RAVENSDOWN STORMWATER AND PROCESS WATER DISCHARGE - LAND DISCHARGE EFFECTS AND MANAGEMENT

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Executive Summary

Ravensdown Limited have developed a water discharge strategy relating to the continued management of stormwater from its Napier Works. The discharge strategy has been developed to support a consent renewal process for stormwater and process water that is discharged from Site. The current consent expires 31 May 2022.

Ravensdown has formed a Technical Focus Group (TFG) (formed with representatives from key stakeholder groups) to assist in the assessment of various options to manage the ongoing effects of stormwater and process water from Site. To guide the assessment of options the TFG agreed the following objective:

To establish the most sustainable long-term solution for the treatment and discharge of stormwater and process water from the Ravensdown Napier Works to enable the continued operation of the site

As a result of this process a water discharge strategy has been developed, which includes the preferential discharge to land, following treatment. This assessment forms part of that strategy and specifically relates to the discharge of treated stormwater and process water to land and the operational management of a cut and carry system to remove or bind any residual contaminants.

Potential Effects Covered

The potential effects covered within this assessment are.

- The loss or potential loss of applied contaminants to the confined aquifer.
- The capacity within the site to effectively manage stormwater applications in a manner that accommodates the volumes expected from the treatment process.
- Whether the site has any inherent characteristics that would deem it unsuitable for the proposed activity.

Assessment undertaken

This report assesses several aspects of the proposed process against the TFG objective. Specifically, these include:

- An assessment of soils for suitability for irrigation and potential contaminant loading. This assessment included the digging of test pits to confirm on site soil conditions to depth, analysis of the soil profile to various rooting depths to ascertain available water capacity and electromagnetic mapping of the site to determine soil heterogeneity.
- Baseline monitoring to account for current soil loadings through the establishment of monitor soil test transects that represent historical use and potential soil fertility status.
- Investigations relating to sub regional geology (as relates to ground water) and on-site investigation to ascertain on site conditions. Bore logs from a range of neighbouring bores used for agricultural and drinking water were reviewed and two test pits were dug on site to confirm local conditions.
- Analysis of the projected load of contaminants reviewed against baseline soil loadings and properties.
- A review of monitoring protocols to guide adaptive management of site going forward

Results of assessments

An assessment of soils for suitability for irrigation and potential contaminant loading

Key aspects of the soil on the proposed discharge site were examined. Test pits were dug, and soil textural assessment was completed. The soils on the site have high Available Water Capacity (AWC) and no limitation to rooting depth in the top 1.2 meters. The soils are predominately silt based and largely consistent across the site. The capacity of the soils to absorb and retain the proposed contaminant loading is adequate for the foreseeable future (decades).

The soils on site are of reasonably uniform parent material and function.

Baseline monitoring to account for current soil loadings

A comprehensive soil testing regime was initiated across the site based on historical use. The results have shown that pH, Olsen P, extractable cations (e.g., QTK = Quicktest K) and soil sulphur all exceed the optimum ranges (Table 1) by a considerable amount. Therefore, there are no soil fertility limitations for the use of this site for the purpose of a cut and carry system. Indeed, there are opportunities to reduce soil fertility status in the short term before following a maintenance fertiliser program to keep fertility status within agronomic optimums.

The current levels of heavy metals were also measured. It was concluded from those samples that there are no limitations to a cut and carry operation. This is because the key risk pathway is via direct ingestion by animals. There will be no animals on site.

Investigations relating to sub regional geology (as relates to ground water) and on-site investigation to ascertain on site conditions.

On site investigation of test pits and review of bore logs and literature relating to the local area found there are thick layers of impermeable substrate beneath the site. An independent analysis found ‘’ The thickness of the low permeability clay and silts, along with artesian pressure and vertically upwards groundwater gradient would help restrict the downwards movement of contaminants into the deeper strata and is regarded as one of the barriers to prevent microbial contamination (Tonkin and Taylor, 2019; PDP, 2021). There is no evidence of springs or discharging groundwater within the vicinity of the project area or Waitangi Estuary, inferring that the confining layer is likely intact.

Onsite investigations confirmed the existence of non-permeable layers identified in bore logs from neighboring sites beneath the discharge area.

Analysis of the projected load of contaminants reviewed against baseline soil loadings and properties.

The effect of adding to the baseline loads was analysed. It was found that the low annual loadings (as proposed) will have a marginal effect on accumulation rates assuming there are no losses from the site. The addition of 7.9 kg F/ha will only increase the soil F concentration by 8.25 mg/kg annually, assuming there are no losses. Given that the other 5 elements listed in Table 3 are orders of magnitude lower than the estimated F addition, there is extremely low accumulation of these elements at the site over the 35 year consent period assuming no losses.

A review of monitoring protocols to guide adaptive management of site going forward.

A set of recommendations for further baseline and ongoing monitoring have been made (section 4). These relate to two key areas, firstly on-site effective management in a manner that allows for long-term understanding and adaption. Secondly, environmental monitoring of ground and surface water to assess the effectiveness of on-site management.

It is recommended that monitoring protocols are established to address trends in soil fertility status, soil heavy metal loads, foliar analysis, surface water and both shallow groundwater and the confined aquifer. This information should form the core of an annual irrigation and site management report.

All the recommendations relating to monitoring are based upon commonly used and accepted methods of analysis. Accurate monitoring of parameters relating to mass balance of contaminants on site and review of management settings and integration of any future recommendations are critical.

Suggested approach

It was concluded that the discharge of treated process water stormwater to land, based on analysis of soil chemistry, geology, and agricultural systems, will have no effect on the current condition of the source protection zone. This is because the annual additions of contaminants in the treated irrigation water are quantitatively small and will either be utilised and removed in the harvested forage or bound tightly to soil colloids on site and sits over a thick layer of low permeability sediments.

To support this conclusion going forward a set of monitoring outcomes have been suggested. In addition to monitoring, it is recommended to proceed with the design of an irrigation design concept that accommodates the final design of the treatment process, and is cognizant of the site, soil, and climate. The dual focus of both stormwater discharge and maximization of dry matter exported off site are compatible and desirable outcomes.

In the interim a continued focus on establishing and collecting baseline data from ground and surface water is recommended. This data should be used to guide the final design of tactical operational management. Baseline data is a key requirement for any necessary adaptive management going forward.

Contents

1. Introduction

Ravensdown Limited ('Ravensdown') have developed a strategy to manage the stormwater and process water discharge at its Napier Works to support the renewal of the current water discharge permit that expires 31 May 2022.

Currently, stormwater and process water that is not reused on site is collected in a discharge pond and pumped into the Ravensdown and Awatoto Drain, with the ultimate receiving environment being the Tūtaekurī River and Waitangi Estuary.

Ravensdown initiated an assessment of alternative options for the treatment and discharge of the stormwater and process water from the site to review both the method of treatment and the receiving environment utilising a multi criteria decision analysis process (MCDA).

In doing this a Technical Focus Group made up of representatives from key stakeholder groups provided their feedback on each option with the following objective for the MCDA process:

> *To establish the most sustainable long-term solution for the treatment and discharge of stormwater and process water from the Ravensdown Napier Works to enable the continued operation of the site*

As a result of this process a water discharge strategy with a preferential land-based discharge approach has been developed by Ravensdown. This assessment forms part of the execution of that strategy and specifically relates to the effects of the discharge of treated stormwater and process water to land.

The proposed stormwater and process water management system will reduce contaminant loads being discharged to the estuary from the Site via a substantial source control programme, the commissioning of new on-site treatment technology and the diversion (after treatment) of as much stormwater as technically feasible to land via spray irrigation.

This report assesses several aspects of the proposed process against the MCDA objective. Specifically, these include:

- An assessment of soils and site for suitability for irrigation and potential contaminant loading.
- Baseline monitoring to account for current soil loadings.
- Investigations relating to sub regional geology (as relates to ground water) and on-site investigation to ascertain on site conditions.
- Analysis of the projected load of contaminants reviewed against baseline soil loadings and properties and compared against relevant soil standards.
- A review of monitoring protocols to guide adaptive management of the site going forward.

2. Site and Investigations

The proposed irrigation area (the site) is situated on Waitangi Road immediately to the west of the Ravensdown site The site is 17.5 ha of predominately flat land with approximately 17.1ha being effective. There is one natural ephemeral channel that runs diagonally across the block near the north-eastern corner.

Surface drains run adjacent to the western, southern, and eastern boundaries with several short shallow surface drains running from within the eastern half of the block to drains on the eastern boundary. Drains on the western and eastern (photo point 1) boundaries are deep (approx. 1.6m) and drain to a pumping station maintained and operated by Hawkes Bay Regional Council (HBRC). These drains from part of an extensive drainage network in the wider area. They successfully maintain the water table within a lower and manageable range. The pumping station discharges to the estuary near to the Ravensdown discharge site.

A combination of the drainage network and natural slope of the site (aligning with drainage network) has resulted in the discharge site being effectively isolated from the surrounding landscape.

The site currently receives intermittent irrigation from neighbouring compost operation.

Shelter belts surround the site on all sides except the northern boundary.

Several critical aspects of the site have been investigated, including:

- Soil profile texture and depth.
- Soil sampling to ascertain nutrient status and related parameters.
- Soil test pits dug to a depth of 1.6 meters to compare deep soil profiles against other known bore logs in the area.
- Electromagnetic mapping of the site to evaluate distribution and variation in soil particle size. (Electromagnetic mapping of site was completed by landvision Ltd September 20201 using a DUALEM sensor to measure terrain conductivity in millisiemens/meter(mS/m). Conductivity is the inverse of resistivity. Ground with 1 mS/m conductivity has 1000 ohm-m resistivity).

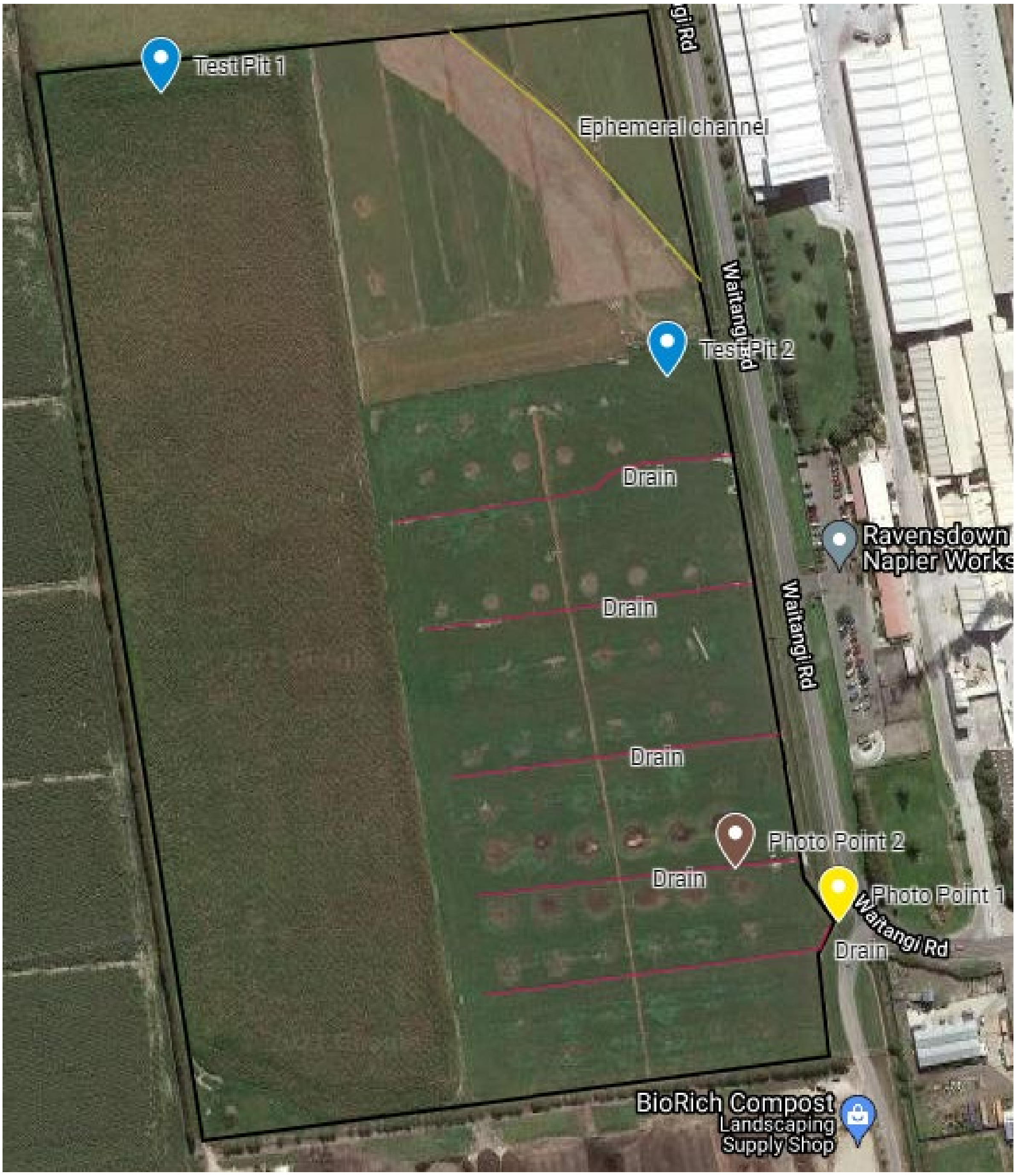


Figure 1: Base image of site (effective area) including ephemeral channel, drains, Photo Points, and site location

Figure 2: base image of Cadastral boundaries and location of drains on western and eastern boundaries

Figure 3: Photo point 1 (facing north). Deep drain on eastern boundary connected to HBRC pumping station. Discharge site is to the left behind established riparian vegetation. Position of photo points shown in figure 1.

Figure 4: Photo Point 2(facing west). Shallow surface drains within discharge area

Soils on the site are alluvial derived from mudstone parent material and are predominately silt (approx. 70%) with minor amounts of sand and clay. Topsoil is deep (35- 40cm) with no barriers to rooting depth in the top 1.2 metres.

Organic matter was evident throughout the soil profile to depths exceeding 500mm.

Electrical conductivity mapping of the site indicates that the soil is consistent across the proposed discharge site apart from an area of finer particles near the ephemeral pathway (Appendix 2).

Soils are gleyed with slight to moderate mottling visible from 350mm down the profile.

Total Available Water (TAW) has been assessed at 170mm under pasture and over 300mm under maize silage indicating the capacity of these soils to absorb and retain water is high.

Key characteristics of these soils are:

- Susceptibility to compaction therefore cultivation needs to be carefully planned.
- Risk of nitrogen leaching is low.

- Good suitability to well managed spray irrigation due to high TAW and potential rooting depth enabling reliable deficit irrigation.

Figure 5: Proposed land-based discharge site

Figure 6: Soil profile

Geology

A summary of geological investigations is presented here. The full report is attached as Appendix 1.

The hydrogeology of the proposed irrigation area was reviewed to provide an assessment of the productive aquifers. The site lies along the coastal periphery of the fault-controlled Heretaunga Plains mid-Pleistocene sedimentary basin, infilled with Quaternary marine sediments and alluvium deposited by the Ngaruroro, Tukituki and Tūtaekurī rivers. The main aquifer system of the Heretaunga Plains is generally unconfined in the west and increasingly confined to the east, with confinement as a result of successive sequences of marine transgressional and subsequent fluvial progradational deposition (Dravid and Brown 1997; Rakowski and Knowling 2018). The most recent marine transgressive sequence formed a wedge of low permeability sediments 40 to 50 m in thickness, capping deep gravel aquifers, and deep gravel wells near the coast screened across the confined gravel aquifer typically exhibit flowing artesian conditions suggesting upward flow of groundwater from the confined aquifers (Dravid and Brown 1997; Lee et al 2014).

The near-surface soil conditions were investigated by excavating test pits and reviewing nearby soils data which revealed estuarine muds, silts, sands and vegetation across the low-lying site. A narrow band of Holocene beach deposits are mapped east of Waitangi Road forming slightly elevated topography parallel to the coast (Lee et al, 2011), with gravelly alluvium adjacent to the Waitangi Estuary south of the BioRich site (PDP, 2021).

