- Gel present all through the specimens



Pre-test



After consolidation

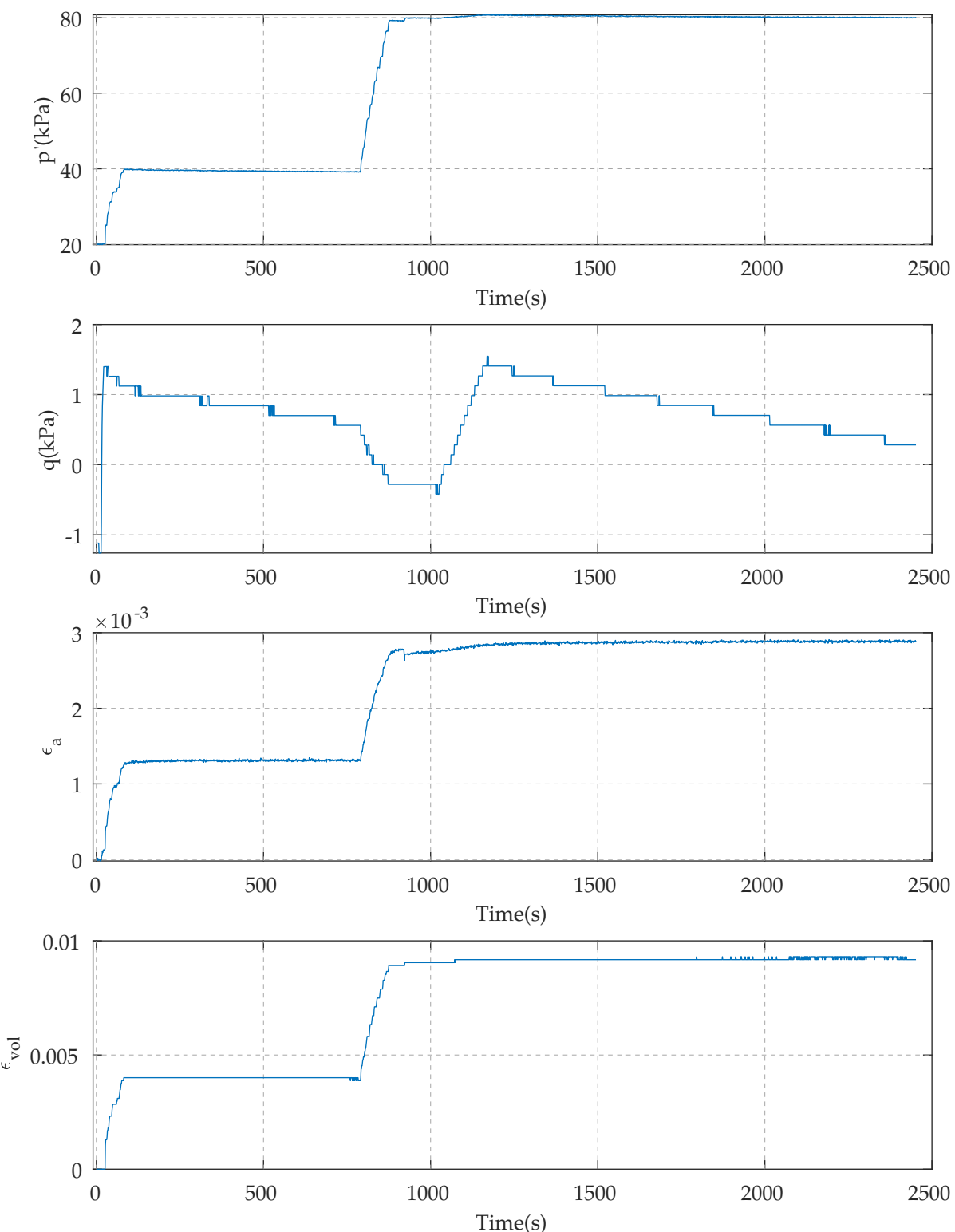


Post-test



View of inside of specimen

RM-BH9-GPTR1 B - Consolidation

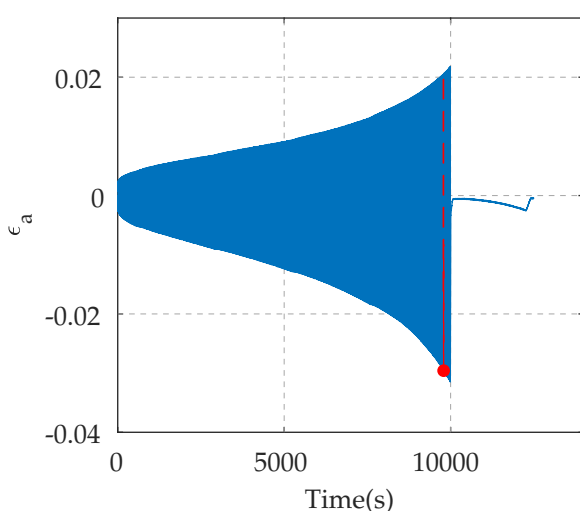
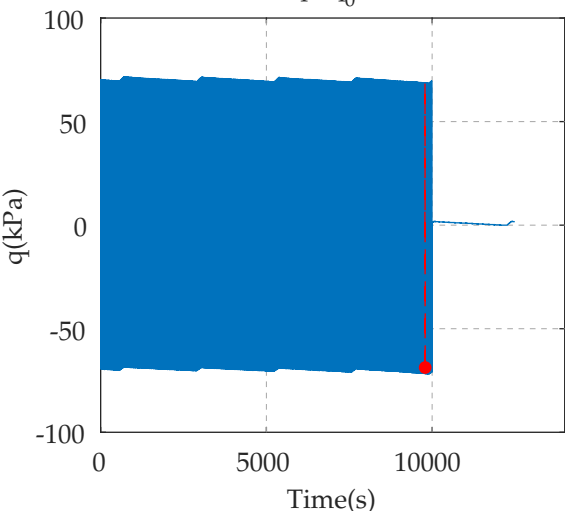
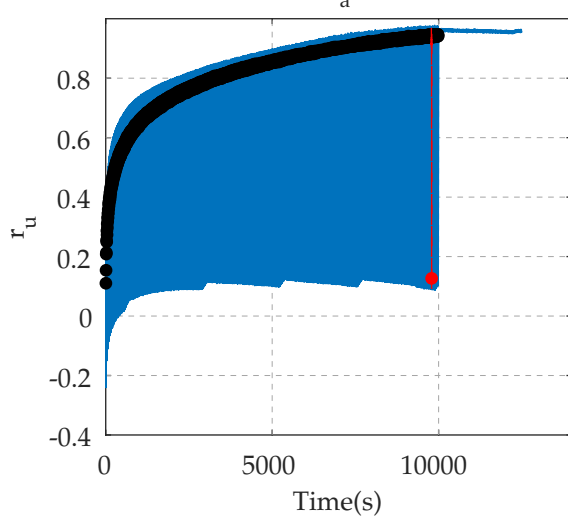
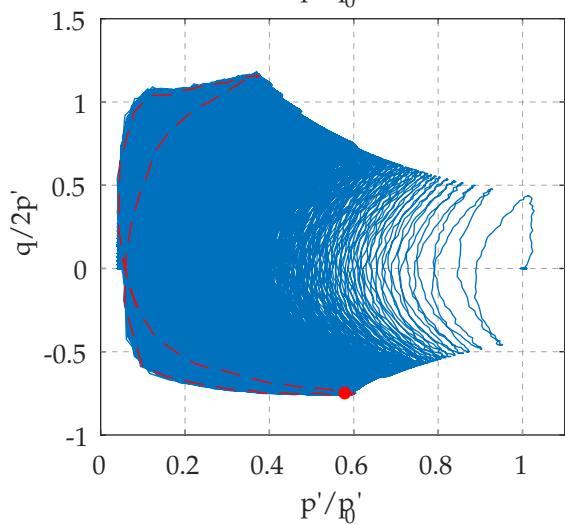
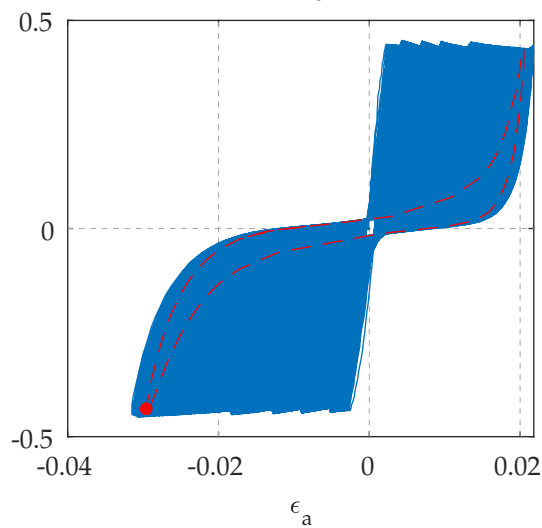
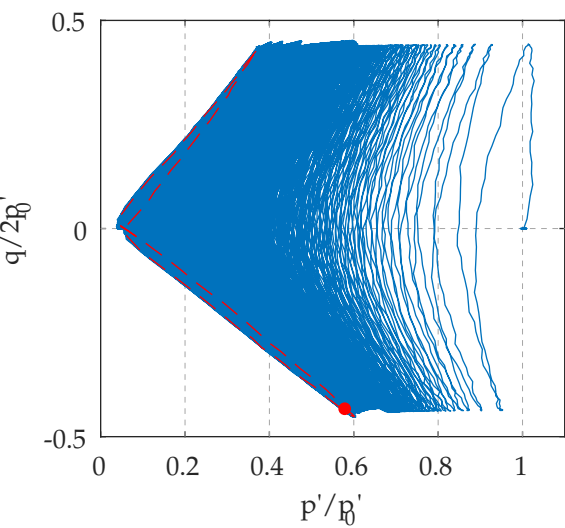


RM-BH9-GPTR1 B - CTX

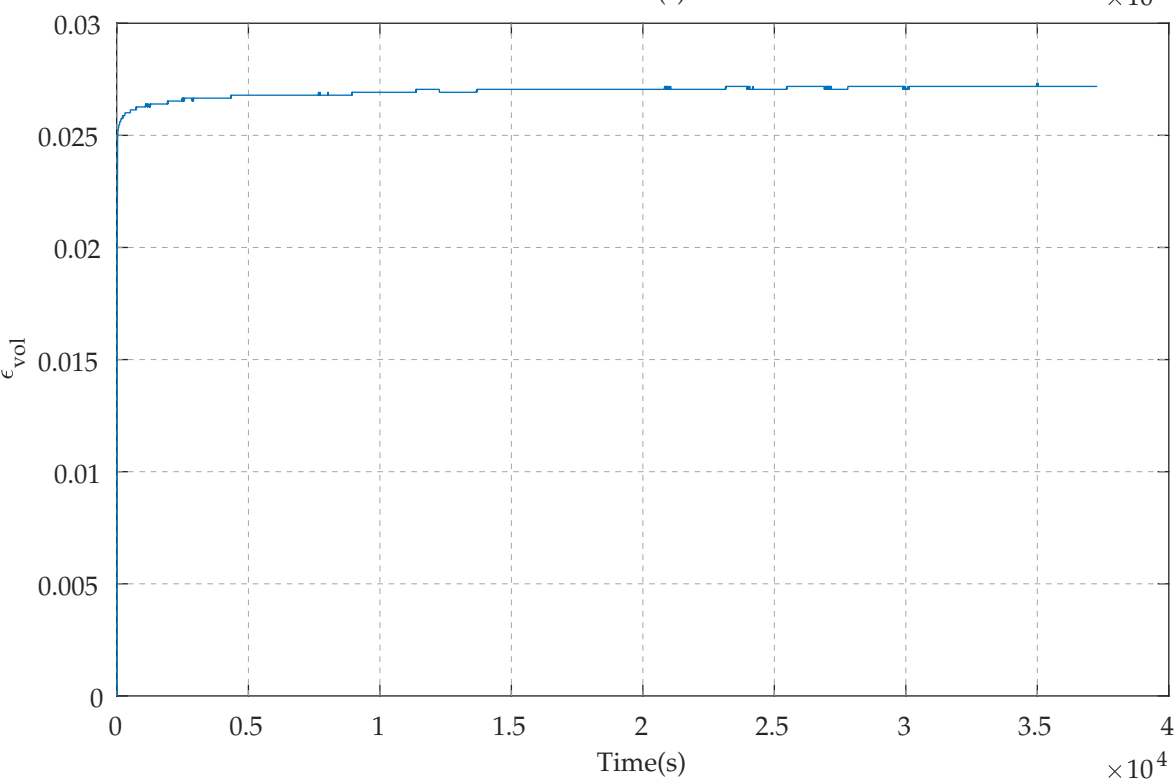
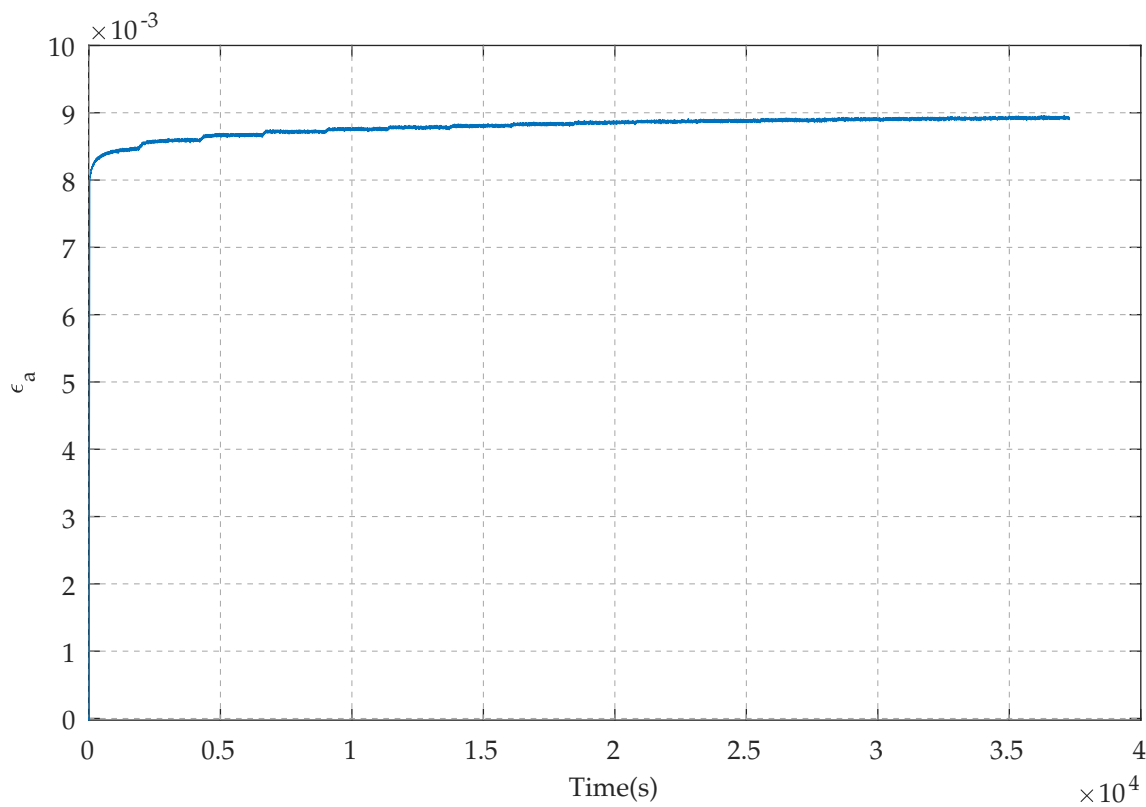
$N_{5\%DA} = 976$ cycles

CSR' = 0.44

$p_0' = 79.5$ kPa

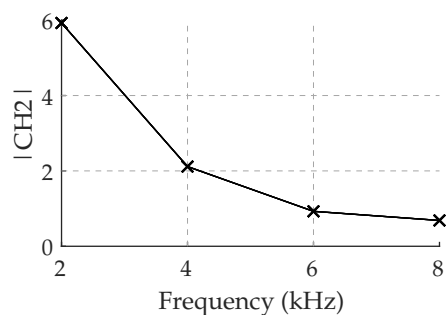
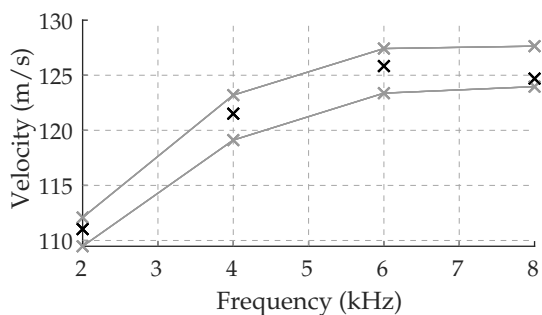
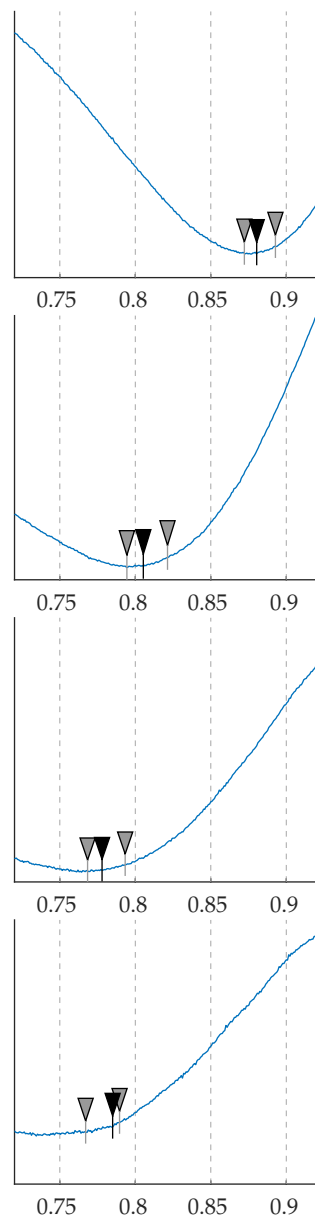
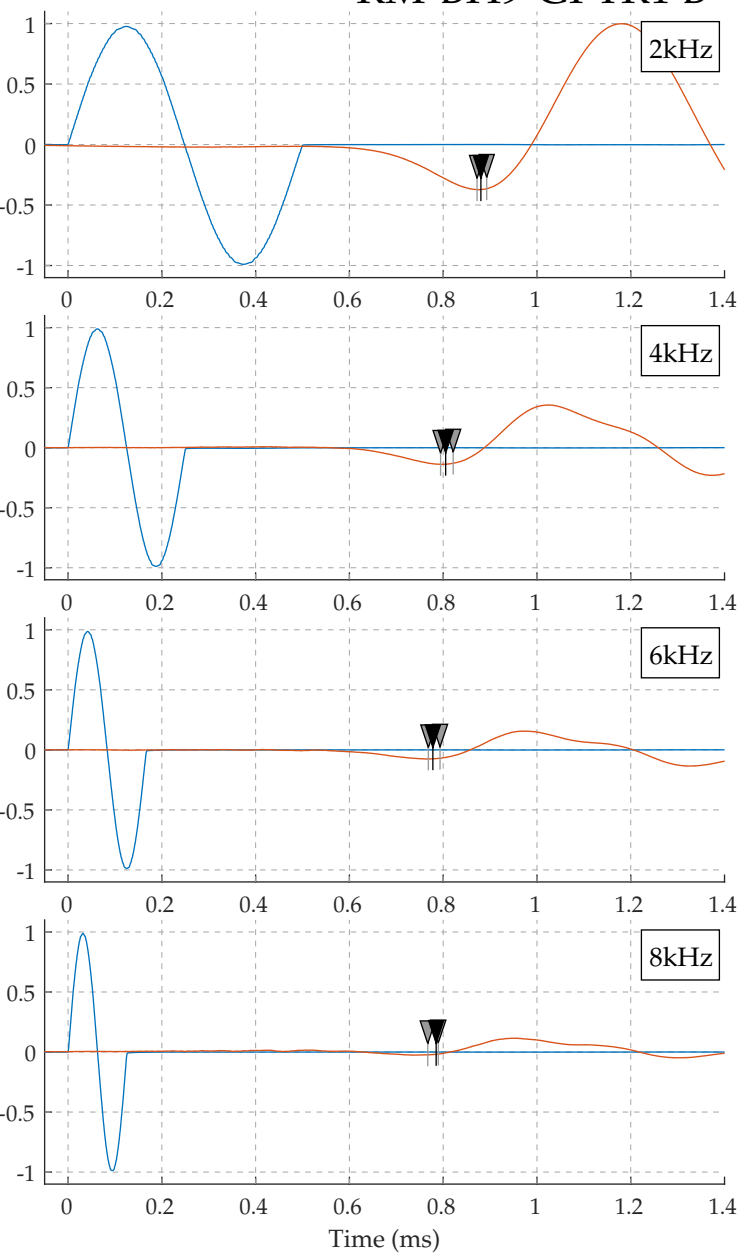


RM-BH9-GPTR1 B - Reconsolidation



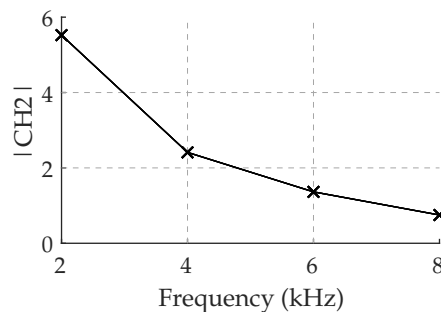
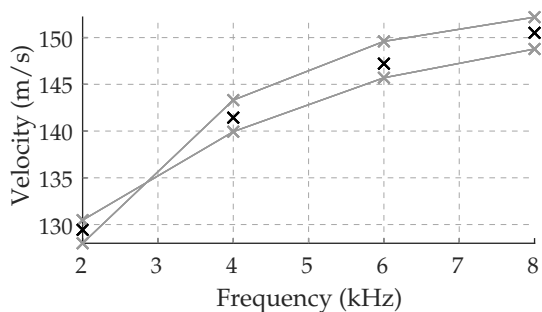
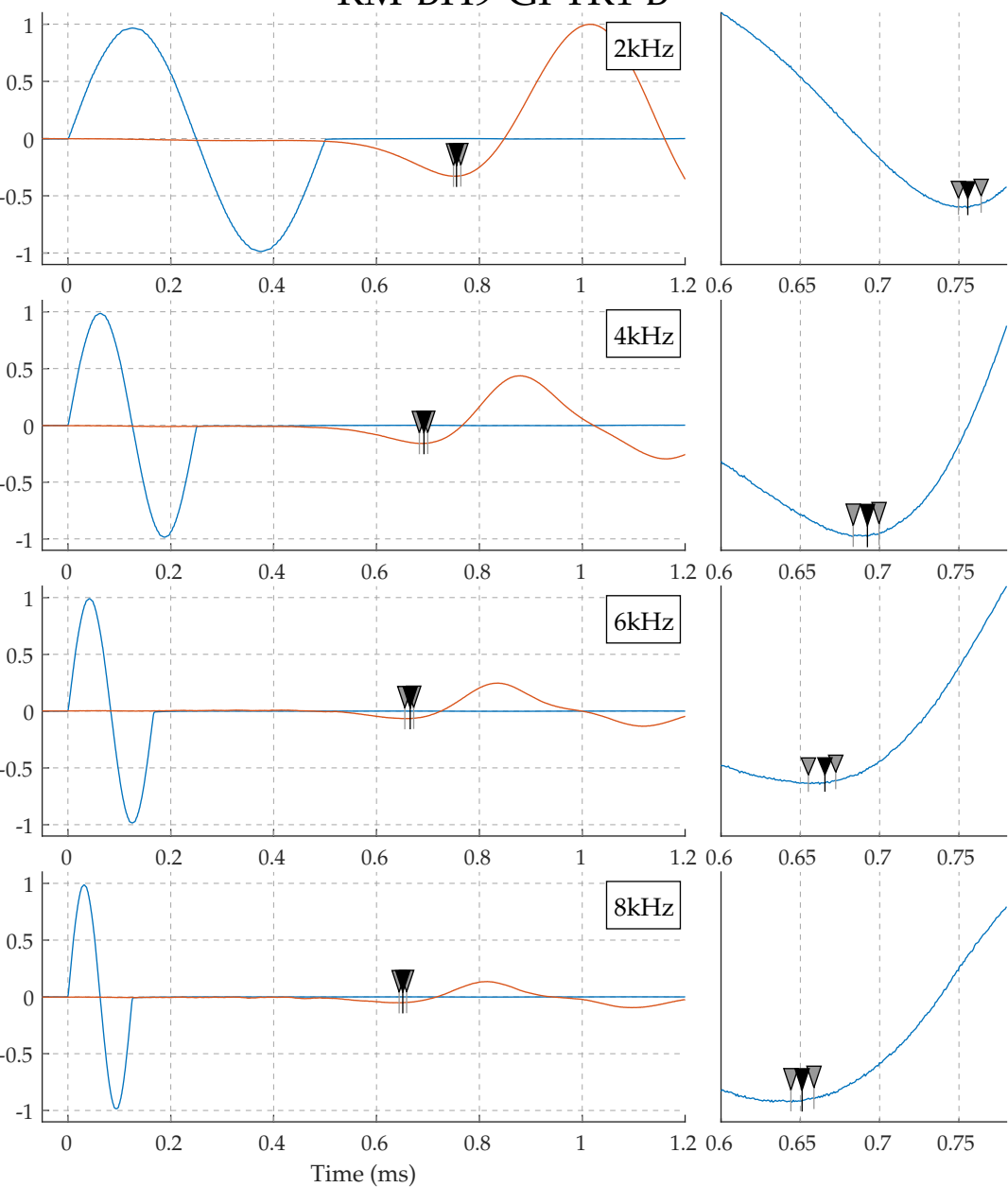
RM-BH9-GPTR1 B

$p^* = 20\text{kPa}$



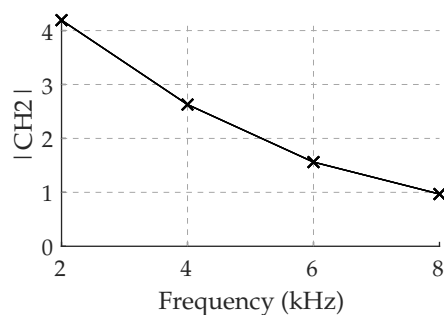
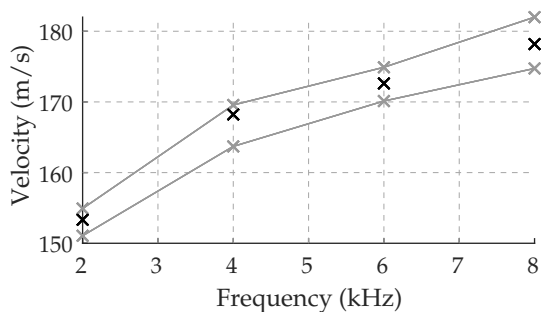
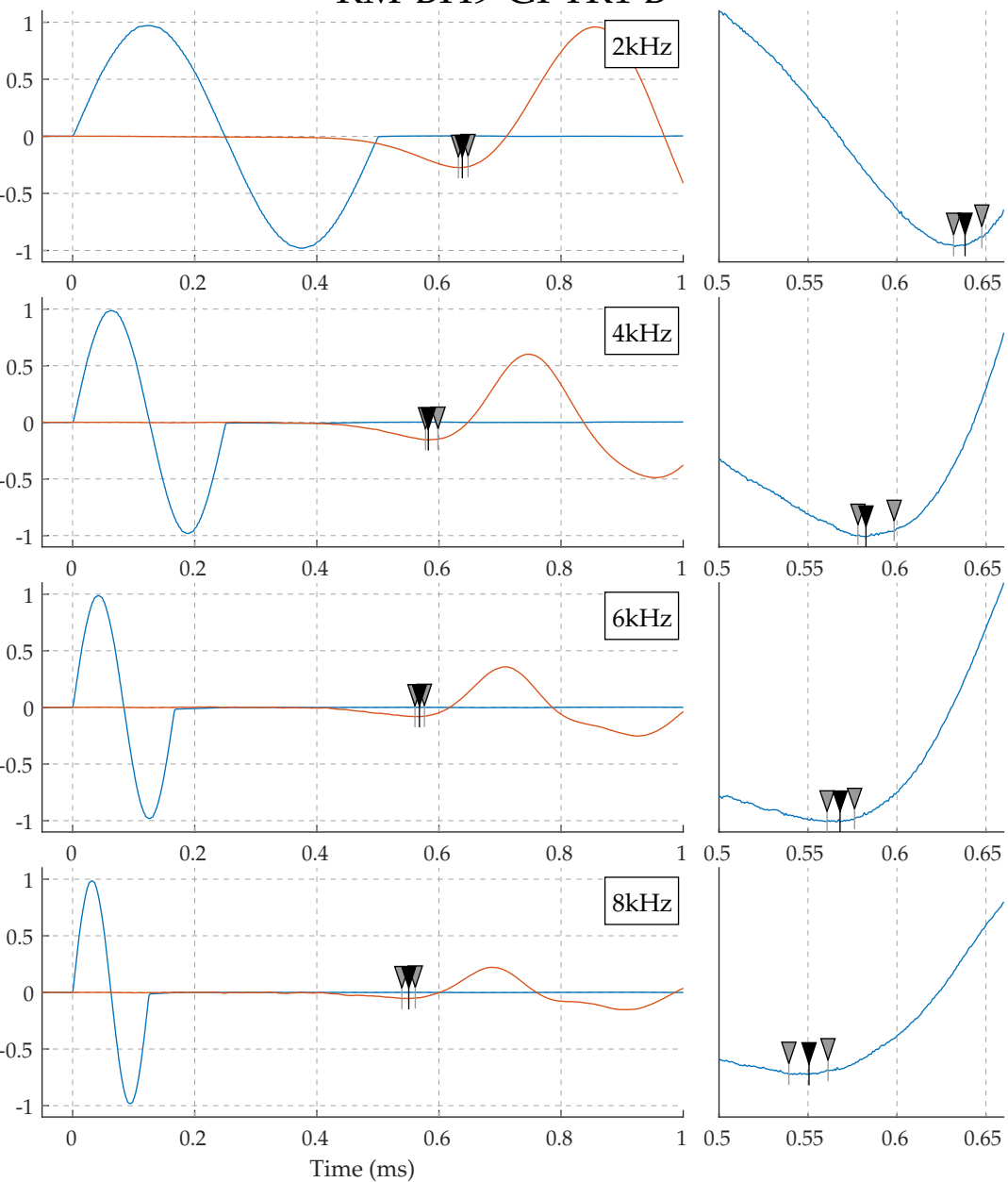
RM-BH9-GPTR1 B

$p^* = 40\text{kPa}$



RM-BH9-GPTR1 B

$p^* = 80 \text{ kPa}$



3.3 RM BH9 GPTR1 D

Test date: 10/02/22

End of Saturation			End of consolidation				Post test
Height	Diameter	Dry Density	Height	Diameter	Dry Density	Water Content	Water content
(mm)	(mm)	(kg/m ³)	(mm)	(mm)	(kg/m ³)	(%)	(%)
100.60	49.60	531.0	100.05	49.21	542.4	1.400	1.400

Back pressure (kPa)	p' _c (kPa)	B-Value	CSR ¹	N _{failure} ²	γ _{max} (%)	q _{max,post-cyclic} (kPa)
200.9	79.1	0.97	0.518	15	7.6	208

Note 1: Cyclic Stress Ratio, CSR_{TX}, corresponds to the triaxial test condition. Correction(s) should be made to adjust these values to estimated in-situ conditions.

Note 2: Number of cycles to failure, N_{cr}, is defined as the loading cycle number at which the test specimen reached a double-amplitude axial strain equal to 5 %.

Shear Wave Velocity Data (consolidation):

Excitation Freq	4kHz	6kHz	8kHz	Average
p'	Measured Shear Wave Velocities (m/s)			
20.3	130.9	136.2	137.2	134.8
40	152.6	155.1	160.5	156.1
80	184.5	193.4	203.5	193.8

Best fit curve: $v_s = A p'^B$

A = 60.05 B = 0.2649

Additional test notes:

- Noticeable smell (Sulphur?) present on specimens
- Gel present all through the specimens
- Sample fell apart when removed from membrane at end of test.



Pre test

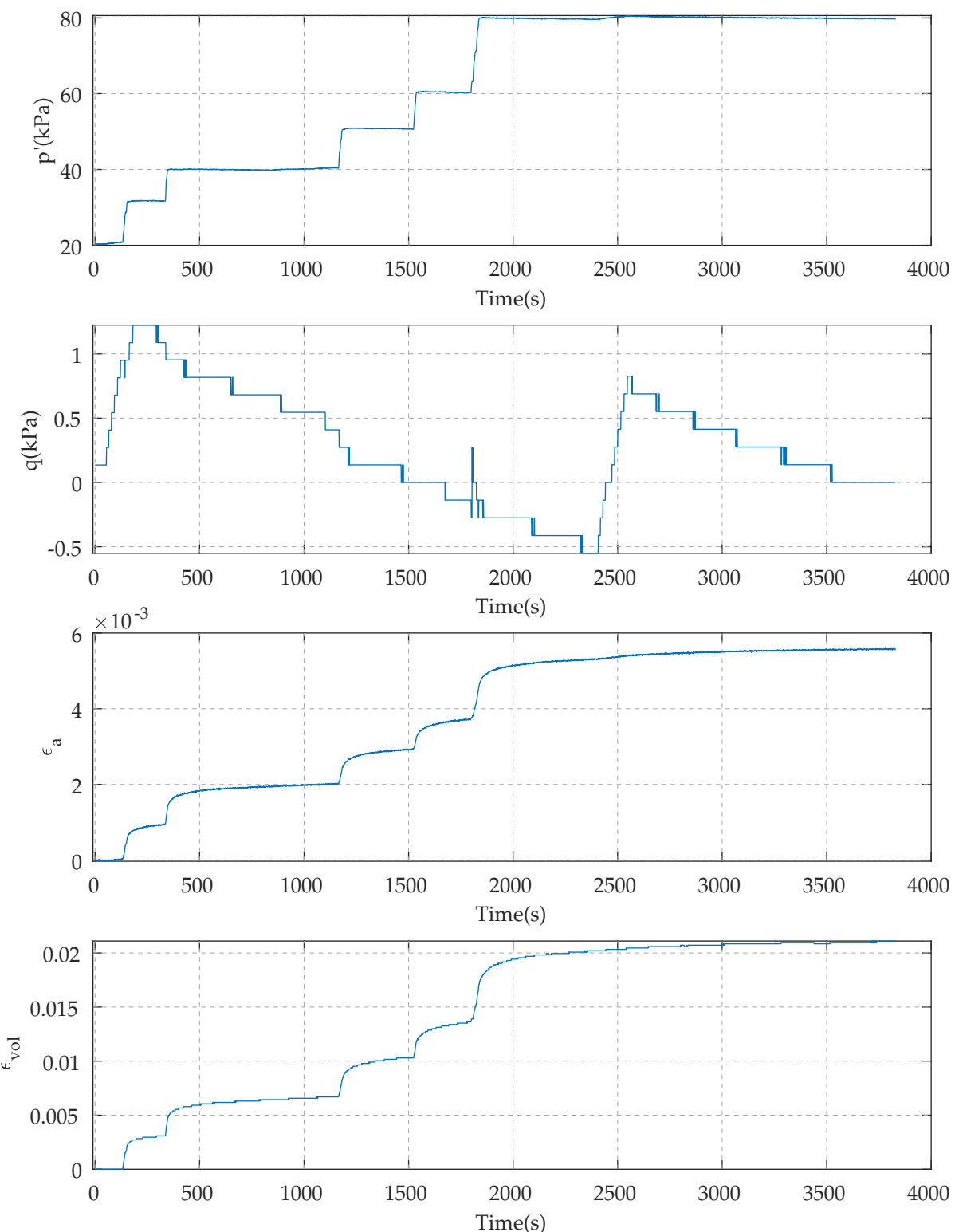


After consolidation



After shearing

RM-BH9-GPTR1 D - Consolidation

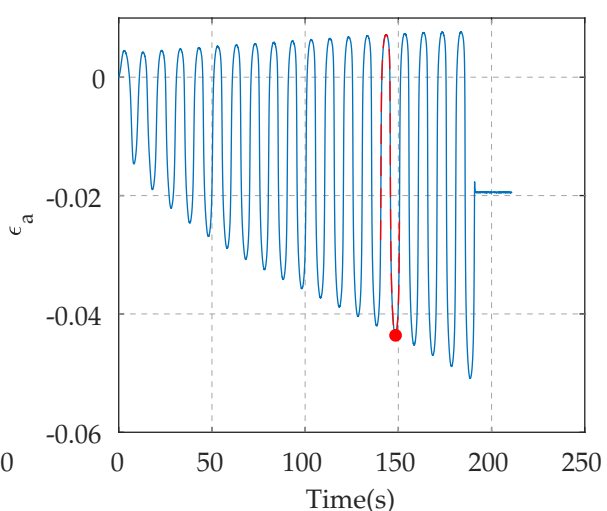
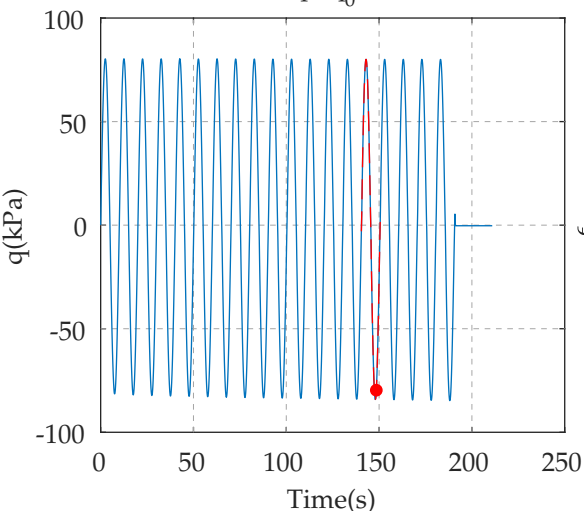
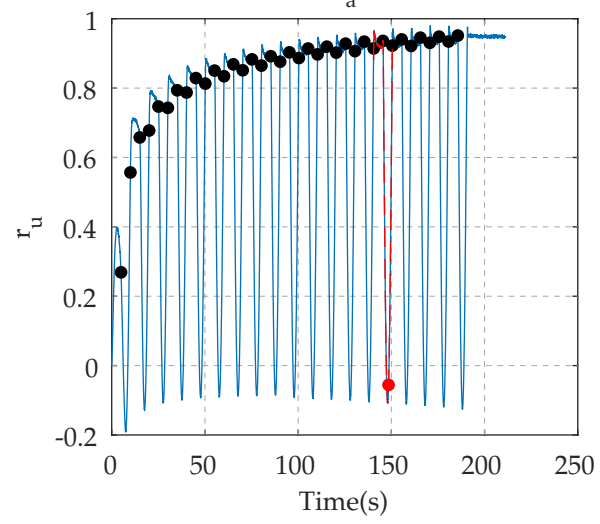
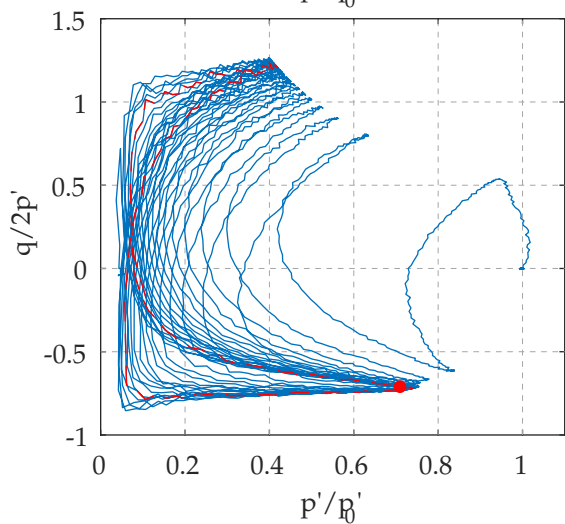
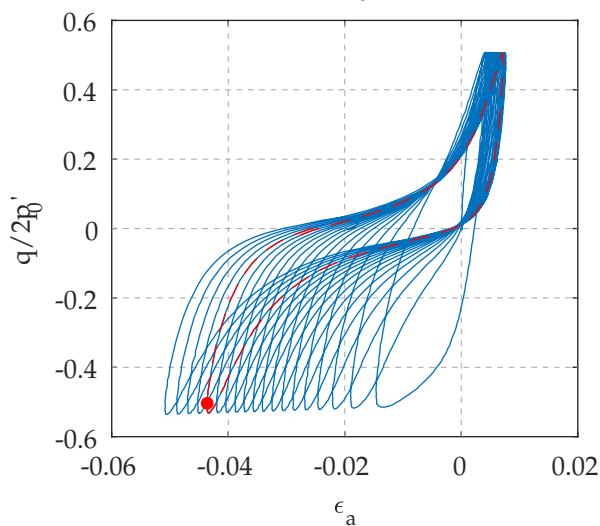
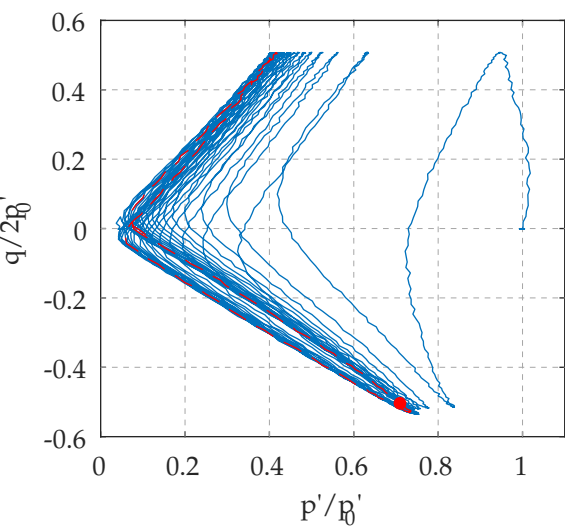


RM-BH9-GPTR1 D - CTX

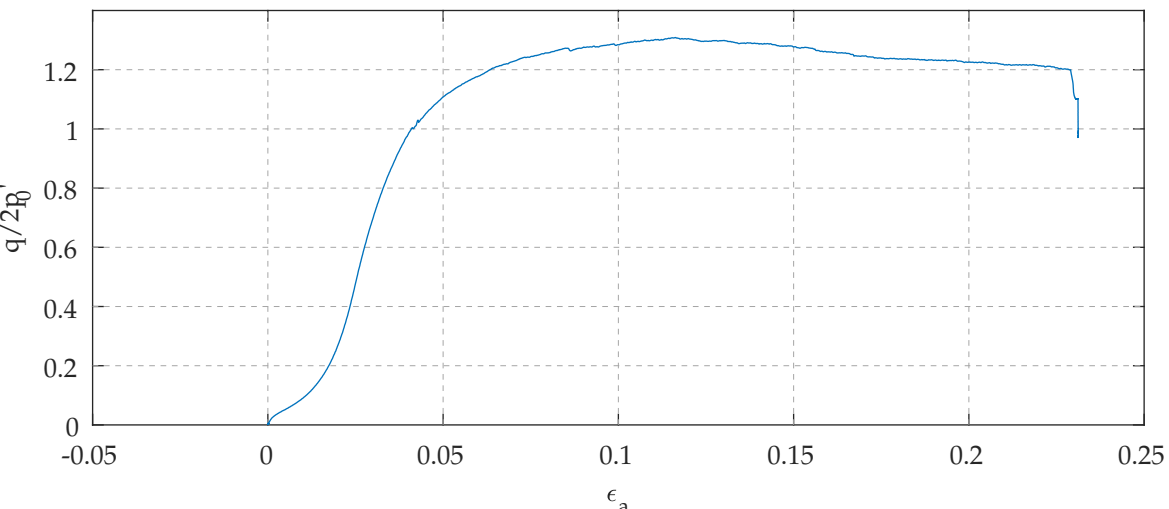
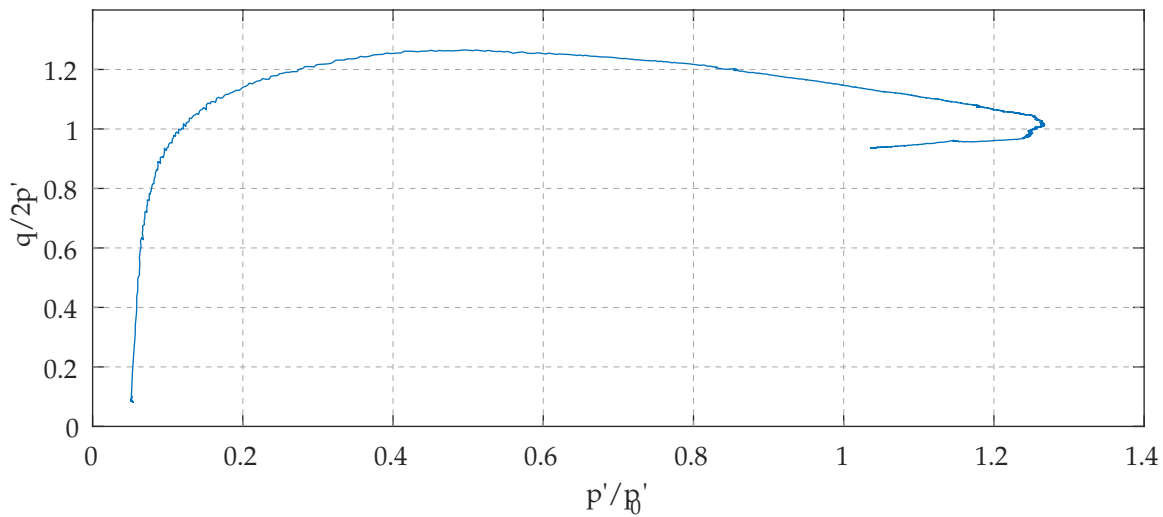
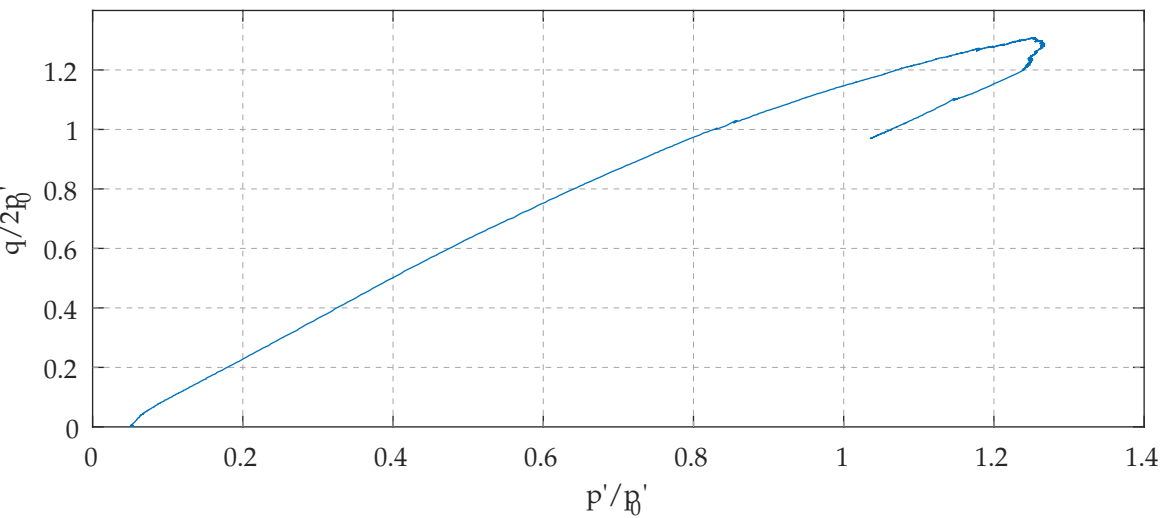
$N_{5\%DA} = 15$ cycles

CSR' = 0.518

$p_0' = 79.0$ kPa

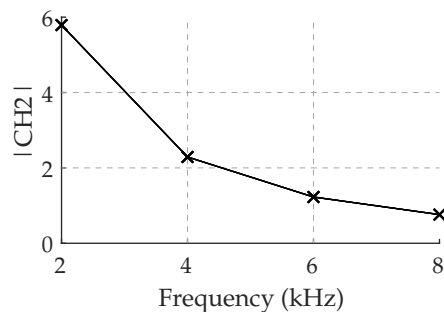
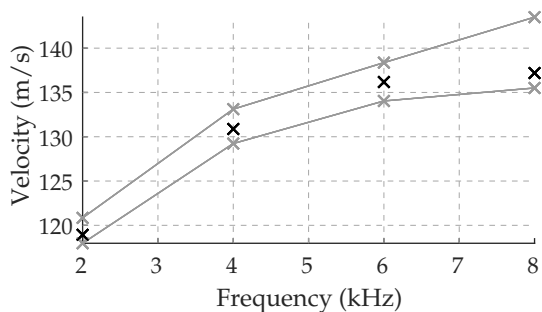
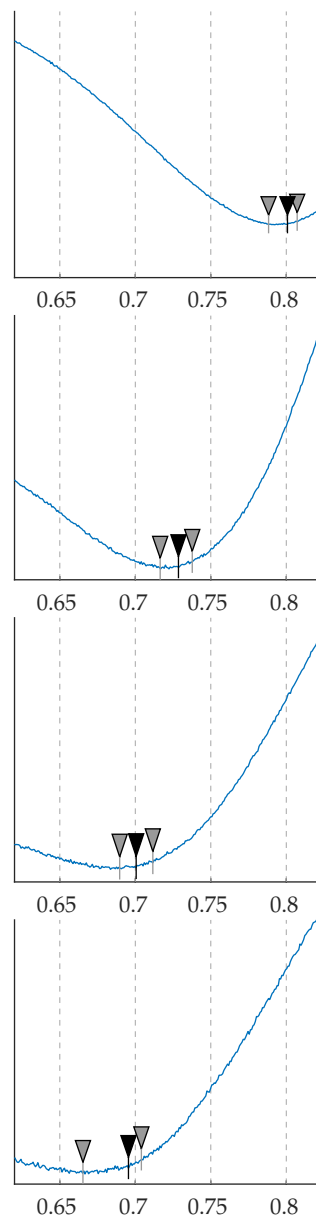
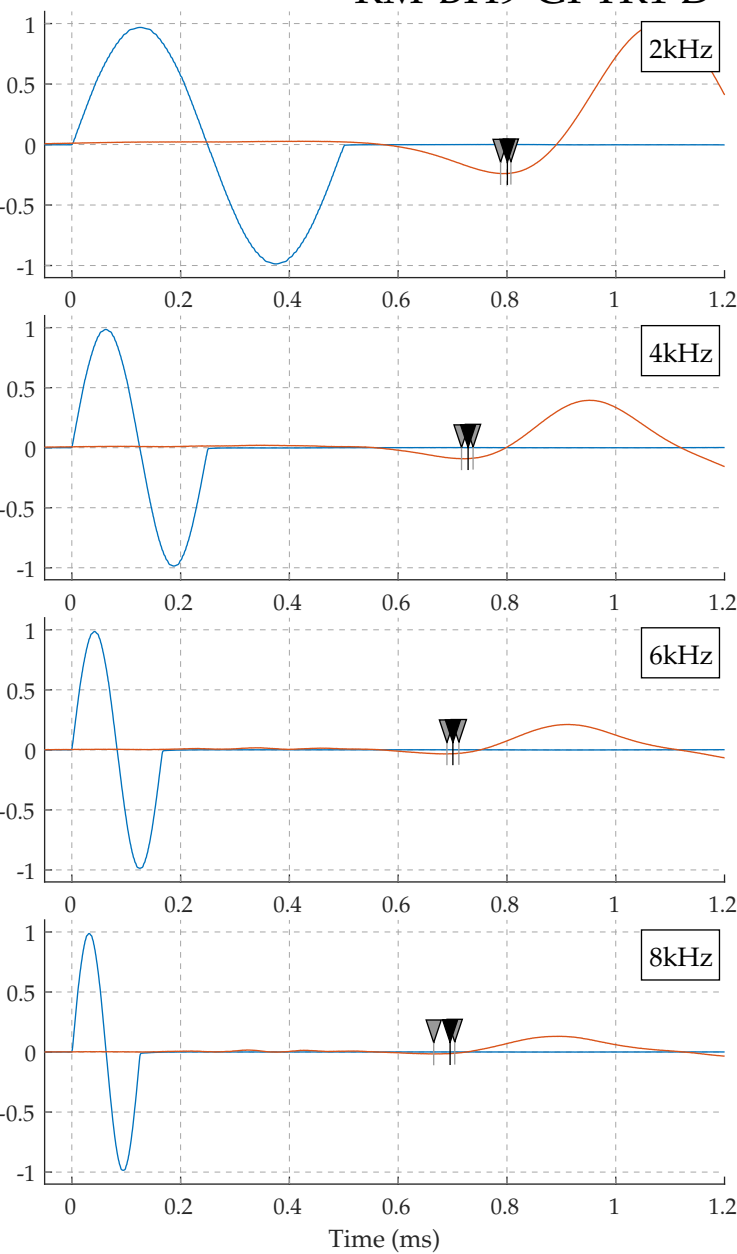


RM-BH9-GPTR1 D - Postcyclic monotonic shear



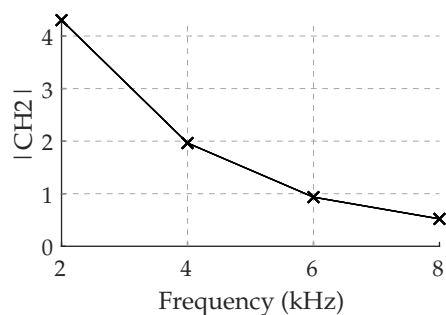
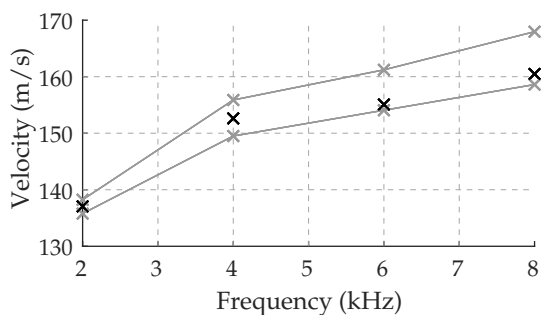
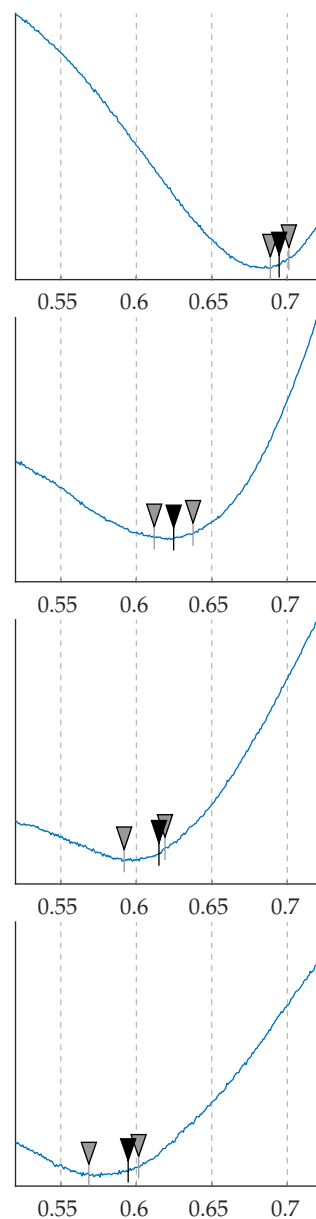
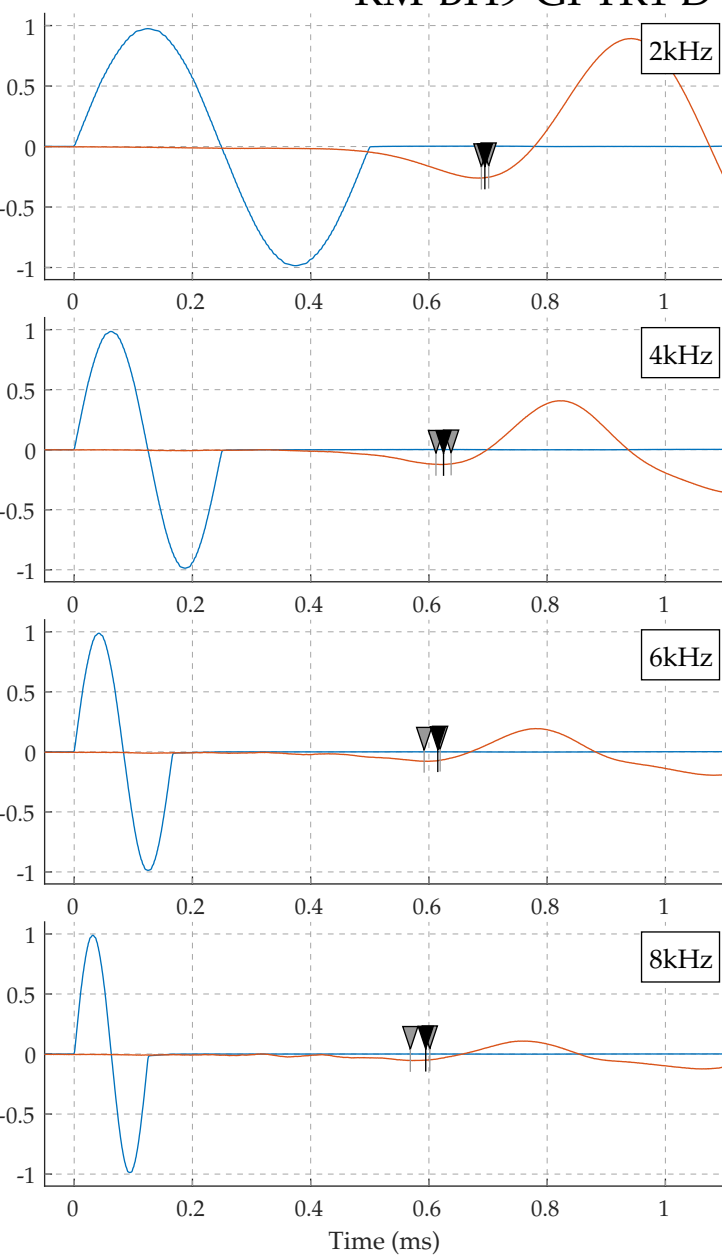
RM-BH9-GPTR1 D

$p^* = 20\text{kPa}$



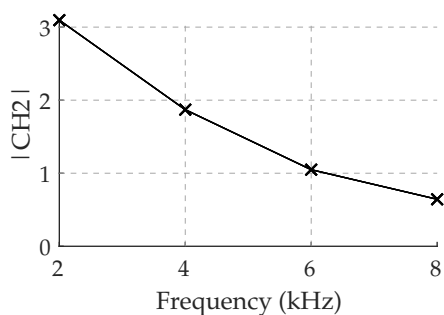
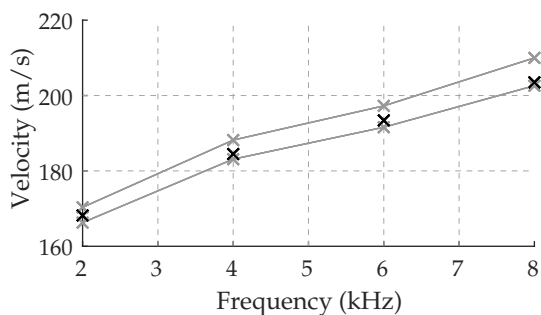
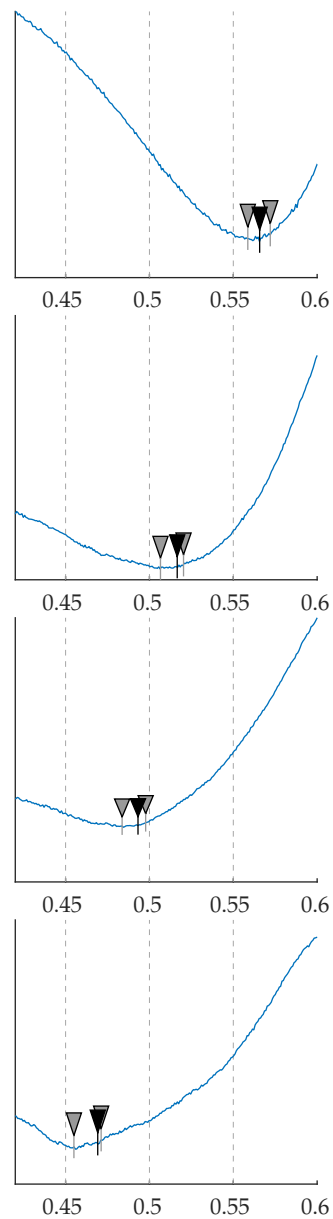
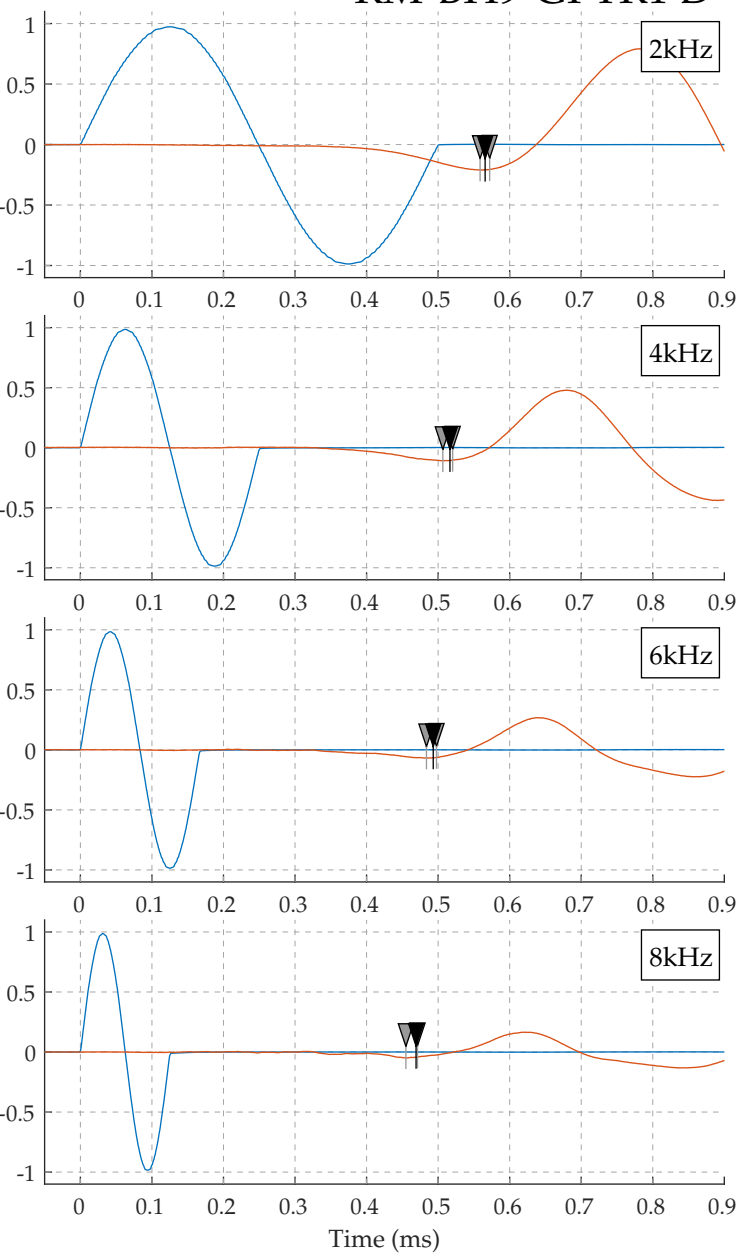
RM-BH9-GPTR1 D

$p^* = 40\text{kPa}$



RM-BH9-GPTR1 D

$p' = 80\text{kPa}$





Our Ref: 2021018.0000/Rep1
Customer Ref: RLP025538
6 April 2022

Rotorua District Council Trading as Rotorua Lakes Council
c/- WSP
E-mail: kareen.mclaren@wsp.com

Attention: Kareen McLaren

Dear Kareen

Rotorua Museum Development Laboratory Test Report

Customer's Instructions

We were instructed to perform dynamic triaxial and bender element testing on each of the specimens scheduled. The effective consolidation stress and CSR for each of the dynamic triaxial tests was provided by Mr. Sutejo Tjokro of Tonkin & Taylor.

Sampling Procedure

Samples have been tested as received from the customer.

Sample Location Plan

Not applicable.

Samples

8 gel push tube samples were received. The samples were labelled with a borehole number and depth.

Date of Sample Receipt

22/11/2021

Test Method(s)

ASTM D5311/D5311M-13 – Load Controlled Cyclic Triaxial Strength of Soil

NZS 4402: 1986 Test 2.1 - Water Content

Material Description

Descriptions are provided in the attached presentation pages.

Test Results

Test results are attached.

Test Remarks

Bender element test results are not included in this report as the test specifications we used were not suitable for the test / material. As a consequence, the results obtained may not be reliable.

