Plan Change 14 to the Waipā District Plan – Mangaone Precinct

Hydrogeological Assessment

Prepared for Fonterra Limited
Prepared by Beca Limited

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Revision History

Revision Nº	Prepared By	Description	Date
01	Henry Foster	Draft interim letter report following initial site investigations	20/09/2023
02	Jose Cervan	Revised and expanded draft for Client comment, following additional site testing	27/11/2023
03	Jose Cervan	Final version	10/01/2024
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Document Acceptance

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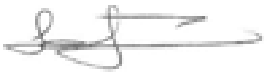
Prepared by	Jose Cervan	*pp* 	15/04/2024
Reviewed and approved by	Sian France		15/04/2024
on behalf of	Beca Limited		

Executive Summary

Fonterra Limited propose to undertake a plan change (PC14) to enable industrial development for a block of rural land at 185 Swayne Road, Hautapu (herein referred to as “the Site”). The Site is located within a wider area (C10 Industrial Growth Cell) identified by Waipā District Council for industrial zoning,

The preliminary Master Plan for the C10 Industrial Growth Cell (McCaffrey and Cable, 2022) identified soakage as a key element of the preliminary stormwater design, in accordance with the stormwater disposal hierarchy outlined in the Regional Infrastructure Technical Specifications (RITS). However, the preliminary Master Plan also recognized that shallow groundwater levels might pose a risk to stormwater soakage on the site and recommended that further site investigation and technical assessment be undertaken.

Initial site testing undertaken by Soil and Rock Limited in 2023 indicated highly variable ground conditions, raw unfactored infiltration rates that ranged from 0 mm/hour (i.e. no infiltration) to ~300 mm/hour and a shallow groundwater table typically encountered at depths of less than 2 metres below ground level.

Areas of poorer test results correlate with areas where the soil type is predominantly silt, where the groundwater level was shallowest, and, in areas of the Site already identified as being of low irrigation capacity. Conversely, the highest test results correlate to areas where the soil type is predominantly sand and gravel.

The shallow groundwater level identified by this initial testing was considered to be a significant limitation on the potential for soakage, and so further investigation and testing were undertaken to assess if the groundwater level might be perched, and if there might be a deeper unsaturated zone below this that could be targeted for soakage. However subsequent testing undertaken in late 2023 has confirmed that the shallow water level is extensive across the site and did not identify any deeper horizons that would be suitable for soakage of stormwater.

With regards to the Master Plan and recommendations for the stormwater strategy:

- The combination of a shallow depth to water table, prevalence of fine-grained soils and only moderate raw infiltration rates is an impediment to centralised (large scale) soakage.
- It is recommended that the stormwater designers consider alternative stormwater management philosophies that do not rely on centralised soakage.
- Some on-lot soakage may be possible but would require careful siting and site-specific testing and design at each location. On-lot soakage could be identified as a future design opportunity for individual sites but should not be relied upon now.
- The shallow depth to groundwater in the vicinity of the stream will also be a consideration for attenuation basins. Basins that extend below the groundwater table will either require lining (and provision for uplift) or, may require some permanent discharge of groundwater to provide the necessary storage volumes.

Ongoing monitoring of groundwater levels is recommended to support future design stages, including the design of attenuation basins.

1 Introduction

1.1 Project Description

Fonterra Limited propose to undertake a plan change (PC14) to enable industrial development for a block of rural land at 185 Swayne Road, Hautapu (herein referred to as “the Site”).

The Site is part of the wider C10 Industrial Growth Cell identified by Waipā District Council (WDC) for industrial zoning (Figure 1).

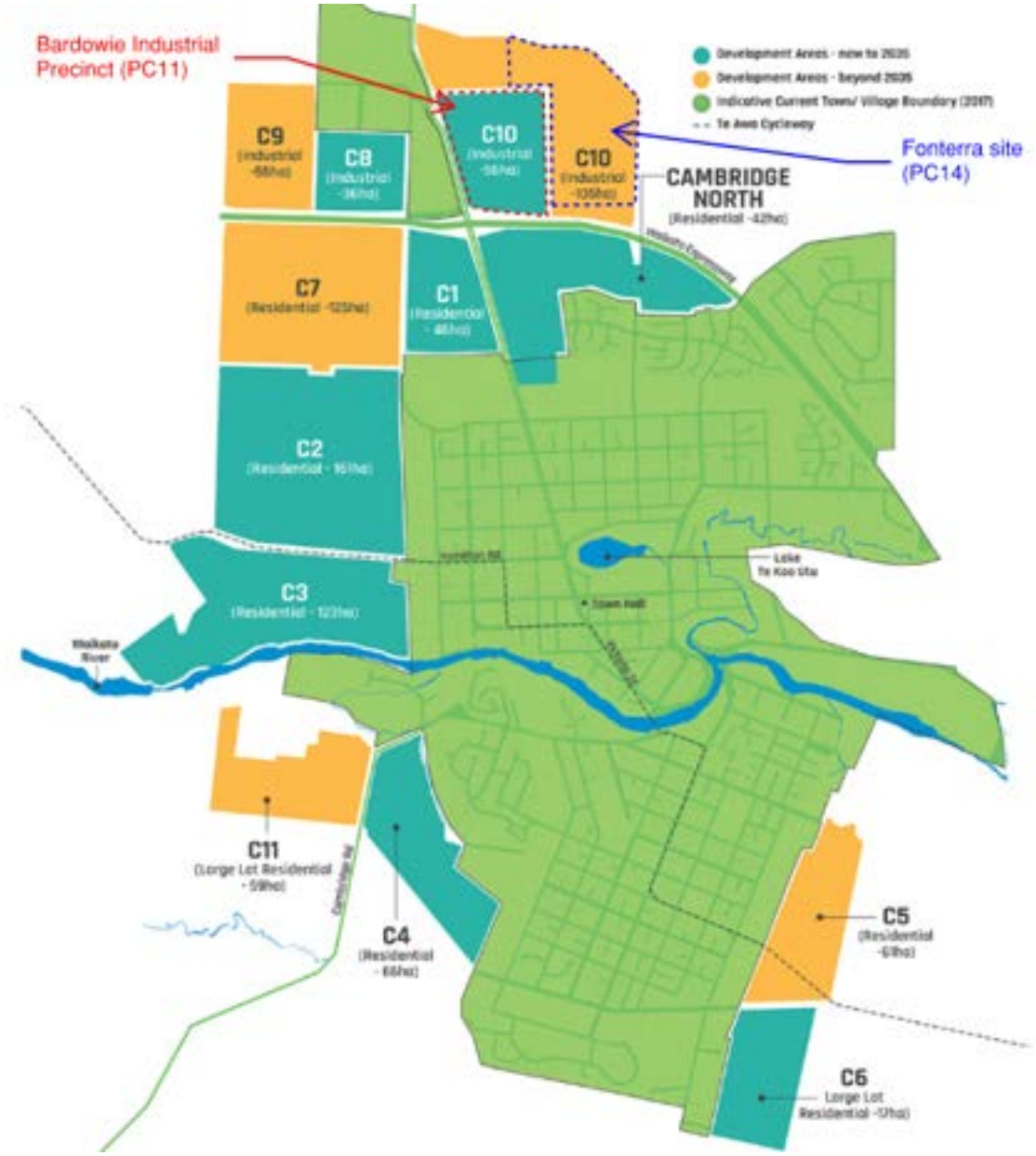


Figure 1: Location plan of proposed Waipā District Council growth cells, showing location of the Site (blue) and adjacent Bardowie Industrial Precinct (already subject to industrial development). Source: https://www.waipadc.govt.nz/your-waipa/majorprojects/growth/cambridge-growth

The C10 Growth Cell Preliminary Master Plan (McCaffrey and Cable Consultants, 2022; see Figure 2) assumed that the stormwater system would be designed to maximise stormwater retention and disposal on

site (i.e., smaller design events soak to ground via public soakage), and to attenuate the peak flow and volume of larger events that are discharged to the Mangaone Stream.

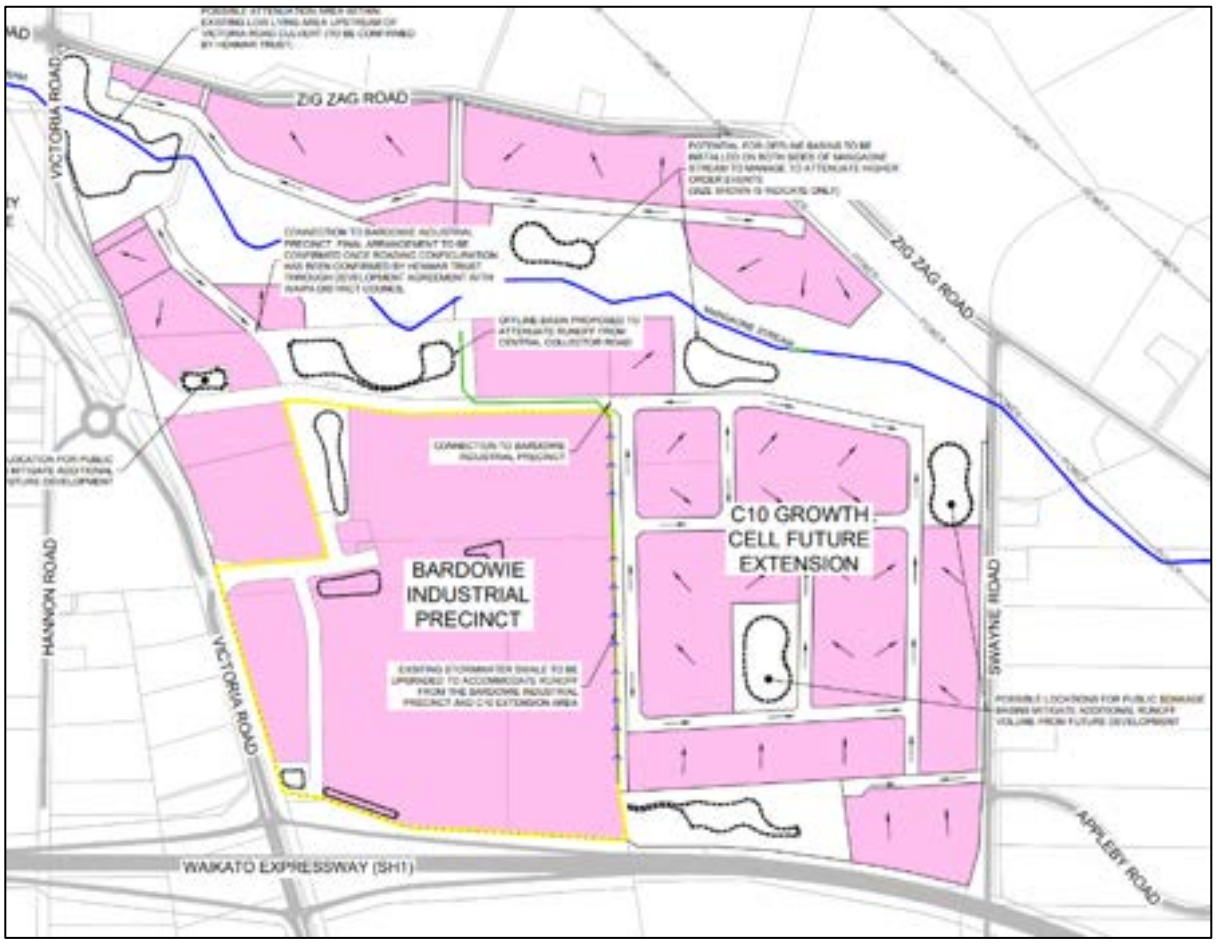


Figure 2: Excerpt from McCaffrey and Cable Consultants (2022) showing the preliminary stormwater strategy for C10 Industrial Growth Cell, including the adjacent Bardowie Industrial Precinct (BIP).

Soakage was proposed as a key component of the preliminary stormwater design in accordance with the Regional Infrastructure Technical Specifications (RITS) stormwater disposal hierarchy. However, the preliminary Master Plan also recognized that shallow groundwater levels might pose a risk to progressing stormwater soakage on the site and recommended that further site investigation and technical assessment would be required to support design of appropriate stormwater solutions. This report presents an assessment of the capacity of the Site to discharge stormwater to ground.

1.2 Scope of this Report

Beca Ltd was initially commissioned by Fonterra Limited (Fonterra) to undertake a desktop hydrogeological assessment of the Site to support PC14. The intent of that assessment was to review site-specific and publicly available data, as well as initial site testing undertaken by others (Soil and Rock, 2023) to confirm the likely suitability of the Site for stormwater soakage.