The HBRC online bore logs for nearby wells were reviewed which record near-surface silts and clays from 4 to 30 m depth below ground level (bgl), or sands and gravels to depths between 10 and 16 m bgl. Beneath this, layers of marine sediments including blue clay with shells, sand and wood form a confining layer to a depth of approximately 40 m bgl. Below approximately 40 m depth, alluvial gravel intervals are recorded which typically present flowing artesian conditions. Of the 67 bores recorded within 1500 m of the project area, the designated use for 39 of the wells is provided on HBRC bore logs, with 11 of Unknown Use; 10 bores used for Industry, 5 for Irrigation purposes, 4 Exploratory bores, 4 Domestic Use, 3 for Environmental purposes and 2 for Stock water.

The closest potable supply wells include two NCC municipal supply Well Nos. 5913 and 16352, approximately 1.6 and 1.7 km NNW from the northern boundary of the proposed irrigation area. The wells are screened greater than 74.00 and 110.97 m depth, respectively across the confined gravel aquifer. There are four wells within 1200 m of the site that hold resource consents for activities involving abstraction of potable water, including water bottling, with records showing three of the bores are screened across the confined gravel aquifer, and there is no data for the fourth bore.

A study on the hydraulic gradient of the confined aquifer (>50 m deep) determined flow direction toward the northeast (EAM, 2009). Shallow groundwater samples collected at three nearby monitoring bores indicate a mixing of fresh and saline water, although the direction of *groundwater flow in the shallow aquifer is unknown due to the strong tidal effect in close proximity to the coast strongly influencing the hydraulic gradient (Baalousha, 2009).*

The thickness of the low permeability, confining clay and silts, along with artesian pressure and vertically upwards groundwater gradient would impede downward movement of contaminants into the confined strata, and is regarded as one of the barriers to prevent microbial contamination (Tonkin and Taylor, 2019; PDP, 2021). There is no evidence of springs or discharging groundwater within the vicinity of the project area or Waitangi Estuary, inferring that the confining layer is likely intact.

The age-testing of NCC Well No.5913 by GNS, revealed a 51-year mean residence time with a young water fraction of <0.005%, although the introduction pathway is uncertain (PDP, 2021) and the very minor fraction infers that no localised recharge of the aquifer is occurring (Tonkin and Taylor, 2019). Upon further analysis of drawdown responses from the aquifer testing of NCC wells, vertical leakage was observed which suggests that there is the potential for slow downward migration of contaminants if the hydraulic gradient was reversed (PDP, 2021).

It is further noted that the microbial water quality information suggests that over a shorter period of time, the NCC municipal supply bores may be at risk from surface influences; however, this may be the result of poorly maintained nearby bores providing pathways from the surface to the confined pumped aquifer (PDP, 2021). The Tonkin and Taylor (2019) study concludes that the development of downward hydraulic gradients is unlikely due to the combination of relatively high artesian pressure aquifer overlain by a relatively thick, low permeability aquitard within the vicinity of the NCC bore field and associated SPZ.

The installation of groundwater monitoring bores is recommended along the bounds of the proposed irrigation area in order to track any potential contamination of unconfined aquifers. It is recommended that three bores (up to 6 m depth) be drilled in a triangular formation across the site to map groundwater contours in the unconfined aquifer and establish the groundwater flow direction in conjunction with information gained from the BioRich monitor bores. Once the hydraulic gradient is confirmed, two of the three bores will be completed as monitor wells, located hydraulically up and down-gradient of the discharge area.

A series of water quality sampling and SWL recording should be undertaken prior to commencement of the irrigation of stormwater and process water in order to collect a robust set of baseline water quality data and establish groundwater levels in the unconfined aquifer. Ongoing groundwater sampling should be completed on a six-monthly basis. Water level data can be recorded by downhole pressure transducers which will reveal long-term trends and document tidal flux which can be used to aid scheduling of irrigation application and mitigate groundwater mounding at the site and neighbouring blocks.

2.2. Baseline Nutrient Status

2.2.1. Current soil nutrient status

Soil sampling was undertaken at the site on 1 September 2021 along 9 transects to a depth of 15cm. The samples were tested for essential major nutrients for plants, and other elements as shown in Table 1 below.

Table 1: Average (and range) soil fertility status of the proposed site

Test	pH	Olsen P	QTK	Sulphate S	Organic S	QTCa	QTMg	QTNa	PMN[1] kg N/ha	ASC[2] %
Average	6.5	59	39	46	19	14	67	84	149	28
Range	5.8-7.1	33-71	33-49	18- >250	12-28	8-21	31-118	9-155	94-231	22-31
Optimum	5.8-6.0	30-40	7-10	10-12	15-20	Na[3]	8-10	na	na	na

[1]*Potentially mineralisable N*
[2]*Anion storage capacity*
[3]*Not applicable*

The optimum values for the different soil test parameters at 7.5cm are taken from Roberts and Morton (2016) and are appropriate for growing high production grass/legume forages on dairy farms. The pH, Olsen P, extractable cations (e.g., QTK = Quicktest K) and soil sulphur tests all exceed the optimum ranges (Table 1) by a considerable amount. This will mean that there are no soil fertility limitations to its use as a cut and carry block to provide forage for livestock farms. Initially there will be little requirement for additional fertiliser application to allow for nutrient 'mining'. This mining, especially of soil P, will assist in lowering the risk of P loss in surface runoff on these sedimentary soils of relatively low ASC (Morton et al. 2003). The proposed solution being a cut and carry operation with no livestock will minimise soil disturbance and therefore associated risk of loss.

The exception will be the requirement for tactical N fertiliser applications to assist in crop establishment and continued resilient production, as the average PMN values are in the medium range (Table 1). As soil fertility levels drop to optimal levels because of the extractive cut and carry operation, maintenance nutrient applications will be required.

The average QTNa level on the site is 84 with some samples exceeding 100 (Table 1). This indicates that there is, or has been, sea water incursion either over the surface or as subsurface flow. Relatively salt tolerant plants may need to be used in the forage system planted on site. This is not limiting as there are many suitable forage and crop varieties available, including those already growing on site.

2.2.2. Current levels of heavy metals and nonmetals.

Other potential contaminant metals and non-metals were also measured, as a baseline status for the site, on the soils collected and the results for all elements are from the standard US Environmental Protection Agency extraction method except for fluoride (F) which is total F (Table 2).

Table 2: Average concentration (mg/kg) and range of other elements at the site

Element	Fluoride (F)	Cadmium (Cd)	Mercury (Hg)	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Arsenic (As)	Chromium (Cr)	Nickel (Ni)
Average	613	0.46	0.08	15.3	21.8	78.1	8.5	22.6	18
Range	510-770	0.27-0.80	0.07-0.1	14-16.1	18-34.6	74.1-83.1	7.9-9.5	20.5-24.9	16.2-20.5
Typical ranges	212-617	0.1-0.67	nd[1]	8.7-32.3	6-16	42-91	nd	nd	nd

[1]*No data*

The typical ranges in Table 2 (where available) are taken from published surveys of pastoral farms throughout New Zealand (Longhurst et al. 2004). The average F of 613 mg/kg (Table 2) at this site falls just within the range published in Loganathan et al. (2006) and this is not surprising given the proximity to the Ravensdown manufacturing facility where aerosol F may have been deposited over the more than 50 years of superphosphate manufacture at the plant.

The average concentrations of Cd, and Cu (Table 2) are within the ranges for pastoral soils published in Longhurst et al. (2004), while the Pb level is elevated above the 'normal' average range in pastoral soils.

3. Proposed Spray Irrigation Solution

To manage the effective application of treated stormwater to land a linear irrigator (or equivalent) is to be installed on the site. This will allow the effective and efficient application of stormwater within soil moisture parameters and allow for a range of crops and associated management.

A range of potential pasture and crop systems are suitable for the site. Decisions about which crop (or range of crops) can be made seasonally but for simplicity it is assumed that a semi-permanent pasture will be established and maintained.

It is intended that pasture (or other crops) will be cut on a regular basis and made into baleage (a portable and common form of silage. Currently, the plastic wrapping from baleage is recycled into plastic products like fence posts and traffic calming devices. Options have been developed using cellulose based wrapping that is edible). Other options are to make into hay or cut and transport off site fresh. Primarily this feed will be made available to contribute to drought relief efforts (as needed). The advantage of exporting dry matter from the site is the associated removal of plant available nutrients thereby reducing the accumulation and associated risk of nutrient accumulation on site. In addition to the potential removal of nutrients from the site, other benefits of cut and carry include:

- The absence of livestock on site which in turn reduces potential internal transfers and accumulation of nutrients which can result in site specific loadings being more than monitored levels.
- Excellent control over residual pasture height which in turn reduces potential losses via overland flow.
- The ability to specifically maintain grass buffer strips within and surrounding any identified flow path.

3.1. Infrastructure

3.1.1. Linear irrigator

It is proposed that a linear irrigator is installed on site to apply the treated process water and stormwater via spray irrigation.

The supply of treated process water and stormwater will be limited by the throughput of the treatment system. This limit will by default govern the necessary capacity of the irrigation system. A full design specification and commissioning process will need to be undertaken to settle on a final design. The key attributes of the irrigation design will need to address are:

- Flow rate to accommodate treatment system. Provisional estimates are that 20 litres/second maximum flow rate will be adequate.
- Application rates that are within infiltration rates for the soils on site.
- Distribution uniformity allows for predictable and accurate distribution of stormwater.
- Variable application is allowed for to enable preferential application to dryer parts of the discharge site when soil moisture levels are high and help manage spray drift

The advantages of a linear spray irrigation system are:

- The efficient use of the area available.
- The ability to isolate all or parts of system when near sensitive areas e.g., surface drains.

- The ability to vary application rates to suit soil moisture levels and infiltration rates. Maintenance of soil moisture deficit will be a significant component of a sound discharge strategy. Tight control on application rates is closely aligned with this.
- Ability to alter height and type of nozzles to minimise potential spray drift

3.1.2. Potential application volumes

Niwa generated data for Nelson Park (Napier) is a useful comparison for the potential irrigation demand on this site (Table 3). it indicates that on average 449mm of soil moisture deficit will occur. With significant deficits occurring during traditionally dry months (Spring – Autumn). On average there are negligible soil moisture deficits expected between May and September. Therefore, it is expected that most irrigation on this site will occur between late September and late April with some targeted applications in areas with lower monitored soil moisture levels possible most of the year. 449mm of irrigation equates to approximately 76 779m^3 per annum for the 17.1 effective hectares. A standard irrigation schedule to support plant growth in Hawkes Bay would typically apply between 42750m^3 (arable) and 68400m^3 (Grass based Dairy) per annum.

Table 3: Niwa generated values for monthly soil moisture deficit and days of deficit for Nelson Park Napier

Average /mm	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Soil Moisture Deficit	107	65	44	15	3	1	0	0	1	39	74	98	449
Days of deficit	22	15	13	8	3	1	0	0	0	11	17	20	111

Modelled data (Mr David Delagarza, personal Communication) suggests the total volume of stormwater potentially supplied at 20l/s or less (post wetland) is approximately 55758 m^3 . Comparison of total supply vs soil moisture deficit indicates a gap between supply and demand of 54252m^3 between October and late April (blue line over orange line figure 7). This means that on average the discharge area can accommodate the storm water supplied post wetland during the critical summer months. During wetter months (late April – late September) there is a surplus of water post wetland of approximately 33570m^3 (orange line over blue line figure 7).

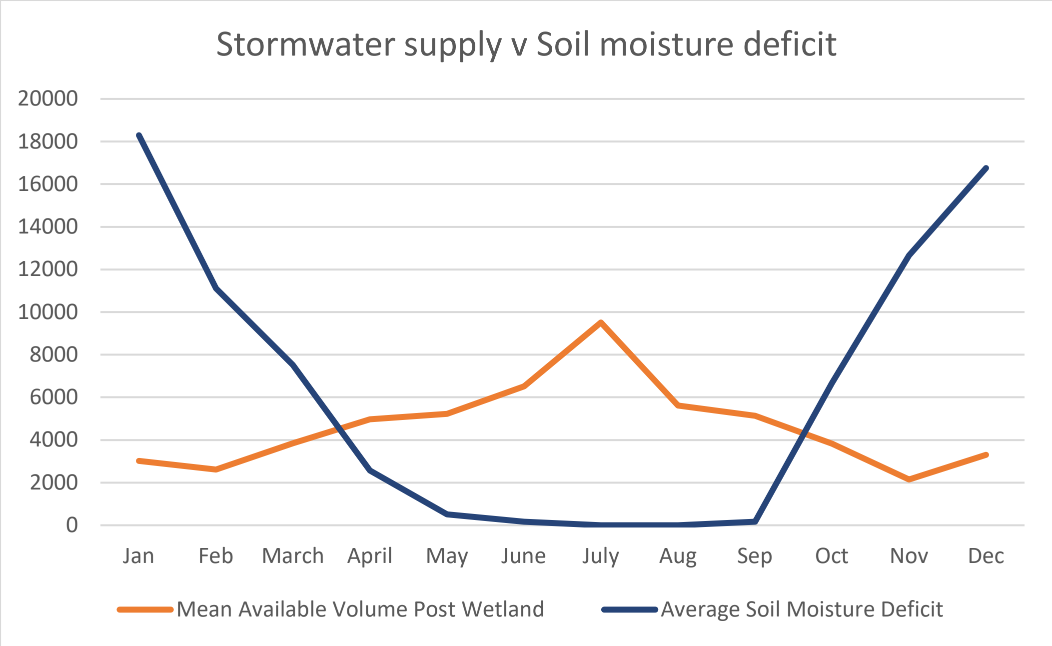


Figure 7: Graph of mass balance between soil moisture deficit and stormwater supply post wetland

Figure 8: Example of Linear irrigator

3.2. Potential effects of estimated nutrient and other element applications to the forage block in the treated irrigation water

The amounts of nutrients and other elements which will be applied to the cut and carry forage block has been estimated using load data calculated by Mr D Delagarza of Aurecon Ltd. using available data on the amount of process water and stormwater (including rainfall runoff) produced on site on an annual basis and the estimated quality of that water in terms of nutrients and other elements it contains. It must be stressed that the data in Table 3 are median values calculated using necessary assumptions where there are inadequate data in terms of number of samples or long-term recording of stormwater runoff throughout the whole year. Additionally, the collection, treatment and land application of the process water and stormwater will be a phased introduction of different technologies over two stages. The Stage 1 modifications are proposed to be implemented as soon as practicably possible after the grant of the new discharge permit(s), with Stage 2 improvements being implemented within five years of granting of the new discharge permit(s). The approximate loading rates of the nutrients and other elements are presented as Stage 1 and Stage 2 in Table 3.

Table 4: Estimates of annual nutrient loads and other elements (kg/ha) to the forage cropping area [reference source data table when complete]

Element	DRP	Total N	F	Al	Cu	Cd	Cr	Zn
Stage 1	6.9	18.6	7.9	0.6	0.02	0.001	0.09	0.38
Stage 2	5.3	7.5	7.9	0.25	0.01	0.0001	0.009	0.09

Due to the efficacy of the proposed treatment clarifier, the dissolved reactive phosphate (DRP) additions are estimated to be a very small ~7 kg P/ha in Stage 1 and ~5 kg P/ha in Stage 2 (Table 3) and so present no issue for the site, as the removal of P from the site in the cut and carry forage will exceed the input of P in the irrigated water (see Section 3.3 below). Similarly, N inputs will be ~19 kg/ha in Stage 1 and drop to ~8 kg/ha in Stage 2 (Table 3) and, as with P, will be removed in far greater quantity with the forage than these small inputs.

In terms of non-essential elements, the most significant addition will be F at 7.9 kg/ha annually but by way of comparison single superphosphate (SSP) contains between 120-204 g F/kg P (*Kieran Murray, personal communication)* which means that at an annual addition of 330 kg SSP/ha between 3.6 and 6.1 kg F/ha would be applied onto farmland. It is well known that P fertiliser application increases soil F concentrations with long term applications (Gray 2018). While this soil accumulation creates an increased risk to grazing livestock through geophagy (soil ingestion) there is no risk to the pasture growing in those soils as plants do not take up F through their root systems.