The remaining test remarks are included in the presentation pages.

General Remarks

Samples not destroyed during testing, will be retained for one month from the date of this report before being discarded.

This report has been prepared for the benefit of Rotorua District Council Trading as Rotorua Lakes Council, with respect to the particular brief given to us and it cannot be relied upon in other contexts or for any other purpose without our prior review and agreement.

Please reproduce this report in full when transmitting to others or including in internal reports.

If we can be of any further assistance, feel free to get in touch. Contact details are provided at the bottom of the letterhead page.

GEOTECHNICS LTD

Report prepared by:



.....
Cameron Tier
Triaxial Laboratory Technician

Authorised for Geotechnics by:



.....
Anthony Gilliland
Project Director

Report checked by:



.....
Helen Wang
Triaxial Laboratory Manager

6-Apr-22

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1 Hill Street
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p. +64 9 356 3510

Geotechnics Project ID: 2021018.0000
QESTLab Work Order ID:
Customer Project ID: RLP025538

Site: Rotorua Museum Development Location ID: BH2
Sample Ref.: Sample 3 Depth: 3.81 - 3.95 (m)
Test method used: ASTM D5311/D5311M-13 Load Controlled Cyclic Triaxial Strength of Soil
NZS 4402:1986 Test 2.1 Determination of Water Content

CYCLIC TRIAXIAL STRENGTH (CIU)

General Sample Parameters

Initial Sample Height:	144.97	mm	Initial Water Content:	105	%
Initial Sample Diameter:	71.77	mm	Initial Bulk Density:	1.35	t/m ³
Initial Sample Area:	4045.82	mm ²	Initial Dry Density:	0.66	t/m ³
B Value before Consolidation:	99	%	Final Water Content:	93.8	%

Consolidation

Cell Pressure:	500	kPa	Consolidated Height	144.2	mm
Back Pressure:	450	kPa	Consolidated Diameter:	71.41	mm
Effective Consolidation Stress (σ_{1c} , σ_{3c}):	50	kPa	Consolidated Area:	4004.54	mm ²

Dynamic Triaxial Strength

Cyclic Number:	212		Vertical Strain in Compression:	3.28	%
Cyclic Compression Stress:	48.42	kPa	Vertical Strain in Extension:	-1.72	%
Cyclic Extension Stress:	-48.80	kPa	Double Amplitude Vertical Strain:	5.00	%
Average Cycle Vertical Stress:	48.61	kPa	Maximum Pore Pressure:	50.4	kPa
Cyclic Stress Ratio	0.49		Cyclic Pore Pressure Ratio:	1.0	
Difference from Programmed Load:	0.20	%			

Sample History

The sample was received in a gel push tube with a nominal diameter of 85mm. The push tube was transported frozen in an insulated container with ice and stored in a freezer upon arrival to the lab. The frozen push tube was cut with a bandsaw and extruded. The frozen sample diameter was trimmed down to remove contamination of the gel. The frozen sample was then defrosted after having been setup in the triaxial cell.

Soil description

SILT, sandy, with some gravel, brown with grey.

Test Remarks

The sample was saturated by increments of cell pressure and back pressure. It was drained from radial boundary and both ends in the consolidation stage.

Photos

Pre-test

NA

Post-test



Approved by:

Date: 11/03/2022



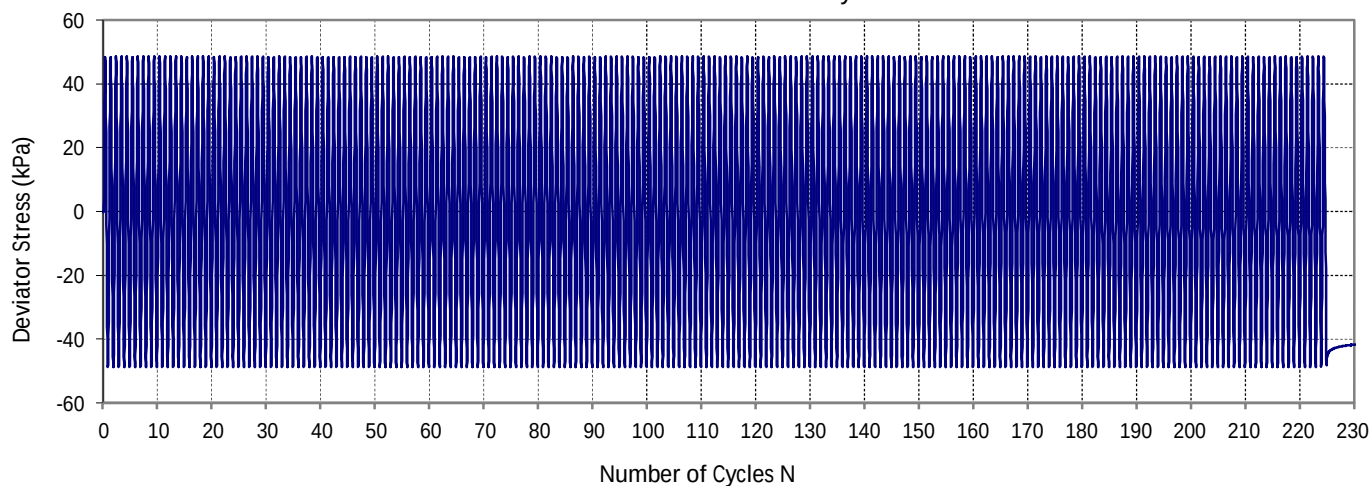
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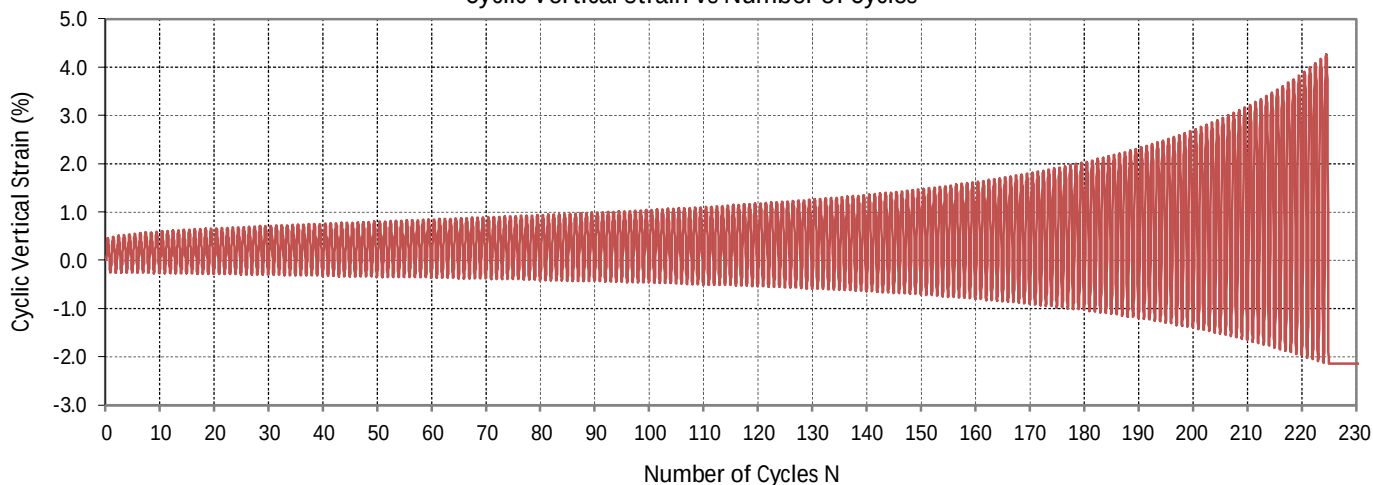
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Sample Ref.: Sample 3 Depth: 3.81 - 3.95 (m)
Test method used: ASTM D5311/D5311M-13 Load Controlled Cyclic Triaxial Strength of Soil
NZS 4402:1986 Test 2.1 Determination of Water Content

CYCLIC LOADING GRAPHS 1

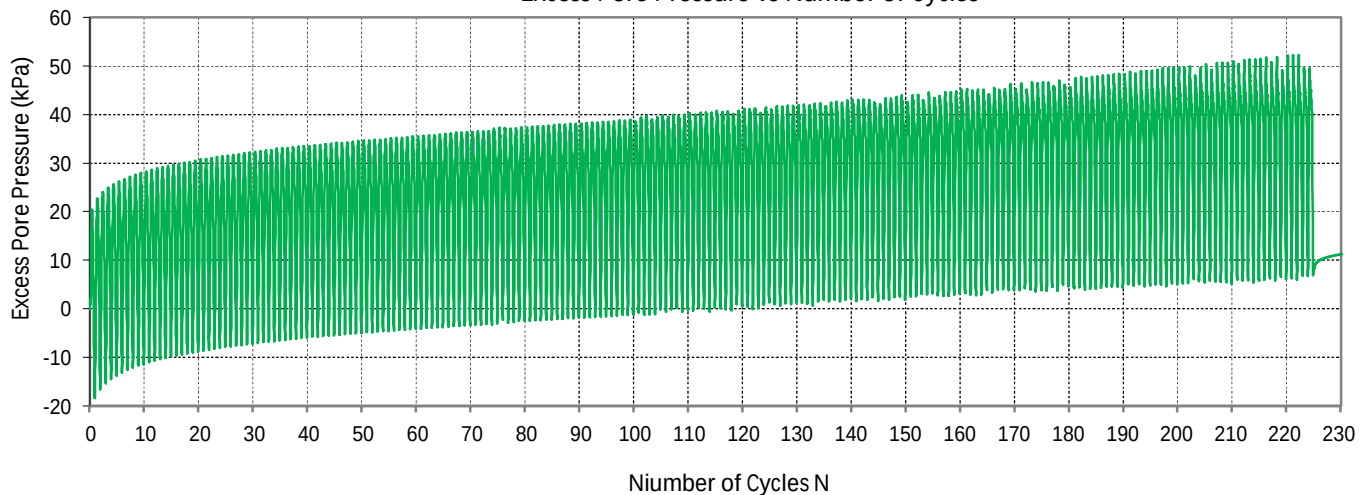
Deviator Stress vs Number of Cycles



Cyclic Vertical Strain vs Number of Cycles



Excess Pore Pressure vs Number of Cycles



Approved by:

Date: 11/03/2022



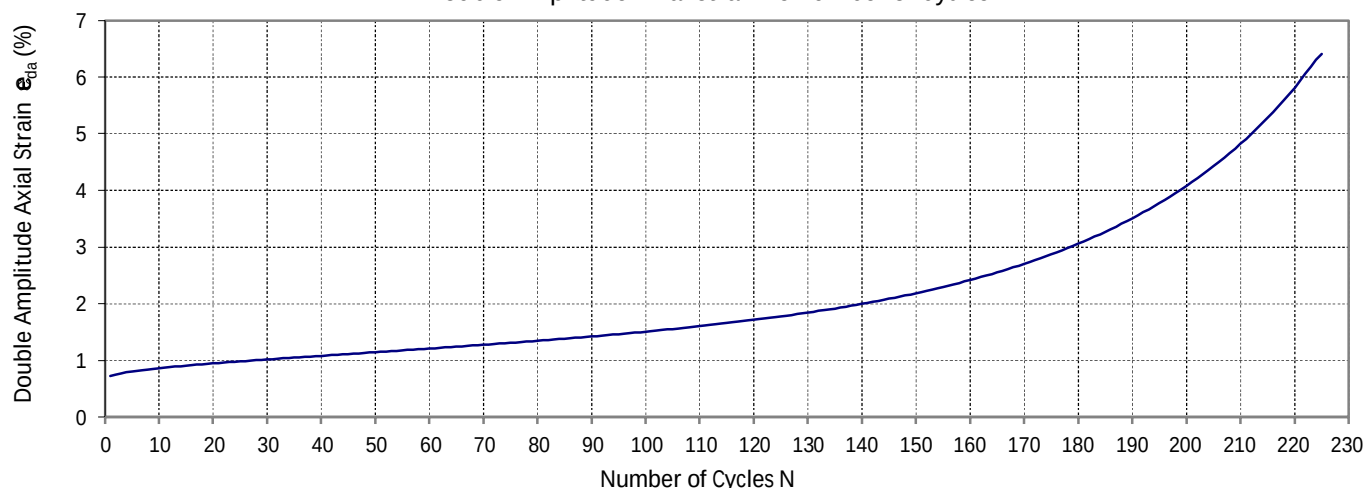
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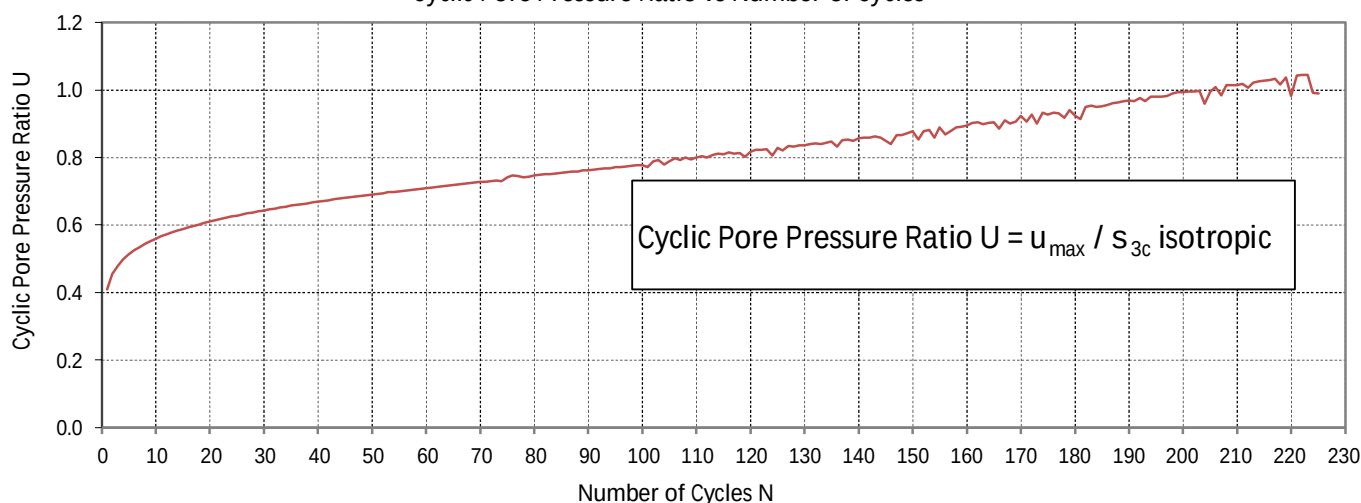
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Sample Ref.: Sample 3 Depth: 3.81 - 3.95 (m)
Test method used: ASTM D5311/D5311M-13 Load Controlled Cyclic Triaxial Strength of Soil
NZS 4402:1986 Test 2.1 Determination of Water Content

CYCLIC LOADING GRAPHS 3

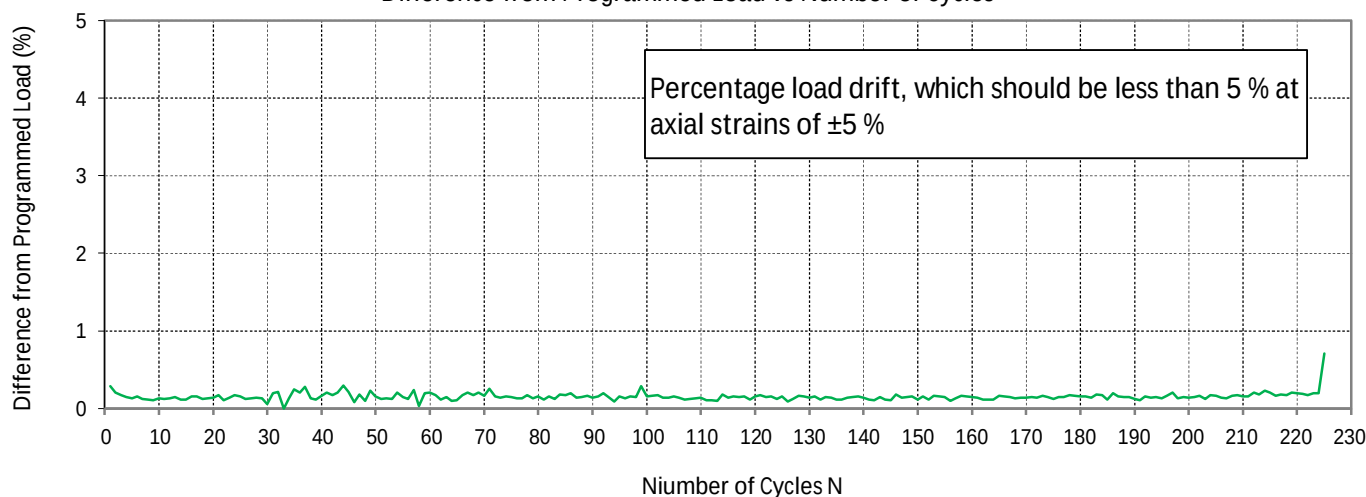
Double Amplitude Axial Strain vs Number of Cycles



Cyclic Pore Pressure Ratio vs Number of Cycles



Difference from Programmed Load vs Number of Cycles



Approved by:

Date: 11/03/2022

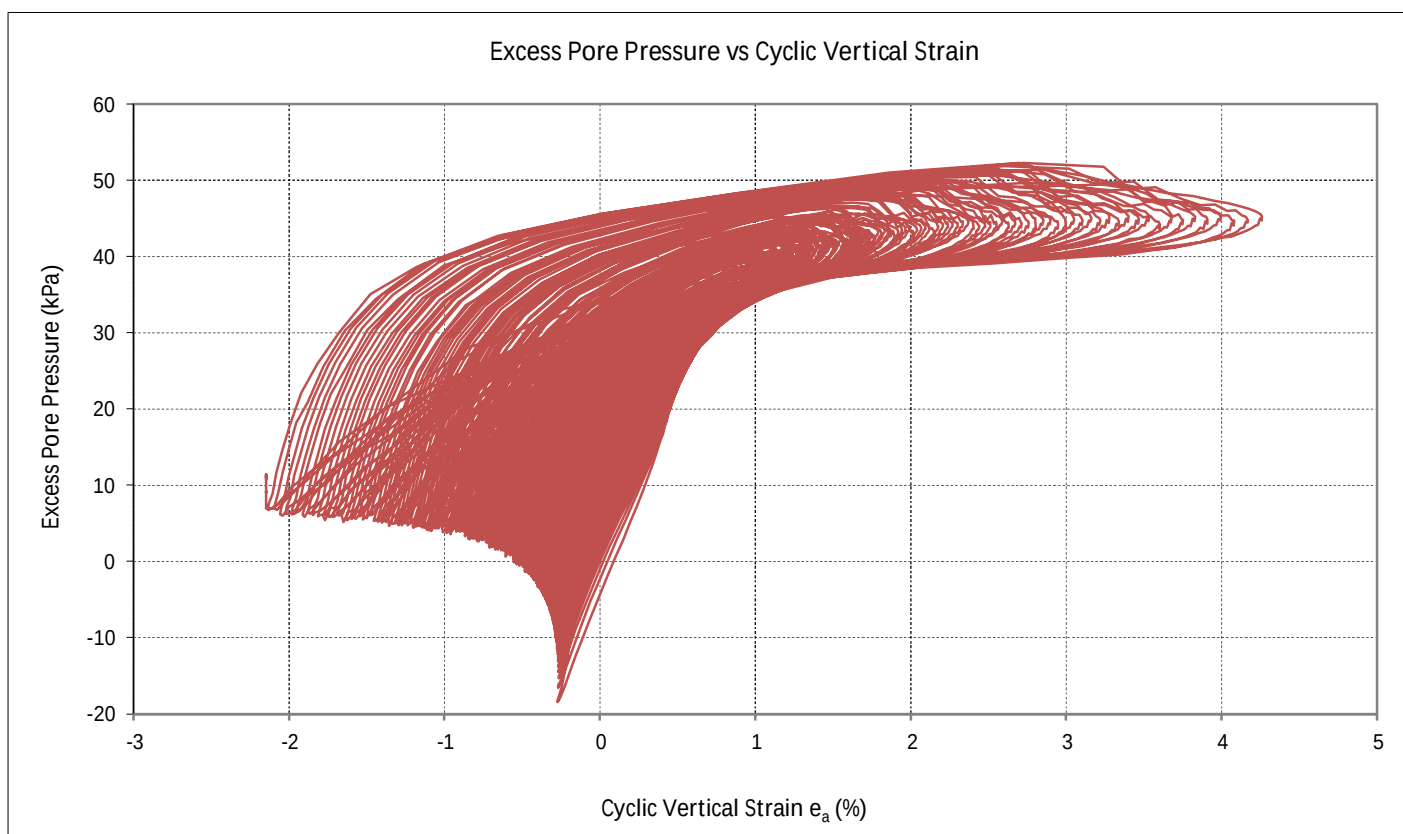
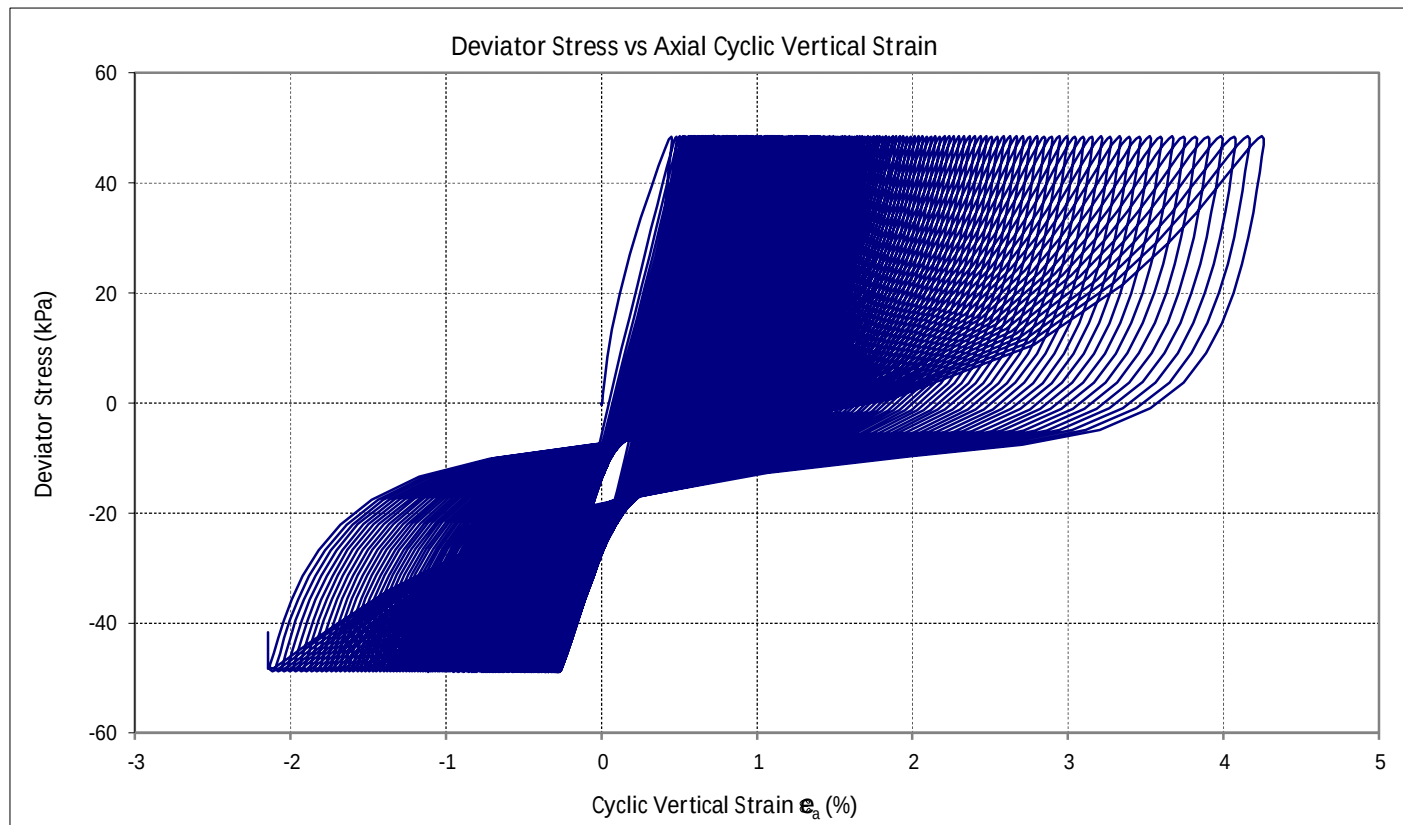


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Geotechnics Project ID: 2021018.0000
QESTLab Work Order ID:
Customer Project ID: RLP025538

Site: Rotorua Museum Development Location ID: BH2
Sample Ref.: Sample 3 Depth: 3.81 - 3.95 (m)
Test method used: ASTM D5311/D5311M-13 Load Controlled Cyclic Triaxial Strength of Soil
NZS 4402:1986 Test 2.1 Determination of Water Content

CYCLIC LOADING GRAPHS 3



Approved by:

Date: 11/03/2022



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Geotechnics Project ID: 2021018.0000
QESTLab Work Order ID:
Customer Project ID: RLP025538

Site: Rotorua Museum Development Location ID: BH7
Sample Ref.: Sample 3 Depth: 4.94 - 5.09 (m)
Test method used: ASTM D5311/D5311M-13 Load Controlled Cyclic Triaxial Strength of Soil
NZS 4402:1986 Test 2.1 Determination of Water Content

CYCLIC TRIAXIAL STRENGTH (CIU)

General Sample Parameters

Initial Sample Height:	144.24	mm	Initial Water Content:	184	%
Initial Sample Diameter:	72.24	mm	Initial Bulk Density:	1.13	t/m ³
Initial Sample Area:	4098.41	mm ²	Initial Dry Density:	0.40	t/m ³
B Value before Consolidation:	98	%	Final Water Content:	190	%

Consolidation

Cell Pressure:	350	kPa	Consolidated Height	142.0	mm
Back Pressure:	300	kPa	Consolidated Diameter:	71.11	mm
Effective Consolidation Stress (σ_{1c} , σ_{3c}):	50	kPa	Consolidated Area:	3971.74	mm ²

Dynamic Triaxial Strength

Cyclic Number:	65		Vertical Strain in Compression:	3.50	%
Cyclic Compression Stress:	41.31	kPa	Vertical Strain in Extension:	-1.53	%
Cyclic Extension Stress:	-41.53	kPa	Double Amplitude Vertical Strain:	5.03	%
Average Cycle Vertical Stress:	41.42	kPa	Maximum Pore Pressure:	50.0	kPa
Cyclic Stress Ratio	0.41		Cyclic Pore Pressure Ratio:	1.0	
Difference from Programmed Load:	0.26	%			

Sample History

The sample was received in a gel push tube with a nominal diameter of 85mm. The push tube was transported frozen in an insulated container with ice and stored in a freezer upon arrival to the lab. The frozen push tube was cut with a bandsaw and extruded. The frozen sample diameter was trimmed down to remove contamination of the gel. The frozen sample was then defrosted after having been setup in the triaxial cell.

Soil description

SILT, with some sand and gravel, grey.

Test Remarks

The sample was saturated by increments of cell pressure and back pressure. It was drained from radial boundary and both ends in the consolidation stage.

Photos

Pre-test

NA

Post-test



Approved by:

Date: 11/03/2022



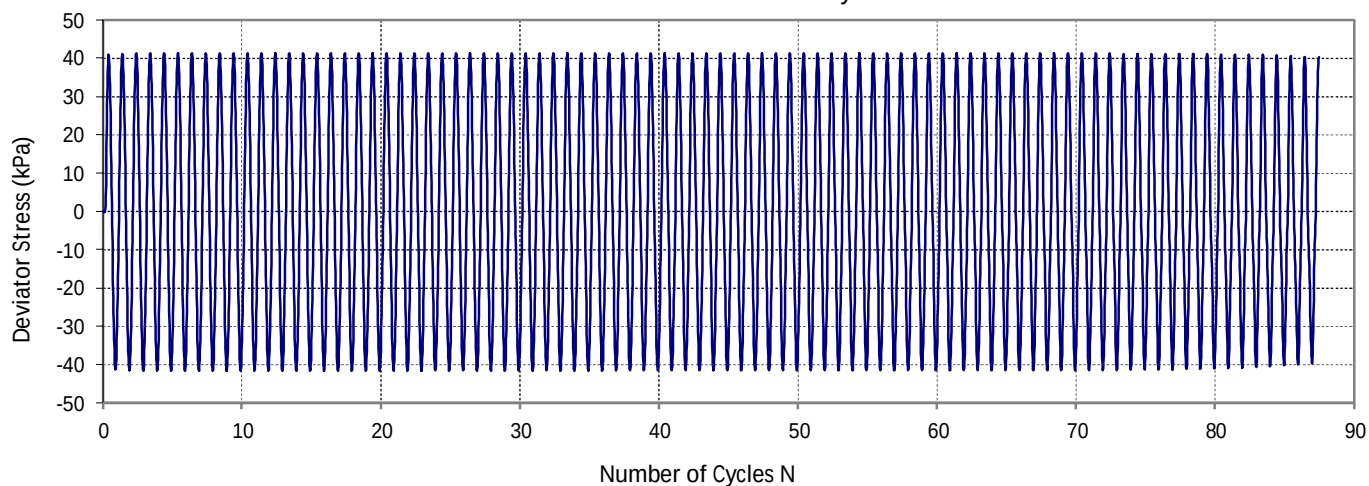
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QESTLab Work Order ID:
Customer Project ID: RLP025538

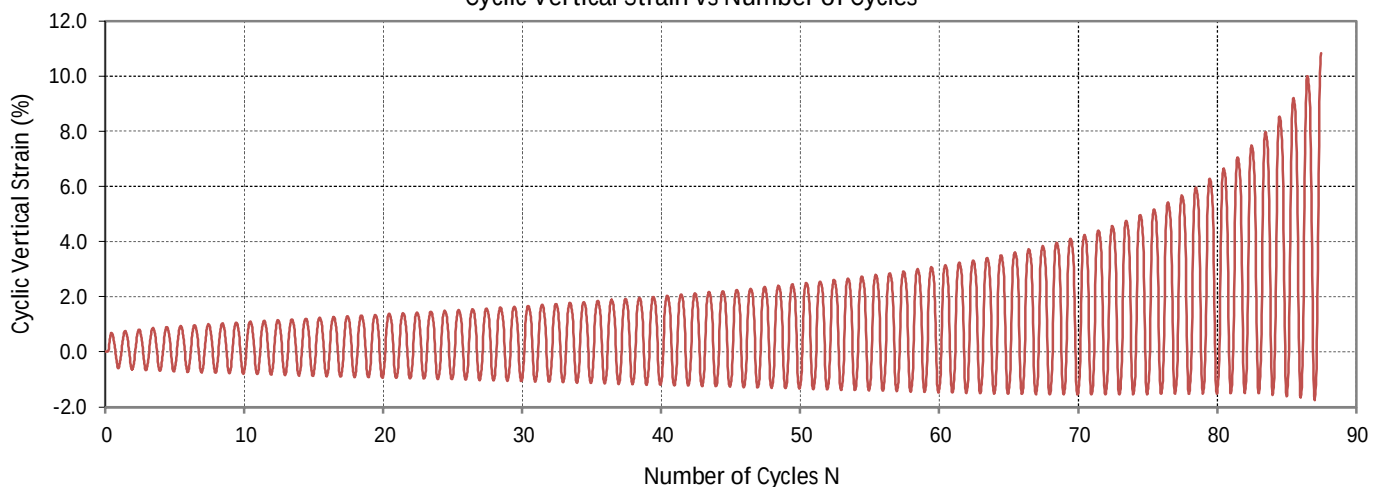
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Sample Ref.: Sample 3 Depth: 4.94 - 5.09 (m)
Test method used: ASTM D5311/D5311M-13 Load Controlled Cyclic Triaxial Strength of Soil
NZS 4402:1986 Test 2.1 Determination of Water Content

CYCLIC LOADING GRAPHS 1

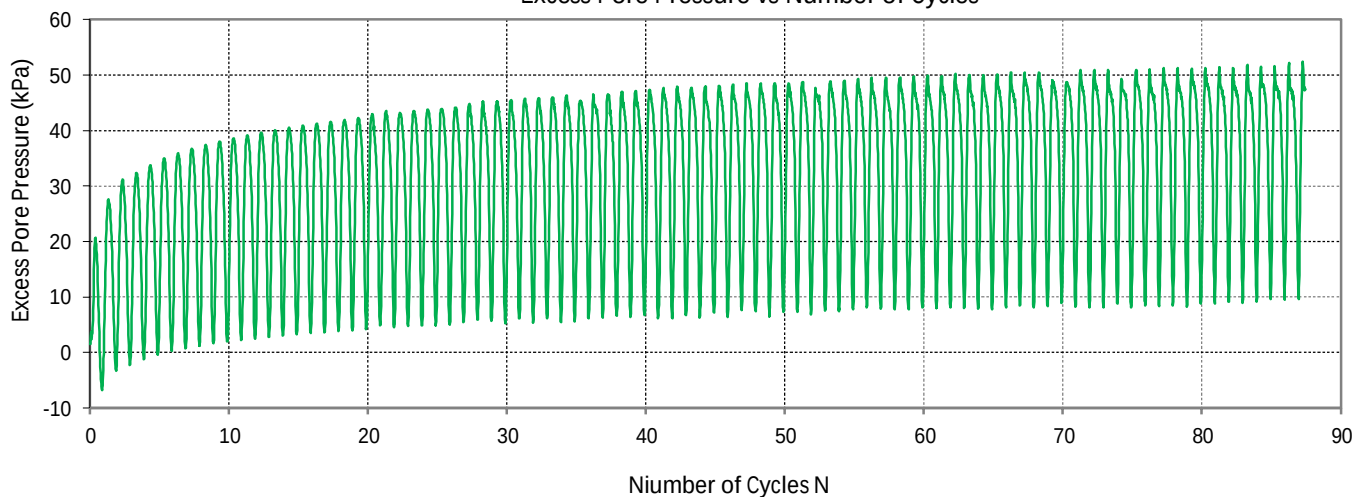
Deviator Stress vs Number of Cycles



Cyclic Vertical Strain vs Number of Cycles



Excess Pore Pressure vs Number of Cycles



Approved by:

Date: 11/03/2022



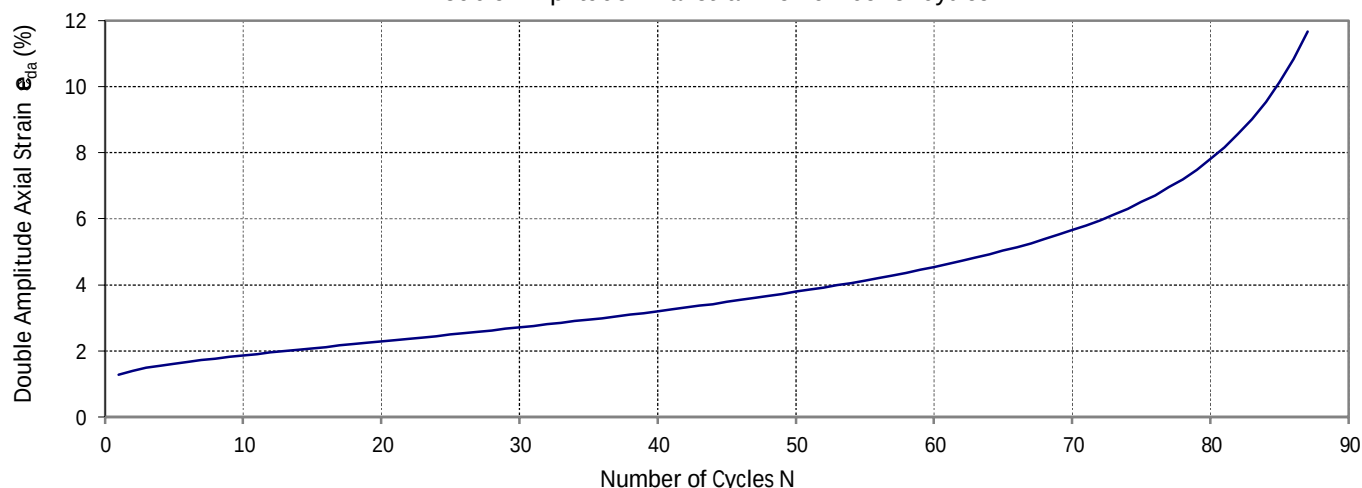
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Geotechnics Project ID: 2021018.0000
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Customer Project ID: RLP025538

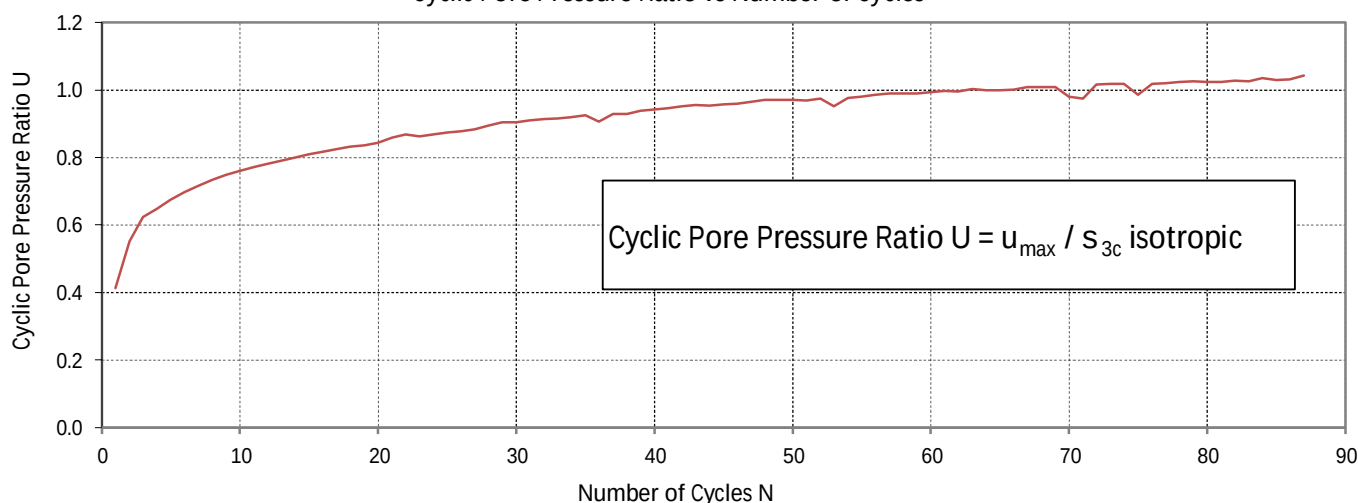
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Sample Ref.: Sample 3 Depth: 4.94 - 5.09 (m)
Test method used: ASTM D5311/D5311M-13 Load Controlled Cyclic Triaxial Strength of Soil
NZS 4402:1986 Test 2.1 Determination of Water Content

CYCLIC LOADING GRAPHS 3

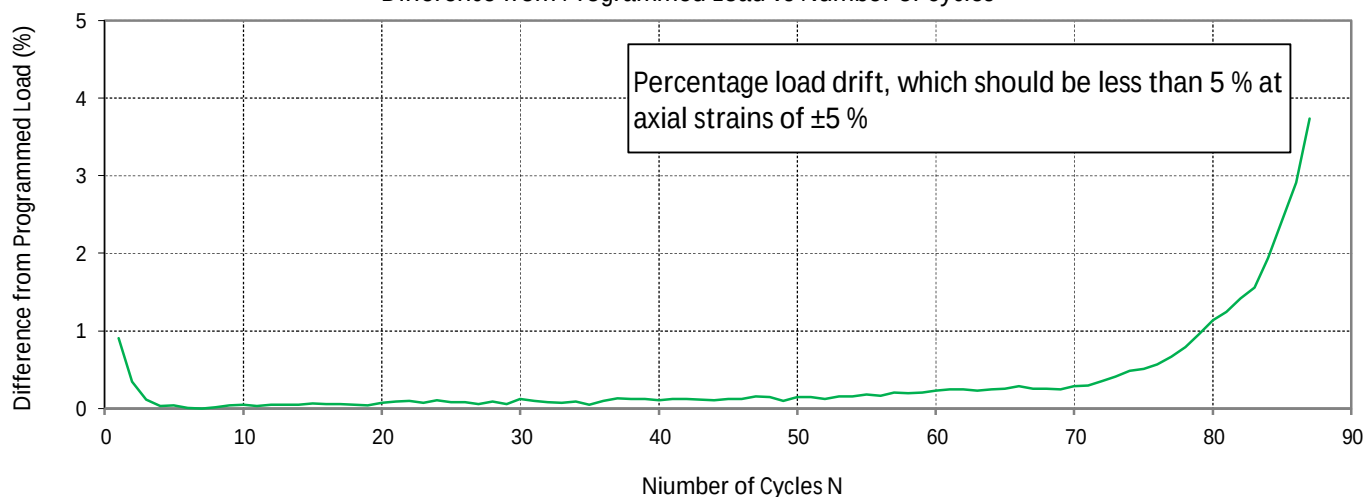
Double Amplitude Axial Strain vs Number of Cycles



Cyclic Pore Pressure Ratio vs Number of Cycles



Difference from Programmed Load vs Number of Cycles



Approved by:

Date: 11/03/2022

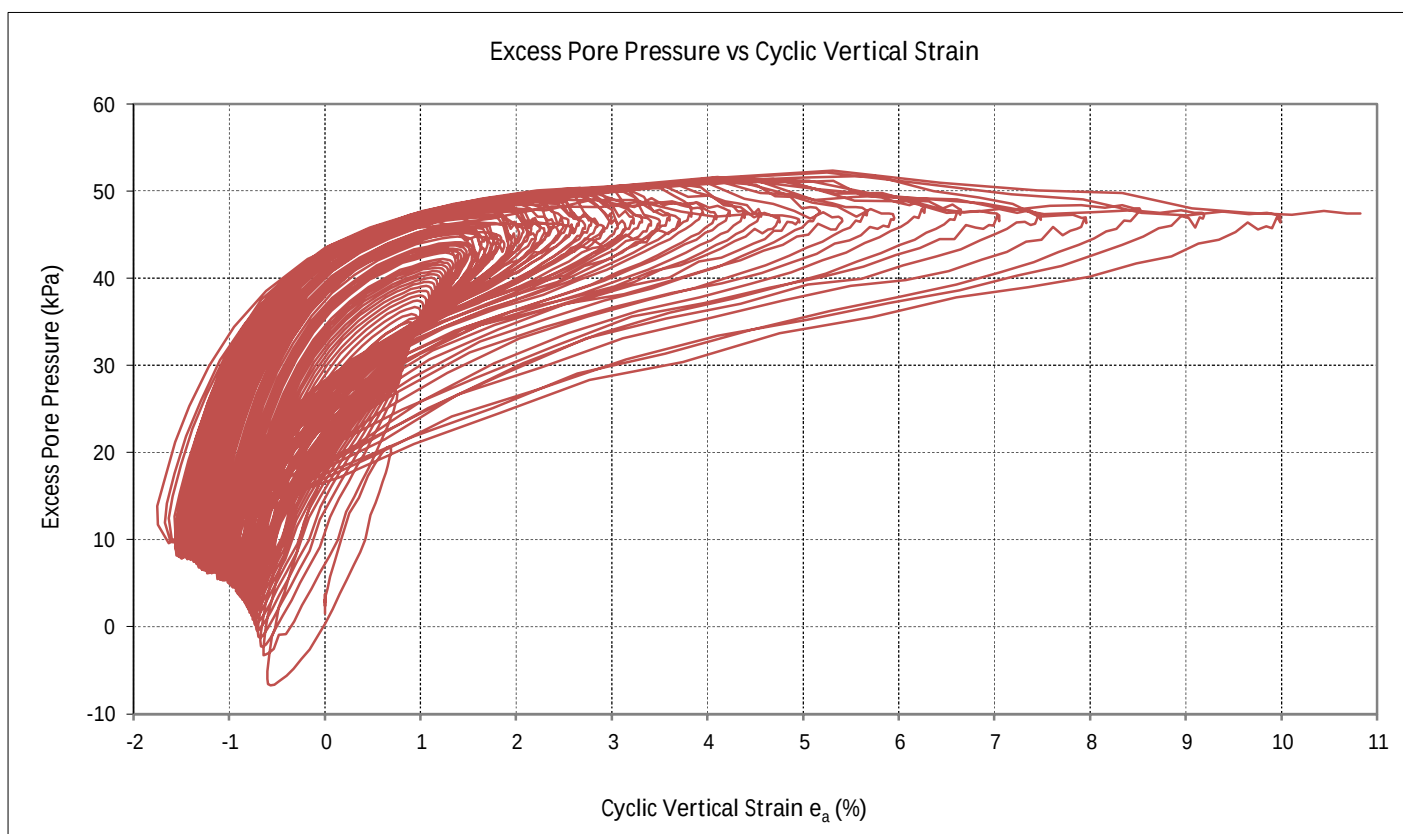
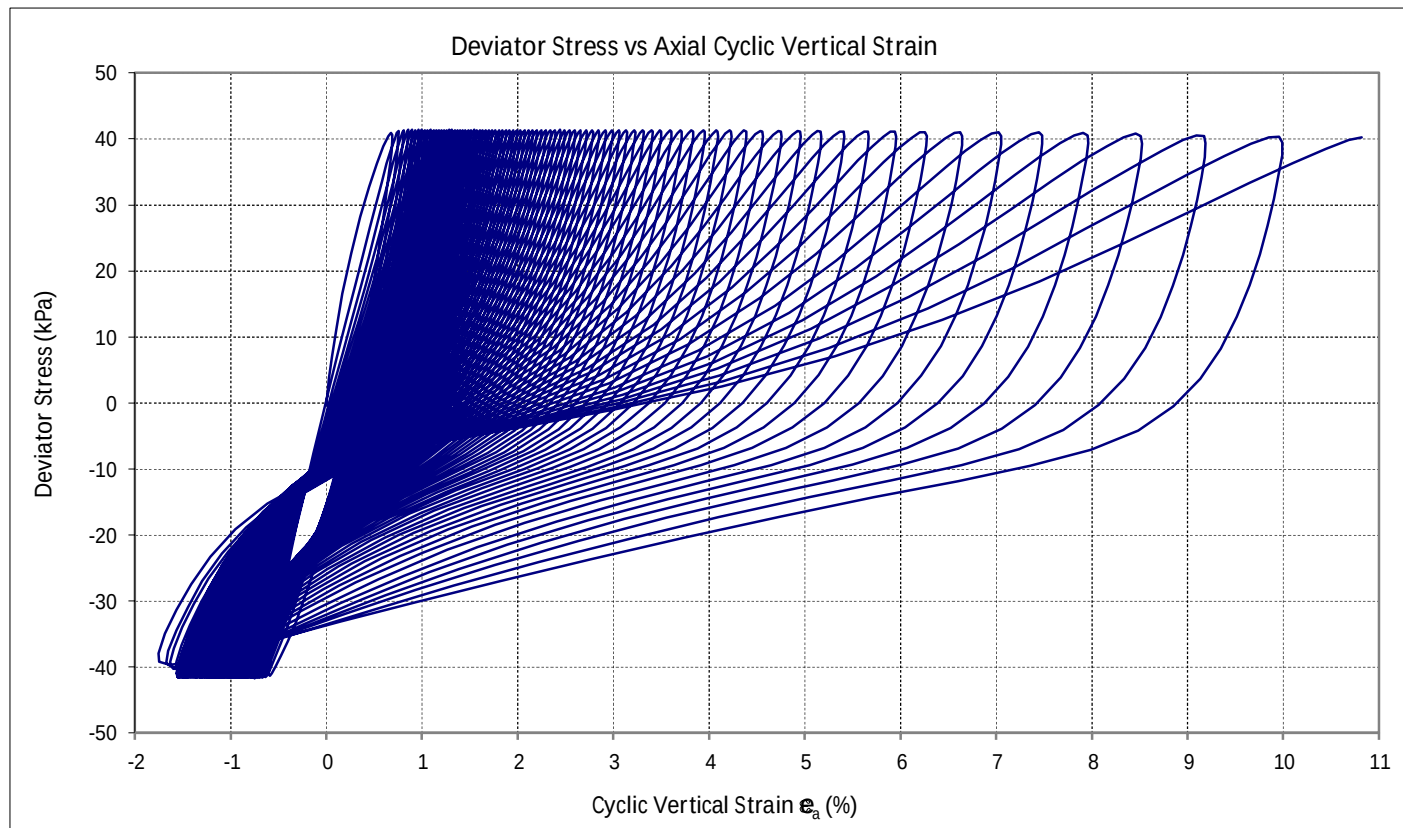


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Geotechnics Project ID: 2021018.0000
QESTLab Work Order ID:
Customer Project ID: RLP025538

Site: Rotorua Museum Development Location ID: BH7
Sample Ref.: Sample 3 Depth: 4.94 - 5.09 (m)
Test method used: ASTM D5311/D5311M-13 Load Controlled Cyclic Triaxial Strength of Soil
NZS 4402:1986 Test 2.1 Determination of Water Content

CYCLIC LOADING GRAPHS 3



Approved by:

Date:

11/03/2022



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Geotechnics Project ID: 2021018.0000
QESTLab Work Order ID:
Customer Project ID: RLP025538

Site: Rotorua Museum Development Location ID: BH7
Sample Ref.: Sample 4 Depth: 5.14 - 5.29 (m)
Test method used: ASTM D5311/D5311M-13 Load Controlled Cyclic Triaxial Strength of Soil
NZS 4402:1986 Test 2.1 Determination of Water Content

CYCLIC TRIAXIAL STRENGTH (CIU)

General Sample Parameters

Initial Sample Height:	143.43	mm	Initial Water Content:	172	%
Initial Sample Diameter:	73.51	mm	Initial Bulk Density:	1.15	t/m ³
Initial Sample Area:	4243.78	mm ²	Initial Dry Density:	0.42	t/m ³
B Value before Consolidation:	98	%	Final Water Content:	162	%

Consolidation

Cell Pressure:	400	kPa	Consolidated Height	141.8	mm
Back Pressure:	350	kPa	Consolidated Diameter:	72.67	mm
Effective Consolidation Stress (σ_{1c} , σ_{3c}):	50	kPa	Consolidated Area:	4147.95	mm ²

Dynamic Triaxial Strength

Cyclic Number:	5		Vertical Strain in Compression:	3.80	%
Cyclic Compression Stress:	52.76	kPa	Vertical Strain in Extension:	-1.76	%
Cyclic Extension Stress:	-53.02	kPa	Double Amplitude Vertical Strain:	5.56	%
Average Cycle Vertical Stress:	52.89	kPa	Maximum Pore Pressure:	48.8	kPa
Cyclic Stress Ratio	0.53		Cyclic Pore Pressure Ratio:	1.0	
Difference from Programmed Load:	0.00	%			

Sample History

The sample was received in a gel push tube with a nominal diameter of 85mm. The push tube was transported frozen in an insulated container with ice and stored in a freezer upon arrival to the lab. The frozen push tube was cut with a bandsaw and extruded. The frozen sample diameter was trimmed down to remove contamination of the gel. The frozen sample was then defrosted after having been setup in the triaxial cell.

Soil description

SILT, with some sand and gravel, dark grey.

Test Remarks

The sample was saturated by increments of cell pressure and back pressure. It was drained from radial boundary and both ends in the consolidation stage.

Photos

Pre-test

NA

Post-test



Approved by:

Date: 11/03/2022



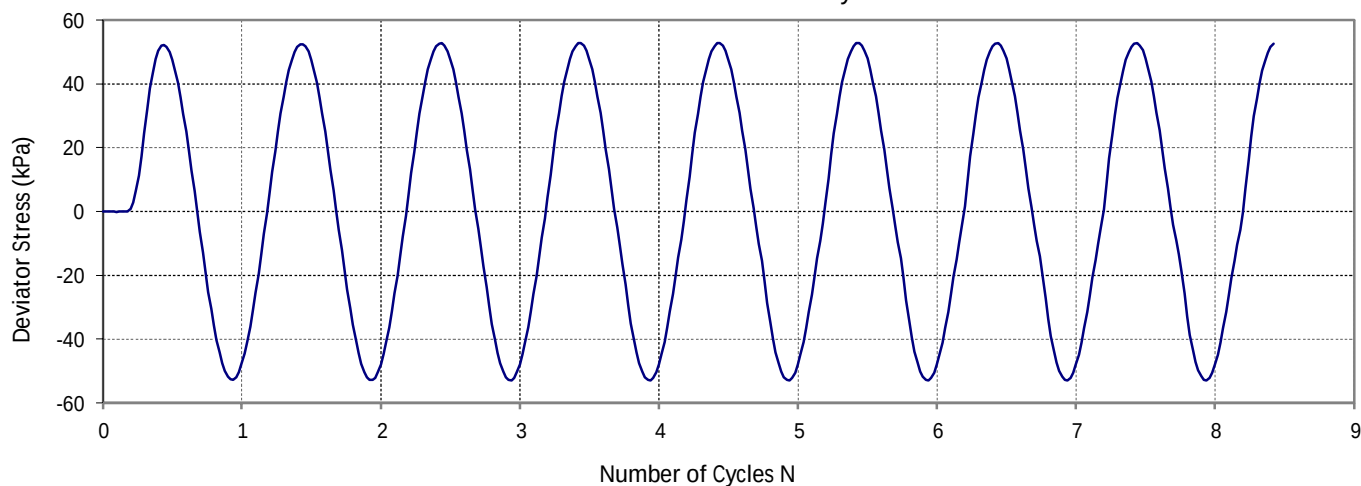
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Geotechnics Project ID: 2021018.0000
QESTLab Work Order ID:
Customer Project ID: RLP025538

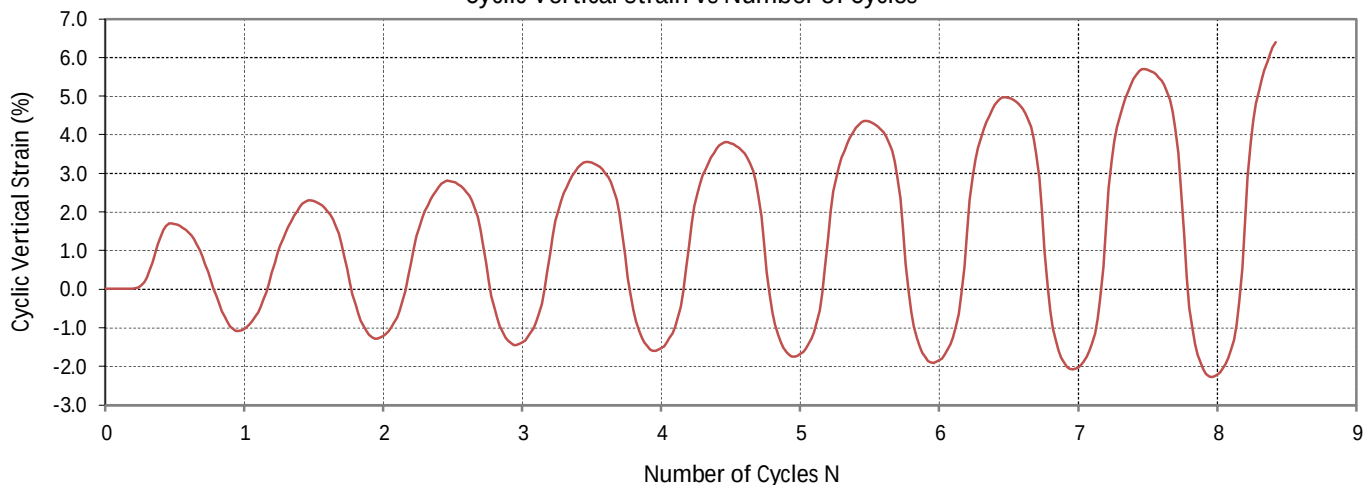
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Sample Ref.:	Sample 4	Depth:	5.14 - 5.29 (m)
Test method used:	ASTM D5311/D5311M-13 Load Controlled Cyclic Triaxial Strength of Soil NZS 4402:1986 Test 2.1 Determination of Water Content		

CYCLIC LOADING GRAPHS 1

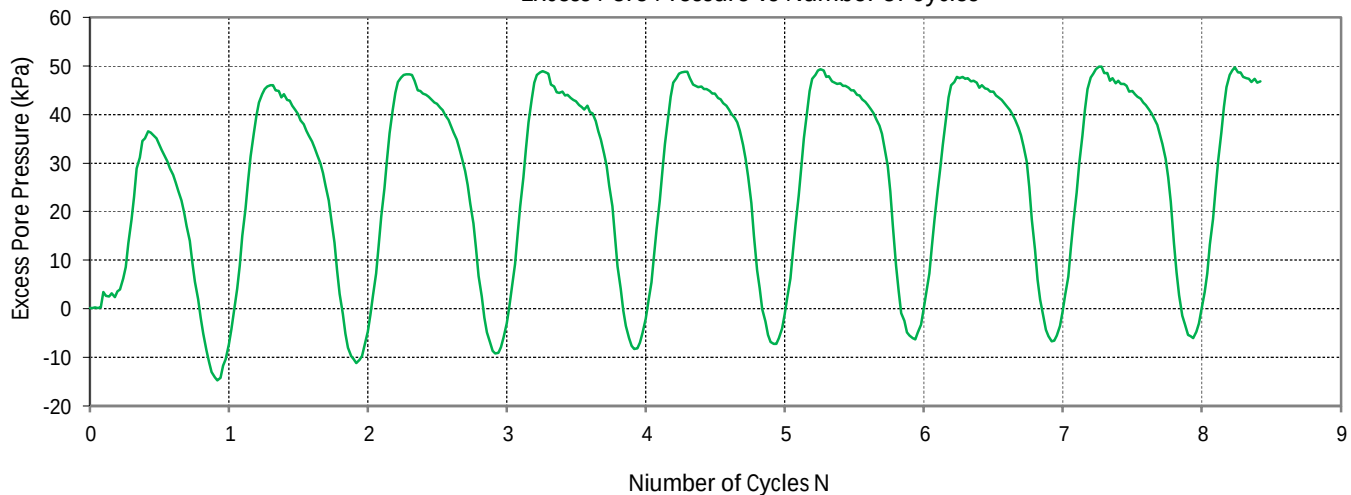
Deviator Stress vs Number of Cycles



Cyclic Vertical Strain vs Number of Cycles



Excess Pore Pressure vs Number of Cycles



Approved by:

Date:

11/03/2022



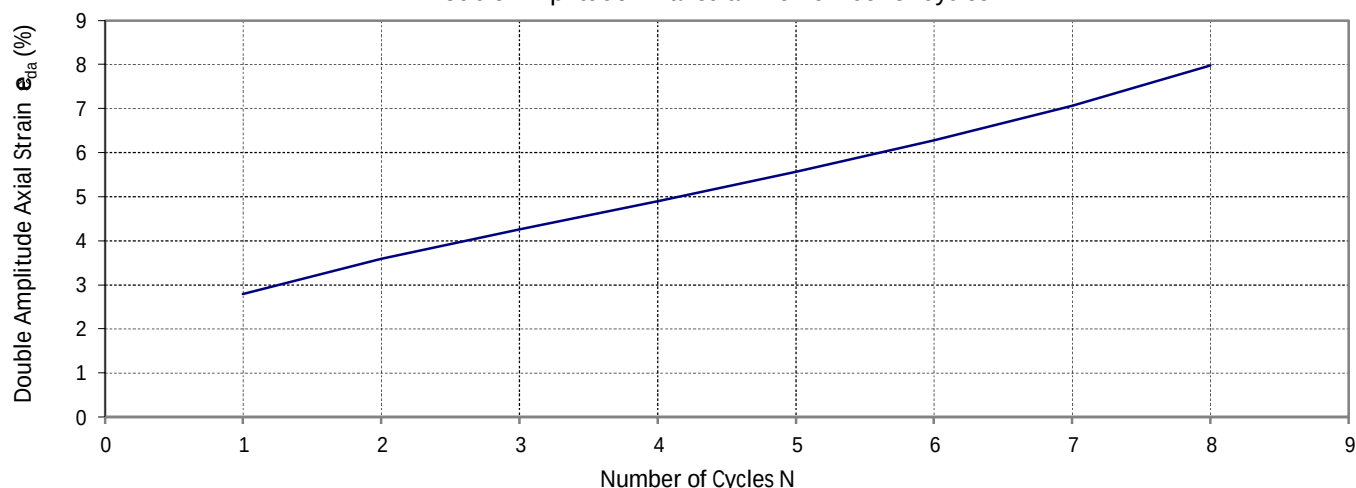
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Geotechnics Project ID: 2021018.0000
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 Customer Project ID: RLP025538

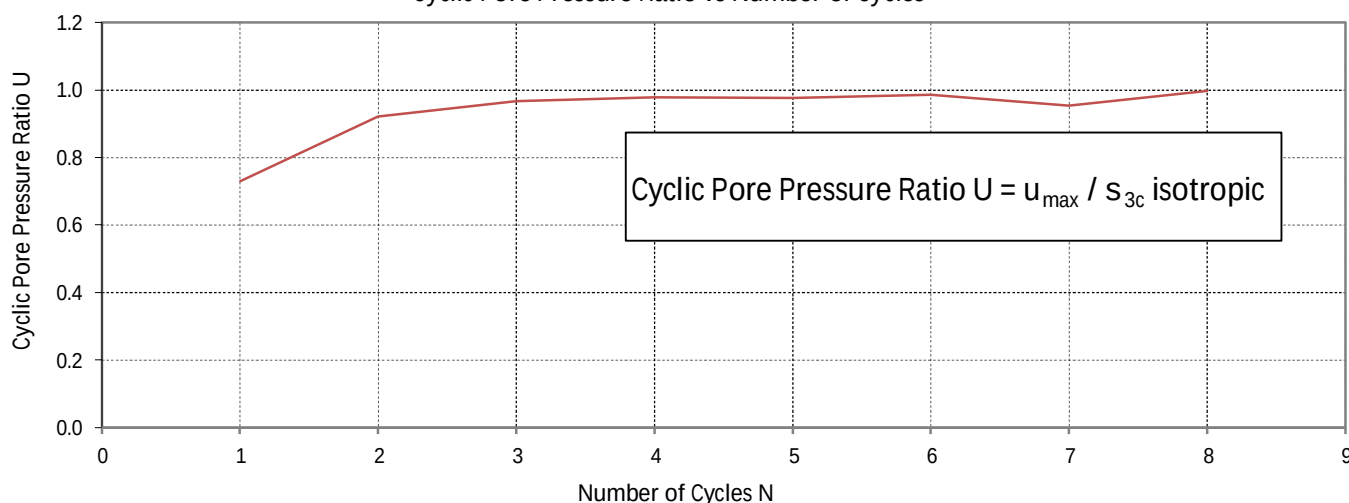
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 Sample Ref.: Sample 4 Depth: 5.14 - 5.29 (m)
 Test method used: ASTM D5311/D5311M-13 Load Controlled Cyclic Triaxial Strength of Soil
 NZS 4402:1986 Test 2.1 Determination of Water Content

CYCLIC LOADING GRAPHS 3

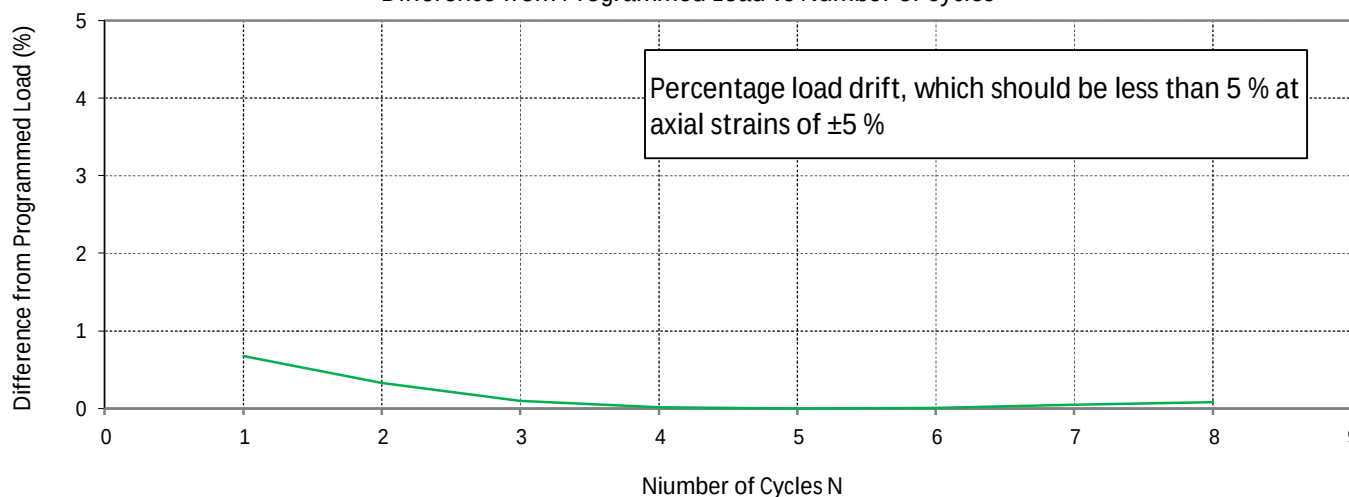
Double Amplitude Axial Strain vs Number of Cycles