The initial assessment (Beca, 2023) confirmed that shallow groundwater may be a constraint on soakage. Further site investigation and testing was recommended to confirm groundwater levels before the stormwater philosophy could be confirmed and progressed.

This report compiles the previous desktop work, alongside the review of new site investigation data to confirm groundwater conditions, assess the capacity of the Site to discharge stormwater to ground and provide recommendations into the updated Master Plan.

1.3 Glossary of Terms

Bardowie Industrial Precinct (BIP)	The western extent of C10 Industrial Growth Cell, already subject to industrial development by Bardowie Investments Limited. Authorised by Plan Change 11.
Factor of Safety	A factor which is applied to the raw (field) infiltration test results to determine the design infiltration rate. The design rate is lower than the raw test rate to account for uncertainties in ground conditions and longer term design performance.
Growth cell	Structured areas identified by Waipā District Council for future town growth – can be residential or industrial.
Hydraulic conductivity	The ability of a fluid to pass through a ***saturated*** medium, in this case the pore space between soil grains. Hydraulic conductivity is specific to the fluid (saturation, viscosity, temperature, and density), in this case water. Reported as a speed (distance over time)
Infiltration rate	The rate at which water can enter a soil, generally refers to the ***unsaturated*** movement of water above the groundwater table.
Mounding	A localised rise in the groundwater table beneath a soakage device, occurs because the rate of water entering the ground is greater than the rate at which water can conveyed away.
Perched groundwater level	A shallow body of water that develops above a deeper water table, due to the infiltration of water being slowed down or “hung up” on lower permeability layers. Can result in unsaturated or variably saturated zones at depth.
Permeability	The intrinsic ability (i.e., it only depends on properties such as pore size, tortuosity, and surface area) of a porous material to transmit fluid. Often used interchangeably (incorrectly) with hydraulic conductivity. Is more appropriate to use as a relative term for comparing two soils types, i.e. gravel is more permeable than silt, clay has lower permeability than a sand.
Piezometer	A monitoring instrument which measures the elevation of the ground water table. For this project, piezometers are all standpipe piezometers – a narrow diameter well comprised of a length of slotted pipe which is open to the ground and allows the water to enter and equilibrate with the surrounding ground.
Seasonal range	The range of groundwater levels that naturally occurs over a longer timeframe due to variations in climate, rainfall, evapotranspiration etc.
Soakage	In this report used in reference to any unlined stormwater device (soak hole, basin, pit, permeably paving etc) that will rely on discharging stormwater to ground to reduce the volume directed towards the Mangaone Stream.

2 Site Geology

2.1 Geological Context

The Site is located within the Hamilton Basin, which is infilled with a thick sequence of largely Tauranga Group (Hinuera Formation) sediments which are comprised of pumiceous silts and sands. The Hinuera Formation has been deposited by the paleo-Waikato River (Hadfield, 2001). This depositional environment results in a complex and laterally variable distribution of lithologies, with an accompanying wide range of infiltration rates and hydraulic conductivities and in some locations the potential for multiple perched water levels.

2.2 Site Investigation

Two site specific investigation campaigns have been undertaken to support the proposed Plan Change:

1. Soil and Rock, 2023: Investigations conducted in June 2023 consist of fifty-five (55) hand auger holes, installation of nine (9) standpipe piezometers (PZ01 – PZ09), six (6) slug tests undertaken in completed piezometers, nine (9) Double Ring Infiltrometer tests in shallow test pits and twenty-four (24) Cone Penetration Tests (CPTs).

   Refer to Soil and Rock, 2023 for a plan showing the June 2023 site investigations.

2. Beca, 2023: Between October to November 2023, and additional five (5) machine boreholes were drilled, completed as a standpipe piezometer, and a Constant Head Test (CHT) undertaken. Two further CHTs were also conducted on existing piezometers at PZ01 and PZ09.

   Refer to Appendix A for a location plan of the October / November 2023 site investigations.

The primary purpose of the additional drilling was to:

- Allow for installation of deeper piezometers to confirm groundwater levels where shallow piezometers installed in June were subsequently found to be “dry”.
- Determine if the shallow groundwater levels recorded elsewhere in the initial monitoring might be a perched water level, with a deeper unsaturated zone below which could be targeted for soakage.
- Undertake permeability testing to confirm suitability for soakage.
- Confirm the deeper soil profile.

2.3 Soil Profile

Topsoil was found at each investigation to a maximum depth of 0.6 metres below ground level (m bgl). Peat and organic materials were encountered in three locations (AH10, AH14, and AH40).

Underneath the topsoil, to the termination depths of the boreholes and auger holes, the lithology consists of alluvial deposits of the Hinuera Formation. The alluvial soils found in the area were typically a mixture of loosely packed to moderately compacted sands, or sandy silts with varying degrees of stiffness. These soils also contained smaller amounts of clay and gravel.

Generally, the soils near the surface (less than 0.5m deep) appear to be dominated by silt sized lithology, with coarser grained sands and gravels below.

Deposits characterized by a higher gravel content and hence expected to be of higher permeability, were predominantly observed in the southwestern region of the Site. Gravelly soils were encountered at nine (9) locations (PZ05, PZ05A, PZ4A, PZ10, AH23, AH27, AH29, AH44, and AH50). Medium to coarse sands and smaller sized gravels were also found elsewhere across the site, however these were generally thinner beds or, were interbedded with finer grained deposits.

Review of deeper CPT traces suggests that sand may be the predominant lithology to depths of up to 10 m; however, logging of the retrieved core from the deeper boreholes in October 2023 indicates these deposits are "well graded" i.e., comprising of a wide range of particle sizes from silt to coarse gravel meaning that hydraulic behaviour may be closer to that of a fine-grained (silt or clay) material.

Notably and as is typical of Hinuera Formation, gravel, sand, and silt beds cannot be consistently traced between investigation locations, indicating that the individual deposits can be quite localized.

Thicker deposits of silty soils that are expected to be of lower permeability, and hence would typically hinder infiltration and groundwater flow, were identified in the southern-central portion of the Site, in the vicinity of a topographic swale orientated in a northwest – southeast direction centred beneath the ancillary pump station. The Soil and Rock 2023 auger hole investigations in this swale encountered closely spaced silt beds to a maximum augered depth of 3 m. The extent of this swale aligns closely with the 'poor ground condition' area identified in a Fonterra sourced drawing (Byron Smith, personal communication, 20th July 2023; Figure 3) and indicates an area that is unlikely to be suitable for soakage of stormwater.

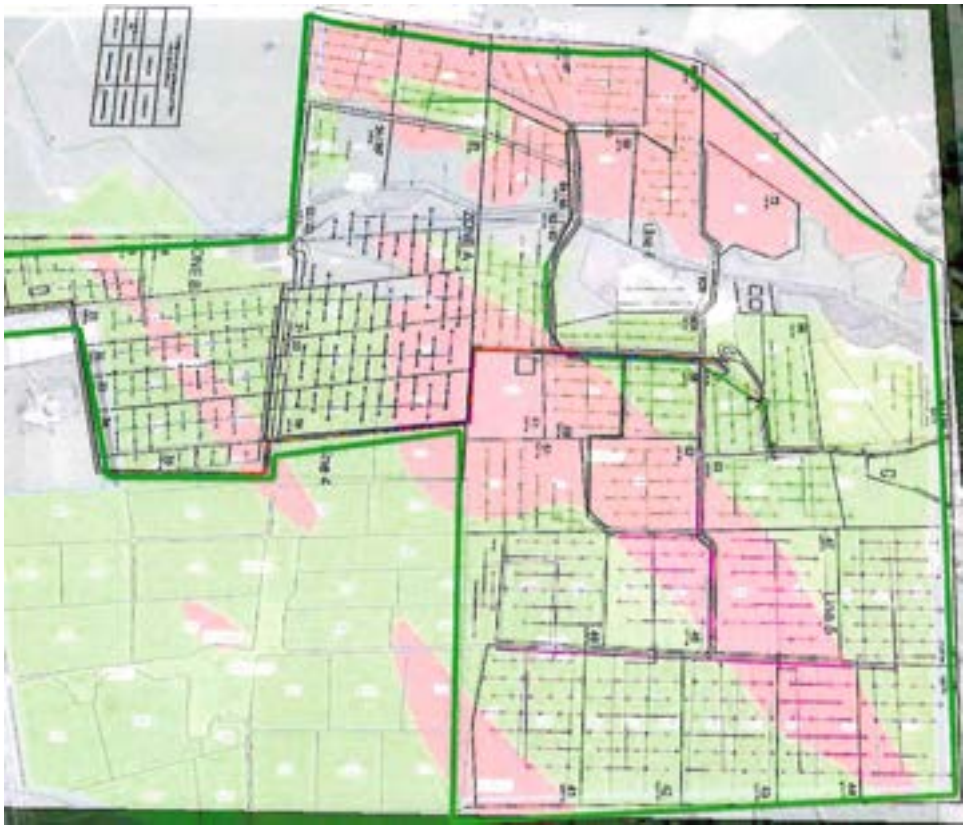


Figure 3: Excerpt of "poor ground condition" plan provided by Fonterra site manager to Soil and Rock Limited and forwarded to Beca 20th July 2023. Areas in in pink are understood to be "poor" in terms of existing site performance. Note image shows land beyond the PC14 boundary, including areas that now form part of the BIP area.

Investigations carried out on the low-lying flood plain (<65 m Reduced Level (RL) on the southern banks of the Mangaone Stream typically encountered silt and peat deposits to termination depth. North of the Mangaone Stream, sand was not frequently encountered.

3 Site Hydrogeology

3.1 Groundwater Levels

Groundwater levels across the site have been monitored in fourteen (14) piezometers:

- Monitoring during a three-week period late June to late July in nine (9) shallow piezometers installed by Soil and Rock in June 2023, and
- One off monitoring immediately following completion of five (5) deeper piezometers installed between October 30th and November 2nd 2023.

Indicative groundwater measurements were also taken in the wider investigations (augers and CPTs), though are less reliable as they are a one-off reading in undeveloped holes, which may be influenced by the site investigation and will not have had time to stabilise to “natural” conditions.

The groundwater levels recorded in the piezometers during the monitoring periods are given in Table 1 and presented as inferred groundwater level contours in Figure 4.

Table 1: Highest (shallowest) measured groundwater levels (Jun-Jul 2023). New boreholes with limited data shown bold

Piezometer I.D	Easting (NZTM)	Northing (NZTM)	Ground Elevation (m RL)	Depth of Piezometer (m bgl)	Maximum Groundwater Elevation (m RL)	Minimum Depth to Groundwater (m bgl)
PZ01	1816553.718	5807121.936	63.5	1.1	63.1	0.4
PZ02	1816753.17	5806951.606	60.75	2.7	60.5	0.3
PZ03	1817081.527	5806683.999	65	2.3	NE	NE
PZ03A	**1817066.10**	**5806692.90**	**65**	**7.5**	**61.7**	**3.3**
PZ04	1817308.84	5806449.596	66	2.0	64.3	1.7
PZ04A	**1817303.60**	**5806433.60**	**66**	**7.5**	**63.8**	**2.2**
PZ05	1816790.939	5806347.624	65	2.0	NE	NE
PZ05A	**1816793.40**	**5806348.10**	**65**	**7.5**	**62.3**	**2.7**
PZ06	1817093.126	5806270	66.3	3.4	66.1	0.2
PZ06A	**1817085.00**	**5806272.70**	**66**	**8**	**64.8**	**1.2**
PZ07	1817040.984	5806058.418	66.6	2.9	NE	NE
PZ08	1816789.42	5806742.395	65.2	3.0	63	2.2
PZ09	1817105.708	5807048.062	64.5	1.9	63	1.5
PZ10	**1816912.70**	**5806895.30**	**66**	**7.5**	**63.8**	**2.2**

Notes:
(m bgl) metres below ground level
(m RL) metres Relative Level
(NE) Not encountered i.e., piezometer is above the water level at this location

The results of a relatively short period of monitoring indicates that groundwater at elevations ranging from 60.5 to 66.1 m RL (0.2 to 3.3 m bgl) in the piezometers.

Regional groundwater in the Hautapu area is known to deepen (and thus flow) in a southwest direction towards the Waikato River, however monitoring on site suggests that shallow flow is influenced by discharge to streamflow (i.e. locally towards the Mangaone Stream, Figure 4).

The overall flow pattern and levels are broadly consistent with longer term monitoring of shallow groundwater levels in the adjacent Bardowie Industrial Precinct and from C8/C9 (to the west of Victoria Road).