Table 5: Estimates of total additions of fluoride and metallic elements (kg/ha) to the forage cropping area over the 35 year consent period

Element	F	Al	Cu	Cd	Cr	Zn
Stage 1	289	21.9	0.70	0.035	3.15	14
Stage 2	289	9.1	0.35	0.0035	0.315	3.15

Table 4 shows the total loading (kg/ha) over the 35 year consent period for the non-essential elements added in the spray irrigation. These loads can be converted to soil concentrations considering soil bulk density. The laboratory bulk density of the soils taken for analysis average 0.64 g/mL (range 0.54 to 0.72). Using the average laboratory bulk density this means that in a hectare to a depth of 15cm (the depth the soil samples were collected at) there is approximately 960,000 kg of soil. The total additions of the elements in Table 4 over 35 years equates to the potential increase in soil concentrations after 35 years, assuming no losses, shown in Table 5.

Table 6: Estimates of increase in concentrations of fluoride and metallic elements (mg/kg) on the forage cropping area over the 35 year consent period

Element	F	Al	Cu	Cd	Cr	Zn
Stage 1	301	22.8	0.73	0.036	3.28	14.5
Stage 2	301	9.5	0.36	0.0036	0.328	3.28

The effect of the accumulation of non-essential elements added in the discharge water (using Stage 1 levels as the worst-case scenario) shows that the soil F levels are likely to increase by a third (Table 6) while the other elements Cu, Cd, Cr and Zn show very small changes in baseline concentrations. Furthermore, the As, Cd, Cr, Cu and Pb levels are all significantly below the most protective (rural lifestyle, 25% produce) MfE soil contamination standards for health (Table 7).

Table 7: Increase in estimated baseline soil concentrations of fluoride and metallic elements (kg/ha), using Stage 1 values, on the forage cropping area over the 35 year consent period

Element	F	Al	Cu	Cd	Cr	Zn	Pb	As
Baseline	613	nd	15.3	0.46	22.6	78.1	21.8	8.5
+35 years	904	nd	16.0	0.50	25.9	92.6	21.8	8.5

Table 7: Ministry for the Environment soil contamination standards for health

Land Use	Arsenic (mg/kg)	Cadmium (mg/kg)	Chromium III (mg/kg)	Chromium VI (mg/kg)	Copper (mg/kg)	Lead (mg/kg)
[1]**Rural/lifestyle block** 25% produce	17	0.8	>10,000	290	>10,000	160
[2]**Residential** 10% produce	20	3	>10,000	460	>10,000	210
[3]**High-density residential** 0% produce	45	230	>10,000	1500	>10,000	500

[1] Non-urban property where 25% of resident diet is made up of home-grown produce. [2] Urban properties where 10% of resident diet is made up of fruit and vegetables grown on the property. [3] Properties with limited soil contact and no vegetable gardens.

3.3. Estimated nutrient removal by the cut and carry forage system

The intention is to use the irrigated site to produce acceptable forage for supply to surrounding pastoral land holders as supplementary feed to feed their livestock when pasture supply on farm is inadequate. The western side of the site has been used in the past to grow maize silage crops in the spring to autumn season and annual ryegrass over winter. The eastern side of the site is in a variety of grass species.

The intention is to simplify the management of the site and avoid a complex crop rotation which will require cultivation of the soil at times to introduce the new crops. It is proposed to spray out existing forage species and resow the whole 17.1ha (effective area) into a productive grass/clover pasture system. It is anticipated that a tall fescue/cocksfoot/perennial ryegrass combination with red and white clover will be established after first cultivating and contouring (as required) the site. Depending on how well the site produces it is anticipated that the pasture will be harvested at around herbage mass of 3t DM/ha[1] as haylage/baleage two to three times a year. Based on an annual yield of 6 to 8t DM/ha the nutrients removed are shown in Table 8. The haylage/baleage will be sampled for dry matter and metabolisable energy according to the code of practice for the trading of pasture and whole crop forages. These samples will also be analysed for macronutrients to confirm the estimate of nutrients removed in Table 8. [2]

Table 8: Estimates nutrients removed (kg/ha) by the cut and carry system used on the site

Yield	N	P	K	S	Mg	Ca
6t DM/ha	240	30	180	18	18	30
8t DM/ha	320	40	240	24	24	40

The estimated N and P removed by the cut and carry system (Table 8) is an order of magnitude greater than the estimated inputs from the treated process water and stormwater at either Stage 1 or 2 (Table 3) and, as would be expected, there will be a requirement to apply fertiliser nutrients in the future to maintain soil health and productivity.

Over time, if the sward deteriorates, a direct drilled oats/annual ryegrass cropping phase can be undertaken before resowing in the perennial pasture phase.

Given the measured levels and the intention of growing forage for a cut and carry system there is no risk of animal ingestion of toxic amounts of any of the elements listed in Table 2, and there will be low to normal levels of these elements in the plants grown on the site. This contention is supported by comparison of the site soil to the range of soil levels reported in Longhurst et al. (2004) for nearly 400 farmed and unfarmed sites throughout New Zealand (Table 9).

Table 9: Comparison of some elements mean soil content (mg/kg) for the site with soils throughout New Zealand

Element	As	Cd	Cu	Pb	Zn
This site	8.5	0.46	15.3	21.8	78.1
NZ	2.3-9.5	0.1-0.67	8.7-32.3	6-16	70-96

Given that these elements closely align with the range in farmed (including livestock) soils throughout New Zealand, there will be the same minimal risk to both animal and human health from any of these elements in the cut and carry pasture (excluding livestock).

[1] Tonne of dry matter per hectare.

[2] Results to be stored under customer account 60895393.

4. Monitoring and Reporting

To support an adaptive management approach to land-based discharge a comprehensive monitoring program is essential. Within the land discharge activity, the following is recommended. The monitoring sites described in this section are shown in figure 10.

4.1. Soil Moisture

Installation of four soil moisture monitoring points at two depths (to reflect crop grown and rooting depth). Monitoring should be autonomous and continuous. Irrigation triggers and refill points will be developed as part of the detailed irrigation design, however it is clear, that due to the high TAW of the soil on site a trigger point of 85mm will be possible (depending on crop and rooting depth). In a typical irrigated scenario, a refill point of approximately 80% of the trigger point would be desired. This would allow for 18mm rainfall event before the soil was saturated. In this situation a lower refill point can be managed as to maximise excess capacity for irrigation. The actual amount will depend on seasons and crop rooting depth and should be manged via careful monitoring and use of a continuous soil moisture budget.

4.2. Soil Testing

Soil testing protocols for the site have been established to provide ongoing monitoring. These are designed to adequately represent the 17.5 ha and reduce the variability associated with making biological measurements. These are:

- Establishment of nine sampling sites across the 17.5 ha to represent the overall sites' soil chemical and physical properties. Each sampling site is represented by GPS points within Ravensdown's spatial information system (Hawkeye™) to ensure that ongoing monitoring is from the same geospatial locations (Figure 1).
- Sampling sites are to be sampled at a 15cm depth and represented by 15 to 20 cores from each site.
- Sampling sites are to be resampled on an annual basis for the first five years to establish baseline data. From then on they are to be sampled on a biannual basis during late winter/early spring to monitor trends over time (or as required). Results are to be stored within Hawkeye.[3]
- The soil analysis will consist of:
    - Soil pH, Olsen P, K, Mg, Ca, Na, Sulphate S and Organic Sulphur,
    - Potentially Mineralisable Nitrogen (PMN)
    - EDTA (Co, Mn, Fe, Cu, Zn)
    - EPA Heavy Metal Suite (As, Cd, Cr, Cu, Pb, Hg, Ni, Zn)
    - Total soil F.

[3] Results to be stored under customer account 60895393.

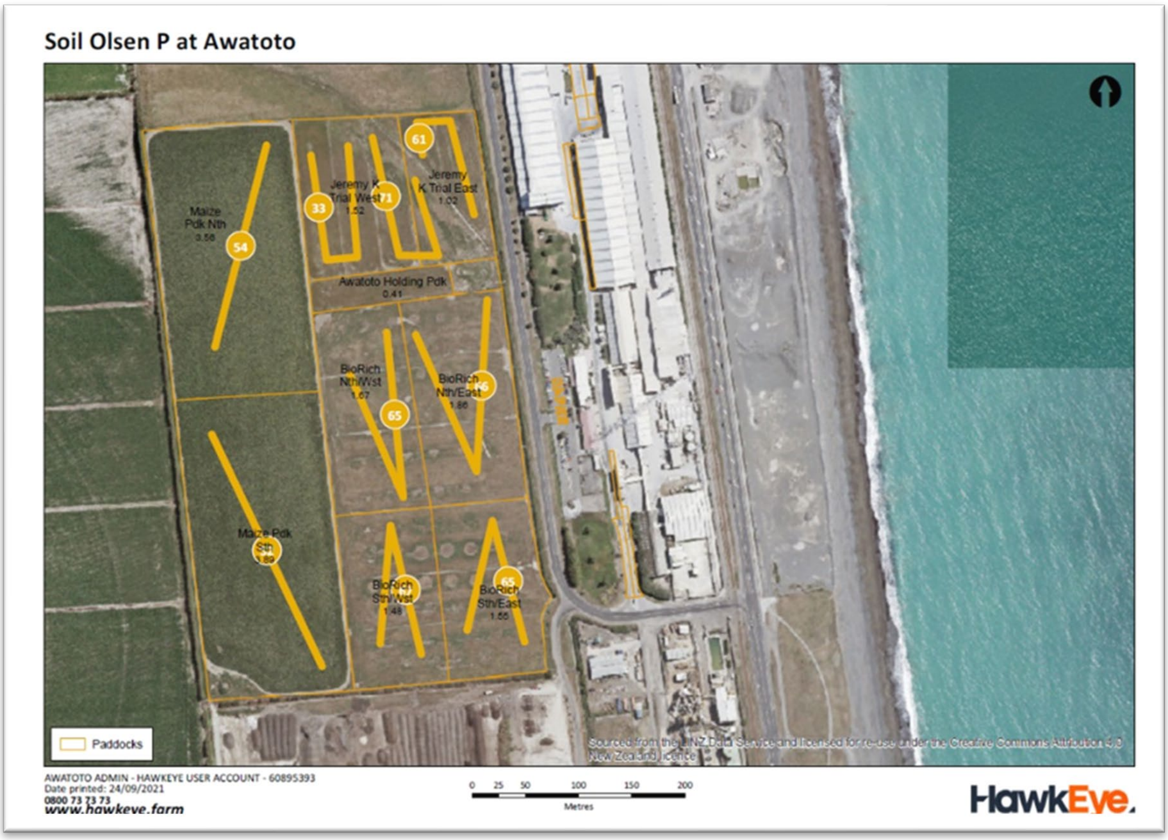


Figure 9: Soil sampling site locations across the 17.5 ha site adjacent to Waitangi Road

4.3. Foliage Sampling

The haylage/baleage should be sampled for dry matter and metabolisable energy according to the code of practice for the trading of pasture and whole crop forages. These samples should also be analysed for macronutrients to confirm the estimate of nutrients removed in Table 8.[4]

Test unwashed samples from each forage cut intended for livestock consumption for fluoride levels in accordance with ANZEC guidelines.

For clarification, the ANZEC guidelines are to manage the potential effect of aerosols containing fluoride being deposited on vegetation not from the discharge activity itself.

4.4. Shallow Groundwater

The installation of groundwater monitoring bores is recommended along the bounds of the proposed irrigation area in order to track any potential contamination of unconfined aquifers. It is recommended that three bores (up to 6 m depth) be drilled in a triangular formation across the site to map groundwater contours in the unconfined aquifer and establish the groundwater flow direction in conjunction with information gained from the BioRich monitor bores. Once the hydraulic gradient is confirmed, two of the three bores will be completed as monitor wells, located hydraulically up and down-gradient of the discharge area

A series of water quality sampling and SWL recording should be undertaken prior to commencement of the irrigation of stormwater and process water in order to collect a robust set of baseline water

[4] Results to be stored under customer account 60895393.

quality data and establish groundwater levels in the unconfined aquifer. Ongoing groundwater sampling should be completed on a six-monthly basis. Water level data can be recorded by downhole pressure transducers which will reveal long-term trends and document tidal flux which can be used to aid scheduling of irrigation application and mitigate groundwater mounding at the site and neighbouring blocks

4.5. Confined aquifer.

A biannual sampling program should be initiated using established bores on the Ravensdown site (directly east of discharge site). After two years this should become an annual sample, this should be initiated as soon as practical to establish baseline data.

4.6. Irrigation Design and Commissioning

As is typical for all irrigation systems of this type, Ravensdown will contract the services of a suitably experienced contractor to provide full design specifications and management options for the irrigation system to ensure that it is fit for purpose.

Propose soil moisture monitoring points(SMMP) are identified in figure 10. These areas have been identified based on a detailed site elevation plan (created as part of the EM mapping exercise). This map effectively provides monitoring zones based on elevation that when combined with variable rate irrigation enables precision irrigation. Variable rate irrigation allows for differential application down to $10m^2$ which in turn maximises irrigation opportunities when soil moisture conditions are approaching the upper limit for irrigation

Figure 10 also identifies the site for two shallow monitoring bores to monitor over time any changes in shallow groundwater characteristics.

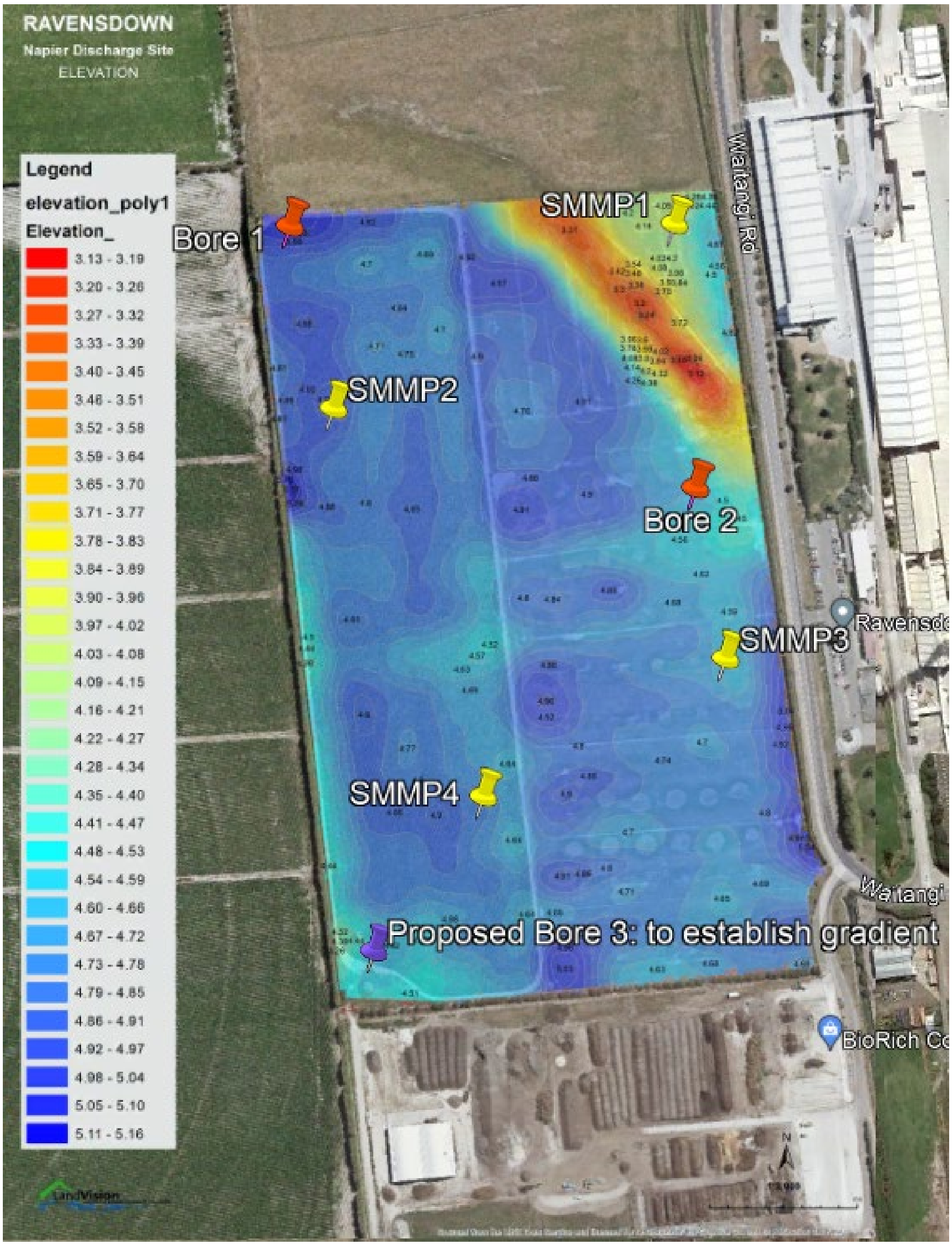


Figure 10: proposed soil moisture monitoring points(SMMP) and Proposed monitoring bores imposed on an elevation map of discharge site

5. Conclusion relating to effects and recommendations

The reduction of direct discharge of treated process stormwater to the Waitangi Estuary will reduce the load of contaminants entering the estuary. However, to be confident that the net effect of that on the surrounding environment is positive a range of assessments were carried out. These are addressed individually as below.

