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Rātana WWTP Groundwater Investigation

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CONFIDENTIAL

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Disclaimers and Limitations

This report ('**Report**') has been prepared by WSP exclusively for [Rangitikei District Council] ('**Client**') in relation to [Rātana WWTP Irrigation Proposal] ('**Purpose**') and in accordance with the methodology dated 22 December 2021. The findings in this Report are based on and are subject to the assumptions specified in the Report. WSP accepts no liability whatsoever for any reliance on or use of this Report, in whole or in part, for any use or purpose other than the Purpose or any use or reliance on the Report by any third party.

1 Introduction

WSP has been engaged by Rangitikei District Council (RDC) to assist with a consenting programme for wastewater treatment plants in the district, including a new discharge system and site for Ratana. RDC have now purchased a parcel of land and intend to apply for consent to discharge treated wastewater to this site.

This report outlines the information gathered both from desktop assessments as well field investigations that have been undertaken to assess the potential effects of this irrigation on the groundwater in the surrounding environment to support the consent application.

1.1 Description of proposed activity

RDC intend to apply for necessary consents to authorise the irrigation of treated wastewater to land at a site at the end of Whangaehu Beach Road in Rātana. Currently the wastewater treated at the Rātana WWTP is discharged into a local stream, which drains into Lake Waipu.

The proposal includes provision of storage of treated wastewater so that deficit irrigation can be undertaken. Further details regarding the design of the irrigation system are outlined in the Irrigation report and consent application reports. Deficit irrigation of the wastewater to land, which entails irrigation during periods of crop growth when the crops need water, is preferred to manage any potential effects of a discharge to land. Therefore, the majority of the water will be taken up by the plants and will not cause saturation of the soils. However, deficit irrigation is not always possible, therefore there will be periods where wastewater will either need to be stored or directly irrigated, irrigated wastewater in this situation may then result in infiltration into the underlying groundwater. The non-deficit irrigation is the focus of this assessment.

1.1.1 Irrigation

The following key assumptions have been made when considering the initial irrigation design:

- The system design criteria allows for deficit irrigation during a median year. During a wet year, deficit irrigation will be restricted to a shorter period of time and shoulder months (September, October, November and April) would receive non-deficit irrigation.
- Irrigation will generally not occur during the winter and early spring months (May – August). Storage will be provided to hold treated wastewater volumes over these periods.
- The site has different irrigation management zones, each zone will be managed differently.
- Irrigation to dune land present on the land is to be sought but this would only be allowed for sparingly, but as such it is not accounted for in nitrogen loading calculations. Further details regarding the dune land proposed management is described below.
- It is proposed to irrigate to the wetlands when deficit irrigation can occur in the wetland management zone, when non-deficit irrigation is undertaken irrigation to this area will be avoided as much as practical.

The proposed **average maximum daily volume**:

- 523m^3/day – based on maximum monthly application of 16,200m^3/month, emergency contingency applications would be additional to this.

- The proposed daily maximum application rate;
  7mm/day (average 3.5mm).

Except as required for contingency situations which will be outlined in the irrigation management plan.

Nitrogen loading rate;
Nitrogen would be managed so as not to exceed 150kgN/ha/year

Table 1: Future Flows with median rainfall and evapotranspiration extended irrigation period and dunelands

Future Flows with median rainfall and evapotranspiration extended irrigation period and dunelands		
Irrigation Philosophy	Mixed	
Rainfall-Evapotranspiration Data Period	Median year	
Irrigation area	20 ha	
WW water flow scenario	Based on Future maximum average flows	
Months of deficit Irrigation	5	November - March
Months of non-deficit irrigation.	2	September, October
Months of no irrigation	5	April to August
Buffer Storage Required	28,500	m^3

1.1.2 Loading Rates

Typically, treated wastewater is enriched in nitrogen and phosphorous and can have high micro-bacterial counts. Thus, the treated wastewater may contribute to increased rates of nutrients being introduced into the groundwater underlying the site. An analysis of the nitrogen loading rates has been undertaken as part of investigation into the potential effects of the discharge of wastewater to land (WSP, 2022).

Based on the existing effluent quality regularly achieved by the WWTP the nitrogen loading is estimated at 56 kg N/ha/year – that is when existing flows and loads are applied to the 15-hectare plot of land proposed for the discharge of wastewater. The nitrogen loading is estimated to increase to 103 kg N/ha/year, which is an increase of 47 kg N/ha/year, to allow for predicted population growth in Ratana (see WSP, 2022 report for more details). In addition to the nutrient loading rates the irrigation will result in additional hydraulic loading onto the site of 187 m^3/day and an average irrigation depth of approximately 1 mm/day.

2 Current Environment

2.1 Site Setting

The site selected for the proposed irrigation of wastewater to land is located in a predominantly agricultural area approximately 4 km north-east of the township of Rātana. The site is located at the end of Whangaehu Beach Road, approximately 1 km from the west coast of the North Island. The land parcel is situated between the two large rivers, the Whangaehu River to the north, and the Turakina River to the south, which are located approximately 750 m and 1 km from the site respectively.

The topography is variable across the site, with both active and relict dunes resulting in rolling hills across much of the site. The central portion of the site has much flatter topography, with a number of small natural depressions. There are also two natural wetlands on the site, these are described further in the Ecological Assessment.

Figure 2-1: Map of the proposed irrigation site located on Whangaehu Road, Rātana. Wetland and dune environments indicated on the figure.

2.2 Geology

The geology of the Rātana area is comprised mainly of Holocene deposits of sand, peat and mud, combined with layers of Holocene gravel, alluvium and active dune deposits close to the coast. Dune deposits are prevalent along the coast throughout the entire Manawatū-Whanganui region. These dunes have formed after the last glacial maxima and comprise the largest dune field in New Zealand (Townsend et al., 2008). These Quaternary sand deposits can be either fixed or mobile.

The surface geology of the area proposed for wastewater irrigation is predominantly active dune deposits. The deposits are a mixture of stable dune deposits, river deposits, and beach deposits.

2.2.1 Soils

The soils in the Rātana area are predominantly comprised of gley and recent soil orders along the coast, with brown and palic soils further inland toward the township of Rātana. The soil textures are typically a mixture of clay, silt, loam, and sand (Manaaki Whenua, 2022).

Test pits were excavated on site in March 2022 as part of the site-specific investigations for the irrigation discharge to land. The soil textures were visually inspected at that time. As expected, the most prevalent soil texture identified was sandy soils, specifically sandy topsoil with traces of silt is present in the first 0-0.3 m, grading into sandy soils to the bottom of each test pit (maximum depth of ~3 m).

Further investigation of the soil profiles across the site was carried out when bores were installed at the site during July 2022. The cores extracted during the drilling of each of the five bores were photographed and logged to further understand the subsurface characteristics of the site (Appendix A). The logged composition of the bores is consistent with the initial observations made during excavation of the test pits, indicating predominantly sand. Layers of sand interspersed with traces of silt were also identified in each of the five bores on site, typically occurring at depths between one and four metres depth towards the eastern side of the site.

2.2.1 Monitoring Bore Hydraulic Testing Results

Slug tests were carried out on each of the bores in September 2022 to gain an understanding of the hydraulic properties of the underlying groundwater zone. The results of the analysis are outlined below in Table 2-1. The hydraulic conductivity of Bore 3 could not be determined due to not containing enough water in the bore to submerge the slug.

Table 2-1: Slug test results for bores at the proposed irrigation site in Rātana.

Bore ID	Average Hydraulic Conductivity (K) (m/day)
BH 1	15.99
BH 2	48.51
BH 3	-
BH 4	11.82
BH 5	12.76

2.3 Regional Hydrogeology

The proposed irrigation site is located in the Whangaehu Groundwater Management Zone (GMZ) (Horizons One Plan, 2016), which spans from the western side of Tongariro National Park following the Whangaehu River to its outlet at the coast approximately 6 km from the township of Rātana. The groundwater volume in this zone has been found to increase towards the coast, with aquifers from the deep sand and gravel layers commonly used as a water source for agricultural needs (LAWA, 2022).

2.3.1 Neighbouring Bores

Hydrogeology and groundwater information close to the proposed irrigation site is supplemented by information from consented groundwater activities in the area. This information was obtained from Horizons Regional Council (HRC). 22 bores were identified within a 3 km radius of the proposed wastewater irrigation site (Figure 2-2). Analysis of these bores and their characteristics can provide an indication of the likely groundwater conditions beneath the proposed irrigation site.

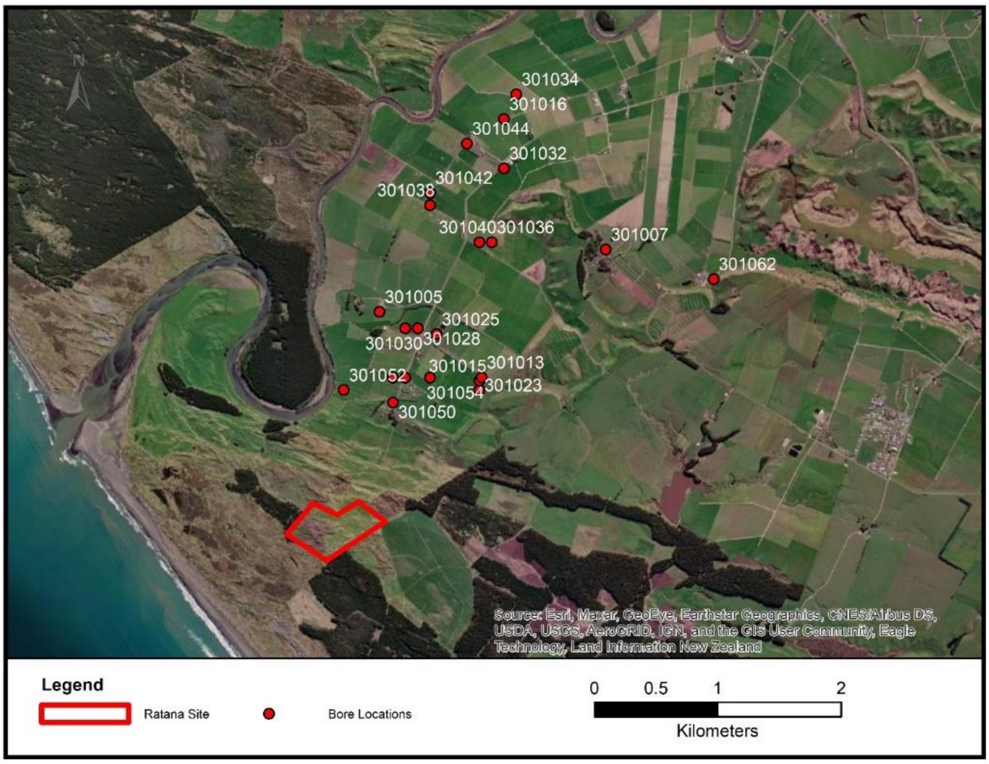

Figure 2-2: Bores within a 3 km radius of the proposed Rātana wastewater irrigation site.