South of the Mangaone Stream, the shallowest groundwater level was recorded at a depth of 0.2 m (66.1 m RL) in PZ06 near the centre of the Site, beside the ancillary pump station. Several investigations around the swale encountered shallow groundwater (less than 1 m bgl). A deeper piezometer (PZ06A) installed immediately adjacent PZ06 indicates a different and deeper groundwater level of 1.16 m bgl. The difference in water level confirms that perching of groundwater is occurring due to the slow downward movement of rainfall infiltration at this location. However, the difference is not sufficiently great that it results in an unsaturated zone, rather the soils appear fully saturated down to a depth of at least 8 m bgl.

Topographically this area appears to be drained by a broad shallow swale, identified in a drawing supplied by Fonterra to Soil and Rock as being an area of 'poor ground condition' (Figure 2), and which is understood to require less irrigation and is typically boggy. Observations of surface water ponding made by Soil and Rock, and of shallow groundwater in both rounds of site investigations, generally occurred within the bounds of the identified area of 'poor ground condition' i.e., all sources of information (anecdotal and from site testing) indicate this area to be of low permeability and high (shallow) groundwater level.

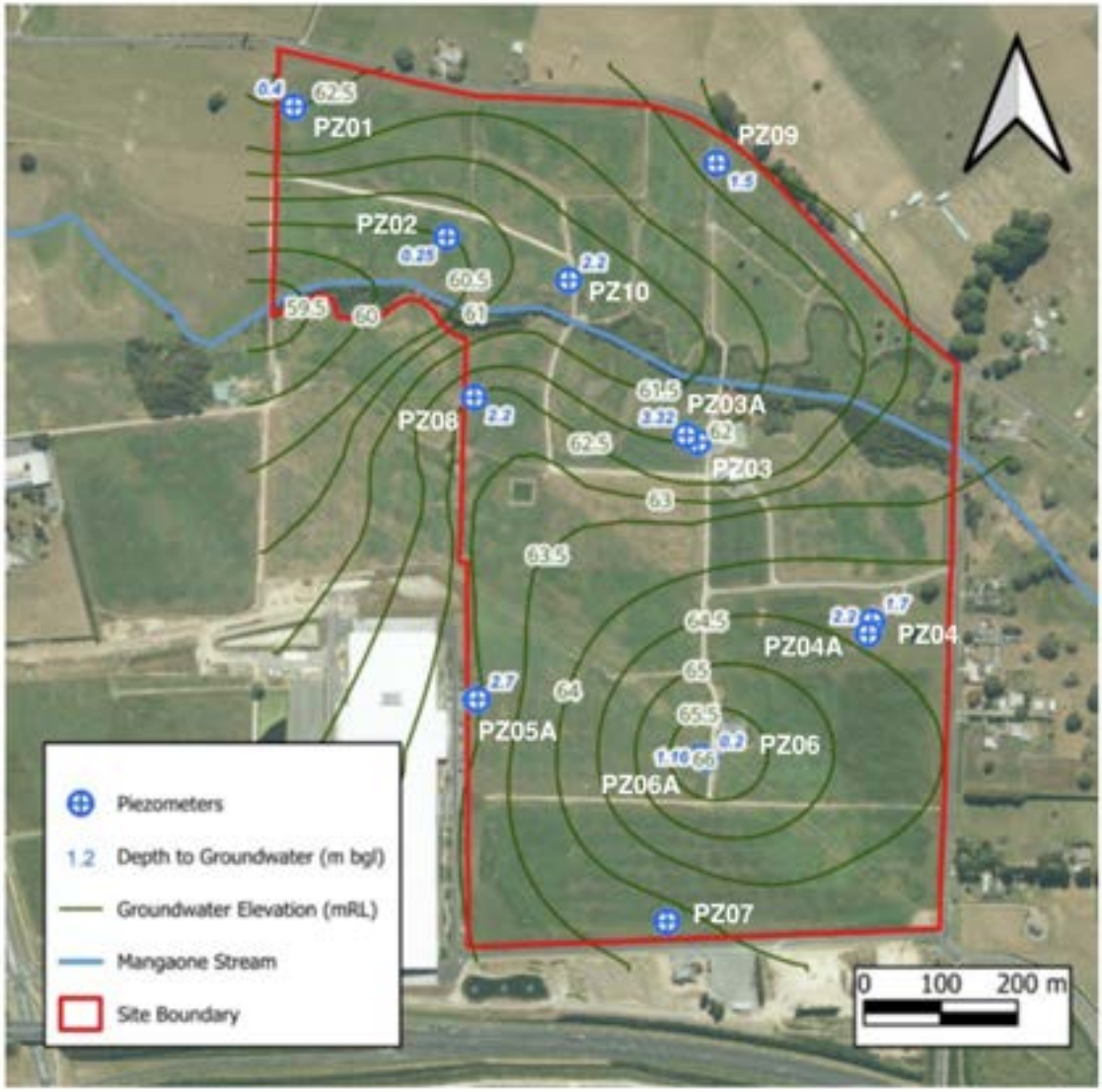


Figure 4: Inferred Groundwater Level Contours; where piezometer monitoring indicates perched levels, the shallowest (highest) water level is shown.

Deeper water levels, albeit still within 2 to 3 m of the ground surface were encountered to the southwest and northeast of the swale.

The groundwater level is inferred to deepen towards the north where it discharges to the stream; however, the depth will vary locally depending on elevation. The ~3.3 m depth encountered in PZ03A was recorded from the upper terrace level (65 mRL). Down on the lower floodplain level, one-off readings in AH14 and AH43 (approx. ground surface 61 – 63 mRL) suggest the groundwater may be less than 0.5 m deep.

North of the Mangaone Stream, the depth to groundwater varies from <0.3 to 2.2 m. The shallowest groundwater levels (60.5 m RL) are again on the low-lying floodplain of the Mangaone Stream at PZ02. Deeper groundwater between 1.6 and 1.8 m bgl exists on the more elevated terraces at the eastern border of the Site, however this is a small area. Overall, we expect groundwater north of the Mangaone Stream to drain in a southwest direction before discharging as streamflow.

During the monitoring period June-July 2023 groundwater levels were observed to rise by ~300 mm in response to rainfall events, but were relatively short duration peaks, returning back to lower levels in less than a week (Soil & Rock Ltd, 2023). Groundwater level monitoring was undertaken over a very limited time frame and will not be representative of the full seasonal range or rainfall response.

Longer term groundwater level monitoring in the wider Hautapu area indicates that the peak, winter high level generally occurs in September / October of each year, and the summer low level in March to May, hence water levels from, June 2023 (the initial site campaign) might not generally be considered representative of “high” conditions. However, rainfall in the first three months of 2023 was well above normal and so the levels are likely to have been higher than typical June conditions. Ongoing monitoring will be required to confirm peak design levels and seasonal trends.

Notwithstanding the short duration of monitoring in general it is observed that groundwater levels across the Site are relatively shallow; this will be a constraint on stormwater soakage as discussed further in subsequent sections.

Limitations in Assessment of Groundwater Levels

Ground surface elevations at the piezometers are understood to be estimated from the site survey plan, not from accurate as-built survey (Soil and Rock, 2023). As a result, inaccuracies in local surface elevation estimates may result in incorrect groundwater elevations. Additionally, as noted above groundwater levels have been collected over a relatively short duration and will not reflect the longer-term seasonal range.

As such the groundwater contour map (Figure 4) should be considered a general representation of gradient and flow.

As-built survey of the piezometers is recommended to provide a more accurate level to facilitate future design stages. Ongoing monitoring of piezometers will be required to assess longer term groundwater level trends and seasonal ranges.

3.2 Infiltration Testing

The infiltration rate of the shallow soils beneath any soakage basin will in part[1] dictate the amount of stormwater that can be discharged to ground. To estimate the vertical infiltration rate, nine (9) double ring infiltrometer tests were conducted (Soil and Rock, 2023). A summary of the tests as reported by Soil and Rock, 2023 is given in Table 3.

Table 2. Summary of the infiltration tests.

Test I.D	Test Depth (m bgl)	Depth to Groundwater (m)	Lithology	Field Infiltration Rate (mm / hr)*	Duration of test (min)
DR01	0.3	0.9	SILT, some fine to medium sand, minor clay, minor fine to medium gravel.	0	20
DR02	0.3	0.3	fine to medium SAND, trace silt	0	15
DR03	1.0	-	medium to coarse SAND, trace fine to coarse gravel.	225[+]	~14
DR04	1.0	-	fine to medium sandy SILT	0	35
DR05	1.0	-	fine to coarse SAND, minor fine to medium gravel	66[+]	~54
DR06	1.0	-	clayey SILT, trace fine sand	0	30
DR07	1.0	-	medium to coarse SAND, some silt, trace fine to coarse gravel.	309[+]	~11
DR08	1.0	-	fine to coarse SAND, some fine gravel	147	13
DR09	1.0	-	Fine to coarse sandy SILT	283[+]	22

Notes:

*Field infiltration rate was averaged from the last 4 infiltration measurements.

*Field infiltration rates are unfactored

[+] Test approaching but hadn't reached steady state conditions

The tests indicate that the sand beds are relatively free draining with raw (unfactored) field infiltration rates ranging from 66 (DR05) to 309 mm/hr (DR07). Conversely, no infiltration was observed in DR01, DR04 and DR06 - the tests conducted in silt material. The results also indicate that infiltration is prevented (or hindered) if the groundwater is at (or near) the infiltration surface, regardless of the material (e.g., DR02, in sand but still had no infiltration).

The largest area of well-draining soils is located at the southern end of the property. This area aligns with the greater thicknesses of sand / gravel, deeper groundwater level, and is close to the successful soakage basin at the Bardowie Industrial Precinct (located immediately west of the Site), all of which suggests this area might be suitable for soakage. However, it is noted that whilst testing had approached steady state conditions, they had not been fully reached, and the rates are still lower than that tested on the adjacent BIP site. Infiltration rates are expected to reduce significantly towards the pump station where groundwater is shallow and silty soils dominate; this is consistent with the area previously identified as 'poor' (Figure 3).

[1] The saturated hydraulic conductivity at depth, depth to groundwater and groundwater gradient will determine how quickly infiltrated volumes can be moved away from the site or if mounding (a rise in groundwater level) might occur.

Through the middle of the Site the raw (unfactored) infiltration rate varies from 0 mm to 225 mm/hr, this likely reflects the heterogeneous nature of the Hinuera Formation and highlights the need for site specific testing at any final soakage locations.

On the northern side of the Mangaone Stream no infiltration was observed in either of the tests (DR01 and DR02). This is likely due to the shallow depth to groundwater.

Overall, the tests with high infiltration rates generally occur inside the “good ground condition” areas previous identified by Fonterra (Figure 3) and in areas where sand is dominant. The tests with low infiltration occur within the ”poor ground condition” areas and correlate to areas where silt is dominant and the groundwater level is closest to surface.

Limitations of Infiltration Testing

The infiltration rates presented above are raw, unfactored infiltration rates. Because the inherent soil heterogeneity cannot be fully understood and because infiltration rates are known to decrease with time due to increase ground saturation, clogging of the pores, and groundwater mounding, a factor of safety should be applied to the raw rates to determine design infiltration rates. This should be set in conjunction with review of the hydraulic conductivity testing (Section 3.3)

Because the material below the base of the test was not logged, the actual layer in which testing was undertaken cannot be known with certainty. However, there is a reasonably clear correlation that the sandier material generally will have a higher infiltration rate.

The small infiltrometer used in tests is limited in the hydraulic head it can apply. This is potentially why no infiltration (rather than a minimal amount) was observed at DR01, DR02, DR04 and DR06. Additionally, the small hydraulic head applied during the test will not always be representative of the conditions in a large-scale soakage device at maximum capacity.

The tests were conducted over a short duration, with no pre-soak and often the head dropped completely to base at the end of each step. Further, as noted above tests approached but did not reach a steady state condition, and so the test results may not be representative of long-term saturated conditions and may overestimate the infiltration rate.

3.3 Hydraulic Conductivity Testing

Whilst the vertical infiltration rate dictates how quickly stormwater can discharge out of the base, the horizontal hydraulic conductivity will determine how readily the disposed stormwater will be transported away from the site, and hence the degree of mounding that can occur beneath soakage devices.

A total of twelve (12) permeability tests have been conducted in order to assess the saturated horizontal hydraulic conductivity.

Soil and Rock (2023) conducted five (5) permeability tests on site between June and July 2023. Falling head tests (FHT) were conducted in the dry piezometers (PZ03, PZ04, PZ05) and rising head tests (RHT) were conducted in piezometers screened below the water table (PZ02, PZ06). No permeability tests were undertaken in the remaining piezometers.