1. **An assessment of soils for suitability for irrigation and potential contaminant loading.**

   Key aspects of the soil on the proposed discharge site were examined. Test pits were dug, and soil textural assessment was completed. The soils on the site have high AWC and no limitation to rooting depth in the top 1.2 meters. The soils are predominately silt based and largely consistent across the site. The capacity of the soils to absorb and retain the proposed contaminant loading is adequate for the foreseeable future (decades).

   The site is within a managed drainage network that effectively maintains the localised water table at a constant level (drains are attached to an HBRC pumping station). This drainage network also isolates the site from neighbouring sites.

2. **Baseline monitoring to account for current soil loadings - Analysis of the projected load of contaminants reviewed against baseline soil loadings and properties.**

   Several soil monitoring transects (representing differences in historical management) were sampled and analysed by ARL (independent accredited lab). The analysis led to the conclusion that "Given the measured levels and the intention of growing forage for a cut and carry system there is no risk of animal ingestion of toxic amounts of any of the elements listed in Table 2, and there will be low to normal levels of these elements in the plants grown on the site.''

   The effect of adding to the baseline loads was analysed. It was found that the low annual loadings (as proposed) will have a marginal effect on accumulation rates assuming there are no losses from the site. The addition of 7.9 kg F/ha will only increase the soil F concentration by 8.25 mg/kg annually, assuming there are no losses. The amount of fluoride predicted to be added across the discharge site is comparable to that added during maintenance applications of superphosphate nationally as permitted activity. Given that the other five elements listed in Table 3 are orders of magnitude lower than the estimated F addition, there is unlikely to be any significant accumulation of these elements at the site for decades and for the duration of this consent will remain below recommended guidelines.

   It is expected that there will be some minor uptake of soil contaminants by pasture (or crops) but the actual amounts will be variable. Therefore, no specific assumptions regarding uptake have been made except where monitoring of measured accumulations in foliage is to be conducted to facilitate a mass balance of soil contaminant loadings for the site.

   No crops for human consumption will be grown on site therefore the effect on human health via the ingestion of produce is not relevant. The direct exposure to spray drift during windy conditions is also not considered a public health risk[5]. . Any possible direct exposure of animals to fluoride is removed as they will not be on site and forage exported off site will be tested and manged in accordance with ANZEC guidelines. Potential exposure via spray drift is very minor as drift can be managed through design and management of the irrigator, the site is well buffered

[5] Environmental Medicine Limited (2021), Reconsenting of Ravensdown Napier Works, Assessment of Environmental Health Effects. Prepared for Ravensdown Limited Napier

(shelter belts and distance to public areas) and there will be no people on site when the irrigator is operating.

For the duration of this consent, an upper management threshold (1085 mg F/kg) for soil fluoride levels is recommended as described in Cronin 2010. This threshold is recommended as the upper limit for toxicity for cattle.

3. **Investigations relating to sub regional geology (as relates to ground water) and on-site investigation to ascertain on site conditions.**

   On site investigation of test pits and review of bore logs and literature relating to the local area found there are thick layers of impermeable substrate beneath the site. An independent analysis found '' The thickness of the low permeability clay and silts, along with artesian pressure and vertically upwards groundwater gradient would help restrict the downwards movement of contaminants into the deeper strata and is regarded as one of the barriers to prevent microbial contamination (Tonkin and Taylor, 2019; PDP, 2021). There is no evidence of springs or discharging groundwater within the vicinity of the project area or Waitangi Estuary, inferring that the confining layer is likely intact.

   Onsite investigations confirmed the existence of non-permeable layers identified in bore logs from neighbouring sites at 1.6m depth.

4. **A review of monitoring protocols to guide adaptive management of site going forward.**

   A set of recommendations for further baseline and ongoing monitoring have been made (Section 3). These relate to two key areas, firstly on-site effective management in a manner that allows for long-term understanding and adaption. Secondly, environmental monitoring of shallow and deep ground to assess the effectiveness of on-site management.

   All the recommendations relating to monitoring are based upon commonly used and accepted methods of analysis. Accurate monitoring of parameters relating to mass balance of contaminants on site and review of management settings and integration of any future recommendations are critical.

In summary, this assessment has identified that:

- The soils on site are suitable for irrigation of stormwater.
- The soils on site are well suited to the adhering of contaminates and have significant capacity to do so.
- The site sits on top of sedimentary layers that impede the loss of drainage water from the site to the confined aquifer. Water applied to the site will either be transpired by plants on site, evaporated directly off the site or drain (over time) via surface and subsurface flow into the surrounding drainage network and HBRC pumping station.
- There is a set of standard management and monitoring methods that can effectively manage risk relating to contaminant loads and losses that can effectively guide an adaptive management approach.
- The closest potable supply wells include two NCC municipal supply Well Nos. 5913 and 16352, approximately 1.6 and 1.7 km NNW from the northern boundary of the proposed irrigation area. The wells are screened greater than 74.00 and 110.97 m depth, respectively across the deep confined gravel aquifer. There are four wells within 1200 m of the site that hold resource consents for activities involving abstraction of potable water, including water

bottling, with records showing three of the bores are screened across the deep confined gravel aquifer.

Therefore, it is concluded that the discharge of treated process water stormwater to land, based on analysis of soil chemistry, geology (including depth to confined aquifer), and agricultural systems, will have no effect on the current condition of the source protection zone. This is because the annual additions of contaminants in the treated irrigation water are quantitatively small and will either be bound tightly to soil colloids on site or taken up and removed in the harvested forage and the site sits over a thick layer of low permeability sediments.

Any potential on site effects relating to the application of fluoride are effectively manged via monitoring of sol moisture levels to guide initial application, soil testing to assess total load and foliage sampling to mange off site effect on livestock.

6. References

Australian and New Zealand Environment Council, March 1990. National Goals for Fluoride in Ambient Air and Forage.

Chappell, P.R. The Climate and Weather of Hawkes Bay. NIWA SCIENCE AND TECHNOLOGY SERIES NUMBER 58

Cronin S. J. Manoharan V. Hedley M. J. & Loganathan P. (2000) Fluoride: A review of its fate, bioavailability, and risks of fluorosis in grazed-pasture systems in New Zealand, New Zealand Journal of Agricultural Research, 43:3, 295-321

Gray, C.W. 2018. Fluorine in soils under pasture following long-term application of phosphate fertiliser in New Zealand. Geoderma Regional 14 *doi.org/10.1016/j.geodrs.2018.e00183*

Loganathan, P.; Gray, C.W.; Hedley, M.J.; Roberts, A.H.C. 2006. Total and soluble fluorine concentrations in relation to properties of soils in New Zealand. European Journal of Soil Science. 57: 411 – 421.

Longhurst, R. D.; Roberts, A.H.C.; Waller, J.E. 2004. Concentrations of arsenic, cadmium, copper, lead and zinc in New Zealand pastoral topsoils and herbage. New Zealand Journal of Agricultural Research 47(1): 23-32.

Morton J D, McDowell R W, Monaghan R M and Roberts A. H. C. 2003. Balancing phosphorus requirements for milk production and water quality. New Zealand Grassland Association 65: 111-115.

Roberts, A.H.C.; Morton, J.D. 2016. Fertiliser Use on New Zealand Dairy Farms. 4th Revised Edition. Fertiliser Association of New Zealand, Wellington. 52p.

Appendix 1: Hydrogeological Assessment

Bay Geological Services Ltd.

Hydrogeological Assessment of Proposed Irrigation Area

165 and 195 Waitangi Road, Awatoto, Napier

for
Ravensdown
Private Bag 6012
Napier 4142

September, 2021
Project No. BGS292_01
Prepared by: A C. Johansen

CONTENTS

EXECUTIVE SUMMARY

Ravensdown Limited (the Applicant) is investigating a potential site adjacent to Waitangi Road, directly west of the Awatoto production facility (the Napier Works), across which to irrigate pasture and crops with treated stormwater and process water collected from the Napier Works. The site comprises four paddocks totaling 17.5 ha off the southern end of 165 and 195 Waitangi Road, which is currently grazed and cropped, lying approximately 300 m west of the coastline and 550 m north of the blind arm of the Tutaekuri River, which flows into the Waitangi Estuary. The proposed site lies within the Napier Source Protection Zone (SPZ)[1] associated with the public water supply bore field for Napier City.

The hydrogeology of the proposed irrigation area was reviewed to provide an assessment of the productive aquifers. The site lies along the coastal periphery of the fault-controlled Heretaunga Plains mid-Pleistocene sedimentary basin, infilled with Quaternary marine sediments and alluvium deposited by the Ngaruroro, Tukituki and Tūtaekurī rivers. The main aquifer system of the Heretaunga Plains is generally unconfined in the west and increasingly confined to the east, with confinement as a result of successive sequences of marine transgressional and subsequent fluvial progradational deposition (Dravid and Brown 1997; Rakowski and Knowling 2018). The most recent marine transgressive sequence formed a wedge of low permeability sediments 40 to 50 m in thickness, capping deep gravel aquifers, and deep gravel wells near the coast screened across the confined gravel aquifer typically exhibit flowing artesian conditions suggesting upward flow of groundwater from the confined aquifers (Dravid and Brown 1997; Lee et al 2014).

The near-surface soil conditions were investigated by excavating test pits and reviewing nearby soils data which revealed estuarine muds, silts, sands and vegetation across the low-lying site. A narrow band of Holocene beach deposits are mapped east of Waitangi Road forming slightly elevated topography parallel to the coast (Lee et al, 2011), with gravelly alluvium adjacent to the Waitangi Estuary south of the BioRich site (PDP, 2021).

The HBRC online bore logs for nearby wells were reviewed which record near-surface silts and clays from 4 to 30 m depth below ground level (bgl), or sands and gravels to depths between 10 and 16 m bgl. Beneath this, layers of marine sediments including blue clay with shells, sand and wood form a confining layer to a depth of approximately 40 m bgl. Below approximately 40 m depth, alluvial gravel intervals are recorded which typically present flowing artesian conditions. Of the 67 bores recorded within 1500 m of the project area, the designated use for 39 of the wells is provided on HBRC bore logs, with 11 of Unknown Use; 10 bores used for Industry, 5 for Irrigation purposes, 4 Exploratory bores, 4 Domestic Use, 3 for Environmental purposes and 2 for Stock water.

The closest potable supply wells include two NCC municipal supply Well Nos. 5913 and 16352, approximately 1.6 and 1.7 km NNW from the northern boundary of the proposed irrigation area. The wells are screened greater than 74.00 and 110.97 m depth, respectively across the confined gravel aquifer. There are four wells within 1200 m of the site that hold resource consents for activities involving abstraction of potable water, including water bottling, with records showing three of the bores are screened across the confined gravel aquifer, and there is no data for the fourth bore.

A study on the hydraulic gradient of the confined aquifer (>50 m deep) determined flow direction toward the northeast (EAM, 2009). Shallow groundwater samples collected at three nearby monitoring bores indicate a mixing of fresh and saline water, although the direction of groundwater flow in the shallow aquifer is unknown due to the strong tidal effect in close proximity to the coast strongly influencing the hydraulic gradient (Baalousha, 2009).

[1] Proposed Plan Change 9 (TANK)

The thickness of the low permeability, confining clay and silts, along with artesian pressure and vertically upwards groundwater gradient would impede downward movement of contaminants into the confined strata, and is regarded as one of the barriers to prevent microbial contamination (Tonkin and Taylor, 2019; PDP, 2021). There is no evidence of springs or discharging groundwater within the vicinity of the project area or Waitangi Estuary, inferring that the confining layer is likely intact.

The age-testing of NCC Well No.5913 by GNS, revealed a 51-year mean residence time with a young water fraction of <0.005%, although the introduction pathway is uncertain (PDP, 2021) and the very minor fraction infers that no localised recharge of the aquifer is occurring (Tonkin and Taylor, 2019). Upon further analysis of drawdown responses from the aquifer testing of NCC wells, vertical leakage was observed which suggests that there is the potential for slow downward migration of contaminants if the hydraulic gradient was reversed (PDP, 2021).

It is further noted that the microbial water quality information suggests that over a shorter period of time, the NCC municipal supply bores may be at risk from surface influences; however, this may be the result of poorly maintained nearby bores providing pathways from the surface to the confined pumped aquifer (PDP, 2021). The Tonkin and Taylor (2019) study concludes that the development of downward hydraulic gradients is unlikely due to the combination of relatively high artesian pressure aquifer overlain by a relatively thick, low permeability aquitard within the vicinity of the NCC bore field and associated SPZ.

The installation of groundwater monitoring bores is recommended along the bounds of the proposed irrigation area in order to track any potential contamination of unconfined aquifers. It is recommended that three bores (up to 6 m depth) be drilled in a triangular formation across the site to map groundwater contours in the unconfined aquifer and establish the groundwater flow direction in conjunction with information gained from the BioRich monitor bores. Once the hydraulic gradient is confirmed, two of the three bores will be completed as monitor wells, located hydraulically up and down-gradient of the discharge area.

A series of water quality sampling and SWL recording should be undertaken prior to commencement of the irrigation of stormwater and process water in order to collect a robust set of baseline water quality data and establish groundwater levels in the unconfined aquifer. Ongoing groundwater sampling should be completed on a six-monthly basis. Water level data can be recorded by downhole pressure transducers which will reveal long-term trends and document tidal flux which can be used to aid scheduling of irrigation application and mitigate groundwater mounding at the site and neighbouring blocks.

1. INTRODUCTION

It is understood that Ravensdown Limited (the Applicant) is considering disposal of treated stormwater and process water by irrigation across 17.5 ha of farmland located off Waitangi Road, Awatoto, Napier.

The farmland lies immediately west of the Applicant's Awatoto fertiliser production facility, at 165 and 195 Waitangi Road which is currently grazed by dry stock and cropped with maize during the summer/autumn seasons.

In order to fully assess the proposed irrigation area, a review of the hydrogeology is required which includes an assessment of productive aquifers in the area.

2. SITE DESCRIPTION

The Ravensdown Napier plant is located adjacent to the Hawke's Bay coastline approximately 6 km south of Napier City as shown in Figure 1. The project site is across part of Nos. 165 and 195 Waitangi Road, Awatoto, immediately west of the production facility on Waitangi Road. The proposed site is approximately 300 m east of the coastline and 550 m north of the blind arm of the Tutaekuri River, which flows into the Tutaekuri River and Waitangi Estuary.