Cyclic Pore Pressure Ratio vs Number of Cycles



Difference from Programmed Load vs Number of Cycles



Approved by:

Date:

11/03/2022

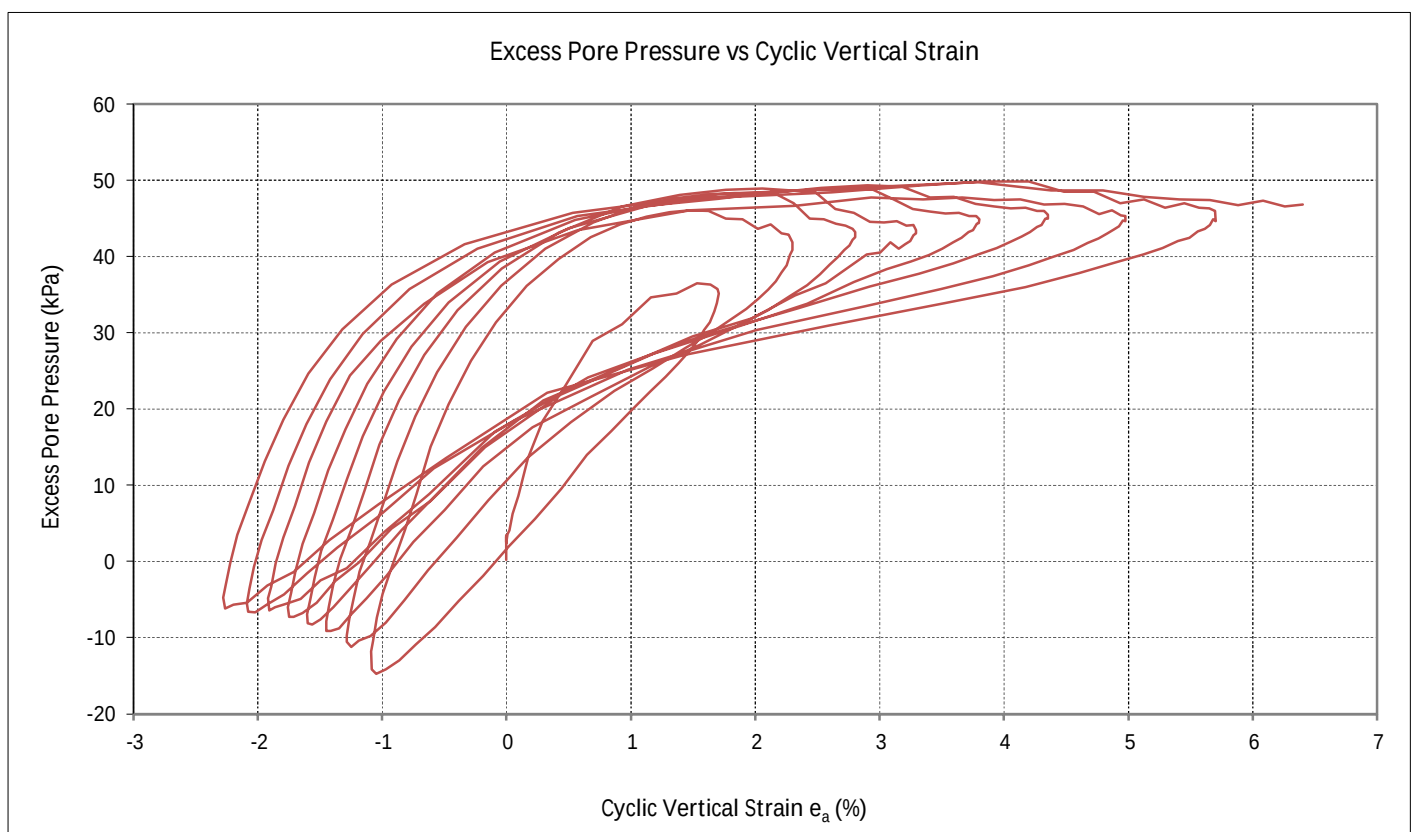
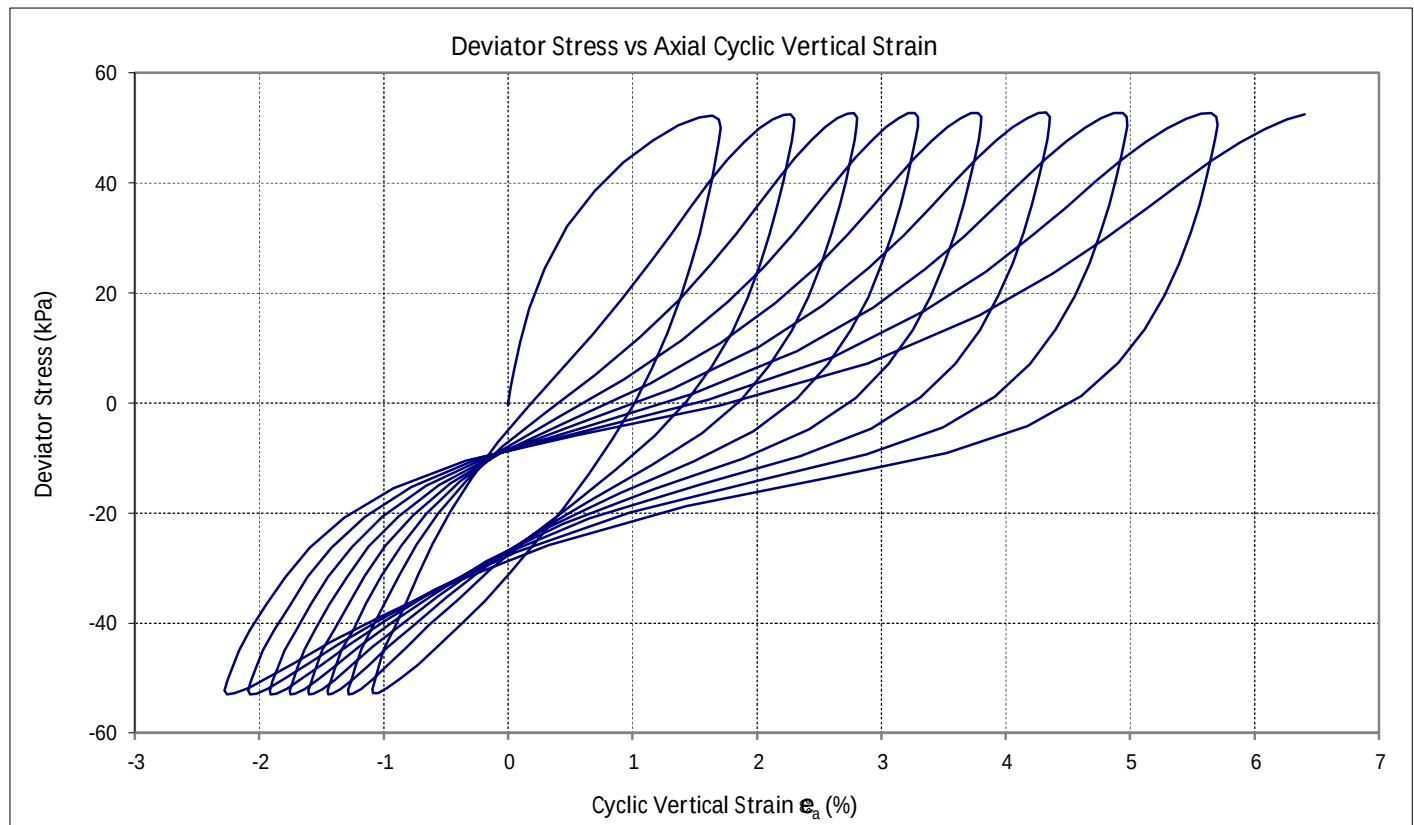


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Geotechnics Project ID: 2021018.0000
QESTLab Work Order ID:
Customer Project ID: RLP025538

Site: Rotorua Museum Development Location ID: BH7
Sample Ref.: Sample 4 Depth: 5.14 - 5.29 (m)
Test method used: ASTM D5311/D5311M-13 Load Controlled Cyclic Triaxial Strength of Soil
NZS 4402:1986 Test 2.1 Determination of Water Content

CYCLIC LOADING GRAPHS 3



Approved by:

Date:

11/03/2022



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Geotechnics Project ID: 2021018.0000
QESTLab Work Order ID:
Customer Project ID: RLP025538

Site: Rotorua Museum Development Location ID: BH7
Sample Ref.: Sample 5 Depth: 6.26 - 6.41 (m)
Test method used: ASTM D5311/D5311M-13 Load Controlled Cyclic Triaxial Strength of Soil
NZS 4402:1986 Test 2.1 Determination of Water Content

CYCLIC TRIAXIAL STRENGTH (CIU)

General Sample Parameters

Initial Sample Height:	144.74	mm	Initial Water Content:	88.7	%
Initial Sample Diameter:	71.82	mm	Initial Bulk Density:	1.41	t/m ³
Initial Sample Area:	4050.89	mm ²	Initial Dry Density:	0.75	t/m ³
B Value before Consolidation:	99	%	Final Water Content:	85.2	%

Consolidation

Cell Pressure:	360	kPa	Consolidated Height	141.8	mm
Back Pressure:	300	kPa	Consolidated Diameter:	70.29	mm
Effective Consolidation Stress (σ_{1c} , σ_{3c}):	60	kPa	Consolidated Area:	3880.26	mm ²

Dynamic Triaxial Strength

Cyclic Number:	3		Vertical Strain in Compression:	3.84	%
Cyclic Compression Stress:	54.43	kPa	Vertical Strain in Extension:	-1.63	%
Cyclic Extension Stress:	-55.22	kPa	Double Amplitude Vertical Strain:	5.46	%
Average Cycle Vertical Stress:	54.83	kPa	Maximum Pore Pressure:	60.8	kPa
Cyclic Stress Ratio:	0.46		Cyclic Pore Pressure Ratio:	1.0	
Difference from Programmed Load:	0.14	%			

Sample History

The sample was received in a gel push tube with a nominal diameter of 85mm. The push tube was transported frozen in an insulated container with ice and stored in a freezer upon arrival to the lab. The frozen push tube was cut with a bandsaw and extruded. The frozen sample diameter was trimmed down to remove contamination of the gel. The frozen sample was then defrosted after having been setup in the triaxial cell.

Soil description

SILT, with some sand and a trace of gravel, light grey with black and white.

Test Remarks

The sample was saturated by increments of cell pressure and back pressure. It was drained from radial boundary and both ends in the consolidation stage.

Photos

Pre-test



Post-test



Approved by:

Date: 11/03/2022



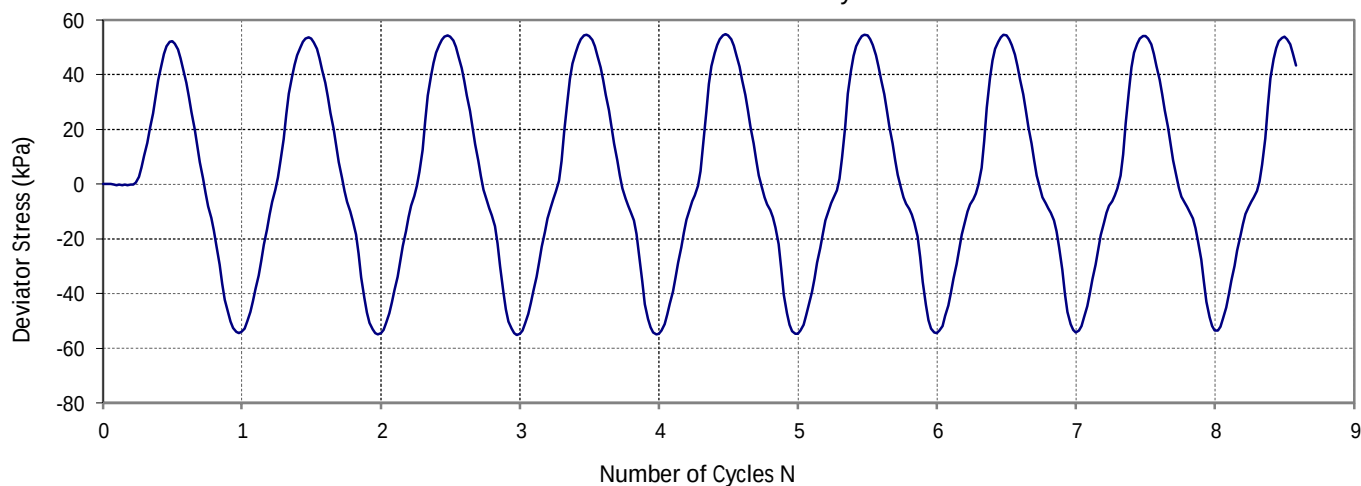
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Geotechnics Project ID: 2021018.0000
QESTLab Work Order ID:
Customer Project ID: RLP025538

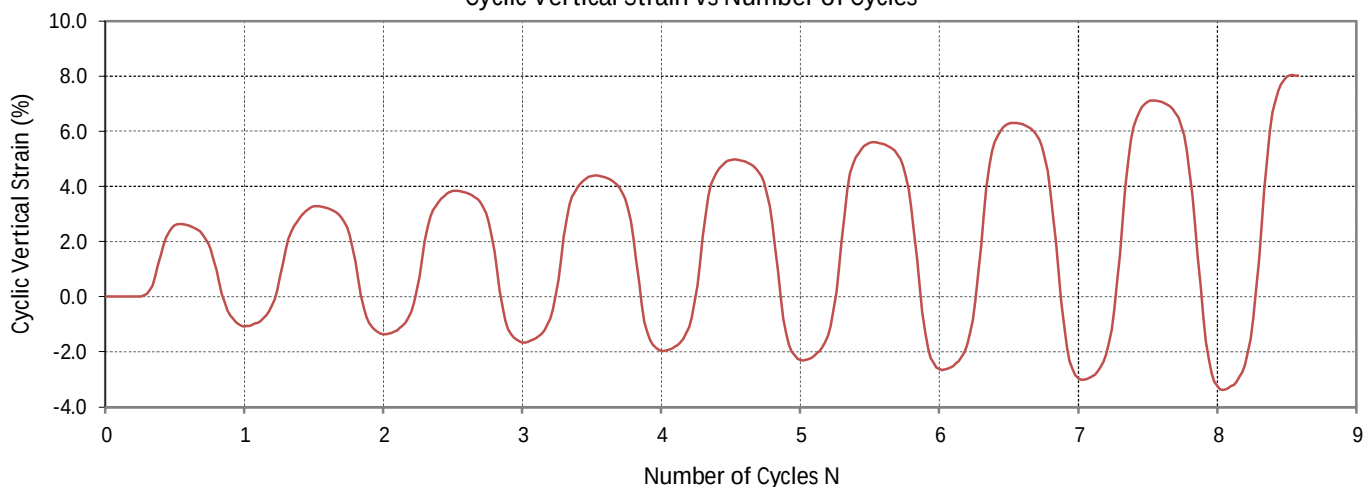
Site:	Rotorua Museum Development	Location ID:	BH7
Sample Ref.:	Sample 5	Depth:	6.26 - 6.41 (m)
Test method used:	ASTM D5311/D5311M-13 Load Controlled Cyclic Triaxial Strength of Soil NZS 4402:1986 Test 2.1 Determination of Water Content		

CYCLIC LOADING GRAPHS 1

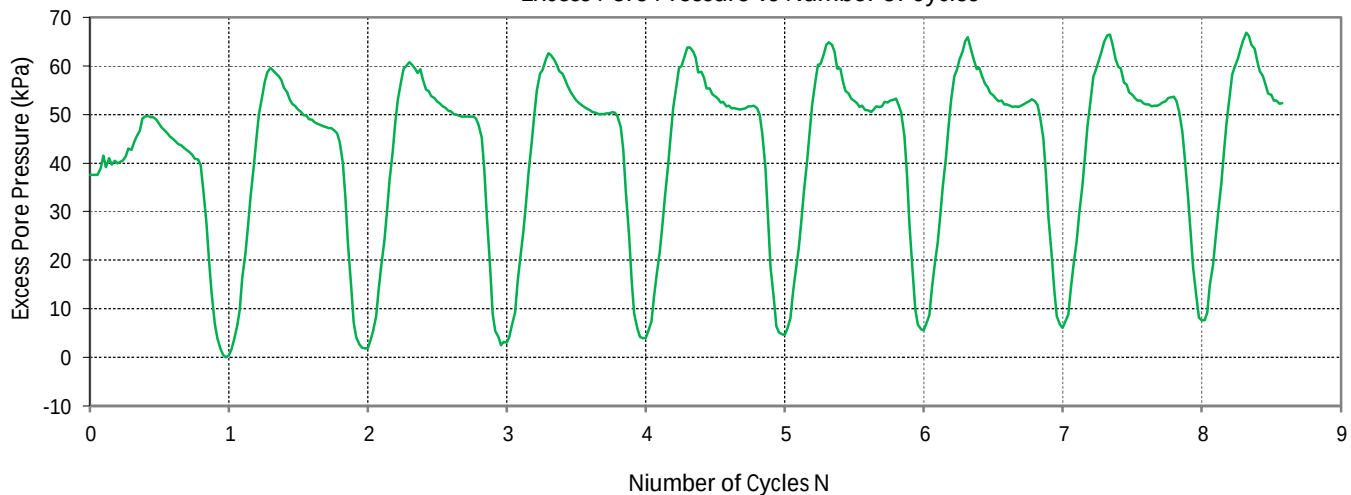
Deviator Stress vs Number of Cycles



Cyclic Vertical Strain vs Number of Cycles



Excess Pore Pressure vs Number of Cycles



Approved by:

Date:

11/03/2022



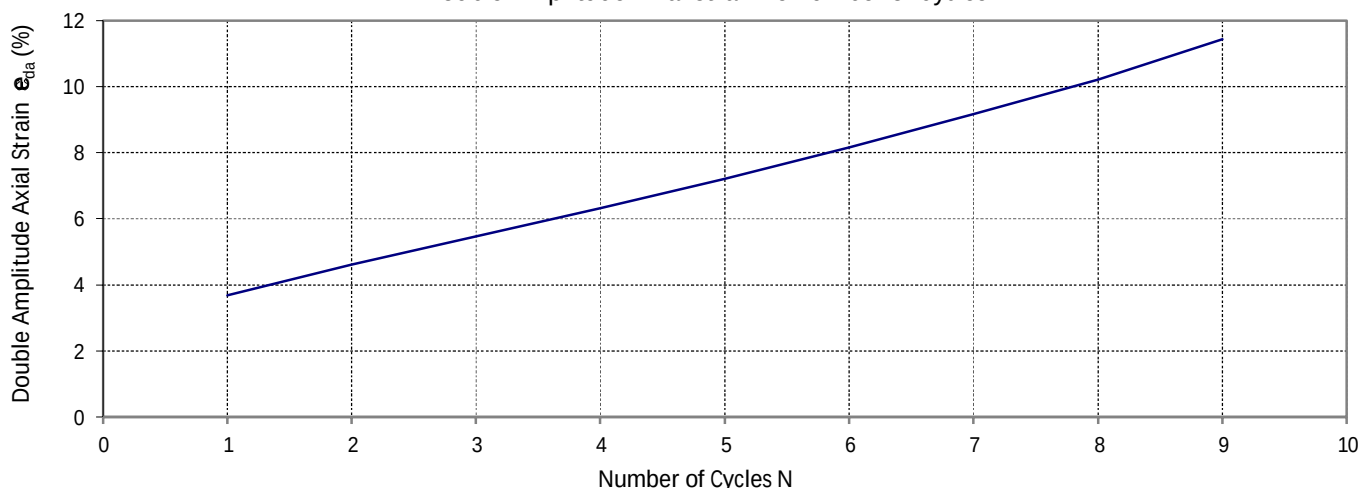
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Geotechnics Project ID: 2021018.0000
QESTLab Work Order ID:
Customer Project ID: RLP025538

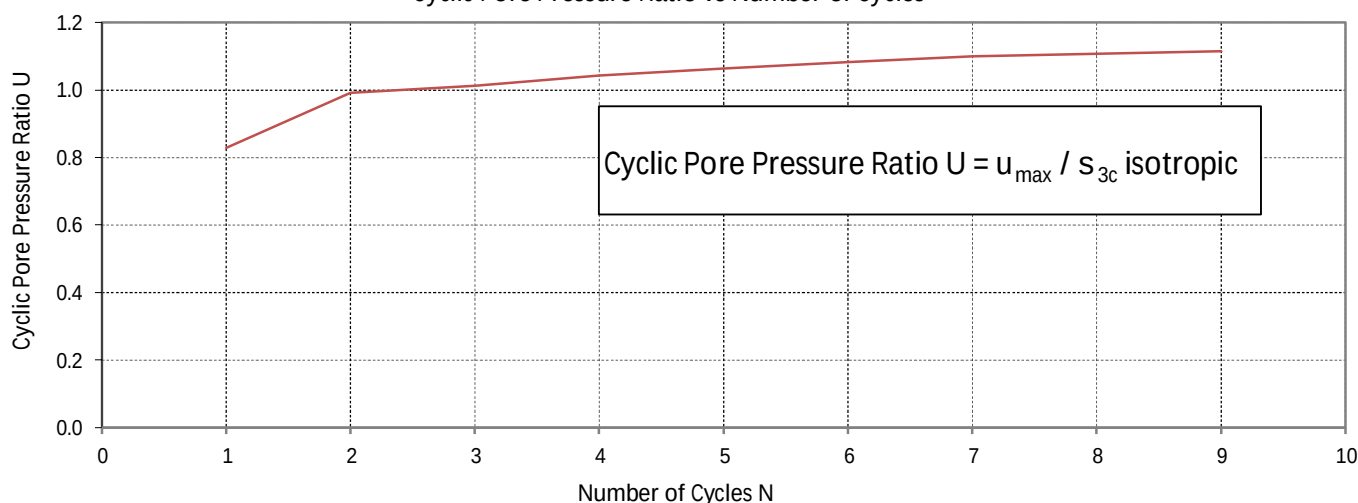
Site: Rotorua Museum Development Location ID: BH7
Sample Ref.: Sample 5 Depth: 6.26 - 6.41 (m)
Test method used: ASTM D5311/D5311M-13 Load Controlled Cyclic Triaxial Strength of Soil
NZS 4402:1986 Test 2.1 Determination of Water Content

CYCLIC LOADING GRAPHS 3

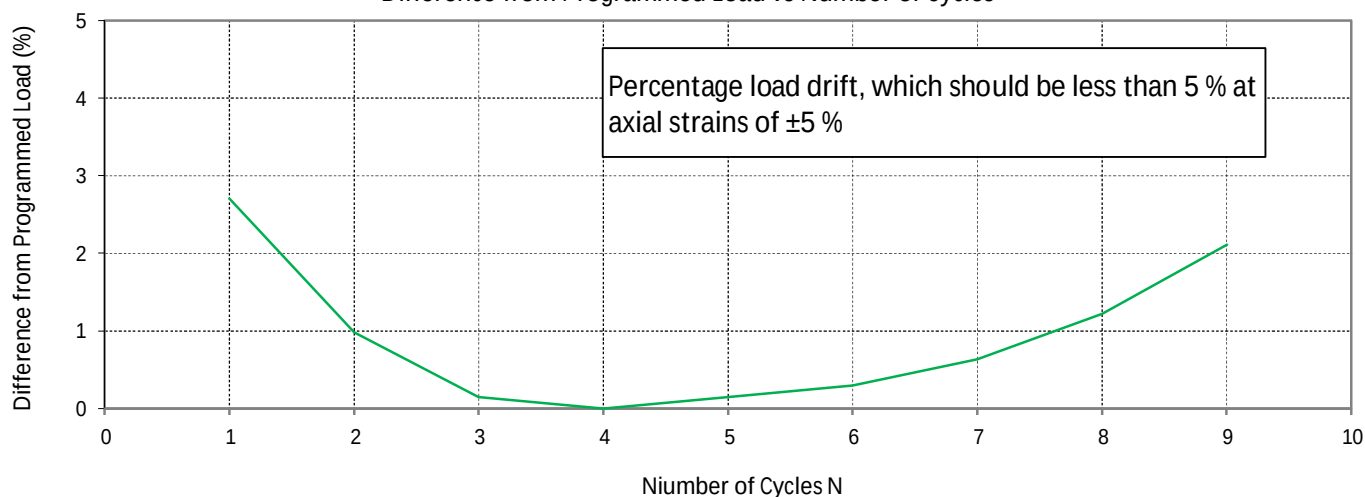
Double Amplitude Axial Strain vs Number of Cycles



Cyclic Pore Pressure Ratio vs Number of Cycles



Difference from Programmed Load vs Number of Cycles



Approved by:

Date:

11/03/2022

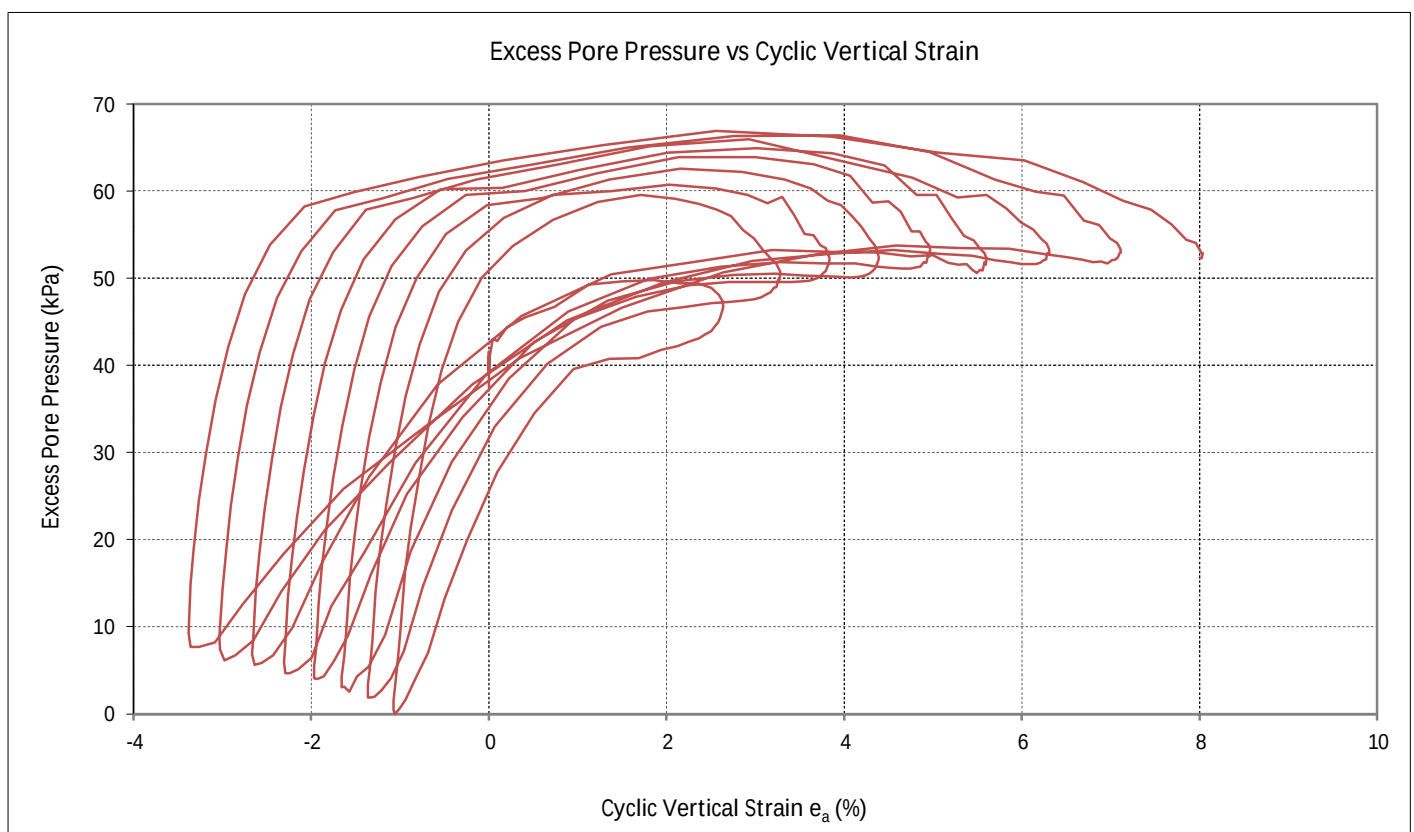
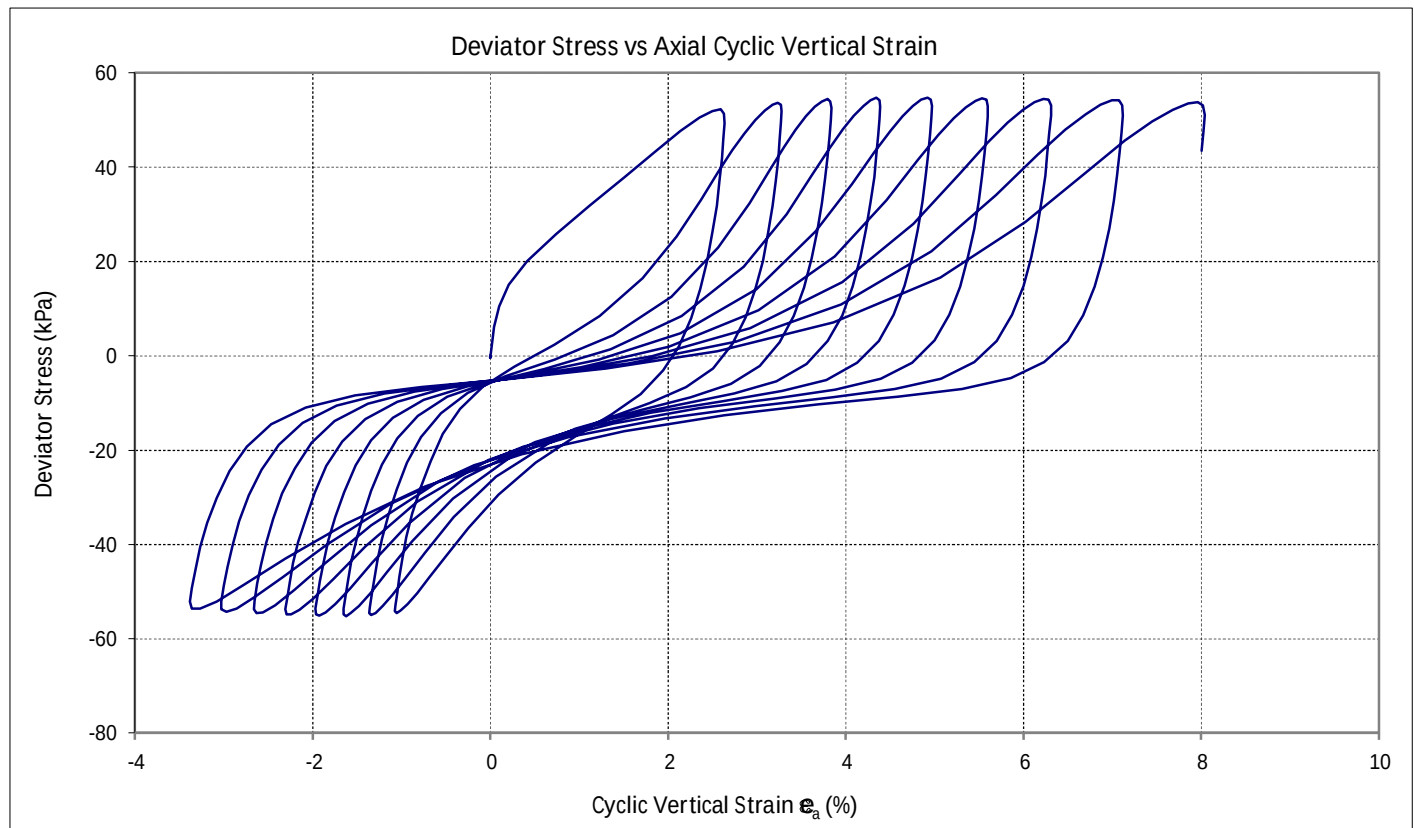


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Geotechnics Project ID: 2021018.0000
QESTLab Work Order ID:
Customer Project ID: RLP025538

Site: Rotorua Museum Development Location ID: BH7
Sample Ref.: Sample 5 Depth: 6.26 - 6.41 (m)
Test method used: ASTM D5311/D5311M-13 Load Controlled Cyclic Triaxial Strength of Soil
NZS 4402:1986 Test 2.1 Determination of Water Content

CYCLIC LOADING GRAPHS 3



Approved by:

Date:

11/03/2022

C4 - One-dimensional consolidation test results

Please reply to: W.E. Campton

Page 1 of 5

Tonkin & Taylor Ltd.
PO Box 5271,
Wellesley Street,
Auckland 1141

Job Number: 65344#L
BGL Registration Number: 2977
Checked by: WEC

11th February 2022

Attention: **SUTEJO TJOKRO**

ONE DIMENSIONAL CONSOLIDATION TESTING

Dear Sir,

Re: ROTORUA MUSEUM

Report Number: 65344#L/Consol BH02 2.42 – 2.50m Revision A

Borehole No: BH02

Sample No: S1.Test 1

Depth: 2.42 – 2.50m

The following report presents the results of one dimensional consolidation testing at BGL of a soil sample delivered to this laboratory on the 26th of January 2022. Our instructions were to carry out a one dimensional consolidation test using cycle times that would give both the $\sqrt{T_{90}}$ and T_{50} values, and using a standard pressure sequence. The push-tube sample was tested in accordance with the following standards:

Water Content: NZS4402:1986:Test 2.1

One Dimensional Consolidation: NZS4402:1986:Test 7.1

This report has been issued as an amendment to report number 65344#L/Consol BH02 2.42-2.50m, and supersedes it. The reason for issuing this amended report is that the client asked for the coefficients of secondary compression to be calculated & reported after reviewing the Logarithm of Time graphs. The changes from the superseded report are the coefficient of secondary compression values are now presented in the table on page 5 of this amended report. Also, the following sentence was added to page 2 of this amended report "The coefficient of secondary compression values were requested by our client after reviewing the Logarithm of Time graphs, and was calculated accordingly based on initial sample height. These figures are not part of the IANZ endorsement for this report."

Please note that consolidation cycles were of a variable time duration, and hence is a departure from the test standard which states that the cycle time period for the consolidation loads after the initial cycle should be of approximately the same length. The time for each consolidation cycle was determined by observing consolidation data until the secondary consolidation could be assessed. Subsequent load cycles were taken to at least the time of the previous cycle.

The sample was trimmed into the consolidation ring in small increments, until the sample protruded from both sides of the ring. A scalpel and straight edge were then used to trim the sample flat in the ring.

These test results only relate to the sample tested. The values of m_v shown on the table have been calculated for each pressure increment, using void ratio difference for that increment. Note that a solid density value of 2.65 t/m^3 was assumed for this test, and is not part of the IANZ endorsement for this report. This test was carried out in a laboratory in which the temperature is controlled to be kept within the specification of the test standard.

As per the reporting requirements of NZS4402: 1986: Test 2.1: water content is reported to two significant figures for values below 10%, and to three significant figures for values of 10% or greater. As per the reporting requirements of NZS4402: 1986: Test 7.1: one dimensional consolidation, the coefficients of consolidation (c_v 's), and coefficients of volume compressibility (m_v 's) are reported to two significant figures.

The "Void Ratio vs. Applied Pressure – Linear Scale" plot presented on page 4 is included for your information, and is based on the paper "Soil stiffness measured in oedometer tests" by L. Wesley & M. Pender, Proc. 18th NZGS Geotechnical Symposium on Soil-Structure Interaction, 2008. Please note that the presentation of the data on a linear scale is not part of the test standard, hence page 4 does not form part of the IANZ endorsement for this report.

Note that the $c_v(\log)$ values and the Coefficient of Permeability (k) values reported for all cycles on page 5 have been calculated based on the methods described in "Manual of Soil Laboratory Testing Volume 2: Permeability, Shear Strength & Compressibility Tests" by K.H. Head & R.J. Epps, 3rd Edition, 2011 (*as the logarithm of time graphs did not allow graphical determination of the $c_v(\log)$ values*). The coefficient of secondary compression values were requested by our client after reviewing the Logarithm of Time graphs, and was calculated accordingly based on initial sample height. These figures are not part of the IANZ endorsement for this report. The Coefficient of Permeability values were calculated using the $c_v(\log)$ values determined in the test. The reporting of these permeability figures is not part of NZS4402:1986:Test 7.1, therefore these figures are not part of the IANZ endorsement for this report.

Sample Description (not part of BGL IANZ Accreditation)

BH02 / S1.Test 1 / 2.42 – 2.50m: CLAY, silty, soft to firm, moderately plastic, blackish dark brown with white speckles, slightly moist.

Each test result is data obtained at a specific test location. The nature and continuity of subsoil conditions away from the test area could vary from the data recovered during this testing, therefore the test results relate only to the sample as-received, and relate only to the sample under test.

Thank you for the opportunity to carry out this testing. If you have any queries regarding the content of this report please contact the person authorising this report below at your convenience.

Yours faithfully,

Wayne Campton
Signatory (Laboratory Manager)
Babbage Geotechnical Laboratory



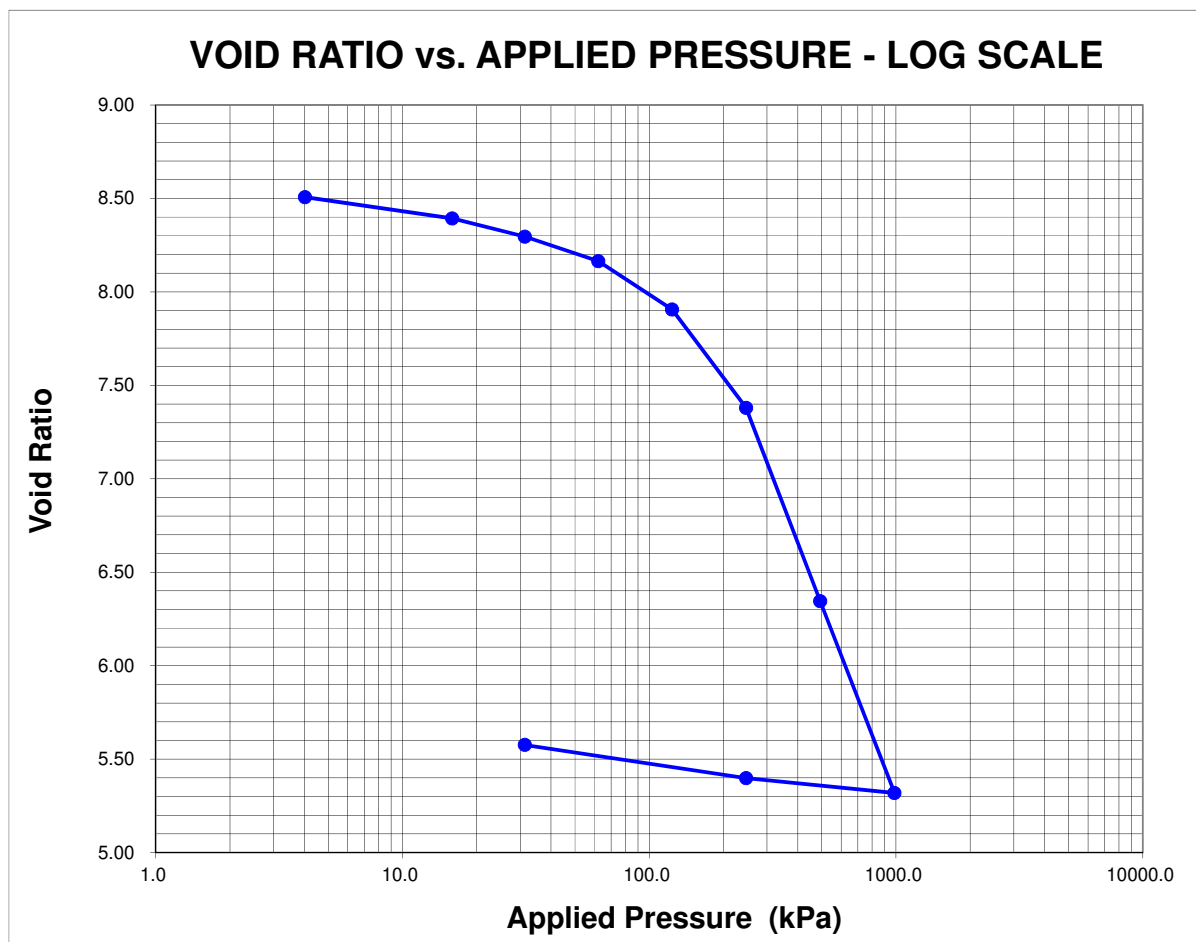
All tests reported herein have been performed in accordance with the laboratory's scope of accreditation. This report may not be reproduced except in full & with written approval from BGL.

Job No:	Reg. No:	Page	of	Version No:	11
65344#L	2977	3	5	Issue Date:	December 2021
PROJECT:				Auth. By:	WEC
ROTORUA MUSEUM					
ONE DIMENSIONAL CONSOLIDATION				Tested By:	WEC
Test Method: NZS4402:1986:Test 2.1 - Water Content				Compiled By:	WEC
Test Method: NZS4402:1986:Test 7.1 - Consolidation				Checked By:	WEC
					January 2022
					11-Feb-22
					11-Feb-22

Borehole No: **BH02**

Sample No: **S1.Test 1**

Depth: **2.42 - 2.50m**



SAMPLE HISTORY & PREPARATION

undisturbed / ~~disturbed~~
Sample from PVC tube

Sample trimmed in small increments into consol ring. Both sides of ring then trimmed flat with a scalpel & straight edge.

TEST DETAILS

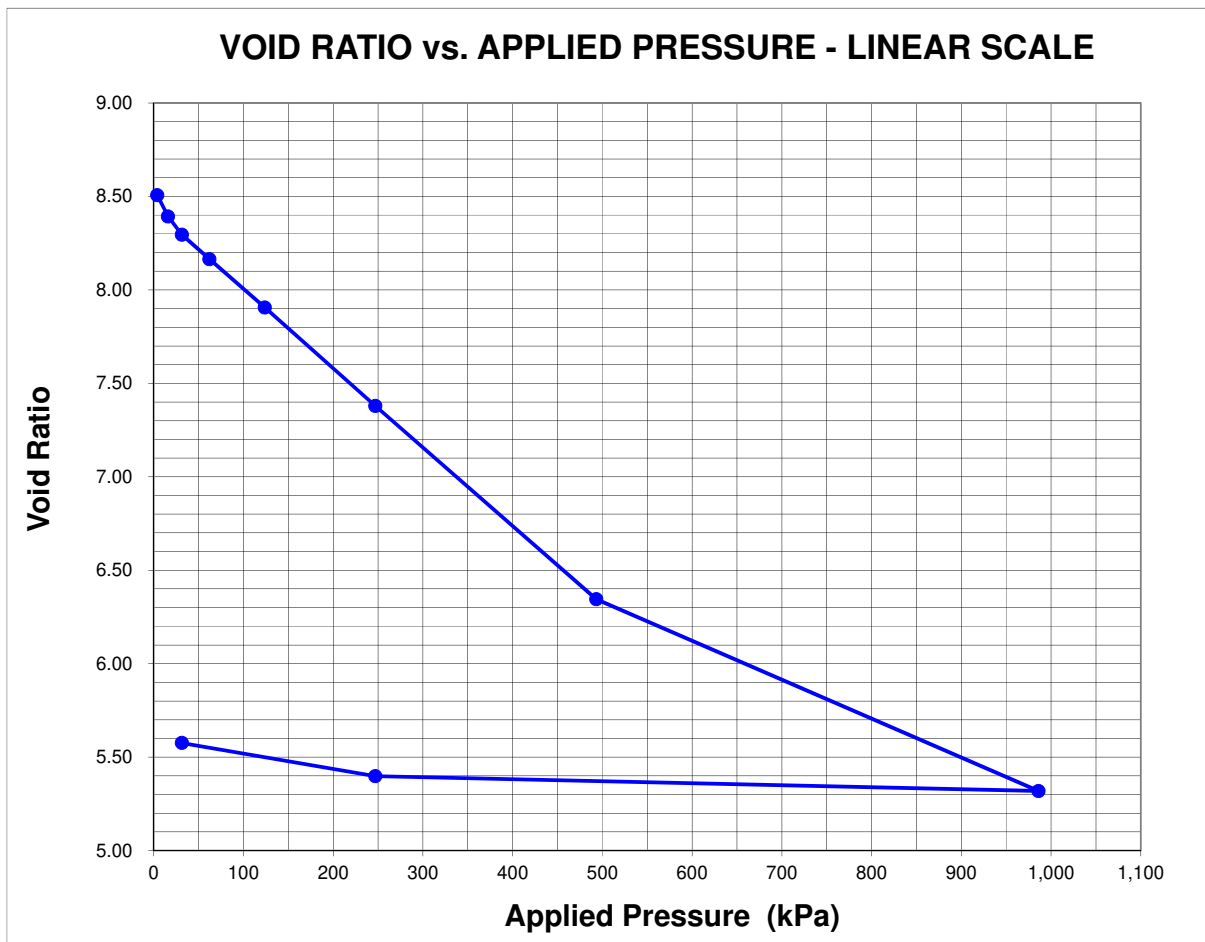
Consol machine number:	4	Surface area of sample top:	1990	mm ²	
Consol ring number:	4e	Sample mass:	45.747	g	
Sample diameter:	50.34	mm	Initial bulk density:	1.14	t/m ³
Sample height:	20.09	mm	Assumed solid density of soil particles:	2.65	t/m ³

Job No:	Reg. No:	Page	of	Version No:	11
65344#L	2977	4	5	Issue Date:	December 2021
PROJECT:				Auth. By:	WEC
ROTORUA MUSEUM					
ONE DIMENSIONAL CONSOLIDATION				Tested By:	WEC
Test Method: NZS4402:1986:Test 2.1 - Water Content				Compiled By:	WEC
Test Method: NZS4402:1986:Test 7.1 - Consolidation				Checked By:	WEC
					January 2022
					11-Feb-22
					11-Feb-22

Borehole No: **BH02**

Sample No: **S1.Test 1**

Depth: **2.42 - 2.50m**



PHOTOGRAPH OF THE SAMPLE PRIOR TO TESTING



ONE DIMENSIONAL CONSOLIDATION

Test Method: NZS4402:1986:Test 2.1 - Water Content

Test Method: NZS4402:1986:Test 7.1 - Consolidation

Tested By: WEC January 2022

Compiled By: WEC 11-Feb-22

Checked By: WEC 11-Feb-22

Borehole No: **BH02**

Sample No: **S1.Test 1**

Depth: **2.42 - 2.50m**

Applied Pressure	Incremental Deflection	Sample Height	Compression Ratio	Height of Voids	Void Ratio	Coefficient of Volume Compressibility m_v	Coefficient of Consolidation - c_v	
kPa	mm	mm		mm	e	m^2/MN	(log time) $m^2/year$	(sqrt time) $m^2/year$
4.0	0.000	20.090	1.000	17.977	8.507			
15.9	0.241	19.849	0.988	17.736	8.393		seating cycle	
31.3	0.206	19.643	0.978	17.530	8.296	0.67	34	36
62.1	0.277	19.366	0.964	17.253	8.164	0.46	28	24
123.7	0.546	18.819	0.937	16.706	7.906	0.46	27	34
246.9	1.112	17.707	0.881	15.594	7.380	0.48	26	32
493.3	2.186	15.521	0.773	13.408	6.345	0.50	17	12
986.0	2.168	13.353	0.665	11.240	5.319	0.28	11	11
246.9	-0.168	13.521	0.673	11.408	5.398		BACKLOAD 1	
31.3	-0.375	13.896	0.692	11.783	5.576		BACKLOAD 2	

Coefficient of Secondary Compression - C_{sec}	
Applied Pressure	C_{sec}
15.9	-
31.3	0.001
62.1	0.001
123.7	0.003
246.9	0.006
493.3	0.013
986.0	0.012

Coefficient of Permeability - k	
Applied Pressure	k (m/s)
15.9	-
31.3	7.1E-09
62.1	4.0E-09
123.7	3.9E-09
246.9	3.8E-09
493.3	2.6E-09
986.0	9.5E-10

Mass of dry sample (g)

Height of sample (mm)

Water Content (%)

Dry Density (t/m^3)

Height of soil particles (mm)

Void Ratio

Degree of saturation (%)

INITIAL	FINAL
11.15	11.15
20.090	13.353 (after consolidation) 13.896 (after rebound)
310	222
0.28	0.42
2.113	2.113
8.507	5.319 (after consolidation) 5.576 (after rebound)
96.7	-

Please reply to: W.E. Campton

Page 1 of 5

Tonkin & Taylor Ltd.
PO Box 5271,
Wellesley Street,
Auckland 1141

Job Number: 65344#L
BGL Registration Number: 2977
Checked by: JF

11th February 2022

Attention: **SUTEJO TJOKRO**

ONE DIMENSIONAL CONSOLIDATION TESTING

Dear Sir,

Re: ROTORUA MUSEUM

Report Number: 65344#L/Consol BH09 4.13 – 4.23m Revision A

Borehole No: BH09

Sample No: S2.Test 1

Depth: 4.13 – 4.23m

The following report presents the results of one dimensional consolidation testing at BGL of a soil sample delivered to this laboratory on the 26th of January 2022. Our instructions were to carry out a one dimensional consolidation test using cycle times that would give both the $\sqrt{T_{90}}$ and T_{50} values, and using a standard pressure sequence. The push-tube sample was tested in accordance with the following standards:

Water Content: NZS4402:1986:Test 2.1

One Dimensional Consolidation: NZS4402:1986:Test 7.1

This report has been issued as an amendment to report number 65344#L/Consol BH09 4.13 – 4.23m, and supersedes it. The reason for issuing this amended report is that the coefficient of secondary compression value for the 100.9kPa cycle in the table on page 5 was missing. The change from the superseded report is that the coefficient of secondary compression value for the 100.9kPa cycle in the table on page 5 has been included in this amended report.

Please note that consolidation cycles were of a variable time duration, and hence is a departure from the test standard which states that the cycle time period for the consolidation loads after the initial cycle should be of approximately the same length. The time for each consolidation cycle was determined by observing consolidation data until the secondary consolidation could be assessed. Subsequent load cycles were taken to at least the time of the previous cycle.

The sample was trimmed into the consolidation ring in small increments, until the sample protruded from both sides of the ring. A scalpel and straight edge were then used to trim the sample flat in the ring.

These test results only relate to the sample tested. The values of m_v shown on the table have been calculated for each pressure increment, using void ratio difference for that increment. Note that a solid density value of 2.65 t/m^3 was assumed for this test, and is not part of the IANZ endorsement for this report. This test was carried out in a laboratory in which the temperature is controlled to be kept within the specification of the test standard.

As per the reporting requirements of NZS4402: 1986: Test 2.1: water content is reported to two significant figures for values below 10%, and to three significant figures for values of 10% or greater. As per the reporting requirements of NZS4402: 1986: Test 7.1: one dimensional consolidation, the coefficients of consolidation (c_v 's), and coefficients of volume compressibility (m_v 's) are reported to two significant figures.

The "Void Ratio vs. Applied Pressure – Linear Scale" plot presented on page 4 is included for your information, and is based on the paper "Soil stiffness measured in oedometer tests" by L. Wesley & M. Pender, Proc. 18th NZGS Geotechnical Symposium on Soil-Structure Interaction, 2008. Please note that the presentation of the data on a linear scale is not part of the test standard, hence page 4 does not form part of the IANZ endorsement for this report.

Note that the Coefficient of Secondary Compression (C_{sec}) and the Coefficient of Permeability (k) values reported on page 5 have been calculated based on the methods described in "Manual of Soil Laboratory Testing Volume 2: Permeability, Shear Strength & Compressibility Tests" by K.H. Head & R.J. Epps, 3rd Edition, 2011. The Coefficient of Permeability values were calculated using the $c_v(\log)$ values determined in the test. The reporting of these figures is not part of NZS4402:1986:Test 7.1, therefore these figures are not part of the IANZ endorsement for this report.

Sample Description (not part of BGL IANZ Accreditation)

BH09 / S2.Test 1 / 4.13 – 4.23m: SILT, soft, slightly plastic to non-plastic, yellowish light brown, saturated, dilatant.

Each test result is data obtained at a specific test location. The nature and continuity of subsoil conditions away from the test area could vary from the data recovered during this testing, therefore the test results relate only to the sample as-received, and relate only to the sample under test.

Thank you for the opportunity to carry out this testing. If you have any queries regarding the content of this report please contact the person authorising this report below at your convenience.

Yours faithfully,

Wayne Campton
Signatory (Laboratory Manager)
Babbage Geotechnical Laboratory



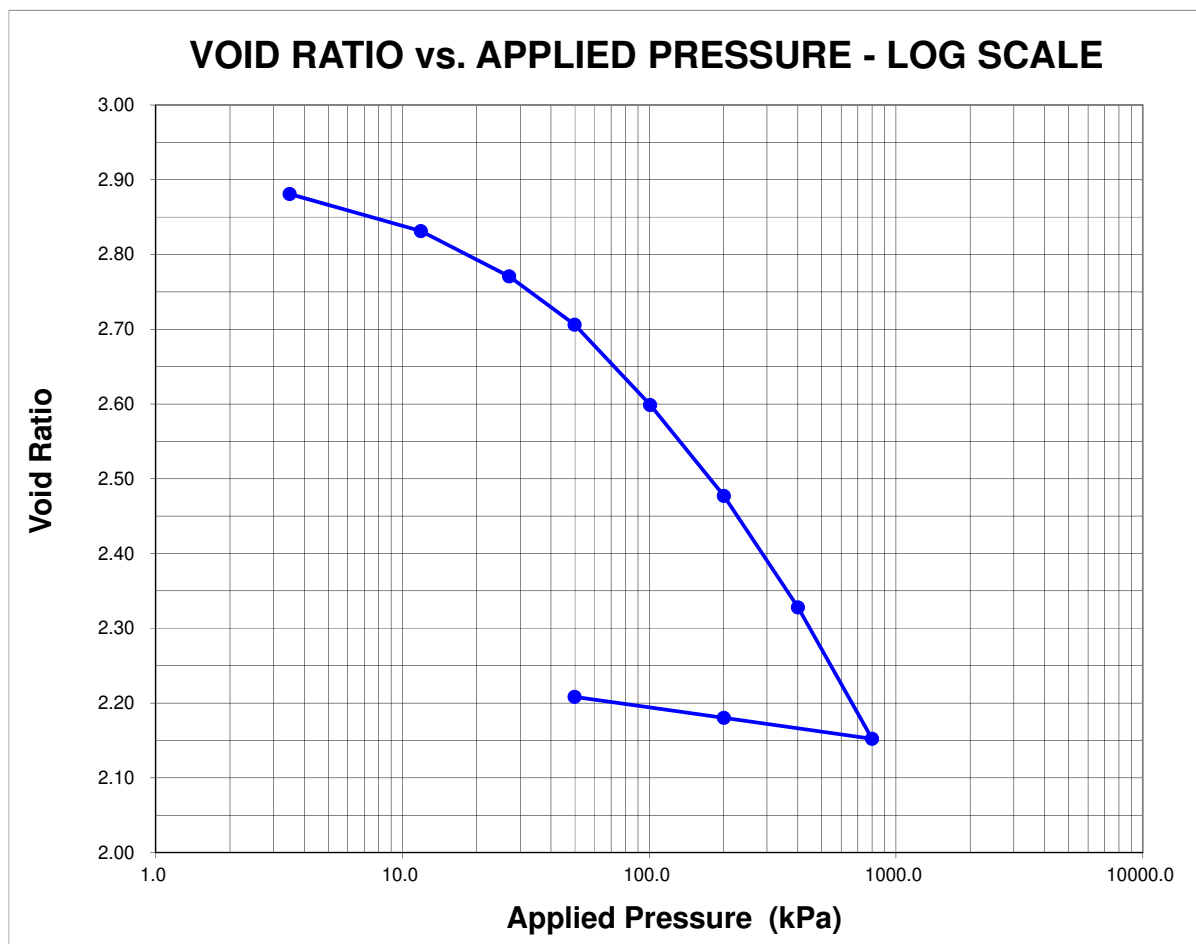
All tests reported herein have been performed in accordance with the laboratory's scope of accreditation. This report may not be reproduced except in full & with written approval from BGL.

Job No:	Reg. No:	Page	of	Version No:	11
65344#L	2977	3	5	Issue Date:	December 2021
PROJECT:				Auth. By:	WEC
ROTORUA MUSEUM					
ONE DIMENSIONAL CONSOLIDATION				Tested By:	WEC Jan / Feb 2022
Test Method: NZS4402:1986:Test 2.1 - Water Content				Compiled By:	WEC 11-Feb-22
Test Method: NZS4402:1986:Test 7.1 - Consolidation				Checked By:	JF 11-Feb-22

Borehole No: **BH09**

Sample No: **S2.Test 1**

Depth: **4.13 - 4.23m**



SAMPLE HISTORY & PREPARATION

undisturbed / ~~disturbed~~
Sample from PVC tube

Sample trimmed in small increments into consol ring. Both sides of ring then trimmed flat with a scalpel & straight edge.

TEST DETAILS

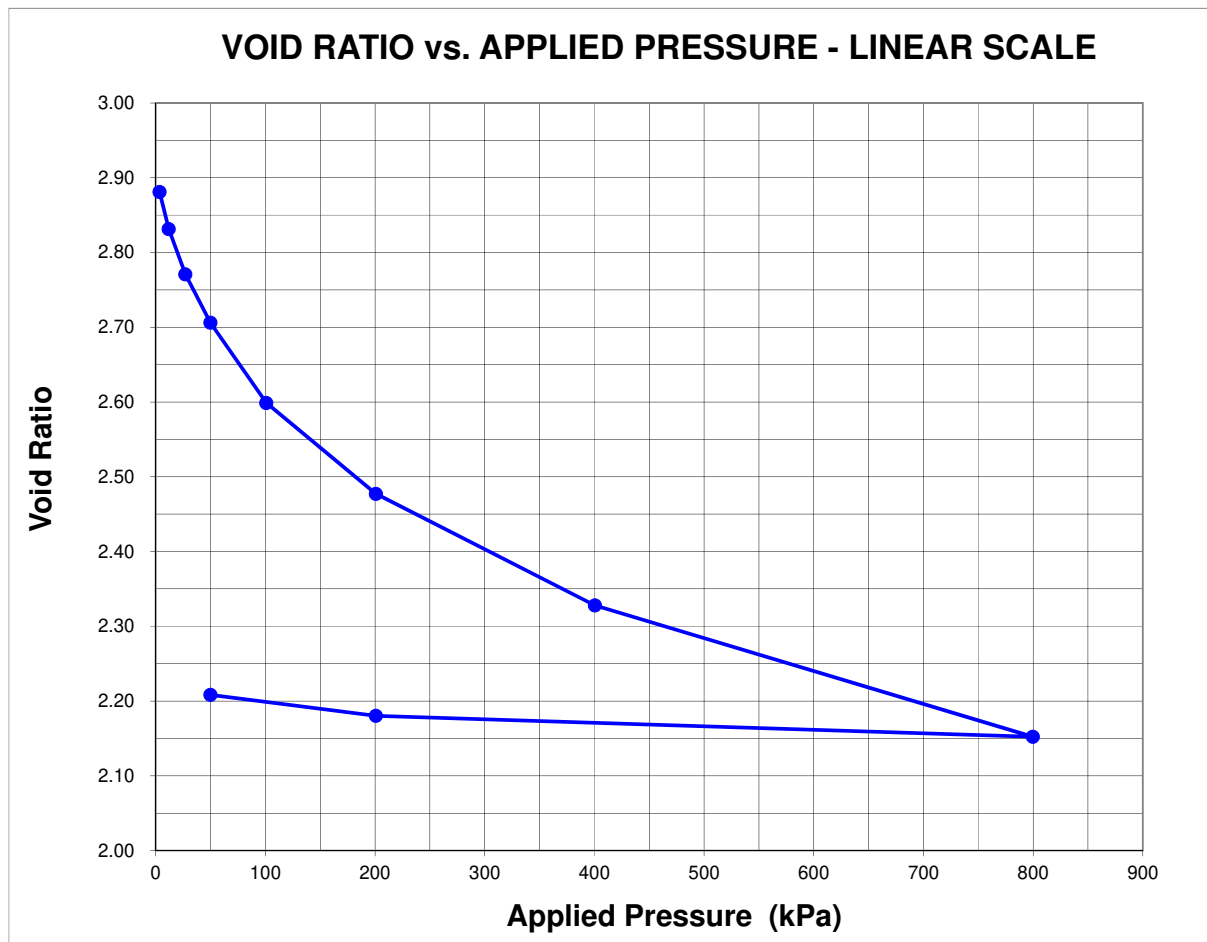
Consol machine number:	2	Surface area of sample top:	2824	mm ²	
Consol ring number:	60	Sample mass:	81.053	g	
Sample diameter:	59.96	mm	Initial bulk density:	1.40	t/m ³
Sample height:	20.55	mm	Assumed solid density of soil particles:	2.65	t/m ³

Job No:	Reg. No:	Page	of	Version No:	11
65344#L	2977	4	5	Issue Date:	December 2021
PROJECT:				Auth. By:	WEC
ROTORUA MUSEUM					
ONE DIMENSIONAL CONSOLIDATION				Tested By:	WEC Jan / Feb 2022
Test Method: NZS4402:1986:Test 2.1 - Water Content				Compiled By:	WEC 11-Feb-22
Test Method: NZS4402:1986:Test 7.1 - Consolidation				Checked By:	JF 11-Feb-22

Borehole No: **BH09**

Sample No: **S2.Test 1**

Depth: **4.13 - 4.23m**



PHOTOGRAPH OF THE SAMPLE PRIOR TO TESTING



ONE DIMENSIONAL CONSOLIDATION

Test Method: NZS4402:1986:Test 2.1 - Water Content

Test Method: NZS4402:1986:Test 7.1 - Consolidation

Tested By: WEC Jan / Feb 2022

Compiled By: WEC 11-Feb-22

Checked By: JF 11-Feb-22

Borehole No: **BH09**

Sample No: **S2.Test 1**

Depth: **4.13 - 4.23m**

Applied Pressure	Incremental Deflection	Sample Height	Compression Ratio	Height of Voids	Void Ratio	Coefficient of Volume Compressibility m_v	Coefficient of Consolidation - c_v	
							(log time) m^2/year	(sqrt time) m^2/year
kPa	mm	mm		mm	e	m^2/MN	m^2/year	m^2/year
3.5	0.000	20.550	1.000	15.255	2.881			
11.9	0.262	20.288	0.987	14.992	2.831	1.5	41	43
27.1	0.321	19.967	0.972	14.672	2.771	1.0	36	38
49.9	0.343	19.624	0.955	14.329	2.706	0.75	19	18
100.9	0.569	19.056	0.927	13.761	2.599	0.57	25	27
200.7	0.644	18.412	0.896	13.117	2.477	0.34	21	28
400.4	0.790	17.622	0.858	12.327	2.328	0.21	22	26
799.8	0.931	16.691	0.812	11.396	2.152	0.13	20	26
200.7	-0.149	16.840	0.819	11.545	2.180	BACKLOAD 1		
49.9	-0.149	16.989	0.827	11.694	2.208	BACKLOAD 2		

Coefficient of Secondary Compression - C_{sec}	
Applied Pressure	C_{sec}
11.9	0.002
27.1	0.002
49.9	0.003
100.9	0.004
200.7	0.004
400.4	0.005
799.8	0.005

Coefficient of Permeability - k	
Applied Pressure	k (m/s)
11.9	1.9E-08
27.1	1.2E-08
49.9	4.4E-09
100.9	4.4E-09
200.7	2.2E-09
400.4	1.5E-09
799.8	8.3E-10

Mass of dry sample (g)

Height of sample (mm)

Water Content (%)

Dry Density (t/m^3)

Height of soil particles (mm)

Void Ratio

Degree of saturation (%)

INITIAL	FINAL
39.62	39.62
20.550	16.691 (after consolidation) 16.989 (after rebound)
105	80.4
0.68	0.84
5.295	5.295
2.881	2.152 (after consolidation) 2.208 (after rebound)
96.2	96.5

C5 - Shear wave velocity report

**TECHNICAL REPORT ON:
CROSSHOLE AND DOWNHOLE SEISMIC INVESTIGATION**

**PROJECT:
ROTORUA MUSEUM GEOPHYSICAL INVESTIGATION**

**CLIENT:
ROTORUA LAKES COUNCIL
CIVIC CENTRE
1061 HAUPAPA STREET
ROTORUA
NEW ZEALAND**

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1 OVERVIEW

Tonkin + Taylor (T+T), on behalf of Rotorua Lakes Council (the client) engaged Resource Development Consultants Limited (RDCL) to undertake geophysical logging in eight (8) single drill holes and two (2) drill hole pairs. The work was part of the earthquake strengthening assessments at Rotorua Museum undertaken by T+T.