During the drilling campaign in October and November 2023, constant head permeability tests (CHT) were carried out by Beca in the following piezometers: PZ01, PZ03A, PZ04A, PZ05A, PZ06A, PZ09 and PZ10. The tests were conducted after the installation of the piezometer and after its development (until the water ran clear to remove all mud and cuttings and once the water levels had returned to equilibrium). Since the compressor hose couldn’t fit, the development was done using pressurized water instead of air-lift surge.

The results of site-specific hydraulic conductivity tests are given in Table 3.

Table 3. Summary of hydraulic conductivity test results.

Test I.D	Test Depth (m bgl)	Lithology	Horizontal Hydraulic Conductivity K_h (m/s) *	Type of test
PZ01	0.95–1.10	Fine SAND, some fine angular gravel, trace silt.	$2x10^{-5}$	CHT
PZ02	0.9-1.0	Fine SAND, some fine angular gravel, trace silt.	$1x10^{-7}$	RHT*
PZ03	1.5-2.2	Medium to coarse SAND, some fine to medium gravel.	$8x10^{-6}$	FHT*
PZ03A	6.5-7.5	Silty medium to coarse SAND, minor gravel.	$7x10^{-5}$	CHT
PZ04	1.5-1.9	Medium to coarse SAND, some fine to coarse gravel.	$6x10^{-6}$	FHT*
PZ04A	6.5-7.5	Loosely packed GRAVEL, minor coarse sand.	$2x10^{-5}$	CHT
PZ05	1.5-1.9	Fine to medium gravelly coarse SAND.	$6x10^{-6}$	FHT*
PZ05A	6.0-7.5	Sandy fine GRAVEL, minor coarse to medium sand.	$6x10^{-5}$	CHT
PZ06	1.5-3.3	Fine to medium SAND, some silt.	$2x10^{-7}$	RHT*
PZ06A	5.5-8.0	Silty fine to coarse SAND, trace fine gravel.	$4x10^{-5}$	CHT
PZ09	1.2-7.9	Silty fine to medium SAND, minor coarse sand, trace fine angular gravel.	$2x10^{-3}$	CHT
PZ10	5.5-7.5	Medium to coarse SAND, fine to medium gravel	$2x10^{-5}$	CHT

Notes:
*Testing and interpretation undertaken by Soil and Rock, 2023

Due to the high variability in particle sizes and their distribution at site, a clear correlation between units cannot be defined. However, more generally median values of around 10^{-05} m/s can be observed for gravels and coarser sands, around 10^{-06} m/s in fine to coarse sands and, the lowest values of around 10^{-07} m/s tend to correlate to finer grained soils with the highest proportions of silt. The range of testing is consistent with our broader experience in the Cambridge area, and ultimately, the controlling factor on hydraulic conductivity of the different lithologic units will be the proportion of fine grained particles (silts and clays).

Limitations on Hydraulic Conductivity Testing

All forms of hydraulic testing have limitations. Testing assumes uniformity throughout the soil, which is not the case due to the soil heterogeneity. Twelve tests is a statistically reasonable sample size, and as described above there is a general correlation to grain size. However, testing in piezometers can only provide information on the immediate surrounds and, given the inherent variability of Hinuera Formation may not provide a true representation of mass behaviour, some variation laterally and in profile from the above range should be expected given the depositional history of the site.

3.3.1 Soil Risk Map

Waikato Regional Council (WRC) have prepared a map showing the risk that soil will impede infiltration of effluent into the subsurface (Figure 5).

Soils marked as low risk (green on Figure 5) will drain effluent more freely through the soil profile as a result of their porosity and soil structure. These soils are mapped as the Horotiu series which are characterized as “well-draining allophonic soils with low risk of runoff”. These tend to correlate to the sandier Hinuera Formation soils encountered on the Site.

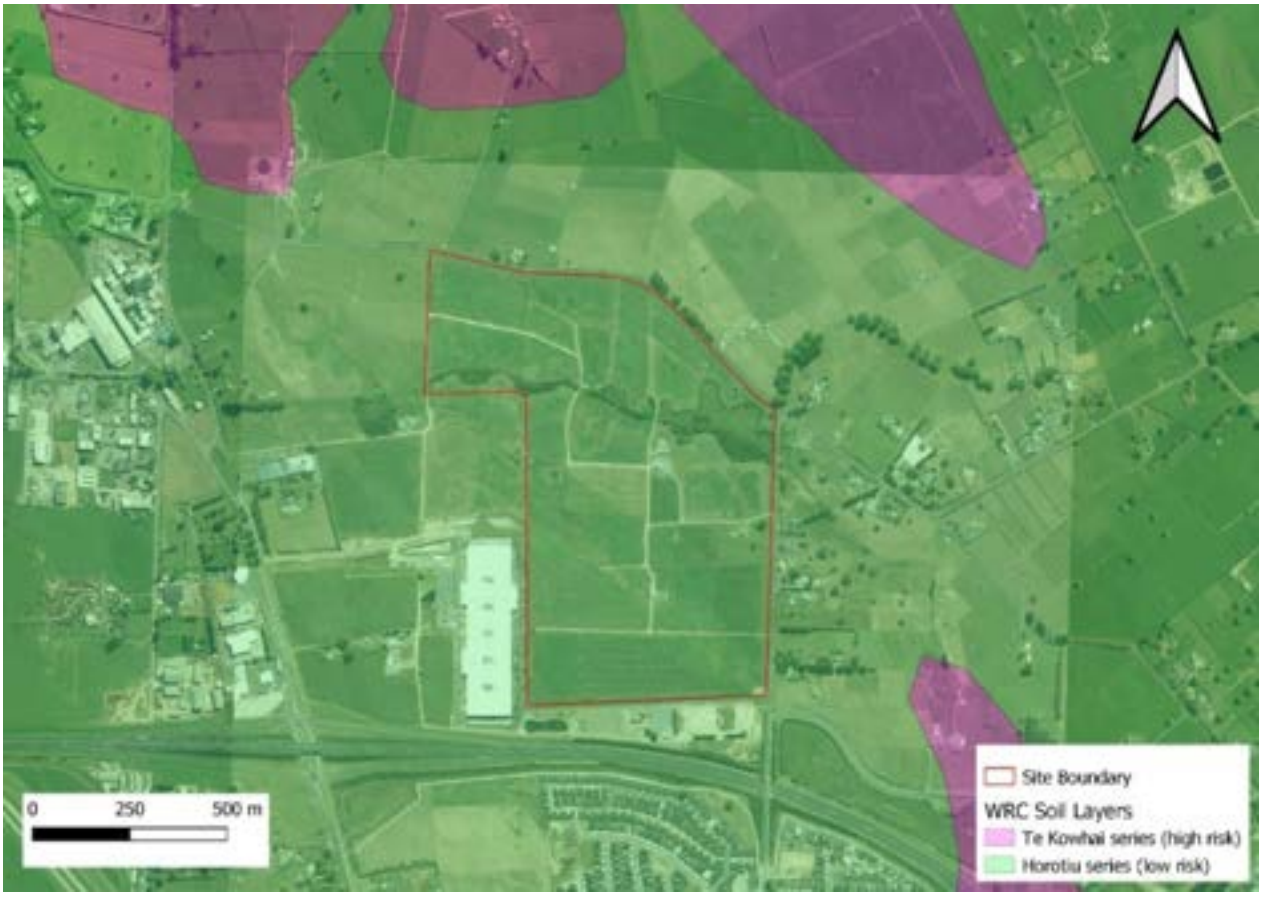


Figure 5: WRC Soil Risk Map

Soils marked as high risk (purple on Figure 5) have an increased risk of effluent runoff into waterways due to reduced drainage (infiltration). These are generally low permeability soils i.e. silts and clays however it is noted that Figure 5 does not appear to capture the 'poor ground conditions' that are anecdotally reported from site (Figure 3).

Further it is cautioned that the map is prepared with effluent discharge in mind. This is generally undertaken at much lower infiltration rates (<< 5 mm/hr) than stormwater soakage (>> 20 mm/hr) and so areas that allow low-rate effluent to infiltrate, might not be suitable for larger rate stormwater discharge.

3.4 Wider Hautapu Experience

Beca has previously undertaken desktop and site investigation of soakage potential at several sites across the wider Hautapu area. Where this information is publicly available and or permission has been received to share data, this is discussed below for wider context.

Site investigation in the existing Bardowie Industrial Precinct (immediately west of the Site, see Figure 1) indicated variable groundwater levels (ranging from 1.4 m bgl to deeper groundwater levels exceeding 4 – 6 m bgl). The groundwater table generally deepens from southeast to northwest, consistent with the observations on the Fonterra site.

Site investigations indicated suitable soakage conditions might exist in areas where a fine to coarse sand is present and groundwater is sufficiently deep. There is an existing soakage basin immediately south of the Fonterra site ("APL Basin 1"). We note slightly higher infiltration rates were generally recorded in testing for this basin (an "equivalent field infiltration rate" of ~400 mm / hour, based on long duration constant head testing in a piezometer at the basin) i.e. infiltration rates were higher than those indicated but current testing on the Fonterra PC14 site.

In WDC growth cells C8/C9 (see Figure 1) to the west of Victoria Road, longer term groundwater level monitoring indicates the groundwater level ranges between some 4 m to 5 m deep. The permeability of near surface soils varies laterally across the site, with the lowest values coinciding with zones of bedded silts and sands and higher values typically recorded in an underlying layer of gravel and sand Unfactored field infiltration rates varied from < 10 mm/hour to ~300 mm/hour.

Site investigations in residential growth cell C2 (see Figure 1) suggest shallow, but small / discontinuous perched horizons can be present, with a deeper more extensive perched water table at 6 m to m depth. Multiple perched water levels were encountered in growth cell C3 to the south of Cambridge Road, with the deepest groundwater level being coincident with the Waikato River (some 30 to 40 m below the terrace level).

Site investigations in C2 indicate unfactored field infiltration rates may vary from < 50 mm/hour to almost 900 mm/hour again highlighting that soakage suitability and performance is highly variable across the wider Cambridge area. Investigation and testing in C2 identified that, like with C8 and C9 the potential for soakage is most favourable where devices can discharge below a shallow perched water table.

Whilst soakage has been employed, or identified as practical in a number of the growth cells, we are also aware anecdotally of more challenging soakage conditions (very low infiltration rates and groundwater levels at the surface) at the eastern extents of Cambridge North (located immediately south of the Fonterra site). This area correlates to the high-risk areas identified by WRC and shown in Figure 5.

We are also aware anecdotally that the Expressway (south and west of the BIP site) has had some areas of poor soakage.

Summary of Wider Experience and Implications for Fonterra site

In summary, depths to groundwater level and soakage suitability are highly variable across the wider Hautapu and Cambridge area. This is consistent with the fluvial depositional history of the Hinuera Formation.

The range of unfactored infiltration rates from site specific testing at the Fonterra site (PC14 area) is broadly consistent with the wider area, albeit that site specific testing appears to be at the lower end of the range. Additionally, water levels are generally shallower on the Fonterra site, than those encountered elsewhere. Both of these factors are likely to be an impediment to use of soakage on the PC14 site.

4 Hydrogeological Constraints and Opportunities for Stormwater Design

4.1 Stormwater options

The Preliminary Master Plan assumed that the stormwater system would likely comprise of a number of primary storage / soakage basins connected by a network of conveyance / soakage channels. Run off would be diverted to the nearest channel which in turn will drain into one of soakage basins, or offline attenuation basins near the stream. Any stormwater that could not be contained on site would be directed towards an outflow channel which will discharge into the Mangaone Stream.

The preliminary locations for the basins had been identified at earlier master planning for the wider C10 Industrial Growth Cell, however as set out below site specific testing has indicated that there are likely to be significant constraints to centralised soakage.

4.2 Hydrogeological constraints and opportunities

4.2.1 Depth to groundwater

Ideally, the base of any soakage device should be at least 1 m above the winter high groundwater level to allow for a degree of mounding. Based on the anticipated cut depths shown in the C10 Growth Cell Preliminary Master Plan drawings (McCaffrey and Cable, 2022), the depth to groundwater would therefore need to be of the order of 4 to 5 m in depth in the vicinity of soakage devices. Groundwater depths recorded across the site are much shallower than this, hence for soakage to work, basins would need to be carefully sited, may need to be shallowed and widened and site-specific mounding assessment would be required to confirm likely infiltration rates and the size of design events that could be accommodated without risk of adverse effects (mounding etc).

