REPORT

Tonkin+Taylor

Omokoroa Stage 3 Structure Plan Area

Supplementary Level B Liquefaction Assessment

Prepared for
Bay of Plenty Regional Council
Prepared by
Tonkin & Taylor Ltd
Date
May 2020
Job Number
1008683.0000.v2

Exceptional thinking together
www.tonkintaylor.co.nz

Document Control

Title: Omokoroa Stage 3 Structure Plan Area					
Date	**Version**	**Description**	**Prepared by:**	**Reviewed by:**	**Authorised by:**
03/04/20	1	Draft for comment	GUMC	JICR	DMMM
26/05/20	2	Final with peer review comments addressed	GUMC	JICR	DMMM

Distribution:

Bay of Plenty Regional Council	1 PDF copy
Tonkin & Taylor Ltd (FILE)	1 PDF copy

Table of contents

Executive summary

Liquefaction assessment summary	
This liquefaction assessment has been undertaken in general accordance with the guidance document 'Assessment of Liquefaction-induced Ground Damage to Inform Planning Processes' published by the Ministry of Business, Innovation and Employment in 2017. https://www.building.govt.nz/building-code-compliance/b-stability/b1-structure/planning-engineering-liquefaction-land/	
Client	Bay of Plenty Regional Council (BOPRC)
Assessment undertaken by	Tonkin & Taylor Ltd. PO Box 5271 Wellesley Street Auckland 1141
Extent of the study area	• Total: 280 ha (2.8 km^2), Area of development: 150 ha (1.5 km^2)
Intended RMA planning and consenting purposes	• Information to support land use plan change application
Other intended purposes	• Input to a risk assessment in accordance with the BOPRC Regional Policy Statement
Level of detail within the area of development	• Level B (calibrated desktop assessment)
Notes regarding base information	• This assessment includes consideration of available geotechnical investigations that were within the study area extent and land adjacent to the study area extent on the NZ Geotechnical Database as at 6 May 2019 and additional project specific investigation completed in February 2020. • The mapped depth to groundwater was developed from point measurements of groundwater levels and with engineering judgement. It is intended to be used at a high level to assess suitability of land for land use plan change purposes.
Other notes	• The assessment is not suitable for other purposes (e.g. for appending to Land Information Memorandum reports or detailed design) • The portions of land classified as *liquefaction damage is possible* have been established based on: - Data and information summarised in this report. If more information becomes available, the liquefaction damage category may change for certain areas of land. - The primary indicator of liquefaction vulnerability has been based on the assessment that the Rotoehu Ash is not susceptible to liquefaction and this layer being less than 4 m depth. - The current information indicates that the majority of the proposed development area is likely to have none to minor liquefaction-induced land damage following levels of earthquake shaking up to 500 year ARI.

1 Introduction

Tonkin & Taylor Ltd (T+T) was engaged by Western Bay of Plenty District Council (WBOPDC) and Bay of Plenty Regional Council (BOPRC) to undertake ground investigation and liquefaction risk assessments for the Omokoroa Stage 3 Structure Plan Area in general accordance with the MBIE/MfE Guidelines (2017) in order to inform the suitability of land for the structure plan change. The study area is shown in Figure A1 of Appendix A.

A liquefaction assessment was completed in September 2019 to a Level A (desktop assessment) level of detail. The September 2019 assessment recommended further work to obtain a Level B (calibrated desktop assessment) level of detail suitable for a change in land use and Regional Policy Statement (RPS) risk assessment. To support this increased level of detail, a ground investigation and factual report was completed in February 2020 by T+T.

This report is intended to provide a Level B level of detail with use of the previous Level A assessment of the same study area in Omokoroa (T+T, 2019), and the recent project specific ground investigation data (T+T, 2020). This report is supplementary to the Level A report (T+T, 2019) and therefore should be read in conjunction with that report. The Level A report is included in Appendix C.

This report has been completed for BOPRC in accordance with the scope included in the T+T variation dated March 2020.

2 Objectives from the Level A assessment

The performance criteria for determining the liquefaction vulnerability category from Table 4.4 of the MBIE/MfE Guidelines (2017) was mapped in the Level A study (T+T, 2019). The main outcome of that mapping process was that the land was categorised into two liquefaction vulnerability areas as described below:

- Type A sub area (stream channel and coastal margin areas): *Liquefaction Damage is Possible.*
- Type B sub area (within elevated terraces): *Liquefaction Damage is Unlikely* subject to confirmation that the depth to groundwater is deeper than 4 m and the presence of the Rotoehu Ash layer is confirmed across the area under consideration at a depth of 4 m or less.

The outcomes of the Level A study (T+T, 2019) assisted with targeting the investigation to establish objectives for the investigation. The main objectives were to:

- Assess the depth to groundwater across the study area from standpipe piezometer and other investigation records.
- Assess the presence and depth to the top of the Rotoehu Ash layer (base of the Younger Ash).
- Complete additional CPT investigations for liquefaction analysis.

3 Risk identification

3.1 Target level of detail required for intended purposes

The primary purpose of this assessment is to assess suitability for a land use plan change. T+T understands that the proposed density of dwellings for the study area is likely to be 20 dwellings per hectare. This is consistent with an "urban residential development" as described in the MBIE/MfE Guidelines (2017) (i.e. typically 15 - 60 households per hectare). Table 3.5 of the MBIE/MfE Guidelines (2017) recommends the following minimum level of detail to support a plan change for an "urban residential development":

- Level A for land categorised as Very Low liquefaction vulnerability category; or
- Level B for land categorised as Low, Medium or High liquefaction vulnerability category.

The previous Level A assessment (T+T, 2019) did not demonstrate a Very Low liquefaction vulnerability, therefore a Level B assessment is targeted to support the proposed land use planning change.

3.2 Base information currently available

3.2.1 Ground surface levels

Additional ground surface level information has not been obtained since the Level A study. The ground level information (2015 LiDAR) is shown in Figure A2 of Appendix A. The resolution is 1.0 m.

3.2.2 Geology and geomorphology

Additional published geological or geomorphological information has not been obtained since the Level A study. However, refinement has been made to the geomorphological mapping as a result of more detailed ground investigation discussed in Section 3.2.3.

The depth and extent of the Rotoehu Ash is a key component of this study because this layer and the underlying soils have been assessed as not susceptible to liquefaction for reasons discussed in Section 4.4. The investigations identified the top of the Rotoehu Ash at depths between 0.9 m and 3.1 m within the terrace areas of the site (Type B sub area). In the stream gullies the Rotoehu Ash was not investigated as stream processes are likely to have eroded this ash material away.

The geomorphology is shown in Figure A3 of Appendix A and the measured depth to the top of the Rotoehu Ash layer is shown in Figure A5 of Appendix A.

3.2.3 Geotechnical investigations

Additional geotechnical information has been obtained from two primary sources since the Level A study:

- Project specific ground investigation as described in the February 2020 geotechnical factual report (T+T, 2020).
- Geotechnical investigation (ten hand augers) for a subdivision at 58 and 70A Francis Road (Aurecon, 2017).

The following table summarises the currently available information within and adjacent to the study area. The ground investigation locations are included in Figure A1 of Appendix A.

Table 3.1: Geotechnical information available within and adjacent to the study area

Source	CPT	HA	SP	BH
Inside the study area				
Project specific geotechnical report (T+T, 2020)	9	10	6	-
New Zealand Geotechnical Database (NZGD)	4	-	-	-
Geotechnical Assessment Report – 58 and 70A Francis Road	-	10	-	-
Preliminary Geotechnical Investigation Report – 452 Omokoroa Road, Omokoroa	-	9	-	-
Sub-total	**13**	**29**	**6**	**-**
Adjacent to the study area				
New Zealand Geotechnical Database (NZGD)	3	-	-	2
Geotechnical Completion Report – Stage 1A Kaimai Views Subdivision, 336, 340 and 344 Omokoroa Road, Omokoroa	18	14	-	-
Geotechnical Completion Report – Stage 1, 423 Omokoroa Road, Omokoroa	-	27	-	-
Geotechnical Completion Report – Stage 1C of the Harbour Ridge Subdivision at 351 Omokoroa Road, Omokoroa	-	15	-	-
Sub-total	**21**	**56**	**-**	**2**
Total	**34**	**85**	**6**	**-**

Notes: CPT = Cone Penetration Test, HA = Hand Auger Borehole, BH = Machine Borehole, SP = Standpipe piezometer

3.2.4 Groundwater

The project specific geotechnical investigations (T+T, 2020) involved installation of six standpipe piezometers within the study area to inform the qualitative assessment of depth to groundwater developed as part of the Level A study. Measurements of the groundwater levels within the standpipes were recorded over four visits. Some of the earlier measurements were variable indicating that the standpipe was equilibrating with the natural groundwater level. The measurements obtained on 18 February 2020 indicate that the water level in the piezometers has stabilised to in-situ groundwater levels.

Figure A4 of Appendix A shows the measured groundwater depths. Within the terraced areas the measurements ranged between 4.41 m (CPT106) and 9.07 m (CPT105) below ground level (m bgl). CPT106 and 107b had relatively shallow measurements, even though they are located at higher elevations. These shallower measurements indicate the potential for locally perched groundwater within the study area, an observation supported by previous geotechnical reports (CMW, 2017; CMW, 2018) and T+T's field experience. Only one standpipe piezometers was located within the stream gully and coastal margin areas, and the depth to groundwater measured at this location was 2.17 m bgl.

3.2.5 Regional seismicity

The adopted ground seismic hazard is documented within the Level A study. The estimated 500 year return period peak ground acceleration (PGA) and effective magnitude utilised for this assessment are 0.26g and 5.9, respectively. This has been calculated in accordance with the NZTA Bridge Manual methodology (2018) assuming subsoil class D.

Since the Level A study was undertaken, Tauranga City Council (TCC) engaged Bradley Seismic Limited (BSL) to undertake a high-level regional seismic hazard assessment (BSL, 2019) for the purposes of informing the seismic hazard component of a regional liquefaction assessment across the Tauranga City area. A comparison of the predicted PGA and Magnitude (M) is provided in Table

4.1. The table shows that BSL predicts PGAs that are 20 to 30% less than the NZTA bridge manual and the magnitudes are slightly higher. If the BSL estimates were utilised to for the Omokoroa liquefaction assessment it is likely that reduced consequences of liquefaction-induced ground damage would be predicted. The Omokoroa Study Area is approximately 7 km northwest of the TCC study area boundary.

Table 3.2: Comparison of seismic parameters between BSL and NZTA Bridge Manual

		BSL Seismic Parameters for Tauranga City		NZTA Bridge Manual Seismic Parameters[(a)]	
		PGA	**M**	**PGA**	**M**
Return period	**25**	0.06	6.1	0.07	5.9
	100	0.11	6.1	0.13	5.9
	250	0.16	6.2	0.20	5.9
	500	0.20	6.2	0.26	5.9
	1000	0.24	6.3	0.35	5.9

Notes: a. Assumed variables: Subsoil class D, Location = Tauranga

3.2.6 Historical observations of liquefaction

Additional historic observations of liquefaction have not been obtained since the Level A study.

3.3 Level of detail supported by currently available information

The currently available information supports a Level B (calibrated desktop) level of detail.

Table 3.3 of MBIE (2017) provides the indicative spatial density for a Level B ground investigation. Table 3.3 provides comparison between the guidance and what is achieved within the study area. The proposed development area is approximately 1.5 km^2 (excluded stream gullies).

Table 3.3: Comparison of investigations completed against MBIE (2017) Guidance

MBIE guidance	**Guidance**	**Achieved**
Minimum of 0.5 to 20 deep investigations per km^2	0.75 to 30[(1)]	13
Maximum average deep investigation spacing (m)	220 to 1400	400 to 600
Minimum number of deep investigations for each geological sub-unit[(2)]	3	13

Notes: (1) An area of development of 1.5 km^2 has been determined. (2) The development area is underlain by the same series of ash and sedimentary soil units. The main units being Younger Ash, Rotoehu Ash and Hamilton Ash all underlain by soils within the Matua Subgroup.

Table 3.3 shows that the investigations completed achieve a number and density that is in the middle of the range that would be expected for a Level B assessment.

Based on review of the base information available for this study and consideration of the recommendations provided in Table 3.1 of the MBIE/MfE Guidelines (2017), T+T have assessed the level of detail supported by the currently available information to be as follows for each Geomorphic Zone:

- Stream gullies and coastal margin – Level A
- Terraces – Level B

These geomorphic zones are provided in Figure A3 of Appendix A.

4 MBIE/MfE risk analysis

4.1 Definition of sub-areas

The sub-areas have been defined based on the previous Level A study. However, refinement has been made to the sub-areas based on the new ground investigation information. The sub-areas are as follows:

- Sub-area Type A comprises the stream gullies and coastal margins
- Sub-area Type B comprises the more elevated terrace areas

These are shown on Figure A3 of Appendix A.

4.2 Groundwater depths for analysis

The monitoring period within the study area has not been long enough to assess seasonal fluctuations in groundwater level. To estimate seasonal fluctuations in groundwater level in the study area we have reviewed data from standpipes at Ruamoana Place, Omokoroa (north of the site) where similar soils are present and continuous monitoring has taken place over a number of years.

The location of Ruamoana Place in relation to the site is provided in Figure 4.1.

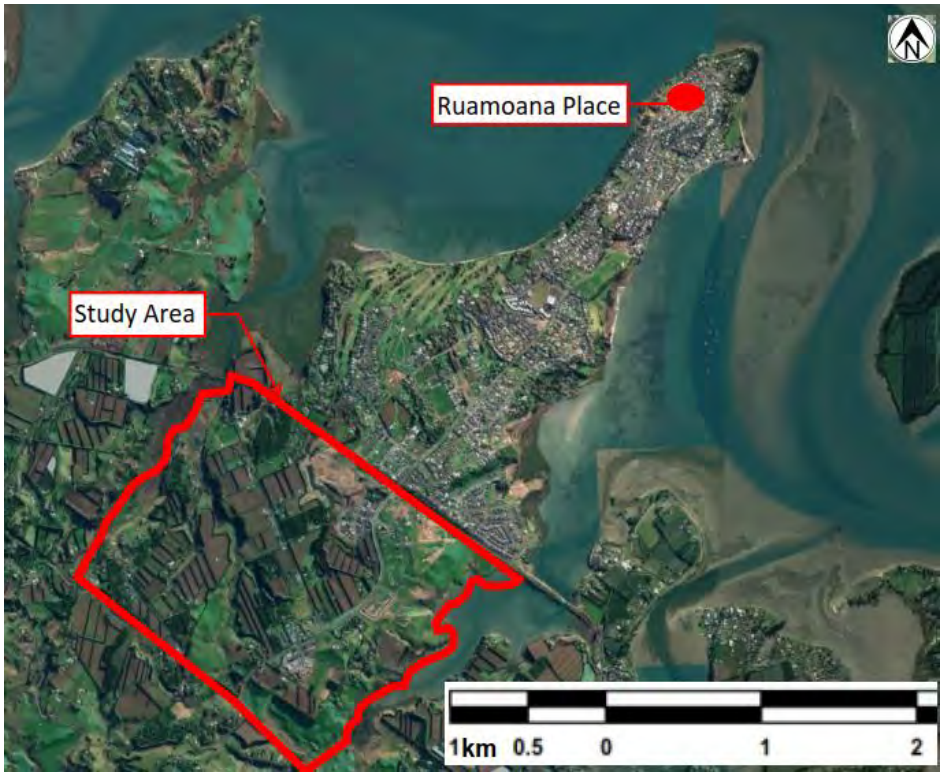


Figure 4.1: Omokoroa Study Area in relation to Ruamoana Place overlain on an Aerial Photograph

Water levels at Ruamoana Place have been recorded in six standpipes, however we have conservatively selected the two records shown in Figure 4.2 as they exhibit the greatest seasonal fluctuations. Based on the records from these two standpipes we have estimated seasonal groundwater level maxima and minima within the study area.

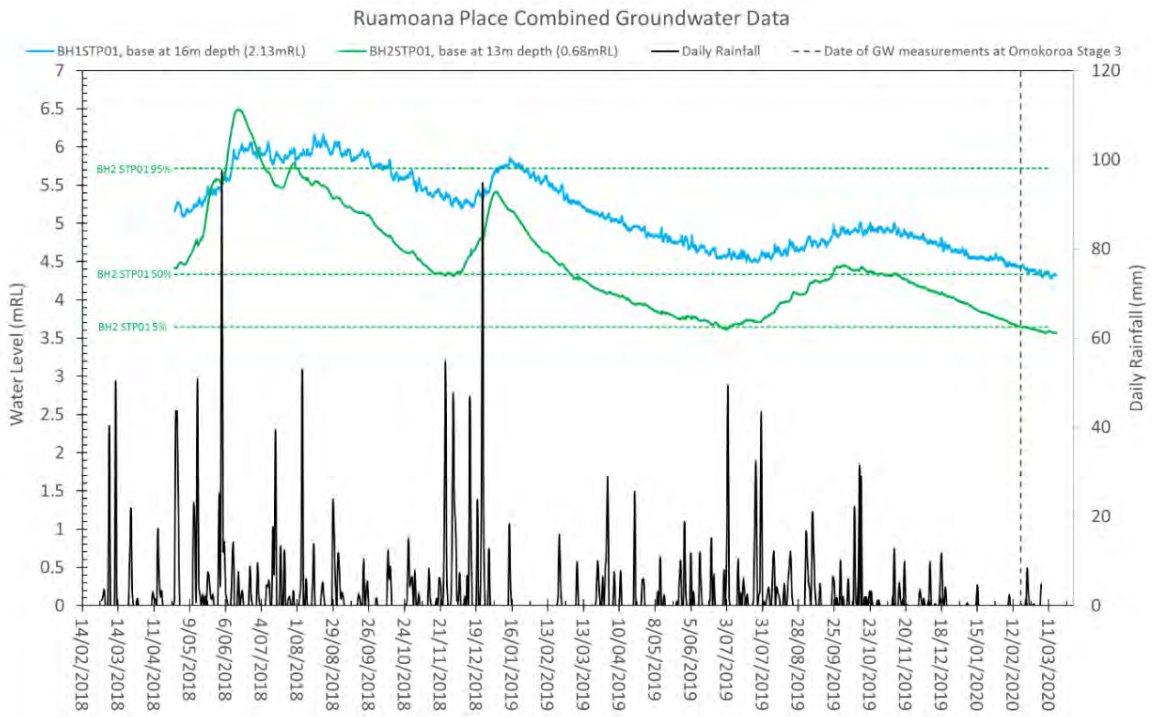


Figure 4.2: Ruamoana Place groundwater monitoring data and rainfall data

Figure 4.2 shows that seasonal fluctuations of between 2.0 and 3.0 m in groundwater level have been observed at Ruamoana Place. We note though that the difference between the 5th percentile and the median is around 0.7 m in these records.

Measurements of groundwater levels within the study area were obtained during summer months, i.e. when the groundwater level was likely to be close to its lowest point (5th percentile). Due to the potential variance between Ruamoana Place and the study area, the median groundwater level has been estimated as 1 m above the measurements obtained from the site on 18 February 2020. This provides median groundwater depth estimates of between 4 and 6 m bgl within the area of proposed development.

We note that there are differences between Ruamoana Place and the study area, such as topography, catchment areas, area of paved surfaces, proximity to the harbour margin, etc. These features influence ground water levels in different ways. However, in the absence of any other local seasonal records, the use of this information is considered appropriate for this study.

Both the measured and estimated median groundwater levels across the site are provided in Figure A4 of Appendix A. The extent of the groundwater depth layer has also been modified since the Level A study based on refinement of the geomorphology and the new groundwater level measurements.

4.3 Earthquake scenarios

This risk analysis has primarily used the ground damage response for a 500 year average recurrence interval using the NZTA Bridge Manual (2018) which results in a PGA of 0.26g and effective magnitude of 5.9. Qualitative considerations have been made regarding the ground damage response for a range of return periods. This is described in the Section 4.4.

The 2019 BSL regional seismic hazard assessment identified that lower PGAs may occur at high return periods within the Tauranga City area, 7 km south east of the Omokoroa study area. These reduced PGAs have not been specifically incorporated into the liquefaction analysis. However, this has supported the overall risk assessment in a qualitative sense, as it provides an indication that the seismic risk is likely to be lower than expected.

4.4 Determination of expected degree of liquefaction-induced ground damage

To determine the expected degree of liquefaction-induced ground damage for each sub area it is necessary to evaluate the liquefaction vulnerability indicators available.

Tables 2 and 3 of Appendix B present the risk analysis based on liquefaction vulnerability indicators. Figure B1 provides a spatial understanding of the expected degree of liquefaction induced ground damage at 500 year levels of earthquake shaking based on the interpreted CPT based liquefaction vulnerability indicators. It is important to note that there is significant residual uncertainty associated with CPT based liquefaction vulnerability indicators and the actual liquefaction induced land damage may differ from that indicated using this analysis.

The primary indicator of liquefaction vulnerability has been the assessment of depth to the Rotoehu Ash layer based on hand auger boreholes. The Rotoehu Ash layer has been assessed as not susceptible to liquefaction for the following reasons:

- The soil is pumiceous with a high apparent cohesion. Vertical cuts of this material have been observed to free stand at near vertical.
- The Rotoehu Ash layer is Pleistocene age airfall deposit (>50,000 years old). The case history of Youd and Perkins (1978) indicates that liquefaction is more common in younger (i.e. Holocene age) soil deposits than older (i.e. Pleistocene age and older) soil deposits. The MBIE/MfE Guidelines (2017) also recognises this differentiation in liquefaction vulnerability based on soil age.

Figure A5 of Appendix A shows spatially the depth of the Rotoehu Ash determined based on the hand auger boreholes. The top of the Rotoehu Ash (or base of Younger Ash) is measured to range in depth between 0.9 m and 3.1 m bgl. In all cases, the depth was measured as less than 4.0 m bgl.

In the CPT based liquefaction analysis in Appendix B, soils within and below the Rotoehu Ash (or below the Younger Ash) have been assumed as not susceptible to liquefaction. The relevant input parameters to the CPT based liquefaction analysis have been included in Appendix B Table 1.

Using the this risk analysis for each sub area, the expected degree of liquefaction induced ground damage by ARI of earthquake shaking for each sub area is summarised in Table 4.1.

Table 4.1: Expected degree of liquefaction induced ground damage by ARI and sub area (refer Figure A3 of Appendix A for each area)

		Expected degree of liquefaction induced ground damage		
		25 year ARI	**100 year ARI**	**500 year ARI**
Sub area	**Type A (stream gullies and coastal margin)**	None-to-minor	None-to-minor	Minor to moderate or moderate to severe
	Type B (terraces)	None-to-minor	None-to-minor	None-to-minor

Because of the proximity of the Rotoehu Ash to the ground surface, the Type B sub area is expected to have 'none-to-minor' liquefaction-induced land damage under earthquake shaking up to at least 500 year ARI levels.

Beyond 500 year ARI levels of earthquake shaking, the expected liquefaction related land damage generally plateaus (i.e. regardless of how much more the shaking intensity increases, the expected liquefaction related land damage is likely to remain the same).

Consideration has also been given to the potential increase in liquefaction vulnerability if the groundwater was shallower than estimated or perched within the Type B sub area. The CPT based liquefaction analysis in Appendix B indicates that groundwater would need to be as shallow as 1 to 2 m bgl for there to be any liquefaction triggering within the soil profile. This is considered unlikely, as the sandy, high permeability Rotoehu Ash is likely to prevent increases in groundwater of this magnitude.

4.5 Liquefaction vulnerability against performance criteria

The methodology described in the MBIE/MfE Guidelines (2017) recommends liquefaction vulnerability categorisation of the land based on the performance criteria described in Figure 4.3 below.

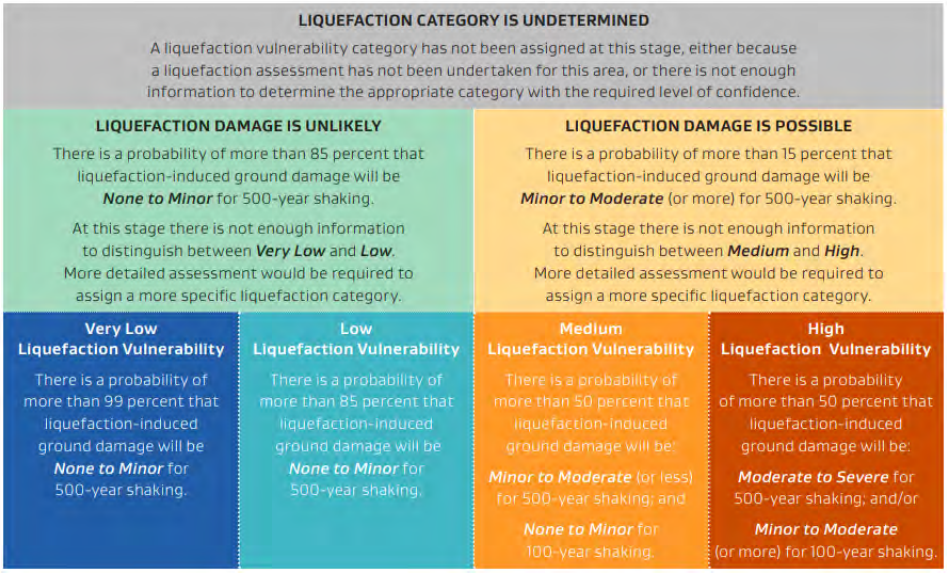


Figure 4.3: Performance criteria for determining the liquefaction vulnerability category - reproduced from Table 4.4 of the MBIE/MfE Guidelines (2017)

The performance criteria listed in Figure 4.3 relate the liquefaction vulnerability category to the expected liquefaction-induced land damage at a given ARI level of earthquake shaking. The assessment requires the assessor to consider the probability that a particular level of liquefaction-induced land damage will occur for a given level of shaking. In undertaking this assessment it is important to understand the following note attached to the table in the guidance document:

"The probabilities listed in this table are intended to provide a general indication of the level of confidence required to assign a particular category, rather than to be a specific numerical criteria for calculation. Conceptually, these probabilities relate to the total effect of all uncertainties in the assessment…"

In the above statement, the guidance recommends the assessor consider the combined effect of all the uncertainties associated with the available information in the determination of the land damage category.

T+T's assessment of the liquefaction vulnerability category for Omokoroa is presented spatially in Figure B2. Typical cross section schematics of near stream gullies and coastal margins are provided in Figure 4.4 and Figure 4.5 in order to show how sub area boundaries have been classified spatially.

Within the Omokoroa study area, the Type B sup-area (terraces) has been classified as *"liquefaction damage is unlikely".* This is because the Rotoehu Ash is likely to be present at shallow depth. The areas classified as *"liquefaction damage is possible"* comprise locations downslope of the terraces where:

- Rotoehu Ash is unlikely to be present.
- Holocene-aged alluvial soils are likely to be present (increasing in thickness with distance from the terraces.
- Groundwater is likely to be shallower than 4 m bgl.

If further investigation analysis was completed, this boundary may sit closer to the toe of the slopes. However, using the definition based on slope crest creates a buffer zone to account for residual uncertainty associated with:

- The potential for lateral spreading associated with free faces and sloping land within the study area.
- The resolution of the geomorphic mapping which was undertaken largely a desktop exercise.

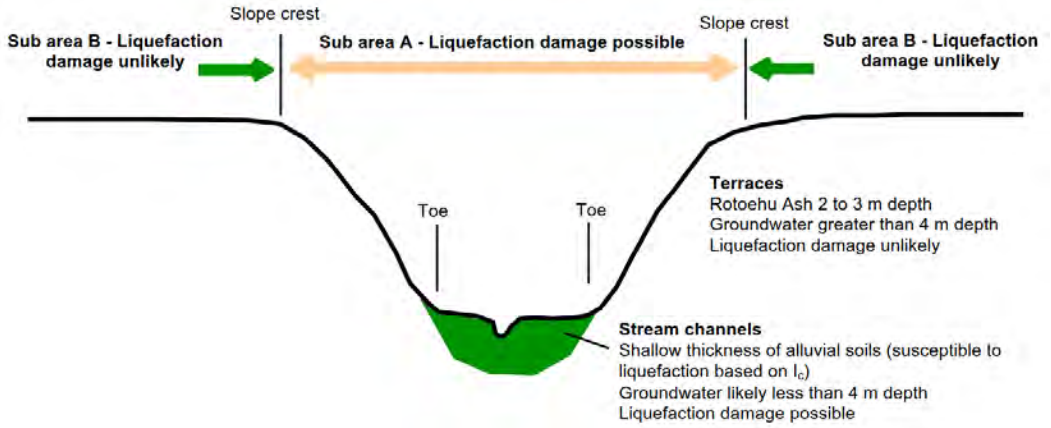


Figure 4.4: Typical cross section showing classification of liquefaction vulnerability near stream channels

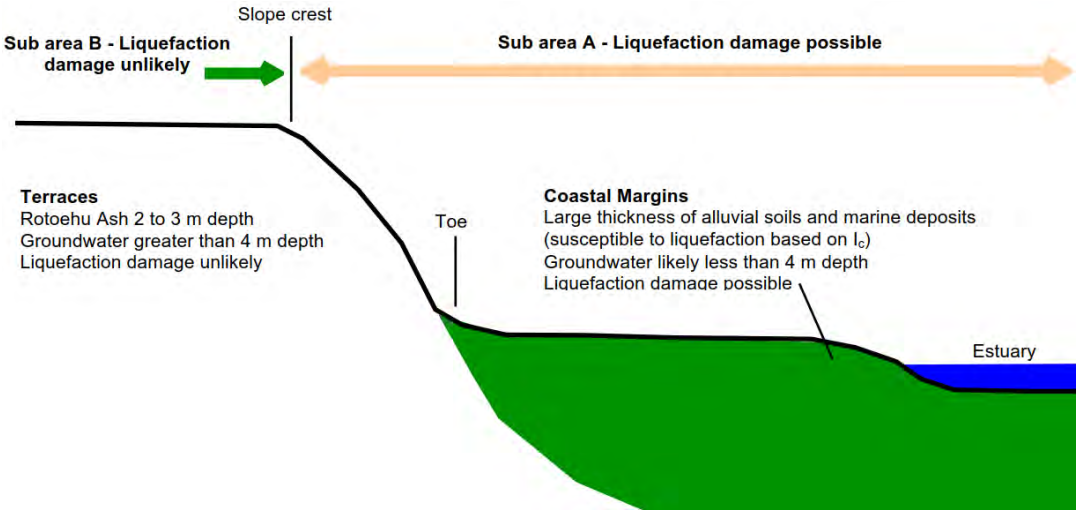


Figure 4.5: Typical cross section showing classification of liquefaction vulnerability near costal margins

It is important to note that the categorisation of land as *Liquefaction Damage Is Possible* does not preclude later assessment of the damage category as either *Low* or *Very Low* liquefaction vulnerability based on additional investigations and analysis. Similarly the categorisation of land as *Liquefaction Damage is Unlikely* does not preclude the modification of the damage category into either *Medium* or *High* liquefaction vulnerability based on additional investigations and analysis – however we note that the way that the performance criteria are assessed makes a shift in this direction less likely.

5 Regional Policy Statement (RPS) risk assessment

The previous RPS risk assessment in the Level A study (T+T, 2019) obtained a low level of liquefaction risk.

The initial process of the RPS risk assessment involves identification of the Hazard Susceptibility Area (HSA). The HSA has been identified as sub area Type A (liquefaction damage is possible) which has substantially reduced since the Level A study. Figure B3 in Appendix B shows the HSA (or sub area Type A) in relation to the structure plan development area. A small portion of the development area is within the HSA (approximately 0.01 km^2 of 1.5 km^2) near to stream gullies. Because the HSA has substantially reduced since the Level A study, and the proposed development has not changed, a low level of liquefaction risk is considered appropriate under the RPS.

For small areas of development located within the HSA, more robust foundation systems may be adopted to reduce the consequence level. However, this would be subject to further investigation and assessment by the geotechnical practitioner and subdivision or building consent stage. Further information on foundation types is provide in Section 5.5.3 of the Level A study (T+T, 2019).

T+T are not aware of any lifelines infrastructure currently planned within the HSA. However, if this is proposed in future, a liquefaction hazard assessment on these lifelines may be required.

6 Conclusions and recommendations

6.1 MBIE/MfE Guidelines (2017)

T+T has undertaken a liquefaction risk assessment in accordance with the MBIE/MfE Guidelines (2017) to a Level B level of detail for the Omokoroa Structure Plan Stage 3 area. The following are the key conclusions from this assessment:

- The currently available base information supports a Level B (calibrated desktop) level of detail assessment within the development area (terraces) and a Level A level of detail within stream channel and coastal margin areas.
- The current information indicates that because the majority of the proposed development area is located on elevated terraces, this land is likely to have none to minor liquefaction-induced land damage following levels of earthquake shaking up to 500 year ARI. Beyond 500 year ARI levels of earthquake shaking, the expected liquefaction related land damage generally plateaus (i.e. regardless of how much more the shaking intensity increases, the expected liquefaction related land damage is likely to remain the same).
- The liquefaction vulnerability mapping process indicates that the land within the Omokoroa study area that is defined as Type A sub area (coastal margin and stream gullies) should be categorised as *Liquefaction Damage is Possible.* These areas are primarily located in stream gullies and coastal margins. The land that is defined as Type B sub area (terrace areas) should be categorised as *Liquefaction Damage is Unlikely.* The Type B sub areas are primarily located in elevated terrace landforms.
- The ground surface elevation information and geomorphological map indicate that there are free-faces and sloping landforms that could enable lateral spreading to occur. These areas are primarily located near stream gullies and coastal margins within areas defined as the Type A sub area where *Liquefaction Damage is Possible.*

We recommend the following geotechnical assessment practices are incorporated as part of future subdivision and building development within the area of proposed development (Figure B3 of Appendix B):

- A geotechnical engineer should consider liquefaction risk based on the results of future geotechnical investigations in accordance with MBIE/Mfe Guidelines (2017). In the development area (Figure B3 of Appendix B) assessment could involve identification of the presence of Rotoehu Ash horizon in the soil profile in relation to groundwater levels. As part of further development, shallow geotechnical investigations (such as Hand Augers) could be sufficient for the purposes for initial screening of liquefaction risk in the development area. This does not preclude the need for deep investigations (such as CPT or boreholes) if the ground conditions differ from those anticipated, for development proposed within the stream gullies and coastal margins, and for assessment of other geotechnical hazards (such as slope instability).
- Assessment of land stability and earthworks design for construction of buildings, roads, and infrastructure in accordance with Section 4.10 (DS10 Natural Hazards and Earthworks) of the WBOPDC Development Code. The geotechnical engineer shall define any development restrictions at resource consent stage and complete certificate 10b (geotechnical suitability of land for development) and 10c (geotechnical suitability of land for building).
- The structure plan has taken account of land stability through identifying land slopes greater than 1V:4H as constrained land (not to be developed). Given the historic observations of slope instability on the Omokoroa Peninsula to the north east of the study area, future geotechnical assessment should take consideration of more detailed slope instability and its effects on land and building development. Building restriction lines near to gully extents may need to be considered.

7 Applicability

This report has been prepared for the exclusive use of our client Bay of Plenty Regional 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.

We understand and agree that this report will be used by Western Bay of Plenty District Council and Bay of Plenty Regional Council in undertaking its regulatory functions in connection with the plan change for the Omokoroa Structure Plan Stage 3 Area.

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

The susceptibility analyses carried out represent probabilistic analyses of empirical liquefaction databases under various earthquakes. Earthquakes are unique and impose different levels of shaking in different directions on different sites. The results of the liquefaction susceptibility analyses and the estimates of consequences presented within this document are based on regional seismic demand and published analysis methods, but it is important to understand that the actual performance may vary from that calculated.

Tonkin & Taylor Ltd

Report prepared by:

.....

Guy McDougall

Geotechnical Engineer

Technical Review by James Russell

Authorised for Tonkin & Taylor Ltd by:

.....

David Milner

Project Director

gumc
p:\1008683\issueddocuments\20200526 omokoroa level b final\20200526.gumc.omokoroa.levelb.report_final.docx

8 References

Aurecon New Zealand Limited, 7 February 2017, Subdivision of 58 and 70 Francis Road (the 'Hicks' Subdivision), Omokoroa – Geotechnical Assessment Report, Proposed Lots 1, 3, 4, 5 and 6

Bradley Seismic Ltd, (BSL. (2019). Regional ground motion hazard for liquefaction and landslide assessment, Tauranga City

Bay of Plenty Regional Council, 2014. "Bay of Plenty Regional Policy Statement." Retrieved from https://www.boprc.govt.nz/knowledge-centre/policies/operative-regional-policy-statement/

CMW Geosciences, 2017. "Geotechnical Completion Report – Stage 1A Kaimai Views Subdivision, 336, 340 and 344 Omokoroa Rd, Omokoroa."

CMW Geosciences, 2018. "Preliminary Geotechnical Investigation Report – 452 Omokoroa Road, Omokoroa."

Ministry of Business Innovation & Employment (MBIE), 2017. "Planning and engineering guidance for potentially liquefaction-prone land". Retrieved from https://www.building.govt.nz/building-code-compliance/b-stability/b1-structure/planning-engineering-liquefaction-land/

New Zealand Transport Agency Bridge Manual, manual number: SP/M/022. Third edition, Amendment 3, October 2018

Standards New Zealand, 2004. "NZS1170.5:2004 Structural Design Actions Part 5: Earthquake actions - New Zealand". Standards New Zealand. Retrieved from https://www.standards.govt.nz/

Tonkin & Taylor Ltd, Katikati and Omokoroa Liquefaction Assessment, Level A, Regional Liquefaction Hazard Study for Bay of Plenty Regional Council, dated 9 September 2019, T+T Ref: 1008683

Tonkin & Taylor Ltd, Omokoroa Structure Plan Stage 3, Geotechnical Factual Report for Western Bay of Plenty District Council, dated 9 February 2020, T+T Ref: 1008683.1000

Tonkin & Taylor Ltd, Variation 3, Supplementary (Level B) Liquefaction Assessment for Bay of Plenty Regional Council, dated 4 March 2020, T+T Ref: 1008683.1000

Youd, T.L., and Perkins, D.M., (1978) Mapping liquefaction-induced ground failure potential. Journal of the Geotechnical Engineering Division, p. 443-446.

Appendix A: MBIE/Risk identification

- **Figure Appendix A1: Existing geotechnical investigations and report locations overlaid on structure plan**
- **Figure Appendix A2: Geotechnical investigations overlaid on 2015 LiDAR DEM**
- **Figure Appendix A3: Geotechnical investigations overlaid on geomorphology**
- **Figure Appendix A4: Estimated depth to groundwater with measured groundwater depths**
- **Figure Appendix A5: Estimated depth to Rotoehu Ash layer**

COPYRIGHT ON THIS FIGURE IS RESERVED DO NOT SCALE FROM THIS FIGURE - IF IN DOUBT, ASK.

\\ttgroup.local\corporate\Tauranga\Projects\1008683\WorkingMaterial\GIS\MapDocuments\SupplementaryLiquefactionAssessment\1008683_FIGA1.mxd 2020-Mar-26 2:38:45 PM Drawn by GUMC

LEGEND

Project specific geotechnical investigations

- Cone Penetration Test
- Cone Penetration Test (with Piezometer)
- Hand Auger

Other geotechnical investigations

- Hand Auger
- Cone Penetrometer Test
- Level A Study: Geotechnical Report Locations
- Study Area

Structure Plan

- Active Reserve
- Industrial Land
- Constrained Land*
- Residential Land
- Rural Residential
- Primary and Secondary School
- Retail and Commercial

CPT109, HA101, CPT101, HA102, CPT102, CMW, 2017, HA06-S, HA05-N, HA06-N, HA05-S, HA103, CPT103, HA04-N, HA03-N, HA04-S, CPT104, HA104, HA110, Terrane, 2018, HA03-S, CPT105, HA01-S, HA01-N, HA105, S&L, 2018, HA109, CMW, 2018, CPT106, HA106, CPT110, CPT_91891, CPT_91893, CPT_91890, CPT_91892, CPT107b, HA107, HA108

Constrained Land*: Inclusive of:
- Slope greater than 1:4 (25%)
- Stormwater ponds, stormwater management reserves & stormwater reserves
- Tsunami evacuation zones - red, orange & yellow
- Partial areas of widespread liquefaction
- Archaeological sites
- Significant ecological features/RAP
- Areas prone to instability
- Landscape feature S8/S8A - Tauranga Harbour

Landscape management area
- Private conservation reserves

A3 SCALE 1:11,000

0 0.1 0.2 0.3 0.4 0.5 (km)

ORIGINAL IN COLOUR

Tonkin+Taylor

Exceptional thinking together www.tonkintaylor.co.nz

NOTES: Basemap: Sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 4.0 New Zealand license.
Project specific geotechnical Investigations sourced from the New Zealand Geotechnical Database and other geotechnical investigations (Hand Augers) sourced from the 70A Francis Road Central Land Information Memorandum.

REV	DESCRIPTION	GIS	CHK	DATE
0	First version	MOLI	YYYY	18/03/2020

LOCATION PLAN: Tauranga

PROJECT No.	1008683.0000		
DESIGNED	GUMC	APR.20	
DRAWN	MOLI	APR.20	
CHECKED	JICR	APR.20	
APPROVED		26/05/2020	DATE

CLIENT BAY OF PLENTY REGIONAL COUNCIL

PROJECT OMOKOROA STRUCTURE PLAN STAGE 3

TITLE SUPPLEMENTARY LEVEL B LIQUEFACTION ASSESSMENT- EXISTING GEOTECHNICAL INVESTIGATIONS OVERLAID ON STRUCTURE PLAN

SCALE (A3) 1:11,000 FIG No. FIGURE A1 REV 0

COPYRIGHT ON THIS FIGURE IS RESERVED DO NOT SCALE FROM THIS FIGURE - IF IN DOUBT, ASK.

\\ttgroup.local\corporate\Tauranga\Projects\1008683\WorkingMaterial\GIS\MapDocuments\SupplementaryLiquefactionAssessment\1008683_FIGA2.mxd 2020-Mar-26 2:42:16 PM Drawn by GUMC

LEGEND

Project specific geotechnical investigations

- Cone Penetration Test
- Cone Penetration Test (with Piezometer)
- Hand Auger

Other geotechnical investigations

- Hand Auger
- Cone Penetrometer Test
- Level A Study: Geotechnical Report Locations
- Study Area

Ground Surface Elevation (mRL)

- < 2.5
- 2.5 - 5
- 5 - 7.5
- 7.5 - 10
- 10 - 12.5
- 12.5 - 15
- 15 - 17.5
- 17.5 - 20
- 20 - 22.5
- 22.5 - 25
- 25 - 27.5
- 27.5 - 30
- > 30

CPT109
CPT101
HA101
CPT102
HA102
CMW, 2017
HA06-S
HA05-N
HA06-N
HA05-S
CPT103
HA04-N
HA04-S
HA03-N
HA103
CPT104
HA104
Terrane, 2018
HA110
HA03-S
CPT105
HA01-S
HA01-N
HA105
S&L, 2018
HA109
CMW, 2018
CPT106
HA106
CPT110
CPT_91891
CPT_91893
CPT_91890
CPT_91892
CPT107b
HA107
HA108

A3 SCALE 1:11,000

0 0.1 0.2 0.3 0.4 0.5 (km)

ORIGINAL IN COLOUR

Tonkin+Taylor

Exceptional thinking together www.tonkintaylor.co.nz

NOTES: Basemap: Sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 4.0 New Zealand license.
Project specific geotechnical Investigations sourced from the New Zealand Geotechnical Database and other geotechnical investigations (Hand Augers) sourced from the 70A Francis Road Central Land Information Memorandum.
Horizontal Datum: New Zealand Transverse Mercator, Vertical Datum: NZVD 2016.

REV	DESCRIPTION	GIS	CHK	DATE
0	First version	MOLI	YYYY	18/03/2020

Tauranga

PROJECT No.	1008683.0000	
DESIGNED	GUMC	APR.20
DRAWN	MOLI	APR.20
CHECKED	JICR	APR.20
APPROVED		26/05/2020

CLIENT **BAY OF PLENTY REGIONAL COUNCIL**

PROJECT **OMOKOROA STRUCTURE PLAN STAGE 3**

TITLE SUPPLEMENTARY LEVEL B LIQUEFACTION ASSESSMENT- GEOTECHNICAL INVESTIGATIONS OVERLAID ON 2015 LIDAR DEM

SCALE (A3) 1:11,000 FIG No. FIGURE A2 REV 0

COPYRIGHT ON THIS FIGURE IS RESERVED DO NOT SCALE FROM THIS FIGURE - IF IN DOUBT, ASK.

\\ttgroup.local\corporate\Tauranga\Projects\1008683\WorkingMaterial\GIS\MapDocuments\SupplementaryLiquefactionAssessment\1008683_FIGA3.mxd 2020-Apr-01 1:22:01 PM Drawn by GUMC

LEGEND

Project specific geotechnical investigations

- Cone Penetration Test
- Cone Penetration Test (with Piezometer)
- Hand Auger

Other geotechnical investigations

- Hand Auger
- Cone Penetrometer Test
- Level A Study: Geotechnical Report Locations
- Study Area

Geomorphology

- Stream channels
- Low-lying coastal margin
- Terraces

CPT109
CPT101
HA101
CPT102
HA102
HA06-S
HA05-N
HA06-N
HA05-S
CPT103
HA103
HA04-N
HA04-S
HA03-N
HA03-S
HA01-S
HA01-N
CPT105
HA105
HA109
CPT104
HA104
HA110
CMW, 2017
Terrane, 2018
S&L, 2018
CMW, 2018
CPT106
HA106
CPT110
CPT_91893
CPT_91890
CPT_91892
CPT107b
HA107
HA108

A3 SCALE 1:11,000

0 0.1 0.2 0.3 0.4 0.5 (km)

ORIGINAL IN COLOUR

Tonkin+Taylor

Exceptional thinking together www.tonkintaylor.co.nz

NOTES: Basemap: Sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 4.0 New Zealand license.
Project specific geotechnical Investigations sourced from the New Zealand Geotechnical Database and other geotechnical investigations (Hand Augers) sourced from the 70A Francis Road Central Land Information Memorandum.

REV	DESCRIPTION	GIS	CHK	DATE
0	First version	MOLI	YYYY	18/03/2020

Tauranga

PROJECT No.	1008683.0000		
DESIGNED	GUMC	APR.20	
DRAWN	MOLI	APR.20	
CHECKED	JICR	APR.20	
APPROVED		26/05/2020	

CLIENT BAY OF PLENTY REGIONAL COUNCIL

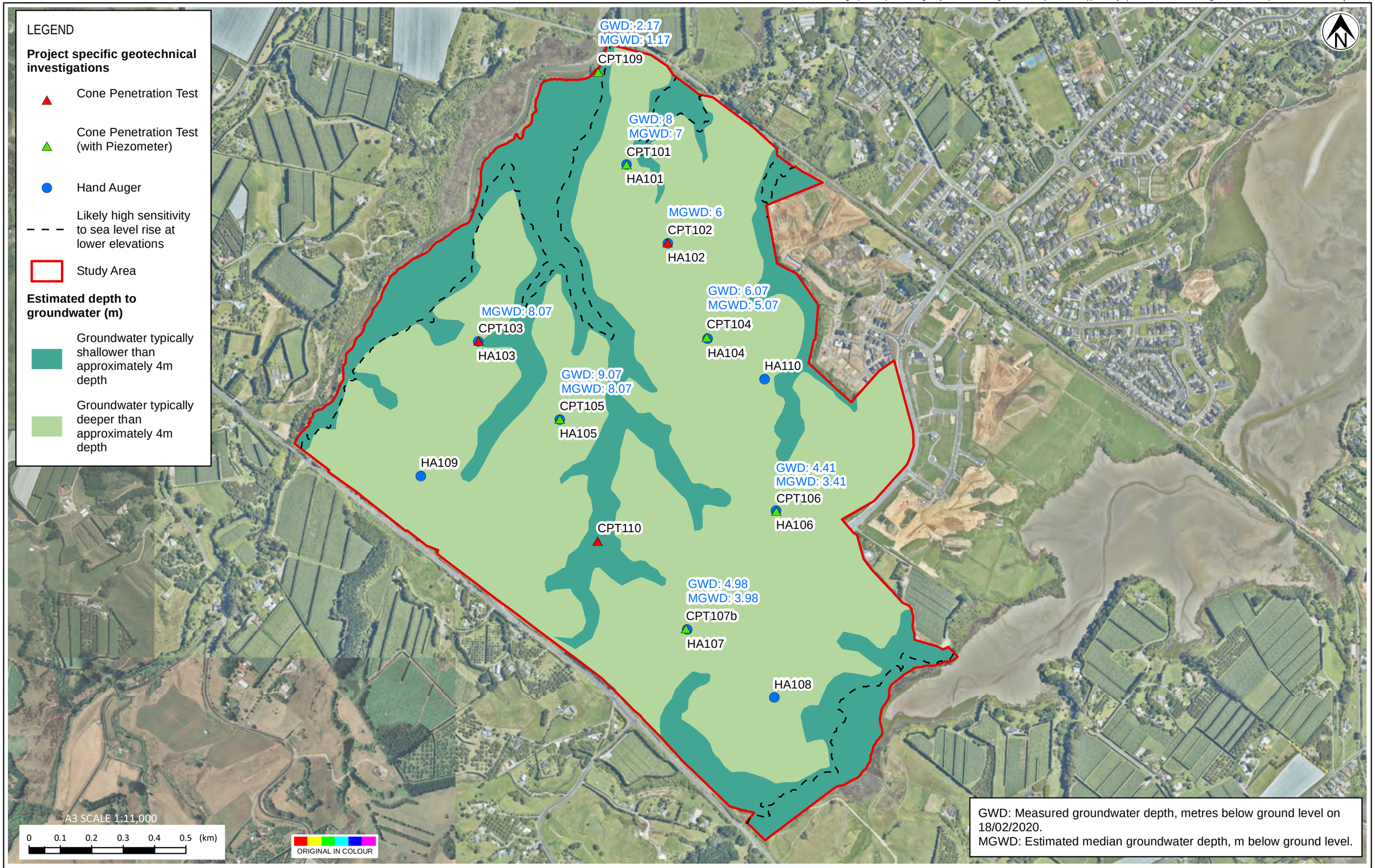
PROJECT OMOKOROA STRUCTURE PLAN STAGE 3

TITLE SUPPLEMENTARY LEVEL B LIQUEFACTION ASSESSMENT - GEOTECHNICAL INVESTIGATIONS OVERLAID ON GEOMORPHOLOGY

SCALE (A3) 1:11,000 FIG No. FIGURE A3 REV 0

COPYRIGHT ON THIS FIGURE IS RESERVED DO NOT SCALE FROM THIS FIGURE - IF IN DOUBT, ASK.

\\ttgroup.local\corporate\Tauranga\Projects\1008683\WorkingMaterial\GIS\MapDocuments\SupplementaryLiquefactionAssessment\1008683_FIGA4.mxd 2020-Apr-01 1:24:07 PM Drawn by GUMC



Tonkin+Taylor
Exceptional thinking together www.tonkintaylor.co.nz

NOTES: Basemap: Sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 4.0 New Zealand licence
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Project specific geotechnical Investigations sourced from the New Zealand Geotechnical Database.
Sea level rise sensitivity line derived from the 1m contour.

REV	DESCRIPTION	GIS	CHK	DATE
0	First version	MOLI	YYYY	18/03/2020

LOCATION PLAN: Tauranga

PROJECT No.	1008683.0000		
DESIGNED	GUMC	APR.20	
DRAWN	MOLI	APR.20	
CHECKED	JICR	APR.20	
APPROVED		26/05/2020	DATE

CLIENT WESTERN BAY OF PLENTY DISTRICT COUNCIL
PROJECT OMOKOROA STRUCTURE PLAN STAGE 3
TITLE SUPPLEMENTARY LEVEL B LIQUEFACTION ASSESSMENT - ESTIMATED DEPTH TO GROUNDWATER
SCALE (A3) 1:11,000 FIG No. FIGURE A4 REV 0

COPYRIGHT ON THIS FIGURE IS RESERVED DO NOT SCALE FROM THIS FIGURE - IF IN DOUBT, ASK.

\\ttgroup.local\corporate\Tauranga\Projects\1008683\WorkingMaterial\GIS\MapDocuments\SupplementaryLiquefactionAssessment\1008683_FIGA5.mxd 2020-Apr-01 1:33:59 PM Drawn by GUMC

LEGEND

Project specific geotechnical investigations

- Cone Penetration Test
- Cone Penetration Test (with Piezometer)
- *1.7m* — *Measured depth to top of Rotoehu Ash layer* — Hand Auger

Other geotechnical investigations

- *1.7m* — *Measured depth to top of Rotoehu Ash layer* — Hand Auger
- Study Area

Geomorphology

- Stream channels
- Low-lying coastal margin
- Terraces

1.6m
0.9m
1.6m
2.0m
1.6m
1.6m
1.6m
1.6m
1.55m
1.7m
1.6m
2.6m
2.1m
1.7m
2m
3.1m
2.15m
1.7m

A3 SCALE 1:11,000

0 0.1 0.2 0.3 0.4 0.5 (km)

ORIGINAL IN COLOUR

Tonkin+Taylor

Exceptional thinking together www.tonkintaylor.co.nz

NOTES: Basemap: Sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 4.0 New Zealand licence
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Project specific geotechnical Investigations sourced from the New Zealand Geotechnical Database and other geotechnical investigations sourced from the 70A Francis Road Central Land Information

REV	DESCRIPTION	GIS	CHK	DATE
0	First version	MOLI	YYYY	18/03/2020

LOCATION PLAN: Tauranga

PROJECT No.	1008683.0000		
DESIGNED	GUMC	APR.20	
DRAWN	MOLI	APR.20	
CHECKED	JICR	APR.20	
APPROVED		26/05/2020	DATE

CLIENT **BAY OF PLENTY REGIONAL COUNCIL**

PROJECT **OMOKOROA STRUCTURE PLAN**

TITLE SUPPLEMENTARY LEVEL B LIQUEFACTION ASSESSMENT - ESTIMATED DEPTH TO ROTOEHU ASH LAYER

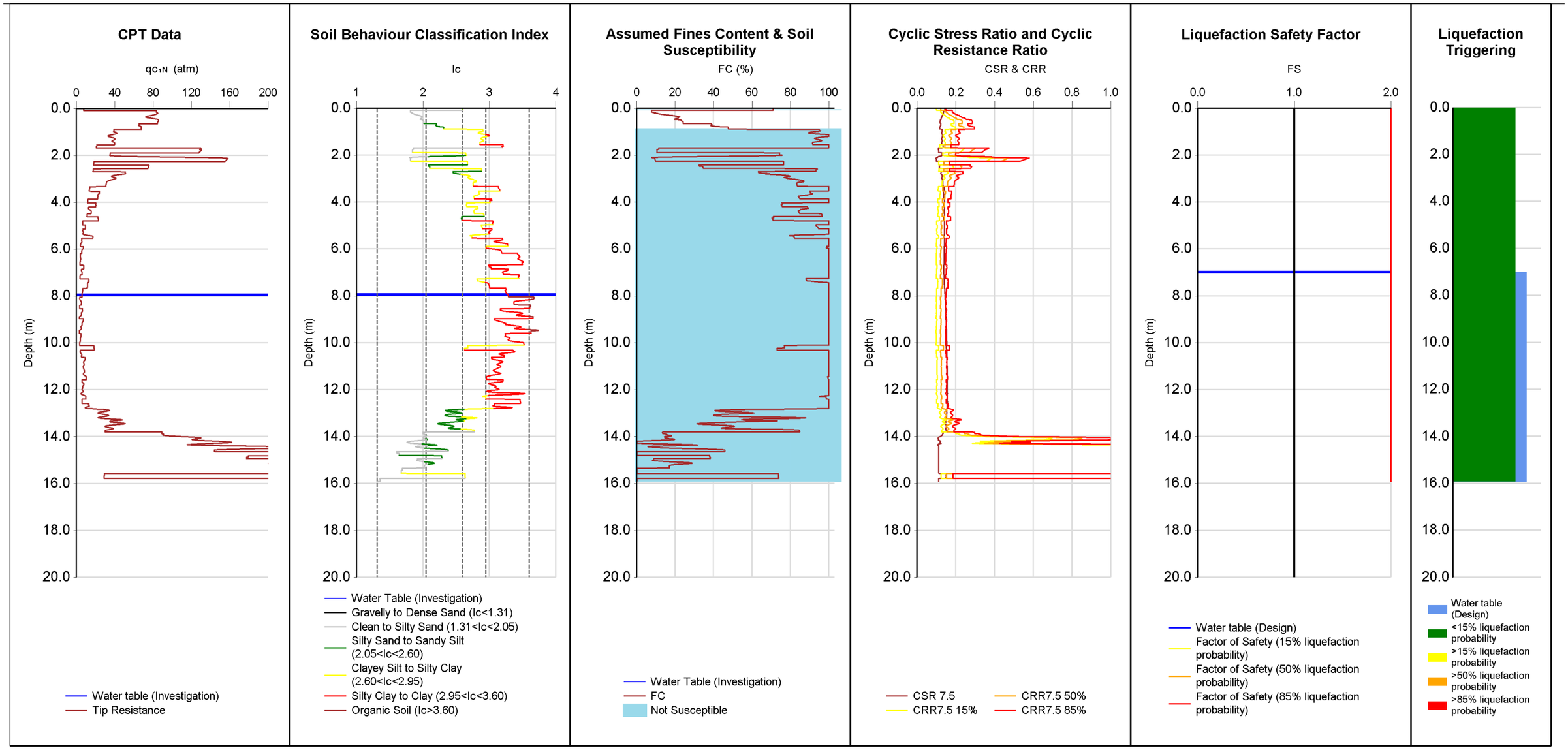
SCALE (A3) 1:11,000 FIG No. FIGURE A5 REV 0

Appendix B: MBIE/Risk analysis

- **CPT-based liquefaction analysis:**
    - **Appendix B Table 1: Input parameters for Boulanger and Idriss (2014)**
    - **CPT-based liquefaction analysis of project specific investigations**
- **Summary of risk analysis and determination of expected degree of liquefaction-induced ground damage:**
    - **Appendix B Table 2: Type A sub area**
    - **Appendix B Table 3: Type B sub area**
- **Figure Appendix B1: Liquefaction land damage overlying sub-areas (groundwater, geomorphology)**
- **Figure Appendix B2: Liquefaction vulnerability map**
- **Figure Appendix B3: Liquefaction vulnerability map overlying the structure plan**

Appendix B Table 1: Input parameters for Boulanger and Idriss (2014)

Input parameter	Value adopted	Comments
Cone area	a=10 cm^2	Inverse filter/fine layer correction base on the size of the cone.
Groundwater	N/A	The groundwater level is based on measured levels in February 2020 with a 1.0 m reduction in depth (shallower) to account for an expected median level.
Soil density	18 kN/m^3	Not sensitive to the typical variability in soil density in the study area.
FC - I_c correlation	C_{FC} = 0.0	Appropriate default value for soils in the study area.
Soil susceptibility Or I_c - cut off	Rotoehu Ash and below is not susceptible. Alluvium - I_c cut off = 2.6	The depth where soil is not susceptible is based on the measured depth to the top of the Rotoehu Ash layer.
Magnitude of earthquake shaking	M_w = 5.9	Calculated effective magnitude as discussed in Section 3.2.5.
Peak Ground Acceleration (g)	0.26	500 year ARI estimate (other ARI can be considered by inspection of the PGA response curves.
Probability of Liquefaction, P_L (%)	P_L = 15%	Based on standard engineering design practice.



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

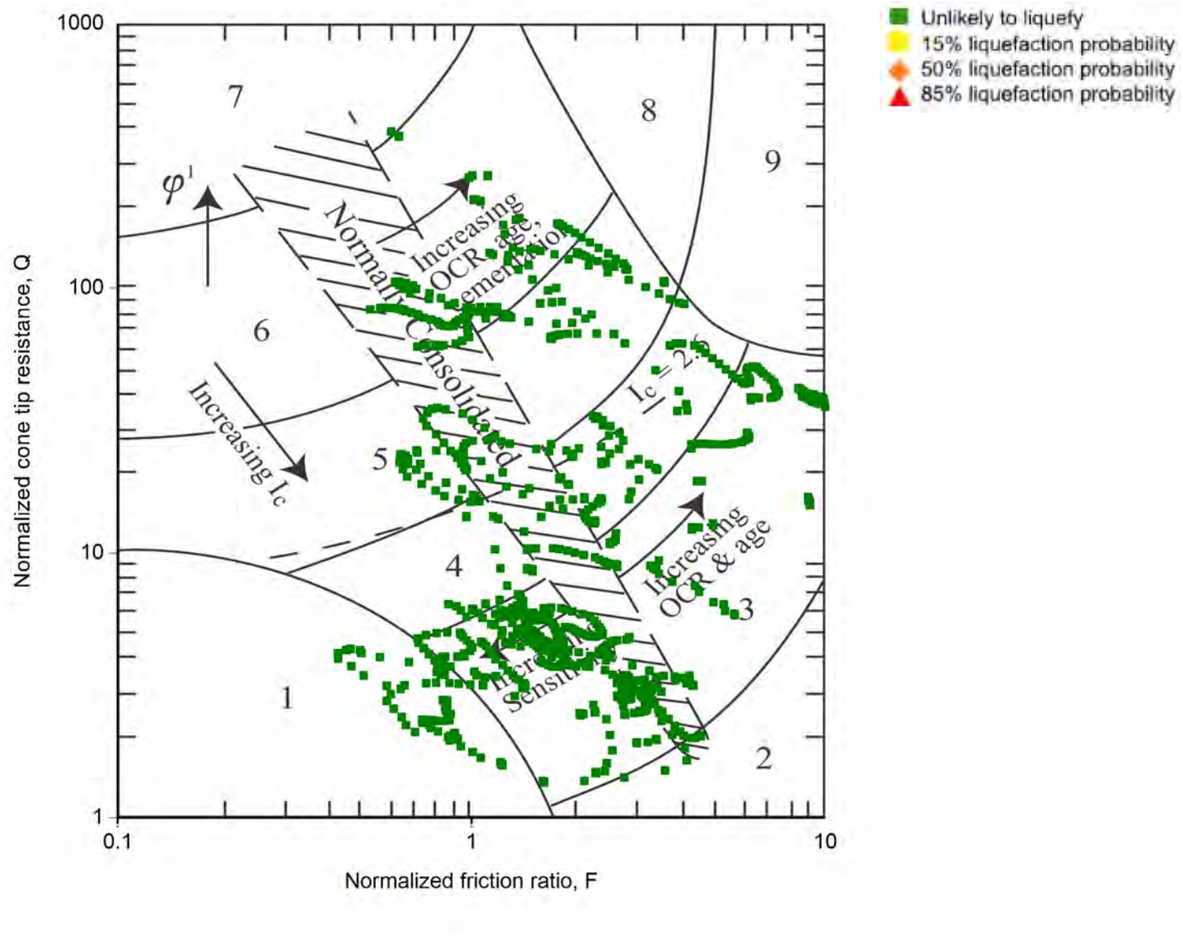
	Run Description	NZGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT	CPT101	138340	28/01/2020	0	5.9	0.26	BI-2014	ZRB-2002	18		0	

	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPIish
OUTPUT	15%	0	0	0	0	15.9	0
	50%	0	0	0	0	15.9	0
	85%	0	0	0	0	15.9	0

Reviewed by:

CPT Inversion	JICR
Groundwater	JICR
Susceptibility	JICR
Triggering	JICR
Consequence	JICR

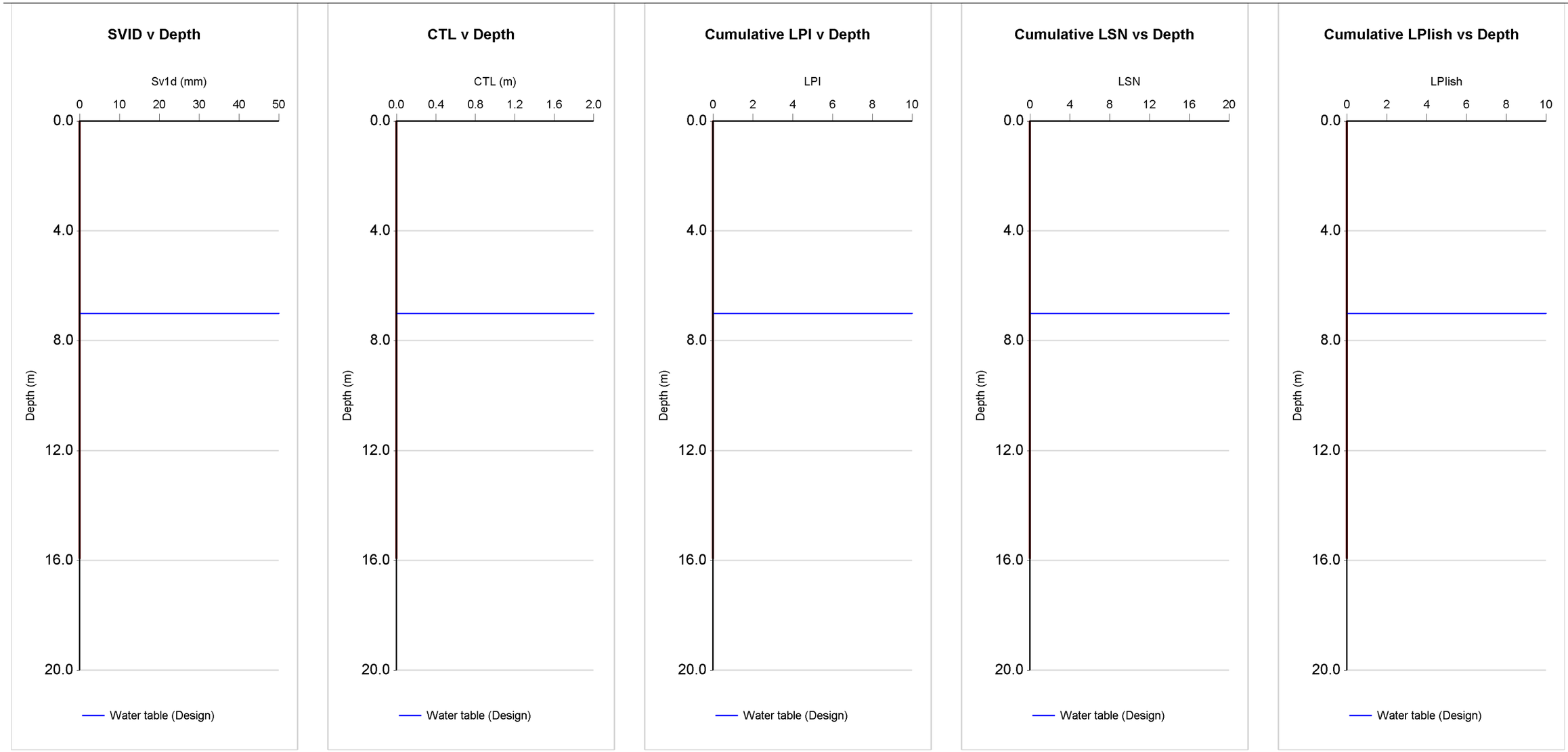
Tonkin + Taylor Exceptional thinking together V2.4.15	CLIENT	**BOPRC**	LOCATION	Omokoroa Stage 3 Study Area	DATE 16/03/2020
	PROJECT	**Omokoroa Structure Plan Stage 3**			ANALYSED gumc
	TITLE	**ARI=500 yr: PGA=0.26g, Mw=5.9**	JOB NUMBER	**1008683.0000**	
	COMMENT	CPT101 to CPT105 with susceptibility cut-off within the Rotoehu Ash and below.			PAGE 1 of 18 pages



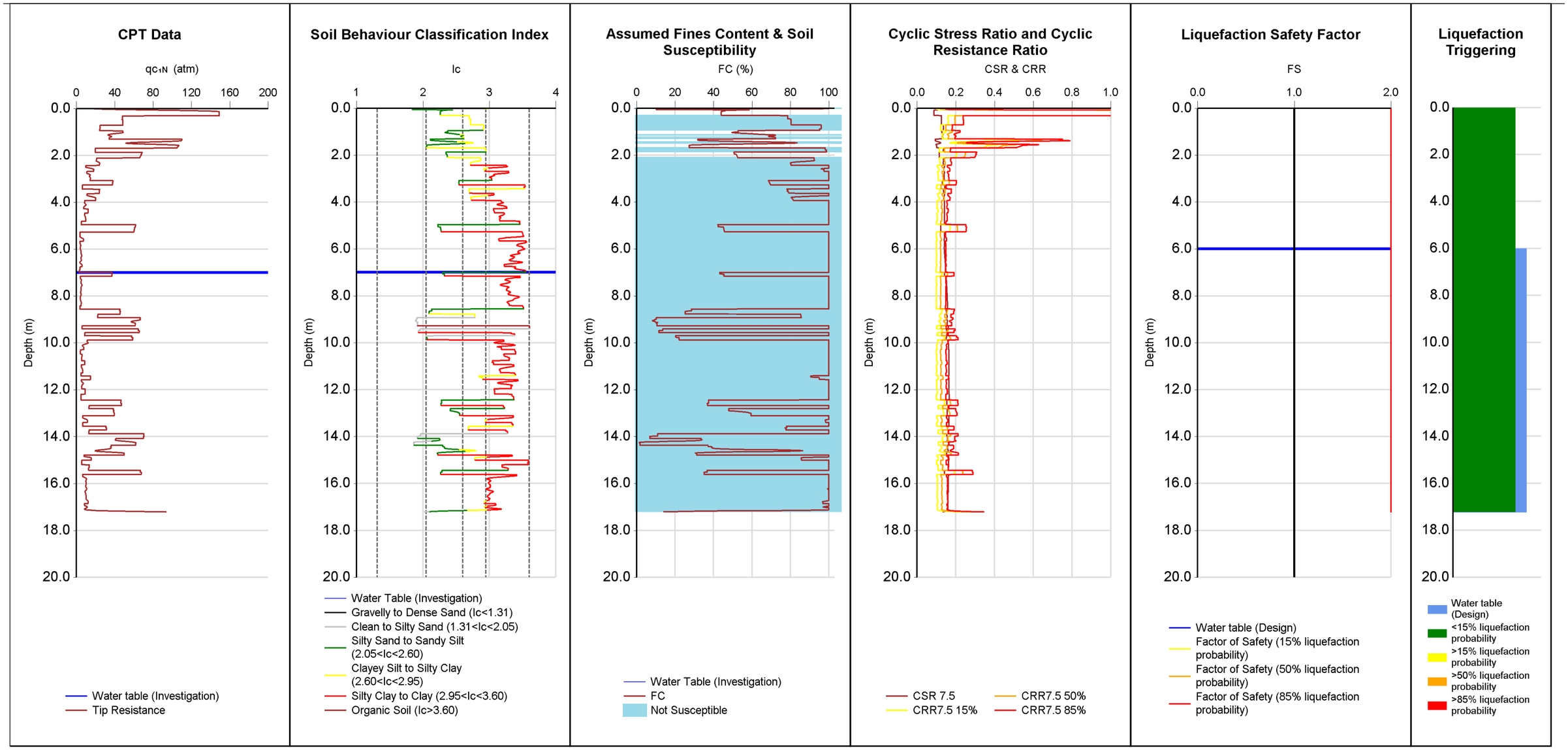
1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt mixtures - clayey silt to silty clay
5. Sand mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand *
9. Very stiff, fine grained *

*Heavily overconsolidated or cemented

CPT-based soil behavior type classification chart by Robertson (1990)



	Run Description	NZGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT	CPT101	138340	28/01/2020	0	5.9	0.26	BI-2014	ZRB-2002	18		0	



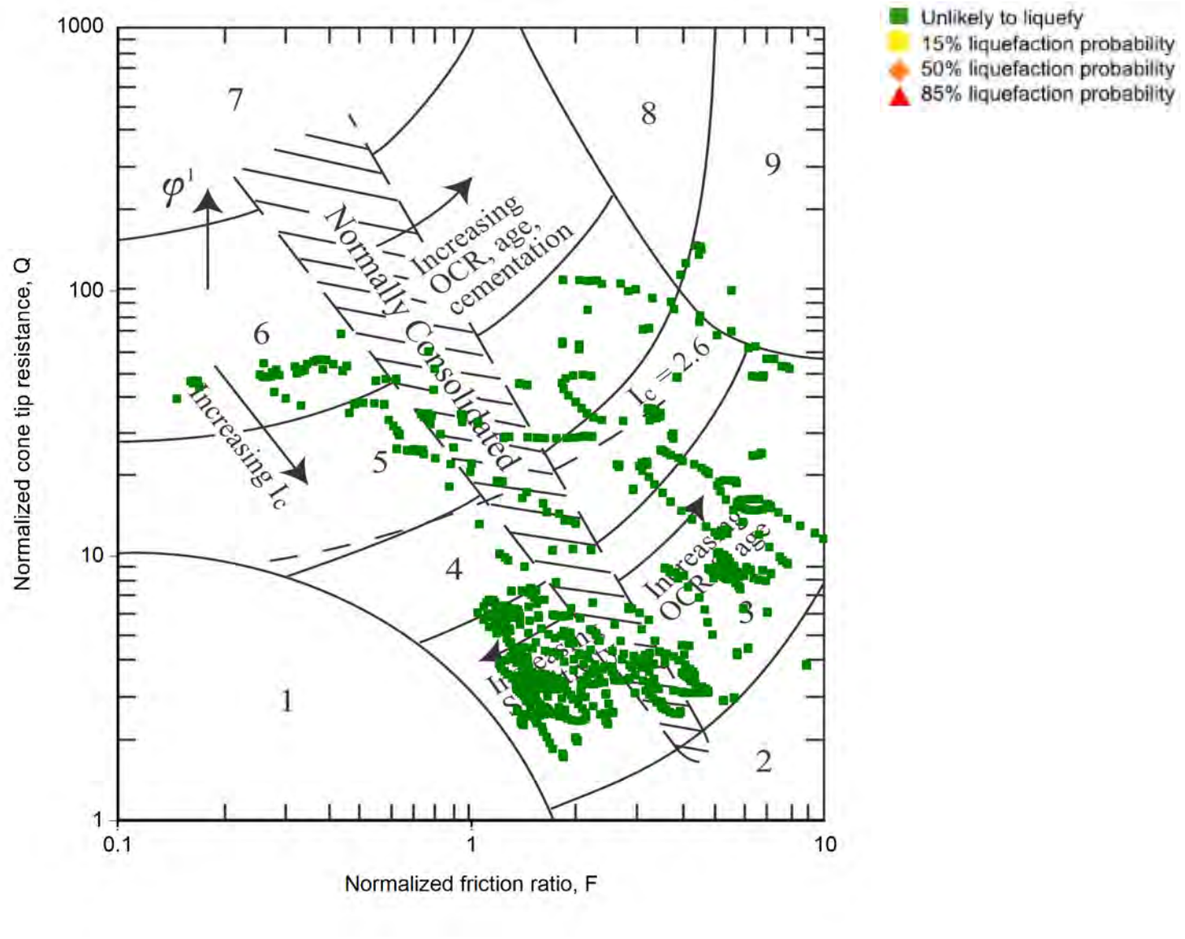
Note: Inverse filtered Qc/Fs data (10 cm²) used.

	Run Description	NZGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT	CPT102	138341	28/01/2020	0	5.9	0.26	BI-2014	ZRB-2002	18		0	

	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPIish
OUTPUT	15%	0	0	0	0	17.2	0
	50%	0	0	0	0	17.2	0
	85%	0	0	0	0	17.2	0

Reviewed by:

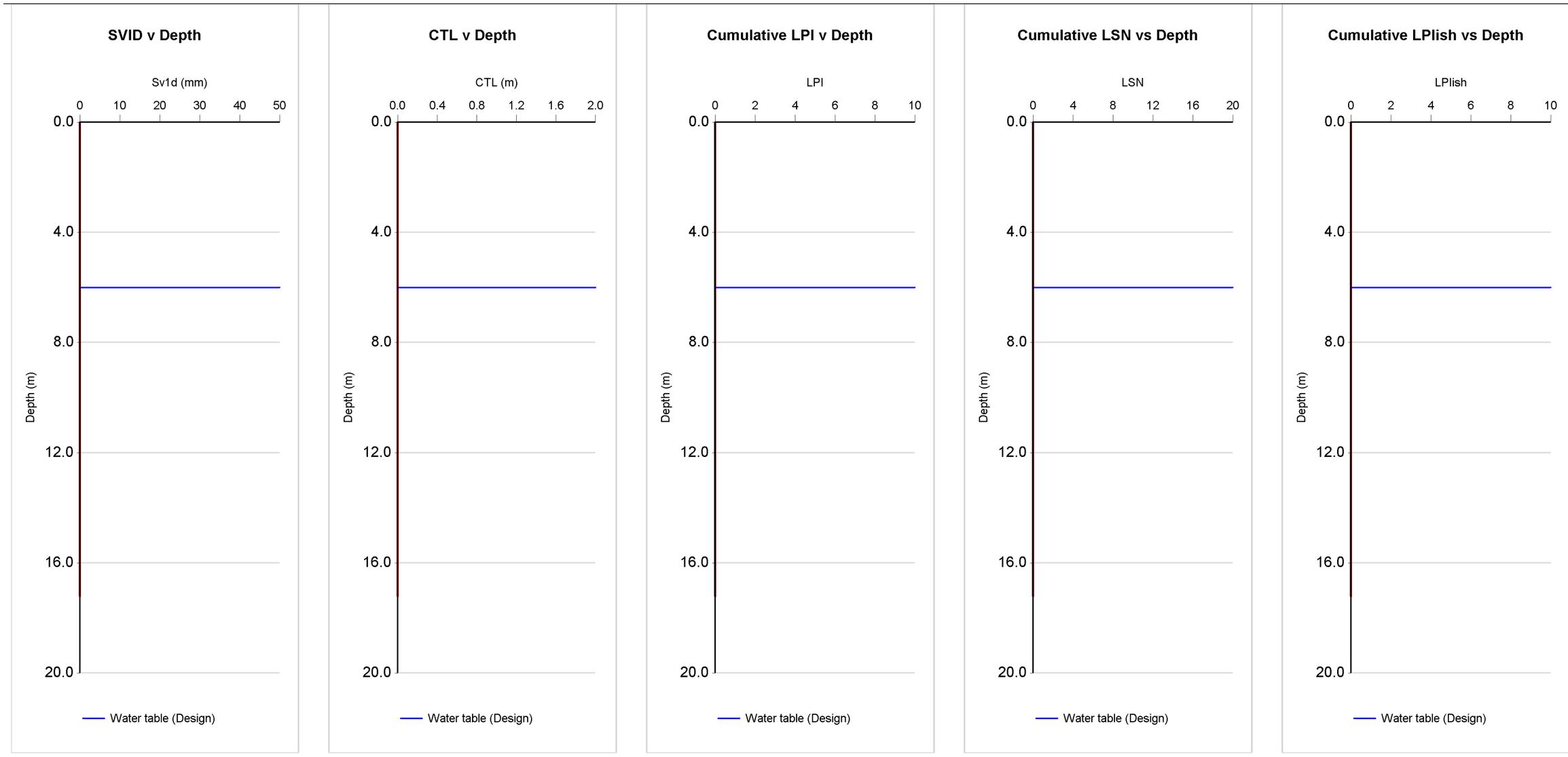
CPT Inversion	JICR
Groundwater	JICR
Susceptibility	JICR
Triggering	JICR
Consequence	JICR



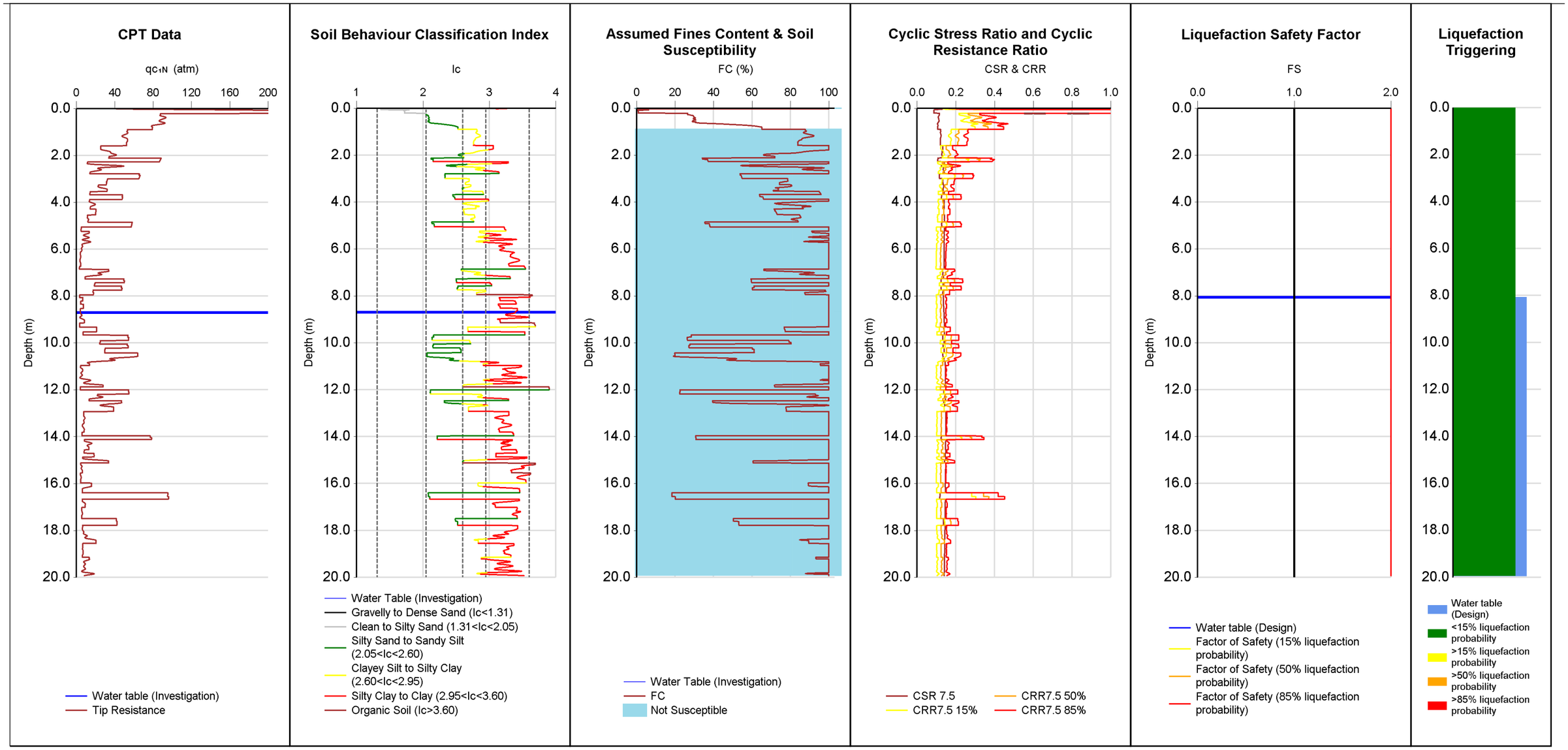
1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt mixtures - clayey silt to silty clay
5. Sand mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand *
9. Very stiff, fine grained *

*Heavily overconsolidated or cemented

CPT-based soil behavior type classification chart by Robertson (1990)



	Run Description	NZGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT	CPT102	138341	28/01/2020	0	5.9	0.26	BI-2014	ZRB-2002	18		0	



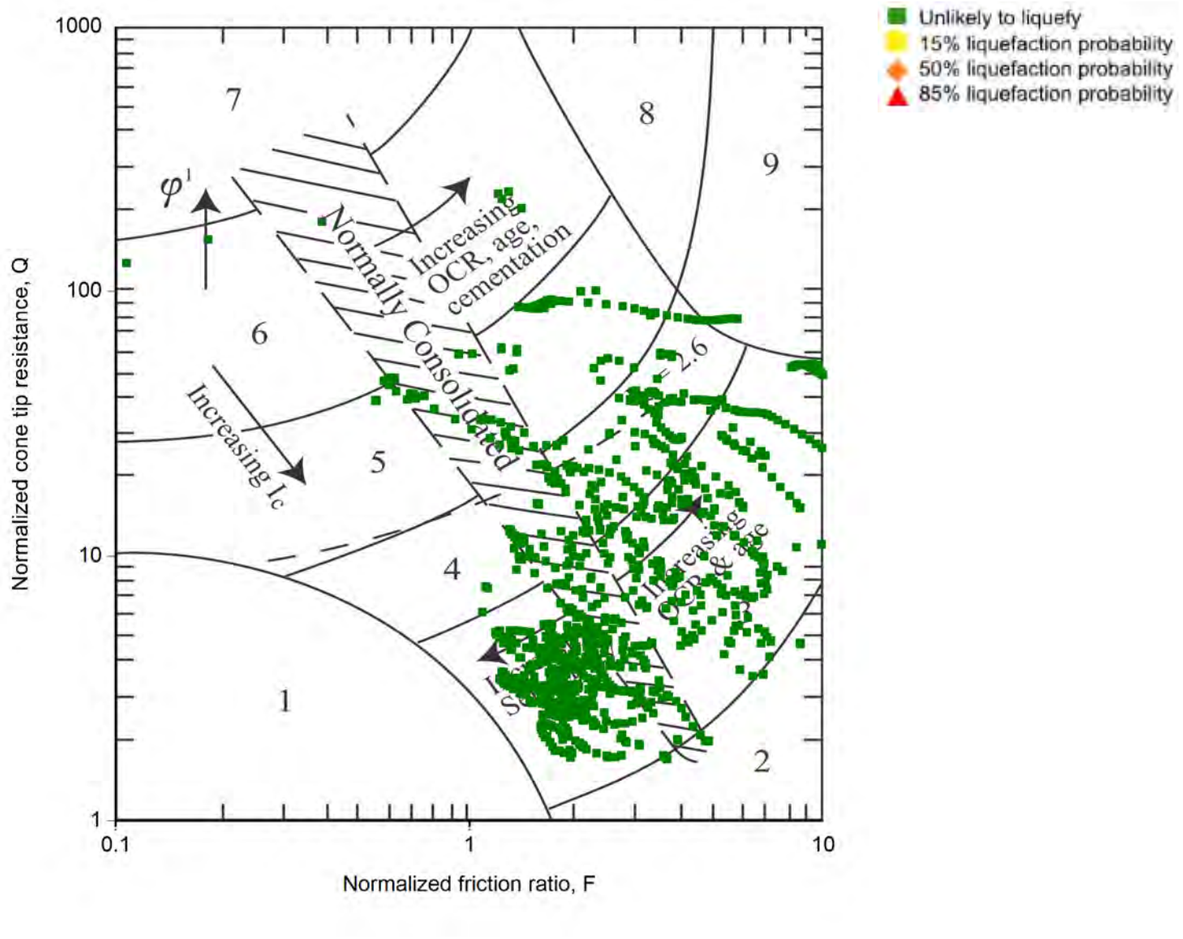
Note: Inverse filtered Qc/Fs data (10 cm²) used.