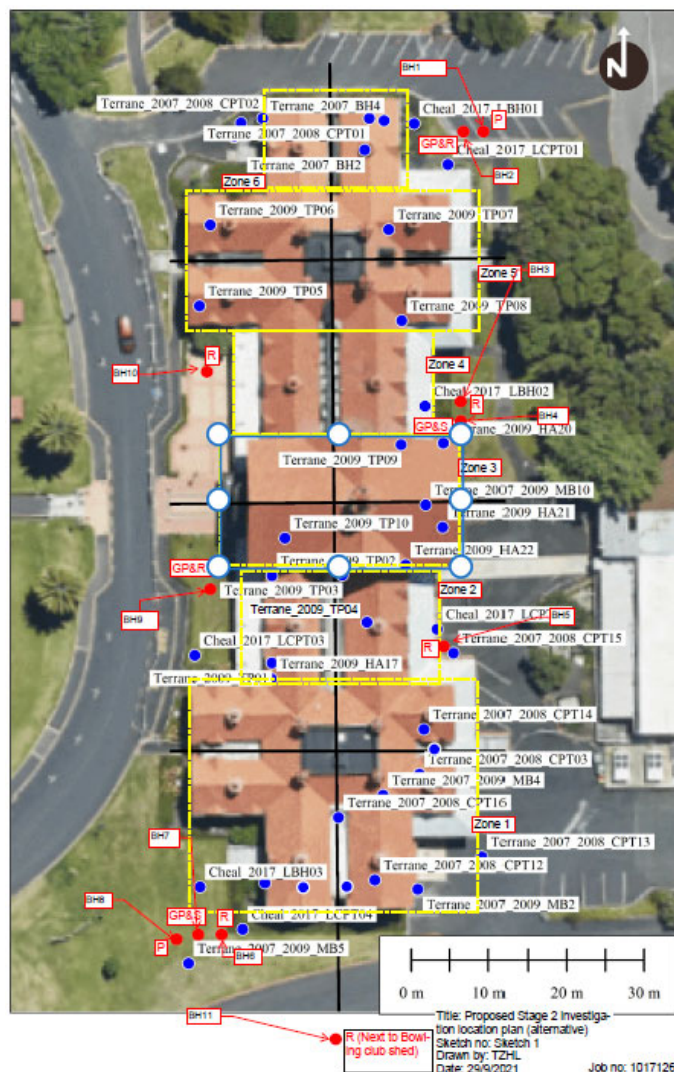
The purpose of the investigation was to measure shear wave velocity (V_s) in the existing drillholes.

This technical report details the crosshole seismic testing of drill hole pairs BH03 & BH04 and BH06 & BH07. Downhole seismic testing of drillholes BH02, BH03, BH06, BH07, BH09, BH10 & BH11 are also reported.

Each drillhole had either 50 mm or 100 mm internal diameter PVC grouted pipe installed.

Figure 1 below shows the testing locations (provided by the client).

DIAGRAM 1 - TEST LOCATIONS



2 SCOPE OF WORK

The project scope of work included:

- Downhole geophysical data acquisition using:
 - Direct raypath crosshole seismic.
 - Direct raypath downhole seismic.
- Data Processing and Quality Assurance.
- Interpretation of geophysical logs in a geotechnical setting, including:
 - Shear wave velocity (both downhole and crosshole).

Table 1 below defines the testing depths achieved at each location.

TABLE 1 - DRILLHOLE TESTING DEPTHS

Drill hole ID	Downhole Testing Depth (m)	Crosshole Testing Depth (m)
BH02	6.9	N/A
BH03	6.5	7.0
BH04	N/A	7.0
BH06	4.5	4.5
BH07	6.5	4.5
BH09	8.5	N/A
BH10	9.0	N/A
BH11	4.0	N/A

2.1 TERMS OF REFERENCE

This investigation employed geophysical methods and therefore the findings presented here are the result of the measurement and interpretation of seismic (acoustic) signals. As such any results derived from the geophysical investigation should be taken in the context of and in reference to the complete ground investigation. Reasonable skill and care were taken to ensure that the results are accurate and reliable, including reference where appropriate to published data from this and/or other sites. However, as with other indirect methods there is a possibility of localised inconsistencies and inaccuracies within the results.

3 HEALTH AND SAFETY

A site induction was attended and daily toolbox meeting conducted by RDCL site staff. A H₂S gas monitor was carried by RDCL field personnel while undertaking field testing.

4 GEOPHYSICAL SURVEY

Data was acquired on the 12th – 14th of January 2022.

4.1 SURVEY RATIONALE

4.1.1 CROSSHOLE SEISMIC

Crosshole seismic testing was used to provide an indication of variation in shear wave velocity (Vs) between two drillholes. The advantage of this method is that it is a measure of a direct raypath at depth and not subject to variations of geology above the testing depth.

This method utilised a downhole clamped seismic source (R T Clark Ballard Borehole Shear Wave Source) down the transmitter hole to generate polarised shear waves.

4.1.2 DOWNHOLE SEISMIC

Downhole seismic testing was used to provide an indication of variation in shear wave velocity (Vs) downhole. By measuring the difference in arrival times of the shear waves at known depths, the velocities can be calculated.

Key to the survey is accurate identification of shear waves. This was achieved by utilising the fact that shear waves can be polarised. By striking a shear beam in opposing directions, polarised shear waves are created. Seismic traces can then be superimposed allowing the polarisation to be observed, and shear waves to be therefore distinguished from the coda (“tail”) of the earlier arriving compressional waves.

4.2 DATA ACQUISITION METHOD

4.2.1 ACQUISITION SYSTEM

4.2.1.1 CROSSHOLE SEISMIC TESTING

The Ballard shear wave source and BHG-3 triaxial geophone tools were inserted into the transmitter (Tx) and receiver (Rx) respectively in each drill hole pair. Each tool was

lowered to the first test interval by recording depth markers on their associated data cables. The Ballard shear wave source was clamped to the drill hole wall using an inflatable bladder. The BHG-3 was clamped to the drill hole wall using a mechanical bowstring clamp.

Seismic Source Shots were:

- Produced from the Ballard source in the up and down directions.
- Typically five shots were recorded in each direction. Each shot was saved as a separate, unstacked seismic file.
- The source and receiver were then moved to the next test interval, which were typically every 0.5 m.

4.2.1.2 DOWNHOLE SEISMIC TESTING

Acquisition of downhole seismic data was conducted using a Geometrics Geode seismograph addressing a tri-axial Geostuff BHG-3 downhole clamping geophone.

Test intervals were spaced at 0.5 metre from surface to bottom depth.

Shots were:

- Produced by a sledgehammer for seismic signal generation (“shots”).
- Stacked (three shots) to improve signal to noise ratio.
- Horizontally polarised “shear” wave shots were acquired in opposite directions by striking a shear beam weighted by a vehicle (to improve coupling). The shear beam was orientated to align with the orientation of one of the transverse components of the tri-axial geophone sensor. For the purposes of this survey, this was the north-south component.

4.2.1.3 ACQUISITION PARAMETERS

Acquisition parameters are defined in Table 2 below:

TABLE 2 - ACQUISITION PARAMETERS

Parameter	Downhole Acquisition Settings	Crosshole Acquisition Settings
Trigger Delay	0 ms	-10 ms
Total record length	600 ms	60 ms
Sample Interval	62.5 μ s	20.833 μ s
Acquisition Filters	OUT	OUT

4.2.2 POSITIONAL CONTROL

Positional control downhole was obtained using 1 m interval marks on the geophone and Ballard cable. Downhole measurements were made relative to ground level during acquisition.

- Therefore, downhole positional accuracy is likely to be of the order of ± 0.05 m.

4.2.3 VERTICALITY

Drill hole verticality was assumed and no travel time corrections are applied associated with variations in verticality. This is a direct ray path method.

4.2.4 QUALITY ASSURANCE

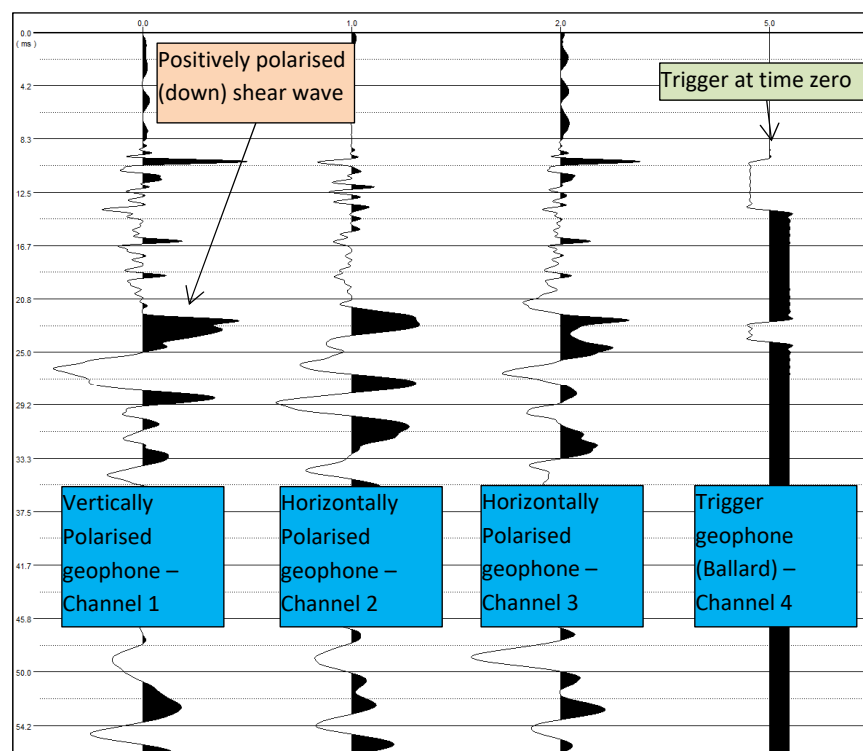
There are four main field-testing QC steps.

- First, the drill holes are checked for any water with a dip meter. If water is present, this is bailed out to leave a dry hole. Water in the drill hole may cause a tube wave and so it is imperative that the seismic testing is done in a dry drill hole.
- Before data acquisition seismic channels are checked for signal to noise interference. This is used to assess poor drill hole wall coupling or external noise on site (unwanted sound). This is commonly referred to as a noise shot.
 - A noise shot is recorded at surface, to assess signal to noise ratio and to confirm electronic systems are functioning and correct timing and trigger errors.
 - A noise shot is also recorded at depth, typically at a mid-point in the drill hole. This confirms in-hole signal to noise ratio and to ensure the tool is functioning after deployment.
- Every shot interval has stacked signal shots of three shots per test depth (at least). Each shot is checked for timing errors and poor coupling before being saved to the data sets. Shots were stacked in field to improve signal to noise ratios.
- Shear wave seismic shots are recorded in opposing directions to establish a polarised shear wave. Polarised shear waves reduce the chances of tube waves being confused with shear wave arrivals.

In addition to the above, the crosshole seismic quality control measures included:

- Qualitative assessment of the recorded zero trigger times from the Ballard geophone.
- Qualitative assessment of the signal to noise ratio on the tri-axial geophone traces. Where there were concerns data was read into a processing package and the data converted to the frequency domain and filtered as appropriate.
- Assessment of the direction of the up and down shots of the shear wave. The direction (either a positive or negative amplitude) of the first arrival of the shear wave should be consistent but opposite for up and down shots. For the purposes of this survey up shots of the shear wave always had a positive first break amplitude and down shots always had a negative first break amplitude.
- Where shots were qualitatively assessed to be of low quality, extra shots were recorded to improve signal to noise ratio

DIAGRAM 2 - CROSSHOLE SEISMIC ONSITE QUALITY CONTROL



4.2.5 RESOLUTION LIMITATIONS

4.2.5.1 DOWNHOLE SEISMIC

Layer velocities were defined based on changes in arrival time slopes and geological intervals detailed in drill hole logs provided to RDCL. Velocities are calculated from calculating the slope from the Tx curves (time depth). It is usually not appropriate to

calculate interval velocities using just two points (over successive measurements) as large errors in velocity are likely (ASTM – D7400-08).

Testing in all holes were undertaken at 0.5 m intervals, and therefore typical resolution is to the order of ± 1 m.

4.2.5.2 CROSSHOLE SEISMIC

Measurements were recorded at 0.5 m intervals. This interval effectively defines the resolution of the test. The assumption is that the raypaths travel directly between the source and receiver.

5 PROCESSING

5.1 CROSSHOLE SEISMIC PROCESSING

Data processing of the crosshole seismic data consisted of:

- Phase 1 – Initial data inspection and quality control (QC).
- Phase 2 – Inspection of trigger signals.
- Phase 3 – Generation of trace gather.
- Phase 4 – Frequency filtering.
- Phase 5 – First break picking and shear wave picking.
- Phase 6 – Velocity calculations.

5.1.1 PHASE 1 – INITIAL DATA INSPECTION

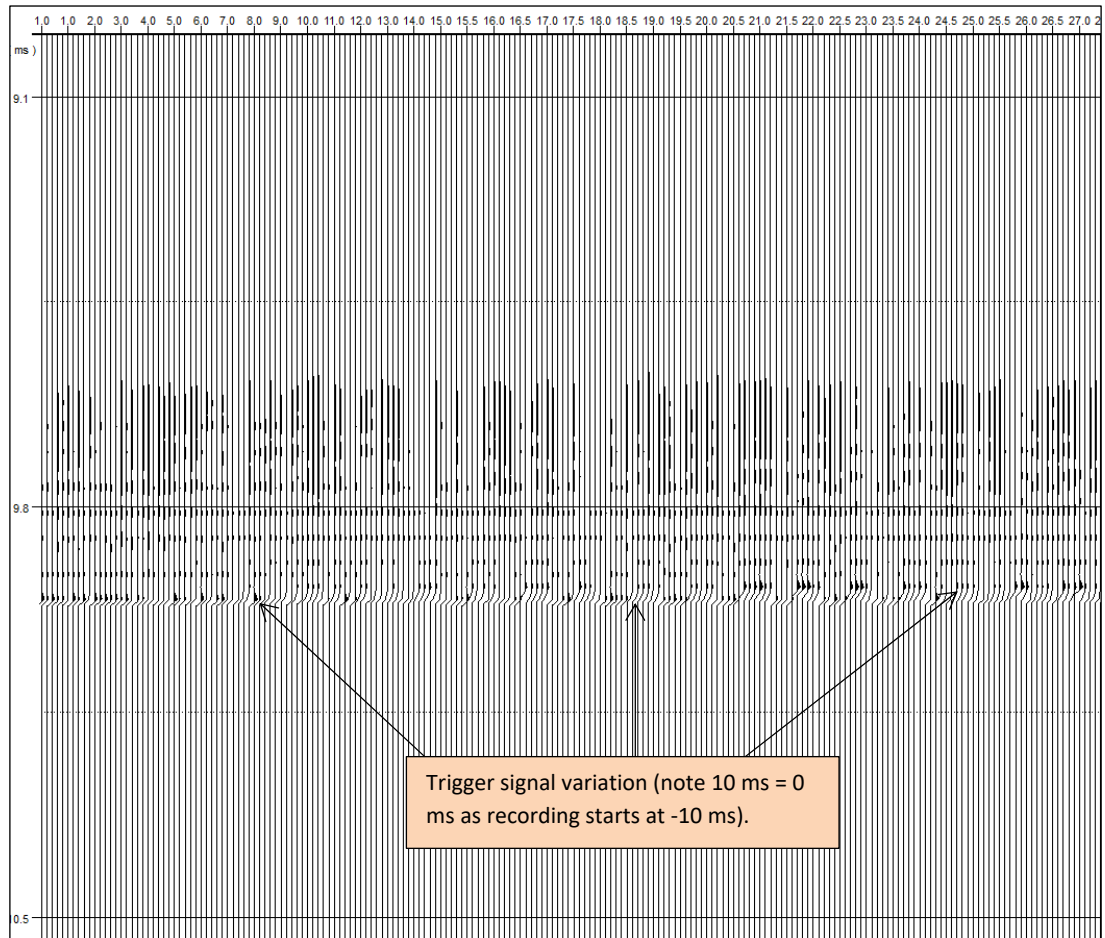
Raw data files were imported into Geogiga Seismic Pro 7.1 software for initial data inspection including:

- Data import of .dat (seg-2) files.
- Visual inspection of seismic traces and geometry information.

5.1.2 PHASE 2 – INSPECTION OF TRIGGER SIGNAL

- Each .dat file was imported into Python 3.6 using the Obspy package.
- The recorded trigger signal for each shot (channel 4 - Diagram 3) was copied and appended to trace gathers for the up and down shot types.
- Shot type trace gathers of trigger signal were imported into Geogiga Seismic Pro 7.1 and inspected for triggering errors (Diagram 3). Any .dat files that contained trigger errors were either marked for removal from further processing or the timing error was manually picked and recorded for correction during the next stage of processing.

DIAGRAM 3 - GATHER OF PRE-STACKED TRIGGER SIGNALS



5.1.3 PHASE 3 – GENERATION OF TRACE GATHER

- Each .dat file was imported into Python 3.6 using the Obspy package. Each file contains signal channel 1, 2 and 3 (Diagram 3), corresponding to vertical, horizontal 1 and 2 respectively.
- Traces were converted to the seg-y data format and resampled to integer sampling rates in milliseconds to satisfy seg-y data type requirements.
- The system or manually picked trigger delay is removed from each channel trace.
- Traces for each channel, depth and shot type are stacked and appended to a trace gather for each channel and shot type (Appendix A).
- Channel and shot type trace gathers are sorted by depth and written to disk in the seg-y data format.

5.1.4 PHASE 4 – FREQUENCY FILTERING

Shot type trace gathers are imported into Geogiga Seismic Pro 7.1 and frequency filtered to remove seismic noise outside of the signal frequency bandwidth.

- Generation of a frequency spectrum via a fast Fourier transform (FFT).
- Frequency filtering using a low-pass, high-pass or band-pass filter.
- For the purposes of this survey shear wave gathers were typically filtered with a band pass filter between 25-1000 Hz.
- The filtered trace gathers were saved to disk.

5.1.5 PHASE 5 – FIRST BREAK PICKING AND SHEAR WAVE PICKING

Shot type trace gathers were imported into the Seisimager module - Pickwin. Shear wave arrival times were picked by identifying waves that were polarised (Appendix A). In crosshole seismic, this was on the vertical channel (channel 1) as it is transverse to the direction of wave propagation. Where shear waves could not be reliably identified, a gap was left and that data was not picked. Shear wave identification may be affected by:

- Decreases in signal to noise ratio.
- Interference from tube waves.
- Disturbance by the coda of the P-wave arrivals

For the purposes of this survey three first break arrival times were picked for each depth interval specifically, best, minimum and maximum (Figure 1 & 2). The reason for this was define the human error influence on the data (picking) which for this dataset is likely to be the largest source of data (relative to random and systematic error).

5.1.6 PHASE 6 – VELOCITY CALCULATION

Arrival times were imported into Microsoft Excel for presentation and calculation of velocities between source and receiver at each depth interval.

No geometric corrections to account for drill hole deviation of the source and receiver drill holes were made to the straight ray path distance. Due to the shallow nature of the holes it is unlikely drillhole deviation would have a significant effect on calculated velocities.

5.2 DOWNHOLE SEISMIC DATA PROCESSING

Data processing consisted of:

- Phase 1 – Initial processing and data filtering.
- Phase 2 – First break picking and shear wave picking.
- Phase 3 – Data presentation and calculation of interval velocities.

5.2.1 PHASE 1 – INITIAL PROCESSING

Raw data files were imported into an RDCL proprietary Python script. The script undertook the following generalised processes:

- Split of channels 1, 2 and 3 (data orientated in the vertical, north and east components).
- Sort into left, right and vertically polarised shots.
- Deletion of unrequired traces.
- Correct assignment of depth geometry from header.
- Merge of traces into separate gathers for left, right and vertical polarised shots.
- Bandpass-filtering.
- Visual assessment of traces.

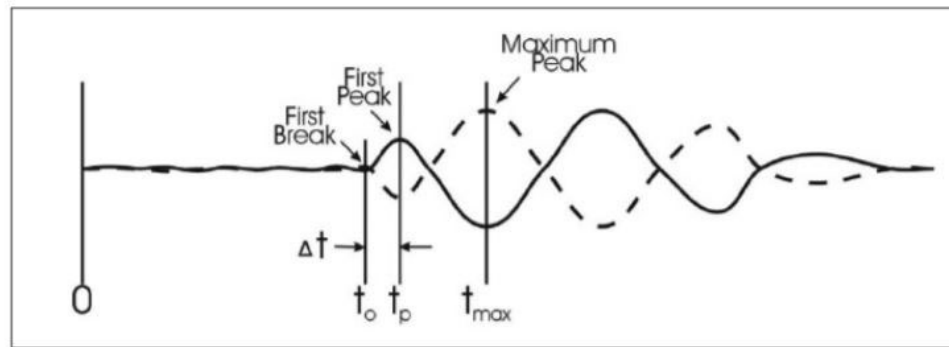
5.2.2 PHASE 2 – ARRIVAL TIME 'PICKS'

Gathers were subsequently imported into the Seisimager Pickwin module software for picking. Shear wave arrival times were manually picked by identifying waves that were polarised. Where shear waves could not be reliably identified, a gap was left and that data was not picked. Shear wave identification may be affected by:

- Decreases in signal to noise ratio.
- Interference from tube waves.
- Disturbance by the coda of the P-wave arrivals.

For the purposes of this survey shear waves were picked at three separate locations on each trace (Schematic 1) and interval/layer velocities calculated using the three picking methods.

SCHEMATIC 1 - SHEAR WAVE VELOCITY PICKING



The three methods are called:

- First Break.
- First Peak.
- Maximum Peak.

Three methods of shear wave picking were used to reduce and assess the uncertainty in the shear wave velocity interval/layer calculations.

Note in some cases it was not possible to pick all parts of the wave.

5.2.3 PHASE 3 – VELOCITY CALCULATIONS

Arrival times were imported into an RDCL proprietary Python script for presentation and calculation of interval velocities and layer velocities. Intervals were defined from changes in slope in the arrival time data and the drill hole logs provided to RDCL by the client.

Geometric corrections were made to the travel times for shot/collar horizontal offsets and casing stick up.

5.3 EQUIPMENT

Geophysical logging was carried out using:

- Geostuff BHG-3 Triaxial Clamping geophone.
- R T Clark Ballard Borehole Shear Wave Source.
- Geometrics Geode Seismograph – 24 channel

6 GEOPHYSICAL OBSERVATIONS

6.1 CROSSHOLE

Crosshole seismic measurements were successfully undertaken between each drill hole pair.

Crosshole gathers are plotted in Appendix A, seismic data is tabulated in Appendix B and plotted in Figures 1 & 2. Typically the seismic data was:

- Repeatable.
- Able to be successfully stacked.
- Demonstrated good polarisation between up and down shots allowing the shear wave to be readily identified.
- Exhibited small to negligible trigger errors that were readily correctable by recording trigger geophone signal.
- High signal to noise ratios.
- Not corrected for drill hole deviation from vertical.

6.1.1 BH03 & BH04

The following observations may be made regarding the seismic data acquired in BH03 & BH04:

- Signal to noise ratio drops significantly below 6.5 m bgl. A shear wave was still identified at 7 m bgl.
- Measured shear wave velocities were very low above 2.5 m bgl.
- No direct effect was observed from the metal blow out preventer deployed in drillhole BH03.
- Measured shear wave velocities were similar to those measured from the coincident downhole seismic.
- Picking error was assessed to be low <10 m/s.

6.1.2 BH07 & BH06

The following observations may be made regarding the seismic data acquired in BH06 & BH07:

- Shear wave signals were not perfectly polarised above 1.5 m but a shear wave was still identifiable.
- No direct effect was observed from the metal blow out preventer deployed in drillhole BH06.
- Measured shear wave velocities were similar to those measured from the coincident downhole seismic.
- Picking error was assessed to be low <8 m/s.

6.2 DOWNHOLE SEISMIC

Downhole seismic measurements were successfully undertaken in BH02, BH03, BH06, BH07, BH09, BH10 & BH11.

Downhole data is plotted in Appendix A (trace gathers), Appendix C and seismic data is tabulated in Appendix D. Typically the seismic data was:

- Repeatable.
- Demonstrated acceptable polarisation between up and down shots allowing the shear wave to be readily identified.
- Exhibited small to negligible trigger errors.
- Had moderate but acceptable signal to noise ratios.

The downhole seismic holes were all shallow with a maximum test depth of 9 m bgl. Downhole seismic data is optimal at depths deeper than 5 m because:

- The angle the raypaths arrive at are steeper and closer to the assumed vertical.
- The shear wave has a chance to separate from the faster travel compressional wave.
- Coupling between the grouted drillhole wall and formation is normally better (as materials are stiffer).

As a result it was not always possible to pick all parts of the shear wave (first break, first peak and maximum peak) for all drillholes.

6.2.1 BH06

The measured downhole seismic shear wave velocity data in BH06 is higher than that exhibited in the crosshole seismic panel BH06-BH07 and in the nearby BH07.

This may be due to:

- The shear wave refracting in an unexpected way down the infilled grout between the PVC and the annulus. This may occur in the annulus is large (due to hole blowout) and a large amount of grout has been used to infill.
- Unexpected highly localised geological change (a gravel lens or similar) resulting in stiffer materials between the shear beam the hole on one side than another.

This is unlikely to be due to:

- Incorrect picking of the shear wave – the wave shows acceptable polarisation even in the near surface and it is possible to identify it across multiple traces.
- Tube waves – sometimes tube waves may be misidentified as shear waves (they can exhibit polarisation and travel at similar velocities). Tube waves only occur in fluid filled holes and RDCL manually bailed each hole to total depth before undertaking testing.

7 DATA DELIVERABLES

Data deliverables include:

- Crosshole Trace Gathers (Appendix A).
- Tabulated crosshole shear wave velocities (Appendix B).
- Downhole Seismic Interval Velocity Plots (Appendix C).
- Tabulated downhole seismic shear wave velocities (Appendix D).
- Raw .dat seismic files. (Appendix E – electronic).

8 CLOSING

We trust this report meets your current needs. Should you wish to discuss any aspect of the contents of this document please contact me the undersigned on 06 877 1652.

Faithfully,

O. Gibson



Ollie Gibson

Krish Korla

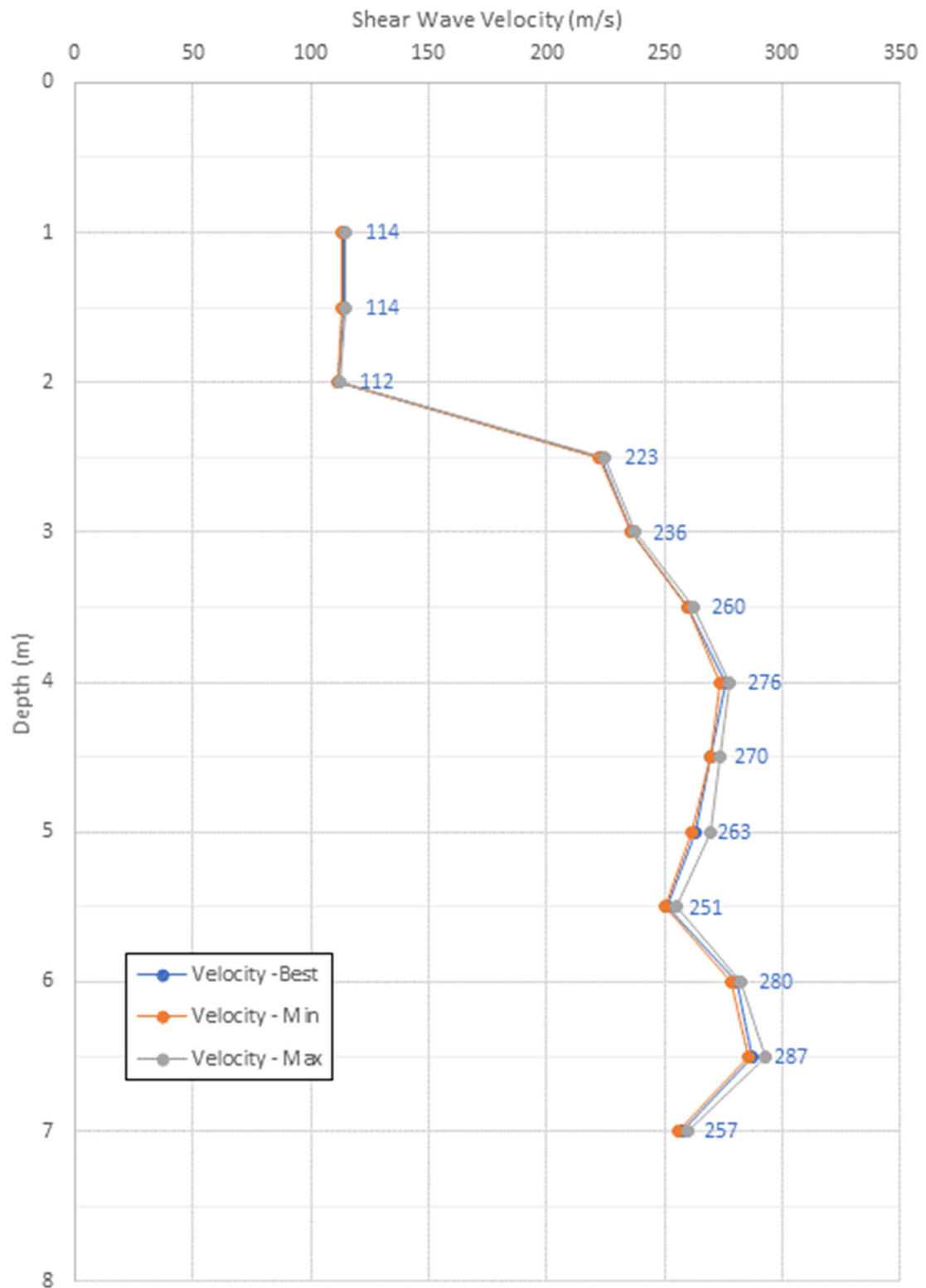
BSc, MRes

BSc, MEngNZ, FGS

Senior Geophysicist

Senior Engineering Geologist

Crosshole - Vs - BH03-BH04



RDCL

TITLE

B H03—BH04 Crosshole Shear Wave Velocity

PROJECT

Rotorua Museum

DRAWN BY

OG

DATE

01/02/22

CLIENT

Rotorua Lakes Council

CHECKED BY

KK

DATE

02/02/22

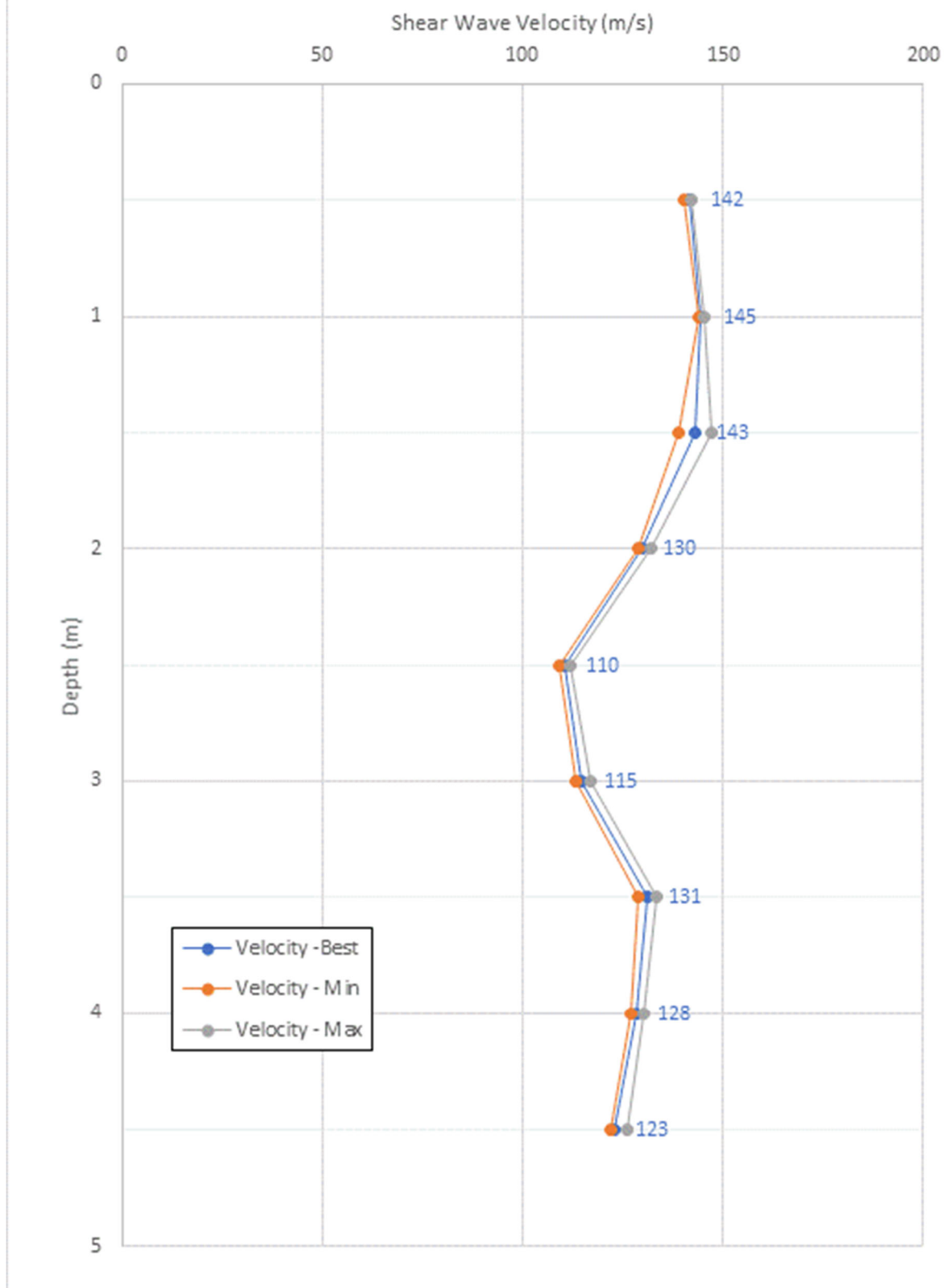
PROJECT No.

210754

Figure No.

01

Crosshole - Vs - BH07-BH06



RDCL

TITLE

B H07—BH06 Crosshole Shear Wave Velocity

PROJECT

Rotorua Museum

DRAWN BY

OG

DATE

01/02/22

CLIENT

Rotorua Lakes Council

CHECKED BY

KK

DATE

02/02/22

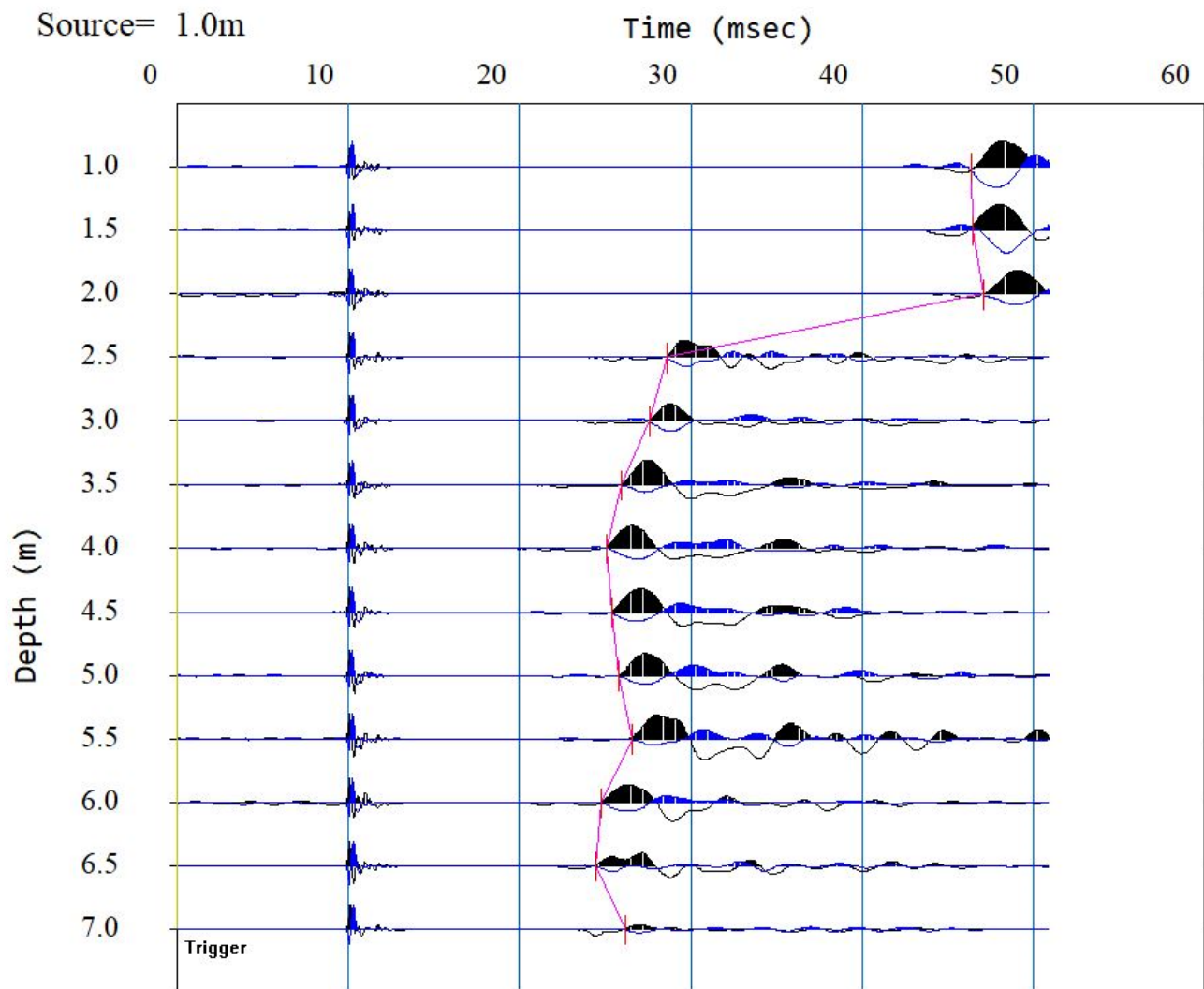
PROJECT No.

210754

Figure No.

02

APPENDIX A – CROSSHOLE & DOWNHOLE TRACE GATHERS



RDCL

TITLE

B H03—BH04 Crosshole Trace Gather

PROJECT

Rotorua Museum

DRAWN BY

OG

DATE

01/02/22

CLIENT

Rotorua Lakes Council

CHECKED BY

KK

DATE

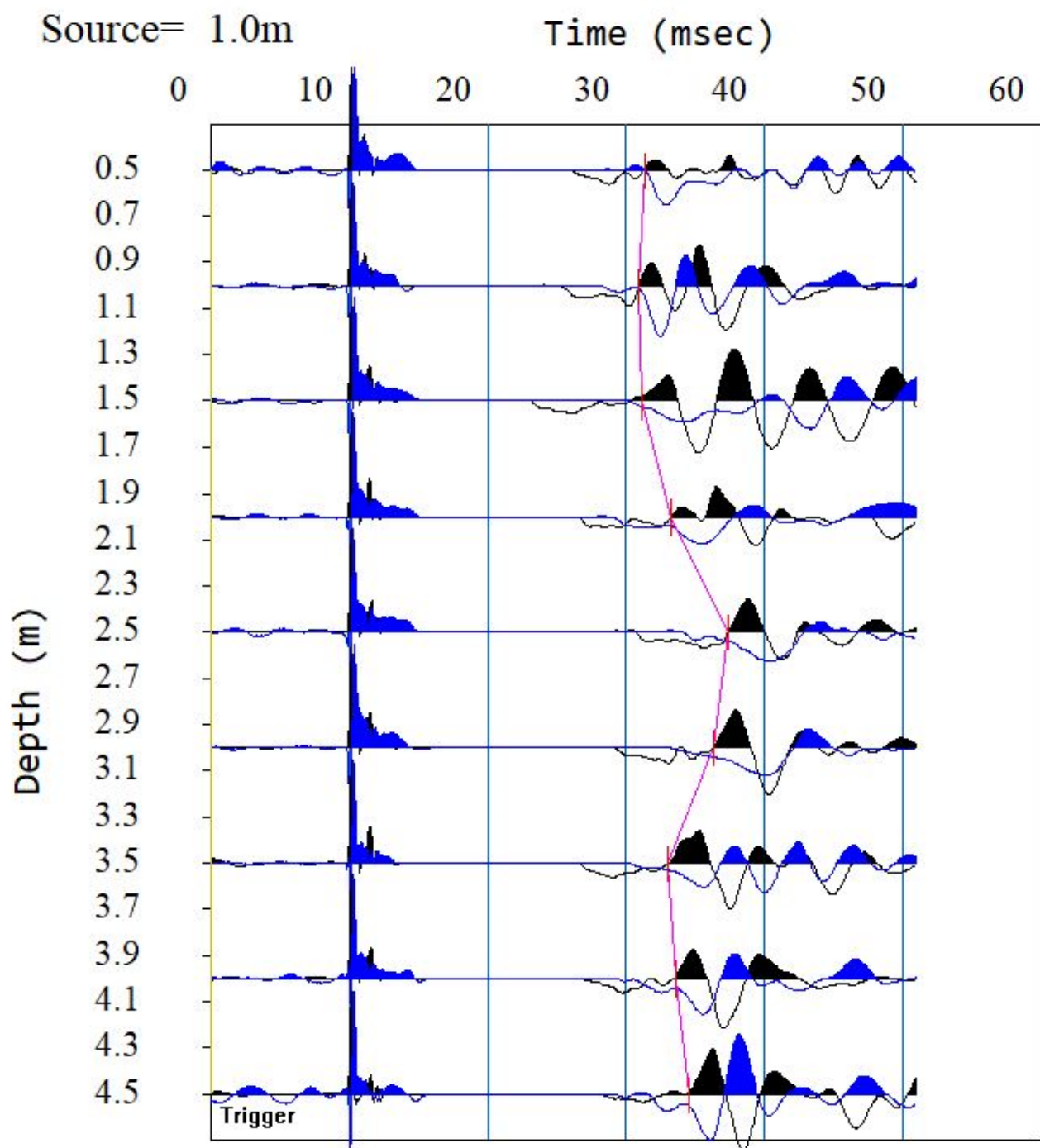
02/02/22

PROJECT No.

210754

Figure No.

A01



RDCL

TITLE

B H07—BH06 Crosshole Trace Gather

PROJECT

Rotorua Museum

DRAWN BY

OG

DATE

01/02/22

CLIENT

Rotorua Lakes Council

CHECKED BY

KK

DATE

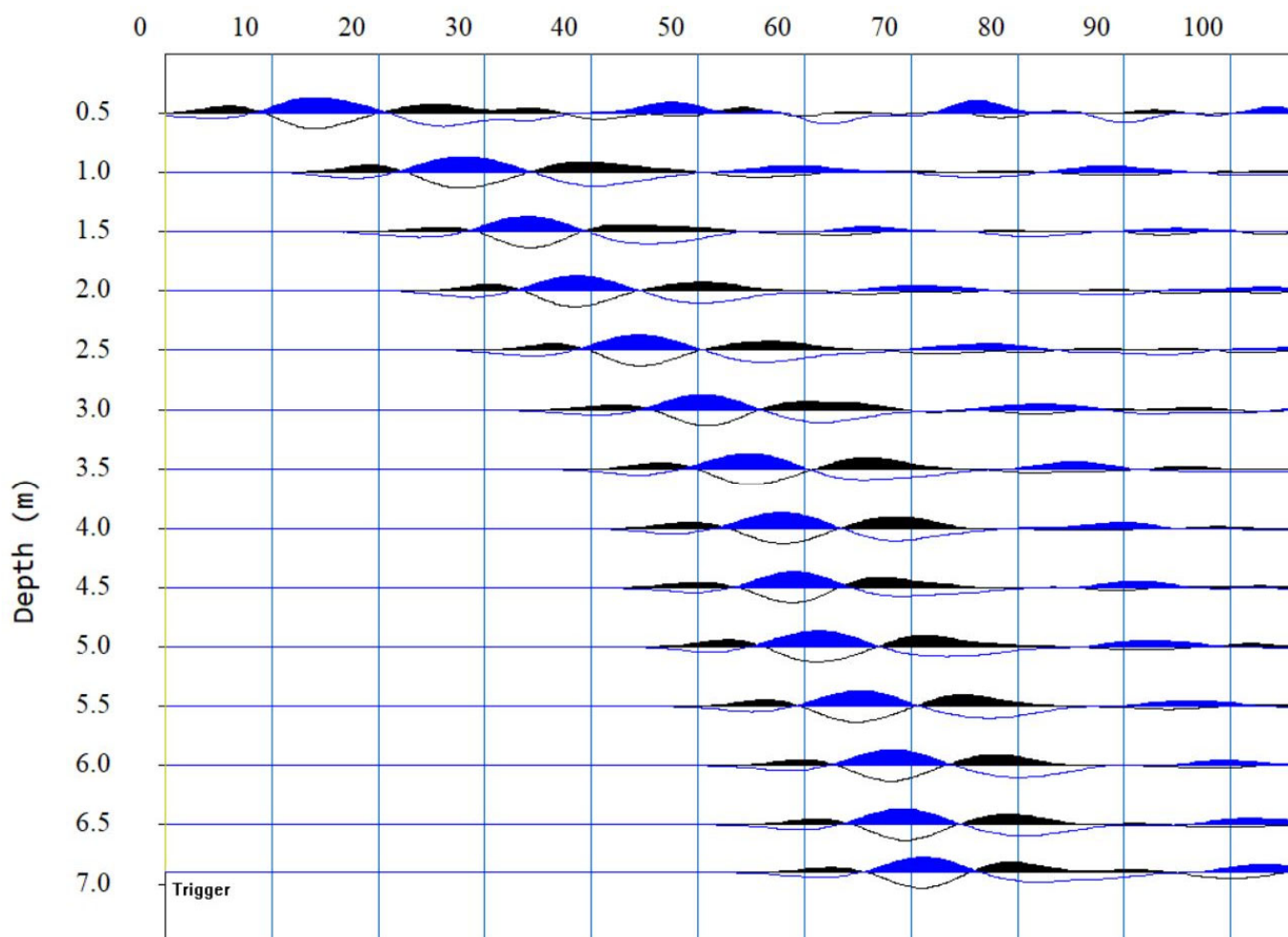
02/02/22

PROJECT No.

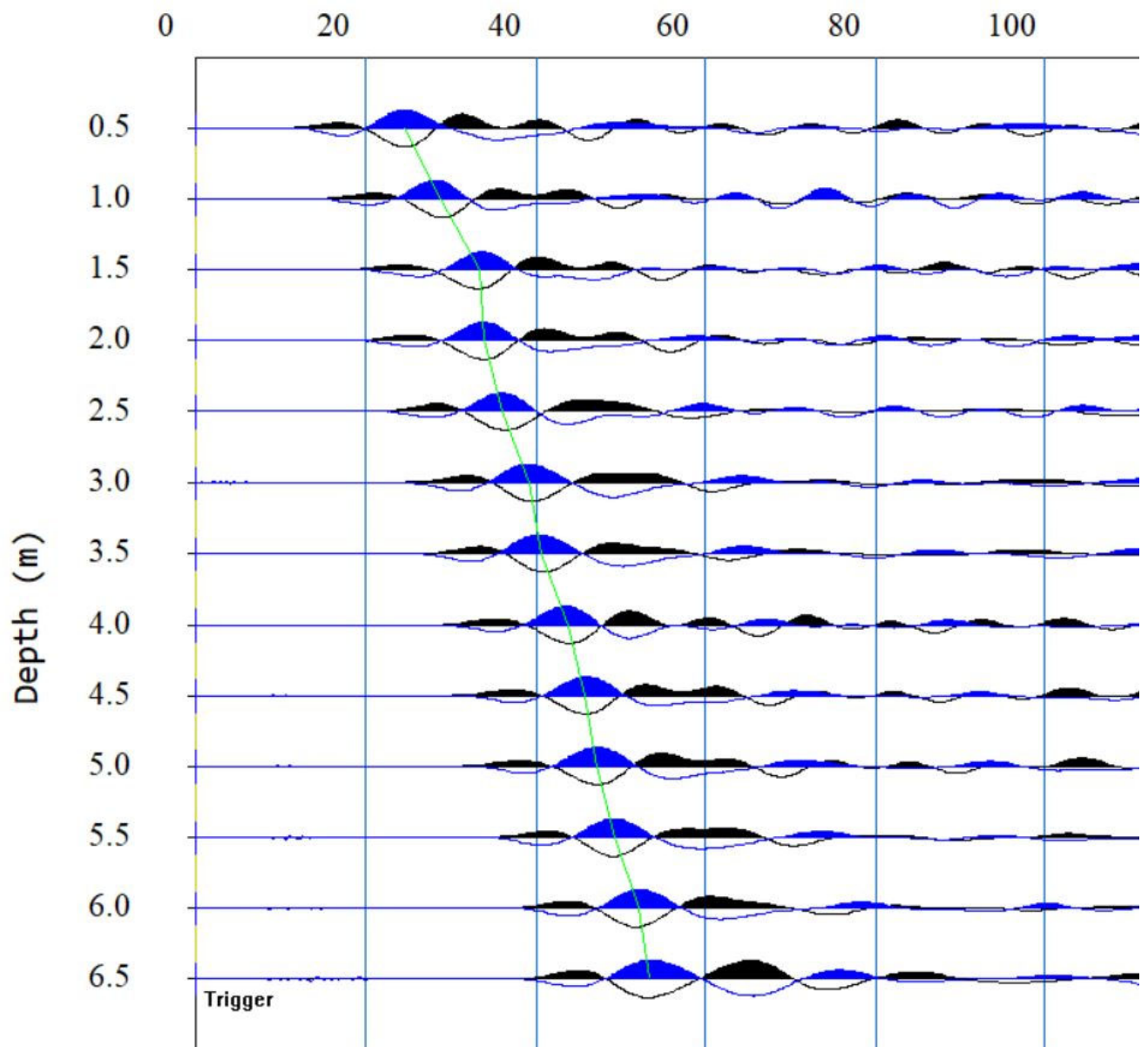
210754

Figure No.

A02



 RDCL				TITLE	BH02 Downhole Trace Gather			
				PROJECT	Rotorua Museum			
DRAWN BY	OG	DATE	12/02/22	CLIENT	Rotorua Lakes Council			
CHECKED BY	KK	DATE	14/02/22	PROJECT No.	210754	Figure No.	A03	



RDCL

TITLE

BH03 Downhole Trace Gather

PROJECT

Rotorua Museum

DRAWN BY

OG

DATE

12/02/22

CLIENT

Rotorua Lakes Council

CHECKED BY

KK

DATE

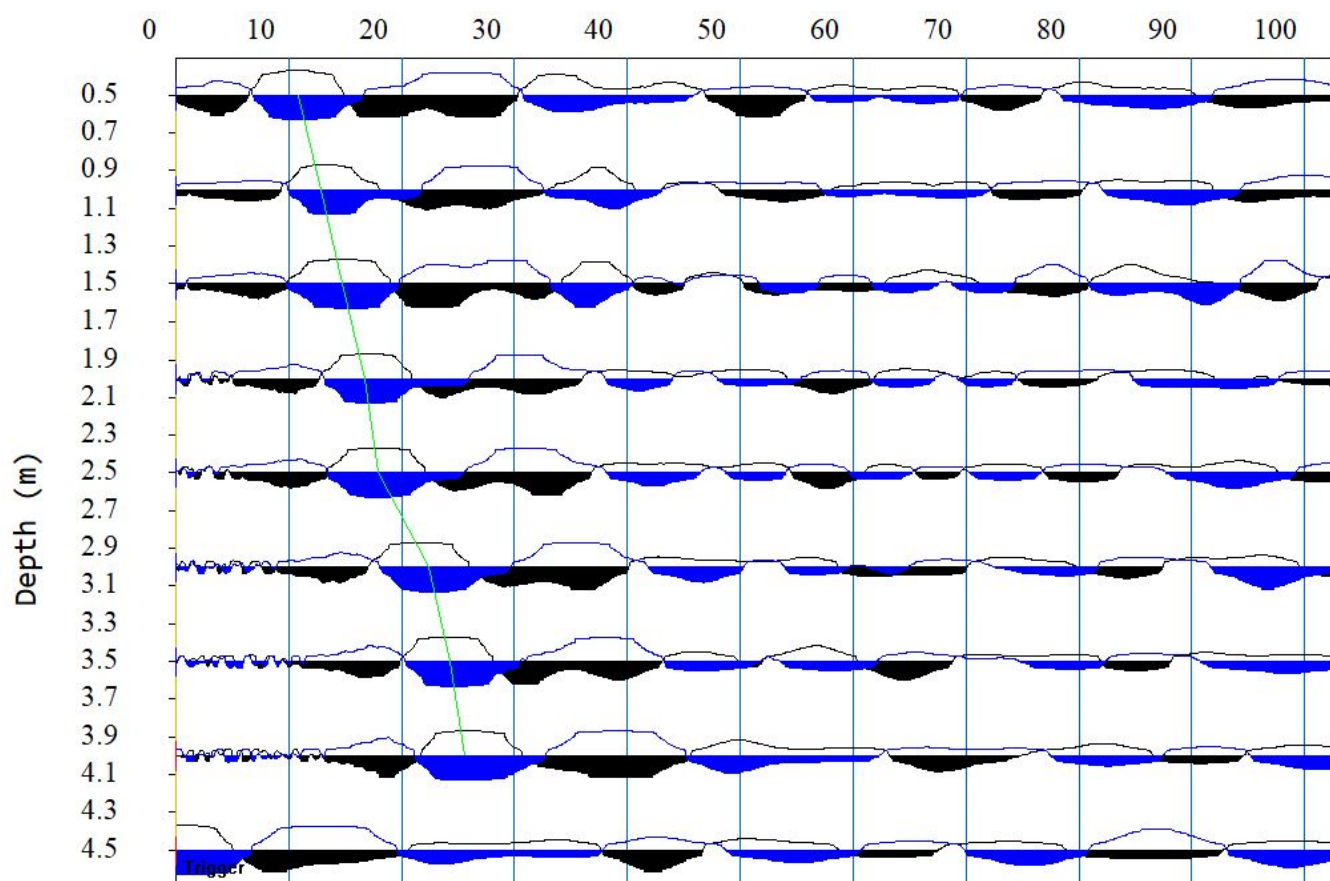
14/02/22

PROJECT No.

210754

Figure No.

A04



RDCL

TITLE

BH06 Downhole Trace Gather

PROJECT

Rotorua Museum

DRAWN BY

OG

DATE

12/02/22

CLIENT

Rotorua Lakes Council

CHECKED BY

KK

DATE

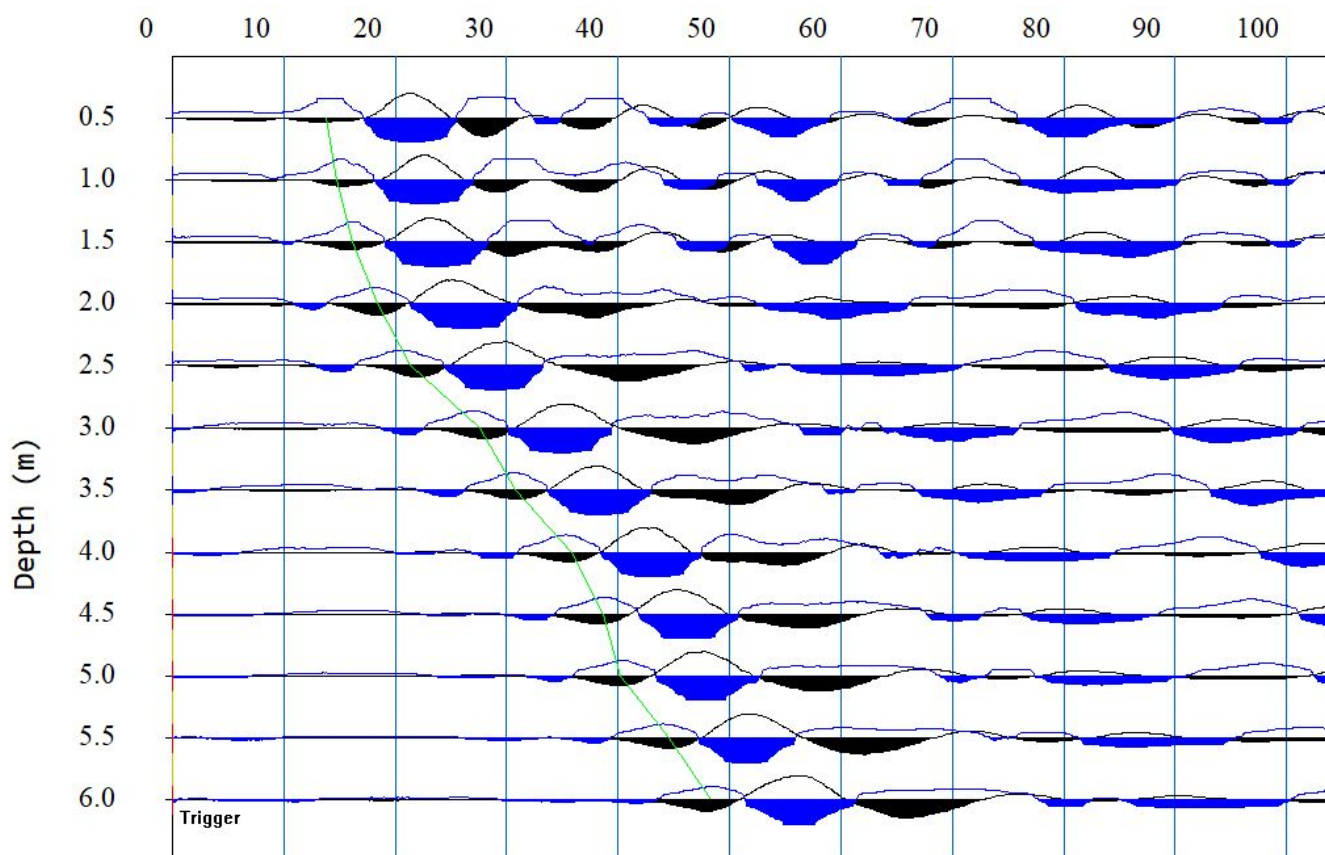
14/02/22

PROJECT No.

210754

Figure No.

A05



RDCL

TITLE

BH07 Downhole Trace Gather

PROJECT

Rotorua Museum

DRAWN BY

OG

DATE

12/02/22

CLIENT

Rotorua Lakes Council

CHECKED BY

KK

DATE

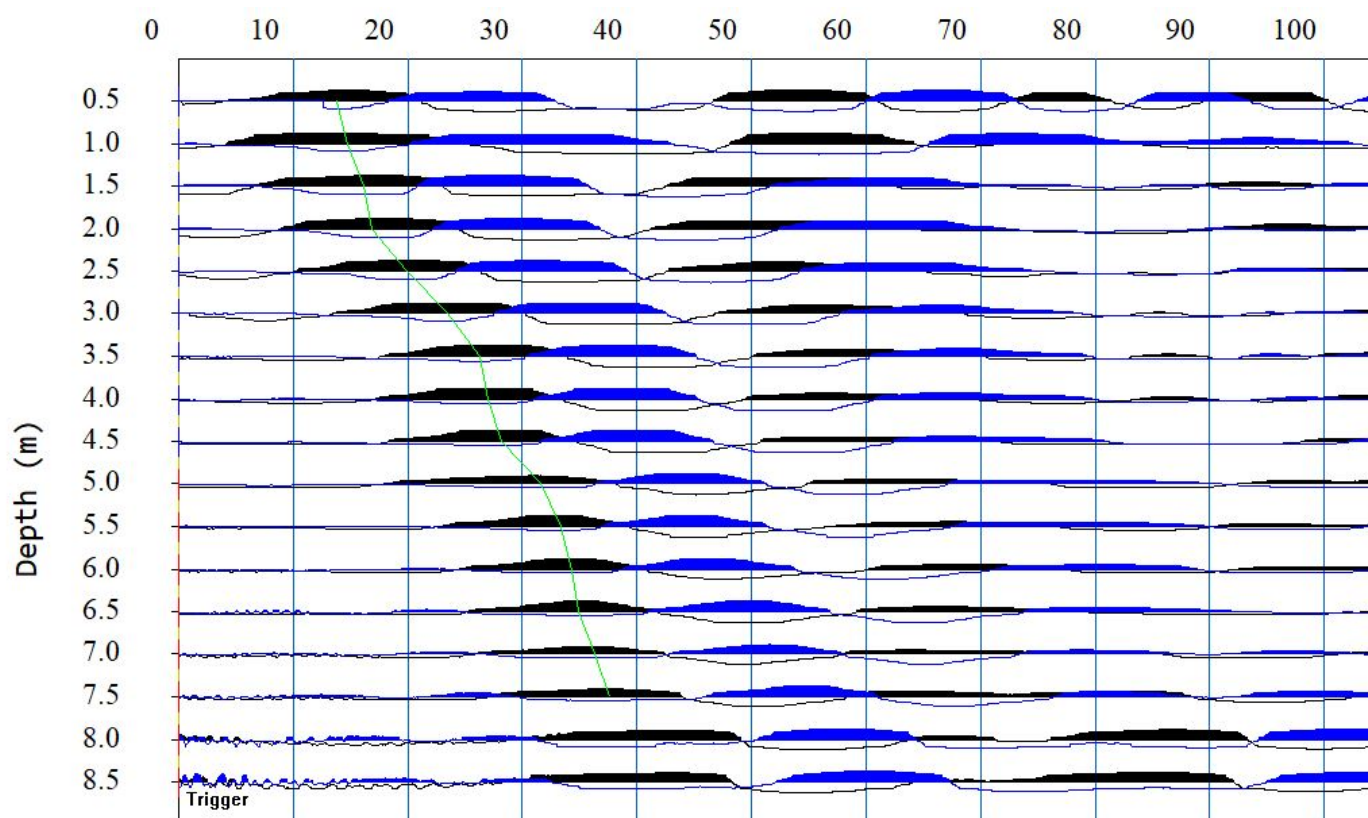
14/02/22

PROJECT No.

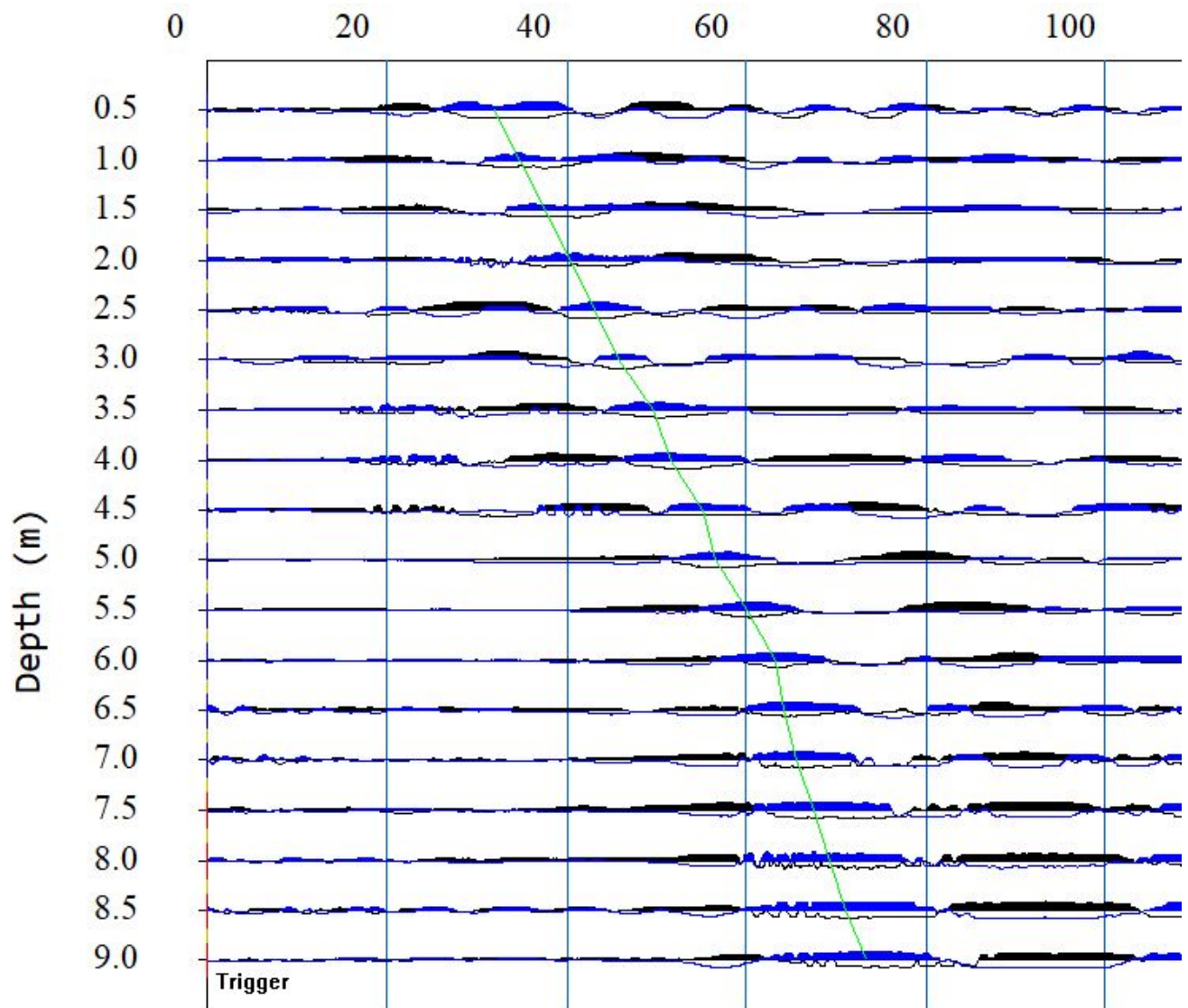
210754

Figure No.

