

# Characteristics of sub-surface sediments in southern Stella Passage, Tauranga Harbour

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## Executive summary

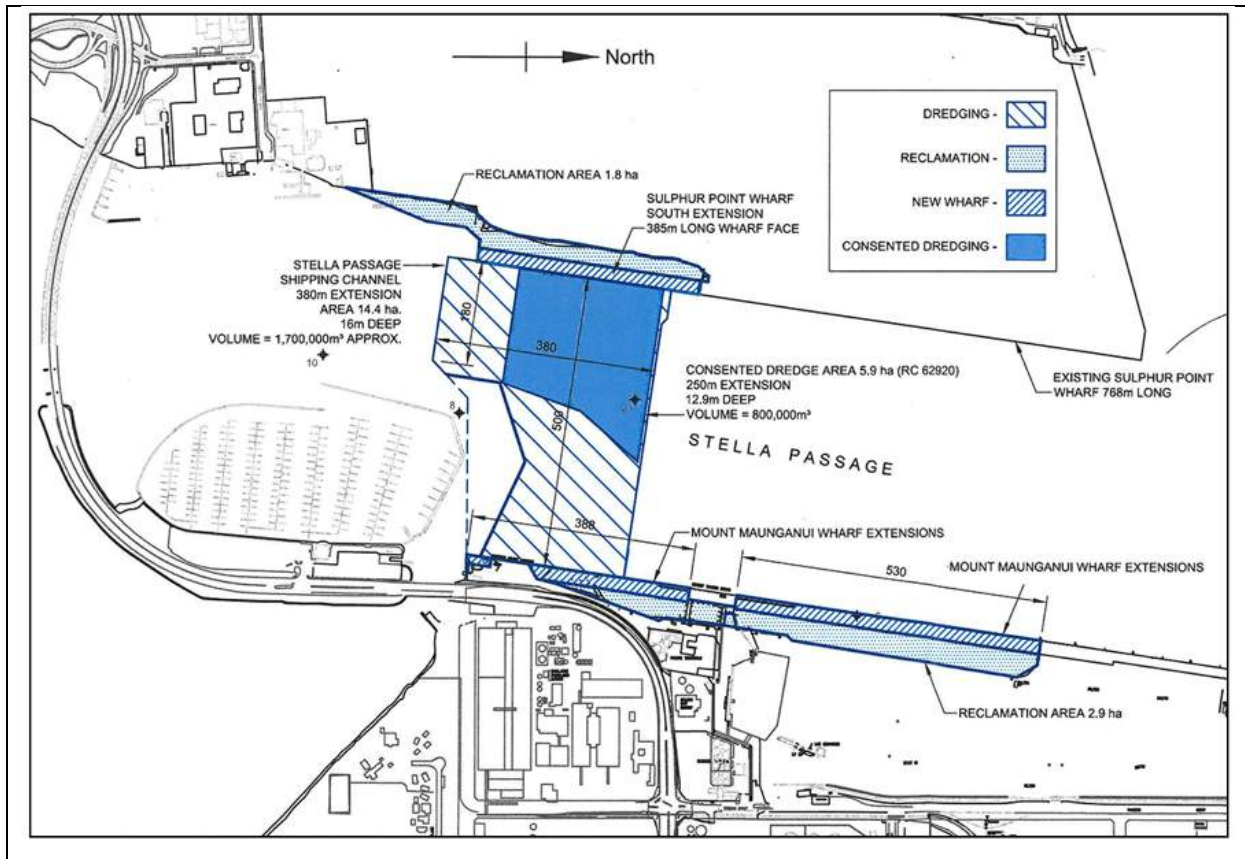
The Port of Tauranga is considering port developments that would require capital dredging of a section of the southern Stella Passage to achieve depths comparable to the northern Stella Passage. Seismic profiles, core samples, and CPT data were collected by the University of Waikato and OPUS for the area impacted by proposed development.

The core samples were analysed for sediment texture, including assessment of the fines (silt + clay) content. Four main stratigraphic units were identified from the available data. These were, in order of increasing stratigraphic depth and age: Holocene sand; Pleistocene alluvial fan; Pleistocene organic silt; and Pleistocene terrestrial and shallow marine sand. In general, the fines content increased with depth and age. Younger units thin southwards along Stella Passage, resulting in increasing fines content southwards along the channel.

A 3D model of the subsurface stratigraphy was created by Leapfrog and is available for viewing, including the ability to generate slices in any required orientation. This model highlights the trends in fines content above, as well as showing that sediments along the western margin of the proposed dredged area have the highest proportion of fines. Apart from the Holocene sands, most of the sediment to be dredged is likely to exceed 25% fines content, and, therefore, would require and is suitable for disposal at offshore site H2.

## Introduction

The Port of Tauranga has consent to extend the shipping channels southwards within Stella Passage, and is considering further developments in this area (Figure 1). Prior to previous capital dredging campaigns within Stella Passage the characteristics of sub-surface sediments within the dredged area were investigated. The findings of these studies in terms of their sedimentary environment interpretation are summarised in Davis and Healy (1994), Jorat *et al* (2017), and MacPherson *et al* (2017). The characteristics of the sub-surface sediments are detailed in Moon *et al* (2013), and de Lange *et al* (2014).



**Figure 1.** Consented dredging and possible future development of the Port of Tauranga within the southern Stella Passage.

It is proposed that material dredged from southern Stella Passage will be discharged at existing offshore disposal sites H1 and H2. Sediment containing > 25% of sediment finer than 63 µm will be discharged to site H2.

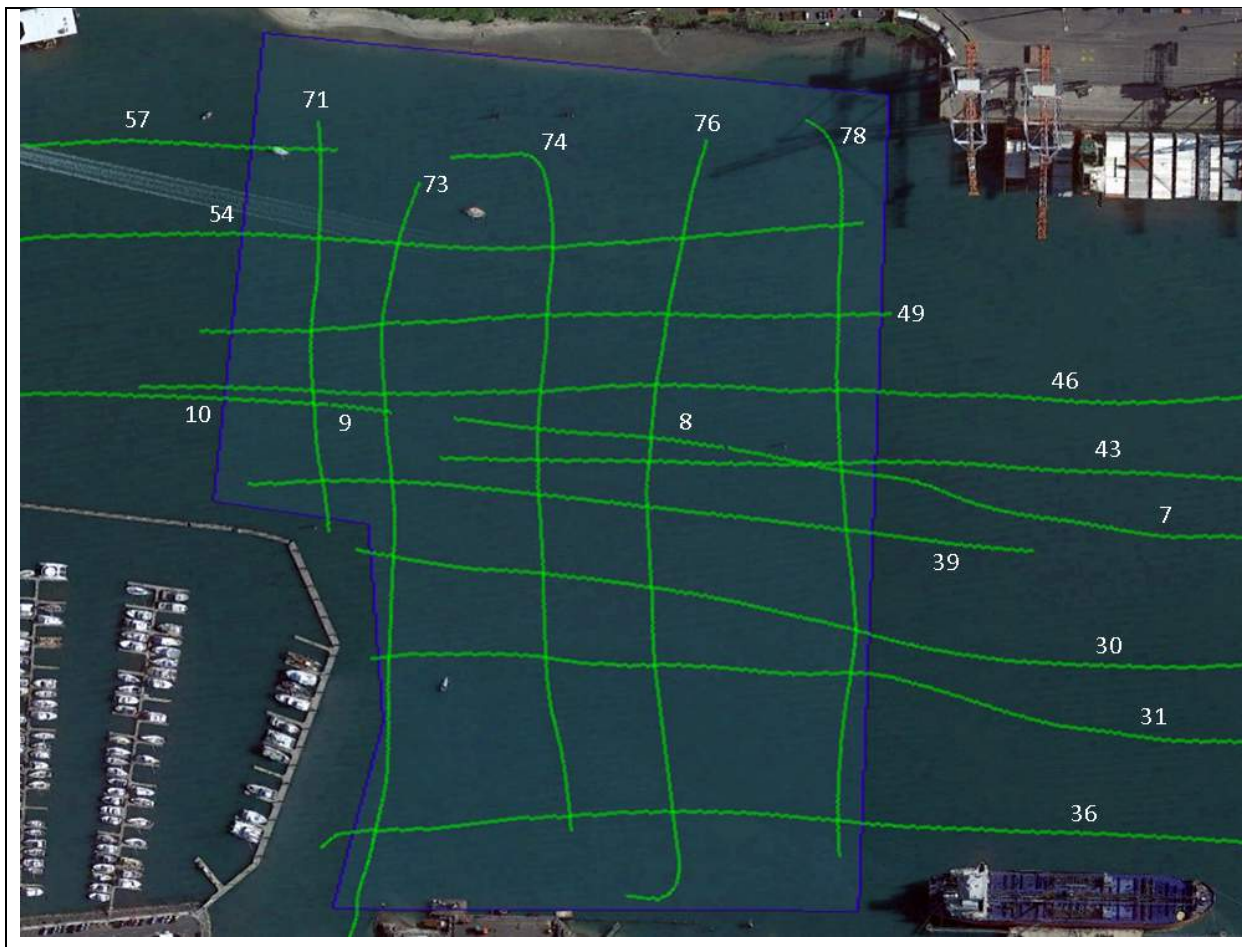
This report summarises the results of a seismic survey, borehole descriptions, sediment textural analyses, and CPT data, that identify areas likely to contain sediment that exceeds the 25% threshold for fines content.

## Methods

Seismic data were collected on 11 January 2018 using SounderSuite-USB software connected to a Knudsen Pinger SBP dual frequency CHIRP portable seismic reflection system operating at 3.5 kHz for seismic and 200 kHz for bottom location. Positional data were also logged by SounderSuite-USB from an OTF kinematic DGPS navigation system. Since the survey involved an area not previously dredged, the Pinger was configured to achieve penetration to a depth of at least 20 m RL, which resulted in relatively low resolution compared to

shorter range settings. The resulting data were exported to SEG-Y format and processed in Matlab, using routines from the package SegyMAT.

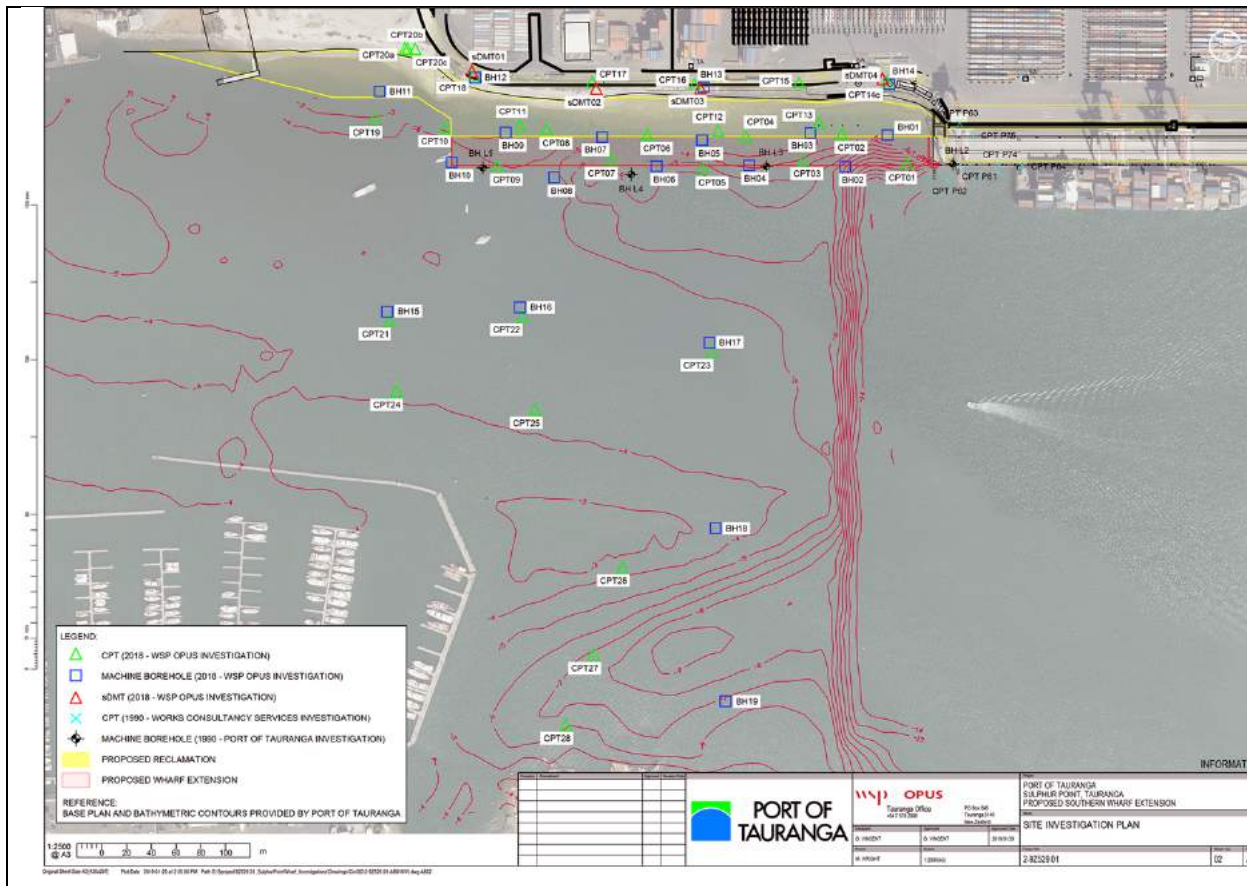
Figure 2 indicates the locations of seismic survey tracks that intersected the potential dredging areas shown in Figure 1. An initial analysis of the seismic data indicated that the higher density of data obtained did not suggest a different sub-surface structure from that proposed by Jorat *et al* (2017) based on an earlier low track density seismic survey.



**Figure 2.** Seismic lines within the southern Stella Passage that intersect the proposed dredging area. The survey was undertaken on 11 January 2018.

The initial seismic analysis was used to inform the placement of boreholes to provide sediment samples for textural analysis, and stratigraphic information to assist with the interpretation of the seismic data. CPT sites were also specified due to the successful use of CPT data for characterising sub-surface stratigraphy in previous studies (*viz.* Jorat *et al*, 2017).

Figure 3 shows the locations of borehole (BH), CPT and seismic dilatometer test (sDMT) sites within southern Stella Passage sampled by OPUS (2019). Sites BH15-19 and CPT21-28 were not interpreted by OPUS (2019) and were specifically intended to characterise the sediment potentially being dredged for this report. Data from all sites were used to develop a 3D stratigraphic model for the dredged area. Boreholes BH15-19 were located along the transect discussed by Jorat *et al* (2017) to allow comparisons with their interpretation, which was based on CPT data collected by the University of Bremen submersible GOST system. CPT21-23 were located adjacent to these boreholes to allow the CPT data to be correlated with stratigraphic information from the boreholes. The remaining BH and CPT sites were distributed to obtain the maximum coverage within the available budget.



**Figure 3.** Location of borehole (BH), CPT, and seismic dilatometer testing (sDMT) sites in southern Stella Passage (Appendix A, OPUS, 2019). This report mainly focusses on boreholes BH15-19, and CPT sites CPT21-28.

The cores from boreholes BH15-19 were transferred to the core storage at the University of Waikato, and subsequently described using standard geotechnical methods and photographed (Appendix A). Subsamples of <1 g were taken from each unit identified in the core for particle size analysis by laser diffraction using a Malvern Mastersizer. The subsampled sediment was not deflocculated with Calgon, and any organics present were retained. The subsamples were pre-sieved through a 2 mm (2000  $\mu\text{m}$ ) sieve to remove gravel and prevent blockages in the Mastersizer, and then the size distributions between 0.05 and 3600  $\mu\text{m}$  were measured. The distribution was analysed using the moment method to determine the sediment textural parameters, and the proportions of sand, silt, clay and fines (silt + clay or <62.5  $\mu\text{m}$ ) were determined. Results for samples that had gravel removed prior to measurement, were adjusted to account for the proportion of gravel in the original sample. The silt to clay boundary was taken to be 2  $\mu\text{m}$ . The detailed textural analysis results are presented in Appendix C.

The results obtained from the (volume distribution) are not directly comparable to the textural analysis results reported by OPUS (2019), which were based on wet sieving (suitable for gravel-sand sediment) and hydrometer (suitable for silt-clay sediment) methods that provide mass distributions. This occurs due to the three techniques measuring different properties related to sediment texture: projected grain volume for the Mastersizer; mass proportion for intermediate axis diameters for wet sieving; and sediment density and settling velocity for the hydrometer method. However, although the Mastersizer estimated proportions of fines (<62.5  $\mu\text{m}$ ) should be reasonably similar to the results determined by the hydrometer method by OPUS.



tends to be concentrated in shell lag layers. In CPT logs, grey shelly sands are characterised by a relatively high tip resistance, which drops significantly (by up to 8 MPa) at the boundary with the underlying facies. The facies corresponds to the Coarse Sand (CS) and Pumiceous Sand (PS) facies of MacPherson *et al* (2017) and UNIT1 (Holocene marine sand and silt) of Jorat *et al* (2017). It

The thickest grey shelly sands unit occurs at BH18 (~7.2 m), BH19 (~3.5 m including overlying black fine sand unit), and CPT 24 (~2 m). At the remaining sites it is typically ≤1 m thick.

This facies started forming between *c.* 7600 and *c.* 6800 years BP when sea level approximately reached the current elevation. MacPherson *et al* (2017) identified their CS facies as a shoreface deposit that formed before the Mt Maunganui tombolo closed off the harbour from direct wave action, after which the locally-derived PS facies was deposited within the harbour. In the southern Stella Passage grey shelly sand appears to infill channels or valleys in the underlying units, which suggests tidal channel and lower intertidal flat environments comparable to the present-day situation. However, petrographic analysis to determine the relative proportions of CS and PS facies within the grey shelly sand unit has not been undertaken.

### Dark brown organic silts

The dark brown organic silts facies is described in the core-logs of OPUS (2019) report, and consists of organic-rich silts, with wood fragments. The facies was not analysed for sediment texture by OPUS, but is expected to have a high fines content. It is interpreted as mostly likely being an upper intertidal flat salt-marsh deposit.