	Run Description	NZGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT	CPT103	138342	28/01/2020	0	5.9	0.26	BI-2014	ZRB-2002	18		0	

	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPIish
OUTPUT	15%	0	0	0	0	19.9	0
	50%	0	0	0	0	19.9	0
	85%	0	0	0	0	19.9	0

Reviewed by:

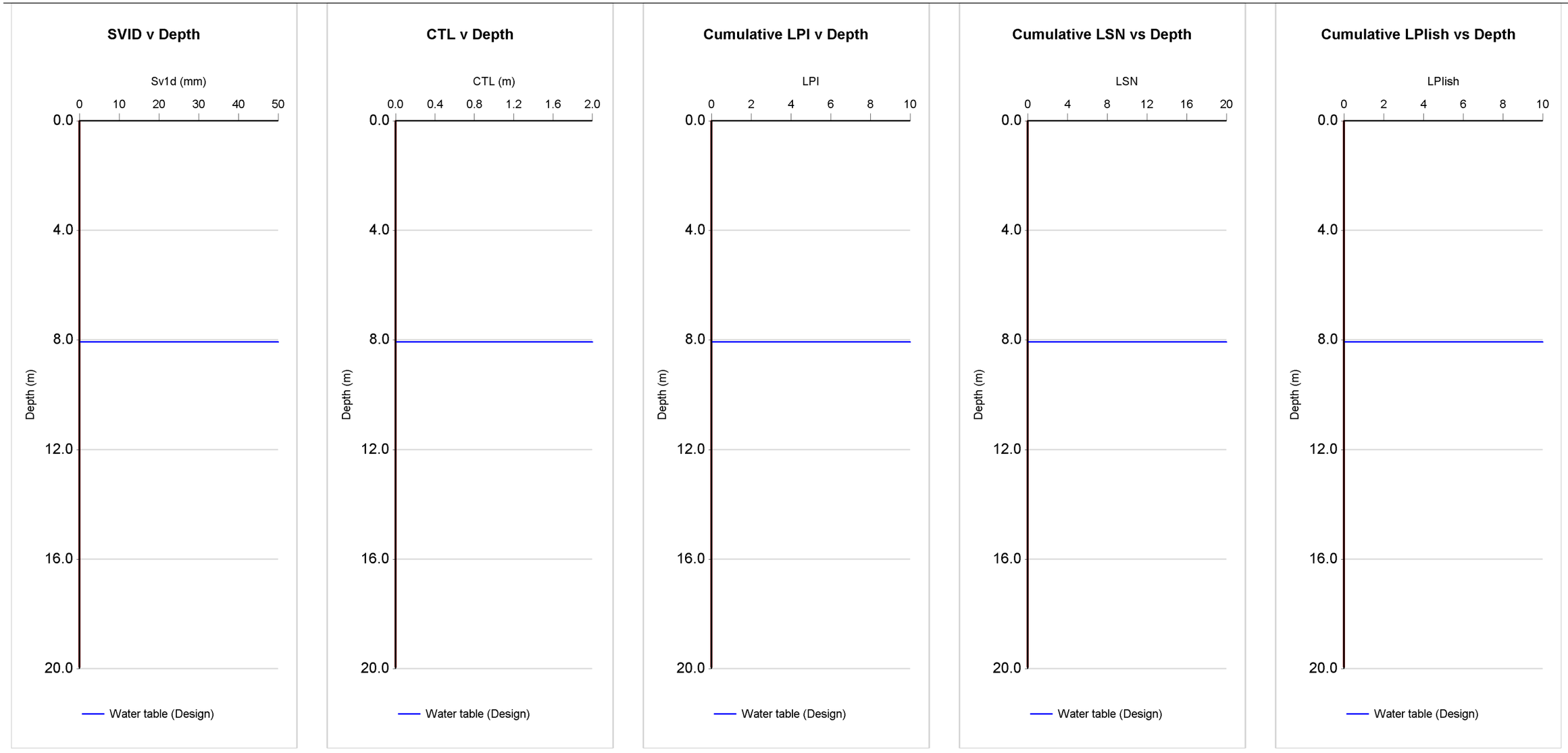
CPT Inversion	JICR
Groundwater	JICR
Susceptibility	JICR
Triggering	JICR
Consequence	JICR



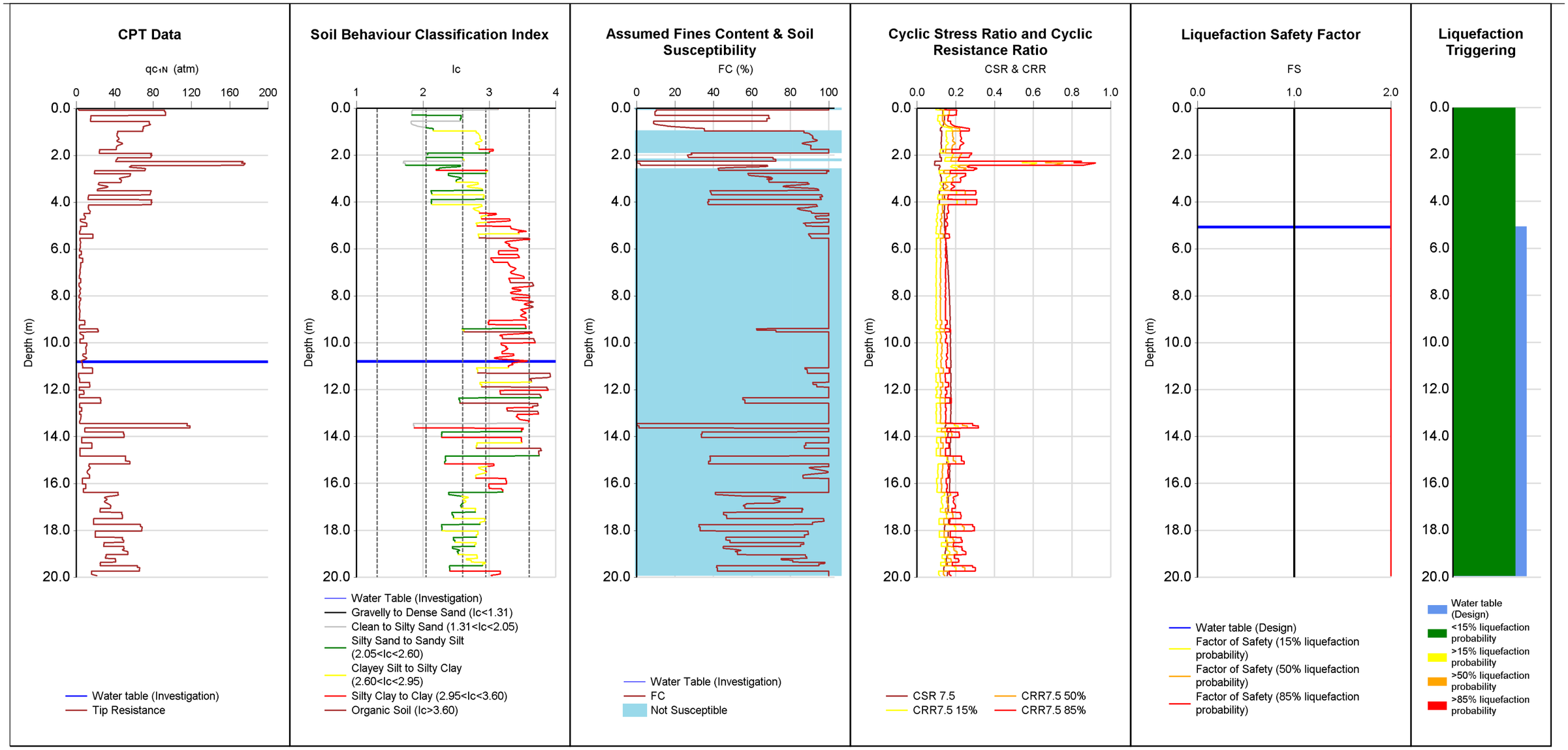
1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt mixtures - clayey silt to silty clay
5. Sand mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand *
9. Very stiff, fine grained *

*Heavily overconsolidated or cemented

CPT-based soil behavior type classification chart by Robertson (1990)



	Run Description	NZGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT	CPT103	138342	28/01/2020	0	5.9	0.26	BI-2014	ZRB-2002	18		0	



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

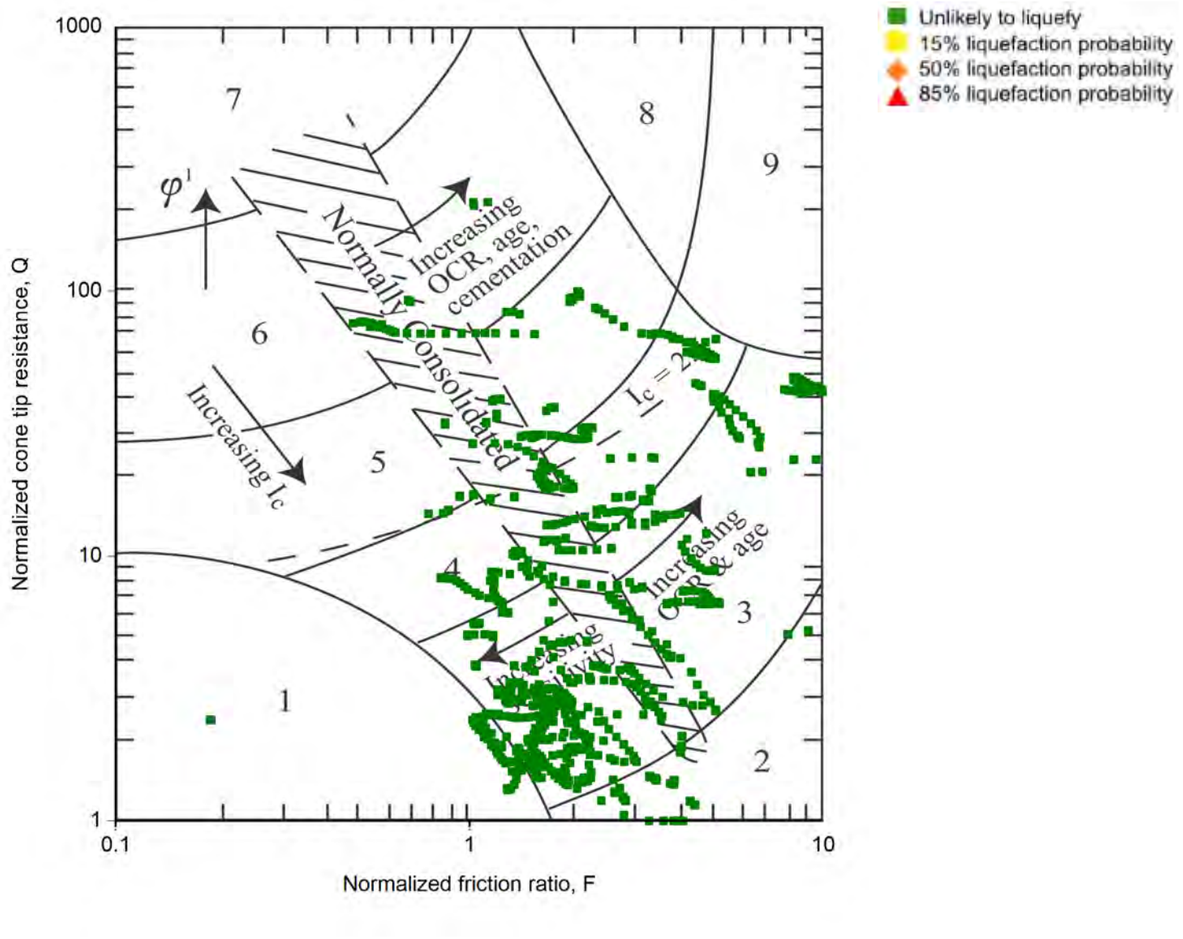
	Run Description	NZGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT	CPT104	138343	28/01/2020	0	5.9	0.26	BI-2014	ZRB-2002	18		0	

	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPIish
OUTPUT	15%	0	0	0	0	19.9	0
	50%	0	0	0	0	19.9	0
	85%	0	0	0	0	19.9	0

Reviewed by:

CPT Inversion	JICR
Groundwater	JICR
Susceptibility	JICR
Triggering	JICR
Consequence	JICR

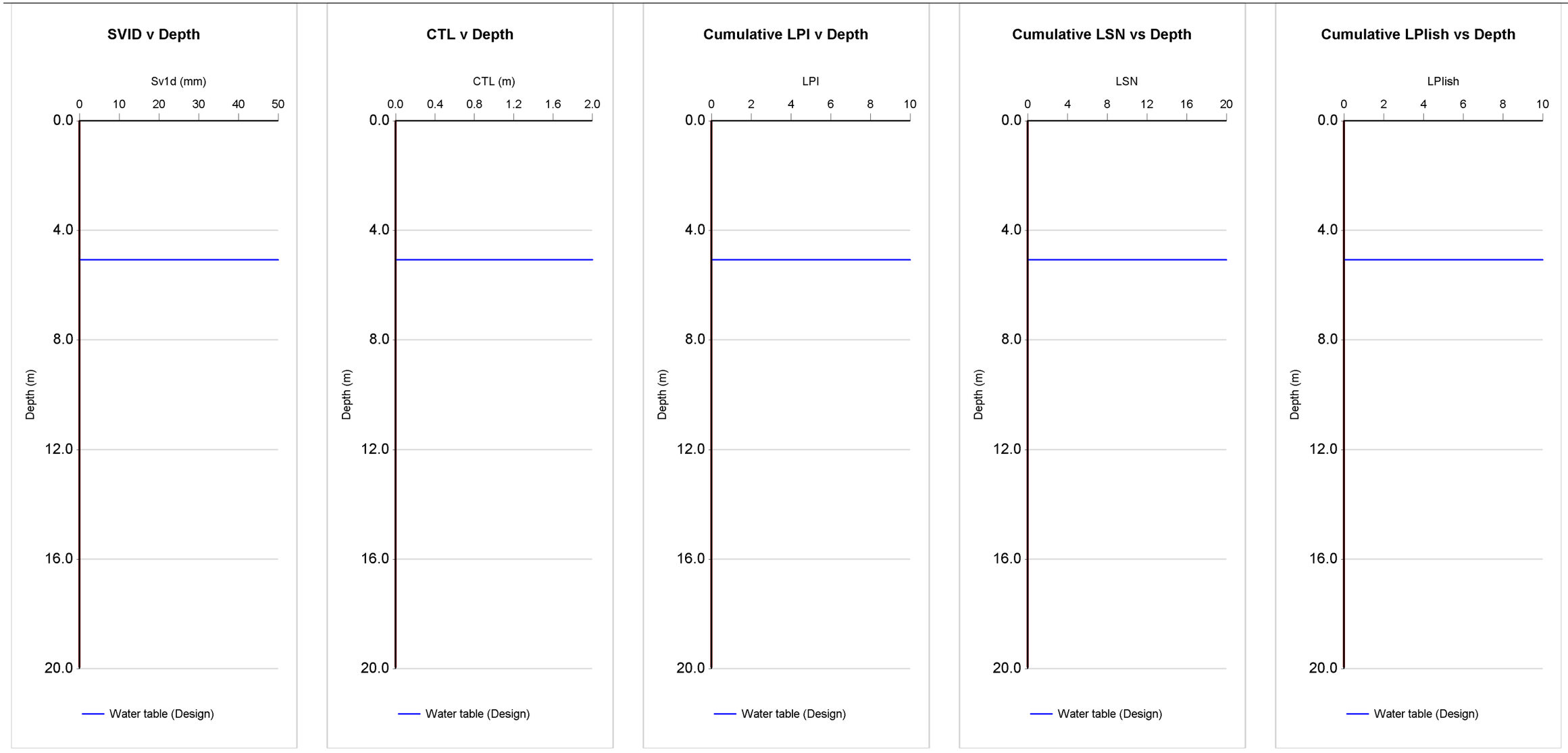
Tonkin + Taylor Exceptional thinking together V2.4.15	CLIENT: **BOPRC** PROJECT: **Omokoroa Structure Plan Stage 3** TITLE: **ARI=500 yr: PGA=0.26g, Mw=5.9** COMMENT: CPT101 to CPT105 with susceptibility cut-off within the Rotoehu Ash and below.	LOCATION: Omokoroa Stage 3 Study Area JOB NUMBER: **1008683.0000**	DATE: 16/03/2020 ANALYSED: gumc PAGE: 10 of 18 pages



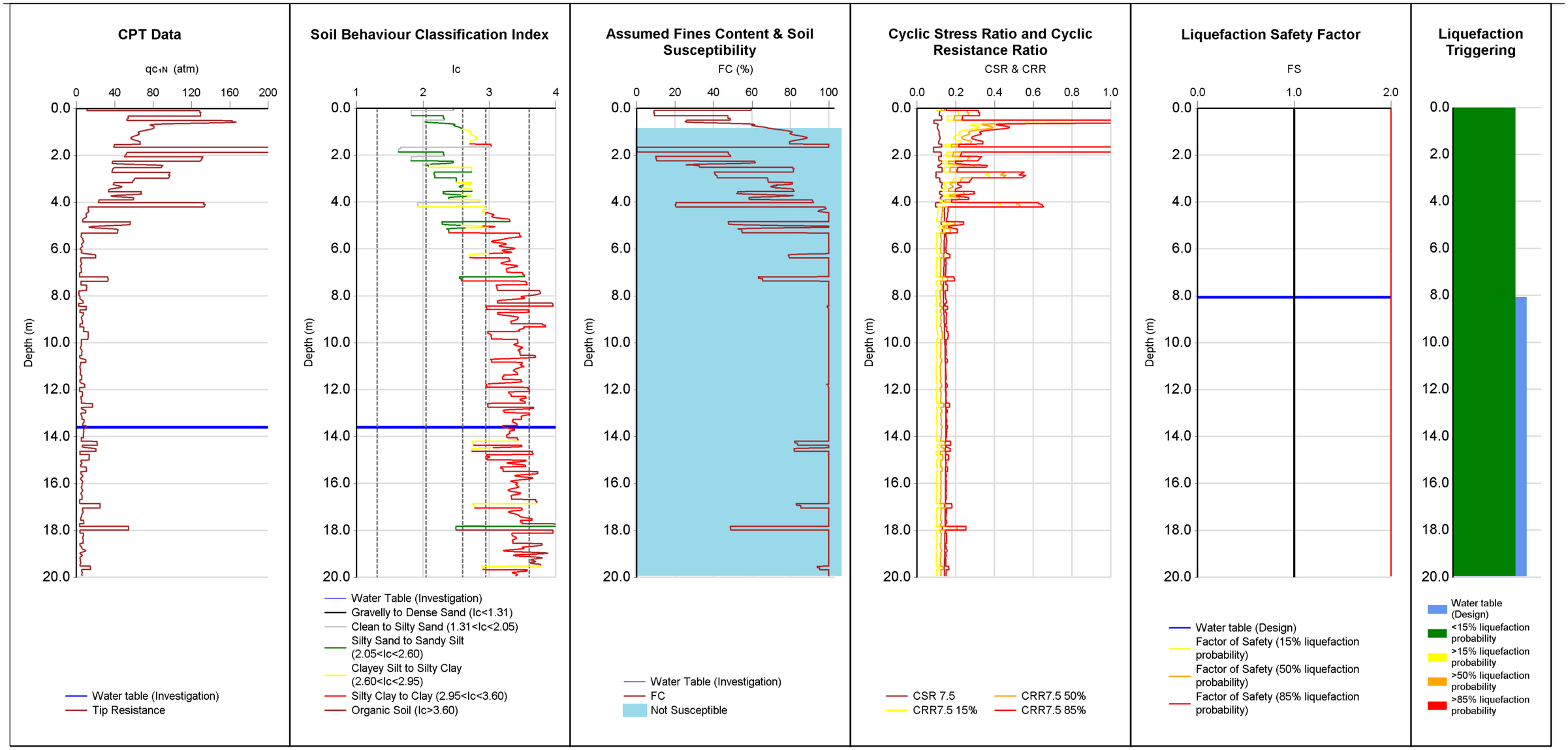
1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt mixtures - clayey silt to silty clay
5. Sand mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand *
9. Very stiff, fine grained *

*Heavily overconsolidated or cemented

CPT-based soil behavior type classification chart by Robertson (1990)



	Run Description	NZGD 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	CPT104	138343	28/01/2020	0	5.9	0.26	BI-2014	ZRB-2002	18		0	



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

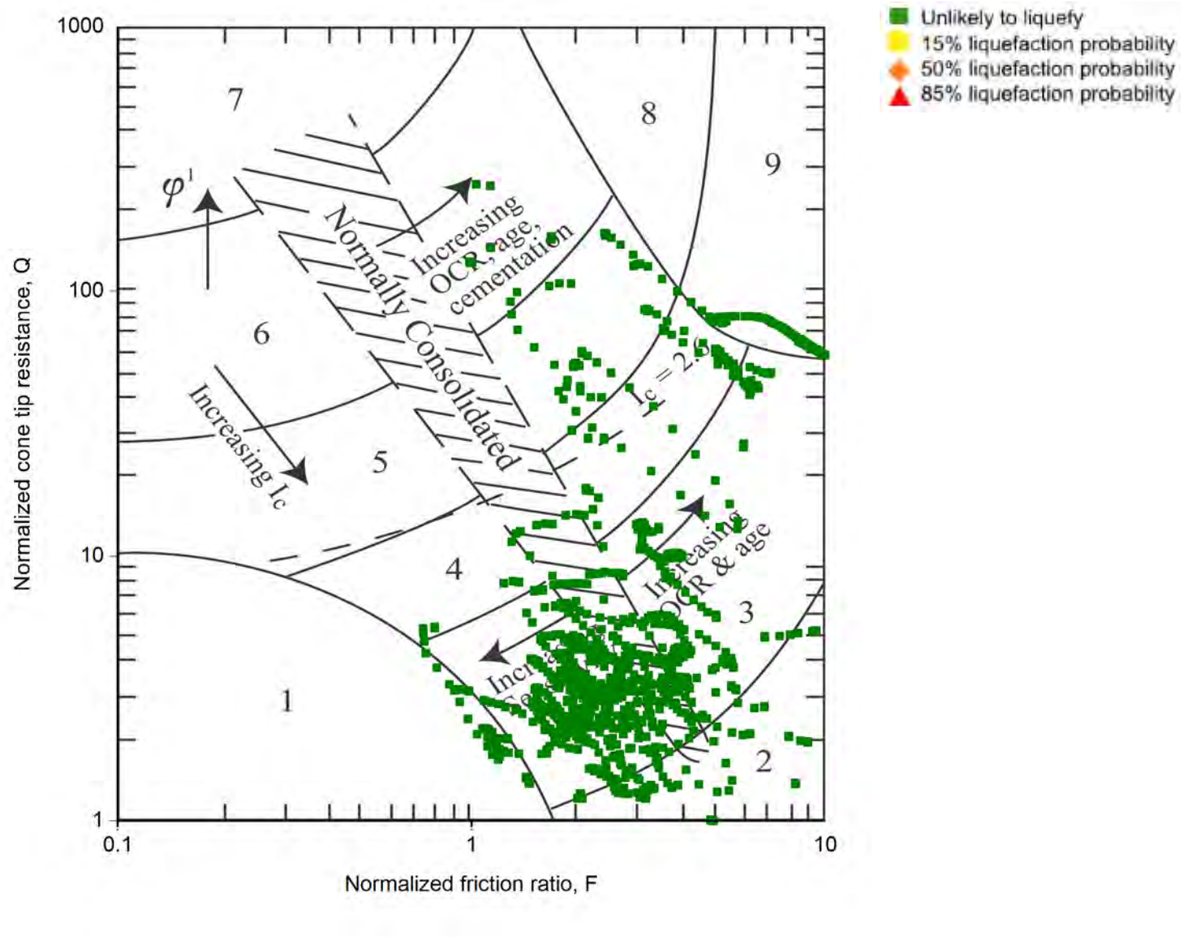
	Run Description	NZGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT	CPT105	138344	28/01/2020	0	5.9	0.26	BI-2014	ZRB-2002	18		0	

	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPIish
OUTPUT	15%	0	0	0	0	19.9	0
	50%	0	0	0	0	19.9	0
	85%	0	0	0	0	19.9	0

Reviewed by:

CPT Inversion	JICR
Groundwater	JICR
Susceptibility	JICR
Triggering	JICR
Consequence	JICR

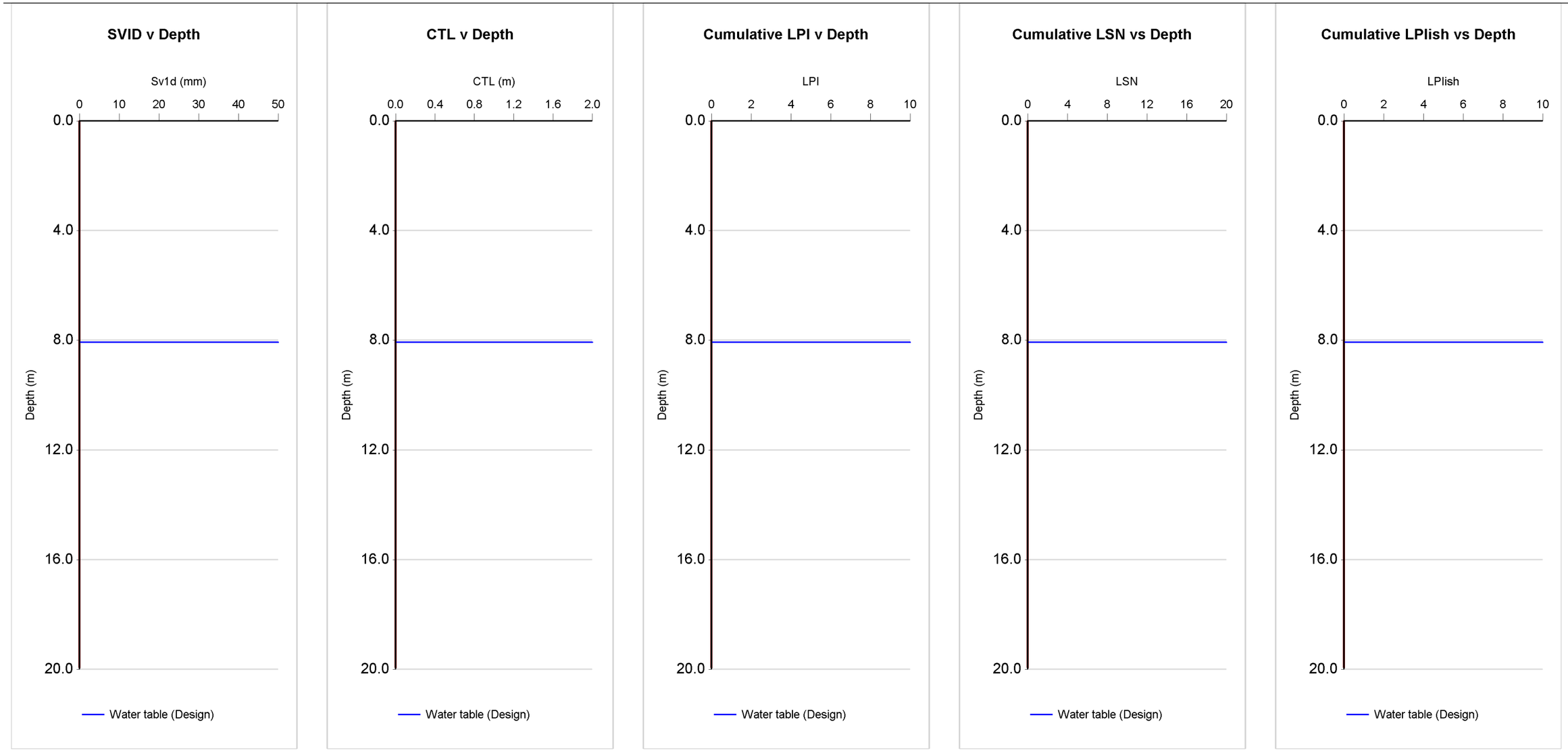
Tonkin + Taylor Exceptional thinking together V2.4.15	CLIENT	**BOPRC**	LOCATION	Omokoroa Stage 3 Study Area	DATE 16/03/2020
	PROJECT	**Omokoroa Structure Plan Stage 3**			ANALYSED gumc
	TITLE	**ARI=500 yr: PGA=0.26g, Mw=5.9**	JOB NUMBER	**1008683.0000**	
	COMMENT	CPT101 to CPT105 with susceptibility cut-off within the Rotoehu Ash and below.			PAGE 13 of 18 pages



1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt mixtures - clayey silt to silty clay
5. Sand mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand *
9. Very stiff, fine grained *

*Heavily overconsolidated or cemented

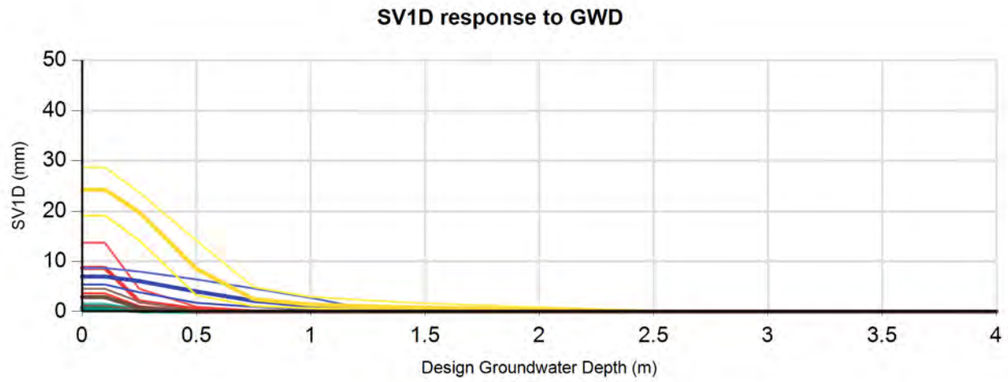
CPT-based soil behavior type classification chart by Robertson (1990)

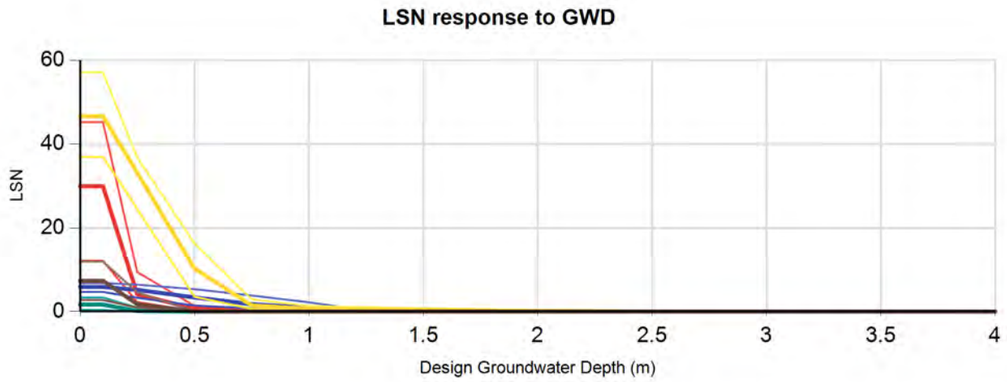


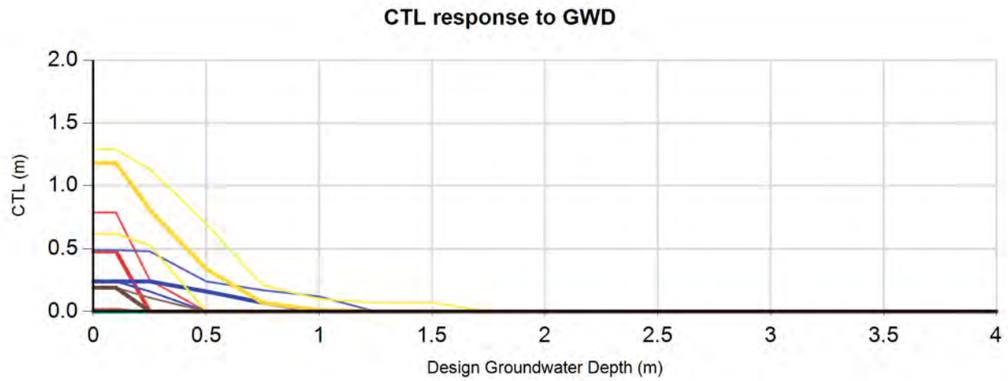
	Run Description	NZGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT	CPT105	138344	28/01/2020	0	5.9	0.26	BI-2014	ZRB-2002	18		0	

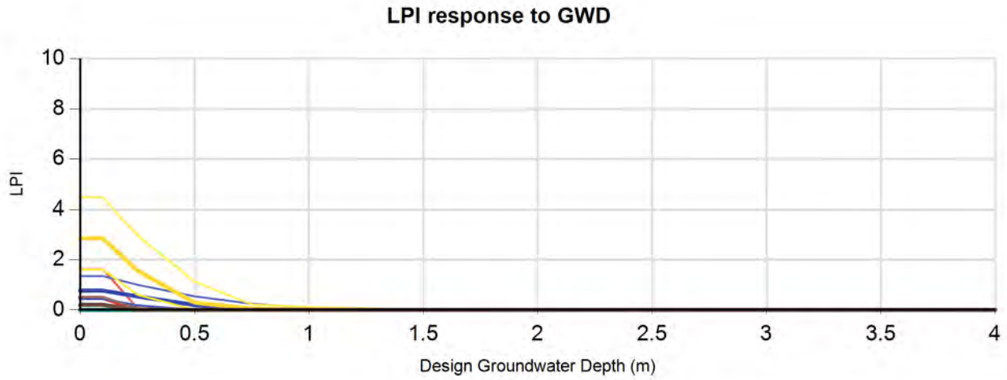
Tonkin+Taylor	Tonkin + Taylor Exceptional thinking together V2.4.15	CLIENT	BOPRC	LOCATION	Omokoroa Stage 3 Study Area
		PROJECT	Omokoroa Structure Plan Stage 3		
		TITLE	ARI=500 yr: PGA=0.26g, Mw=5.9	JOB NUMBER	1008683.0000
		COMMENT	CPT101 to CPT105 with susceptibility cut-off within the Rotoehu Ash and below.		

DATE	16/03/2020
ANALYSED	gumc
PAGE	15 of 18 pages





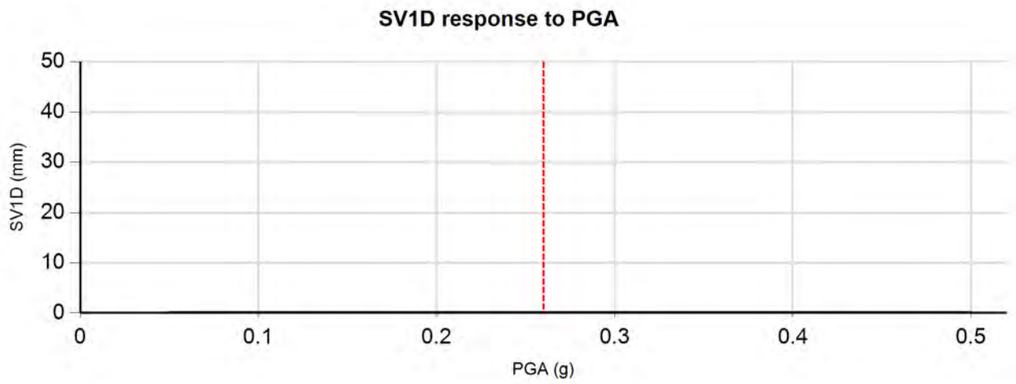


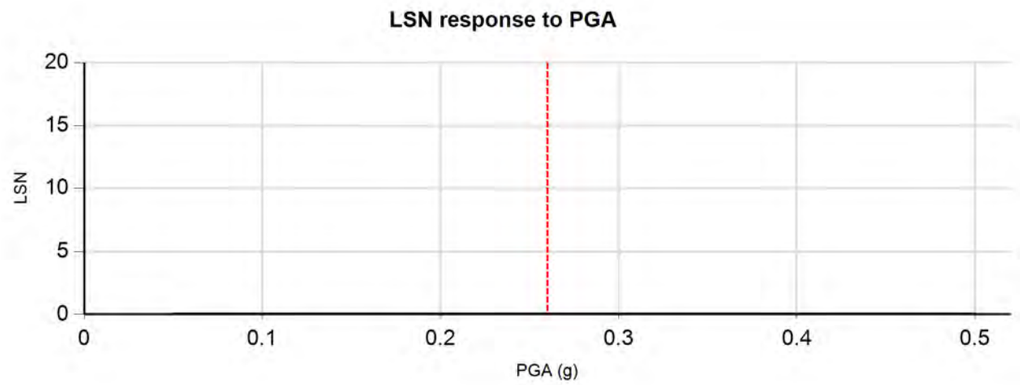


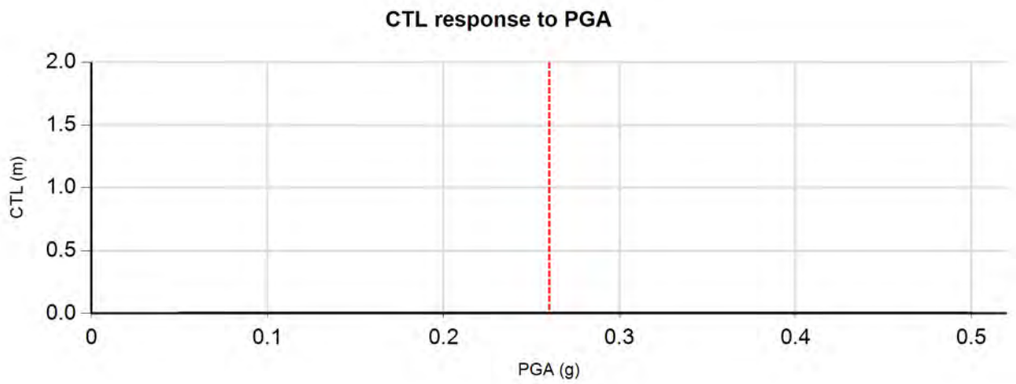
Vertical dotted line/s indicate design groundwater depth at the CPT locations.

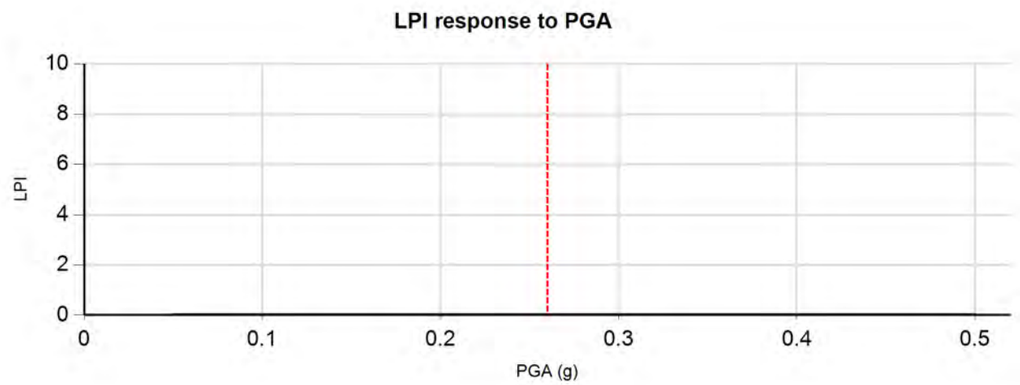
Note: Inverse filtered Qc/Fs data (10 cm²) used.

	Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	CFC	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	CPT101	138340	28/01/2020	5.9	0.26	BI-2014	ZRB-2002		18		0	
	CPT102	138341	28/01/2020	5.9	0.26	BI-2014	ZRB-2002		18		0	
	CPT103	138342	28/01/2020	5.9	0.26	BI-2014	ZRB-2002		18		0	
	CPT104	138343	28/01/2020	5.9	0.26	BI-2014	ZRB-2002		18		0	
	CPT105	138344	28/01/2020	5.9	0.26	BI-2014	ZRB-2002		18		0	
	Thicker lines represent the 50% probability of exceedence case and the thinner lines to the bottom and top of the thicker lines represent the 85% and 15% probability of exceedance cases respectively.											









Vertical dotted line/s indicate user specified PGA at the CPT locations. (actual PGA)

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

Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	CFC	γ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
CPT101	138340	28/01/2020	5.9	0.26	BI-2014	ZRB-2002		18		0	
CPT102	138341	28/01/2020	5.9	0.26	BI-2014	ZRB-2002		18		0	
CPT103	138342	28/01/2020	5.9	0.26	BI-2014	ZRB-2002		18		0	
CPT104	138343	28/01/2020	5.9	0.26	BI-2014	ZRB-2002		18		0	
CPT105	138344	28/01/2020	5.9	0.26	BI-2014	ZRB-2002		18		0	

Thicker lines represent the 50% probability of exceedence case and the thinner lines to the bottom and top of the thicker lines represent the 85% and 15% probability of exceedance cases respectively.

The inputs listed in Table 1.1-1 below have been adopted for the liquefaction analysis.

Table 1.1-1 Summary of inputs for liquefaction analysis

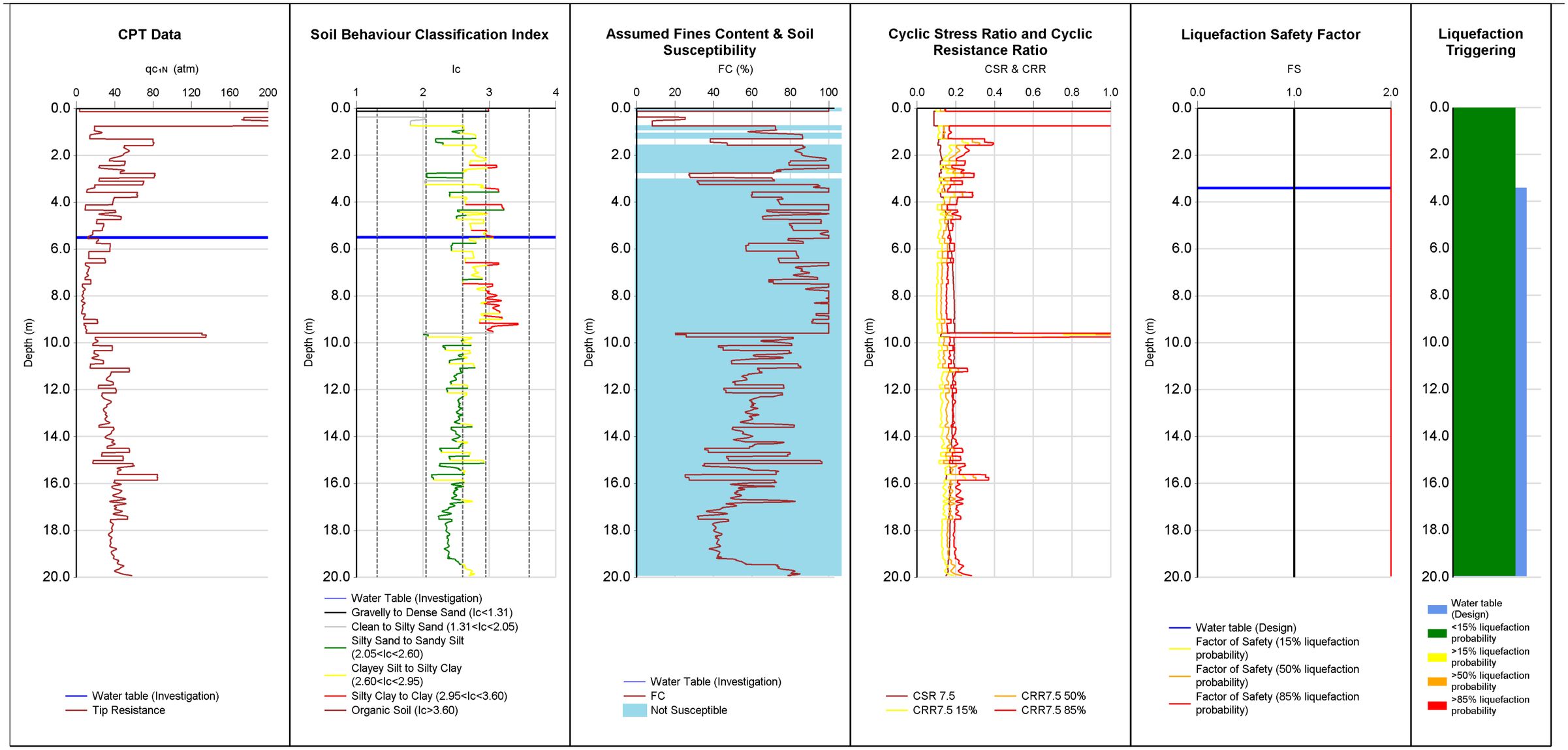
ID	NZGD 138340	NZGD 138341	NZGD 138342	NZGD 138343	NZGD 138344
CPT Name	05TT1_101	05TT1_102	05TT1_103	05TT1_104	05TT1_105
Run description	CPT101	CPT102	CPT103	CPT104	CPT105
PGA	0.26g	0.26g	0.26g	0.26g	0.26g
Magnitude	5.9	5.9	5.9	5.9	5.9
Depth to groundwater at time of Investigation (m)	7.95	7	8.7	10.8	13.6
Depth to groundwater for design (m)	7	6	8.07	5.07	8.07
Predrill depth (m)	0	0	0	0	0
Assumed predrill tip resistance and skin friction	qc= 2 MPa & Fs= 0.01 MPa	qc= 2 MPa & Fs= 0.01 MPa	qc= 2 MPa & Fs= 0.01 MPa	qc= 2 MPa & Fs= 0.01 MPa	qc= 2 MPa & Fs= 0.01 MPa
Trigger method	Boulanger & Idriss (2014)	Boulanger & Idriss (2014)	Boulanger & Idriss (2014)	Boulanger & Idriss (2014)	Boulanger & Idriss (2014)
Settlement method	ZRB-2002	ZRB-2002	ZRB-2002	ZRB-2002	ZRB-2002
Total depth of CPT (m)	15.92	17.21	19.93	19.93	19.93
Minimum depth of analysis (m)	0	0	0	0	0
Maximum depth of analysis (m)	20	20	20	20	20
Inverse Filtering applied?	Yes (10 cm^2)	Yes (10 cm^2)	Yes (10 cm^2)	Yes (10 cm^2)	Yes (10 cm^2)

Table 1.1-2 Summary of Ic inputs for liquefaction analysis

ID	Run description	From (m)	To (m)	Ic
NZGD 138340	CPT101	0	0	0
NZGD 138340	CPT101	0	1.6	2.6
NZGD 138340	CPT101	1.6	20	0
NZGD 138341	CPT102	0	0	0
NZGD 138341	CPT102	0	2.6	2.6
NZGD 138341	CPT102	2.6	20	0
NZGD 138342	CPT103	0	0	0
NZGD 138342	CPT103	0	1.6	2.6
NZGD 138342	CPT103	1.6	20	0
NZGD 138343	CPT104	0	0	0
NZGD 138343	CPT104	0	2.6	2.6
NZGD 138343	CPT104	2.6	20	0
NZGD 138344	CPT105	0	0	0
NZGD 138344	CPT105	0	1.7	2.6
NZGD 138344	CPT105	1.7	20	0

Table 1.1-3 Summary of Fc inputs for liquefaction analysis

ID	Run description	From (m)	To (m)	Fc
NZGD 138340	CPT101	0	20	0 CFC
NZGD 138341	CPT102	0	20	0 CFC
NZGD 138342	CPT103	0	20	0 CFC
NZGD 138343	CPT104	0	20	0 CFC
NZGD 138344	CPT105	0	20	0 CFC



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

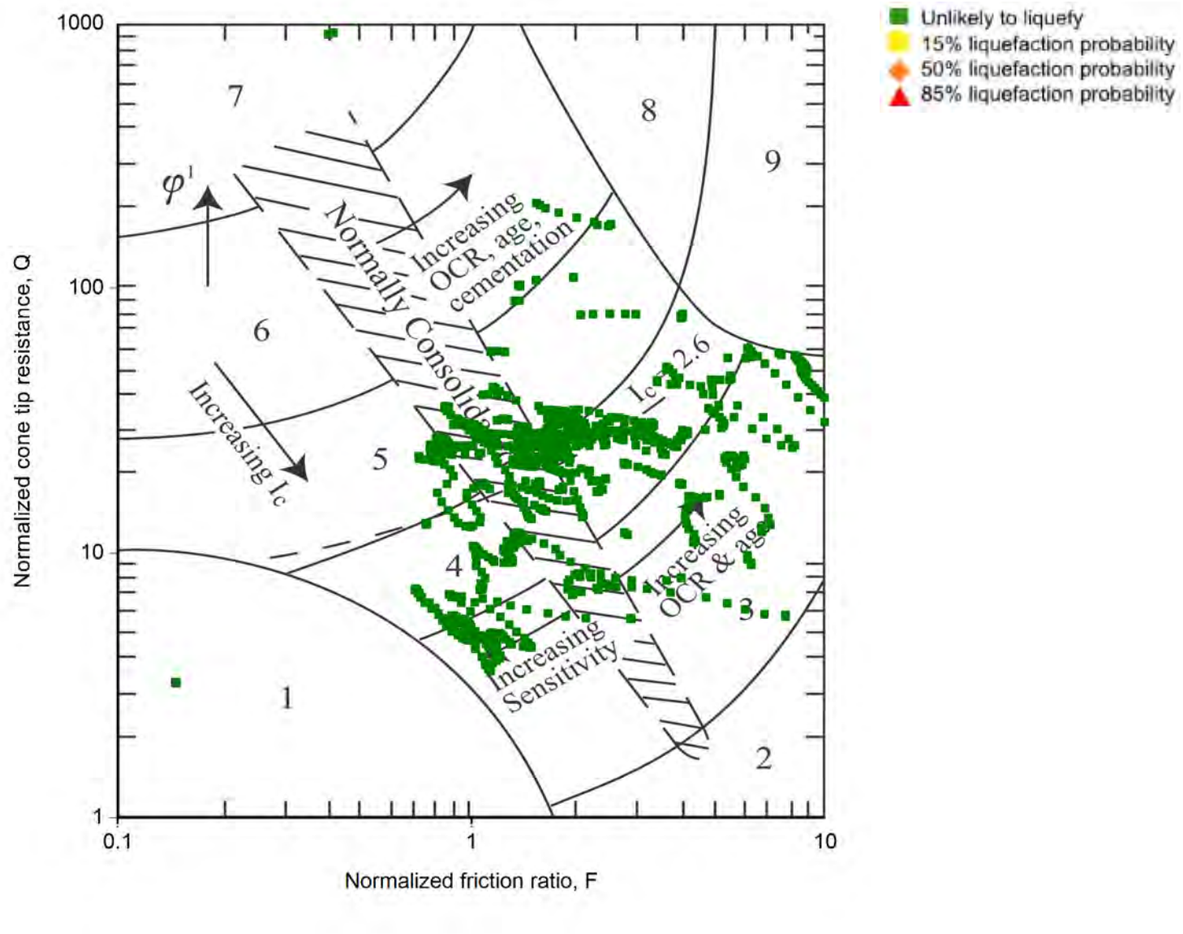
	Run Description	NZGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT	CPT106	138347	3/02/2020	0	5.9	0.26	BI-2014	ZRB-2002	18		0	

	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPIish
OUTPUT	15%	0	0	0	0	19.9	0
	50%	0	0	0	0	19.9	0
	85%	0	0	0	0	19.9	0

Reviewed by:

CPT Inversion	JICR
Groundwater	JICR
Susceptibility	JICR
Triggering	JICR
Consequence	JICR

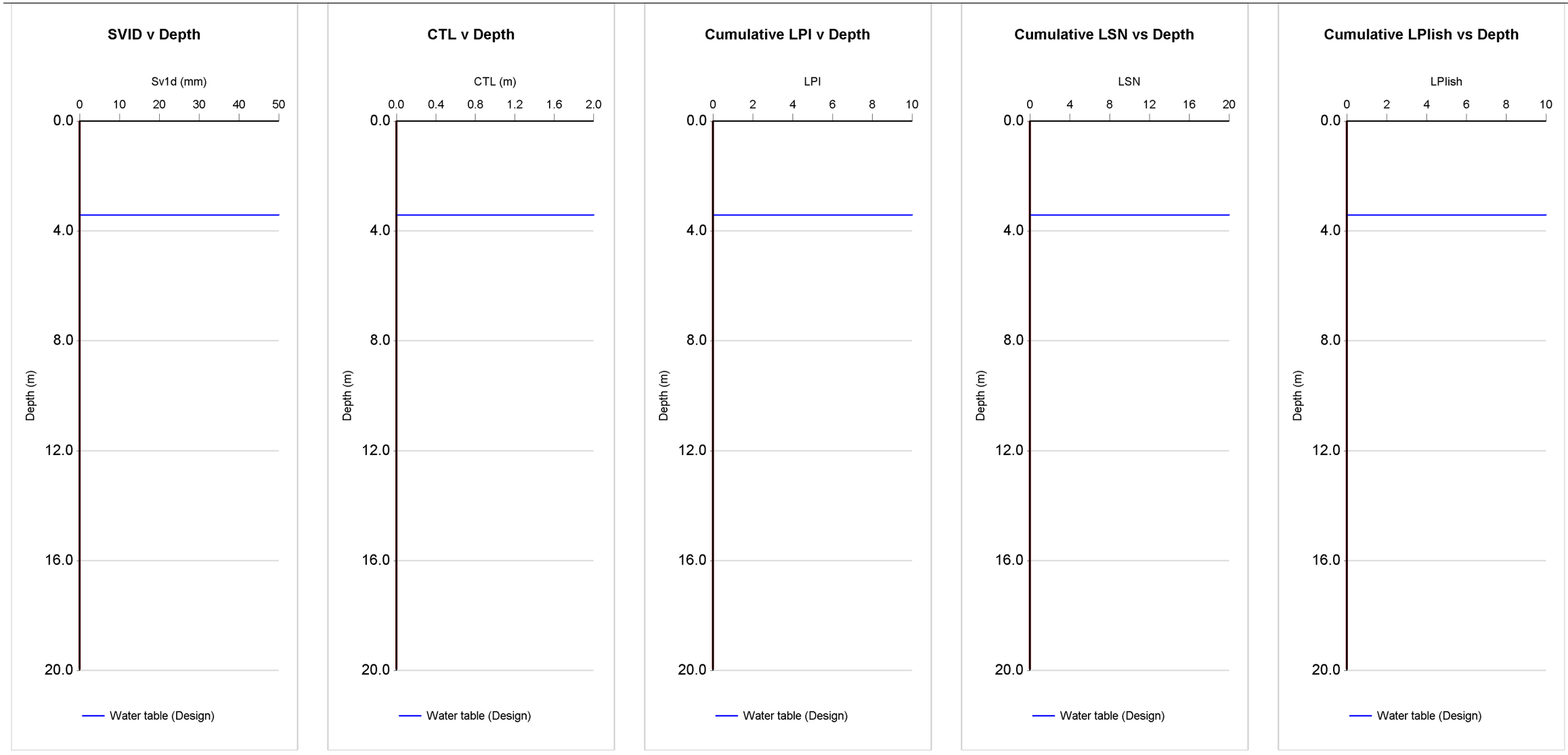
Tonkin + Taylor Exceptional thinking together V2.4.15	CLIENT	**BOPRC**	LOCATION	DATE	20/03/2020
	PROJECT	**Omokoroa Structure Plan Stage 3**	Omokoroa Stage 3 Study Area	ANALYSED	gumc
	TITLE	**ARI=500 yr: PGA=0.26g, Mw=5.9**	JOB NUMBER		
	COMMENT	CPT106 to 110 with susceptibility cut-off within the Rotoehu Ash and below. Exlcudes CPT109, CPT110 (estuarine/alluvial area)	**1008683.0000**	PAGE	1 of 15 pages



1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt mixtures - clayey silt to silty clay
5. Sand mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand *
9. Very stiff, fine grained *

*Heavily overconsolidated or cemented

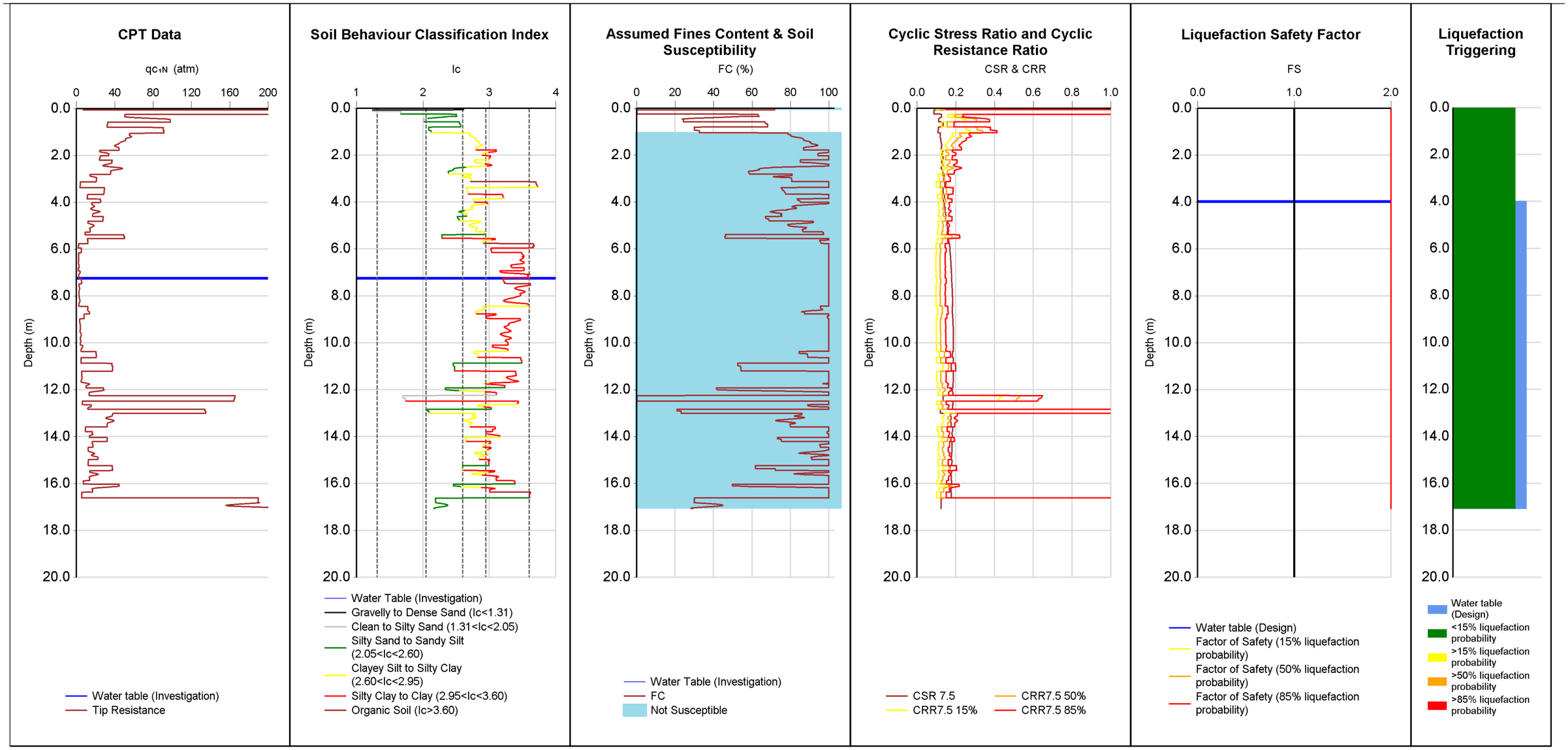
CPT-based soil behavior type classification chart by Robertson (1990)



	Run Description	NZGD 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	CPT106	138347	3/02/2020	0	5.9	0.26	BI-2014	ZRB-2002	18		0	

Tonkin+Taylor	Tonkin + Taylor Exceptional thinking together V2.4.15	CLIENT	**BOPRC**	LOCATION	Omokoroa Stage 3 Study Area
		PROJECT	**Omokoroa Structure Plan Stage 3**		
		TITLE	**ARI=500 yr: PGA=0.26g, Mw=5.9**	JOB NUMBER	**1008683.0000**
		COMMENT	CPT106 to 110 with susceptibility cut-off within the Rotoehu Ash and below. Exlcudes CPT109, CPT110 (estuarine/alluvial area)		

DATE	20/03/2020
ANALYSED	gumc
PAGE	3 of 15 pages



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

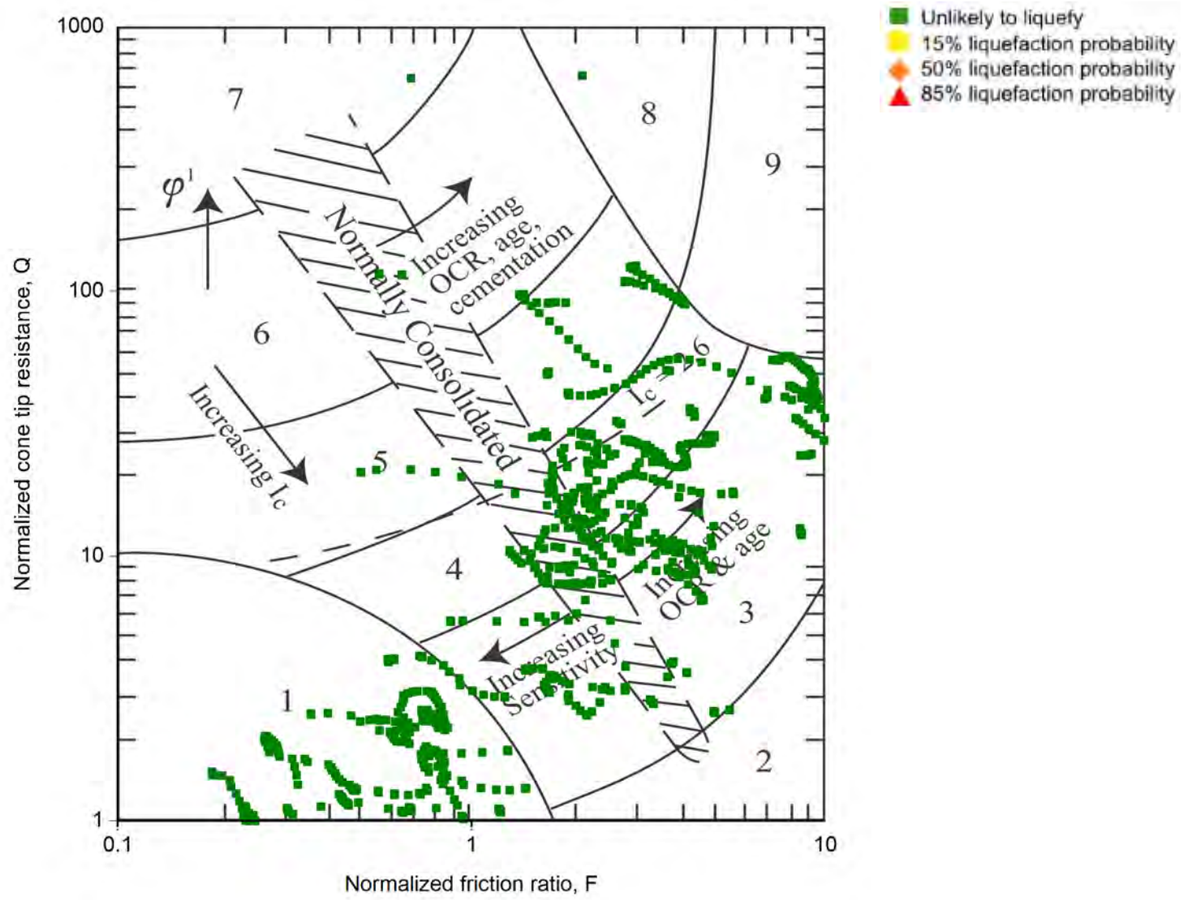
	Run Description	NZGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT	CPT107b	138348	3/02/2020	0	5.9	0.26	BI-2014	ZRB-2002	18		0	

	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPIish
OUTPUT	15%	0	0	0	0	17.1	0
	50%	0	0	0	0	17.1	0
	85%	0	0	0	0	17.1	0

Reviewed by:

CPT Inversion	JICR
Groundwater	JICR
Susceptibility	JICR
Triggering	JICR
Consequence	JICR

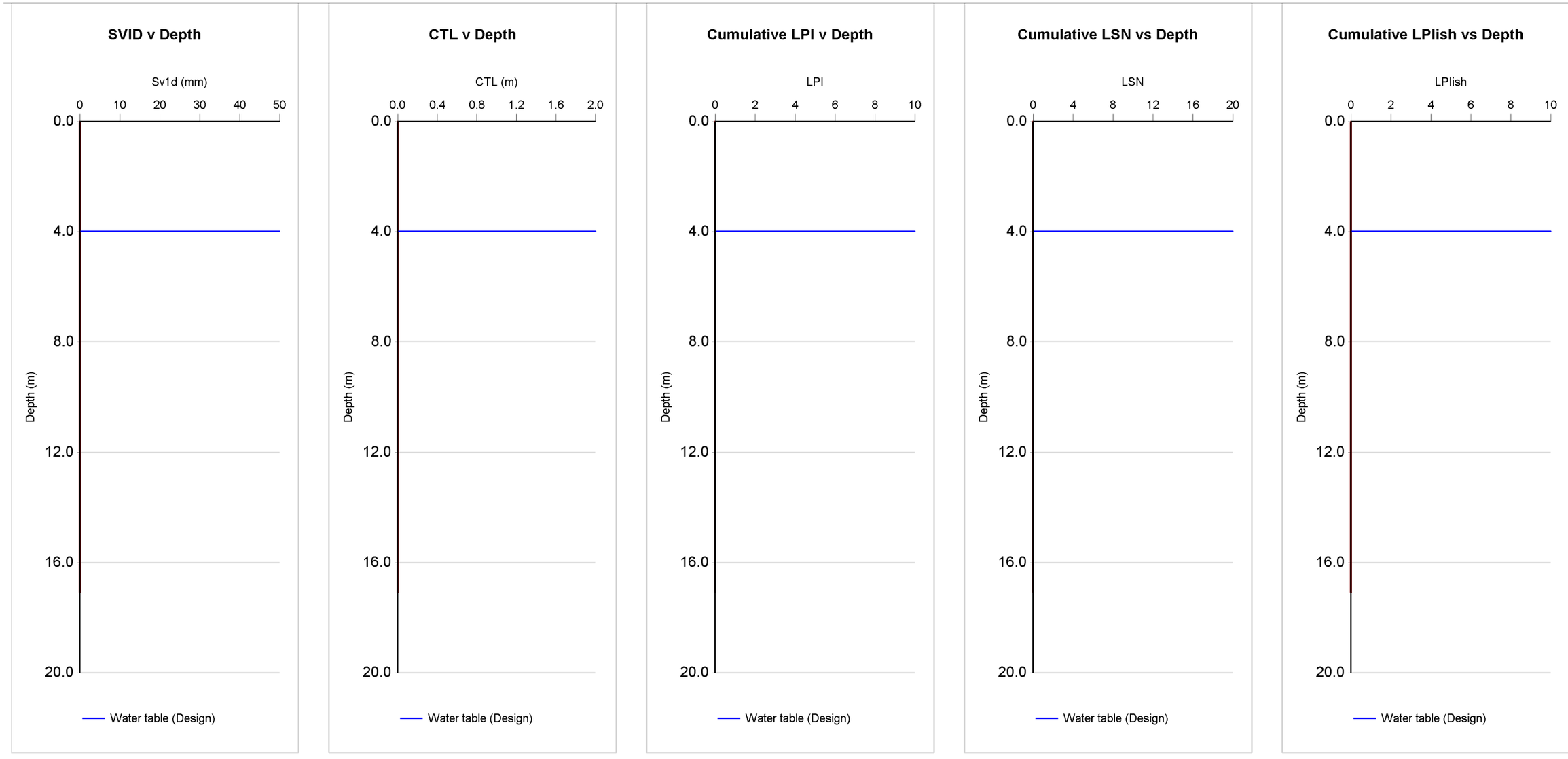
Tonkin + Taylor Exceptional thinking together V2.4.15	CLIENT	**BOPRC**	LOCATION	Omokoroa Stage 3 Study Area	DATE 20/03/2020
	PROJECT	**Omokoroa Structure Plan Stage 3**			ANALYSED gumc
	TITLE	**ARI=500 yr: PGA=0.26g, Mw=5.9**	JOB NUMBER	**1008683.0000**	
	COMMENT	CPT106 to 110 with susceptibility cut-off within the Rotoehu Ash and below. Exlcudes CPT109, CPT110 (estuarine/alluvial area)			PAGE 4 of 15 pages



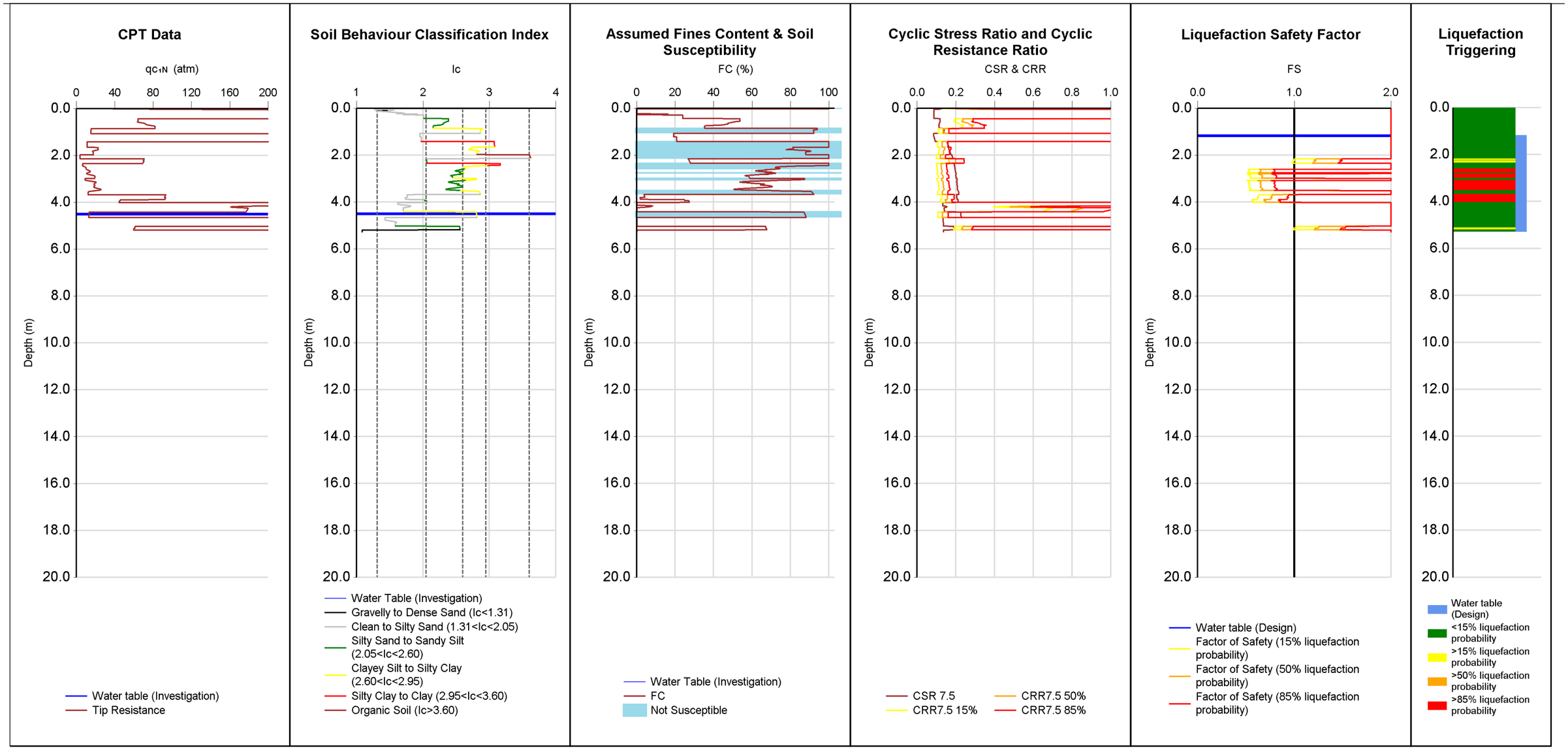
1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt mixtures - clayey silt to silty clay
5. Sand mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand *
9. Very stiff, fine grained *

*Heavily overconsolidated or cemented

CPT-based soil behavior type classification chart by Robertson (1990)



	Run Description	NZGD 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	CPT107b	138348	3/02/2020	0	5.9	0.26	BI-2014	ZRB-2002	18		0	



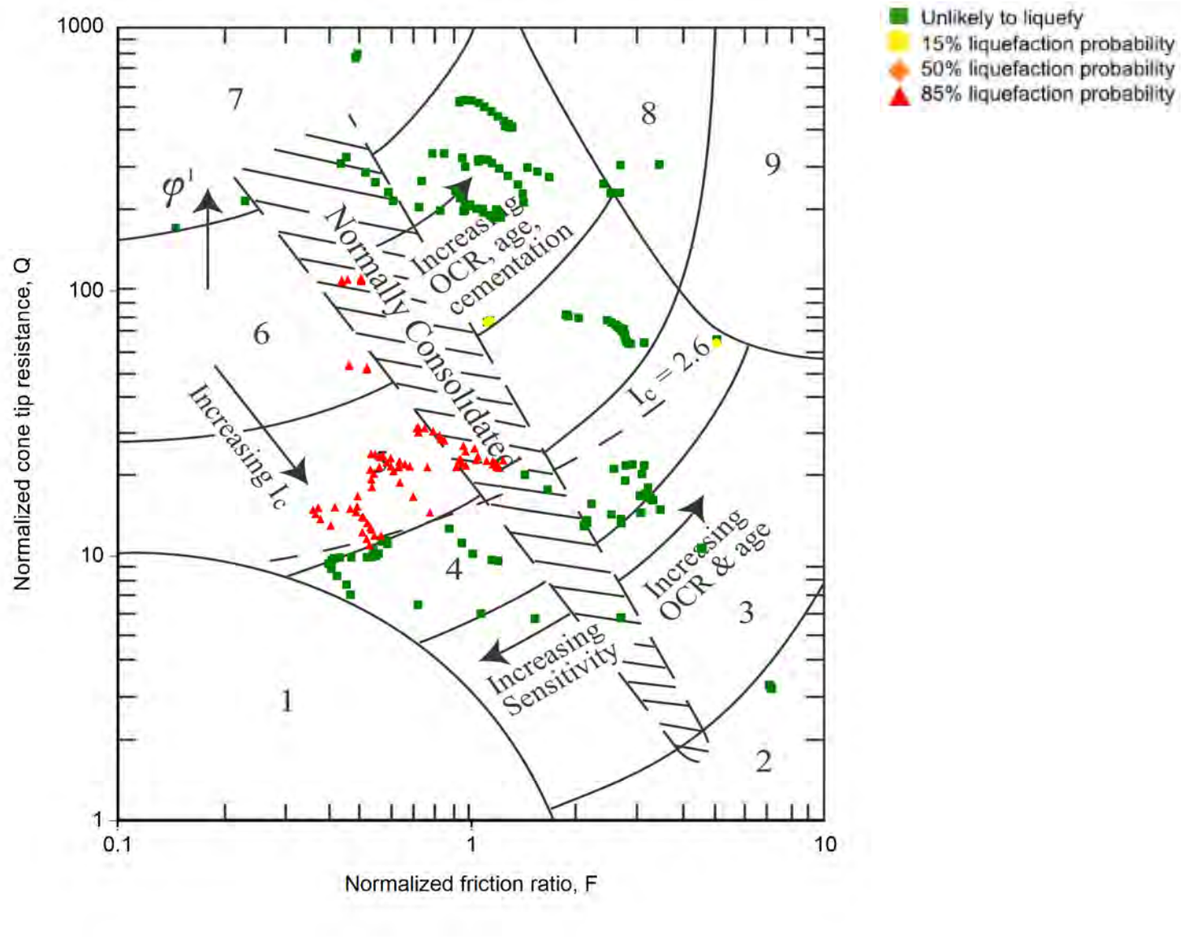
Note: Inverse filtered Qc/Fs data (10 cm²) used.

	Run Description	NZGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT	CPT109	138345	28/01/2020	0	5.9	0.26	BI-2014	ZRB-2002	18		0	

	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPIish
OUTPUT	15%	35	1.4	4	11	2.3	4
	50%	34	1.1	3	11	2.7	3
	85%	31	1.1	2	10	2.7	1

Reviewed by:

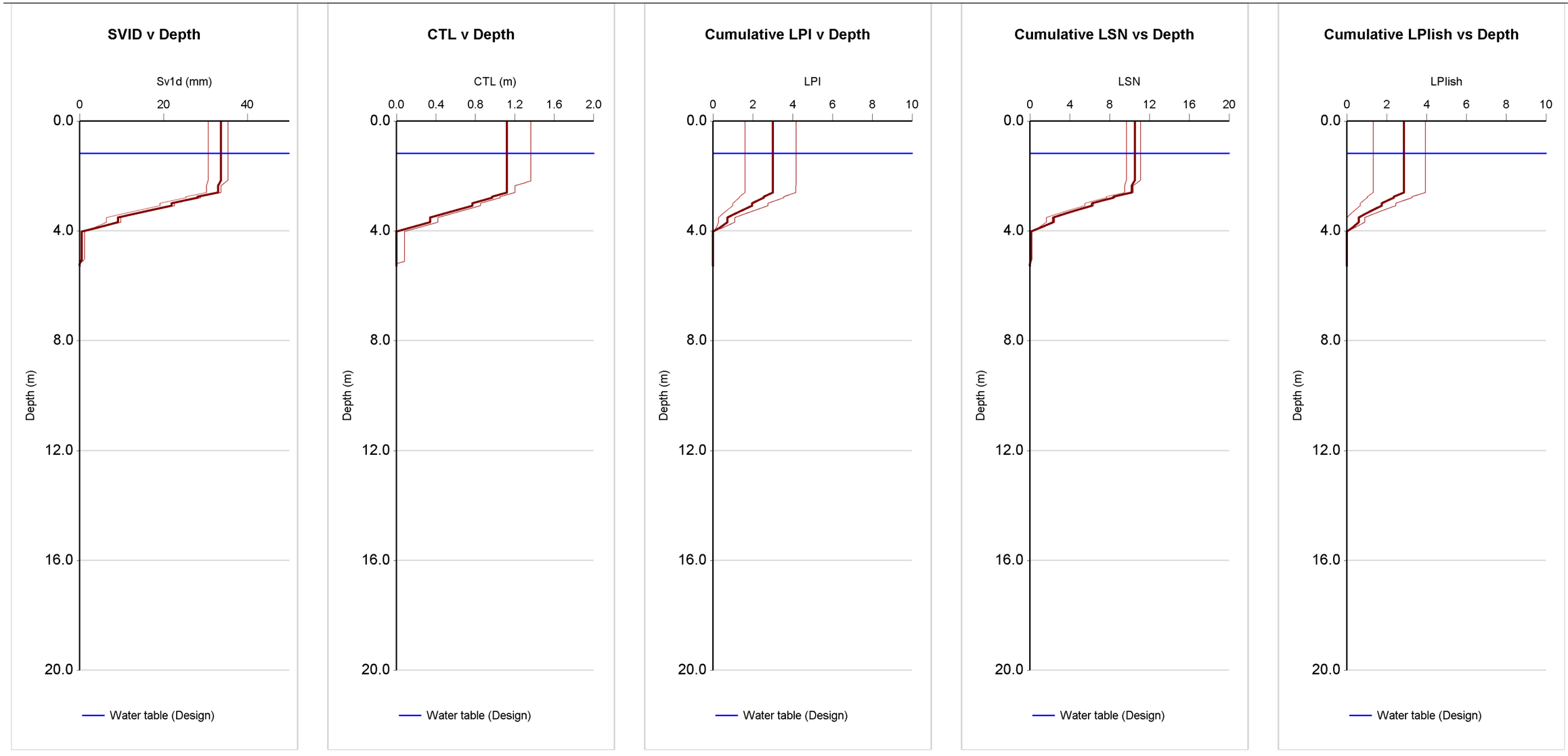
CPT Inversion	JICR
Groundwater	JICR
Susceptibility	JICR
Triggering	JICR
Consequence	JICR



1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt mixtures - clayey silt to silty clay
5. Sand mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand *
9. Very stiff, fine grained *

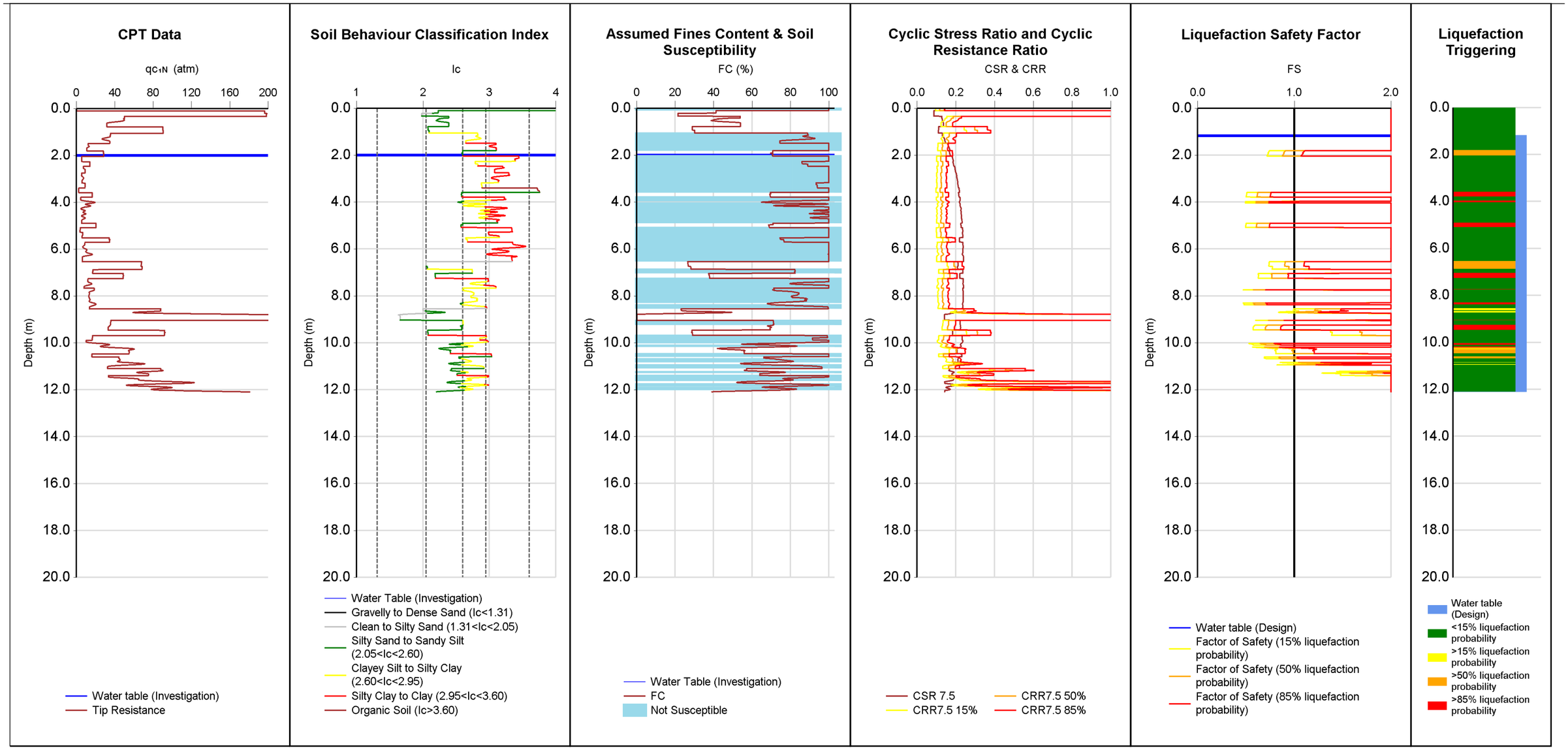
*Heavily overconsolidated or cemented

CPT-based soil behavior type classification chart by Robertson (1990)



	Run Description	NZGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT	CPT109	138345	28/01/2020	0	5.9	0.26	BI-2014	ZRB-2002	18		0	

Tonkin + Taylor Exceptional thinking together V2.4.15	CLIENT	**BOPRC**	LOCATION Omokoroa Stage 3 Study Area	DATE	20/03/2020
	PROJECT	**Omokoroa Structure Plan Stage 3**		ANALYSED	gumc
	TITLE	**ARI=500 yr: PGA=0.26g, Mw=5.9**	JOB NUMBER **1008683.0000**		
	COMMENT	CPT106 to 110 with susceptibility cut-off within the Rotoehu Ash and below. Exlcudes CPT109, CPT110 (estuarine/alluvial area)		PAGE	9 of 15 pages



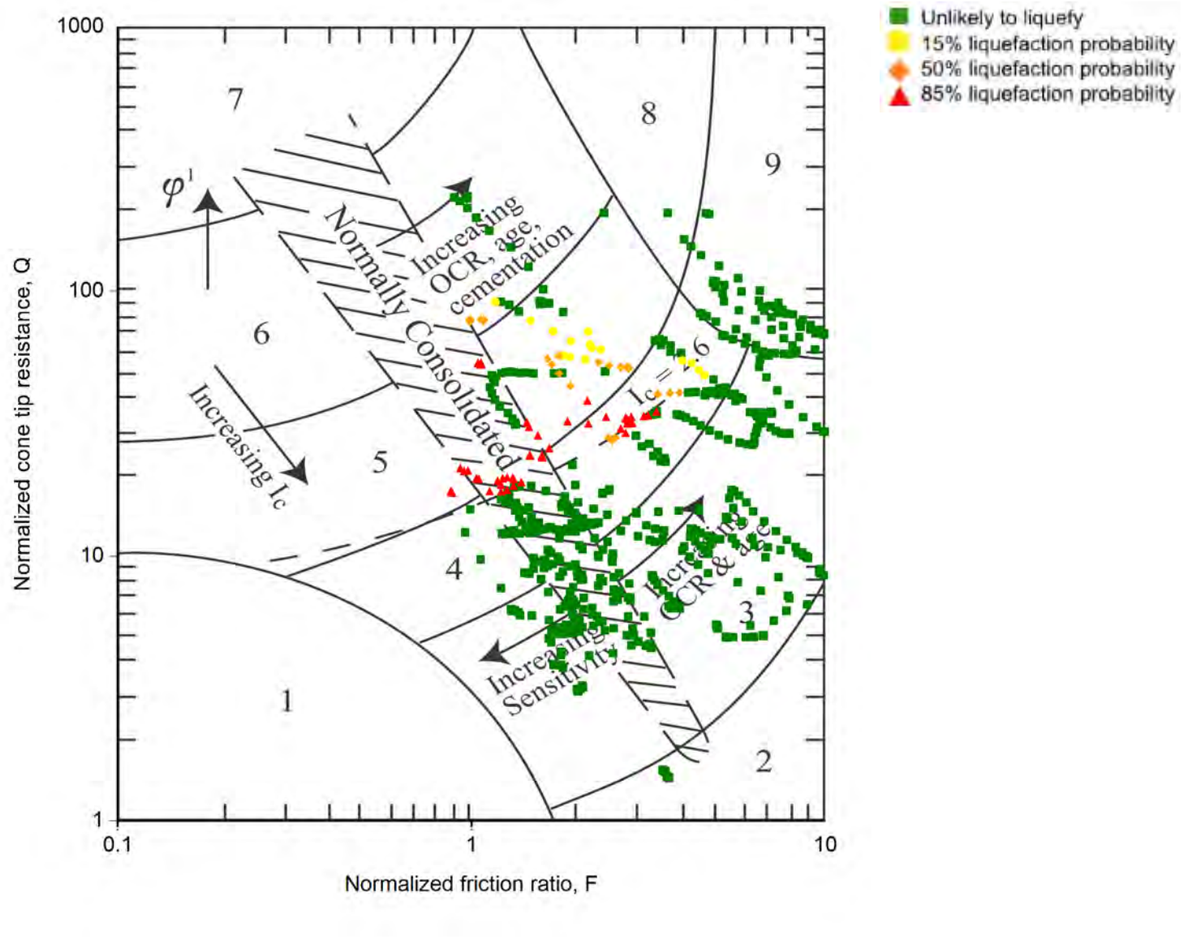
Note: Inverse filtered Qc/Fs data (10 cm²) used.