A06



 RDCL				TITLE	BH09 Downhole Trace Gather			
				PROJECT	Rotorua Museum			
DRAWN BY	OG	DATE	12/02/22	CLIENT	Rotorua Lakes Council			
CHECKED BY	KK	DATE	14/02/22	PROJECT No.	210754	Figure No.	A07	



RDCL

TITLE

BH10 Downhole Trace Gather

PROJECT

Rotorua Museum

DRAWN BY

OG

DATE

12/02/22

CLIENT

Rotorua Lakes Council

CHECKED BY

KK

DATE

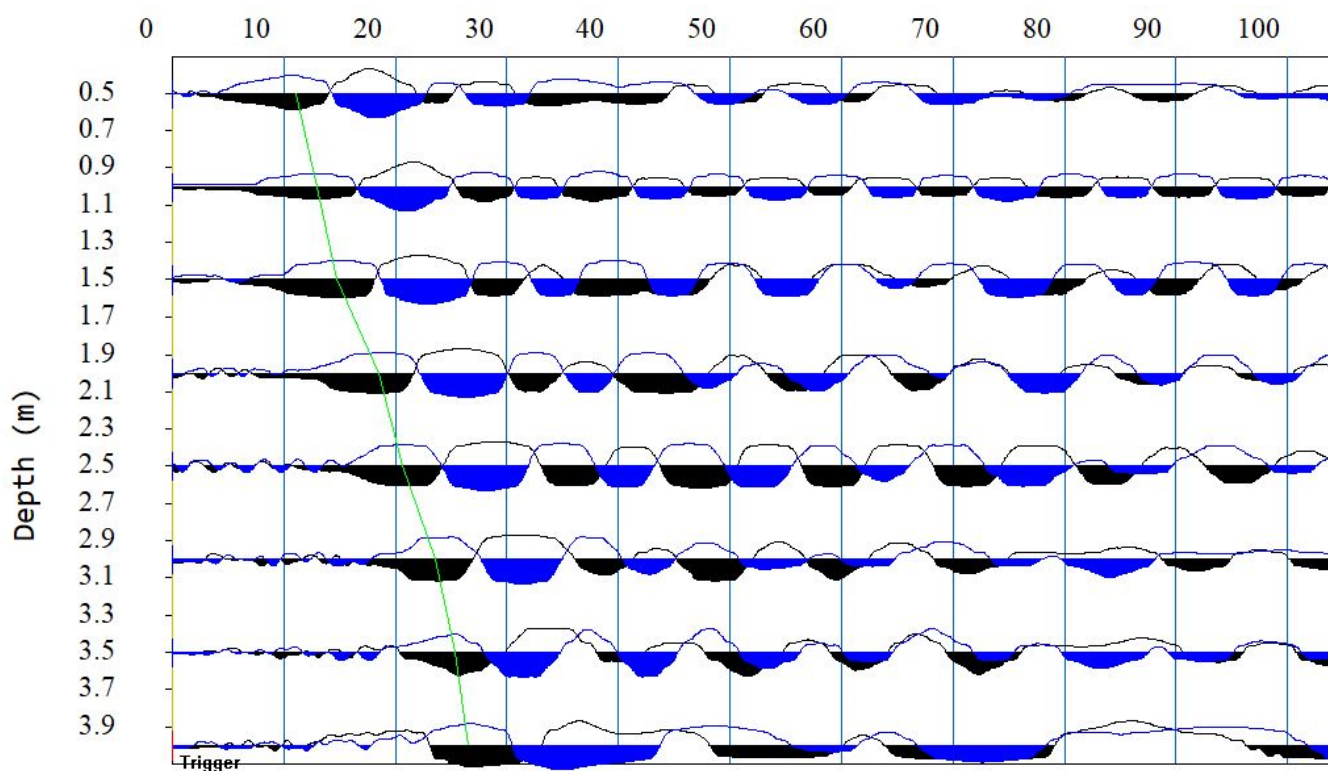
14/02/22

PROJECT No.

210754

Figure No.

A08



RDCL

TITLE

BH11 Downhole Trace Gather

PROJECT

Rotorua Museum

DRAWN BY

OG

DATE

12/02/22

CLIENT

Rotorua Lakes Council

CHECKED BY

KK

DATE

14/02/22

PROJECT No.

210754

Figure No.

A09

APPENDIX B – TABULATED CROSSHOLE VS VALUES

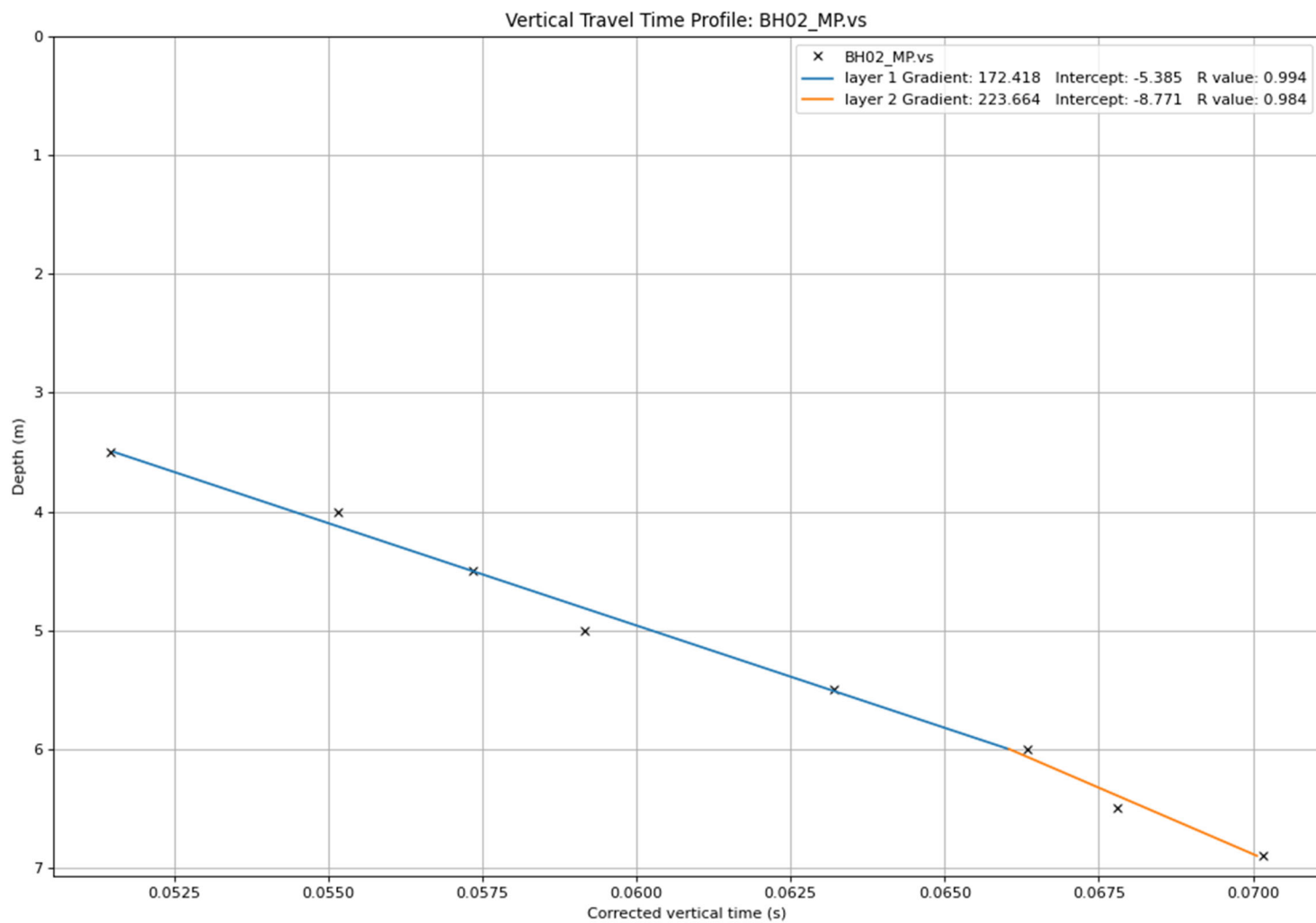
TABLE 1 - TABULATED CROSSHOLE SHEAR WAVE VELOCITY - BH03-BH04

Depth	Velocity - Best	Velocity - Min	Velocity - Max
m	m/s	m/s	m/s
1.0	114	113	115
1.5	114	113	115
2.0	112	112	112
2.5	223	223	225
3.0	236	236	237
3.5	260	260	262
4.0	276	274	278
4.5	270	270	273
5.0	263	262	269
5.5	251	251	256
6.0	280	278	282
6.5	287	286	293
7.0	257	256	260

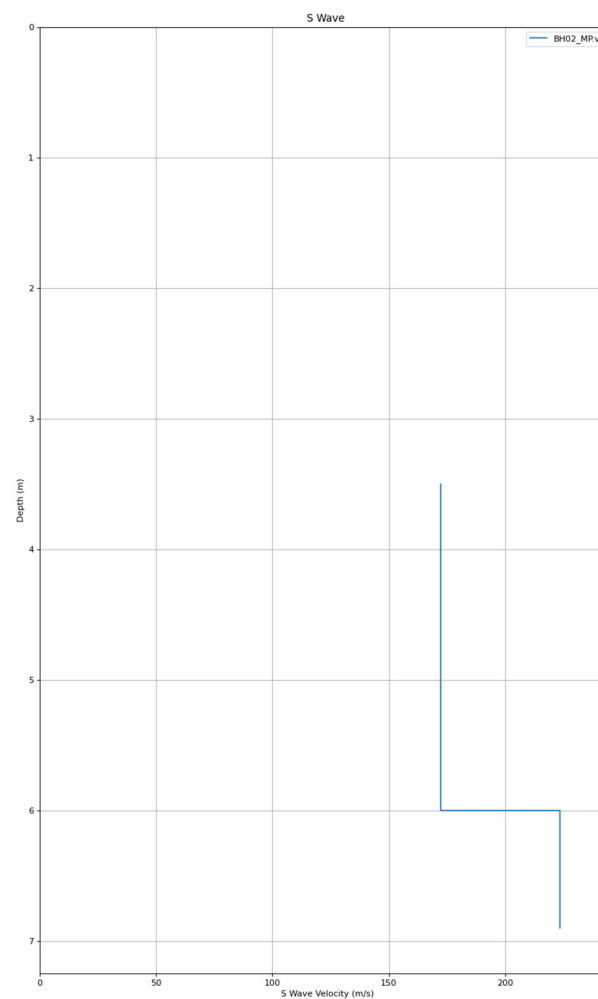
TABLE 2 - TABULATED CROSSHOLE SHEAR WAVE VELOCITY - BH07-BH06

Depth	Velocity - Best	Velocity - Min	Velocity - Max
m	m/s	m/s	m/s
0.5	142	140	142
1.0	145	144	145
1.5	143	139	147
2.0	130	129	132
2.5	110	109	112
3.0	115	113	117
3.5	131	129	134
4.0	128	127	130
4.5	123	122	126

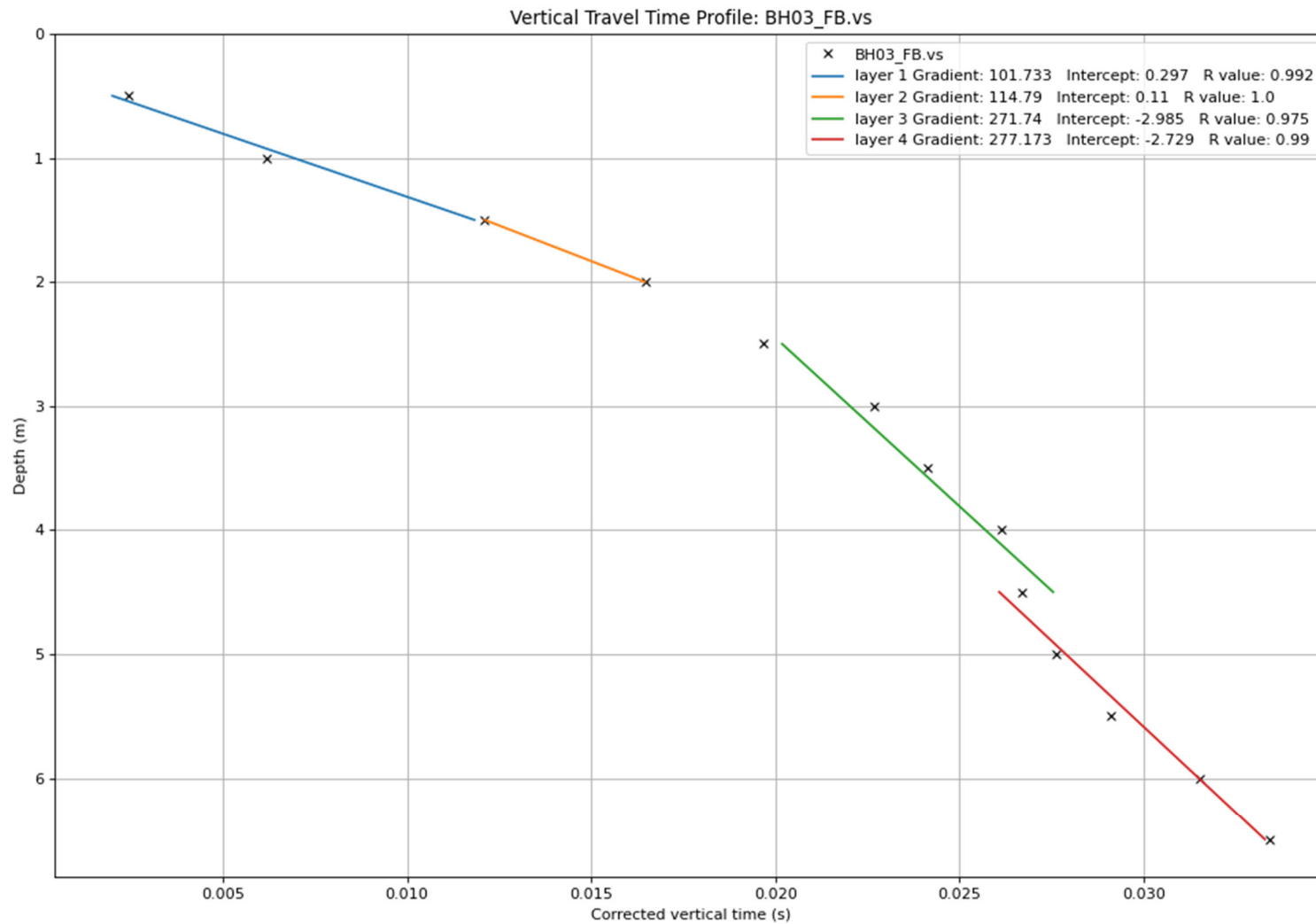
APPENDIX C – DOWNHOLE SEISMIC INTERVAL VELOCITY PLOTS



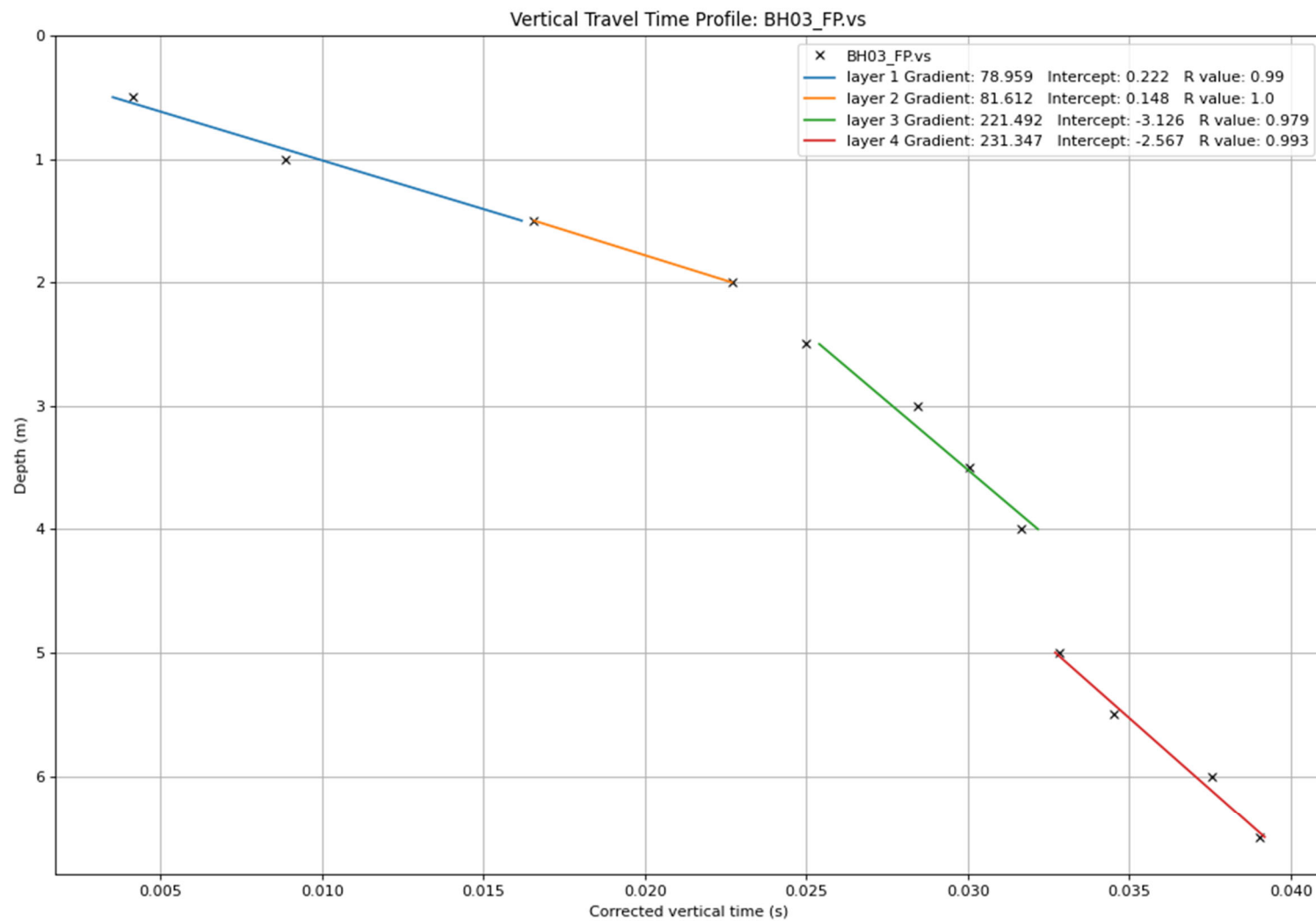
TITLE	BH02—Max Peak Velocity Gradient Calculations	PROJECT	210754				
PROJECT	Rotorua Museum	DRAWN BY	OG	DATE	01/02/22	FIG	
CLIENT	Rotorua Lakes Council	CHECKED BY	KK	DATE	02/02/22	C1	



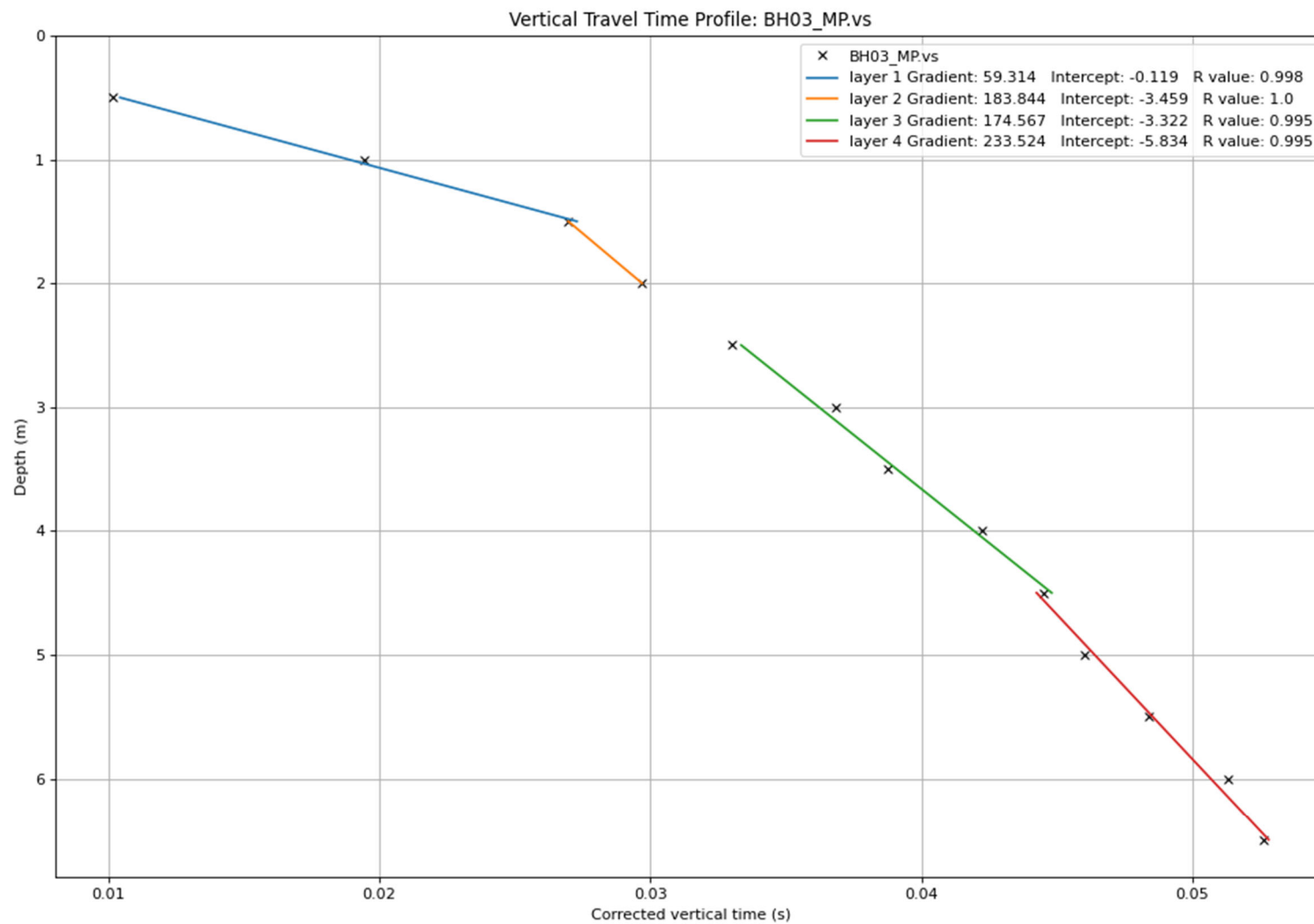
TITLE	BH02— Layer Velocities	PROJECT	210754				
PROJECT	Rotorua Museum	DRAWN BY	OG	DATE	01/02/22	FIG	
CLIENT	Rotorua Lakes Council	CHECKED BY	KK	DATE	02/02/22	C2	



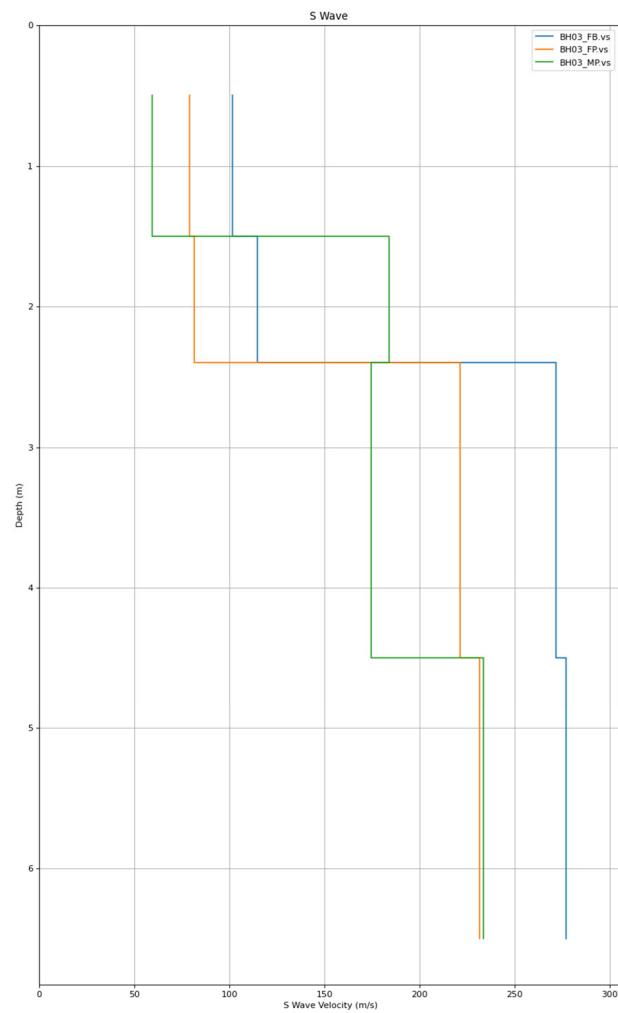
TITLE	BH03—First Break Velocity Gradient Calculations	PROJECT	210754				
PROJECT	Rotorua Museum	DRAWN BY	OG	DATE	01/02/22	FIG	
CLIENT	Rotorua Lakes Council	CHECKED BY	KK	DATE	02/02/22	C3	



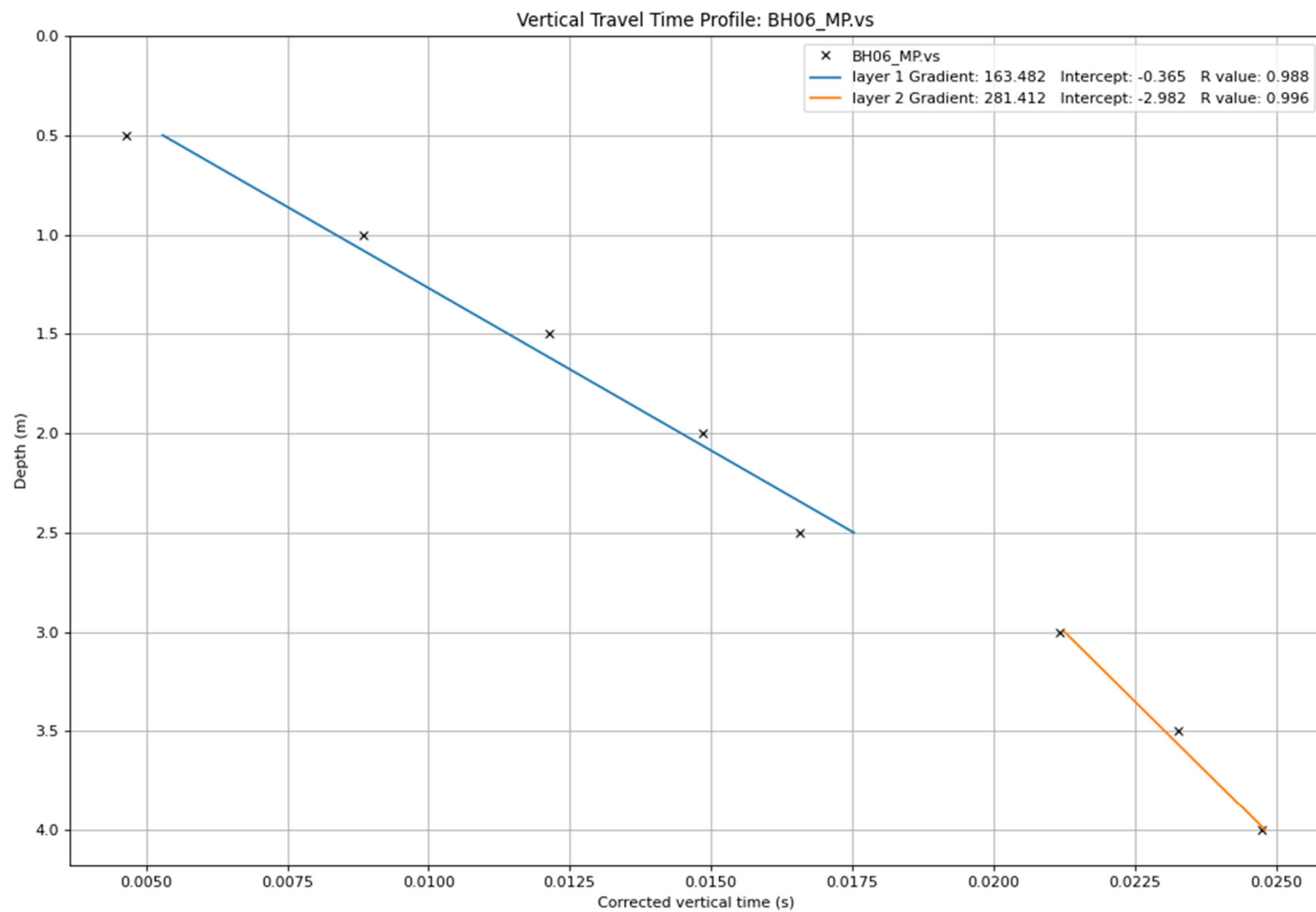
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PROJECT	Rotorua Museum	DRAWN BY	OG	DATE	01/02/22	FIG	
CLIENT	Rotorua Lakes Council	CHECKED BY	KK	DATE	02/02/22	C4	



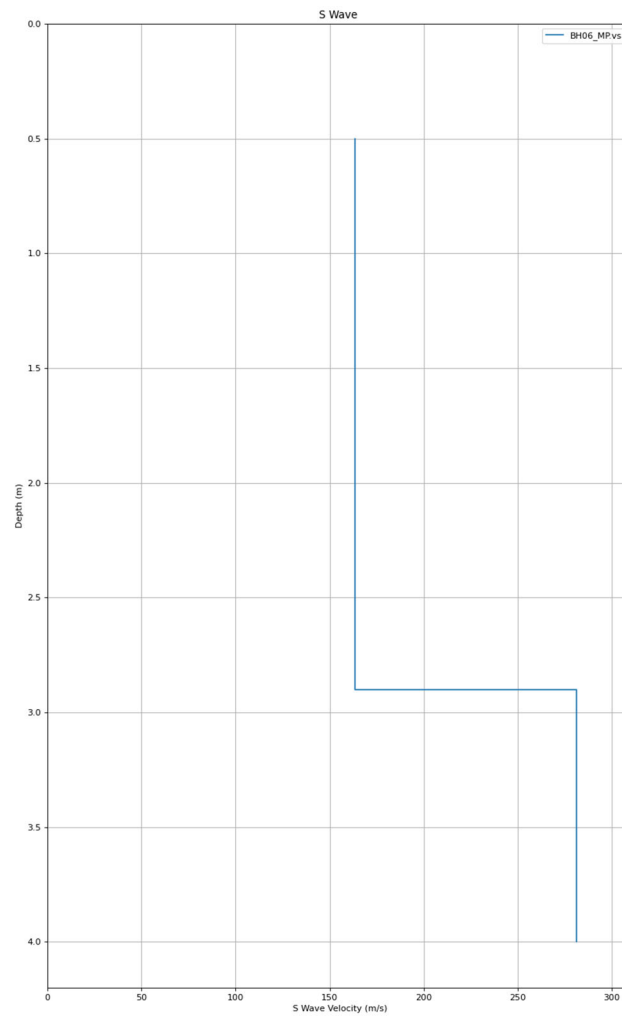
TITLE	BH03—Max Peak Velocity Gradient Calculations	PROJECT	210754				
PROJECT	Rotorua Museum	DRAWN BY	OG	DATE	01/02/22	FIG	
CLIENT	Rotorua Lakes Council	CHECKED BY	KK	DATE	02/02/22	C5	



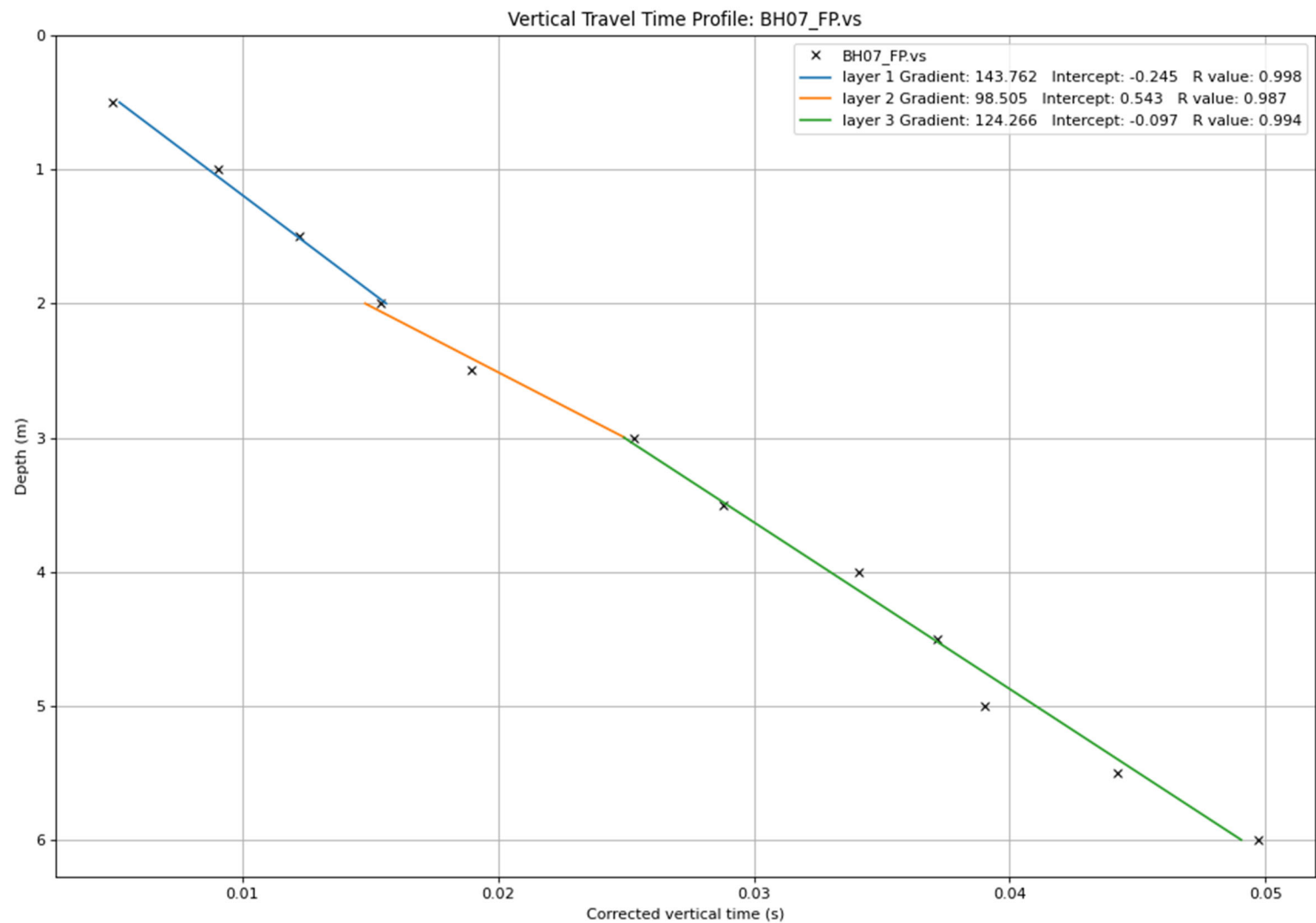
TITLE	BH03—Layer Velocities			PROJECT 210754			
PROJECT	Rotorua Museum			DRAWN BY	OG	DATE 01/02/22	FIG
CLIENT	Rotorua Lakes Council			CHECKED BY	KK	DATE 02/02/22	C6



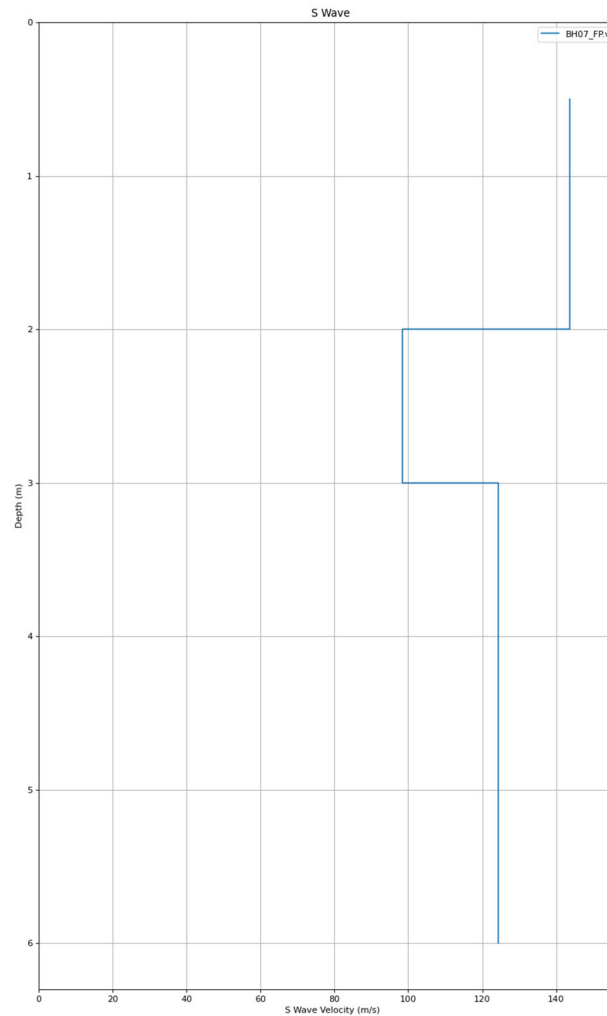
TITLE	BH06—Max Peak Velocity Gradient Calculations			PROJECT	210754			
PROJECT	Rotorua Museum			DRAWN BY	OG	DATE	01/02/22	FIG
CLIENT	Rotorua Lakes Council			CHECKED BY	KK	DATE	02/02/22	C7



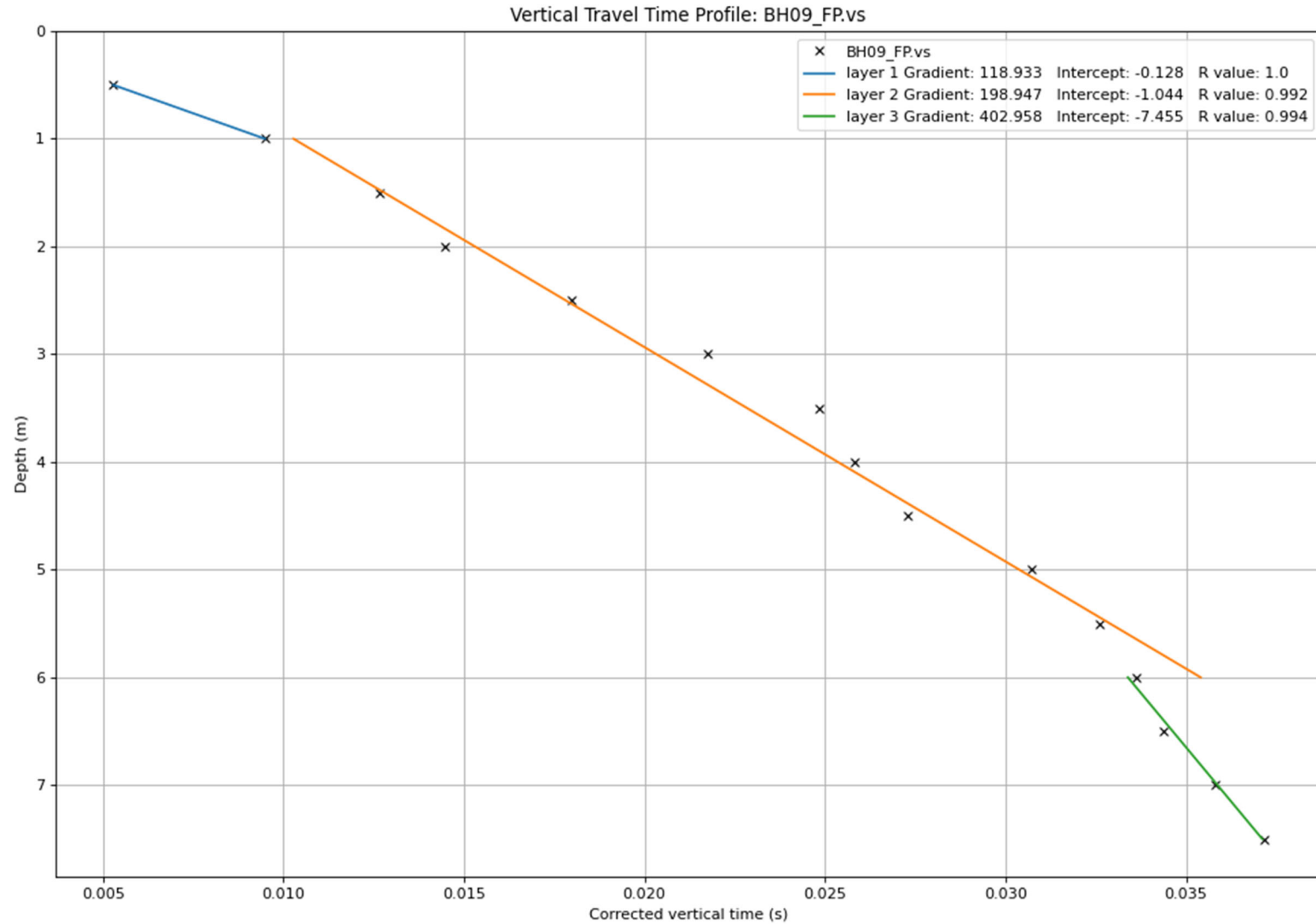
TITLE	BH06—Layer Velocities	PROJECT	210754				
PROJECT	Rotorua Museum	DRAWN BY	OG	DATE	01/02/22	FIG	
CLIENT	Rotorua Lakes Council	CHECKED BY	KK	DATE	02/02/22	C8	



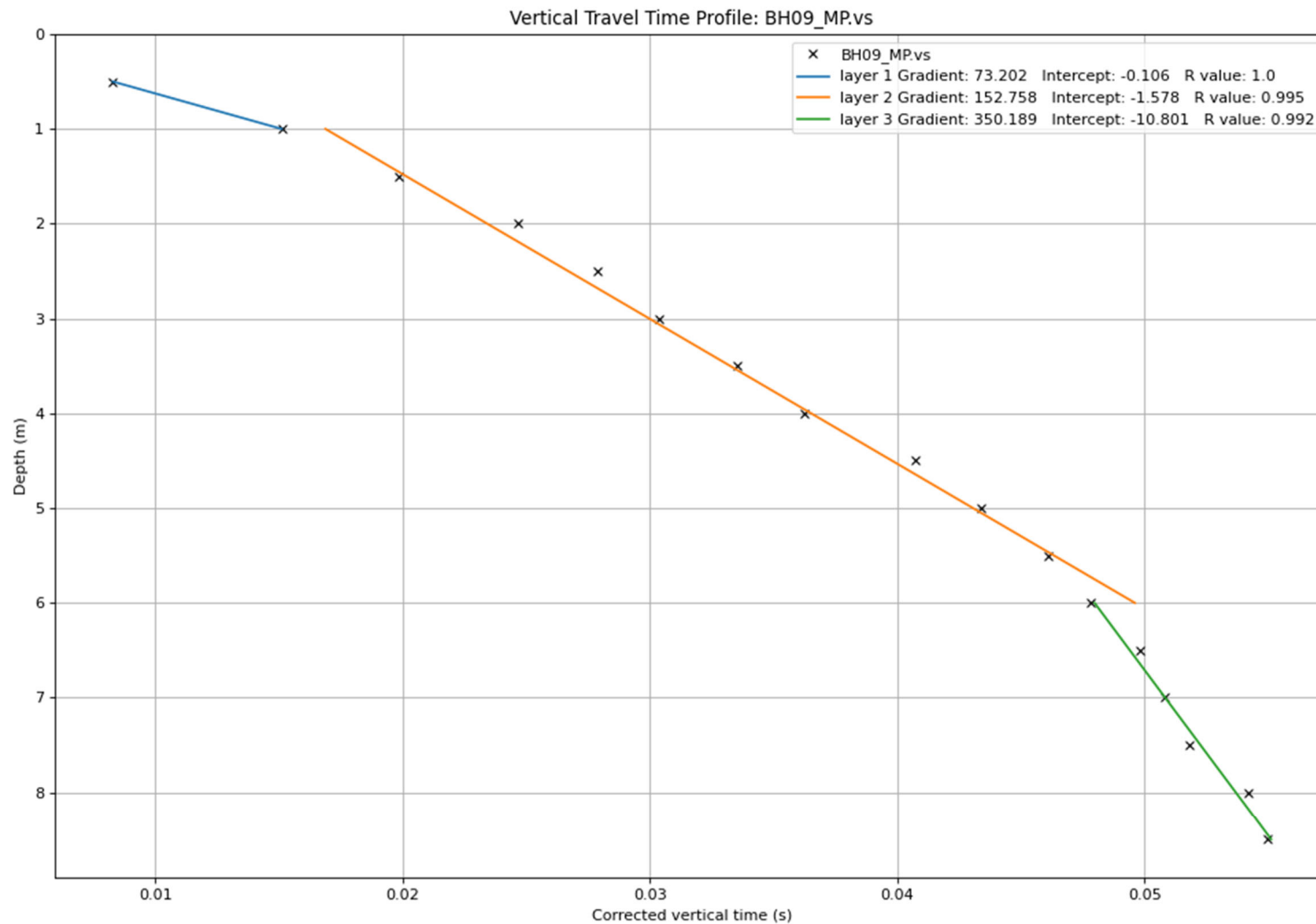
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PROJECT	Rotorua Museum	DRAWN BY	OG	DATE	01/02/22	FIG	
CLIENT	Rotorua Lakes Council	CHECKED BY	KK	DATE	02/02/22	C9	



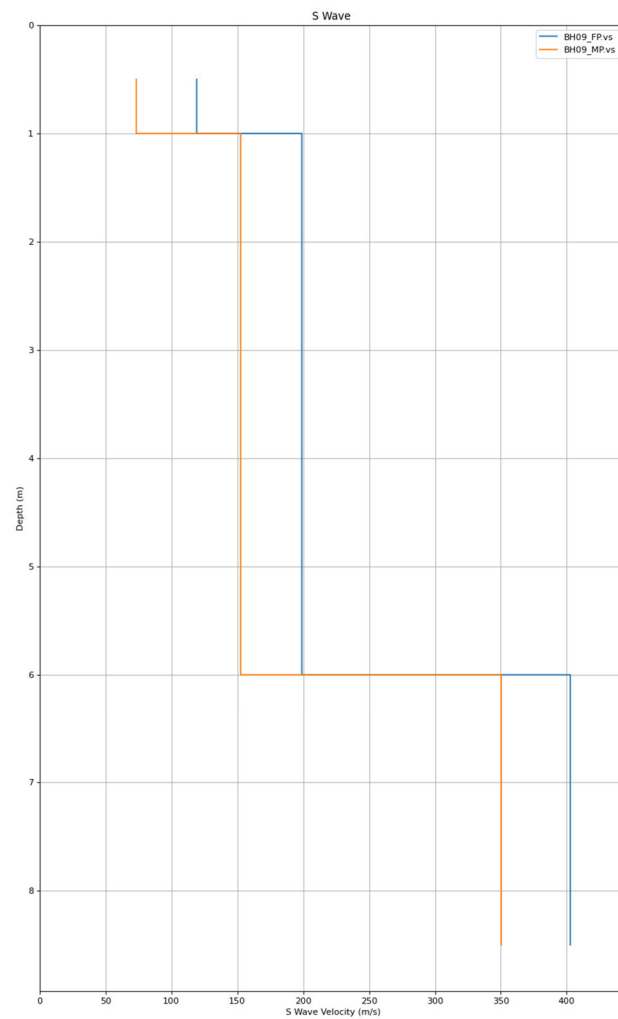
TITLE	BH07—Layer Velocities	PROJECT	210754				
PROJECT	Rotorua Museum	DRAWN BY	OG	DATE	01/02/22	FIG	
CLIENT	Rotorua Lakes Council	CHECKED BY	KK	DATE	02/02/22	C10	



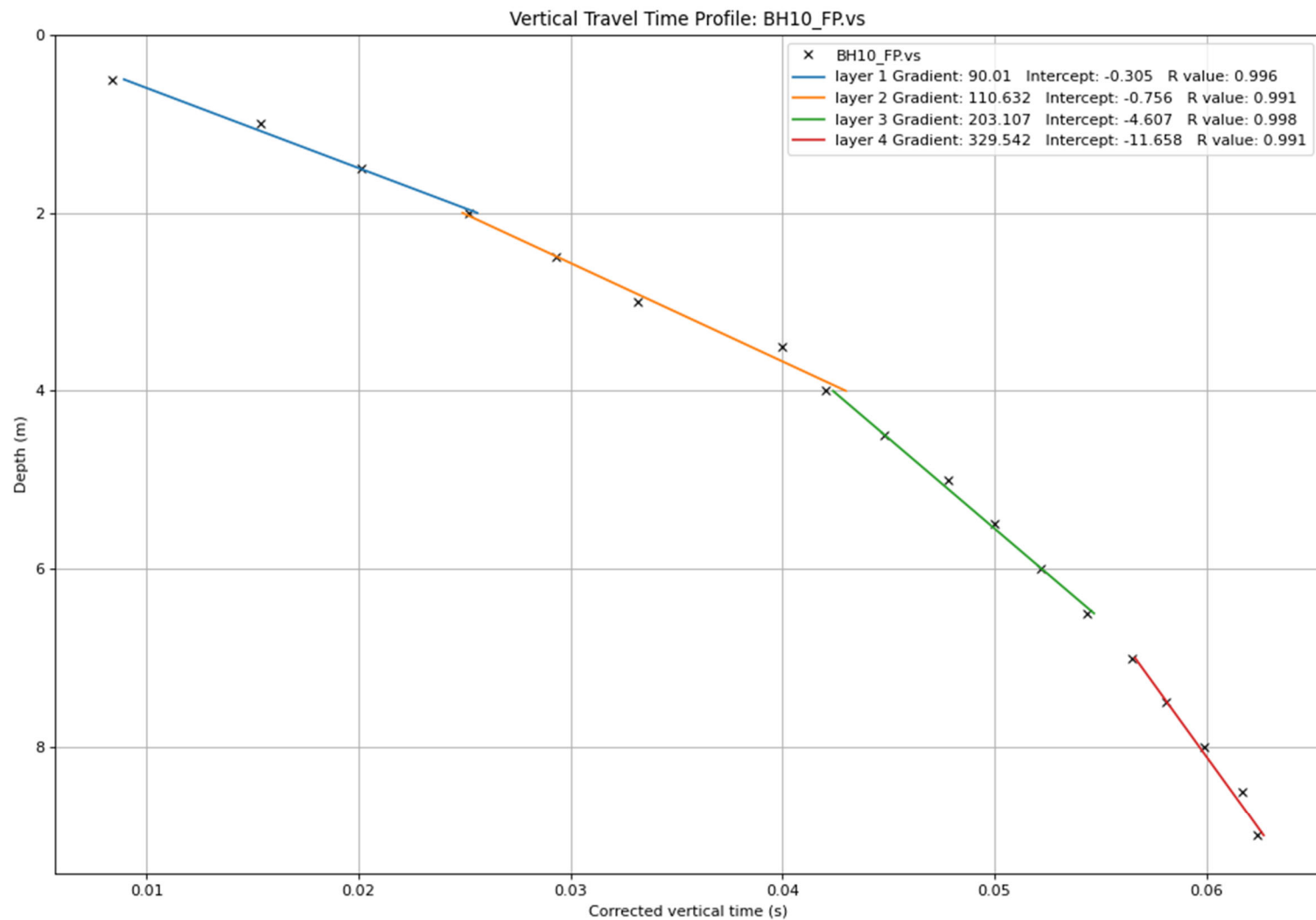
TITLE	BH09—First Peak Velocity Gradient Calculations	PROJECT	210754				
PROJECT	Rotorua Museum	DRAWN BY	OG	DATE	01/02/22	FIG	
CLIENT	Rotorua Lakes Council	CHECKED BY	KK	DATE	02/02/22	C11	



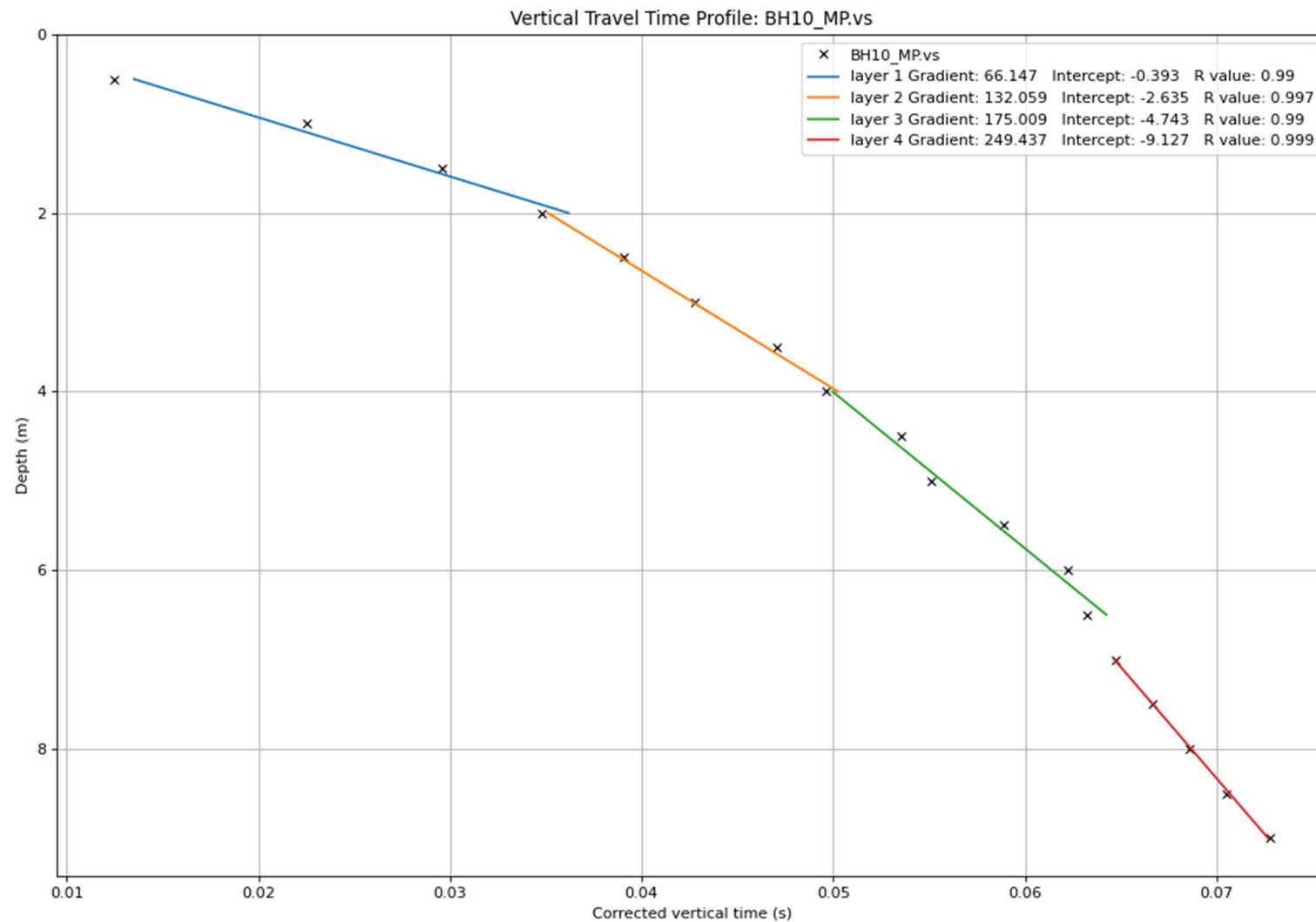
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PROJECT	Rotorua Museum	DRAWN BY	OG	DATE	01/02/22	FIG	
CLIENT	Rotorua Lakes Council	CHECKED BY	KK	DATE	02/02/22	C12	



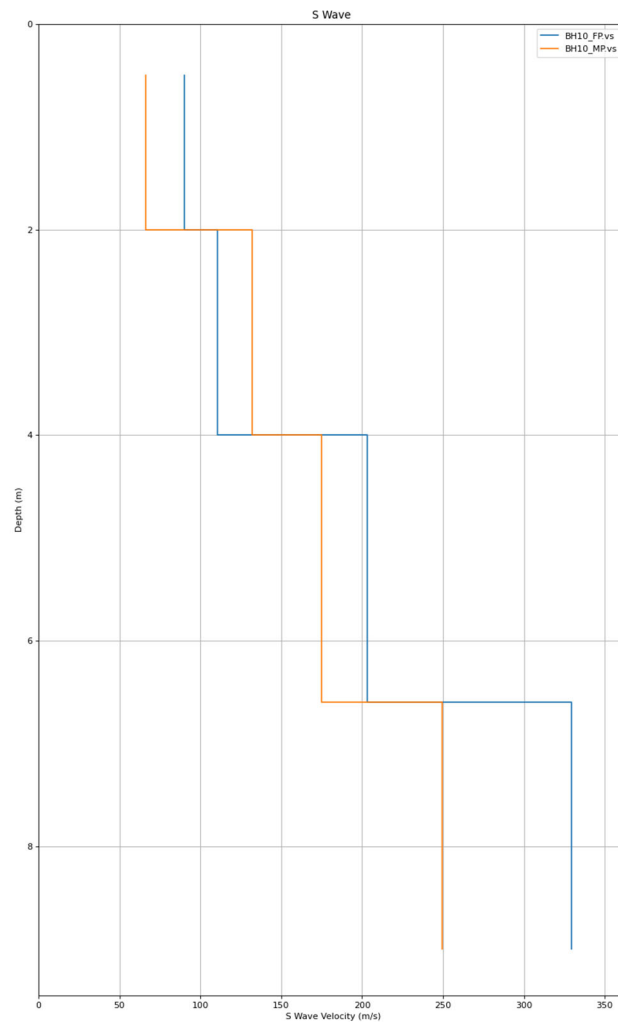
TITLE	BH09—Layer Velocities	PROJECT	210754				
PROJECT	Rotorua Museum	DRAWN BY	OG	DATE	01/02/22	FIG	
CLIENT	Rotorua Lakes Council	CHECKED BY	KK	DATE	02/02/22	C13	



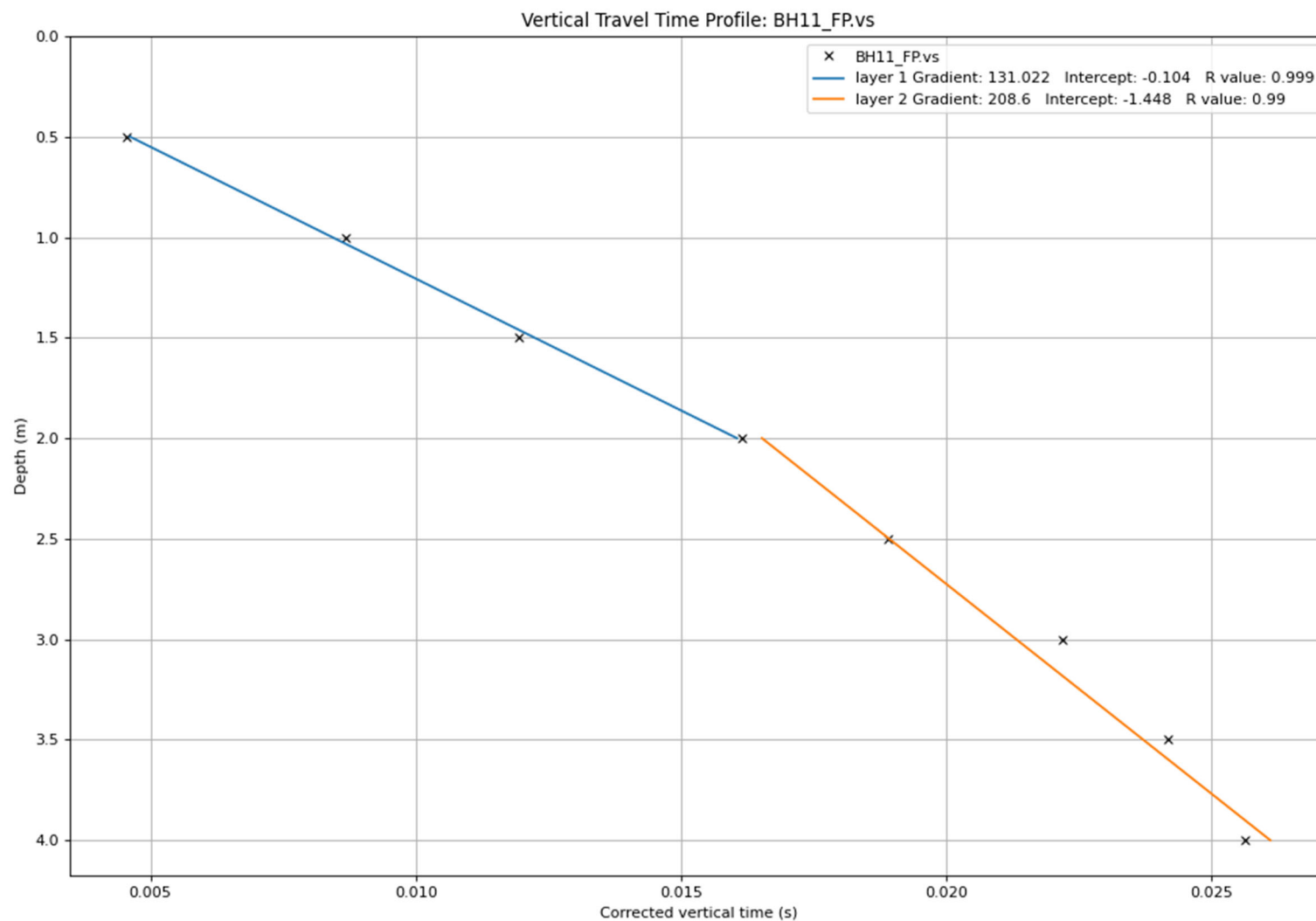
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PROJECT	Rotorua Museum	DRAWN BY	OG	DATE	01/02/22	FIG	
CLIENT	Rotorua Lakes Council	CHECKED BY	KK	DATE	02/02/22	C14	



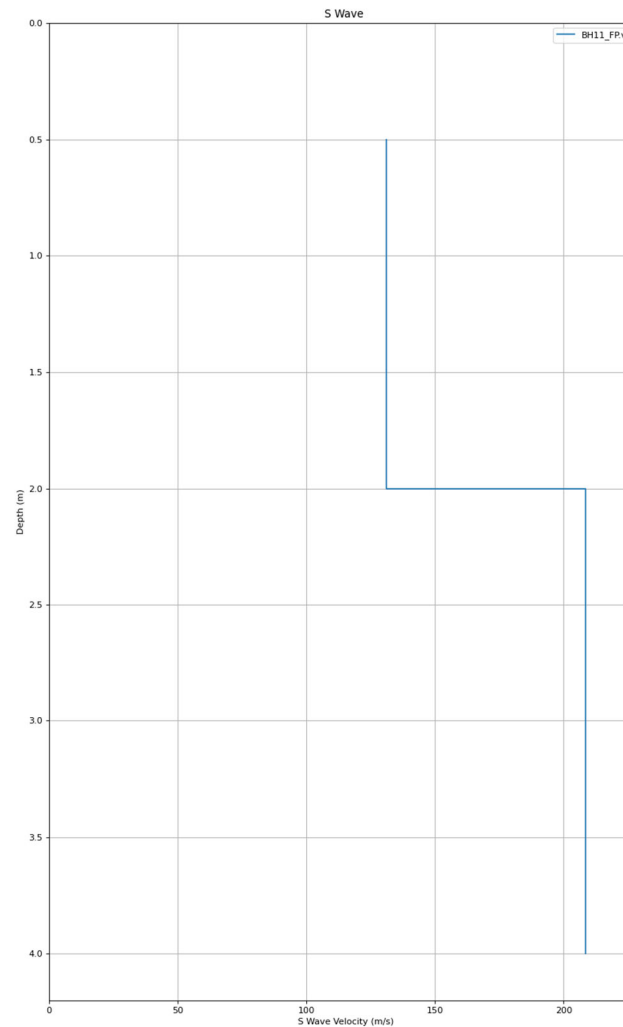
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PROJECT	Rotorua Museum	DRAWN BY	OG	DATE	01/02/22	FIG	
CLIENT	Rotorua Lakes Council	CHECKED BY	KK	DATE	02/02/22	C15	