This facies doesn't correspond to any of the specific facies identified by previous studies, but is noted as occurring within UNIT4 (Middle pumiceous sand and silt) of Jorat *et al* (2017). It occurs in a restricted area, predominantly within the proposed Sulphur Point wharf extension (BH03, BH07, BH09, and BH13) at variable depths with a maximum thickness of ~1.5 m. However, thinner exposures occur along the western margin of the proposed dredged channel (BH12 and BH14). Therefore, it may be exposed by dredging in close proximity to the new wharf.

### Pale yellow pumiceous sands

The pale yellow pumiceous sands correspond to the Volcanic Sand (VS) and Lithic Silt (LS) facies of MacPherson *et al* (2017), and UNIT2 (Upper pumiceous sand and silt) and UNIT3 (Silt-sand-clay) of Jorat *et al* (2017). Although these earlier studies sub-divided this facies using a variety of criteria, it wasn't possible to do so for the southern Stella Passage as the succession in this area consists of lensoidal or lenticular sub-units that have limited areal extent. This lack of continuity made it impossible to correlate individual sub-units between boreholes and CPT sites, even those in close proximity.

Texturally the facies is poorly to very-poorly sorted, with individual lenses varying from very-fine silt to medium sand, with some gravels. The fines content varies from 18-97%, with no systematic variation with depth. Although there is a general trend of increasing cone resistance with depth, CPT logs are highly variable through this unit.

This facies is interpreted as representing fluvially reworked volcaniclastic sediments deposited in an alluvial fan by a braided river system during the last glacial period (20-110 thousand years ago). This environment produces a highly variable deposit including channel, overbank flood, and lake sediments, which can include swamp deposits and paleosols.

Based on previous dredging activities in northern Stella Passage and pipelaying near the railway bridge, it is likely that iron-oxide hardpans (paleosols) and buried logs will be encountered within the pale yellow pumiceous sands. Previous dredging campaigns that encountered hardpans used bucket excavators as the cutter heads from cutter-suction dredges had difficulty breaking through the hardpan. This may be necessary for the proposed southern Stella Passage dredging. Unfortunately, it is not possible to determine the location and extent of hardpans, or locations of buried logs, within this unit. If our interpretation of the depositional environment is correct, hardpans are more likely in southern Stella Passage than within the shipping channels already excavated.

### **Olive-green sands**

The olive-green sands facies is limited in extent and appears to occur within channels in the lowest facies unit. The thickest sequence was found at BH19, where ~1.5 m was recovered from the base of the borehole (>22.5 m below rig level). The unit fines upwards, with the lowest samples containing 7-11% fines, while the uppermost sample contained 27% fines. There are some shell fragments present. This unit is interpreted as grading from shallow marine (shoreface) at the base to intertidal flat and possibly terrestrial dunes, and corresponds to a previous sea level high-stand, probably from the Eemian Interglacial ca. 120 thousand years ago. The depth at which this unit occurs indicates the southern Stella Passage has subsided since the previous interglacial, as previous Pleistocene interglacial sea level high-stands are believed to have been at least at the current interglacial elevation (Pedoja et al, 2011).

This facies shouldn't be encountered during the proposed dredging. It is similar to modern marine sands, but has undergone significant weathering, resulting in the loss of most shell material, an increase in fines content, and olive-green colours associated with reducing conditions.

### **Pale grey quartz sands**

The pale grey quartz sands predominantly consist of moderately-sorted to very poorly-sorted medium to very fine sand. There are some sub-units that consist of very poorly-sorted coarse to very fine silt. Sandy sub-units have fines contents from 6-53%, with the proportion of fines within the entire unit increasing as mean grain size decreases: medium sand 6-11%; fine sand 9-37%; very fine sand 42-53%; coarse silt 68%; fine silt 87%; and very fine silt 95%.

This facies was identified in CPT logs by a sharp increase in relative density compared to the overlying Pleistocene alluvial fan unit. The relative density traces are not included in this report as they generally match the cone resistance traces that are in Appendix B. In most of the CPT logs, the cone resistance increases from 4-8 MPa in the pale yellow pumiceous sands to 8-20 MPa in the pale grey quartz sands.

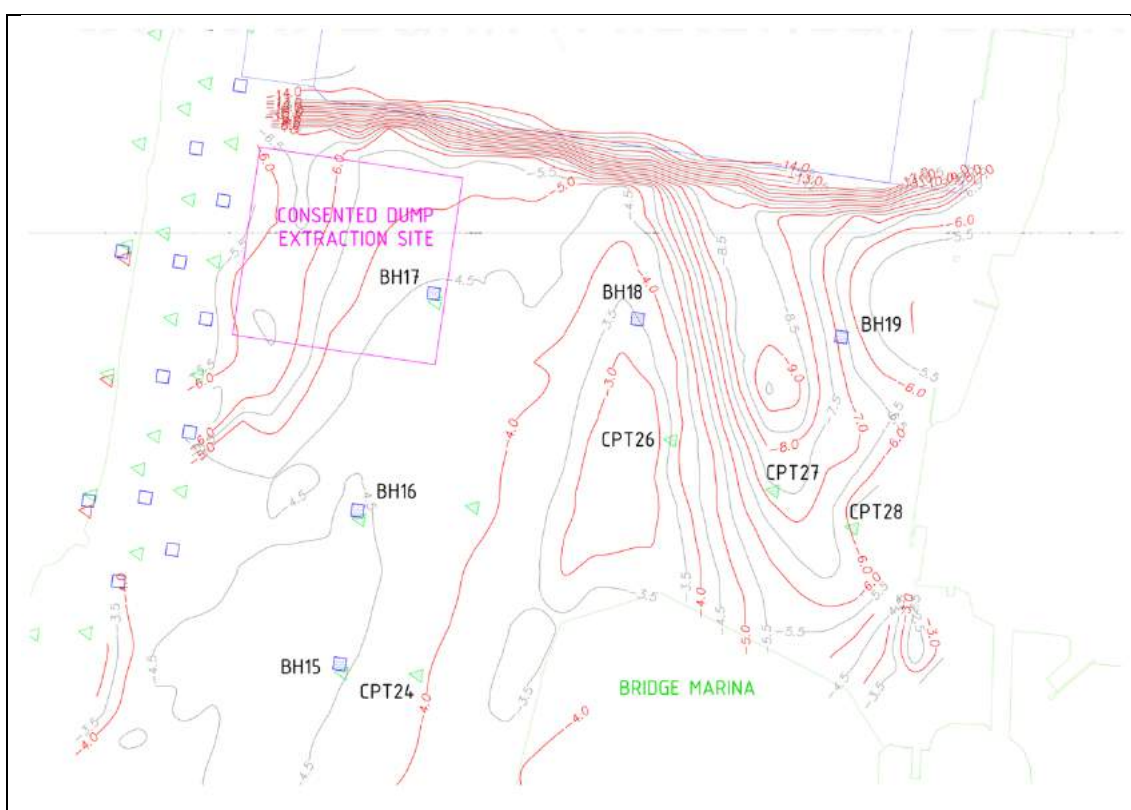
The exceptions are CPT21 and CPT28. CPT21 was located close to BH15, where the boundary between the two facies was a white silty clay associated with a cone resistance increase from 2-4 Ma to 4-6 MPa. CPT28 is not close to a borehole, but the interpreted stratigraphy is most similar to BH19. The transition at the base of the pale yellow pumiceous sands facies in CPT29 is marked by a decrease in cone resistance from 10-11 MPa to 5-6 MPa, before increasing to 20 MPa with depth. The decrease in cone resistance appears to be associated with the uppermost section of the olive-green sands facies, while the subsequent increase in cone resistance corresponds to the lower olive-green sands and underlying pale grey quartz sands.

The pale grey quartz sands and olive-green sands correspond to UNIT4 (Middle pumiceous sand and silt) of Jorat *et al* (2017) and was not exposed in the shallow cores of MacPherson *et al* (2017). This facies is interpreted as being a floodplain environment, probably similar to the younger pale pumiceous sands facies.

### Minor units

There are also some subordinate stratigraphic units with limited distribution within southern Stella Passage, which were not defined as facies. They are summarised below.

Fragments of broken glass were observed within the deeper Holocene sands within BH17. This site is located within a historical consented dump extraction site (Figure 5). The site was used to store maintenance dredging spoil prior to transfer to land on Sulphur Point. The seabed within this extraction site has been repeatedly excavated and refilled, and the uppermost strata are severely disrupted. The sediment at the top of core comprised poorly to very-poorly sorted fine to very-fine sand, with some thin shell-hash gravel layers, and a fines content of 20-43%.



**Figure 5.** Location of excavated pit in seabed used as temporary storage of clean spoil from maintenance dredging prior to transfer to storage piles on Sulphur Point.

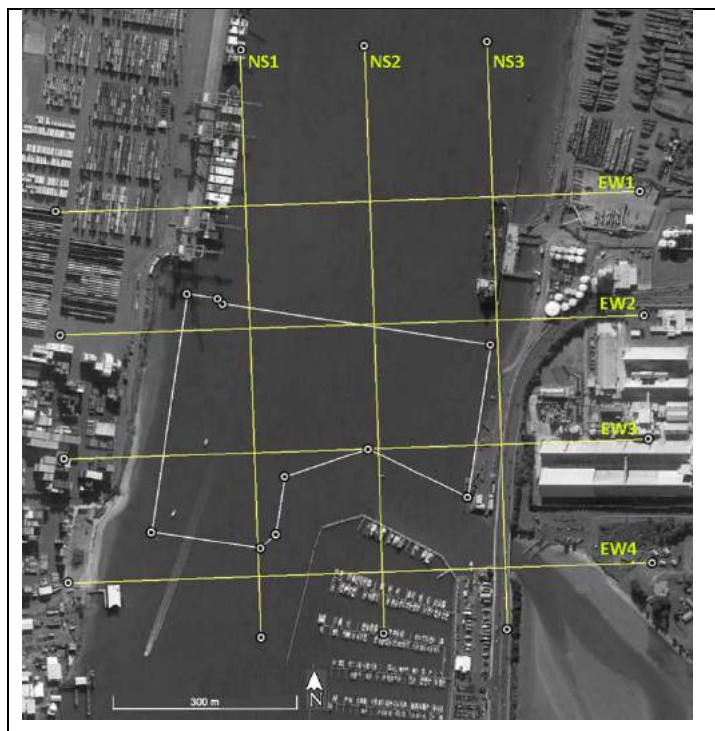
Site BH15 contains ~2 m thick volcanic tephra (and possibly ignimbrites), co-ignimbrite ash and tephra sequences (appendix A). Apart from a thin poorly-sorted medium-coarse sand ignimbrite (14% fines), the unit is dominated by very poorly-sorted fine to coarse silts (64-90% fines). A thinner tephra/ignimbrite (~ 40 cm) occurs in BH17, comprising mostly of a sandy ignimbrite component, which may be a correlative of the sequence at BH15. This unit could not be identified at the remaining sites.

A thin (3-4 cm) organic-rich layer occurs near the base of the Holocene sand unit within BH18. This is interpreted as a swamp or salt marsh deposit. It was not identified at any other site. This unit was analysed as a very poorly-sorted very-fine sand, with 46% fines.

## Leapfrog model

The southern Stella Passage contains correlatives of the stratigraphic succession previously encountered during capital dredging programmes in northern Stella Passage, Maunganui Roads and Cutter Channel. However, with increasing distance from the harbour channel the stratigraphic units are increasingly influenced by terrestrial sedimentary input and less influenced by marine sedimentary input. This is associated with an increasing fines content within the sediment.

To visualise the distribution of the units discussed above, a 3D subsurface Leapfrog model was constructed using all the available data from earlier investigations of Stella Passage (de Lange *et al*, 2014; Upiap, 2015; Jorat *et al*, 2017), OPUS (2019) and this report. The model shows our interpretation of the sub-surface stratigraphy. This model and viewer are available on request to the Port of Tauranga Ltd. To assist with the following discussion, several transects were used to prepare cross-sections of stratigraphic units and estimated fines content (Figure 6).



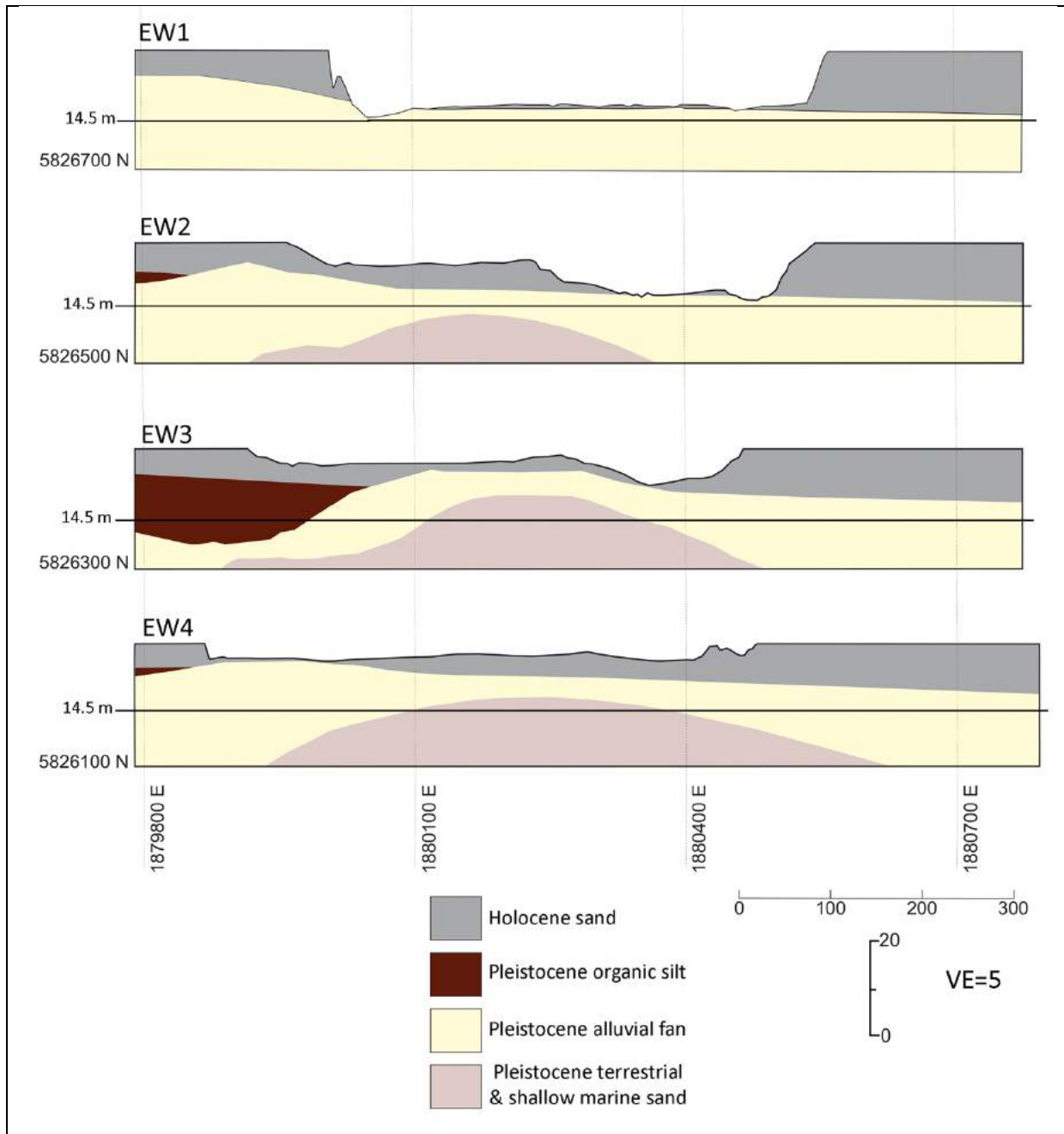
**Figure 6.** Locations of transects through the Leapfrog model relative to Stella Passage and the area of proposed capital dredging.

In order to utilise the stratigraphic data from the short cores obtained prior to the 2015-2016 capital dredging campaign, the Leapfrog model uses the pre-2015 bathymetry. This doesn't impact the sediment volumes within the proposed southwards extension of the shipping channel, as the current bathymetry is very similar. Only minor scour and accretion has occurred since the capital dredging.