	Run Description	NZGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT	CPT110	138346	28/01/2020	0	5.9	0.26	BI-2014	ZRB-2002	18		0	

	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPIish
OUTPUT	15%	51	2.2	5	10	1.9	4
	50%	43	2	3	9	1.9	2
	85%	31	1.1	1	6	3.7	1

Reviewed by:

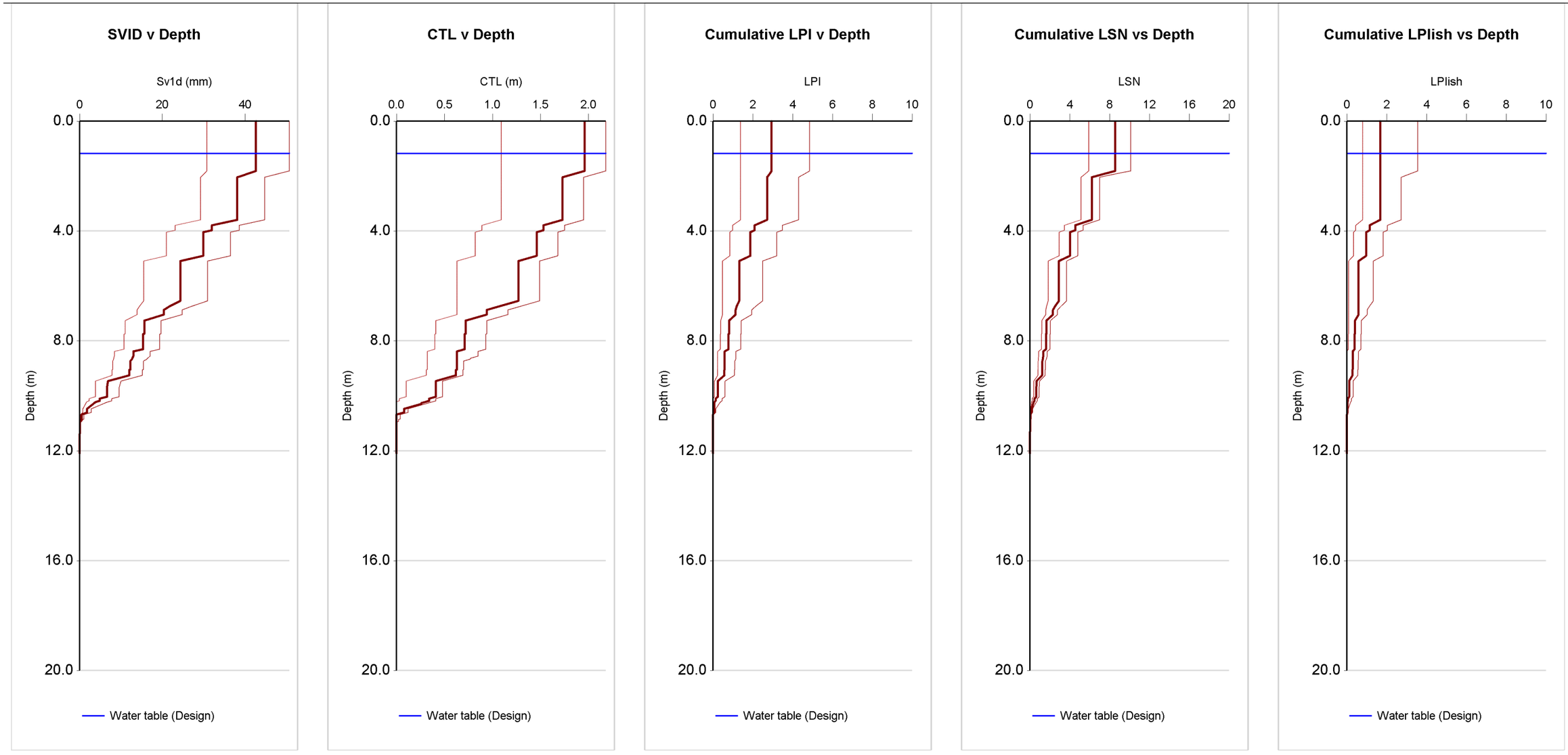
CPT Inversion	JICR
Groundwater	JICR
Susceptibility	JICR
Triggering	JICR
Consequence	JICR



1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt mixtures - clayey silt to silty clay
5. Sand mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand *
9. Very stiff, fine grained *

*Heavily overconsolidated or cemented

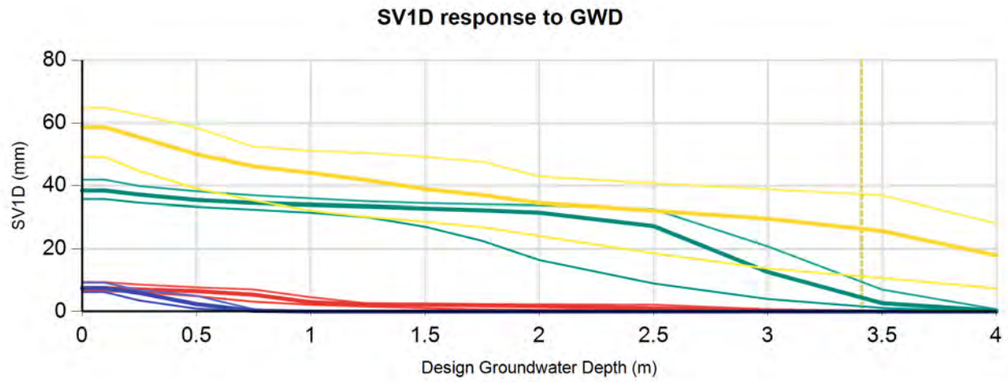
CPT-based soil behavior type classification chart by Robertson (1990)

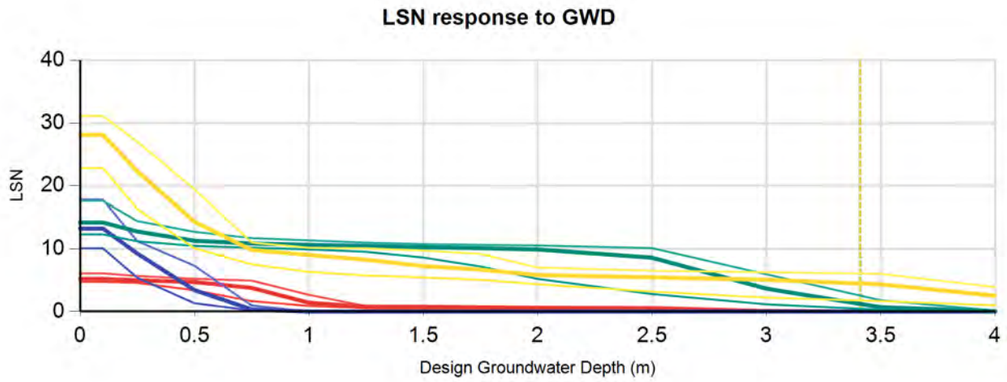


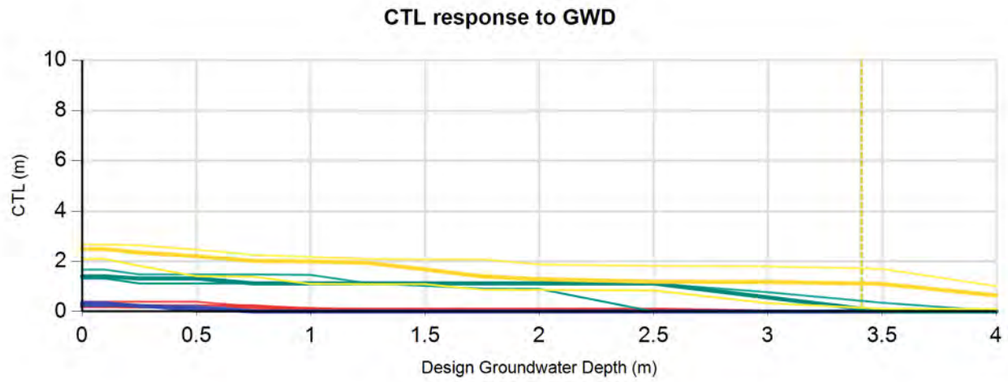
	Run Description	NZGD ID	Investigation Date	Pre-drill (m)	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT	CPT110	138346	28/01/2020	0	5.9	0.26	BI-2014	ZRB-2002	18		0	

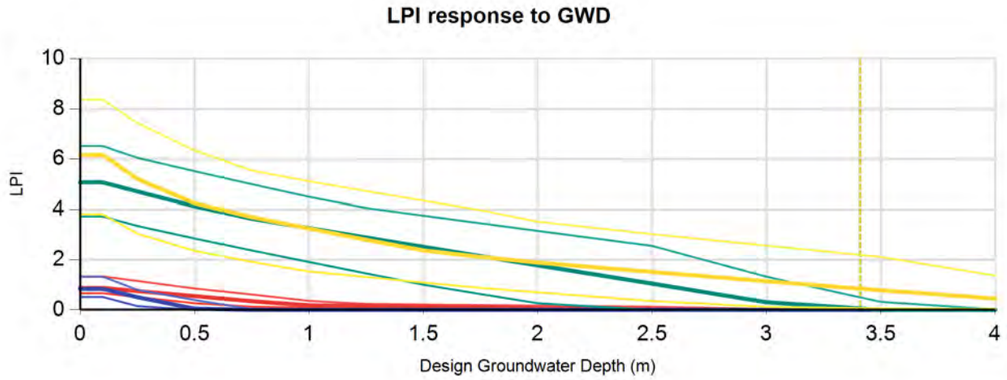
Tonkin+Taylor	Tonkin + Taylor Exceptional thinking together V2.4.15	CLIENT	BOPRC	LOCATION	Omokoroa Stage 3 Study Area
		PROJECT	Omokoroa Structure Plan Stage 3		
		TITLE	ARI=500 yr: PGA=0.26g, Mw=5.9	JOB NUMBER	1008683.0000
		COMMENT	CPT106 to 110 with susceptibility cut-off within the Rotoehu Ash and below. Exlcudes CPT109, CPT110 (estuarine/alluvial area)		

DATE	20/03/2020
ANALYSED	gumc
PAGE	12 of 15 pages





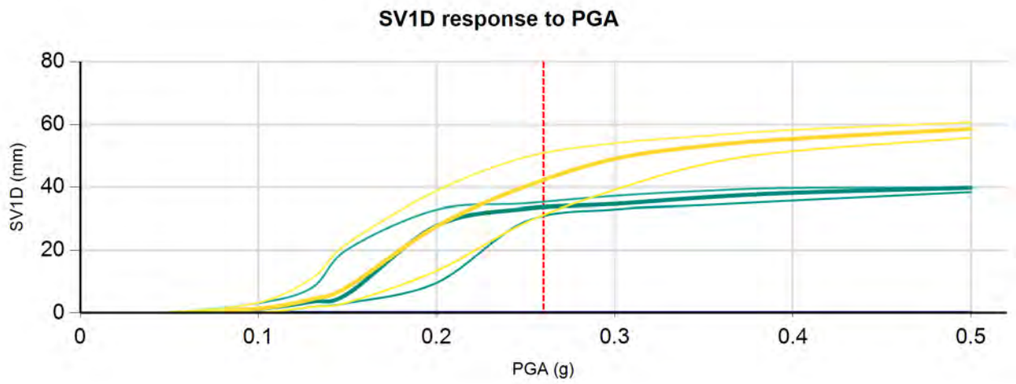


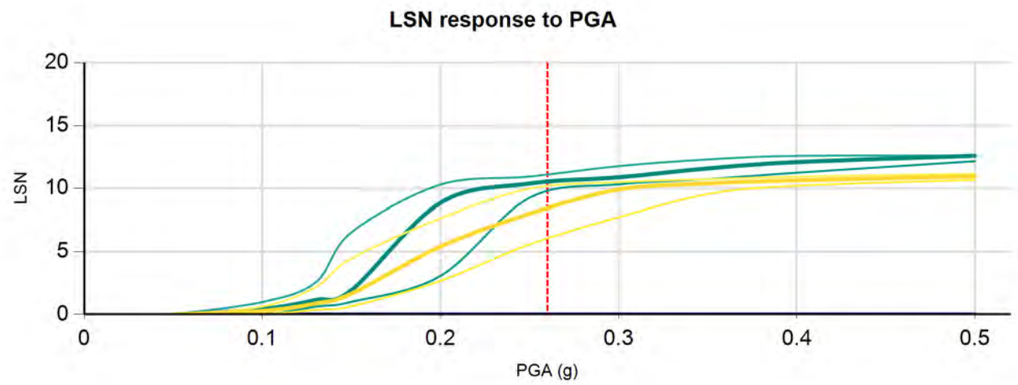


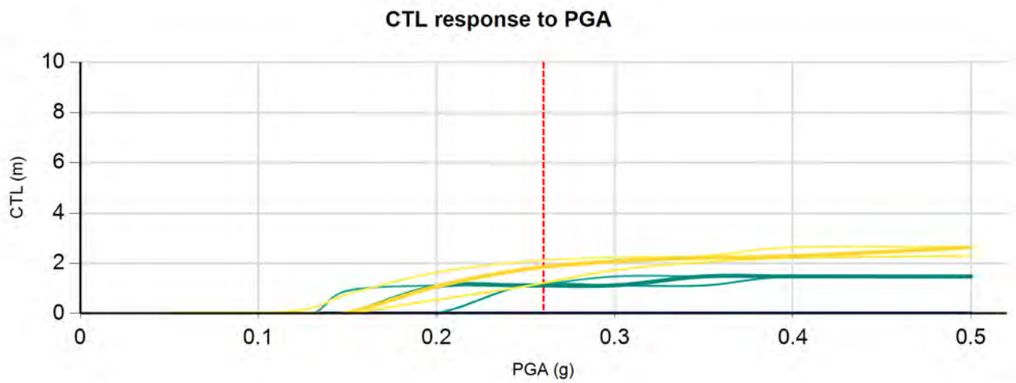
Vertical dotted line/s indicate design groundwater depth at the CPT locations.

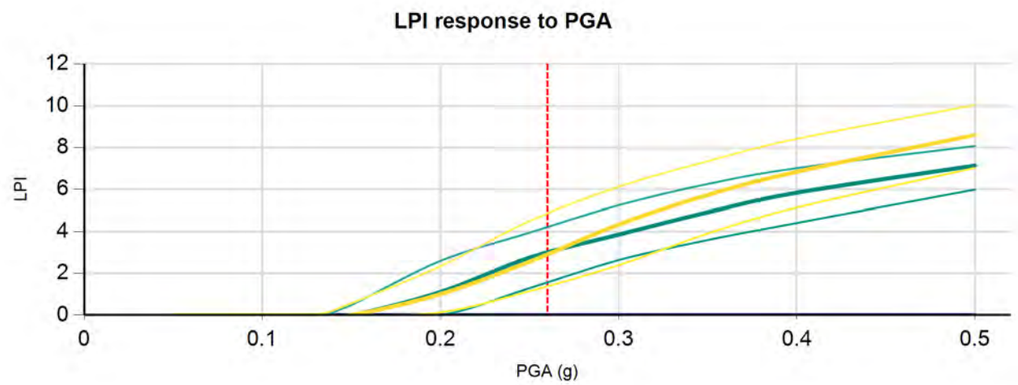
Note: Inverse filtered Qc/Fs data (10 cm²) used.

	Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	CFC	γ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	CPT106	138347	3/02/2020	5.9	0.26	BI-2014	ZRB-2002		18		0	
	CPT107b	138348	3/02/2020	5.9	0.26	BI-2014	ZRB-2002		18		0	
	CPT109	138345	28/01/2020	5.9	0.26	BI-2014	ZRB-2002		18		0	
	CPT110	138346	28/01/2020	5.9	0.26	BI-2014	ZRB-2002		18		0	
	Thicker lines represent the 50% probability of exceedence case and the thinner lines to the bottom and top of the thicker lines represent the 85% and 15% probability of exceedance cases respectively.											









Vertical dotted line/s indicate user specified PGA at the CPT locations. (actual PGA)

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

	Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	CFC	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	CPT106	138347	3/02/2020	5.9	0.26	BI-2014	ZRB-2002		18		0	
	CPT107b	138348	3/02/2020	5.9	0.26	BI-2014	ZRB-2002		18		0	
	CPT109	138345	28/01/2020	5.9	0.26	BI-2014	ZRB-2002		18		0	
	CPT110	138346	28/01/2020	5.9	0.26	BI-2014	ZRB-2002		18		0	
	Thicker lines represent the 50% probability of exceedence case and the thinner lines to the bottom and top of the thicker lines represent the 85% and 15% probability of exceedance cases respectively.											

The inputs listed in Table 1.1-1 below have been adopted for the liquefaction analysis.

Table 1.1-1 Summary of inputs for liquefaction analysis

ID	NZGD 138347	NZGD 138348	NZGD 138345	NZGD 138346
CPT Name	05TT1_106	05TT1_107b	05TT1_109	05TT1_110
Run description	CPT106	CPT107b	CPT109	CPT110
PGA	0.26g	0.26g	0.26g	0.26g
Magnitude	5.9	5.9	5.9	5.9
Depth to groundwater at time of Investigation (m)	5.5	7.25	4.5	2
Depth to groundwater for design (m)	3.41	3.98	1.17	1.17
Predrill depth (m)	0	0	0	0
Assumed predrill tip resistance and skin friction	qc= 2 MPa & Fs= 0.01 MPa	qc= 2 MPa & Fs= 0.01 MPa	qc= 2 MPa & Fs= 0.01 MPa	qc= 2 MPa & Fs= 0.01 MPa
Trigger method	Boulanger & Idriss (2014)	Boulanger & Idriss (2014)	Boulanger & Idriss (2014)	Boulanger & Idriss (2014)
Settlement method	ZRB-2002	ZRB-2002	ZRB-2002	ZRB-2002
Total depth of CPT (m)	19.93	17.07	5.27	12.09
Minimum depth of analysis (m)	0	0	0	0
Maximum depth of analysis (m)	20	20	20	20
Inverse Filtering applied?	Yes (10 cm^2)	Yes (10 cm^2)	Yes (10 cm^2)	Yes (10 cm^2)

Table 1.1-2 Summary of Ic inputs for liquefaction analysis

ID	Run description	From (m)	To (m)	Ic
NZGD 138347	CPT106	0	0	0
NZGD 138347	CPT106	0	3.1	2.6
NZGD 138347	CPT106	3.1	20	0
NZGD 138348	CPT107b	0	0	0
NZGD 138348	CPT107b	0	2.15	2.6
NZGD 138348	CPT107b	2.15	20	0
NZGD 138345	CPT109	0	0	0
NZGD 138345	CPT109	0	20	2.6
NZGD 138346	CPT110	0	0	0
NZGD 138346	CPT110	0	20	2.6

Table 1.1-3 Summary of Fc inputs for liquefaction analysis

ID	Run description	From (m)	To (m)	Fc
NZGD 138347	CPT106	0	20	0 CFC
NZGD 138348	CPT107b	0	20	0 CFC
NZGD 138345	CPT109	0	20	0 CFC
NZGD 138346	CPT110	0	20	0 CFC

Appendix B Table 2: Summary of risk analysis and determination of expected degree of liquefaction-induced ground damage for Omokoroa study area – Type A sub area (primarily stream gullies)

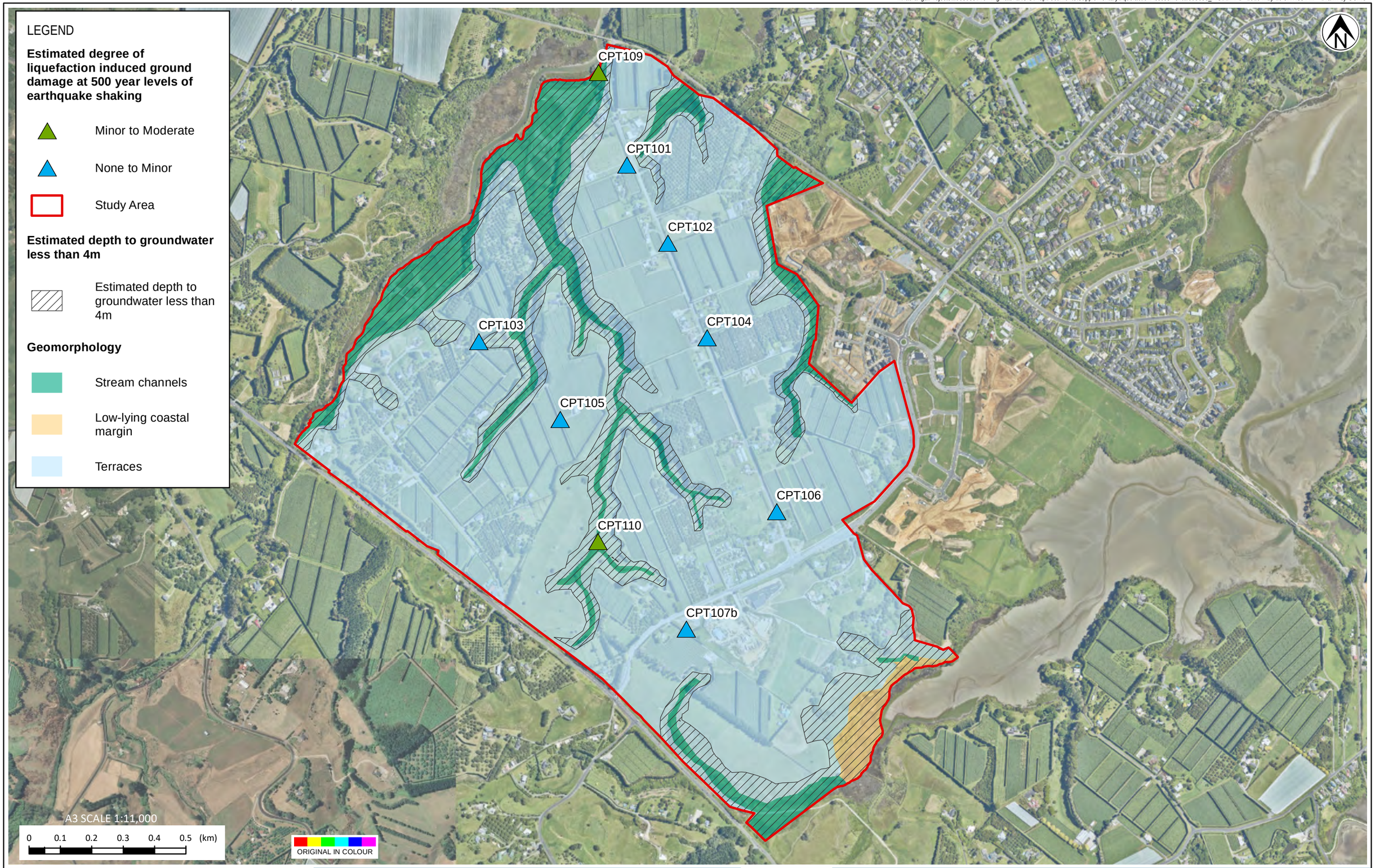
Omokoroa study area – Type A sub area	Liquefaction vulnerability indicators				
	Typical ground conditions	**Non-liquefying crust thickness**	**Topography**	**Assessment of available CPT**	**Determination of expected degree of liquefaction-induced ground damage**
Description	Soil Type: The investigations within this sub area (stream gullies) identified alluvial soils which are considered potentially susceptible to liquefaction based on soil type index (I_c). Soil Age: Typically Holocene age alluvium present within the top ten meters. Likely Pleistocene age and older deposits (e.g. Rotoehu Ash) underlying Holocene material.	Investigations showed groundwater to be less than 4 m from the ground surface, particularly at the invert of any stream channels and other water features. The presence of non-plastic sands and silts that are susceptible to liquefaction combined with a relatively shallow groundwater surface creates the potential for a non-liquefying crust thickness of less than 3 m.	A combination of low-lying flat topography on the coastal margins and steep sloping stream channels. Free faces with the potential to induce lateral spreading are present.	25 year: unlikely to provide sufficient shaking to trigger liquefaction in saturated susceptible soils. Very low liquefaction vulnerability indices calculated for all CPT in this area. 100 year: relatively low levels of shaking with liquefaction only triggered in soils most prone to liquefaction (i.e. loose, clean sandy soils) in thin lenses. PGA response curves indicate that this is at the start of the inflection point. Low liquefaction vulnerability indices are calculated. 500 year: liquefaction triggered in the lenses within the saturated soils. PGA response curves indicate this is towards the end of the inflection point. Calculated liquefaction vulnerability indices range from low to moderate.	25 year: likely none to minor liquefaction related land damage due to low levels of shaking. 100 year: likely none to minor liquefaction related land damage. 500 year: likely minor to moderate liquefaction related land damage.
Assessment of residual uncertainty	The site specific investigations, and consistency with the assumed geological conditions indicate a moderate to low degree of uncertainty. Further ground investigation may reduce uncertainty of the boundary of the sub area.	Groundwater measurements completed have indicated consistency with the original level A assessment. A moderate degree of uncertainty remains in relation to the groundwater fluctuation and spatial variability.	High resolution digital elevation model available means that the topography is well defined and there low residual uncertainty in the spatial distribution of the free faces and steep slopes.	Moderate to low degree of uncertainty due to spatial density of the analysis within this area.	Low to moderate degree residual uncertainty associated with the expected degree of liquefaction-induced ground damage at 100 and 500 year return period levels of earthquake shaking.

Appendix B Table 3: Summary of risk analysis and determination of expected degree of liquefaction-induced ground damage for Omokoroa study area – Type B sub area (terrace areas)

Omokoroa study area – Type B sub area	Liquefaction vulnerability indicators				
	Typical ground conditions	**Non-liquefying crust thickness**	**Topography**	**Assessment of available CPT Analysis**	**Determination of expected degree of liquefaction-induced ground damage**
Description	Soil Type: The investigations within this sub area (stream gullies) identified ash terrace deposit soils which are considered potentially susceptible to liquefaction based on soil type index (I_c) only. Soil Age: The investigations within this sub area determined that the depth to the Rotoehu Ash(>50,000 years old) is typically between 1 and 3 m bgl. The Rotoehu ash is considered to old to be susceptible to liquefaction. Therefore, soils below 1 and 3 m are considered not susceptible to liquefaction.	The median groundwater depth is established as typically greater than 4 m bgl. The depth to groundwater sits within the Rotoehu Ash, or below, which is considered not susceptible to liquefaction.	The majority of the area is either flat or moderately sloping land. There are relatively few free faces with the potential to induce lateral spreading as these are typically confined to the stream channel geomorphology.	25 year, 100 year and 500 year: The analysis in shows that all CPTs within the Type B sub area (8) do not show any liquefaction triggering at all ARI's. This is due to depth to groundwater and soil susceptibility.	25 year: likely none-to-minor liquefaction related land damage. 100 year: likely none-to-minor liquefaction related land damage. 500 year: likely none-to-minor liquefaction related land damage.
Assessment of residual uncertainty	Low residual uncertainty in the spatial distribution (both horizontally and vertically) of soil deposits as all ground investigations showed consistency with the expected conditions.	Low to moderate residual uncertainty. Partial moderate degree due to the number of groundwater records and the potential seasonal variation in groundwater. Further ground investigation at future subdivision development stages would reduce this to low.	High resolution digital elevation model available means that the topography is well defined and there is a low residual uncertainty in the spatial distribution of the topography.	Low residual uncertainty due to the consistency of investigations showing depth to groundwater and depth to the Rotoehu ash layer.	Low residual uncertainty associated with the expected degree of liquefaction-induced ground damage at all year return period levels of earthquake shaking.

COPYRIGHT ON THIS FIGURE IS RESERVED DO NOT SCALE FROM THIS FIGURE - IF IN DOUBT, ASK.

T:\Tauranga\Projects\1008683\WorkingMaterial\GIS\MapDocuments\SupplementaryLiquefactionAssessment\1008683_FIGB1.mxd 2020-May-19 3:47:58 PM Drawn by GUMC



Tonkin+Taylor

Exceptional thinking together www.tonkintaylor.co.nz

1. Basemap sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 4.0 NZ licence.
2. Project specific geotechnical Investigations sourced from the New Zealand Geotechnical Database.
3. The estimated degree of liquefaction induced land damage is based on interpretation of CPT based liquefaction vulnerability parameters. There is significant residual uncertainty associated with CPT based liquefaction vulnerability indicators and the actual liquefaction induced land damage may differ from that indicated in this analysis.

REV	DESCRIPTION	GIS	CHK	DATE
0	First version	MOLI	JORB	18/03/2020

LOCATION PLAN: Tauranga

PROJECT No.	1008683.0000		
DESIGNED	GUMC	MAY.20	
DRAWN	MOLI	MAY.20	
CHECKED	JICR	MAY.20	
APPROVED		26/05/2020	DATE

CLIENT BAY OF PLENTY REGIONAL COUNCIL

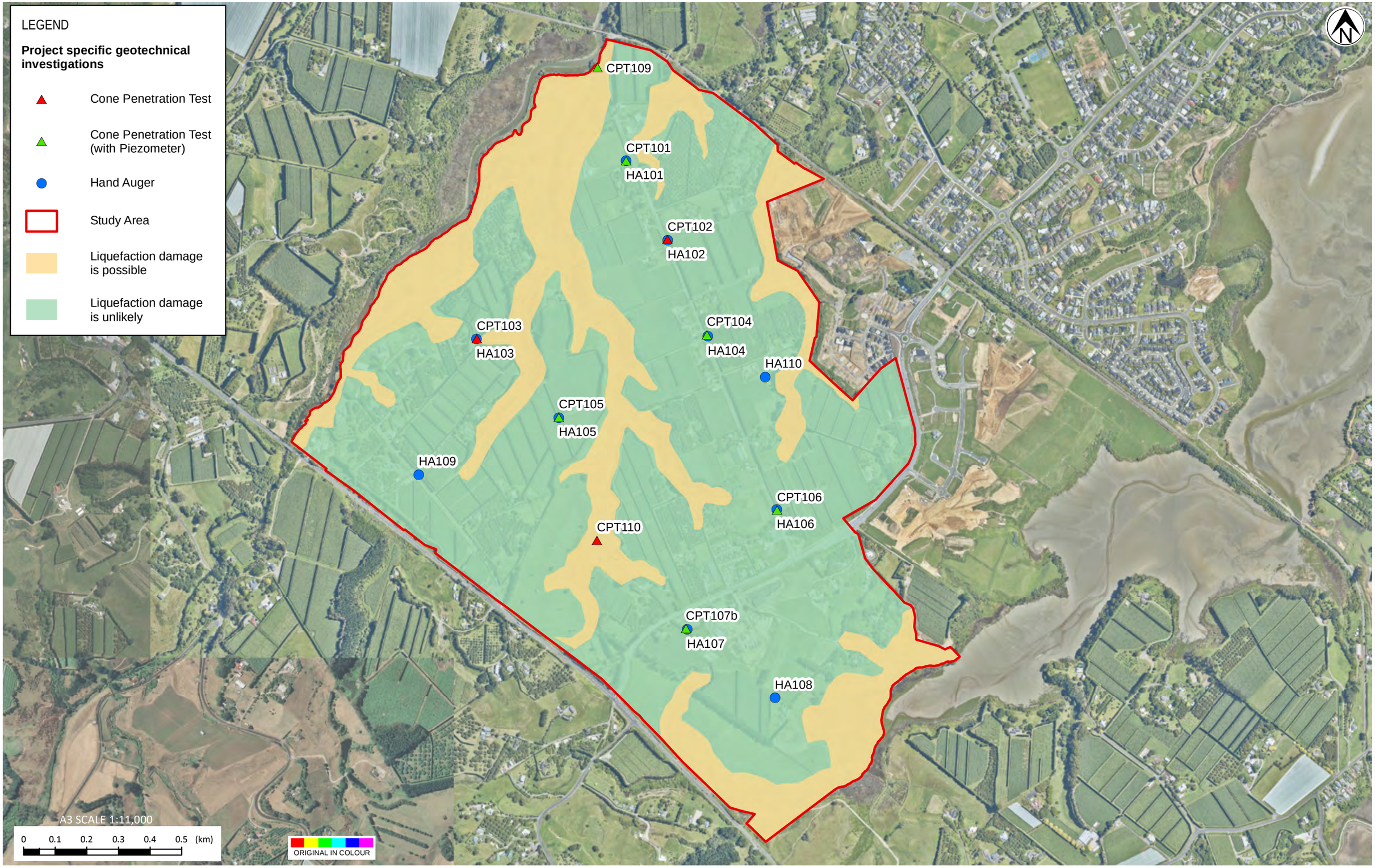
PROJECT OMOKOROA STRUCTURE PLAN STAGE 3

TITLE SUPPLEMENTARY LEVEL B LIQUEFACTION ASSESSMENT - DEGREE OF LIQUEFACTION INDUCED GROUND DAMAGE

SCALE (A3) 1:11,000 FIG No. FIGURE B1 REV 0

COPYRIGHT ON THIS FIGURE IS RESERVED DO NOT SCALE FROM THIS FIGURE - IF IN DOUBT, ASK.

\\ttgroup.local\corporate\Tauranga\Projects\1008683\WorkingMaterial\GIS\MapDocuments\SupplementaryLiquefactionAssessment\1008683_FIGB2.mxd 2020-Apr-01 1:15:57 PM Drawn by GUMC



Tonkin+Taylor

Exceptional thinking together www.tonkintaylor.co.nz

NOTES: Basemap: Sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 4.0 New Zealand licence
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Project specific geotechnical Investigations sourced from the New Zealand Geotechnical Database.

REV	DESCRIPTION	GIS	CHK	DATE
0	First version	MOLI	YYYY	18/03/2020

LOCATION PLAN: Tauranga

PROJECT No.	1008683.0000		
DESIGNED	GUMC	APR.20	
DRAWN	MOLI	APR.20	
CHECKED	JICR	APR.20	
APPROVED		26/05/2020	DATE

CLIENT BAY OF PLENTY REGIONAL COUNCIL
PROJECT OMOKOROA STRUCTURE PLAN STAGE 3
TITLE SUPPLEMENTARY LEVEL B LIQUEFACTION ASSESSMENT - LIQUEFACTION VULNERABILITY MAP
SCALE (A3) 1:11,000 FIG No. FIGURE B2 REV 0

COPYRIGHT ON THIS FIGURE IS RESERVED DO NOT SCALE FROM THIS FIGURE - IF IN DOUBT, ASK.

T:\Tauranga\Projects\1008683\WorkingMaterial\GIS\MapDocuments\SupplementaryLiquefactionAssessment\1008683_FIGB3a.mxd 2020-May-18 2:22:20 PM Drawn by GUMC

LEGEND

Project specific geotechnical investigations

- Cone Penetration Test
- Cone Penetration Test (with Piezometer)
- Hand Auger
- Study Area
- Area of proposed development where liquefaction damage is possible (0.016 km^2)
- Liquefaction damage is possible

Structure Plan

- Active Reserve
- Industrial Land
- Constrained Land*
- Residential Land
- Rural Residential
- Primary and Secondary School
- Retail and Commercial

CPT109
HA101
CPT101
CPT102
HA102
HA103
CPT103
CPT104
HA104
HA110
CPT105
HA105
HA109
HA106
CPT106
CPT110
CPT107b
HA107
HA108

Study Area = 2.8 km²
Area of development (excludes constrained land) = 1.5 km²
Constrained Land*: Inclusive of:
- Slope greater than 1:4 (25%)
- Stormwater ponds, stormwater management reserves & stormwater reserves
- Tsunami evacuation zones - red, orange & yellow
- Partial areas of widespread liquefaction
- Archaeological sites
- Significant ecological features/RAP
- Areas prone to instability
- Landscape feature S8/S8A - Tauranga

A3 SCALE 1:11,000

0 0.1 0.2 0.3 0.4 0.5 (km)

ORIGINAL IN COLOUR

Tonkin+Taylor
Exceptional thinking together www.tonkintaylor.co.nz

NOTES: Basemap: Sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 4.0 New Zealand licence
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Project specific geotechnical Investigations sourced from the New Zealand Geotechnical Database.

REV	DESCRIPTION	GIS	CHK	DATE
0	First version	MOLI	YYYY	18/03/2020

LOCATION PLAN: Tauranga

PROJECT No.	1008683.0000		
DESIGNED	GUMC	MAY.20	
DRAWN	MOLI	MAY.20	
CHECKED	JICR	MAY.20	
APPROVED		26/05/2020	DATE

CLIENT BAY OF PLENTY REGIONAL COUNCIL
PROJECT OMOKOROA STRUCTURE PLAN STAGE 3
TITLE SUPPLEMENTARY LEVEL B LIQUEFACTION ASSESSMENT - LIQUEFACTION VULNERABILITY OVERLAID ON STRUCTURE PLAN

SCALE (A3) 1:11,000 FIG No. FIGURE B3 REV 0

Appendix C: Omokoroa and Katikati Level A liquefaction assessment

REPORT

Tonkin+Taylor

Regional Liquefaction Hazard Study

Katikati and Omokoroa Liquefaction Assessment

Prepared for
Bay of Plenty Regional Council
Prepared by
Tonkin & Taylor Ltd
Date
September 2019
Job Number
1008683

Exceptional thinking together
www.tonkintaylor.co.nz

Document Control

Title: Regional Liquefaction Hazard Study					
Date	**Version**	**Description**	**Prepared by:**	**Reviewed by:**	**Authorised by:**
22/05/19	Draft V1	Draft for comment	VL	JICR	DMMM
20/08/19	Draft V2	Draft for internal review	JICR	MEJ	DMMM
09/09/19	Final V1	Final for issue	JICR	MEJ	DMMM

LIQUEFACTION ASSESSMENT SUMMARY	
This liquefaction assessment has been undertaken in general accordance with the guidance document 'Assessment of Liquefaction-induced Ground Damage to Inform Planning Processes' published by the Ministry of Business, Innovation and Employment in 2017. https://www.building.govt.nz/building-code-compliance/geotechnical-education	
Client	Bay of Plenty Regional Council (BOPRC)
Assessment undertaken by	Tonkin & Taylor Ltd. PO Box 5271 Wellesley Street Auckland 1141
Extent of the study area	• Approximately 302 ha across two sites in Omokoroa and Katikati in the Western Bay of Plenty District (refer to Figure 1.1)
Intended RMA planning and consenting purposes	• Information to support land use plan application change
Other intended purposes	• Input to a risk assessment in accordance with the BOPRC Regional Policy Statement
Level of detail	• Level A (desktop assessment)
Notes regarding base information	• This assessment includes consideration of geotechnical investigations available that were within the study extent and land adjacent to the study extent on the NZ Geotechnical Database as at 6 May 2019. • The mapped depth to groundwater was developed from point measurements of groundwater levels and with engineering judgement. It is only intended to be used as a high level screening tool and should not be used for other purposes without T+T's express consent.
Other notes	• The assessment is not suitable for other purposes (e.g. for appending to Land Information Memorandum reports or detailed design).

Distribution:

Bay of Plenty Regional Council	1 electronic copy
Tonkin & Taylor Ltd (FILE)	1 electronic copy

Table of contents

1 Introduction

Tonkin & Taylor Ltd (T+T) was engaged by Bay of Plenty Regional Council (BOPRC) to undertake liquefaction risk assessments for the Omokoroa Stage 3 Structure Plan Area and the Katikati Urban Growth Area (Beach Road). These risk assessments have been undertaken in a two-step process as follows:

1 A high level assessment of the risk of liquefaction related damage occurring at each of the two sites. This has been undertaken in accordance with the MBIE/MfE (2017) *Planning and engineering guidance for potentially liquefaction prone land* (the MBIE/MfE Guidelines (2017)). Note this has been undertaken to a Level A level of detail as described in Section 3.2 of the MBIE/MfE Guidelines (2017).

2 A qualitative assessment of the risk of damage to buildings and lifeline infrastructure from liquefaction related land damage. This has been undertaken in accordance with Appendix L of the Bay of Plenty Regional Council's (BOPRC) Regional Policy Statement (RPS) (BOPRC, 2014). Note the results of the first step are used as an input to this second step.

The two sites have been identified as potential future urban growth areas by Western Bay of Plenty District Council (WBOPDC) and they wish to take these sites through the land use plan change process. The purpose of this study is to provide BOPRC and WBOPDC with information about the liquefaction vulnerability of the two sites to inform the land use plan changes that are proposed.

This report is structured as follows:

- Section 1 provides an introduction to this study and a brief description of each site.
- Section 2 provides contextual information about liquefaction hazard, the intended purposes and scope of works and summarises the previous information about liquefaction hazard that is available for each site.
- Section 3 outlines the MBIE/MfE risk identification process including definition of the target level of detail for the study, the base information available and the level of detail supported by that base information.
- Section 4 summarises the MBIE/MfE risk analysis process applied to each study area including the definition of sub areas of similar expected performance, groundwater levels and earthquake scenarios considered, the determination of the expected degree of liquefaction induced damage and the categorisation of liquefaction vulnerability within each site in accordance with the MBIE/MfE Guidelines (2017).
- Section 5 summarises the risk assessment undertaken for the buildings and lifeline infrastructure undertaken in accordance with Appendix L of the RPS (BOPRC, 2014).
- Section 6 presents the conclusions and recommendations from both the MBIE/MfE and RPS risk assessments that are outlined in this report.

1.1 Site description

The Omokoroa Stage 3 Structure Plan Area (Omokoroa Study Area) is located approximately 13 km west of Tauranga City and covers approximately 277 ha. The Katikati Urban Growth Area (Katikati Study Area) is located approximately 25 km North West of Tauranga and covers approximately 25 ha. The location and extent of these two areas is shown in Figure 1.1.

Figure 1.1: Map showing the Omokoroa Stage 3 Structure Plan Area (southeast) and the Katikati Urban Growth Area (northwest)

The Omokoroa Peninsula extends into Tauranga Harbour and is bounded in some locations by coastal cliffs. Urban development is currently focused in the north of the Peninsula however WBOPDC propose to increase urban development southwards. The Omokoroa study area is at the southern end of the Omokoroa Peninsula between the Waipapa River and Mangawhai Bay and is currently used for agricultural purposes and lifestyle blocks.

Katikati is a small township in the Bay of Plenty approximately 25 km northwest of Tauranga. The study area is located east of the town along Beach Road. The Katikati study area is in the middle of the Katikati Peninsula and is currently being used predominantly for agricultural purposes.

2 Context

2.1 Liquefaction hazard

Liquefaction is a natural process where earthquake shaking increases the water pressure in the ground in some types of soil, resulting in temporary loss of soil strength. Figure 2.1 summarises the process of liquefaction with a schematic representation. For a more detailed explanation of the liquefaction process, refer to the MBIE/MfE Guidelines (2017).

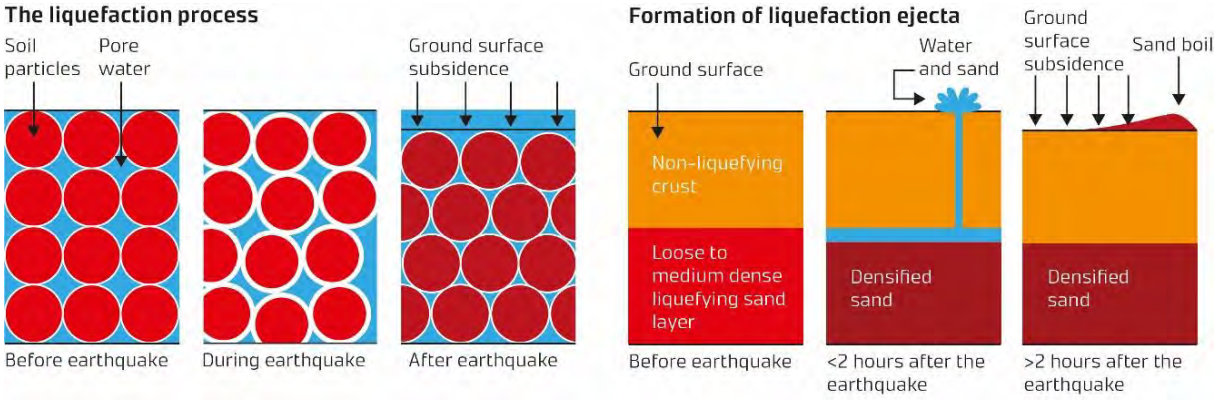


Figure 2.1 Schematic representation of the process of liquefaction and the manifestation of liquefaction ejecta

Liquefaction can give rise to significant land and building damage through, for example, the ejection of sediment to the ground surface, differential settlement of the ground due to volume loss in liquefied soil and lateral movement of the ground (known as lateral spreading). These effects are schematically presented in Figure 2.2.

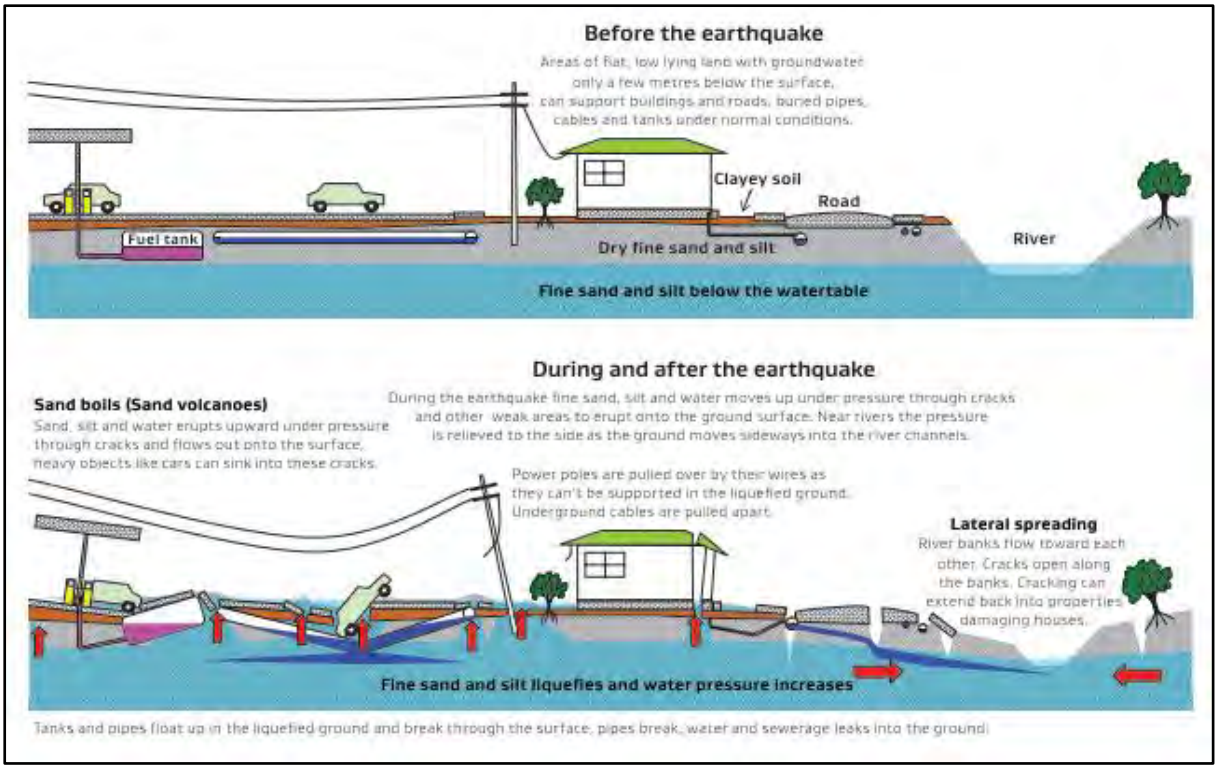


Figure 2.2: Visual schematic of the consequences of liquefaction (reproduced from the MBIE/MfE Guidelines (2017)).

These consequences (summarised in Table A.1 in Appendix A) can have severe impacts that range from land damage through to social disruption as seen in the 2010-2011 Canterbury Earthquake Sequence (CES).

The analysis undertaken for this study took into account how the severity of these consequences at any particular location can vary depending on a range of factors, such as:

- **Strength of earthquake shaking.** Stronger shaking can mean that greater thickness of the soil profile liquefies, resulting in more severe consequences.
- **Depth to groundwater.** Soil can only liquefy if it is below the groundwater table, so deeper groundwater can mean there is a thicker surface "crust" of non-liquefied soil at the ground surface that helps to reduce the consequences from liquefaction below.
- **Layering of the soil profile.** The way in which a soil was deposited (e.g. by a river, an estuary, or the sea) can influence how the soil profile is layered. If there are thick continuous layers of liquefied soil then this can have more severe consequences than if there are thinner isolated layers of liquefied soil interbedded between layers of non-liquefied soil.

2.2 Intended purposes and scope of works

The purpose of this study is to provide BOPRC and WBOPDC with information about the liquefaction vulnerability of two future urban growth sites in Katikati and Omokoroa to inform the land use plan changes that are proposed for each site.

The scope of this project can be summarised as:

1 Collation and review available data that is relevant to this study including:
   - Geological and geomorphological maps;
   - Ground surface elevation levels for the extent of the study area;
   - Geotechnical data that is currently available on the New Zealand Geotechnical Database (NZGD)[1];
   - Groundwater level information for the study extent; and
   - Seismic hazard information.

2 Assessment of the risk of liquefaction related land damage within the study extents in accordance with the MBIE/MfE Guidelines (2017) to a Level A level of detail.

3 A qualitative risk assessment for buildings and lifeline infrastructure in accordance with Appendix L of the RPS.

4 Presentation of a report summarising the methodology and results of this study including the preparation of maps to support the liquefaction hazard assessment.

[1] Retrieved from: https://www.nzgd.org.nz/

2.3 Previous information about liquefaction in Katikati and Omokoroa

Table 2.1 lists previous studies and reports that include information about liquefaction relevant to the two study areas.

Table 2.1: Previous studies and reports that include information about liquefaction relevant to the two study areas

Title	Author(s)	Published date	Relevant study area
Microzoning for Earthquake Hazards for the Western Bay of Plenty	Opus International Consultants	December 2002	Both
Katikati Wastewater Treatment Plant, Geotechnical Investigation and Assessment of Differential Settlement and Liquefaction	Tonkin + Taylor	June 2014	Katikati
Geotechnical Completion Report – Stage 1A Kaimai Views Subdivision, 336, 340 & 344 Omokoroa Road, Omokoroa	CMW Geosciences	December 2017	Omokoroa
Geotechnical Completion Report – Stage 1, 423 Omokoroa Road, Omokoroa	S&L Consultants	April 2018	Omokoroa
Preliminary Geotechnical Investigation Report – 452 Omokoroa Road, Omokoroa	CMW Consultants	August 2018	Omokoroa
Geotechnical Completion Report – Stage 1C of the Harbour Ridge Subdivision at 351 Omokoroa Road, Omokoroa	Terrane Geotechnical Solutions	September 2018	Omokoroa

Figures A1 and A5 in Appendix A show the mapped results of the Opus 2002 study and the approximate extents of the land area covered by each of the geotechnical reports described in Table 2.1.

The Opus (2002) study used available geological, topographic, ground investigation and seismic hazard information to categorise land into different categories that define both the liquefaction damage and lateral spread damage. Table 2.2 provides the liquefaction and lateral spread damage categories for each study area as assessed in the Opus (2002) study. In summary that study identified the potential for liquefaction related land damage to occur to varying degrees in both study areas.

Table 2.2: Liquefaction and lateral spread damage categories for each study area as assessed in the Opus (2002) study

Study area	Liquefaction damage categorisations identified within study area	Lateral spread damage categorisation
Omokoroa Stage 3 Structure Plan Area	Variable across the study area including categorisations of Localised, Minor and Widespread Liquefaction	Major and Extensive Lateral Spreading identified in areas that are in close proximity to water features
Katikati Urban Growth Area	Minor Liquefaction across the entire study area	Lateral spread not identified within the study area

There have been considerable advances in liquefaction science since publication of the Opus (2002) study. Furthermore, the framework applied and the presentation of the results of the Opus (2002) study are not consistent with the recommendations in the MBIE/MfE Guidelines (2017).

Each of the four geotechnical reports listed in Table 2.2 that are relevant to the Omokoroa study area detail geotechnical investigations and assessments that have been undertaken for either completed or proposed residential developments. Each report covers a site positioned on elevated land (i.e. above approx. 20 m RL (NZVD 2016)) within or adjacent to the Omokoroa study area. In summary each of the reports assess the liquefaction potential of each site as low due to either:

- The relatively significant depth to the groundwater table; and/or
- The relatively old age of the soils present at the sites; and/or
- The cohesive nature of the soils; and/or
- Some combination of each of these three factors.

Each of the four geotechnical reports listed in Table 2.1 that are relevant to the Omokoroa study area describe a typical soil stratigraphy as follows:

- Topsoil typically from 0.2 to 0.5m thick.
- Weathered volcanic ash deposits typically from 4.0 to 5.0m thick compromising interbedded stiff clays, and pumiceous silts and sands. These ash deposits include the Rotoehu Ash that is approximately 50,000 years old which is underlain by the older Hamilton Ash.
- Matua Subgroup comprising clays and sandy silts is typically encountered from approximately 5.0m depth.

The T+T geotechnical report that is relevant to the Katikati study area details geotechnical investigations and an assessment of liquefaction and lateral spreading vulnerability of the wastewater treatment ponds at the plant. The report covers a site that is located on relatively low lying land (i.e. approx. 2-4m RL (NZVD 2016)) approximately 500m to the south of the Katikati study area. The report concludes the following with respect to liquefaction related damage:

"Our liquefaction assessment shows the risk of damage to the site to be minor under a SLS event seismic event. However, under a ULS seismic event differential settlement and lateral spreading of the embankments is considered likely."

3 MBIE/MfE risk identification process

3.1 Level of detail required for intended purposes

The primary purpose of this assessment is to provide information to support a land use plan change for each study area. T+T understands that the proposed density of dwellings for both study areas is likely to be consistent with an "urban residential development" as described in the MBIE/MfE Guidelines (2017) (i.e. typically 15 - 60 households per Ha). Table 3.5 of the MBIE/MfE Guidelines (2017) recommends the following minimum level of detail to support a plan change:

- Level A for land categorised as Very Low liquefaction vulnerability category; or
- Level B for land categorised as Low, Medium or High liquefaction vulnerability category.

3.2 Base information currently available

3.2.1 Ground surface levels

The ground surface levels of the study areas are well characterised by LIDAR derived Digital Elevation Model (DEM). Table 3.1 provides information about the most recent LiDAR data acquisition relevant to this work. Maps showing the ground surface elevation for the two study areas are presented in Figures A1 and A5 in Appendix A.

Table 3.1: Recent LiDAR data acquisitions for the study areas

Commissioning agency	Year of acquisition	Acquisition by	DEM resolution (m)	Coverage of study area
Bay of Plenty Local Area Shared Services	2015	Aerial surveys	1.0	Entire

Note that this ground surface information provides sufficient detail to progress this liquefaction assessment for this basic desktop assessment. However for later stages of development (e.g. sub-division and building consenting) proposed finished ground surface levels will need to be considered.

Elevation within the Omokoroa study area varies from approximately 2.5 to 60 m RL although the majority of the site is at elevations above 15 m RL. A map showing the elevation over the Omokoroa study area is included in Figure A2 in Appendix A.

The typical elevation of the Katikati study area from 5 to 6 m RL and is predominantly flat. In the north of the site there is a pond at lower elevations that encompasses an area of approximately 5ha. A map showing the elevation over the Omokoroa peninsula is included in Figure A6 in Appendix A.

3.2.2 Geology and geomorphology

The published geological maps that cover the two study areas are listed in Table 3.2.

Table 3.2: Published geological maps of the region

Title	Authors	Published date	Scale
Geology of the Rotorua Area (QMAP)	Leonard, Begg & Wilson (compilers)	2010	1:250,000
Geology of the Auckland Area (QMAP)	Edbrooke (compiler)	2001	1:250,000
Geology of the Tauranga Area	Briggs et al	1996	1:50,000

Leonard, Begg & Wilson (2010) & Briggs et al (1996) indicate that the Omokoroa study area predominantly is underlain by the Matua Subgroup of Pleistocene Age. Younger Holocene-aged sands and silts are located to the northeast and west of the study area as are younger river deposits. In addition to these deposits, a lobe of crystal-rich ignimbrite known as the Waitearikl Ignimbrite, which is of Pliocene age, is located to the south west of the study area along stream valleys and coastal margins. The two maps vary in the distribution and extent of the mapped deposits within the study area however the descriptions of each unit are generally consistent. Figure 3.1 shows the Omokoroa study area overlain on the Briggs et al (1996) geological map.

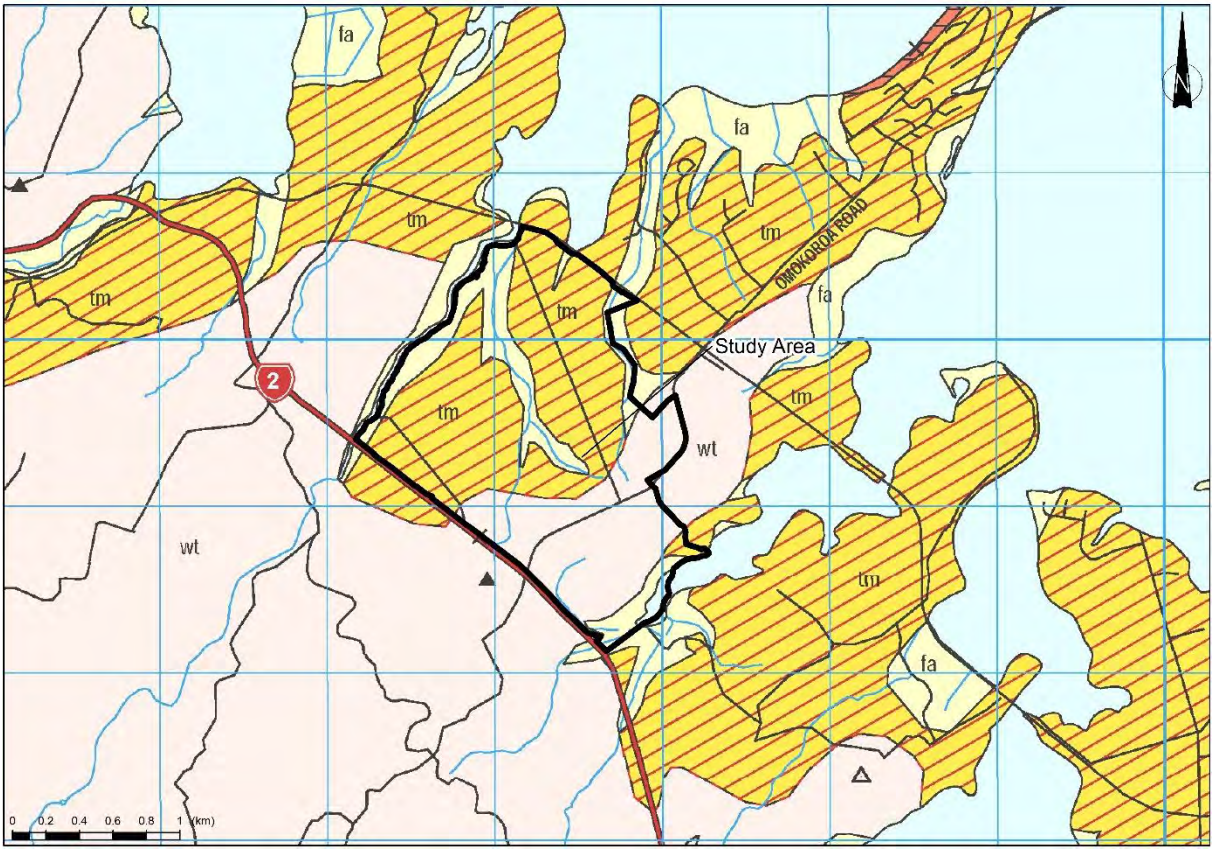


Figure 3.1: Omokoroa study area overlain on the Briggs et al (1996) geological map

The three units mapped within the study area (as shown in Figure 3.1) are described as follows:

- Sand, silt and gravel of modern streams (fa), Holocene Age.
- Fluvial terrace deposits post-dating the Waitearikl Ignimbrite: Matua Subgroup fluvialtile sands and gravels, lignites, estuarine sands, lacustrine silts; Pahoia Tephras (tm), Pleistocene Age.
- Grey to dark brown, non-welded to densely welded and lenticulitic, crystal-rich ignimbrite, with dark grey lenticular pumice and lithics of rhyolite and andesite (wt), Pliocene Age.

Edbrooke (2001) indicates that the Katikati study area is also underlain by fluvial terrace deposits. These deposits comprise fluvial sands and gravels, tephra and estuarine sands of the Matua Subgroup (unit mQm), dating back to the late Pleistocene era. Figure 3.2 shows the approximate location of the Katikati study area overlain on the Edbrooke (2001) geological map. Note the Holocene Age deposit (Q1a) to the north is not mapped in the Katikati study area on the Edbrooke (2001) geological map.

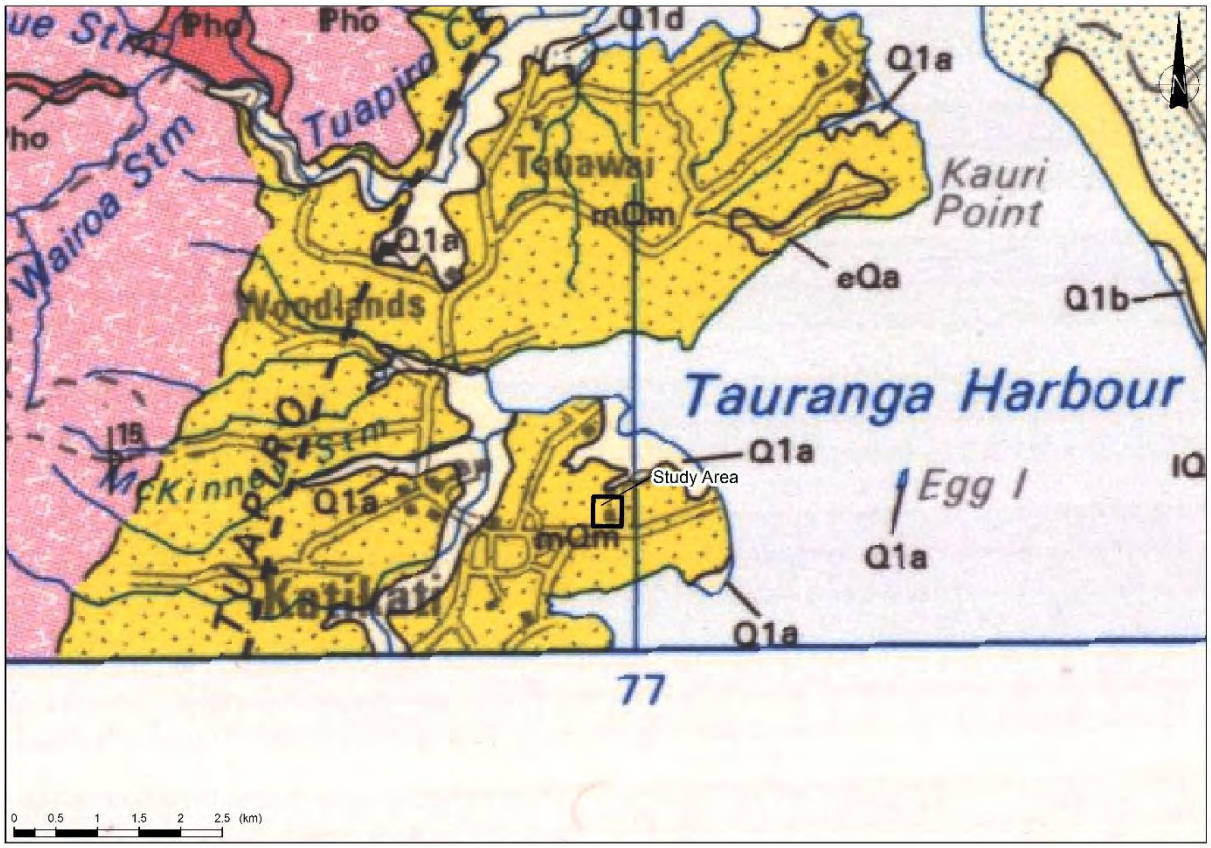


Figure 3.2: Katikati study area overlain on the Edbrooke (2001) geological map

Based on the information presented in Section 2.3 and field experience in the area, we note that a volcanic ash layer known as the Rotoehu Ash, which is dated at more than 50,000 years old, is likely to be present at relatively shallow depths in large parts of the Omokoroa study area.

For the purposes of this study, geomorphological mapping was undertaken at both sites to understand the nature of the landscape. Figures A3 and A6 in Appendix A show the show the results and Table 3.3 describes the three geomorphic features identified across the site.

Table 3.3: Geomorphologies mapped within each study area

Geomorphology	Description
Stream channels	Geomorphology predominantly influenced by fluvial processes associated with modern streams and other water features. Typically coincident with mapped Holocene age deposits.
Low lying coastal margins	Geomorphology predominantly influenced by coastal processes at elevations below 5m RL. Typically coincident with mapped Holocene age deposits.
Terraces	Geomorphology predominantly influenced by the erosion of fluvial deposits. Typically coincident with mapped Pleistocene age (and older) deposits.

The Omokoroa Study Area mainly comprises terraces with some stream channels and a small area of low lying coastal margins. The stream channels represent low points and areas in which groundwater is likely to be shallow. The Katikati Study Area also mainly comprises terraces, with a small area of stream channels to the northwest of the site.

3.2.3 Geotechnical investigations

Existing publicly available geotechnical investigation data from the New Zealand Geotechnical Database (NZGD) has been considered for this study. The locations of the investigations available on the NZGD are presented in Figures A1, A2, A3, A5, A6 and A7 in Appendix A.

The only geotechnical investigation data available on the NZGD within the Omokoroa study area consists of four Cone Penetration Tests (CPT) that are located on elevated land. However, there are also three CPT and two Boreholes on low lying land adjacent to the northern boundary.

WBOPDC also provided T+T with four site specific geotechnical reports within or adjacent to the Omokoroa study area. Each of the reports includes information about the geotechnical investigations associated with these reports, however T+T has not been provided with copies of digital records of any CPT investigations and these are not currently available on the NZGD. Table 3.4 lists the geotechnical investigations available from each of these data sources. Refer to Section 2.3 for further information about the contents of each report.

Table 3.4: Geotechnical investigations within and adjacent to the Omokoroa Study Area

Source	Cone Penetration Test (CPT)	Borehole (BH)	Hand Auger (HA)
New Zealand Geotechnical Database (NZGD)	7	2	0
Geotechnical Completion Report – Stage 1A Kaimai Views Subdivision, 336, 340 & 344 Omokoroa Road, Omokoroa	18	0	14
Geotechnical Completion Report – Stage 1, 423 Omokoroa Road, Omokoroa	0	0	27[1]
Preliminary Geotechnical Investigation Report – 452 Omokoroa Road, Omokoroa	0	0	9
Geotechnical Completion Report – Stage 1C of the Harbour Ridge Subdivision at 351 Omokoroa Road, Omokoroa	6	0	15

[1] The excavation method was a 150mm diameter machine open flight auger

There are currently no geotechnical investigations on the NZGD within or immediately adjacent to the Katikati study area and T+T is not aware of any geotechnical reports within or immediately adjacent to the Katikati study area. The nearest geotechnical investigations on the NZGD consist of two machine boreholes and eight CPT that were undertaken within the property boundary of the Katikati Wastewater Treatment Plant approximately 500 m to the south of the study area. These investigations were utilised in the T+T geotechnical report described in Section 2.3.

3.2.4 Groundwater

An indicative groundwater surface level was created for the purpose of undertaking the high-level liquefaction assessment. The groundwater surface can be used in conjunction with the LiDAR DEM as a rough indication of the depth to groundwater (i.e. the depth the groundwater level is below the ground surface) in the study areas.

The data used to create the groundwater surface levels was sourced from BOPRC[2] and from T+T's database of ground investigation data in the local areas of Katikati and Omokoroa. Depth to groundwater data was reported based on measurements taken at the time of drilling. Unfortunately,

[2] Retrieved from: https://data-boprc.opendata.arcgis.com/datasets/well-bore-locations-in-the-bay-of-plenty

scarce data exists within close proximity to the study areas. Mean sea level was also used as an input to the models.

A geostatistical model of groundwater levels was derived from the BOPRC and T+T groundwater observations. Due to the scarcity of the data, additional data points were estimated using the observed linear relationships between the groundwater level surface and the elevation at each of the monitoring well. The groundwater surface level for both study areas (Figures A3 and A7 in Appendix A) was then estimated at a 10 m resolution using the Kriging method, which integrates both the geostatistical model and the observed (and inferred) data points.

A qualitative assessment of the depth to groundwater for both study areas was undertaken for the purpose of the liquefaction assessment (Figures A4 and A8 in Appendix A). The assessment categorised the depth to groundwater into areas where the groundwater was likely to be shallower than 4m and areas where the depth to groundwater was likely to be deeper than 4 m. This assessment was developed from consideration of the following:

- The geomorphology of the study area such that the depth to groundwater is likely to be shallower in the stream channels and coastal margins and deeper in the terraces.
- Observed groundwater surface levels as described in geotechnical reports provided by WBOPDC (refer to Section 2.3).
- The groundwater surface levels derived in accordance with the modelling methodology described.

It is important when assessing liquefaction vulnerability to consider the potential for future elevated groundwater levels due to the effects of sea level rise, particularly in areas that are at lower elevations and in close proximity to the coast.

Elevation within the Omokoroa study area varies from 5 m to 60 m above sea level. The low-lying areas within the Omokoroa study area are likely to be impacted by a future increase in sea level but the areas of higher elevation are very unlikely to the impacted by a future increase in sea level. Therefore, the impact of sea level rise on liquefaction vulnerability only needs to be considered for areas of lower elevation. To indicate the areas that are most likely to be sensitive to future increases in sea level rise a dashed line has been drawn along the 5m RL contour line on Figure A4 in Appendix A.

The Katikati study area is relatively flat and low-lying (typically 5 m to 6 m above sea level). Therefore, the groundwater table in the area is likely to be impacted by a future increase in sea level and sensitivity to groundwater rise should be considered across the entire site.

3.2.5 Regional seismicity

The seismic subsoil class in accordance with NZS 1170.5:2004 (Section 3.1.3) for the sites is considered to be 'Class D – Deep or Soft Soil Sites' due to the likely large depth to bedrock. Further investigations and assessment of subsoil class (e.g. deep borehole or microtremor testing) are unlikely to modify the conclusion of Class D.

In accordance with the natural hazard provisions of the BOPRC RPS, the liquefaction hazard for the study areas should be examined at 4.0%, 1.0%, 0.2%, 0.1%, 0.04% and 0.033% annual exceedance probabilities (AEP). These AEP correspond to 25, 100, 500, 1,000, 2,500 and 3,030 year ARI levels of earthquake shaking respectively. The MBIE/MfE Guidelines (2017) recommend considering a range of ARI levels of earthquake shaking which is discussed further in Section 4.3 of this report.

The seismic shaking hazard in terms of peak ground acceleration (PGA) and magnitude (M_{eff}) for the area has been assessed based on the NZTA Bridge Manual. Table 3.5 presents the return periods,

PGAs and corresponding earthquake magnitudes. The PGAs were determined using building importance level 2 (single storey family residential dwelling)[3] given the expected use of the land.

Table 3.5: Ground seismic hazard

BOPRC RPS AEP (%)	ARI (years)	PGA (g)	Magnitude (M_{eff})
4.0	25	0.07	5.9
1.0	100	0.13	5.9
0.2	500	0.26	5.9
0.1	1,000	0.34	5.9
0.04	2,500	0.47	5.9
0.033	3,030	0.52	5.9

Note:

PGA and M_{eff} has been assessed based on the Bridge Manual SP/M/022 Third Edition for the following:

Building design life	50 years
Building importance level	2 (NZS 1170.0:2004, Table 3.2) – single family residential dwellings
Return period factor, Ru	0.25 for 25yr; 0.5 for 100 yr; 1.0 for 500yr; 1.3 for 1000yr; 1.8 for 2500yr return period (NZS 1170.5:2004, Table 3.5)
Subsoil class	D (Deep soil).
Return period PGA coefficient, $C_{0,1000}$	0.34 (Bridge Manual Commentary Table C6.1)
Site subsoil class factor, f	1.0 (Bridge Manual Section 6.2)
PGA	$C_{0,1000}$ x Ru/1.3 x f x g (Bridge Manual Section 6.2)
Effective Magnitude, M_{eff}	5.9 (Bridge Manual Commentary Table C6.1)

3.2.6 Historical observations of liquefaction

A literature review of historic earthquake studies indicated that there are no recorded observations of liquefaction related land damage in either the Omokoroa or Katikati study areas. Ogden (2017) provides an overview of land damage observations from the 1987 M_W 6.5 Edgecumbe earthquake. This shows that observations of liquefaction related land damage were limited to the land within and proximal to Edgecumbe and Whakatane.

3.3 Level of detail supported by currently available base information

The currently available base information supports a Level A (basic desktop) level of detail assessment. To support a Level B (calibrated desktop) level of detail assessment the following additional information would need to be collected and analysed:

- Geotechnical investigation data in accordance with the recommendations of the MBIE/MfE Guidelines (2017); and
- Site specific groundwater monitoring of sufficient length of record to confirm seasonal variability in groundwater across the site (at least one calendar year).

[3] Standards New Zealand, 2004. "NZS1170.5:2004 Structural Design Actions Part 5: Earthquake actions - New Zealand". Standards New Zealand. Retrieved from https://www.standards.govt.nz/

4 MBIE/MfE risk analysis process

4.1 Definition of sub areas

Due to the limited amount of geotechnical investigations available for both study areas, the screening criteria provided in the MBIE/MfE Guidelines (2017) have been applied to define areas that are likely to perform similarly under earthquake loading.

First, consideration was given to the potential for "free field" liquefaction related land damage. Table 4.3 in the MBIE/MfE Guidelines (2017) provides guidance for this and the relevant screening criteria are repeated in here in Table 4.1.

Table 4.1: Screening criteria for identifying land where liquefaction-induced ground surface damage is unlikely (refer to Table 4.3 in the MBIE/MfE Guidelines (2017))

Type of soil deposit	Depth to groundwater[4]
Late Holocene age (current river channels and their historical floodplains, marshes and estuaries, reclamation fills)	More than 8 m
Holocene age (Less than 11,000 years old)	More than 6 m
Latest Pleistocene age (Between 11,000 and 15,000 years old)	More than 4 m

Second consideration was given to the potential for lateral spreading. The MBIE/MfE Guidelines (2017) provide the following recommendations with respect to lateral spreading:

"…particular attention should be given to liquefaction-susceptible land that is within 200 m of a free-face greater than 2m high; or within 100 m of a free face less than 2 m high."

Using the base information presented in Section 3.2 of this report and the screening criteria described above, the conditions described in Table 4.2 were developed to define sub areas of similar expected performance.

Table 4.2: Characteristics used to define sub areas expected to have similar levels of performance

Characteristic	Type A sub area	Type B sub area
Age of soil deposit	Holocene age (e.g. stream valleys and estuarine deposits); or	Pleistocene age or older; and
Depth to groundwater	Less than 4 m; or	Greater than 4 m; and
Lateral spreading controls	Relatively steep land with free faces present.	Relatively flat land and free faces are absent.

Note that in order to be categorised as Type A, only one of the characteristics needs to be present, however to be categorised as Type B all three of the characteristics need to be present.

Only the area identified as Terrace geomorphology (refer to Figure A3 in Appendix A) in the Omokoroa study area can be defined as a Type B sub area. The remaining areas of the Omokoroa study area and all of the Katikati study area are defined as Type A sub areas.

[4] A high groundwater scenario should be assumed (e.g. a typical seasonal high groundwater level).

4.2 Groundwater levels for analysis

The model of groundwater levels developed for this study is described in Section 3.2.4. The accuracy of the modelled groundwater levels is such that this has been simplified to a qualitative representation of depth to groundwater for use in the screening criteria described above. However, depth to groundwater is a key input parameter for liquefaction analysis using CPT data and therefore specific groundwater levels have been assumed for the CPT-based liquefaction analysis. Table 4.3 provides the groundwater level assumed for each sub area and provides discussion about the relevance of this assumption.

Table 4.3: Groundwater level assumed for each sub area

Sub area	Groundwater depth assumed	Discussion
Type A	1 m	1 m depth to groundwater is considered to be representative of an average or typical groundwater condition although the actual groundwater could be shallower or deeper.
Type B	4 m	4 m depth to groundwater is considered to be a representative of a conservative depth to groundwater for the purposes of liquefaction assessment. However, in most Type B areas the actual depth to groundwater is likely to be deeper than this (as described in Section 2.3). This conservative assumption has been used for Type B areas to test the applicability of the screening criteria relative to the soil conditions as measured by the available CPT data.

4.3 Earthquake scenarios

In Section 4.3.2, the MBIE/MfE Guidelines (2017) recommends considering the ground damage response for a range of different return periods. This is because, as stated in the MBIE/MfE Guidelines (2017), *"…the relationship between the intensity of earthquake shaking and the severity of liquefaction-induced ground damage can be highly non-linear."* This non-linear response is illustrated with the example conceptual response curve shown in Figure 4.1.

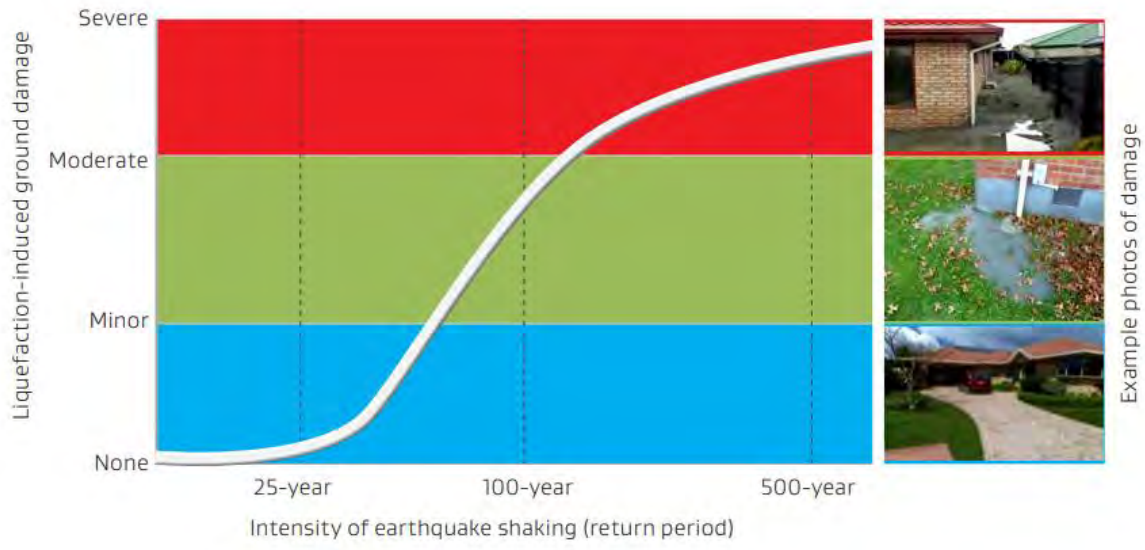


Figure 4.1: Example conceptual response curve showing the degree of liquefaction-induced ground damage at different strengths of earthquake shaking – reproduced from Figure 4.1 of the MBIE/MfE Guidelines (2017)

Table 4.2 of the MBIE/MfE Guidelines (2017) presents the recommended minimum earthquake scenarios for liquefaction assessment for each level of detail. This table is reproduced in Figure 4.2 and shows that the recommended minimum for both Level A and Level B studies is a 500-year return period.

LEVEL OF DETAIL IN THE LIQUEFACTION ASSESSMENT	RECOMMENDED MINIMUM EARTHQUAKE SCENARIOS
Level A Basic desktop assessment	500-year return period (0.2 percent AEP)
Level B Calibrated desktop assessment	
Level C Detailed area-wide assessment	100-year return period (1 percent AEP), and 500-year return period (0.2 percent AEP)
Level D Site-specific assessment	

Figure 4.2: Recommended minimum earthquake scenarios for liquefaction assessment – reproduced from Table 4.2 of the MBIE/MfE Guidelines (2017)

For this MBIE/MfE risk analysis T+T has considered the ground damage response for a range of different return periods and has estimated the expected degree of land damage for the 25, 100 and 500 year ARI levels of earthquake shaking (refer to Table 3.5 of this report for the PGAs and corresponding earthquake magnitudes).

4.4 Determination of expected degree of liquefaction-induced ground damage

In order to determine the expected degree of liquefaction-induced ground damage for each sub area it is necessary to evaluate liquefaction vulnerability indicators available. The liquefaction vulnerability indicators which have been evaluated for the purposes of this risk analysis are summarised in Table 4.4.

Table 4.4: Liquefaction vulnerability indicators considered in this assessment

Vulnerability indicator	Comments and observations from past events
Ground conditions	Using a combination of the mapped geology and geomorphology along with the available geotechnical investigations the following characteristics and their influence on liquefaction vulnerability can be evaluated: • Soil type – loose, granular non-plastic soils such as sands, gravels and non-plastic silts are considered susceptible to liquefaction (i.e. have the potential to liquefy at a given level of earthquake shaking). Whereas plastic, fine-grained soils are considered not-susceptible to liquefaction (i.e. they will not liquefy under any level of earthquake shaking). • Soil age – empirical observations indicate that liquefaction occurs more commonly in younger (e.g. Holocene age) soil deposits than older (e.g. Pleistocene age and older) soil deposits.
Non-liquefying crust thickness	Observations from Christchurch and Japan indicate that the greater the thickness of the non-liquefying crust the less damage is likely to be reflected at the ground surface. Examples of sand boils and damaging differential settlement are very few for sites with a non-liquefying crust thickness greater than 3 m (Ishihara, 1985). The thickness of the non-liquefying crust is a function of the depth to

	groundwater and whether or not the soils that the crust is comprised of are susceptible to liquefaction.
Topography	Observations from previous earthquakes indicate that severe damage to ground, buildings, infrastructure and the environment can be caused by lateral spreading. The presence of free-faces and/or sloping ground is a key lateral spreading vulnerability indicator. Higher free faces and more sloping ground indicates a greater likelihood of lateral spreading related land damage.
CPT-based liquefaction analyses	Summary outputs of CPT-based liquefaction analyses for the relevant CPT available on the NZGD (Section 3.2.3) are presented in Appendix B[5]. While there aren't sufficient CPT investigations available to undertake a Level B (quantitative desktop assessment), analysis of the CPT that are available can provide an indication of the potential land performance. In particular consideration of the following outputs is of use: • Qc and Ic vs. depth plots • Liquefaction triggering vs. depth plots • Interpretation of calculated liquefaction vulnerability indices including PGA response curves

Tables B2, B3 and B4 in Appendix B present the risk analysis for each of the liquefaction vulnerability indicators described in Table 4.4 and determination of expected degree of liquefaction-induced ground damage for each study area and the associated sub areas. The expected degree of liquefaction induced ground damage by ARI of earthquake shaking for each sub area is summarised in Table 4.5.

Table 4.5: Expected degree of liquefaction induced ground damage by ARI and sub area.

		Expected degree of liquefaction induced ground damage		
		25 year ARI	**100 year ARI**	**500 year ARI**
Sub area	**Omokoroa study area – Type A**	None-to-minor	No more than minor-to-moderate	None-to-minor or minor-to-moderate or moderate-to-severe
	Omokoroa study area – Type B	None-to-minor	None-to-minor[6]	None-to-minor[6]
	Katikati study area – Type A	None-to-minor	No more than minor-to-moderate	None-to-minor or minor-to-moderate or moderate-to-severe

Note, due to the limited availability of geotechnical investigations, the expected degree of liquefaction induced ground damage for the 100 year and 500 year ARI for the Type B sub area is subject to on site confirmation that the depth to groundwater is more than 4m BGL and the Rotoehu Ash layer is present at depths shallower than 4m BGL.

While there is the potential for moderate-to-severe liquefaction induced ground damage at 500 year ARI in Type A sub areas, the information the information which T+T has reviewed it is not expected

[5] For this assessment, the level of earthquake shaking (in terms of peak ground acceleration (PGA) and magnitude (M)) at which liquefaction triggering occurs for each soil layer has been assessed by the method proposed by Boulanger and Idriss (2014). The input parameters that have been adopted for the Boulanger and Idriss (2014) liquefaction triggering assessment for this study are listed in Table B1.

[6] Subject to on site confirmation that the depth to groundwater is more than 4m BGL and the Rotoehu ash layer is shallower than 4m BGL.

that this will affect large parts of the sites. It is more likely that moderate-to-severe land damage would be isolated in small pockets.

Inspection of the available CPT analysis presented in Appendix B indicates that it is likely that liquefaction will be triggered in the majority of saturated soils in each of the sub-areas at 500 year ARI level of earthquake shaking. This is supported by the PGA response curves for the CPT-based liquefaction parameters that indicate that the 500 year ARI level of shaking is towards the end of the inflection point. Therefore, beyond 500 year ARI levels of earthquake shaking, it is unlikely that the expected degree of liquefaction induced ground damage would be significantly worse than that indicated in Table 4.5.

4.5 Liquefaction vulnerability against performance criteria

The methodology described in the MBIE/MfE Guidelines (2017) recommends categorisation of the liquefaction vulnerability of the land based on the performance criteria described in Figure 4.3 below.

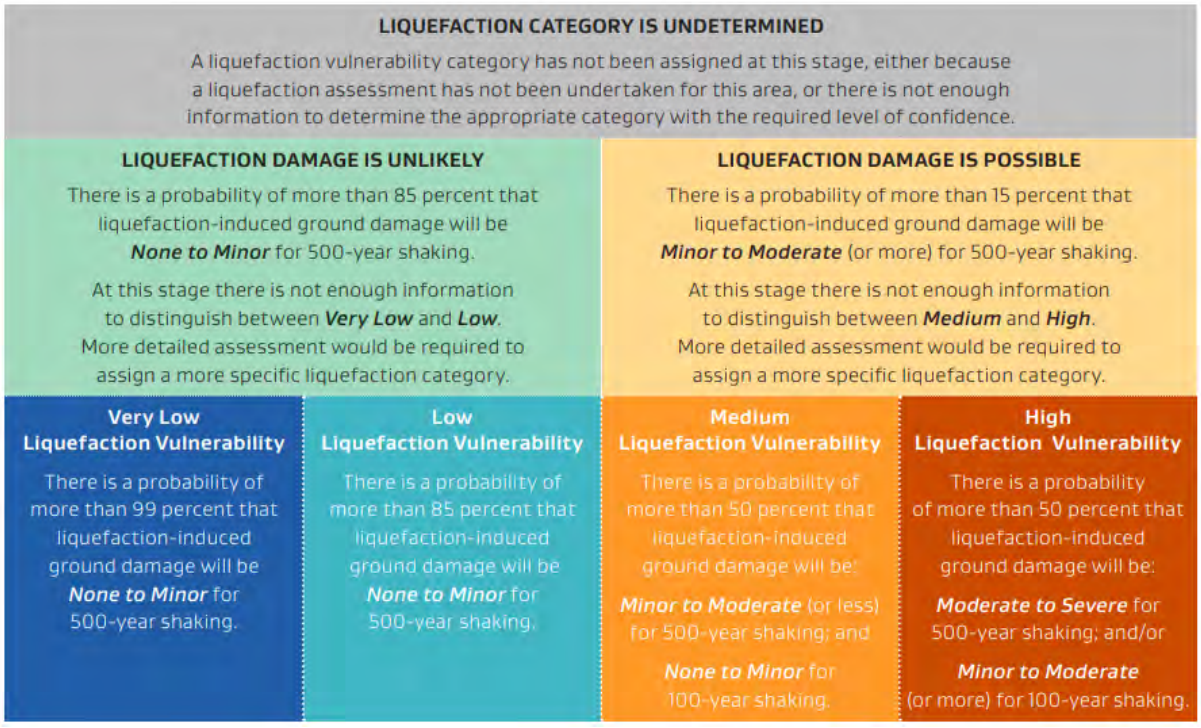


Figure 4.3: Performance criteria for determining the liquefaction vulnerability category - reproduced from Table 4.4 of the MBIE/MfE Guidelines (2017)

The performance criteria listed in Figure 4.3 relate the liquefaction vulnerability category to the expected liquefaction-induced land damage at a given ARI level of earthquake shaking. The assessment requires the assessor to consider the probability that a particular level of liquefaction-induced land damage will occur for a given level of shaking. In undertaking this assessment it is important to understand the following note attached to the table in the guidance document:

"The probabilities listed in this table are intended to provide a general indication of the level of confidence required to assign a particular category, rather than to be a specific numerical criteria for calculation. Conceptually, these probabilities relate to the total effect of all uncertainties in the assessment…"

That is, the guidance recommends the assessor consider the combined effect of all the uncertainties associated with the available information in the determination of the land damage category.

T+T's assessment of the liquefaction vulnerability category for the Omokoroa and Katikati study areas is presented in Figures B1 and B2 in Appendix B respectively.

For the Omokoroa study area the area classified as "liquefaction damage is possible" was determined by applying a 50m buffer to the Type A sub area. This buffer zone was applied to capture the residual uncertainty associated with the mapping of soil conditions and the potential for damaging lateral spread to extend outside of the Type A sub area.

The area in the Omokoroa study area classified as "liquefaction damage is unlikely" is the remaining Type B sub area. This classification is subject to confirmation of the depth to groundwater being greater than 4 m and the Rotoehu Ash layer is encountered at depths shallower than 4 m.

The entire Katikati study area is classified as "liquefaction damage is possible".

5 RPS risk assessment

5.1 General

The results generated from the MBIE/MfE risk analysis process described in Section 4 have been used to undertake a natural hazard risk assessment in accordance the natural hazard provisions of the BOPRC RPS, Appendix L. In Appendix L, a method is presented whereby the risk exposure of a particular area to a given hazard can be evaluated. This risk assessment has been undertaken for residential buildings, lifeline infrastructure and health and safety.

T+T has been provided with the draft structure plan information for each site presented in Appendix C. The draft structure plan of the Omokoroa study area indicates that the majority of the proposed residential zoned land is confined to the elevated terraces and therefore (subject to confirmation) is located on land for which "liquefaction damage is considered unlikely". However we note that some residential zoned land is proposed within that have been classified as "liquefaction damage is possible." The entire Katikati study area is defined as "liquefaction damage is possible" and therefore the entire proposed residential zone is contained within this area.

For this study, the risk associated with liquefaction has been assessed for both of the areas. While the study areas provide suitable and convenient scales for the purposes of this risk assessment, the ground conditions are likely to vary within each area, in particular within the Omokoroa study area. Therefore, for more detailed assessments (e.g. studies to support sub-division or building consents), consideration of areas of land that are representative of consistent ground conditions and therefore likely performance should be considered.

Currently there is not sufficient information about the ground conditions and proposed development for either site to undertake a full quantitative risk assessment of liquefaction. Instead, we have undertaken a qualitative risk assessment by considering the mitigation methods that could be adopted to achieve compliance with the BOPRC RPS.

5.2 Event likelihood

Table 5.1 below is taken from the RPS Natural Hazards Risk Assessment User Guide and shows that earthquake events with AEPs of 0.1, 0.2 and 0.033 percent (1,000 year ARI, 500 year ARI and 3,300 year ARI, respectively), should be considered in a risk based assessment.

As discussed in Section 4.4, the available information indicates that the expected liquefaction related land damage plateaus beyond about 0.2% AEP. Therefore, it is likely that the same land damage category will be assigned to a site regardless of whether it is being assessed with AEPs of 0.1, 0.2 or 0.033 percent.

Table 5.1: Event probabilities for analysis (taken from RPS Natural Hazards Risk Assessment User Guide)[7]

Hazard	Column A: Likelihood for initial analysis AEP (%)	Column B: Likelihood for secondary analysis	
		AEP (%) - More likely	AEP (%) - Less likely
Volcanic hazards (including geothermal)	0.1	0.2	0.005
Earthquake (liquefaction)	0.1	0.2	0.033
Earthquakes (fault rupture)	0.017	0.2	0.005
Tsunami	0.1	0.2	0.04
Coastal erosion	1	2	0.2
Landslip (rainfall related)	1	2	0.2
Landslip (seismic related)	0.1	0.2	0.033
Flooding (including coastal inundation)	1	2	0.2

5.3 Hazard Susceptibility Area (HSA)

The Hazard Susceptibility Area (HSA) is defined as the maximum spatial extent of a particular hazard. For this liquefaction risk assessment, it was defined as the entire extents of study areas because there is still a degree of uncertainty about the spatial extent of soil layers that are susceptible to liquefaction.

5.4 Ground elevation

As discussed in Section 3.2.1, this liquefaction assessment has been undertaken based on the current ground surface levels. This provides sufficient information to progress the risk assessment to a preliminary level. However, for later stages of development (e.g. sub-division and building consenting) proposed finished ground surface levels will need to be considered.

5.5 Building risk assessment

This building risk assessment has been undertaken following the general principles provided in the methodology for Primary Analysis (Steps 1-4) of the BOPRC RPS. It does not include the method presented for Secondary Analysis (Step 5) which incorporates the calculation of Annual Individual Fatality Risk (AIFR). The commentary on health and safety provided in Section 5.7 discusses the likelihood of death and injury associated with liquefaction and lateral spreading hazards.

5.5.1 Compromised functionality

In order to undertake a risk assessment as described in Appendix L of the BOPRC RPS, consideration needs to be given to the definition of "functionally compromised." In the context of buildings the BOPRC RPS provides some guidance when it defines "functionally compromised" as "…will generally occur when a building cannot continue to be used for its intended use immediately after an event". The methodology then allows for judgement as to the nature and duration of loss of functioning.

The New Zealand Building Code establishes a similar concept through objective B1.1 (b) that a building is to have a low probability of "loss of amenity" during its life. Amenity is defined in the

[7] Bay of Plenty Regional Council, 2014. "Bay of Plenty Regional Policy Statement." Retrieved from https://www.boprc.govt.nz/knowledge-centre/policies/operative-regional-policy-statement/

Code as "…an attribute of a building which contributes to the health, physical independence and well-being of the building's user but which is not associated with disease or a specific illness."

The MBIE guidance document (2012) "Repairing and rebuilding houses affected by the Canterbury earthquakes" [8] (the MBIE/MfE Guidelines (2012)) defines loss of amenity as the exceedance of the following tolerable impact:

"All parts of the structure shall remain functional so that the building can continue to perform its intended purpose. Minor damage to structure. Some damage to building contents, fabric and lining. Readily repairable. Building accessible and safe to occupy. No loss of life. No injuries..."

For the purposes of this assessment we have considered "functionally compromised" as synonymous with "loss of amenity" as defined above.

One of the key performance measures in the definition above is the terminology of "readily repairable." The MBIE/MfE Guidelines (2012) defines this as "…repairable without relocation of occupants for more than four weeks." Therefore, with respect to the duration of loss of functionality, we have assumed that a "functionally compromised" building will be damaged beyond a "readily repairable" state i.e. it will require relocation of the occupants for more than four weeks to undertake necessary repair.

It is important to note that for this risk assessment we have only considered the performance of the residential buildings, and not the lifelines and utilities associated with the building. There are instances where the building consequence levels could be deemed insignificant or minor, but due to poor performance of the surrounding lifelines and utilities the functionality of the building could be compromised. These instances have not been accounted for as part of this assessment. Refer to Section 5.6 for further commentary on lifelines and utilities.

5.5.2 Building density

Unlike other hazards such as flood and tsunami, the density of buildings typically does not have a significant and measurable impact on the level of risk to liquefaction provided that the same building type is constructed for each case.

For this risk assessment we have made the following assumptions about the buildings constructed on the site:

1 The buildings will be no more than two stories high and constructed of lightweight materials (e.g. timber cladding and frame and steel roof).

2 The buildings will be freestanding (i.e. not large multi-unit buildings).

The first assumption is important because it minimises the weight of the building. Experience in Christchurch following the Canterbury Earthquake Sequence (CES) is that under the same ground conditions heavier buildings are more likely than lightweight buildings to sustain damage by settling into the ground either uniformly or differentially. A guiding principle of the MBIE/MfE Guidelines (2012) is that *"…to mitigate the effects of liquefaction…it is preferable to build using lightweight materials rather than heavy materials"*.

The second assumption is important because free standing dwellings with relatively small footprints are less susceptible to the effects of lateral stretch than multi-unit buildings with relatively large footprints. This is because the comparatively large area of a multi-unit building means that a larger magnitude of lateral stretch is likely to occur across the building footprint. As a result, it is more

[8] Ministry of Business Innovation & Employment (MBIE), 2012. "Repairing and rebuilding houses affected by the Canterbury earthquakes". New Zealand.

likely for significant cracking to occur within the foundation of a multi-unit building in ground where lateral stretching occurs.