The data from HRC included detailed information for eight of the 22 bores. The analysis of this indicated of the bores with a known depth the depth ranged of 29–103 m, with a mean average of 73 m.

The stratigraphy logged for these bores provide an indication of the likely stratigraphy beneath the area. The closest bore for which there is stratigraphy available is Bore 301023; approximately 1,340m from the proposed irrigation area. The stratigraphy of this bore shows layers of silt, sand, clay, and gravel (Table 2-2). Stratigraphic logs from other bores within 3 km of the site show similar layers of sand, silt, clay, and papa (mudstone and sandstone matrix).

Table 2-2: Stratigraphy of Bore 301023.

Depth (m)	Stratigraphy
0 – 5.5	Silt
5.5 – 6.4	Peat
6.4 – 6.7	Sand
6.7 – 10.1	Silt
10.1 – 11	Sand
11 – 18	Silt
18 – 20.1	Sand
20.1 – 22	Silt
22 – 24.4	Sand
24.4 – 25.6	Silt
25.6 – 33.6	Gravel
33.6 – 42.7	Sand
42.7 – 43.7	Silt

2.3.2 Onsite Monitoring Bore Observations

Water level data was obtained from five bores that have been installed at the proposed irrigation site (Figure 2-3). The bores were installed at shallow depths (5 - 9.45 m) to understand the baseline shallow groundwater conditions, both water level and groundwater quality to allow any potential variations from this baseline due to the proposed activity to be determined. Groundwater levels were measured on three occasions during September 2022 to provide some baseline groundwater monitoring data for the site (Table 2-3). The ground elevation for each bore was approximated using 1 m DEM (Digital Elevation Map), so that the reduced water level at each bore could be determined, to allow for direct comparison across bores. Some variation in groundwater level was observed across the site, therefore infiltration of the irrigated wastewater through the soils and into the groundwater zone will vary. For example, the reduced water level for Bore 3 is consistently higher than the other bores. Note that the monitoring period is too short to provide information on seasonal changes in groundwater level relative to rainfall infiltration. Although it is important to understand that groundwater levels vary as a result of seasonal changes in rainfall and have also been shown to respond to large magnitude rainfall events.

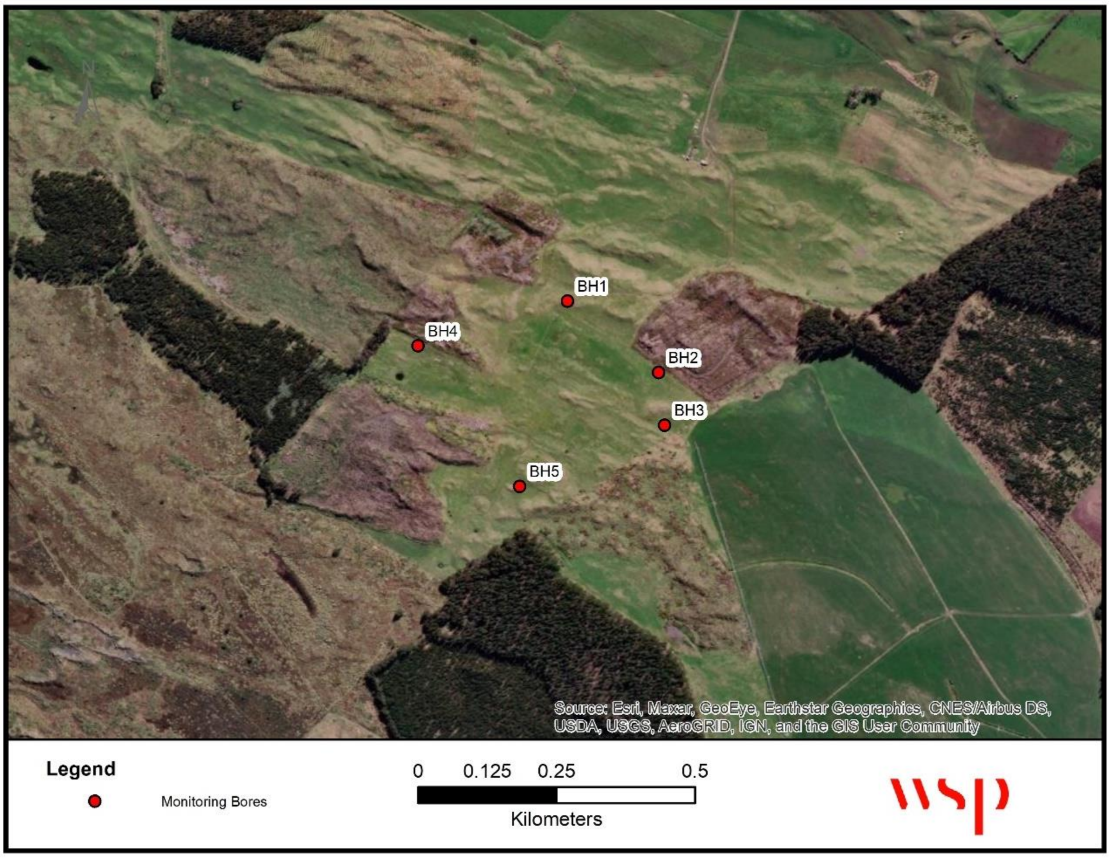

Figure 2-3: Location of monitoring bores installed on the proposed irrigation site.

Table 2-3: Ground level reduced levels and corrected groundwater reduced level for each site in Rātana.

	Ground RL (m)	Reduced water level (m RL) and distance below ground level (in brackets (m))			
		1/9/22	8/9/22	15/9/22	Average
Bore 1	14	11.648 (2.352)	11.615 (2.385)	11.635 (2.365)	11.633 (2.367)
Bore 2	13	11.918 (1.082)	11.895 (1.105)	11.950 (1.050)	11.921 (1.079)
Bore 3	14	13.900 (0.100)	13.876 (0.124)	13.930 (0.070)	13.902 (0.098)
Bore 4	10	9.409 (0.591)	9.405 (0.595)	9.430 (0.570)	9.415 (0.585)
Bore 5	14	12.280 (1.720)	12.255 (1.745)	12.270 (1.730)	12.268 (1.732)

Groundwater contours were derived for the site to indicate the groundwater flow paths. The water level at each point were reduced using the 1 m DEM data available for this site, providing a reduced water level relative to the NZVD2016 datum. The groundwater levels were contoured using AnAqSim modelling and are illustrated in Section 3.2.

2.3.3 Onsite Groundwater Quality

The groundwater from the five site-specific bores were sampled and analysed for a suite of parameters as baseline information on the quality of the groundwater at the site. The parameters were selected based on typical quality of wastewater, to allow for monitoring of changes in water quality that might result from the wastewater infiltration. Three sampling and analyses rounds were undertaken in September 2022, and the results of the analyses are summarised in Table 2-4, further details on the groundwater quality analyses are contained in Appendix B. The quality of groundwater varies across the site, with Bore 3 having the lowest average total Kjeldahl nitrogen (TKN), total suspended solids, and pH, but high conductivity and chloride. In contrast Bore 5, which is closest to the coast has high total suspended solids, chloride, total ammoniacal nitrogen, and conductivity. The variation across the site is likely a result of the influence of both the surrounding land uses and the dominant groundwater flow paths as described in Section 3.2. Bore 1 and two also have elevated Nitrate-Nitrogen concentrations compared to the remaining three bores on the site. The median nitrate concentration of shallow unconfined aquifers in New Zealand is 2.8mg/L, therefore all of the groundwater samples had a mean nitrate value of below this median value (MfE, 2007).

Table 2-4: Average groundwater quality from five bores at the proposed irrigation site between 1st and 15th September 2022.

	Bore 1	Bore 2	Bore 3	Bore 4	Bore 5
Total Suspended Solids (g/m^3)	423	703	32	453	727
Chloride (g/m^3)	13	36	66	38	64
Total Kjeldahl Nitrogen (TKN) (g/m^3)	1.33	1.18	0.41	1.05	0.92
Total Phosphorous (g/m^3)	0.39	0.45	0.0423	0.40	0.25
Carbonaceous Biochemical Oxygen Demand (g O_2/m^3)	< 2	< 2	< 2	< 2	< 2
E.Coli (CFU/100mL)	2	3	2	2	< 1
Total Ammoniacal Nitrogen (g/m^3)	< 0.010	0.022	< 0.010	0.036	0.042
Nitrite-Nitrogen (g/m^3)	0.004	0.045	0.007	0.037	0.013
Nitrate-Nitrogen (g/m^3)	0.82	1.76	0.190	0.150	0.27
Nitrate-Nitrogen + Nitrate-Nitrogen (g/m^3)	0.82	1.79	0.20	0.19	0.29
Dissolved Reactive Phosphorous (g/m^3)	0.041	0.014	< 0.004	0.006	0.006

2.3.4 Conceptual Groundwater Model

A groundwater model has been set-up to estimate groundwater flow direction and flow volumes beneath and downgradient of the wastewater discharge area. The model will be used subsequently to define where irrigation water, that drains through site soils into the underlying groundwater, will flow to. It will also allow the estimation of the change in contaminant concentrations in groundwater beneath the site. The groundwater model has been generated using AnAqSim and is further discussed in Section 3.2 below.

2.4 Surface Water

The proposed site for the wastewater irrigation is approximately 750 m south of the Whangaehu River, 1 km north of the Turakina River, and 985 m east of the coast. The connectivity between groundwater and surface water is an important factor to consider when analysing the actual and potential effects of the proposed wastewater irrigation. The potential effects are further described in Section 3.3.

3 Assessment of actual and potential affects

3.1 Overview

The purpose of this report is to identify any actual and potential effects on the surrounding environment that may occur as a result of the proposed irrigation of wastewater onto land, based on currently known information. A range of analyses have been undertaken to create an understanding of what the baseline groundwater conditions are at the Rātana site as well as to predict any potential effects of the proposed discharges. The potential effects on the groundwater can fall into two broad categories, effects to groundwater quality and effects to groundwater quantity. Due to the proximity of the Rātana site to two surface water bodies (less than 1 km to the north and south) any potential effects on these surface waterbodies as a result of the interaction with groundwater will also need to be considered. Details on the actual or potential effects of the proposed activity are outlined below.