TITLE	BH10—Layer Velocities			PROJECT 210754			
PROJECT	Rotorua Museum			DRAWN BY	OG	DATE 01/02/22	FIG
CLIENT	Rotorua Lakes Council			CHECKED BY	KK	DATE 02/02/22	C16



TITLE	BH11—First Peak Velocity Gradient Calculations	PROJECT	210754				
PROJECT	Rotorua Museum	DRAWN BY	OG	DATE	01/02/22	FIG	
CLIENT	Rotorua Lakes Council	CHECKED BY	KK	DATE	02/02/22	C17	



TITLE	BH11—Layer velocities	PROJECT	210754				
PROJECT	Rotorua Museum	DRAWN BY	OG	DATE	01/02/22	FIG	
CLIENT	Rotorua Lakes Council	CHECKED BY	KK	DATE	02/02/22	C18	

APPENDIX D – TABULATED DOWNHOLE SEISMIC SHEAR WAVE VELOCITIES

TABLE 1 - TABULATED DOWNHOLE SHEAR WAVE VELOCITY - BH02

From	To	Vs – Max Peak
m	m	m/s
3.5	6.0	172
6.0	7.0	224

TABLE 2 - TABULATED DOWNHOLE SHEAR WAVE VELOCITY - BH03

From	To	Vs – First Break	Vs – First Peak	Vs – Max Peak
m	m	m/s	m/s	m/s
0.5	1.5	102	79	59
1.5	2.0	115	82	184
2.0	4.5	272	221	174
4.5	65	277	231	233

TABLE 3 - TABULATED DOWNHOLE SHEAR WAVE VELOCITY - BH06

From	To	Vs – Max Peak
m	m	m/s
0.5	2.5	163
2.5	4.0	281

TABLE 4 - TABULATED DOWNHOLE SHEAR WAVE VELOCITY - BH07

From	To	Vs – First Peak
m	m	m/s
0.5	2.0	144
2.0	3.0	96
3.0	6.0	124

TABLE 5 - TABULATED DOWNHOLE SHEAR WAVE VELOCITY - BH09

From	To	Vs – First Peak	Vs – Max Peak
m	m	m/s	m/s
0.5	1.0	119	73
1.0	6.0	199	153
6.0	7.5	403	350

TABLE 6 - TABULATED DOWNHOLE SHEAR WAVE VELOCITY – BH10

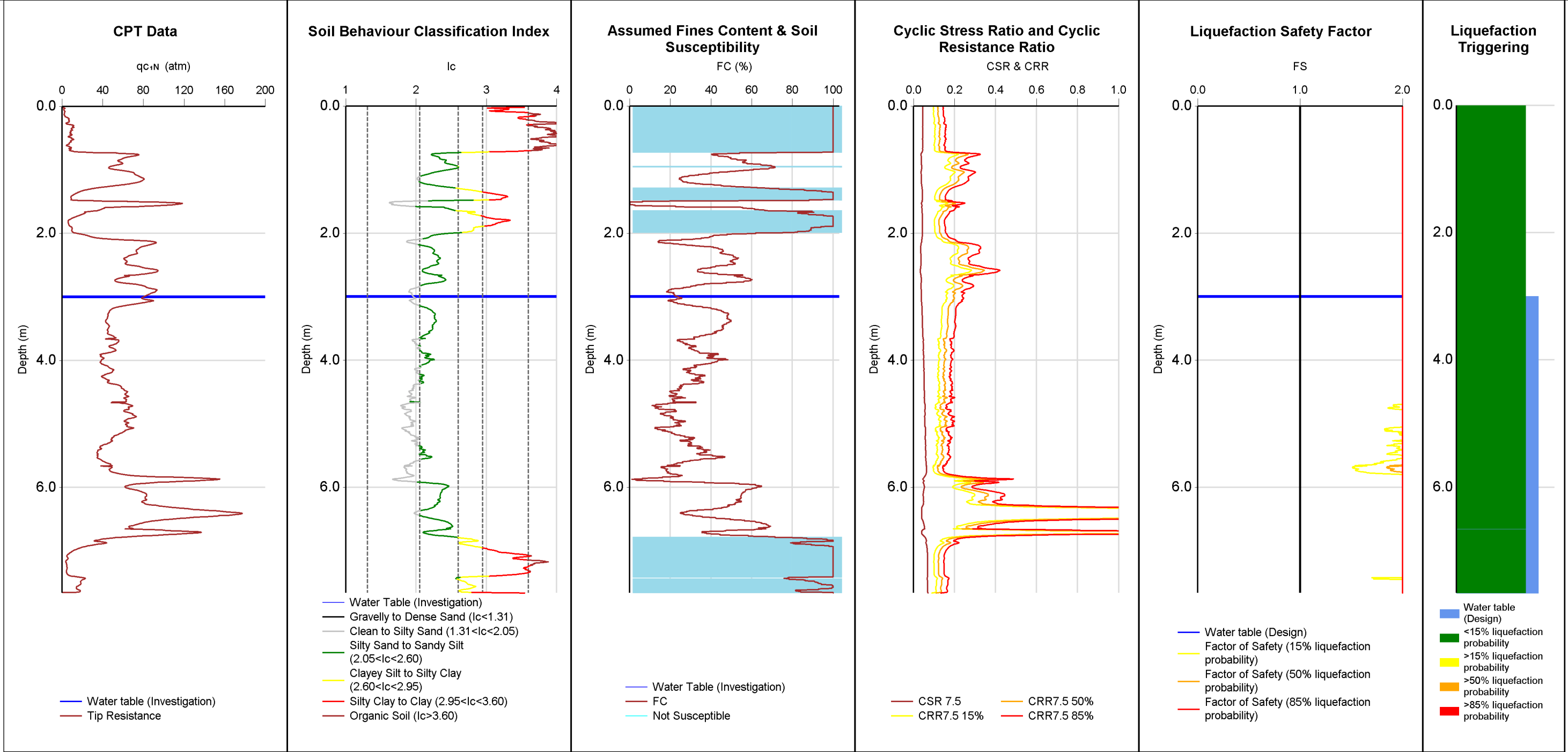
From	To	Vs – First Peak	Vs – Max Peak
m	m	m/s	m/s
0.5	2.0	90	66
2.0	4.0	111	132
4.0	7.0	203	175
7.0	9.0	330	249

TABLE 7 - TABULATED DOWNHOLE SHEAR WAVE VELOCITY – BH11

From	To	Vs – First Peak
m	m	m/s
0.5	2.0	131
2.0	4.0	209

Appendix D: Liquefaction triggering analysis output

Serviceability limit state - 1 in 25 year return period earthquake

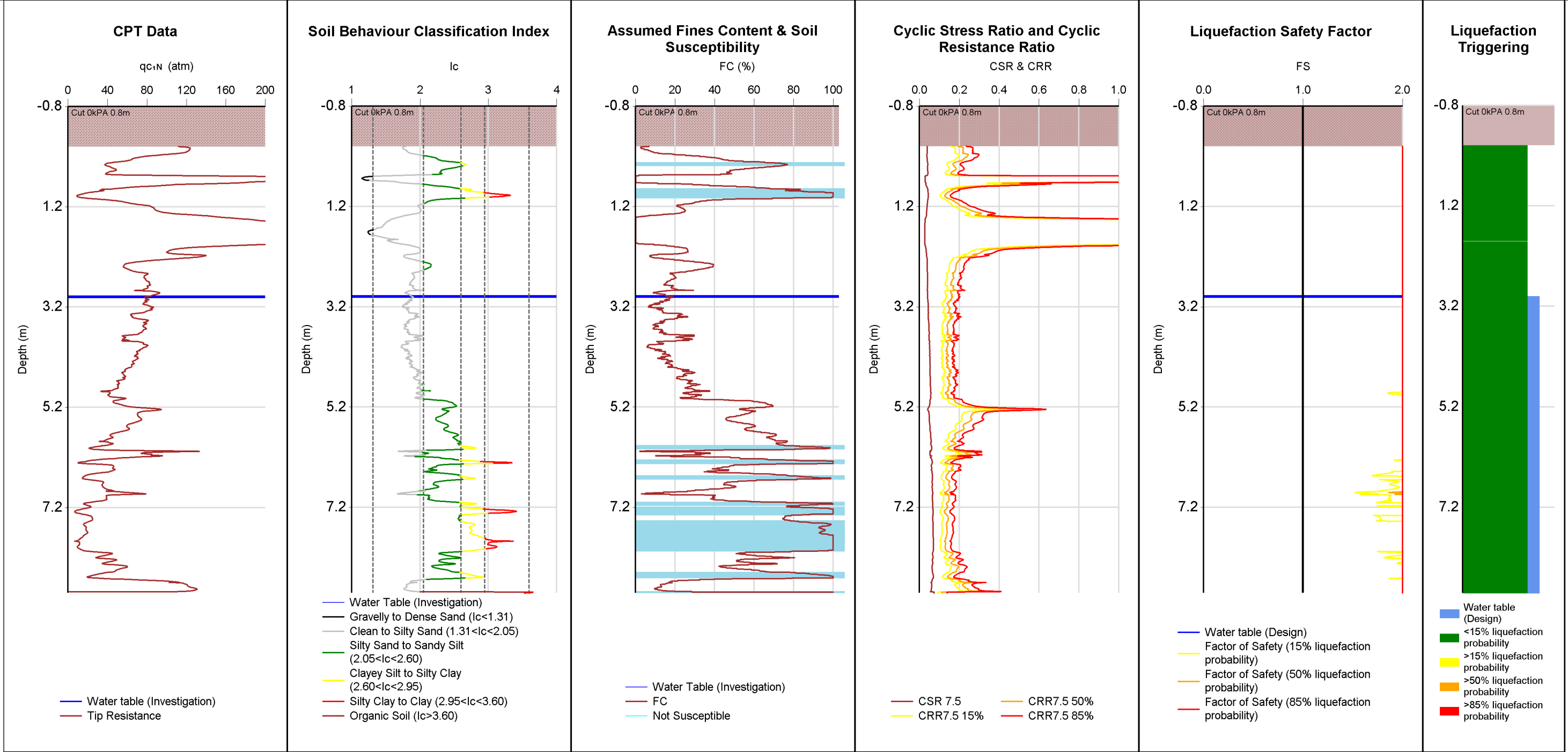


Note: Raw Qc/Fs data used.

INPUT		Run Description	TTGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m ³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
		Terrane_CPT01	178807	8/06/2007	0	6	0.08	BI-2014	ZRB-2002	14		0	
OUTPUT		PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish					
		15%	1	0	0	0	7.7	0					
		50%	0	0	0	0	7.7	0					
		85%	0	0	0	0	7.7	0					

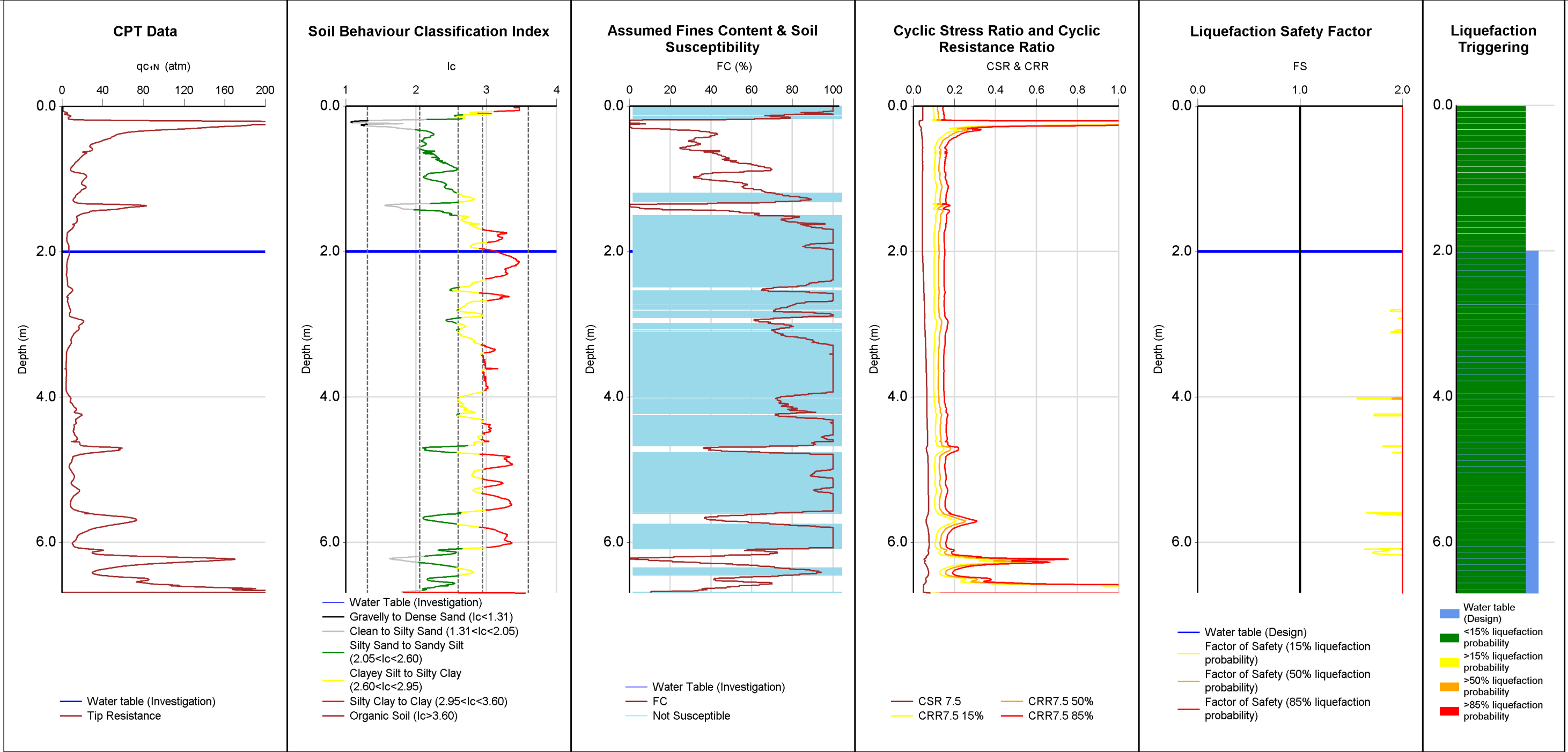
Reviewed by:

CPT Inversion	YUNI
Groundwater	YUNI
Susceptibility	YUNI
Triggering	YUNI
Consequence	YUNI



Note: Raw Qc/Fs data, Cut used.

INPUT		Run Description	TTGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m ³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
		Terrane_CPT02_0.8m cut	178808	8/06/2007	0	6	0.08	BI-2014	ZRB-2002	14	Cut	0	-0.8
OUTPUT		PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish	Reviewed by:				
		15%	1	0	0	0	8.9	0	CPT Inversion	YUNI			
		50%	0	0	0	0	8.9	0	Groundwater	YUNI			
		85%	0	0	0	0	8.9	0	Susceptibility	YUNI			
									Triggering	YUNI			

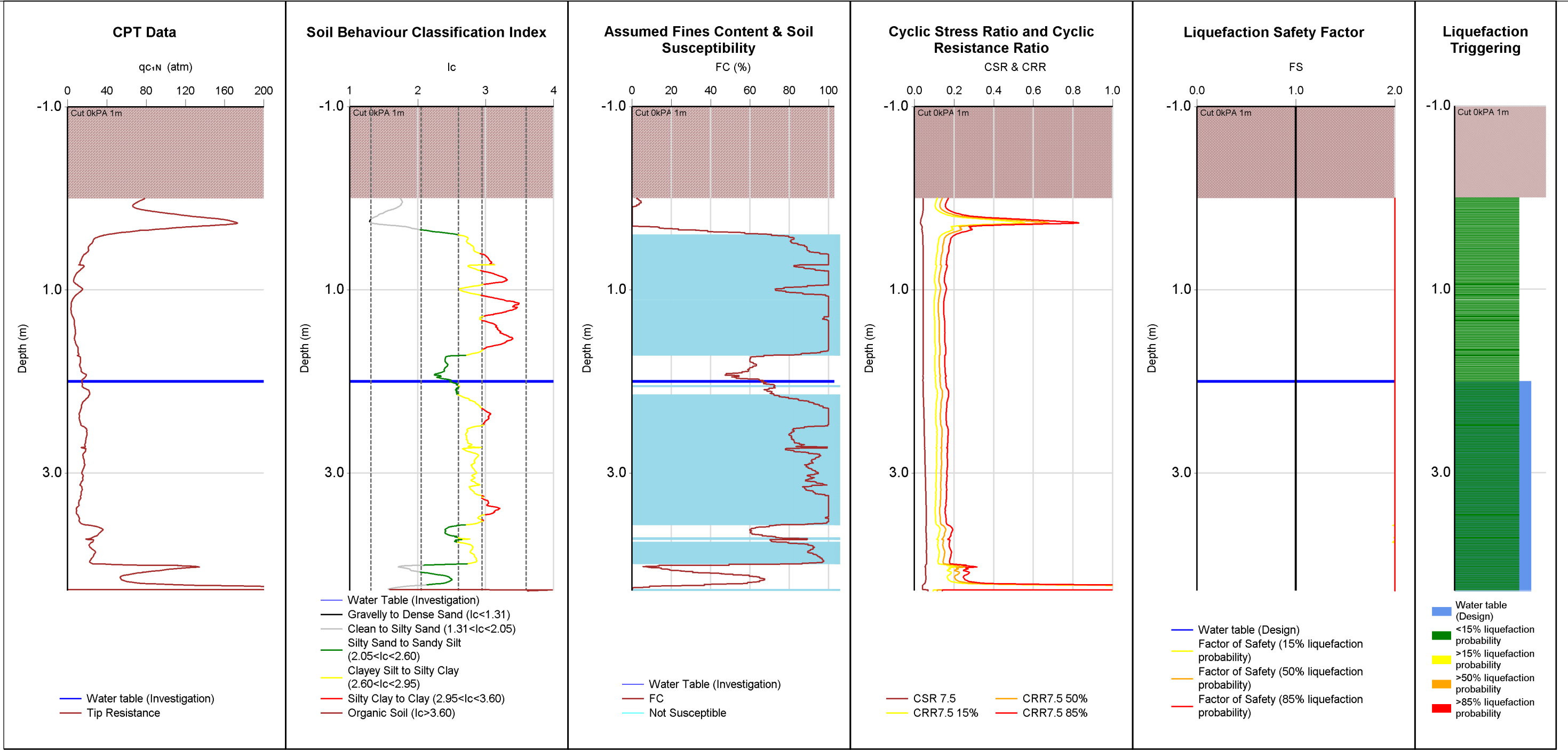


Note: Raw Qc/Fs data used.

INPUT	Run Description		TTGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m ³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	Terrane_CPT03		178809	8/06/2007	0	6	0.08	BI-2014	ZRB-2002	14		0	
OUTPUT	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish						
	15%	0	0	0	0	6.7	0						
	50%	0	0	0	0	6.7	0						
	85%	0	0	0	0	6.7	0						

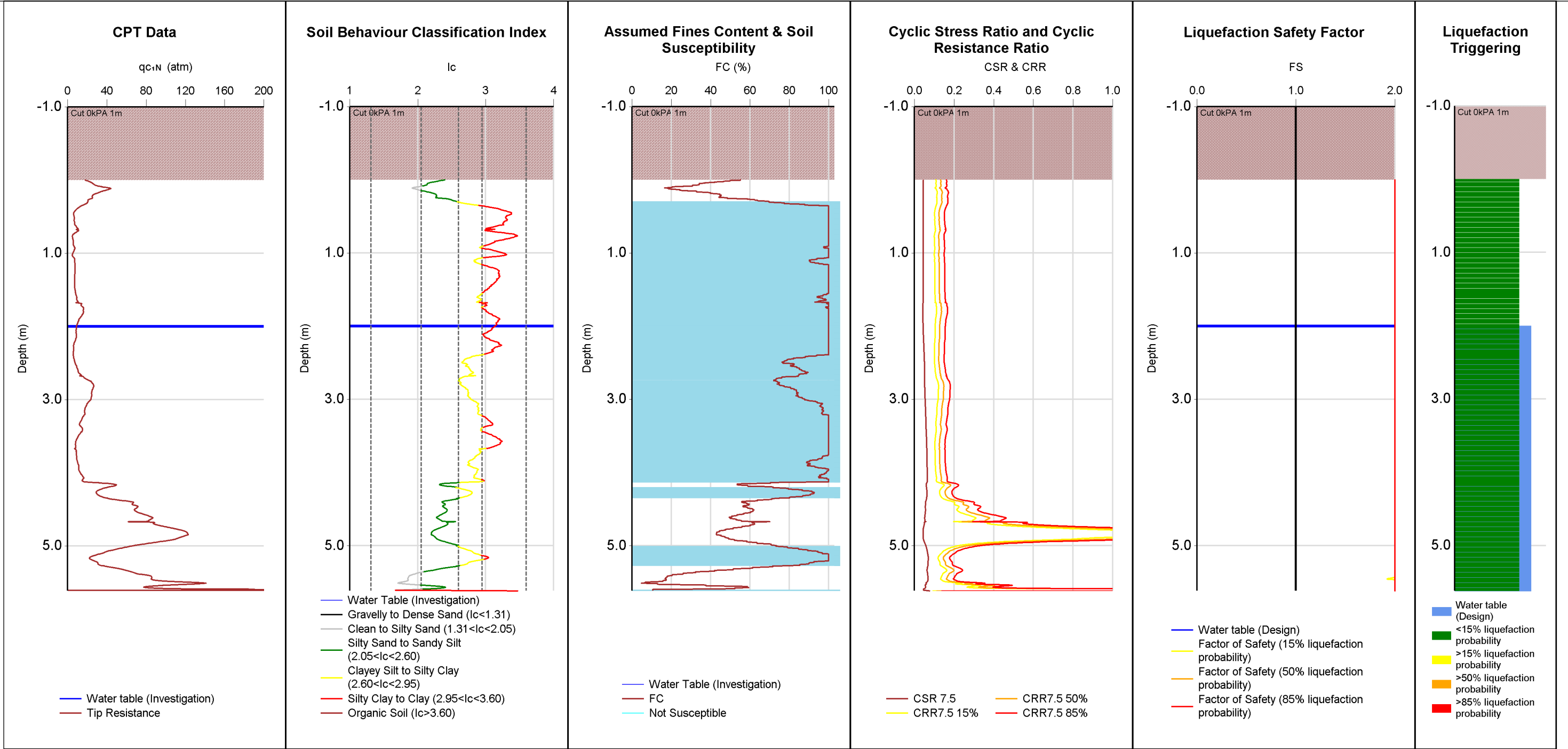
Reviewed by:

CPT Inversion	YUNI
Groundwater	YUNI
Susceptibility	YUNI
Triggering	YUNI
Consequence	YUNI



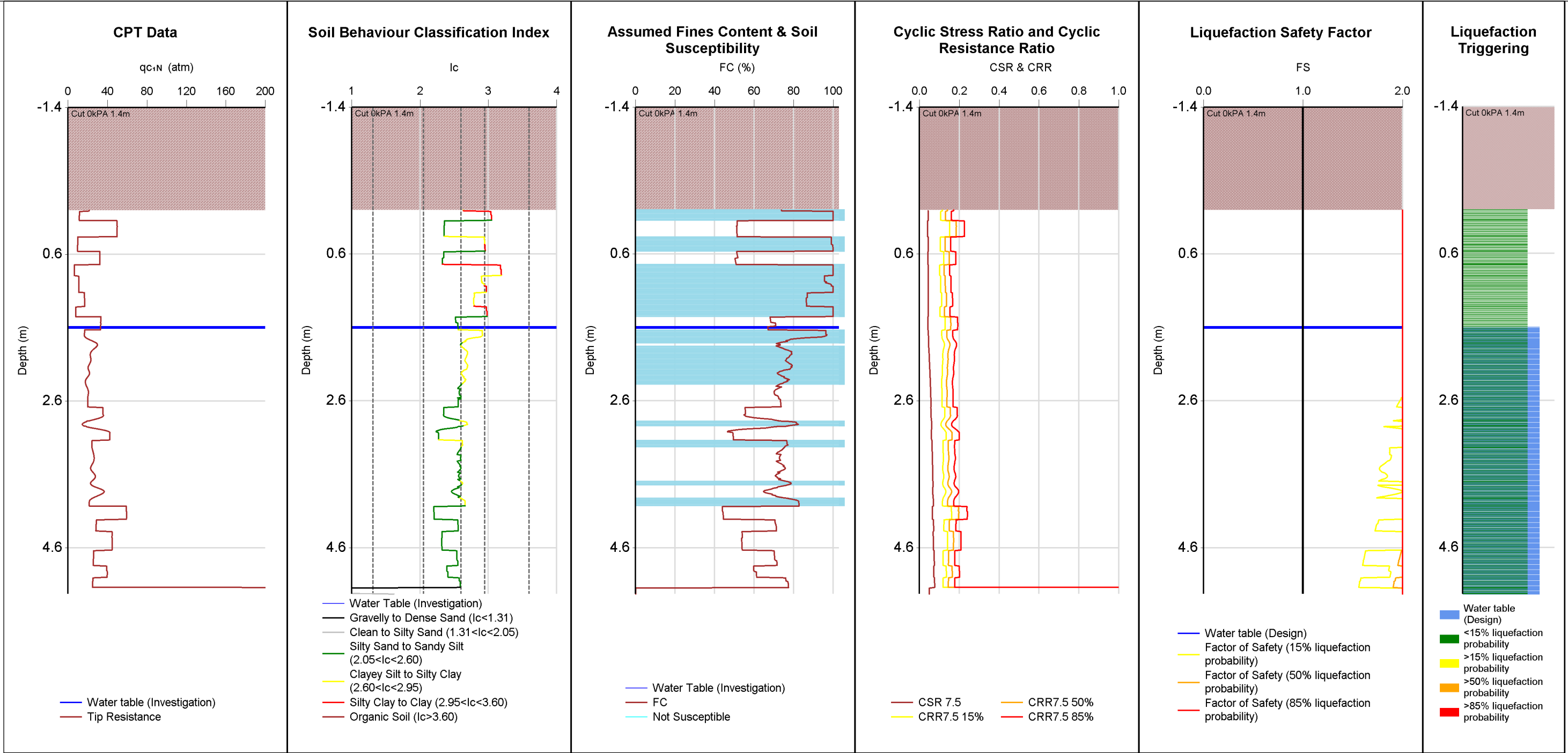
Note: Raw Qc/Fs data, Cut used.

Run Description		TTGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m ³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT	Terrane_CPT04_1.0m	178810	8/06/2007	0	6	0.08	BI-2014	ZRB-2002	14	Cut	0	-1
	cut											
PL		SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish	Reviewed by:				
OUTPUT	15%	0	0	0	0	4.3	0					
	50%	0	0	0	0	4.3	0					
	85%	0	0	0	0	4.3	0					
								CPT Inversion				
								Groundwater				
								Susceptibility				
								Triggering				



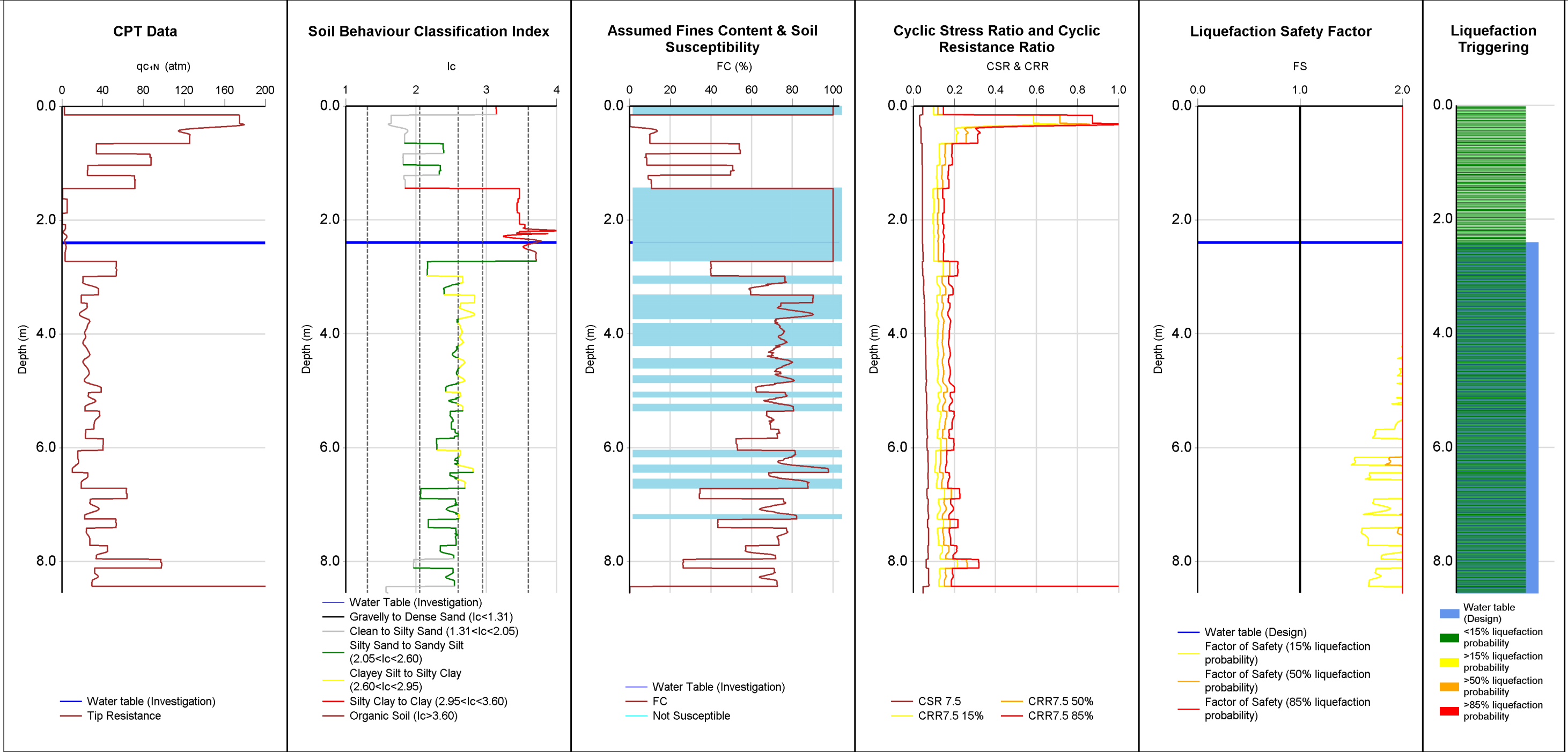
Note: Raw Qc/Fs data, Cut used.

Run Description		TTGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m ³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT	Terrane_CPT05_1.0m	178811	8/06/2007	0	6	0.08	BI-2014	ZRB-2002	14	Cut	0	-1
	cut											
PL		SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish	Reviewed by:				
OUTPUT	15%	0	0	0	0	5.6	0					
	50%	0	0	0	0	5.6	0					
	85%	0	0	0	0	5.6	0					
								CPT Inversion				
								Groundwater				
								Susceptibility				
								Triggering				



Note: Inverse filtered Qc/Fs data (10 cm²), Cut used.

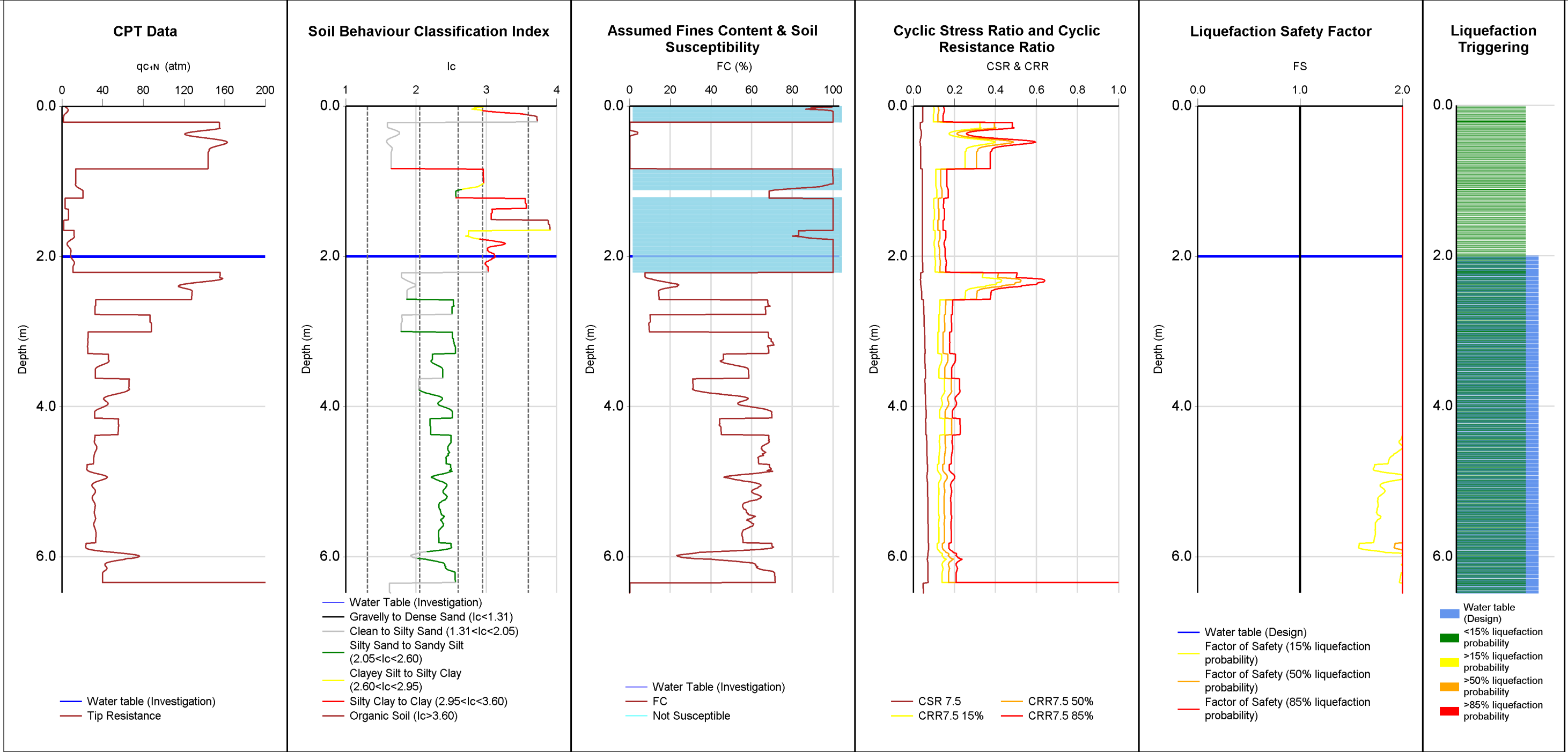
INPUT	Run Description		TTGD ID	Investigation Date		Pre-drill (m)		Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)									
	Terrane_CPT11_1.4m cut		178812	28/10/2008		0		6	0.08	BI-2014	ZRB-2002	14	Cut	0	-1.4									
OUTPUT	PL		SV1D (mm)		CTL (m)		LPI		LSN		CT (m)		LPlish		Reviewed by: <table><tr><td>CPT Inversion</td><td>YUNI</td></tr><tr><td>Groundwater</td><td>YUNI</td></tr><tr><td>Susceptibility</td><td>YUNI</td></tr><tr><td>Triggering</td><td>YUNI</td></tr></table>		CPT Inversion	YUNI	Groundwater	YUNI	Susceptibility	YUNI	Triggering	YUNI
	CPT Inversion	YUNI																						
	Groundwater	YUNI																						
	Susceptibility	YUNI																						
	Triggering	YUNI																						
15%		1		0		0		0		5.2		0												
50%		0		0		0		0		5.2		0												
85%		0		0		0		0		5.2		0												



Note: Inverse filtered Q_c/F_s data (10 cm²) used.

INPUT	Run Description		TTGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m ³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	Terrane_CPT12		178813	28/10/2018	0	6	0.08	BI-2014	ZRB-2002	14		0	
OUTPUT	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish						
	15%	2	0	0	0	8.6	0						
	50%	0	0	0	0	8.6	0						
	85%	0	0	0	0	8.6	0						

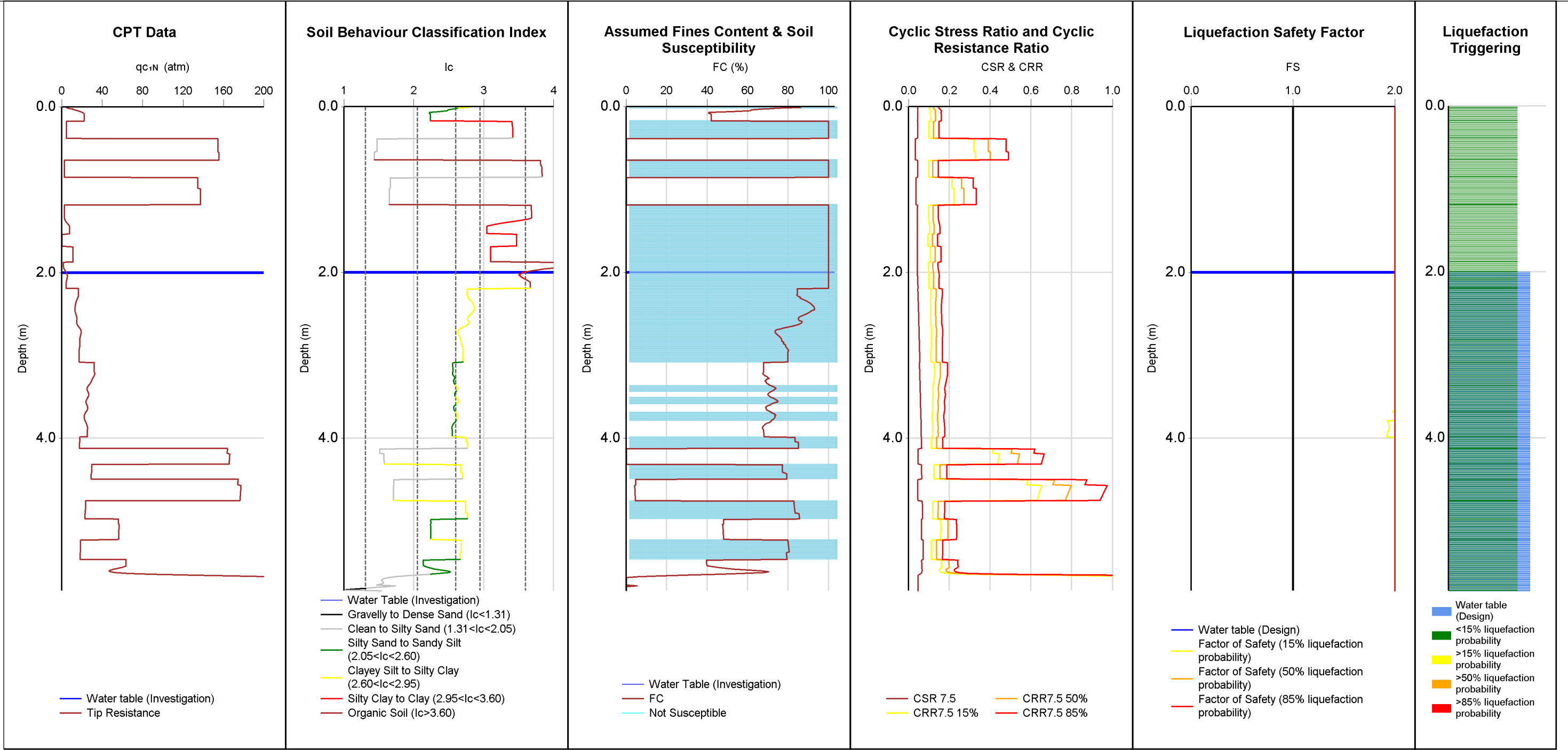
Reviewed by:	
CPT Inversion	YUNI
Groundwater	YUNI
Susceptibility	YUNI
Triggering	YUNI
Consequence	YUNI



Note: Inverse filtered Qc/Fs data (10 cm²) used.

Run Description		TTGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m ³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT Terrane_CPT13		178814	28/10/2008	0	6	0.08	BI-2014	ZRB-2002	14		0	
OUTPUT	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish					
	15%	1	0	0	0	6.5	0					
	50%	0	0	0	0	6.5	0					
	85%	0	0	0	0	6.5	0					

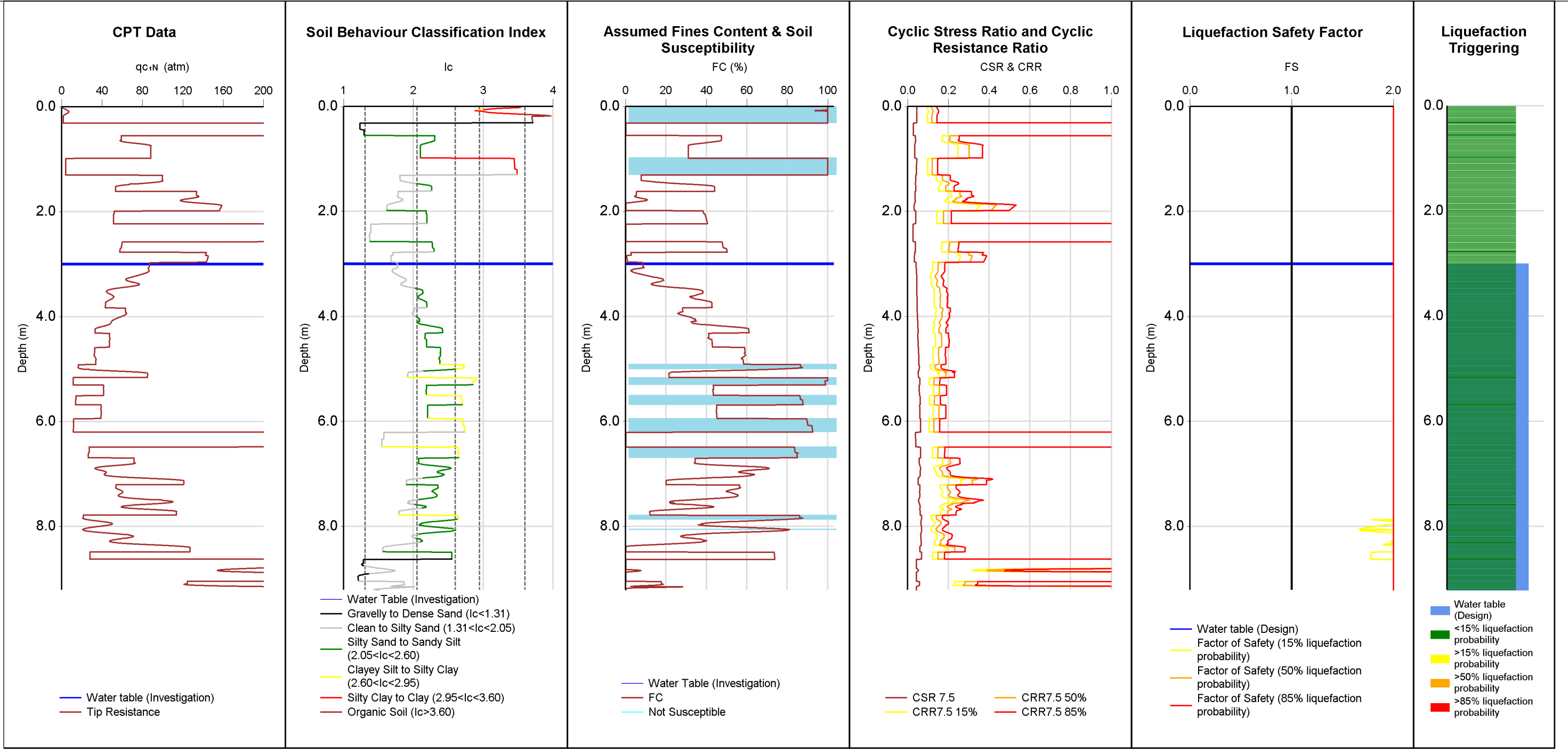
Reviewed by:	
CPT Inversion	YUNI
Groundwater	YUNI
Susceptibility	YUNI
Triggering	YUNI
Consequence	YUNI



Note: Inverse filtered Q_c/F_s data (10 cm^2) used.

Run Description		TTGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m ³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT Terrane_CPT14		178815	28/10/2008	0	6	0.08	BI-2014	ZRB-2002	14		0	
PL		SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish					
OUTPUT 15%		0	0	0	0	5.8	0					
50%		0	0	0	0	5.8	0					
85%		0	0	0	0	5.8	0					

Reviewed by:	
CPT Inversion	YUNI
Groundwater	YUNI
Susceptibility	YUNI
Triggering	YUNI
Consequence	YUNI



Note: Inverse filtered Qc/Fs data (10 cm²) used.

Run Description		TTGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m ³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT Terrane_CPT15		178816	28/10/2008	0	6	0.08	BI-2014	ZRB-2002	14		0	
PL		SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish					
15%		0	0	0	0	9.2	0					
50%		0	0	0	0	9.2	0					
85%		0	0	0	0	9.2	0					

Reviewed by:

CPT Inversion	YUNI
Groundwater	YUNI
Susceptibility	YUNI
Triggering	YUNI
Consequence	YUNI

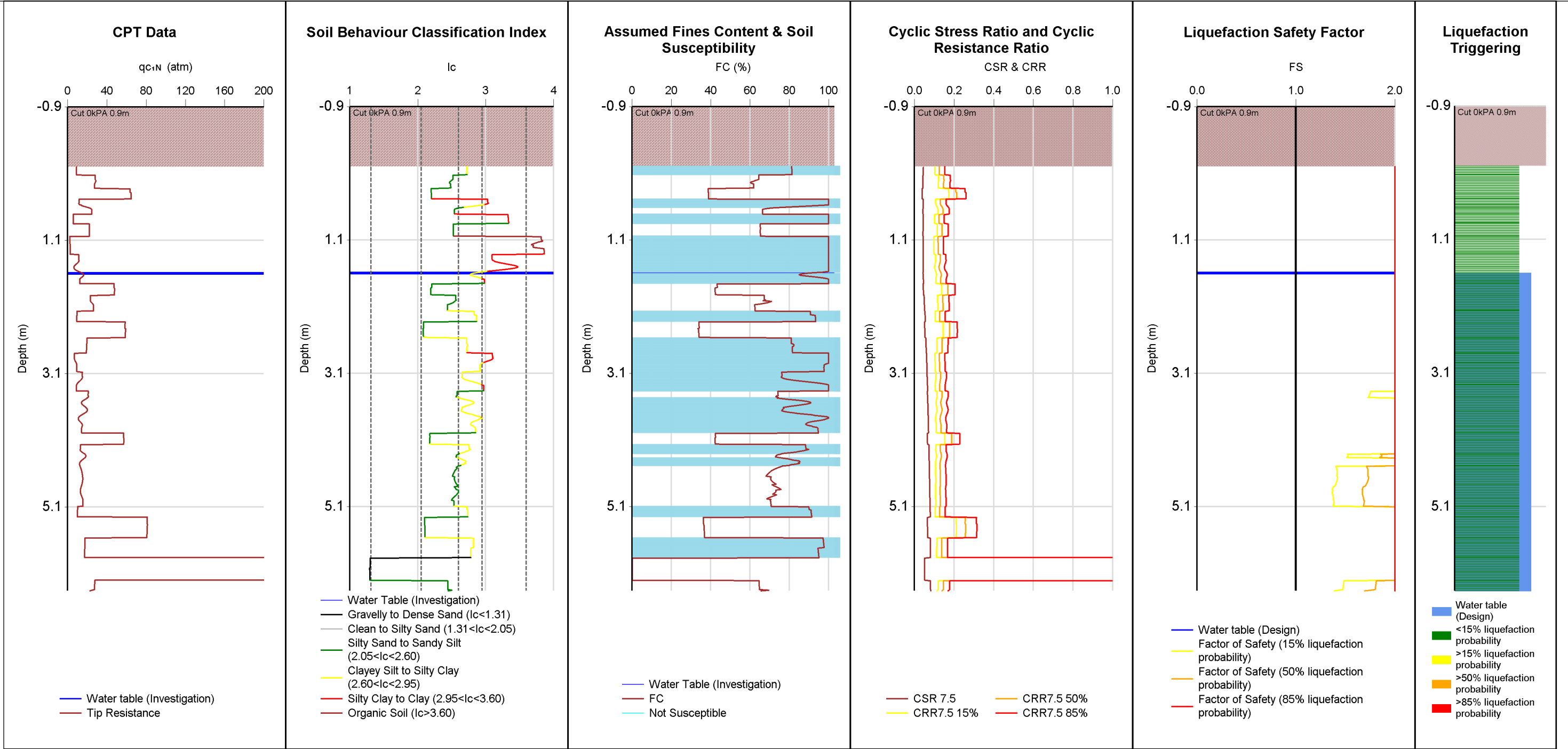


Tonkin + Taylor
Exceptional thinking
together
V2.4.15

CLIENT **Rotorua Lakes Council**
PROJECT **Rotorua Museum Geotechnical Assessment**
TITLE **SLS Seismic Event (PGA 0.08G, Mw 6.0)**
COMMENT Terrane 2008 CPT

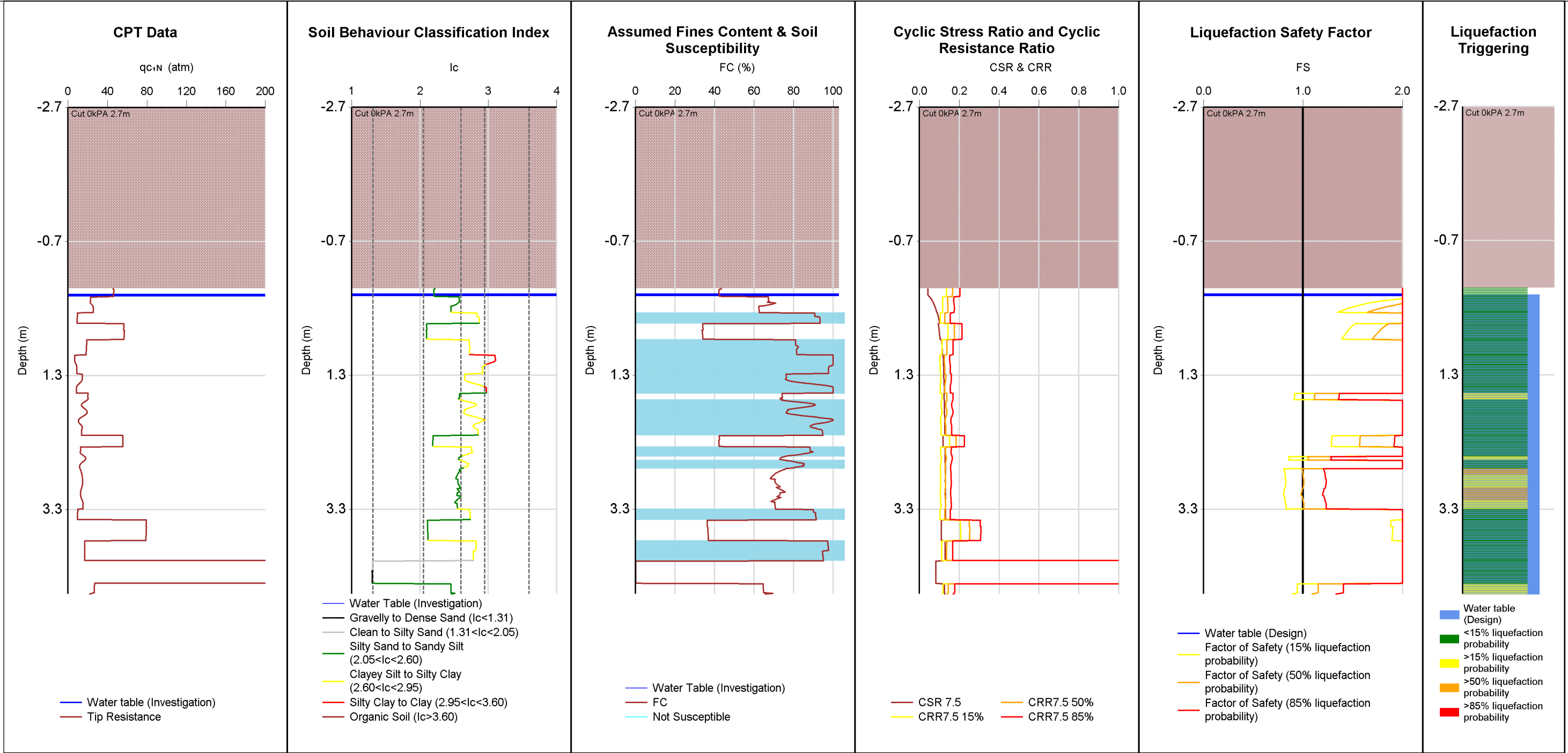
LOCATION **Government
Gardens Oruawhata**
JOB NUMBER **1017126**

DATE **12/07/2021**
ANALYSED **tzh**
PAGE **13 of 23 pages**



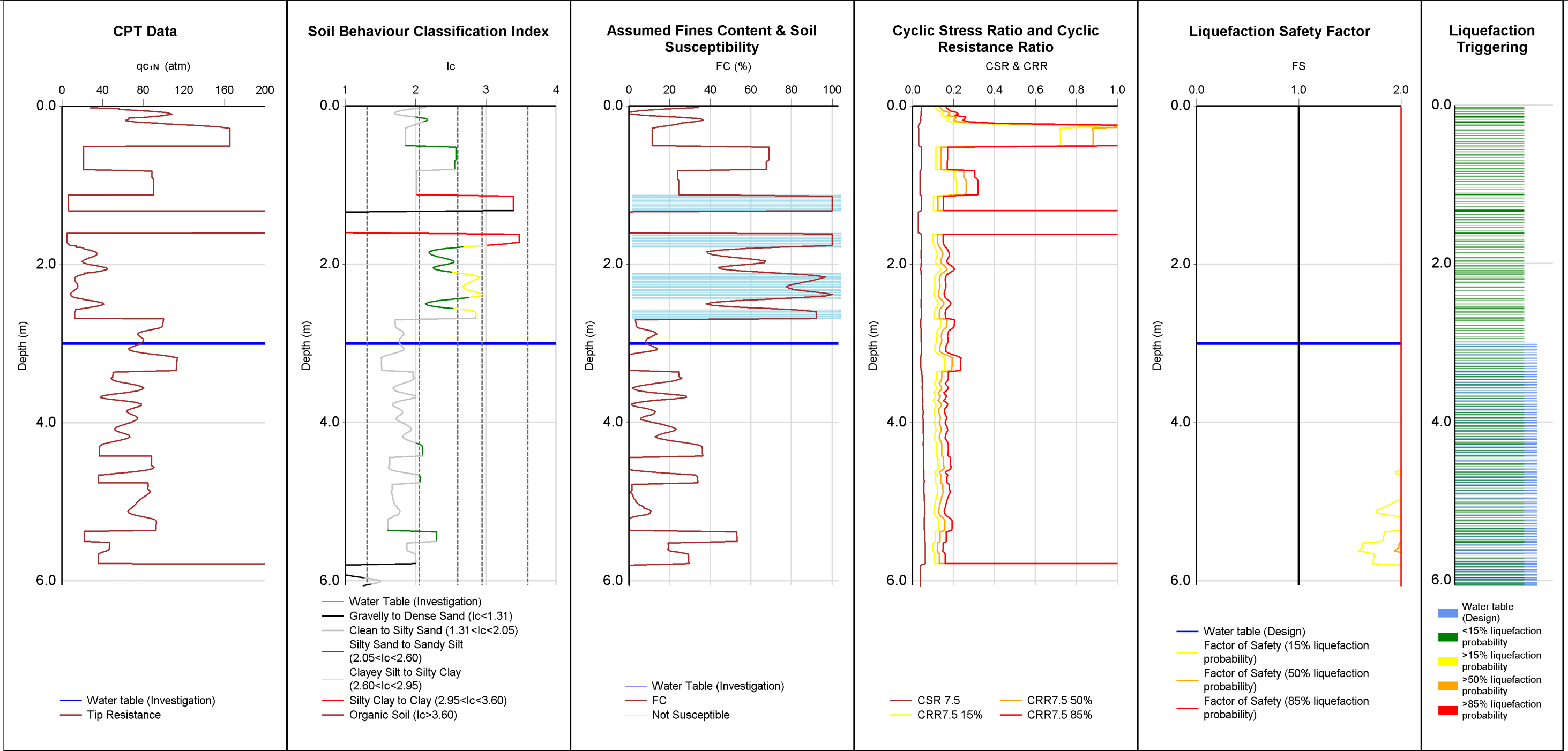
Note: Inverse filtered Q_c/F_s data (10 cm^2), Cut used.

INPUT	Run Description		TTGD ID	Investigation Date		Pre-drill (m)		Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	Terrane_CPT16_0.9m cut		178817	28/10/2008		0		6	0.08	BI-2014	ZRB-2002	14	Cut	0	-0.9
OUTPUT	PL		SV1D (mm)	CTL (m)		LPI		LSN		CT (m)		LPlish		Reviewed by:	
	15%		3	0		0		1		6.4		0		CPT Inversion YUNI	
	50%		1	0		0		0		6.4		0		Groundwater YUNI	
	85%		0	0		0		0		6.4		0		Susceptibility YUNI	



Note: Inverse filtered Qc/Fs data (10 cm²), Cut used.

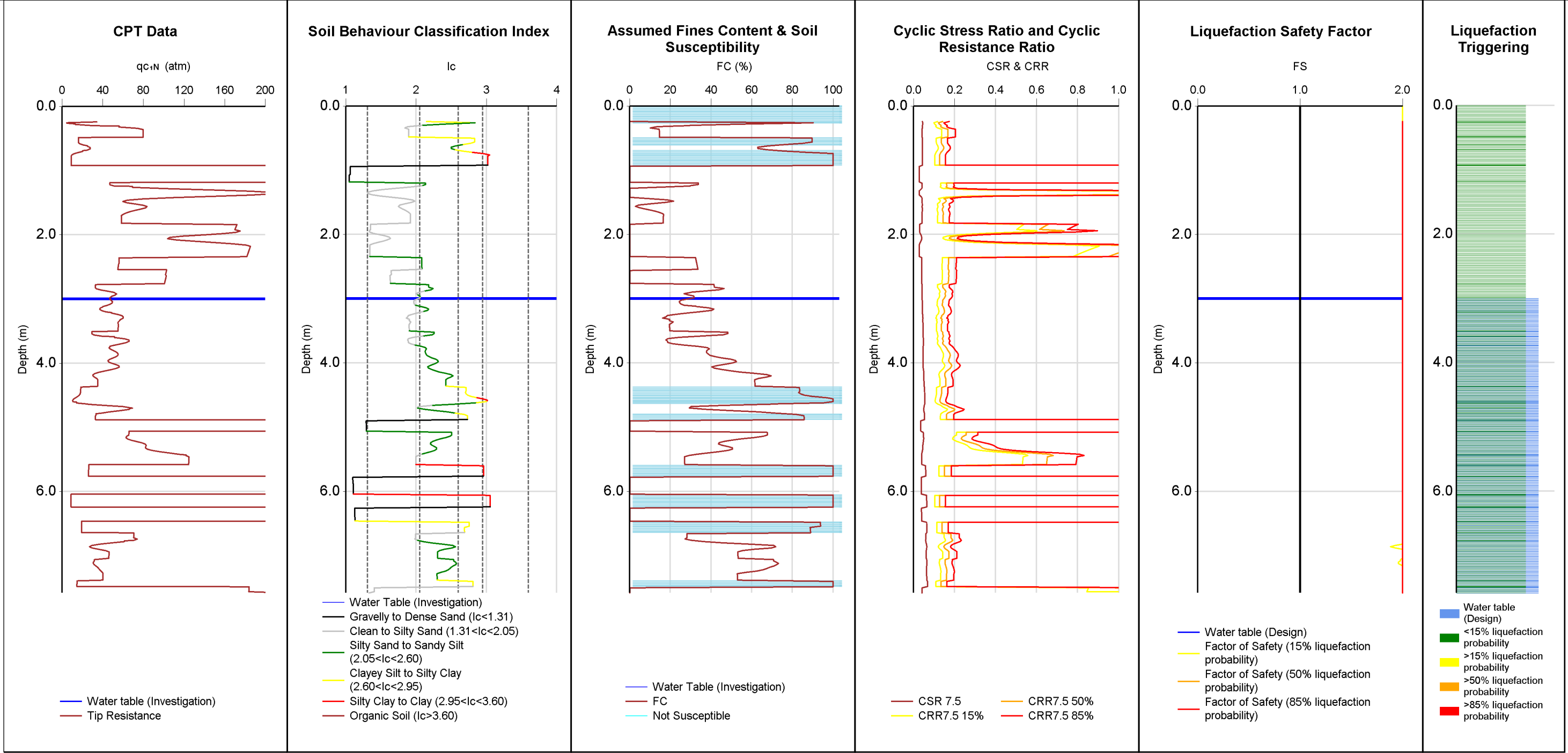
INPUT	Run Description		TTGD ID	Investigation Date		Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	Terrane_CPT16_2.7m cut		178817	28/10/2008		0	6	0.08	BI-2014	ZRB-2002	14	Cut	0	-2.7
OUTPUT	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish	Reviewed by:						
	15%	28	0.9	1	12	1.7	0							
	50%	11	0.3	0	4	2.8	0							
	85%	4	0	0	1	4.6	0							
	CPT Inversion		YUNI											
Groundwater		YUNI												
Susceptibility		YUNI												



Note: Inverse filtered Qc/Fs data (10 cm²) used.