If these conditions cannot be met, it will impact on the validity of this risk assessment and the process should be revisited with more detail about the proposed design of the buildings to be constructed.

5.5.3 Liquefaction risk assessment

The liquefaction vulnerability of the two study areas needs to be considered in accordance with the liquefaction hazard risk assessment presented in the BOPRC RPS and more specifically, the consequence table (Table 21 in Appendix L of the BOPRC RPS) represented in Table 5.2 below. The consequence levels have only been considered for residential dwellings and not critical buildings or buildings of social/cultural importance.

Table 5.2: Consequence table with qualitative and quantitative descriptions (Source: Table 21, Appendix L, BOPRC RPS)

Consequence level	Built			Lifelines utilities	Health & safety
	Social/cultural	Buildings	Critical buildings		
Catastrophic	≥25% of buildings of social/cultural significance within hazard assessment area have functionality compromised.	≥50% of buildings within hazard assessment area have functionality compromised.	≥25% of critical buildings within hazard assessment area have functionality compromised.	A lifeline utility service is out for > 1 month (affecting ≥ 20% of the town/city population) OR out for > 6 months (affecting < 20% of the town/city population).	>101 dead and/or >1001 injured
Major	11–24% of buildings of social/cultural significance within hazard assessment area have functionality compromised.	21–49% of buildings within hazard assessment area have functionality compromised.	11–24% of critical buildings within hazard assessment area have functionality compromised.	A lifeline utility service is out for 1 week – 1 month (affecting ≥ 20% of the town/city population) OR out for 6 weeks to 6 months (affecting < 20% of the town/city population).	11–100 dead and/or 101–1000 injured
Moderate	6–10% of buildings of social/cultural significance within hazard assessment area have functionality compromised.	11–20% of buildings within hazard assessment area have functionality compromised.	6–10% of critical buildings within hazard assessment area have functionality compromised.	A lifeline utility service is out for 1 day to 1 week (affecting ≥ 20% of the town/city population) OR out for 1 week to 6 weeks (affecting < 20% of the town/city population).	2–10 dead and/or 11–100 injured
Minor	1–5% of buildings of social/cultural significance within hazard assessment area have functionality compromised.	2–10% of buildings within hazard assessment area have functionality compromised.	1–5% of critical buildings within hazard assessment area have functionality compromised.	A lifeline utility service is out for 2 hours to 1 day (affecting ≥ 20% of the town/city population) OR out for 1 day to 1 week (affecting < 20% of the town/city population).	≤1 dead and/or 1–10 injured
Insignificant	No buildings of social/cultural significance within hazard assessment area have functionality compromised.	<1% of buildings within hazard assessment area have functionality compromised.	No damage within hazard assessment area, fully functional.	A lifeline utility service is out for up to 2 hours (affecting ≥ 20% of the town/city population) OR out for up to 1 day (affecting < 20% of the town/city population).	No dead No injured

In order to relate liquefaction land damage to the risk assessment outlined in the BOPRC RPS and more specifically the consequence levels for residential dwelling, the estimated liquefaction-induced land damage results from Figure 3.2 have been correlated with the building consequence levels in the BOPRC RPS. The correlation between expected land performance and expected building performance is dependent on the dwelling foundations assumed. Therefore, the correlation has been presented for three different types of foundations:

- Foundation equivalent to a TC1 ”slab-on-grade” type foundation (i.e. using foundations provided in NZS 3604 Timber Framed Buildings, as modified by B1/AS1 which requires ductile reinforcing in slabs).
- Foundation equivalent to a TC2 type foundation (i.e. new houses with light- or medium-weight cladding, light-weight roofing with suspended timber floors and foundations in accordance with NZS 36042 or replace foundation with enhanced slab).
- Foundation equivalent to a TC3 type foundation (where specific geotechnical investigations and engineering design is required).

The choice of foundation type for a residential dwelling can have a significant impact on the expected building consequence level. For example, for moderate-to-severe expected liquefaction-induced land damage, a TC1 concrete slab-on-grade foundation is expected to perform very poorly

and a TC2 type equivalent foundation is expected to perform considerably better. A more robust TC3 type equivalent foundation is expected to perform better than both slab-on-grade and TC2 foundations. Not only are TC3 type foundation expected to perform better, they are also readily repairable. Note, TC2/TC3 hybrid foundation options also exist and can be a feasible option in places.

Following the collation and analysis of additional depth to groundwater data and CPT, the land damage categories within both study areas can be determined for the three different ARI scenarios. In order for the expected land damage within each area to be converted to the consequence level listed in Table 5.2, we have developed the matrix presented in Table 5.3. This matrix has been developed based on T+T's experience following the CES.

Table 5.3: Consequence conversion matrix for land damage and foundation type

Land damage category	Foundation type		
	TC1 "slab on grade"	TC2	TC3
None-to-minor	Minor	Insignificant	Insignificant
Minor-to-moderate	Moderate	Minor	Insignificant to minor
Moderate-to-severe	Major to catastrophic	Moderate to major	Minor to moderate

Table 5.3 indicates the consequence for a site can vary significantly depending on its assessed land damage category and the type of foundation used. It is important to note that the ground conditions are likely to vary within each study area and as a result the consequence levels are also likely to vary. Therefore, for more detailed assessments (e.g. studies to support sub-division or building consents) consideration of blocks of land that are representative of consistent ground conditions and similar expected performance should be considered.

The outcomes presented in Table 5.3 indicate that if a site has a land damage of moderate-to-severe, the estimated residential building consequence level could be as high as major to catastrophic if the dwelling is constructed as a slab-on-grade. The estimated residential building consequence level for the same site could be lowered to minor-to-moderate if the dwelling is constructed as a TC3 type equivalent foundation.

The next step in the BOPRC RPS Risk Assessment process is to determine the risk level. Figure 5.1 shows the matrix provided in the BOPRC RPS to determine the risk level for a given likelihood of occurrence and consequence level. Table 5.4 shows the result of applying the risk level matrix to the consequence levels in Table 5.3.

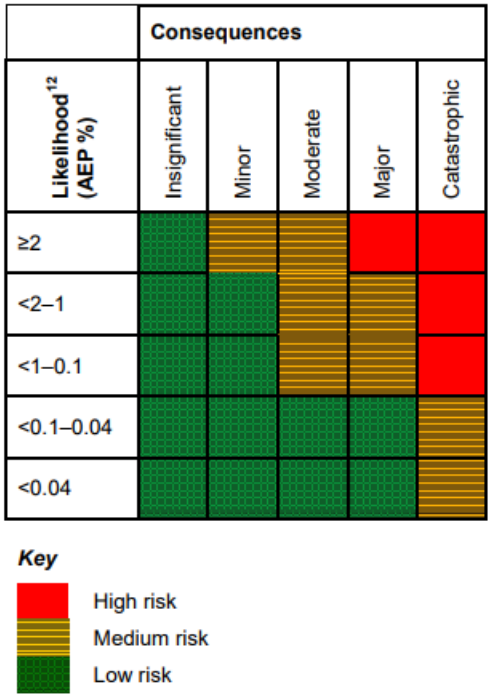


Figure 5.1: BOPRC RPS risk screening matrix

Table 5.4: Summary of derived building related risk levels for the different land damage categories for 0.2% AEP or less

Land damage category	Foundation type		
	TC1 "slab on grade"	TC2	TC3
None-to-minor	Low	Low	Low
Minor-to-moderate	Medium	Low	Low
Moderate-to-severe	Medium to high	Medium	Low to medium

Inspection of Table 5.4 shows that the assessed risk is low in areas with none-to-minor expected land damage at 500 year or more ARI levels of earthquake shaking regardless of whether TC1, TC2 or TC3 type equivalent foundation options are used. In areas with minor-to-moderate expected land damage at 500 year or more ARI levels of earthquake shaking or more, the assessed risk is low only when TC2 or TC3 type equivalent foundation options are used.

As described in Section 4.4, the current information which T+T has reviewed for the Omokoroa and Katikati areas indicates it is unlikely that there are large regions with the study areas with moderate-to-severe expected land damage following 500 year or more ARI levels of earthquake shaking, but small isolated pockets are possible. In those areas, the use of TC3 type equivalent foundations may result in an assessed risk of either low or medium. This can only be confirmed following a more detailed liquefaction hazard assessment. An alternative mitigation strategy is to avoid development in those areas where moderate-to-severe land damage is considered possible.

While the risk assessment indicates that TC1 slab-on-grade foundations could be appropriate in areas with none-to-minor land damage, some TC2 type foundations provide significant improvements for a relatively small additional cost. However, there is a significant increase in cost

between TC2 and TC3 type foundations. In some instances, a TC2/TC3 hybrid foundation may provide a suitable solution.

In summary, following more detailed liquefaction risk assessment in accordance with MBIE/MfE Guidelines (2017) and specification of appropriate mitigation strategies for liquefaction, it is likely that compliance with the BOPRC RPS can be achieved.

5.5.4 Lateral spreading risk assessment

As discussed in Section 4.4, the presence of soils that are susceptible to liquefaction and the topography indicates the presence of free faces and sloping land. These factors indicate the potential for free-faces to occur. However, as discussed, there is currently insufficient information to undertake a quantitative risk assessment. Therefore, we have undertaken a qualitative assessment by considering the lateral spread mitigation methods that could be used to achieve compliance with the RPS.

There are various ways in which the effects of lateral spreading can be mitigated such as the following:

- Applying a large (conservative) setback distance from the free-face.
- Applying a medium setback with appropriate robust detailing for design of buildings and infrastructure.
- Undertaking ground improvements (e.g. installing perimeter treatment or area wide ground densification).
- Removing any free faces by filling the ponds and/or stream and flattening sloping portions of the site.

The binary impact of lateral spreading makes a qualitative risk assessment relatively straight forward. For areas outside of the area affected by lateral spreading, the consequence level for lateral spreading is considered insignificant and therefore the corresponding risk level is low. Similarly, if one of the lateral spreading mitigation options discussed above is adopted, the consequence level of lateral spreading of land within the area affected by lateral spreading is also considered to be insignificant and therefore the corresponding risk level is also low.[9, 10]

In summary, following more detailed lateral spreading assessment in accordance with the MBIE/MfE Guidelines (2017) and specification of appropriate mitigation strategies for lateral spreading, it is likely that compliance with the BOPRC RPS can be achieved.

5.6 Lifelines and utilities

As discussed in Section 5.1, there is currently insufficient information about the ground conditions and proposed development for either site to undertake full quantitative risk assessments of liquefaction for lifelines and utilities. This is particularly relevant for lifeline utilities because the methodology for lifeline utility risk assessment outlined in the BOPRC RPS requires the consideration of both outage time and the percentage of the population affected (refer to Table 5.2). Without more detailed information about the spatial distribution of the likely liquefaction and lateral spread hazard, the lifeline utilities and the population served it is not feasible to apply this process. However, a qualitative assessment of risk has been undertaken.

[9] T+T does not recommend the construction of buildings on land affected by lateral spreading without the adoption of an appropriate mitigation option.

[10] Note that this risk level only applies to lateral spreading and a particular area may be assessed as higher risk of liquefaction related land damage.

We note that liquefaction and lateral spreading has the potential to cause significant damage to lifelines utilities including the following:

- Damage to road through settlement, cracking, sinkholes and ejecta.
- Underground services can be damaged due to ground deformation and blocked due to sedimentation.
- Deformation of embankments and bridge abutments can cause damage to bridge foundations and the super structure.
- Disruption to stormwater drainage can result in significant increase in flooding frequency and severity.

A more detailed list of the consequences of liquefaction and lateral spreading is provided in Table A1 in Appendix A.

Lifelines and utilities should be appropriately designed to mitigate the consequences of liquefaction that are anticipated for the local ground conditions. Potential mitigation strategies for lifeline utilities include the following:

- Where practical, in areas where moderate-to-severe liquefaction damage is possible (including lateral spread), the construction of critical lifelines and utilities should be avoided.
- Ground improvement techniques such as perimeter treatment and area wide densification may be suitable where liquefaction related damage is possible.
- Utilities should be designed such that they are readily repairable should liquefaction related damage be sustained. For example, in areas where there is the potential for liquefaction related land damage, consideration should be given to placing the below ground infrastructure at relatively shallow depths.
- For pipe networks the use of ductile materials (e.g. flexible couplings and polyethylene pipe) and pressurised systems (as opposed to gravity systems) to mitigate the effects of global and differential settlement should be considered.
- Particular attention should be given to the detailing of utility connections with buildings as the differential settlement of buildings relative to the surrounding ground can significantly compromise the functionality of utilities even when the majority of the network is relatively undamaged.

Note that standard designs for lifelines and utilities are likely to be suitable where liquefaction and lateral spreading related land damage is not anticipated.

As discussed in Section 4.4, the current information that we hold for the Omokoroa and Katikati areas indicates it is unlikely that there will be large regions within the study areas that are affected by moderate-to-severe land damage following 500 year or higher ARI levels of earthquake shaking. Therefore, following a more detailed liquefaction risk assessment in accordance with the MBIE/MfE Guidelines (2017) and specification of appropriate mitigation strategies such as those described above, it is considered likely that a low risk can be achieved and compliance with the BOPRC RPS can be demonstrated.

5.7 Health & safety

This health and safety risk assessment considers only the primary effects of liquefaction and lateral spreading on health and safety i.e. the number of lives lost and/or injuries sustained as a direct result of the earthquake event. We have not allowed for secondary effects on health and safety such as respiratory diseases caused by damp homes due to liquefaction ejecta being manifest under building foundations or the mental wellbeing of those affected by the earthquake event.

Despite the potential to cause significant damage to buildings and other infrastructure, the experience in the Christchurch area following the CES is that liquefaction and lateral spreading do not pose a significant risk to life and safety as a primary effect of the earthquake. While 185 people lost their lives as a result the February 2011 earthquake, 130 of these deaths occurred as a result of the collapse of two office buildings due to structural failure induced by severe ground shaking and the remaining deaths were as a result of either collapsed walls, falling masonry or falling rocks. None of these deaths were associated with either liquefaction or lateral spreading.

Based on this experience and our understanding of the mechanisms through which the consequences of liquefaction manifest, we preliminarily consider the health and safety consequence level for liquefaction to be minor for all six of the scenarios considered. Inspection of the BOPRC RPS risk matrix presented in Figure 5.1 indicates that this consequence level translates to a low risk for health and safety.

While not considered as part of this risk assessment, it is important to note that lateral spreading as a result of the CES did cause significant damage to a small number of buildings such that they were close to complete collapse. As such there is some health and safety risk associated with this form of land damage and it is conceivable that injury or death could occur.

6 Conclusions and recommendations

6.1 MBIE/MfE Guidelines (2017)

T+T has undertaken a liquefaction risk assessment in accordance with the MBIE/MfE Guidelines (2017) to a Level A level of detail. The following are the key conclusions from this assessment:

- The currently available base information supports a Level A (basic desktop) level of detail assessment. To support a Level B (calibrated desktop) level of detail assessment the following additional information would need to be collected and analysed:
  - Geotechnical investigation data in accordance with the recommendations of the MBIE/MfE Guidelines (2017); and
  - Site specific groundwater monitoring of sufficient length of record to confirm seasonal variability in groundwater across the site (at least one calendar year).
- The current information indicates that it is unlikely that large regions within the study areas will be affected by moderate-to-severe expected land damage following 500 year or more ARI levels of earthquake shaking, but small isolated pockets are possible. Beyond 500 year ARI levels of earthquake shaking, the expected liquefaction related land damage generally plateaus (i.e. regardless of how much more the shaking intensity increases, the expected liquefaction related land damage is likely to remain the same the same).
- The ground surface elevation information and geomorphological map indicate that there are free-faces and sloping landforms that could enable lateral spreading to occur. These conditions are particularly prevalent in the areas classified as Type A sub areas. Further, both study areas are likely to contain land that is susceptible to liquefaction. Therefore, there is the potential for lateral spreading to occur in both study areas and in particular within and adjacent to the areas identified as Type A sub areas.
- The performance criteria for determining the liquefaction vulnerability category from Table 4.4 of the MBIE/MfE Guidelines (2017) have been mapped and are presented on Figure B1 and Figure B2 of Appendix B. The main findings of that mapping process are as follows:
  - That the land within the Katikati and Omokoroa study areas that is defined as Type A sub area should be categorised as *Liquefaction Damage is Possible.*
  - That the land within the Omokoroa study area that is defined as Type B sub area should be categorised as *Liquefaction Damage is Unlikely* subject to confirmation that the depth to groundwater is deeper than 4 m and the presence of the Rotoehu Ash layer is confirmed across the area under consideration at a depth of 4 m or less.

In order to refine the liquefaction vulnerability categorisation and reduce some of the uncertainties around the current assessment, a more detailed liquefaction hazard assessment would need to be undertaken. A Level B level of detail assessment in accordance with the MBIE/MfE Guidelines (2017) would represent a logical next step. In order to undertake such an assessment T+T recommends the following additional steps to achieve this:

- Obtain additional geotechnical investigation data. This could be achieved by one of the following:
  - Converting CPT traces already on the NZGD into a digital format.
  - Uploading geotechnical investigations that have previously been undertaken in the study area onto the NZGD.
  - Undertaking geotechnical investigations specifically to support liquefaction assessment of the study areas.

- Install a network of piezometers within the study area, undertake a program of medium to long term groundwater monitoring and develop refined groundwater models from this information.

6.2 RPS risk assessment

A risk assessment has also been undertaken in accordance with Appendix L of the BOPRC RPS. Due to the limited liquefaction information available, this risk assessment has adopted a qualitative rather than a quantitative approach. Based on this qualitative assessment we consider that, following more detailed assessment, and with the adoption of appropriate mitigation strategies, it is likely that a low level of risk can be demonstrated and compliance with the RPS can be achieved.

7 Applicability

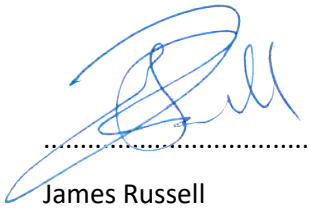
This report has been prepared for the exclusive use of our client Bay of Plenty Regional Council, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

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

The susceptibility analyses carried out represent probabilistic analyses of empirical liquefaction databases under various earthquakes. Earthquakes are unique and impose different levels of shaking in different directions on different sites. The results of the liquefaction susceptibility analyses and the estimates of consequences presented within this document are based on regional seismic demand and published analysis methods, but it is important to understand that the actual performance may vary from that calculated.

Tonkin & Taylor Ltd

Report prepared by:

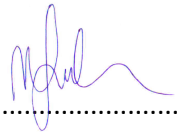


.....

James Russell

Natural Hazard Engineer

Report reviewed by:



.....

Mike Jacka

Geotechnical Engineer

Authorised for Tonkin & Taylor Ltd by:

.....

David Milner

Project Director

JICR
\\ttgroup.local\corporate\tauranga\projects\1008683\issueddocuments\20190909.katikati and omokoroa liquefaction assessment final.docx

8 References

Bay of Plenty Regional Council, 2014. “Bay of Plenty Regional Policy Statement.” Retrieved from https://www.boprc.govt.nz/knowledge-centre/policies/operative-regional-policy-statement/

Ministry of Business Innovation & Employment (MBIE), 2017. “Planning and engineering guidance for potentially liquefaction-prone land”. Retrieved from https://www.building.govt.nz/building-code-compliance/b-stability/b1-structure/planning-engineering-liquefaction-land/

New Zealand Transport Agency Bridge Manual, manual number: SP/M/022. Third edition, Amendment 3, October 2018.

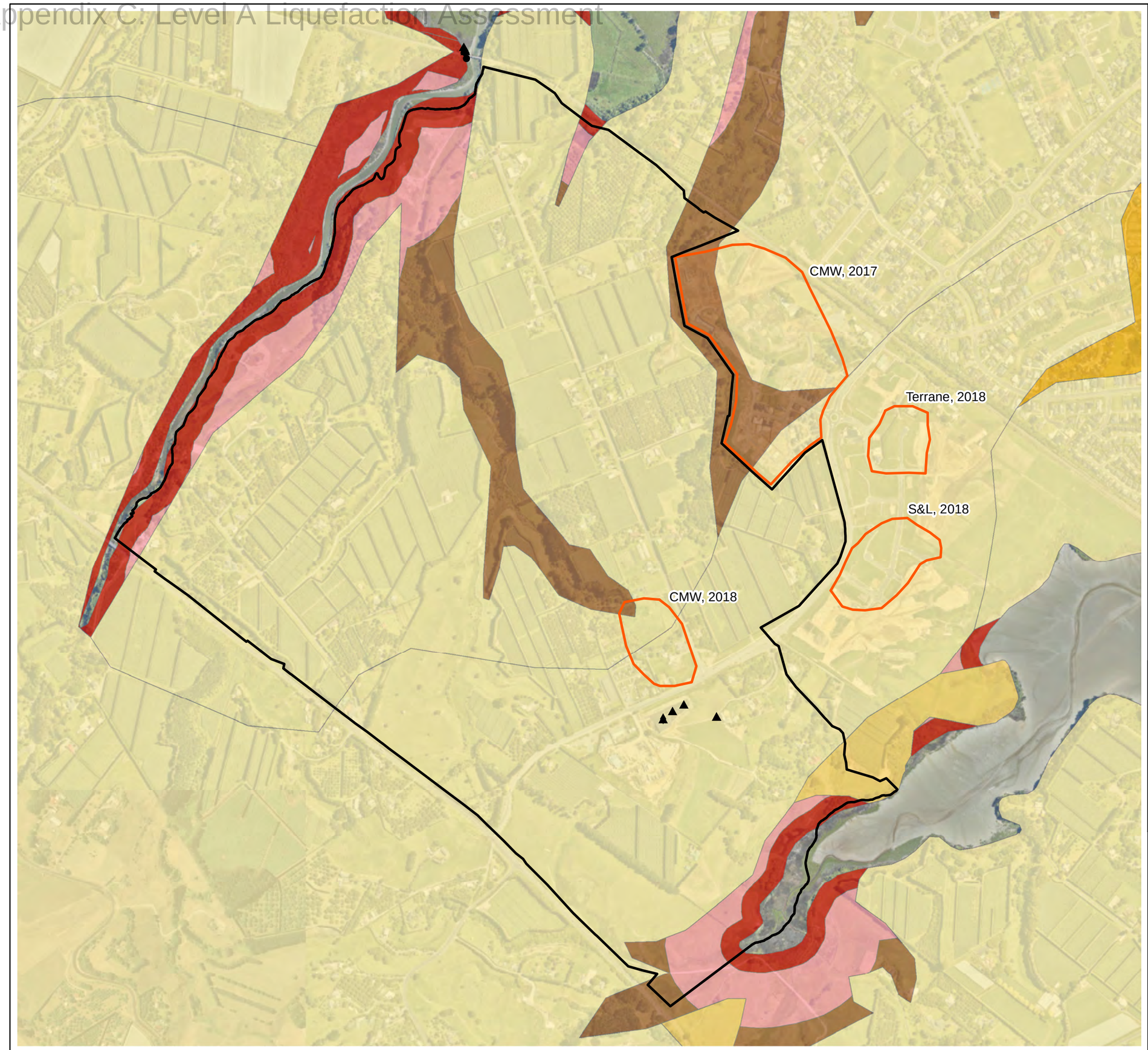
Standards New Zealand, 2004. “NZS1170.5:2004 Structural Design Actions Part 5: Earthquake actions - New Zealand”. Standards New Zealand. Retrieved from https://www.standards.govt.nz/

Appendix A: MBIE/MfE risk identification

- **Table A1: Consequences of liquefaction (reproduced from the MBIE/MfE Guidelines (2017))**
- **Omokoroa Figures:**
    - **Figure A1: Existing geotechnical investigations and report locations overlaid on Opus 2002 liquefaction hazard layer**
    - **Figure A2: Geotechnical investigations overlaid on 2015 LiDAR DEM**
    - **Figure A3: Geotechnical investigations overlaid on geomorphology**
    - **Figure A4: Estimated depth to groundwater**
- **Katikati Figures:**
    - **Figure A5: Existing geotechnical investigations and report locations overlaid on Opus 2002 liquefaction hazard layer**
    - **Figure A6: Geotechnical investigations overlaid on 2015 LiDAR DEM**
    - **Figure A7: Geotechnical investigations overlaid on geomorphology**
    - **Figure A8: Estimated depth to groundwater**

Table A1: Consequences of liquefaction (reproduced from the MBIE/MfE Guidelines (2017))

Land	• Sand boils, where pressurised liquefied material is ejected to the surface (ejecta). • Ground settlement and undulation, due to consolidation and ejection of liquefied soil. • Ground cracking from lateral spreading, where the ground moves downslope or towards an unsupported face (e.g. a river channel or terrace edge).
Environment	• Discharge of sediment into waterways, impacting water quality and habitat. • Fine airborne dust from dried ejecta, impacting air quality. • Potential contamination issues from ejected soil. • Potential alteration of groundwater flow paths and formation of new springs.
Buildings	• Distortion of the structure due to differential settlement of the underlying ground, impacting the amenity and weather-tightness of the building. • Loss of foundation-bearing capacity, resulting in settlement of the structure. In some cases this can result in tilting or overturning of multi-level buildings. • Stretch of the foundation due to lateral spreading, pulling the structure apart. In some cases this can result in collapse or near-collapse of buildings. • Damage to piles due to lateral ground movements, and settlement of piles due to down drag from ground settlement. • Damage to service connections due to ground and building deformations.
Infrastructure	• Damage to road, rail and port infrastructure (settlement, cracking, sinkholes, ejecta). • Damage to underground services due to ground deformation (e.g. 'three waters', power and gas networks). • Ongoing issues with sediment blocking pipes and chambers. • Uplift of buoyant buried structures (e.g. pipes, pump stations, manholes and tanks). • Damage to port facilities. • Sedimentation and 'squeezing' of waterway channels, reducing drainage capacity. • Deformation of embankments and bridge abutments (causing damage to bridge foundations and superstructure). • Settlement and cracking of flood stop banks, resulting in leakage and loss of freeboard. • Disruption of stormwater drainage and increased flooding due to ground settlement.
Economic	• Lost productivity due to damage to commercial facilities, and disruption to the utilities, transport networks and other businesses that are relied upon. • Absence of staff who are displaced due to damage to their homes or unable to travel due to transport disruption. • Cost of repairing damage.
Social	• Community disruption and displacement – initially due to damage to buildings and infrastructure, then the complex and lengthy process of repairing and rebuilding. • Potential ongoing health issues (e.g. respiratory and psychological health issues).



LEGEND

NZGD Geotechnical Investigations

Investigation Type

- Cone Penetrometer Test
- Hand Auger
- Machine Borehole
- Other
- Omokoroa Site Extent
- Existing Geotechnical Report Locations

Opus 2002 Liquefaction Hazard

- None
- Localised Minor
- Minor
- Limited
- Moderate
- Large
- Major
- Widespread
- Extensive

A3 SCALE: 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

Notes:

0.3m Rural Aerial Photos (2016-2017) and 1m resolution elevation data (2015) sourced from BOPLASS Ltd.

Geotechnical Investigations sourced from the New Zealand Geotechnical Database.

Opus 2002 Liquefaction Hazard layer sourced from TCC Mapi, re-use under Creative Commons.

For details on existing geotechnical reports, refer to Table 2.1 in Section 2.3 of this report.

DRAWN	MOLI	Sep.19
CHECKED	JICR	Sep.19
APPROVED	DMM	Sep.19

ARCFILE: 1008683_200_FIG005_Omok.mxd

SCALE (AT A3 SIZE): 1:10,000

PROJECT No.: 1008683.200

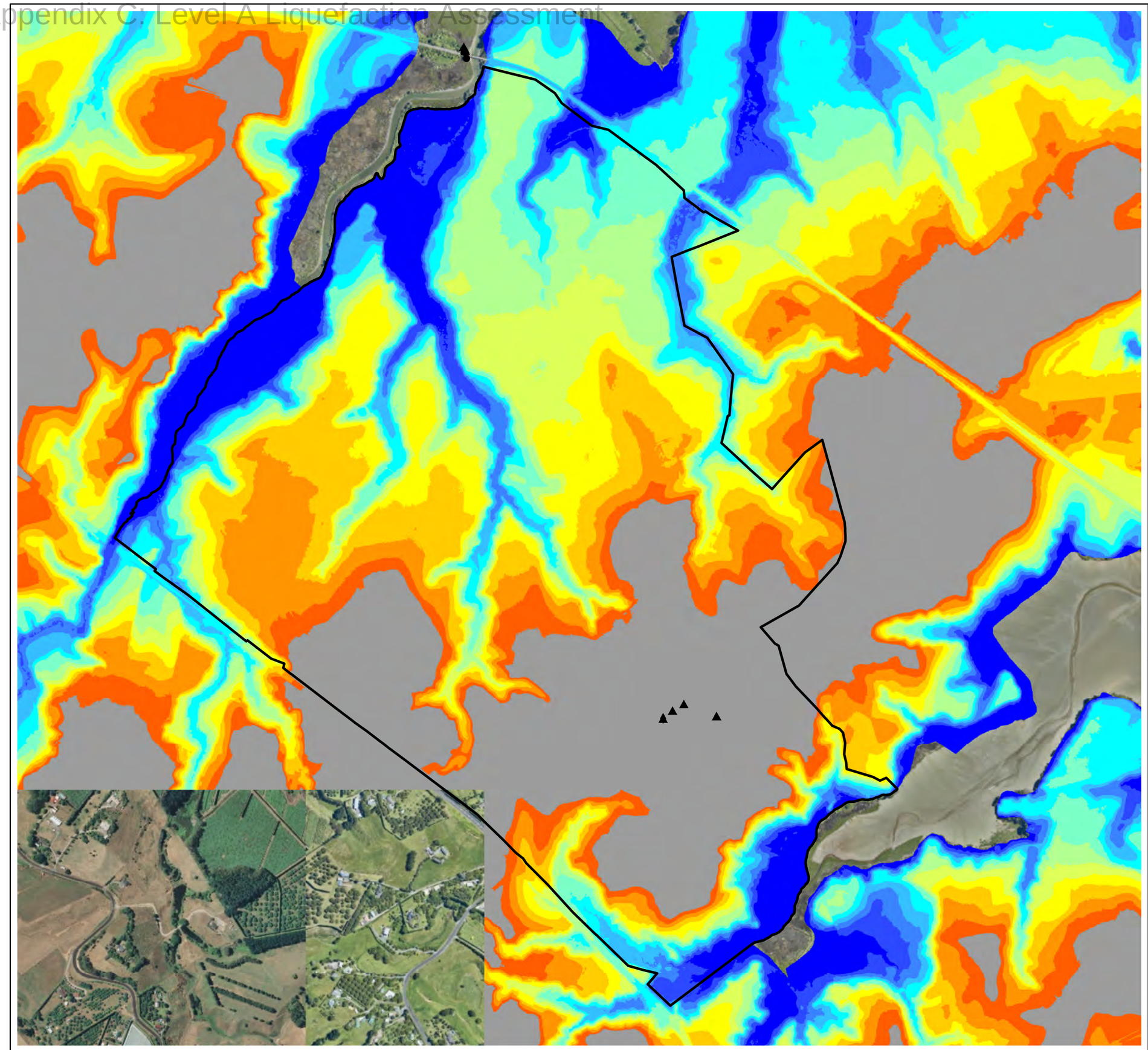
Tonkin+Taylor
105 Carlton Gore Road, Newmarket, Auckland
www.tonkintaylor.co.nz

BAY OF PLENTY REGIONAL COUNCIL

OMOKOROA LIQUEFACTION ASSESSMENT

Existing geotechnical investigations and report locations overlaid on Opus 2002 Liquefaction Hazard Layer

Figure A1



LEGEND

NZGD Geotechnical Investigations

- ▲ Cone Penetrometer Test
- ■ Hand Auger
- ● Machine Borehole
- ♦ Other
- Omokoroa Site Extent

Ground Surface Elevation (mRL)

- < 2.5
- 2.5 - 5
- 5 - 7.5
- 7.5 - 10
- 10 - 12.5
- 12.5 - 15
- 15 - 17.5
- 17.5 - 20
- 20 - 22.5
- 22.5 - 25
- 25 - 27.5
- 27.5 - 30
- > 30

A3 SCALE: 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

Notes:

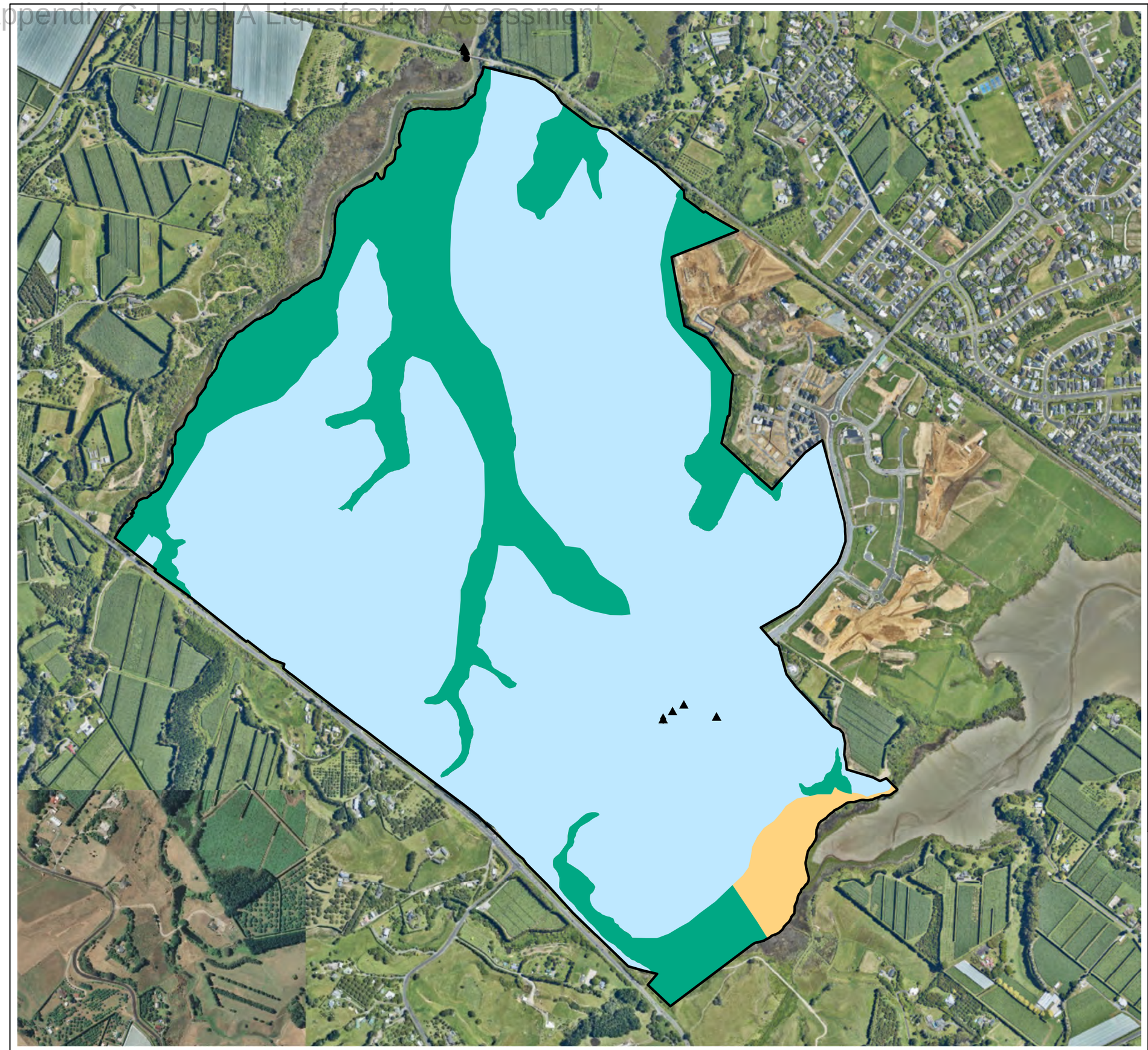
0.3m Rural Aerial Photos (2016-2017) and 1m resolution elevation data (2015) sourced from BOPLASS Ltd.
Vertical datum: NZVD 2016
Geotechnical Investigations sourced from the New Zealand Geotechnical Database.

DRAWN	MOLI	Aug.19
CHECKED	JICR	Sep.19
APPROVED	DMM	Sep.19
ARCFILE	1008683_200_FIG001.mxd	
SCALE (AT A3 SIZE)	1:10,000	
PROJECT No.	1008683.200	

Tonkin+Taylor
105 Carlton Gore Road, Newmarket, Auckland
www.tonkintaylor.co.nz

BAY OF PLENTY REGIONAL COUNCIL
OMOKOROA LIQUEFACTION ASSESSMENT
Geotechnical Investigations overlaid on 2015 LiDAR DEM

Figure A2



LEGEND

NZGD Geotechnical Investigations

Investigation Type

- ▲ Cone Penetrometer Test
- ■ Hand Auger
- ● Machine Borehole
- ♦ Other
- Omokoroa Site Extent

Geomorphology

- Stream Channels
- Low-lying Coastal Margin
- Terraces

A3 SCALE: 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

Notes:

0.3m Rural Aerial Photos (2016-2017) and 1m resolution elevation data (2015) sourced from BOPLASS Ltd.

Geotechnical Investigations are sourced from the New Zealand Geotechnical Database.

DRAWN	MOLI	Aug.19
CHECKED	JICR	Sep.19
APPROVED	DMM	Sep.19
ARCFILE	1008683_200_FIG003.mxd	
SCALE (AT A3 SIZE)	1:10,000	
PROJECT No.	1008683.200	

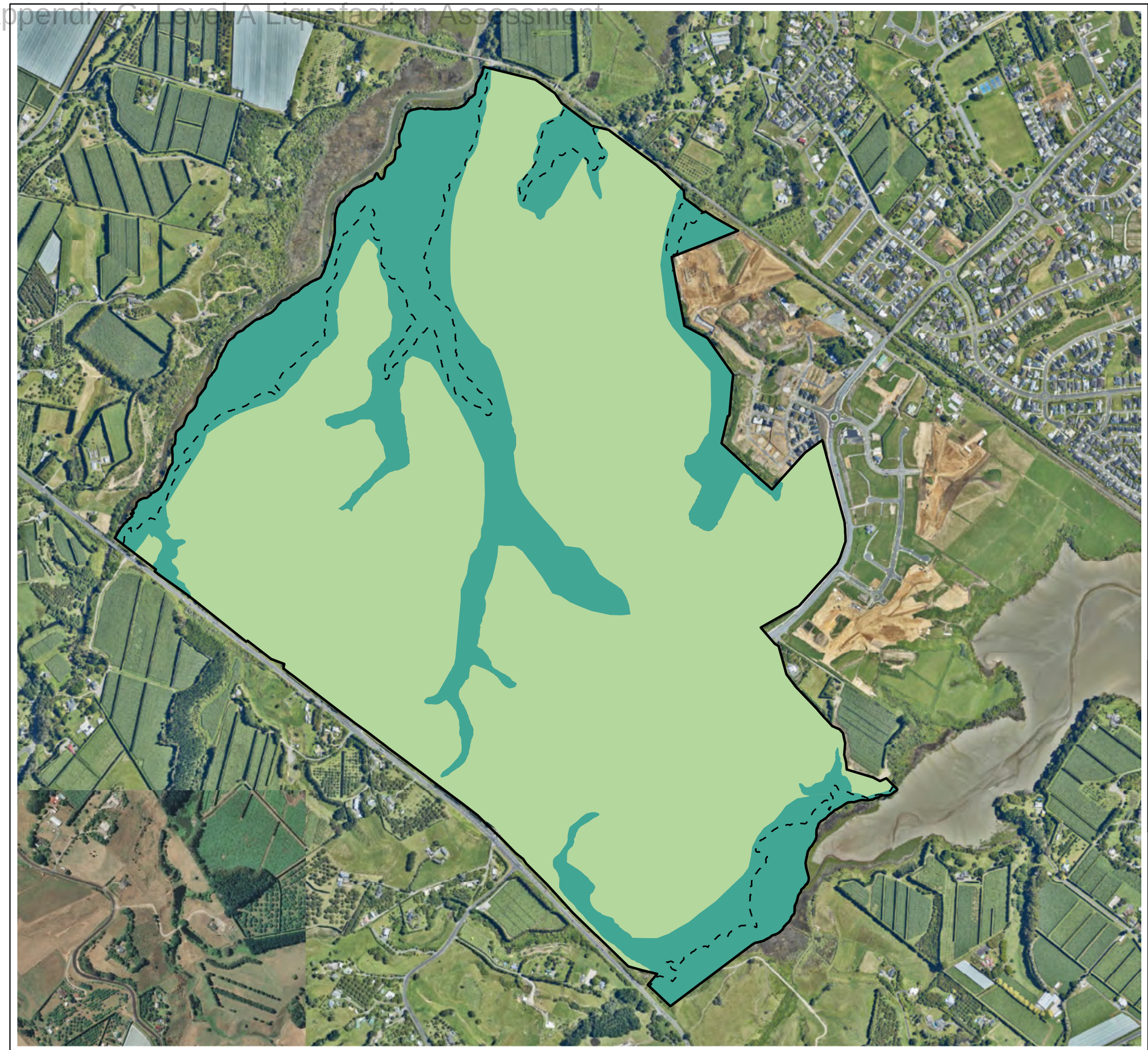
Tonkin+Taylor
105 Carlton Gore Road, Newmarket, Auckland
www.tonkintaylor.co.nz

BAY OF PLENTY REGIONAL COUNCIL

OMOKOROA LIQUEFACTION ASSESSMENT

Geotechnical Investigations overlaid on Geomorphology

Figure A3



LEGEND

- Likely high sensitivity to sea level rise at lower elevations
- Omokoroa Site Extent

Estimated Depth to Groundwater (m)

- Groundwater typically shallower than approximately 4m depth
- Groundwater typically deeper than approximately 4m depth

A3 SCALE: 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

N

Notes:

0.3m Rural Aerial Photos (2016-2017) and 1m resolution elevation data (2015) sourced from BOPLASS Ltd.

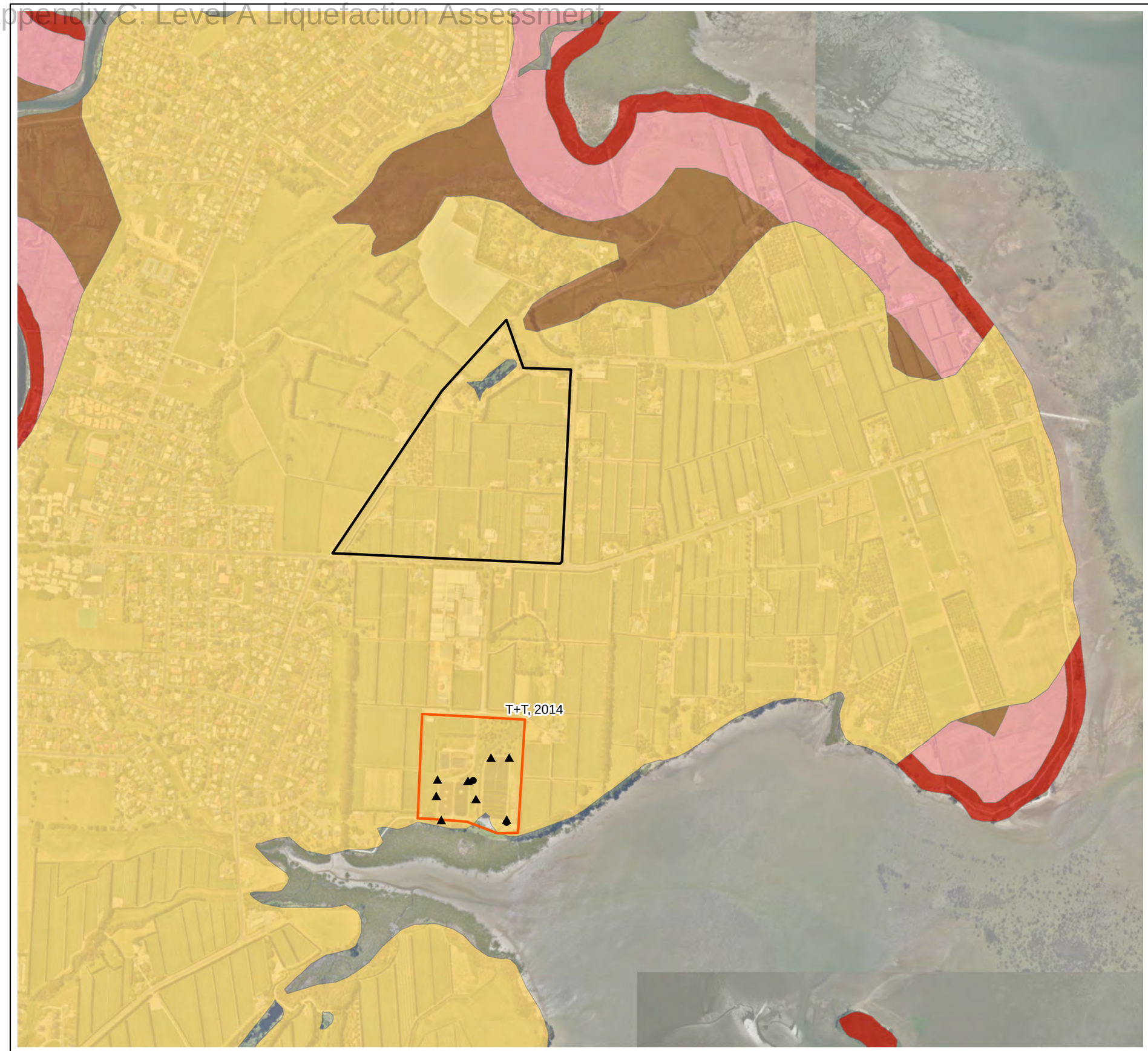
DRAWN	MOLI	Aug.19
CHECKED	JICR	Sep.19
APPROVED	DMM	Sep.19
ARCFILE	1008683_200_FIG007.mxd	
SCALE (AT A3 SIZE)	1:10,000	
PROJECT No.	1008683.200	

Tonkin+Taylor
105 Carlton Gore Road, Newmarket, Auckland
www.tonkintaylor.co.nz

BAY OF PLENTY REGIONAL COUNCIL

OMOKOROA LIQUEFACTION ASSESSMENT
Estimated Depth to Groundwater

Figure A4



LEGEND

NZGD Geotechnical Investigations

Investigation Type

- Cone Penetrometer Test
- Hand Auger
- Machine Borehole
- Other
- Katikati Site Extent
- Existing Geotechnical Report Locations

Opus 2002 Liquefaction Hazard

- None
- Localised Minor
- Minor
- Limited
- Moderate
- Large
- Major
- Widespread
- Extensive

A3 SCALE: 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

Notes:

0.3m Rural Aerial Photos (2016-2017) and 1m resolution elevation data (2015) sourced from BOPLASS Ltd.

Geotechnical Investigations sourced from the New Zealand Geotechnical Database.

Opus 2002 Liquefaction Hazard layer sourced from TCC Mapi, re-use under Creative Commons.

For details on existing geotechnical reports, refer to Table 2.1 in Section 2.3 of this report.

DRAWN	MOLI	Sep.19
CHECKED	JICR	Sep.19
APPROVED	DMM	Sep.19

ARCFILE: 1008683_200_FIG006_Kati.mxd

SCALE (AT A3 SIZE): 1:10,000

PROJECT No.: 1008683.200

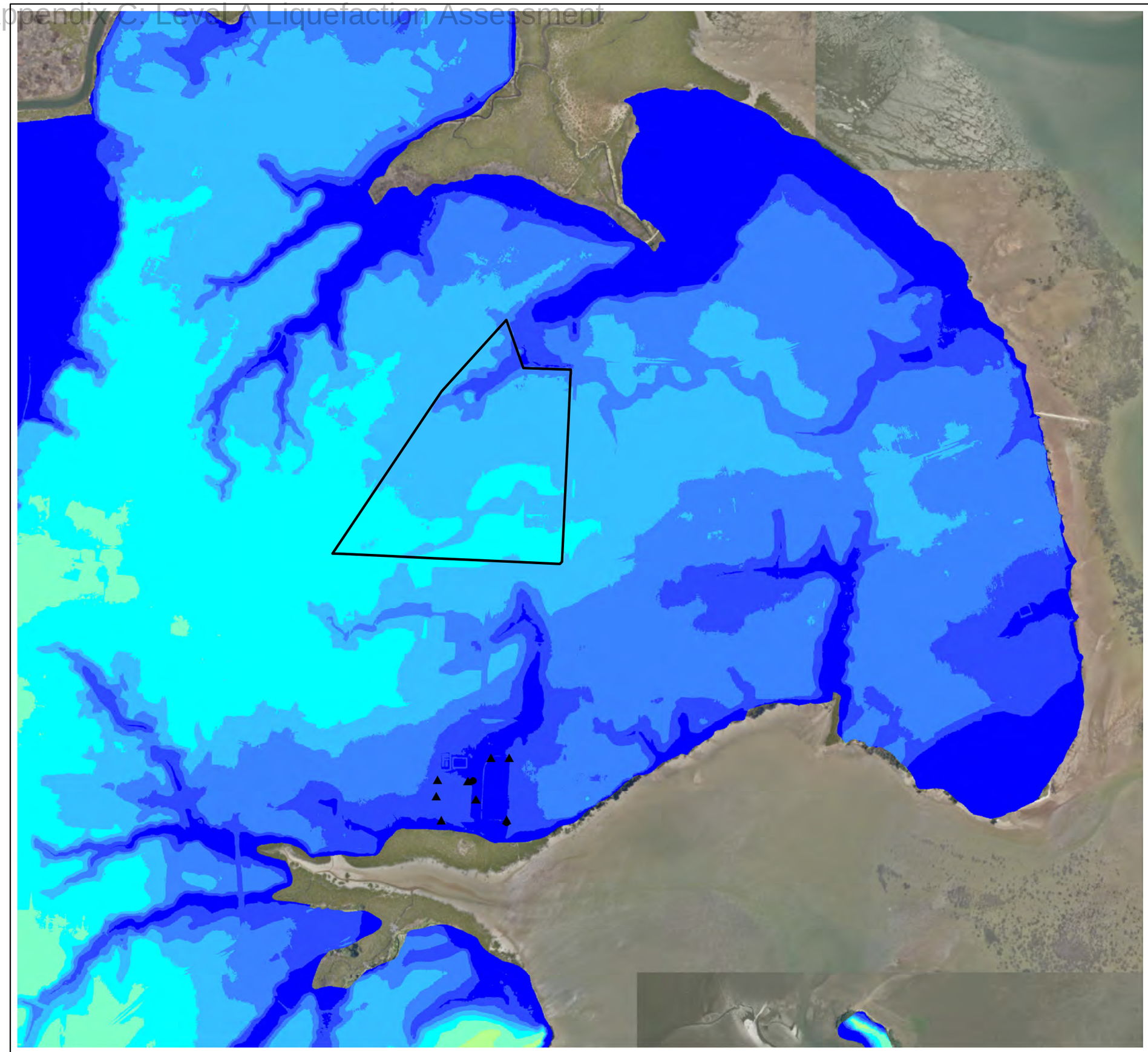
Tonkin+Taylor
105 Carlton Gore Road, Newmarket, Auckland
www.tonkintaylor.co.nz

BAY OF PLENTY REGIONAL COUNCIL

KATIKATI LIQUEFACTION ASSESSMENT

Existing geotechnical investigations and report locations overlaid on Opus 2002 Liquefaction Hazard Layer

Figure A5



LEGEND

NZGD Geotechnical Investigations

Investigation Type

- ▲ Cone Penetrometer Test
- ■ Hand Auger
- ● Machine Borehole
- ♦ Other
- Katikati Site Extent

Ground Surface Elevation (mRL)

- < 2.5
- 2.5 - 5
- 5 - 7.5
- 7.5 - 10
- 10 - 12.5
- 12.5 - 15
- 15 - 17.5
- 17.5 - 20
- 20 - 22.5
- 22.5 - 25
- 25 - 27.5
- 27.5 - 30
- > 30

A3 SCALE: 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

N

Notes:

0.3m Rural Aerial Photos (2016-2017) and 1m resolution elevation data (2015) sourced from BOPLASS Ltd.
Vertical datum: NZVD 2016
Geotechnical Investigations sourced from the New Zealand Geotechnical Database. There are no geotechnical investigations within this area.

DRAWN	MOLI	Aug.19
CHECKED	JICR	Sep.19
APPROVED	DMM	Sep.19
ARCFILE	1008683_200_FIG002.mxd	
SCALE (AT A3 SIZE)	1:10,000	
PROJECT No.	1008683.200	

Tonkin+Taylor
105 Carlton Gore Road, Newmarket, Auckland
www.tonkintaylor.co.nz

BAY OF PLENTY REGIONAL COUNCIL
KATIKATI LIQUEFACTION ASSESSMENT
Geotechnical Investigations overlaid on 2015 LiDAR DEM

Figure A6

LEGEND

NZGD Geotechnical Investigations

Investigation Type

- ▲ Cone Penetrometer Test
- ■ Hand Auger
- ● Machine Borehole
- ♦ Other
- Katikati Site Extent

Geomorphology

- Stream Channels
- Terraces

A3 SCALE: 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

N

Notes:

0.3m Rural Aerial Photos (2016-2017) and 1m resolution elevation data (2015) sourced from BOPLASS Ltd.
Geotechnical Investigations sourced from the New Zealand Geotechnical Database. There are no geotechnical investigations within this area.

DRAWN	MOLI	Sep.19
CHECKED	JICR	Sep.19
APPROVED	DMM	Sep.19
ARCFILE	1008683_200_FIG004.mxd	
SCALE (AT A3 SIZE)	1:10,000	
PROJECT No.	1008683.200	

Tonkin+Taylor
105 Carlton Gore Road, Newmarket, Auckland
www.tonkintaylor.co.nz

BAY OF PLENTY REGIONAL COUNCIL
KATIKATI LIQUEFACTION ASSESSMENT
Geotechnical Investigations overlaid on Geomorphology

Figure A7

LEGEND

Katikati Site Extent

Estimated Depth to Groundwater (m)

Groundwater typically shallower than approximately 4m depth

A3 SCALE: 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

N

Notes:

0.3m Rural Aerial Photos (2016-2017) and 1m resolution elevation data (2015) sourced from BOPLASS Ltd.

DRAWN	MOLI	Aug.19
CHECKED	JICR	Sep.19
APPROVED	DMM	Sep.19
ARCFILE	1008683_200_FIG008.mxd	
SCALE (AT A3 SIZE)	1:10,000	
PROJECT No.	1008683.200	

Tonkin+Taylor
105 Carlton Gore Road, Newmarket, Auckland
www.tonkintaylor.co.nz

BAY OF PLENTY REGIONAL COUNCIL

KATIKATI LIQUEFACTION ASSESSMENT

Estimated Depth to Groundwater

Figure A8

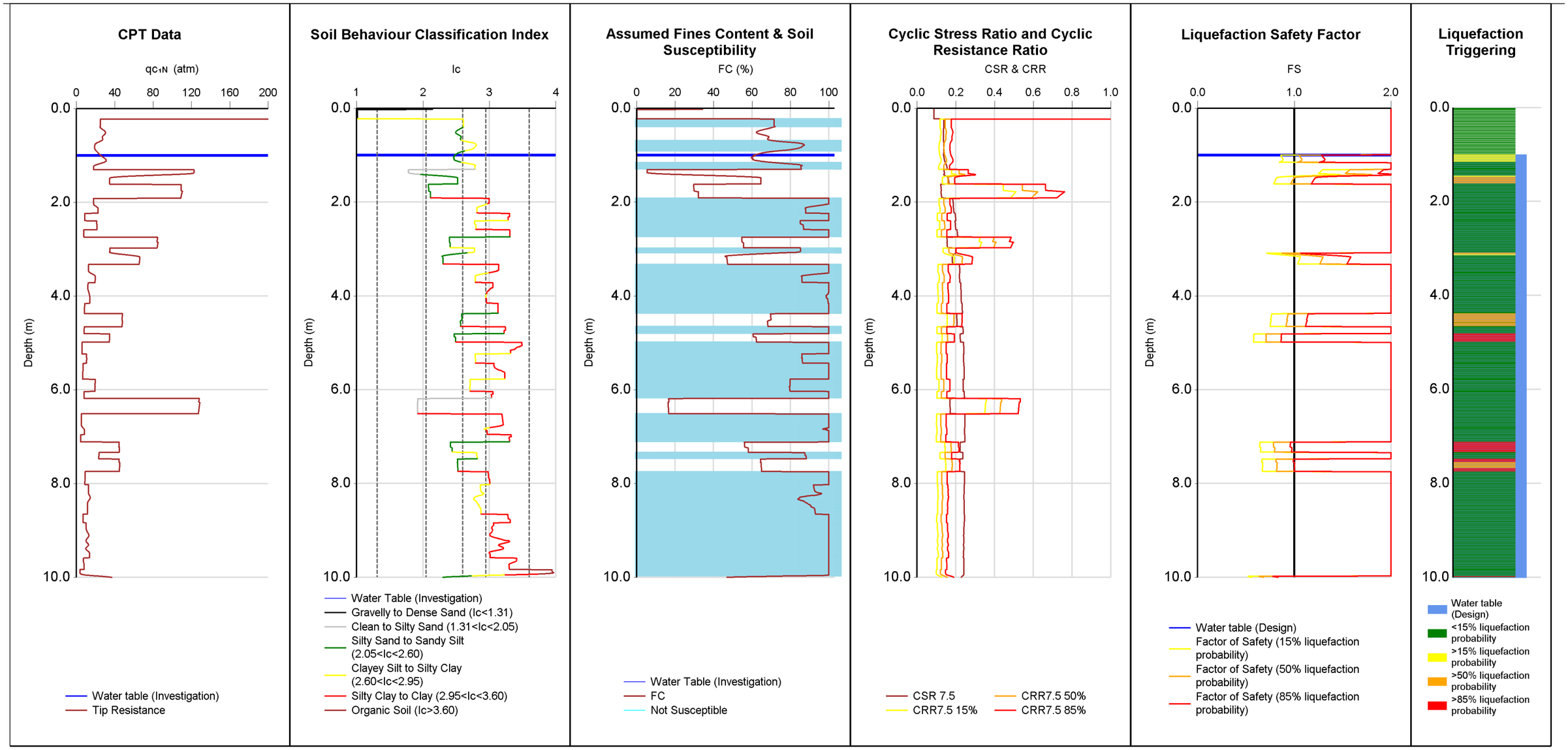
Appendix B: MBIE/MfE risk analysis

- **CPT-based analysis:**
    - **Table B1: Input parameters for Boulanger and Idriss (2014)**
    - **CPT-based analysis Omokoroa lowland site**
    - **CPT-based analysis Omokoroa elevated site**
    - **CPT-based analysis Katikati Wastewater Treatment Plant**
- **Summary of risk analysis and determination of expected degree of liquefaction-induced ground damage:**
    - **Table B2: Omokoroa study area – Type A sub area**
    - **Table B3: Omokoroa study area – Type B sub area**
    - **Table B4: Katikati study area – Type A sub area**
- **Results of performance criteria assessment:**
    - **Figure B1: Liquefaction risk assessment map for Omokoroa study area**
    - **Figure B2: Liquefaction risk assessment map for Katikati study area**

Table B1: Input parameters for Boulanger and Idriss (2014)

Input parameter	Default value adopted	Comments
Soil density	18 kN/m^3	Not sensitive to the typical variability in soil density in the study area.
FC - I_c correlation	C_{FC} = 0.0	Appropriate default value for soils in the study area.
I_c - cut off	I_c cut off = 2.6	Appropriate default value for soils in study area.
Magnitude of earthquake shaking	M_w = 5.9	Calculated effective magnitude as discussed in Section 3.2.5.
Peak Ground Acceleration (g)	0.26	500 year ARI estimate (other ARI can be considered by inspection of the PGA response curves.
Probability of Liquefaction, P_L (%)	P_L = 15%	Based on standard engineering design practice.

CPT-based analysis: Omokoroa lowland site



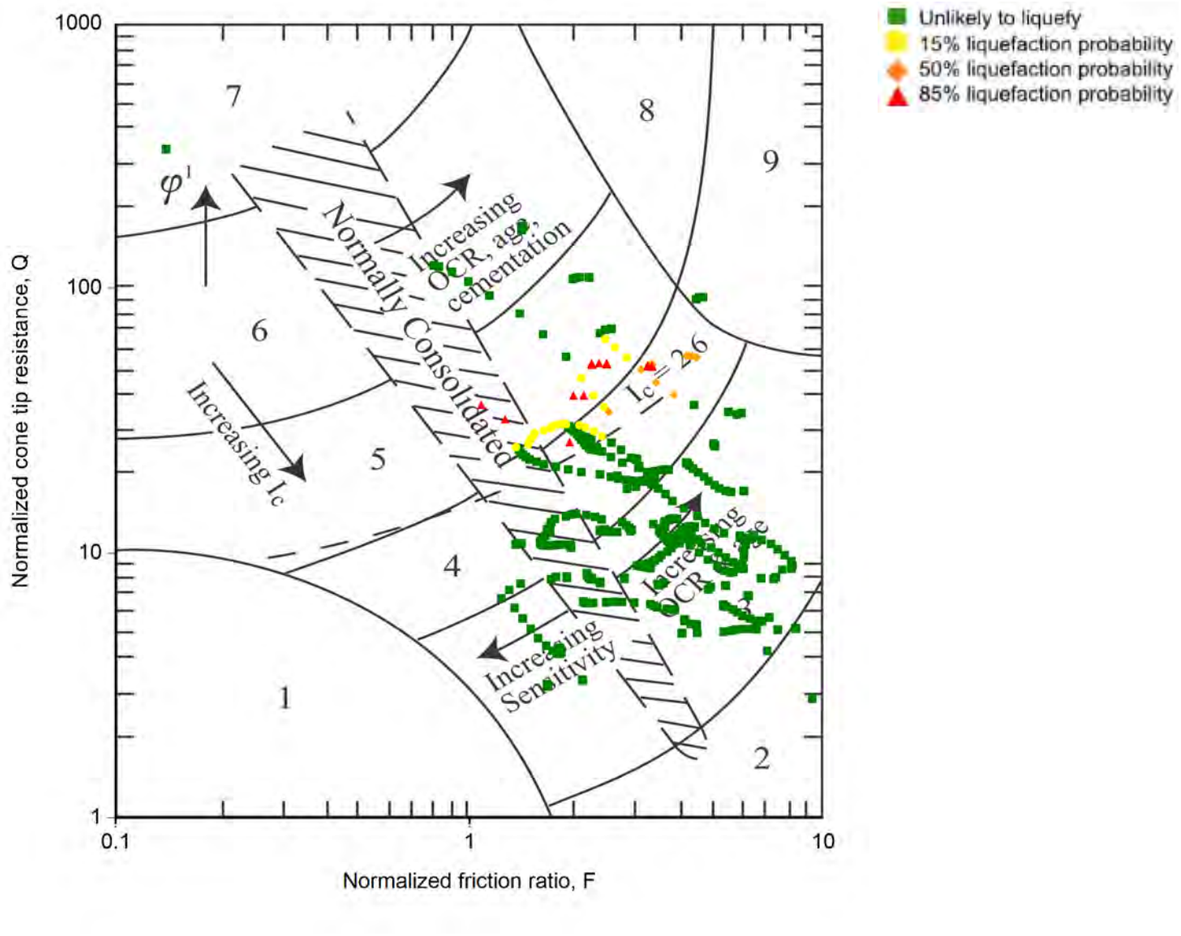
Note: Inverse filtered Qc/Fs data used (10 cm²)

	Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT		91890	19/04/2017	5.9	0.26	BI-2014	ZRB-2002	18		0	

	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPIish
OUTPUT	15%	31	1.4	3	10	1.1	2
	50%	22	1.2	1	6	1.6	1
	85%	12	0.6	0	3	4.9	0

Reviewed by:

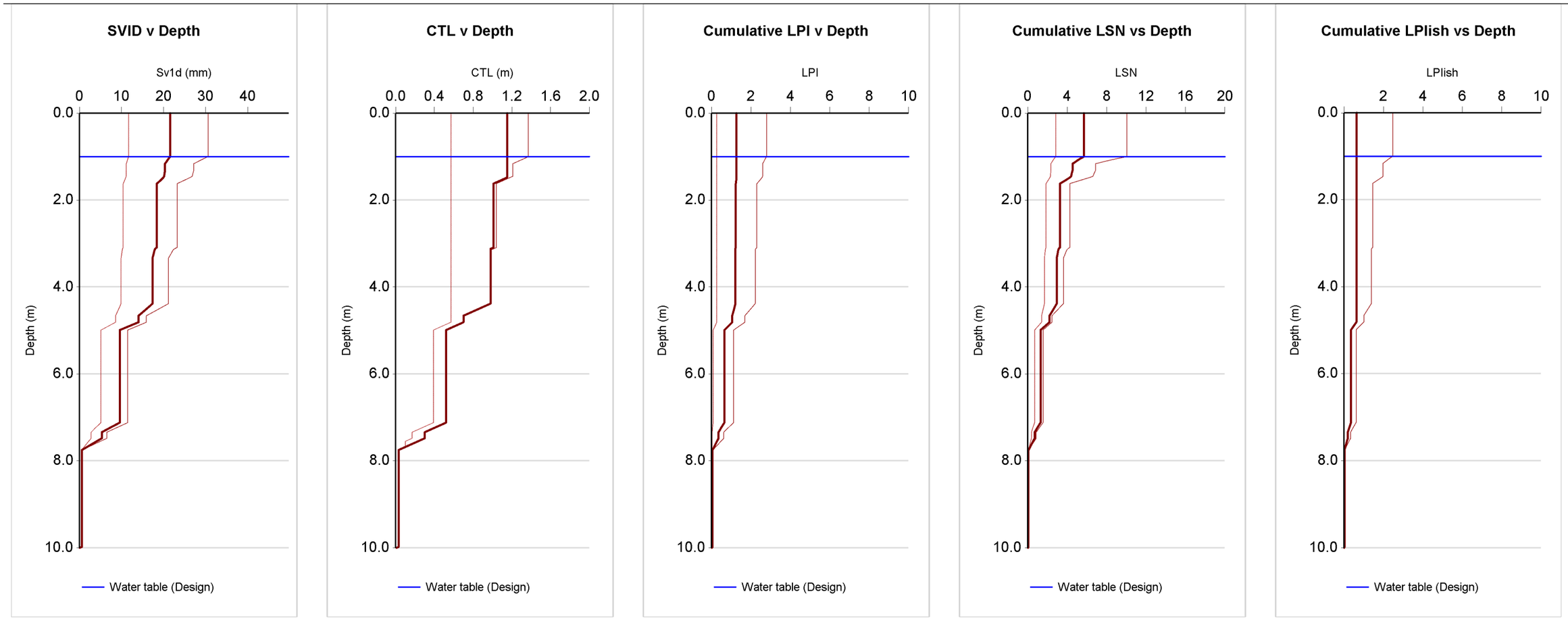
CPT Inversion	JICR
Groundwater	JICR
Susceptibility	JICR
Triggering	JICR
Consequence	JICR



1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt mixtures - clayey silt to silty clay
5. Sand mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand *
9. Very stiff, fine grained *

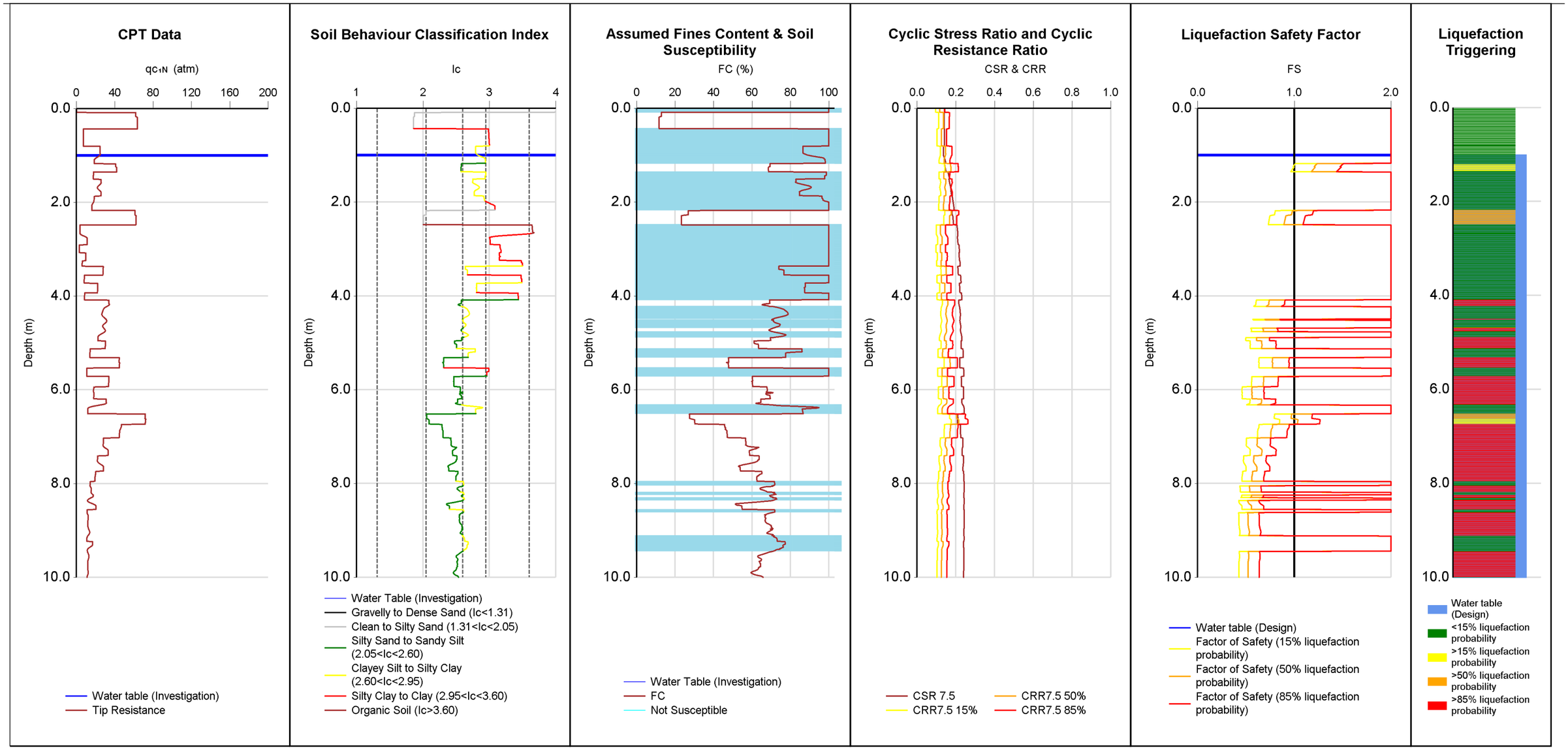
*Heavily overconsolidated or cemented

CPT-based soil behavior type classification chart by Robertson (1990)



Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	91890	19/04/2017	5.9	0.26	BI-2014	ZRB-2002	18		0	

Thicker lines represent the 50% probability of exceedence case and the thinner lines to the left and right of the thicker lines represent the 85% and 15% probability of exceedance cases respectively.



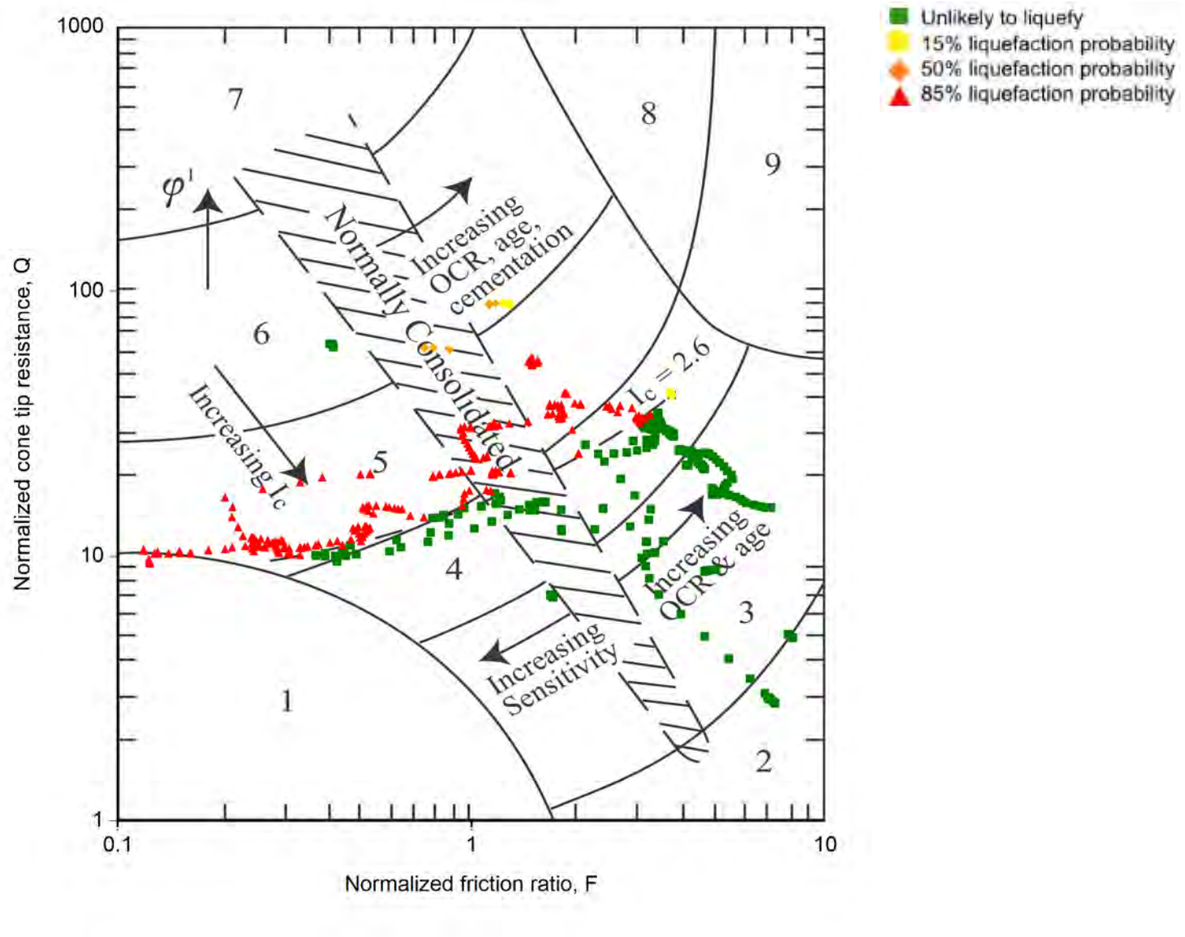
Note: Inverse filtered Qc/Fs data used (10 cm²)

	Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT		91891	19/04/2017	5.9	0.26	BI-2014	ZRB-2002	18		0	

	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPIish
OUTPUT	15%	126	4.7	13	21	1.3	8
	50%	120	4.4	10	18	2.3	6
	85%	109	4	6	16	4.2	2

Reviewed by:

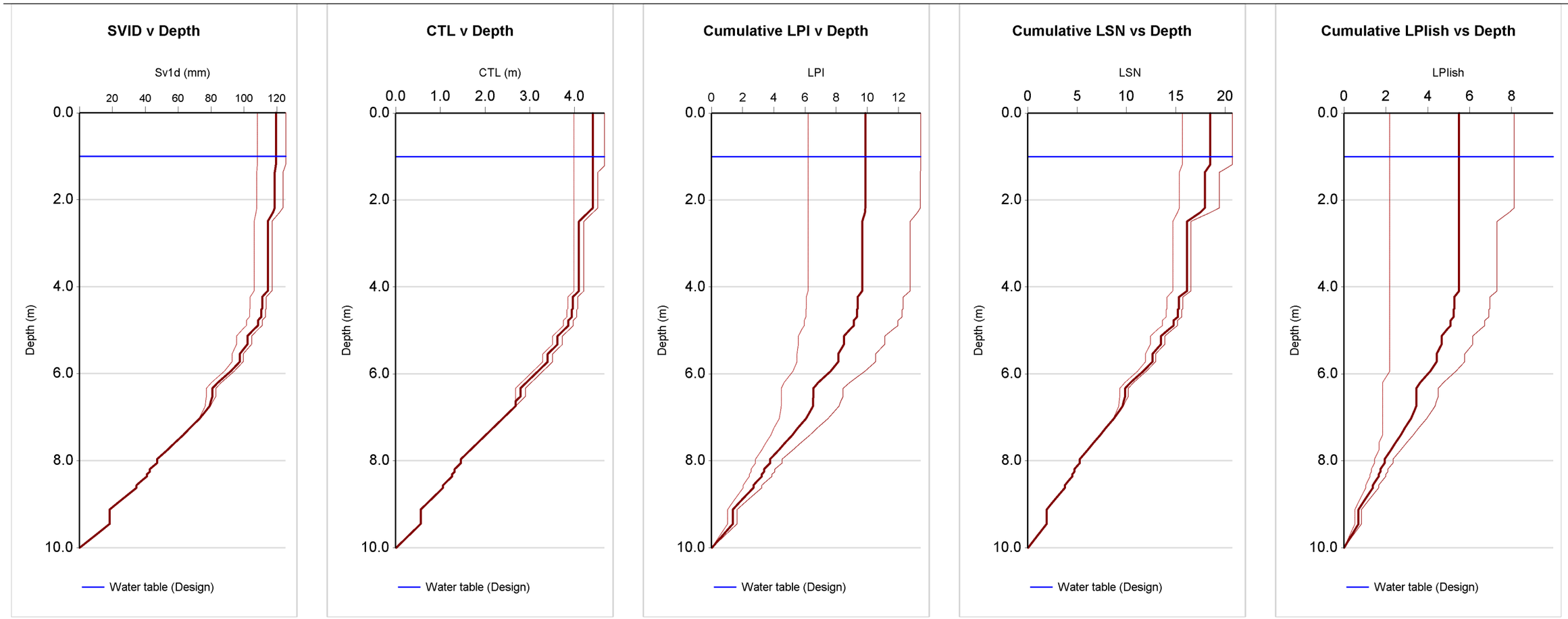
CPT Inversion	JICR
Groundwater	JICR
Susceptibility	JICR
Triggering	JICR
Consequence	JICR



1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt mixtures - clayey silt to silty clay
5. Sand mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand *
9. Very stiff, fine grained *

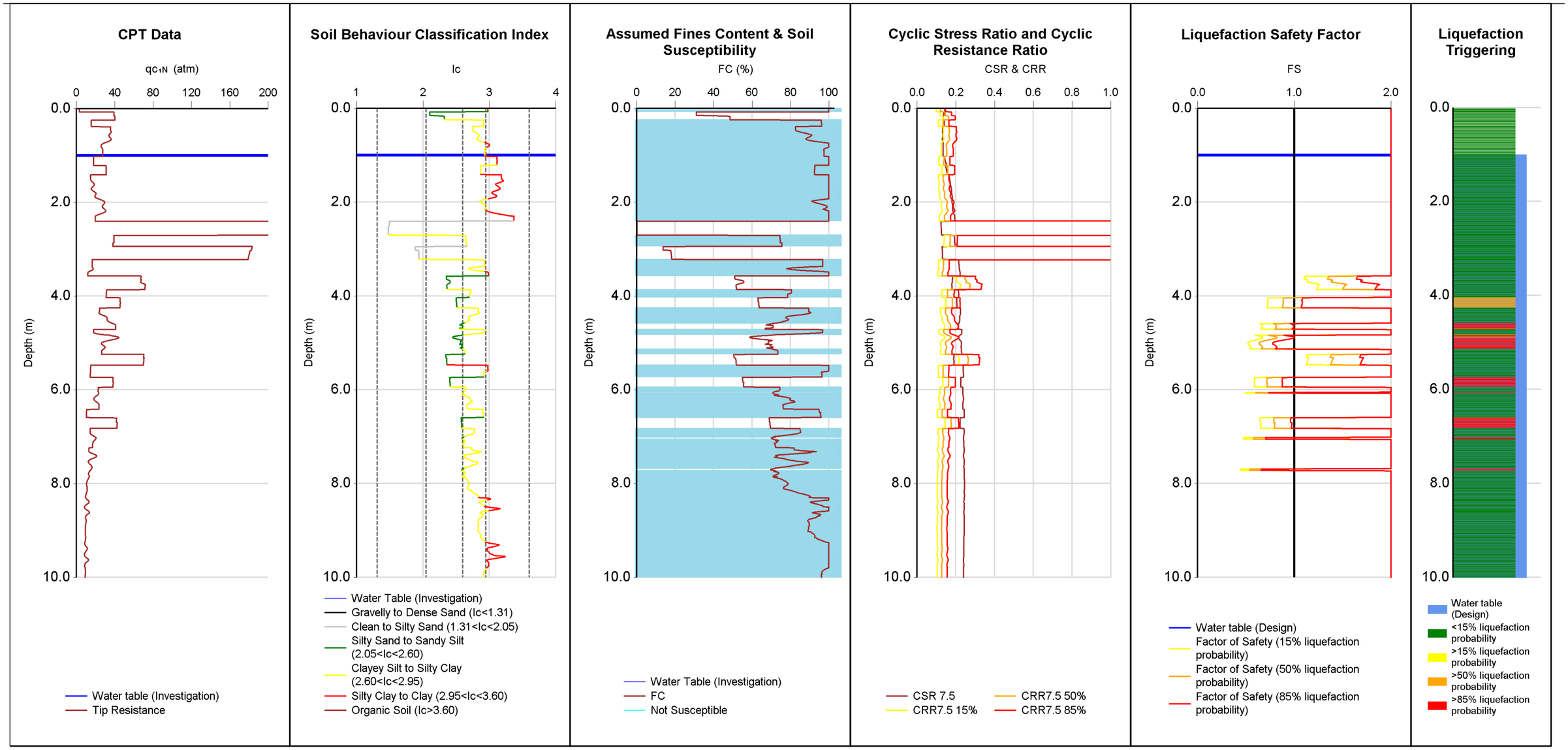
*Heavily overconsolidated or cemented

CPT-based soil behavior type classification chart by Robertson (1990)



Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	91891	19/04/2017	5.9	0.26	BI-2014	ZRB-2002	18		0	

Thicker lines represent the 50% probability of exceedence case and the thinner lines to the left and right of the thicker lines represent the 85% and 15% probability of exceedance cases respectively.



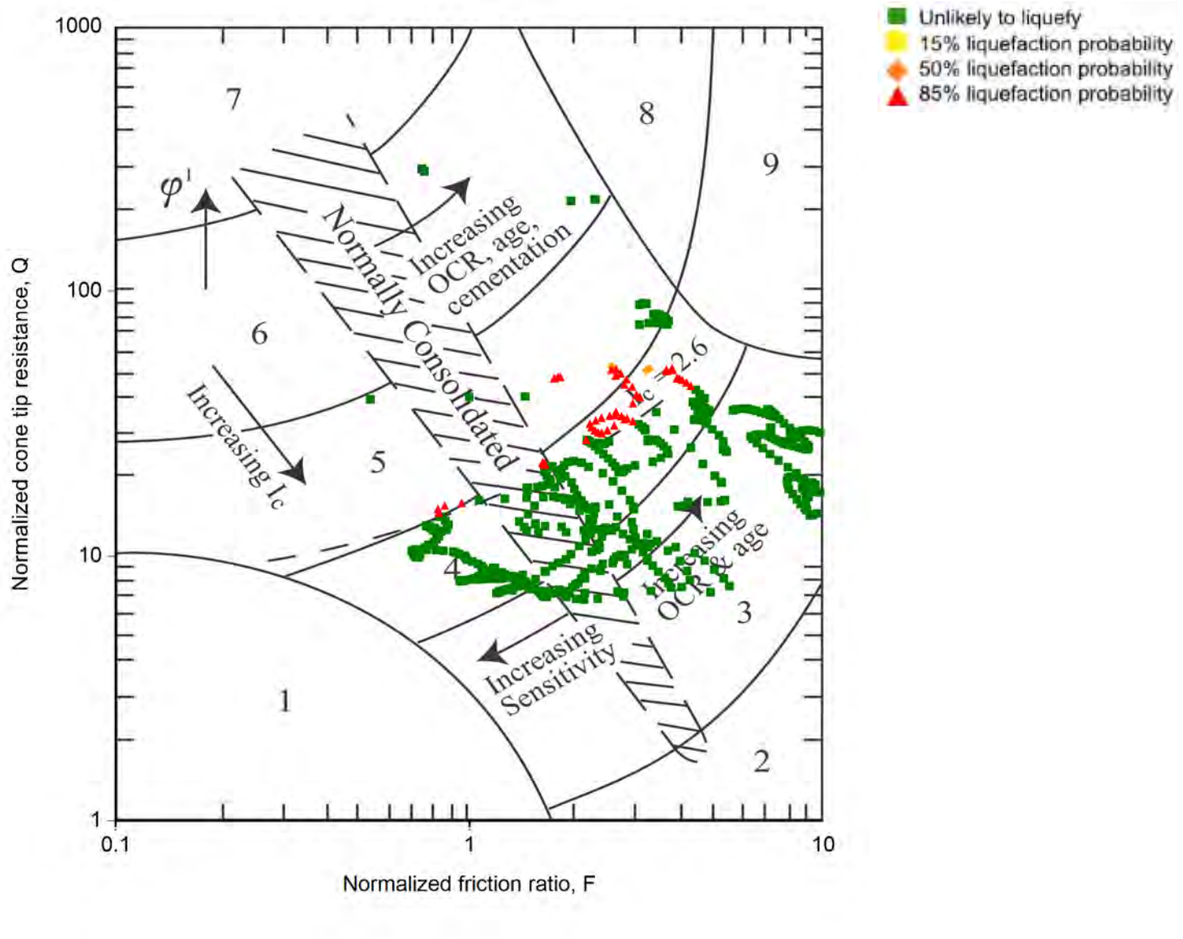
Note: Inverse filtered Qc/Fs data used (10 cm²)

	Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT		91892	19/04/2017	5.9	0.26	BI-2014	ZRB-2002	18		0	

	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPIish
OUTPUT	15%	30	1.2	3	6	4.1	2
	50%	26	1.2	2	5	4.1	1
	85%	18	1	1	3	4.7	0

Reviewed by:

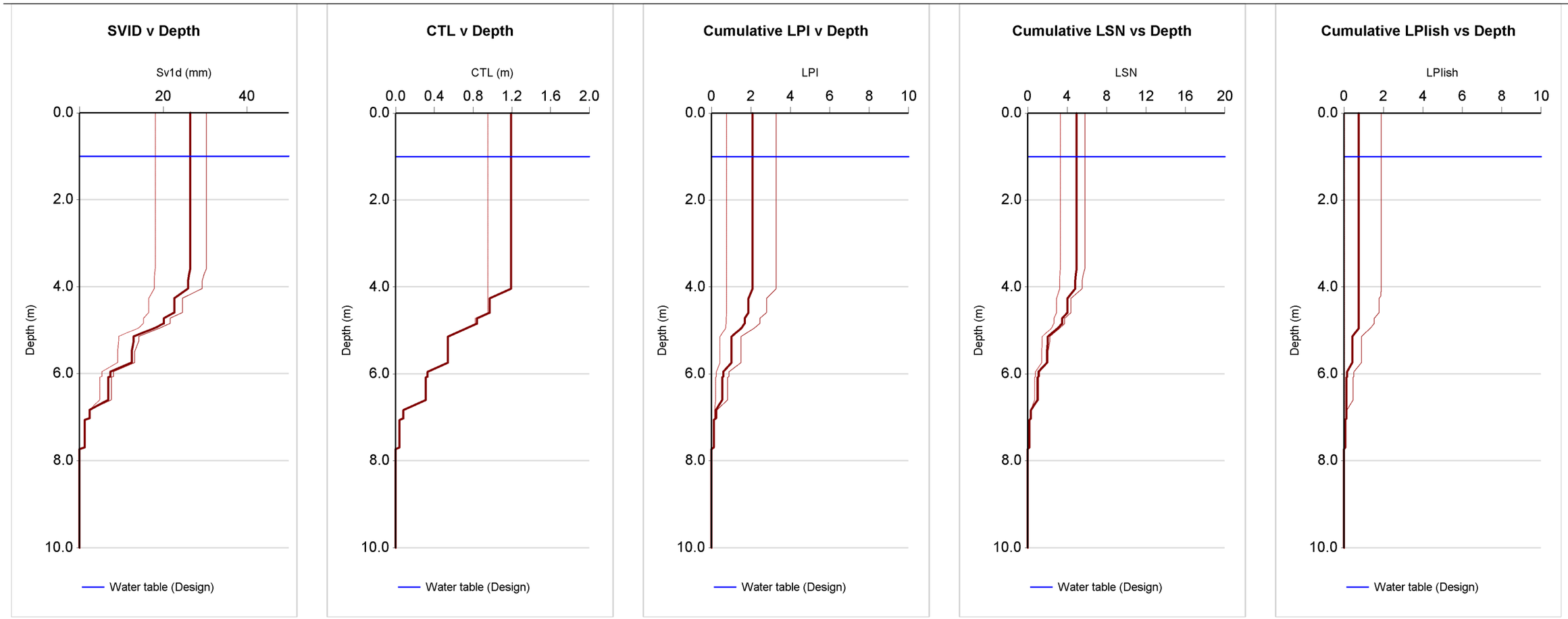
CPT Inversion	JICR
Groundwater	JICR
Susceptibility	JICR
Triggering	JICR
Consequence	JICR



1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt mixtures - clayey silt to silty clay
5. Sand mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand *
9. Very stiff, fine grained *

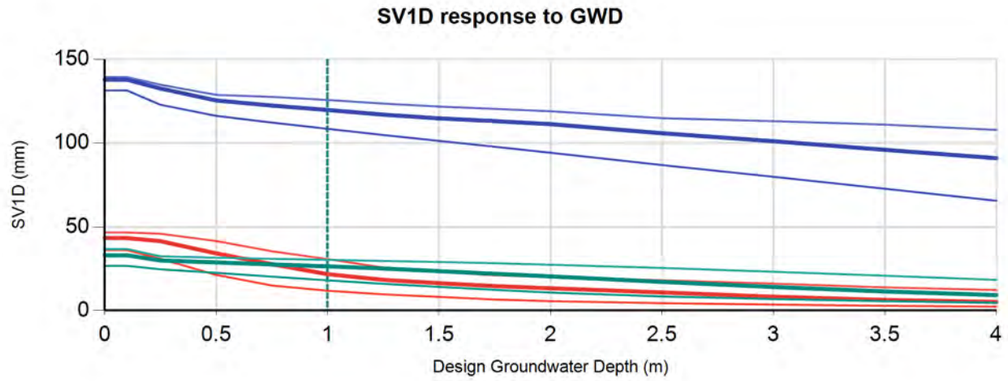
*Heavily overconsolidated or cemented

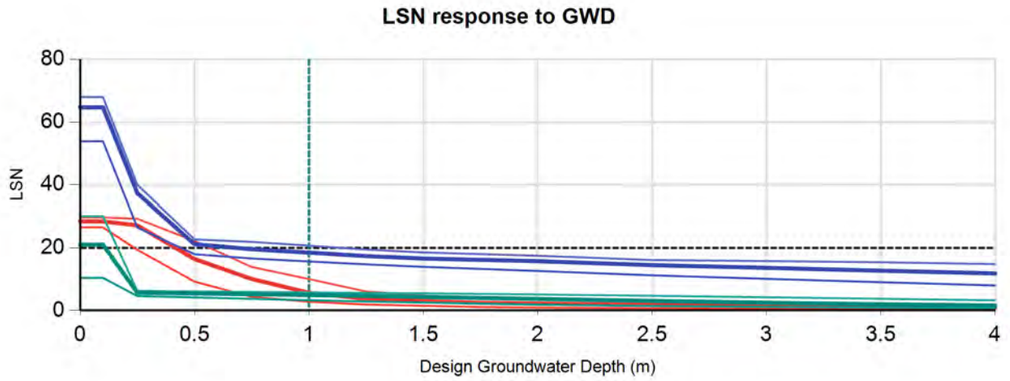
CPT-based soil behavior type classification chart by Robertson (1990)

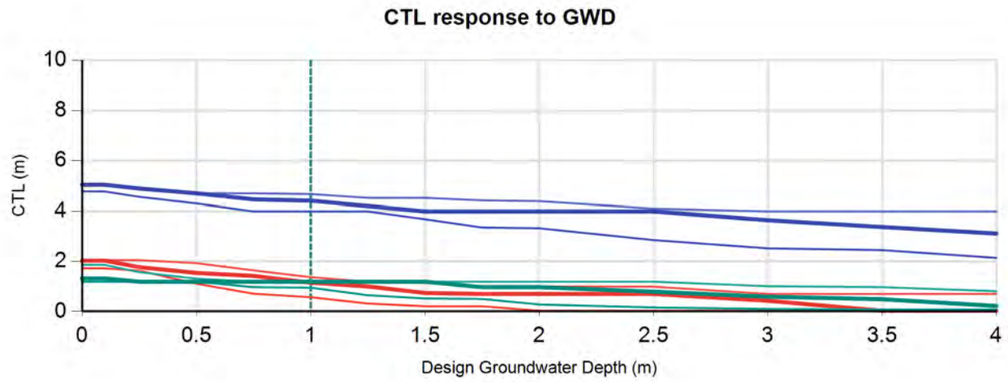


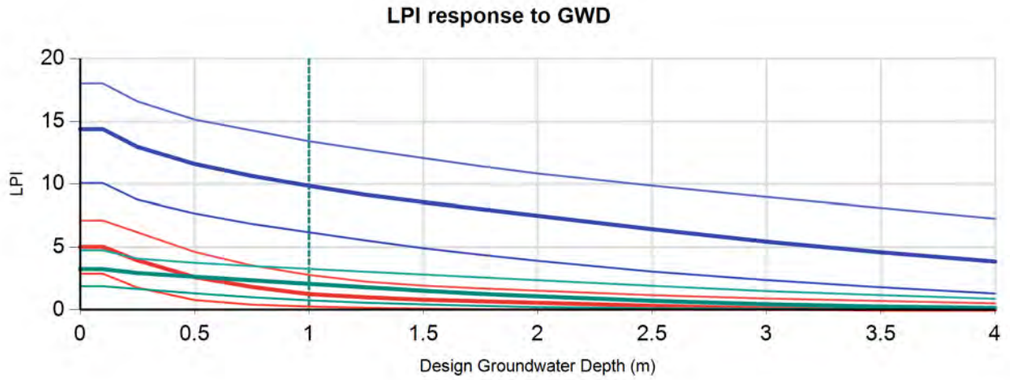
Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	91892	19/04/2017	5.9	0.26	BI-2014	ZRB-2002	18		0	

Thicker lines represent the 50% probability of exceedence case and the thinner lines to the left and right of the thicker lines represent the 85% and 15% probability of exceedance cases respectively.