3.2 Effects on Groundwater Quality

3.2.1 Groundwater Model

Effects on groundwater quality need to be determined because the application of wastewater to land can result in infiltration into the groundwater. At the proposed land treatment site (LTA), soils are mostly free draining and groundwater is near to the ground surface i.e. less than 3.0 m bgl. Groundwater levels will also vary seasonally depending on rainfall and recharge. This means that any drainage events (generated from irrigation) will travel quickly and directly to groundwater and therefore a groundwater model is required to determine:

- Groundwater flow volumes so that wastewater that drains to groundwater can be added to the entire system and resulting contaminant concentrations can be calculated and subsequently assessed
- Groundwater flow direction so that flow to nearby surface water receptors such as the Whangaehu and Turakina Rivers can be determined and subsequently assessed.

AnAqSim has been selected to generate a groundwater model to satisfy the above requirements. AnAqSim is an industry standard 3-dimensional analytical elements software package that arranges calculation points, based on the hydrogeological conceptual model of the activity concerned, and seeks to solve groundwater equations (e.g., Darcy, Dupuit) between those calculation points. Activities such as well abstraction, dewatering, stream routing and mounding can be modelled quickly and effectively using AnAqSim.

Given that the site is sandwiched in between two relatively large regional rivers, the Whangaehu and Turakina Rivers, it is assumed that groundwater levels in between them will be constrained by their stage heights and flow will be to the coast. However, this is not strictly observed within the onsite boreholes indicating that some local influence is affecting groundwater levels and flow direction. It is assumed that the topographic high to the southeast, which appears to be an elevated sand dune terrace is creating a local groundwater mound and causing localised groundwater flow towards the northwest.

The groundwater level data obtained from the onsite monitoring bores (BH 1 to BH 5) were used to model the following two scenarios using AnAqSim:

1. Model the groundwater environment that is only constrained by constant head boundaries representing the Whangaehu and Turakina Rivers and the coast to the west. A no-flow boundary has been added between the northern ends of both river boundaries

2. Model the groundwater environment in response to groundwater levels observed in onsite bores, constrained within Scenario 1. model. It is considered that these water levels observed in the onsite monitoring bores are influenced by localised groundwater mounding to the east within the elevated dune sand area. A constant head boundary has been used to elevate groundwater levels locally to model this dune sand mounding effect.

These scenarios have been tested to further improve the understanding of the regional and local groundwater flow direction and ultimate receiving environment of the wastewater application. Both models will estimate flow volumes per day along any line section applied within the model extent.

The AnAqSim inputs and conditions are listed below:

- A steady state model has been used.
- The model is bounded by three constant head boundaries to represent the rivers to the north and south, and the coast to the west. The coast has been set at sea level (0 m RL) and variations due to tidal influence have not been considered. The stage height of both rivers increase to approximately 5 m RL at a distance of approximately 1 km, which is at the same relative distance from the coast as the LTA. The stage heights then increase further upstream to 20 m RL at approximately 6.2 km from the coast, for both rivers. The stage heights at 1 km inland were estimated from LINZ LiDAR data, whilst the NZ topographic series maps were used for the upgradient stage height level.
- The model is set to unconfined, with a specific yield of 0.1 and a horizontal hydraulic conductivity of 22 m/day, which has been calculated using the weighted mean from the four slug tests undertaken at the site. Anisotropy (vertical hydraulic conductivity relative to the horizontal hydraulic conductivity) has been set at 10% of the horizontal conductivity (22 m/day), which is a default ratio for an environment typical of the proposed LTA.
- The layer thickness of the model, which is the silty sands observed in the onsite bores has been effectively set to 10 m, hence the bottom of the layer has been set to 0 m RL. This allows for a conservative assessment of effects because the dune sands are likely thicker and deeper. If dune sands were thicker and deeper, the flow of groundwater would be greater, given that there would be a greater volume of soil to contain the groundwater flow. This is an important condition to consider when interpreting the model outputs.

The river boundary only constrained model (scenario 1) is presented in Figure 3-1 below. The results indicate groundwater flow directly from the LTA to the coast, in a south-westerly direction.

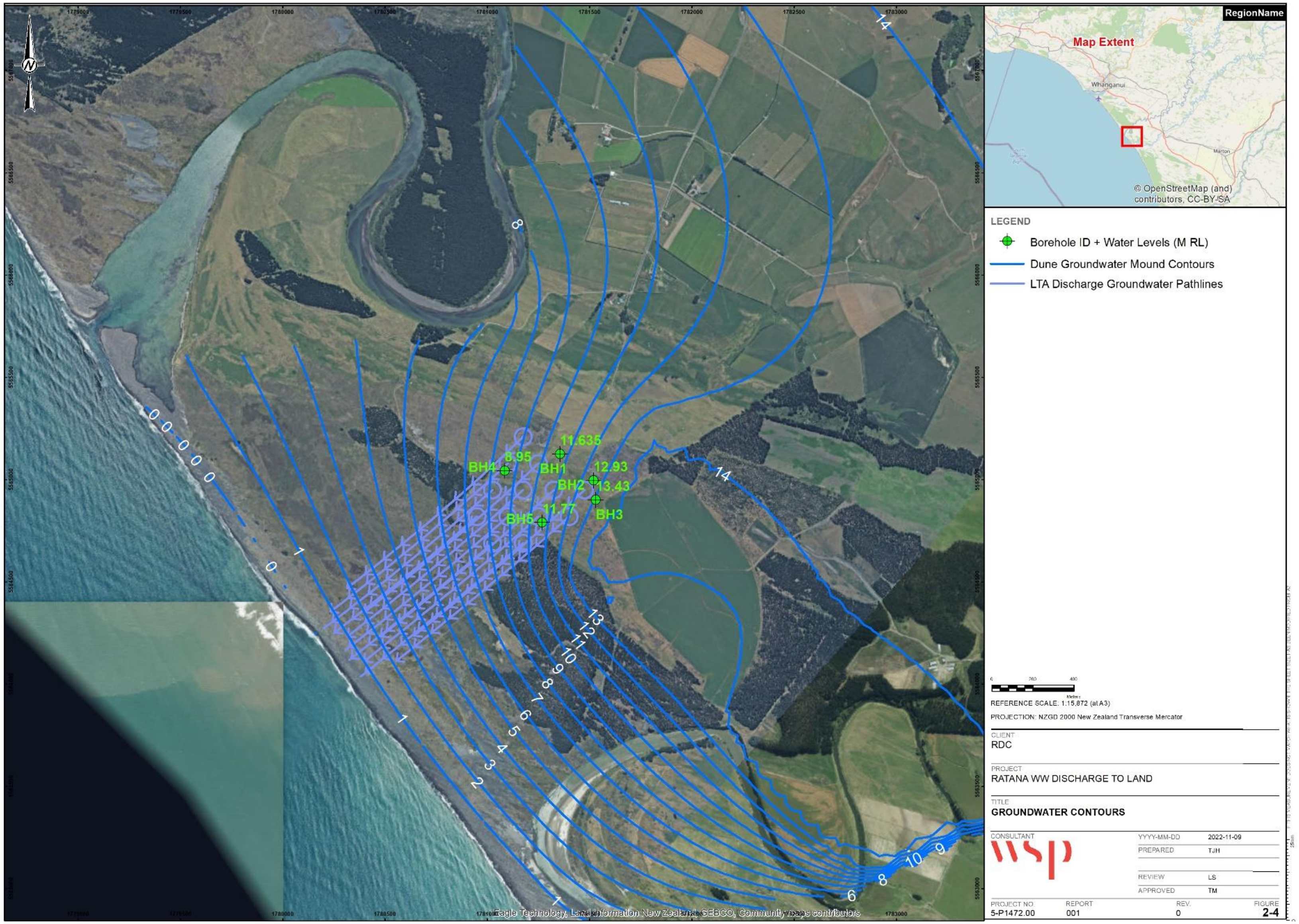

Figure 3-1: Groundwater contours indicating groundwater flow direction at the Rātana site.

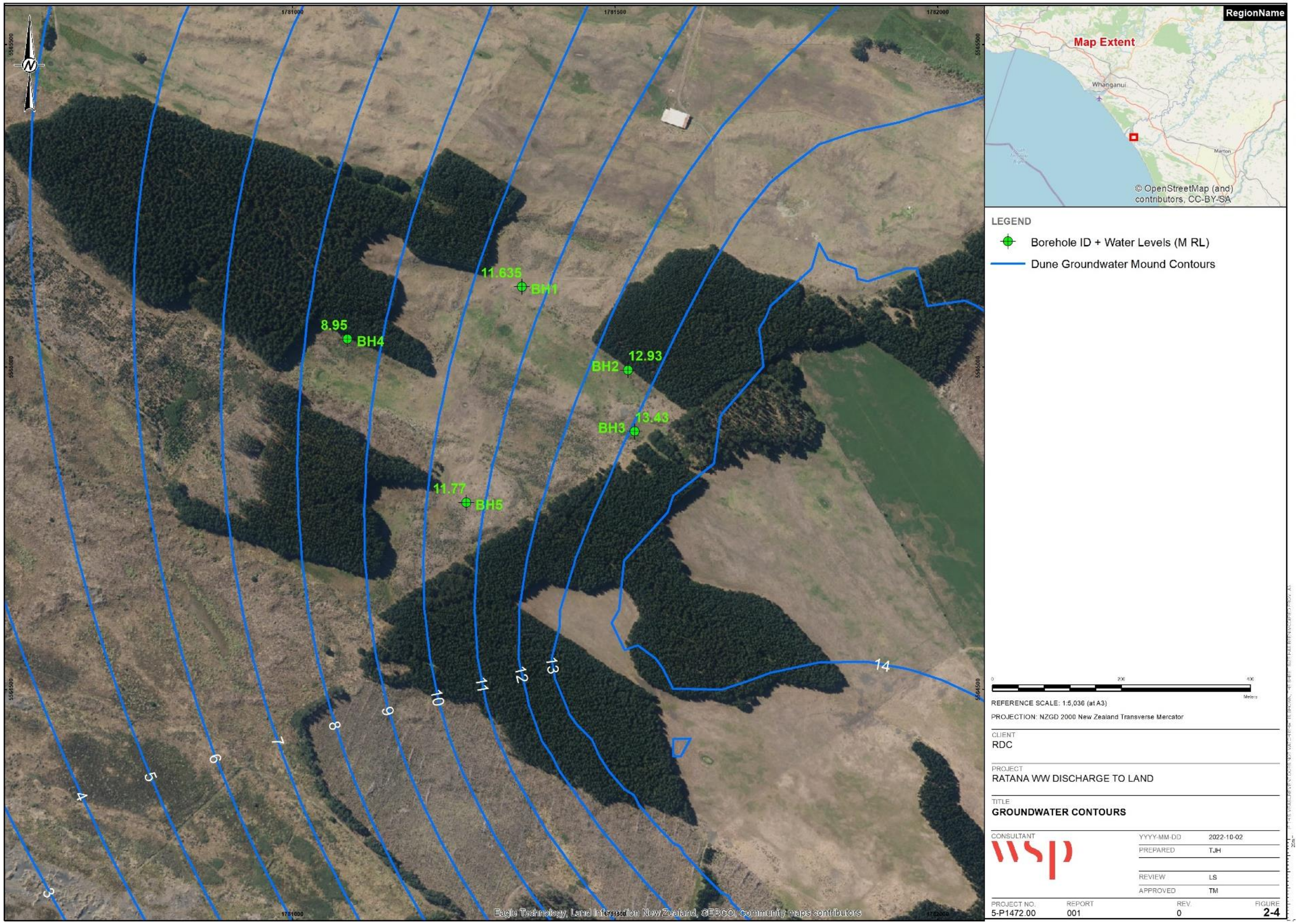

Figure 3-2: Rātana Groundwater Contours with nearby Dune Sand Mounding Influence.