The 17.5 ha site comprises flat, low elevation cultivated farmland, about 200 m west of State Highway 2. The site is drained by 1 metre-deep peripheral ditches along the bounding fence lines, along with additional shallow swales oriented west-east across the grassed paddocks. A slightly low-lying depression was noted in the northeastern corner of the site, likely associated with an ephemeral waterway that tracks northwest-southeast across the northern paddock and into the Waitangi Road drains. The site details are as follows:

Address of Site	Nos. 165 and 195 Waitangi Road, Awatoto, Napier
Legal Description:	Lots 6 and 7 DP 25683

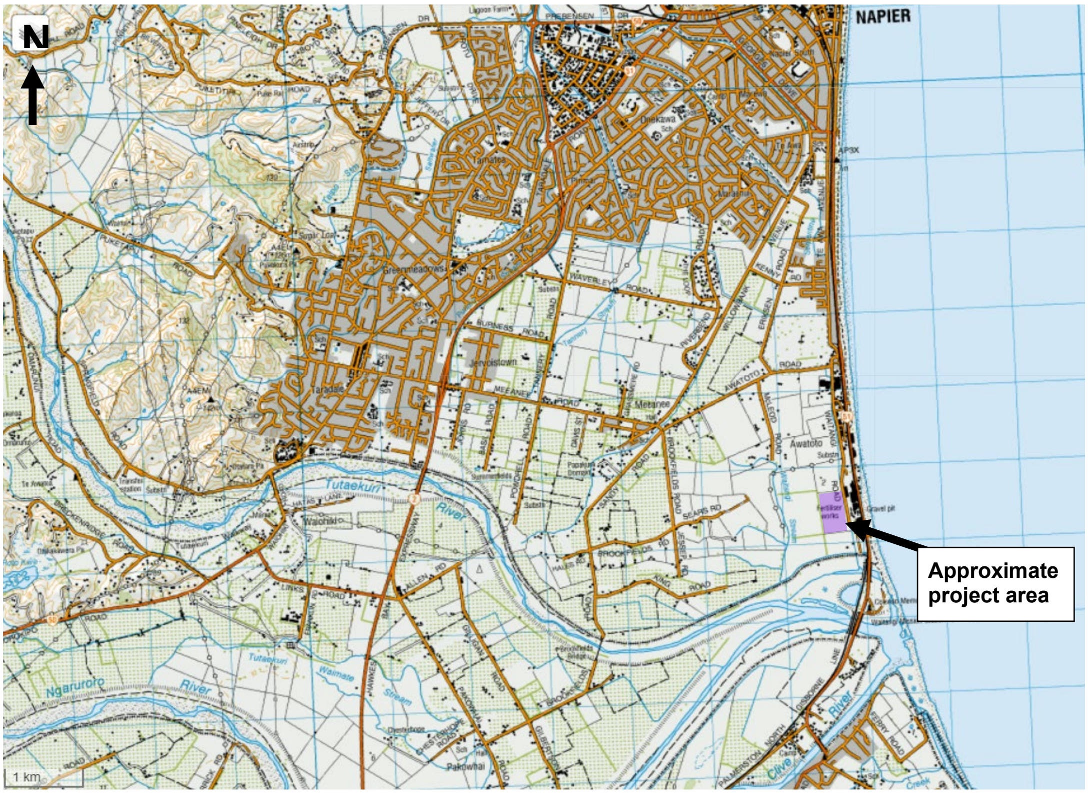


Figure 1. Topographic map showing the project area south of Napier City (NZ Topomap)

3. SITE GEOLOGY AND HYDROGEOLOGY

3.1 Local and Site Geology

The Heretaunga Plains area is mapped as a relatively deep, fault-controlled mid-Pleistocene sedimentary basin, downthrown to the southeast, bound by limestone-capped siltstone, sandstone and mudstone hillslopes to the north, south and west (Lee et al, 2011). The generally southwest-northeast oriented basin is approximately 900 m deep, infilled with Quaternary marine sediments and alluvium deposited by the Ngaruroro, Tukituki and Tutaekuri rivers which flow eastward to the coast.

Published geological maps indicate the presence of faulting and folding across the plains, near the foot of the western Taradale hills, and north and south of the Awatoto area (Lee et al, 2011). Furthermore, the online GNS Active Fault Database indicates the presence of the active Awanui Fault which is mapped through Pakowhai and Meeanee, tracking approximately 2 km northwest of the project area (gns.cri.nz/af) as displayed in Figure 2.

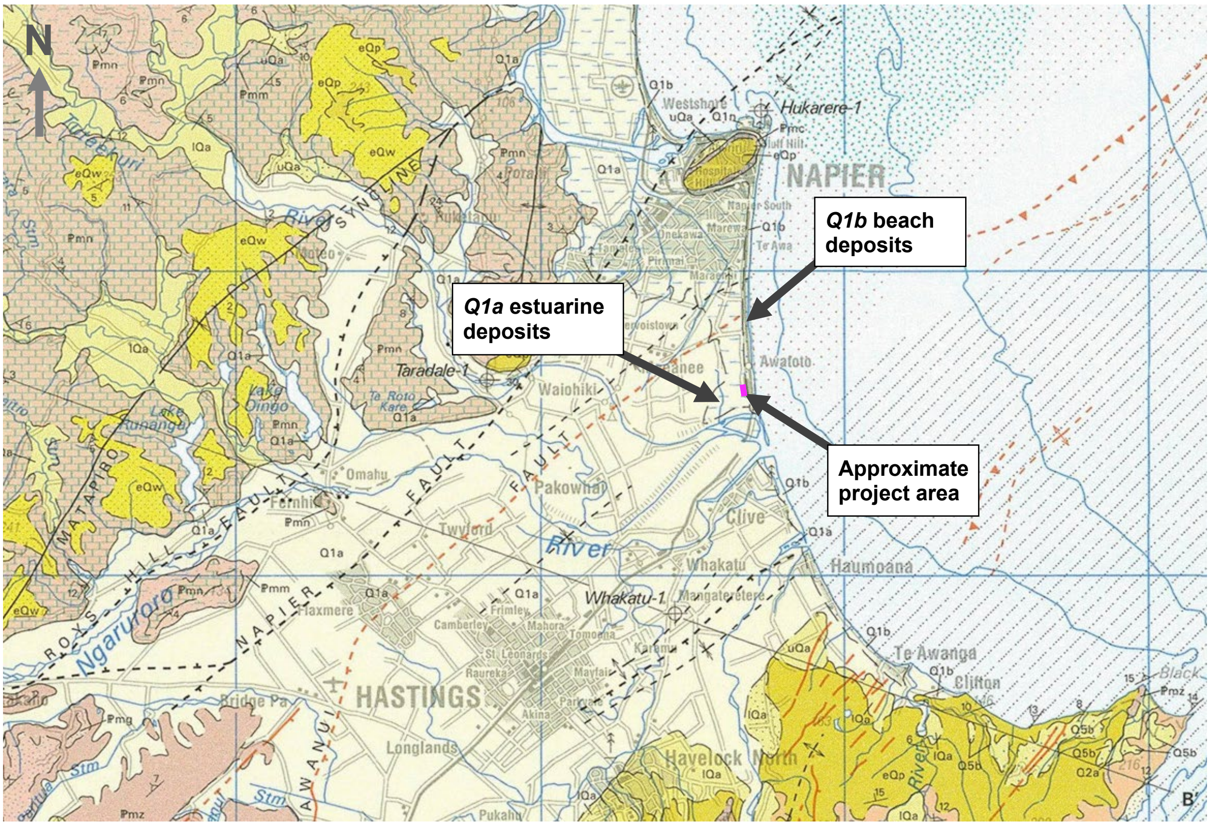


Figure 2. HBRC map GNS 1:250,000 geological Qmap across the Heretaunga Aquifer System (Lee et al, 2011).

Although modified, the topography of the area infers that the project site lies adjacent to the foredune zone west of the dune crest which is currently occupied by the state highway. The location behind the foredune is typically estuarine/salt marsh depositional environment, observed as a relatively deep trough influenced by tidal circulation. The geology across the project area is mapped as Holocene estuarine deposits comprising unconsolidated silt, mud, peat and sand (*Q1a*); with beach deposits (*Q1b*) mapped along a narrow strip adjacent to the coastline.

A localised geological map compiled by PDP (2021) included in Appendix A, further describes the site conditions as estuarine muds, with a narrow band of near-surface gravelly alluvium south of the BioRich site adjacent to the Waitangi Estuary and parallel to the Tutaekuri River.

3.2 Hydrogeology of the Heretaunga Plains and Awatoto Area

Subsurface conditions across the Heretaunga Plains comprise sequences of fluvial deposits, alluvial sands and silts, and marine clays as a result of fluctuating sea levels during glacial and interglacial periods. This formed a complex system of multilayered, interconnected aquifer systems as a result of ancient braided rivers depositing significant gravel loads across the plains and out into Hawke Bay during glaciations over the past 250,000 years. The overlying marine/marginal marine sediments reflect interglacial and post-glacial sequences and that act as confining aquicludes and cap the deep gravel intervals.

The main aquifer system is generally unconfined in the west and becomes increasingly confined to the east (as shown in Figure 3). The aquifer units are variably sandy gravel channel deposits of the Tukituki, Tutaekuri and Ngaruroro rivers, along with beach gravel and sand. The confinement is provided by successive sequences of interglacial marine transgressional and progradational deposits that comprise generally thick, laterally continuous, low permeability marine silts and clays (Dravid and Brown 1997; Rakowski and Knowling 2018).

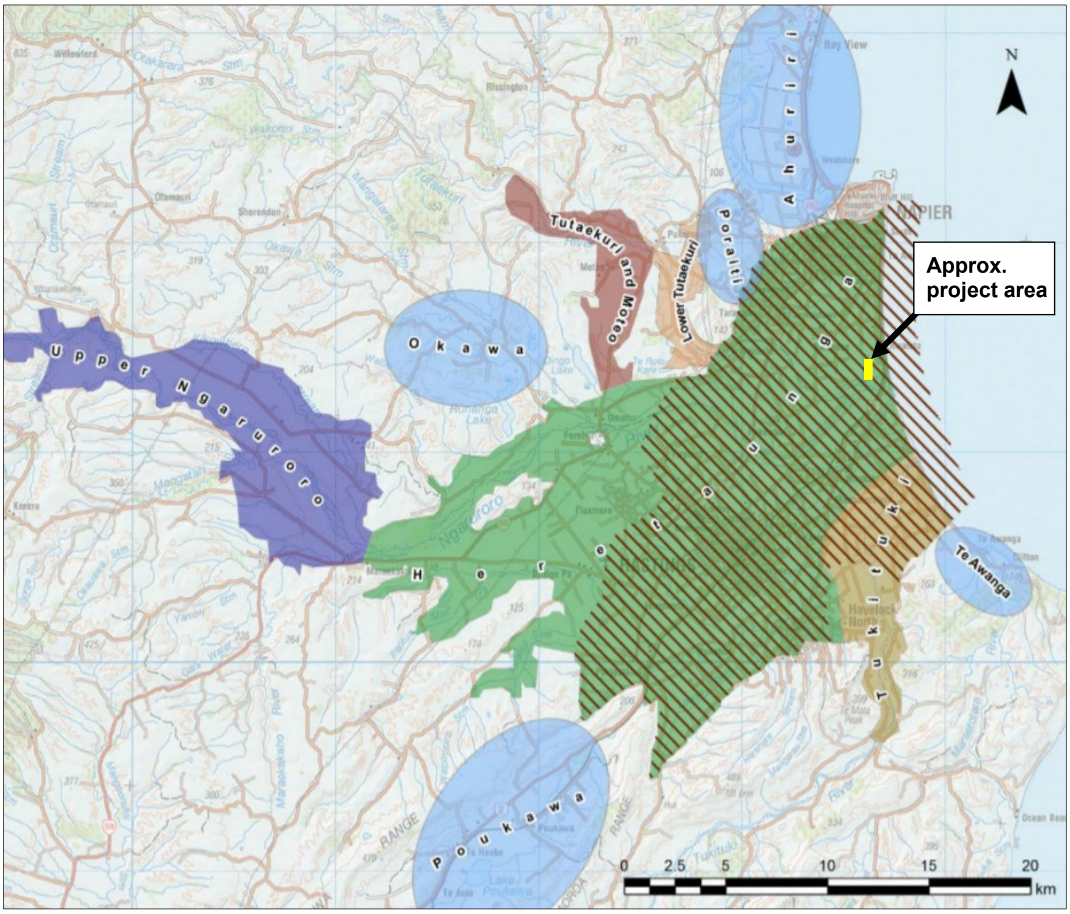


Figure 3. HBRC map showing extent of the Heretaunga Aquifer System, with the confined portion shown as brown hatch. Blue circles show other aquifer systems (from Rakowski and Knowling, 2018).

The geological map presented in Appendix A (PDP, 2021) displays a dashed green line trending approximately southwest-northeast consistent with the regional geology, tracking through Flaxmere toward Korokipo Road. The line corresponds to the boundary between the unconfined and confined zones of the Heretaunga Aquifer, with the latter represented by brown hatching in Figure 3. The confined potion of the basin extends east of the green line to beyond the coastline, where the most recent marine transgressive sequence formed a wedge of fine-grained sediments, capping the deep gravel aquifers. Contour maps produced by Dravid and Brown (1997) indicate that the thickness of low permeability confining strata is about 40 m within the vicinity of the project area.

The shallow aquifers are recharged by the Tukituki and Tutaekuri rivers, and confined aquifers are interconnected to the Ngaruroro River recharge zone of unconfined gravel sequences being buried former river channels near Roy's Hill. The deep wells at the coast and near Awatoto area typically exhibit flowing artesian conditions suggesting upward flow of groundwater from the confined aquifers (Dravid and Brown 1997; Lee et al 2014), although this is coupled with seasonal variations and tidal effects. Seasonal fluctuations in groundwater levels occur within bores across the Heretaunga Plains in response to rainfall recharge and irrigation abstractions.

There is no evidence of springs or discharging groundwater within the vicinity of the project area or Waitangi Estuary, inferring that the confining layer is likely intact. Furthermore, in the Heretaunga Aquifer and surface water-groundwater interaction study, Rakowski and Knowling (2018), suggest that hydraulic connection with the nearby Tutaekuri aquifer downstream of Puketapu is unlikely. Bore logs suggest that the more permeable sand layers recorded within the confining layer are laterally discontinuous and unlikely to act as significant conduits for groundwater (Tonkin and Taylor, 2019). It is noted in the PDP (2021) letter that the thickness of the lower permeability clay and silts, along with artesian pressure and vertically upwards groundwater gradient would impede downward movement of contaminants into the deeper, confined strata (Tonkin and Taylor, 2019; PDP, 2021).

The age-testing of NCC Well No.5913 by GNS, revealed a 51-year mean residence time with a young water fraction of <0.005%, although the introduction pathway is uncertain (PDP, 2021) and the very minor fraction infers that no localised recharge of the aquifer is occurring (Tonkin and Taylor, 2019).

However, upon analysis of drawdown responses from aquifer testing NCC wells, vertical leakage was observed which suggests the potential for slow downward migration of contaminants if the hydraulic gradient is reversed (PDP, 2021). It is further noted that the microbial water quality information suggests that over a shorter period of time, the NCC municipal supply bores may be at risk from surface influences; however, poorly maintained nearby bores may be responsible providing pathways from the surface to the confined pumped aquifer (PDP, 2021). The Tonkin and Taylor (2019) study concludes that development of downward hydraulic gradients is unlikely due to the combination of relatively high artesian pressure aquifer overlain by a relatively thick, low permeability aquitard within the vicinity of the NCC bore field. If a downward hydraulic gradient did develop, then downward travel times through the aquitard would likely be significantly longer than 365 days.

4. FIELD INVESTIGATION: TEST PITS

Near-surface strata are often not logged in detail during groundwater well drilling, therefore, existing test pit records from the BioRich site were reviewed, and field investigations were carried out to document the near-surface hydrogeological conditions.

4.1 RDCL Test Pits (2016)

In 2016, a geotechnical investigation was completed by RDCL Consulting Engineers for the BioRich facility located at 201 Waitangi Road, immediately to the south of the project area (RDCL, 2016). The investigation included Cone Penetrometer Tests (CPT) and four Test Pits, excavated up to 4.8 m depth. The test pits TP01 to TP04 revealed the following descriptions as reported by RDCL (2016), and as kindly provided to the Applicant by BioRich Ltd:

- up to 2 m of 'gravelly fill' described as being clean including some building material, and dense; overlying
- clay of high plasticity and which is soft; interbedded with
- sand which may be dense; and
- groundwater at 4.7m below natural ground.

The TP01 and TP04 test pit logs also recorded that water ingress (seeping) was noted at the bottom of the pits within the sandy Clay interval. The test pit logs are included in Appendix B.

4.2 Ravensdown Test Pits (September 2021)

In early September 2021, two test pits (TP1 and TP2) were completed across the project area using a small excavator at locations as displayed in Figure 4. The 1.8 and 1.5 m deep test pit sites (TP1 and TP2) were selected across the northern end of the project area to provide information as to near-surface soil types that are typically not detailed during groundwater bore logging. The test pits completed by RDCL at the BioRich facility provided detail for near-surface soils to the south of the project area.