An initial model was developed using a simplified stratigraphy to help interpret the borehole and CPT data. This model extended well beyond the margins as shown by the transects in Figure 6. The simplified stratigraphic units (Figure 7) were:

- *Holocene sand* consisting of the black fine sand and grey shelly sand facies;
- *Pleistocene organic silt* consisting of the dark-brown organic silt facies;
- *Pleistocene alluvial fan* consisting of the pale yellow pumiceous sand facies; and
- *Pleistocene terrestrial and shallow marine sand* consisting of the olive-green sands and pale grey quartz sands facies

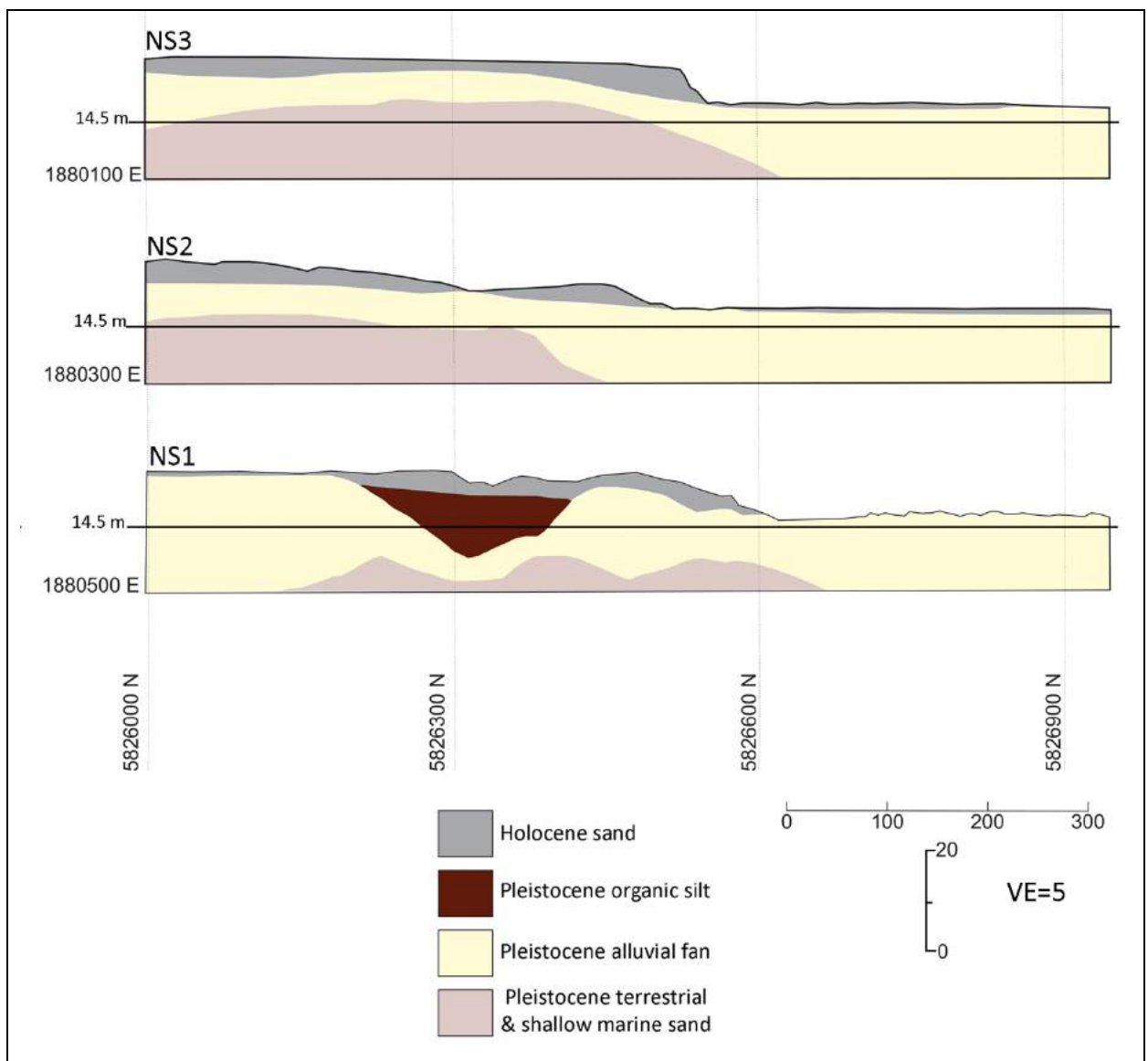
This model was then refined using the six main facies units and the boundaries of the proposed capital dredging (Figure 6). To maximise the available information by including the results reported by OPUS (2019), the model boundaries were extended beyond the area marked in Figure 6, particularly on the western margin. The refined model was used to produce estimates of surface areas and volumes, and is available for viewing and analysis from the Port of Tauranga.



**Figure 7.** East-west slices through the Leapfrog subsurface stratigraphic model, from the existing shipping channel in the north (top) to the marina in the south (bottom), showing the distribution of the 4 main units discussed in the text. The proposed 14.5 m channel depth is marked.

Overall, the highest volume of silt and clay occurs within Pleistocene alluvial fan unit (pale yellow pumiceous sands) due to the combination of terrestrial sediment input, as well as weathering and associated soil formation during the last glacial period. Due to the laterally discontinuous nature of sub-units the deposit and limited borehole and CPT data, it is not possible to define the 3D distribution of silts and clays within this unit. Although deposits

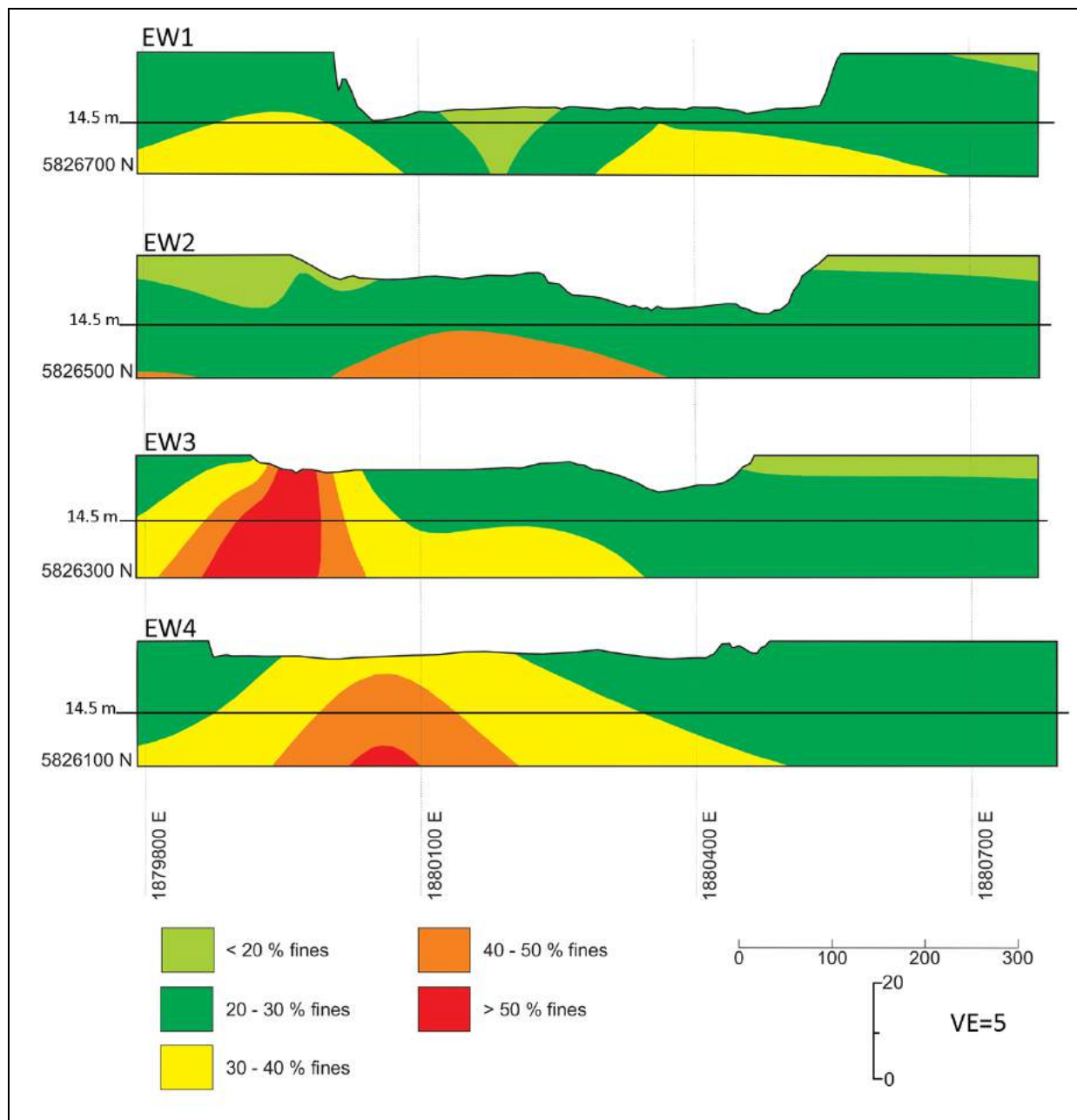
associated with volcanic eruptions (ignimbrites and tephras) generally form a continuous layer when deposited, it is clear that these have been largely reworked within the alluvial fan deposits and now have patchy distributions. Therefore, this unit has been treated as a single heterogenous succession in the Leapfrog model. The dark-brown organic silt unit has the highest proportion of fines within relatively thick layers (1-2 m), as well as a significant proportion of woody debris. The boreholes containing this facies were located close to the eastern boundary of the Leapfrog model, which made it difficult to determine the three-dimensional extent of the facies. Therefore, the model was adjusted to maximise the extent of the facies to provide a worst-case estimate of the volume (Table 1). However, most of this unit lies under the proposed wharf, which may affect wharf construction, but reduces the likely impact on dredging.



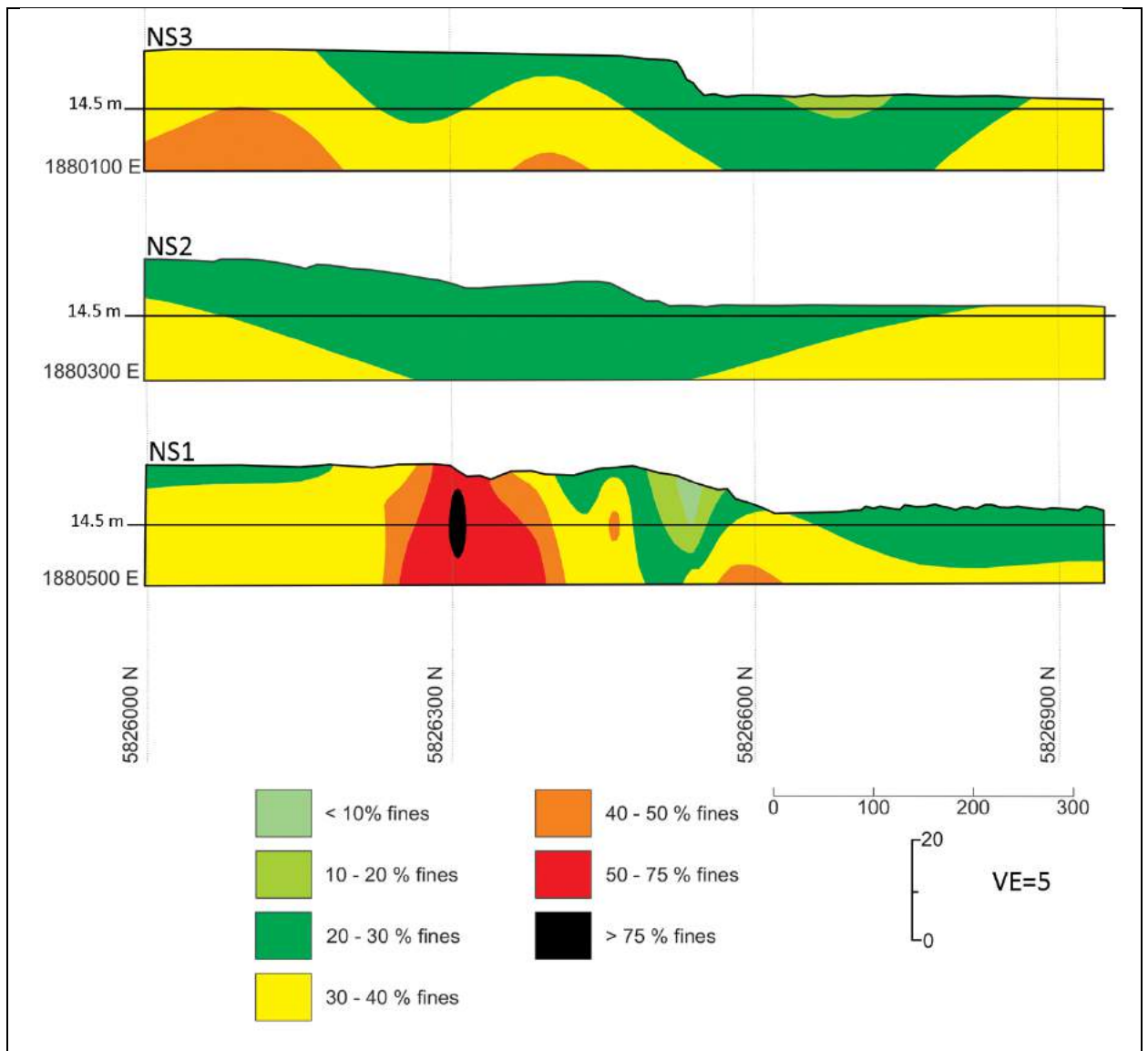
**Figure 8.** North-south slices through the Leapfrog subsurface stratigraphic model, from the Mt Maunganui wharves in the east (top) to the Sulphur Pt wharves on the west (bottom), showing the distribution of the 4 main units discussed in the text. The proposed 14.5 m channel depth is marked.

Figures 7 & 8 show stratigraphic slices through the subsurface model as indicated in Figure 6. These slices highlight the increasing thickness of Pleistocene alluvial fan sediments and decreasing thickness of Holocene sand with distance southwards through Stella Passage. Depending on the final design depth, and amount of over-deepening that occurs during dredging, the Pleistocene terrestrial and marine sand should not be encountered during

dredging. If the interpretation by MacPherson *et al* (2017) of a meandering channel incised into the Pleistocene alluvial fan unit is correct, then there will be a thicker deposit of Holocene sand infilling the channel. Using the fines content determined by the Mastersizer, supplemented with the OPUS particle size data, a model of the proportion of fines was also created using Leapfrog. To simplify the model, the data were aggregated into bins of fine proportions. The results are shown in Figures 9 and 10 for the slices in Figures 7 and 8 respectively. This highlights the increase in fines proportion with depth, and distance southwards within Stella Passage. The fines model also indicates that the highest silt and clay proportions occur along the western margin of the proposed dredged area.



**Figure 9.** Slices through the Leapfrog subsurface stratigraphic model, from the existing shipping channel in the north (top) to the marina in the south (bottom), showing the distribution of the estimated proportions of fines as discussed in the text. The proposed 14.5 m channel depth is marked.



**Figure 10.** Slices through the Leapfrog subsurface stratigraphic model, from the Mt Maunganui wharves in the east (top) to the Sulphur Pt wharves on the west (bottom), showing the distribution of the estimated proportions of fines as discussed in the text. The proposed 14.5 m channel depth is marked.

The upper surface area and volumes of each main facies (except the olive-green sands) within the proposed dredged area were estimated by Leapfrog. The volumes of sediment within specific ranges of fines content were also estimated. These estimates are summarised in Table 1.

## Conclusion

It is evident from Figures 7–10 and Table 1 that most (>75%) of the sediment to be dredged is likely to exceed the 25% threshold requiring disposal at offshore site H2. Otherwise, there are no characteristics that make the sediment unsuitable for disposal at offshore site H2. The upper grey shelly sands also meet the requirements for disposal site H1. No facies was identified that is suitable for shallow-water disposal.

**Table 1.** Summary of estimated areas for the upper surface and volumes for the main facies within dredged area above a depth of 16 m (channel depth of 14.5 m plus 1.5 m over-deepening allowance). The olive-green sands facies was omitted due to its' very limited extent. Estimated volumes for specified ranges of fines content are also summarised.

<b>Facies</b>	<b>Area (m<sup>2</sup>)</b>	<b>Volume (m<sup>3</sup>)</b>
Black fine sands	5,581	4,868
Grey shelly sands	371,450	693,900
Dark brown organic silts	72,625	126,660
Pale yellow pumiceous sands	310,000	715,910
Pale grey quartz sands	352,640	411,910
<b>Fines bins</b>		
<10%		12,595
10-20%		165,950
20-30%		709,820
30-40%		476,960
40-50%		388,080
50-75%		198,780
>75%		1,072

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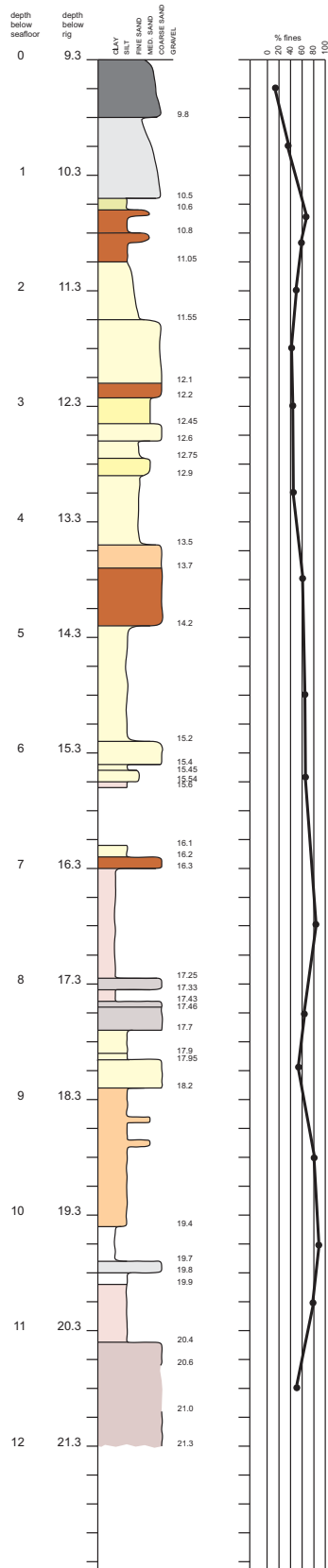
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## **Appendix A – Core descriptions and images**

The following pages consist of bore logs and photographs for boreholes BH15 to BH19 collected from southern Stella Passage (Figure 3). These data supplement the results presented by OPUS (2019)



modern sands

aluvial fan

eruptives

terrestrial / shallow marine sands and silts

co-ignimbrite ash? ignimbrite? tephra sequence?