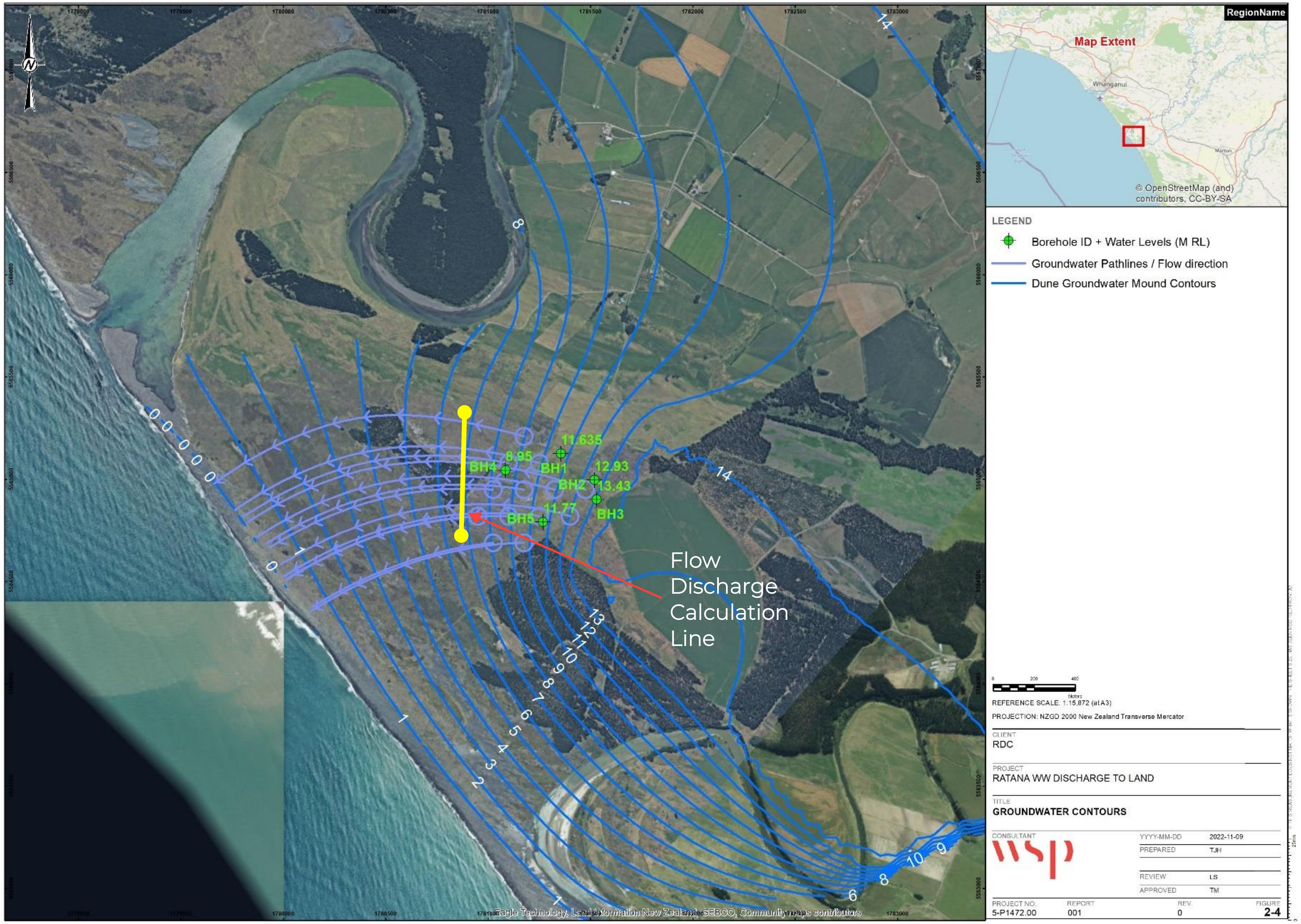

Figure 3-3. Rātana Groundwater contours and flow direction due to nearby dune sand mounding effects.

The measured groundwater levels on site does not agree with the groundwater contours presented in Figure 3-1. The measured water levels are much higher than the groundwater contours generated, and it is considered that the elevated terrace to the southeast of the site is locally influencing the groundwater levels due to mounding groundwater beneath the terrace itself, indicating a localised topographic control on groundwater. A constant head boundary has been added and adjusted to approximate groundwater levels within the onsite monitoring bores due to the dune sand localised mounding effect. The water level contours generated using this constant head boundary for the terrace agree with the measured water levels as presented in Figure 3-2 above.

This adjustment in groundwater levels across the proposed LTA results in a change in groundwater flow direction and flow paths. The groundwater flows initially towards the northwest before changing to a westerly flow direction, which is considered the regional groundwater flow to the coast, controlled by stage heights in both the Whangaehu and Turakina Rivers. These flow paths are presented as red lines with source origin in the proposed LTA field in Figure 3-3. Each tick-mark on the flow line represents one year of travel time, indicating that discharge from the LTA takes approximately 6 to 9 years to travel to the coast.

A discharge line, indicated in Figure 3-3 was drawn across the field flow paths to estimate the volume of groundwater flow travelling through the proposed LTA field. This volume was calculated in the model to be approximately 4,300 m^3/day, based on an aquifer thickness of approximately 10 m and the aquifer parameters and assumptions outlined in the model description above.

3.2.2 Nitrogen

Non-deferred irrigation (non-deficit) is proposed to occur in the months of April, September, October and November during a median rainfall year. Periods of deficit irrigation and storage have been ignored for this assessment as it is presumed that no drainage to groundwater will occur during these times. Wastewater volumes generated in the remaining months will either be stored or irrigated when deficit irrigation can be achieved. The potential nitrate loadings during these four months are presented in Table 3-1 below. Calculations for these loadings are presented in the accompanying irrigation report that discuss the assimilation of wastewater nutrients into either a pasture or woody vegetation system.

Table 3-1: Non-deficit nitrate loading in a median rainfall year.

Month	*Nitrate Loading (kg/day)*
September	*2.77*
October	*1.81*
November	*3.09*

These loadings have been added to the current groundwater concentrations and flow volumes. These nitrate additions are not leachate concentrations from the root zone, which are likely to be significantly less than the loadings listed in Table 3-1 above.

It has been assumed that the pre-wastewater application state concentration of nitrate (baseline) flowing in groundwater underneath the proposed LTA is estimated as the average concentration within downgradient bores BH1, BH4 and BH5, which is 0.43 mg/L of nitrate.

The cumulative nitrate concentration in the groundwater resulting from the addition of nitrate due to non-deficit irrigation in the months of April, September, October and November have been calculated and are presented in Table 3-2 below:

Table 3-2: Groundwater Nitrate-Nitrogen Concentrations after Wastewater Irrigation.

Month	Groundwater Flow (m^3/day)	Nitrate-Nitrogen (mg/L)	Nitrate-Nitrogen (kg/day)	Nitrate-Nitrogen Applied (kg/day)	Cumulative Nitrate-Nitrogen Concentration (mg/L)
September	4,342	0.43	1.87	3.4	1.06
October	4,342	0.43	1.87	4.39	0.84
November	4,342	0.43	1.87	7.15	1.14

Drinking water toxicity is the main concern for nitrate when it comes to assessing groundwater effects of nitrate-nitrogen. Based on the Drinking Water Standards of New Zealand (MoH, 2018), the Maximum Allowable Value (MAV) for nitrate-nitrogen is 11.3 mg/L. The maximum increase in nitrate-nitrogen concentration in the groundwater is 1.64 mg/L up from 0.43 mg/L in November, giving a total of 2.07 mg/L. This is well below the MAV value of 11.3 mg/L. The effect of nitrate concentration increases in receiving groundwater downgradient of the proposed LTA is therefore small.

3.2.3 Microbial contamination

Escherichia coli (E. coli) is an organism found in the intestines of warm-blooded animals and are used as an indicator of possible sewage contamination in groundwater. *E-coli* counts are low in the groundwater from the new bores (<1-3), however *E. coli* is present in the shallow groundwater already, however the source of this has not been defined, and is not part of this study. The DWSNZ specify an MAV of <1 CPU, hence the groundwater currently does not comply with the DWSNZ. When irrigation at the LTA occurs, groundwater levels are likely to be well below the surface providing approximately 1.5 m of unsaturated sandy soils. This thickness of soil will likely attenuate most of the bacterial contamination before drainage water intercepts groundwater and it is understood (Moore et al, 2010 and Seitz et al, 2011) that saturated groundwater in the sand environment also has the ability to attenuate microbes (viral and bacterial). The infiltration of wastewater during non-deficit irrigation is thus considered unlikely to add to the microbiological count in the groundwater and the effects on groundwater quality are thus considered negligible.

Effects on groundwater beneath the coastal (beach) margin if encountered by beach recreators are considered very small. The water within the sand is not likely to be used for drinking and tolerance of microbial counts for contact recreation is much higher. In addition, groundwater is estimated (Figure 3-3) to take at least 6 years to travel to the coastal margin from the proposed LTA (Section and this will provide enough time for viral and bacterial contamination to attenuate and die off before reaching the beach.

Effects due to microbial contamination of the groundwater as a result of wastewater application to land at the proposed land treatment area are thus considered small.

3.2.4 Phosphorus

Phosphorus is generally considered not mobile in groundwater and depending on the form may be able to be taken up by plants. The effects on groundwater due to the application of phosphorus are considered to be small.