Depth to groundwater on the southern side of the Mangaone Stream, above the 65 mRL terrace offers the most freeboard but would still not fully meet the 1 m separation. Basin 1 on the APL site has been operated successfully despite a shallow water table, however the soil permeability at this location of the order of 5-10x higher than what was encountered on the Fonterra site, highlighting the variability of soils in this area.

Elevated (very shallow and potentially perched) groundwater was encountered in several investigations centred around the ancillary pump station, located in the south-central portion of the site. Whilst a deeper groundwater level was encountered in PZ06 (measured at a depth of 1.1 m bgl) this is still too shallow to support soakage. This area correlates to poor ground conditions identified by current site operations (Figure 3). Soakage of any form is unlikely to be viable in this area.

Whilst deeper water levels and granular soils are encountered at the southwest corner of the site, any soakage in this area is likely to result in cumulative mounding with the existing APL basin 1 to the south and for this reason, this area is unlikely to be suitable for any centralised soakage.

Depth to groundwater on the northern side of the Mangaone is typically less than 2 m and will not allow sufficient freeboard for soakage devices (unless they are built up, rather than cut down).

Depth to groundwater in the vicinity of the stream will also be a consideration for attenuation basins. Basins that extend below the groundwater table will either require lining (and provision for uplift) or, may require some permanent discharge of groundwater to provide the necessary storage volumes. A groundwater level of around 60.5 mRL to 62 mRL is possible in the vicinity of the attenuation basins; as this is based on only limited monitoring, ongoing data collection will be required to confirm the high groundwater.

4.2.2 Infiltration rates and Hydraulic Conductivities

Whilst site specific infiltration testing and hydraulic conductivities are in the range of wider Cambridge / Hautapu experience, they are closer to the lower bound and when a suitable Factor of Safety is applied to the design rate, this in combination with relatively shallow groundwater is considered to be a significant impediment to centralised soakage.

Experience from the wider area indicates that where sand and gravel layers can be targeted, that some smaller scale, more distributed soakage to ground (i.e., on-lot) may be possible, though generally the high groundwater table will limit infiltration rates, which are already smaller than those identified on sites in the surrounding areas, where the groundwater level is deeper. Any on-lot soakage will require careful siting, in particular the central, boggy swale area and other areas where silt is dominant should be avoided. Site specific testing at every device would be required to confirm design infiltration rates.

4.2.3 Cumulative Effects of Multiple Sites Discharging to Groundwater

Because stormwater discharge to ground is known / proposed to occur in the development immediately to the west and south of the Site, there is the potential for cumulative effects to arise. Because the site is located upgradient of the neighbouring devices, this may not be a constraint on the site itself, however it will important that discharge on the Site does not adversely affect existing consented soakage at the Bardowie site or cause flooding of the Waikato Expressway.

Further assessment would be required to understand the risk posed by multiple sites discharging to groundwater and to confirm suitable setback distances between basins. However, as noted above centralised soakage is not recommended more generally due to the shallow groundwater levels and wide range of infiltration / hydraulic conductivity testing results.

4.3 Recommendations for the Current Site Master Plan

As outlined above, the shallow depth to water table, prevalence of fine-grained soils and only moderate raw infiltration / hydraulic conductivity rates combined, are considered to be an impediment to centralised soakage.

Some on-lot soakage may be possible but would require careful siting and sizing and would need to be supported by a more intensive level of site investigation and design than is typically undertaken for Plan Change.

It is recommended that the stormwater designers consider alternative stormwater management philosophies that do not rely on centralised (large scale) soakage.

5 Conclusions

The results of site investigations on the PC14 site have indicated a high degree of variability in ground conditions, in particular the lithology (grain size), depth to groundwater and infiltration rates.

High groundwater levels across the site are likely to be a constraint on the location and design of stormwater devices. Further, the design infiltration rates are at the lower bound of those commonly found across the Hautapu and Cambridge area. On this basis, centralised stormwater discharge to ground is generally not considered feasible for this site.

In the areas of relatively deeper groundwater levels and higher infiltration rates, some on-lot soakage may be possible, however the inherent variability in Hinuera Formation means this area cannot be reliably delimited without further investigation and testing (at a level not commonly adopted for a plan change). Accordingly, it is recommended that the Plan Change does not rely on soakage, though it could be maintained as a future design opportunity for individual sites in accordance with the RITS. Specific mounding assessment would be recommended to inform any future design.

Ongoing monitoring of groundwater levels is recommended to support future design stages, including the design of attenuation basins.

6 Applicability Statement

This report has been prepared by Beca Ltd (Beca) on the specific instructions of Fonterra Limited (Client). It is solely for our Client’s use for the purpose for which it is intended in accordance with the agreed scope of work. Any use or reliance by any person contrary to the above, to which Beca has not given its prior written consent, is at that person's own risk.

Should you be in any doubt as to the applicability of this report and/or its recommendations for the proposed development as described herein, and/or encounter materials on site that differ from those described herein, it is essential that you discuss these issues with the authors before proceeding with any work based on this document.

In preparing this report Beca has relied on key information including the following:

- Geotechnical Interpretive Report, provided by Soil and Rock Ltd on 1/09/2023
- Hydraulic Conductivity raw field data, provided by Soil and Rock Ltd by email on 5/09/2023
- C10 Growth Cell Preliminary Master Planning, provided by Waipā District Council on 10/10/2022

Unless specifically stated otherwise in this report, Beca has relied on the accuracy, completeness, currency and sufficiency of all information provided to it by, or on behalf of, the Client, including the information listed above, and has not sought independently to verify the information provided.

This report should be read in full, having regard to all stated assumptions, limitations and disclaimers. No part of this report shall be taken out of context, and, to the maximum extent permitted by law, no responsibility is accepted by Beca for the use of any part of this report in any context, or for any purpose, other than that stated herein.

7 References

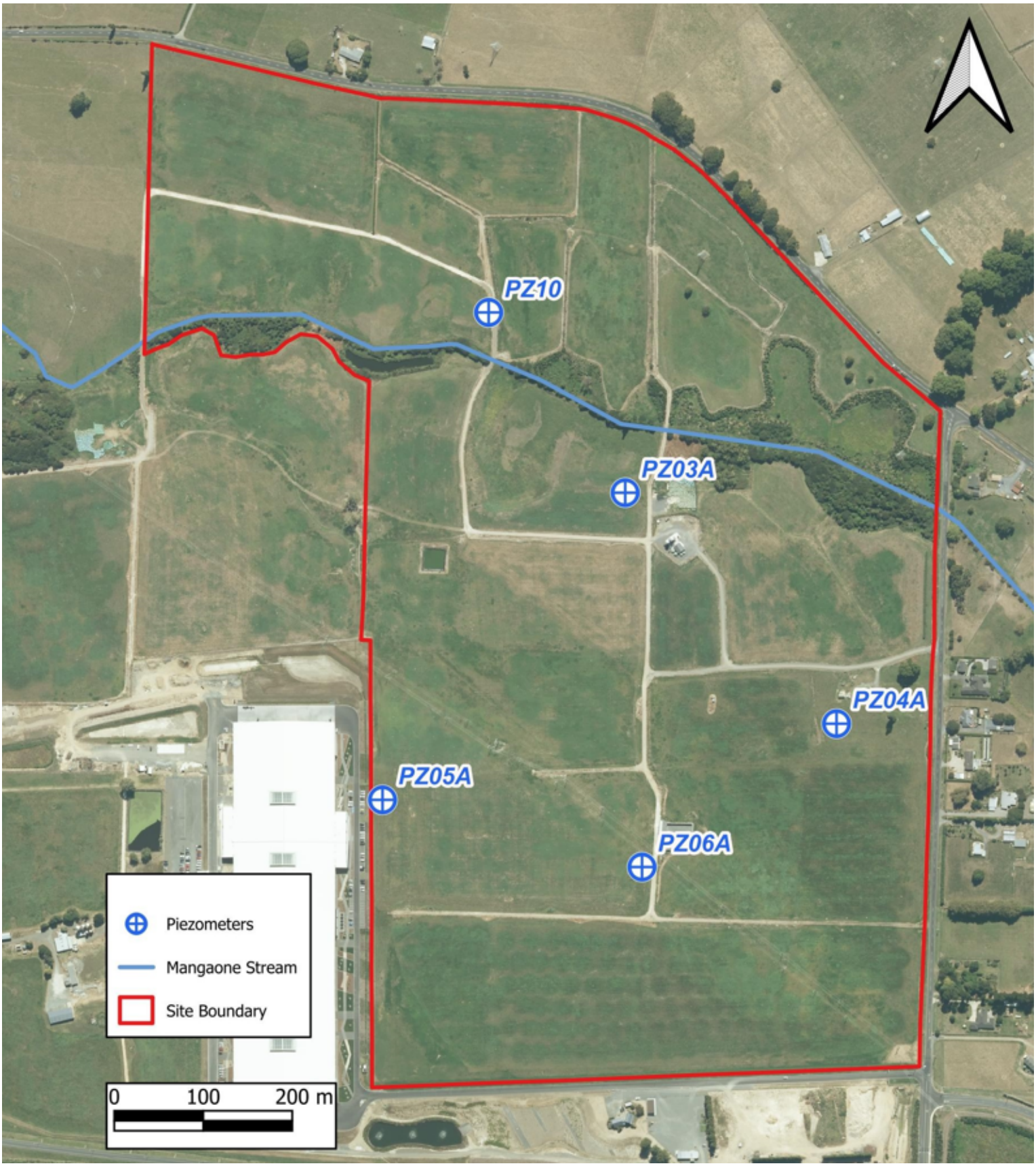
Beca Ltd. (2018). *Proposed Plan Change 11 to the Waipā District Plan - Bardowie Industrial Precinct Hydrogeological Assessment*.

McCaffrey and Cable Consultants Ltd. (2022). *Project C10 Growth Cell - Preliminary Master Plan.*

Soil & Rock Ltd. (2023). *Geotechnical Investigation for Proposed Private Plan Change at Fonterra Hautapu, 195 Swayne Road, Cambridge*

A

Appendix A – October 2023 Borehole Logs and Photos



Approximate location of October 2023 investigations
NB: locations are estimated, not surveyed

Geotechnical Log Key Sheet

SOIL AND ROCK DESCRIPTIONS

Soil and Rock Descriptions are in general accordance with the NZ Geotechnical Society (NZGS), 2005.
Hand-held Vane Shear Strength measurements are in general accordance with the NZGS, 2001.

METHODS

BH	Machine Borehole
CPT	Cone Penetration Test
DCP	Dynamic Cone Penetration
HA	Hand Auger
SPT	Standard Penetration Test
IVAN	In-situ Vane Test
MA	Machine Auger
OB	Open Barrel
SNC	Sonic Core Drilling
TP	Test Pit/Trench
TT	Triple Tube
PT	Thin-walled Open Drive Tube
VE	Vacuum Excavation
W	Wash Boring

WEATHERING

CW	Completely Weathered
HW	Highly Weathered
MW	Moderately Weathered
SW	Slightly Weathered
UW	Unweathered

SAMPLES

B	Bulk Disturbed Sample
C	Core Sample
D	Small Disturbed Sample
U	Thin-wall Open Drive (Push) Tube Sample

WATER

Groundwater Level (GWL)

IN-SITU TESTS

Shear Vane

Su	In-situ peak undrained shear strength and remoulded undrained shear strength
UTP	Unable to Penetrate
CB	Pilcon-type vane tested in Core Barrel
DH	Pilcon-type vane tested in-situ (downhole)
GV	Geonor vane, tested in-situ
IcV	Icone vane, tested in-situ

Standard Penetration Test (SPT)

N	SPTn Sampler (Split-spoon)
Nc	SPTn Solid Cone
HB	SPT Hammer Bouncing

TERMINOLOGY

RL	Relative Ground Level
RQD	Rock Quality Designation

GRAPHIC LOG (1 or a combination of the following)

Clay, Silt, Sandstone (SST), Conglomerate, Fine Igneous
Gravel, Sand, Siltstone (ZST), Limestone, Coarse Igneous
Shells, Organic Material, Mudstone, Foliated Metamorphic, Ignimbrite
Cobbles / Boulders, Wood, Interbedded SST & ZST, Asphalt, No Core

MONITORING INSTALLATION

Backfill Material

Sand, Grout, Bentonite
Gravel, Cement Mixes

Standpipe

Plain, Slotted, Vibrated Wire

ORGANIC SOILS

Von Post Degree of Humification

H1	Completely unconverted and mud-free peat, when pressed gives clear water and plant structure is visible.
H2	Partially unconverted and mud-free peat, when pressed gives almost clear water and plant structure is visible.
H3	Very slightly decomposed or very slightly muddy peat, when pressed gives marked muddy water, no peat substance passes through the fingers and plant structure is less visible.
H4	Slightly decomposed or slightly muddy peat, when pressed gives muddy water and plant structure is less visible.
H5	Moderately decomposed or very muddy peat with growth structure evident but slightly obliterated.
H6	Moderately decomposed or very muddy peat with indistinct growth structure.
H7	Fairly well decomposed or very muddy peat but the growth structure can just be seen.
H8	Well decomposed or very muddy peat with very indistinct growth structure.
H9	Practically decomposed or mud-like peat in which almost no growth structure is evident.
H10	Completely decomposed or mud peat where no growth structure can be seen, entire substance passes through the fingers when pressed.