1 SAND with abundant shell fragments; dark grey

2 SAND with minor silt and shell fragments; light grey

3 sandy SILT ; pale yellow

4 SAND; brown

5 sandy SILT; pale yellow

6 SAND; brown

7 sandy SILT; pale brown

8 sandy SILT; pale yellow grades down to silty fine SAND, light grey

9 SAND with minor silt; light yellow grades to SAND; dark grey

10 SAND with minor silt; brown (3 cm) pales to light yellow

11 SAND with some silt; yellowish brown (1 cm) pales to light yellow

12 SAND, brown (1cm) on SAND with some silt, light yellow

13 sandy SILT, pale yellow

14 SAND; yellowish brown

15 SAND with some silt; pale yellow grades to SAND with minor silt, pale yellow

16 SAND with minor silt; dull yellowish orange

17 SAND with some silt; bright brown, colour fades with depth

18 sandy SILT, pale yellow

19 SAND, pale brown upper 6 cm, fading to light yellow

20 SILT with some clay and trace sand, pale yellow

21 SAND with minor silt, pale yellow

22 SILT with trace fine sand, light pinkish white

23 clayey SILT with minor fine sand, pale yellow

24 SAND with minor silt, pale brown

25 CLAY with trace fine sand, light pinkish white

26 SAND, pale brownish grey

27 CLAY, light pinkish white

28 SAND with trace clay, pale brownish grey

29 silty SAND, pale yellowish white grading to pale pinkish white

30 sandy SILT, pale yellow

31 clayey SILT with minor sand, pale yellow

32 SAND with some silt/clay, pale yellow

33 clayey SILT, pale pinkish orange thin bands SAND

34 silty CLAY, white

35 SAND, pale greyish white

36 clayey SILT, white

37 SILT with some clay, light pinkish white

38 silty SAND, pale pinkish brown

39 silty SAND, pale pinkish brown

modern sands

aluvial fan

eruptives

terrestrial / shallow marine sands and silts

PLEISTOCENE

Holocene

BH15 1880051 mE 5826154 mN -4.61 m

Port of Tauranga - Borehole BH15

NAME (grain size)	borehole (m)		colour		structure	moisture	coarse-grained characteristics				fine-grained characteristics				comments			
	upper depth	lower depth	upper depth	lower depth			relative density	sorting	grain size	grain shape	weathering	mineralogy	plasticity	consistency		sensitivity	stickiness	
1 SAND with abundant shell fragments	9.3	9.8	0	0.5	dark grey	homogeneous	wet	loose	moderate	medium sand	angular	fresh	quartz, dark lithoc, shell	slightly	soft	sensitive	non-sticky	
2 SAND with abundant shell fragments	9.8	10.5	0.5	1.2	light grey	homogeneous	wet	loose	poor	coarse sand	angular	fresh	quartz, dark lithoc, shell, mica?	slightly	soft	sensitive	non-sticky	
3 sandy SILT	10.5	10.6	1.2	1.3	pale yellow	homogeneous	wet	poor	poor	fine sand	subrounded	fresh	dark lithoc	slightly	soft	sensitive	non-sticky	
4 SAND	10.6	10.7	1.3	1.4	brown	homogeneous	wet	poor	poor	coarse sand	subrounded	fresh	quartz, dark lithoc	slightly	soft	sensitive	non-sticky	
5 sandy SILT	10.7	10.8	1.4	1.5	pale yellow	homogeneous	wet	poor	poor	fine sand	rounded	fresh	quartz, dark lithoc	slightly	soft	sensitive	non-sticky	
6 SAND	10.8	10.85	1.5	1.55	brown	homogeneous	wet	poor	poor	coarse sand	subrounded	fresh	quartz, dark lithoc	slightly	soft	sensitive	non-sticky	
7 sandy SILT	10.85	11.05	1.55	1.75	pale brown	homogeneous	wet	poor	poor	fine sand	subrounded	fresh	quartz, dark lithoc	slightly	soft	sensitive	non-sticky	
8 SAND	11.05	11.55	1.75	2.25	pale yellow to light grey	homogeneous	wet	poor	moderate	fine sand	subangular	fresh	quartz, dark lithoc	none	soft	sensitive	non-sticky	
9 SAND	11.55	12.1	2.25	2.8	light yellow	homogeneous	wet	loose	poor	coarse sand	angular	fresh	quartz, feldspar, dark lithoc (>50 %)	low	soft	sensitive	non-sticky	occasional Mn to 10 mm
10 SAND	12.1	12.22	2.8	2.92	brown to light yellow	homogeneous	wet	loose	moderate	coarse sand	angular	fresh	quartz, feldspar, dark lithoc stained quartz, feldspar, dark lithoc	low	soft	sensitive	non-sticky	5-10 mm layers dark/pale
11 SAND	12.22	12.45	2.92	3.15	yellowish brown to light yellow	homogeneous	wet	loose	poor	medium sand	angular	slight	quartz, feldspar, dark lithoc	low	soft	sensitive	non-sticky	
12 SAND	12.45	12.6	3.15	3.3	brown to light yellow	homogeneous	wet	loose	moderate	coarse sand	angular	slight	quartz, feldspar, dark lithoc (40 %)	low	soft	sensitive	non-sticky	
13 sandy SILT	12.6	12.77	3.3	3.47	pale yellow	homogeneous	wet	moderate	well	fine sand	rounded	fresh	quartz, minor dark lithoc	low	soft	sensitive	non-sticky	
14 SAND	12.77	12.89	3.47	3.59	yellowish brown	bedded	wet	loose	moderate	medium sand	angular	fresh	quartz, dark lithoc (7-10 %)	low	soft	sensitive	non-sticky	
15 SAND with some silt	12.89	13.5	3.59	4.2	pale yellow	homogeneous	saturated	loose	moderate	fine sand	angular	fresh	quartz, dark lithoc	very soft				
16 SAND with minor silt	13.5	13.7	4.2	4.4	dull yellowish orange	homogeneous	wet	loose	well	coarse sand	angular	fresh	dark lithoc	soft				
17 SAND with some silt	13.7	14.19	4.4	4.89	bright brown	homogeneous	wet	loose	moderate	coarse sand	subangular	fresh	dark lithoc	soft				
18 sandy SILT	14.19	15.2	4.89	5.9	pale yellow	homogeneous	wet	loose	well	fine sand	angular	fresh	quartz, dark lithoc	slightly	firm	sensitive	non-sticky	
19 SAND	15.2	15.4	5.9	6.1	pale brown to light yellow	homogeneous	wet	loose - mod.	poor	coarse sand	subangular	fresh	quartz, dark lithoc	firm				
20 SILT with some clay and trace sand	15.4	15.45	6.1	6.15	pale yellow	fissured	wet	loose - mod.	well	medium sand	subrounded	fresh	quartz, dark lithoc	low/moderate	firm	sensitive	non-sticky	Mn
21 SAND with minor silt	15.45	15.54	6.15	6.24	pale yellow	homogeneous	wet	loose - mod.	well	medium sand	subrounded	fresh	quartz, dark lithoc	firm				
22 SILT with trace fine sand	15.54	15.57	6.24	6.27	light pinkish white	homogeneous	wet	loose	moderate	coarse sand	subangular	fresh	quartz, dark lithoc	low	firm	moderate	non-sticky	
23 clayey SILT with minor fine sand	15.57	16.2	6.27	6.9	pale brownish grey	homogeneous	wet	loose	moderate	coarse sand	subangular	fresh	quartz, dark lithoc	low	very soft	sensitive	slightly	
24 SAND with minor silt	16.2	16.27	6.9	6.97	pale brown	homogeneous	wet	loose - mod.	poor	coarse sand	subangular	fresh	quartz, dark lithoc	high	soft - firm	sensitive?	moderate	fin bands medium SAND, bright orange, - 2 mm thick spaced 20 mm, core discolor bands
25 CLAY with trace fine sand	16.27	17.25	6.97	7.95	light pinkish white	homogeneous	wet	loose	poor	coarse sand	subrounded	fresh	quartz, dark lithoc	high	very soft	sensitive	moderate	17.36 m: fin fine SAND band, bright orange, 2mm thick
26 SAND	17.25	17.33	7.96	8.03	pale brownish grey	bedded	wet	loose	poor	coarse sand	subrounded	fresh	quartz, dark lithoc (> 30 %)	low/moderate	soft - firm	insensitive	moderate	
27 CLAY	17.33	17.43	8.03	8.13	light pinkish white	homogeneous	wet	loose	moderate	coarse sand	subangular	fresh	quartz, dark lithoc (> 30 %)	moderate	firm	insensitive	non-sticky	
28 SAND with trace clay	17.43	17.46	8.13	8.16	pale brownish grey	homogeneous	wet	loose	poor	coarse sand	subrounded	fresh	quartz, dark lithoc (> 30 %)	low/moderate	soft - firm	insensitive	moderate	
29 silty SAND	17.46	17.7	8.16	8.4	pale yellowish white to pale pinkish white	homogeneous	wet	loose	poor	coarse sand	subrounded	fresh	quartz, dark lithoc (> 30 %)	moderate	firm	insensitive	non-sticky	
30 sandy SILT	17.7	17.93	8.4	8.63	pale yellow	homogeneous	moist	loose - mod.	well	medium sand	subrounded	fresh	quartz	low	very soft	sensitive	moderate	some slight textural variations - sand content increases and fines to some extent
31 clayey SILT with minor sand	17.93	17.95	8.63	8.65	pale yellow	homogeneous	wet	loose	poor	coarse sand	angular	fresh	quartz, some dark lithoc	low	very soft	sensitive	moderate	some slight textural variations - sand content increases and fines to some extent
32 SAND with some silt / clay	17.95	18.2	8.65	8.9	pale yellow	homogeneous	wet	loose	poor	coarse sand	angular	fresh	quartz, dark crystals?	low	very soft	sensitive	slightly	bases with well-sorted medium sand regions from trace to dominant up to 7 cm thick spaced 15-20 cm, gradational boundaries
33 clayey SILT	18.2	19.4	8.9	10.1	pale pinkish orange	bedded	wet	well	well	medium sand	angular	fresh	quartz, dark lithoc	low	soft - firm	extra	slightly	
34 silty CLAY	19.4	19.7	10.1	10.4	white	homogeneous	wet	loose - mod.	well	coarse sand	angular	fresh	quartz, dark lithoc?	moderate	firm	moderately	slightly	
35 SAND	19.7	19.8	10.4	10.5	pale greyish white	homogeneous	wet	loose - mod.	well	coarse sand	angular	fresh	quartz, dark lithoc?	low	firm	moderately	slightly	
36 clayey SILT	19.8	19.86	10.5	10.56	white	homogeneous	wet	loose	poor	coarse sand	angular	fresh	quartz, dark lithoc?	low	firm - stiff	sensitive	slightly	
37 SILT with some clay and trace sand	19.86	20.4	10.56	11.1	light pinkish white	homogeneous	moist	loose - mod.	well	coarse sand	angular	fresh	quartz, dark lithoc?	low	firm - stiff	sensitive	slightly	

Port of Tauranga - Borehole BH15

NAME (grain size)	below 75 (µm)		below 60 (µm)		colour	structure	moisture	coarse-grained characteristics			fine-grained characteristics				comments	
	upper depth	lower depth	upper depth	lower depth				relative density	sorting	grain size	grain shape	weathering	mineralogy	plasticity		consistency
38   silty SAND	20.1	21	10.8	11.7	pale pinkish brown	homogeneous	moist	moderate	coarse sand	subangular	fresh	quartz	moderate	stiff	non-sticky	
39   silty SAND	21	21.3	11.7	12	pale pinkish brown	homogeneous	moist	mod. - light	well	subrounded	fresh	feldspar?	firm			



PoT 23/11/18  
BH15 Box 1  
9.3 - 12.6m





326115 RM 205 ROY 1

15.4m

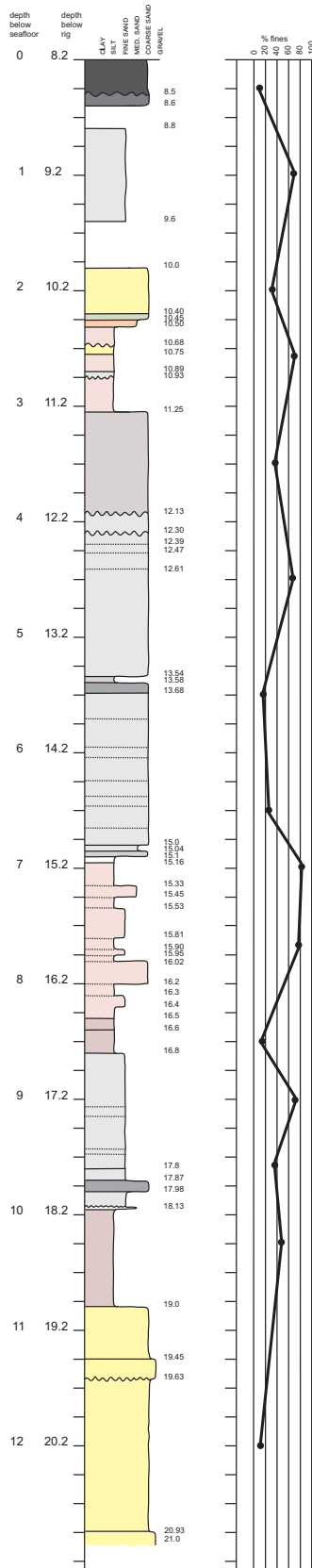
18.0m

18.9m

16.5

PoT 23/11/18  
BH15 Box 3  
15.4 - 18.9 m





- 1 SAND with abundant some shell fragments; black
- 2 SAND with abundant shell fragments; dark grey
- 3 clayey SILT with trace fine sand ; pale whitish grey
- 4 SAND with minor fines; pale yellowish brown
- 5 SAND; pale grey
- 6 SAND with trace fines; pale yellowish white
- 7 SAND with minor fines; greenish grey
- 8 sandy SILT; pale orangish white
- 9 SILT with minor fine sand; pale pinkish white
- 10 clayey SILT with trace fine sand; pale pinkish white
- 11 SILT with minor sand; pale brown
- 12 clayey SILT with trace medium sand; pale pinkish white
- 13 clayey SILT with some fine sand; pale grey
- 14 clayey SILT with trace fine sand; pale pinkish white
- 15 SAND with minor fines; pale brownish grey
- 16 SAND; pale grey
- 17 SAND with minor fines; pale whitish grey  
BAND 1; 12.39-12.40 reddish orange SAND  
 BAND 2; 12.47-12.49 reddish orange SILT with minor medium sand  
 BAND 3; 12.61-12.63 pale grey SILT
- 18 SILT with trace medium sand; pale brownish yellow
- 19 SAND; grey
- 20 SAND; pale whitish grey  
BAND 1; 13.91-13.94 contains minor small (<7 mm) white gravels  
 BAND 2; 14.15-14.25 contains minor silt  
 BAND 3; 14.29-14.32 contains minor silt  
 BAND 4; 14.43-14.45 contains minor small gravel  
 BAND 5; 14.55-14.59 contains minor silt; pinkish  
 BAND 6; 14.65-14.67 contains minor silt; pinkish  
 BAND 7; 14.84-14.87 contains minor silt; pinkish
- 21 SAND; whitish grey
- 22 SAND; pale grey
- 23 SILT with trace fine sand; white
- 24 SILT; pale pinkish brown alternating with SAND; pale brown
- 25 SILT with some fine sand; pale pinkish brown
- 26 SILT; pale pinkish brown
- 27 SAND; pale grey
- 28 silty SAND; pale grey
- 29 SAND; grey
- 30 silty SAND; pale grey
- 31 silty SAND; white
- 32 clayey SILT; pale pinkish brown grading downwards to SILT with some medium sand; pale pinkish brown
- 33 SAND with minor gravel; yellowish brown
- 34 gravelly SAND; yellowish brown
- 35 SAND with some gravel; yellowish brown
- 36 gravelly SAND; pale yellowish brown