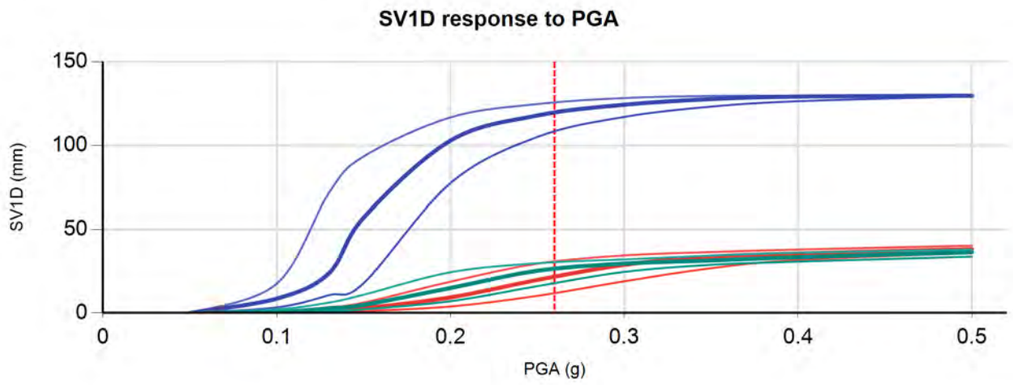


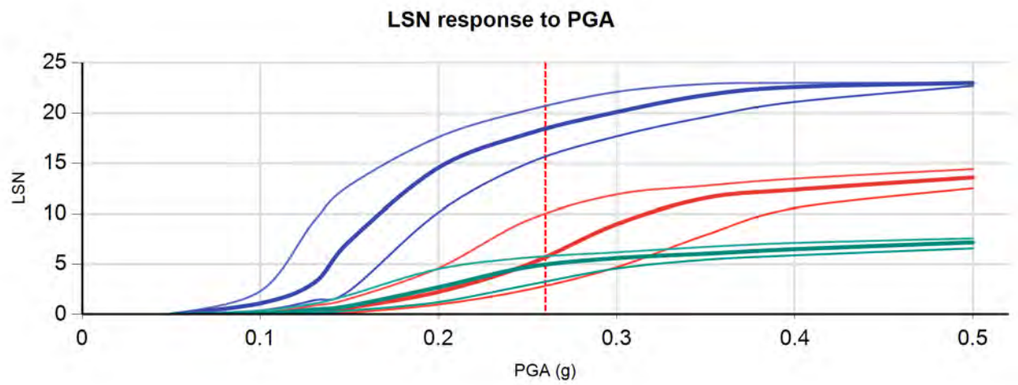


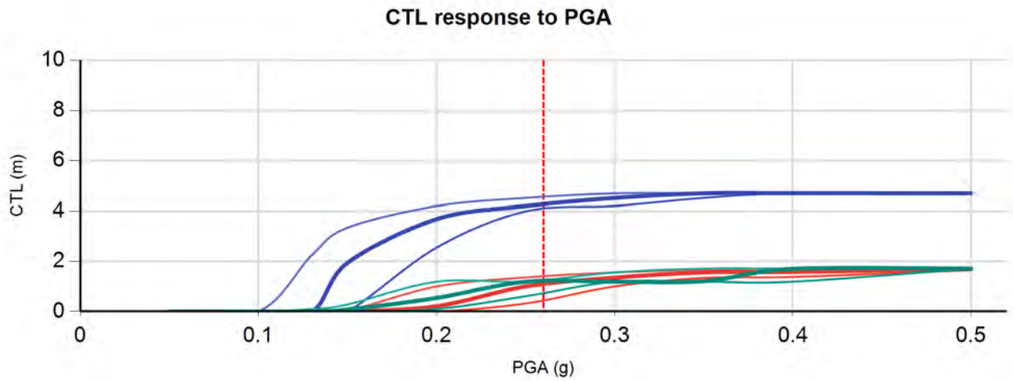


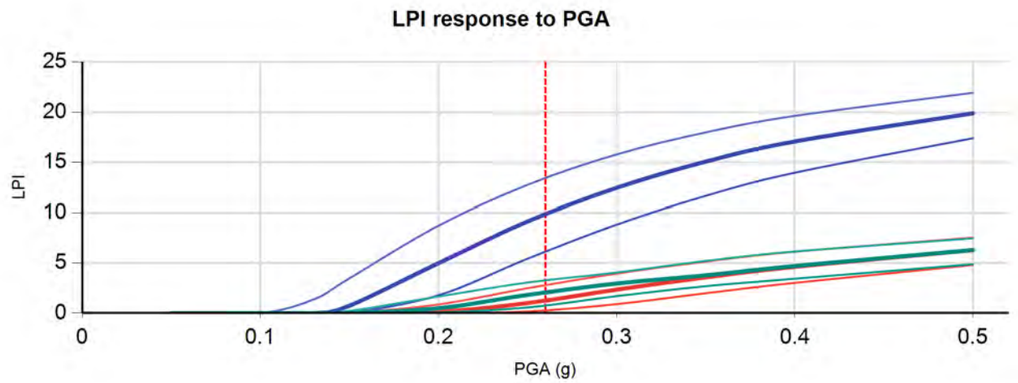
Vertical dotted line/s indicate design groundwater depth at the CPT locations.

	Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	CFC	γ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
		91890	19/04/2017	5.9	0.26	BI-2014	ZRB-2002		18		0	
		91891	19/04/2017	5.9	0.26	BI-2014	ZRB-2002		18		0	
		91892	19/04/2017	5.9	0.26	BI-2014	ZRB-2002		18		0	
	Thicker lines represent the 50% probability of exceedence case and the thinner lines to the bottom and top of the thicker lines represent the 85% and 15% probability of exceedance cases respectively.											





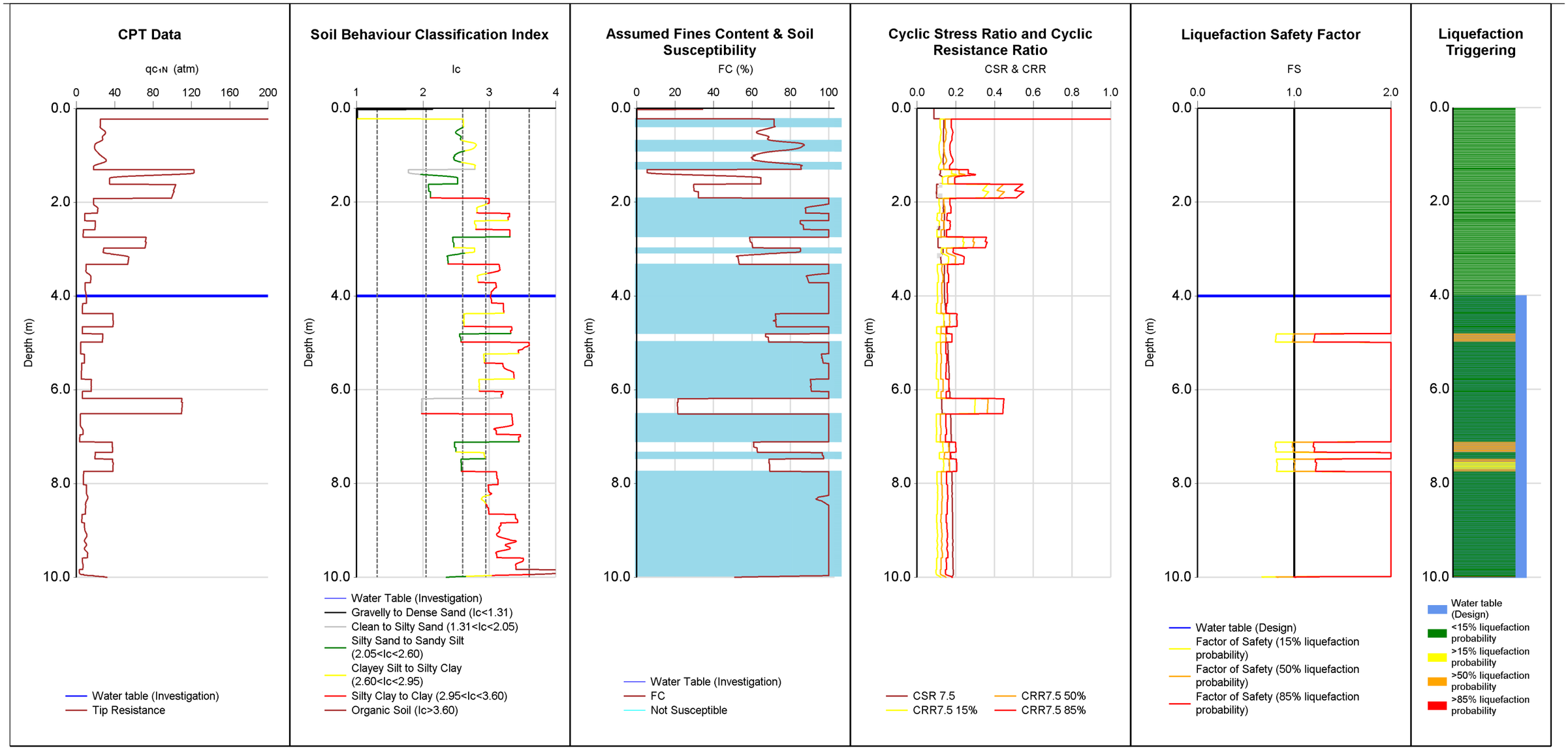




Vertical dotted line/s indicate user specified PGA at the CPT locations. (actual PGA)

	Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	CFC	γ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
		91890	19/04/2017	5.9	0.26	BI-2014	ZRB-2002		18		0	
		91891	19/04/2017	5.9	0.26	BI-2014	ZRB-2002		18		0	
		91892	19/04/2017	5.9	0.26	BI-2014	ZRB-2002		18		0	
	Thicker lines represent the 50% probability of exceedence case and the thinner lines to the bottom and top of the thicker lines represent the 85% and 15% probability of exceedance cases respectively.											

CPT-based analysis: Omokoroa elevated site



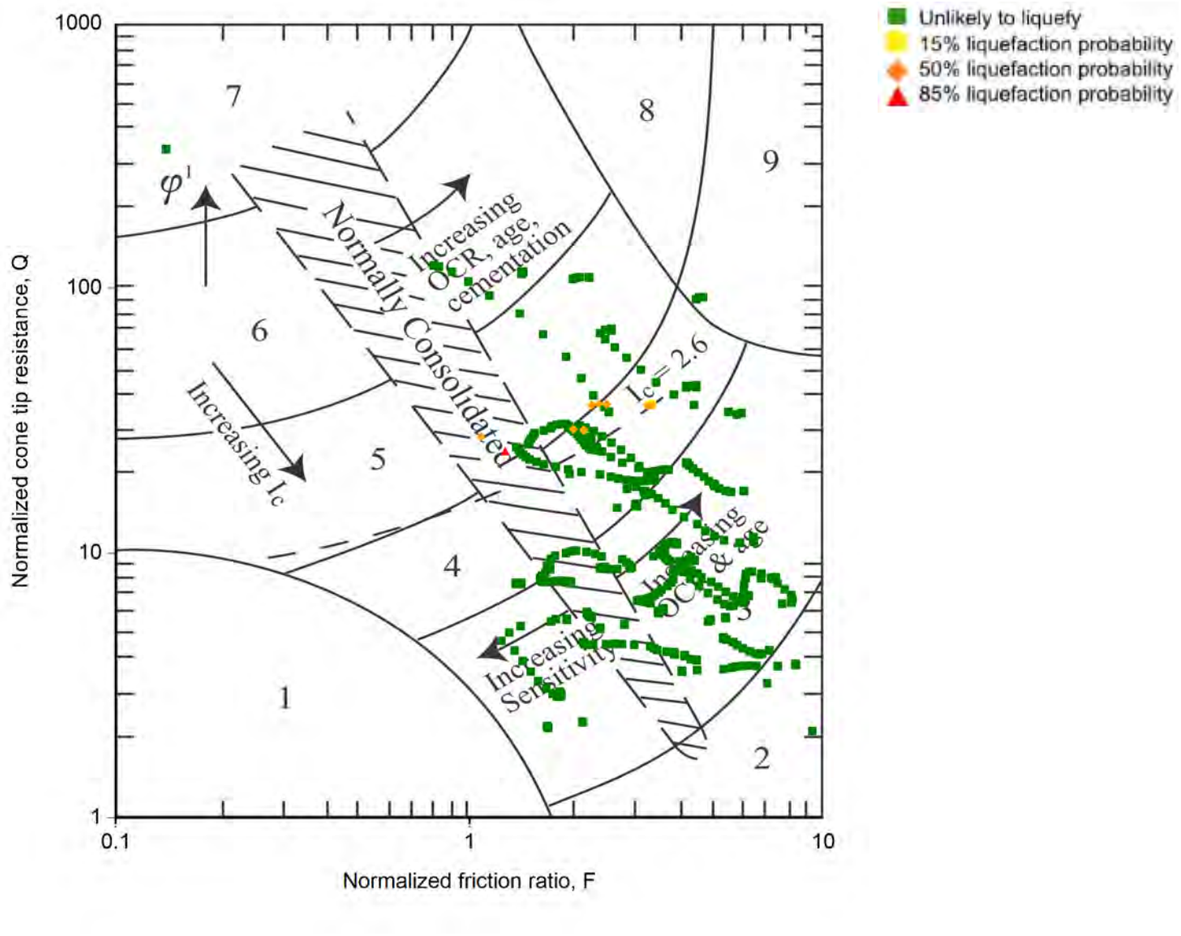
Note: Inverse filtered Qc/Fs data used (10 cm²)

	Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT		91890	19/04/2017	5.9	0.26	BI-2014	ZRB-2002	18		0	

	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPIish
OUTPUT	15%	15	0.7	1	2	4.9	0
	50%	7	0.5	0	1	4.9	0
	85%	3	0	0	0	10	0

Reviewed by:

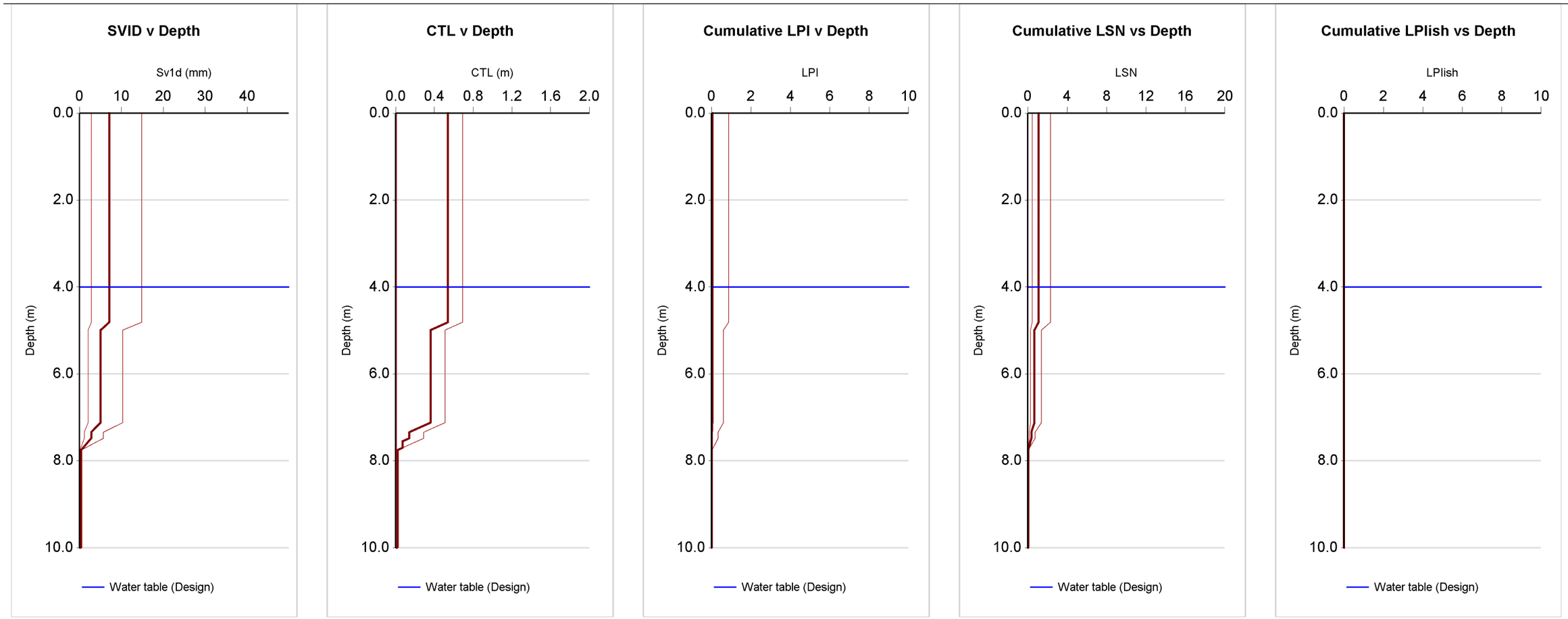
CPT Inversion	JICR
Groundwater	JICR
Susceptibility	JICR
Triggering	JICR
Consequence	JICR



1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt mixtures - clayey silt to silty clay
5. Sand mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand *
9. Very stiff, fine grained *

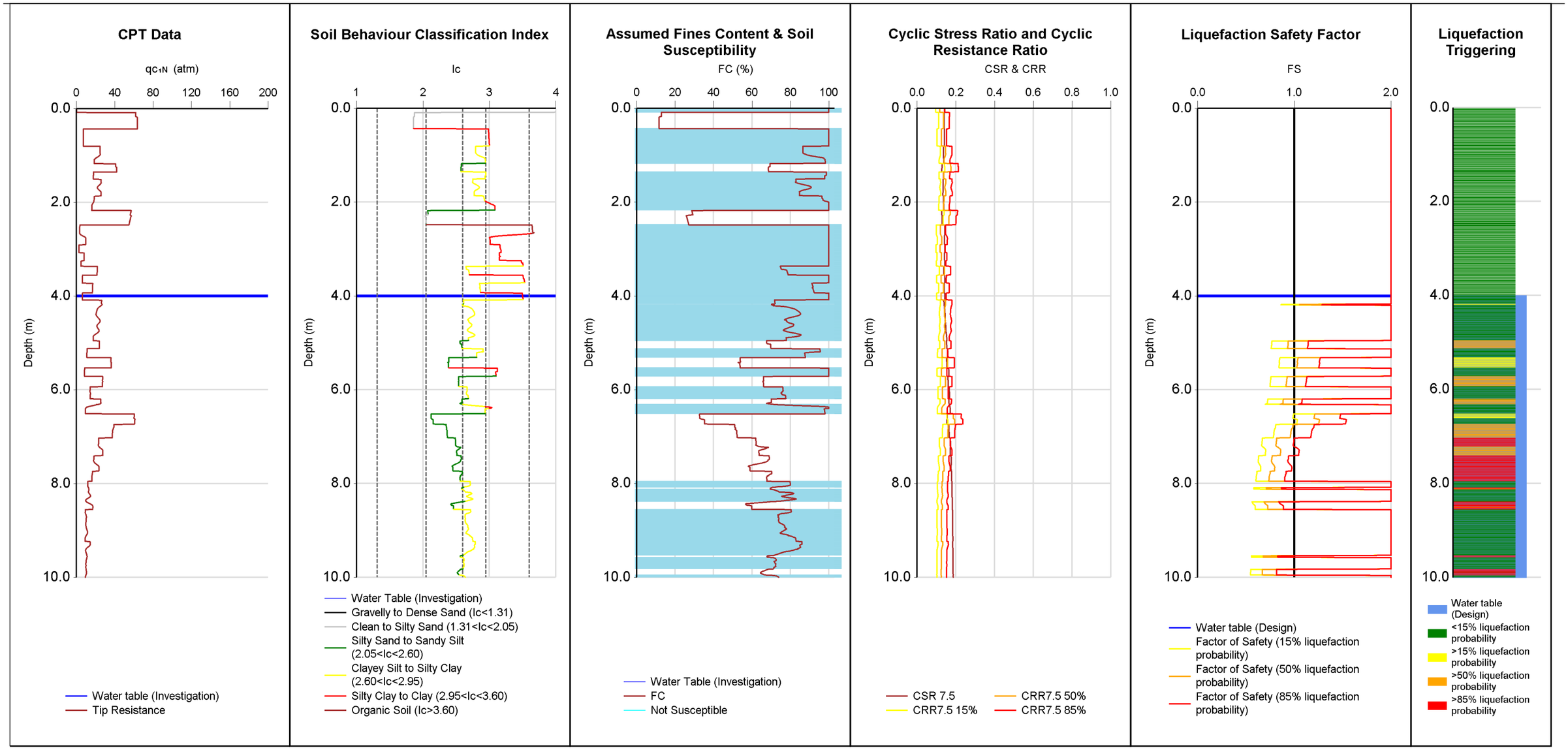
*Heavily overconsolidated or cemented

CPT-based soil behavior type classification chart by Robertson (1990)



Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	91890	19/04/2017	5.9	0.26	BI-2014	ZRB-2002	18		0	

Thicker lines represent the 50% probability of exceedence case and the thinner lines to the left and right of the thicker lines represent the 85% and 15% probability of exceedance cases respectively.



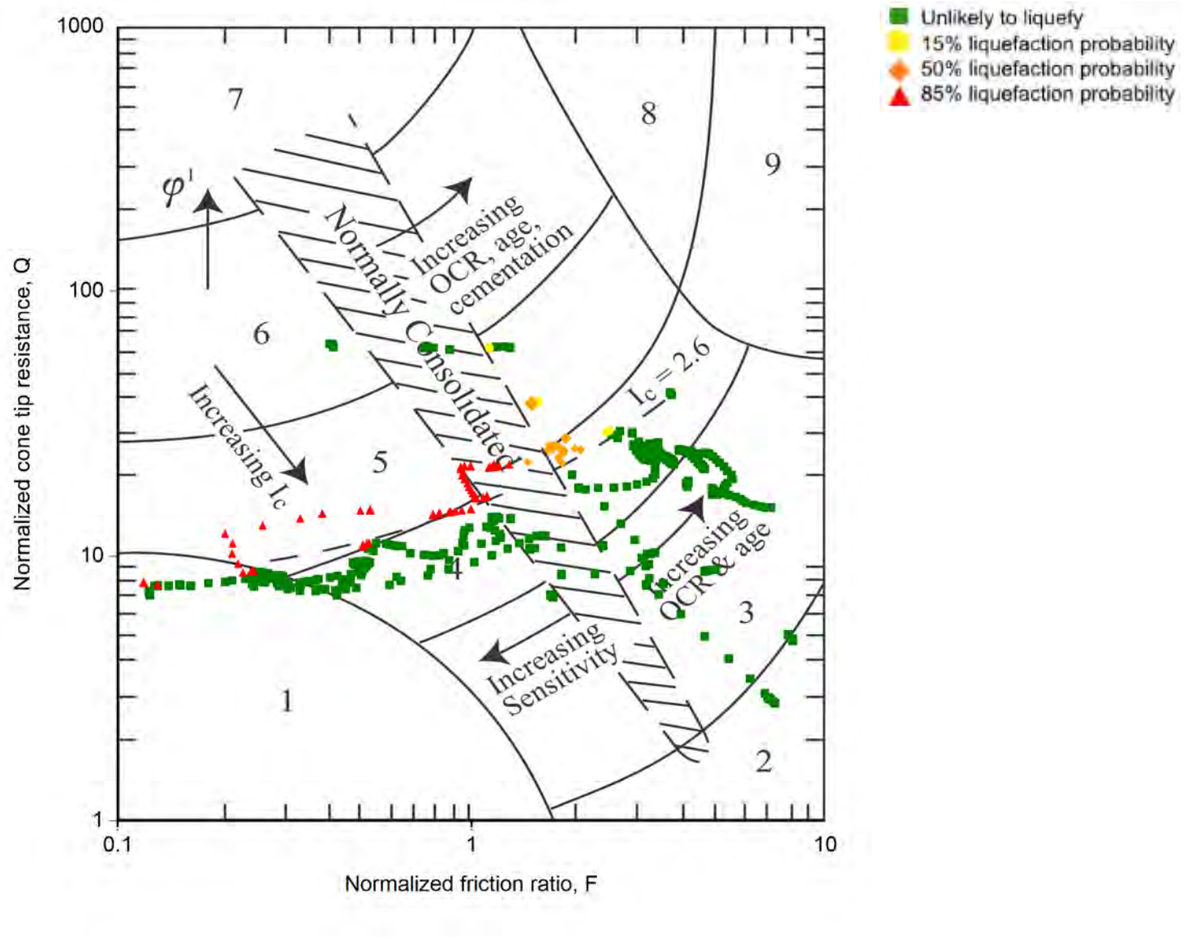
Note: Inverse filtered Qc/Fs data used (10 cm²)

	Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT		91891	19/04/2017	5.9	0.26	BI-2014	ZRB-2002	18		0	

	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPIish
OUTPUT	15%	66	2.4	5	10	5	2
	50%	54	2.1	2	8	5	0
	85%	33	1.1	1	4	7.1	0

Reviewed by:

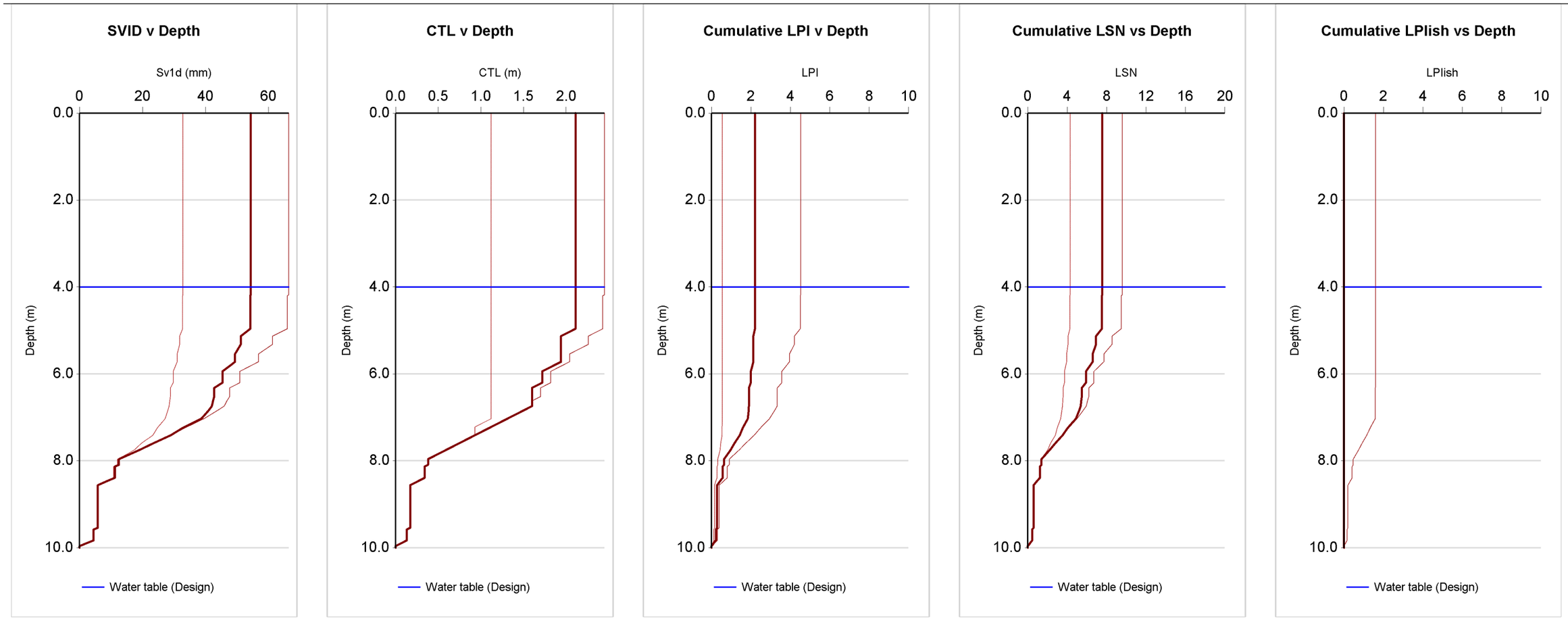
CPT Inversion	JICR
Groundwater	JICR
Susceptibility	JICR
Triggering	JICR
Consequence	JICR



1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt mixtures - clayey silt to silty clay
5. Sand mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand *
9. Very stiff, fine grained *

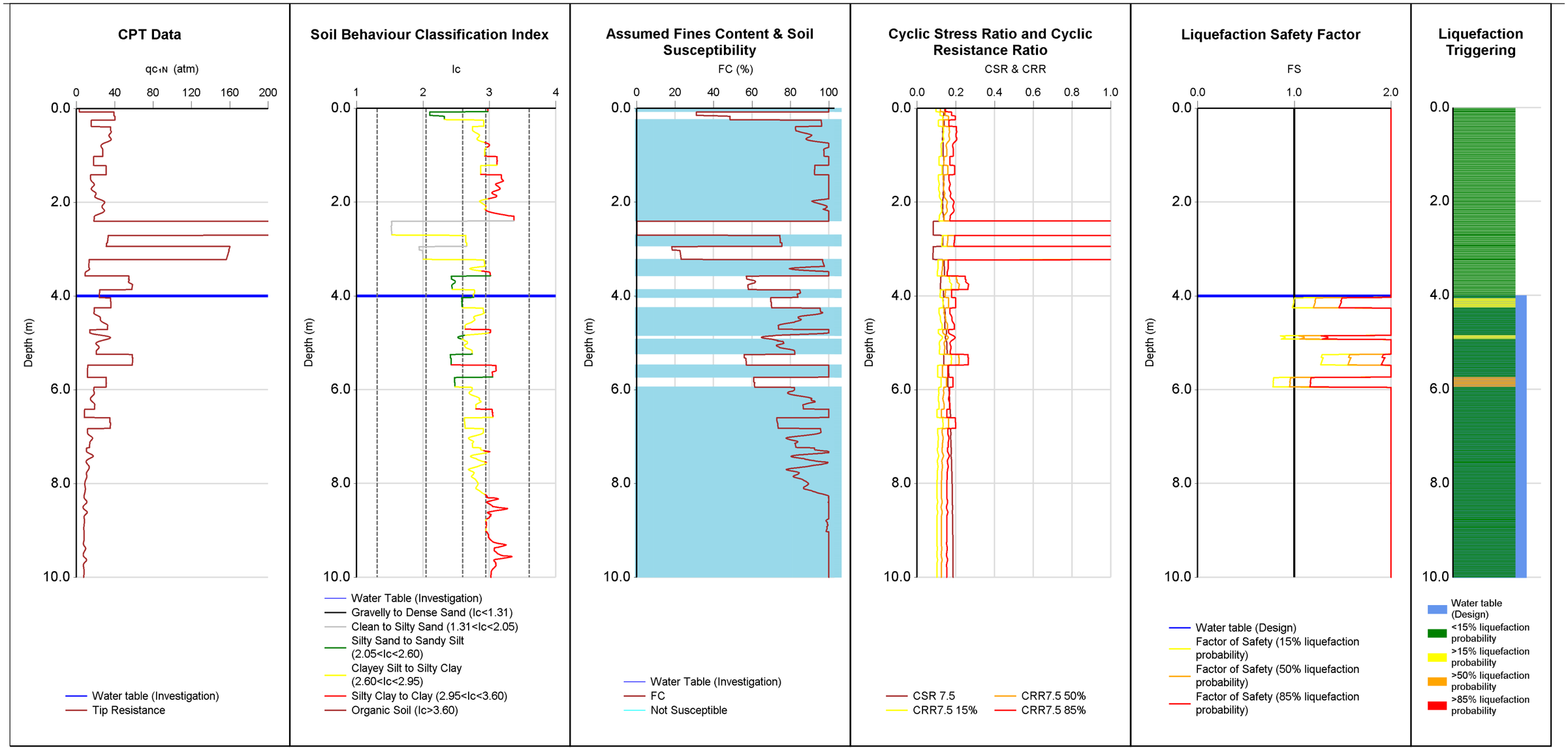
*Heavily overconsolidated or cemented

CPT-based soil behavior type classification chart by Robertson (1990)



Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	91891	19/04/2017	5.9	0.26	BI-2014	ZRB-2002	18		0	

Thicker lines represent the 50% probability of exceedence case and the thinner lines to the left and right of the thicker lines represent the 85% and 15% probability of exceedance cases respectively.



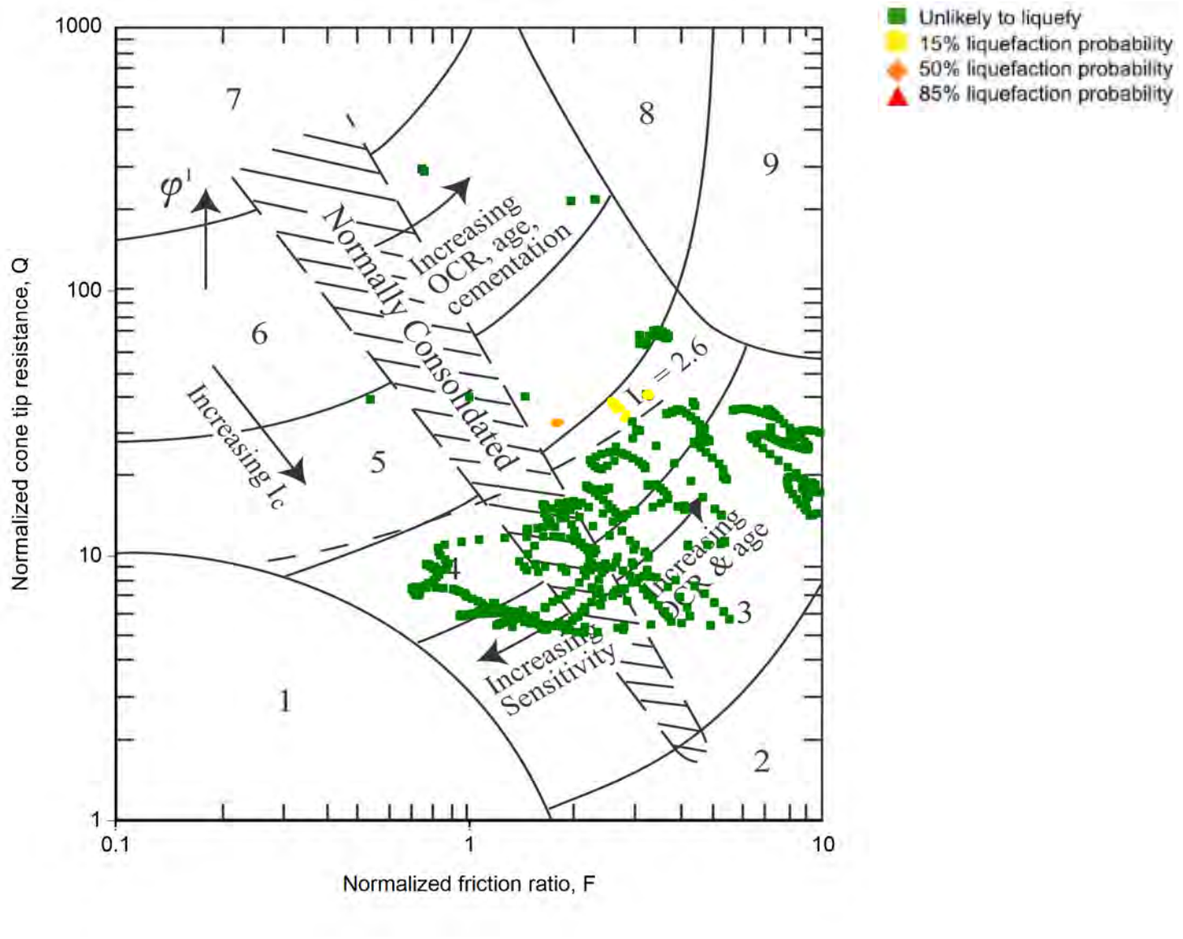
Note: Inverse filtered Qc/Fs data used (10 cm²)

	Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT		91892	19/04/2017	5.9	0.26	BI-2014	ZRB-2002	18		0	

	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPIish
OUTPUT	15%	9	0.5	0	2	4.2	0
	50%	5	0.2	0	1	5.8	0
	85%	2	0	0	0	10	0

Reviewed by:

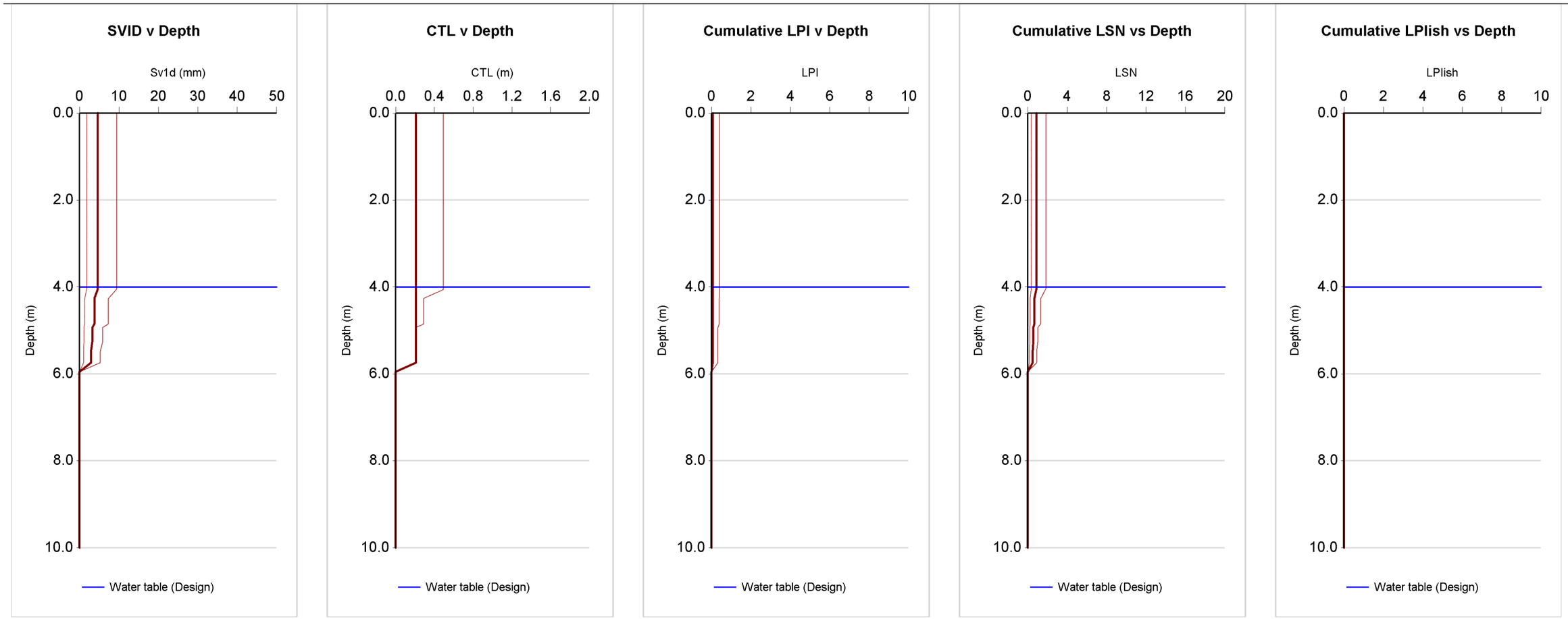
CPT Inversion	JICR
Groundwater	JICR
Susceptibility	JICR
Triggering	JICR
Consequence	JICR



1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt mixtures - clayey silt to silty clay
5. Sand mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand *
9. Very stiff, fine grained *

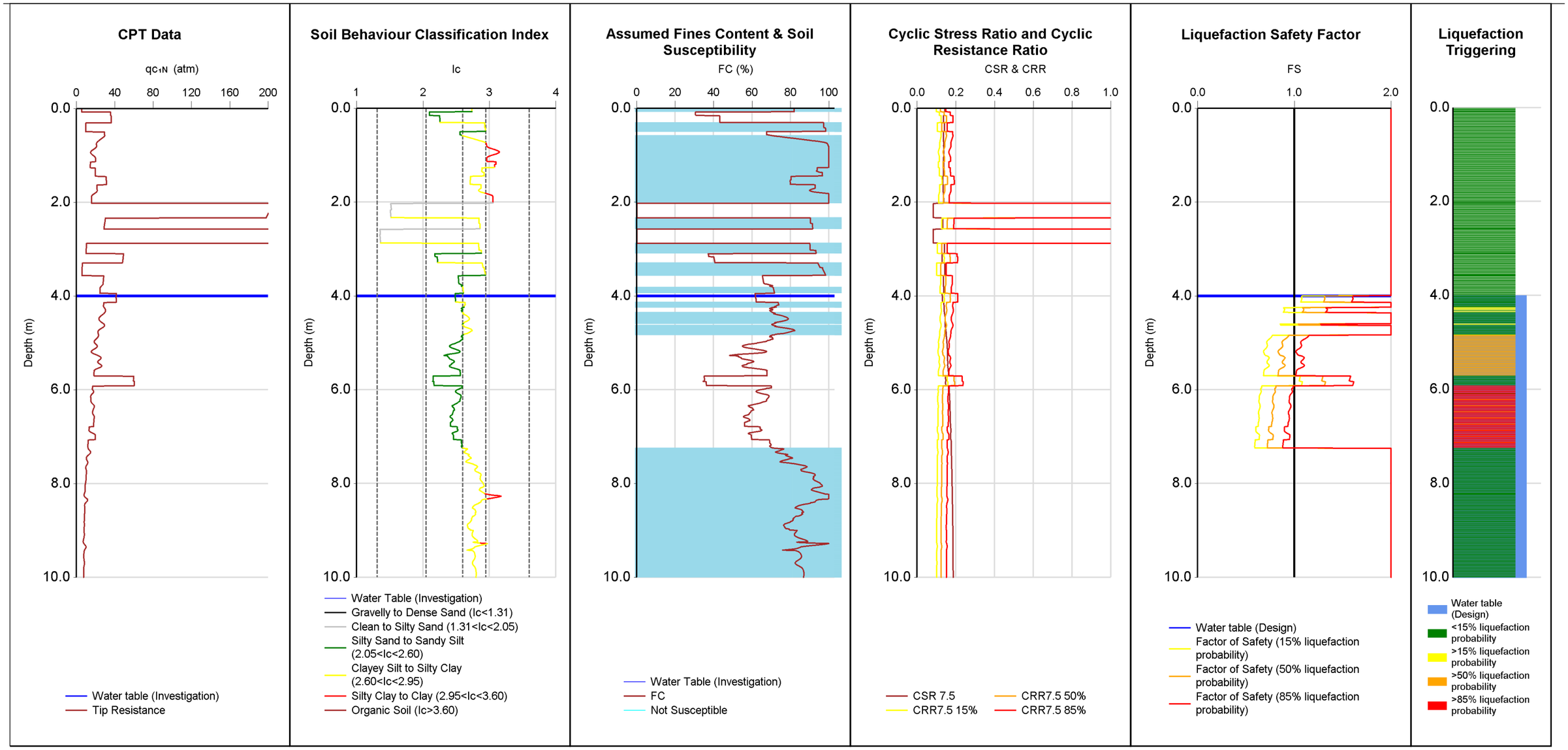
*Heavily overconsolidated or cemented

CPT-based soil behavior type classification chart by Robertson (1990)



Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	91892	19/04/2017	5.9	0.26	BI-2014	ZRB-2002	18		0	

Thicker lines represent the 50% probability of exceedence case and the thinner lines to the left and right of the thicker lines represent the 85% and 15% probability of exceedance cases respectively.



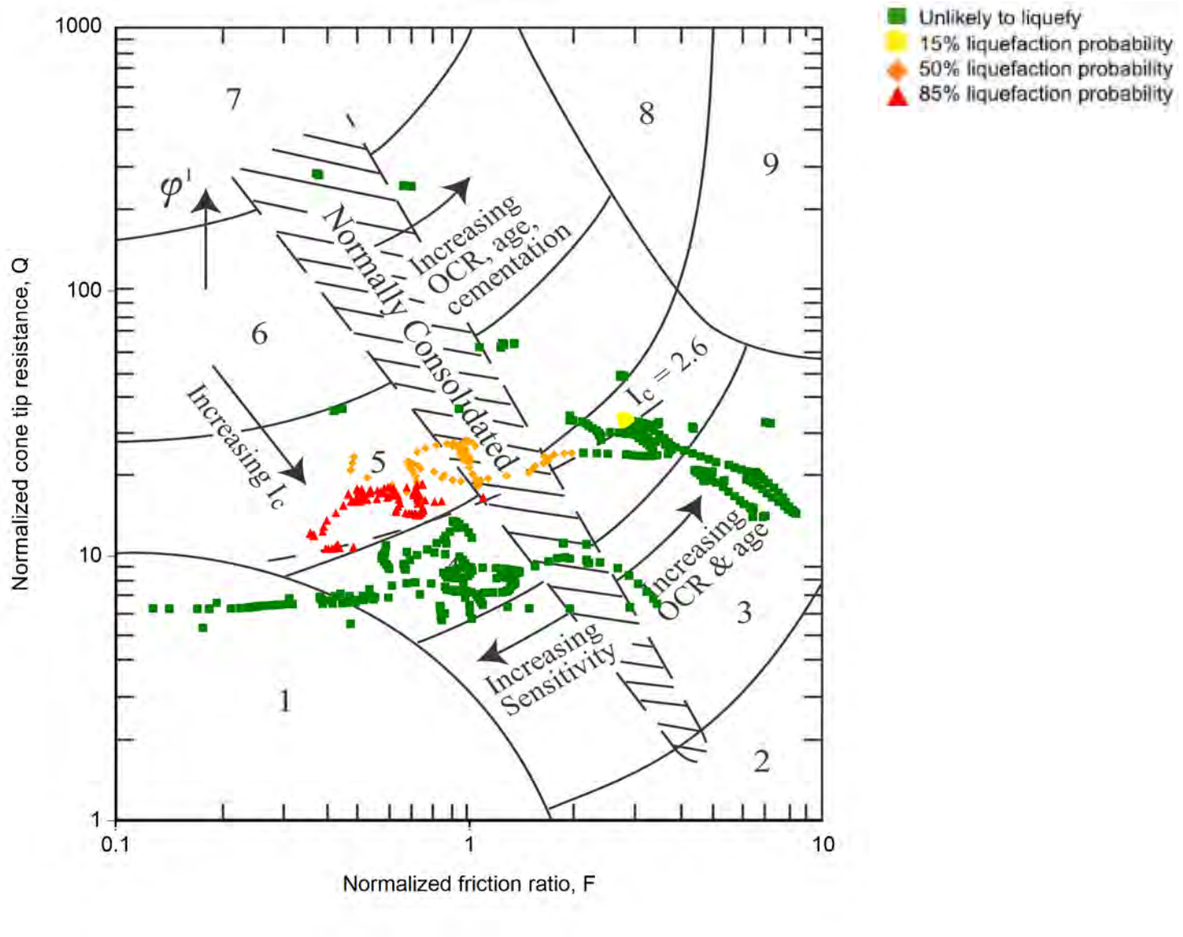
Note: Inverse filtered Qc/Fs data used (10 cm²)

	Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT		91893	19/04/2017	5.9	0.26	BI-2014	ZRB-2002	18		0	

	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPIish
OUTPUT	15%	72	2.3	5	12	4.3	2
	50%	66	2.2	3	11	4.9	0
	85%	36	1.3	1	6	6	0

Reviewed by:

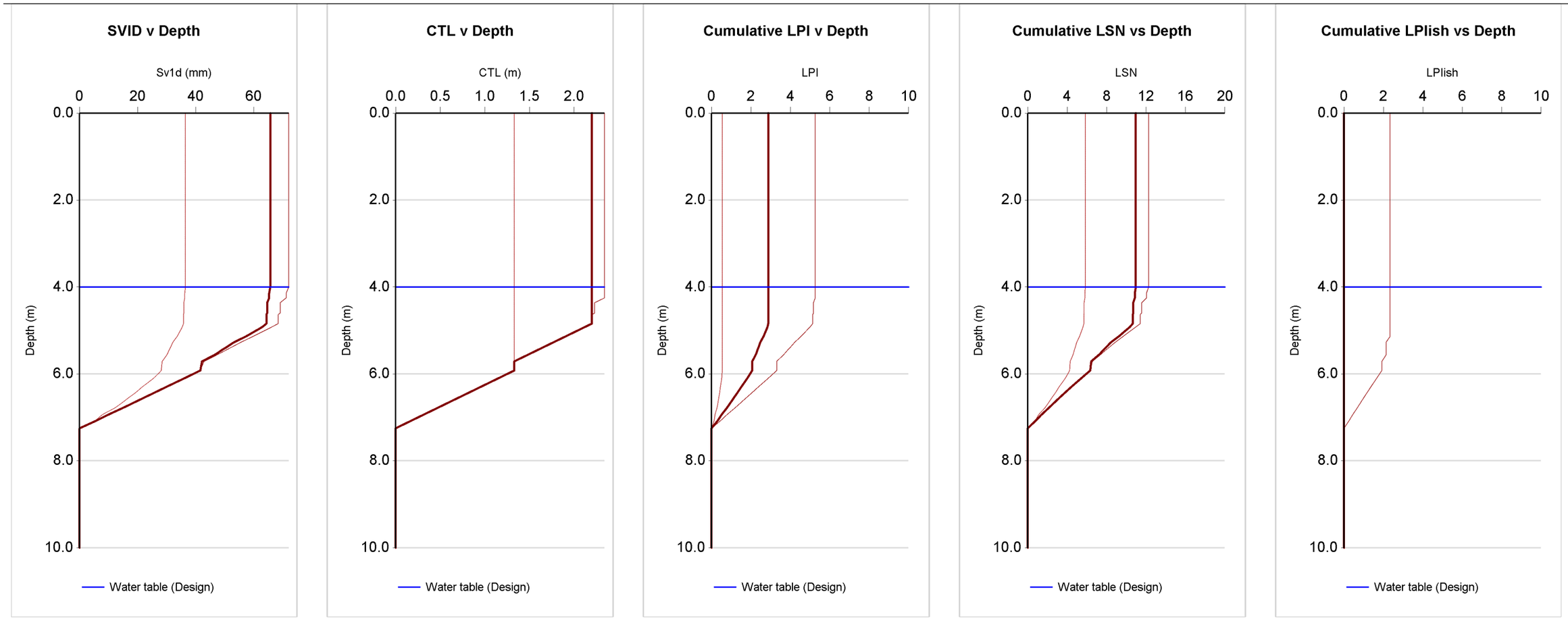
CPT Inversion	JICR
Groundwater	JICR
Susceptibility	JICR
Triggering	JICR
Consequence	JICR



1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt mixtures - clayey silt to silty clay
5. Sand mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand *
9. Very stiff, fine grained *

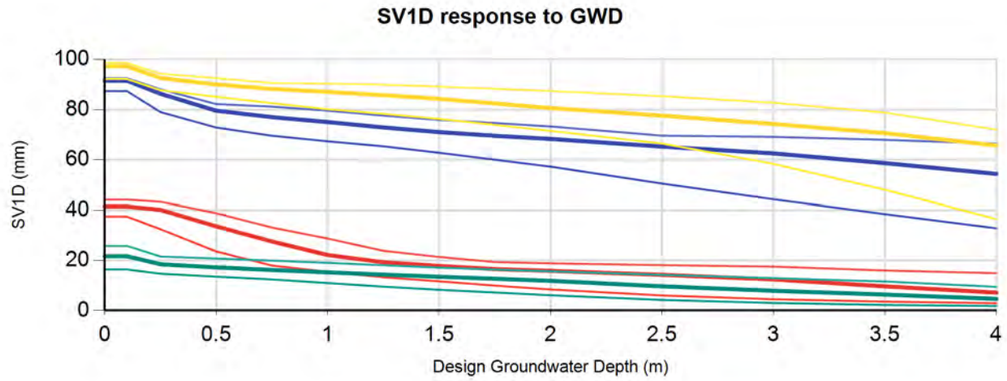
*Heavily overconsolidated or cemented

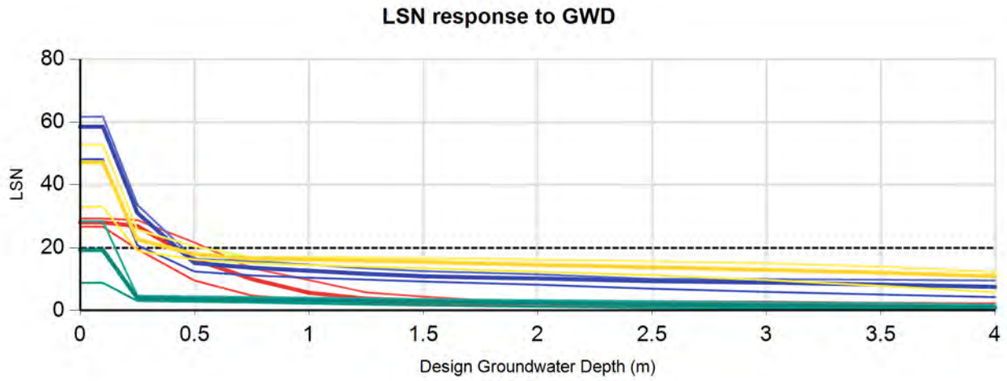
CPT-based soil behavior type classification chart by Robertson (1990)

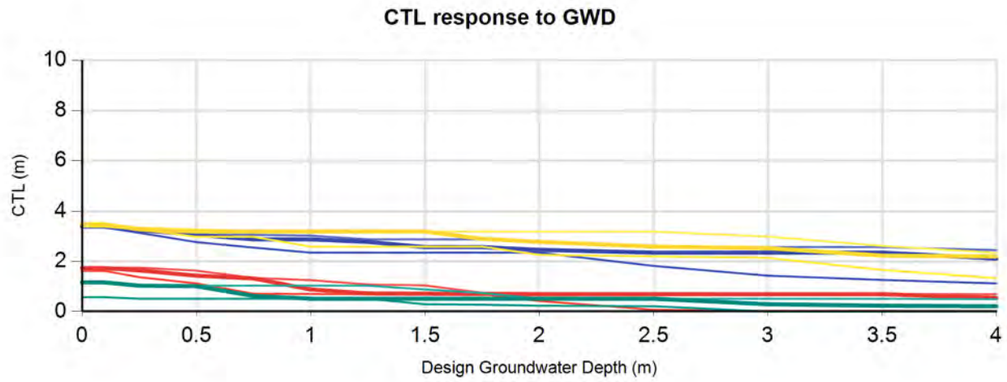


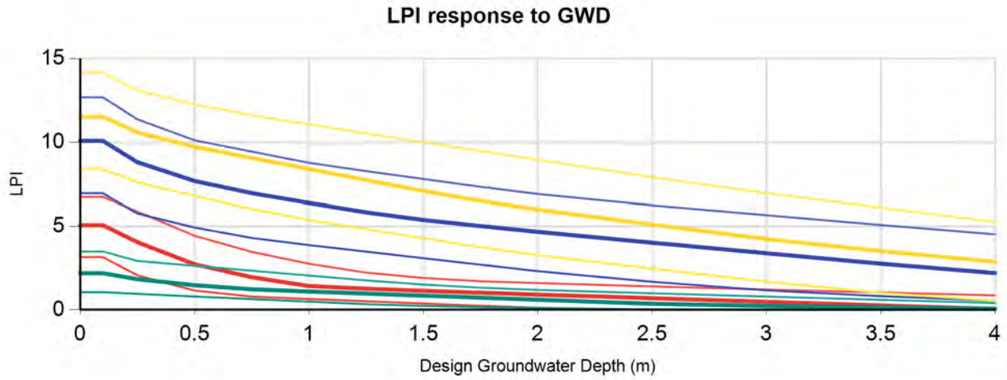
Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	91893	19/04/2017	5.9	0.26	BI-2014	ZRB-2002	18		0	

Thicker lines represent the 50% probability of exceedence case and the thinner lines to the left and right of the thicker lines represent the 85% and 15% probability of exceedance cases respectively.



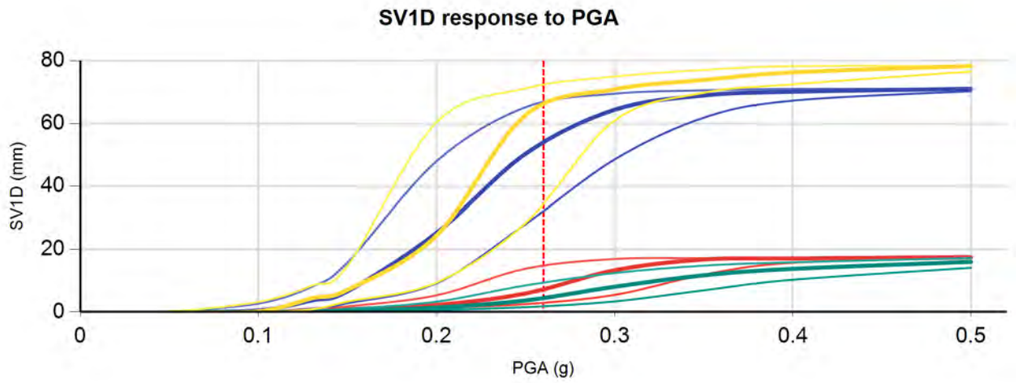


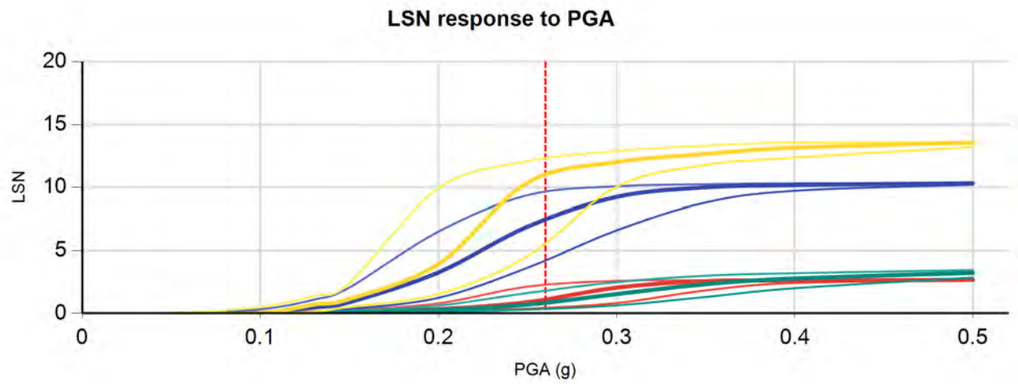


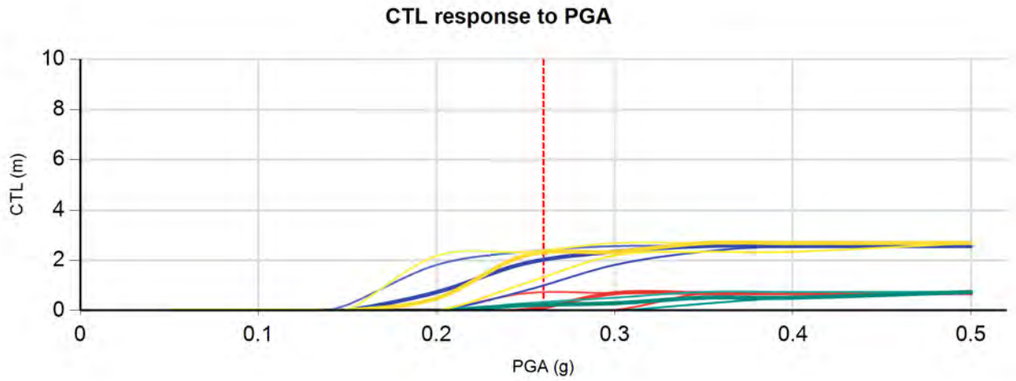


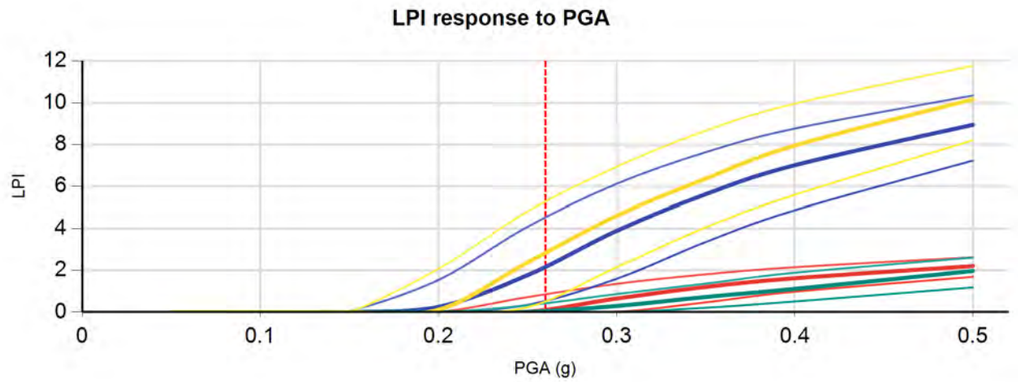
Vertical dotted line/s indicate design groundwater depth at the CPT locations.

	Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	CFC	γ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
		91890	19/04/2017	5.9	0.26	BI-2014	ZRB-2002		18		0	
		91891	19/04/2017	5.9	0.26	BI-2014	ZRB-2002		18		0	
		91892	19/04/2017	5.9	0.26	BI-2014	ZRB-2002		18		0	
		91893	19/04/2017	5.9	0.26	BI-2014	ZRB-2002		18		0	
	Thicker lines represent the 50% probability of exceedence case and the thinner lines to the bottom and top of the thicker lines represent the 85% and 15% probability of exceedance cases respectively.											





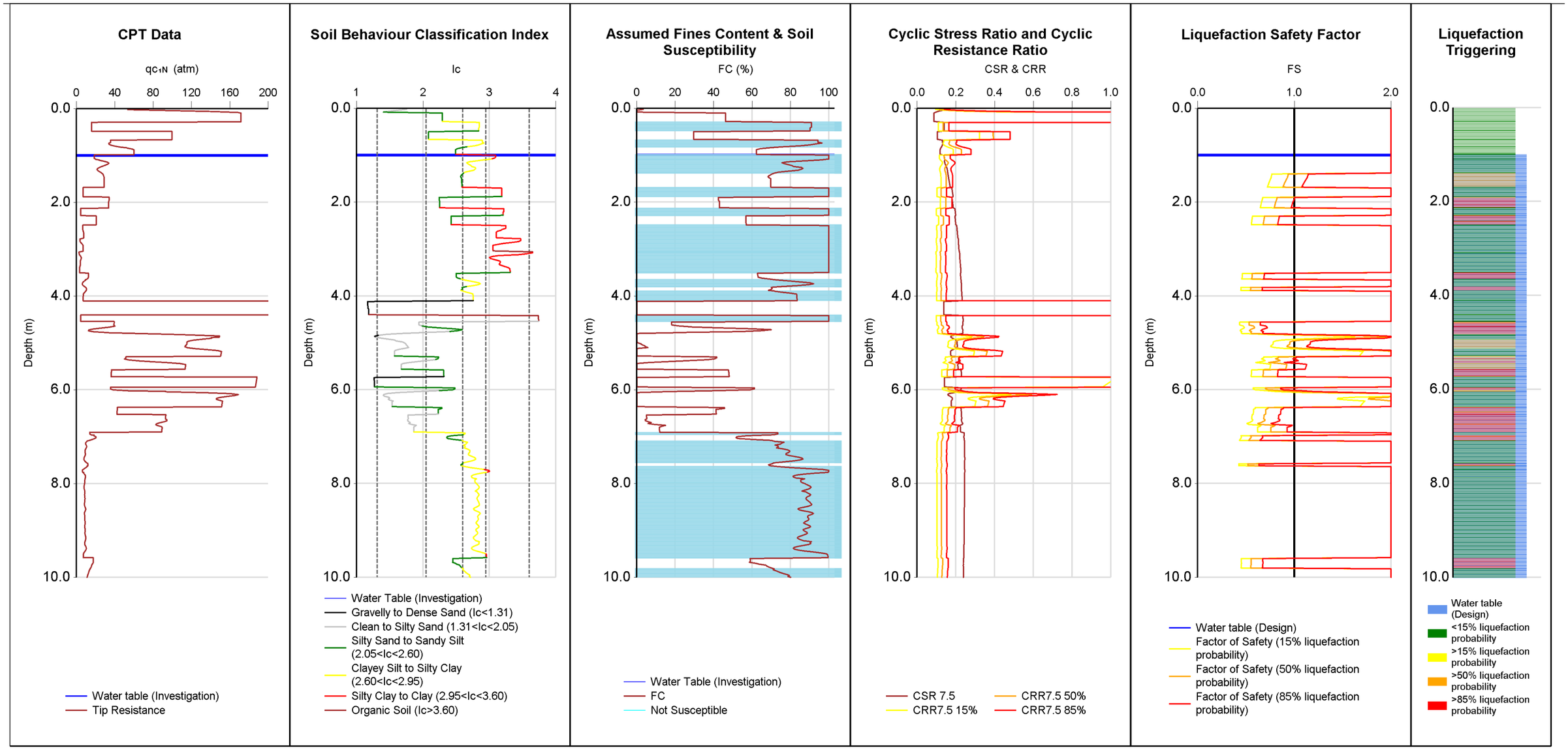




Vertical dotted line/s indicate user specified PGA at the CPT locations. (actual PGA)

	Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	CFC	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
		91890	19/04/2017	5.9	0.26	BI-2014	ZRB-2002		18		0	
		91891	19/04/2017	5.9	0.26	BI-2014	ZRB-2002		18		0	
		91892	19/04/2017	5.9	0.26	BI-2014	ZRB-2002		18		0	
		91893	19/04/2017	5.9	0.26	BI-2014	ZRB-2002		18		0	
	Thicker lines represent the 50% probability of exceedence case and the thinner lines to the bottom and top of the thicker lines represent the 85% and 15% probability of exceedance cases respectively.											

CPT-based analysis: Katikati Wastewater Treatment Plant



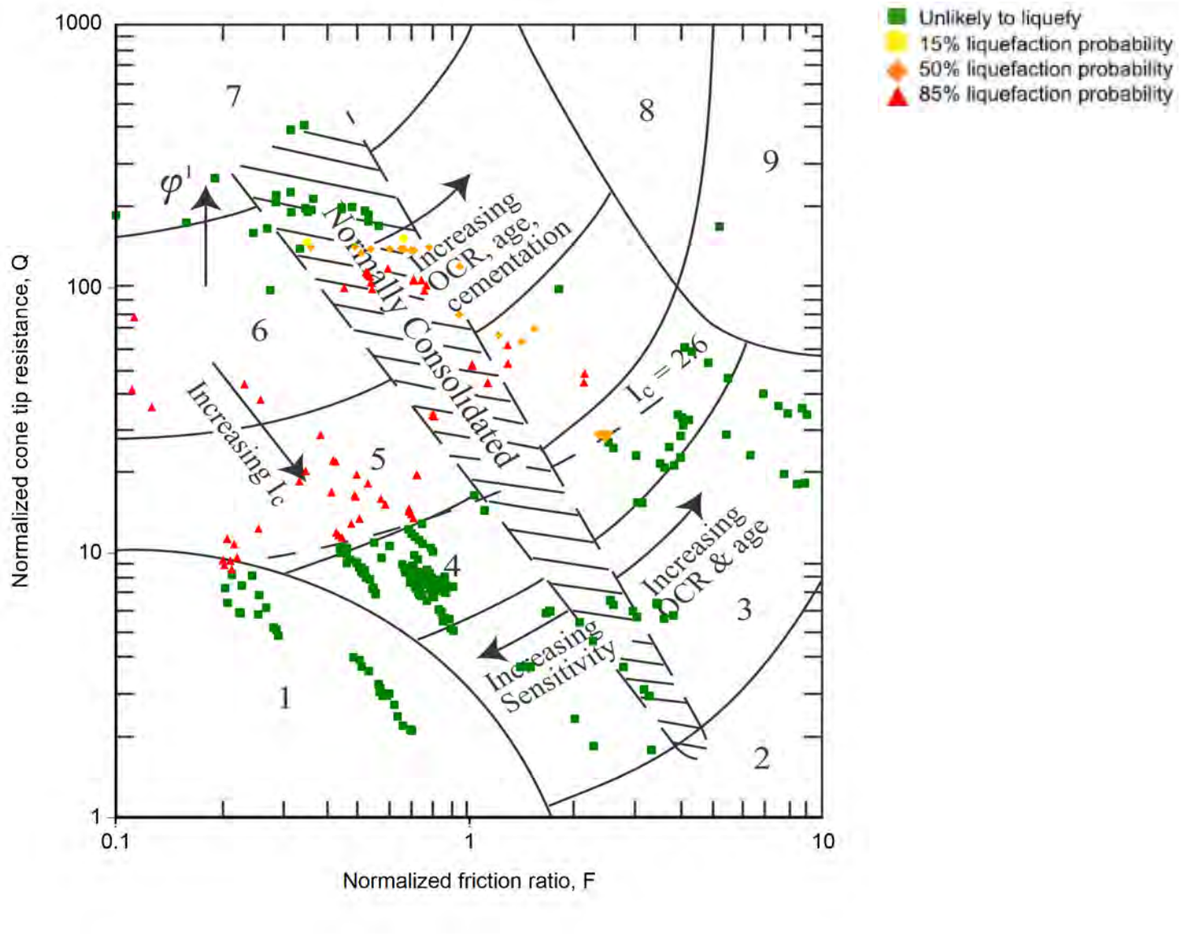
Note: Inverse filtered Qc/Fs data used (10 cm²)

	Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT		123584	14/03/2014	5.9	0.26	BI-2014	ZRB-2002	18		0	

	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPIish
OUTPUT	15%	78	2.9	9	21	1.5	7
	50%	71	2.9	6	19	1.5	4
	85%	56	2.1	3	13	2	2

Reviewed by:

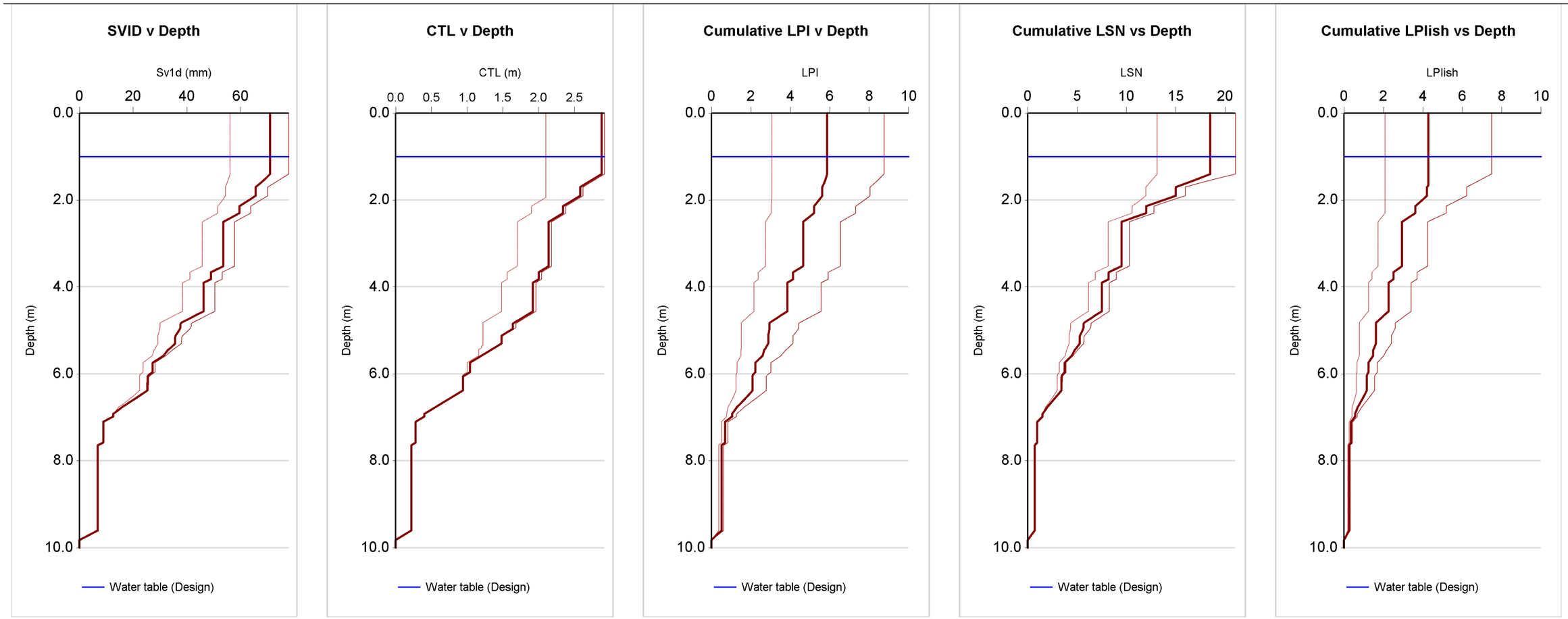
CPT Inversion	JICR
Groundwater	JICR
Susceptibility	JICR
Triggering	JICR
Consequence	JICR



1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt mixtures - clayey silt to silty clay
5. Sand mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand *
9. Very stiff, fine grained *

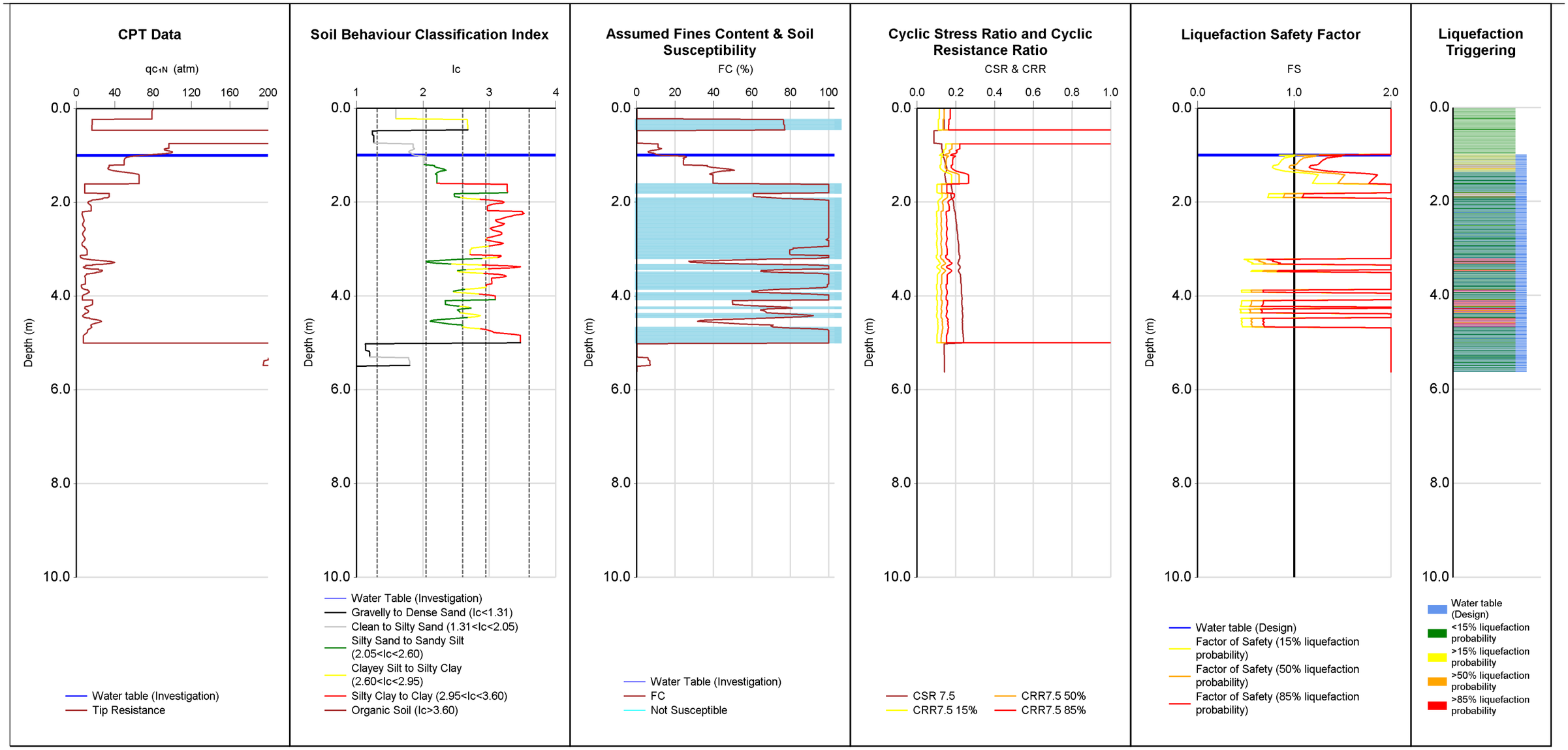
*Heavily overconsolidated or cemented

CPT-based soil behavior type classification chart by Robertson (1990)



Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	123584	14/03/2014	5.9	0.26	BI-2014	ZRB-2002	18		0	

Thicker lines represent the 50% probability of exceedence case and the thinner lines to the left and right of the thicker lines represent the 85% and 15% probability of exceedance cases respectively.



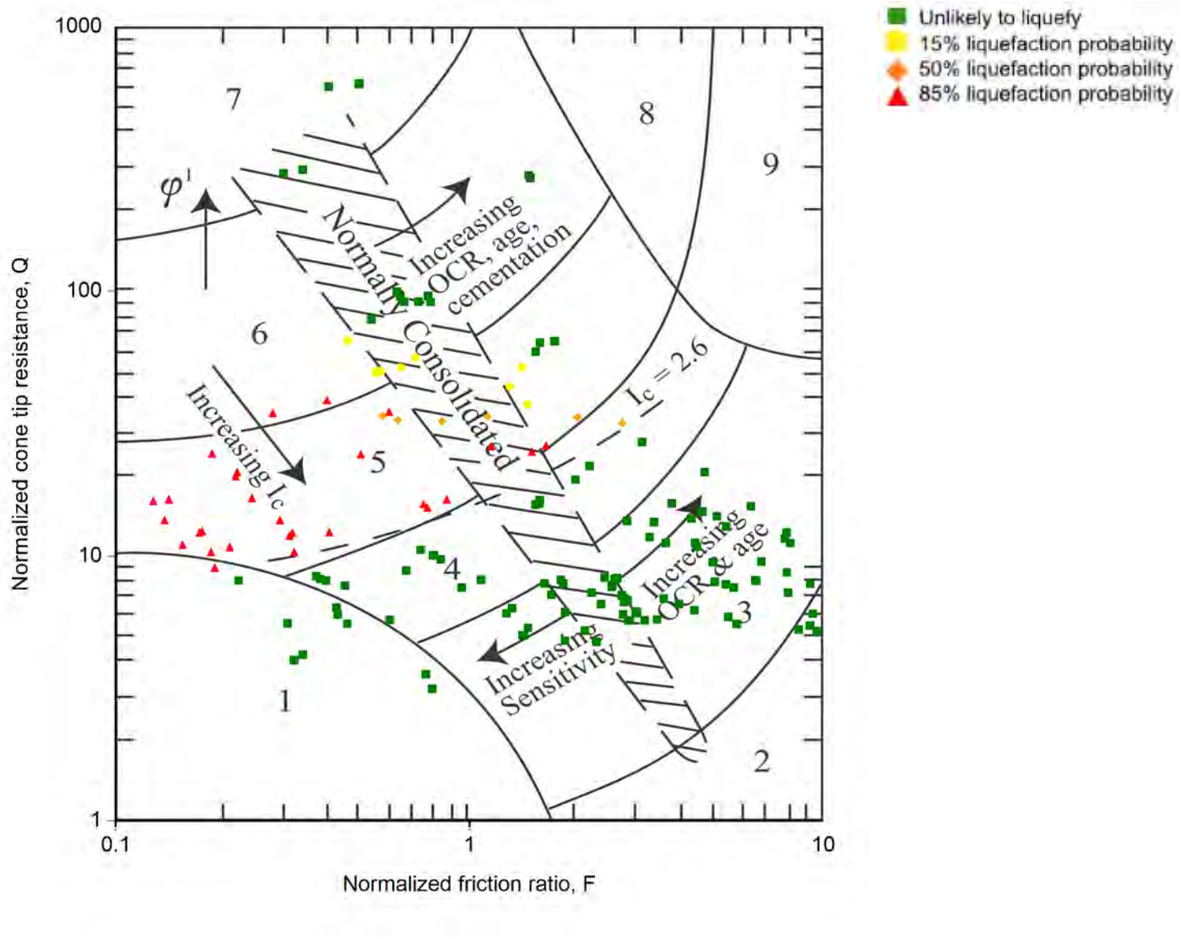
Note: Inverse filtered Qc/Fs data used (10 cm²)

	Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT		123585	14/03/2014	5.9	0.26	BI-2014	ZRB-2002	18		0	

	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPIish
OUTPUT	15%	32	1.1	4	14	1.1	4
	50%	26	0.9	2	9	1.3	2
	85%	23	0.7	2	7	3.3	1

Reviewed by:

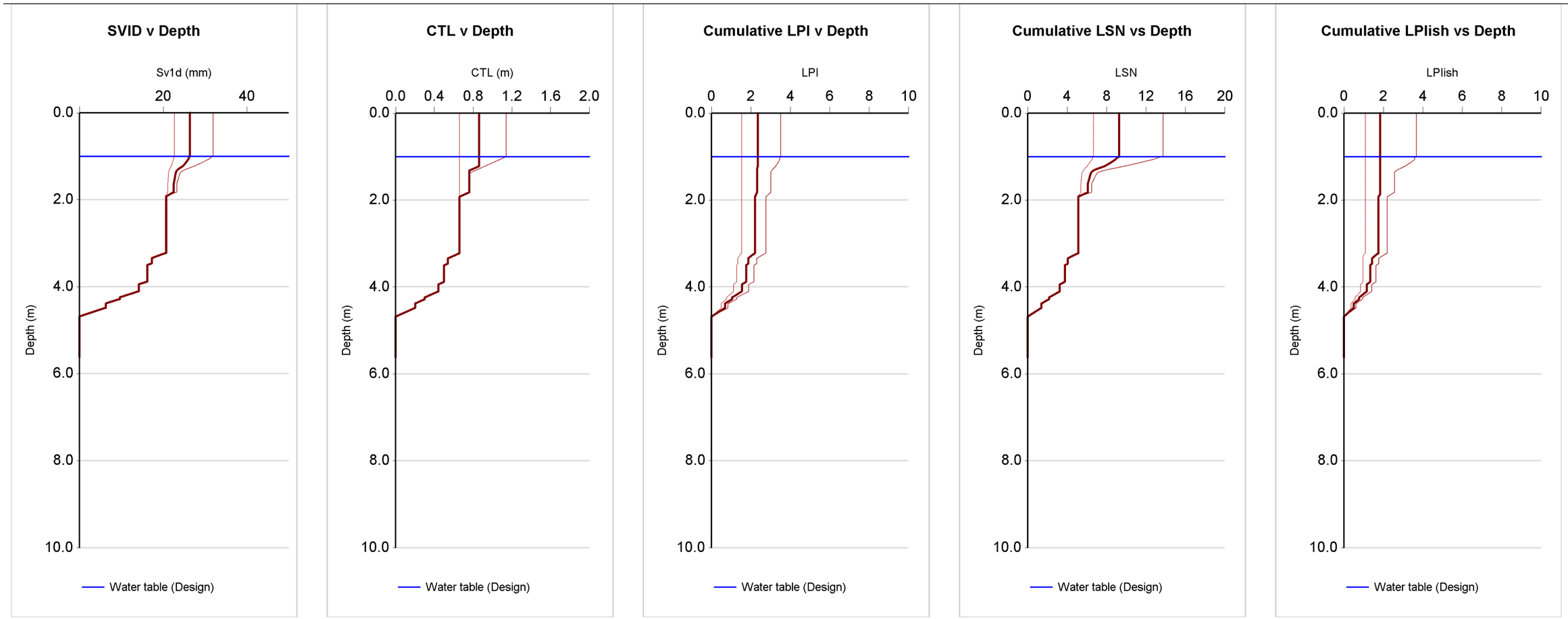
CPT Inversion	JICR
Groundwater	JICR
Susceptibility	JICR
Triggering	JICR
Consequence	JICR



1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt mixtures - clayey silt to silty clay
5. Sand mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand *
9. Very stiff, fine grained *

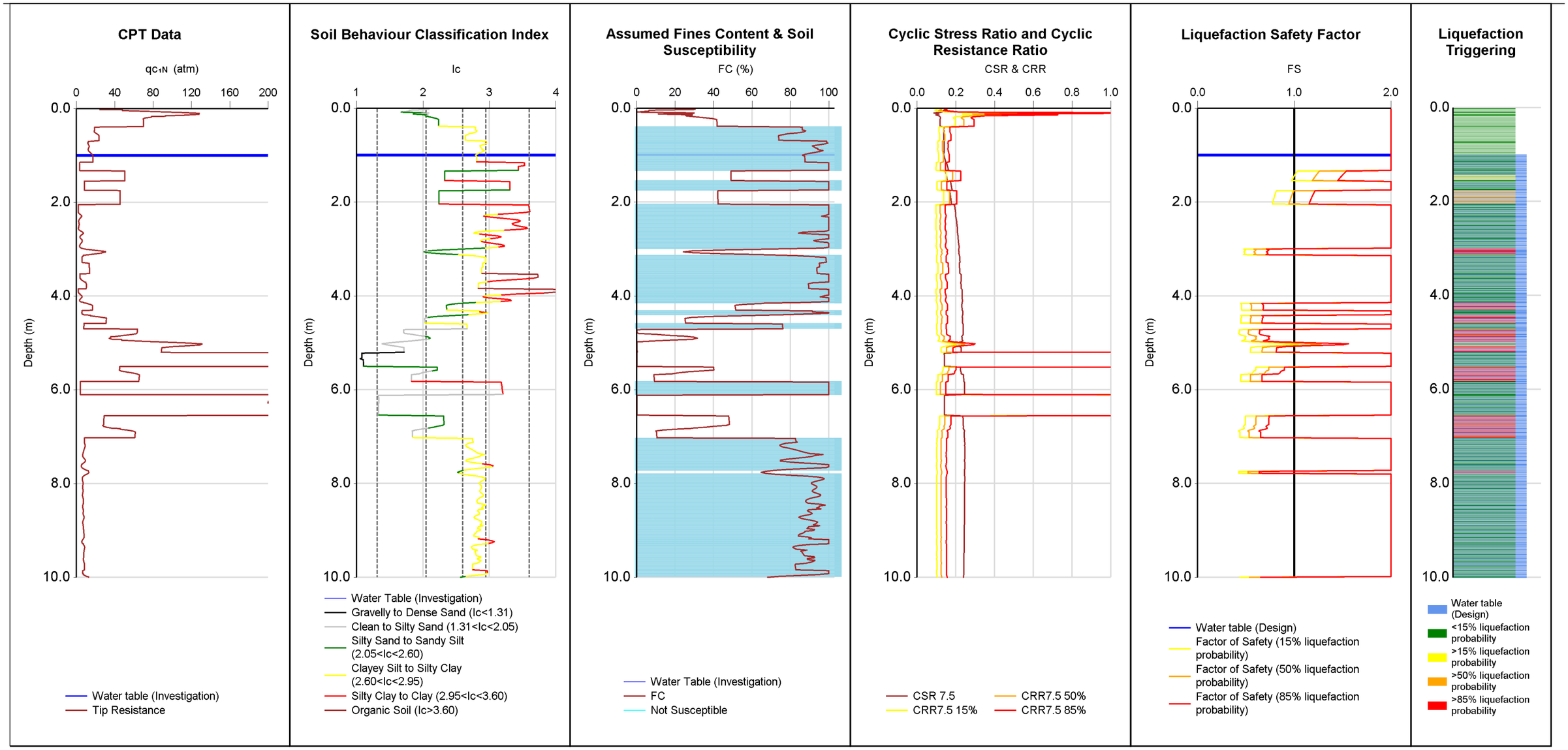
*Heavily overconsolidated or cemented

CPT-based soil behavior type classification chart by Robertson (1990)



Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	123585	14/03/2014	5.9	0.26	BI-2014	ZRB-2002	18		0	

Thicker lines represent the 50% probability of exceedence case and the thinner lines to the left and right of the thicker lines represent the 85% and 15% probability of exceedance cases respectively.