3.3 Effects on Surface Water

The irrigated wastewater may travel to nearby surface water via groundwater pathways However, given that the groundwater quality is unlikely to change significantly, as well as the distance of these water bodies from the site, any likelihood of effect on the water quality of these water features are considered to be low. For example, the Whangaehu River is approximately 750 m to the north of the site, and the Turakina River is approximately 1 km to the south. Groundwater modelling (Figure 3-3) suggests that flow will not travel to either river. This will reduce the already low risk of contamination even further.

The regular monitoring of groundwater at five locations within the site will allow some advanced warning if water quality begins to degrade. The groundwater monitoring network layout and the understanding of groundwater flow paths and gradients is considered sufficient to allow for surface water sources that might be affected by potential degradation in groundwater quality as a result of the irrigated wastewater to be identified and monitored as a mitigation measure in future, should this be required.

3.4 Effects on Groundwater Levels

Given the high hydraulic conductivities of the soils underlying the LTA and the associated high infiltration capacity of the soils, groundwater mounding (elevation in groundwater levels beneath the LTA) in response to applying 1 mm of irrigation per day when doing non-deficit irrigation (on average over an entire irrigation season) is expected to be negligible.

4 Monitoring Recommendations

- A network of monitoring bores should be maintained on the proposed site to understand the baseline groundwater conditions, both quality and quantity.
- Groundwater samples should be taken from the monitoring bores prior to the start of irrigation to establish baseline conditions as well as three times per year coinciding with the change in irrigation period (deficit, non-deficit, and storage). The parameters sampled should include:
  - Water level
  - Nitrate nitrogen
  - Escherichia coli
  - Dissolved reactive phosphorous
  - Electrical Conductance
  - pH
  - Dissolved Oxygen
- If the difference in average concentration between up and downgradient bores (upgradient bores are Bore 2 and 3, and downgradient are Bores 4 and 5) show an annual mean difference of 2.0 milligrams per litre nitrate-nitrogen over any consecutive two year period from the median of the first 12 months of sampling then increase monitoring and further investigation to determine the cause should be undertaken and mitigation measure put in place.

5 References

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Appendix A

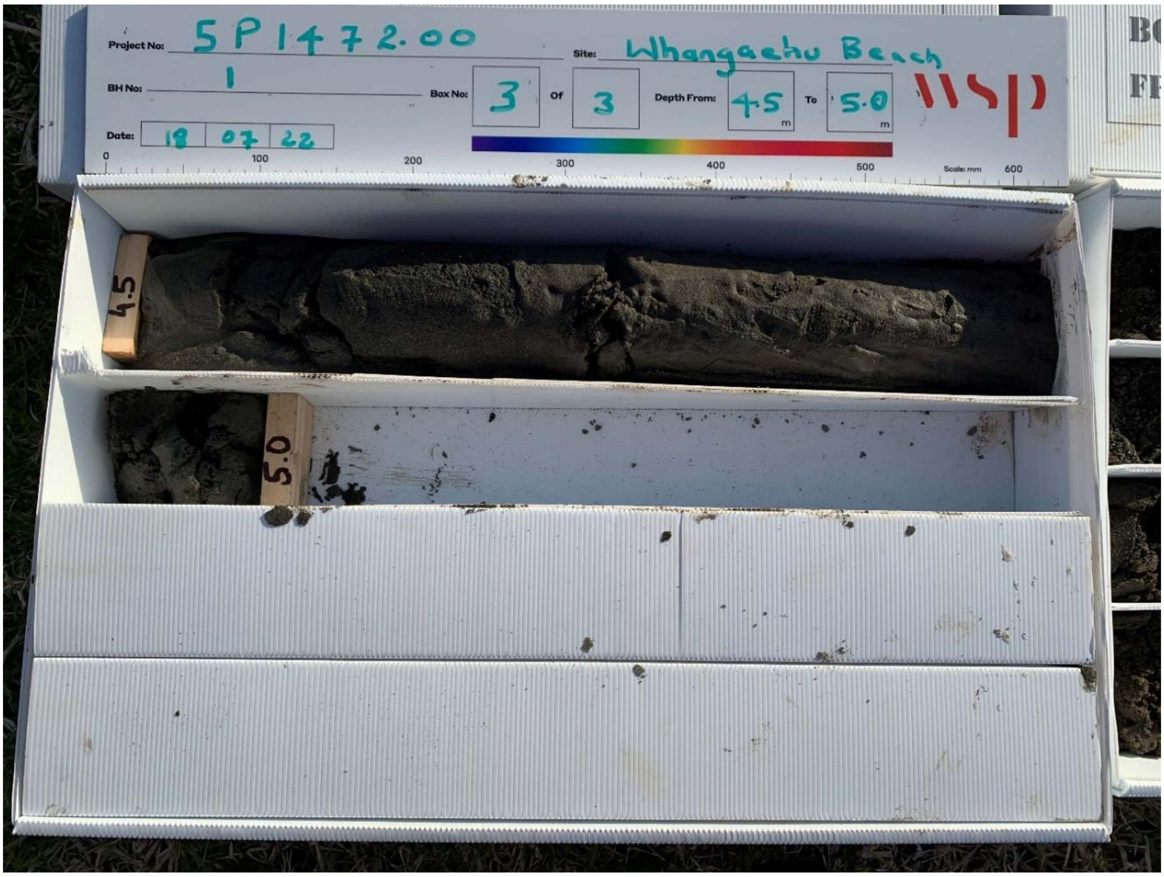
Appendix A

Borehole Logs

BH- 1 Whangaehu Beach

Project No: 5P1472.00
Site: Whangaehu Beach
BH No: 1
Box No: 1 Of 3
Depth From: 0 m To 2.1 m
Date: 18 07 22

Project No: 5P1472.00
Site: Whangaehu Beach
BH No: 1
Box No: 2 Of 3
Depth From: 2.1 m To 4.5 m
Date: 18 07 22



BH-2 Whangaehu Beach

BORE NO: 02 DATE: 18/7/22

Project No: 5P1472.00 Site: Whangaehu Beach

BH No: 2 Box No: 2 of 3 Depth From: 3.45 m To 6.45 m

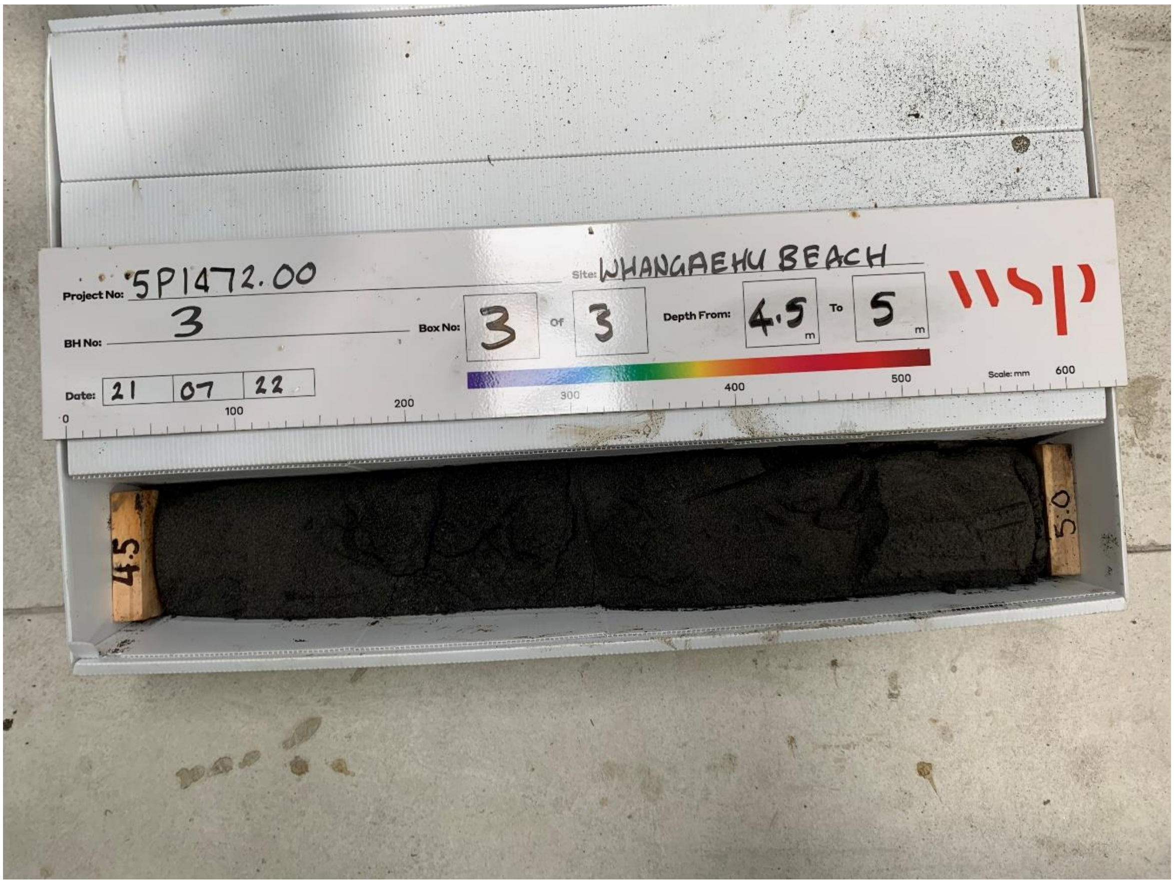
Date: 18 07 22

Project No: 5P1472.00 Site: WHANGAEHU BEACH

BH No: 2 Box No: 3 of 3 Depth From: 6.5 m To 9.5 m

Date: 21 07 22

BH-3 Whangaehu Beach



BH-4 Whangaehu Beach


Project No: 5P1472.00
Site: WHANGAEHU BEACH
BH No: 4
Box No: 2 Of 3
Depth From: 2.1 m To 4.5 m
Date: 21 07 22
wsp
0
100
200
300
400
500
Scale: mm
600
2.1M
3.0M
4.5M


Project No: 5P1472.00
Site: WHANGAEHU BEACH
BH No: 4
Box No: 3 Of 3
Depth From: 4.5 m To 5 m
wsp
4.5
5.0m