modern sands

alluvial fan

HOLOCENE

PLEISTOCENE

BH16 1880068 mE 5826259 mN -4.50 m

Port of Tauranga - Borehole BH16

NAME (grain size)	behaving (m)		below seafloor (m)		colour	structure	moisture	coarse-grained characteristics				fine-grained characteristics				comments		
	upper depth	lower depth	upper depth	lower depth				relative density	sorting	grain size	grain shape	weathering	mineralogy	plasticity	consistency		sensitivity	stickiness
1 SAND with some shell fragments	8.2	8.5	0	0.3	black	homogeneous	moist	loose	poor	coarse sand	angular	fresh	quartz, lithics, shell	medium	firm	sensitive	none	black, silty/ous smell abundant large shell fragments, coarse shell hash - 6.65 m cone loss upper 3 cm sandy SILT, colour grades down to pale whitish yellow cone loss sand with more fines than at top of cone same as layer 4
2 finely SAND	8.5	8.6	0.3	0.4	dark grey	bedded	moist	loose	poor	very coarse sand	angular	fresh	quartz, shell					
3 clayey SILT with trace fine sand	8.6	8.8																
4 SAND with minor fines	8.8	9.6	0.6	1.4	pale whitish grey	homogeneous	moist	loose	poor	coarse sand	angular	fresh	quartz, lithics, shell					
5 SAND	9.6	10	1.4	1.8	pale yellowish brown	homogeneous	moist	loose	poor	coarse sand	angular	fresh	abundant lithics					
6 SAND with trace fines	10	10.4	1.8	2.2	pale grey	homogeneous	moist	loose	poor	coarse sand	angular	fresh	quartz, lithics, shell					
7 SAND with minor fines	10.4	10.42	2.2	2.22	pale yellowish white	homogeneous	moist	loose	poor	coarse sand	angular	fresh	quartz, lithics, shell					
8 sandy SILT	10.42	10.45	2.22	2.25	greenish grey	homogeneous	wet	loose	poor	medium sand	sub-angular	slight	lob lithics					
9 SILT with minor fine sand	10.45	10.48	2.25	2.28	pale orangish white	homogeneous	moist	loose	poor	medium, coarse sand		slight						
10 clayey SILT with trace fine sand	10.48	10.5	2.28	2.3	pale pinkish white	homogeneous	moist	loose	poor	fine sand								
11 SILT with minor sand	10.5	10.68	2.3	2.48	pale pinkish white	homogeneous	moist	loose	poor	fine sand								
12 clayey SILT with trace medium sand	10.68	10.75	2.48	2.55	pale pinkish white	homogeneous	moist	loose	poor	fine sand	rounded	fresh						
13 clayey SILT with some fine sand	10.75	10.78	2.55	2.58	pale brown	homogeneous	moist	loose	poor	medium sand								
14 clayey SILT with trace fine sand	10.78	10.89	2.58	2.69	pale pinkish white	homogeneous	moist	loose	poor	fine sand	rounded	fresh						
15 SAND with minor fines	10.89	10.93	2.69	2.73	pale grey	homogeneous	moist	loose	poor	fine sand	sub-rounded	fresh						
16 SAND	10.93	11.33	2.73	3.13	pale pinkish white	bedded	moist	loose	poor	fine sand								
17 SAND with minor fines	11.33	12.13	3.13	3.93	pale brownish grey	homogeneous	moist	loose	poor	coarse sand	sub-angular	fresh	quartz, lithics					
18 SAND with trace fine-medium sand	12.13	12.3	3.93	4.1	pale whitish grey	bedded	moist	loose	poor	coarse sand	sub-angular	fresh	quartz, lithics					
19 SAND	12.3	13.54	4.1	5.34	pale brownish yellow	bedded	moist	loose	poor	medium sand								
20 SAND	13.54	13.68	5.34	5.38	grey	homogeneous	moist	loose	poor	very coarse sand	sub-angular	fresh	quartz, lithics, white grains					
21 SAND	13.68	15	5.48	6.84	pale whitish grey	homogeneous	moist	loose	poor	sub-angular sand		fresh	quartz, lithics, white grains					
22 SAND	15	15.04	6.8	6.84	whitish grey	homogeneous	wet	loose	poor	medium sand	rounded	fresh	almost all quartz, few lithics					
23 SILT with trace fine sand	15.04	15.1	6.84	6.9	pale grey	homogeneous	moist	loose	poor	coarse sand		fresh	commonly clean quartz, few lithics					
24A SILT	15.1	15.16	6.9	6.96	white	homogeneous	wet	loose	poor	fine-medium sand	rounded	fresh	mainly quartz					
24B SAND with trace silt	15.16	15.33	6.96	7.13	pale pinkish brown	homogeneous	wet	loose	poor	fine sand	rounded	fresh	quartz					
24C SILT with trace fine sand	15.33	15.45	7.13	7.25	pale brown	bedded	moist	loose	poor	fine sand	rounded	fresh	quartz					
24D SAND	15.45	15.53	7.25	7.33	pale pinkish brown	homogeneous	wet	loose	poor	coarse sand	sub-rounded	fresh						
24E SILT	15.53	15.81	7.33	7.61	pale brown	bedded	moist	loose	poor	fine sand	rounded	fresh						
24G SAND	15.81	16.02	7.61	8.2	pale pinkish brown	homogeneous	wet	loose	poor	fine sand	rounded	fresh						
24H SAND	16.02	16.2	8.2	8.3	pale pinkish brown	homogeneous	wet	loose	poor	coarse sand	sub-rounded	fresh						
24I SILT	16.2	16.2	8.2	8.2	pale brown	bedded	moist	loose	poor	fine sand	rounded	fresh						
24J SAND	16.2	16.2	8.2	8.2	pale pinkish brown	homogeneous	moist	loose	poor	fine sand	rounded	fresh						
24K SILT	16.2	16.5	8.2	8.3	pale pinkish brown	homogeneous	wet	loose	poor	fine sand	rounded	fresh						
25 SILT with some fine sand	16.5	16.6	8.3	8.4	pale pinkish brown	homogeneous	moist	loose	poor	fine sand	rounded	fresh						
26 SILT	16.6	16.8	8.4	8.6	pale pinkish brown	homogeneous	moist	loose	poor	fine sand	rounded	fresh						

Port of Tauranga - Borehole BH16

NAME (grain size)	below rig (m)		below seafloor (m)		colour	structure	moisture	coarse-grained characteristics				fine-grained characteristics				comments		
	upper depth	lower depth	upper depth	lower depth				relative density	sorting	grain size	grain shape	weathering	mineralogy	plasticity	consistency		sensitivity	stickiness
27 SAND	16.8	17.8	8.6	9.6	pale grey	bedded	moist	loose	well	fine sand	angular	fresh	quartz	none	firm - stiff	insensitive	none	plates) up to 15 mm spaced, 2-40 mm (variable) of thin bands of fine sand containing minor (10 %) small pumice gravels to 4 mm.
28 silty SAND	17.8	17.87	9.6	9.67	pale grey	bedded	dry - moist	tight	well	fine sand	sub-rounded	fresh	quartz, few lithics	none	firm - stiff	insensitive	none	thin band orange SILT 5 mm thick at 17.83 m
29 SAND	17.87	17.98	9.67	9.78	grey	homogeneous	moist	loose	moderate	coarse sand	sub-angular	fresh	quartz with minor lithics	none	firm			grades to medium sand in last 2 cm at base
30 silty SAND	17.98	18.13	9.78	9.93	pale grey	homogeneous	dry	tight	well	fine sand	rounded	fresh	quartz	none	firm			same as layer 28
31 SAND with some silt	18.13	18.15	9.93	9.95	white	homogeneous	dry	tight	well	medium sand	sub-angular	fresh	quartz with trace lithics	low	firm			
32 SILT with minor clay grades to SILT with silt	18.15	19	9.95	10.8	pale pinkish brown	homogeneous	moist	very loose	very poor	dominates: gravel to 10 (rounded)	(lithics)	slight	minerals / lithics, occasional pumice gravel	none	firm			slight discoloration quartz grains
33 SAND with minor gravel	19	19.45	10.8	11.25	yellowish brown	homogeneous	moist	very loose	very poor	10mm in coarse sand	sub-rounded	slight	loos lithics, quartz stained	none	firm			same as 33 but gravel content increases markedly/lithics to 10 mm.
34 gravelly SAND	19.45	19.63	11.25	11.43	yellowish brown	homogeneous	moist	very loose	very poor	in coarse sand	rounded	slight	quartz, abundant lithics;	none	firm			rounded, coarse sand sub-rounded
35 SAND with some gravel	19.63	20.93	11.43	12.73	yellowish brown	homogeneous	moist	loose	very poor	mm, mostly 5-8 mm	sub-rounded	slight	quartz, dark grains, lithics;	none	firm			slight discoloration quartz grains
36 gravelly SAND	20.93	21	12.73	12.8	pale yellowish brown	homogeneous	moist	loose	very poor	8 mm, in	sub-rounded	slight	pumice	none	firm			minor staining, quartz (less than overlying layers), large gravel = dense pumice



P07 26/11/18  
BH 16 Box 1  
8.2 - 12.0m



POT cores 26/11/18  
BH 16 Box 2  
12.0 - 15.0 m



PoT cores 29/11/18  
BH 16 Box 3  
15.0 - 17.8 m



BH 16 29/11/18 17.8 - 21.0 m

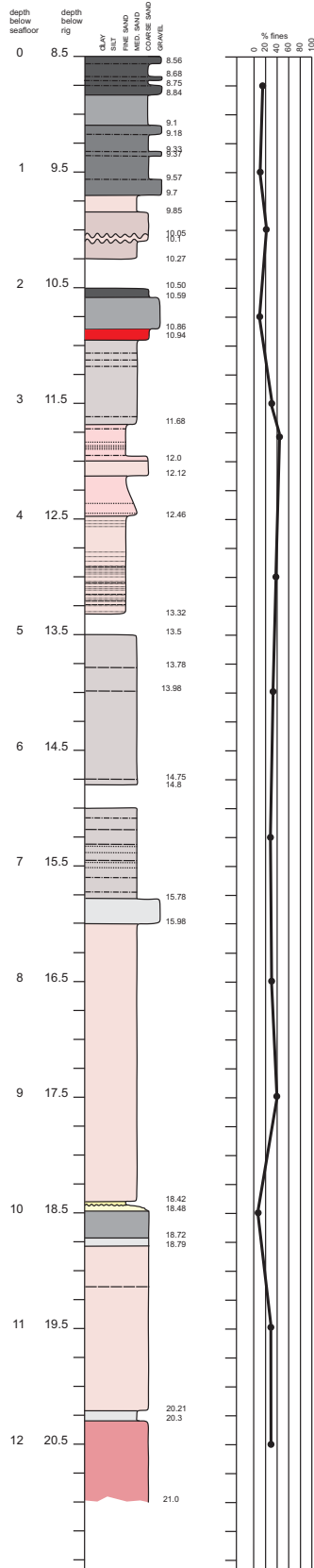
17.8m

18.0m

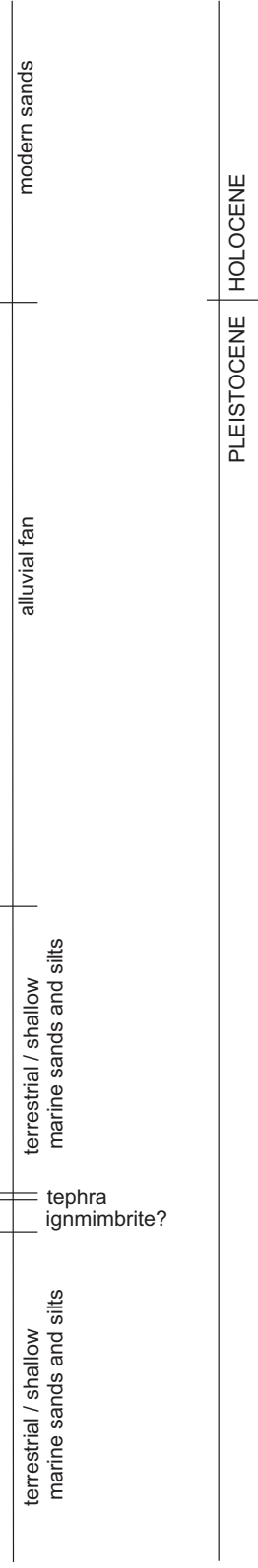
19.5m

21.0m

PoT cores  
29/11/18  
BH 16 Box 4  
17.8 - 21.0 m



- 1 SAND with some shell; black
- 2 SAND with minor shell; grey
- 3 SAND with some shell; dark grey
- 4 SAND with trace silt; pale pinkish grey
- 5 SAND; pale pinkish brown
- 6 SAND with trace fine pumiceous gravel; pale pinkish grey
- 7 SAND with minor silt; pale pinkish brown
- 8 SAND; black
- 9 sandy shell GRAVEL; grey
- 10 SAND with some shell; grey
- 11 SAND with trace shell; pale brownish grey
- 12 SAND; pale pink
- 13 SAND with minor gravel; pale pinkish grey
- 14 SAND; pale pink
- 15 SAND; pale pinkish grey
- 16 SAND; brownish grey
- 16 SAND; brownish grey
- 17 sandy GRAVEL; whitish grey
- 18 SAND; pale pinkish grey
- 19 SAND; pale yellowish cream
- 20 SAND with some gravel, pale yellow
- 21 SAND; grey
- 22 SAND; pale grey
- 23 SAND; pinkish grey
- 24 silty SAND; pale grey
- 25 SAND dark reddish pink



BH17 1880125 mE 5826406 mN -4.42 m

Port of Tauranga - Borehole BH17

NAME (grain size)	below rig (m)		colour	structure	moisture	coarse-grained characteristics			fine-grained characteristics			comments					
	upper depth	lower depth				below seafloor (m)	relative density	sorting	grain size	grain shape	weathering		mineralogy	plasticity	consistency	sensitivity	stickiness
1 SAND with some shell	8.5	8.64	0	0.34	black	bedded	wet	loose	poor	coarse sand	rounded	fresh	abundant shell fragments				
2 SAND with minor shell	8.84	9.1	0.34	0.6	grey	homogeneous	wet	loose	poor	coarse sand	sub-rounded	fresh	fresh quartz, lithics, shell fragments				
3 SAND with some shell	9.1	9.7	0.6	1.2	dark grey	weakly bedded	moist	loose	poor	coarse sand	sub-rounded	fresh	fresh quartz, lithics, shell fragments				occasional thin, pinkish silt bands
4 SAND with trace silt	9.7	9.85	1.2	1.35	pale pinkish grey	homogeneous	moist	tight	moderate	medium sand	sub-angular	fresh	quartz, lithics				
5 SAND	9.85	10.05	1.35	1.55	pale pinkish brown	homogeneous	wet	loose	moderate	coarse sand	angular	fresh	quartz, lithics				
6 SAND with trace fine pumiceous gravel	10.05	10.1	1.55	1.6	pale pinkish grey	homogeneous	moist	loose	poor	coarse sand	sub-angular	fresh	quartz, lithics, pumice				thin, convoluted silt layers
7 SAND with minor silt	10.1	10.27	1.6	1.77	pale pinkish brown	bedded	moist	loose	poor	medium sand	sub-angular	fresh	quartz, lithics				
8 SAND	10.5	10.59	2	2.09	black	homogeneous	moist	loose	moderate	coarse sand	sub-rounded	fresh	mostly lithics				shell hash with glass (beer bottle?); likely disturbed
9 sandy shell GRAVEL	10.59	10.86	2.09	2.36	grey	homogeneous	moist	loose	poor	coarse sand	sub-rounded	fresh	quartz, lithics, shell				
10 SAND with some shell	10.86	10.94	2.36	2.44	grey	homogeneous	moist	moderate	poor	medium-coarse sand	sub-angular	fresh	lithics, shell, quartz				thin bands of shell hash or pink silt
11 SAND with trace shell	10.94	11.69	2.44	3.19	pale brownish grey	homogeneous	moist	moderate	poor	fine-med. sand	sub-angular	fresh	quartz, lithics				variable - minor pumiceous gravel, silt bands, shell hash layers
12 SAND	11.69	12	3.19	3.5	pale pink	homogeneous	wet	tight	poor	coarse sand	sub-rounded	fresh	pumice gravels, shell, lithics				
13 SAND with minor gravel	12	12.12	3.5	3.62	pale pinkish grey	homogeneous	moist	tight	poor	fine-med. Sand	sub-angular	fresh	some pumice				
14 SAND	12.12	12.46	3.62	3.96	pale pink	homogeneous	moist	tight	moderate	Sand	sub-angular	fresh	quartz, lithics				
15 SAND	12.46	13.32	3.96	4.62	pale pinkish grey	homogeneous	moist	tight	moderate	fine sand	sub-angular	fresh	quartz, lithics				silt laminations
16 SAND	13.5	15.78	5	7.28	brownish grey	homogeneous	moist	loose	well sorted	medium sand	sub-angular	fresh	quartz				silt / gravel laminations
17 sandy GRAVEL	15.78	15.96	7.28	7.48	whitish grey	bedded	moist	loose	very poor	10 mm sand	sub-rounded	fresh	pumiceous				gravel to 50 mm, density varies with grain size - fine = loose, coarse = 1.4 bands to 3 mm
18 SAND	15.96	18.42	7.48	9.92	pale pinkish grey	bedded	moist	loose-light	moderate	fine sand	sub-angular	fresh	quartz, pumice, lithics				
19 SAND with some silt	18.42	18.44	9.92	9.94	pale yellowish cream	homogeneous	dry	loose	well sorted	fine sand	angular	fresh	quartz?				leptine?
20 SAND with some gravel	18.44	18.48	9.94	9.98	pale yellow	bedded	dry	loose	poor	coarse sand	sub-angular	fresh	pale quartz(?) sand, pumice gravels, few lithics				graded coarse at base, fine upwards - leptine?
21 SAND	18.48	18.72	9.98	10.22	grey	homogeneous	wet	loose	mod. - well sorted	very coarse sand	angular	slight	lithics, slightly yellow stained crystals				coarsens towards base
22 SAND	18.72	18.79	10.22	10.29	pale grey	bedded	moist	loose	moderate	coarse sand	sub-rounded	fresh	clean grains, trace lithics				
23 SAND	18.79	20.21	10.29	11.71	pinkish grey	homogeneous	moist	loose	moderate	coarse sand	sub-angular	fresh	pale grains, trace lithics				
24 silty SAND	20.21	20.3	11.71	11.8	pale grey	homogeneous	saturated	very loose	very poor	medium sand	sub-angular	slight	white crystals, few lithics				trace Mn to 3 mm
25 SAND	20.3	21	11.8	12.5	dark reddish pink	homogeneous	moist	loose	moderate	coarse sand	sub-angular	slight	few lithics				



PoT cores  
4/12/18  
BH17 Box 1  
8.5 - 11.7 m

11.03  
11.07  
11.08  
11.13  
11.14  
11.19  
11.62  
11.63  
11.68  
LAYER  
11



3261115 BOX 7 BH 304

15.0m

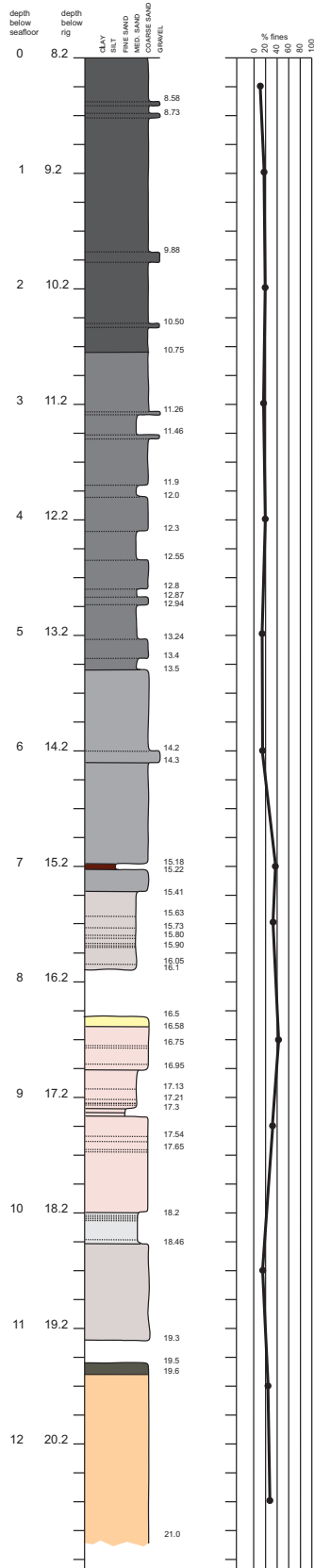
13.5m

12.0m

Pot cores  
5/12/18  
BH17 Box 2  
11.7 - 15.0 m







1 SAND with some shell fragments to shelly SAND; black

2 SAND with minor shell fragments; dark grey

3 shelly SAND coarsening to shell GRAVEL; grey

4 SAND with some shell; grey

5 ORGANIC; very dark brown  
6 sandy shell GRAVEL; grey

7 SAND; pale brownish grey

8 SAND; pale yellowish brown  
9 SAND; pale pinkish grey

10 SAND; pale pinkish grey

11 SAND with minor silt; pale pinkish grey  
12 sandy GRAVEL with some silt; pale pinkish grey  
13 SAND; pale pinkish grey