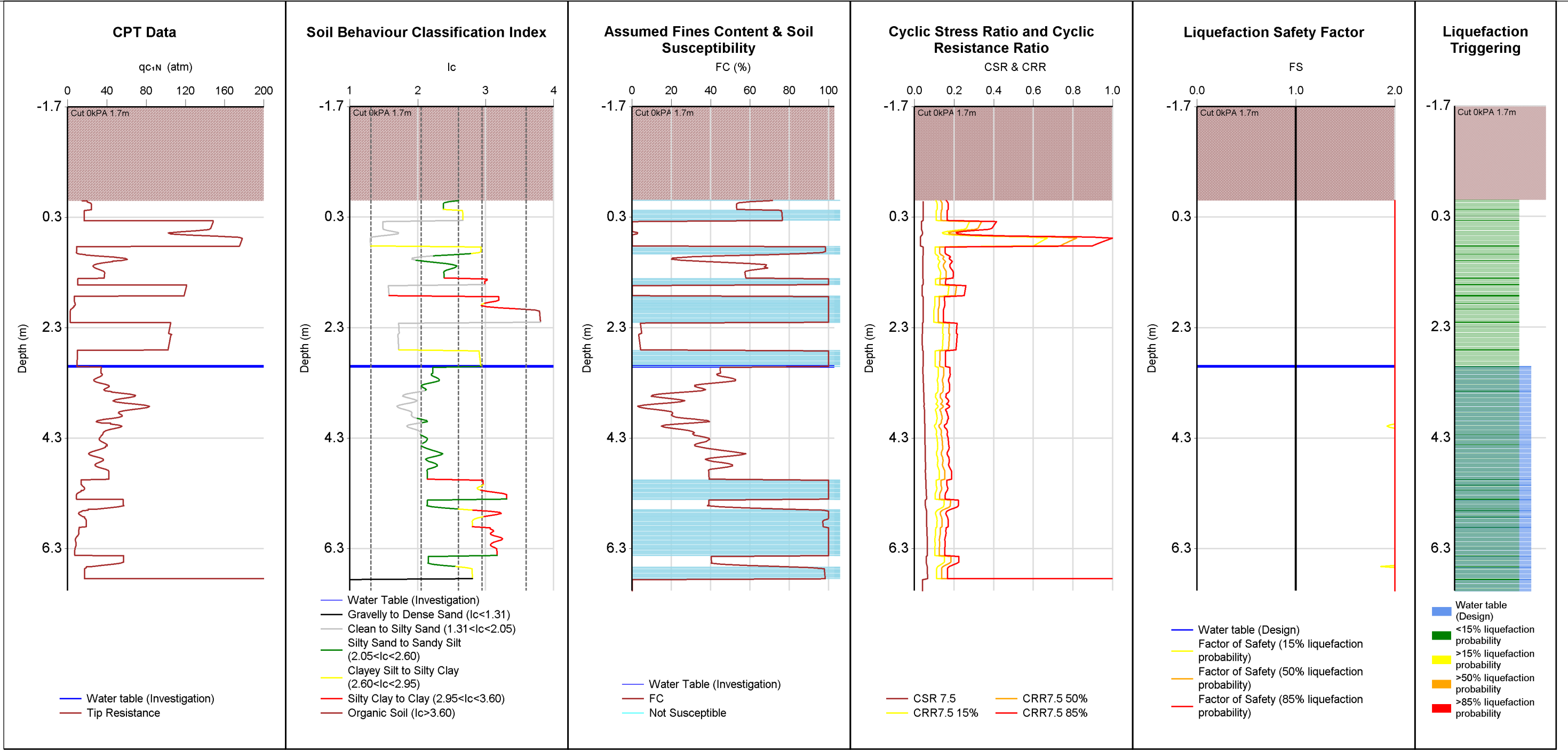
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INPUT		Cheal_CPT01	178713	3/04/2017	0	6	0.08	BI-2014	ZRB-2002	14	0	
PL		SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish					
OUTPUT		15%	1	0	0	0	6.1	0				
		50%	0	0	0	0	6.1	0				
		85%	0	0	0	0	6.1	0				

Reviewed by:	
CPT Inversion	YUNI
Groundwater	YUNI
Susceptibility	YUNI
Triggering	YUNI
Consequence	YUNI



INPUT	Run Description		TTGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m ³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	Cheal_CPT02		178714	3/04/2017	0.25	6	0.08	BI-2014	ZRB-2002	14		0	
OUTPUT	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish						
	15%	0	0	0	0	0	7.6	0					
	50%	0	0	0	0	0	7.6	0					
	85%	0	0	0	0	0	7.6	0					

Reviewed by:	
CPT Inversion	YUNI
Groundwater	YUNI
Susceptibility	YUNI
Triggering	YUNI
Consequence	YUNI

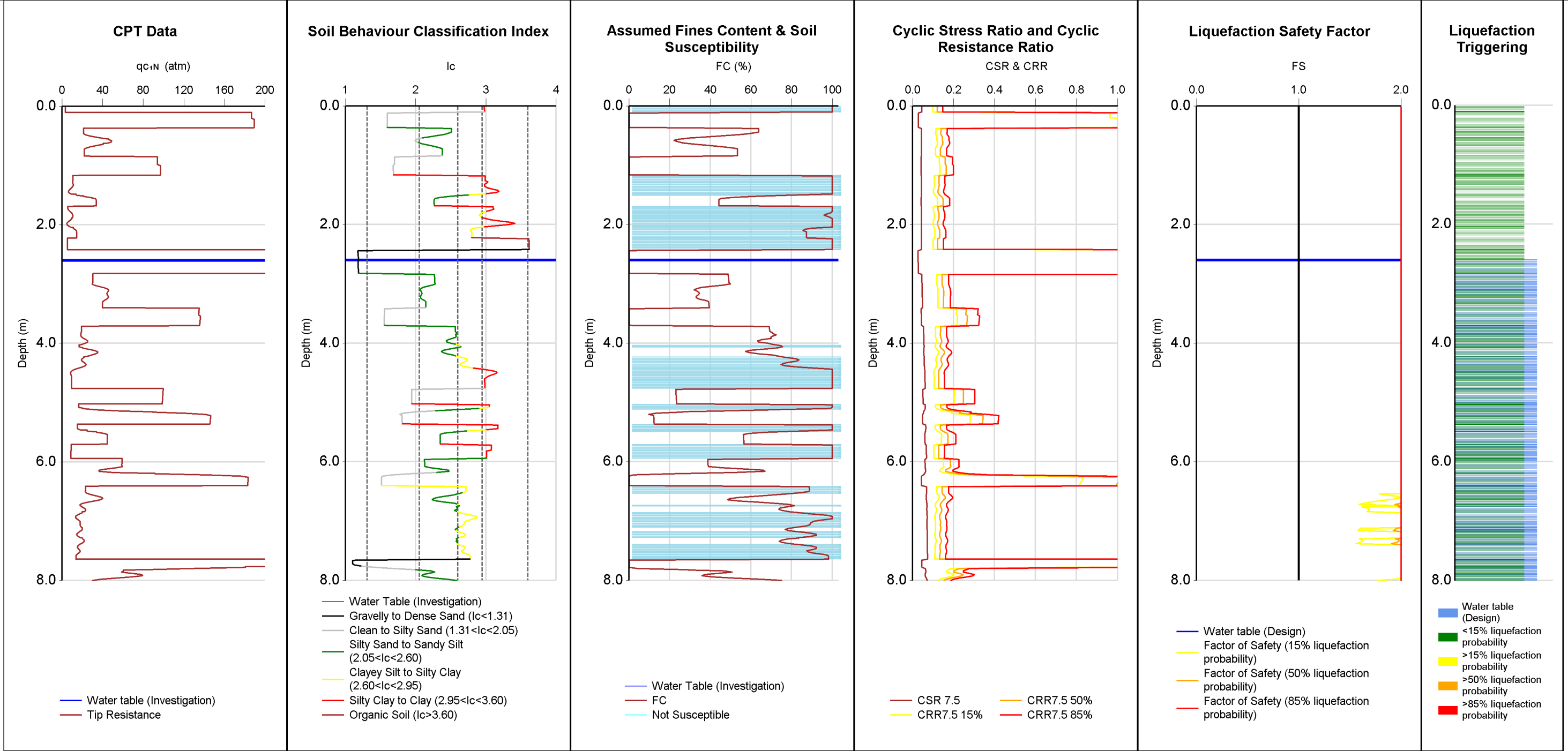


Note: Inverse filtered Qc/Fs data (10 cm²), Cut used.

Run Description		TTGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)		
INPUT	Cheal_CPT03_1.7m cut		178715	3/04/2017	0	6	0.08	BI-2014	ZRB-2002	14	Cut	0	-1.7	
	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish	Reviewed by:						
OUTPUT	15%	0	0	0	0	7.1	0	CPT Inversion						YUNI
	50%	0	0	0	0	7.1	0	Groundwater						YUNI
	85%	0	0	0	0	7.1	0	Susceptibility						YUNI

Reviewed by:

CPT Inversion	YUNI
Groundwater	YUNI
Susceptibility	YUNI
Triggering	YUNI
Consequence	YUNI

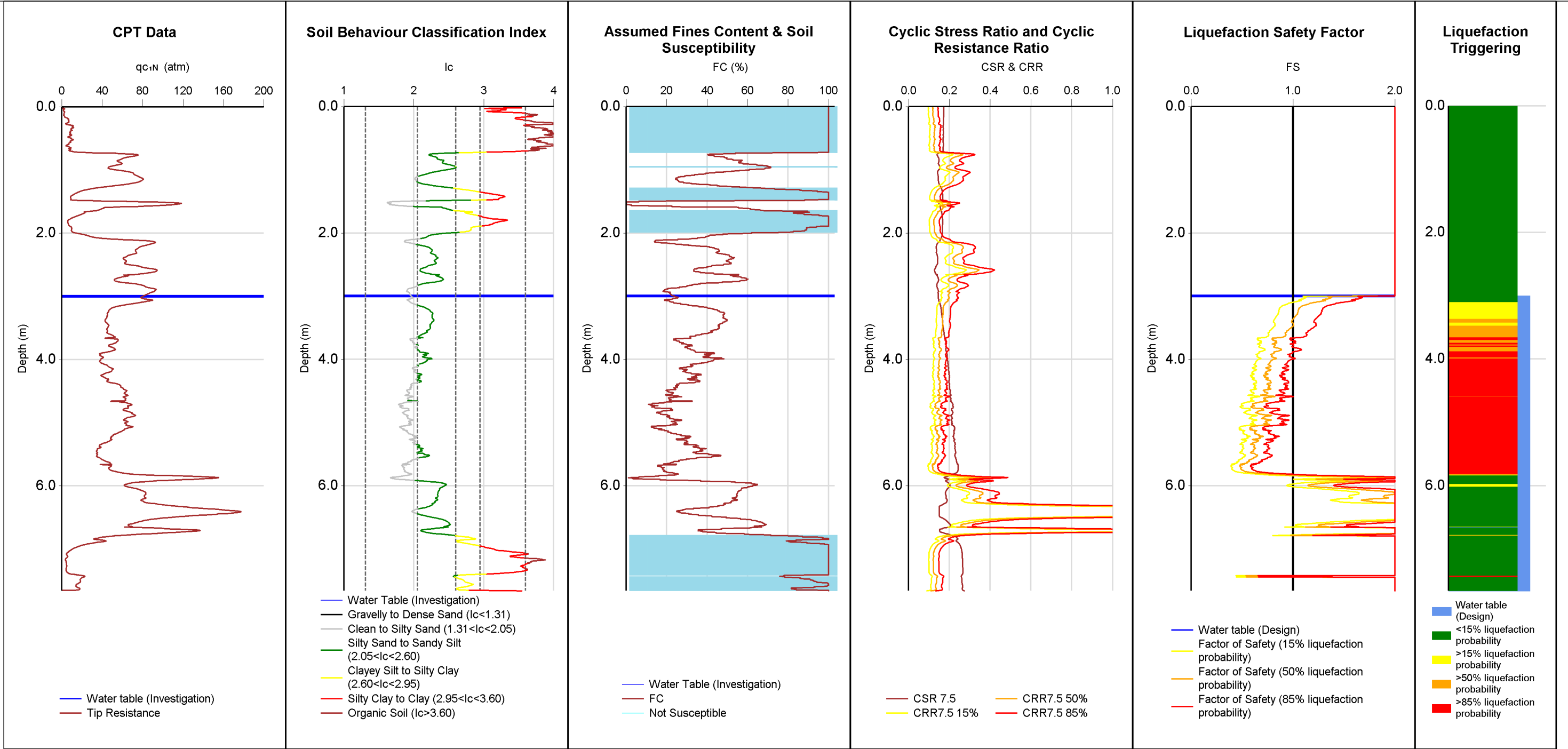


Note: Inverse filtered Q_c/F_s data (10 cm²) used.

INPUT		Run Description	TTGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m ³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
OUTPUT		Cheal_CPT04	178716	3/04/2017	0	6	0.08	BI-2014	ZRB-2002	14		0	
		PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish					
		15%	1	0	0	0	8	0					
		50%	0	0	0	0	8	0					
		85%	0	0	0	0	8	0					

Reviewed by:	
CPT Inversion	YUNI
Groundwater	YUNI
Susceptibility	YUNI
Triggering	YUNI
Consequence	YUNI

Ultimate limit state, 80% shaking, 50 year design life
1 in 1000 year return period earthquake

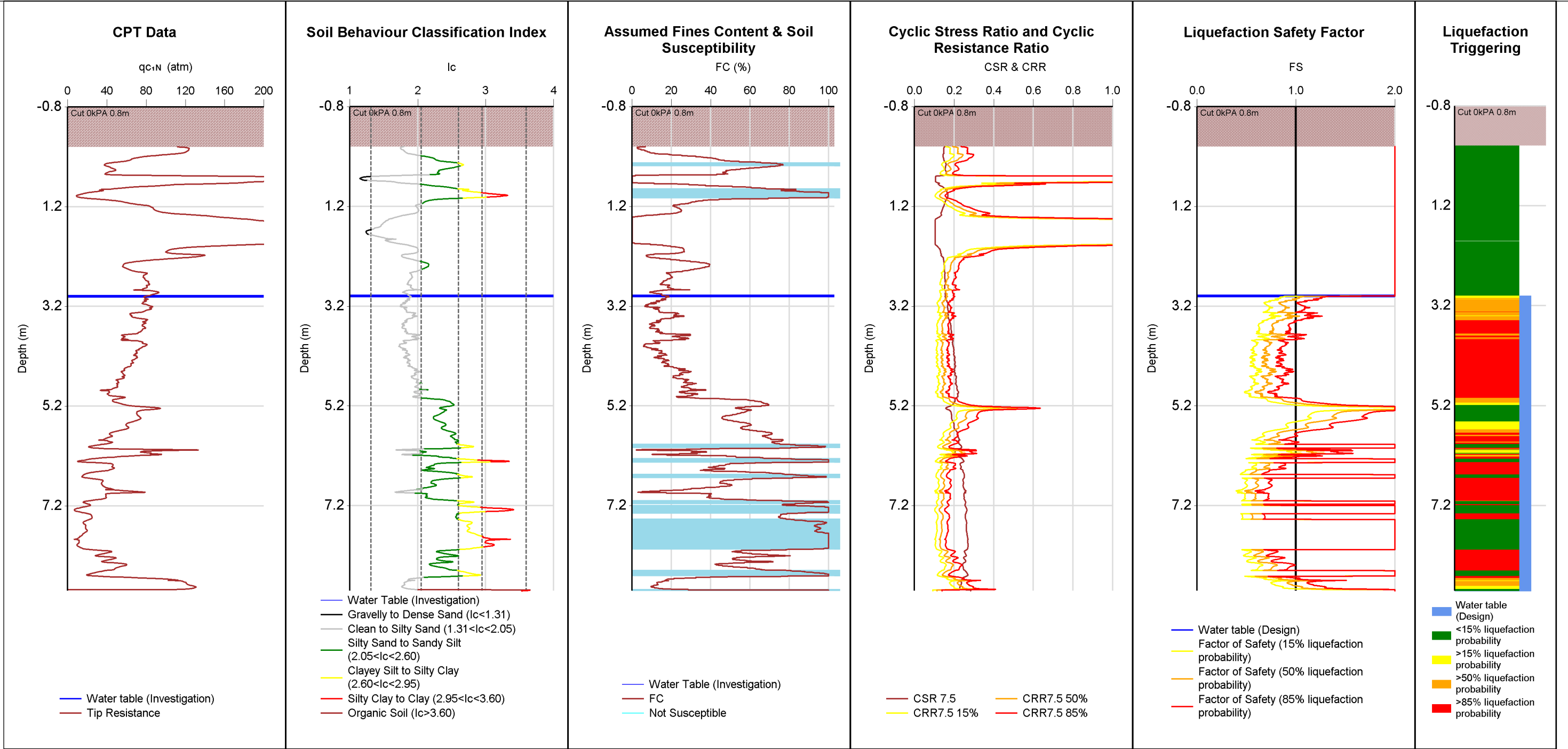


Note: Raw Qc/Fs data used.

INPUT	Run Description		TTGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m ³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	Terrane_CPT01		178807	8/06/2007	0	6	0.31	BI-2014	ZRB-2002	14		0	
OUTPUT	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish						
	15%	74	2.8	8	17	3.2	5						
	50%	66	2.4	5	14	3.5	3						
	85%	50	2	2	11	3.9	1						

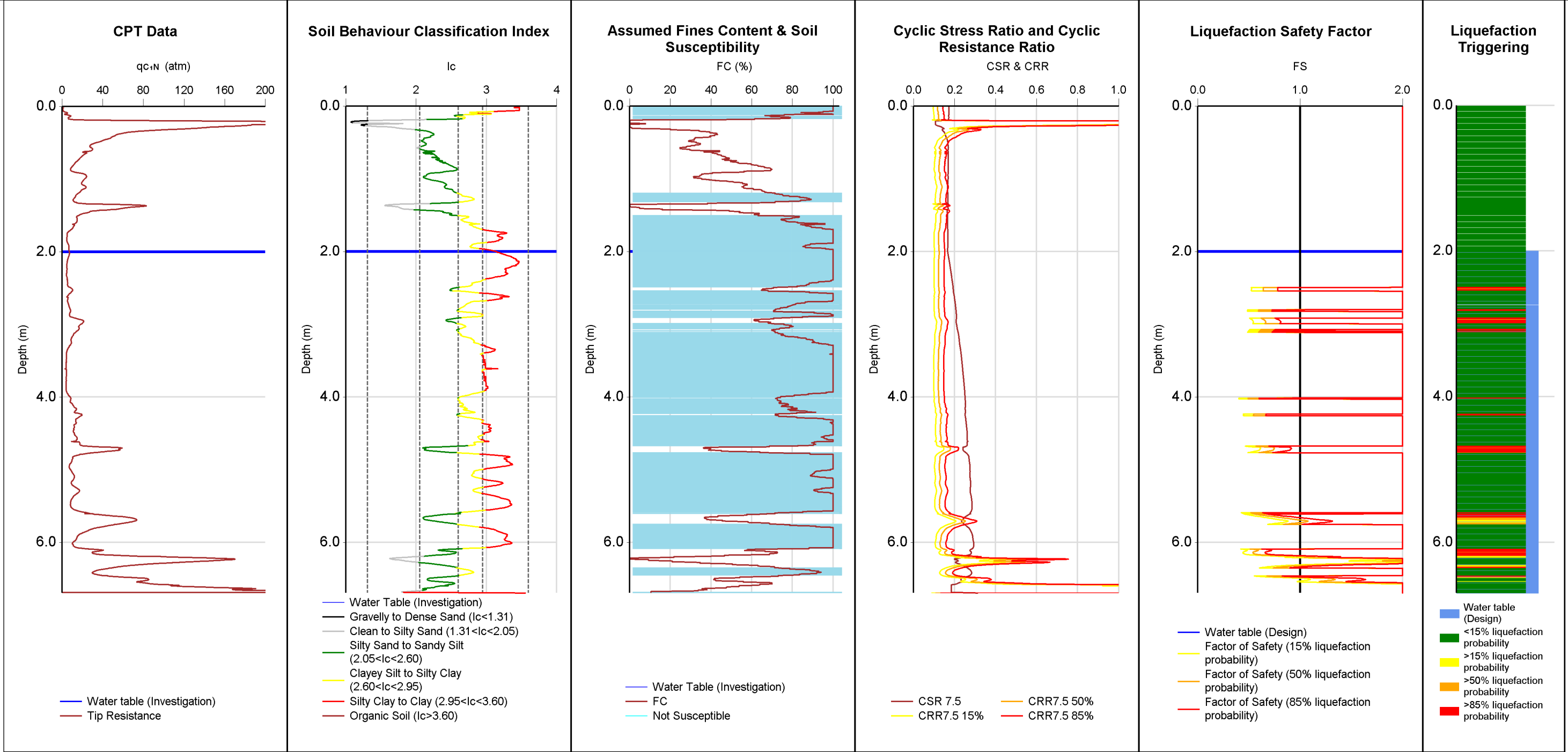
Reviewed by:

CPT Inversion	YUNI
Groundwater	YUNI
Susceptibility	YUNI
Triggering	YUNI
Consequence	YUNI



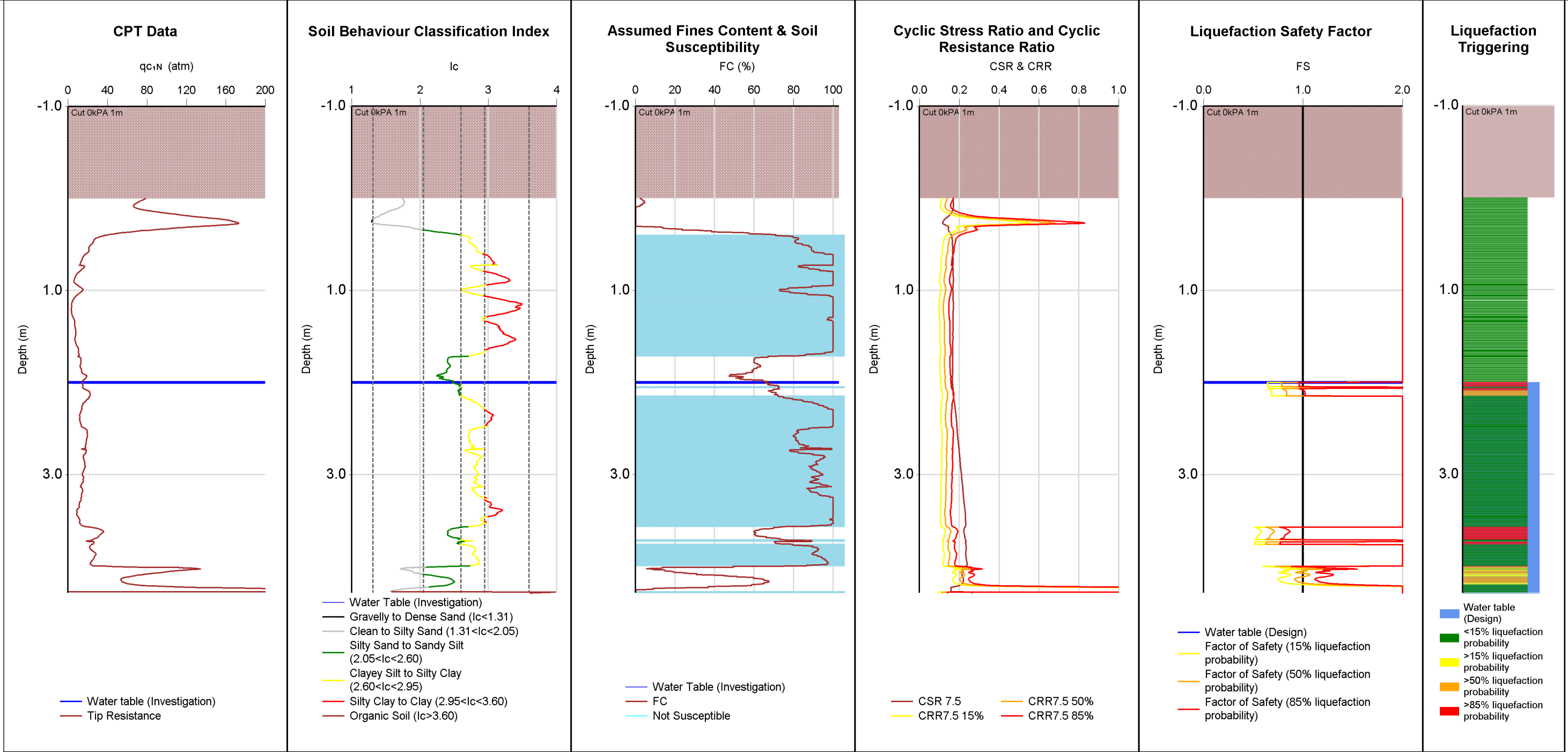
Note: Raw Qc/Fs data, Cut used.

INPUT	Run Description		TTGD ID	Investigation Date		Pre-drill (m)		Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	Terrane_CPT02_0.8m cut		178808	8/06/2007		0		6	0.31	BI-2014	ZRB-2002	14	Cut	0	-0.8
OUTPUT	PL	SV1D (mm)	CTL (m)	LPI	LSN		CT (m)		LPlish		Reviewed by:				
	15%	107	4.3	12	22		3.1		6						
	50%	97	3.9	8	19		3.2		3		CPT Inversion	YUNI			
											Groundwater	YUNI			
	85%	75	3	4	14		3.6		0		Susceptibility	YUNI			



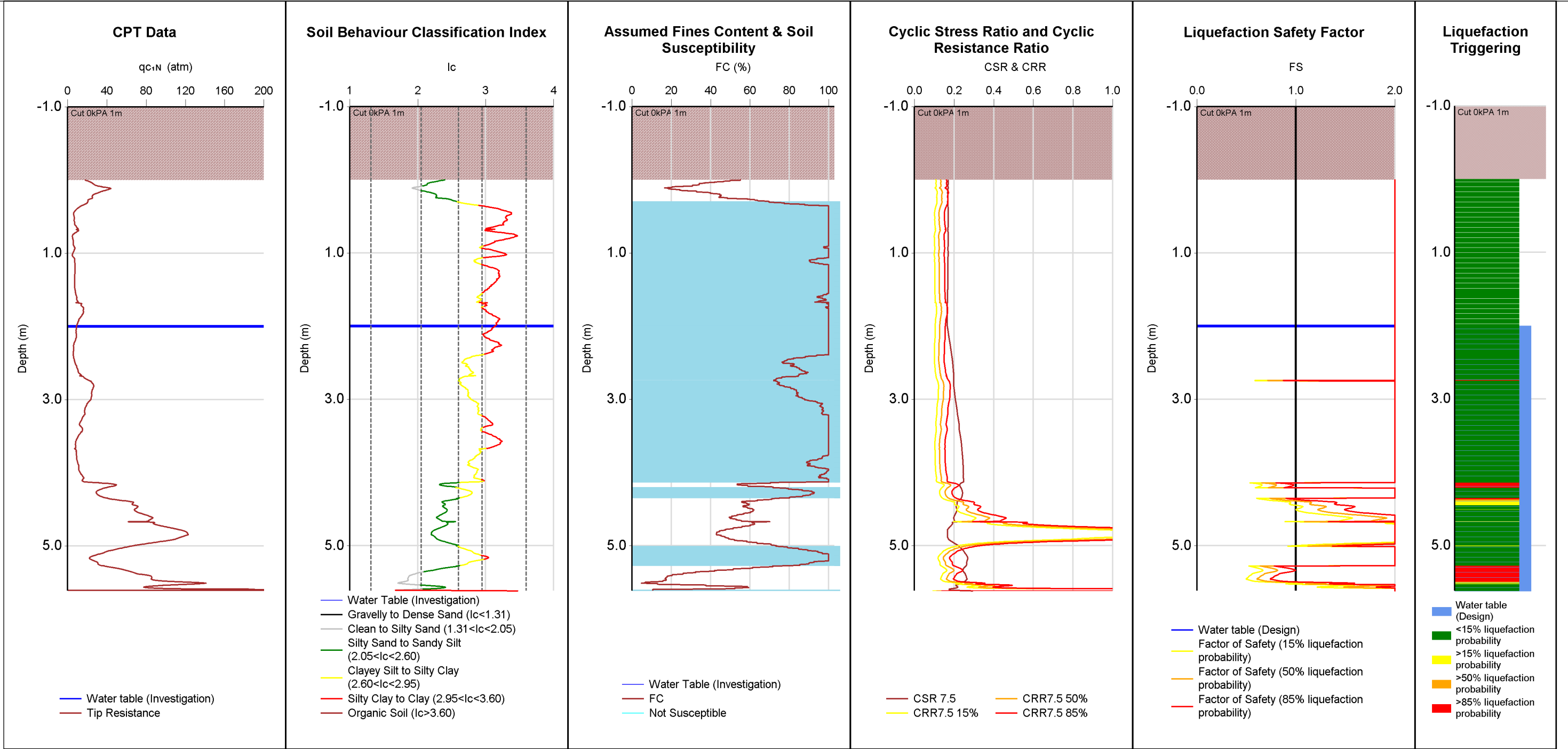
Note: Raw Qc/Fs data used.

INPUT	Run Description		TTGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	Terrane_CPT03		178809	8/06/2007	0	6	0.31	BI-2014	ZRB-2002	14		0	
OUTPUT	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish	Reviewed by: CPT Inversion YUNI Groundwater YUNI Susceptibility YUNI					
	15%	17	0.7	2	4	2.9	2						
	50%	16	0.6	2	4	2.9	1						
	85%	14	0.5	1	4	2.9	1						



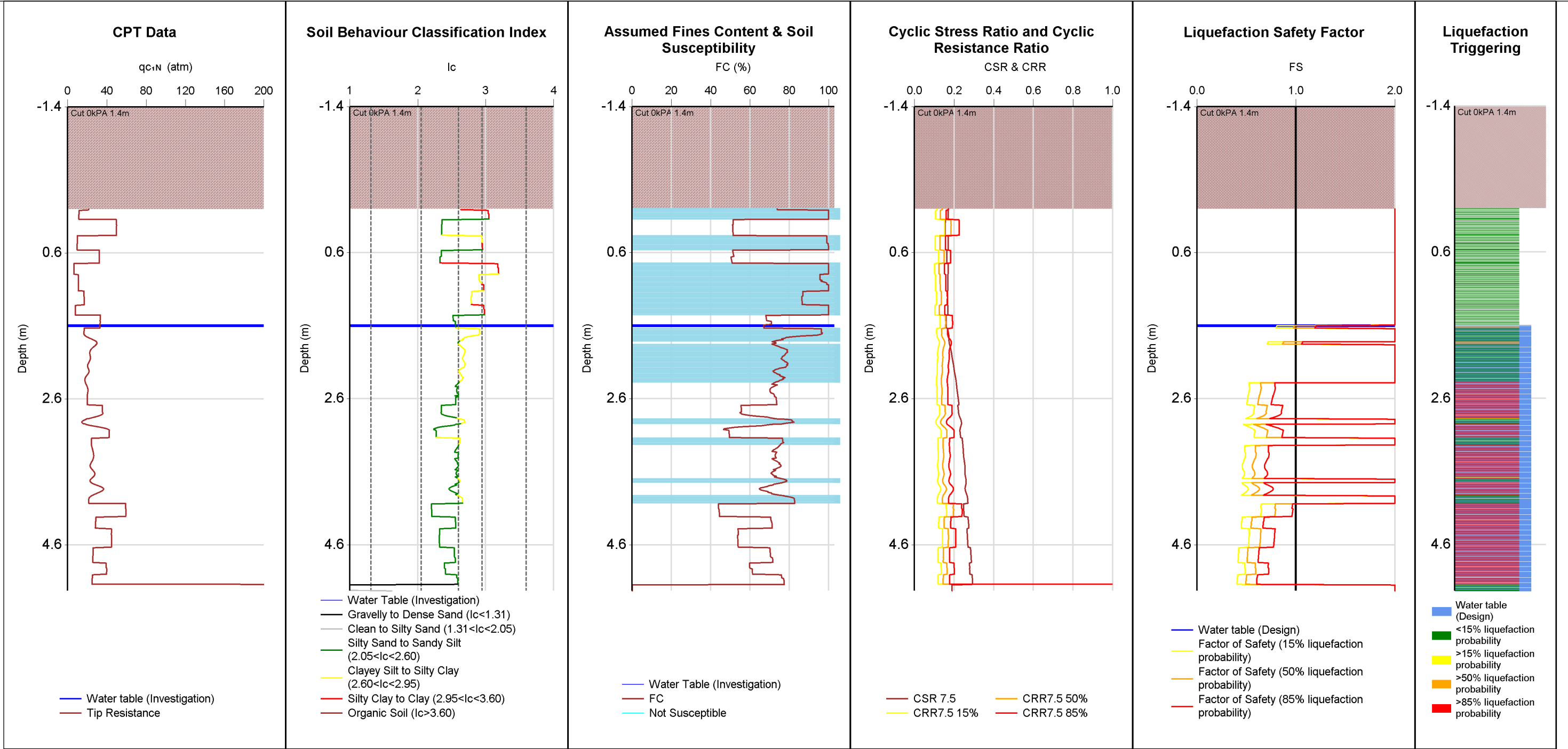
Note: Raw Q_c/F_s data, Cut used.

INPUT		Run Description	TTGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m ³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
		Terrane_CPT04_1.0m cut	178810	8/06/2007	0	6	0.31	BI-2014	ZRB-2002	14	Cut	0	-1
OUTPUT		PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish	Reviewed by:				
		15%	12	0.5	1	4	2.1	1	CPT Inversion	YUNI			
		50%	10	0.4	1	4	2.1	0	Groundwater	YUNI			
		85%	7	0.2	0	2	3.6	0	Susceptibility	YUNI			
									Triggering	YUNI			



Note: Raw Qc/Fs data, Cut used.

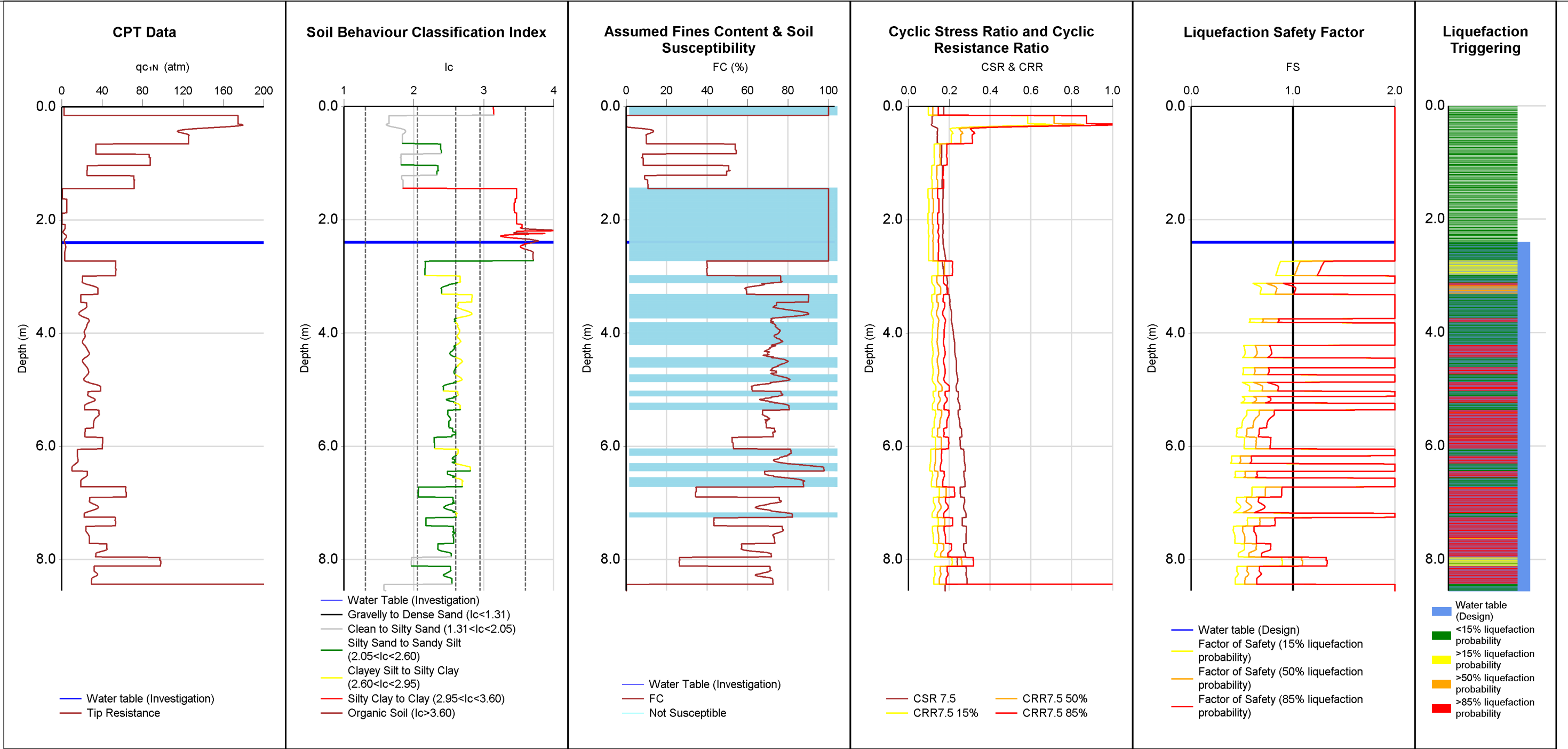
INPUT	Run Description		TTGD ID	Investigation Date		Pre-drill (m)		Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)	
	Terrane_CPT05_1.0m cut		178811	8/06/2007		0		6	0.31	BI-2014	ZRB-2002	14	Cut	0	-1	
OUTPUT	PL		SV1D (mm)	CTL (m)		LPI		LSN		CT (m)		LPlish		Reviewed by:		
	15%		10	0.4		1		2		4.4		1		CPT Inversion		YUNI
	50%		8	0.3		1		2		4.4		0		Groundwater		YUNI
	85%		6	0.3		0		1		4.4		0		Susceptibility		YUNI



Note: Inverse filtered Qc/Fs data (10 cm²), Cut used.

Run Description		TTGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m ³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT	Terrane_CPT11_1.4m	178812	28/10/2008	0	6	0.31	BI-2014	ZRB-2002	14	Cut	0	-1.4
	cut											
PL		SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish					
OUTPUT	15%	65	2.5	10	19	2.4	6					
	50%	64	2.5	8	18	2.4	5					
	85%	59	2.4	5	17	2.5	2					

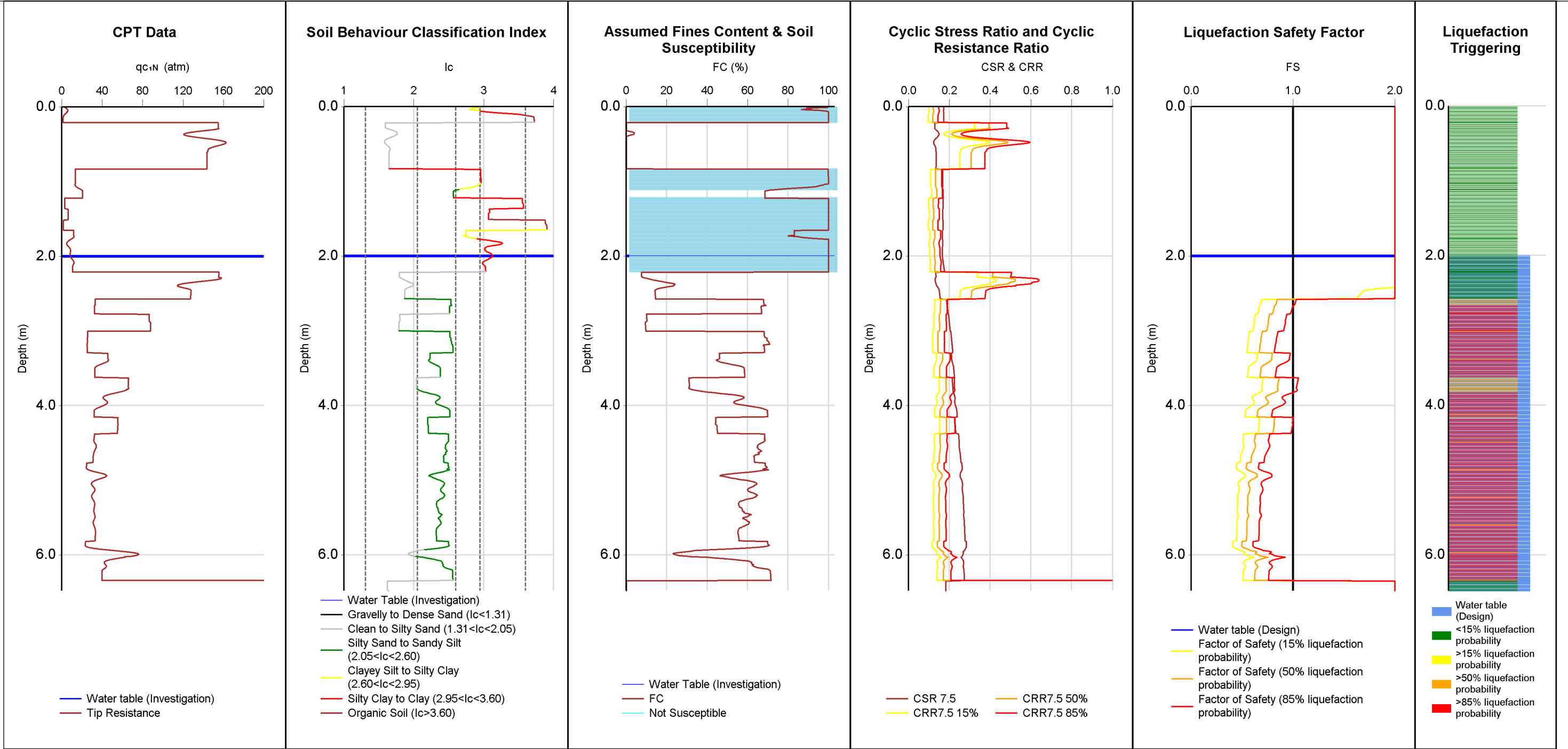
Reviewed by:	
CPT Inversion	YUNI
Groundwater	YUNI
Susceptibility	YUNI
Triggering	YUNI



Note: Inverse filtered Q_c/F_s data (10 cm^2) used.

INPUT		Run Description	TTGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m ³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
		Terrane_CPT12	178813	28/10/2018	0	6	0.31	BI-2014	ZRB-2002	14		0	
OUTPUT		PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish					
		15%	91	3.7	12	17	2.8	7					
		50%	87	3.3	9	15	3.2	5					
		85%	80	3.2	6	14	3.8	3					

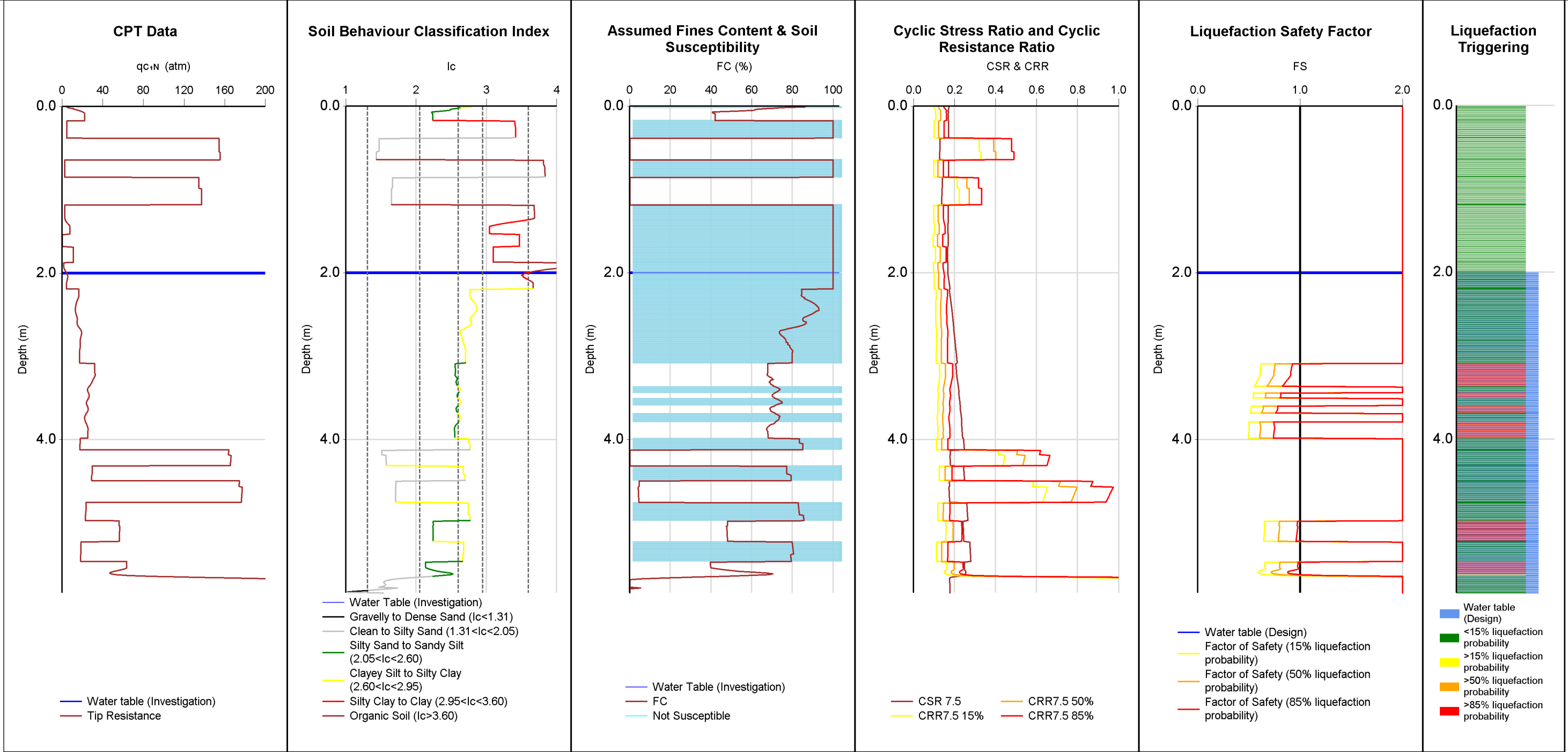
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CPT Inversion	YUNI
Groundwater	YUNI
Susceptibility	YUNI
Triggering	YUNI
Consequence	YUNI



Note: Inverse filtered Qc/Fs data (10 cm²) used.

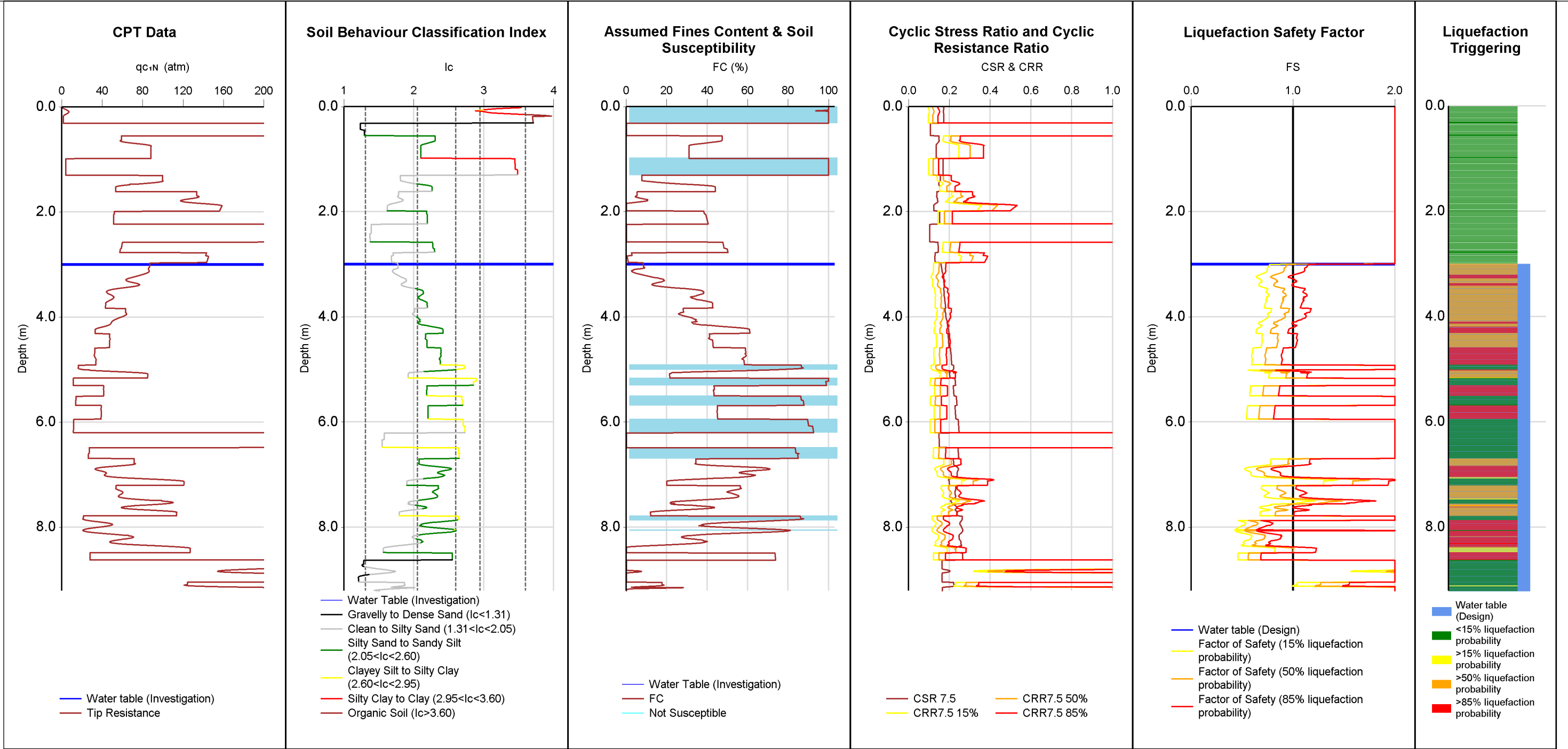
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INPUT Terrane_CPT13		178814	28/10/2008	0	6	0.31	BI-2014	ZRB-2002	14		0	
OUTPUT	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish					
	15%	94	3.8	13	23	2.7	10					
	50%	91	3.8	10	22	2.7	7					
	85%	77	3.5	5	18	2.8	3					

Reviewed by:	
CPT Inversion	YUNI
Groundwater	YUNI
Susceptibility	YUNI
Triggering	YUNI
Consequence	YUNI



Note: Inverse filtered Q_c/F_s data (10 cm^2) used.

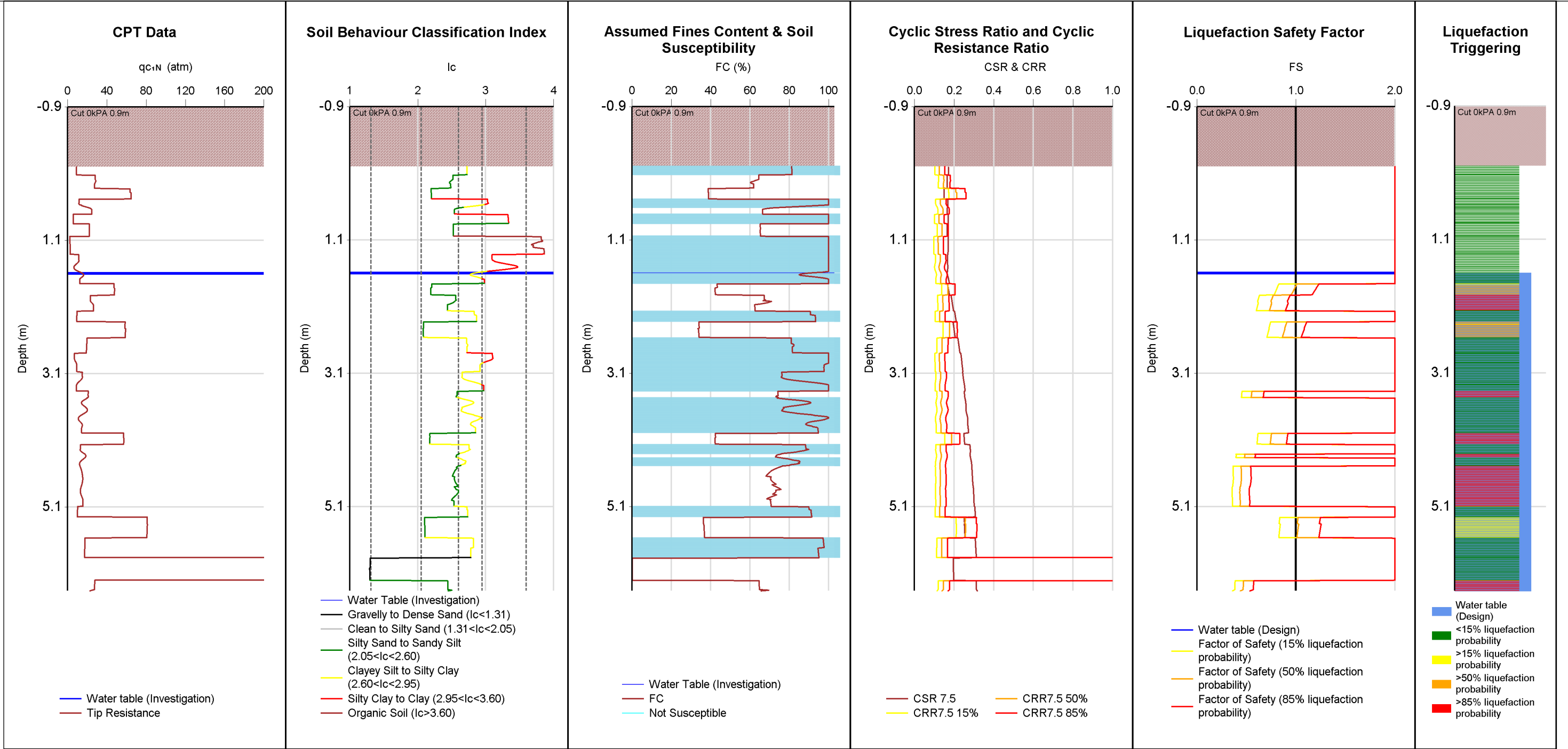
INPUT	Run Description		TTGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	Terrane_CPT14		178815	28/10/2008	0	6	0.31	BI-2014	ZRB-2002	14		0	
OUTPUT	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish	Reviewed by:					
	15%	26	1.1	3	7	3.2	3						
	50%	24	1.1	2	6	3.2	2						
	85%	19	1	1	5	3.2	0						
								CPT Inversion	YUNI				
								Groundwater	YUNI				
								Susceptibility	YUNI				



Note: Inverse filtered Q_c/F_s data (10 cm^2) used.

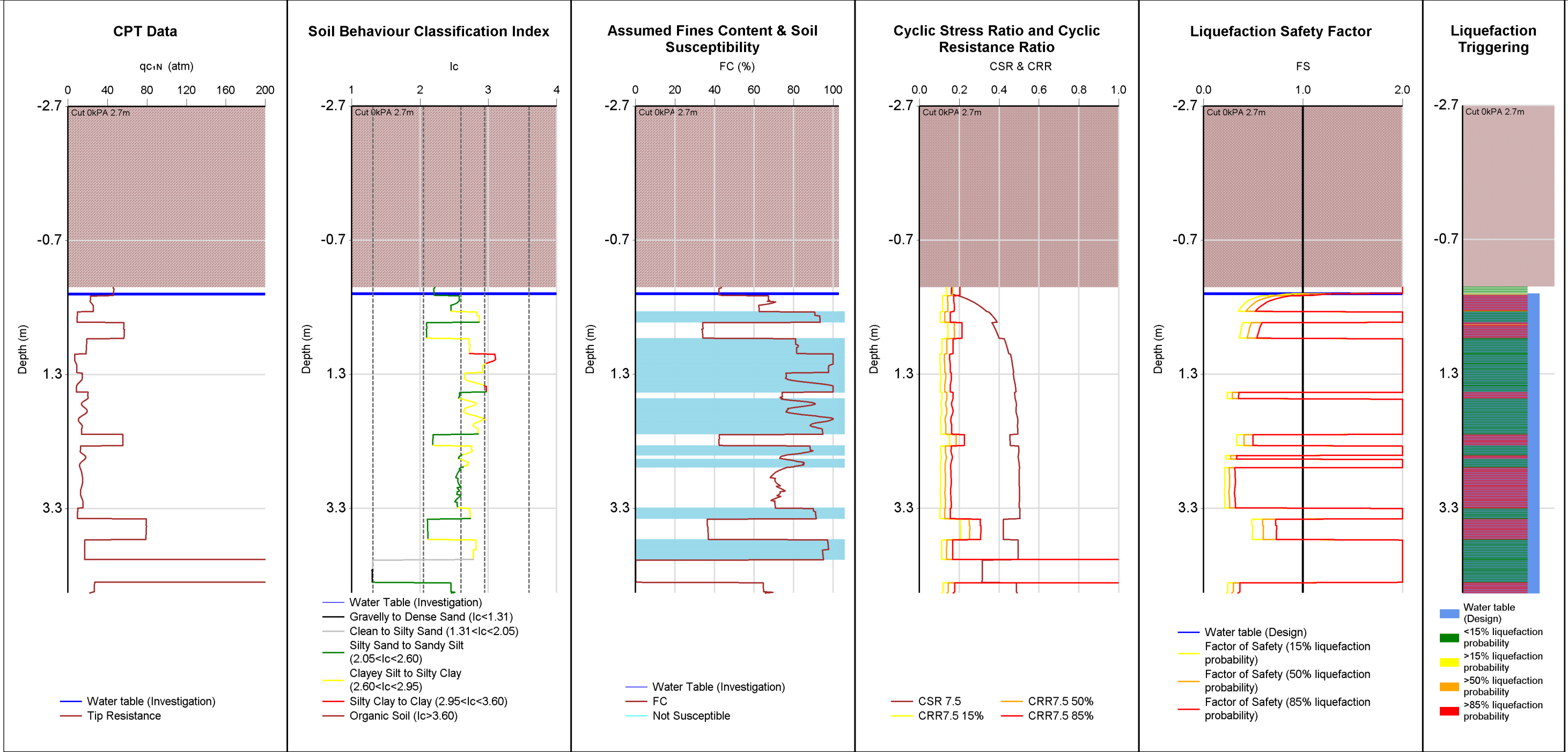
INPUT		Run Description	TTGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m ³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
		Terrane_CPT15	178816	28/10/2008	0	6	0.31	BI-2014	ZRB-2002	14		0	
OUTPUT		PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish					
		15%	99	4.2	10	20	3.1	7					
		50%	83	4	6	16	3.1	2					
		85%	52	1.9	2	10	3.4	0					

Reviewed by:	
CPT Inversion	YUNI
Groundwater	YUNI
Susceptibility	YUNI
Triggering	YUNI
Consequence	YUNI



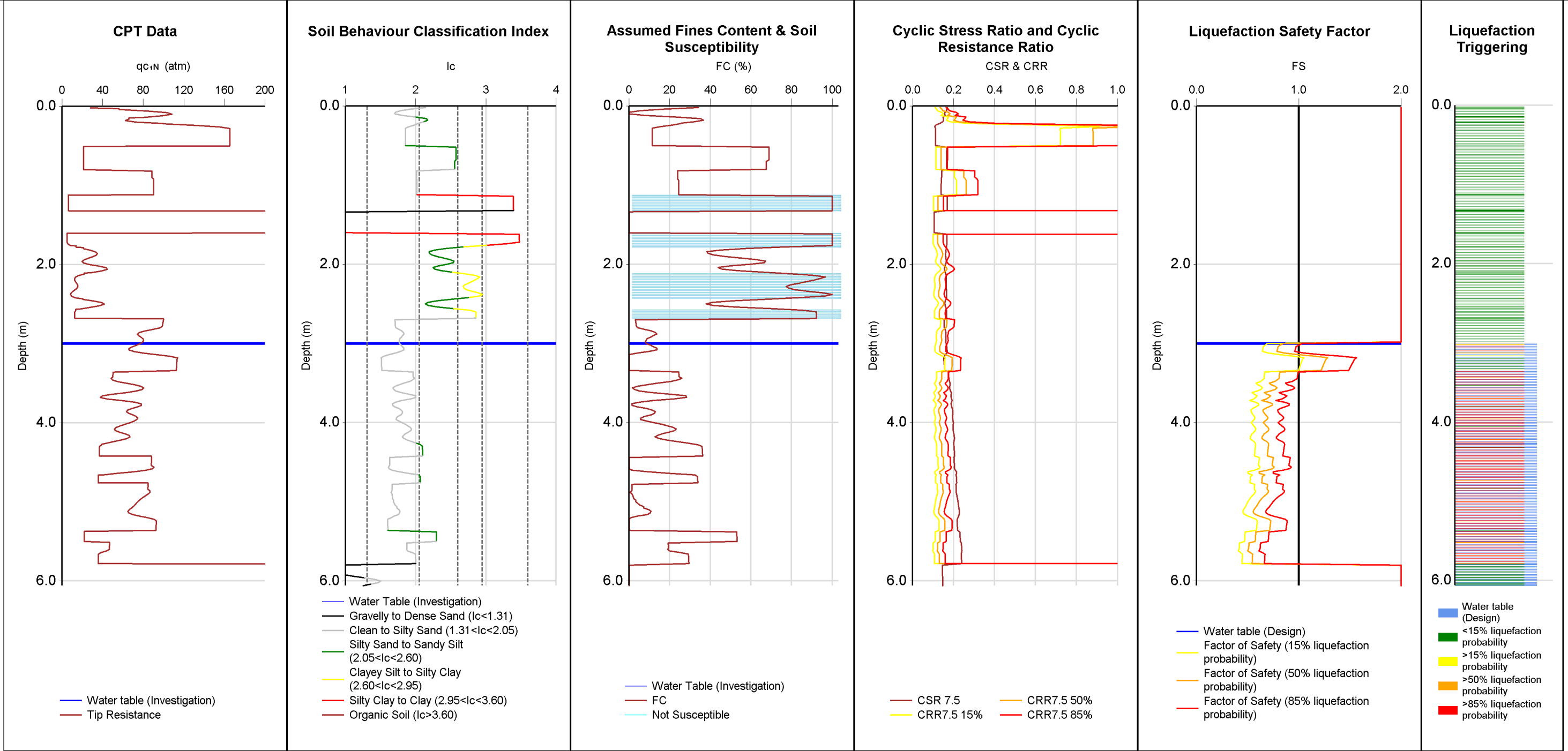
Note: Inverse filtered Qc/Fs data (10 cm²), Cut used.

INPUT	Run Description		TTGD ID	Investigation Date		Pre-drill (m)		Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)	
	Terrane_CPT16_0.9m cut		178817	28/10/2008		0		6	0.31	BI-2014	ZRB-2002	14	Cut	0	-0.9	
OUTPUT	PL		SV1D (mm)		CTL (m)		LPI		LSN		CT (m)		LPlish		Reviewed by: CPT InversionYUNI GroundwaterYUNI SusceptibilityYUNI TriggeringYUNI	
	15%		51		2.1		7		15		1.8		5			
	50%		46		1.7		5		13		1.9		3			
	85%		38		1.3		3		10		2		2			



Note: Inverse filtered Qc/Fs data (10 cm²), Cut used.

INPUT	Run Description		TTGD ID	Investigation Date		Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	Terrane_CPT16_2.7m cut		178817	28/10/2008		0	6	0.31	BI-2014	ZRB-2002	14	Cut	0	-2.7
OUTPUT	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish	Reviewed by:						
	15%	51	1.9	11	58	0.2	7							
	50%	51	1.9	10	55	0.2	6							
	85%	49	1.9	9	52	0.2	5							
	CPT Inversion		YUNI											
Groundwater		YUNI												
Susceptibility		YUNI												



Note: Inverse filtered Q_c/F_s data (10 cm^2) used.