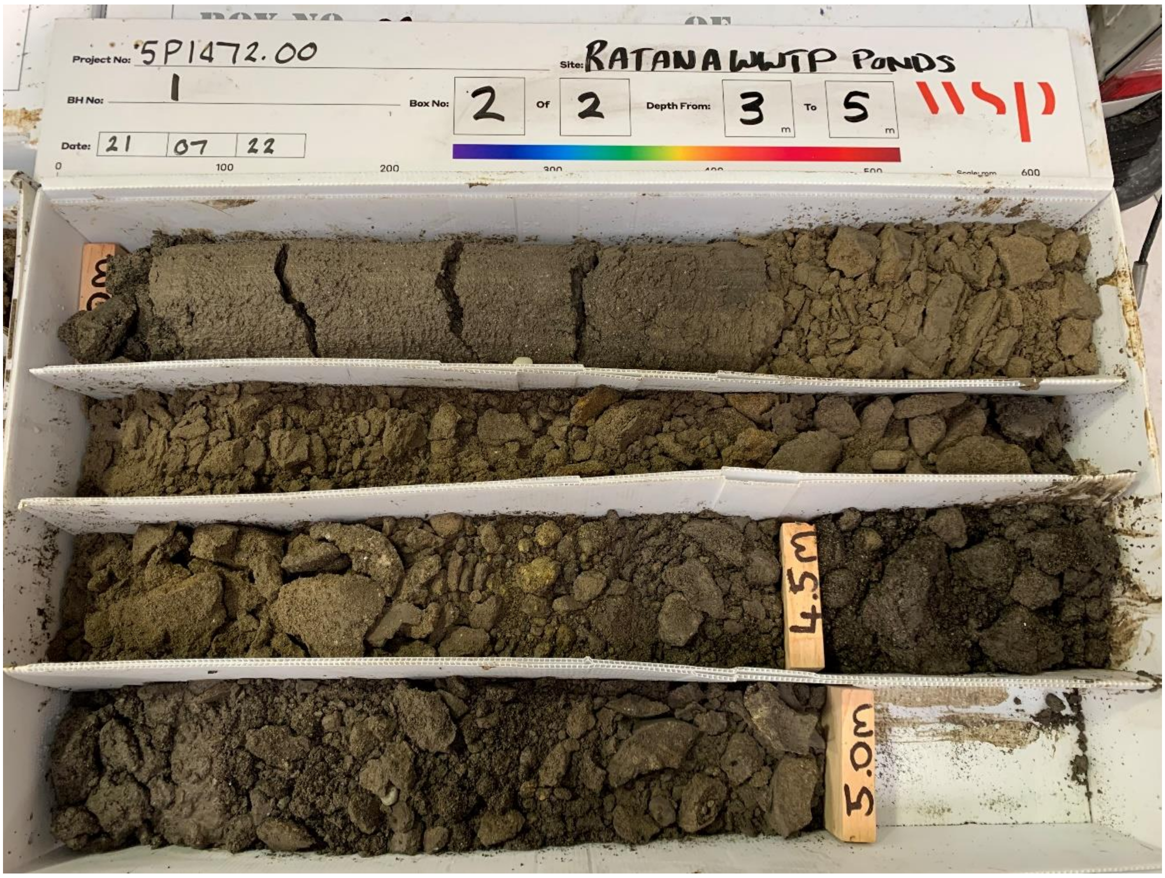
BH-5 Whangaehu Beach

Project No: 5P1472.00
Site: WHANGAEHU BEACH
BH No: 5
Box No: 1 Of 3
Depth From: 0 m To 2.1 m
Date: 21 07 22

BORE NO: 5
BOX NO: 2 OF 3

Project No: 5P1472.00
Site: WHANGAEHU BEACH
BH No: 5
Box No: 2 Of 3
Depth From: 2.1 m To 4.5 m
Date: 21 07 22

BH-1 Ratana WWTP



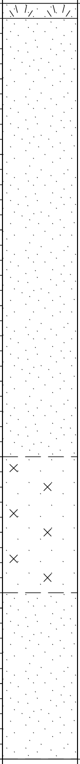
BH-2 Ratana WWTP

Project No: 5P1472.00
Site: RATANA WWTP PONDS
BH No: 2
Box No: 2 Of 3
Depth From: 2.1 m To 4.3 m
Date: 21 07 22

Project No: 5P1472.00
Site: RATANA WWTP PONDS
BH No: 2
Box No: 3 Of 3
Depth From: 4.3 m To 5 m
Date: 21 07 22

Borehole No. BH-1 WHANGAEHU BEACH

Project:	Ratana WWTP	*Coordinates:*	175126 E 40045 N		
Client:	Rangtikei District Council	*Ref. Grid:*	NZTM	*Depth:*	5 m
Project No.:	5-P1472.00	*R.L.:*	Ground Level. 0 m	*Inclination:*	Vertical
Location:	Whangaehu Beach Whangaehu Beach & Ratana WWTP	*Datum:*			



GEOLOGY	MAIN DESCRIPTION / DETAIL DESCRIPTION	R.L. (m)	DEPTH (m)	TESTS: SPT 'N' VALUE	TESTS: SPT BLOW COUNTS OR SHEAR VALUE	CORE: CORE TYPE	CORE: TOTAL CORE RECOVERY (%)	DRILLING: DRILLING METHOD	DRILLING: CASING	DRILLING: BASE OF HOLE & WATER LEVEL	NOTES / OTHER TESTS	INSTALLATION DETAILS
Holocene Active Wind Blown Dune Deposits	Sand with trace of silt, black with rootlets. Loose; moist; non-plastic [Topsoil]					Sonic	100	Sonic core drilling	50mm PVC pipe installed with filter socks and toby caps	SWL 1.50m 18/07		
	SAND with shell fragments, black. Medium Dense; moist; non-plastic. Medium to coarse grain.		1 2									
	Silty Sand with a trace of clay and oragnic material (visable roots). Black; loose-medium; moist; slightly plastic		3									
	SAND, black. Medium Dense; moist; non-plastic. Medium to coarse grain.		4									
	END OF BOREHOLE AT 5m - Target Depth Reached		5 6 7 8 9									

Notes:

Started:	18/07/2022	*Finished:*	18/07/2022
Drilling Co.:	Geotech Drilling	*Drilling Rig:*	Sonic Rig
Logged by:	MC	*Checked by:*	RS

Logged in accordance with NZ Geotechnical Society Guidelines (2005). See attached key sheet for explanation of symbols.

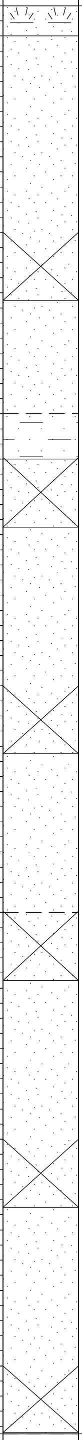
Scale 1:50 @ A4

Borehole No. BH-2 WHANGAEHU BEACH

Project: Ratana WWTP
Client: Rangtikei District Council
Project No.: 5-P1472.00
Location: Whangaehu Beach
Whangaehu Beach & Ratana WWTP

Coordinates: 175128 E 40046 N
Ref. Grid: NZTM
R.L.: Ground Level. 0 m
Datum:

Depth: 9.45 m
Inclination: Vertical



GEOLOGY	MAIN DESCRIPTION / DETAIL DESCRIPTION	SPT 'N' VALUE	SPT BLOW COUNTS OR SHEAR VALUE	CORE TYPE	TOTAL CORE RECOVERY (%)	DRILLING METHOD	CASING	BASE OF HOLE & WATER LEVEL	NOTES / OTHER TESTS	INSTALLATION DETAILS
	Sand with trace of silt, black with rootlets. Loose; moist; non-plastic [Topsoil] SAND with shell fragments, black. Medium Dense; moist; non-plastic. Medium grained.			Sonic	76	Sonic core drilling	50mm PVC pipe installed with filter socks and toby caps			
	Core Loss	13	3// 2/3/4/4	SPT	100			SWL 1.50m 18/07		
Holocene Active Wind Blown Dune Deposits	Sand with trace of silt and clay. Reddish-brown; medium-dense; moist; slightly plastic			Sonic	100					
	Core Loss SAND with shell fragments, black. Medium Dense; moist; non-plastic. Medium grained.	17	5// 3/4/5/5	SPT	90					
				Sonic	100					
	Core Loss	19	1// 4/4/5/6	SPT	30					
				Sonic	85					
	Core Loss SAND, black. Medium Dense; moist; non-plastic. Medium grained.	50+	7// 4/10/17/19	SPT	100					
				Sonic	100					
	Core Loss	28	6// 5/6/8/9	SPT	90					
				Sonic	100					
	Core Loss	49	12// 11/12/12/14	SPT	90					
	END OF BOREHOLE AT 9.45m - Target Depth Reached									

Notes:
SPT

Started: 18/07/2022
Drilling Co.: Geotech Drilling
Logged by: MC

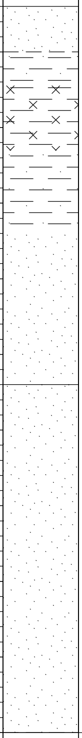
Finished: 18/07/2022
Drilling Rig: Sonic Rig
Checked by: RS

Logged in accordance with NZ Geotechnical Society Guidelines (2005). See attached key sheet for explanation of symbols.

Scale 1:50 @ A4

Borehole No. BH- 3 WHANGAEHU BEACH

Project:	Ratana WWTP	*Coordinates:*	175128 E 40047 N		
Client:	Rangtikei District Council	*Ref. Grid:*	NZTM	*Depth:*	5 m
Project No.:	5-P1472.00	*R.L.:*	Ground Level. 0 m	*Inclination:*	Vertical
Location:	Whangaehu Beach Whangaehu Beach & Ratana WWTP	*Datum:*			



GEOLOGY	MAIN DESCRIPTION / DETAIL DESCRIPTION	R.L. (m)	DEPTH (m)	TESTS: SPT 'N' VALUE	TESTS: SPT BLOW COUNTS OR SHEAR VALUE	CORE: CORE TYPE	CORE: TOTAL CORE RECOVERY (%)	DRILLING: DRILLING METHOD	DRILLING: CASING	DRILLING: BASE OF HOLE & WATER LEVEL	NOTES / OTHER TESTS	INSTALLATION DETAILS
	Sand, dark-grey with rootlets, coarse grained with quartz grains. Moist and firm.											
	SAND, black. Medium Dense; moist; non-plastic. Medium grained.											
Holocene active and stable dune deposits	Silty Sandy Clay. Medium Brown; moist; slightly plastic; dense.					Sonic	100	Sonic core drilling	50mm PVC pipe installed with filter socks and toby caps			
	Silty Clay. Medium Brown; moist; dense; slightly plastic; firm.		1									
	Silty Sandy Clay. Medium Brown; moist-wet; slightly plastic; dense.									SWL 1.00m 19/07		
	SAND, black with red/brown oxidisation. Medium Dense; moist; non-plastic. Medium grained.		2									
	SAND, black. Medium Dense; moist; non-plastic. Medium grained.		3 4									
	END OF BOREHOLE AT 5m - Target Depth Reached		5 6 7 8 9									

Notes:

Started:	19/07/2022	*Finished:*	19/07/2022
Drilling Co.:	Geotech Drilling	*Drilling Rig:*	Sonic Rig
Logged by:	MC	*Checked by:*	RS

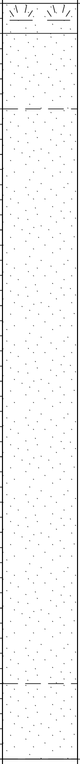
Logged in accordance with NZ Geotechnical Society Guidelines (2005). See attached key sheet for explanation of symbols.