14 SAND; pale grey

15 SAND with minor gravel; pale brownish grey

16 SAND; black

17 SAND; pale pinkish orange

modern sands

swamp

alluvial fan

terrestrial / shallow marine  
sands and silts

Holocene  
PLEISTOCENE

BH18 1880264 mE 5826383 mN -3.67 m

Port of Tauranga - Borehole BH18

NAME (grain size)	below rig (m)		below seafloor (m)		colour	structure	moisture	coarse-grained characteristics				fine-grained characteristics				comments	
	upper depth	lower depth	upper depth	lower depth				relative density	sorting	grain size	grain shape	weathering	mineralogy	plasticity	consistency		sensitivity
1 SAND with some shell to shelly SAND	8.2	10.75	0	2.55	black	bedded	moist	loose	poor	coarse sand	sub-rounded	fresh	iliths, clear shalis				siliceous small, most shell fragmented; internal layering
2 SAND with minor shell	10.75	13.5	2.55	5.3	dark grey	bedded	wet	loose	moderate	coarse sand	rounded	fresh	iliths, quartz, clear shalis				regularly bedded with shell trash layers; internal layering
3 shelly SAND	13.5	14.3	5.3	6.1	grey	homogeneous	moist	loose	poor	coarse sand	sub-rounded	fresh	iliths, clear shalis				coarsens to shelly GRAVEL at base
4 SAND with some shell	14.3	15.18	6.1	6.98	grey	homogeneous	wet	loose	poor	coarse sand	sub-rounded	fresh	shell, iliths, clear shalis				
5 ORGANICS with minor sand	15.18	15.22	6.98	7.02	black	homogeneous	moist	loose	moderate	coarse sand	sub-angular	fresh	organic woody fragments to 20mm				dominantly organic
6 sandy shell GRAVEL	15.22	15.41	7.02	7.21	grey	homogeneous	moist	loose	very poor	coarse sand	sub-angular	fresh	iliths, fragments, iliths, quartz				
7 SAND	15.41	16.5	7.21	8.3	pale brownish grey	homogeneous	moist	tight	moderate	medium sand	angular	fresh	quartz, trace iliths				finer layers with orange discoloration; soil top 2 mm?
8 SAND	16.5	16.58	8.3	8.38	pale yellowish brown	bedded	dry	tight	poor	coarse sand	sub-angular	slight	quartz, trace iliths				lamin bedding shown by subtle colour changes
9 SAND	16.58	16.95	8.38	8.75	pale pinkish grey to pale yellowish brown	homogeneous	moist	loose	poor	coarse sand	sub-angular	slight	quartz, some iliths, pumiceous				internal layering, pale orange
10 SAND	16.95	17.3	8.75	9.1	pale pinkish grey	homogeneous	moist	tight	poor	medium sand	sub-angular	fresh	quartz, trace iliths				some bands coarse sand / silt
11 SAND with minor silt	17.3	17.34	9.1	9.14	pale pinkish grey	homogeneous	moist	tight	well	fine sand	angular	fresh	quartz, iliths				
12 sandy GRAVEL with some silt	17.34	17.37	9.14	9.17	pale pinkish grey	homogeneous	wet	tight	poor	fine sand	rounded	fresh	pumiceous				charcoal near surface clear?
13 SAND	17.37	18.2	9.17	10	pale pinkish grey	homogeneous	moist	tight	poor	coarse sand	sub-angular	fresh	white shalis & minor iliths				gravel increases downwards
14 SAND	18.2	18.46	10	10.26	pale grey	bedded	moist	tight	poor	medium sand	sub-angular	fresh	quartz, iliths, pumice				some pumiceous gravels to 6 mm; numerous pale pinkish layers
15 SAND with minor gravel	18.46	19.3	10.26	11.1	pale brownish grey	bedded	moist	loose	poor	coarse sand	sub-angular	fresh	quartz, trace iliths, pumiceous				bedding on cm scale
16 SAND	19.3	19.6	11.1	11.4	black	homogeneous	saturated	loose	poor	coarse sand	sub-rounded	slight	quartz, iliths				slippy, anaerobic, siliceous
17 SAND	19.6	21	11.4	12.8	pale pinkish orange	homogeneous	wet	moderate	moderate	coarse sand	sub-rounded	slight	quartz, iliths				drier, not smelly, homogeneous





Pot cores

11/12/18

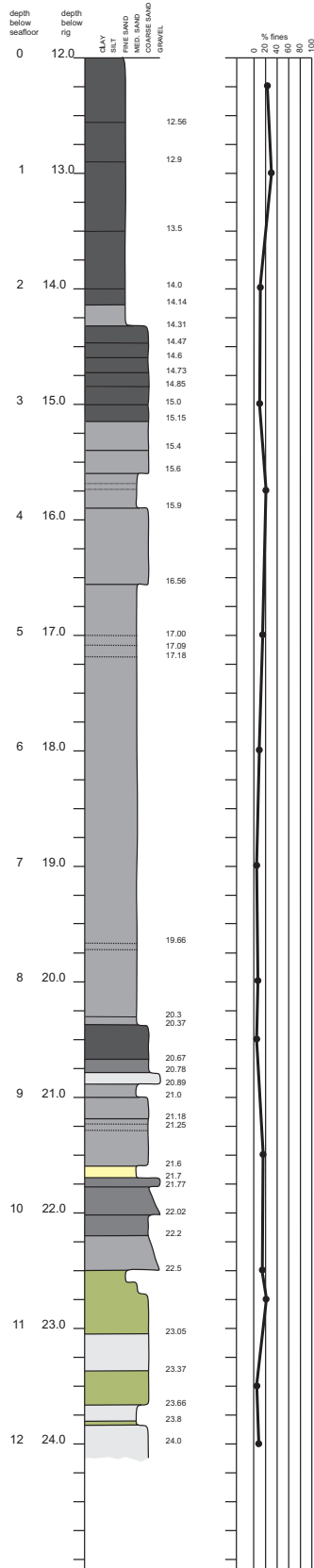
BH 18 box 2

11.8 - 15.0m



POT cores  
12/12/18  
BH18 Box 3  
15.0 - 18.3m





1 SAND; black

2 SAND; grey

3 SAND; black

4 SAND grades to SAND with trace shell; black

5 SAND with minor shell; black

6 SAND with minor shell and trace gravel; black

7 SAND with minor shell; black

8 SAND with some shell; black

9 shelly SAND; grey

10 SAND with trace shell; grey

11 gravelly SAND grading to sandy GRAVEL; grey

12 SAND; grey

13 SAND; black

14 SAND with trace fines; dark grey

15 sandy shell GRAVEL; pale grey

16 SAND; grey

17 coarse SAND grading to fine GRAVEL; grey

18 coarse SAND grading to fine GRAVEL with some shell; grey

19 SAND; grey

20 fine GRAVEL; pale yellowish grey

21 coarse SAND grading to fine GRAVEL; dark grey

22 SAND with trace shell fragments; dark grey

23 SAND; grey

24 SAND; white - pale greenish grey - olive green

25 SAND; pale grey

26 SAND; grey - dark grey - olive green

27 SAND; pale grey

28 SAND; olive green paling to white

29 SAND; pale whitish grey

fine sand

modern sands

terrestrial / shallow marine sands and silts

older marine sands

HOLOCENE  
PLEISTOCENE

BH19 1880404 mE 5826366 mN -7.88 m

Port of Tauranga - Borehole BH19

NAME (grain size)	below rig (m)		below seafloor (m)	colour	structure	moisture	coarse-grained characteristics				fine-grained characteristics				comments	
	upper depth	lower depth					upper depth	lower depth	relative density	soring	grain size	grain shape	weathering	mineralogy		plasticity
1 SAND	12	14.14	0	2.14	black	homogeneous	moist	tight	well	fine sand	sub-rounded	fresh	clear shells	firm		sulfurous
2 SAND with minor silt	14.14	14.31	2.14	2.31	grey	homogeneous	wet	tight	well	fine sand	sub-angular	fresh	clear quartz	firm		no shell
3 SAND	14.31	14.47	2.31	2.47	black	homogeneous	wet	tight	well	medium sand	sub-rounded	fresh	clear shells, lots illichs	firm		traces shell fragments
4 SAND, grades SAND with trace shell	14.47	14.73	2.47	2.73	black	homogeneous	wet	moderate	moderate	coarse sand	sub-rounded	fresh	clear quartz, lots illichs; shell fragments to 5 mm	firm		weathers to olive green
5 SAND with minor shell	14.73	14.85	2.73	2.85	black	homogeneous	wet	loose	moderate	very coarse sand	sub-rounded	fresh	quartz, illichs, shell fragments	soft		
6 SAND with minor shell & trace gravel	14.85	15	2.85	3	black	homogeneous	wet	loose	poor	fine gravel	sub-rounded	fresh	quartz, lots illichs; shell fragments	soft		
7 SAND with minor shell	15	15.15	3	3.15	black	homogeneous	wet	loose	poor	coarse sand	sub-angular	fresh	quartz, lots illichs; shell fragments	firm		coarser than layer 7
8 SAND with some shell	15.15	15.4	3.15	3.4	black	homogeneous	wet	loose	poor	coarse sand	sub-rounded	fresh	quartz, illichs, shell fragments	firm		very shelly layer
9 shelly SAND	15.4	15.6	3.4	3.6	grey	homogeneous	moist	loose	moderate	sand	sub-rounded	fresh	quartz, illichs, shell fragments			large piece wood 15.65 m
10 SAND with trace shell	15.6	15.9	3.6	3.9	grey	homogeneous	wet	tight	well	medium sand	sub-angular	fresh	quartz, illichs, shell fragments	firm-stiff		
11 sandy shell GRAVEL	15.9	16.56	3.9	4.56	grey	homogeneous	wet	loose	poor	v coarse sand	sub-angular	fresh	quartz, illichs; shell fragments			
12 SAND	16.56	20.37	4.56	8.37	grey	homogeneous	moist	tight	moderate	medium sand	angular	fresh	quartz, illichs, shell fragments, clear quartz, trace shell	firm-stiff		some bands with shell fragments
13 SAND	20.37	20.67	8.37	8.67	black	homogeneous	wet	loose	poor	coarse sand	rounded	fresh	illichs, quartz			sulfurous
14 SAND with trace shells	20.67	20.78	8.67	8.78	dark grey	homogeneous	moist	tight	poor	coarse sand	sub-angular	fresh	illichs, quartz			layers 17 & 18 repeated sequence of fine (top) to coarse (base)
15 sandy shell GRAVEL	20.78	20.89	8.78	8.89	pale grey	homogeneous	moist	loose	moderate	v coarse sand	angular	fresh	shell, illichs, minor quartz			essentially the same
16 SAND	20.89	21	8.89	9	grey	homogeneous	moist	tight	well	medium sand	sub-rounded	fresh	quartz, illichs			
17 SAND	21	21.18	9	9.18	grey	bedded	moist	loose	moderate	coarse sand	rounded	fresh	illichs, quartz, shell			
18 SAND	21.18	21.6	9.18	9.6	grey	bedded	moist	loose	moderate	coarse sand	sub-rounded	fresh	quartz, illichs, some shell	firm		
19 SAND	21.6	21.74	9.6	9.74	grey	homogeneous	dry	tight	moderate	medium sand	sub-rounded	fresh	quartz, illichs			
20 fine GRAVEL	21.74	21.77	9.74	9.77	pale yellowish brown	homogeneous	moist	loose	moderate	fine gravel	sub-rounded	fresh	quartz, illichs			no shell
21 SAND	21.77	22.02	9.77	10.02	dark grey	bedded	moist	loose	moderate	coarse sand	sub-rounded	fresh	quartz, illichs			grades downwards
22 SAND	22.02	22.2	10.02	10.2	dark grey	homogeneous	moist	loose	moderate	coarse sand	sub-rounded	fresh	quartz, illichs			traces discoloured shell fragments
23 SAND	22.2	22.5	10.2	10.5	grey	bedded	moist	loose	poor	coarse sand	sub-angular	fresh	quartz, illichs, shell			grades to sandy shell GRAVEL
24 SAND	22.5	23.05	10.5	11.05	white to olive green	homogeneous	dry	tight	well	fine sand	sub-angular	fresh	quartz	stiff		looser, softer & coarser with depth, becomes green
25 SAND	23.05	23.37	11.05	11.37	pale grey	bedded	moist	tight	moderate	coarse sand	sub-angular	fresh	quartz, illichs			shell fragments to 15 mm
26 SAND	23.37	23.66	11.37	11.66	dark grey - olive green	bedded	moist	loose	moderate	coarse sand	sub-rounded	fresh	quartz, illichs			vague horizontal bedding
27 SAND	23.66	23.8	11.66	11.8	pale grey	homogeneous	moist	tight	well	medium sand	sub-angular	fresh	quartz, few illichs			
28 SAND	23.8	23.84	11.8	11.84	olive green to white	bedded	dry	tight	moderate	medium sand	angular	fresh	quartz, illichs			
29 SAND	23.84	24	11.84	12	pale whitish grey	homogeneous	moist	tight	moderate	coarse sand	sub-rounded	fresh	quartz, illichs			



PoT cores

13/12/18

BH19 Box 1

12.0 - 15.8 m



SPITTS  
GARDEN BOX 1

18.0m

15.8m

16.5m

18.5m

POT cores  
13/12/18  
BH19 box 2  
15.8 - 18.5m



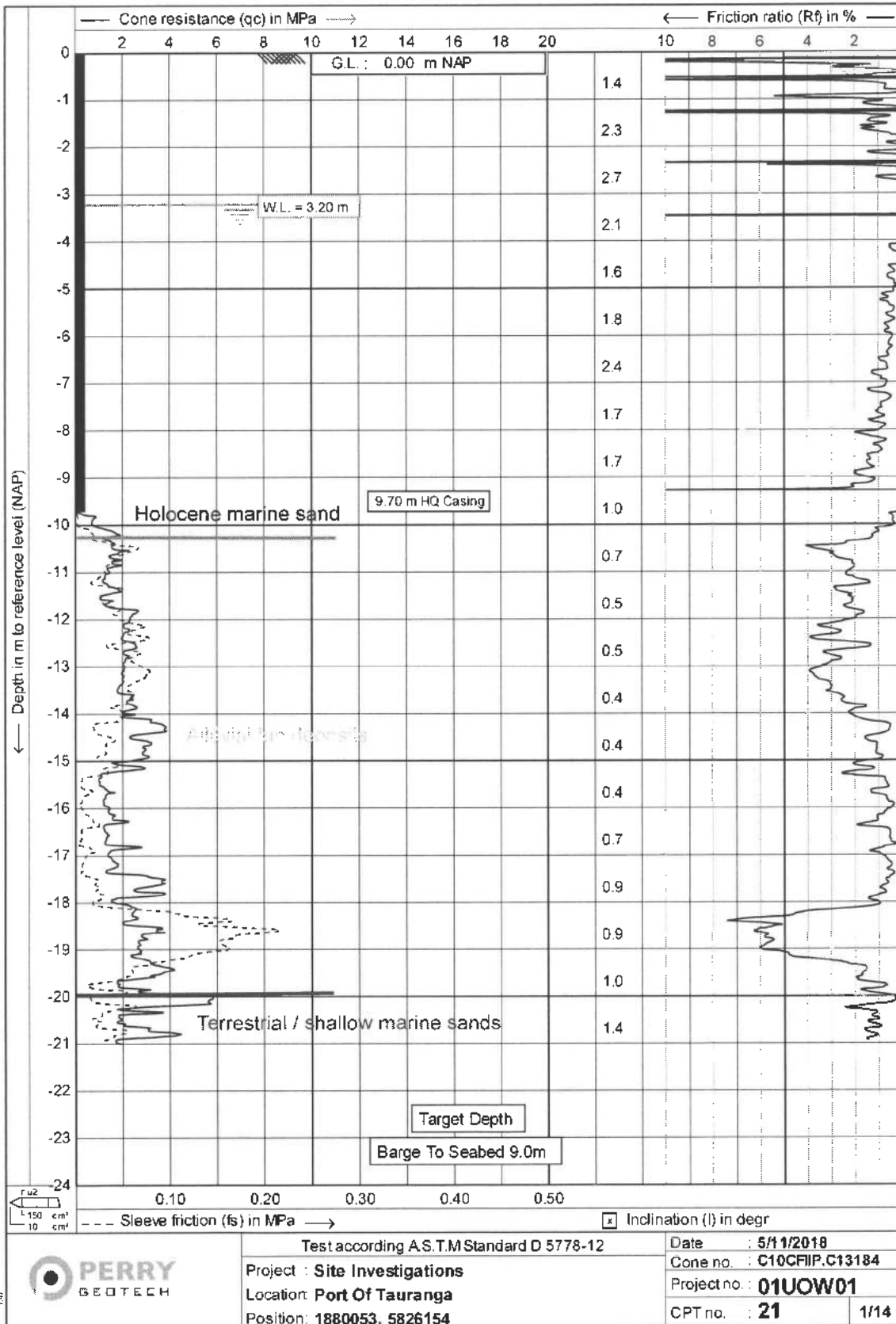
POT cores  
13/12/18  
BH19 Box 3  
18.5 - 22.2m