Run Description		TTGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m ³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT		Cheal_CPT01	178713	3/04/2017	0	6	0.31	BI-2014	ZRB-2002	14	0	
PL		SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish					
OUTPUT		15%	78	2.6	9	18	3.1	7				
		50%	77	2.6	7	18	3.1	5				
		85%	67	2.5	4	15	3.4	1				

Reviewed by:

CPT Inversion	YUNI
Groundwater	YUNI
Susceptibility	YUNI
Triggering	YUNI
Consequence	YUNI

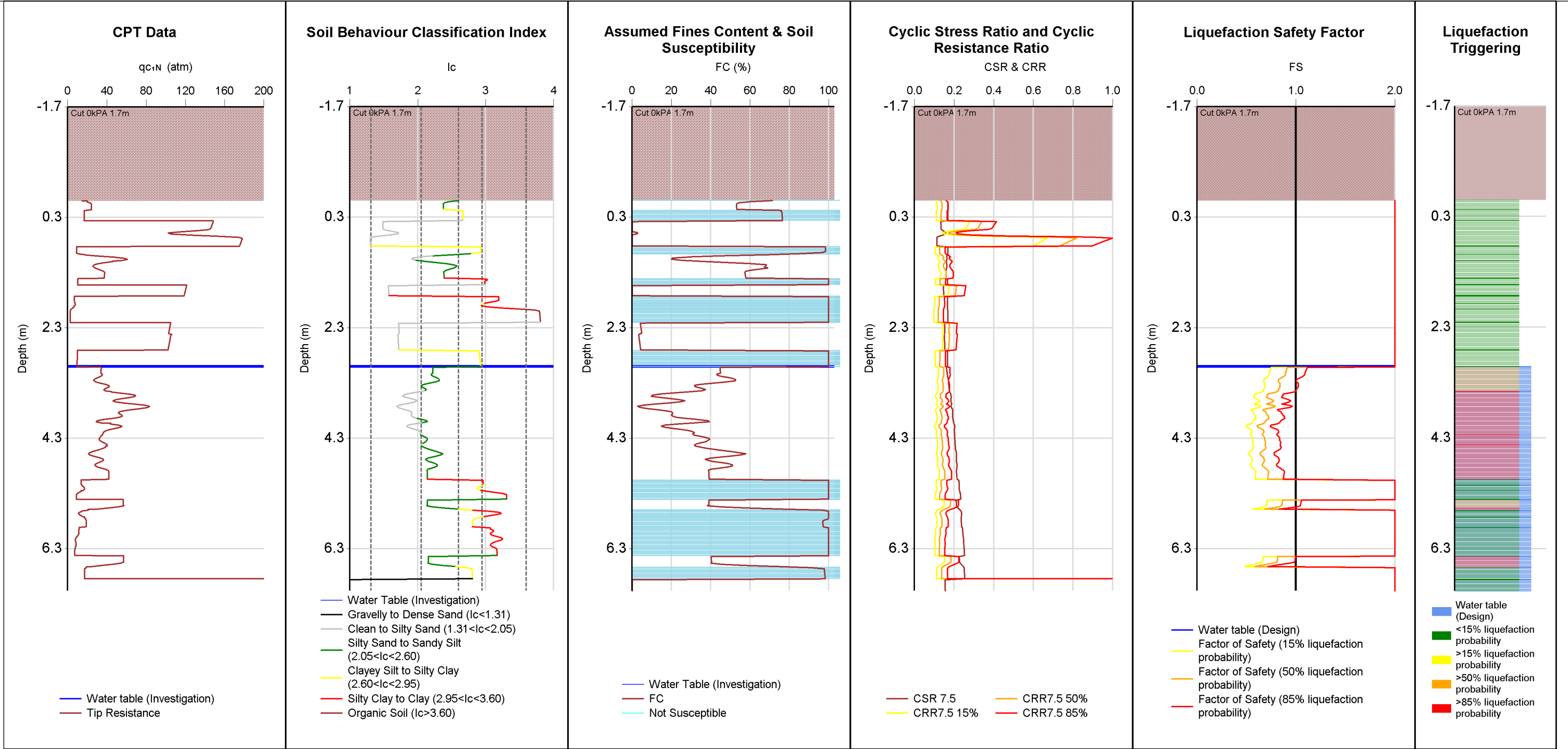


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V2.4.15

CLIENT
Rotorua Lakes Council
PROJECT
Rotorua Museum Geotechnical Assessment
TITLE
ULS Seismic Event (80%NBS, 50year design life, PGA 0.31G, Mw 6.0)
COMMENT
Cheal 2017 CPT

LOCATION
Government
Gardens Oruawhata
JOB NUMBER
1017126

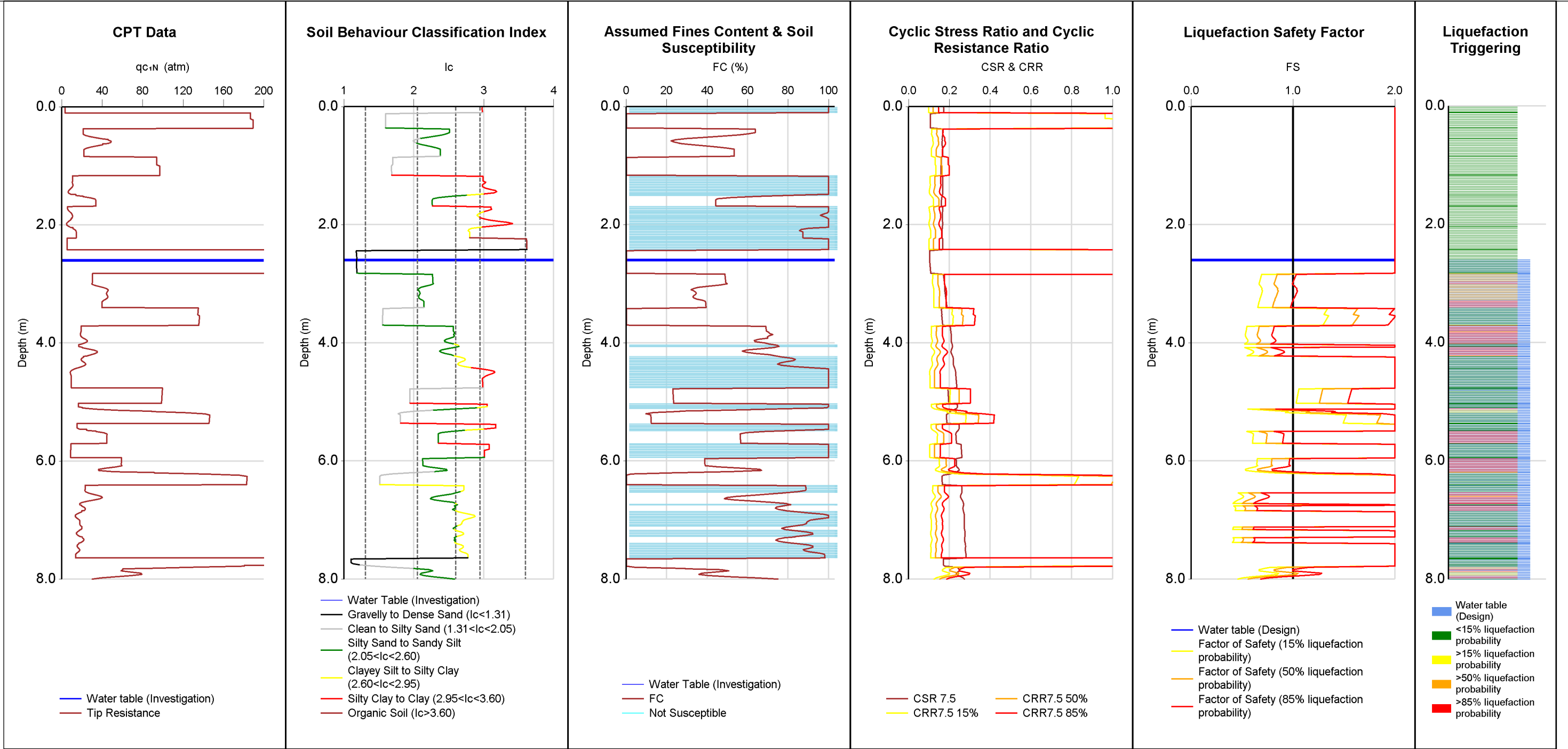
DATE
12/07/2021
ANALYSED
tzh
PAGE
1 of 13 pages



Note: Inverse filtered Q_c/F_s data (10 cm^2), Cut used.

INPUT	Run Description	TTGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	Cheal_CPT03_1.7m cut	178715	3/04/2017	0	6	0.31	BI-2014	ZRB-2002	14	Cut	0	-1.7
OUTPUT	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish	Reviewed by: CPT Inversion YUNI Groundwater YUNI Susceptibility YUNI				
	15%	67	2.4	7	16	3.1	3					
	50%	64	2.4	5	15	3.1	0					
	85%	50	1.8	2	12	3.5	0					

Reviewed by:	
CPT Inversion	YUNI
Groundwater	YUNI
Susceptibility	YUNI
Triggering	YUNI
Consequence	YUNI



Note: Inverse filtered Q_c/F_s data (10 cm^2) used.

INPUT	Run Description		TTGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m ³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	Cheal_CPT04		178716	3/04/2017	0	6	0.31	BI-2014	ZRB-2002	14		0	
OUTPUT	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPlish						
	15%	60	2.3	7	13	2.9	5						
	50%	55	2.2	5	12	2.9	3						
	85%	41	1.7	2	9	3.3	1						

Reviewed by:	
CPT Inversion	YUNI
Groundwater	YUNI
Susceptibility	YUNI
Triggering	YUNI
Consequence	YUNI

Appendix E: Foundation assessment output

- **Figure E1 - Foundation mark-up**
- **Figure E2 - Liquefaction reconsolidation and ejecta induced settlement (for information only, for structural analysis use values presented in 6.2.5.1)**
- **Table and Figure E3 - Summary of subgrade reaction modulus and bearing capacity table**

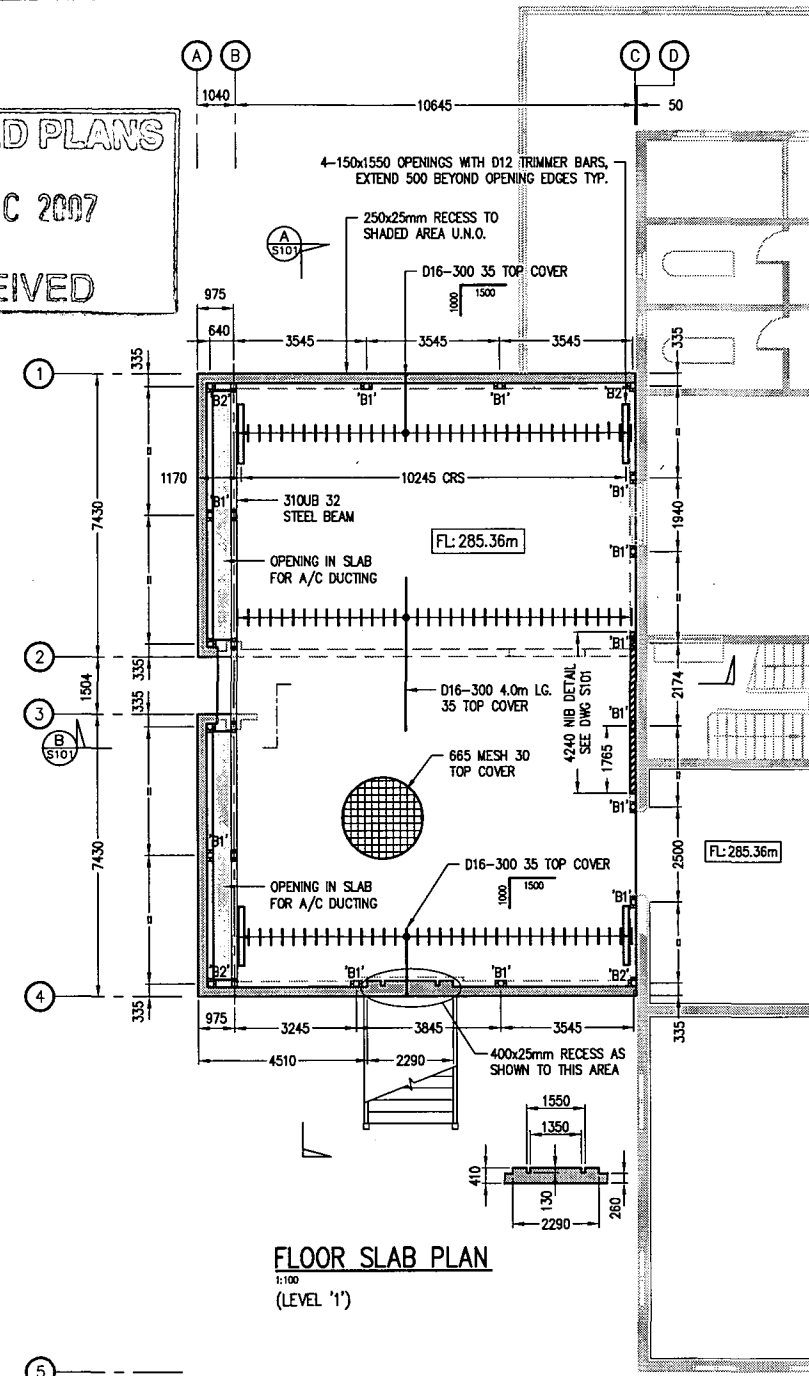
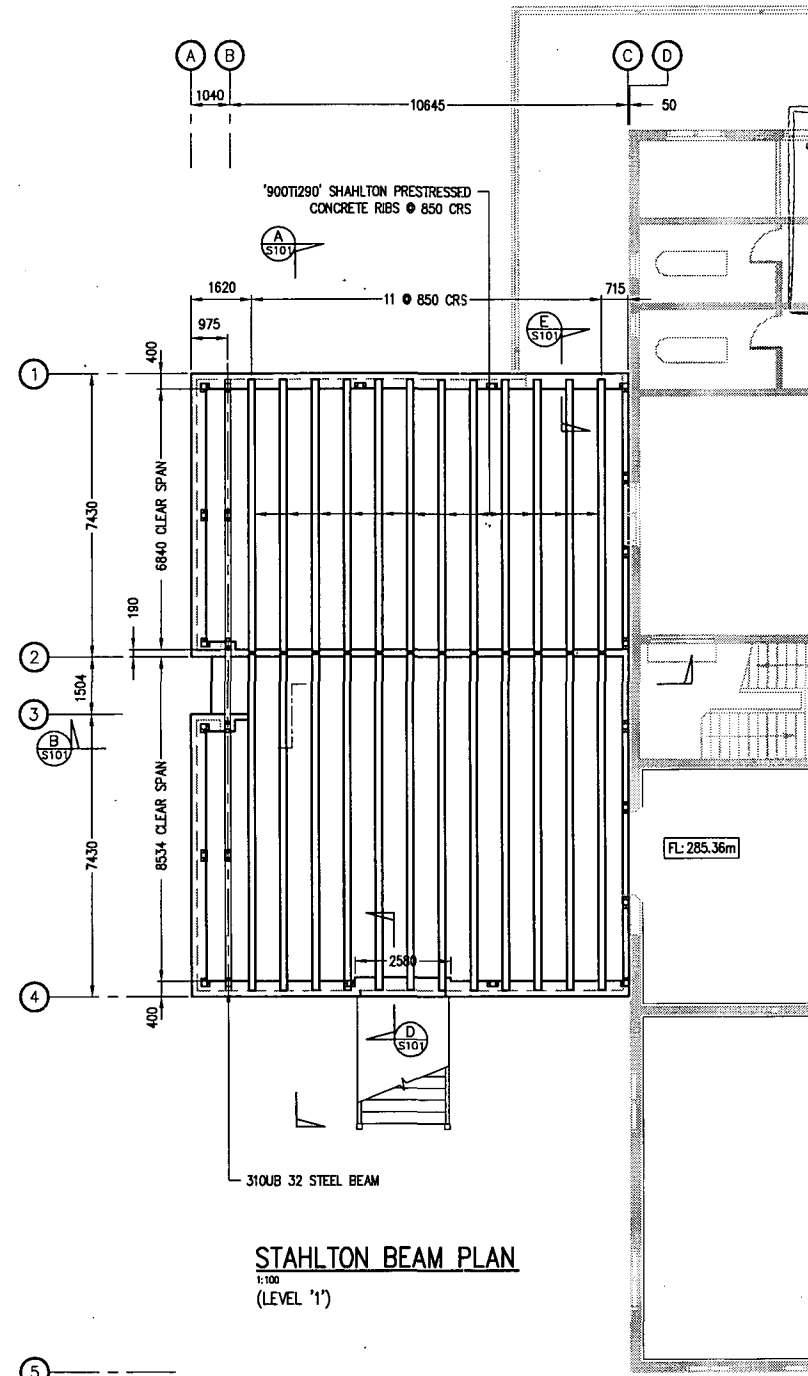
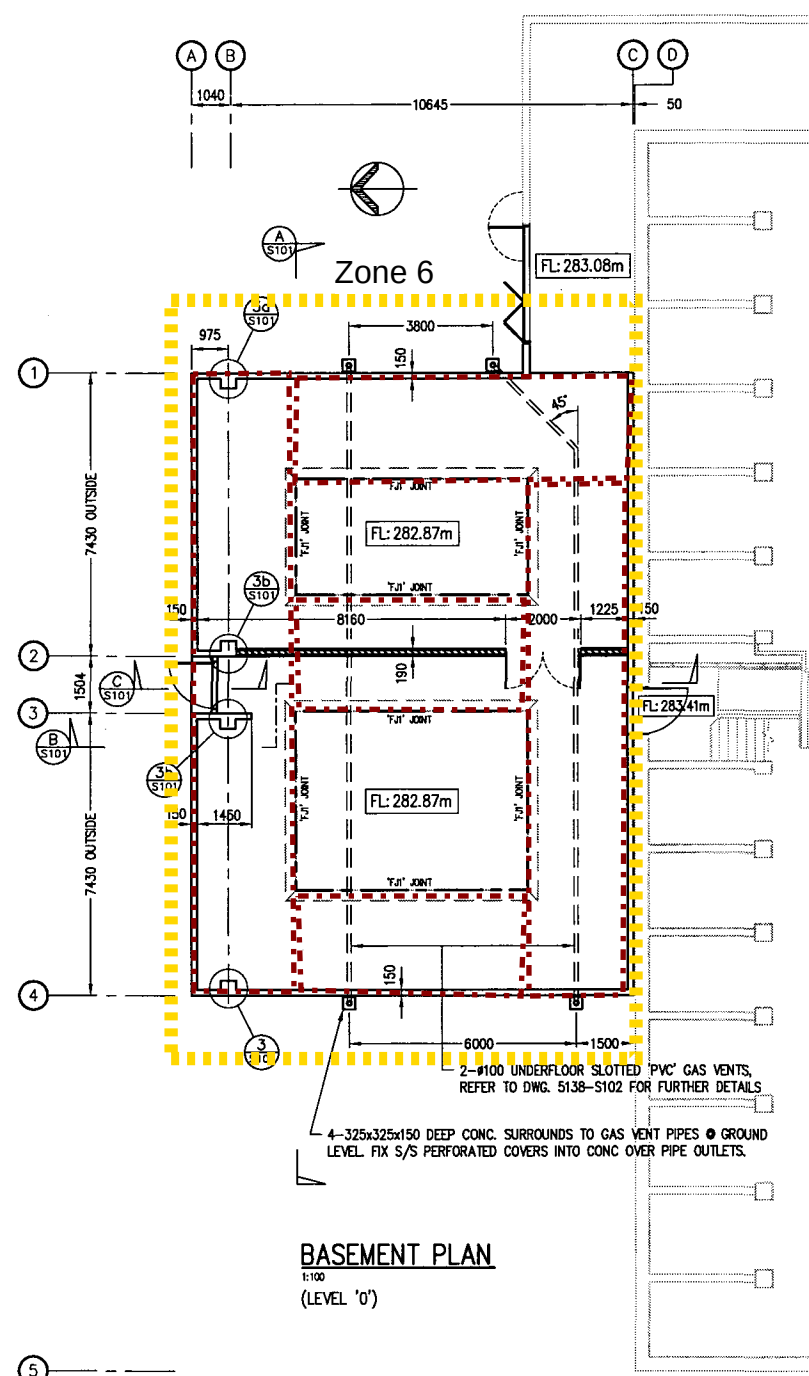
APPENDIX E1 - FOUNDATION MARKUP

 2500mm wide strip footing

 Zones

RECEIVED
14 DEC 2007
B.C.No. 60933

P00030
PS-305D



no	date	issue/revision detail	by	chk
2	5/12/07	GRIDLINES MODIFIED	MJ	PF
1	15/10/07	FOR CONSTRUCTION	MJ	PF
T	20/8/07	FOR TENDER	MJ	PF
A	3/8/07	PRELIMINARY	MJ	PF

client
**ROTORUA TRUST GALLERY
CENTENNIAL DEVELOPMENT
NORTH WING**

project
**NORTH WING
EXTENSION**

drawing title
**BASEMENT AND
FLOOR PLANS**

Scale
As Shown @ 'A1'

File Number
W:\5000\5138\Structure\5138-S100

drawing number
5138 - S100

rev.
2

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450 to 600 mm wide strip footing



700 to 800 mm wide strip footing



1150mm wide strip footing



600mm wide square footing



800 to 1000mm wide square footing



1800 to 2300mm wide square footing



Special cases



Zones



SERIAL No R 12158

NOTE: Metric dimensions of length where
no symbol is given =
(I) WHOLE NUMBERS = mm
(II) DECIMALISED EXPRESSIONS = m

DRAWING REFERENCES

FOR KEY TO SYMBOLS
USED; REFER DRG CK 4.

Zone 3

Zone 2

UNABLE TO GAIN ACCESS TO
THIS AREA. SLAB AND COLUMN
APPEARED SATISFACTORY FROM
VIEWING HOLE IN EAST WALL.

JOIN LINE 4602 CK-2

OLD MUD
BATH.

CONCRETE FLOOR AT FOUNDATION
PAD LEVEL IN MUD BATH DISPLAY.

EXTENT OF
CONCRETE FLOOR

150x150 UNREINFORCED
CONCRETE COLUMNS.
750x750 PADS (TYPICAL)

300x300 UNREINFORCED
CONCRETE COLUMNS
500x600 PADS (TYPICAL)

SPALLING
OF SLAB

SEVERE SPALLING AT JUNCTION
BETWEEN COLUMN AND SLAB
(60 mm DEEP)

350x350 REINFORCED
CONCRETE COLUMNS
(TYPICAL)

350x350 REINF.
CONC. COLUMNS
(TYPICAL)

200 WIDE REINF.
CONC. WALL.
400 WIDE FOOTING

SUGGESTED ADDITIONAL
SUPPORT REQUIRED

SEVERE SPALLING
OF SLAB

Coarse-
grained

Undeter-
mined

Fine-
grained
JOIN LINE 4602 CK-4

3340 3200 3230 1920 1900 1920 1940

1	FOR REPORT	23/6/85 A.K.
0	FOR INFORMATION	5/85 G.P.
No.	ISSUE REVISIONS	Date Drawn/Co-ord

METRIC SCALE
1:50
Contractor must verify all dimensions
on the job before commencing any
work or making any shop drawings

Designed	A.K. ; G.P.	5/85
Drawn		
Traced		
Checked		
Co-ord		
Approved		

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ENERGY AND BUILDING SERVICES ENGINEERS

TUDOR TOWERS
FOUNDATION REPORT

FOUNDATION LAYOUT

SHEET 3 OF 4

C/N	DWG No	Metric
4602	CK 3	
ISSUE No	1 of 1	Design

SERIAL No. R 12159

NOTE: Metric dimensions of length where no symbol is given:
(1) WHOLE NUMBERS = mm
(2) DECIMALISED EXPRESSIONS = m

DRAWING REFERENCES

KEY TO SYMBOLS

- CRACKS IN BARREL-VAULT FLOOR SLAB.
- SCALA PENETROMETER TEST POSITIONS.
- FOUNDATION WALL CORE SAMPLE POSITIONS.
- EXTENT OF SPALLING OF SLAB
- AREA OF WALL SPALLING

1. FOR REPORT	23/6/85 A.K.
0 FOR INFORMATION	5/85 G.P.
No.	ISSUE REVISIONS
METRIC SCALE	
1: 50	
Contractor must verify all dimensions on the job before commencing any work or making any shop drawings	
Designed	A.K.; G.P.
Drawn	5/85
Traced	
Checked	
Co-ord	
Approved	Alan Porter G.P.

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ENERGY AND BUILDING SERVICES ENGINEERS

TUDOR TOWERS
FOUNDATION REPORT

FOUNDATION LAYOUT

SHEET 4 OF 4

C/N	DWG No	Metric
4602	CK 4	000
ISSUE No	0	1
		Design

Zone 2

A 2500 D 2250 F 4500 I 3340 L 3200 R 3230 T 1920 V 1900 Y 1920 BB 1340 EE

JOIN LINE 4602 CK-3

FLOOR BROKEN OUT AT BATH POSITION

SUGGESTED ADDITIONAL SUPPORT REQUIRED (TYP.)

SPALLING SLAB

CONCRETE FLOOR AT FOUNDATION LEVEL TIMBER FLOORING ABOVE.

THIS AREA IS ENCLOSED BY WALLS, WHICH PREVENT INSPECTION OF SLAB AND SLAB SUPPORTS. SMALL PIPE OPENINGS IN THE WALLS SUGGEST IT MAY HAVE BEEN AN OLD BATH OR SIMILAR AND HAS BEEN BACKFILLED WITH PUMICE AND RUBBLE. DRAWING R2 1967 MODIFICATION INDICATE A TIMBER FLOOR RAISED OVER THIS AREA.

TIMBER FLOORING ABOVE

SPALLING OF REINFORCED PUMICE CONCRETE BEAMS AND SLABS REINFORCING RUSTING AND EXPOSED.

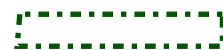
CONCRETE FLOOR AT FOUNDATION LEVEL, HENCE WE ARE UNABLE TO COMMENT ON COLUMN PADS.

EXTENT OF FOUNDATIONS COVERED IN THIS REPORT

SUGGESTED SUPPORT UNDER EXISTING TEAM

CONCRETE SPALLED, REINFORCING RUSTING AND EXPOSED.

This section has been demolished



400mm wide footing



500mm wide footing



800mm wide footing



1400mm wide footing



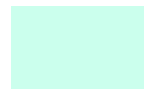
1840mm wide strip footing



2500mm wide strip footing



2.0m wide square footing



Double 2.0m wide square footing



2.6m wide square footing



7x5m wide rectangular footing



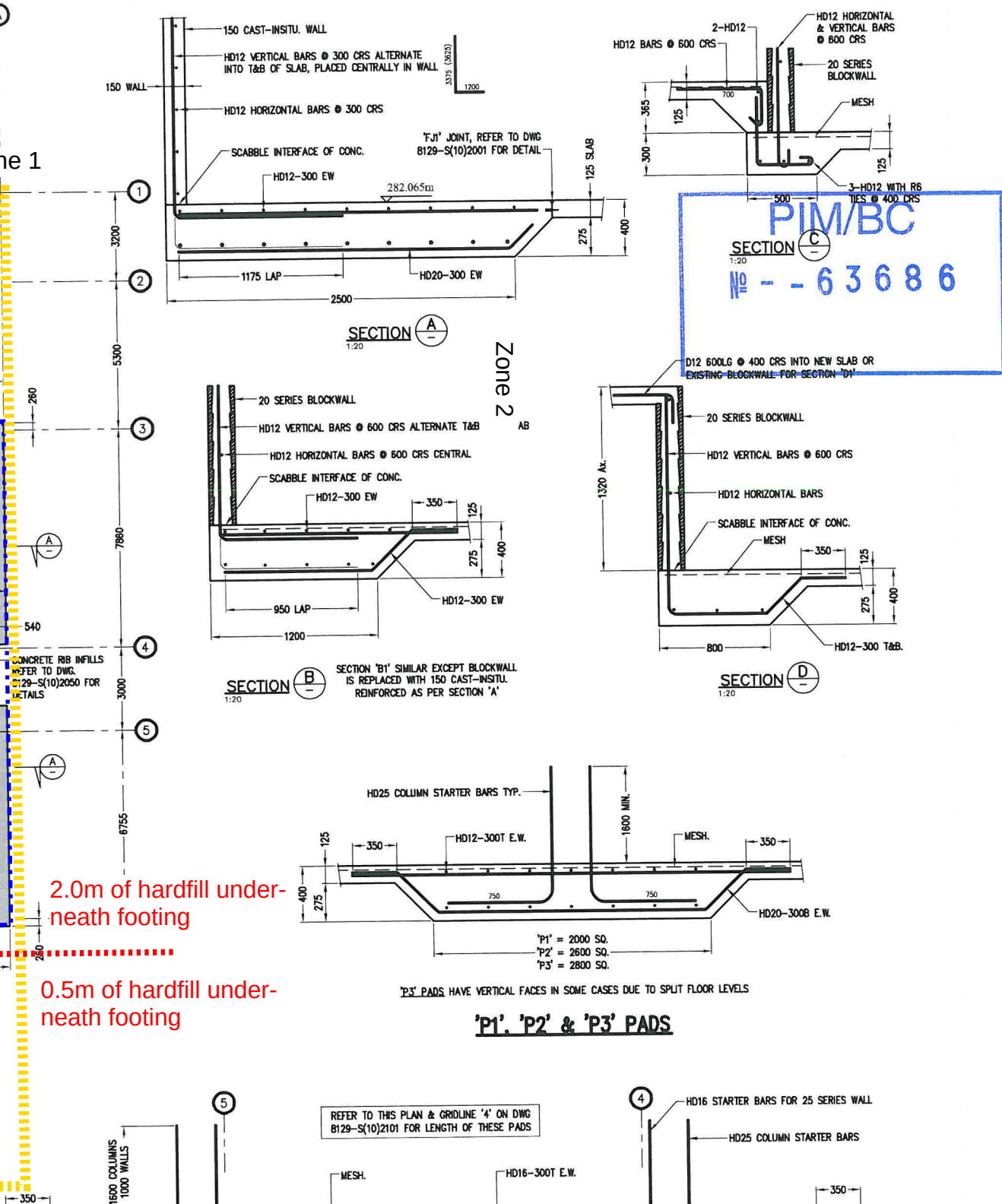
7.7 x 5m wide lift shaft footing



Zones



Boundary between 2.0m and 0.5m engineered hardfill



2.0m of hardfill under-
neath footing

0.5m of hardfill under-
neath footing

'P4' & 'P5' PADS

AS BUILT PLAN

500
YES @ 400 CRS
PIM/BC
SECTION C
1:20
NO - - 6 3 6 8 6
600LG @ 400 CRS INTO NEW SLAB OR
ENCLAVE WALL FOR SECTION D-V

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APPENDIX E2 - LIQUEFACTION RECONSOLIDATION AND EJECTA INDUCED SETTLEMENT

LEGEND

160 Combined consolidation and ejecta values

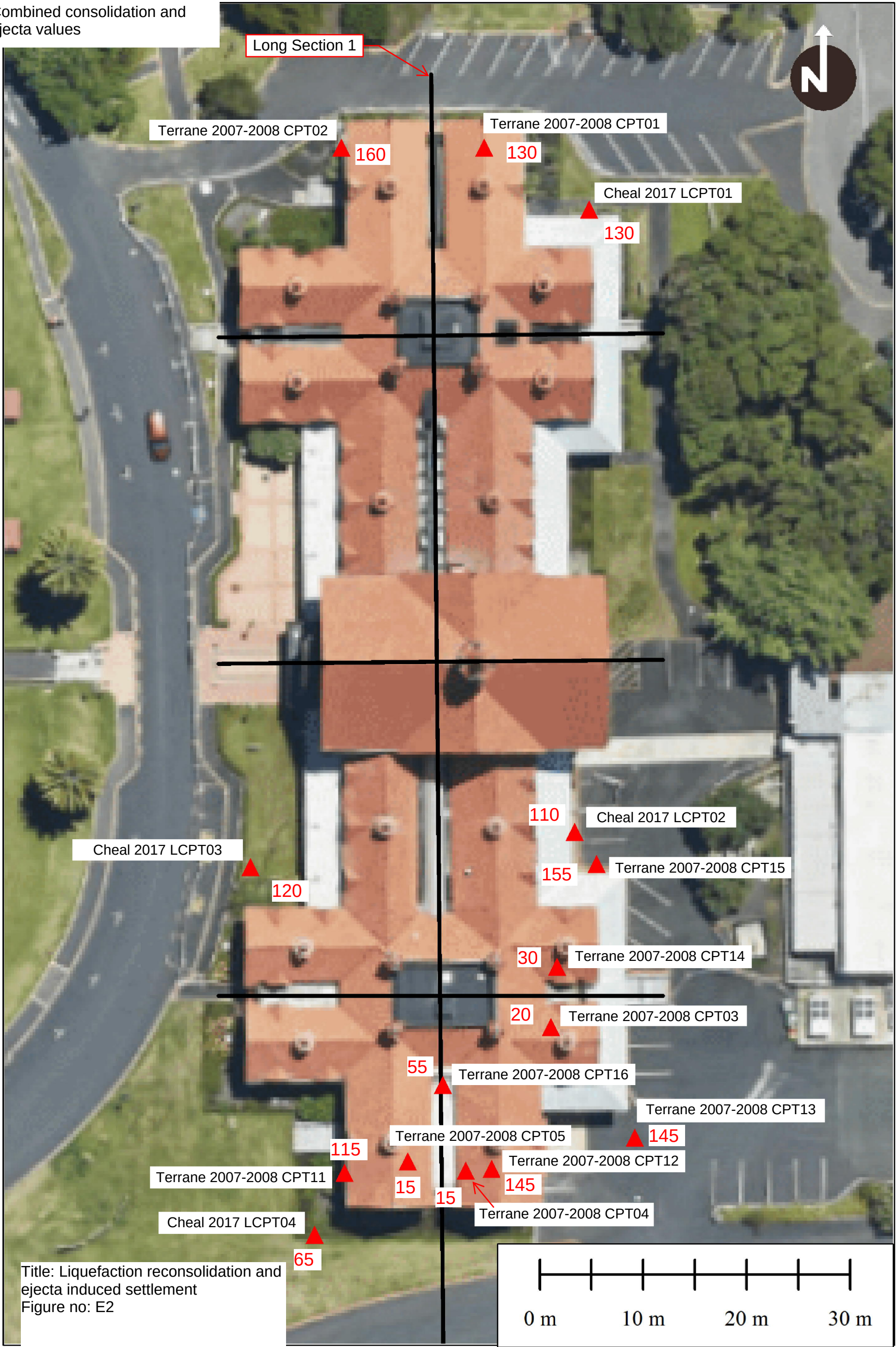


Figure E3 shows the terminology used in Table E3 below.

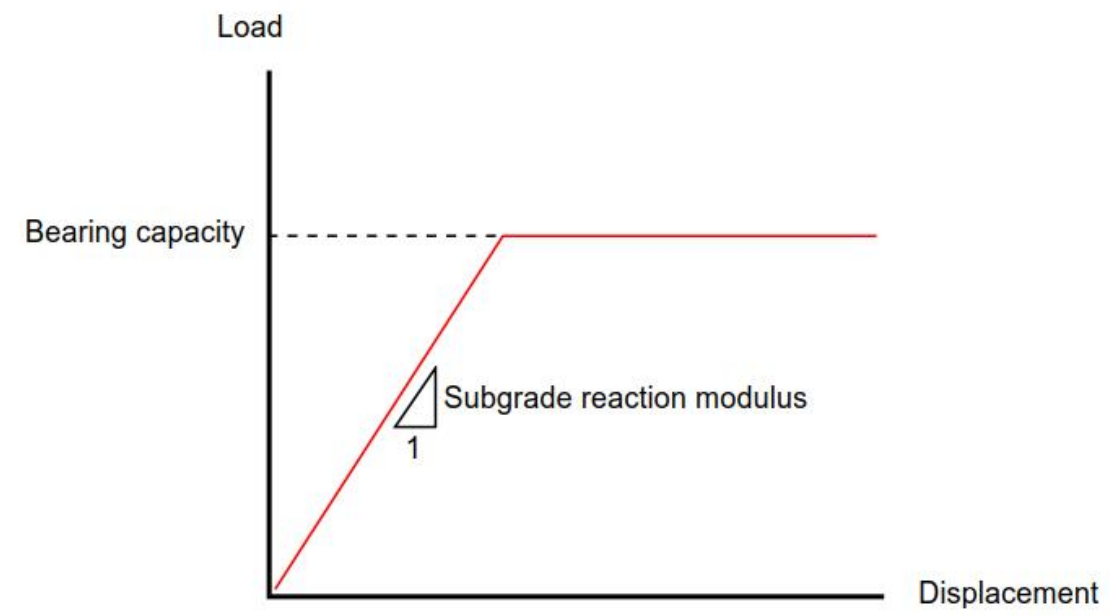


Figure E3: Load displacement curve defined by subgrade reaction modulus and bearing capacity

Table E3: Summary subgrade reaction modulus and bearing capacity

Zone	Founding layer	Founding level (m RL)	Footing type	Footing size (mm)	Non-liquefied geotechnical ultimate bearing capacity (kPa)	Geotechnical ultimate bearing capacity at 70%ULS shaking (kPa) ^(Note 2)	Geotechnical ultimate bearing capacity at full liquefaction (kPa)	Modulus of subgrade reaction in non-liquefied case (kPa/m)	Modulus of subgrade reaction at 70%ULS shaking (kPa/m)	Modulus of subgrade reaction at full liquefaction (kPa/m)	Modulus of subgrade reaction at full liquefaction for perimeter foundation (kPa/m) ^(Note 1)
1	2.0 m of engineered hardfill	282.0	Strip	400	260	260	260	11500 to 23000	As per non-liquefied	3000 to 9000	1100 to 1800
				500	310	310	280	9000 to 18000	As per non-liquefied	2200 to 6600	1000 to 1700
				1200	670	165	130	4850 to 9700	50% non-liquefied value	1125 to 3375	700 to 1300
				1840	680	130	90	3300 to 6600	50% non-liquefied value	750 to 2250	500 to 1100
				2500	570	110	75	2650 to 5300	50% non-liquefied value	575 to 1725	400 to 1000
			Square pad	2000 x 2000	1330	190	145	6100 to 12200	50% non-liquefied value	1600 to 4800	800 to 1500
				Double 2000 x 2000	950	155	115	5000 to 10000	50% non-liquefied value	1050 to 3150	700 to 1300
				2600 x 2600	1020	160	120	4200 to 8400	50% non-liquefied value	1000 to 3000	600 to 1300
			Pad	7000 x 5000	540	100	60	1850 to 3700	50% non-liquefied value	385 to 1155	300 to 800
	1.3 m of engineered hardfill	279.8	Pad	7700 x 5000 (lift shaft)	470	25	25	1600 to 3200	50% non-liquefied value	385 to 1155	N/A
	0.5 m of engineered hardfill	282.0	Strip	400	260	260	260	4850 to 9700	As per non-liquefied	2500 to 7500	1000 to 1700
				800	410	185	150	3850 to 7700	50% non-liquefied value	1300 to 3900	800 to 1400
				1200	350	140	105	2900 to 5800	50% non-liquefied value	1000 to 3000	600 to 1300
				1400	330	130	95	2550 to 5100	50% non-liquefied value	825 to 2475	600 to 1200
			Pad	Double 2000 x 2000	360	130	95	2700 to 5400	50% non-liquefied value	930 to 2790	600 to 1200
2	All soil type	283.0	Strip	450 to 600	210	210	210	3900 to 7800	As per non-liquefied	1900 to 5700	900 to 1600
				700 to 800	210 to 270	210 to 270	210 to 270	3050 to 12200	As per non-liquefied	1450 to 5250	800 to 1600
			Pad	600	270 to 310	270 to 310	270 to 310	7000 to 28000	As per non-liquefied	7000 to 28000	1300 to 2000
				800 to 1000	270 to 370	270 to 370	270 to 370	4750 to 19000	As per non-liquefied	4750 to 19000	1200 to 1900
				1800 to 2300	270 to 480	220	200	2600 to 10400	As per non-liquefied	1400 to 5250	800 to 1600
3	All soil type	283.0	Strip	450 to 600	210	210	210	3900 to 15600	As per non-liquefied	1900 to 7050	900 to 1700
				1150	210 to 350	210	180	2350 to 9400	As per non-liquefied	1050 to 3750	700 to 1400
			Pad	800 to 1000	270 to 360	270 to 360	270 to 360	4750 to 19000	As per non-liquefied	4750 to 19000	1200 to 1900
			Special	S1 - Circle 3700mm diameter	260 to 510	170	130	1700 to 6800	As per non-liquefied	750 to 2550	500 to 1200
			Special	S2 - 1500 x 1200mm	250 to 390	250 to 320	250	3500 to 14000	As per non-liquefied	3500 to 14000	1000 to 1800

Zone	Founding layer	Founding level (m RL)	Footing type	Footing size (mm)	Static geotechnical ultimate bearing capacity (kPa)	Geotechnical ultimate bearing capacity at 70%ULS shaking (kPa) ^(Note 2)	Geotechnical ultimate bearing capacity at full liquefaction (kPa)	Modulus of subgrade reaction in non-liquefied case (kPa/m)	Modulus of subgrade reaction at 70%ULS shaking (kPa/m)	Modulus of subgrade reaction at full liquefaction (kPa/m)	Modulus of subgrade reaction at full liquefaction for perimeter foundation (kPa/m) ^(Note 1)
4	All soil type	283.0	Strip	450 to 600	210	210	210	3900 to 15600	As per non-liquefied	1900 to 7050	900 to 1700
				700 to 800	210 to 270	210 to 270	210 to 270	3050 to 12200	As per non-liquefied	1450 to 5250	800 to 1600
			Pad	600	270 to 310	270 to 310	270 to 310	7000 to 28000	As per non-liquefied	7000 to 28000	400 to 2000
				800 to 1000	270 to 360	270 to 360	270 to 360	4750 to 19000	As per non-liquefied	4750 to 19000	1200 to 1900
				1800 to 2300	270 to 460	240	200	2600 to 10400	As per non-liquefied	1400 to 5250	800 to 1600
5	All soil type	283.0	Strip	450 to 600	210	210	210	3900 to 15600	As per non-liquefied	1900 to 7050	900 to 1700
				700 to 800	210 to 270	210 to 270	210 to 270	3050 to 12200	As per non-liquefied	1450 to 5250	800 to 1600
			Pad	600	270 to 310	270 to 310	270 to 310	7000 to 28000	As per non-liquefied	7000 to 28000	400 to 2000
				800 to 1000	270 to 370	270 to 370	270 to 370	4750 to 19000	As per non-liquefied	4750 to 19000	1200 to 1900
6	All soil type	282.8	Strip	2500	210 to 460	135	90	5800 to 11600	50% non-liquefied value	650 to 1950	500 to 1000

Note: 1. Need only be considered when the factor of safety against bearing failure is less than 1.5 (i.e. bearing capacity < 1.5 x bearing pressure)
2. Based on 1000-year return period ULS earthquake as per MBIE Earthquake geotechnical engineering practice Module 1 guideline issued March 2016

Appendix F: Secondary settlement calculation

Settlement calculation

Objective: To estimate settlement that had occurred to date, and estimate potential future settlement

Calculation by: TZHL 16/02/2022
Checked by: STT 1/03/2022

Dimension of gable wall foundation is 1150mm. Loads provided by structural engineer is approx 120kN/m. Giving a pressure of 100kPa
The secondary coefficient for this load range is expected to be between 0.004 and 0.006

Settlement at first point in time		
Assumed thickness	3000 mm	
Secondary compression coefficient	0.006	
Time (year)	114 year	<<<
Time (Mins)	59918400 mins	
Predicted settlement	139.9961 mm	(appears the secondary settlement could cause 90-140mm of differential settlement based on sec coefficient of 0.004-0.006)
Settlement at second point in time		
Time (year)	164 year	<<<
Time (Mins)	86198400 mins	
Predicted settlement	142.839 mm	
Increase in differential settlement	2.842902 mm	However further differential settlement in the next 50 years is small (less than 10mm)

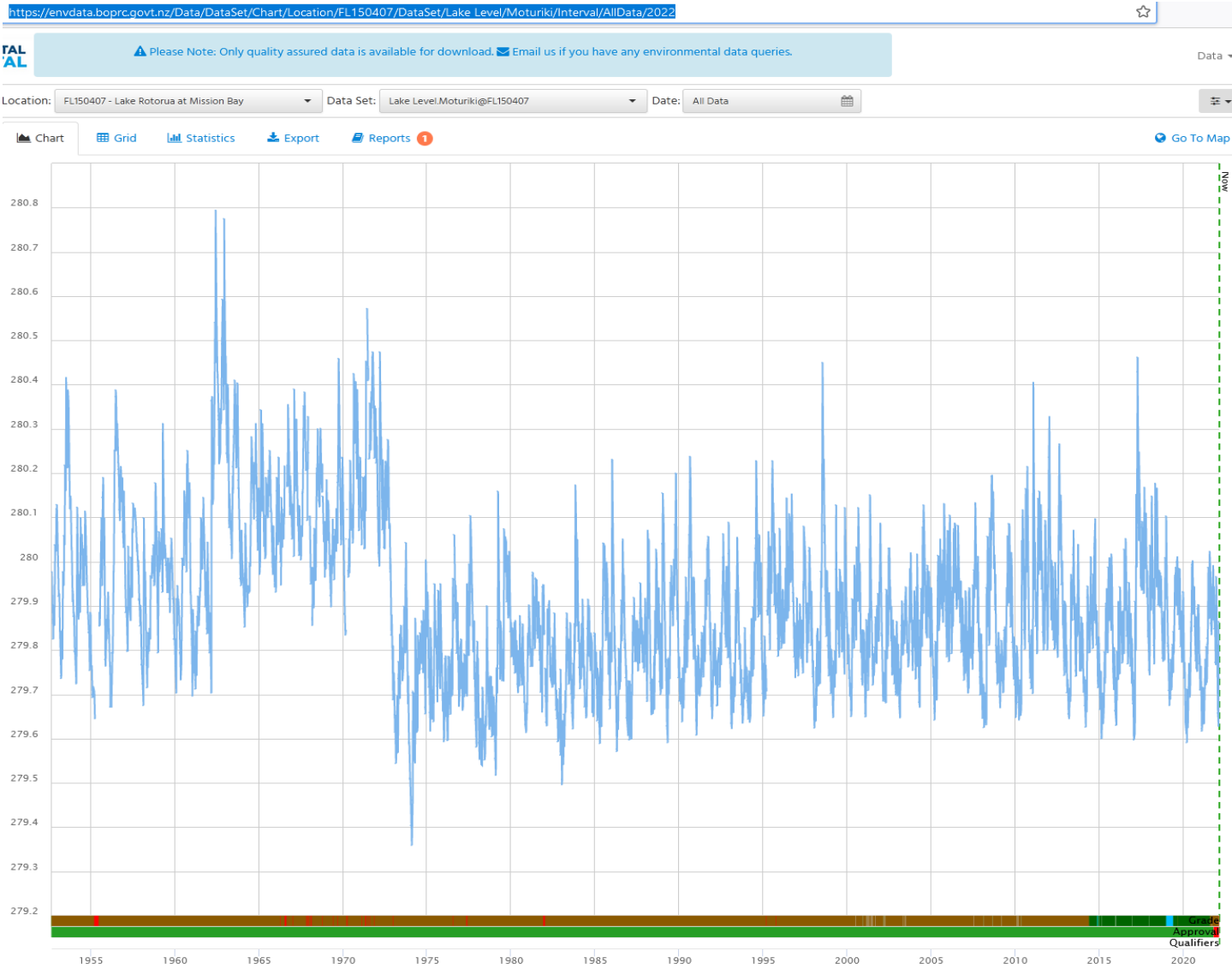
Using the worst secondary compression coefficient from the 1D consol test

Assumed thickness	3000 mm	
Secondary compression coefficient	0.013	
Time (year)	114 year	<<<
Time (Mins)	59918400 mins	
Predicted settlement	303.3248 mm	
Settlement at second point in time		
Time (year)	164 year	<<<
Time (Mins)	86198400 mins	
Predicted settlement	309.4845 mm	
Increase in differential settlement	6.159621 mm	However further differential settlement in the next 50 years is still small (less than 10mm)

If stress state in the ground is changed in 1970 due to change in lake level by 1m (as provided in BOP Regional Council website)
<https://envdata.boprc.govt.nz/Data/DataSet/Chart/Location/FL150407/DataSet/Lake%20Level/Moturiki/Interval/AllData/2022>

Settlement at first point in time		
Assumed thickness	3000 mm	
Secondary compression coefficient	0.006	
Time (year)	62 year	<<<
Time (Mins)	32587200 mins	
Predicted settlement	135.2348 mm	
Settlement at second point in time		
Time (year)	52 year	<<<
Time (Mins)	27331200 mins	
Predicted settlement	133.8599 mm	
Settlement at third point in time		
Time (year)	102 year	<<<
Time (Mins)	53611200 mins	
Predicted settlement	139.1266 mm	
Increase in differential settlement	5.266743 mm	
Using the worst secondary compression coefficient from the 1D consol test		
Settlement at first point in time		
Assumed thickness	3000 mm	
Secondary compression coefficient	0.013	
Time (year)	62 year	<<<
Time (Mins)	32587200 mins	
Predicted settlement	293.0088 mm	
Settlement at second point in time		
Time (year)	52 year	<<<
Time (Mins)	27331200 mins	
Predicted settlement	290.0297 mm	
Settlement at third point in time		
Time (year)	102 year	<<<
Time (Mins)	53611200 mins	
Predicted settlement	301.441 mm	
Increase in differential settlement	11.41128 mm	

Considering possibility of change the stress state in the ground changed due to change in groundwater level
(lake level drop about 1m in 1970's) that could "reset" the rate of secondary settlement, the differential settlement could be as high as 11mm.
Considering the uncertainties of the secondary settlement rate and soil properties and in the absence of sufficient and reliable monitoring data, the secondary settlement for the next 50 years is estimated to be approximately 25mm (doubling the rate calculated above).



Appendix G: Assessment of “onset” of liquefaction using laboratory cyclic triaxial testing

Assessment of “onset” of liquefaction using laboratory cyclic triaxial testing

Project name: Rotorua Museum seismic strengthening

Job no: 1017126

Analysed by STT dated 3 March 2022 Checked by MEJ dated 4 April 2022

Objective 1

To estimate the level of earthquake shaking when the geotechnical step change (from liquefaction point of view) is deemed to occur, using the recent laboratory cyclic triaxial testing information.

Magnitude 6 is equivalent to approx. 5 cycles according to Figure 62 in B&I 2008

Page 3 shows the plot of r_u vs CSR at 5 cycles of laboratory cyclic triaxial testing

Page 4 shows the plot of max. cyclic shear strain vs CSR at 5 cycles of laboratory cyclic triaxial testing

From those plots, it can be seen that excess pore water pressures (r_u) and cyclic shear strains are moderately elevated but remain stable for CSR_{field} values in the range of 0.18 – 0.25, which corresponds to 50 – 70% of ULS shaking demand (for IL3, from the older MBIE 2016 guidance).

Above a CSR_{field} value of 0.25 the cyclic response quickly becomes unstable and large excess pore pressures and shear strains developed, indicating liquefaction triggering along with more substantial strength loss and reconsolidation settlement.

Objective 2

To estimate the consolidation-related settlement immediately prior to the geotechnical step change i.e. at 70% of ULS (IL3) shaking.

Page 5 shows the volumetric strains measured in the post-cyclic reconsolidation phase of cyclic triaxial testing for Rotorua Museum BH9 samples, compared to the trendlines for conventional clean sands proposed in Ishihara & Yoshimine (1992). The Rotorua Museum results show a trend similar to that for a conventional sand with a relative density of 40%. We understand from the University of Canterbury that this trend is similar to recent testing they have undertaken for various pumice samples from Edgumbe and Hamilton (albeit that the volumetric strain from the Rotorua Museum samples was slightly higher than for the samples from elsewhere).

Page 4 shows that for the cyclic triaxial tests where the shear strains remained stable for 50 – 70% of ULS (IL3) shaking, the shear strain ranged from 0.33 to 1.31. Plotting this range on Page 5 shows this corresponds to volumetric strain in the range of 0.23 to 0.76%. Taking an average of this range (as appropriate for estimating total settlements from a volume of soil) provides a representative volumetric consolidation strain of 0.5% for these soils at 70% of ULS (IL3) shaking.

However, as shown on Page 4, the sample from BH7 6.2-6.4m depth exhibited noticeably lower cyclic resistance than the other samples tested. It liquefied at approximately 70% of ULS (IL3) shaking, resulting in a shear strain of 7.5% at 5 cycles. For this soil layer (assessed to be 1m thick based on the CPT and borehole information), a volumetric consolidation strain of 4.5% was assumed at 70% of ULS (IL3) shaking.

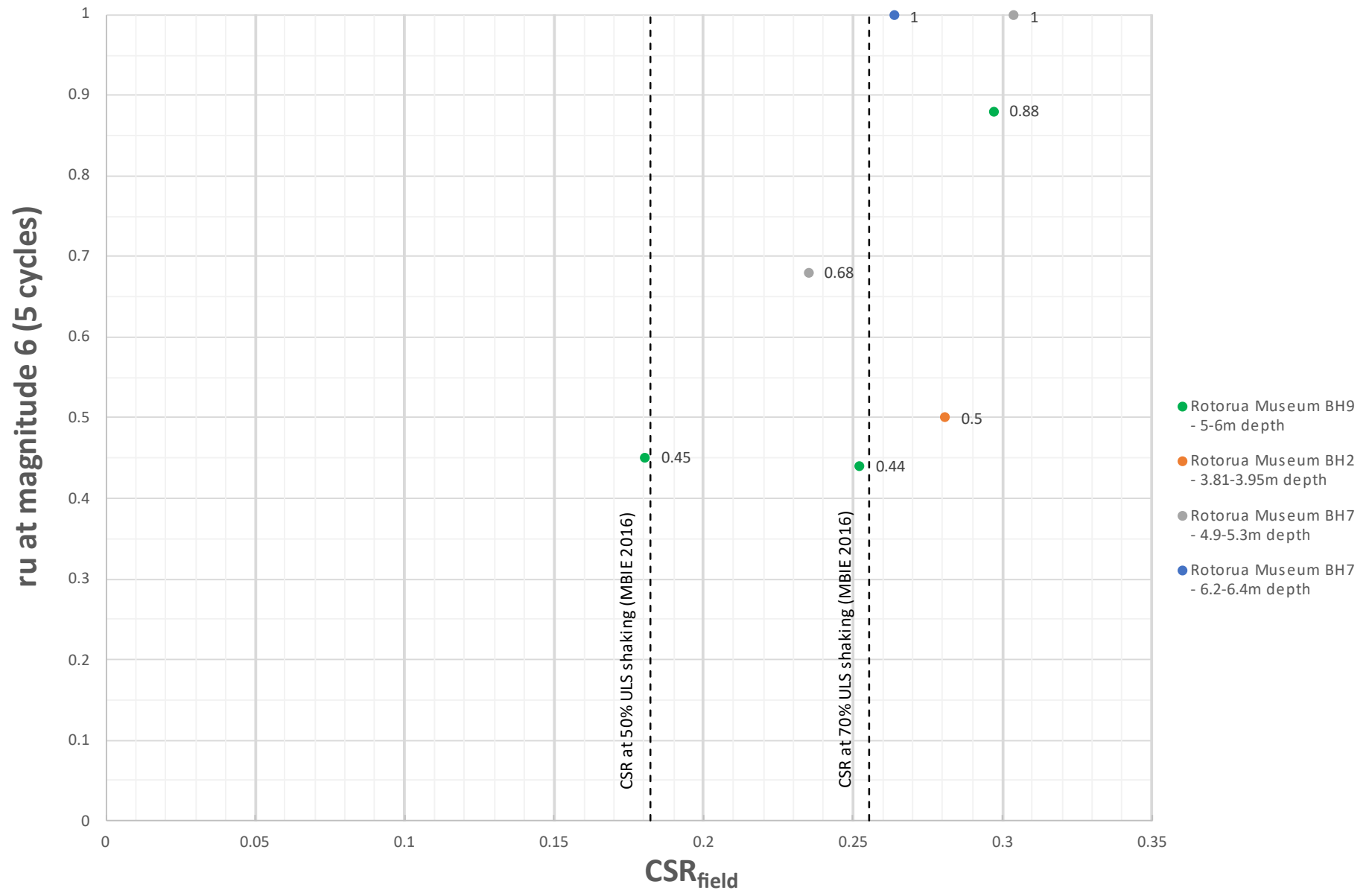
Page 6 summarises the simplified ground model adopted for the consolidation settlement calculation, and the resulting estimate of total and differential settlement across the various building zones.

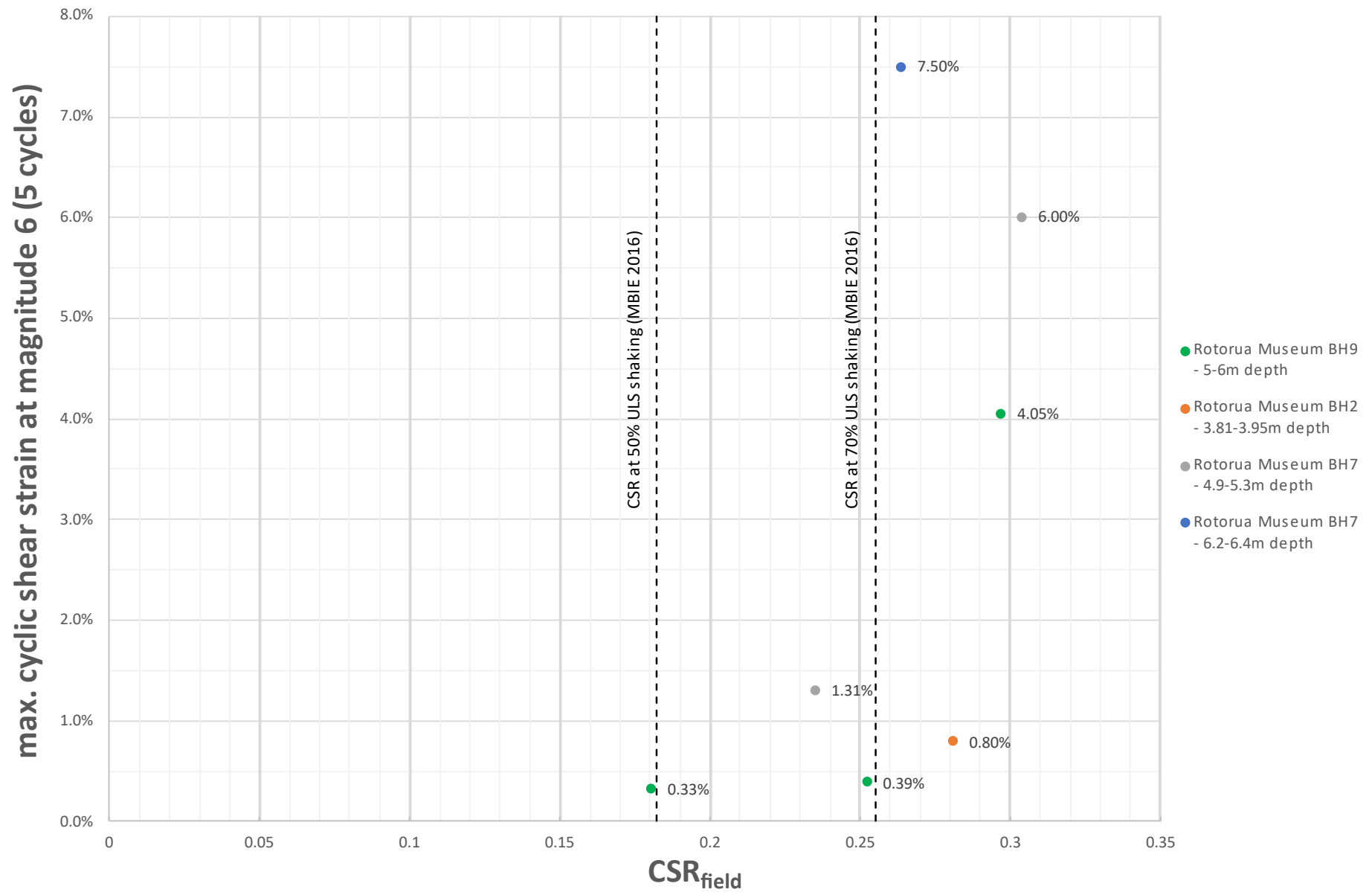
Objective 3

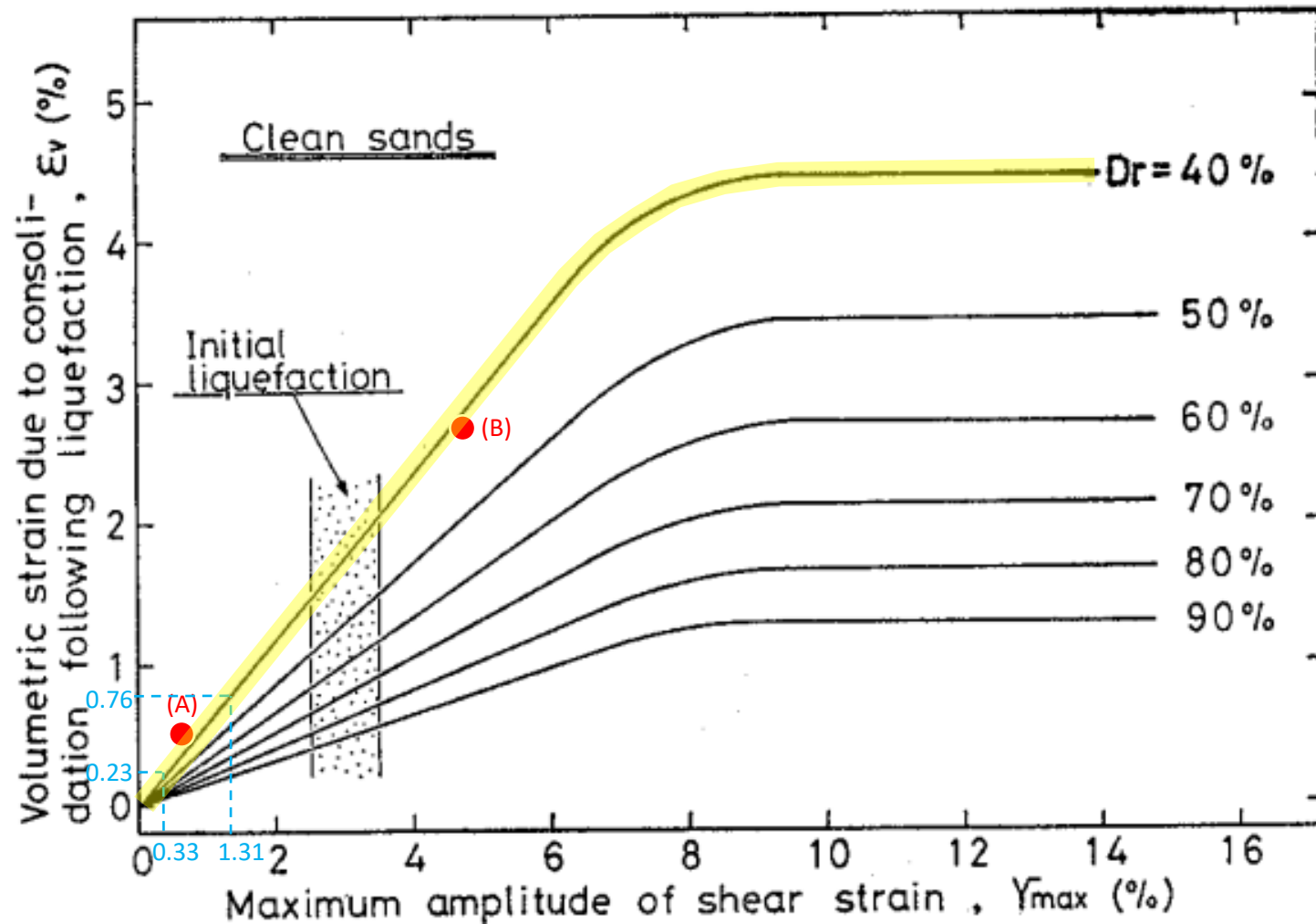
To estimate the foundation punching bearing capacity immediately prior to the geotechnical step change i.e. at 70% of ULS (IL3) shaking.

The critical layer for foundation punching is Layer 2b (silty SAND and sandy SILT). The adopted static design parameters for this layer are $\phi' = 28^\circ$ $c' = 3 \text{ kPa}$ (Table 5.1 of main report).

Page 3 shows that for the cyclic triaxial tests where the shear strains remained stable for 50 – 70% of ULS (IL3) shaking, the excess pore pressure ranged from $r_u = 0.44$ to 0.68, with a representative average value of approximately $r_u = 0.5$. This excess pore pressure reduces the frictional contribution to the shear strength of Layer 2b by 50%, resulting in an equivalent shear strength ratio of $s_u/\sigma'_{v0} = 0.27$ (this compares to a value of 0.09 adopted for the fully liquefied condition). This reduced shear strength was included in the Meyerhof punching shear bearing capacity calculations summarised in Appendix E of this report.







(A) Rotorua Museum BH9,
5-9m depth
 $CSR_{field} = 0.18$
failure not reached
 $\gamma_{max} = 0.6\%$, $\varepsilon_v = 0.5\%$

(B) Rotorua Museum BH9,
5-9m depth
 $CSR_{field} = 0.25$
failure at 976 cycles
 $\gamma_{max} = 4.7\%$, $\varepsilon_v = 2.7\%$

Red markup: Volumetric strains measured in post-cyclic reconsolidation phase of cyclic triaxial testing for Rotorua Museum BH9 samples.

Blue markup: Range of shear strains from cyclic triaxial testing at 50 – 70% of ULS (IL3) level shaking.

Background chart is Figure 3 from Ishihara & Yoshimine (1992) "Evaluation of settlements in sand deposits following liquefaction during earthquakes"

Estimate of volumetric consolidation settlement at 70% of ULS (IL3) level of shaking

Zones 1 & 2			
Depth	Performance at 70% of ULS (IL3) level of shaking	Volumetric consolidation strain	Volumetric settlement contribution
0 – 3m	Not liquefiable (above water table)	0%	0mm
3 – 6m	Moderate excess pore water pressure ($r_u \sim 0.5$) & cyclic strains ($\gamma \sim 0.5\%$)	0.5%	15mm
6 – 7m	Fully liquefied ($r_u = 1$) with substantial cyclic strains ($\gamma \sim 7.5\%$)	4.5%	45mm
7 – 8m	Moderate excess pore water pressure ($r_u \sim 0.5$) & cyclic strains ($\gamma \sim 0.5\%$)	0.5%	5mm
Below 8m	Hard sinter layer, not liquefiable	0%	0mm
TOTAL SETTLEMENT			65mm

Zones 3 to 6			
Depth	Performance at 70% of ULS (IL3) level of shaking	Volumetric consolidation strain	Volumetric settlement contribution
0 – 3m	Not liquefiable (above water table)	0%	0mm
3 – 6m	Moderate excess pore water pressure ($r_u \sim 0.5$) & cyclic strains ($\gamma \sim 0.5\%$)	0.5%	15mm
Below 6m	Hard sinter layer, not liquefiable	0%	0mm
TOTAL SETTLEMENT			15mm

For differential settlement:

- Assume 75% of the total settlement in Zones 1 & 2 could occur differentially over a horizontal distance of 10m: $(0.75 \times 65\text{mm}) / 10\text{m} = 1:200$
- Assume 100% of the total settlement in Zones 3 to 6 could occur differentially over a horizontal distance of 10m: $15\text{mm} / 10\text{m} = 1:667$ (say 1:600)
- Assume the difference in total settlement between Zone 2 & 3 could occur differentially over a horizontal distance of 10m: $(65\text{mm} - 15\text{mm}) / 10\text{m} = 1:200$