Scale 1:50 @ A4

Borehole No. BH- 4 WHANGAEHU BEACH

Project:	Ratana WWTP	*Coordinates:*	175123 E 40045 N		
Client:	Rangtikei District Council	*Ref. Grid:*	NZTM	*Depth:*	5 m
Project No.:	5-P1472.00	*R.L.:*	Ground Level. 0 m	*Inclination:*	Vertical
Location:	Whangaehu Beach Whangaehu Beach & Ratana WWTP	*Datum:*			

GEOLOGY	MAIN DESCRIPTION / DETAIL DESCRIPTION	R.L. (m)	DEPTH (m)	GRAPHIC LOG	TESTS: SPT 'N' VALUE	TESTS: SPT BLOW COUNTS OR SHEAR VALUE	CORE: CORE TYPE	CORE: TOTAL CORE RECOVERY (%)	DRILLING: DRILLING METHOD	DRILLING: CASING	DRILLING: BASE OF HOLE & WATER LEVEL	NOTES / OTHER TESTS	INSTALLATION DETAILS
	Sand with trace of silt, black with rootlets. Loose; moist; non-plastic [Topsoil]												
	SAND with shell fragments, black. Medium Dense; moist; non-plastic. Medium to coarse grain.												
Holocene Active Wind Blown Dune Deposits	SAND, black. Medium Dense; moist; non-plastic. Medium grain.		1								SWL 1.00m 19/07		
	Becomes wetter and slightly brown		2				Sonic	100	Sonic core drilling	50mm PVC pipe installed with filter socks and toby caps			
			3										
			4										
	SAND, black. Medium Dense; wet; non-plastic. Medium grain.												
	END OF BOREHOLE AT 5m - Target Depth Reached		5										
			6										
			7										
			8										
			9										



Notes:

Started:	19/07/2022	*Finished:*	19/07/2022
Drilling Co.:	Geotech Drilling	*Drilling Rig:*	Sonic Rig
Logged by:	MC	*Checked by:*	RS

Logged in accordance with NZ Geotechnical Society Guidelines (2005). See attached key sheet for explanation of symbols.

Scale 1:50 @ A4

Borehole No. BH- 5 WHANGAEHU BEACH

Project:	Ratana WWTP	*Coordinates:*	175125 E 40048 N		
Client:	Rangtikei District Council	*Ref. Grid:*	NZTM	*Depth:*	5 m
Project No.:	5-P1472.00	*R.L.:*	Ground Level. 0 m	*Inclination:*	Vertical
Location:	Whangaehu Beach Whangaehu Beach & Ratana WWTP	*Datum:*			

GEOLOGY	MAIN DESCRIPTION / DETAIL DESCRIPTION	R.L. (m)	DEPTH (m)	GRAPHIC LOG	TESTS: SPT 'N' VALUE	TESTS: SPT BLOW COUNTS OR SHEAR VALUE	CORE: CORE TYPE	CORE: TOTAL CORE RECOVERY (%)	DRILLING: DRILLING METHOD	DRILLING: CASING	DRILLING: BASE OF HOLE & WATER LEVEL	NOTES / OTHER TESTS	INSTALLATION DETAILS
Holocene Active Wind Blown Dune Deposits	Sand with rootlets. Coarse grained, black and moist						Sonic	100	Sonic core drilling	50mm PVC pipe installed with filter socks and toby caps			
	SAND with shell fragments, black. Medium Dense; moist; non-plastic. Medium to coarse grain.		1 2								SWL 2.10m 19/07		
	Traces of silt and becomes wetter		3										
	SAND, black. Medium Dense; moist; non-plastic. Medium to coarse grain.		4										
	END OF BOREHOLE AT 5m - Target Depth Reached		5 6 7 8 9										

BOREHOLE SOIL LOG A4 - WSP RATANA WWTP BH.GPJ WSP-OPUS2018_TEM.GDT 8/8/22

Notes:

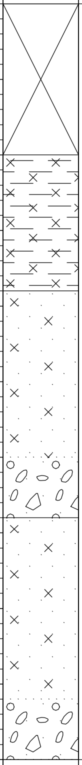
Started:	19/07/2022	*Finished:*	19/07/2022
Drilling Co.:	Geotech Drilling	*Drilling Rig:*	Sonic Rig
Logged by:	MC	*Checked by:*	RS

Logged in accordance with NZ Geotechnical Society Guidelines (2005). See attached key sheet for explanation of symbols.

Scale 1:50 @ A4

Borehole No. BH-1 RATANA WWTP

Project:	Ratana WWTP	*Coordinates:*	175169 E 40040 N		
Client:	Rangtikei District Council	*Ref. Grid:*	NZTM	*Depth:*	5 m
Project No.:	5-P1472.00	*R.L.:*	Ground Level. 0 m	*Inclination:*	Vertical
Location:	Ratana WWTP Whangaehu Beach & Ratana WWTP	*Datum:*			



GEOLOGY	MAIN DESCRIPTION / DETAIL DESCRIPTION	R.L. (m)	DEPTH (m)	GRAPHIC LOG	TESTS: SPT 'N' VALUE	TESTS: SPT BLOW COUNTS OR SHEAR VALUE	CORE: CORE TYPE	CORE: TOTAL CORE RECOVERY (%)	DRILLING: DRILLING METHOD	DRILLING: CASING	DRILLING: BASE OF HOLE & WATER LEVEL	NOTES / OTHER TESTS	INSTALLATION DETAILS
Middle Pleistocene shoreline deposits- Ngarino formation	Hand Auger by drillers												
	Silty sandy Clay. Medium brown; moist, dense; firm; slightly plastic; Becoming more sandy		1										
	Silty sand. Dark grey- slightly brown; medium dense; moist; loose; medium grained.		2				Sonic	80	Sonic core drilling	50mm PVC pipe installed with filter socks and toby caps	SWL 2.00m 19/07		
	Gravel Sand. Dark grey; coarse sand to cobble; moist		3										
	Sand. Meduim to fine grained. Medium brown with Fe concentrations. Moist; friable thin layers of silt sand.		4										
	Gravel sand. Coarse sand to cobble (Scoria and quartz). Moist; friable thin layers of silt sand.												
	END OF BOREHOLE AT 5m - Target Depth Reached		5										
			6										
			7										
			8										
			9										

Notes:

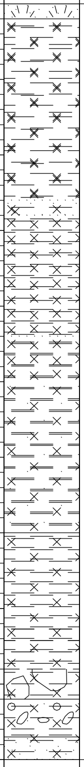
Started:	19/07/2022	*Finished:*	19/07/2022
Drilling Co.:	Geotech Drilling	*Drilling Rig:*	Sonic Rig
Logged by:	MC	*Checked by:*	RS

Logged in accordance with NZ Geotechnical Society Guidelines (2005). See attached key sheet for explanation of symbols.

Scale 1:50 @ A4

Borehole No. BH-2 RATANA WWTP

Project:	Ratana WWTP	*Coordinates:*	175167 E 40040 N		
Client:	Rangtikei District Council	*Ref. Grid:*	NZTM	*Depth:*	5 m
Project No.:	5-P1472.00	*R.L.:*	Ground Level. 0 m	*Inclination:*	Vertical
Location:	Ratana WWTP Whangaehu Beach & Ratana WWTP	*Datum:*			

					TESTS		CORE		DRILLING				
GEOLOGY	MAIN DESCRIPTION / DETAIL DESCRIPTION	R.L. (m)	DEPTH (m)	GRAPHIC LOG	SPT 'N' VALUE	SPT BLOW COUNTS OR SHEAR VALUE	CORE TYPE	TOTAL CORE RECOVERY (%)	DRILLING METHOD	CASING	BASE OF HOLE & WATER LEVEL	NOTES / OTHER TESTS	INSTALLATION DETAILS
Middle Pleistocene Shoreline deposits- Ngarino Formation	Clayey Silt with rootlets and cobbles. Dark Brown; moist; firm Silty Clay. Meduim brown with Fe oxidation and light grey laminations; moist; firm; dense; low plasticity. Silty Sand. Moist; Medium brown. Silty Clay. Light brown-grey. Moist; dense; firm; medium plasticity. Becomes wetter Coarse sandy silty Clay. Medium brown; moist; dense; firm; medium plasticity. Clay. Grey-Blue, dense moist Becomes more clay like; medium plasticity; firm-stiff; dense; moist Cobble layer [10-80mm dia] Silty Gravel grading into a sandy gravel. Moist and loose Clay. Light grey- blue. soft; moist; dense. Sand. Dark brown; medium grain; moist; loose. END OF BOREHOLE AT 5m - Target Depth Reached		1 2 3 4 5 6 7 8 9				Sonic	100	Sonic core drilling	50mm PVC pipe installed with filter socks and toby caps			

Notes:

Started:	20/07/2022	*Finished:*	20/07/2022
Drilling Co.:	Geotech Drilling	*Drilling Rig:*	Sonic Rig
Logged by:	MC	*Checked by:*	RS

Logged in accordance with NZ Geotechnical Society Guidelines (2005). See attached key sheet for explanation of symbols.

Scale 1:50 @ A4

Appendix B

Hill Laboratories
TRIED, TESTED **AND TRUSTED**

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

T 0508 HILL LAB (44 555 22)
T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis

Client:	WSP New Zealand Limited	**Lab No:**	3077898	SPv1
Contact:	G Hamblyn C/- WSP New Zealand Limited PO Box 654 Whanganui 4540	**Date Received:**	16-Sep-2022	
		Date Reported:	27-Sep-2022	
		Quote No:	119466	
		Order No:		
		Client Reference:	Whangaehu Beach	
		Submitted By:	G Hamblyn	

Sample Type: Aqueous

Sample Name:		WB-BH-1 5m depth 15-Sep-2022 10:00 am	WB-BH-2 7m depth 15-Sep-2022 10:20 am	WB-BH-3 5m depth 15-Sep-2022 10:45 am	WB-BH-4 5m depth 15-Sep-2022 9:15 am	WB-BH-5 5m depth 15-Sep-2022 9:40 am
Lab Number:		3077898.1	3077898.2	3077898.3	3077898.4	3077898.5
Individual Tests						
Total Suspended Solids	g/m^3	620	420	12	360	370
Chloride	g/m^3	14.3	33	66	33	67
Total Kjeldahl Nitrogen (TKN)	g/m^3	1.48	1.20	0.44	0.93	0.71
Total Phosphorus	g/m^3	0.59	0.56	0.022	0.41	0.120
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$)	g O_2/m^3	< 2 [#1]	< 2 [#1]	< 2 [#1]	< 2 [#1]	< 2 [#1]
Escherichia coli	cfu / 100mL	2 [#2]	4 [#2]	5 [#2]	3 [#2]	< 1 [#2]
Nutrient Profile						
Total Ammoniacal-N	g/m^3	< 0.010	0.018	0.011	< 0.010	0.014
Nitrite-N	g/m^3	0.004	0.033	0.011	0.042	0.009
Nitrate-N	g/m^3	0.67	1.60	0.24	0.179	0.28
Nitrate-N + Nitrite-N	g/m^3	0.68	1.64	0.25	0.22	0.29
Dissolved Reactive Phosphorus	g/m^3	0.045	0.012	< 0.004	0.009	< 0.004

Analyst's Comments

[#1] Due to unexpected sample numbers and limited resources, we were unable to commence the carbonaceous Biochemical Oxygen Demand(cBOD5) analyses on the day that they arrived at the laboratory. The analysis was performed, as soon as possible, on the frozen sample.