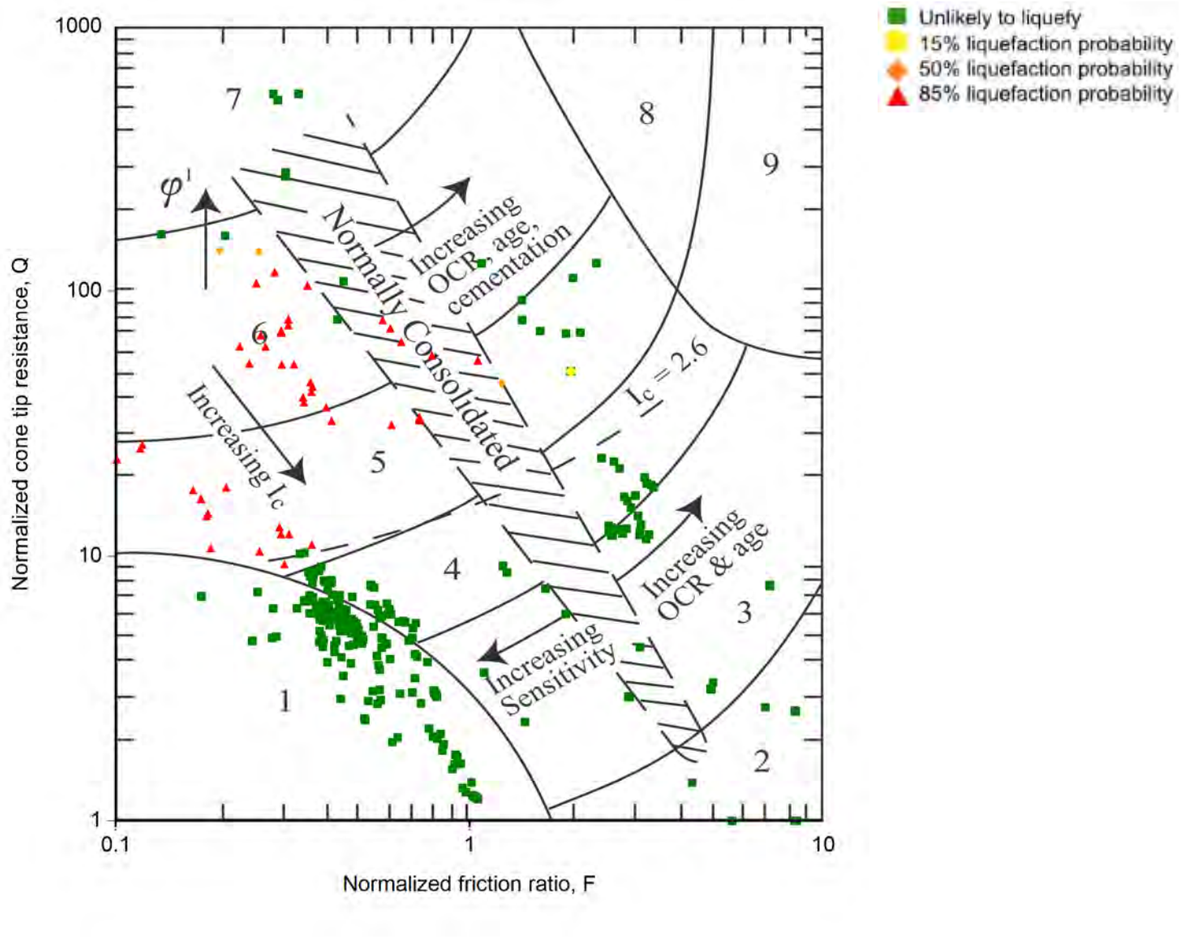
Note: Inverse filtered Qc/Fs data used (10 cm²)

	Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT		123586	14/03/2014	5.9	0.26	BI-2014	ZRB-2002	18		0	

	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPIish
OUTPUT	15%	63	2.2	7	15	1.5	5
	50%	58	2.1	5	13	1.8	4
	85%	54	1.8	4	11	3.1	2

Reviewed by:

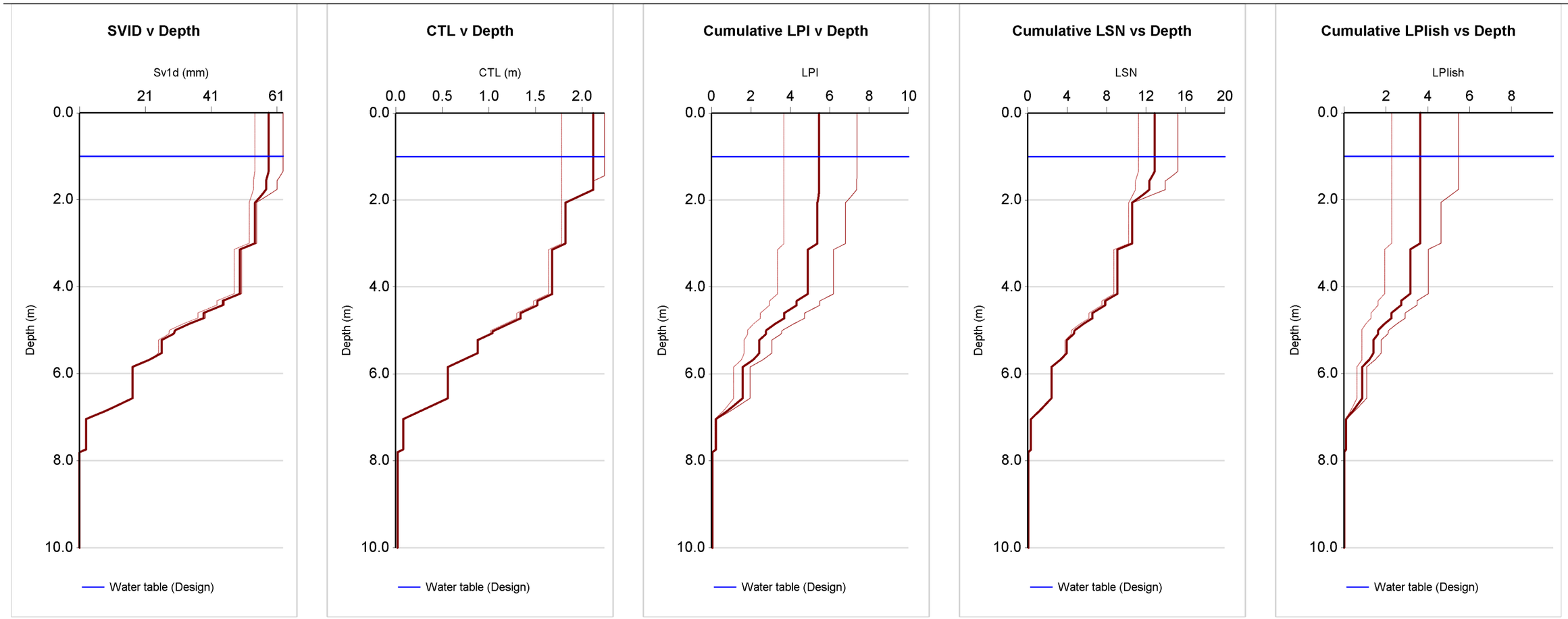
CPT Inversion	JICR
Groundwater	JICR
Susceptibility	JICR
Triggering	JICR
Consequence	JICR



1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt mixtures - clayey silt to silty clay
5. Sand mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand *
9. Very stiff, fine grained *

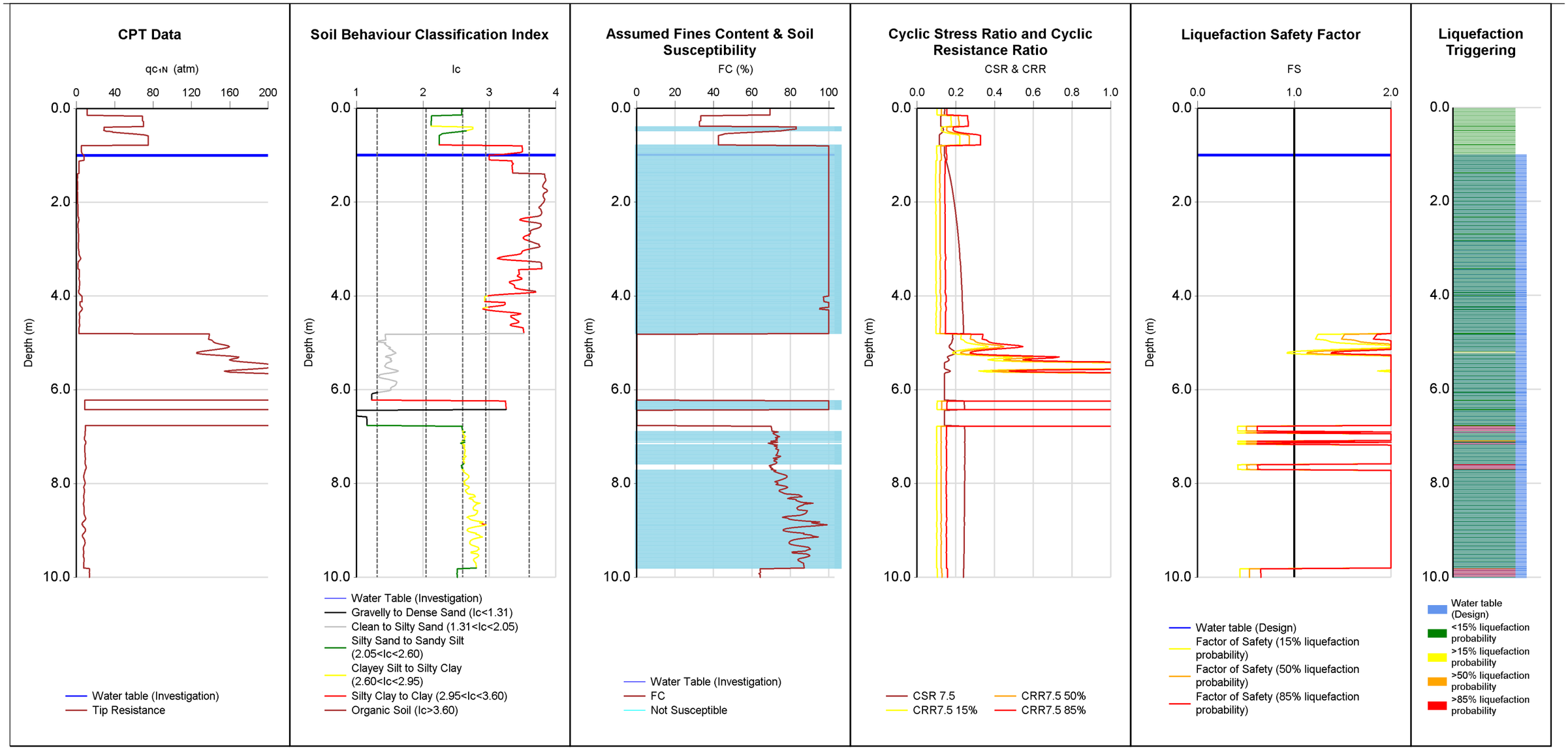
*Heavily overconsolidated or cemented

CPT-based soil behavior type classification chart by Robertson (1990)



Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	123586	14/03/2014	5.9	0.26	BI-2014	ZRB-2002	18		0	

Thicker lines represent the 50% probability of exceedence case and the thinner lines to the left and right of the thicker lines represent the 85% and 15% probability of exceedance cases respectively.



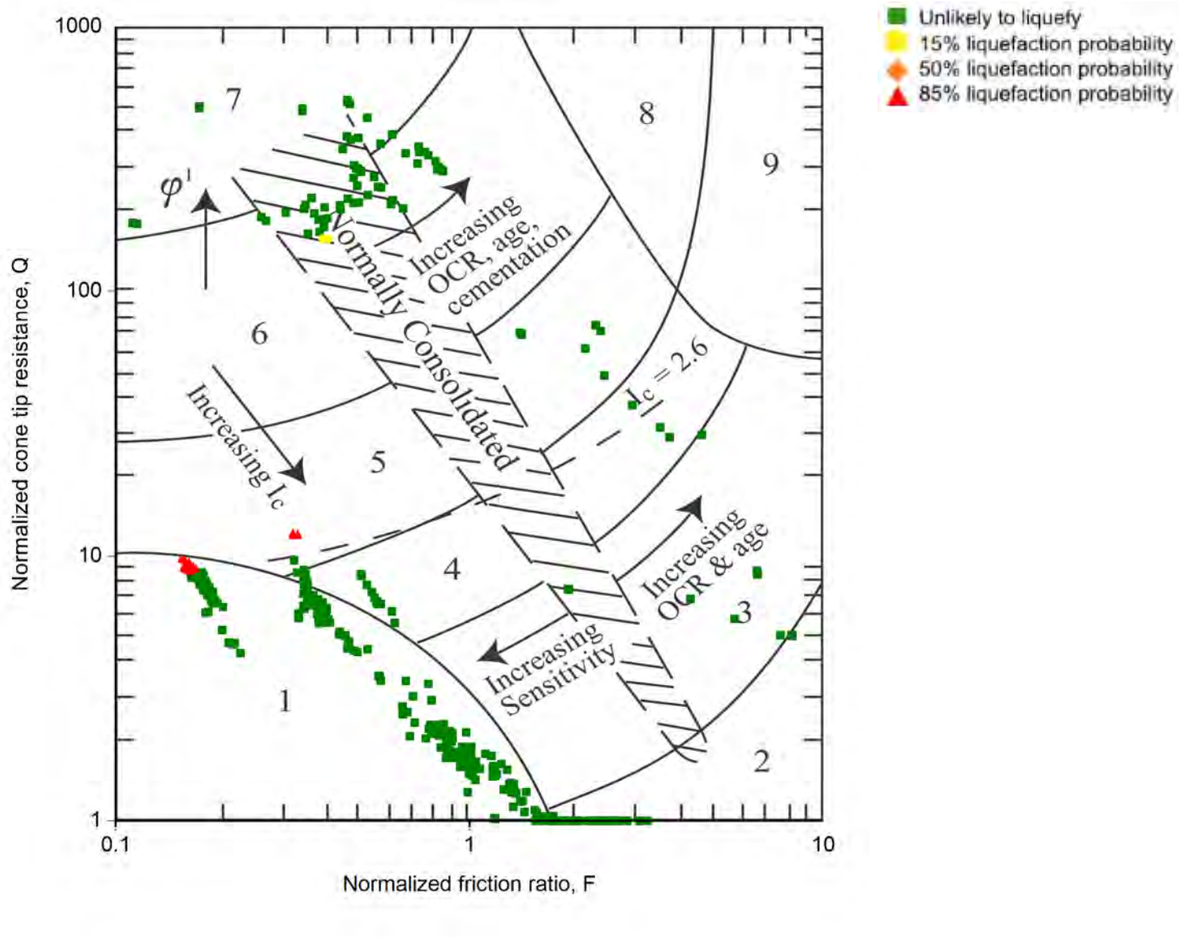
Note: Inverse filtered Qc/Fs data used (10 cm²)

	Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT		123587	14/03/2014	5.9	0.26	BI-2014	ZRB-2002	18		0	

	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPIish
OUTPUT	15%	19	0.6	2	2	6.8	1
	50%	18	0.5	1	2	6.9	0
	85%	18	0.5	1	2	6.9	0

Reviewed by:

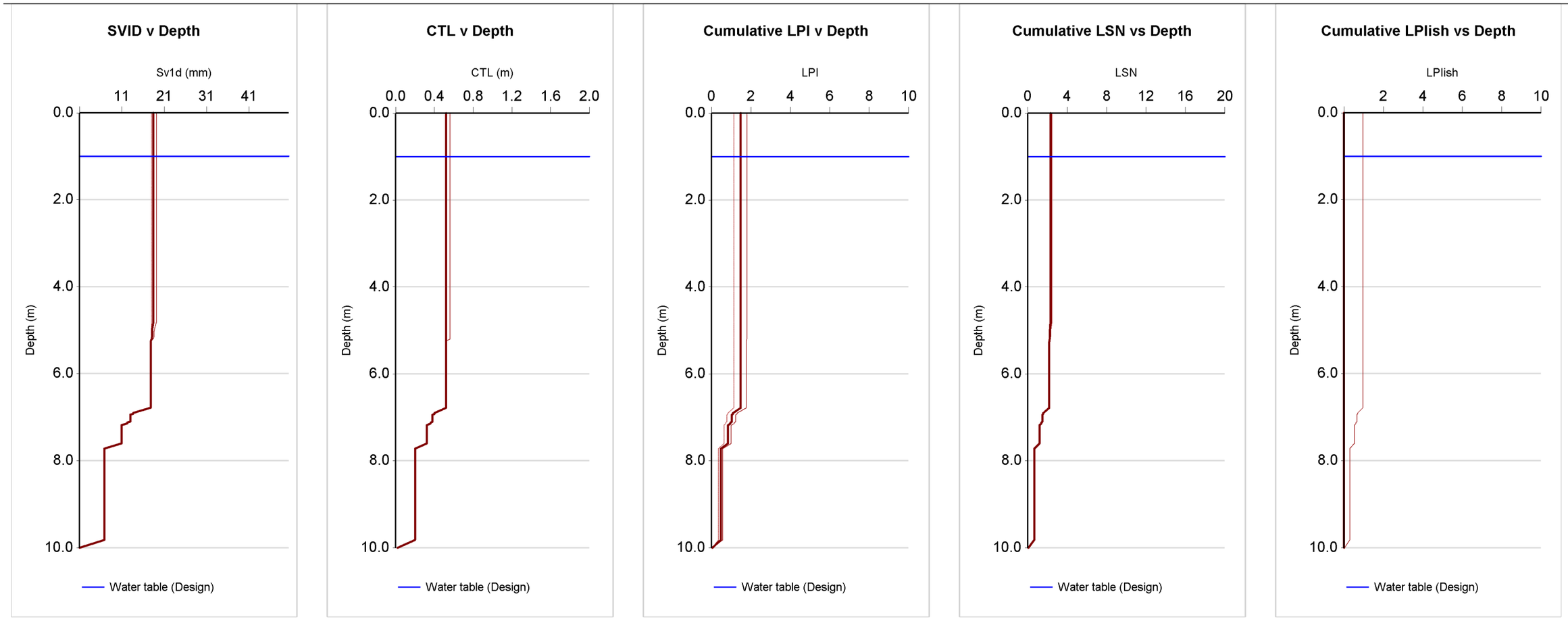
CPT Inversion	JICR
Groundwater	JICR
Susceptibility	JICR
Triggering	JICR
Consequence	JICR



1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt mixtures - clayey silt to silty clay
5. Sand mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand *
9. Very stiff, fine grained *

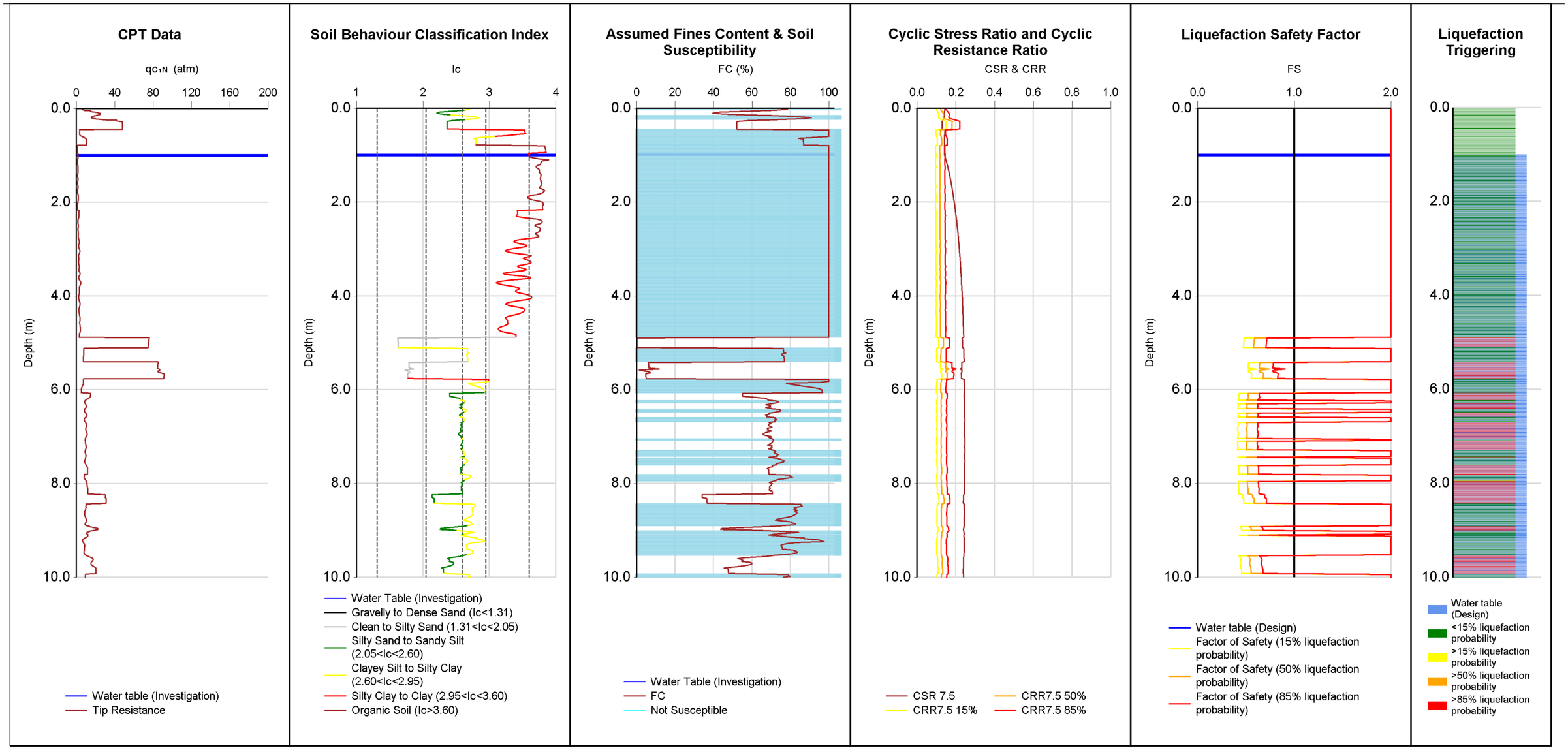
*Heavily overconsolidated or cemented

CPT-based soil behavior type classification chart by Robertson (1990)



Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	123587	14/03/2014	5.9	0.26	BI-2014	ZRB-2002	18		0	

Thicker lines represent the 50% probability of exceedence case and the thinner lines to the left and right of the thicker lines represent the 85% and 15% probability of exceedance cases respectively.



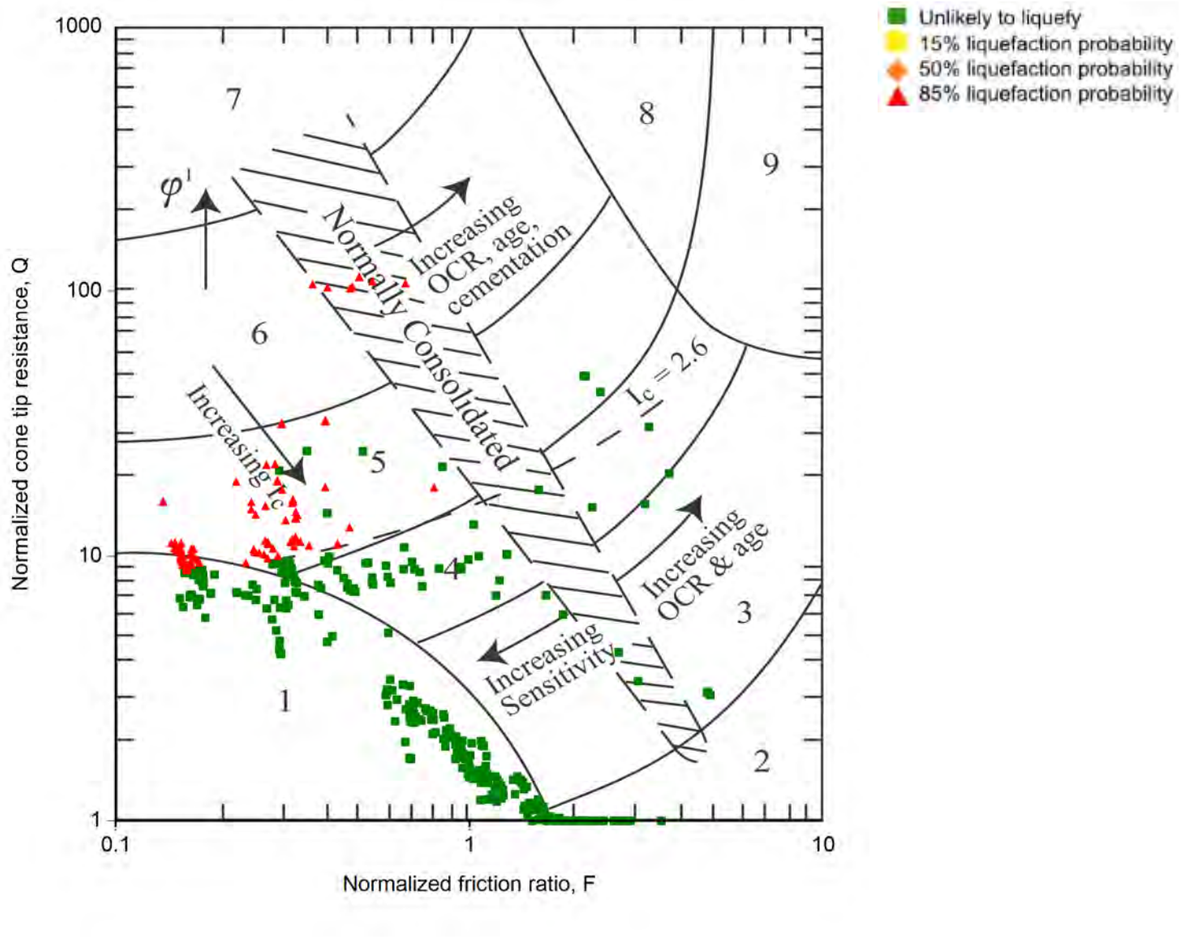
Note: Inverse filtered Qc/Fs data used (10 cm²)

	Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	γ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT		123588	14/03/2014	5.9	0.26	BI-2014	ZRB-2002	18		0	

	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPIish
OUTPUT	15%	86	2.7	10	12	5	5
	50%	86	2.7	8	12	5	4
	85%	86	2.7	6	12	5	0

Reviewed by:

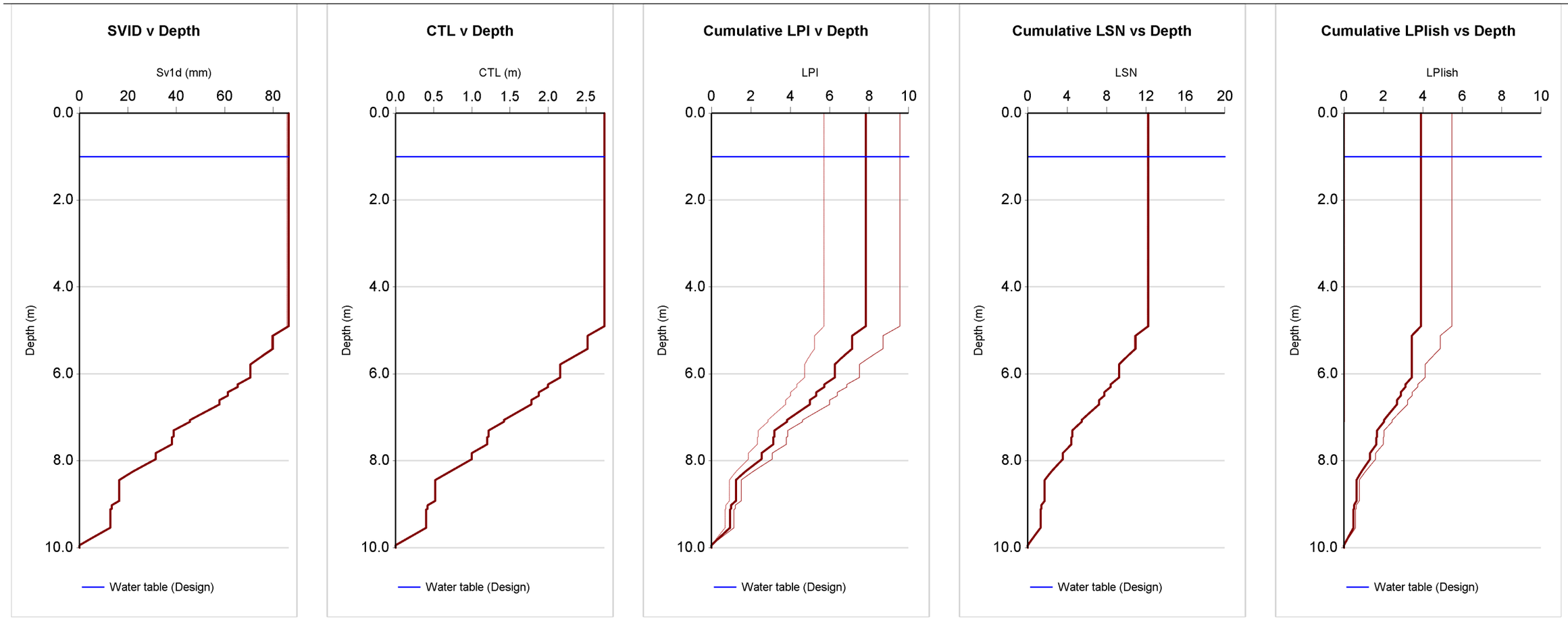
CPT Inversion	JICR
Groundwater	JICR
Susceptibility	JICR
Triggering	JICR
Consequence	JICR



1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt mixtures - clayey silt to silty clay
5. Sand mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand *
9. Very stiff, fine grained *

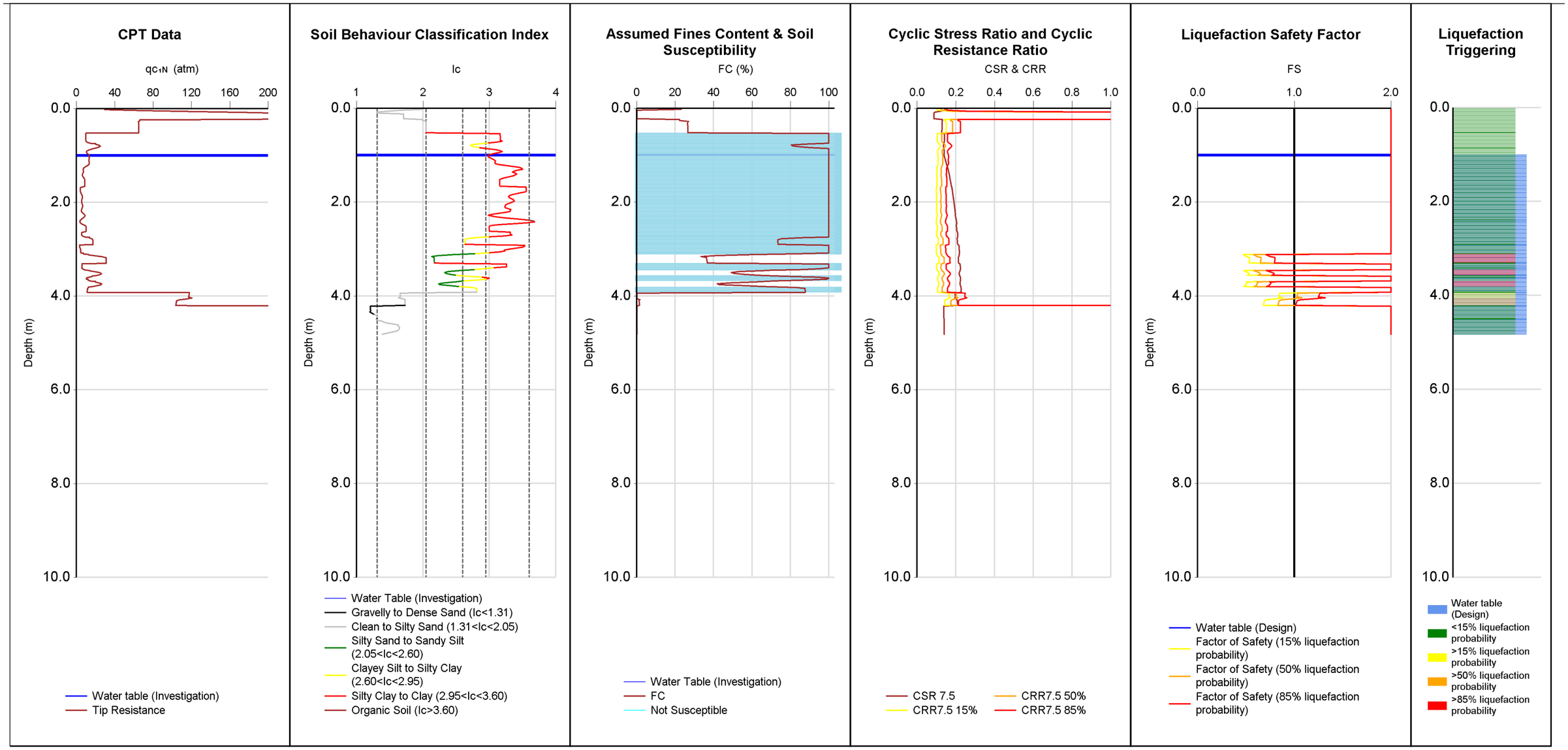
*Heavily overconsolidated or cemented

CPT-based soil behavior type classification chart by Robertson (1990)



Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	123588	14/03/2014	5.9	0.26	BI-2014	ZRB-2002	18		0	

Thicker lines represent the 50% probability of exceedence case and the thinner lines to the left and right of the thicker lines represent the 85% and 15% probability of exceedance cases respectively.



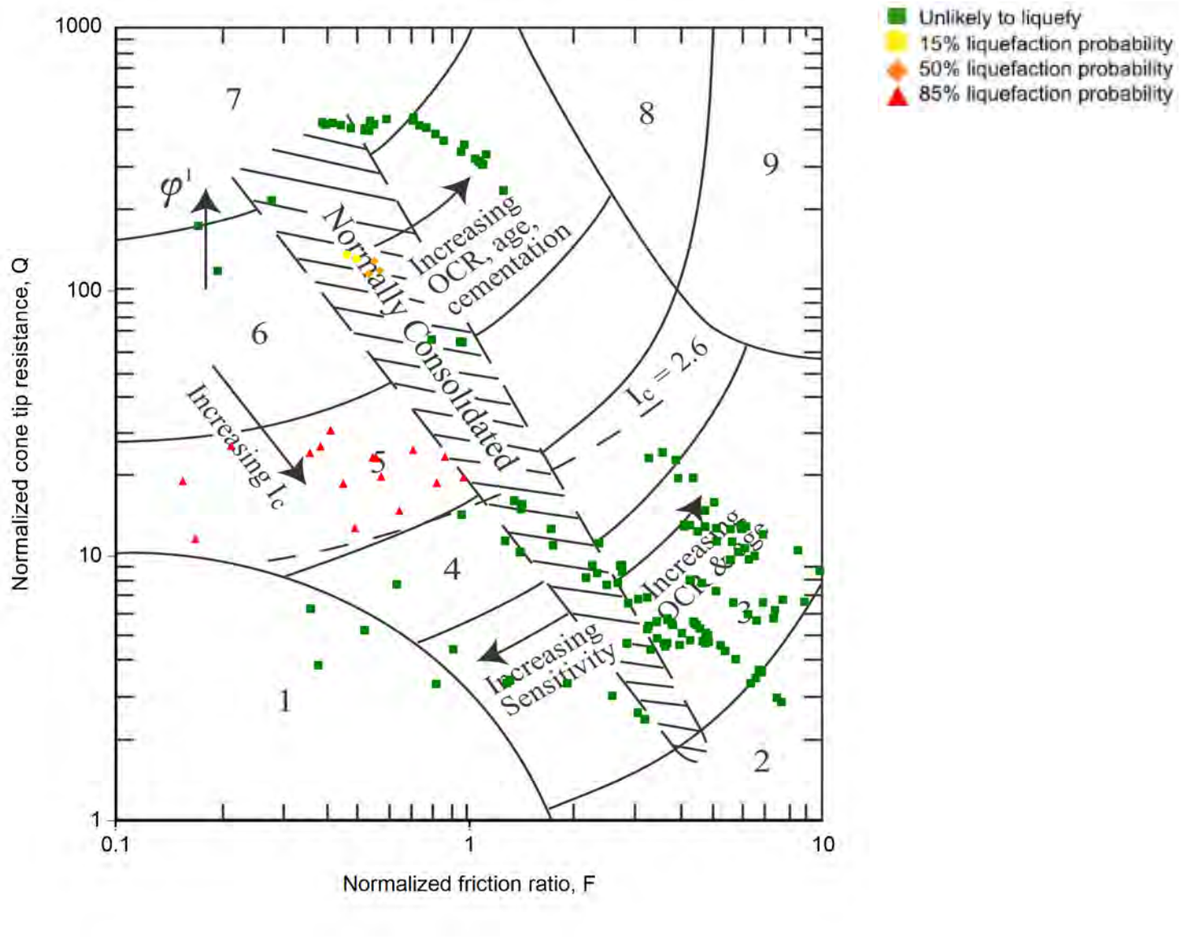
Note: Inverse filtered Qc/Fs data used (10 cm²)

	Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT		123589	14/03/2014	5.9	0.26	BI-2014	ZRB-2002	18		0	

	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPIish
OUTPUT	15%	18	0.7	2	5	3.2	2
	50%	16	0.6	2	5	3.2	1
	85%	15	0.4	1	4	3.2	1

Reviewed by:

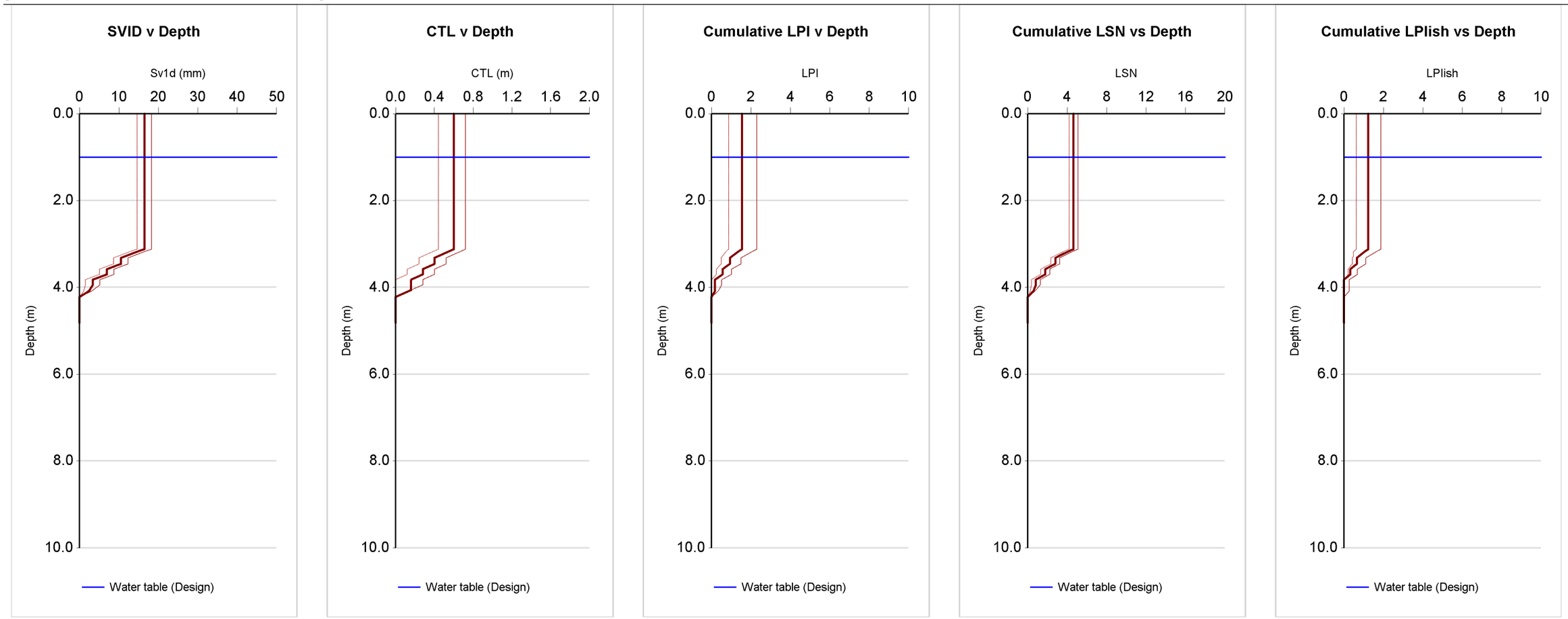
CPT Inversion	JICR
Groundwater	JICR
Susceptibility	JICR
Triggering	JICR
Consequence	JICR



1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt mixtures - clayey silt to silty clay
5. Sand mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand *
9. Very stiff, fine grained *

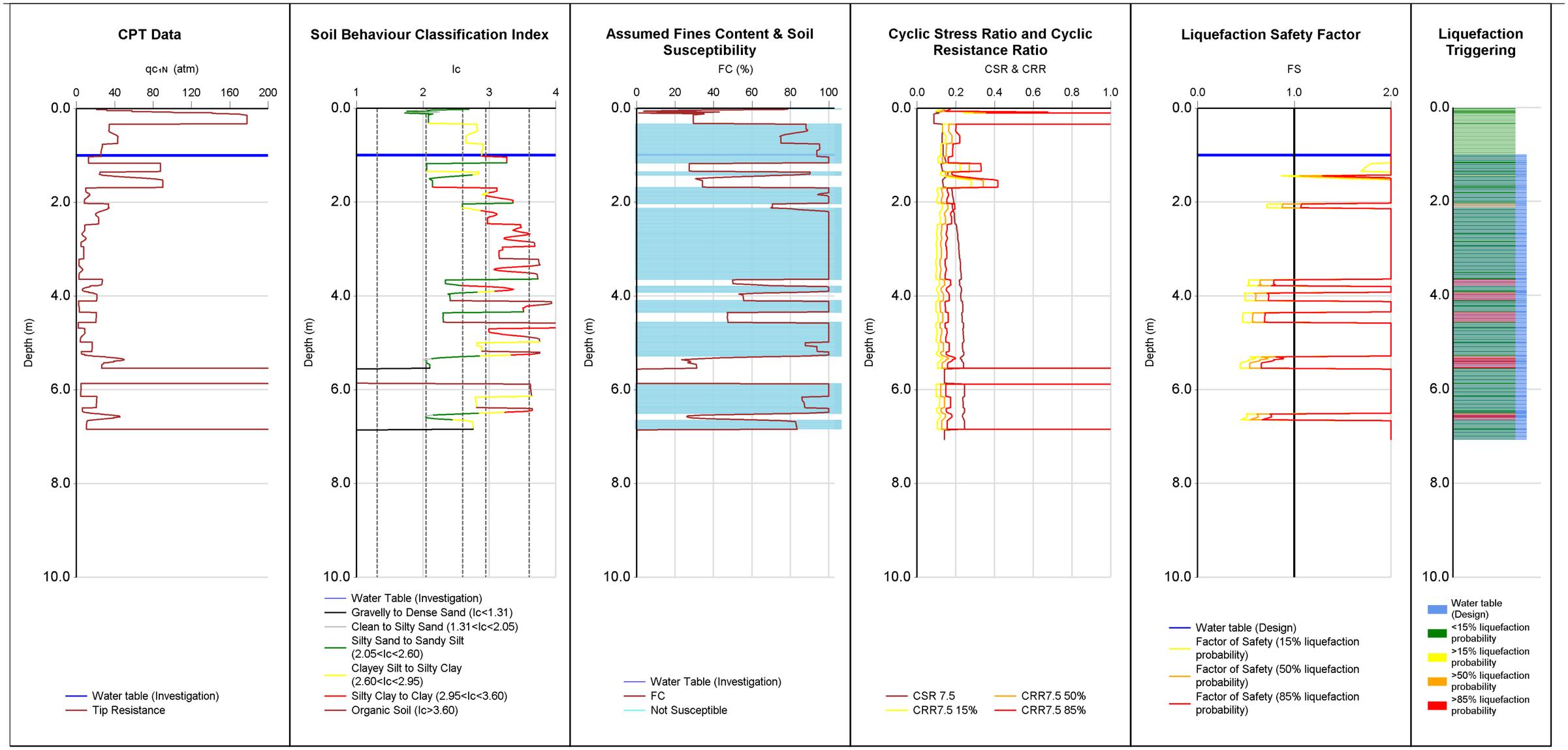
*Heavily overconsolidated or cemented

CPT-based soil behavior type classification chart by Robertson (1990)



Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	123589	14/03/2014	5.9	0.26	BI-2014	ZRB-2002	18		0	

Thicker lines represent the 50% probability of exceedence case and the thinner lines to the left and right of the thicker lines represent the 85% and 15% probability of exceedance cases respectively.



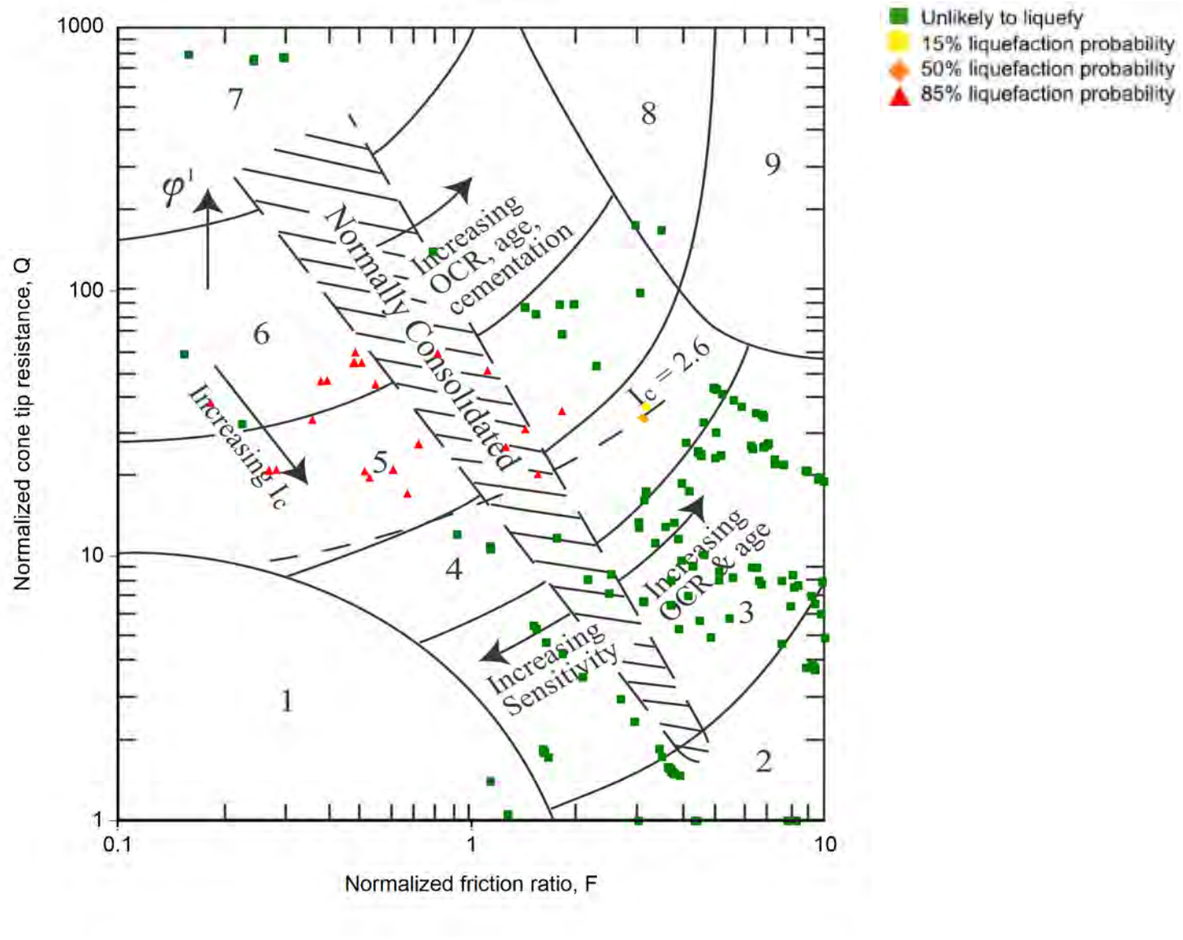
Note: Inverse filtered Qc/Fs data used (10 cm²)

	Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT		123590	14/03/2014	5.9	0.26	BI-2014	ZRB-2002	18		0	

	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPIish
OUTPUT	15%	31	1.1	4	8	2.1	3
	50%	30	1	3	7	2.1	2
	85%	28	0.9	2	6	3.7	1

Reviewed by:

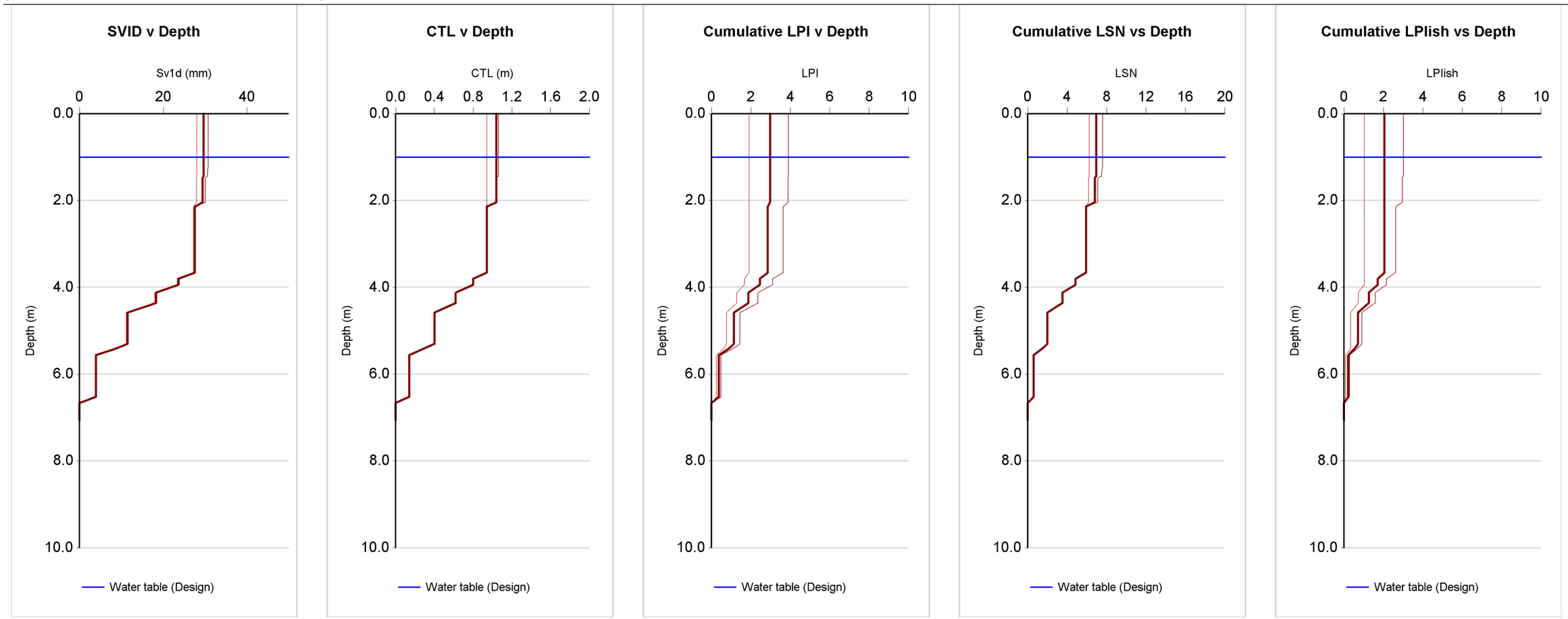
CPT Inversion	JICR
Groundwater	JICR
Susceptibility	JICR
Triggering	JICR
Consequence	JICR



1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt mixtures - clayey silt to silty clay
5. Sand mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand *
9. Very stiff, fine grained *

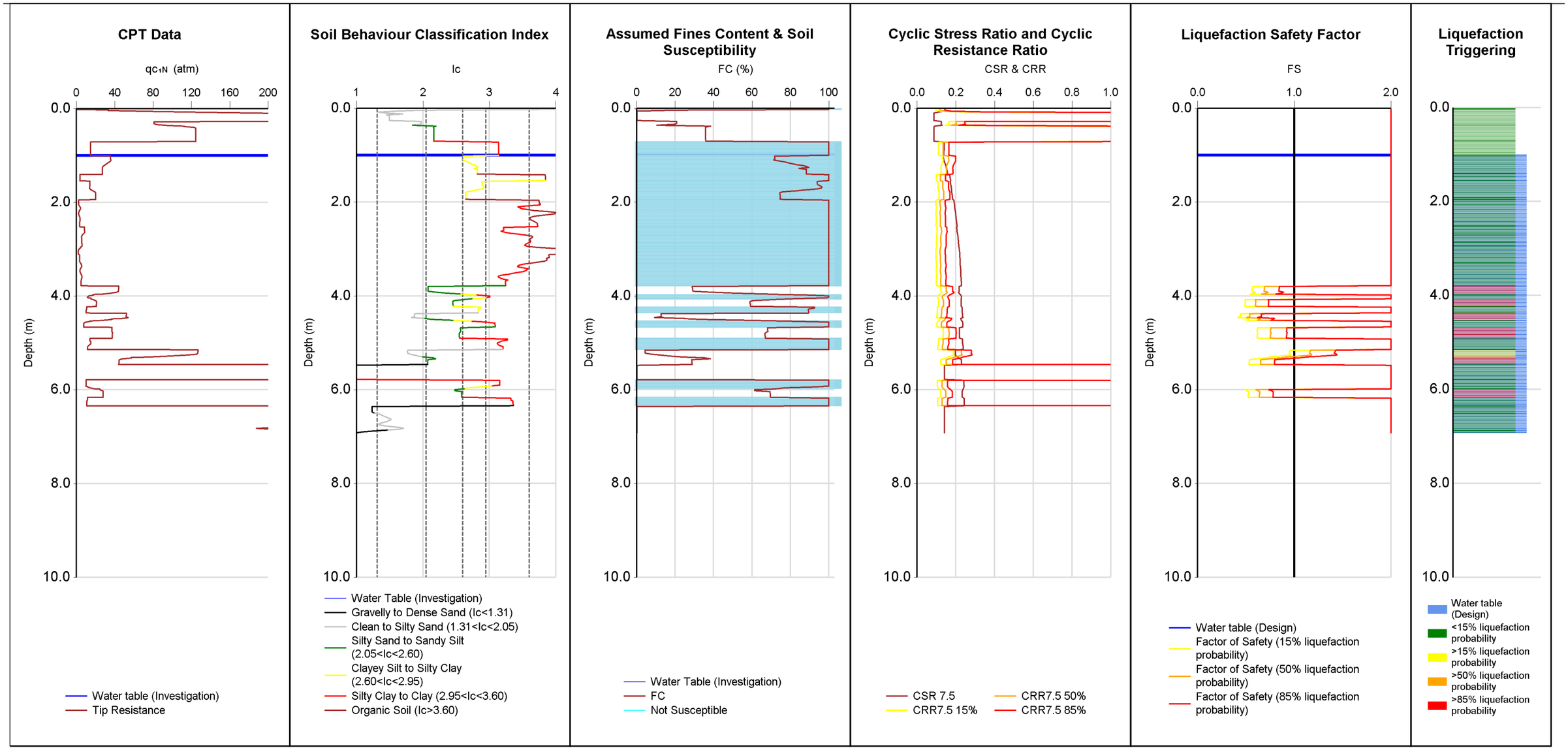
*Heavily overconsolidated or cemented

CPT-based soil behavior type classification chart by Robertson (1990)



Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	123590	14/03/2014	5.9	0.26	BI-2014	ZRB-2002	18		0	

Thicker lines represent the 50% probability of exceedence case and the thinner lines to the left and right of the thicker lines represent the 85% and 15% probability of exceedance cases respectively.



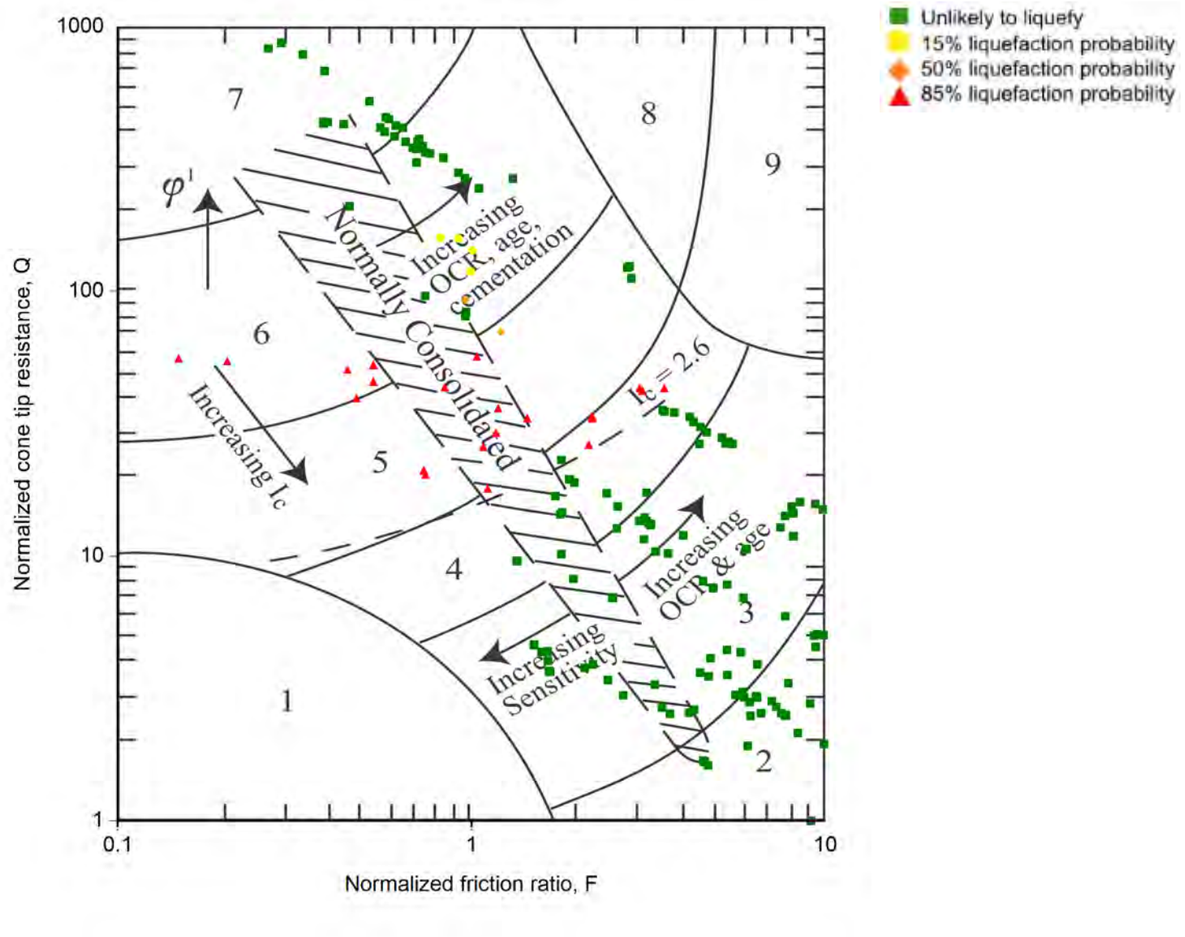
Note: Inverse filtered Qc/Fs data used (10 cm²)

	Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
INPUT		123591	14/03/2014	5.9	0.26	BI-2014	ZRB-2002	18		0	

	PL	SV1D (mm)	CTL (m)	LPI	LSN	CT (m)	LPIish
OUTPUT	15%	31	1.2	4	7	3.9	3
	50%	29	1.1	3	6	3.9	2
	85%	26	1.1	2	6	3.9	0

Reviewed by:

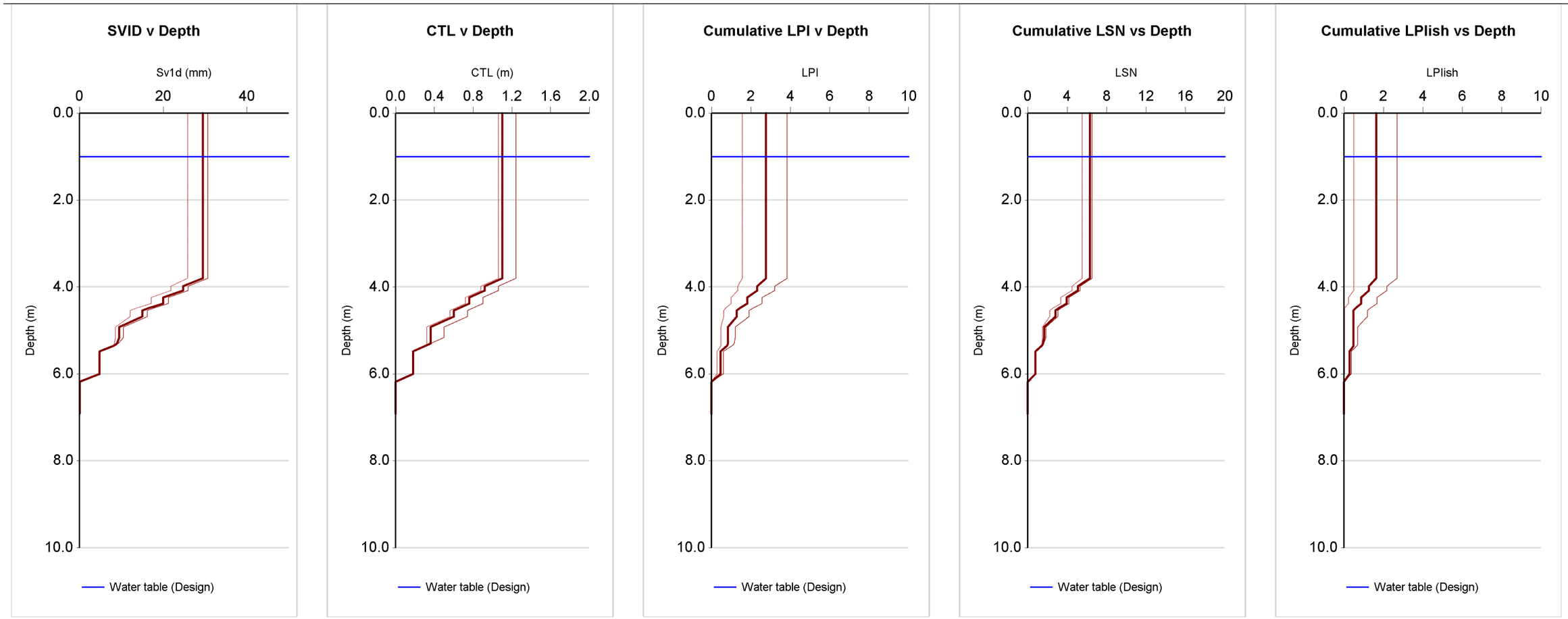
CPT Inversion	JICR
Groundwater	JICR
Susceptibility	JICR
Triggering	JICR
Consequence	JICR



1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt mixtures - clayey silt to silty clay
5. Sand mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand *
9. Very stiff, fine grained *

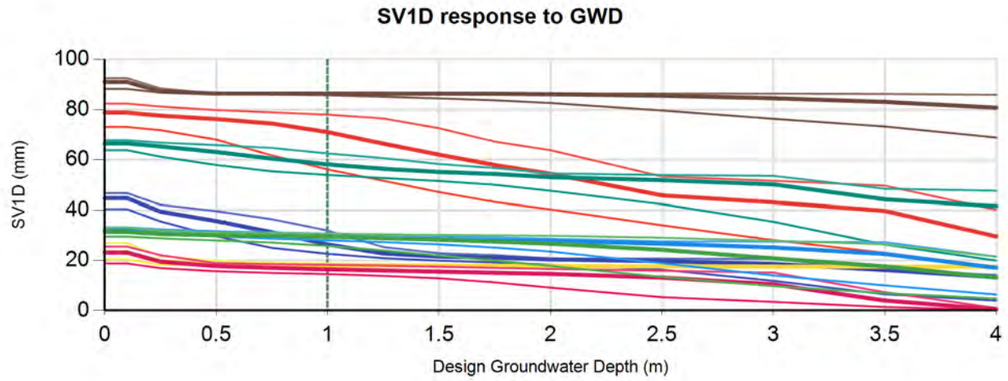
*Heavily overconsolidated or cemented

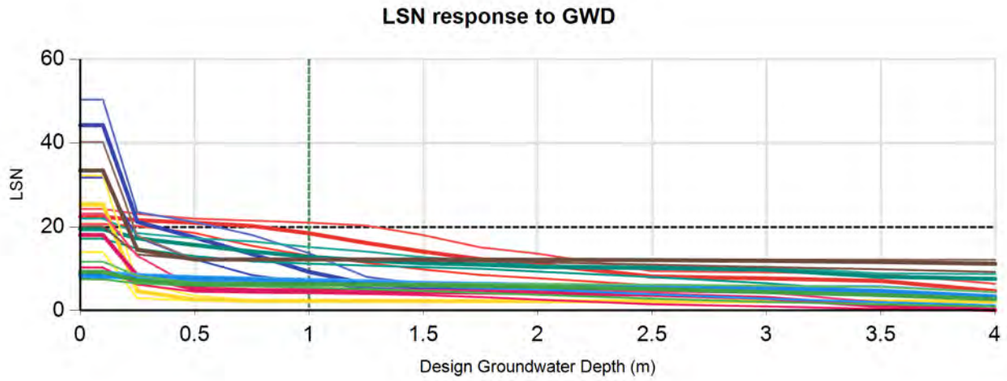
CPT-based soil behavior type classification chart by Robertson (1990)

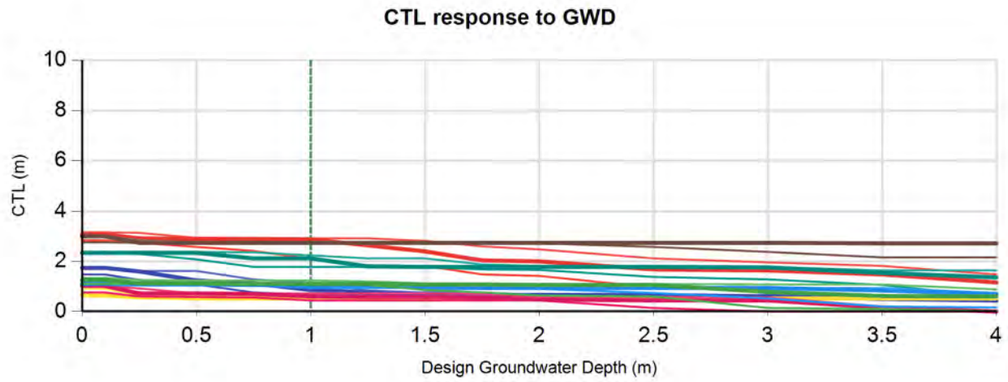


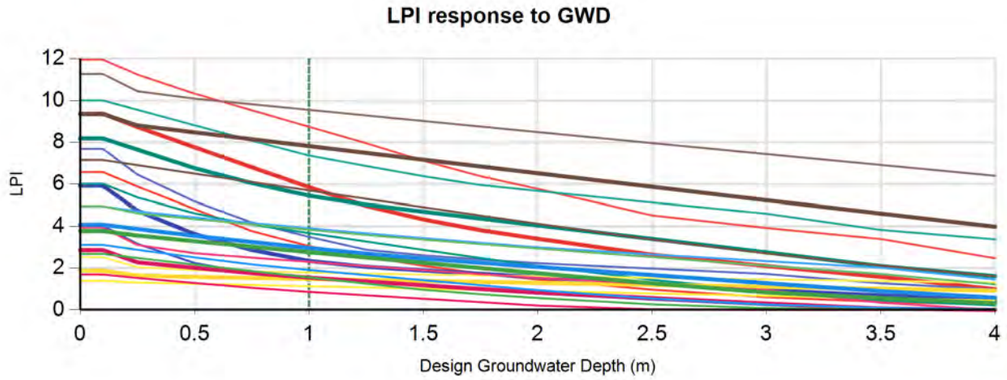
Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
	123591	14/03/2014	5.9	0.26	BI-2014	ZRB-2002	18		0	

Thicker lines represent the 50% probability of exceedence case and the thinner lines to the left and right of the thicker lines represent the 85% and 15% probability of exceedance cases respectively.



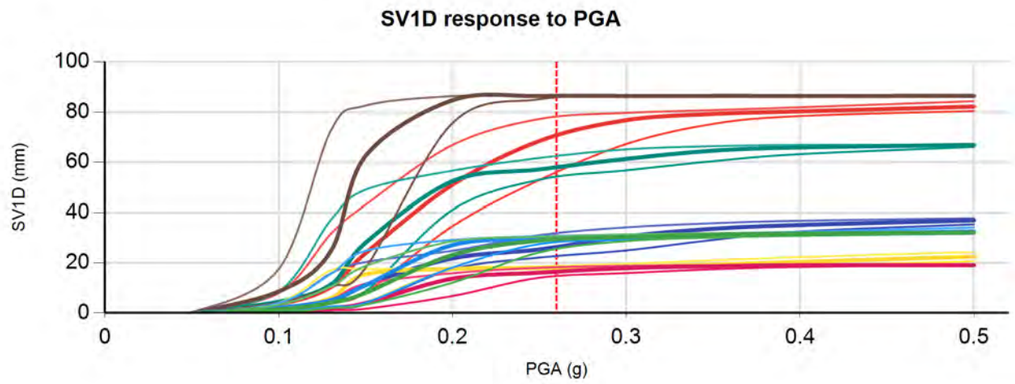


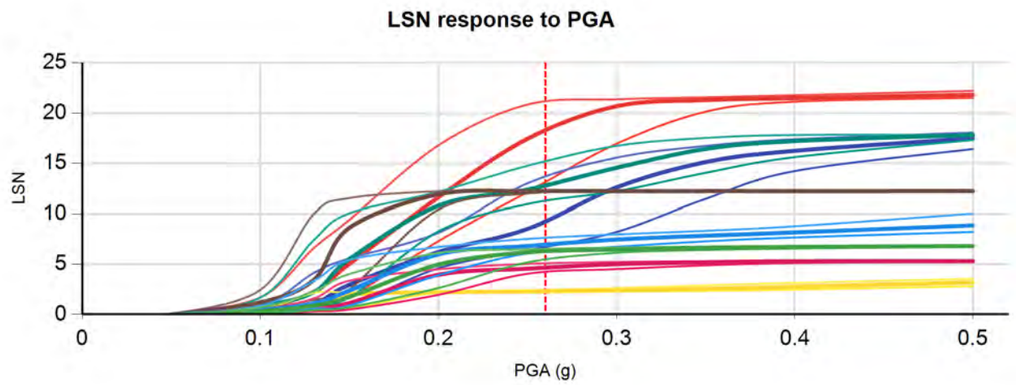


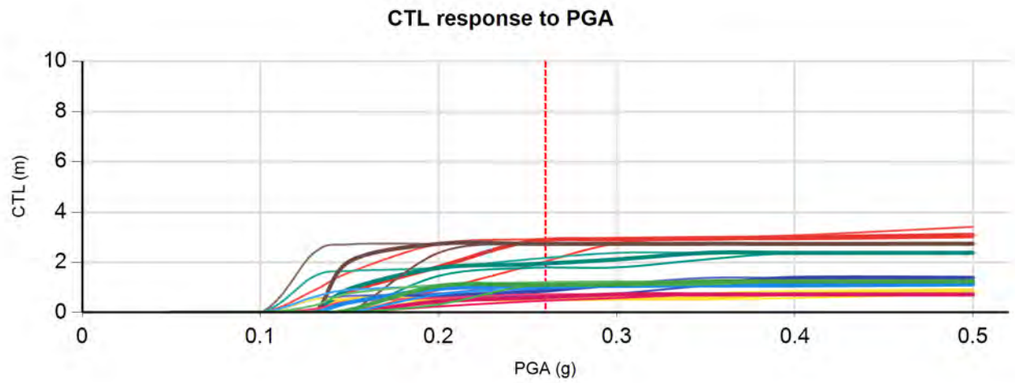


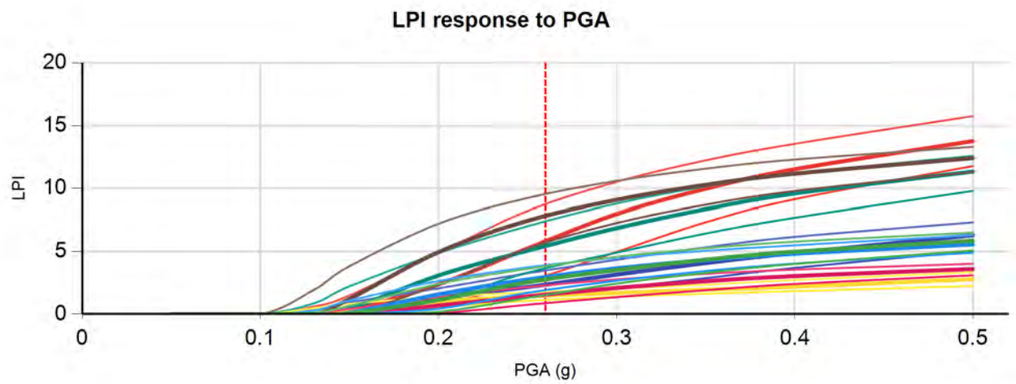
Vertical dotted line/s indicate design groundwater depth at the CPT locations.

	Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	CFC	ɣ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
		123584	14/03/2014	5.9	0.26	BI-2014	ZRB-2002		18		0	
		123585	14/03/2014	5.9	0.26	BI-2014	ZRB-2002		18		0	
		123586	14/03/2014	5.9	0.26	BI-2014	ZRB-2002		18		0	
		123587	14/03/2014	5.9	0.26	BI-2014	ZRB-2002		18		0	
		123588	14/03/2014	5.9	0.26	BI-2014	ZRB-2002		18		0	
		123589	14/03/2014	5.9	0.26	BI-2014	ZRB-2002		18		0	
		123590	14/03/2014	5.9	0.26	BI-2014	ZRB-2002		18		0	
		123591	14/03/2014	5.9	0.26	BI-2014	ZRB-2002		18		0	
	Thicker lines represent the 50% probability of exceedence case and the thinner lines to the bottom and top of the thicker lines represent the 85% and 15% probability of exceedance cases respectively.											









Vertical dotted line/s indicate user specified PGA at the CPT locations. (actual PGA)

	Run Description	NZGD ID	Investigation Date	Magnitude	PGA (g)	Trigger Method	Settlement Method	CFC	γ (kN/m³)	Surcharge/Cut/Fill	Surcharge (kPa)	Cut/Fill Height (m)
		123584	14/03/2014	5.9	0.26	BI-2014	ZRB-2002		18		0	
		123585	14/03/2014	5.9	0.26	BI-2014	ZRB-2002		18		0	
		123586	14/03/2014	5.9	0.26	BI-2014	ZRB-2002		18		0	
		123587	14/03/2014	5.9	0.26	BI-2014	ZRB-2002		18		0	
		123588	14/03/2014	5.9	0.26	BI-2014	ZRB-2002		18		0	
		123589	14/03/2014	5.9	0.26	BI-2014	ZRB-2002		18		0	
		123590	14/03/2014	5.9	0.26	BI-2014	ZRB-2002		18		0	
		123591	14/03/2014	5.9	0.26	BI-2014	ZRB-2002		18		0	
	Thicker lines represent the 50% probability of exceedence case and the thinner lines to the bottom and top of the thicker lines represent the 85% and 15% probability of exceedance cases respectively.											

Table B2: Summary of risk analysis and determination of expected degree of liquefaction-induced ground damage for Omokoroa study area – Type A sub area

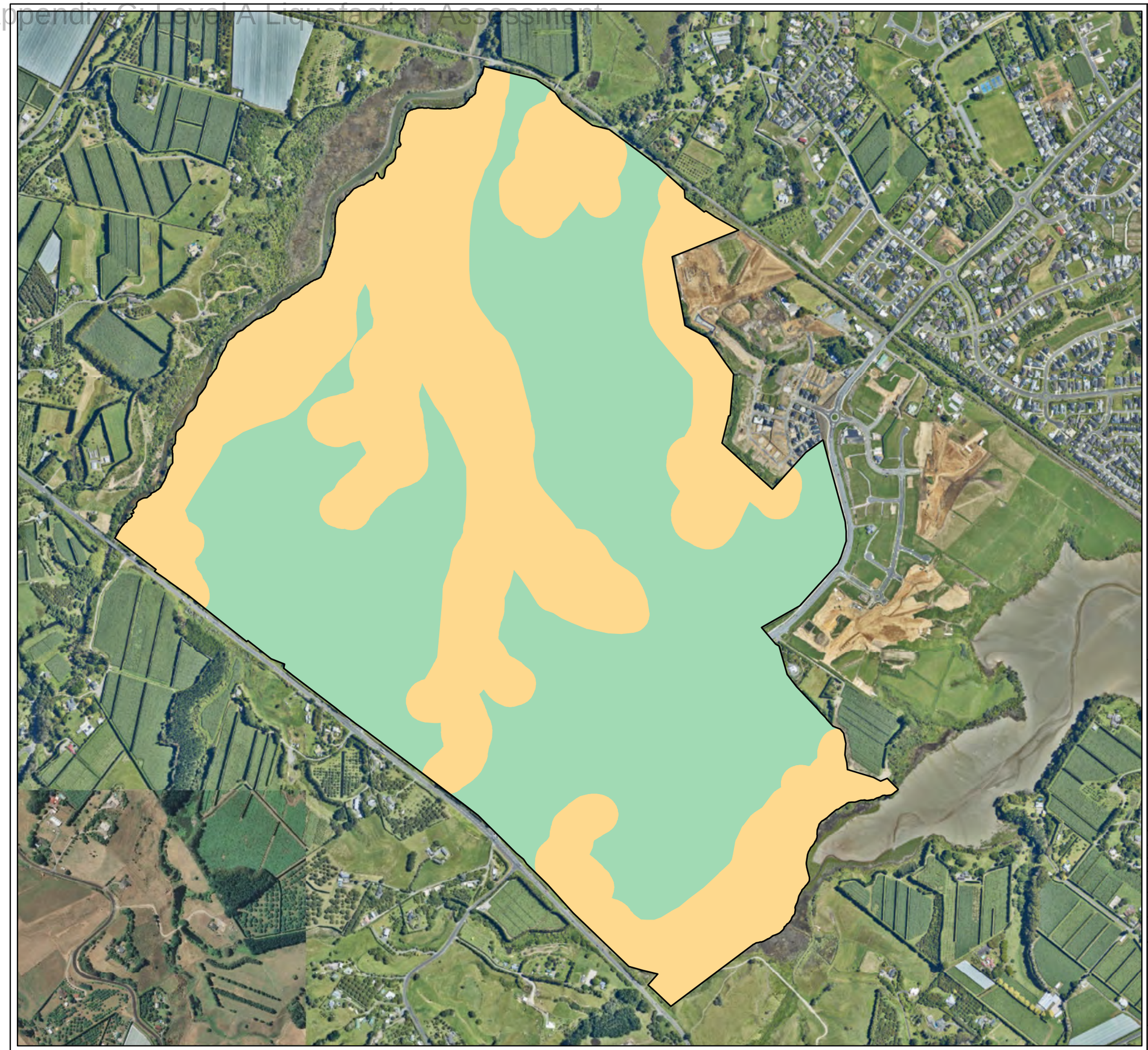
Omokoroa study area – Type A sub area	Liquefaction vulnerability indicators				
	Typical ground conditions	**Non-liquefying crust thickness**	**Topography**	**Assessment of Available CPT Analysis**	**Determination of expected degree of liquefaction-induced ground damage**
Description	Soil Type: Typically non-plastic sands and silts interbedded with low to moderate plasticity clay. Potential for pumiceous sands to be present. Soil Age: Typically Holocene age alluvium present within the top ten meters. Likely Pleistocene age and older deposits (e.g. Rotoehu Ash) underlying Holocene material.	Potential for groundwater to be less than 4m from the ground surface, particularly at the invert of any stream channels and other water features. The presence of non-plastic sands and silts that are susceptible to liquefaction combined with a relatively shallow groundwater surface creates the potential for a non-liquefying crust thickness of less than 3 m.	A combination of low-lying flat topography on the coastal margins and steep sloping stream channels. Free faces with the potential to induce lateral spreading are present.	25 year: unlikely to provide sufficient shaking to trigger liquefaction in saturated susceptible soils. Very low liquefaction vulnerability indices calculated for all CPT. 100 year: relatively low levels of shaking with liquefaction only triggered in soils most prone to liquefaction (i.e. loose, clean sandy soils). PGA response curves indicate that this is at the start of the inflection point. Low liquefaction vulnerability indices are calculated for most CPT. 500 year: liquefaction triggered in the majority of saturated susceptible soils. PGA response curves indicate this is towards the end of the inflection point. Calculated liquefaction vulnerability indices range from low to high for the CPT analysed.	25 year: likely none-to-minor liquefaction related land damage due to low levels of shaking. 100 year: likely no more than minor-to-moderate liquefaction related land damage. 500 year: none-to-minor or minor-to-moderate or moderate-to-severe liquefaction related land damage is possible.
Assessment of residual uncertainty	Due to the lack of geotechnical investigations there is a high residual uncertainty in the spatial distribution (both horizontally and vertically) of soil deposits.	Due to the lack of groundwater measurements there is high residual uncertainty in the spatial variability in groundwater levels and liquefiable soil deposits. This uncertainty is reduced in soils at lower elevations within close proximity to the coast where the groundwater is likely to be shallow (i.e. typically less than 4 m from the ground surface).	High resolution digital elevation model available means that the topography is well defined and there low residual uncertainty in the spatial distribution of the free faces and steep slopes.	High residual uncertainty in the applicability of these analyses due to the lack of geotechnical investigations, the highly interbedded nature of the deposits, the liquefaction potential of pumiceous soils is not well understood and the majority of the soils that are analysed as susceptible to liquefaction are on the threshold (Ic = 2.6) of liquefaction triggering. Laboratory testing may indicate that these soils are not susceptible to liquefaction.	High residual uncertainty associated with the expected degree of liquefaction-induced ground damage at 100 and 500 year return period levels of earthquake shaking.

Table B3: Summary of risk analysis and determination of expected degree of liquefaction-induced ground damage for Omokoroa study area – Type B sub area

Omokoroa study area – Type B sub area	Liquefaction vulnerability indicators				
	Typical ground conditions	**Non-liquefying crust thickness**	**Topography**	**Assessment of available CPT Analysis**	**Determination of expected degree of liquefaction-induced ground damage**
Description	Soil Type: Typically non-plastic sandy silt to silt interbedded with low to moderate plasticity clay. Potential for pumiceous sands to be present. Soil Age: Likely Pleistocene age and older deposits. The available geotechnical reports and local experience indicates that the Rotoehu Ash (>50,000 years old) is likely present across the site at relatively shallow depths (<4 m BGL).	The topography and available information from geotechnical reports undertaken in the area indicate that it is likely that the groundwater is significantly deeper than 4m BGL. This means that it is likely that the majority of the site has a non-liquefying crust thickness greater than 4 m.	The majority of the area is either flat or moderately sloping land. There are relatively few free faces with the potential to induce lateral spreading as these are typically confined to the stream channel geomorphology.	25 year: unlikely to provide sufficient shaking to trigger liquefaction in saturated susceptible soils. Very low liquefaction vulnerability indices calculated for all CPT. 100 year: relatively low levels of shaking with liquefaction only triggered in soils most prone to liquefaction (i.e. loose, clean sandy soils). Very low liquefaction vulnerability indices calculated for all CPT and the PGA response curves are well before the inflection point. 500 year: liquefaction triggered in the majority of saturated susceptible soils. PGA response curves indicate this is towards the end of the inflection point. Low to moderate liquefaction vulnerability indices are calculated for the CPT analysed.	25 year: likely none-to-minor liquefaction related land damage. 100 year: likely none-to-minor liquefaction related land damage. 500 year: likely none-to-minor liquefaction related land damage subject to on site confirmation that the depth to groundwater is more than 4 m BGL and the Rotuhue ash layer is shallower than 4 m BGL.
Assessment of residual uncertainty	Due to the lack of geotechnical investigations there is high residual uncertainty in the spatial distribution (both horizontally and vertically) of soil deposits. However, the age of these soil deposits indicates with a moderate degree of certainty that the soils are unlikely to be susceptible to liquefaction.	Due to the lack of groundwater measurements there is significant residual uncertainty in the spatial variability in groundwater levels. However it is reasonable to assume that the non-liquefying crust thickness is greater than 4 m because it is likely that the groundwater is deeper than 4m BGL across the majority of this area.	High resolution digital elevation model available means that the topography is well defined and there is a low residual uncertainty in the spatial distribution of the topography.	High residual uncertainty in the applicability of these analyses due to the limited number of geotechnical investigations, the highly interbedded nature of the deposits, the liquefaction potential of pumiceous soils is not well understood and the majority of the soils that are analysed as susceptible to liquefaction are on the threshold (Ic = 2.6) of liquefaction triggering (laboratory testing may indicate that these soils are not susceptible to liquefaction). It is critical to note that the 4 m depth to groundwater assumed for these analyses is representative of worst case (unlikely) conditions and therefore these analyses are considered to be conservative and therefore unlikely to be representative of the expected degree of liquefaction-induced ground damage.	Low residual uncertainty associated with the expected degree of liquefaction-induced ground damage at all year return period levels of earthquake shaking - subject to on site confirmation that the depth to groundwater is more than 4 m BGL and the Rotuhue ash layer is shallower than 4 m BGL.

Table B4: Summary of risk analysis and determination of expected degree of liquefaction-induced ground damage for Katikati study area – Type A sub area

Katikati study area – Type A sub area	Liquefaction vulnerability indicators				
	Typical ground conditions	**Non-liquefying crust thickness**	**Topography**	**Assessment of available CPT Analysis**	**Determination of expected degree of liquefaction-induced ground damage**
Description	Soil Type: Typically non-plastic sands and silts interbedded with low to moderate plasticity clay. Potential for pumiceous sands to be present. Soil Age: Typically Holocene age alluvium present within the top ten meters. Likely Pleistocene age and older deposits (e.g. Rotoehu Ash) underlying Holocene material.	Potential for groundwater to be less than 4m from the ground surface, particularly at the invert of any stream channels and other water features. The presence of non-plastic sands and silts that are susceptible to liquefaction combined with a relatively shallow groundwater surface creates the potential for a non-liquefying crust thickness of less than 3 m.	A combination of low-lying flat topography and moderately sloping land within the area mapped as stream channel. Free faces with the potential to induce lateral spreading are confined to the stream channels.	25 year: unlikely to provide sufficient shaking to trigger liquefaction in saturated susceptible soils. Very low liquefaction vulnerability indices calculated for all CPT. 100 year: relatively low levels of shaking with liquefaction only triggered in soils most prone to liquefaction (i.e. loose, clean sandy soils). PGA response curves indicate that this is at the start of the inflection point for most. Low to moderate liquefaction vulnerability indices are calculated for the CPT analysed. 500 year: liquefaction triggered in the majority of saturated susceptible soils. PGA response curves indicate this is towards the end of the inflection point. Calculated liquefaction vulnerability indices range from moderate to high for the CPT analysed.	25 year: likely none-to-minor liquefaction related land damage due to low levels of shaking. 100 year: likely no more than minor-to-moderate liquefaction related land damage. 500 year: none-to-minor or minor-to-moderate or moderate-to-severe liquefaction related land damage is possible.
Assessment of residual uncertainty	Due to the lack of geotechnical investigations there is a high residual uncertainty in the spatial distribution (both horizontally and vertically) of soil deposits.	Due to the lack of groundwater measurements there is high residual uncertainty in the spatial variability in groundwater levels and liquefiable soil deposits.	High resolution digital elevation model available means that the topography is well defined and there is a relatively low residual uncertainty in the spatial distribution of the topography.	High residual uncertainty in the applicability of these analyses due to the lack of geotechnical investigations, the highly interbedded nature of the deposits and the liquefaction potential of pumiceous soils is not well understood.	Low residual uncertainty associated with the expected degree of liquefaction induced ground damage at 25 year return period levels of earthquake shaking. High residual uncertainty associated with the expected degree of liquefaction-induced ground damage at 100 and 500 year return period levels of earthquake shaking



LEGEND

- Study Area
- Liquefaction damage is possible
- Liquefaction damage is unlikely (subject to on site confirmation*)

A3 SCALE: 1:9,980

0 0.1 0.2 0.3 0.4 0.5 (km)

N

Notes:

Bay of Plenty 0.3m Rural Aerial Photos (2016-2017) sourced from LINZ Data Serivice, re-use under Creative Commons 4.0 license.
Liquefaction vulnerability derived using MBIE Guidelines 2017, see table 4.4.
* Subject to on site confirmation that the depth to groundwater is deeper than 4m and the presence of the Rotoehu Ash layer is confirmed across the area under consideration at a depth of 4m or less.