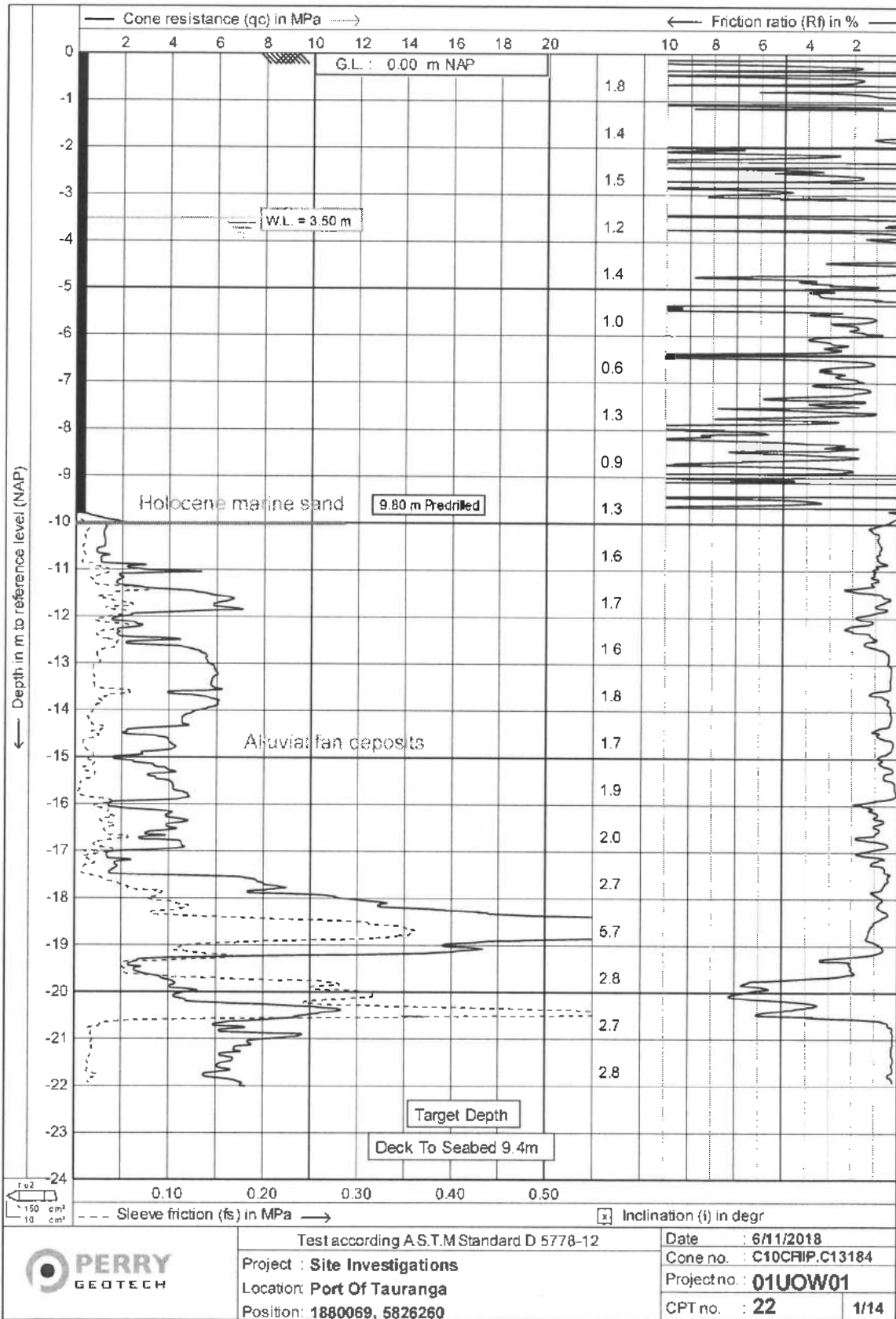


POT cores  
13/12/18  
BH19 Box 4  
22.2 - 24.0 m

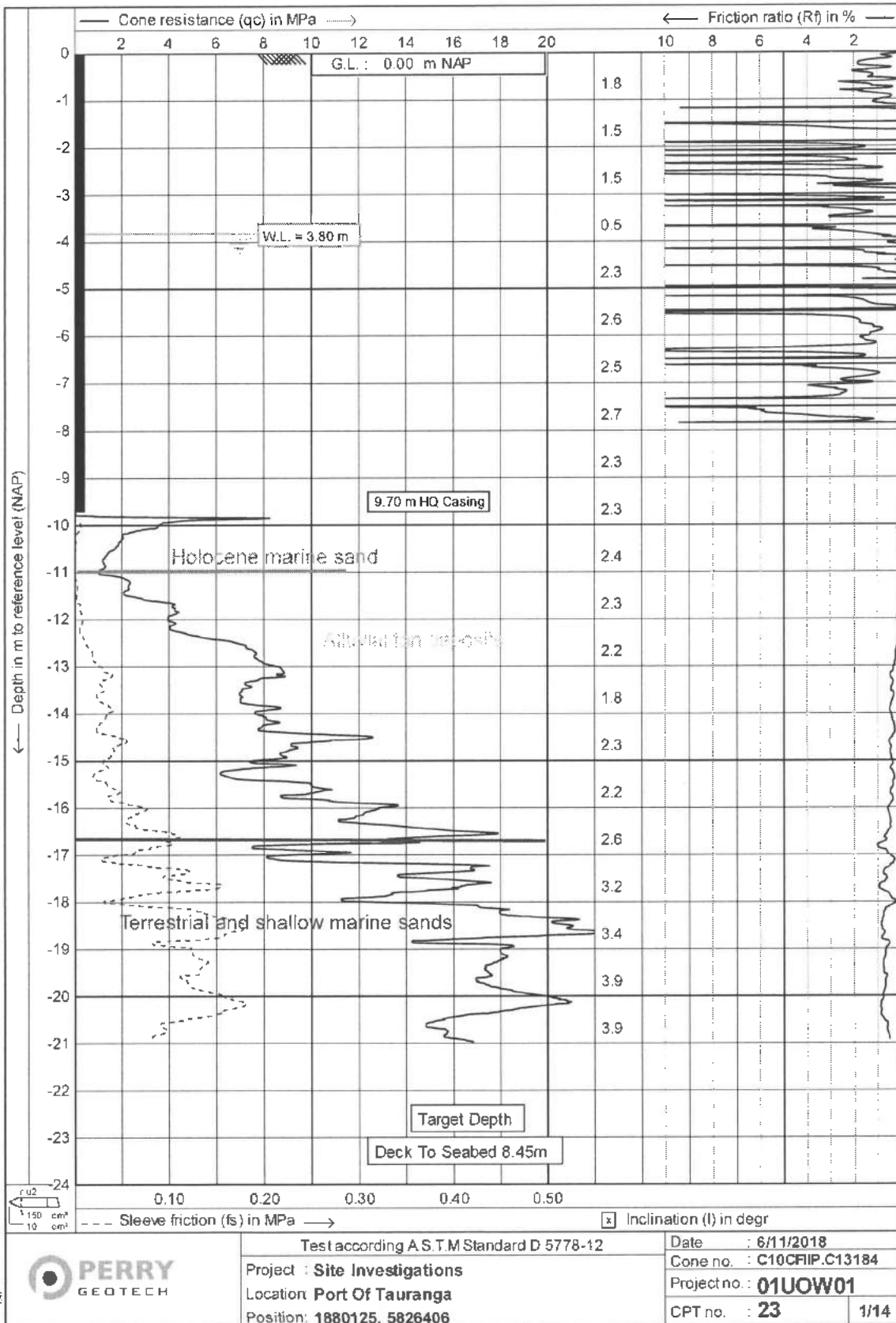
## **Appendix B – CPT traces and interpretation**

The following pages include the CPT data obtained for CPT21 to CPT28 in the southern Stella Passage (Figure 3). The traces are annotated with the interpreted stratigraphic units based on borehole data.





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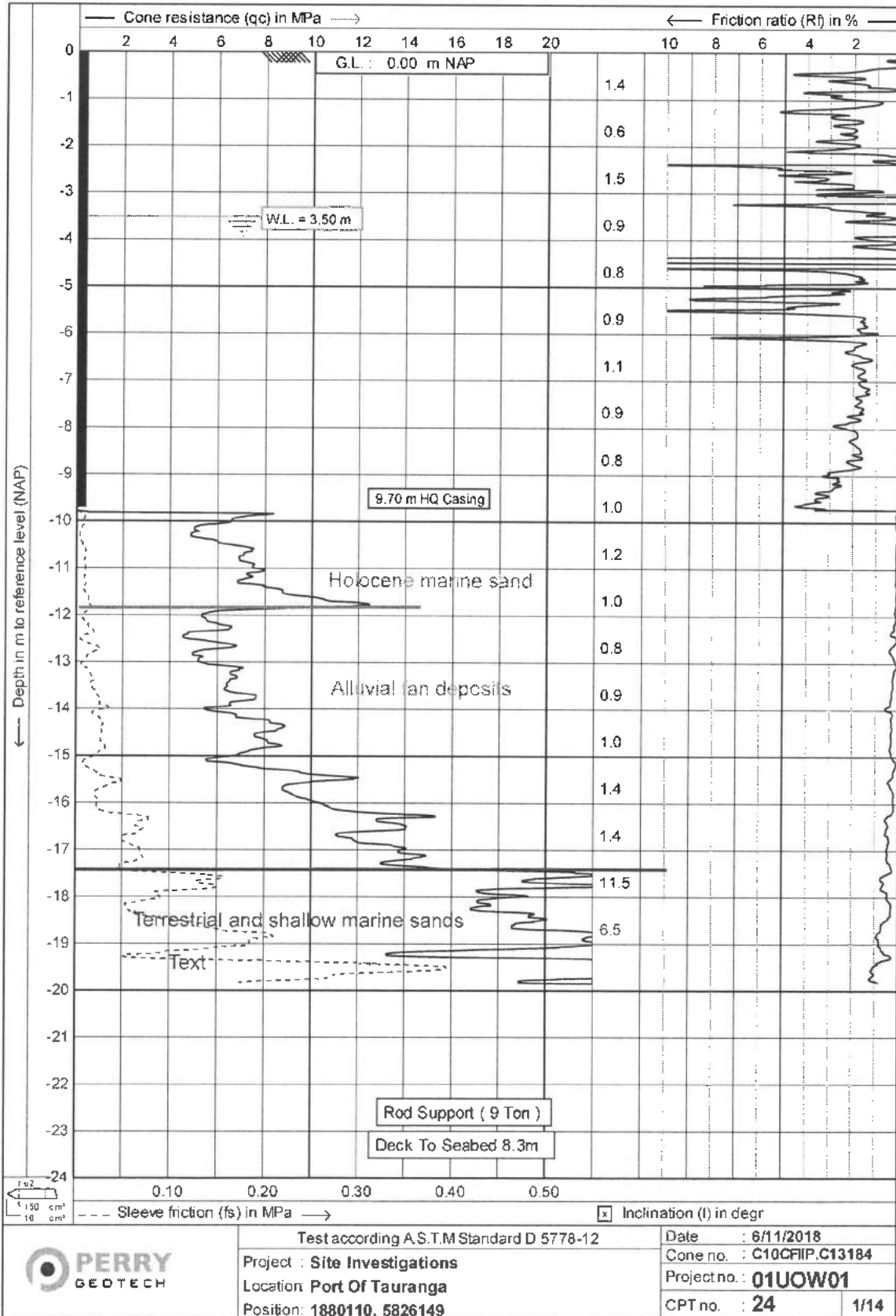


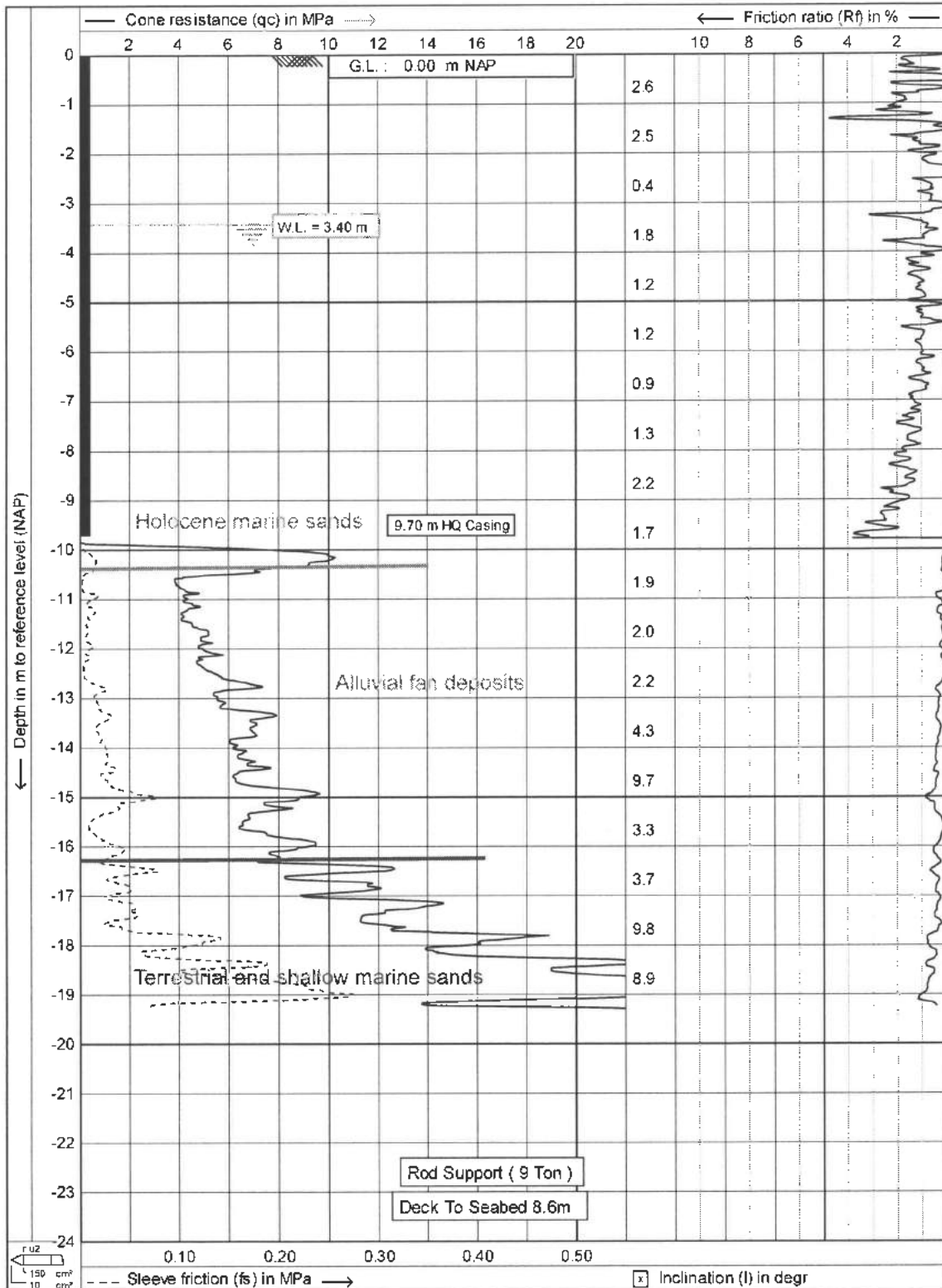
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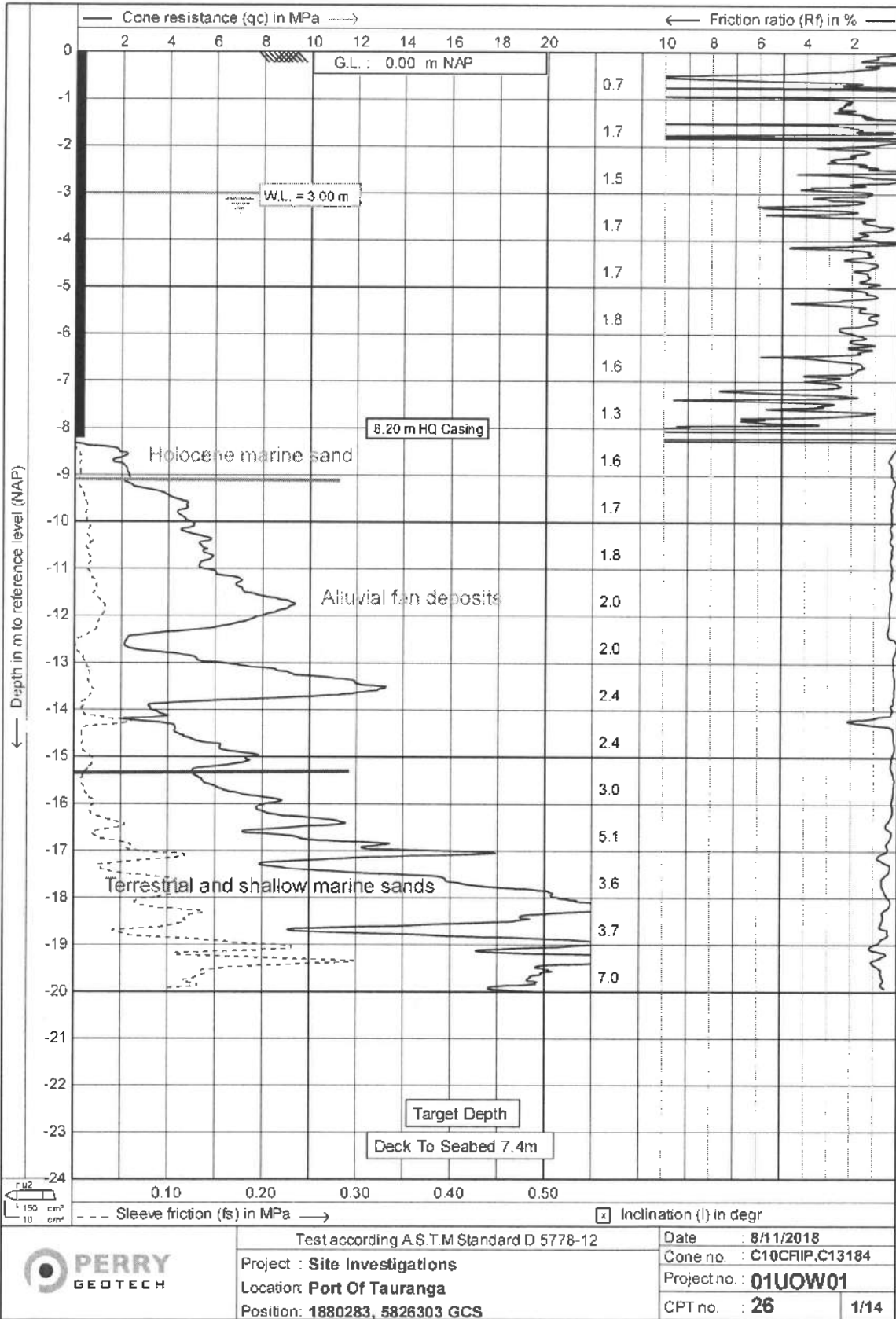
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 Position: 1880125, 5826406