The sediments as mapped in TP1 include the following descriptions with logs and site photographs included in Appendix C:

- 0.00 – 0.30 m: Topsoil: friable overlying compacted soil, mottled brown/black;
- 0.30 – 0.45 m: clayey Silt: brown, slightly fine sandy;
- 0.45 – 1.20 m: clayey Silt: pale brownish grey, mottled;
- 1.20 – 1.40 m: clayey Silt: pale blue, slightly fine sandy, shell material (bivalves);
- 1.40 – 1.80 m (BOTP): silty Clay: blue, estuarine.

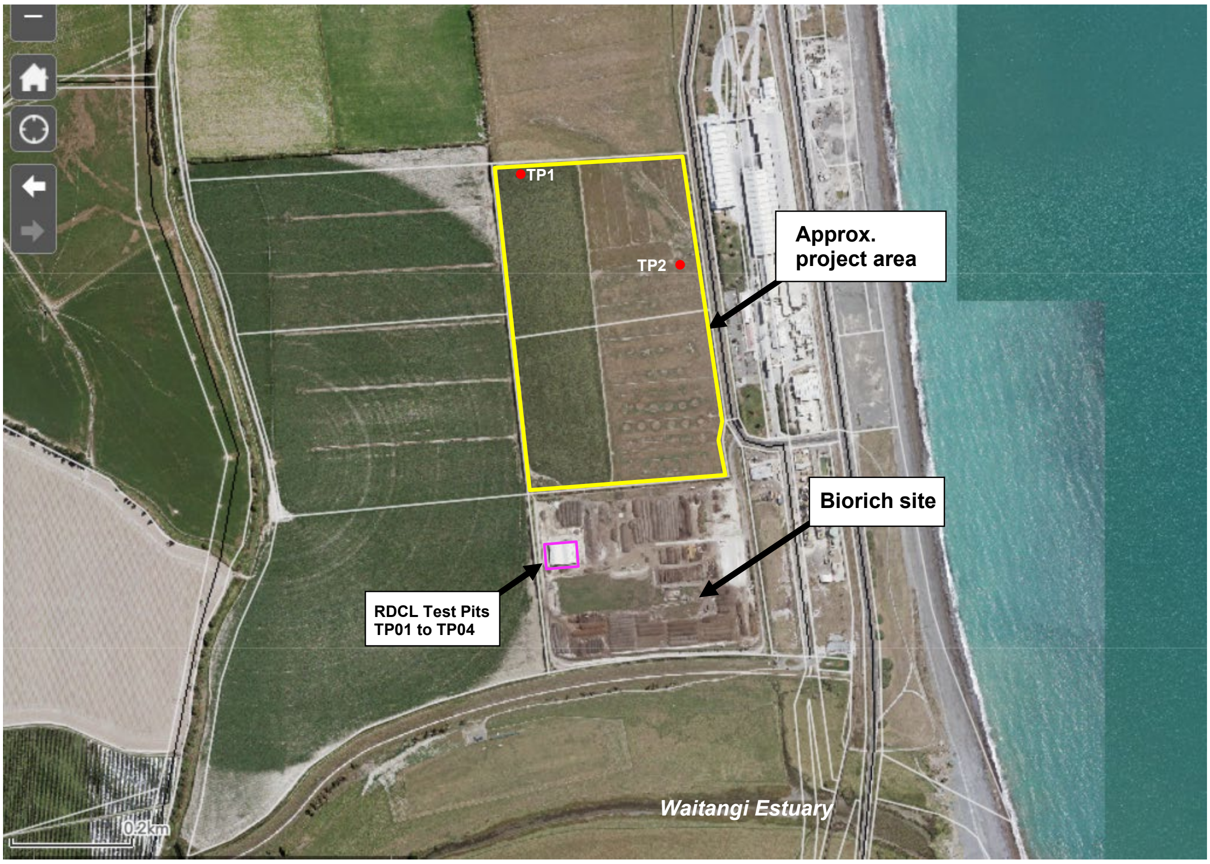


Figure 4. Map showing Test Pit locations across the project area along with the RDCL test pit site at BioRich.

No shell material was encountered from 1.20 m to 1.40 m depth within TP2; however, the same interval revealed a dark blue, well sorted marine sand with vegetation. Groundwater was noted seeping in at 1.2 m depth zone within the test pits. Both sets of test pit data provide detail on the near-surface soils and indicate that predominantly estuarine silts and clays are evident within the upper 4.8 m, along with sand beds and lenses, shell material and layers of vegetation.

5. REVIEW OF PRODUCTIVE AQUIFERS

A review of HBRC online bore log records was completed to understand the depth and extent of productive aquifer systems across the Awatoto area. While the online bore logs are an important source of information, typically the near-surface soils and upper section of the bore are not logged in detail.

Generally, drillers bore logs record within the nearby area describe near-surface silts and clays from 4 to 30 m depth bgl, or sands and gravels to depths between 10 and 16 m bgl. Beneath this, layers of marine sediments including blue clay with shells, sand and wood form a confining layer to a depth of approximately 40 m bgl. Below approximately 40 m depth, alluvial gravel intervals are recorded which typically present flowing artesian conditions.

5.1 Surrounding Well Details

The HBRC wells search revealed 67 bores within 1500 m of the project site which range in depth from 2.40 to 64.90 m bgl as displayed in Figure 5. The majority of the bores are screened across the deep, confined aquifer greater than 40 m depth. The HBRC bore log record reveals that many of the wells drilled across the area abstract groundwater from a deep gravel aquifer exhibiting flowing confined conditions, with static water levels (SWL) ranging from +7.00 m above ground level (agl) to -15.60 m bgl.

Eight shallow wells are either drilled to or screened above 18.00 m depth across the unconfined sand and gravel aquifer, with details provided in Table 1 and included in Appendix D. It is noted that the bores that have detail provided and described as environmental/exploration bores and are not screened for the purposes of groundwater abstraction.

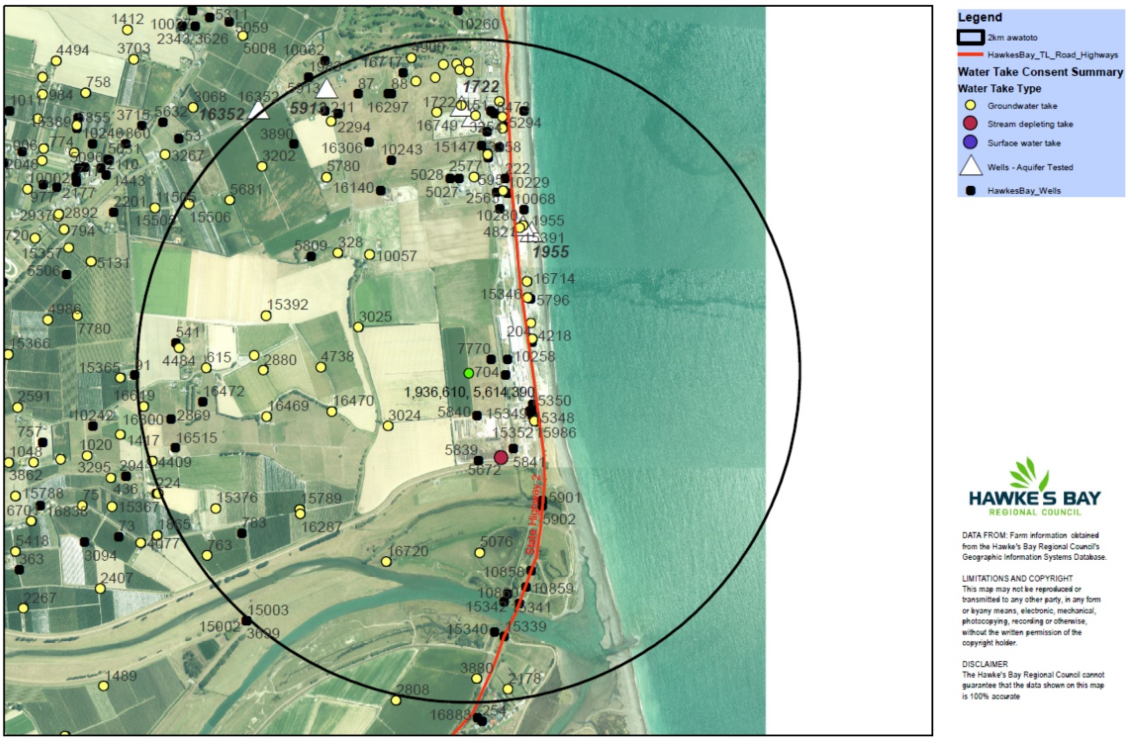


Figure 5. HBRC wells map showing surrounding bore locations in a 2 km radius.

Information for designated bore use is provided for 39 of the wells, with 11 of Unknown Use; 10 bores used for Industry, 5 for Irrigation purposes, 4 Exploratory bores, 4 Domestic Use, 3 for Environmental and 2 for Stockwater.

The online bore logs provided by HBRC as recorded by Welldrillers, confirm near surface sands and gravels east of Waitangi Road, as evidenced by lithology details for nearby Well Nos. 4218, 10258 and 15986. These wells indicate near surface gravels extend to depths between 10 and 16 m bgl. The exception is Well No. 7770 which lies west of the road, but logs 13 m of gravel from the surface. Beneath the shallow sand and gravel zone is a relatively thick interval of clay or silt that extends to approximately 40 m depth bgl. Underlying the clay is the productive, confined gravel layer, across which the majority of bores are screened. It is noted that the bore was not observed at the recorded grid reference during the field inspection.

The nearby bores to the west of Waitangi Road (excluding Well No. 7770) log near-surface soils comprising silts and clays to depths between 4 and 30 m bgl. This concurs with the geological mapping which denotes a thin zone of beach deposits parallel to the coastline, east of Waitangi Road; and estuarine conditions to the west of the road within which low permeability/fine grained sediments would be deposited.

Table 1. Details of shallow unconfined bores

Well No.	Distance (m)	Depth (bore)(m)	Diam. (mm)	Screen Details (m)	Aquifer	SWL (m toc)	USE
5840	259	5.95	50	-	blue Sand (unconfined)	0.00	Environ expl.
5841	528	5.69	50	-	fine blue Gravel (unconfined)	-1.50	Environ expl.
5839	533	5.94	50	-	fine blue Sand with gravel (unconfined)	-1.10	Environ expl.
5901	887	27.00	100	5.00-7.00	grey Sand with gravel	-	Environ expl.
5902	913	27.00	100	5.00-7.00	grey Gravel with sand	-	Environ expl.
5027	1175	18.00	50	16.30-18.00	Sand with silt (banded) (flowing conf)	-	Environ expl.
15147	1371	2.40	105	*no data*			
15148	1371	3.40	105	*no data*			

A 2019 report by Tonkin and Taylor investigating the SPZ for the NCC public supply bore fields includes a well correlation across the Awatoto area, which is based upon HBRC website bore logs and intercepts the NCC municipal supply wells (refer Figure 6). The maps and well correlation are included in Appendix E. The well correlation clearly illustrates the majority of the bore logs describe aquicludes comprising clay (grey fill on Figure 6) that extend from the near-surface to 40 to 55 m elevation below mean sea level (m bsl).

Several wells also display clays to depths between 5 and 10 m bgl, with interbedded sand and ash (black mottle) in the upper 15 m. The productive, confined gravel aquifer (blue and brown mottle) are evident at depths below 40 to 55 m bmsl.

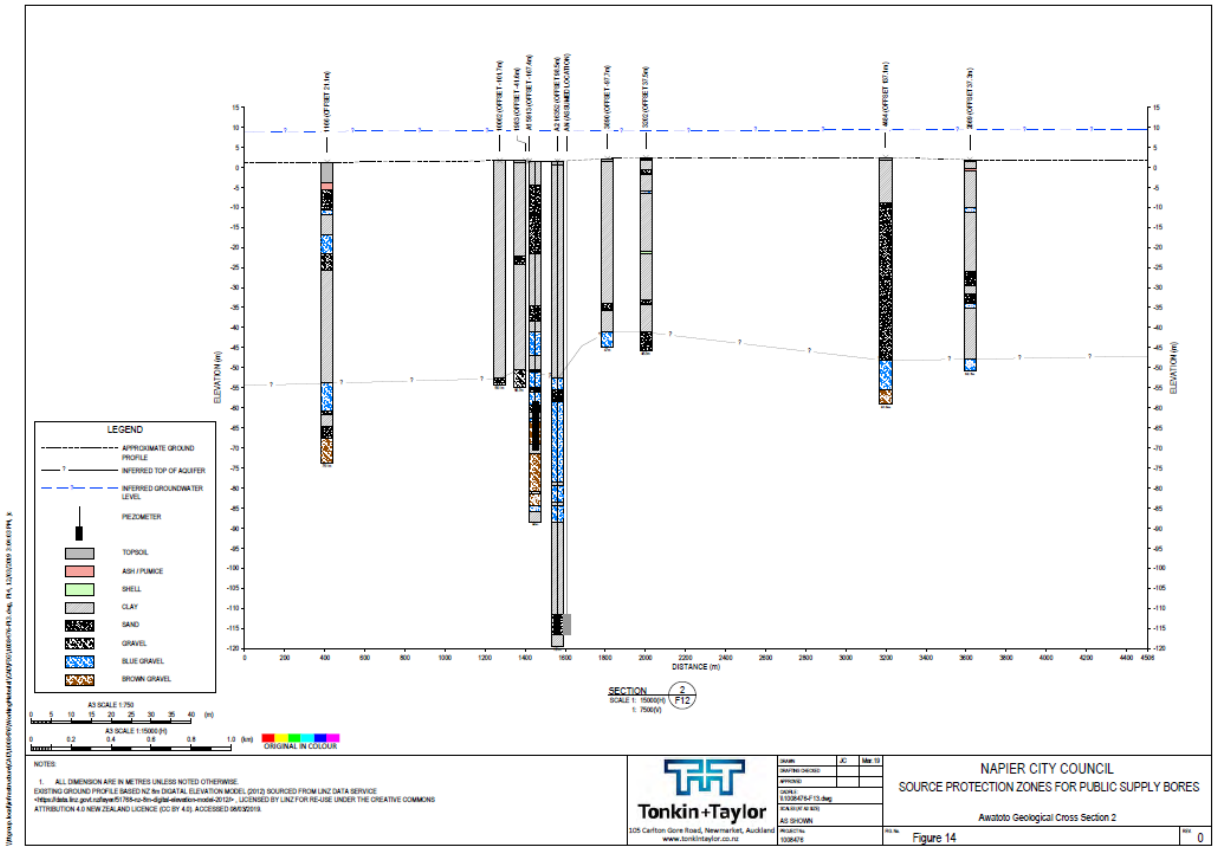


Figure 6. **Well correlation 2 across the Awatoto area (Tonkin and Taylor, 2019).**

5.2 Closest Consented Potable Supply and Municipal Wells

A search of the HBRC online wells database revealed two Government bores, being Well Nos. 5913 and 16352, the former being utilised for a public potable supply. The wells are located approximately 1.6 and 1.7 km NNW from the northern boundary of the proposed irrigation area, and are screened across the confined gravel aquifer. The details for the wells are outlined in Table 2.

Table 2. Details of nearby municipal supply wells

Well No.	Distance (m)	Depth (bore)(m)	Diam. (mm)	Screen Details (m)	Aquifer	SWL (m toc)	USE
5913	1600	90.00	300	74.00-76.00	brown Gravel (flowing confined)	+6.00	Public potable supply
16352	1725	133.25	300	110.97-120.66	coarse brown Gravel	+6.00	Govt. water

The HBRC online Resource Consents database indicates that four wells within 1200 m of the site hold current consents for activities involving abstraction of potable water, including water bottling as outlined in Table 3. The data available for three of the bores indicate that the wells are screened across the confined gravel aquifer.

Table 3. Details of nearby resource consents for potable supply wells

Well No. (diam)	Distance (m)	Consent No.	Screen Details (m)	Aquifer	SWL (m toc)	USE
16341 (200 mm)	930	AUTH-120235-02	60.64-62.00	blue/brown Gravel	+3.00	Water Supply - Potable - Bottling
15391 (200 mm)	950	AUTH-120793-01		*no data*		Water Supply - Potable - Bottling
595 (100 mm)	1120	AUTH-115985-03	53.34-56.39	- (flowing confined)	-	Water Supply - Potable - Bottling
2577 (150 mm)	1183	AUTH-109680-02	51.82-53.34	coarse blue Gravel	-	Government - Water Supply - Potable

6. HYDRAULIC GRADIENT

Understanding the direction of groundwater flow provides an opportunity to position monitoring wells in upgradient and downgradient locations in order to track any potential contamination of shallow, unconfined aquifers.