DRAWN	MOLI	Sep.19
CHECKED	JICR	Sep.19
APPROVED	DMM	Sep.19
ARCFILE	1008683_200_FIG009a.mxd	
SCALE (AT A3 SIZE)		
PROJECT No.	1008683.000	

Tonkin+Taylor
105 Carlton Gore Road, Newmarket, Auckland
www.tonkintaylor.co.nz

BAY OF PLENTY REGIONAL COUNCIL

OMOKOROA LIQUEFACTION ASSESSMENT

Liquefaction risk assessment maps for Omokoroa

Figure B1

LEGEND

- Study Area
- Liquefaction damage is unlikely
- Liquefaction damage is possible

A3 SCALE: 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

N

Notes:

Bay of Plenty 0.3m Rural Aerial Photos (2016-2017) sourced from LINZ Data Serivice, re-use under Creative Commons 4.0 license.

Liquefaction vulnerability derived using MBIE Guidelines 2017, see table 4.4.

DRAWN	MOLI	Sep.19
CHECKED	JICR	Sep.19
APPROVED	DMM	Sep.19

ARCFILE: 1008683_200_FIG009.mxd

SCALE (AT A3 SIZE): 1:10,000

PROJECT No.: 1008683.000

Tonkin+Taylor
105 Carlton Gore Road, Newmarket, Auckland
www.tonkintaylor.co.nz

BAY OF PLENTY REGIONAL COUNCIL

KATIKATI LIQUEFACTION ASSESSMENT

Liquefaction risk assessment maps for Katikati

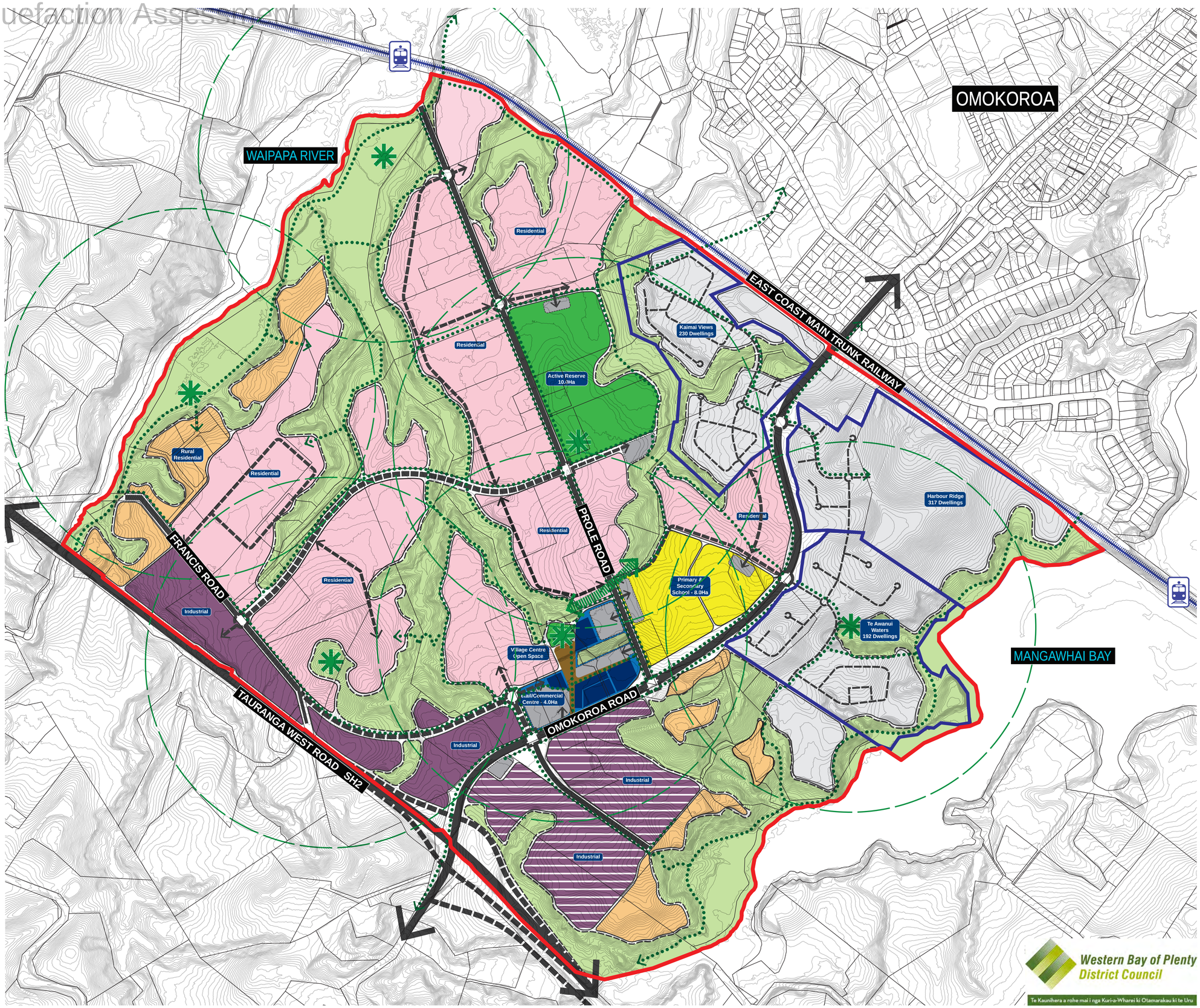
Figure B2

Appendix C: RPS risk assessment

- **Omokoroa structure plan**
- **Katikati Beach Road residential structure plan:**
    - **Roading, shared paths and reserve plan**
    - **Utilities plan**

LEGEND

- Study Area
- Existing road network
- Possible future urban road network consideration
- Proposed signalised intersection
- Proposed roundabout
- Proposed major pedestrian/cycle network
- Local Park - 500m Catchment (5min walk)
- Constrained Land. Inclusive of:
  - Slope greater than 1:4 (25%)
  - Stormwater ponds, stormwater management reserves & stormwater reserves
  - Tsunami evacuation zones - red, orange & yellow
  - Partial areas of widespread liquefaction
  - Archaeological sites
  - Significant ecological features/RAP
  - Areas prone to instability
  - Landscape feature S8/S8A - Tauranga Harbour Landscape management area
  - Private conservation reserves
- Active Reserve
- WBOPDC owned land, inclusive of community centre.
- Village Centre
- Low Density Residential
- Rural Residential
- Primary and Secondary School
- Retail and Commercial
- Industrial Land



Western Bay of Plenty District Council

Te Kaunihera a rohe mai i nga Kuri-a-Wharei ki Otamarakau ki te Uru

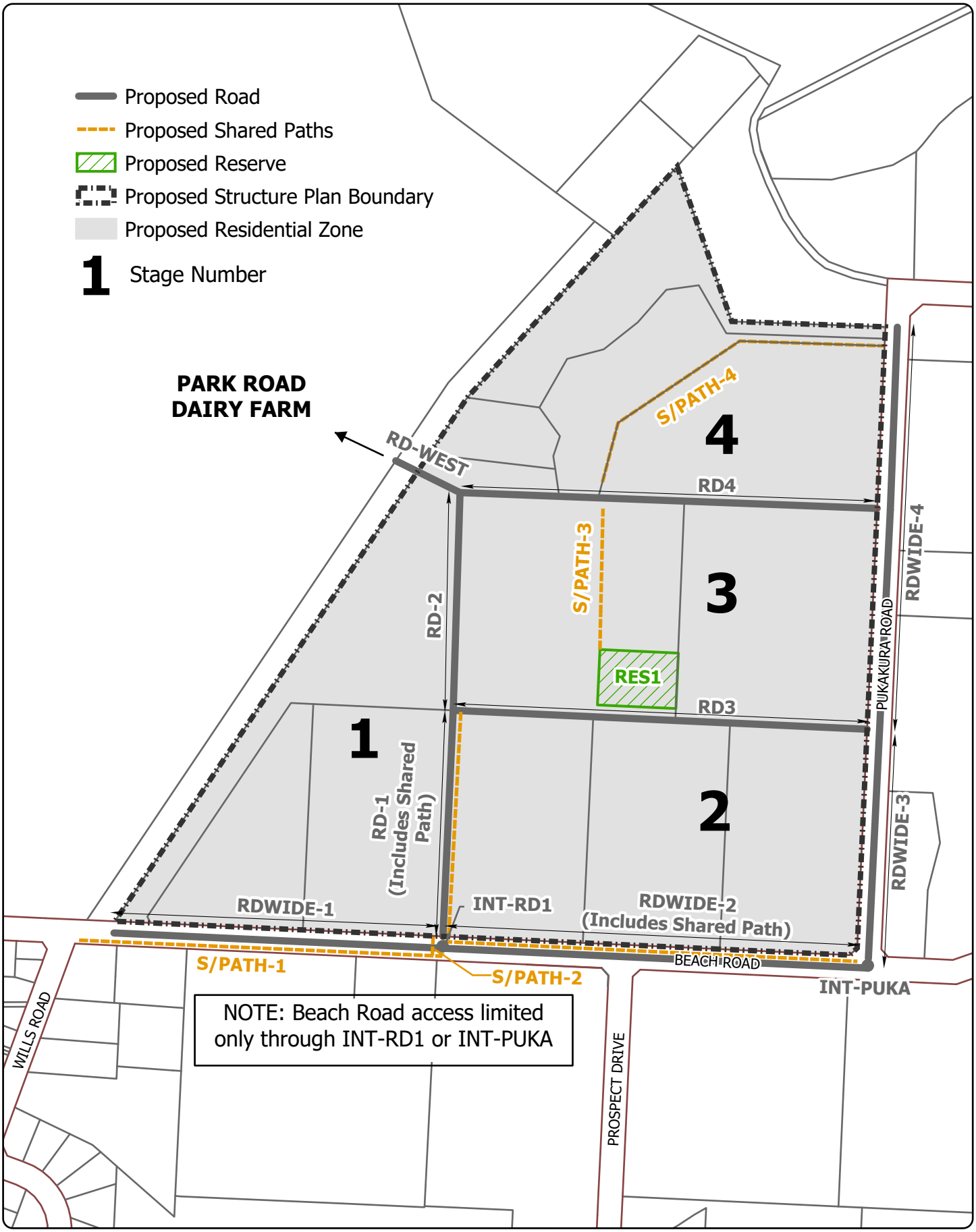
Omokoroa
Structure Plan Option 5

PRELIMINARY FOR DISCUSSION PURPOSES ONLY
Scale 1:5000 @ A1 | 28th November 2018 | Project No 138288-17

0 100 200 500

© COPYRIGHT PROTECTS THIS PLAN
Unauthorised reproduction or amendment not permitted. Please contact the author.

RPS



Produced using ArcMap by the Western Bay of Plenty District Council GIS Team.
Crown copyright reserved. LINZ digital license no. HN/352200/03 & TD093522.
Location of services is indicative only. Council accepts no liability for any error.
Archaeological data supplied by NZ Archaeological Assoc/Dept. of Conservation.

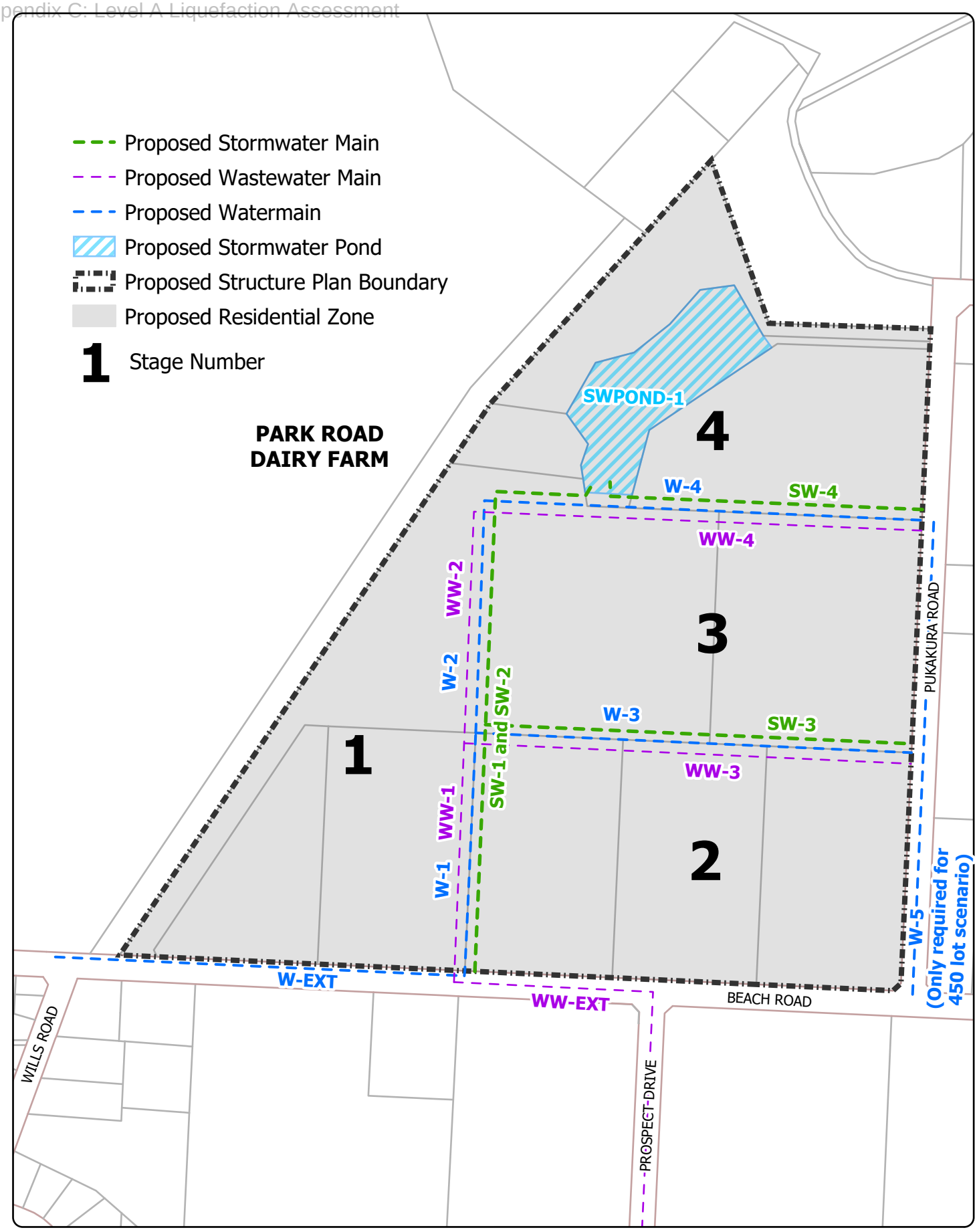
Email: gis@westernbay.govt.nz
Date: 7/10/2019
Operator: mlb
Map: E:\Shape\MLB\Map\Structure Plans\Beach Road 1 Area Structure Plan.aprx

Scale A4 - 1:4,250
0 25 50 100 150 200 250 Meters

Western Bay of Plenty District Council

350 LOT AND 450 LOT SCENARIOS
KATIKATI BEACH ROAD
RESIDENTIAL STRUCTURE PLAN
ROADING, SHARED PATHS AND RESERVE PLAN

N



Produced using ArcMap by the Western Bay of Plenty District Council GIS Team.
Crown copyright reserved. LINZ digital license no. HN/352200/03 & TD093522.
Location of services is indicative only. Council accepts no liability for any error.
Archaeological data supplied by NZ Archaeological Assoc/Dept. of Conservation.

Email: gis@westernbay.govt.nz
Date: 7/10/2019
Operator: mlb
Map: E:\Shape\MLB\Map\Structure Plans\Beach Road 1 Area Structure Plan.aprx

Scale A4 - 1:4,000
0 25 50 100 150 200 Meters

Western Bay of Plenty District Council

350 LOT AND 450 LOT SCENARIOS
KATIKATI BEACH ROAD RESIDENTIAL
STRUCTURE PLAN
UTILITIES PLAN

N

Appendix D: Omokoroa Geotechnical Factual Report

REPORT

Tonkin+Taylor

Exceptional thinking together

www.tonkintaylor.co.nz

Document Control

Title: Omokoroa Structure Plan Stage 3					
Date	**Version**	**Description**	**Prepared by:**	**Reviewed by:**	**Authorised by:**
27/02/20	1	First Issue	Caitlin Murphy	Guy McDougall	David Milner

Distribution:

Western Bay of Plenty District Council	1 electronic copy
Tonkin & Taylor Ltd (FILE)	1 electronic copy

Table of contents

1 Introduction

Tonkin & Taylor Ltd (T+T) was engaged by Western Bay of Plenty District Council (WBOPDC) to complete ground investigation and factual reporting for the Omokoroa Structure Plan Stage 3 area. The investigation was undertaken to provide geotechnical information that will later inform a liquefaction assessment for the site.

Geotechnical services were provided in accordance with our proposal dated 20 January 2020[1] and included the following scope of work:

- Supervision of ground investigation and sub-contractor liaison.
- 10 No. cone penetration tests[2] (CPTs) to approximately 20 m depth or refusal.
- 10 No. hand auger to 5 m depth or refusal.
- 5 No. Standpipe piezometers installed within CPTs[3].
- Groundwater monitoring for a period of 1 to 2 weeks following level logger installation.
- Installation of automated level loggers within the standpipe piezometers.

This factual report details the results of the geotechnical investigations.

2 Site description

Stage 3 of the Omokoroa Structure Plan area extends from State Highway 2 in the south to the railway in north and is bound by the Waipapa River to the west and Mangawhai Estuary to the east. Stage 3 has a total area of approximately 360 hectares. The site topography is general characterised as gently undulating terraces interrupted by incised stream gullies and several knolls. Elevations range from 0 m RL adjacent to the harbour, to 75 m RL (relative to Moturiki Vertical Datum (MVD1959)) in the middle of the site. The sides of the stream gullies are steep in places, but the slope angles decrease within the gully floors. Slope gradients vary from 1V:1H to 1V:3H with the majority of slopes approximately 1V:2H in stream gullies and on the harbour margins. Away from the stream gullies and harbour margins, the slopes within the site are generally less than 10 degrees.

3 Published geology

Published geology Briggs et al. 1996[4] indicates that the site is underlain by three different geological units. Terrace deposits (tm) of the Matua Subgroup make up the majority of the study area. The Matua Subgroup comprises sands, gravels and lignites. A lobe of crystal-rich ignimbrite known as the Waiteariki Ignimbrite is mapped in the east of the study area. Along coastal margins and modern streams sand, silt and gravel have been deposited forming Holocene deposits.

There are some geotechnical investigations (including hand augers and CPT) available within and around the study area. Information about the existing investigations is available in the T+T report *Regional Liquefaction Hazard Study – Katikati and Omokoroa Liquefaction Assessment* dated September 2019[5]. The data collected from these boreholes indicate that the local geology is variable

[1] Tonkin & Taylor Ltd (20 January 2020), Offer of Service, Omokoroa Structure Plan – Geotechnical Investigation. T+T Ref: 1008683.1000.
[2] One CPT (CPT108) was unable to be completed due to access restrictions from the property owner. This reduced the total CPTs to 9. Further details are in this report.
[3] An additional Piezometer was installed. This increased the piezometers to 6. Further details are in this report.
[4] Briggs, R. M., Hall, G. J., Harmsworth, G. R., Hollis, A. G., Houghton, B. F., Hughes, G. R., ... & Whitbread-Edwards, A. R. (1996). Geology of the Tauranga area. Department of Earth Sciences Occasional Report, (22).
[5] Tonkin & Taylor Ltd (2019) Regional Liquefaction Hazard Study Katikati and Omokoroa Liquefaction Assessment.

both laterally and vertically, but show that the area is mostly underlain by clayey and sandy sediments. This geology is typical of the Tauranga Area.

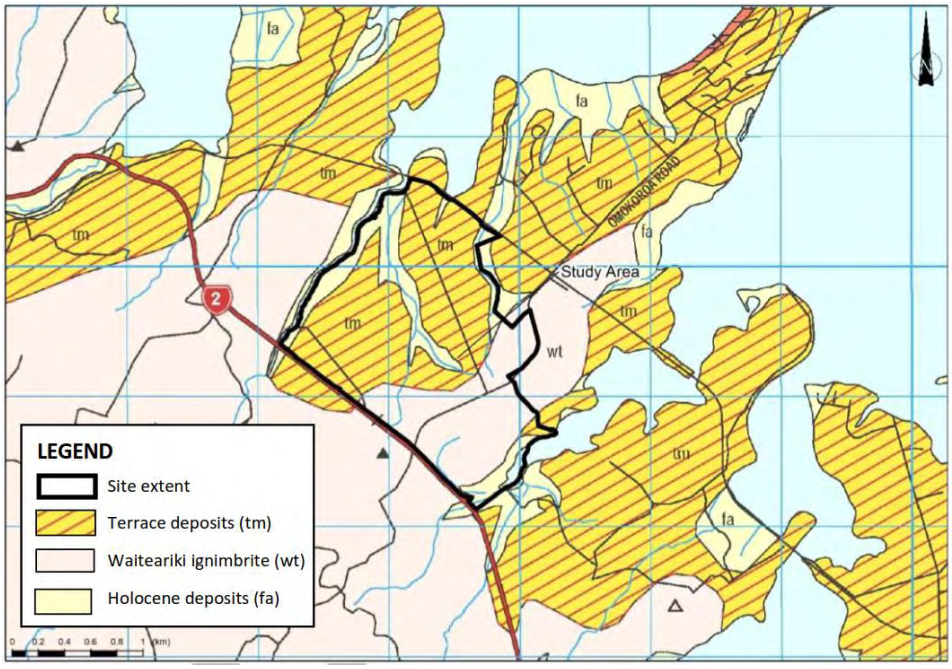


Figure 3.1: Geological setting (Source: Briggs et al. (1996))

4 Site investigations

4.1 Investigations undertaken

The following investigations were completed at the site between 22 January 2020 and 3 February 2020.

- 10 No. hand augured boreholes 5 m below ground level on 22 January 2020 with shear vanes in increments of 0.5 m within cohesive material.
- 9 No. CPTs to a target depth of 20 m on 22 January 2020.
- 6 No. Standpipe piezometers with automated level loggers.

Investigation locations were selected by T+T on the basis of access, presence of overhead and buried services and traffic management considerations.

The locations of the investigations were surveyed by hand held GPS survey and are presented on Figure A1 in Appendix A.

The following sections provide more detail on the geotechnical investigations undertaken for this project. Investigation locations are presented on Figure A1 and Figure A2 in Appendix A.

4.2 Hand augered boreholes

The drilling of 10 No. hand auger boreholes was undertaken on 22 January 2020. The works were carried out by a geologist from Geotechnics Ltd. In situ shear strength testing was undertaken at 500 mm intervals throughout the soil horizon.

Investigation locations are presented on Figure A1. Borehole logs are presented in Appendix B. A summary of the hand auger borehole details is presented in Table 4.1.

The hand auger boreholes have also been uploaded to the New Zealand Geotechnical Database (NZGD).

Table 4.1: Hand auger borehole summary

HA ID	NZGD ID	Location (NZTM)(1)		Ground Surface Elevation(1) RL (m)	Depth (m)
		Easting (m)	Northing (m)		
HA101	HA_138349	1865983.0	5828768.9	15	5.0
HA102	HA_138350	1866114.6	5828519.2	18	5.0
HA103	HA_138351	1865510.4	5828206.7	23	5.0
HA104	HA_138352	1866241.0	5828215.0	22	5.0
HA105	HA_138353	1865770.8	5827958.1	23	5.0
HA106	HA_138354	1866459.3	5827668.7	33	5.0
HA107	HA_138355	1866176.0	5827289.7	36	5.0
HA108	HA_138356	1866453.4	5827074.3	40	5.0
HA109	HA_138357	1865328.4	5827778.3	26	5.0
HA110	HA_138817	1866422.9	5828086.6	25	5.0

Notes: (1) The location information has been determined by handheld GPS. The elevation data has been determined based on LIDAR with 1 m resolution (sourced from BOPLASS Ltd., 2015).

4.3 Cone penetration tests

9 No. CPTs were undertaken by Perry Geotech Ltd on 28 January 2020 and 3 February 2020. In all cases, the CPTs were taken to either a target depth of 20 m or 'refusal' whichever was shallower. Refusal occurred due to the cone terminating on or within a hard, impenetrable strata such as a dense sand layer or hard clay material with high sleeve friction.

The CPT locations are presented on Figure A1 of Appendix A. The CPT logs are provided in Appendix C. A summary of the CPTs and termination depths is presented in Table 4.2.

The CPTs have been uploaded to the NZGD.

Table 4.2: CPT Summary

CPT ID	NZGD ID	Location (NZTM)(1)		Ground Surface Elevation(1) RL (m)	Test depth (m)	Reason for termination
		Easting (m)	Northing (m)			
CPT101	CPT_138340	1865983.2	5828769.6	15	15.99	Sleeve friction exceeds 0.9 MPa
CPT102	CPT_138341	1866113.9	5828520.4	18	17.28	Tip resistance exceeds 40 MPa
CPT103	CPT_138342	1865512.0	5828207.6	23	20.00	Target depth reached
CPT104	CPT_138343	1866238.7	5828219.6	22	20.00	Target depth reached
CPT105	CPT_138344	1865770.2	5827960.0	23	20.00	Target depth reached
CPT106	CPT_138347	1866460.0	5827666.3	33	20.00	Target depth reached
CPT107b	CPT_138348	1866172.2	5827293.1	36	17.07	Sleeve friction exceeds 0.9 MPa
CPT109	CPT_138345	1865892.7	5829063.9	2.8	5.34	Tip resistance exceeds 40 MPa
CPT110	CPT_138346	1865890.6	5827571.1	20	12.16	Sleeve friction exceeds 0.9 MPa

Notes: (1) The location information has been determined by handheld GPS. The elevation data has been determined based on LIDAR with 1m resolution (sourced from BOPLASS Ltd., 2015).

4.4 Groundwater monitoring

4.4.1 Standpipe piezometer details

Groundwater standpipe piezometers were installed in six of the CPTs. Summary details of the piezometer installations are presented in Table 4.3 below. Installation records are attached in Appendix D.

Table 4.3: Piezometer details

CPT ID	NZGD ID	Screen top and bottom depth (m below ground level)	Screen top and bottom level (mRL)	Based of PVC piezometer (m)	Standpipe Type and Diameter
CPT101	CPT_138340	6.2 to 7	8.8 to 7	8.2	PVC, 20 mm
CPT104	CPT_138343	9.3 to 10.8	12.7 to 11.2	14	PVC, 20 mm
CPT105	CPT_138344	12 to 13.5	11.0 to 9.5	14	PVC, 20 mm
CPT106	CPT_138347	5.5 to 7	27.5 to 26.0	8	PVC, 20 mm
CPT107b	CPT_138348	5.5 to 7	30.5 to 29	8	PVC, 20 mm
CPT109	CPT_138345	2.5 to 4	0.3 to -1.2	4.5	PVC, 20 mm

4.4.2 Groundwater levels

Groundwater levels within the piezometers were recorded using an electronic dip meter at an approximate frequency of once a week. Installation of level loggers within the piezometers is planned at a future date following release of this report. The recorded groundwater levels are presented below in Table 4.4.

Table 4.4: Groundwater levels

Standpipe ID	Base of piezo (m)	28/01/2020		3/02/2020		11/02/2020		18/02/2020	
		GWD (m)	GWL (mRL)	GWD (m)	GWD (m)	GWD (m)	GWL (mRL)	GWD (m)	GWL (mRL)
CPT101	8.2	6.7	8.3(1)	7.99	7.01	7.95	7.05	8	7
CPT104	14	10.8	11.2(1)	7.92	14.08	6.35	15.65	6.07	15.93
CPT105	14	13.6	9.4(1)	10.7	12.3	8.99	14.01	9.07	13.93
CPT106	8	-	-	Dry(1)	-	4.18	28.82	4.41	28.59
CPT107	8	-	-	7.25(1)	28.75	5	31	4.98	31.02
CPT109	4.5	4.5	-1.7(1)	3.56	-0.76	2.57	0.23	2.17	0.63

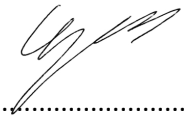
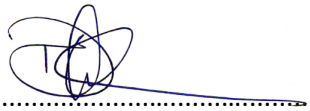
Notes: (1) Measurement taken within 30 minutes of test completion. Therefore, this measurement is of a low accuracy compared to other readings.

GWD = Groundwater depth, GWL = Groundwater level

5 Applicability

This report has been prepared for the exclusive use of our client Western Bay of Plenty District 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.

Tonkin & Taylor Ltd

Report prepared by:	Authorised for Tonkin & Taylor Ltd by:
	
.....	.....
Caitlin Murphy	David Milner
Engineering Geologist	Project Director

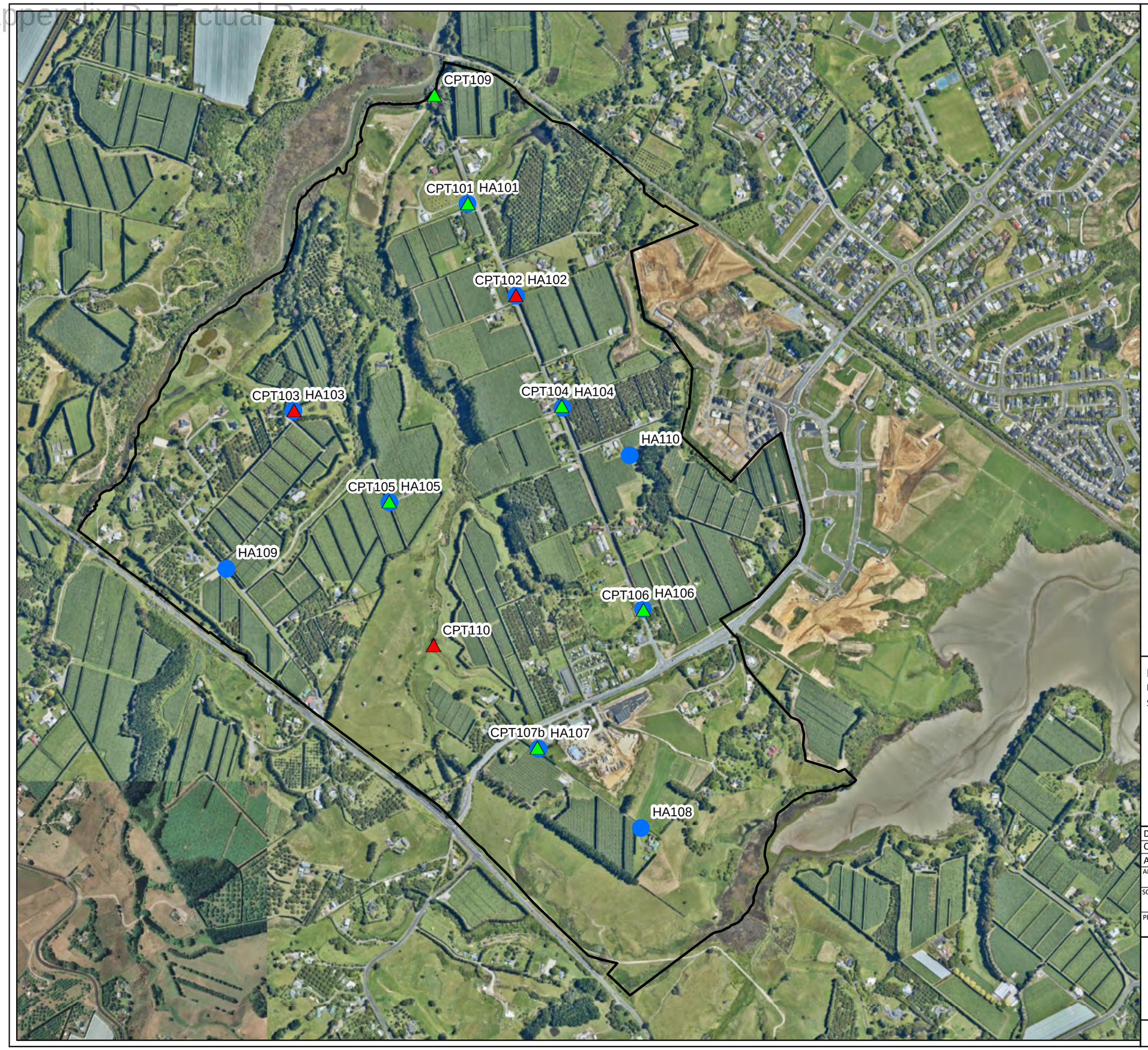
Review completed by Guy McDougall (Geotechnical Engineer)

CAMY
\\ttgroup.local\files\tgaprojects\1008683\1008683.1000\issueddocuments\factual report\20200227.camy.factualreport.docx

Appendix A: Figures

Figure A1: Ground investigation location plan

Figure A2: Ground investigation location plan with structure plan overlay



Legend

Completed Geotechnical Investigation

- Cone Penetration Test (CPT)
- Standpipe Piezometer and CPT
- Hand Auger
- Extent of Study Area

A3 SCALE: 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

N

Notes:

Bay of Plenty 0.3m Rural Aerial Photos (2016-2017) sourced from LINZ Data Service, re-use under Creative Commons 4.0 license.

DRAWN	GUMC	Feb.20
CHECKED	CAMY	Feb. 20
APPROVED	DMMM	Feb. 20

ARCFILE: 1008683.1000.mxd

SCALE (AT A3 SIZE): 1:20,000

PROJECT No.: 1008683.1000

Tonkin+Taylor
105 Carlton Gore Road, Newmarket, Auckland
www.tonkintaylor.co.nz

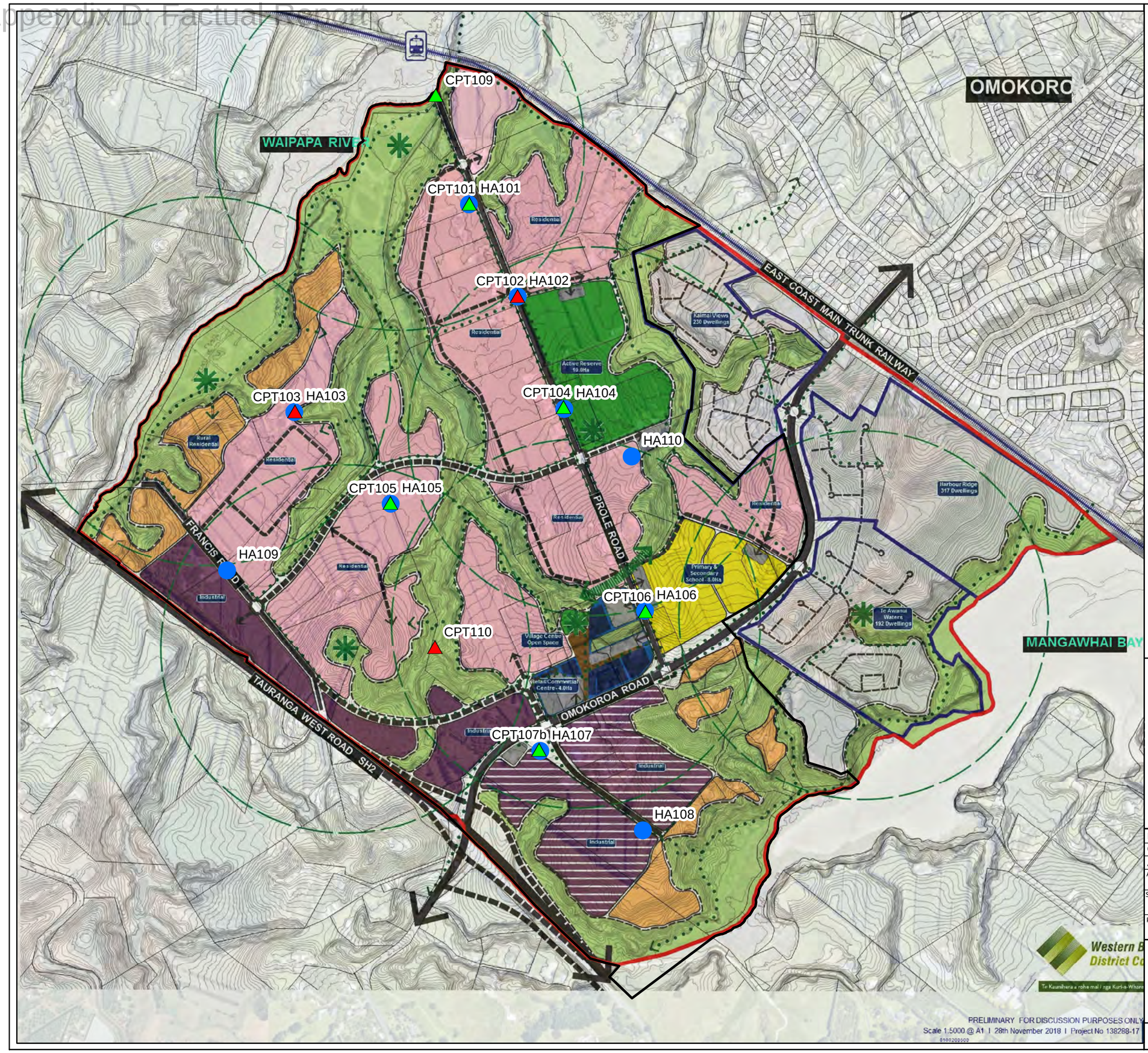
WESTERN BAY OF PLENTY DISTRICT COUNCIL

OMOKOROA STRUCTURE PLAN STAGE 3

GEOTECHNICAL FACTUAL REPORT

COMPLETED GROUND INVESTIGATION LOCATIONS

Figure A1



Legend

Completed Geotechnical Investigation

- Cone Penetration Test (CPT)
- Standpipe Piezometer and CPT
- Hand Auger
- Extent of Study Area

- Existing road network
- Possible future urban road network consideration
- Proposed signalised intersection
- Proposed roundabout
- Proposed major pedestrian/cycle network
- Local Park - 500m Catchment (5min walk)
- Constrained Land. Inclusive of:
- Active Reserve
- WBOPDC owned land, inclusive of community centre.
- Village Centre
- Low Density Residential
- Rural Residential
- Primary and Secondary School
- Retail and Commercial
- Industrial Land

A3 SCALE: 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

N

Notes:

Bay of Plenty 0.3m Rural Aerial Photos (2016-2017) sourced from LINZ Data Service, re-use under Creative Commons 4.0 license.

Structure plan basemap sourced from Western Bay of Plenty District Council, Structure Plan Option 5, 28 November 2018

DRAWN	GUMC	Feb.20
CHECKED	CAMY	Feb. 20
APPROVED	DMMM	Feb. 20
ARCFILE	1008683.1000.mxd	
SCALE (AT A3 SIZE)	1:20,000	
PROJECT No.	1008683.1000	

Tonkin+Taylor
105 Carlton Gore Road, Newmarket, Auckland
www.tonkintaylor.co.nz

WESTERN BAY OF PLENTY DISTRICT COUNCIL

OMOKOROA STRUCTURE PLAN STAGE 3

GEOTECHNICAL FACTUAL REPORT

COMPLETED GROUND INVESTIGATION LOCATIONS

Figure A2

Appendix B: Hand auger logs

GEOTECHNICS

HAND AUGER LOG

HOLE Id: **HA101**

Hole Location: See Location Plan

SHEET: 1 OF 1

PROJECT: Omokoroa Site Investigation	LOCATION: Omokoroa	JOB No.: 1013262.0000
CO-ORDINATES: (NZTM2000) 5828768.90 mN 1865983.00 mE	DRILL TYPE: 50mm Hand Auger	HOLE STARTED: 22/01/2020
	DRILL METHOD: HA	HOLE FINISHED: 22/01/2020
R.L.: 15.00m		DRILLED BY: GEOTECHNICS
DATUM: MOTUHT1953		LOGGED BY: ALRI CHECKED: TASR

GEOLOGICAL											ENGINEERING DESCRIPTION
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MATERIAL COMPOSITION.	WATER	CORE RECOVERY (%)	METHOD	SCALA PENETROMETER (Blows/100mm) 0 1 2 3 4 5 6 7 8 9	TESTS	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	Description and Additional Observations
Topsoil					HA101/0.05 @ 0.1m					D-M	St		Organic SILT, with minor sand; dark brownish black. Stiff, dry to moist, low plasticity; sand, fine.
					HA101/0.5 @ 0.5m						H		SILT, with minor sand; light brown. Hard, dry to moist, low plasticity; sand, fine.
Younger Ash					>214 kPa								
					183/49 kPa		14	1			VSt		0.9m: Changes to very stiff.
					>214 kPa						H		1.2m: Changes to hard.
					199/52 kPa								
Rotoehu Ash		100	HA				13	2		M	MD		Silty, fine to coarse SAND; light orange brown. Medium dense, moist, well graded. 2.2m: Changes to fine to medium grain; yellowish brown. 2.3m: Changes to greyish brown.
					131/40 kPa						VSt		SILT, with minor sand; dark brown. Very stiff, moist, low plasticity; sand, fine. 2.75m: Changes to dark orange brown.
					128/76 kPa		12	3					3.15m: Changes to light orange brown.
Hamilton Ash					107/40 kPa								3.4m: Changes to light yellowish brown.
					95/31 kPa						St		3.6m: Changes to stiff.
					92/24 kPa		11	4					SILT, with some clay, trace sand; light yellowish brown. Stiff, moist, high plasticity; sand, fine.
					104/34 kPa								Silty CLAY, with minor sand; light grey. Stiff, moist, high plasticity; sand, fine.
Matua Subgroup	DRY 22/01/2020				>214 kPa						H		4.5m: Changes to hard.
					76/21 kPa						St		4.8m: Changes to stiff.
							10	5					End of borehole at 5.00mbgl. No standing groundwater encountered.

COMMENTS: Customer Reference: 1013262.0.0.0

Hole Depth 5m

Scale 1:28

Rev.: A

HandAugerLog - 27/02/2020 11:39:03 a.m. - Produced with Core-GS by GeRoc

GEOTECHNICS

HAND AUGER LOG

HOLE Id: **HA102**

Hole Location: See Location Plan

SHEET: 1 OF 1

PROJECT: Omokoroa Site Investigation	LOCATION: Omokoroa	JOB No.: 1013262.0000
CO-ORDINATES: (NZTM2000) 5828519.20 mN 1866114.60 mE	DRILL TYPE: 50mm Hand Auger	HOLE STARTED: 22/01/2020
	DRILL METHOD: HA	HOLE FINISHED: 22/01/2020
R.L.: 18.00m		DRILLED BY: GEOTECHNICS
DATUM: MOTUHT1953		LOGGED BY: DBRU CHECKED: TASR

GEOLOGICAL													ENGINEERING DESCRIPTION
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MATERIAL COMPOSITION.	WATER	CORE RECOVERY (%)	METHOD	SCALA PENETROMETER (Blows/100mm) 0 1 2 3 4 5 6 7 8 9	TESTS	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	MOISTURE CONDITION \ WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	Description and Additional Observations
Younger Ash					HA102/0.05 @ 0.1m					M	St		SILT, with minor sand; orange brown. Stiff, moist, low plasticity; sand, fine to medium.
					>214 kPa						H		0.3m: Changes to hard.
					HA102/0.5 @ 0.5m								
					141/34 kPa					M	VSt		0.6m: Changes to orange brown. Very stiff, moist.
					153/28 kPa								
Rotoehu Ash							17	1					Sandy SILT; light brown. Very stiff, moist, low plasticity; sand, fine to coarse.
					98/31 kPa						St		1.2m: Changes to stiff.
					61/28 kPa								
					>214 kPa								
Hamilton Ash		100					16	2			H		SILT, with minor sand; dark brownish black, with orange brown mottling. Hard, moist, low plasticity; sand, fine to medium.
					UTP								
					202/46 kPa								SILT, with minor sand; dark orange brown. Hard, moist, low plasticity; sand, fine to medium.
					141/34 kPa						VSt		2.7m: Changes to very stiff.
					>214 kPa		15	3			H		2.9m: Changes to orange mottling. 3.0m: Changes to hard.
					168/49 kPa						VSt		CLAY, with some silt, minor sand; light grey, with brownish orange mottling. Very stiff, moist, high plasticity; sand, fine to medium.
					214/- kPa						H		3.6m: Changes to hard.
					31/15 kPa					M-W	F		Silty CLAY, with some sand; light orange brown, with light grey mottling. Firm, moist to wet, high plasticity; sand, fine to coarse.
Matua Subgroup	DRY 22/01/2020						14	4			St		CLAY, with some silt, trace sand; brownish orange. Stiff, moist to wet, high plasticity; sand, fine. 4.3m: Changes to light brownish orange, with light grey mottling.
					92/37 kPa								
					86/31 kPa								
					61/24 kPa								
							13	5					End of borehole at 5.00mbgl. No standing groundwater encountered.

COMMENTS: Rotoehu Ash not encountered.Customer Reference: 1013262.0.0.0

Hole Depth 5m

Scale 1:28

Rev.: A

HandAugerLog - 27/02/2020 11:39:05 a.m. - Produced with Core-GS by GeRoc

GEOTECHNICS

HAND AUGER LOG

HOLE Id: **HA103**

Hole Location: See Location Plan

SHEET: 1 OF 1

PROJECT: Omokoroa Site Investigation	LOCATION: Omokoroa	JOB No.: 1013262.0000
CO-ORDINATES: (NZTM2000) 5828206.70 mN 1865510.40 mE	DRILL TYPE: 50mm Hand Auger	HOLE STARTED: 22/01/2020
	DRILL METHOD: HA	HOLE FINISHED: 22/01/2020
R.L.: 23.00m		DRILLED BY: GEOTECHNICS
DATUM: MOTUHT1953		LOGGED BY: ALRI CHECKED: TASR

GEOLOGICAL												ENGINEERING DESCRIPTION
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MATERIAL COMPOSITION.	WATER	CORE RECOVERY (%)	METHOD	SCALA PENETROMETER (Blows/100mm) 0 1 2 3 4 5 6 7 8 9	TESTS	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	Description and Additional Observations
Topsoil					HA103/0.05 @ 0.1m				TS	D-M	St		Organic SILT, with minor sand; dark brownish black. Stiff, dry to moist, low plasticity; sand, fine.
					●>213 kPa						H		SILT, with minor sand; light brown. Hard, dry to moist, low plasticity; sand, fine.
					HA013.0.5 @ 0.5m								
					●158/33 kPa						VSt		0.6m: Changes to very stiff.
Younger Ash					●>213 kPa		22	1			H		0.9m: Changes to hard.
					●>213 kPa								1.1m: Changes to brownish orange.
					●213/- kPa								
Rotoehu Ash					●UTP						MD		Silty, fine to coarse SAND; light brown. Medium dense, dry to moist, well graded.
					●UTP		21	2					
					●137/49 kPa					M	VSt		SILT, with trace sand; dark brown. Very stiff, moist, low plasticity; sand, fine.
					●140/61 kPa								
Hamilton Ash		100	HA		●167/76 kPa		20	3					2.8m: Changes to dark brownish orange.
					●152/67 kPa								
					●152/61 kPa								
					●152/55 kPa		19	4					SILT, with some clay, trace sand; reddish brown, with grey mottling. Very stiff, moist, high plasticity; sand, fine.
					●155/49 kPa								
Matua Subgroup	DRY 22/01/2020				●UTP						H		SILT, with some sand; greyish brown. Very stiff, moist, low plasticity; sand, fine to coarse.
					●UTP								4.5m: Changes to hard.
										M-W			4.8m: Changes to moist to wet.
							18	5					End of borehole at 5.00mbgl.
													No standing groundwater encountered.

COMMENTS: Customer Reference: 1013262.0.0.0

Hole Depth 5m

Scale 1:28

Rev.: A

HandAugerLog - 27/02/2020 11:39:07 a.m. - Produced with Core-GS by GeRoc

GEOTECHNICS

HAND AUGER LOG

HOLE Id: **HA104**

Hole Location: See Location Plan

SHEET: 1 OF 1

PROJECT: Omokoroa Site Investigation	LOCATION: Omokoroa	JOB No.: 1013262.0000
CO-ORDINATES: 5828215.00 mN (NZTM2000) 1866241.00 mE	DRILL TYPE: 50mm Hand Auger	HOLE STARTED: 22/01/2020
	DRILL METHOD: HA	HOLE FINISHED: 22/01/2020
R.L.: 22.00m		DRILLED BY: GEOTECHNICS
DATUM: MOTUHT1953		LOGGED BY: DBRU CHECKED: TASR

GEOLOGICAL												ENGINEERING DESCRIPTION
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MATERIAL COMPOSITION.	WATER	CORE RECOVERY (%)	METHOD	SCALA PENETROMETER (Blows/100mm) 0 1 2 3 4 5 6 7 8 9	TESTS	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	MOISTURE CONDITION \ WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	Description and Additional Observations
Topsoil					HA104/0.05 @ 0.1m				TS	D-M	F		Organic SILT, with minor sand; dark brown. Firm, dry to moist, low plasticity; sand, fine to medium.
Younger Ash					HA104/0.5 @ 0.5m 55/14 kPa >193 kPa >193 kPa >193 kPa		21	1			St H		SILT, with minor sand; brown. Stiff, dry to moist, low plasticity; sand, fine to medium. 0.9m: Changes to hard.
		100	HA		UTP		20	2					Sandy SILT; orange brown. Hard, dry to moist, low plasticity; sand, fine to coarse.
Matua Subgroup	DRY 22/01/2020				UTP UTP 176/44 kPa >193 kPa 124/61 kPa 96/41 kPa 83/28 kPa		19 18 17	3 4 5		M M-W	VSt H St		Silty CLAY, with minor sand; light grey, with brownish orange mottling. Hard, moist, high plasticity; sand, fine to medium. 3.3m: Changes to very stiff. SILT, with some clay and sand; light grey, with brownish orange mottling. Hard, moist, high plasticity; sand, fine to coarse. 4.2m: Changes to stiff. 4.6m: Changes to moist to wet.
													End of borehole at 5.00mbgl. No standing groundwater encountered.

COMMENTS: Rotoehu Ash and Hamilton Ash not encountered.Customer Reference: 1013262.0.0.0

Hole Depth 5m

Scale 1:28

Rev.: A

HandAugerLog - 27/02/2020 11:39:09 a.m. - Produced with Core-GS by GeRoc

GEOTECHNICS

HAND AUGER LOG

HOLE Id: **HA105**

Hole Location: See Location Plan

SHEET: 1 OF 1

PROJECT: Omokoroa Site Investigation	LOCATION: Omokoroa	JOB No.: 1013262.0000
CO-ORDINATES: 5827958.10 mN (NZTM2000) 1865770.80 mE	DRILL TYPE: 50mm Hand Auger	HOLE STARTED: 22/01/2020
	DRILL METHOD: HA	HOLE FINISHED: 22/01/2020
R.L.: 23.00m		DRILLED BY: GEOTECHNICS
DATUM: MOTUHT1953		LOGGED BY: ALRI CHECKED: TASR

GEOLOGICAL										ENGINEERING DESCRIPTION			
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MATERIAL COMPOSITION.	WATER	CORE RECOVERY (%)	METHOD	SCALA PENETROMETER (Blows/100mm) 0 1 2 3 4 5 6 7 8 9	TESTS	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	Description and Additional Observations
Topsoil					HA105/0.05 @ 0.1m				TS	D-M	St		Organic SILT, with minor sand; dark brownish black. Stiff, dry to moist, low plasticity; sand, fine.
					● 155/46 kPa								
					HA105/0.5 @ 0.5m						VSt		SILT, with minor sand; brown. Very stiff, dry to moist, low plasticity; sand, fine.
					● >213 kPa						H		0.6m: Changes to hard.
Younger Ash					● >213 kPa		22	1					1.3m: Changes to orange brown.
					● >213 kPa								
					● >213 kPa								
Rotoehu Ash							21	2			MD		Silty ,fine to coarse SAND; light brown. Medium dense, dry to moist, well graded. 2.2 - 2.3m: Changes to fine to medium grain.
					● >213 kPa						H		SILT, with minor sand; dark brown. Hard, dry to moist, low plasticity; sand, fine.
					● >213 kPa								2.7m: Changes to brownish orange.
					● >213 kPa		20	3					
Hamilton Ash		100	HA		● UTP								
					● UTP								
					● UTP		19	4					SILT, with some sand; brownish orange. Hard, moist, low plasticity; sand, fine to coarse.
					● UTP								
					● 91/30 kPa					M	St		Silty CLAY, with trace sand; brownish orange. Stiff, moist, high plasticity; sand, fine. 4.5m: Changes to greyish brown. Stiff.
Matua Subgroup	DRY 22/01/2020				● 88/33 kPa		18	5					CLAY, with some silt, minor sand; light brownish grey. Stiff, moist, high plasticity; sand, fine to coarse.
													End of borehole at 5.00mbgl. No standing groundwater encountered.

COMMENTS: Customer Reference: 1013262.0.0.0

Hole Depth 5m

Scale 1:28

Rev.: A

HandAugerLog - 27/02/2020 11:39:11 a.m. - Produced with Core-GS by GeRoc

GEOTECHNICS

HAND AUGER LOG

HOLE Id: **HA106**

Hole Location: See Location Plan

SHEET: 1 OF 1

PROJECT: Omokoroa Site Investigation	LOCATION: Omokoroa	JOB No.: 1013262.0000
CO-ORDINATES: (NZTM2000) 5827668.70 mN 1866459.30 mE	DRILL TYPE: 50mm Hand Auger	HOLE STARTED: 22/01/2020
	DRILL METHOD: HA	HOLE FINISHED: 22/01/2020
R.L.: 33.00m		DRILLED BY: GEOTECHNICS
DATUM: MOTUHT1953		LOGGED BY: DBRU CHECKED: TASR

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MATERIAL COMPOSITION.	WATER	CORE RECOVERY (%)	METHOD	SCALA PENETROMETER (Blows/100mm) 0 1 2 3 4 5 6 7 8 9	TESTS	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	Description and Additional Observations
Topsoil					HA106/0.05 @ 0.1m				TS	D-M	St		Organic SILT, with some gravel, minor sand; dark brown. Stiff, dry to moist, low plasticity; gravel, fine to coarse, subangular to subrounded; sand, fine to coarse.
Fill					HA106/0.5 @ 0.5m ●>214 kPa						VSt		SILT, with minor sand and gravel; brown. Very stiff, dry to moist, low plasticity; sand, fine to coarse, gravel, fine to coarse, subangular to subrounded. 0.5m: Gravel absent.
Buried Topsoil					●61/15 kPa						St		Organic SILT, with minor sand, trace rootlets; dark brown. Stiff, dry to moist, low plasticity; sand, fine to medium; rootlets (10 - 20mm).
Younger Ash		100	HA		●UTP ●>214 kPa ●>214 kPa ●>214 kPa ●>214 kPa ●116/43 kPa ●122/70 kPa		32 31 30	1 2 3		M	H VSt		SILT, with minor sand; orange brown. Hard, dry to moist, low plasticity; sand, fine to medium. 1.35m: Changes to moist. SILT, with some sand; brown. Hard, moist, low plasticity; sand, fine to medium. 2.7m: Changes to light yellowish brown. Very stiff.
Hamilton Ash					●>214 kPa ●>214 kPa ●>214 kPa		29	4			H		SILT, with minor sand; dark brown. Very stiff, moist, low plasticity; sand, fine. 3.3m: Changes to brownish orange mottling. Hard. SILT, with minor sand, trace rootlets; brownish orange. Hard, moist, low plasticity; sand, fine to medium; rootlets (10 - 20mm). 3.85m: Changes to dark brownish black mottling.
Matua Subgroup	DRY 21/01/2020				●125/37 kPa ●>214 kPa ●>214 kPa		28	5			VSt H		CLAY, with some silt, trace sand; light orange brown, with dark brownish orange mottling. Very stiff, moist, high plasticity; sand, fine. Silty CLAY, with trace sand; brownish orange. Very stiff, moist, high plasticity; sand, fine to medium. 4.5m: Changes to minor sand; light orange brown, with brownish orange mottling. Hard.
													End of borehole at 5.00mbgl. No standing groundwater encountered.

COMMENTS: Rotoehu Ash not encountered.Customer Reference: 1013262.0.0.0

Hole Depth 5m

Scale 1:28

Rev.: A

HandAugerLog - 27/02/2020 11:39:13 a.m. - Produced with Core-GS by GeRoc

GEOTECHNICS

HAND AUGER LOG

HOLE Id: **HA107**

Hole Location: See Location Plan

SHEET: 1 OF 1

PROJECT: Omokoroa Site Investigation	LOCATION: Omokoroa	JOB No.: 1013262.0000
CO-ORDINATES: (NZTM2000) 5827289.70 mN 1866176.00 mE	DRILL TYPE: 50mm Hand Auger	HOLE STARTED: 22/01/2020
	DRILL METHOD: HA	HOLE FINISHED: 22/01/2020
R.L.: 36.00m		DRILLED BY: GEOTECHNICS
DATUM: MOTUHT1953		LOGGED BY: ALRI CHECKED: TASR

GEOLOGICAL												ENGINEERING DESCRIPTION
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MATERIAL COMPOSITION.	WATER	CORE RECOVERY (%)	METHOD	SCALA PENETROMETER (Blows/100mm) 0 1 2 3 4 5 6 7 8 9	TESTS	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	MOISTURE CONDITION \ WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	Description and Additional Observations
Fill					HA107/0.05 @ 0.1m					D-M	VSt		SILT, with some sand, trace gravel; purple brown. Very stiff, dry to moist, low plasticity; sand, fine to coarse; gravel, fine to medium, subangular to subrounded. 0.1m: Changes to dark brown.
Buried Topsoil					● 146/30 kPa								Organic SILT, with some sand, trace gravel; dark brownish black. Very stiff, dry to moist, low plasticity; sand, fine to coarse; gravel, fine to medium, subangular to subrounded. 0.4m: Gravel absent.
					HA107/0.5 @ 0.5m						F		
					● 39/14 kPa								
Younger Ash					● 138/30 kPa		35	1			VSt		SILT, with minor sand; brown. Firm, dry to moist, low plasticity; sand, fine to coarse. 0.9m: Changes to very stiff.
					● 107/19 kPa								
					● 176/36 kPa								
					● 168/39 kPa								
					● 138/61 kPa		34	2					
Rotoehu Ash		100	HA							M	MD		Silty, fine to coarse SAND; orange brown. Medium dense, moist, well graded.
					● >193 kPa						H		SILT, with some sand; light yellowish brown. Hard, moist, low plasticity; sand, fine.
											MD		Fine to coarse SAND, with some silt; orange brown. Medium dense, moist, well graded.
					● 80/17 kPa		33	3			St		SILT, with minor sand; dark brown. Stiff, moist, low plasticity; sand, fine. 3.2m: Changes to brownish orange, with black mottling.
Hamilton Ash					● 124/52 kPa								
					● 83/30 kPa								
					● 187/88 kPa		32	4					
	DRY 21/01/2020				● >193 kPa						H		SILT, with some sand and clay; light brown, with reddish brown mottling. Hard, moist, low plasticity; sand, fine to coarse.
					● 58/30 kPa								
					● UTP								
							31	5					End of borehole at 5.00mbgl. No standing groundwater encountered.

COMMENTS: Customer Reference: 1013262.0.0.0

Hole Depth 5m

Scale 1:28

Rev.: A

HandAugerLog - 27/02/2020 11:39:15 a.m. - Produced with Core-GS by GeRoc

GEOTECHNICS

HAND AUGER LOG

HOLE Id: **HA108**

Hole Location: See Location Plan

SHEET: 1 OF 1

PROJECT: Omokoroa Site Investigation	LOCATION: Omokoroa	JOB No.: 1013262.0000
CO-ORDINATES: 5827074.30 mN (NZTM2000) 1866453.40 mE	DRILL TYPE: 50mm Hand Auger	HOLE STARTED: 22/01/2020
	DRILL METHOD: HA	HOLE FINISHED: 22/01/2020
R.L.: 40.00m		DRILLED BY: GEOTECHNICS
DATUM: MOTUHT1953		LOGGED BY: DBRU CHECKED: TASR

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MATERIAL COMPOSITION.	WATER	CORE RECOVERY (%)	METHOD	SCALA PENETROMETER (Blows/100mm) 0 1 2 3 4 5 6 7 8 9	TESTS	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	Description and Additional Observations
Topsoil					HA108/0.05 @ 0.1m				TS	D-M	St		Organic SILT, with minor sand; dark brownish black. Stiff, dry to moist, low plasticity; sand, fine.
Younger Ash					● 155/49 kPa						VSt		SILT, with minor sand; dark brown. Very stiff, dry to moist, low plasticity; sand, fine. 0.4m: Changes to brown.
					HA108/0.5 @ 0.5m								
					● 185/33 kPa								
					● 146/24 kPa		39	1					
					● 76/18 kPa						St		1.2m: Changes to stiff.
					● 167/43 kPa						VSt		1.5m: Changes to very stiff.
Rotoehu Ash										M	MD		Silty, fine to coarse SAND; light orange brown. Medium dense, moist, well graded.
							38	2					
Hamilton Ash		100	HA		● >213 kPa						H		SILT, with trace sand; dark brown. Hard, moist, low plasticity; sand, fine. 2.7m: Changes to minor sand; dark orange brown.
					● UTP		37	3					
					● UTP								
					● 134/43 kPa						VSt		3.6m: Changes to very stiff.
					● 121/43 kPa		36	4					
					● 73/30 kPa								
Matua Subgroup					● 152/46 kPa								SILT, with some clay, trace sand; light brown. Very stiff, moist, high plasticity; sand, fine. 4.7m: Changes to light brown, with black mottling.
	DRY 21/01/2020				● 164/49 kPa								SILT, with trace sand; orange brown. Very stiff, moist, low plasticity; sand, fine.
							35	5					End of borehole at 5.00mbgl. No standing groundwater encountered.

COMMENTS: Customer Reference: 1013262.0.0.0

Hole Depth 5m

Scale 1:28

Rev.: A

HandAugerLog - 27/02/2020 11:39:17 a.m. - Produced with Core-GS by GeRoc

GEOTECHNICS

HAND AUGER LOG

HOLE Id: **HA109**

Hole Location: See Location Plan

SHEET: 1 OF 1

PROJECT: Omokoroa Site Investigation	LOCATION: Omokoroa	JOB No.: 1013262.0000
CO-ORDINATES: (NZTM2000) 5827778.30 mN 1865328.40 mE	DRILL TYPE: 50mm Hand Auger	HOLE STARTED: 22/01/2020
	DRILL METHOD: HA	HOLE FINISHED: 22/01/2020
R.L.: 26.00m		DRILLED BY: GEOTECHNICS
DATUM: MOTUHT1953		LOGGED BY: ALRI CHECKED: TASR

GEOLOGICAL											ENGINEERING DESCRIPTION
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MATERIAL COMPOSITION.	WATER	CORE RECOVERY (%)	METHOD	SCALA PENETROMETER (Blows/100mm) 0 1 2 3 4 5 6 7 8 9	TESTS	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	MOISTURE CONDITION \ WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	Description and Additional Observations
Topsoil					HA109/0.05 @ 0.1m				TS	D-M	St		Organic SILT, with minor sand; dark brown. Stiff, dry to moist, low plasticity; sand, fine.
					● 183/49 kPa								
Younger Ash					HA109/0.5 @ 0.5m						VSt		SILT, with minor sand; brown. Very stiff, dry to moist, low plasticity; sand, fine.
					● 180/31 kPa								
					● >214 kPa		25	1			H		0.9m: Changes to hard.
					● UTP								
					● 211/40 kPa								
					● 183/34 kPa						VSt		1.8m: Changes to very stiff.
Rotoehu Ash							24	2		M	MD		Silty, fine to coarse SAND; light orange brown. Medium dense, moist, well graded.
					● 153/46 kPa						VSt		SILT, with trace sand; dark brown. Very stiff, moist, low plasticity; sand, fine.
					● UTP		23	3			H		3.0m: Changes to dark orange brown. Hard.
					● >214 kPa								3.3 - 3.4m: Black mottling.
Hamilton Ash					● >214 kPa								
					● >214 kPa		22	4					SILT, with some clay, trace sand; light orange brown. Hard, moist, high plasticity; sand, fine.
					● 208/61 kPa								
					● 202/52 kPa								
	DRY 22/01/2020	100	HA		● 153/46 kPa						VSt		4.8m: Changes to very stiff.
							21	5					End of borehole at 5.00mbgl. No standing groundwater encountered.

COMMENTS: Customer Reference: 1013262.0.0.0

Hole Depth 5m

Scale 1:28

Rev.: A

HandAugerLog - 27/02/2020 11:39:20 a.m. - Produced with Core-GS by GeRoc

GEOTECHNICS

HAND AUGER LOG

HOLE Id: **HA110**

Hole Location: See Location Plan

SHEET: 1 OF 1

PROJECT: Omokoroa Site Investigation	LOCATION: Omokoroa	JOB No.: 1013262.0000
CO-ORDINATES: (NZTM2000) 5828086.60 mN 1866422.90 mE	DRILL TYPE: 50mm Hand Auger	HOLE STARTED: 22/01/2020
	DRILL METHOD: HA	HOLE FINISHED: 22/01/2020
R.L.: 25.00m		DRILLED BY: GEOTECHNICS
DATUM: MOTUHT1953		LOGGED BY: DBRU CHECKED: TASR

GEOLOGICAL												ENGINEERING DESCRIPTION
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MATERIAL COMPOSITION.	WATER	CORE RECOVERY (%)	METHOD	SCALA PENETROMETER (Blows/100mm) 0 1 2 3 4 5 6 7 8 9	TESTS	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	MOISTURE CONDITION \ WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	Description and Additional Observations
Topsoil					HA110/0.05 @ 0.1m				TS	M	St		Organic SILT, with minor sand; dark brownish black. Stiff, dry to moist, low plasticity; sand, fine.
Younger Ash					91/46 kPa HA110/0.5 @ 0.5m 182/46 kPa 197/55 kPa 209/55 kPa 194/49 kPa >213 kPa		24 23	1 2			St VSt H VSt H		SILT, with minor sand; orange brown. Stiff, dry to moist, low plasticity; sand, fine. 0.6m: Changes to very stiff. 1.2m: Changes to hard. 1.3m: Changes to brown. 1.5m: Changes to very stiff. 1.8m: Changes to hard.
Rotoehu Ash		100	HA								MD		Silty, fine to coarse SAND; light brownish yellow. Medium dense, moist, poorly graded. 2.3m: Changes to brown. 2.6m: Changes to dark brown. 2.7m: Changes to fine to medium grain; light brownish yellow. 2.8m: Changes to fine to coarse grain; greyish brown.
Hamilton Ash					112/30 kPa 82/33 kPa		22	3			VSt		SILT, with minor sand; dark brown, with brown mottling. Very stiff, moist, low plasticity; sand, fine. SILT, with some clay, trace sand; brown, with orange brown mottling. Very stiff, moist, high plasticity; sand, fine.
Matua Subgroup	DRY 21/01/2020				115/33 kPa 79/30 kPa 58/30 kPa 61/33 kPa 82/49 kPa		21 20	4 5		M-W W	St		Silty CLAY, with trace sand; light greyish brown with light grey mottling. Very stiff, moist, high plasticity; sand, fine. 3.9m: Changes to stiff. 4.0m: Changes to moist to wet. 4.3m: Changes to wet. 4.9m: Changes to minor sand, fine to coarse; orange brown.
													End of borehole at 5.00mbgl. No standing groundwater encountered.

COMMENTS: Customer Reference: 1013262.0.0.0

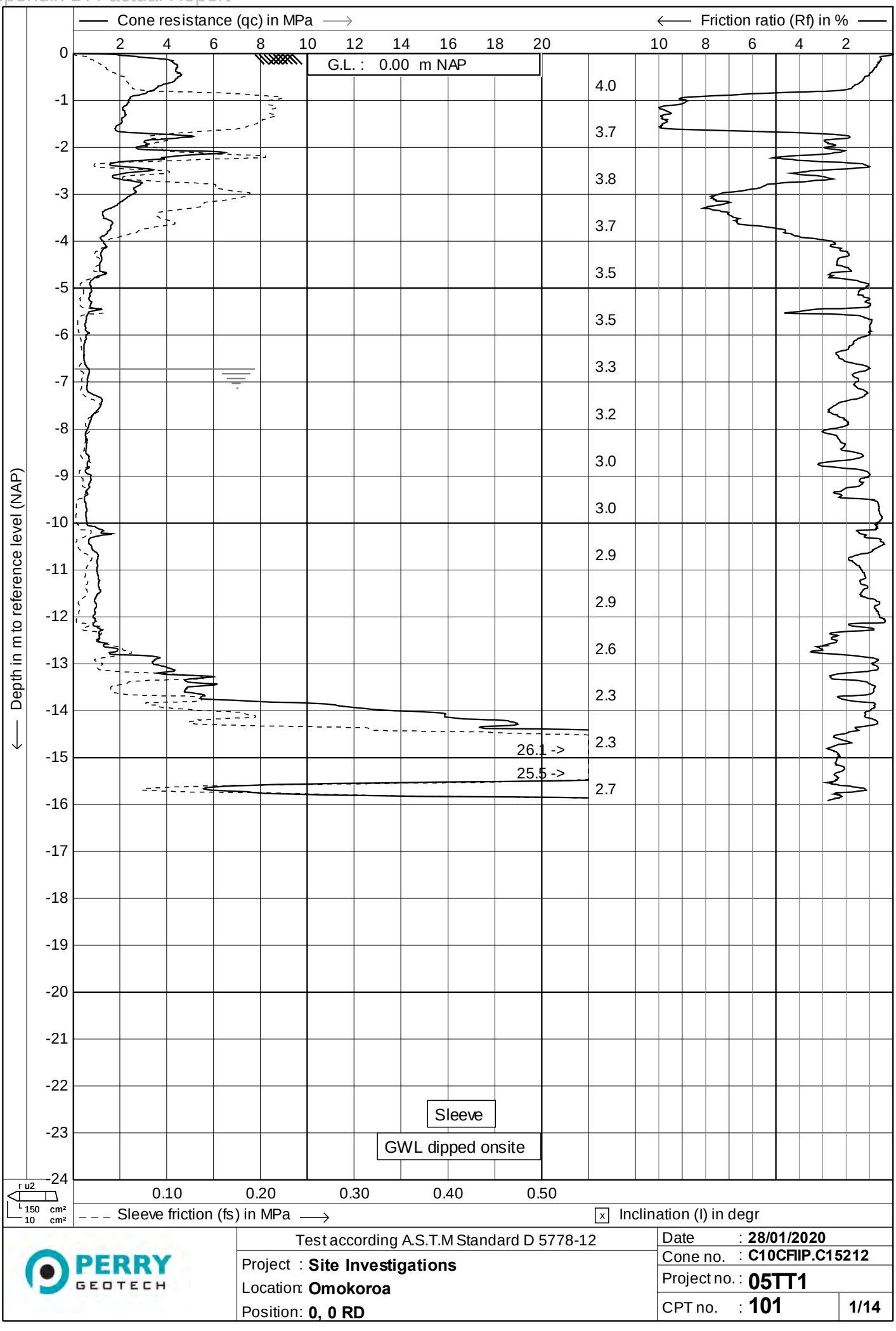
Hole Depth 5m

Scale 1:28

Rev.: A

HandAugerLog - 27/02/2020 11:39:22 a.m. - Produced with Core-GS by GeRoc

Appendix C: CPT records



PERRY GEOTECH

Test according A.S.T.M Standard D 5778-12

Project : **Site Investigations**

Location: **Omokoroa**

Position: **0, 0 RD**

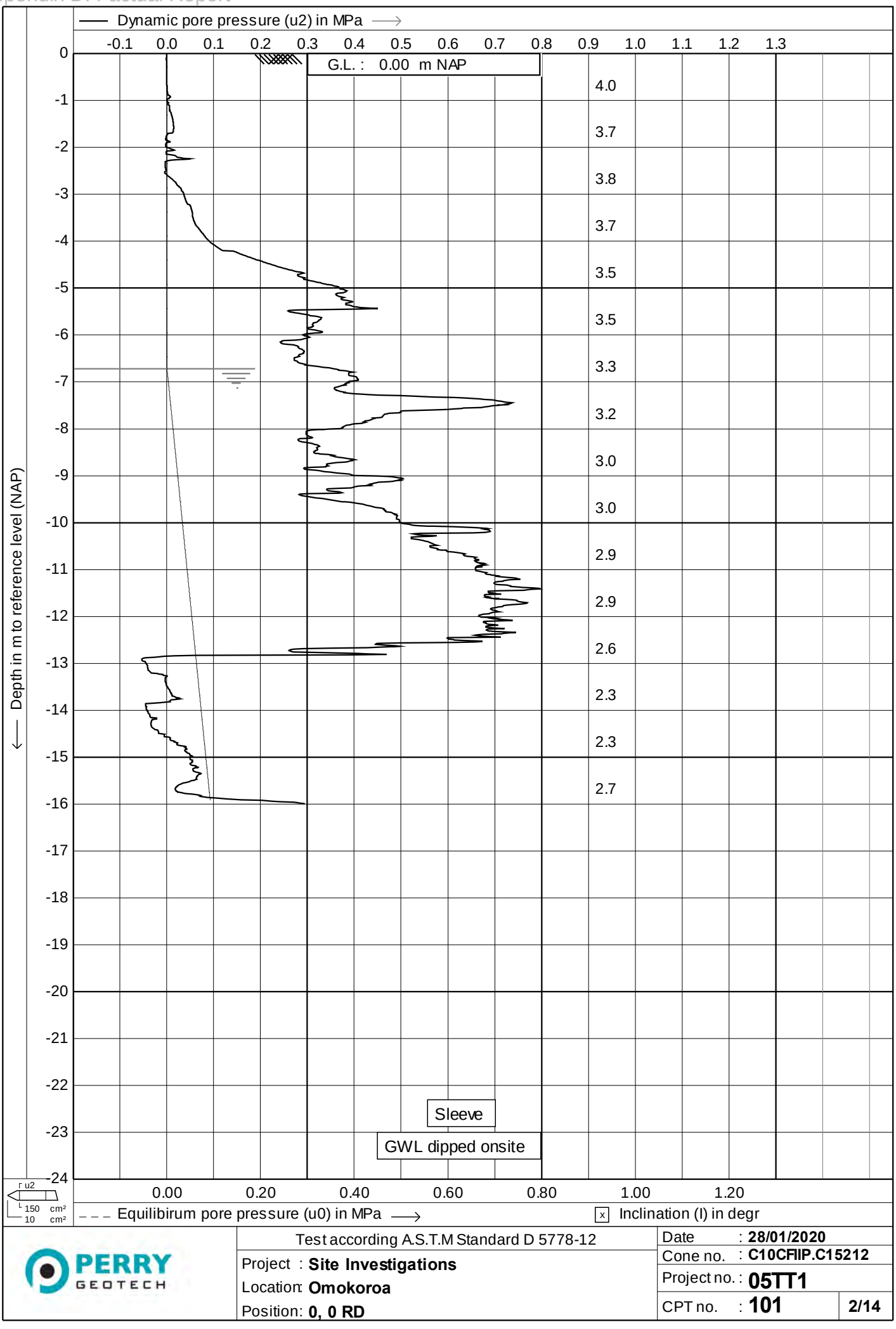
Date : **28/01/2020**

Cone no. : **C10CFIIP.C15212**

Project no. : **05TT1**

CPT no. : **101**

1.48



PERRY GEOTECH

Test according A.S.T.M Standard D 5778-12

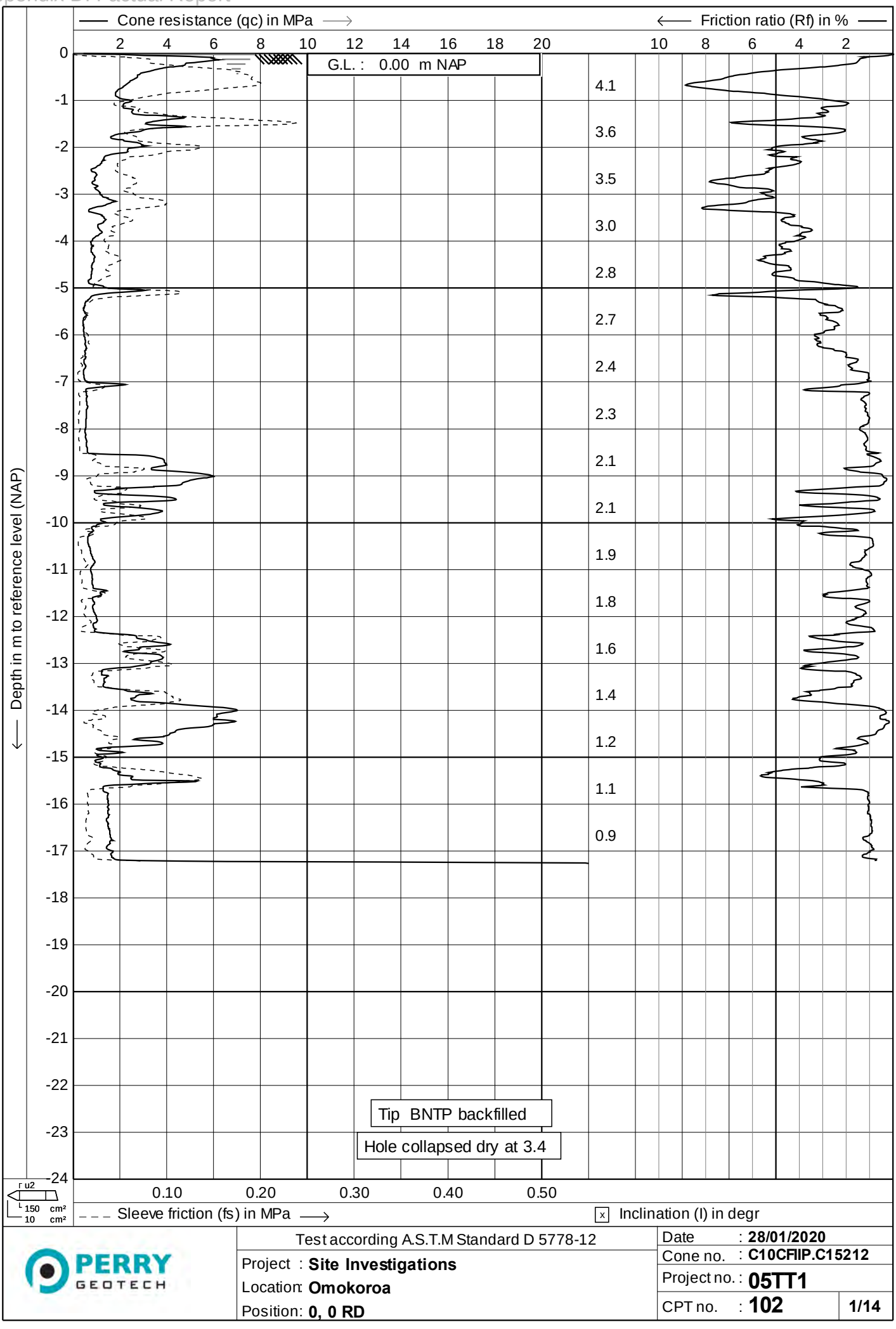
Project : **Site Investigations**

Location: **Omokoroa**

Position: **0, 0 RD**

Date	: **28/01/2020**
Cone no.	: **C10CFIIP.C15212**
Project no.	: **05TT1**
CPT no.	: **101**

1.48



PERRY GEOTECH

Test according A.S.T.M Standard D 5778-12

Project : **Site Investigations**

Location: **Omokoroa**

Position: **0, 0 RD**

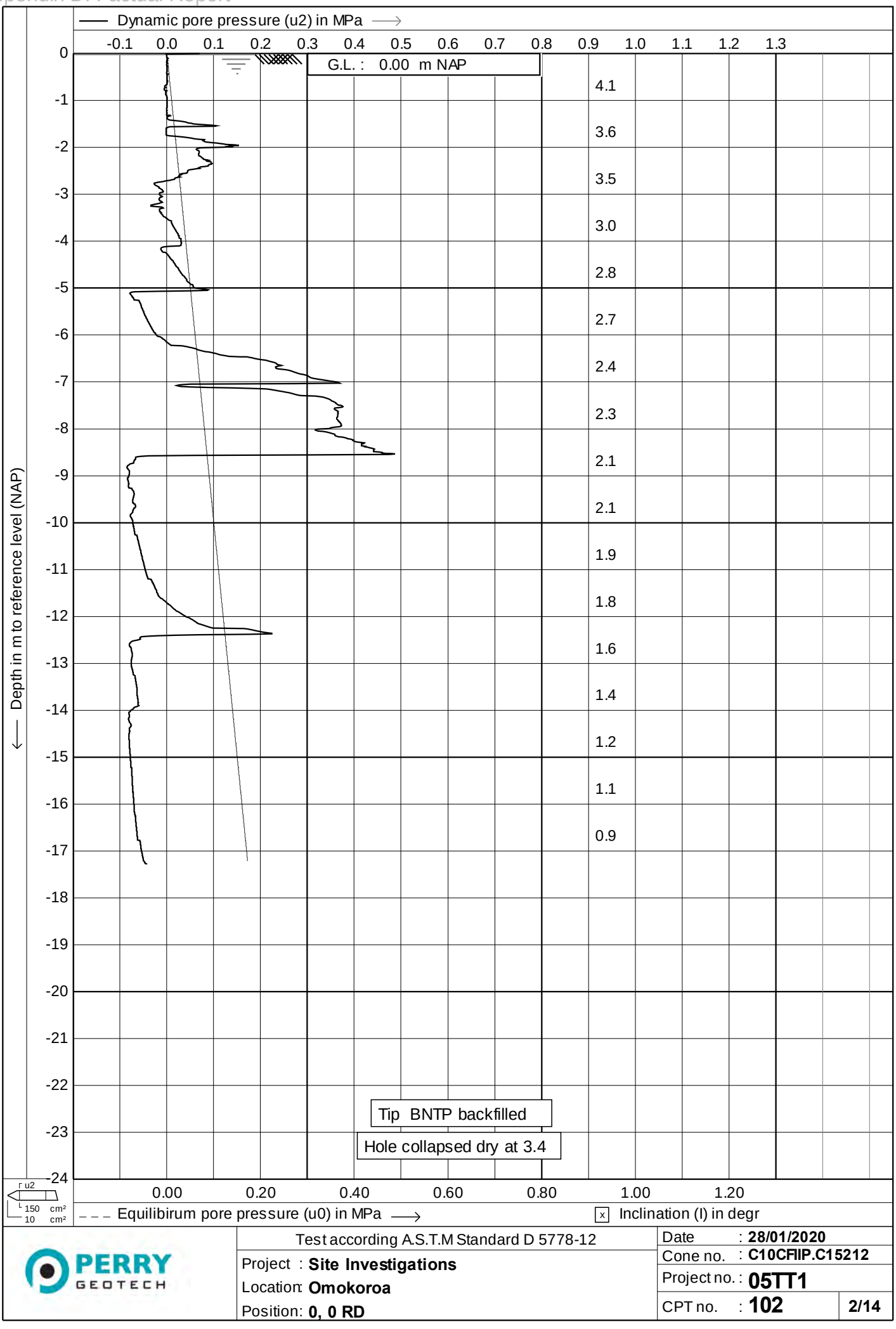
Date : **28/01/2020**

Cone no. : **C10CFIIP.C15212**

Project no. : **05TT1**

CPT no. : **102** **1/14**

1.48



PERRY GEOTECH

Test according A.S.T.M Standard D 5778-12

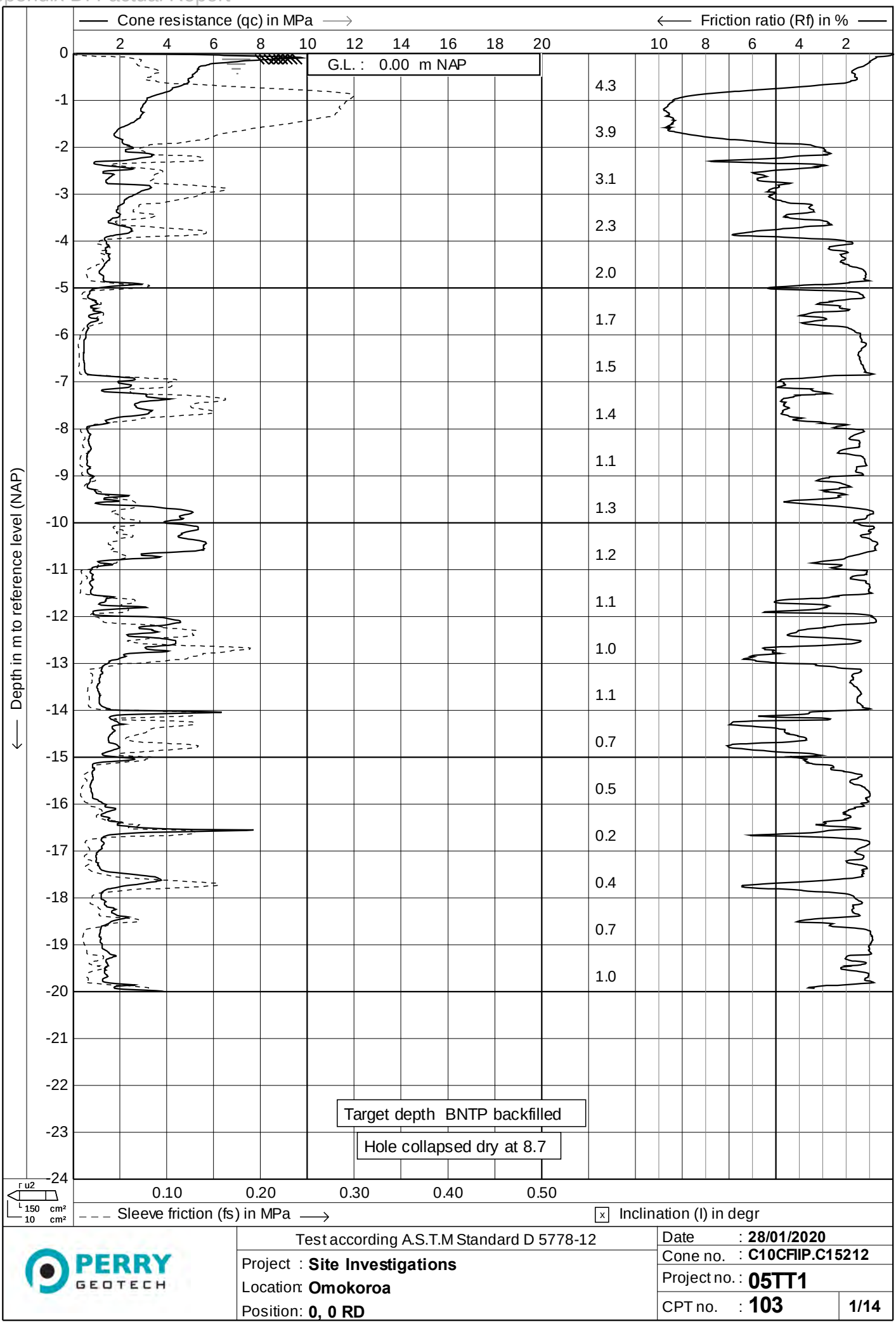
Project : **Site Investigations**

Location: **Omokoroa**

Position: **0, 0 RD**

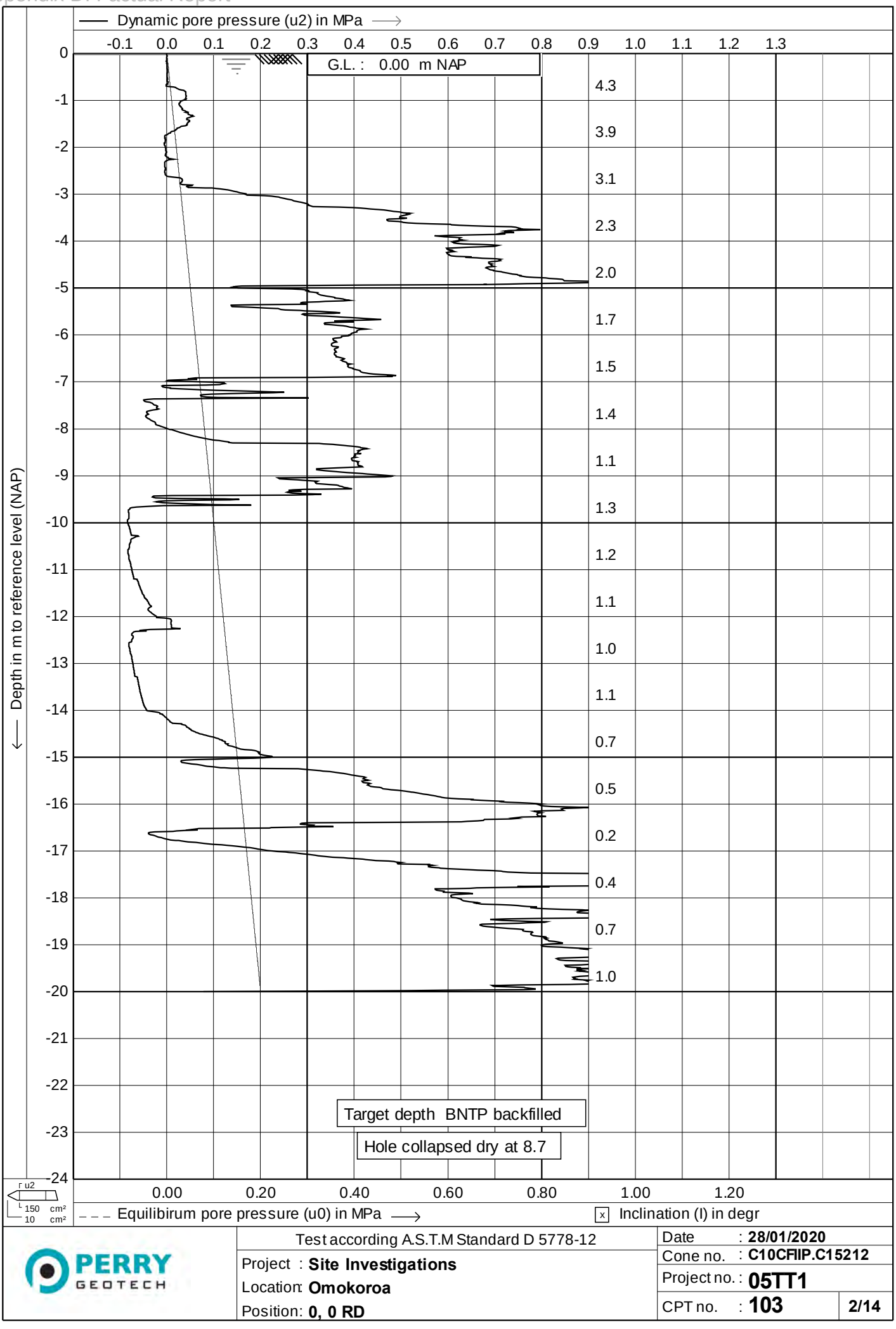
Date	: **28/01/2020**
Cone no.	: **C10CFIIP.C15212**
Project no.	: **05TT1**
CPT no.	: **102**