Document Set ID: 11223918
Version: 1, Version Date: 13/05/2024

Machine Borehole Log

Borehole ID: PZ03A

Sheet 1 of 1

Project:	Fonterra C10 Plan Change Advance	**Project number:**	3200583
Site location:	185 Swaney Road, Hautapu	**Client:**	Fonterra Coorp. Group
Location:	100 m NE of the irrigation station.	**Coordinate system:**	NZTM2000
		Northing:	5806692.9
		Easting:	1817066.1
		Vertical datum:	NZVD 2016
		Ground level (mRL):	64.00
		Location method:	GPS +/- 10m

Installations	Drilling: Return	Drilling: GWL	Drilling: Recovery	Drilling: Method	Drilling: Casing	Drilling: RQD	In Situ Tests: Su (kPa)	In Situ Tests: SPT	Samples	Depth (m)	RL (m)	Graphic Log	Soil/ Rock Description	Geological Unit
			84%	OB						0.0	64.0		Stiff, organic clayey SILT; dark brown; moist, high plasticity. Organics: amorphous.	Topsoil
			92%	OB						0.5	63.5		Firm, clayey SILT; brown; moist, homogenous high plasticity.	Hinuera Formation
			62%	OB						1.0	63.0		No recovery.	
										1.5	62.5		Loosely packed, silty fine SAND, trace clay; dark brown; moist, poorly graded, low plasticity.	
			30%	OB						2.0	62.0		No recovery.	
										2.5	61.5		Loosely packed, coarse SAND, some fine gravel, some silt; brown; moist, poorly graded, non plastic.	
										3.0	61.0		Stiff, SILT, minor fine sand, some fine gravel; dark brown; wet, poorly graded, non plastic.	
		▼	52%	OB						3.5	60.5		Tightly packed, silty medium SAND, some fine gravel; dark brown, mottled black; moist, poorly graded, homogenous, non plastic. Sand: sub-angular to sub-rounded, quartzose.	
										4.0	60.0		No recovery.	
										4.5	59.5		Firm, silty CLAY, trace fine sand; light brown, mottled orange; moist, high plasticity.	
			70%	OB						5.0	59.0		Stiff, silty CLAY, some medium to coarse sand, trace fine gravel, trace clay; greyish light brown; wet, high plasticity.	
										5.5	58.5		No recovery.	
										6.0	58.0		Tightly packed, silty fine SAND, some fine gravel; light brown; wet, well graded, non plastic.	
			50%	OB						6.5	57.5		Stiff, silty CLAY, some fine sand; brownish grey, mottled orange; wet, high plasticity.	
										7.0	57.0		Firm, fine to coarse sandy CLAY; brownish grey; wet, high plasticity.	
										7.5	56.5		Stiff, fine sandy SILT, trace fine gravel, trace clay; light brownish grey, brown; wet, low plasticity, well graded, bedded, sub-horizontal, thinly bedded. Sand: rounded to sub-angular.	
										8.0	56.0		Loosely packed, gravelly coarse SAND, minor silt; reddish brown; moist, well graded, non plastic. Sand: sub-angular to sub-rounded.	
										8.5	55.5		Tightly packed, silty medium SAND, minor fine gravel; dark brown; saturated, poorly graded, homogenous, non plastic. Sand: sub-rounded to sub-angular.	
										9.0	55.0		Tightly packed, silty medium to coarse SAND, minor fine gravel, minor clay; dark greyish brown; moist, poorly graded, low plasticity. Sand: sub-angular to sub-rounded.	
										9.5	54.5		No recovery.	
													8.00m - End of Borehole, Hole terminated at target depth.	

Date started:	30/10/2023	**Date end:**	30/10/2023
Logged by:	JC	**Drilled by:**	Pro-Drill (Auck) Ltd.
Vane ID:	N/A	**Equipment:**	SLG1
Vane type:	N/A	**Method:**	OB
Vane width:	N/A	**Inclination:**	90°
SPT No:	N/A	**Diameter:**	96mm
SPT efficiency:	N/A	**Fluid type:**	Water

Comments:

Groundwater measured from ground level on the 31/10/23 at 16:40.
Following piezometer installation, it was developed using water until it ran clear.
Constant head test performed. Kh: 7x10-5 m/s.

For Explanation of Symbols and Abbreviations See Key Sheet

Photo Log

Location ID: PZ03A

Project:	Fonterra C10 Plan Change Advance			**Project number:**	3200583
Site location:	185 Swaney Road, Hautapu			**Client Name:**	Fonterra Coorp. Group
Location:	100 m NE of the irrigation station.	**Coordinate system:**	NZTM2000	**Vertical datum:**	NZVD 2016
		Northing:	5806692.9	**Ground level (mRL):**	64.00
		Easting:	1817066.1	**Location method:**	GPS +/- 10m

Core Box 01 - 0.00mbgl to 4.50mbgl

Core Box 02 - 4.50mbgl to 8.00mbgl

Machine Borehole Log

Borehole ID: PZ04A

Sheet 1 of 1

Project:	Fonterra C10 Plan Change Advance	**Project number:**	3200583
Site location:	185 Swaney Road, Hautapu	**Client:**	Fonterra Coorp. Group
Location:	Located 25 m South of the house at the entrance of the property and 50 East of the large kauri tree.	**Coordinate system:**	NZTM2000
		Northing:	5806433.6
		Easting:	1817303.6
		Vertical datum:	NZVD 2016
		Ground level (mRL):	66.00
		Location method:	GPS +/- 10m

Installations	Drilling: Return	Drilling: GWL	Drilling: Recovery	Drilling: Method	Drilling: Casing	Drilling: RQD	In Situ Tests: Su (kPa)	In Situ Tests: SPT	Samples	Depth (m)	RL (m)	Graphic Log	Soil/ Rock Description	Geological Unit
			76%	OB						0.0	66.0		Firm, SILT, some fine sand, some organics, trace clay; dark brown; saturated, low plasticity. Organics: amorphous and fibrous.	Top soil
			94%	OB						0.5	65.5		Stiff, sandy SILT, minor fine gravel; brown; moist, poorly graded, non plastic. Gravel: sub-rounded.	
			100%	OB						1.0	65.0		Loosely packed, silty medium SAND, minor fine gravel; light brown; moist, poorly graded, non plastic. Gravel: sub-rounded.	
			48%	OB						1.5	64.5		Loosely packed, coarse sandy fine GRAVEL, some silt; light brownish grey; saturated, well graded, non plastic. Gravel: sub-rounded.	
		▼	76%	OB						2.0	64.0		Loosely packed, silty coarse SAND, trace fine gravel; light greyish brown; moist, poorly graded, non plastic. Gravel: sub-angular to sub-rounded.	
			0%	OB						2.5	63.5		Stiff, clayey SILT, minor fine sand; bluish dark grey; dry, poorly graded, high plasticity. Gravel: sub-angular.	
										3.0	63.0		No recovery.	
			58%	OB						3.5	62.5		Stiff, sandy SILT, minor clay, trace fine gravel; laminated dark, light and greyish brown; mottled white; moist, poorly graded, low plasticity. *3.45 - 3.55m: Loosely packed, silty coarse SAND, trace gravel; light greyish brown; moist, poorly graded, non plastic. Gravel: sub-angular to sub-rounded.*	Hinuera Formation
			100%	OB						4.0	62.0		Loosely packed, coarse SAND, minor silt, some fine gravel; brown; moist, poorly graded, non plastic,. Gravel: sub-angular.	
			49%	OB						4.5	61.5		Stiff, sandy SILT, minor clay, trace fine gravel; laminated dark light greyish brown, mottled white; moist, poorly graded, low plasticity. Gravel: sub-rounded to sub-angular.	
										5.0	61.0		No recovery.	
										5.5	60.5		Loosely packed, coarse SAND, minor silt, some fine gravel; brown, mottled red; moist, poorly graded, low plastic. Gravel: sub-angular.	
										6.0	60.0		Loosely packed, silty SAND, trace fine gravel; brown, streaked light greyish; saturated, non plastic. Gravel: sub-angular.	
			32%	OB						6.5	59.5		Stiff, SILT, some clay, trace sand; grey; moist, high plasticity. No recovery.	
										7.0	59.0		Loosely packed, fine GRAVEL, minor coarse sand; light grey, light brown, dark brown, light black; moist, poorly graded, non plastic. Gravel: sub-angular. *7.35 - 7.55m: Firm, sandy SILT, some clay, trace gravel; light brownish grey.*	
										7.5	58.5		Tightly packed, silty SAND, minor clay, trace fine to medium gravel; dark brownish grey; moist, low plasticity.	
										8.0	58.0		Stiff, sandy SILT, minor clay; dark brownish grey; moist, low plasticity. 8.00m - End of Borehole, Hole terminated at target depth.	
										8.5	57.5			
										9.0	57.0			
										9.5	56.5			

Date started:	02/11/2023	**Date end:**	02/11/2023
Logged by:	JC	**Drilled by:**	Pro-Drill (Auck) Ltd
Vane ID:	N/A	**Equipment:**	SLG1
Vane type:	N/A	**Method:**	OB
Vane width:	N/A	**Inclination:**	90°
SPT No:	N/A	**Diameter:**	96mm
SPT efficiency:	N/A	**Fluid type:**	Water

Comments:

Groundwater measured from ground level on the 02/11/23 at 12:30.
Following piezometer installation, it was developed using water until it ran clear.
Constant head test performed. Kh: 2x10-5 m/s.

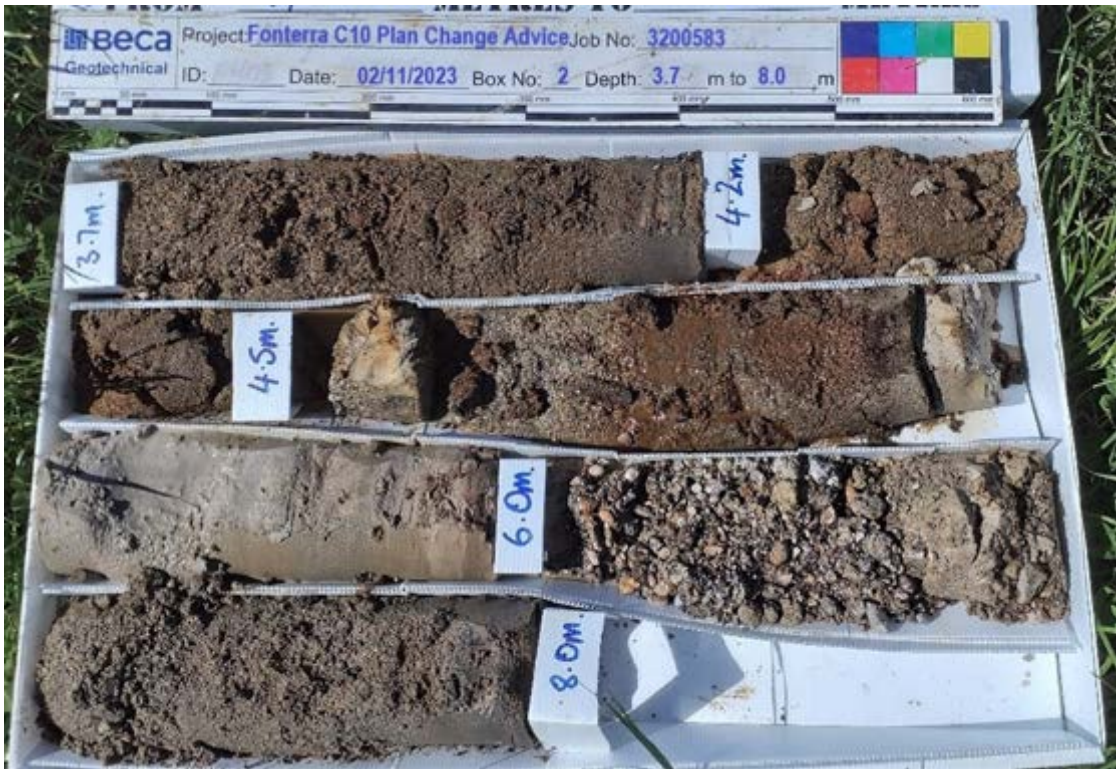
For Explanation of Symbols and Abbreviations See Key Sheet