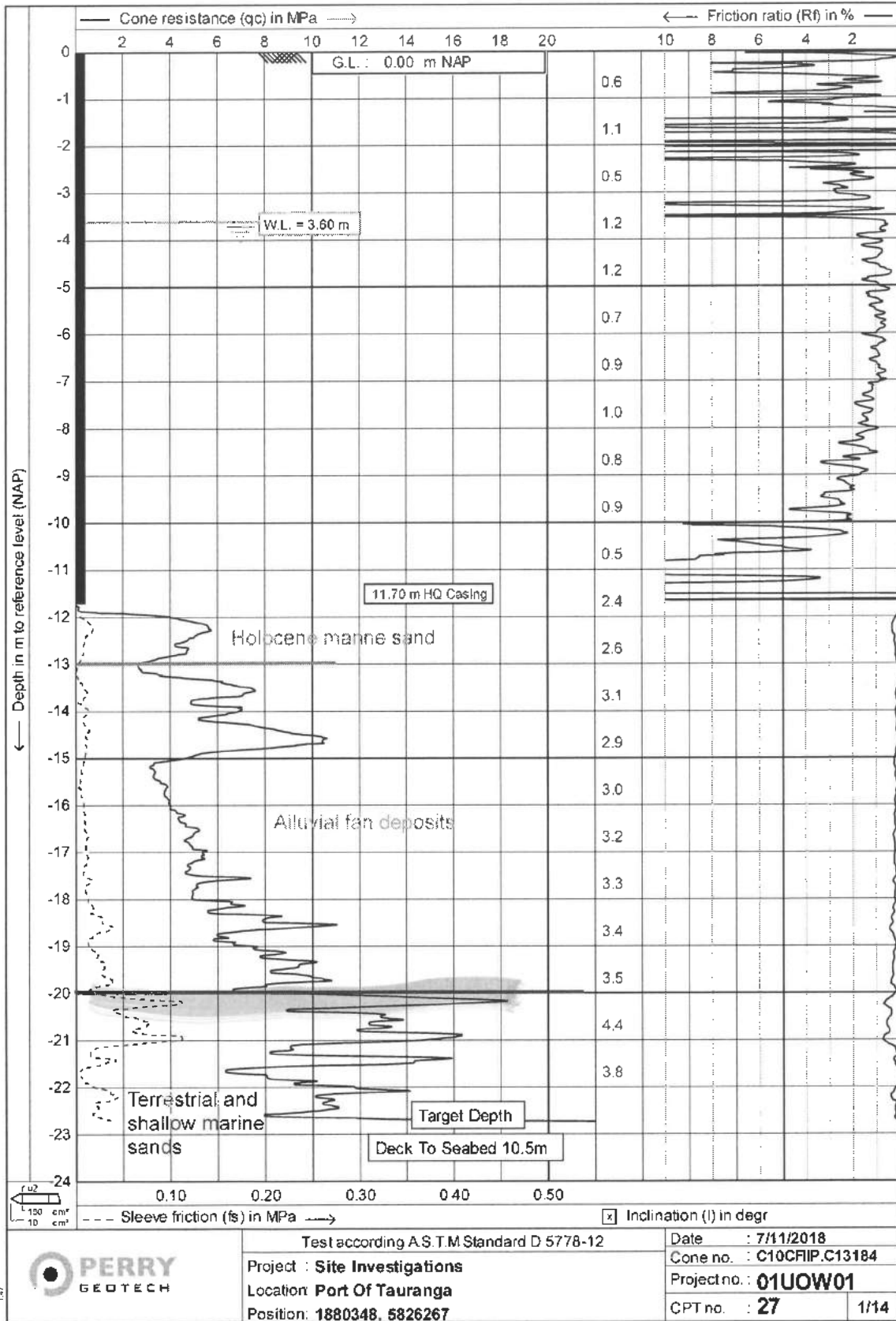
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 Project no. : 01UOW01  
 CPT no. : 23      1/14

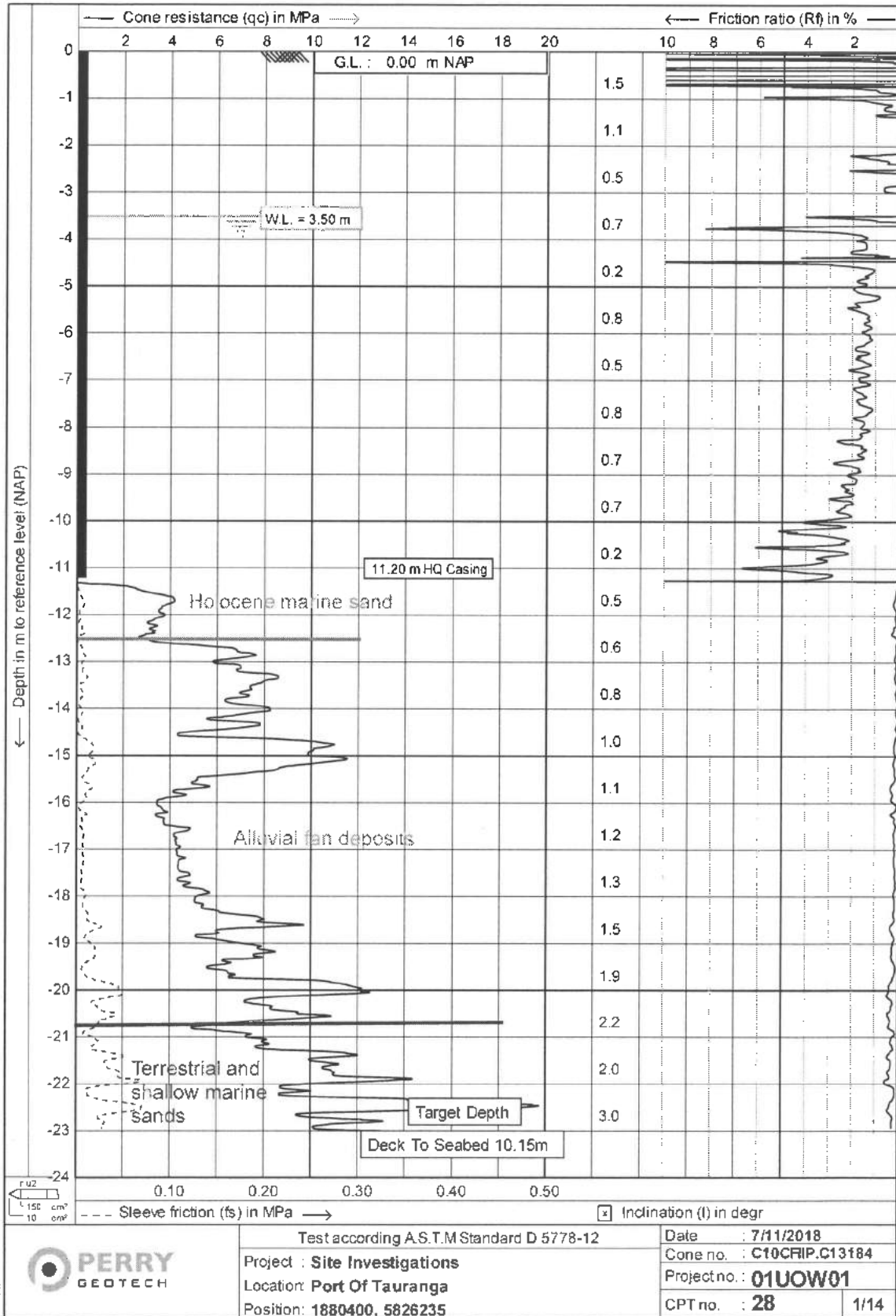




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	Location: Port Of Tauranga		Project no. : 01UOW01
	Position: 1880145, 5826257		CPT no. : 25
			1/14







## Appendix C – Particle size analysis results

The following tables summarise the Malvern Lasersizer textural analysis results for the samples obtained from the borehole cores obtained by OPUS. The depth of the sample is given relative to datum (R.L.) and the seabed as measured during the coring. The proportion of fines represents the sum of silt and clay fractions. The reported mean grain sizes were determined using the moment method. Samples with gravel >2 mm that was removed prior to measurement by the Lasersizer, are corrected for the proportion of gravel present in the original sample.

Sample	Lasersizer analysis										Sieve analysis		
	Sand	Fines	Silt	Clay	Mean	Sorting	Skewness	Kurtosis	Mean		>2mm	<2mm	Corrected
	(%)	(%)	(%)	(%)	(Mz)	(SD)	(Sk)	(KG)	(mm)		(%)	(%)	Fines (%)
BH15-9.55	78.43	21.57	12.15	9.42	2.20	1.98	0.48	1.46	0.217		15.55	84.45	18.22
BH15-10.1	58.07	41.93	22.24	19.69	3.20	2.97	0.42	0.86	0.109				
BH15-10.7	29.63	70.37	24.24	46.13	5.42	3.47	-0.03	0.72	0.023				
BH15-10.9	28.58	71.42	34.80	36.62	5.11	2.68	0.21	0.81	0.029				
BH15-11.3	40.18	59.82	30.57	29.25	4.57	2.96	0.29	0.84	0.042				
BH15-11.8	47.67	52.33	30.96	21.37	3.78	2.81	0.23	0.91	0.073				
BH15-12.3	47.87	52.13	21.99	30.14	4.37	3.26	0.38	0.73	0.048				
BH15-13.05	41.48	58.52	45.15	13.37	3.74	2.05	0.05	0.93	0.075				
BH15-13.8	29.42	70.58	40.6	29.98	4.63	2.56	0.02	0.94	0.040				
BH15-14.8	22.19	77.81	49.97	27.84	4.81	2.01	-0.03	0.99	0.036				
BH15-15.5	22.85	77.15	42.9	34.25	4.94	2.21	-0.10	0.96	0.033				
BH15-16.8	12.12	87.88	22.25	65.63	7.09	2.92	-0.20	0.81	0.007				
BH15-17.55	28.65	71.35	31.24	40.11	5.19	3.01	0.08	0.82	0.027				
BH15-18.0	35.79	64.21	27.22	36.99	4.91	3.25	0.15	0.74	0.033				
BH15-18.8	9.84	90.16	38.12	52.04	6.38	2.54	0.10	0.82	0.012				
BH15-19.55	5.25	94.75	31.13	63.62	7.20	2.54	0.00	0.82	0.007				
BH15-20.05	12.93	87.07	38	49.07	6.02	2.44	0.03	0.91	0.015				
BH15-20.8	32.29	67.71	48.37	19.34	4.17	2.26	0.08	1.12	0.055				
BH16-8.45	86.2	13.8	7.97	5.83	1.65	1.55	0.42	1.69	0.319	5.85	94.15	11.65	
BH16-9.2	23.21	76.79	32.81	43.98	5.70	3.02	0.10	0.79	0.019				
BH16-10.2	60.23	39.77	26.77	13	2.88	2.43	0.34	0.89	0.136				
BH16-10.8	27.52	72.48	25.47	47.01	5.08	3.67	-0.20	0.86	0.030				
BH16-11.7	52.5	47.5	26.58	20.92	3.69	2.72	0.39	0.92	0.078				
BH16-12.7	18.77	81.23	53.85	27.38	5.05	2.22	0.34	1.10	0.030				
BH16-13.7	76.2	23.8	17.19	6.61	2.12	1.96	0.44	1.16	0.230				
BH16-14.7	69.64	30.36	18.11	12.25	2.57	2.45	0.48	1.15	0.168				
BH16-15.2	7.28	92.72	49.44	43.28	6.04	2.29	0.28	0.85	0.015				
BH16-15.9	8.13	91.87	53.98	37.89	5.68	2.08	0.28	0.95	0.019				
BH16-16.7	2.99	97.01	53.01	44	5.99	1.85	0.23	0.95	0.016				
BH16-17.2	8.85	91.15	74.63	16.52	4.75	1.44	0.29	1.30	0.037				
BH16-17.8	17.29	82.71	66.25	16.46	4.51	1.59	0.36	1.28	0.044				
BH16-18.7	39.05	60.95	42.04	18.91	3.86	2.47	0.04	0.96	0.069				
BH16-20.2	81.43	18.57	15.09	3.48	1.76	1.70	0.44	1.31	0.294				
BH17-8.75	73.72	26.28	14.24	12.04	2.69	2.09	0.57	1.35	0.155	25.02	74.98	22.19	
BH17-9.5	80.09	19.91	12.63	7.28	2.18	1.71	0.41	1.61	0.221	25.02	74.98	16.81	
BH17-10.0	62.96	37.04	28.26	8.78	3.03	1.63	0.35	1.48	0.122				
BH17-10.75	57.11	42.89	24.52	18.37	3.42	2.50	0.42	0.90	0.094	72.75	27.25	36.22	
BH17-11.5	54.48	45.52	31.41	14.11	3.44	2.17	0.33	1.28	0.092				
BH17-11.8	37.64	62.36	43.95	18.41	4.16	2.09	0.36	1.17	0.056				
BH17-13.0	37.53	62.47	52.26	10.21	3.80	1.53	0.30	1.36	0.072				
BH17-14.0	49.14	50.86	40.9	9.96	3.50	1.71	0.29	1.20	0.088				
BH17-15.25	59.85	40.15	30.17	9.98	3.11	1.84	0.32	1.21	0.116				
BH17-16.5	51.62	48.38	39.08	9.3	3.44	1.59	0.32	1.17	0.092				
BH17-17.5	46.81	53.19	35.97	17.22	3.75	2.27	0.27	1.03	0.074				
BH17-18.5	86.14	13.86	11.3	2.56	1.86	1.24	0.32	1.29	0.276				
BH17-19.5	58	42	33.46	8.54	3.13	1.73	0.26	1.18	0.114				
BH17-20.5	55.99	44.01	34.55	9.46	3.22	1.81	0.26	1.17	0.108				
BH18-8.45	87.64	12.36	5.23	7.13	1.87	1.32	0.36	2.28	0.273				
BH18-9.2	79.79	20.21	9.27	10.94	2.60	1.97	0.60	1.92	0.165				
BH18-10.2	77.62	22.38	10.14	12.24	2.66	2.13	0.60	1.72	0.159				
BH18-11.2	77.69	22.31	14.42	7.89	2.52	1.69	0.53	1.59	0.175				
BH18-12.2	77.82	22.18	12.22	9.96	2.56	1.94	0.55	1.72	0.169				
BH18-13.2	81.32	18.68	10.77	7.91	2.48	1.52	0.52	1.99	0.180				
BH18-14.2	75.53	24.47	13.75	10.72	2.50	2.04	0.55	1.45	0.177	12.75	87.25	20.66	
BH18-15.2	54.43	45.57	25.26	20.31	3.46	2.81	0.28	0.93	0.091				
BH18-15.7	51.29	48.71	33.98	14.73	3.58	2.08	0.33	1.03	0.084				
BH18-16.7	45.46	54.54	31.47	23.07	4.06	2.50	0.34	0.91	0.060				
BH18-17.7	54.53	45.47	29.42	16.05	3.47	2.32	0.34	1.07	0.090				
BH18-18.7	72.11	27.89	24.81	3.08	2.56	1.36	0.21	1.11	0.169				
BH18-19.7	62.54	37.46	30.16	7.3	2.96	1.69	0.27	1.17	0.129				
BH18-20.7	57.71	42.29	32.42	9.87	3.19	1.87	0.29	1.14	0.110				

Sample	Lasersizer analysis										Sieve analysis		
	Sand	Fines	Silt	Clay	Mean	Sorting	Skewness	Kurtosis	Mean		>2mm	<2mm	Corrected
	(%)	(%)	(%)	(%)	(Mz)	(SD)	(Sk)	(KG)	(mm)		(%)	(%)	Fines (%)
BH19-12.25	67.06	32.94	21.44	11.5	3.17	1.87	0.45	1.48	0.111				
BH19-13.0	59.33	40.67	24.86	15.81	3.56	2.06	0.48	1.12	0.085				
BH19-14.0	86.82	13.18	7.81	5.37	2.01	1.44	0.19	2.10	0.247				
BH19-15.0	86.76	13.24	10.74	2.5	1.69	1.36	0.24	1.48	0.310				
BH19-15.75	67.33	32.67	28.2	4.47	2.57	1.74	0.17	1.01	0.168				
BH19-17.0	81.59	18.41	13.08	5.33	2.11	1.63	0.30	1.49	0.232				
BH19-18.0	89.15	10.85	8.36	2.49	1.87	1.04	0.32	1.70	0.273				
BH19-19.0	92.56	7.44	4.53	2.91	1.88	1.04	0.19	1.56	0.273				
BH19-20.0	90.85	9.15	6.15	3	2.05	0.99	0.26	1.61	0.242				
BH19-20.5	93.43	6.57	4.29	2.28	1.81	0.97	0.22	1.55	0.285				
BH19-21.5	79.86	20.14	13.25	6.89	1.33	2.39	0.51	1.13	0.397				
BH19-22.5	75.99	24.01	14.56	9.45	2.21	2.12	0.47	1.36	0.216	22.74	77.26	20.27	
BH19-22.75	73.66	26.34	18.07	8.27	2.49	1.87	0.58	1.12	0.179				
BH19-23.5	92.69	7.31	5.4	1.91	1.51	0.91	0.30	1.76	0.351				
BH19-24.0	89.51	10.49	7.96	2.53	1.61	1.13	0.32	1.66	0.327				