1.48



PERRY GEOTECH	Test according A.S.T.M Standard D 5778-12	Date : **28/01/2020**
	Project : **Site Investigations**	Cone no. : **C10CFIIP.C15212**
	Location: **Omokoroa**	Project no. : **05TT1**
	Position: **0, 0 RD**	CPT no. : **103** 1/14

1.48



PERRY GEOTECH

Test according A.S.T.M Standard D 5778-12

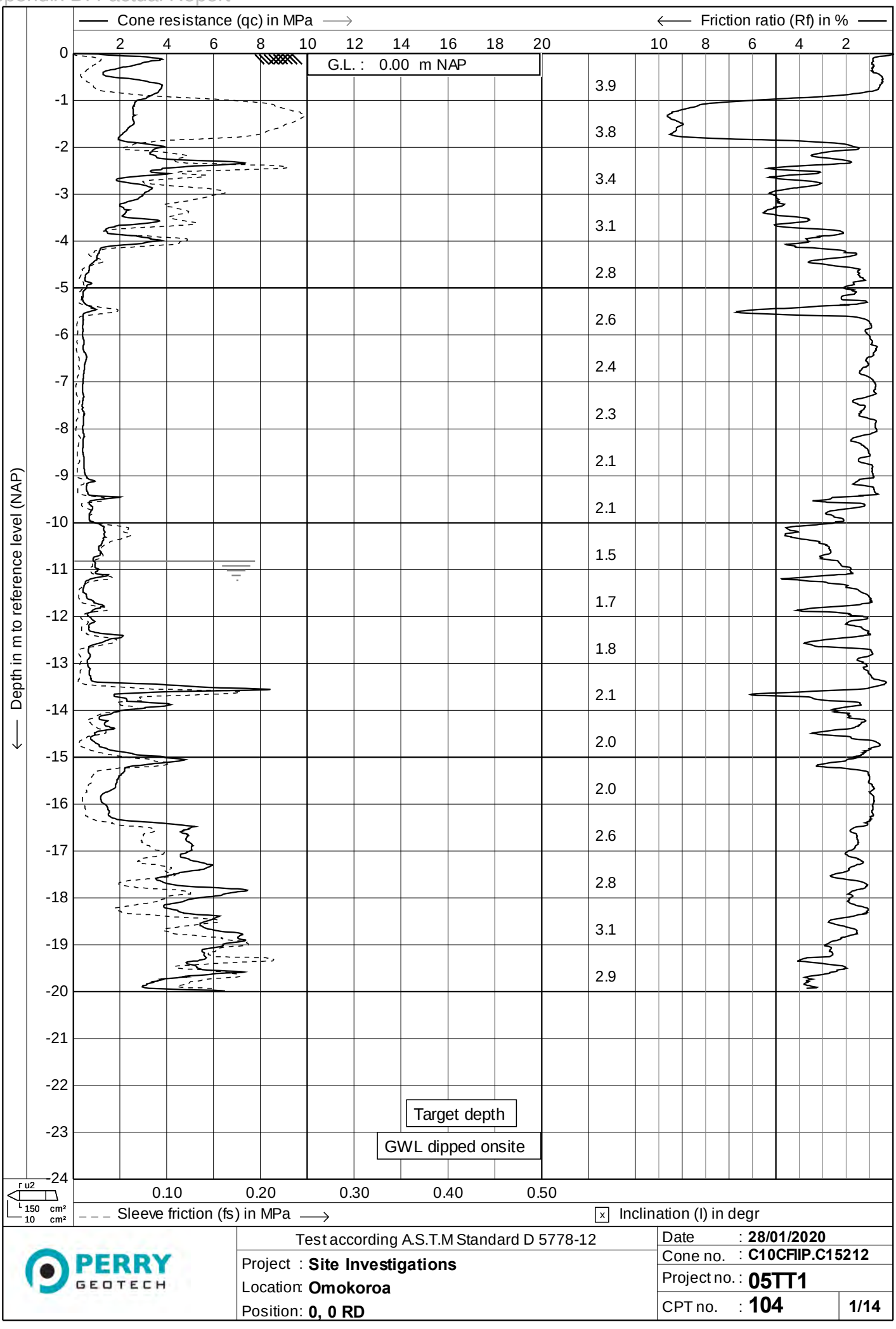
Project : **Site Investigations**

Location: **Omokoroa**

Position: **0, 0 RD**

Date	: **28/01/2020**
Cone no.	: **C10CFIIP.C15212**
Project no.	: **05TT1**
CPT no.	: **103**

1.48



PERRY GEOTECH

Test according A.S.T.M Standard D 5778-12

Project : **Site Investigations**

Location: **Omokoroa**

Position: **0, 0 RD**

Date : **28/01/2020**

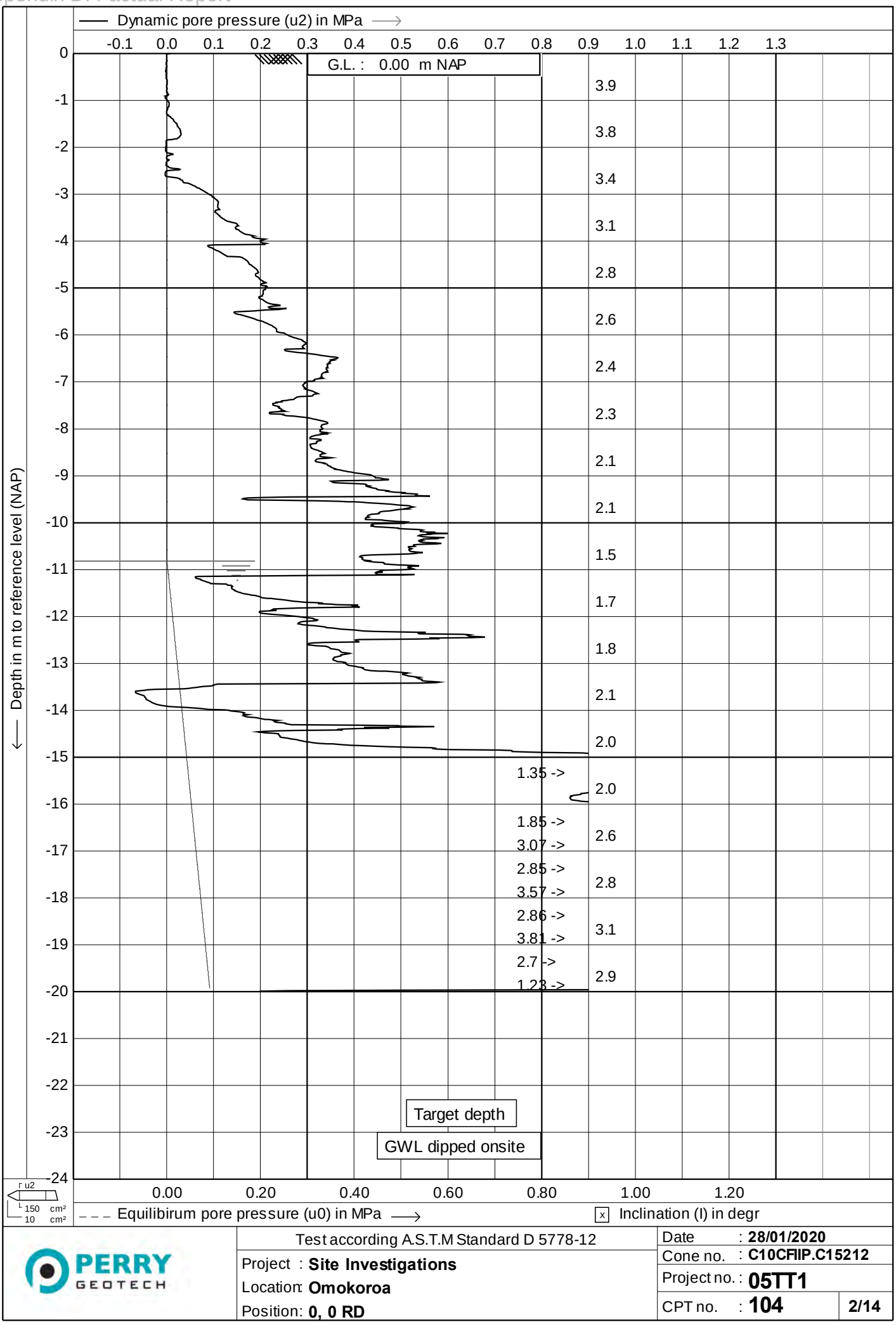
Cone no. : **C10CFIIP.C15212**

Project no. : **05TT1**

CPT no. : **104**

1/14

1.48



PERRY GEOTECH

Test according A.S.T.M Standard D 5778-12

Project : **Site Investigations**

Location: **Omokoroa**

Position: **0, 0 RD**

Date : **28/01/2020**

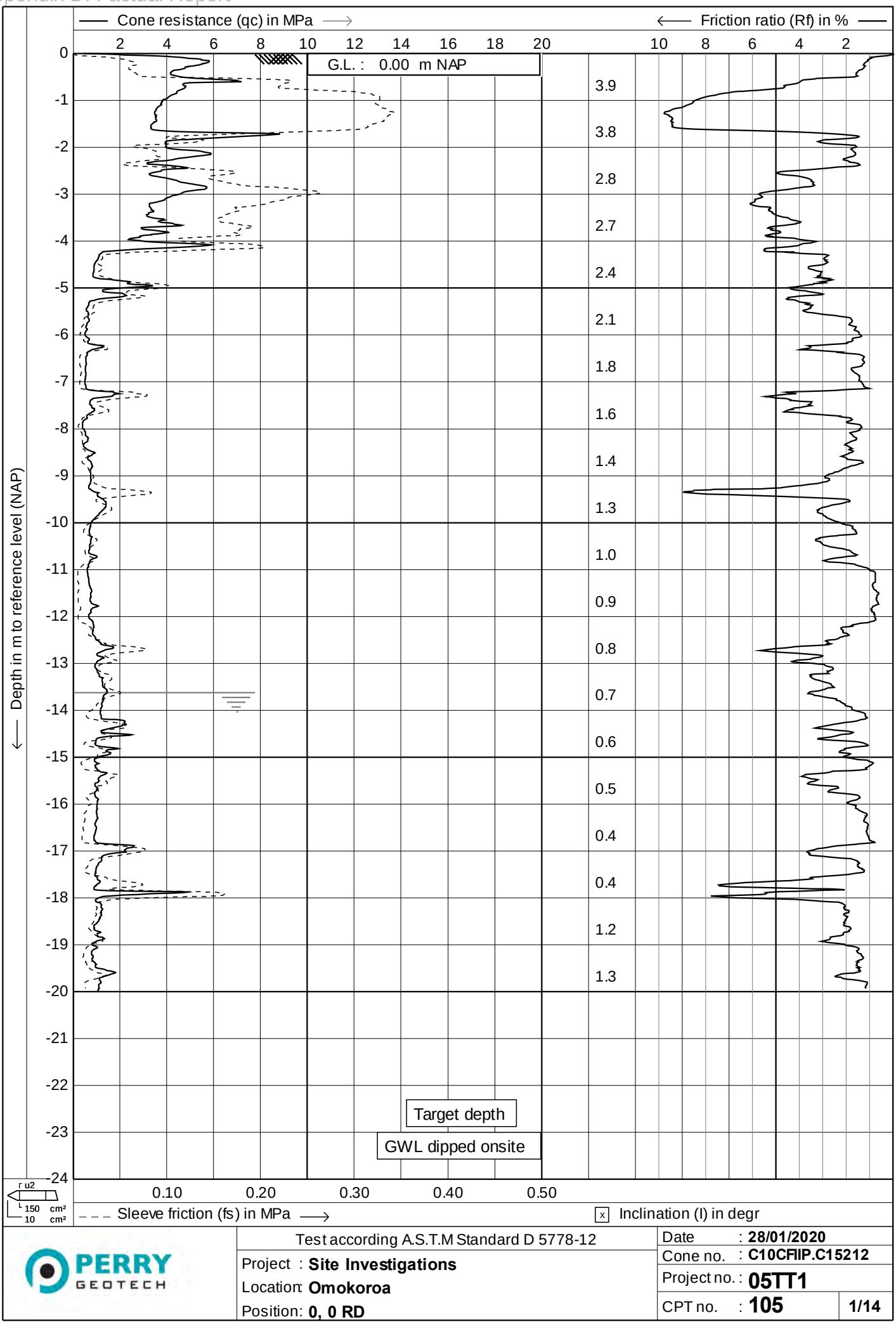
Cone no. : **C10CFIIP.C15212**

Project no. : **05TT1**

CPT no. : **104**

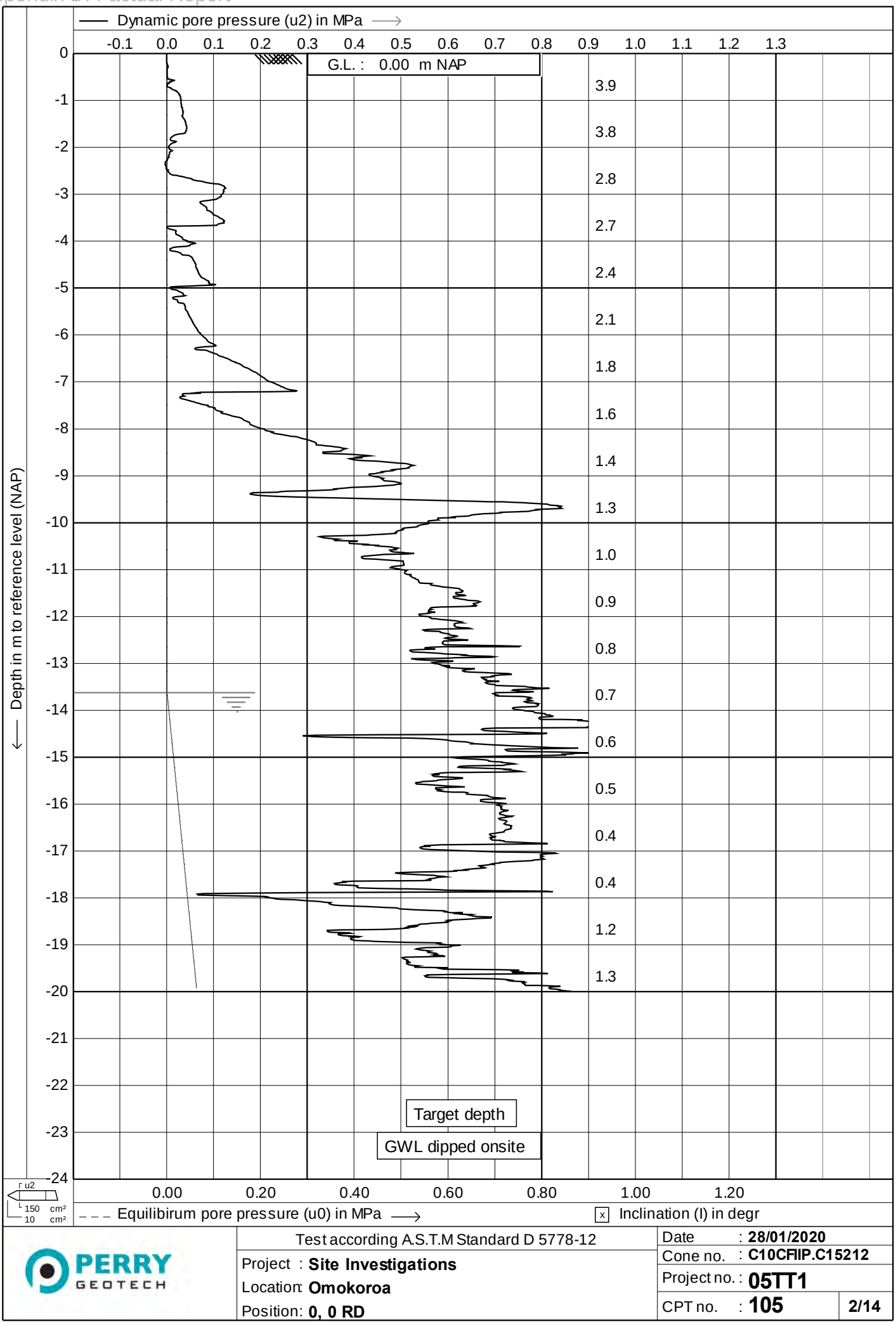
2/14

1.48



PERRY GEOTECH	Test according A.S.T.M Standard D 5778-12	Date : **28/01/2020**
	Project : **Site Investigations**	Cone no. : **C10CFIIP.C15212**
	Location: **Omokoroa**	Project no. : **05TT1**
	Position: **0, 0 RD**	CPT no. : **105** 1/14

1.48



PERRY GEOTECH

Test according A.S.T.M Standard D 5778-12

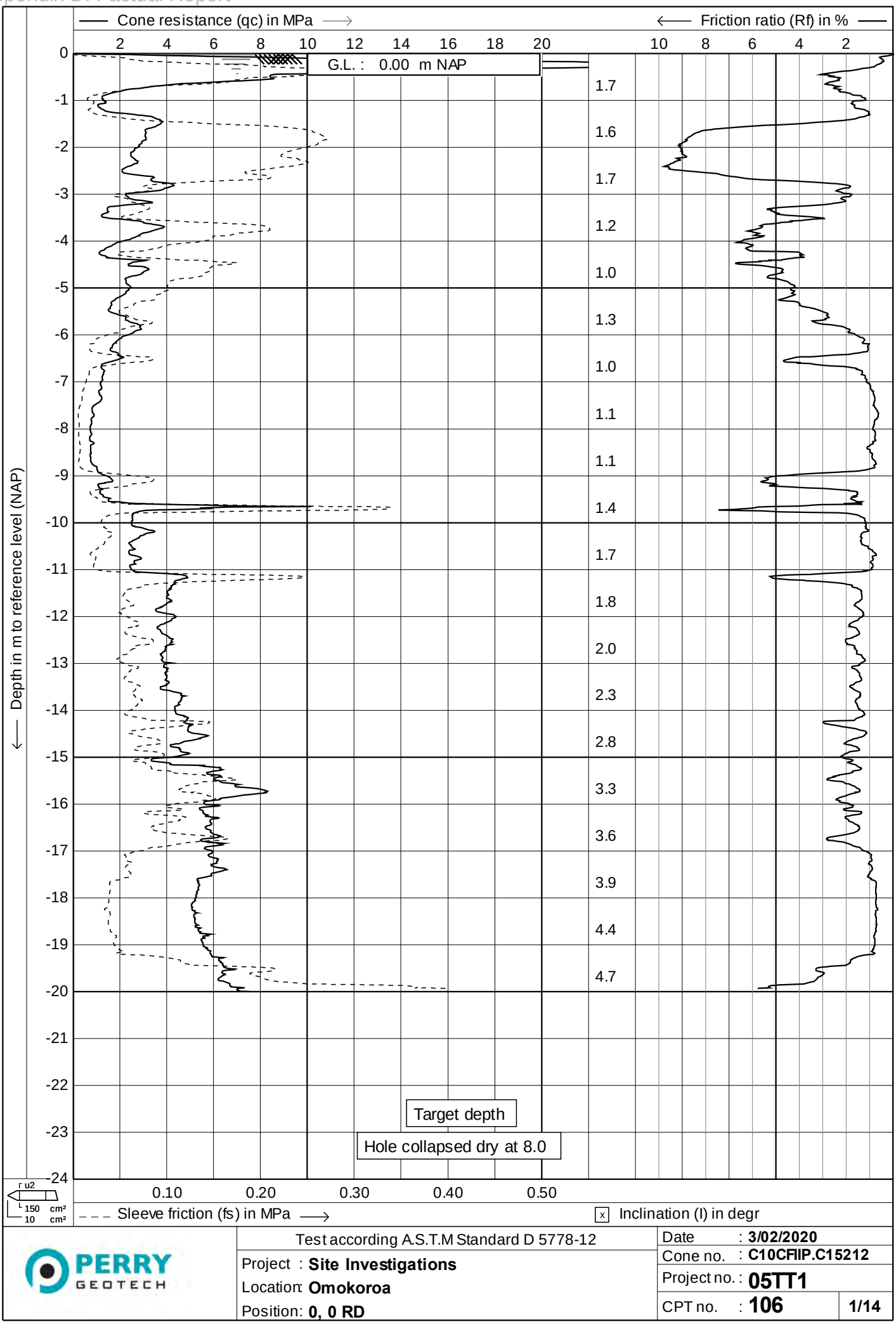
Project : **Site Investigations**

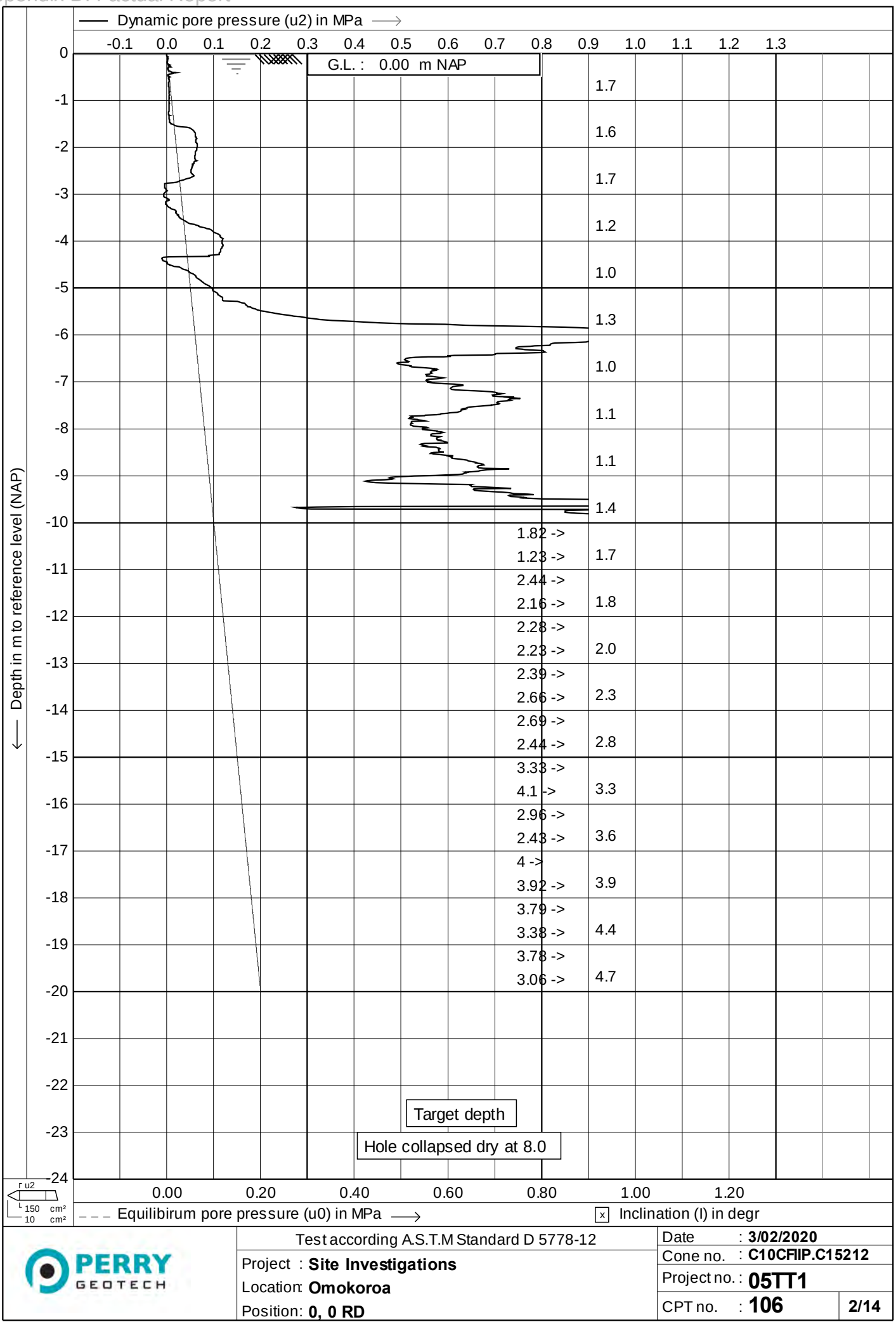
Location: **Omokoroa**

Position: **0, 0 RD**

Date	: **28/01/2020**
Cone no.	: **C10CFIIP.C15212**
Project no.	: **05TT1**
CPT no.	: **105**

1.48


Cone resistance (qc) in MPa
Friction ratio (Rf) in %
G.L. : 0.00 m NAP
Depth in m to reference level (NAP)
Target depth
Hole collapsed dry at 8.0
Sleeve friction (fs) in MPa
Inclination (I) in degr
Test according A.S.T.M Standard D 5778-12
Project : Site Investigations
Location: Omokoroa
Position: 0, 0 RD
Date : 3/02/2020
Cone no. : C10CFIIP.C15212
Project no. : 05TT1
CPT no. : 106
1/14



PERRY GEOTECH

Test according A.S.T.M Standard D 5778-12

Project : **Site Investigations**

Location: **Omokoroa**

Position: **0, 0 RD**

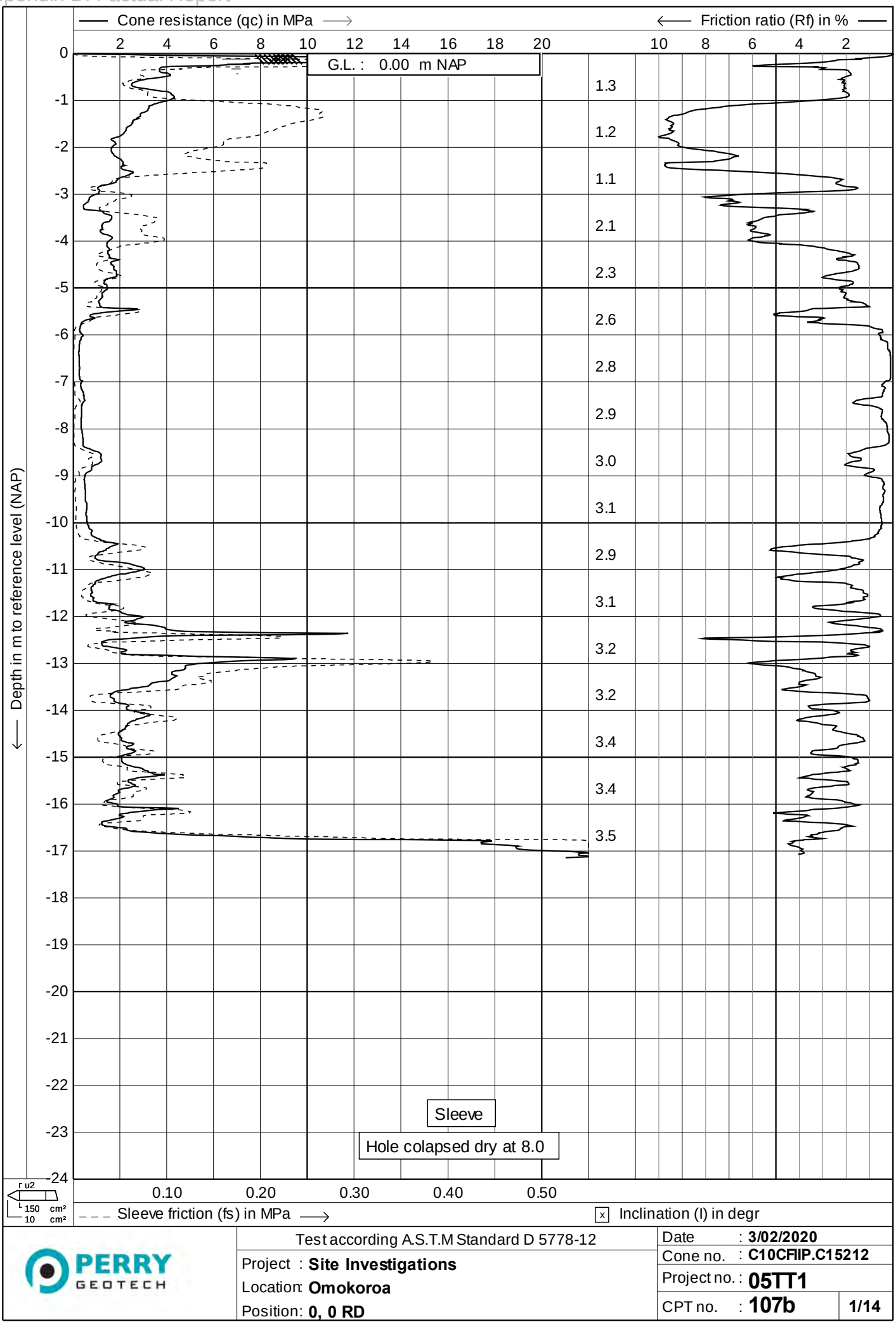
Date : **3/02/2020**

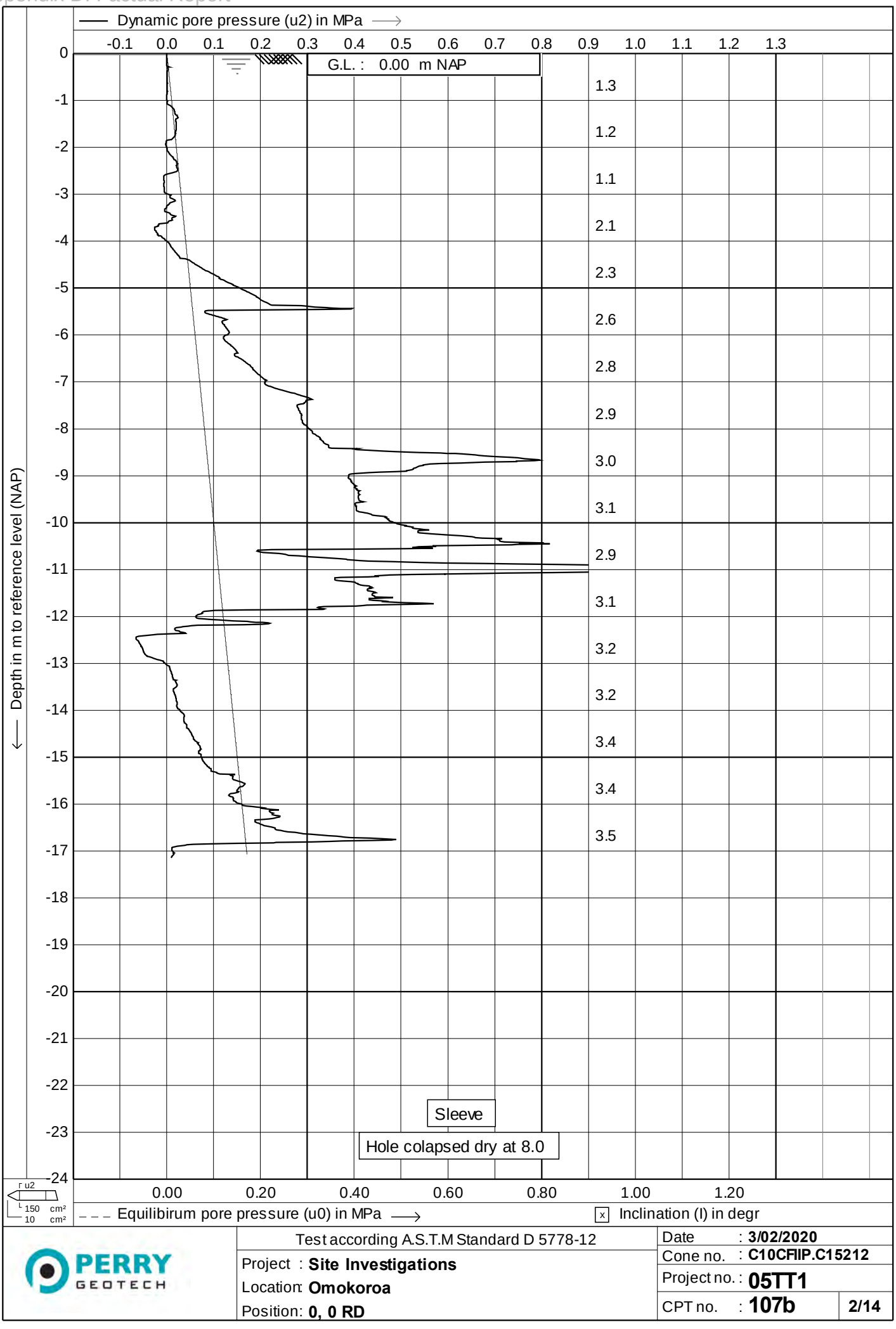
Cone no. : **C10CFIIP.C15212**

Project no. : **05TT1**

CPT no. : **106**

1.48


Cone resistance (qc) in MPa
Friction ratio (Rf) in %
G.L. : 0.00 m NAP
Depth in m to reference level (NAP)
Sleeve
Hole colapsed dry at 8.0
Sleeve friction (fs) in MPa
Inclination (I) in degr
Test according A.S.T.M Standard D 5778-12
Project : Site Investigations
Location: Omokoroa
Position: 0, 0 RD
Date : 3/02/2020
Cone no. : C10CFIIP.C15212
Project no. : 05TT1
CPT no. : 107b
1/14



PERRY GEOTECH

Test according A.S.T.M Standard D 5778-12

Project : **Site Investigations**

Location: **Omokoroa**

Position: **0, 0 RD**

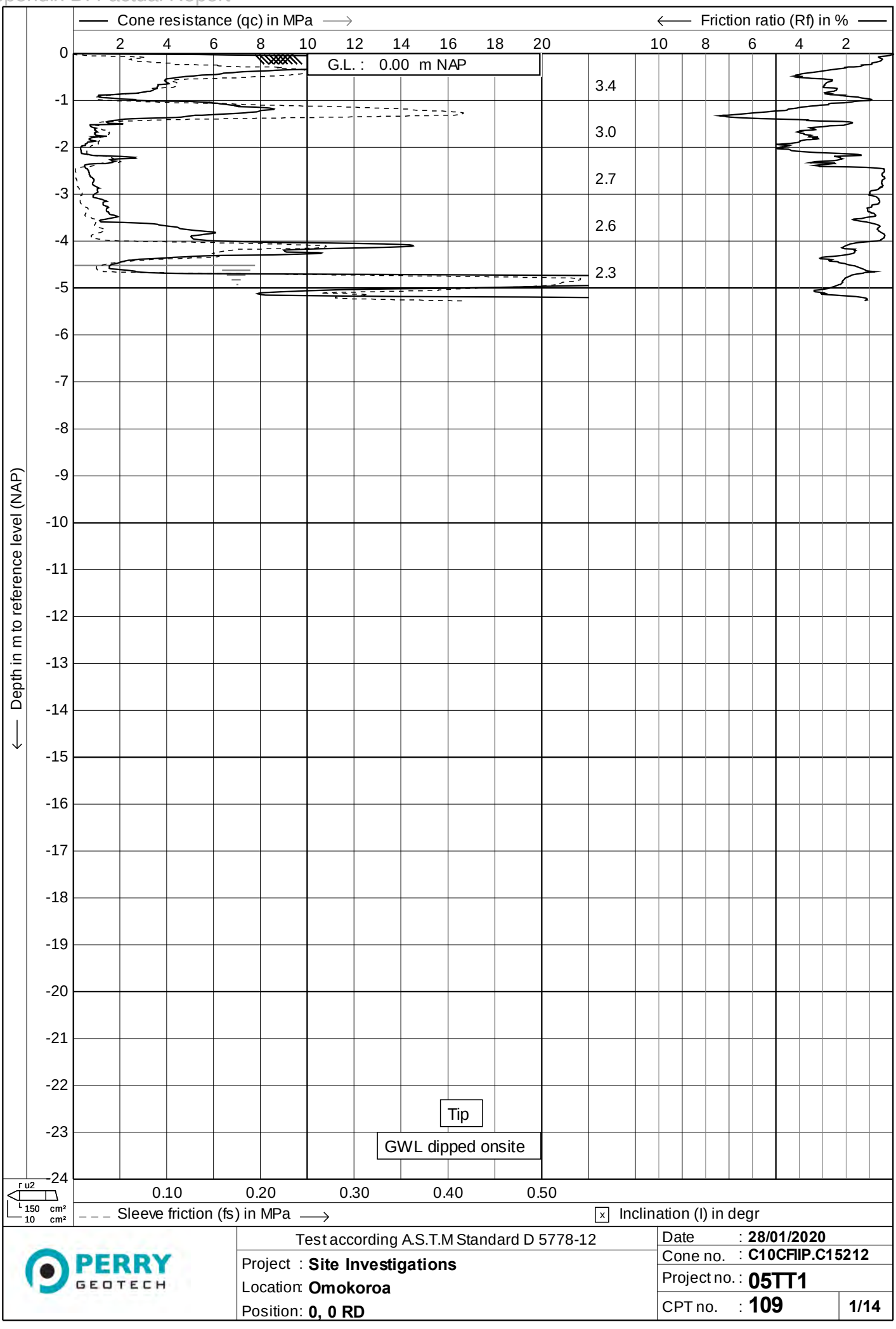
Date : **3/02/2020**

Cone no. : **C10CFIIP.C15212**

Project no. : **05TT1**

CPT no. : **107b**

1.48



PERRY GEOTECH

Test according A.S.T.M Standard D 5778-12

Project : **Site Investigations**

Location: **Omokoroa**

Position: **0, 0 RD**

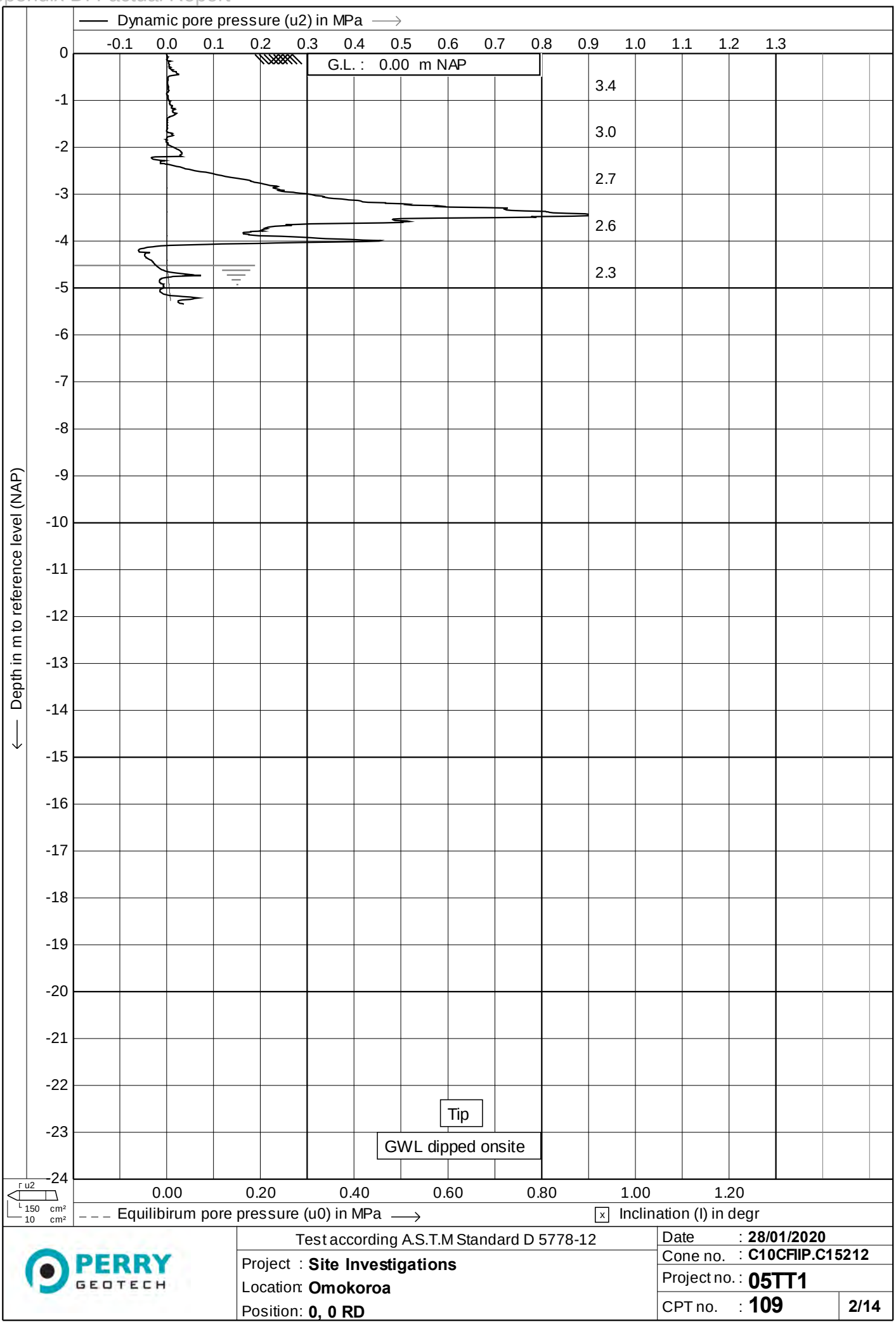
Date : **28/01/2020**

Cone no. : **C10CFIIP.C15212**

Project no. : **05TT1**

CPT no. : **109** **1/14**

1.48



PERRY GEOTECH

Test according A.S.T.M Standard D 5778-12

Project : **Site Investigations**

Location: **Omokoroa**

Position: **0, 0 RD**

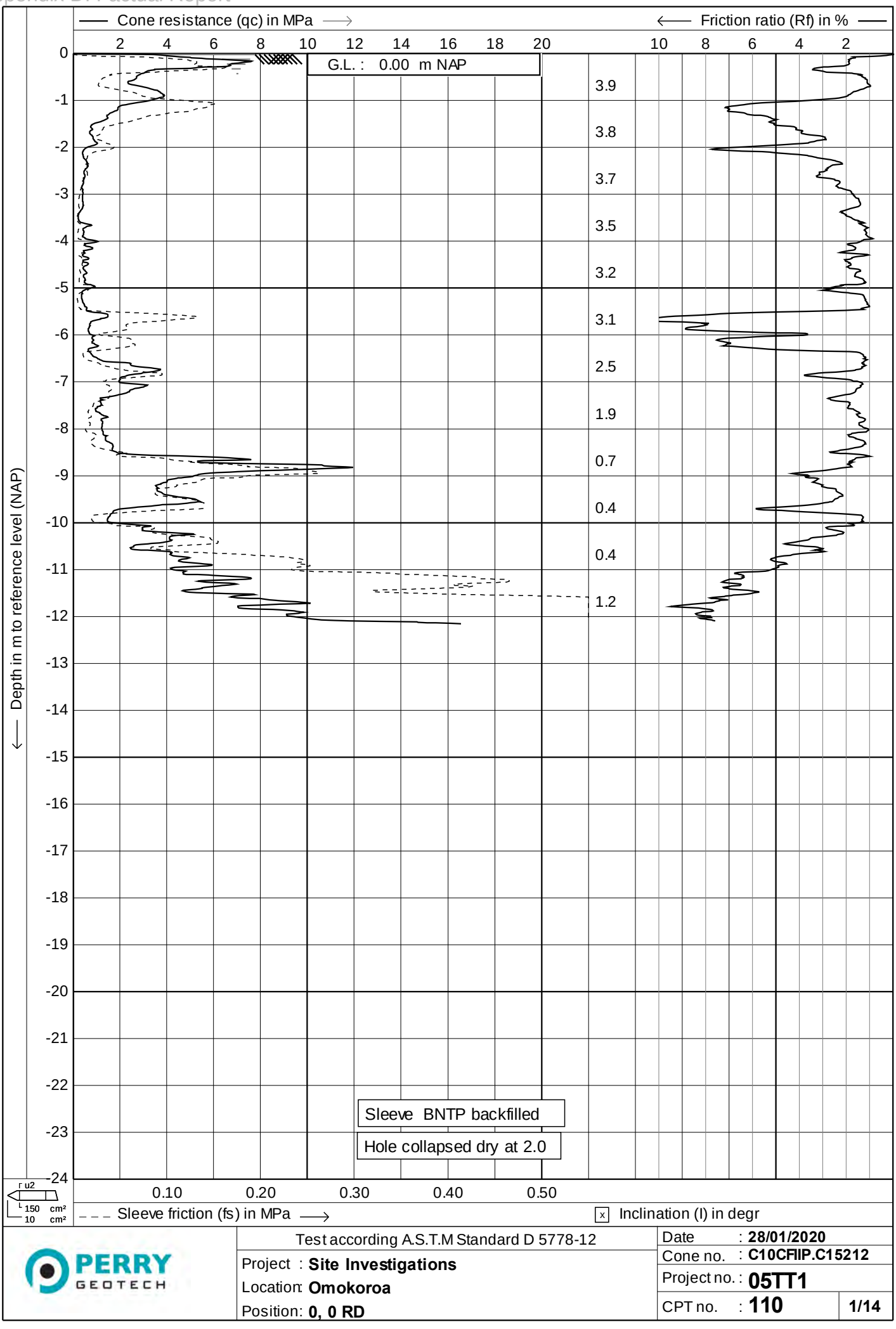
Date : **28/01/2020**

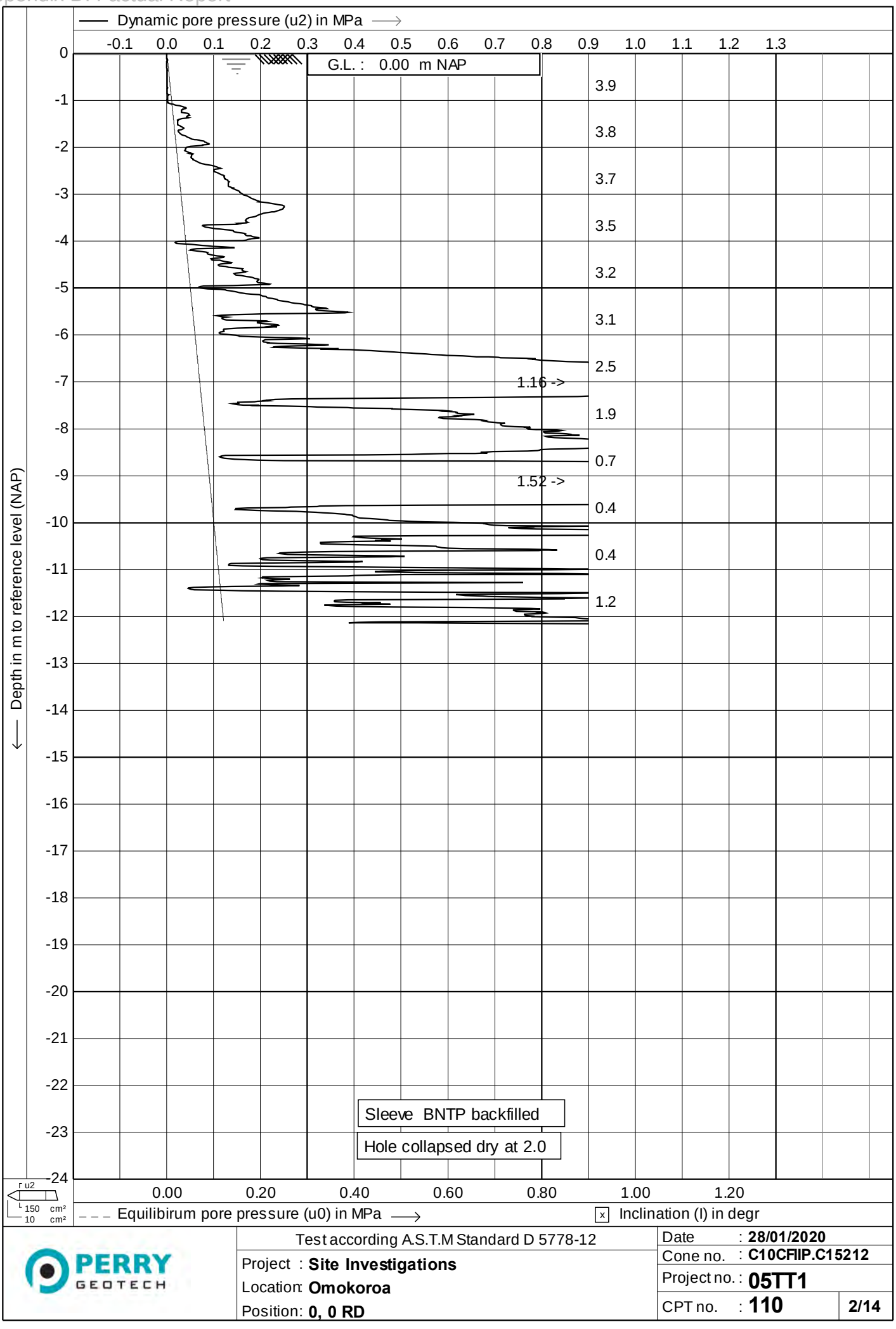
Cone no. : **C10CFIIP.C15212**

Project no. : **05TT1**

CPT no. : **109**

1.48


Cone resistance (qc) in MPa
Friction ratio (Rf) in %
G.L. : 0.00 m NAP
Depth in m to reference level (NAP)
Sleeve BNTP backfilled
Hole collapsed dry at 2.0
Sleeve friction (fs) in MPa
Inclination (I) in degr
Test according A.S.T.M Standard D 5778-12
Project : Site Investigations
Location: Omokoroa
Position: 0, 0 RD
Date : 28/01/2020
Cone no. : C10CFIIP.C15212
Project no. : 05TT1
CPT no. : 110
1/14



PERRY GEOTECH

Test according A.S.T.M Standard D 5778-12

Project : **Site Investigations**

Location: **Omokoroa**

Position: **0, 0 RD**

Date : **28/01/2020**

Cone no. : **C10CFIIP.C15212**

Project no. : **05TT1**

CPT no. : **110**

2/14

1.48

Calibration certificate
GC10CFIIP.C15212 / 001

Geomil equipment

Cone number	GC10CFIIP.C15212	**Client**	Perry Geotech Ltd
Kind of cone	Compression		37 Glenlyon Avenue
Calibration date	21-Dec-15		Greerton
Print date	21-Dec-15		3112 Tauranga
			New Zealand

Channel 1	Cone resistance (q_c)	**Channel 2**	Local sleeve friction (f_s)	**Channel 3**	Pore pressure (u)
Range	0 ... 100 kN	**Range**	0 ... 22.5 kN	**Range**	0 ... 50 bar
A_c	1000 mm²	**A_s**	15000 mm²		
Zero load reading	242 mV	**Zero load reading**	264 mV	**Zero load reading**	219 mV
a-factor	0.8	**b-factor**	0		
		Offset	80 mm		

Load (kN)	Load (MPa)	Output (mV)
0	0	0
10	10	862
20	20	1729
30	30	2592
40	40	3454
50	50	4311
60	60	5180
70	70	6039
80	80	6899
90	90	7758
100	100	8614
90	90	7759
80	80	6903
70	70	6043
60	60	5188
50	50	4316
40	40	3458
30	30	2598
20	20	1732
10	10	864
0	0	0

Load (kN)	Load (MPa)	Output (mV)
0.00	0.00	0
2.25	0.15	779
4.50	0.30	1569
6.75	0.45	2339
9.00	0.60	3124
11.25	0.75	3906
13.50	0.90	4690
18.00	1.20	6254
20.25	1.35	7038
22.50	1.50	7822
20.25	1.35	7036
18.00	1.20	6277
13.50	0.90	4722
11.25	0.75	3940
9.00	0.60	3161
6.75	0.45	2393
4.50	0.30	1618
2.25	0.15	810
0.00	0.00	1

Load (bar)	Load (MPa)	Output (mV)
0	0.0	0
5	0.5	870
10	1.0	1746
15	1.5	2622
20	2.0	3497
25	2.5	4373
30	3.0	5249
35	3.5	6125
40	4.0	7001
45	4.5	7877
50	5.0	8752

Zero load error	0.00 %	**Zero load error**	0.01 %	**Zero load error**	0.06 %
Max. linearity	0.23 %	**Max. linearity**	0.69 %	**Max. linearity**	0.06 %
Max. hysteresis	0.09 %	**Max. hysteresis**	0.69 %		

Westbaan 240 - 2841 MC Moordrecht - The Netherlands
P.O. Box 450 - 2800 AL Gouda - The Netherlands
T. +31 (0) 172 427 800 - F. +31 (0) 172 427 801
info@geomil.com - www.geomil.com

Bank Rabobank - Account no. 1350.49.229
IBAN NL78 RABO 0135 0492 29 - BIC RABONL2U
VAT no. NL812396212B01
Chamber of Commerce no. 2435053

Calibration certificate
GC10CFIIP.C15212 / 001

Geomil equipment

Channel 4 Range	Inclination X -20 ... 20 °	Channel 5 Range	Inclination Y -20 ... 20 °	Channel 6	None

Angle (°)	Output (mV)	Angle (°)	Output (mV)
-20	2511	-20	2476
-15	2578	-15	2541
-10	2645	-10	2610
-5	2716	-5	2679
0	2786	0	2750
5	2855	5	2822
10	2923	10	2888
15	2990	15	2960
20	3059	20	3025

Calibration instrument(s)	Certificate number(s)	Date(s)
CW-921007.01	14203331	21-Aug-14

Remark
We declare that the electrical cone with serial number GC10CFIIP.C15212 has been calibrated and that the specifications are according to the ISO 22476-1:2012 (Geotechnical investigation and testing – Field testing - Part 1: Electrical cone and piezocone penetration test), Application Class 1. The calibrations are traceable to national and international standards.

Date	21-Dec-15	**Date**	21-Dec-15
Calibrated by	Patricia Treffers	**Approved by**	Awring Shaways
Signature		**Signature**	

Westbaan 240 - 2841 MC Moordrecht - The Netherlands
P.O. Box 450 - 2800 AL Gouda - The Netherlands
T. +31 (0) 172 427 800 - F. +31 (0) 172 427 801
info@geomil.com - www.geomil.com

Bank Rabobank - Account no. 1350.49.229
IBAN NL78 RABO 0135 0492 29 - BIC RABONL2U
VAT no. NL812396212B01
Chamber of Commerce no. 2435053

Date: 28/01/2020 Sounding unit:
_____ CPTest version: 3.24 Start time: 8:37:55 AM End time: 8:50:23 AM Project number: 05TT1 CPT number: 09 Length: 5.34 m
Cone: C10CFIIP.C15212 Pre drill depth: 0.00 CH1: (qc)
Maximum value = 40.4 MPa
Zero value before = 191 mV
Zero value after =189 mV, CH2: (fs)
Maximum value = 0.6 MPa
Zero value before = 197 mV
Zero value after =195 mV, CH3: (u2)
Maximum value = 0.952 MPa
Zero value before = 240 mV
Zero value after =230 mV, Inclination: (Total Inclination)
Maximum value = 26.1 °
Zero value before = 2757 mV
Zero value after =2755 mV, _____

CPTest version: 3.24 Start time: 9:32:52 AM End time: 9:56:30 AM Project number: 05TT1
CPT number: 101 Length: 16.00 m Cone: C10CFIIP.C15212 Pre drill depth: 0.00 CH1: (qc)
Maximum value = 36.7 MPa
Zero value before = 189 mV
Zero value after =184 mV, CH2: (fs)
Maximum value = 1.1 MPa
Zero value before = 195 mV
Zero value after =195 mV, CH3: (u2)
Maximum value = 0.797 MPa
Zero value before = 241 mV
Zero value after =237 mV, Inclination: (Total Inclination)
Maximum value = 24.6 °
Zero value before = 2756 mV
Zero value after =2749 mV, _____

CPTest version: 3.24 Start time: 10:46:24 AM End time: 10:47:21 AM Project number: 05TT1
CPT number: 102 Length: 0.94 m Cone: C10CFIIP.C15212 Pre drill depth: 0.00 CH1: (qc)
Maximum value = 1.2 MPa
Zero value before = 188 mV
Zero value after =188 mV, CH2: (fs)
Maximum value = 0.0 MPa
Zero value before = 194 mV
Zero value after =194 mV, CH3: (u2)
Maximum value = 0.230 MPa
Zero value before = 239 mV
Zero value after =239 mV, Inclination: (Total Inclination)
Maximum value = 7.0 °
Zero value before = 2756 mV
Zero value after =2756 mV, _____

CPTest version: 3.24 Start time: 10:47:41 AM End time: 11:11:55 AM Project number: 05TT1
CPT number: 102 Length: 17.30 m Cone: C10CFIIP.C15212 Pre drill depth: 0.00 CH1: (qc)
Maximum value = 43.9 MPa
Zero value before = 188 mV
Zero value after =186 mV, CH2: (fs)
Maximum value = 0.2 MPa
Zero value before = 194 mV
Zero value after =195 mV, CH3: (u2)
Maximum value = 0.487 MPa
Zero value before = 239 mV
Zero value after =240 mV, Inclination: (Total Inclination)
Maximum value = 5.1 °
Zero value before = 2754 mV
Zero value after =2758 mV, _____

CPTest version: 3.24 Start time: 12:23:47 PM End time: 12:51:41 PM Project number: 05TT1
CPT number: 104 Length: 20.00 m Cone: C10CFIIP.C15212 Pre drill depth: 0.00 CH1: (qc)
Maximum value = 8.4 MPa
Zero value before = 189 mV
Zero value after =186 mV, CH2: (fs)
Maximum value = 0.2 MPa
Zero value before = 194 mV

Zero value after =197 mV, CH3: (u2)
Maximum value = 4.434 MPa
Zero value before = 238 mV
Zero value after =237 mV, Inclination: (Total Inclination)
Maximum value = 5.0 °
Zero value before = 2757 mV
Zero value after =2749 mV, _____

CPTest version: 3.24 Start time: 2:13:08 PM End time: 2:30:29 PM Project number: 05TT1
CPT number: 110 Length: 12.20 m Cone: C10CFIIP.C15212 Pre drill depth: 0.00 CH1: (qc)
Maximum value = 16.6 MPa
Zero value before = 189 mV
Zero value after =181 mV, CH2: (fs)
Maximum value = 1.0 MPa
Zero value before = 194 mV
Zero value after =198 mV, CH3: (u2)
Maximum value = 4.544 MPa
Zero value before = 236 mV
Zero value after =236 mV, Inclination: (Total Inclination)
Maximum value = 20.8 °
Zero value before = 2757 mV
Zero value after =2755 mV, _____

CPTest version: 3.24 Start time: 3:24:06 PM End time: 3:53:47 PM Project number: 05TT1
CPT number: 103 Length: 20.00 m Cone: C10CFIIP.C15212 Pre drill depth: 0.00 CH1: (qc)
Maximum value = 9.8 MPa
Zero value before = 187 mV
Zero value after =186 mV, CH2: (fs)
Maximum value = 0.3 MPa
Zero value before = 195 mV
Zero value after =198 mV, CH3: (u2)
Maximum value = 1.806 MPa
Zero value before = 237 mV
Zero value after =239 mV, Inclination: (Total Inclination)
Maximum value = 6.3 °
Zero value before = 2754 mV
Zero value after =2754 mV, _____

CPTest version: 3.24 Start time: 4:28:57 PM End time: 4:53:52 PM Project number: 05TT1
CPT number: 105 Length: 20.00 m Cone: C10CFIIP.C15212 Pre drill depth: 0.00 CH1: (qc)
Maximum value = 8.8 MPa
Zero value before = 189 mV
Zero value after =185 mV, CH2: (fs)
Maximum value = 0.3 MPa
Zero value before = 196 mV
Zero value after =194 mV, CH3: (u2)
Maximum value = 1.017 MPa
Zero value before = 237 mV
Zero value after =240 mV, Inclination: (Total Inclination)
Maximum value = 15.9 °
Zero value before = 2759 mV
Zero value after =2753 mV, _____

Date: 3/02/2020 Sounding unit: _____

CPTest version: 3.24 Start time: 10:41:56 AM End time: 11:10:37 AM Project number: 05TT1
CPT number: 106 Length: 20.00 m Cone: C10CFIIP.C15212 Pre drill depth: 0.00 CH1: (qc)
Maximum value = 30.1 MPa
Zero value before = 190 mV
Zero value after =185 mV, CH2: (fs)
Maximum value = 0.4 MPa
Zero value before = 197 mV
Zero value after =195 mV, CH3: (u2)
Maximum value = 4.811 MPa
Zero value before = 228 mV
Zero value after =231 mV, Inclination: (Total Inclination)
Maximum value = 12.0 °
Zero value before = 2762 mV
Zero value after =2764 mV, _____

CPTest version: 3.24 Start time: 11:40:01 AM End time: 12:03:52 PM Project number: 05TT1
CPT number: 00 Length: 8.10 m Cone: C10CFIIP.C15212 Pre drill depth: 0.00 CH1: (qc)
Maximum value = 0.0 MPa
Zero value before = 89 mV
Zero value after =89 mV, CH2: (fs)
Maximum value = 0.0 MPa
Zero value before = 161 mV
Zero value after =161 mV, CH3: (u2)
Maximum value = 0.000 MPa
Zero value before = 160 mV
Zero value after =160 mV, Inclination: (Total Inclination)
Maximum value = 279.6 °
Zero value before = 161 mV
Zero value after =161 mV, _____

CPTest version: 3.24 Start time: 12:53:04 PM End time: 12:55:02 PM Project number: 05TT1
CPT number: 107 Length: 0.20 m Cone: C10CFIIP.C15212 Pre drill depth: 0.00 CH1: (qc)
Maximum value = 37.4 MPa
Zero value before = 193 mV
Zero value after =193 mV, CH2: (fs)
Maximum value = 0.4 MPa
Zero value before = 199 mV
Zero value after =194 mV, CH3: (u2)
Maximum value = 0.003 MPa
Zero value before = 226 mV
Zero value after =231 mV, Inclination: (Total Inclination)
Maximum value = 21.2 °
Zero value before = 2760 mV
Zero value after =2761 mV, _____
CPTest version: 3.24 Start time: 12:56:15 PM End time: 12:57:32 PM Project number: 05TT1
CPT number: 107a Length: 0.14 m Cone: C10CFIIP.C15212 Pre drill depth: 0.00 CH1: (qc)
Maximum value = 21.9 MPa
Zero value before = 193 mV
Zero value after =185 mV, CH2: (fs)
Maximum value = 0.3 MPa
Zero value before = 198 mV
Zero value after =198 mV, CH3: (u2)
Maximum value = 0.002 MPa
Zero value before = 226 mV
Zero value after =224 mV, Inclination: (Total Inclination)
Maximum value = 13.4 °
Zero value before = 2760 mV
Zero value after =2730 mV, _____

CPTest version: 3.24 Start time: 1:01:22 PM End time: 1:27:49 PM Project number: 05TT1
CPT number: 107b Length: 17.10 m Cone: C10CFIIP.C15212 Pre drill depth: 0.00 CH1: (qc)
Maximum value = 22.1 MPa
Zero value before = 190 mV
Zero value after =187 mV, CH2: (fs)
Maximum value = 0.9 MPa
Zero value before = 195 mV
Zero value after =198 mV, CH3: (u2)
Maximum value = 1.402 MPa

Zero value before = 223 mV
Zero value after =230 mV, Inclination: (Total Inclination)
Maximum value = 9.2 °
Zero value before = 2762 mV
Zero value after =2763 mV, _____

CPTest version: 3.24 Start time: 1:54:05 PM End time: 2:13:33 PM Project number: 05TT1
CPT number: 00 Length: 8.10 m Cone: C10CFIIP.C15212 Pre drill depth: 0.00 CH1: (qc)
Maximum value = 0.0 MPa
Zero value before = 89 mV
Zero value after =89 mV, CH2: (fs)
Maximum value = 0.0 MPa
Zero value before = 161 mV
Zero value after =161 mV, CH3: (u2)
Maximum value = 0.001 MPa
Zero value before = 159 mV
Zero value after =159 mV, Inclination: (Total Inclination)
Maximum value = 279.7 °
Zero value before = 161 mV
Zero value after =161 mV, _____

Appendix D: Standpipe piezometer as-builts

PERRY GEOTECH LTD
PO BOX 9376
GREERTON
TAURANGA 3142

T 07 578 0072

F 07 577 1553

Project: 05TT1

Date: Tuesday, 28 January 2020

Client: T&T

Engineer: Guy

Borehole #: 101

Rig: CPT5

Operator: Troy

SWL: 6.7

PVC Size: 20mm

Plain PVC (m): 6.7m

Screen PVC (m): 1.5m

Sand: 0

Bentonite: 0

Concrete: 0.5

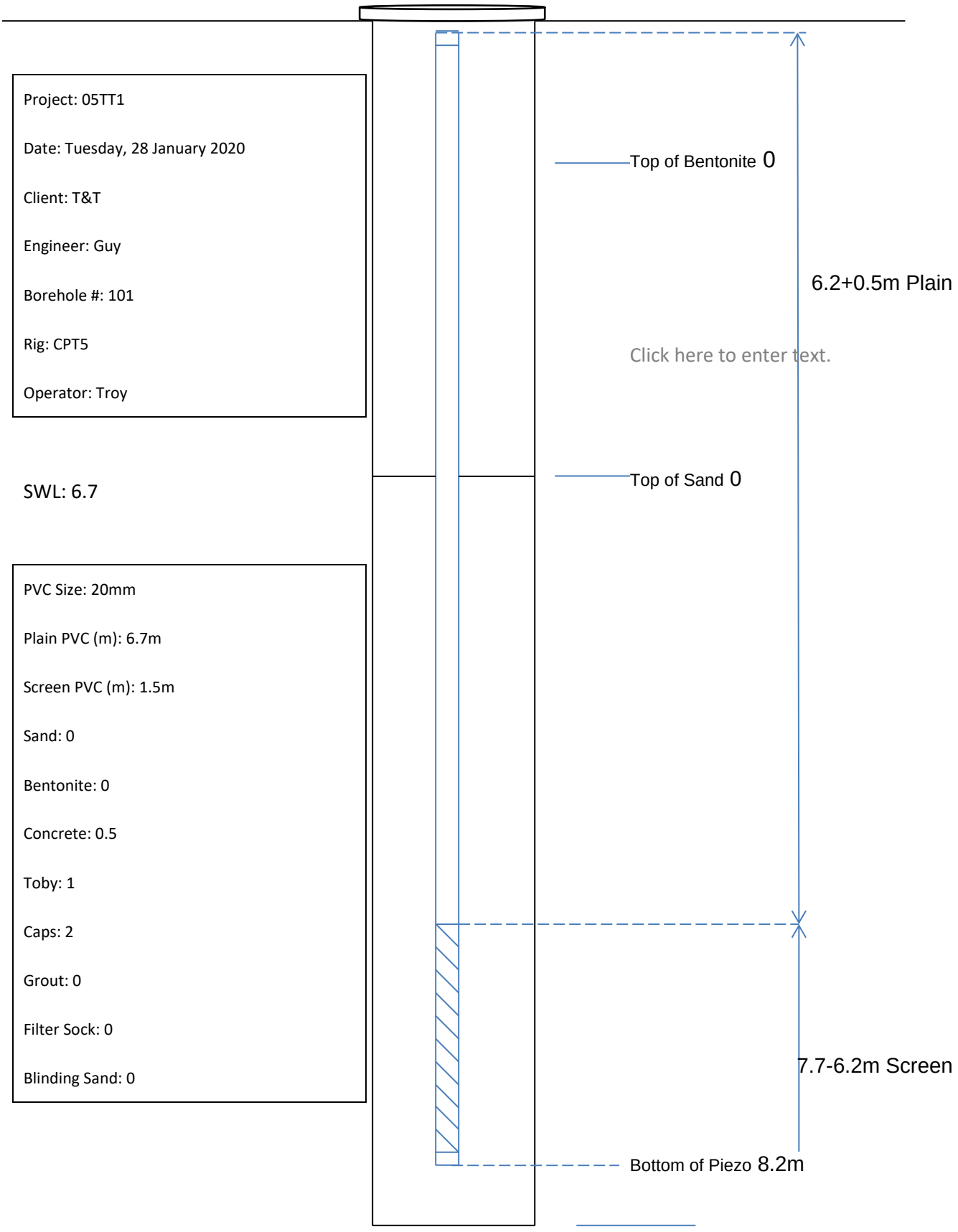
Toby: 1

Caps: 2

Grout: 0

Filter Sock: 0

Blinding Sand: 0



Comments: Click here to enter text.

Depth of Hole 15.99

PERRY GEOTECH LTD
PO BOX 9376
GREERTON
TAURANGA 3142

T 07 578 0072

F 07 577 1553

Project: 05TT1

Date: Tuesday, 28 January 2020

Client: T&T

Engineer: Guy

Borehole #: 104

Rig: CPT5

Operator: Troy

SWL: 10.8

PVC Size: 20mm

Plain PVC (m): 10.3m

Screen PVC (m): 1.5m

Sand: 0

Bentonite: 0

Concrete: 0.5

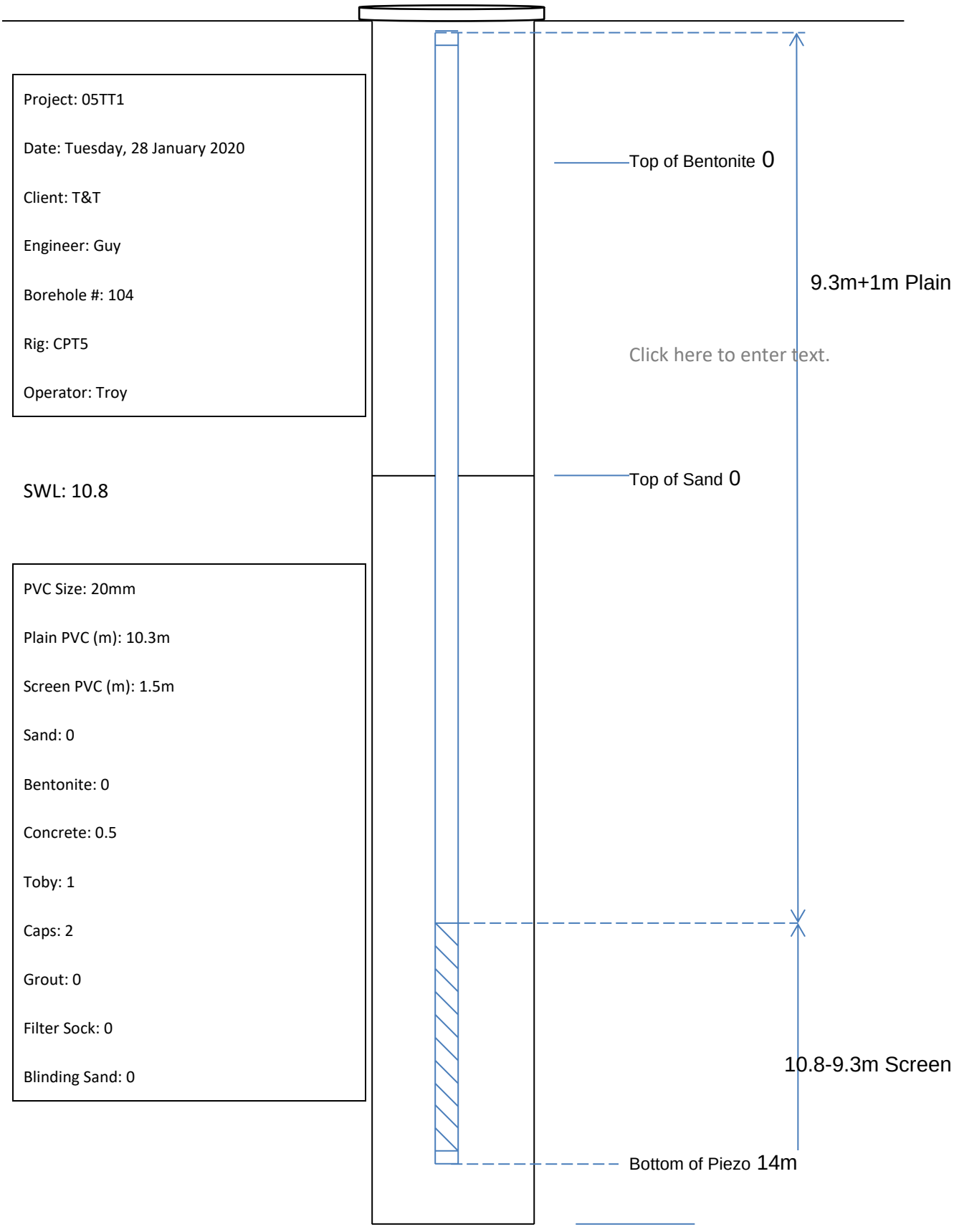
Toby: 1

Caps: 2

Grout: 0

Filter Sock: 0

Blinding Sand: 0



Comments: Click here to enter text.

Depth of Hole 20

PERRY GEOTECH LTD
PO BOX 9376
GREERTON
TAURANGA 3142

T 07 578 0072

F 07 577 1553

Project: 05TT1

Date: Tuesday, 28 January 2020

Client: T&T

Engineer: Guy

Borehole #: 105

Rig: CPT5

Operator: Troy

SWL: 13.6

PVC Size: 20mm

Plain PVC (m): 12.5m

Screen PVC (m): 1.5m

Sand: 0

Bentonite: 0

Concrete: 0.5

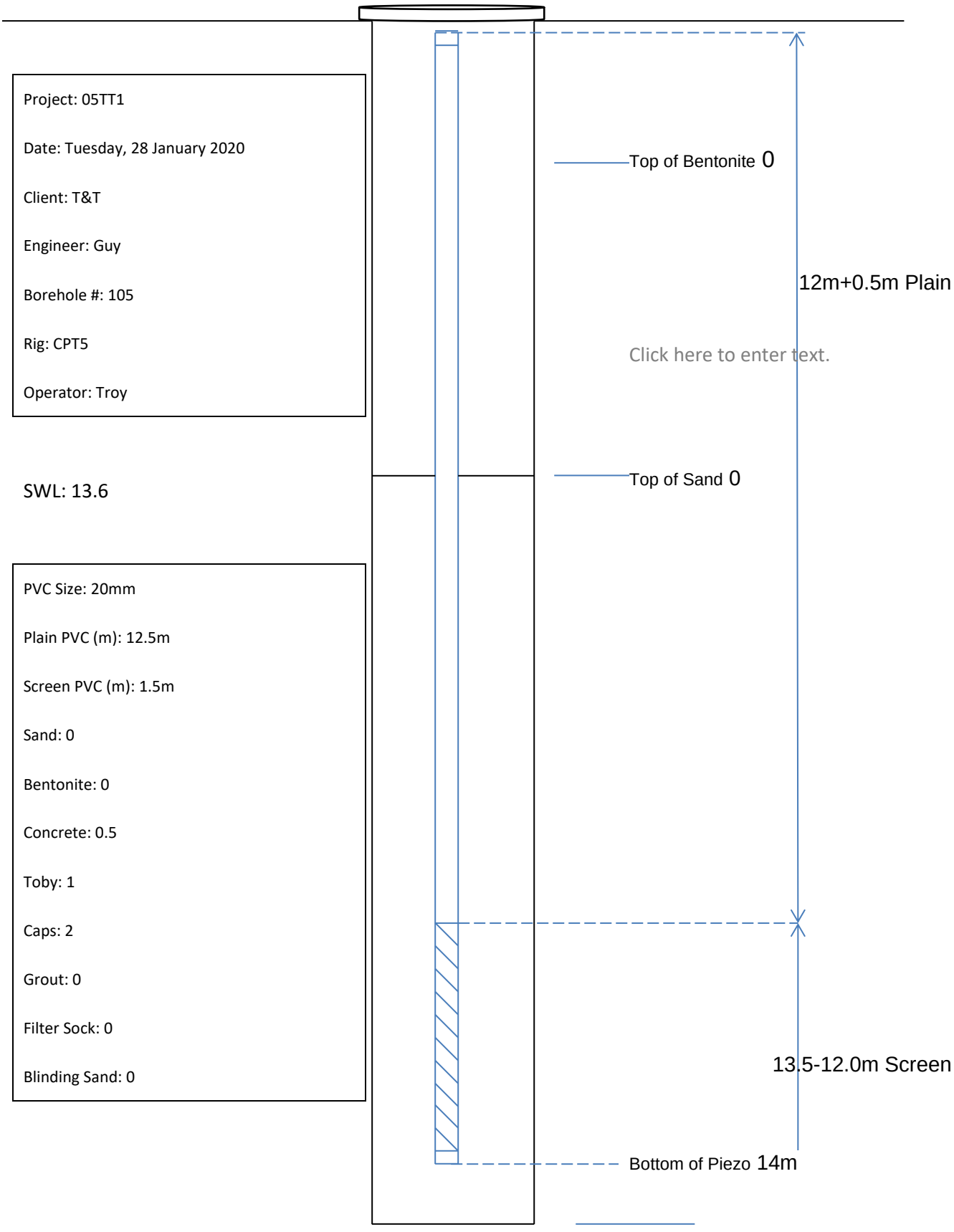
Toby: 1

Caps: 2

Grout: 0

Filter Sock: 0

Blinding Sand: 0



Comments: Click here to enter text.

Depth of Hole 20

PERRY GEOTECH LTD
PO BOX 9376
GREERTON
TAURANGA 3142

T 07 578 0072

F 07 577 1553

Project: 05TT1

Date: Monday, 3 February 2020

Client: T&T

Engineer: Guy

Borehole #: 106

Rig: CPT5

Operator: Troy

SWL: 8.0d

PVC Size: 20mm

Plain PVC (m): 6.5m

Screen PVC (m): 1.5m

Sand: 0

Bentonite: 0

Concrete: 0.5

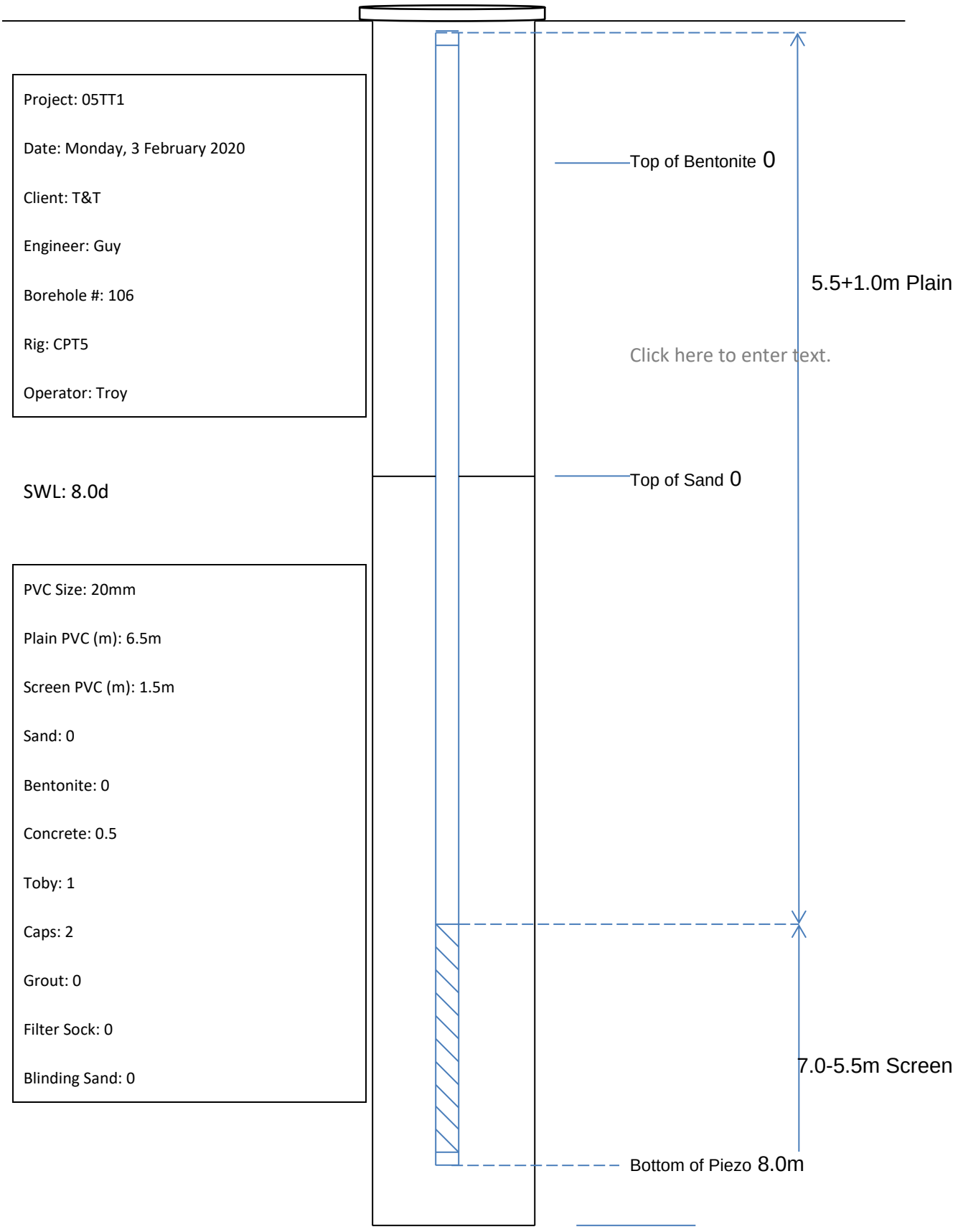
Toby: 1

Caps: 2

Grout: 0

Filter Sock: 0

Blinding Sand: 0



Comments: Click here to enter text.

Depth of Hole 20

PERRY GEOTECH LTD
PO BOX 9376
GREERTON
TAURANGA 3142

T 07 578 0072

F 07 577 1553

Project: 05TT1

Date: Monday, 3 February 2020

Client: T&T

Engineer: Guy

Borehole #: 107

Rig: CPT5

Operator: Troy

SWL: 8.0d

PVC Size: 20mm

Plain PVC (m): 6.5m

Screen PVC (m): 1.5m

Sand: 0

Bentonite: 0

Concrete: 0.5

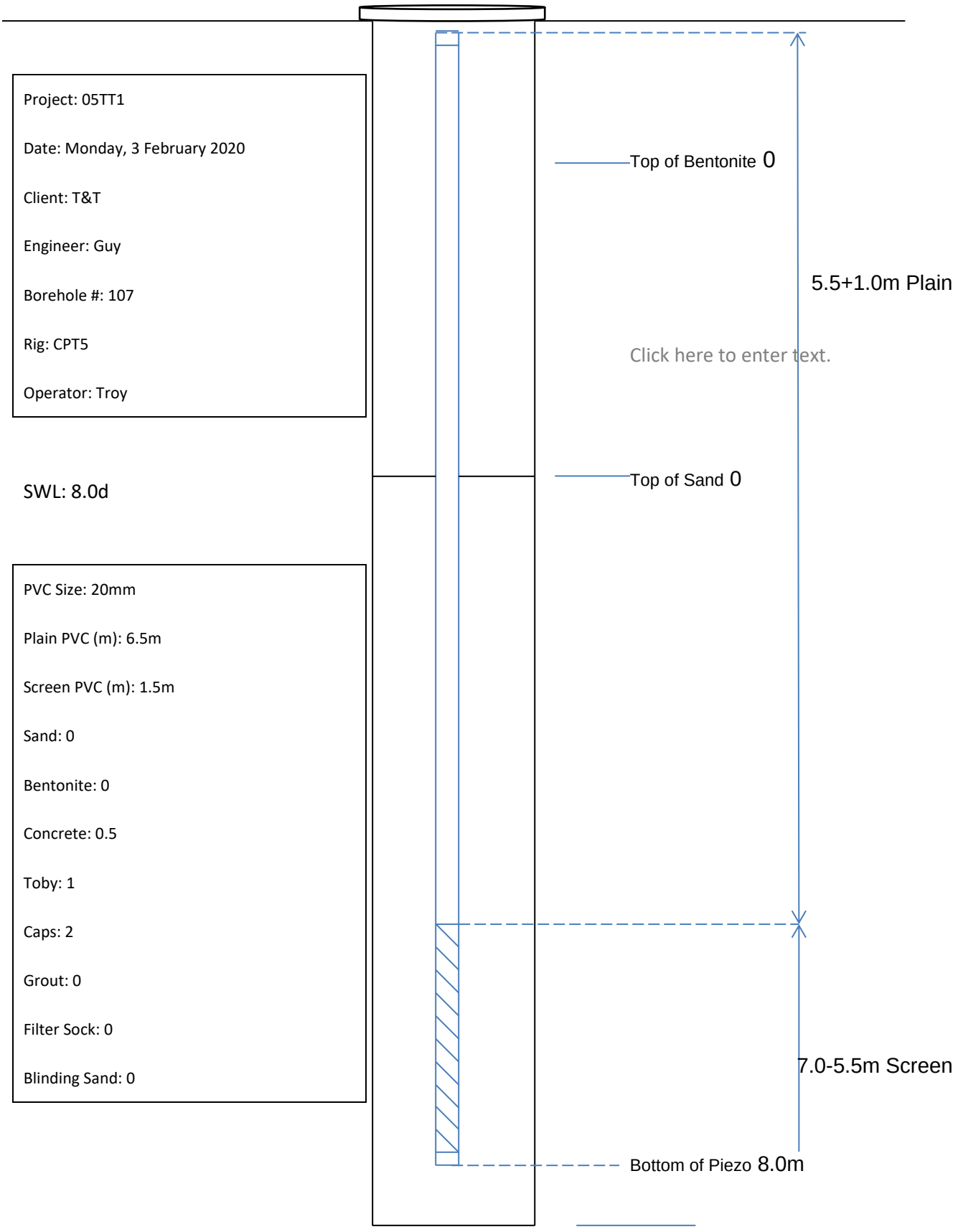
Toby: 1

Caps: 2

Grout: 0

Filter Sock: 0

Blinding Sand: 0



Comments: Click here to enter text.

Depth of Hole 20

PERRY GEOTECH LTD
PO BOX 9376
GREERTON
TAURANGA 3142

T 07 578 0072

F 07 577 1553

Project: 05TT1

Date: Tuesday, 28 January 2020

Client: T&T

Engineer: Guy

Borehole #: 109

Rig: CPT5

Operator: Troy

SWL: 4.5

PVC Size: 20mm

Plain PVC (m): 3.0m

Screen PVC (m): 1.5m

Sand: 0

Bentonite: 0

Concrete: 0.5

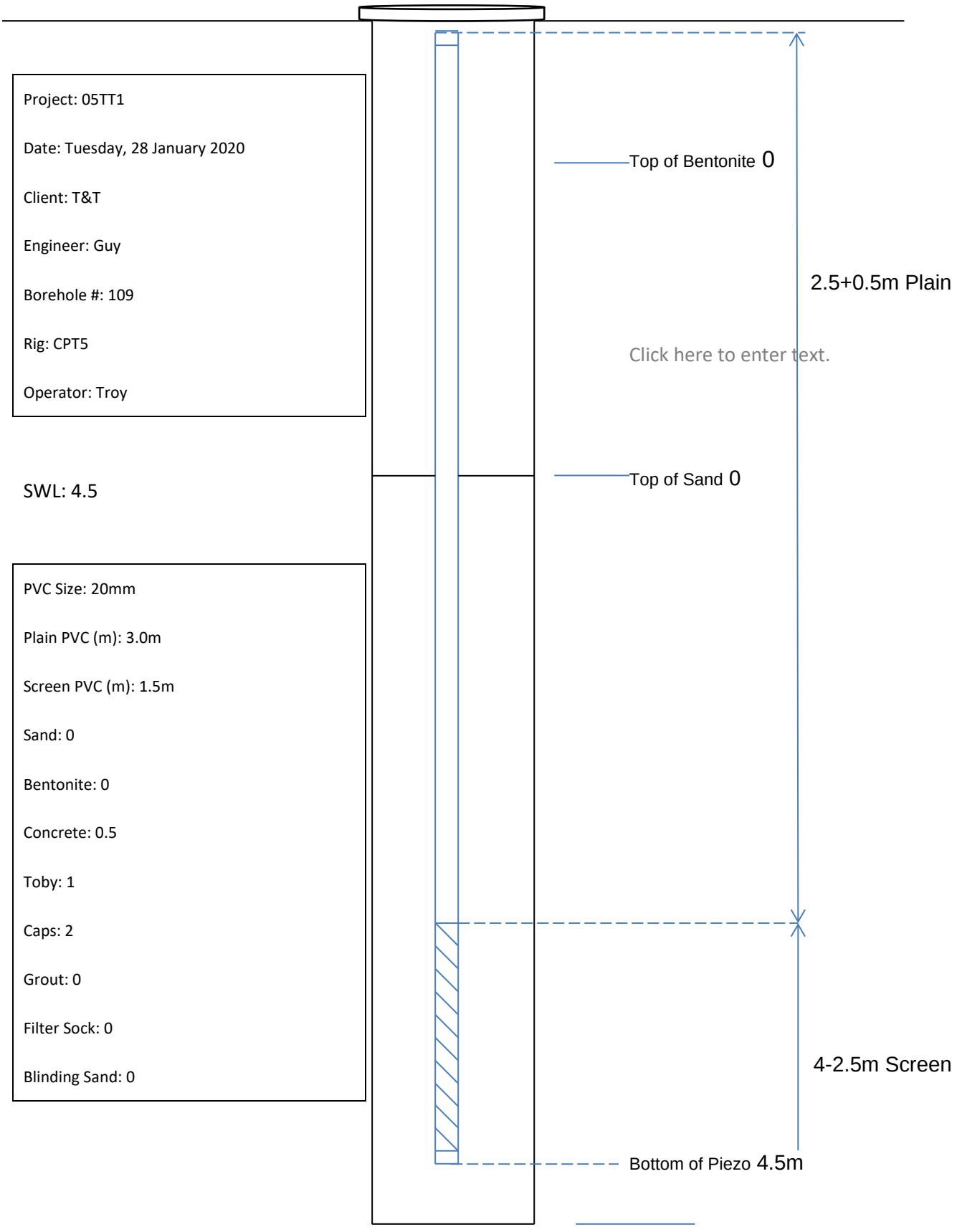
Toby: 1

Caps: 2

Grout: 0

Filter Sock: 0

Blinding Sand: 0



Comments: Click here to enter text.

Depth of Hole 5.34

www.tonkintaylor.co.nz