[#2] Statistically estimated count based on the theoretical countable range for the stated method.
Please interpret this microbiological result with caution as the sample was >24 hours old on receipt at the lab. The sample is required to reach the laboratory with sufficient time to allow testing to commence within 24 hours of sampling.
Please interpret this result with caution as the sample was > 10 °C on receipt at the lab. The sample temperature is recommended by the laboratory's reference methods to be less than 10 °C on receipt at the laboratory (but not frozen). However, it is acknowledged that samples that are transported quickly to the laboratory after sampling, may not have been cooled to this temperature.

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	**Method Description**	**Default Detection Limit**	**Sample No**
Nutrient Profile		0.0010 - 0.010 g/m^3	1-5
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-5
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D (modified) 23rd ed. 2017.	3 g/m^3	1-5

This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised.
The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked * or any comments and interpretations, which are not accredited.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.5 g/m³	1-5
Total Ammoniacal-N	Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) 23rd ed. 2017.	0.010 g/m³	1-5
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m³	1-5
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	1-5
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m³	1-5
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N_{org} D (modified) 4500 NH_3 F (modified) 23rd ed. 2017.	0.10 g/m³	1-5
Dissolved Reactive Phosphorus	Filtered sample. Molybdenum blue colourimetry. Flow injection analyser. APHA 4500-P G (modified) 23rd ed. 2017.	0.004 g/m³	1-5
Total Phosphorus	Total phosphorus digestion, automated ascorbic acid colorimetry. Flow Injection Analyser. APHA 4500-P H (modified) 23rd ed. 2017.	0.002 g/m³	1-5
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$)	Incubation 5 days, DO meter, nitrification inhibitor added, seeded. APHA 5210 B (modified) 23rd ed. 2017.	2 g O_2/m³	1-5
Escherichia coli	Membrane filtration, Count on mFC agar, Incubated at 44.5°C for 22 hours, MUG Confirmation. APHA 9222 I 23rd ed. 2017.	1 cfu / 100mL	1-5

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 20-Sep-2022 and 27-Sep-2022. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

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Graham Corban MSc Tech (Hons)
Client Services Manager - Environmental

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Certificate of Analysis

Client:	WSP New Zealand Limited	**Lab No:**	3067603 SPv1
Contact:	G Hamblyn C/- WSP New Zealand Limited PO Box 654 Whanganui 4540	**Date Received:**	02-Sep-2022
		Date Reported:	12-Sep-2022
		Quote No:	119466
		Order No:	
		Client Reference:	Whangaehu Beach
		Submitted By:	G Hamblyn

Sample Type: Aqueous

Sample Name:		WB-BH-1 5m depth 01-Sep-2022 1:00 pm	WB-BH-2 7m depth 01-Sep-2022 1:40 pm	WB-BH-3 5m depth 01-Sep-2022 2:20 pm	WB-BH-4 5m depth 01-Sep-2022 11:00 am	WB-BH-5 5m depth 01-Sep-2022 11:45 am
Lab Number:		3067603.1	3067603.2	3067603.3	3067603.4	3067603.5
Individual Tests						
Total Suspended Solids	g/m^3	400	360	16	270	940
Chloride	g/m^3	11.3	42	66	39	59
Total Kjeldahl Nitrogen (TKN)	g/m^3	1.01	0.97	0.31	0.95	1.34
Total Phosphorus	g/m^3	0.34	0.33	0.027	0.24	0.31
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$)	$g\ O_2/m^3$	< 2	< 2	< 2	< 2	< 2
Escherichia coli	cfu / 100mL	< 1 [#1]	4 [#1]	1 [#1]	1 [#1]	< 1 [#1]
Nutrient Profile						
Total Ammoniacal-N	g/m^3	< 0.010	0.036	< 0.010	0.070	0.085
Nitrite-N	g/m^3	< 0.002	0.058	0.004	0.028	0.018
Nitrate-N	g/m^3	1.03	1.27	0.121	0.032	0.32
Nitrate-N + Nitrite-N	g/m^3	1.03	1.32	0.124	0.060	0.34
Dissolved Reactive Phosphorus	g/m^3	0.038	0.016	< 0.004	0.004	0.009

Analyst's Comments

[#1] Statistically estimated count based on the theoretical countable range for the stated method.

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Nutrient Profile		0.0010 - 0.010 g/m^3	1-5
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-5
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D (modified) 23rd ed. 2017.	3 g/m^3	1-5
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.5 g/m^3	1-5
Total Ammoniacal-N	Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) 23rd ed. 2017.	0.010 g/m^3	1-5
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m^3	1-5
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	1-5
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m^3	1-5

This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised. The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked * or any comments and interpretations, which are not accredited.

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N_{org} D (modified) 4500 NH_3 F (modified) 23rd ed. 2017.	0.10 g/m^3	1-5
Dissolved Reactive Phosphorus	Filtered sample. Molybdenum blue colourimetry. Flow injection analyser. APHA 4500-P G (modified) 23rd ed. 2017.	0.004 g/m^3	1-5
Total Phosphorus	Total phosphorus digestion, automated ascorbic acid colorimetry. Flow Injection Analyser. APHA 4500-P H (modified) 23rd ed. 2017.	0.002 g/m^3	1-5
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$)	Incubation 5 days, DO meter, nitrification inhibitor added, seeded. APHA 5210 B (modified) 23rd ed. 2017.	2 g O_2/m^3	1-5
Escherichia coli	Membrane filtration, Count on mFC agar, Incubated at 44.5°C for 22 hours, MUG Confirmation. APHA 9222 I 23rd ed. 2017.	1 cfu / 100mL	1-5

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 03-Sep-2022 and 12-Sep-2022. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

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Carole Rodger-Carroll

Carole Rodgers-Carroll BA, NZCS
Client Services Manager - Environmental

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Certificate of Analysis

SPv1

Client: WSP New Zealand Limited
Contact: G Hamblyn
C/- WSP New Zealand Limited
PO Box 654
Whanganui 4540

Lab No: 3072642
Date Received: 09-Sep-2022
Date Reported: 22-Sep-2022
Quote No: 119466
Order No:
Client Reference: Whangaehu Beach
Submitted By: G Hamblyn

Sample Type: Aqueous

Sample Name:		WB-BH-1 5m depth 08-Sep-2022 10:40 am	WB-BH-2 7m depth 08-Sep-2022 11:20 am	WB-BH-3 5m depth 08-Sep-2022 11:40 am	WB-BH-4 5m depth 08-Sep-2022 9:45 am	WB-BH-5 5m depth 08-Sep-2022 10:15 am
Lab Number:		3072642.1	3072642.2	3072642.3	3072642.4	3072642.5
Individual Tests						
Total Suspended Solids	g/m^3	250	1,330	69	730	870
Chloride	g/m^3	13.4	34	67	41	66
Total Kjeldahl Nitrogen (TKN)	g/m^3	1.50	1.38	0.48	1.26	0.71
Total Phosphorus	g/m^3	0.23	0.47	0.078	0.56	0.32
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$)	g O_2/m^3	< 2 [#1]	< 2 [#1]	< 2 [#1]	< 2 [#1]	< 2 [#1]
Escherichia coli	cfu / 100mL	< 1 [#2]	2 [#2]	1 [#2]	1 [#2]	< 1 [#2]
Nutrient Profile						
Total Ammoniacal-N	g/m^3	< 0.010	0.011	< 0.010	0.028	0.028
Nitrite-N	g/m^3	0.007	0.044	0.005	0.041	0.011
Nitrate-N	g/m^3	0.75	2.4	0.21	0.24	0.22
Nitrate-N + Nitrite-N	g/m^3	0.76	2.4	0.22	0.28	0.23
Dissolved Reactive Phosphorus	g/m^3	0.040	0.013	< 0.004	0.004	< 0.004

Analyst's Comments

[#1] The initial result for carbonaceous Biochemical Oxygen Demand ($cBOD_5$) was below detection limit due to over-dilution of the sample. In order to achieve a lower detection limit the $cBOD_5$ analysis was repeated on a sub-sample that had been stored frozen, using a larger volume.

[#2] Statistically estimated count based on the theoretical countable range for the stated method.

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Nutrient Profile		0.0010 - 0.010 g/m^3	1-5
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-5
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D (modified) 23rd ed. 2017.	3 g/m^3	1-5
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.5 g/m^3	1-5
Total Ammoniacal-N	Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) 23rd ed. 2017.	0.010 g/m^3	1-5
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m^3	1-5

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	1-5
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m^3	1-5
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N_{org} D (modified) 4500 NH_3 F (modified) 23rd ed. 2017.	0.10 g/m^3	1-5
Dissolved Reactive Phosphorus	Filtered sample. Molybdenum blue colourimetry. Flow injection analyser. APHA 4500-P G (modified) 23rd ed. 2017.	0.004 g/m^3	1-5
Total Phosphorus	Total phosphorus digestion, automated ascorbic acid colorimetry. Flow Injection Analyser. APHA 4500-P H (modified) 23rd ed. 2017.	0.002 g/m^3	1-5
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$)	Incubation 5 days, DO meter, nitrification inhibitor added, seeded. APHA 5210 B (modified) 23rd ed. 2017.	2 g O_2/m^3	1-5
Escherichia coli	Membrane filtration, Count on mFC agar, Incubated at 44.5°C for 22 hours, MUG Confirmation. APHA 9222 I 23rd ed. 2017.	1 cfu / 100mL	1-5

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 10-Sep-2022 and 22-Sep-2022. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

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Kim Harrison MSc
Client Services Manager - Environmental