The aquifer pump test report (EAM, 2009) on Well No.5913 (McLeod Road, Awatoto) discussed groundwater flow direction; however, the dataset was restricted to the confined gravel aquifer > 50 m depth. The SWL data from the three closest State of the Environment (SOE) well Nos. 222, 1417 and 15003 as recorded by HBRC was used to generate a contour map, and infer the hydraulic gradient as displayed in Figure 7. The contours reflect a flow direction of the groundwater > 50 m depth tracking southwest toward the northeast.

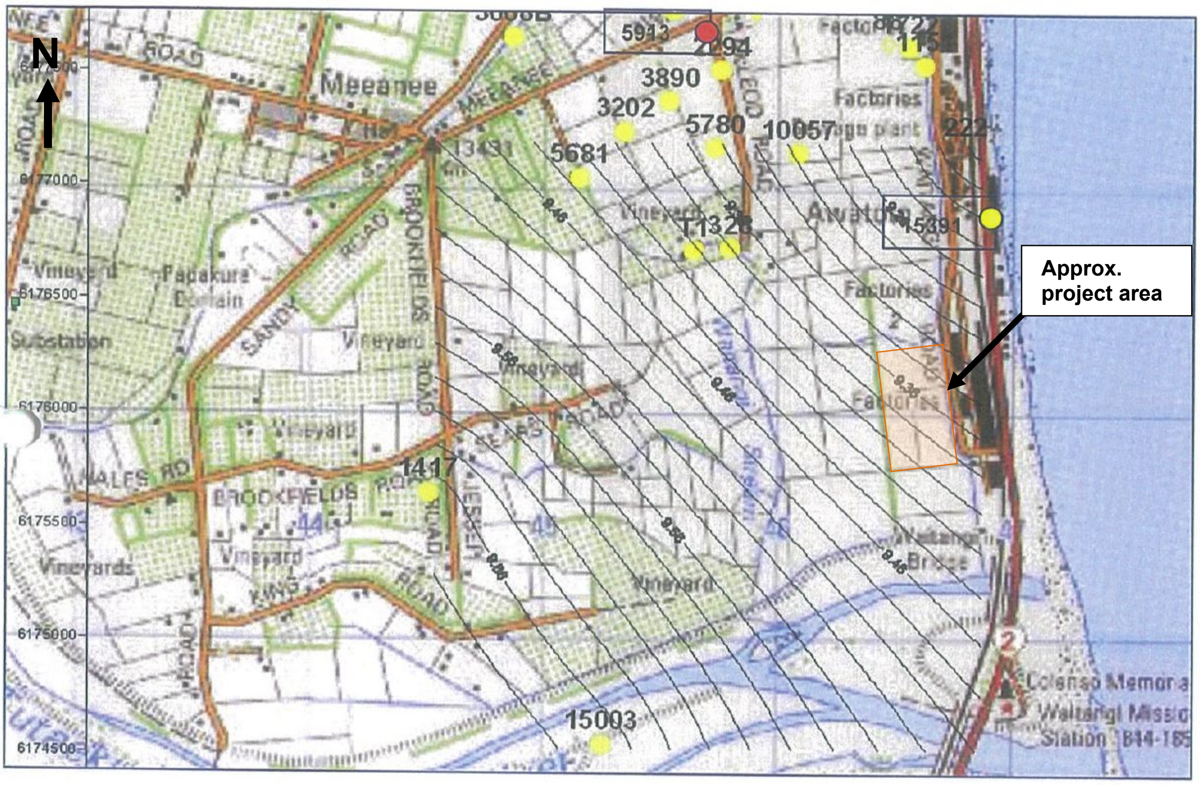


Figure 7. Aquifer (> 50 m depth) SWL contours across the Awatoto-Meeanee area (EAM, 2009).

An internal HBRC memo (*D. Gordon, 28 September, 2009*) regarding the BioRich site discussed interpretation of the groundwater flow direction by the Council's Senior Groundwater Scientist (*H. Baalousha, 14 April and 3 June, 2009*). The memo concluded that due to the strong tidal effect in the shallow groundwater due to the close proximity to the coast, that it was not possible to definitively determine a groundwater flow pattern.

Furthermore, the groundwater samples collected at three monitoring bores indicate a mixing of fresh and saline water (Baalousha, 2009). The memo further infers that any leaching from the BioRich site could move in any direction. Comments from D. Gordon on the same site (HBRC, 2009) discuss the variable flow direction within the shallow unconfined aquifer, from 180 degrees in the winter to 270 degrees in the summer which suggests that the hydraulic gradient is strongly influenced by tidal effects.

7. HBRC SOE WELLS AND PROPOSED MONITOR BORES

7.1 HBRC SOE Wells

HBRC have installed a series of bores across the region that are monitored as part of the State of the Environment (SOE) programme across the Heretaunga Plains. The wells are generally monitored for groundwater quality (orange circle) and water level data (blue circle), with some recorded for both (refer Figure 8). There are four SOE wells within approximately 3.4 m radius of the proposed project area, being Well Nos. 222, 1411, 15022 and 1450. Two of the bores are screened > 50 m depth across the confined gravel aquifer, and Well Nos. 1450 and 15022 are recorded as 46 and 40 m depth bgl, respectively.

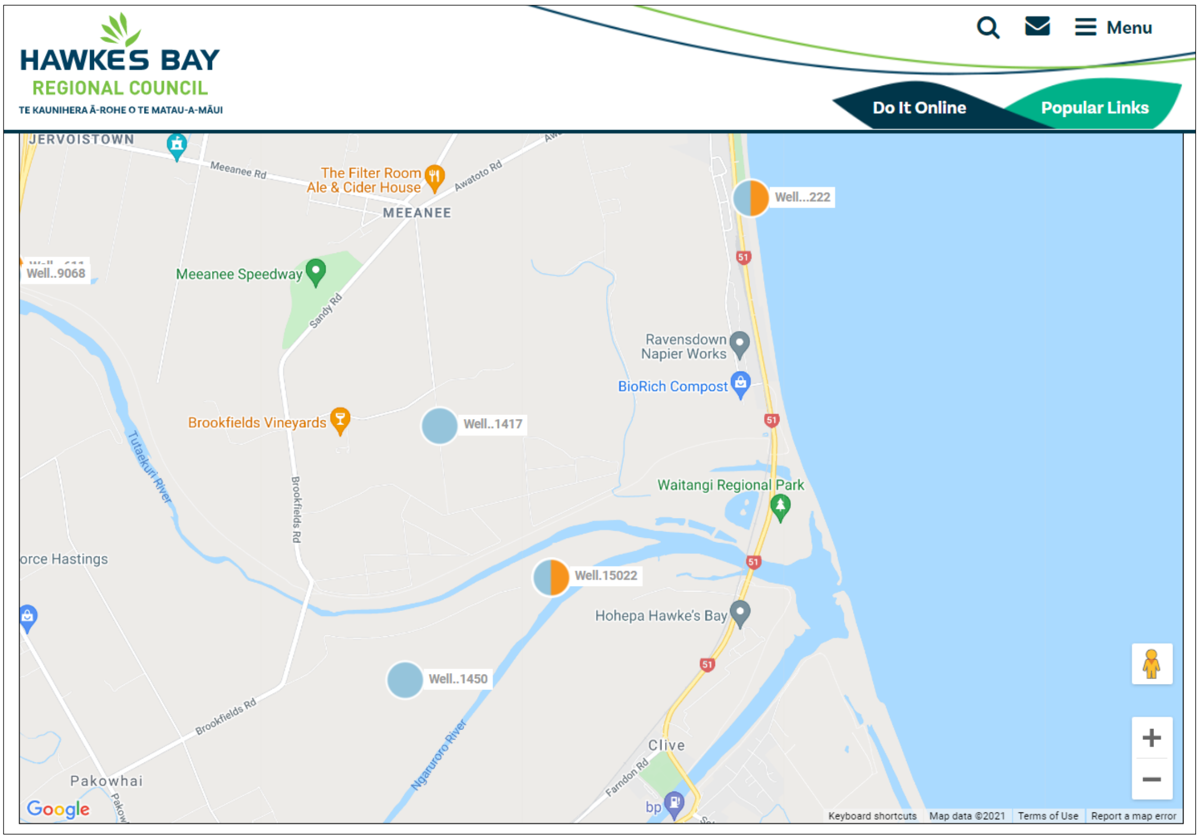


Figure 8. HBRC map showing locatoj of existing SOE bores and proposed Ravensdown Monitor Bores

The closest SOE monitoring Well No. 222 is located off SH51, approximately 1.5 km north of the Production Wells. The 75 mm diam. bore is recorded as 59.13 m deep, screened from 57.30 to 59.13 m across undocumented lithology that is likely to be a confined gravel aquifer, similar to nearby wells.

The Well No. 222 was installed in 1972 and provides an extended record of SWL and seasonal variations. The graph for the SOE Well No.222 exhibits generally consistent seasonal variation, averaging 1.94 m, with recovery of SWL's following summer irrigation periods, punctuated by dry summers and wet winters.

7.2 Recommended Monitoring Bores

It is recommended that groundwater bores be installed across the bounds of the site to monitor water quality in the unconfined aquifer. A review of any shallow groundwater bores reveals that of the twenty-eight bores within 1 km of the project site, only five bores are drilled or screened above 10 m depth bgl. Three of the bores (Well Nos. 5839, 5840 and 5841) and are monitoring wells at the BioRich site, and two wells are geotechnical bores drilled at the Tutaekuri River bridge over SH51.

It is proposed that three bores (up to 6 m depth) be drilled in a triangular formation across the site to map groundwater contours in the unconfined aquifer and establish the groundwater flow direction in conjunction with information gained from the BioRich monitor bores. Once the hydraulic gradient is confirmed, two of the three bores will be completed as monitor wells, located hydraulically up and down-gradient of the discharge area in order to track any potential contamination (refer Figure 9).

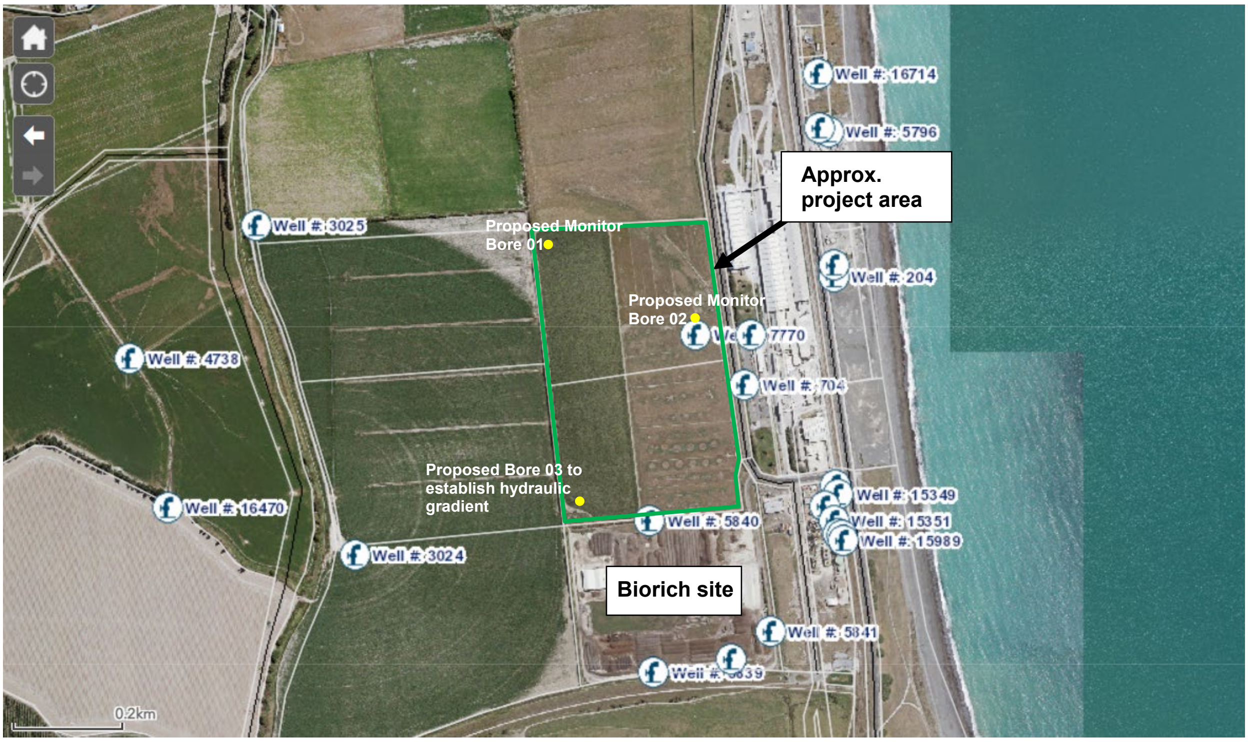


Figure 9. HBRC wells map with proposed monitor bore sites and existing bores.

The bore installed hydraulically upgradient of the proposed irrigation area is to provide baseline levels. A series of water quality sampling and SWL recording should be undertaken prior to commencement of the irrigation of stormwater and process water in order to collect a robust set of baseline water quality data and establish groundwater levels in the unconfined aquifer. The water quality samples should be sent to an approved laboratory to complete the required analysis, with ongoing groundwater sampling and collected on a six-monthly basis.

Water level data can be recorded by downhole pressure transducers which will reveal long-term trends and document tidal flux which can be used to aid scheduling of irrigation application and mitigate groundwater mounding at the site and neighbouring blocks.

8. SUMMARY

The Applicant is applying for consent to disposal of stormwater and process water through irrigation across 17.5, ha of farmland located at 165 and 195 Waitangi Road, Awatoto, Napier, directly across the road from the Applicant's fertiliser production facility. The proposed site currently grazed and cropped, lying approximately 300 m east of the coastline and 550 m north of the blind arm of the Tutaekuri River, which flows into the Waitangi Estuary.

The hydrogeology of the proposed irrigation area was reviewed to provide an assessment of the productive aquifers. The site lies along the coastal periphery of the fault-controlled Heretaunga Plains mid-Pleistocene sedimentary basin, infilled with Quaternary marine sediments and alluvium deposited by the Ngaruroro, Tukituki and Tutaekuri rivers. The main aquifer system of the Heretaunga Plains is generally unconfined in the west and increasingly confined to the east, with confinement as a result of successive sequences of marine transgressional and subsequent fluvial progradational deposition (Dravid and Brown 1997; Rakowski and Knowling 2018). The most recent marine transgressive sequence formed a wedge of low permeability sediments 40 to 50 m in thickness, capping deep gravel aquifers. The deep wells near the coast screened across the gravel aquifer typically exhibit flowing artesian conditions suggesting upward flow of groundwater from the confined aquifers (Dravid and Brown 1997; Lee et al 2014).

The near-surface soil conditions were investigated by excavating test pits and reviewing nearby soils data which revealed estuarine muds, silts, sands and vegetation across the low-lying site. A narrow band of Holocene beach deposits are mapped east of Waitangi Road forming slightly elevated topography parallel to the coast (Lee et al, 2011), with gravelly alluvium adjacent to the Waitangi Estuary south of the BioRich site (PDP, 2021).

The HBRC online bore logs for nearby wells were reviewed which record near-surface silts and clays from 4 to 30 m depth bgl, or sands and gravels to depths between 10 and 16 m bgl. Beneath this, layers of marine sediments including blue clay with shells, sand and wood form a confining layer to a depth of approximately 40 m bgl. Below approximately 40 m depth, alluvial gravel intervals are recorded which typically present flowing artesian conditions. The thickness of the lower permeability clay and silts, along with artesian pressure and the vertically upwards groundwater gradient would impede downward movement of contaminants into the confined strata (PDP, 2021).

The closest potable supply wells include two Government Well Nos. 5913 and 16352, approximately 1.6 and 1.7 km NNW from the northern boundary of the proposed irrigation area. The wells are screened greater than 74.00 and 110.97 m depth bgl, respectively across the confined gravel aquifer. There are four wells within 1200 m of the site that hold resource consents for activities involving abstraction of potable water, including water bottling, with records showing three of the bores are screened across the confined gravel aquifer, and there is no data for the fourth bore.