Photo Log

Location ID: PZ04A

Project:	Fonterra C10 Plan Change Advance		**Project number:**	3200583	
Site location:	185 Swaney Road, Hautapu		**Client Name:**	Fonterra Coorp. Group	
Location:	Located 25 m South of the house at the entrance of the property and 50 East of the large kauri tree.	**Coordinate system:**	NZTM2000	**Vertical datum:**	NZVD 2016
		Northing:	5806433.6	**Ground level (mRL):**	66.00
		Easting:	1817303.6	**Location method:**	GPS +/- 10m

Core Box 01 - 0.00mbgl to 3.70mbgl



Core Box 02 - 3.70mbgl to 8.00mbgl

Machine Borehole Log

Borehole ID: PZ05A

Sheet 1 of 1

Project:	Fonterra C10 Plan Change Advance	**Project number:**	3200583
Site location:	185 Swaney Road, Hautapu	**Client:**	Fonterra Coorp. Group
Location:	Behind the Fonterra building, 5 m away from the fence at the East of the property.	**Coordinate system:**	NZTM2000
		Vertical datum:	NZVD 2016
		Northing:	5806348.1
		Ground level (mRL):	65.00
		Easting:	1816793.4
		Location method:	GPS +/- 10m

Installations	Drilling: Return	Drilling: GWL	Drilling: Recovery	Drilling: Method	Drilling: Casing	Drilling: RQD	In Situ Tests: Su (kPa)	In Situ Tests: SPT	Samples	Depth (m)	RL (m)	Graphic Log	Soil/ Rock Description	Geological Unit
			9%	OB						0.0	65.0		Firm, organic SILT, some fine sand, minor clay; dark brown; moist, low plasticity. Organics: fibrous, amorphous.	Topsoil
													Firm, fine sandy SILT, some fine gravel; brown; moist, non plastic.	
			54%	OB						0.5	64.5		Loosely packed, silty medium to coarse SAND, some fine gravel; dark brown; moist, well graded, non plastic.	
										1.0	64.0		No recovery.	
			56%	OB										
										1.5	63.5		Firm, SILT, minor fine sand; dark brown; moist, non plastic.	
			94%	OB									Loosely packed, fine to medium gravelly coarse SAND; dark brownish grey; moist, poorly graded, non plastic. Gravel: sub-rounded.	
										2.0	63.0		Loosely packed, fine GRAVEL, minor medium to coarse sand; grey; moist, poorly graded, non plastic. Gravel: sub-rounded, pumice.	
			70%	OB									Loosely packed, silty fine to medium SAND, some fine gravel; dark brown; moist, poorly graded, non plastic. Gravel: sub-rounded, pumice.	
										2.5	62.5		Loosely packed, medium to coarse sandy fine to medium GRAVEL, minor silt; light brown; moist, well graded, non plastic. Gravel: sub-rounded, pumice.	
			32%	OB						3.0	62.0		Loosely packed, silty medium to coarse SAND, trace fine gravel; dark grey; moist, well graded, non plastic. Gravel: sub-rounded, pumice.	
													No recovery.	
										3.5	61.5		*3.20 - 3.45m: Silty medium to coarse SAND, some gravel; light brownish grey; moist, non plastic. Gravel: sub-rounded.*	
			47%	OB						4.0	61.0			Hinuera Formation
										4.5	60.5			
										5.0	60.0		Loosely packed, medium to coarse sandy fine GRAVEL, minor silt; dark brown; saturated, poorly graded, non plastic. Gravel: sub-rounded, pumice.	
										5.5	59.5		Firm, sandy SILT, some coarse sand; dark grey; moist, poorly graded, non plastic.	
			100%	OB						6.0	59.0		Loosely packed, sandy fine to coarse GRAVEL; brownish grey, mottled light brown; moist, poorly graded, non plastic. Gravel: sub-rounded, pumice, rhyolite, greywacke.	
			80%	OB						6.5	58.5		Loosely packed, coarse SAND, some fine gravel, minor silt; light brownish grey; moist, well graded, non plastic. Sand: sub-rounded. Gravel: sub-angular to sub-rounded.	
			74%	OB						7.0	58.0		Loosely packed, sandy fine to coarse GRAVEL, some silt; grey; moist, poorly graded, non plastic. Gravel: sub-angular, pumice, greywacke, rhyolite. Sand: sub-angular, quartz.	
													No recovery	
			44%	OB						7.5	57.5		Loosely packed, coarse GRAVEL; brownish grey, brown, red, black; dry, poorly graded, non plastic. Gravel: sub-rounded, pumice, greywacke, rhyolite.	
										8.0	57.0		No recovery.	
													Very stiff, sandy SILT, minor fine gravel; dark brownish grey; moist, gap graded, non plastic. Gravel: sub-angular to sub-rounded.	
										8.5	56.5		8.00m - End of Borehole, Hole terminated at target depth.	
										9.0	56.0			
										9.5	55.5			

Date started:	31/10/2023	**Date end:**	31/10/2023
Logged by:	JC	**Drilled by:**	Pro-Drill (Auck) Ltd
Vane ID:	N/A	**Equipment:**	SLG1
Vane type:	N/A	**Method:**	OB
Vane width:	N/A	**Inclination:**	90°
SPT No:	N/A	**Diameter:**	96mm
SPT efficiency:	N/A	**Fluid type:**	Water

Comments:

Groundwater measured from ground level on the 31/10/23 at 16:35.
Following piezometer installation, it was developed using water until it ran clear.
Constant head test performed. Kh: 6x10-5 m/s.

For Explanation of Symbols and Abbreviations See Key Sheet

Photo Log

Location ID: PZ05A

Project:	Fonterra C10 Plan Change Advance	**Project number:**	3200583
Site location:	185 Swaney Road, Hautapu	**Client Name:**	Fonterra Coorp. Group
Location:	Behind the Fonterra building, 5 m away from the fence at the East of the property.	**Coordinate system:**	NZTM2000
		Northing:	5806348.1
		Easting:	1816793.4
		Vertical datum:	NZVD 2016
		Ground level (mRL):	65.00
		Location method:	GPS +/- 10m

Core Box 01 - 0.00mbgl to 4.00mbgl

Core Box 02 - 4.00mbgl to 7.50mbgl

Photo Log

Location ID: PZ05A

Project:	Fonterra C10 Plan Change Advance			**Project number:**	3200583
Site location:	185 Swaney Road, Hautapu			**Client Name:**	Fonterra Coorp. Group
Location:	Behind the Fonterra building, 5 m away from the fence at the East of the property.	**Coordinate system:**	NZTM2000	**Vertical datum:**	NZVD 2016
		Northing:	5806348.1	**Ground level (mRL):**	65.00
		Easting:	1816793.4	**Location method:**	GPS +/- 10m

Core Box 03 - 7.50mbgl to 8.00mbgl

Machine Borehole Log

Borehole ID: PZ06A

Sheet 1 of 2

Project:	Fonterra C10 Plan Change Advance	**Project number:**	3200583
Site location:	185 Swaney Road, Hautapu	**Client:**	Fonterra Coorp. Group
Location:	Located at the south of the property, 20 m East of the road.	**Coordinate system:**	NZTM2000
		Northing:	5806272.7
		Easting:	1817085.0
		Vertical datum:	NZVD 2016
		Ground level (mRL):	66.00
		Location method:	GPS +/- 10m

Depth (m)	RL (m)	Drilling: Return	Drilling: GWL	Drilling: Recovery	Drilling: Method	Drilling: Casing	Drilling: RQD	In Situ Tests: Su (kPa)	In Situ Tests: SPT	Samples	Graphic Log	Soil/ Rock Description	Geological Unit
0.0	66.00			100%	OB							Firm, organic SILT, minor clay, some organics, trace fine sand; dark brown; moist, low plasticity. Organics: Amorphous, fibrous.	Topsoil
0.5	65.5			100%	OB							Stiff, clayey SILT, trace fine sand; light brown, mottled greyish white; moist, high plasticity.	Hinuera Formation
1.0	65.0		▼	100%	OB							Stiff, SILT, minor fine sand, minor clay; light grey; saturated, low plasticity.	
1.5	64.5												
2.0	64.0			73%	OB								
2.5	63.5											No recovery.	
3.0	63.0											Stiff, SILT, minor fine sand, minor clay; light grey; saturated, low plasticity.	
3.5	62.5			73%	OB								
4.0	62.0											Stiff, fine sandy SILT, some fine gravel; dark grey; moist, well graded, low plasticity.	
4.5	61.5											Stiff, silty fine SAND, trace fine gravel; dark grey; saturated, well graded, non plastic, bedded, sub-horizontal, moderately thin to moderately thick bedded silts. Sand: sub-angular to sub-rounded, quartz, pumice.	
5.0	61.0			85%	OB							Loosely packed, silty coarse SAND, trace fine gravel; dark grey; saturated, well graded, non plastic, bedded, sub-horizontal, moderately thin to moderately thick bedded silts. Sand: sub-angular to sub-rounded, quartz, pumice.	
5.5	60.5											Stiff, SILT, minor fine sand, minor clay; dark greyish brown; saturated, low plasticity.	
6.0	60.0											Loosely packed, silty coarse SAND, trace fine gravel; dark grey; saturated, well graded, non plastic, bedded, sub-horizontal, moderately thin to moderately thick bedded silts. Sand: sub-angular to sub-rounded, quartz, pumice.	
6.5	59.5			85%	OB							Loosely packed, medium to coarse sandy fine to medium GRAVEL, some cobbles; light grey, light brown, dark brown, light black; moist, poorly graded, non plastic. Gravel: sub-angular.	
7.0	59.0			0%	OB							*6.10 - 6.25m: Loosely packed, medium to coarse sandy fine to medium GRAVEL; light grey, light brown, dark brown, light black; moist, poorly graded, non plastic. Gravel: sub-angular.*	
7.5	58.5											Loosely packed, silty coarse SAND; dark brown; saturated, well graded, non plastic. Sand: sub-angular to sub-rounded, quartz, pumice.	
8.0	58.0			44%	OB							No recovery.	
8.5	57.5											Stiff, fine sandy SILT, some fine gravel; light brownish grey; moist, well graded, low plasticity.	
9.0	57.0											Stiff, silty fine to coarse SAND, trace fine gravel; dark grey; saturated, well graded, low plasticity, bedded, sub-horizontal, moderately thin to moderately thick bedded silts.	
9.5	56.5			0%	OB							No recovery.	
												Firm, SILT, minor fine sand, some fine gravel, minor clay, grey to dark grey, mottled greyish white; moist, poorly graded, bedded, low plasticity.	
												No recovery.	

Date started:	01/11/2023	**Date end:**	01/11/2023
Logged by:	JC	**Drilled by:**	Pro-Drill (Auck) Ltd
Vane ID:	N/A	**Equipment:**	SLG1
Vane type:	N/A	**Method:**	OB
Vane width:	N/A	**Inclination:**	90°
SPT No:	N/A	**Diameter:**	96mm
SPT efficiency:	N/A	**Fluid type:**	Polymer/Water

Comments:

Groundwater measured from ground level on the 01/11/23 at 16:00.
Polymer was used at 7.10 m bgl until the end of the perforation.
Following piezometer installation, it was developed using water until it ran clear.
Constant head test performed. Kh: 4x10-5 m/s.

For Explanation of Symbols and Abbreviations See Key Sheet

Machine Borehole Log

Borehole ID: PZ06A

Project:	Fonterra C10 Plan Change Advance	**Project number:**	3200583
Site location:	185 Swaney Road, Hautapu	**Client:**	Fonterra Coorp. Group
Location:	Located at the south of the property, 20 m East of the road.	**Coordinate system:**	NZTM2000
		Northing:	5806272.7
		Easting:	1817085.0
		Vertical datum:	NZVD 2016
		Ground level (mRL):	66.00
		Location method:	GPS +/- 10m

Installations	Drilling: Return	Drilling: GWL	Drilling: Recovery	Drilling: Method	Drilling: Casing	Drilling: RQD	In Situ Tests: Su (kPa)	In Situ Tests: SPT	Samples	Depth (m)	RL (m)	Graphic Log	Soil/ Rock Description	Geological Unit
			0%	OB						10.5	55.5		No recovery.	Hinuera Formation
			100%	OB									Firm, SILT, minor fine sand, minor clay; light grey; moist, low plasticity.	
										11.0	55.0		Loosely packed, silty medium to coarse SAND, trace fine gravel; dark brownish grey, moist, non plastic. Sand: sub-rounded to sub-angular, quartz, pumice.	
													Firm, SILT, minor fine sand, minor clay; light grey; moist, low plasticity.	
										11.5	54.5		Loosely packed, silty medium to coarse SAND, trace fine gravel; dark brownish grey, moist, non plastic. Sand: sub-rounded to sub-angular, quartz, pumice.	
			77%	OB									Firm, SILT, minor fine sand, minor clay; light grey; moist, low plasticity.	
										12.0	54.0			
										12.5	53.5		Loosely packed, silty medium to coarse SAND, trace fine gravel; dark brownish grey, moist, non plastic. Sand: sub-rounded to sub-angular, quartz, pumice.	
													Firm, SILT, minor fine sand, minor clay; light grey; moist, low plasticity.	
			89%	OB						13.0	53.0		Loosely packed, silty medium to coarse SAND, trace fine gravel; dark brownish grey, moist, non plastic. Sand: sub-rounded to sub-angular, quartz, pumice.	
										13.5	52.5		Firm, SILT, minor fine sand, minor clay; light grey; moist, low plasticity.	
										14.0	52.0			
			100%	OB						14.5	51.5			
										15.0	51.0		15.00m - End of Borehole, Hole terminated at target depth.	
										15.5	50.5			
										16.0	50.0			
										16.5	49.5			
										17.0	49.0			
										17.5	48.5			
										18.0	48.0			
										18.5	47.5			
										19.0	47.0			
										19.5	46.5			

Date started:	01/11/2023	**Date end:**	01/11/2023
Logged by:	JC	**Drilled by:**	Pro-Drill (Auck) Ltd
Vane ID:	N/A	**Equipment:**	SLG1
Vane type:	N/A	**Method:**	OB
Vane width:	N/A	**Inclination:**	90°
SPT No:	N/A	**Diameter:**	96mm
SPT efficiency:	N/A	**Fluid type:**	Polymer/Water

Comments:

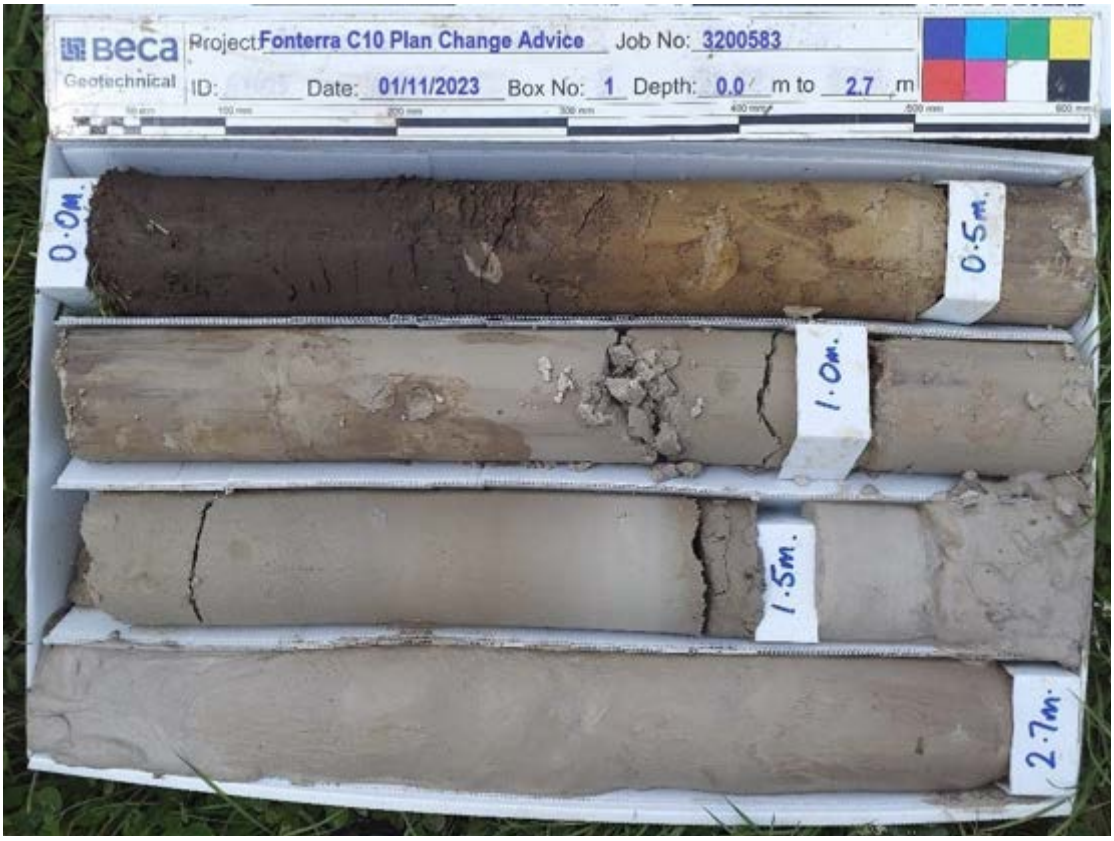
Groundwater measured from ground level on the 01/11/23 at 16:00.
Polymer was used at 7.10 m bgl until the end of the perforation.
Following piezometer installation, it was developed using water until it ran clear.
Constant head test performed. Kh: 4x10-5 m/s.

For Explanation of Symbols and Abbreviations See Key Sheet

Photo Log

Location ID: PZ06A

Project:	Fonterra C10 Plan Change Advance	**Project number:**	3200583
Site location:	185 Swaney Road, Hautapu	**Client Name:**	Fonterra Coorp. Group
Location:	Located at the south of the property, 20 m East of the road.	**Coordinate system:**	NZTM2000
		Northing:	5806272.7
		Easting:	1817085.0
		Vertical datum:	NZVD 2016
		Ground level (mRL):	66.00
		Location method:	GPS +/- 10m



Core Box 01 - 0.00mbgl to 2.70mbgl

Core Box 02 - 2.70mbgl to 5.50mbgl

Photo Log

Location ID: PZ06A

Project:	Fonterra C10 Plan Change Advance	**Project number:**	3200583
Site location:	185 Swaney Road, Hautapu	**Client Name:**	Fonterra Coorp. Group
Location:	Located at the south of the property, 20 m East of the road.	**Coordinate system:**	NZTM2000
		Northing:	5806272.7
		Easting:	1817085.0
		Vertical datum:	NZVD 2016
		Ground level (mRL):	66.00
		Location method:	GPS +/- 10m

Core Box 03 - 5.50mbgl to 9.50mbgl

Core Box 04 - 9.50mbgl to 14.00mbgl

Photo Log

Location ID: **PZ06A**

Project:	Fonterra C10 Plan Change Advance	**Project number:**	3200583
Site location:	185 Swaney Road, Hautapu	**Client Name:**	Fonterra Coorp. Group
Location:	Located at the south of the property, 20 m East of the road.	**Coordinate system:**	NZTM2000
		Northing:	5806272.7
		Easting:	1817085.0
		Vertical datum:	NZVD 2016
		Ground level (mRL):	66.00
		Location method:	GPS +/- 10m

Core Box 05 - 14.00mbgl to 15.00mbgl

Machine Borehole Log

Borehole ID: PZ10

Sheet 1 of 1

Project:	Fonterra C10 Plan Change Advance	**Project number:**	3200583
Site location:	185 Swaney Road, Hautapu	**Client:**	Fonterra Coorp. Group
Location:	Located at the north of the property. 50 m to the NW at the bridge crossing.	**Coordinate system:**	NZTM2000
		Northing:	5806895.3
		Easting:	1816912.7
		Vertical datum:	NZVD 2016
		Ground level (mRL):	64.00
		Location method:	GPS +/- 10m

Installations	Drilling: Return	Drilling: GWL	Drilling: Recovery	Drilling: Method	Drilling: Casing	Drilling: RQD	In Situ Tests: Su (kPa)	In Situ Tests: SPT	Samples	Depth (m)	RL (m)	Graphic Log	Soil/ Rock Description	Geological Unit
			88%	OB						0.0	64.0		Stiff, organic clayey SILT; dark brown; moist, high plasticity. Organics: fibrous, amorphous.	Tops oil
			100%	OB						0.5	63.5		Stiff, clayey SILT, some fine to medium sand; grey mottled orange; moist, high plasticity.	Hinuera Formation
			94%	OB						1.0	63.0		Tightly packed, fine to coarse SAND, minor silt, trace fine to medium gravel; brownish grey; wet, well graded. Gravel: sub-rounded.	
		▼	65%	OB						1.5	62.5		No recovery	
										2.0	62.0			
										2.5	61.5		Loosely packed, fine to coarse SAND, minor silt, trace fine to medium gravel; brownish grey; wet, well graded. Gravel: sub-rounded.	
			83%	OB						3.0	61.0		Very stiff, silty CLAY; grey; wet, high plasticity, bedded, sub-horizontal, very thinly bedded.	
										3.5	60.5		Firm, fine sandy SILT, trace clay; light brownish grey; saturated, low plasticity.	
													Stiff, clayey SILT; grey; wet, high plasticity.	
										4.0	60.0		Tightly packed, fine SAND; grey; saturated, poorly graded, bedded, sub-horizontal, moderately thinly bedded. Sand: pumiceous.	
													Stiff, clayey SILT; grey; moist, high plasticity.	
										4.5	59.5		Tightly packed, fine SAND; grey; saturated, poorly graded, bedded, sub-horizontal, moderately thinly bedded. Sand: pumiceous.	
			43%	OB						5.0	59.0		Loosely packed, fine to coarse SAND, minor fine to medium gravel, minor silt; dark brown; wet, well graded, non plastic. Sand: sub-angular to sub-rounded, quartz, pumice. Gravel: sub-rounded, SW pumice, MW greywacke.	
										5.5	58.5		Tightly packed, coarse SAND, minor fine to medium gravel; dark grey; wet, poorly graded. Sand: sub-angular to sub-rounded, quartz, greywacke. Gravel: sub-rounded, SW pumice, SW greywacke.	
										6.0	58.0		5.1 - 6.25 m: no recovery.	
										6.5	57.5		Loosely packed, fine to medium GRAVEL, minor fine to coarse sand; grey; wet, well graded. Gravel: sub-angular to sub-rounded, SW greywacke, SW andesite.	
			25%	OB						7.0	57.0		Loosely packed, fine to coarse silty SAND, minor fine to medium gravel; dark greenish grey; wet, well graded, non plastic. Sand: sub-angular to sub-rounded, quartz, greywacke. Gravel: sub-rounded, SW pumice, SW greywacke.	
										7.5	56.5		Loosely packed, coarse SAND, minor fine to medium gravel; dark grey; wet, poorly graded, sub-angular to sub-rounded, quartz, greywacke. Gravel: sub-rounded, SW pumice, SW greywacke.	
										8.0	56.0		No recovery.	
													Loosely packed, fine to coarse silty SAND, minor fine to medium gravel; dark grey; wet, poorly graded, non plastic. Sand: sub-angular to sub-rounded, quartz, greywacke. Gravel: sub-rounded, SW greywacke.	
										8.5	55.5		8.00m - End of Borehole, Hole terminated at target depth.	
										9.0	55.0			
										9.5	54.5			

Date started:	30/10/2023	**Date end:**	30/10/2023
Logged by:	JC	**Drilled by:**	Pro-Drill (Auck) Ltd
Vane ID:	N/A	**Equipment:**	SLG1
Vane type:	N/A	**Method:**	OB
Vane width:	N/A	**Inclination:**	90°
SPT No:	N/A	**Diameter:**	96mm
SPT efficiency:	N/A	**Fluid type:**	Water

Comments:

Groundwater measured from ground level on the 31/10/23 at 16:48.
Following piezometer installation, it was developed using water until it ran clear.
Constant head test performed. Kh: 2x10-5 m/s.

For Explanation of Symbols and Abbreviations See Key Sheet

Photo Log

Location ID: PZ10

Project:	Fonterra C10 Plan Change Advance			**Project number:**	3200583
Site location:	185 Swaney Road, Hautapu			**Client Name:**	Fonterra Coorp. Group
Location:	Located at the north of the property. 50 m to the NW at the bridge crossing.	**Coordinate system:**	NZTM2000	**Vertical datum:**	NZVD 2016
		Northing:	5806895.3	**Ground level (mRL):**	64.00
		Easting:	1816912.7	**Location method:**	GPS +/- 10m

Core Box 01 - 0.00mbgl to 3.00mbgl

Core Box 02 - 3.00mbgl to 8.00mbgl