A study on the hydraulic gradient of the confined gravel aquifer (>50 m depth) determined flow direction toward the northeast (EAM, 2009). Shallow groundwater samples collected at three nearby monitoring bores indicate a mixing of fresh and saline water, although the direction of groundwater flow in the shallow aquifer is unknown due to the strong tidal effect in close proximity to the coast strongly influencing the hydraulic gradient (Baalousha, 2009).

The following recommendations are made:

- Three bores (up to 6 m depth) be drilled in a triangular formation across the site to map groundwater contours in the unconfined aquifer and establish the groundwater flow direction in conjunction with information gained from the BioRich monitor bores. Once the hydraulic gradient is confirmed, two of the three bores will be completed as monitor wells, located hydraulically up and down-gradient of the discharge area;

- A series of water quality sampling and SWL recording should be undertaken prior to commencement of the irrigation of stormwater and process water in order to collect a robust set of baseline water quality data and establish groundwater levels in the unconfined aquifer. The bore installed hydraulically upgradient of the proposed irrigation area is to provide baseline levels;

- The water quality samples should be sent to an approved laboratory to complete the required analysis;

- Ongoing groundwater sampling should be completed on a six-monthly basis;

- Water level data can be recorded by downhole pressure transducers which will reveal long-term trends and document tidal flux which can be used to aid scheduling of irrigation application and mitigate groundwater mounding at the site and neighbouring blocks.

9. REFERENCES

Dravid, P.N., Brown, L.J.,1997: Heretaunga Plains Groundwater Study. Volume 1: Findings. Hawke's Bay Regional Council, Napier, New Zealand.

EAM, 2009: Aquifer Test report and Assessment of Environmental Effects Napier City Council New Production Well No.5913. Client Report No. 094b. EAM Ltd., Napier, New Zealand.

GNS Active Faults Database: https://data.gns.cri.nz/af/

Gordon, D., 2009: HBRC Internal memo to J. Matthys, 28 September, 2009. HBRC, Napier, New Zealand.

Hawke's Bay Regional Council website: www.hbrc.govt.nz.

Lee, J.M., Bland, K.J., Townsend, D.B., Kamp, P.J.J. (compilers), 2011: Geology of the Hawke's Bay area. Institute of Geological & Nuclear Sciences 1:250,000 Geological Map 8. GNS Science, Lower Hutt, New Zealand.

NZ Topo Map: www.topomap.co.nz.

PDP, 2021: Preliminary Assessment of Groundwater Data Availability. Letter to Ravensdown, 9 April, 2021. PDP, Christchurch, New Zealand.

PDP, 2021: Chlorine-Free Drinking Water Review. Client Report No. A03420902 prepared for Napier City Council. PDP, Christchurch, New Zealand.

RDCL, 2016: Geotechnical Investigation at 201 Waitangi Road, Awatoto. Client Report No. R-160602159-01 for BioRich Ltd. RDCL, Hastings, New Zealand.

Rakowski, P. and Knowling, M., 2018: Heretaunga Aquifer Groundwater Model Development Report. HBRC Report No. RM18-14 Publication No. 4997. Hawkes Bay Regional Council, Napier, New Zealand.

Tonkin and Taylor, 2019: Source protection zones for new public supply bore fields. Report No. 1008476 prepared for Napier City Council. Tonkin and Taylor Ltd., New Zealand.

Report Limitations

This report has been written based on conditions as they existed at the time of the desk-top study and limited scope field investigation, and there is no interpretation made on potential changes that may occur within the project area. Subsurface conditions may exist across the project site that are not able to be detected or revealed by the desk-top study or within the scope of the project, and therefore are not taken into account.

APPENDICES

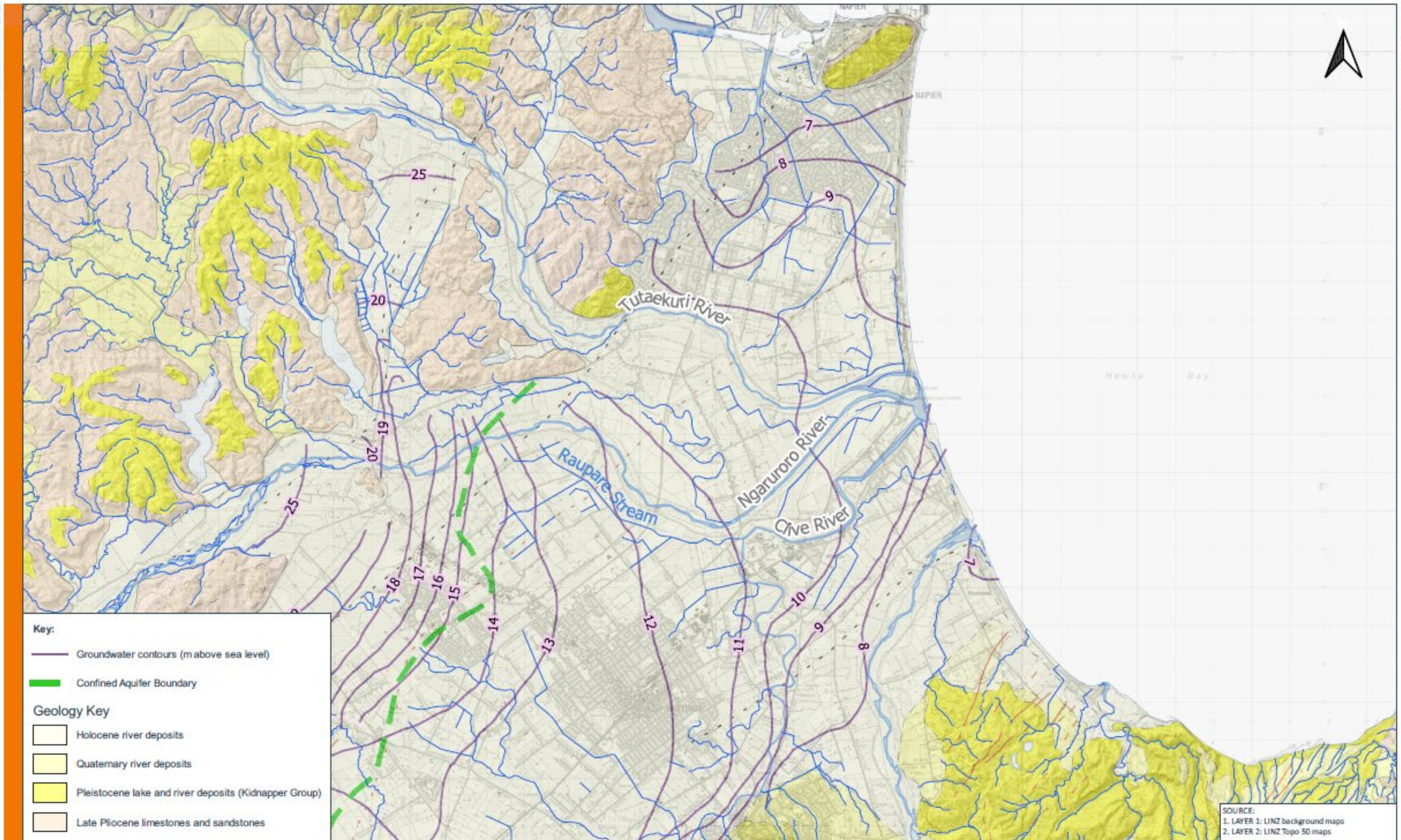
APPENDIX A

Geological Map of the Heretaunga Plains

(PDP, 2021)

Local Geology and surrounding Bores Map

(PDP, 2021)



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CLIENT
ravensdown

FIGURE
FIGURE 2: Geological Map of the Heretaunga Plains

PROJECT
STAGE 1 GROUNDWATER ASSESSMENT: RAVENSDOWN NAPIER SITE

FIGURE 3: LOCAL GEOLOGY AND BORES

PROJECT
GROUNDWATER ASSESSMENT FOR RAVENSDOWN

APPENDIX B

RDCL Test Pit Logs at BioRich Site

B1: RDCL Test Pit TP01 (BioRich site)

RDCL

TP01

Client	Project No.	Location
BioRich Ltd	160602162	201 Waitangi Rd, Awatoto Geotechnical Investigation

Started: 16-09-2016 Finished: 16-09-2016	Logged By: TW - 16-09-2016 Checked By: SLK - 19-09-2016 Status: FINAL	Contractor: Ontrax Operator: Joel Plant: 12 ton excavator	Easting: 1936535.00 m Northing: 5614036.00 m R. L.: 12.00 m

Depth (m)	Geology	Graphic Log	ROCK / SOIL DESCRIPTION	WATER	MOISTURE	CONSISTENCY/ DENSITY	Tests & Samples	ADDITIONAL REMARKS	R.L. (m)
0.0			**LIMESTONE CHIP** sandy gravel.						12.0
			CRUSHED CONCRETE FILL crushed concrete fill.						
0.5			**GRAVELLY FILL** sand and gravel contains concrete and bricks.						11.5
1.0									11.0
1.5									10.5
2.0			Sandy **CLAY** soft, moist, high plasticity, organic and sand lenses. eoh: water ingress bottom of hole.		M	S			10.0
2.5									9.5
3.0									9.0
3.5									8.5
4.0									8.0
4.5									7.5
4.7			EOH: 4.7m	▼					

Remarks:

Elevation Datum: NCC Intra Maps
Coordinate System: NZTM2000
Log Scale at A4 - 1:25

Report ID: RDCL_NZGS_HATP LOG CURRENT || Project: 160602162_GINT_DRAFT01.GPJ || Library: RDCL_GINT_V5d_DCP_TP_BH_07-07-2016-CURRENT.GLB || Date: 28 September 2016

Resource Development Consultants Ltd.
Cnr Porter Dr & Havelock Rd | PO Box 28057 | Havelock North 4130 | New Zealand
Ph: +64 6 8771652 | Fax: +64 6 8775015 | Email: info@rdcl.co.nz

B2: RDCL Test Pit TP02 (BioRich site)

RDCL

TP02

Client: BioRich Ltd	Project No.: 160602162	Location: 201 Waitangi Rd, Awatoto Geotechnical Investigation

Started: 16-09-2016 Finished: 16-09-2016	Logged By: TW - 16-09-2016 Checked By: SLK - 19-09-2016 Status: FINAL	Contractor: Ontrax Operator: Joel Plant: 12 ton excavator	Easting: 1936568.00 m Northing: 5614032.00 m R. L.: 12.00 m

Depth (m)	Geology	Graphic Log	ROCK / SOIL DESCRIPTION	WATER	MOISTURE	CONSISTENCY / DENSITY	Tests & Samples	ADDITIONAL REMARKS	R.L. (m)
			LIMESTONE CHIP.						
			GRAVELLY FILL dry, well graded concrete blocks.		D				
0.5									11.5
1.0									11.0
1.5									10.5
			CLAY bluish grey, firm, moist, high plasticity.		M	F			
2.0			Sandy **CLAY** bluish grey, soft, moist, high plasticity, organics, trace orange mottle. eoh:.		M	S			10.0
2.5									9.5
3.0			EOH: 3m						9.0

Remarks:

Elevation Datum: NCC Intra Maps
Coordinate System: NZTM2000
Log Scale at A4 - 1:25

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B3: RDCL Test Pit TP03 (BioRich site)

RDCL

TP03

Client: BioRich Ltd	Project No. 160602162	Location: 201 Waitangi Rd, Awatoto Geotechnical Investigation	
Started: 16-09-2016 Finished: 16-09-2016	Logged By: TW - 16-09-2016 Checked By: SLK - 19-09-2016 Status: FINAL	Contractor: Ontrax Operator: Joel Plant: 12 ton excavator	Easting: 1936558.00 m Northing: 5613998.00 m R. L.: 12.00 m

Depth (m)	Geology	Graphic Log	ROCK / SOIL DESCRIPTION	WATER	MOISTURE	CONSISTENCY / DENSITY	Tests & Samples	ADDITIONAL REMARKS	R.L. (m)
0.0			**LIMESTONE CHIP.**						12.0
			GRAVELLY FILL.						
0.5									11.5
1.0									11.0
1.5									10.5
2.0			Sandy **CLAY** bluish grey, soft, wet, high plasticity, lenses of sand, trace organics.		W	S			10.0
2.5									9.5
3.0									9.0
3.5									8.5
4.0									8.0
4.5									7.5
4.7			EOH: 4.7m	▼					

Remarks:

Elevation Datum: NCC Intra Maps
Coordinate System: NZTM2000
Log Scale at A4 - 1:25

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Ph: +64 6 8771652 | Fax: +64 6 8775015 | Email: info@rdcl.co.nz

B4: RDCL Test Pit TP04 (BioRich site)

RDCL	TP04	
Client: BioRich Ltd	Project No. 160602162	Location: 201 Waitangi Rd, Awatoto Geotechnical Investigation

Started: 16-09-2016 Finished: 16-09-2016	Logged By: TW - 16-09-2016 Checked By: SLK - 19-09-2016 Status: FINAL	Contractor: Ontrax Operator: Joel Plant: 12 ton excavator	Easting: 1936533.00 m Northing: 5613992.00 m R. L.: 12.00 m

Depth (m)	Geology	Graphic Log	ROCK / SOIL DESCRIPTION	WATER	MOISTURE	CONSISTENCY/ DENSITY	Tests & Samples	ADDITIONAL REMARKS	R.L. (m)
0.0			**LIME CHIP** well compacted.						12.0
0.3			**FILL** concrete blocks and brick.						
0.5									11.5
1.0									11.0
1.5									10.5
2.0			Sandy **CLAY** bluish green, high plasticity, soft to firm, trace organics, water ingress (seeping).						10.0
2.5									9.5
3.0									9.0
3.5									8.5
4.0									8.0
4.5									7.5
4.8			EOH: 4.8m						

Remarks:

Elevation Datum: NCC Intra Maps
Coordinate System: NZTM2000
Log Scale at A4 - 1:25

Report ID: RDCL_NZGS_HATTP LOG CURRENT || Project: 160602162_GINT_DRAFT01.GPJ || Library: RDCL_GINT_V5.0_DCP_TP_BH_07-07-2016-CURRENT.GLB || Date: 28 September 2016

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APPENDIX C

Ravensdown Test Pit Logs

and

Site Photographs

C1: Ravensdown Test Pit No. 1 (BGSL)

GRAPHIC LOG	TEST PIT LOG No. 1 SOIL DESCRIPTION	DEPTH (metres)	GEOLOGICAL FORMATION		DETAILS	PIEZOMETER / WATER LEVEL
	TOPSOIL.		T/S			
	SILT: clayey, slightly fine sandy, brown.		Marine Deposits			
	SILT: clayey, pale brownish grey (mottled).	1				
	SILT: clayey, slightly fine sandy, pale bluish grey, shell fragments (bivalves).					
	CLAY: silty, blue grey, plastic.					
	Bottom of Test Pit completed 02/09/21	2				
		3				
		4				

NOTES

The stratification lines represent the approximate boundary between soil types and the transition may be gradual.

PROJECT: RAVENSDOWN LTD.
LOCATION: Nos. 165 and 195 Waitangi Road, Awatoto, Napier
PROJECT NO.: BGS292-01

METHOD: Hydraulic Excavator
CONTRACTOR: Wrightson

LOGGED: AJ
DATE LOGGED: 02/09/21
PLOTTED: AJ

BAY GEOLOGICAL SERVICES LTD
m: +64 27 501 4984

TEST PIT LOG

TEST PIT No. 01 RL (m):
GRID REF (NZTM): E1936481, N5614660
SHEET: 1 OF 1 Fig. No. C-1

C2: Ravensdown Test Pit No. 2 (BGSL)

GRAPHIC LOG	TEST PIT LOG No. 2 SOIL DESCRIPTION	DEPTH (metres)	GEOLOGICAL FORMATION	DETAILS	PIEZOMETER / WATER LEVEL
	TOPSOIL.		T/S		
	SILT: clayey, greysih brown (mottled), iron, manganese.		Marine Deposits		
	SILT: clayey, pale brownish grey (mottled).	1			
	SAND: fine, silty, slightly clayey, dark bluish grey, vegetation (wood).				
	CLAY: silty, blue grey, plastic.				
	Bottom of Test Pit completed 02/09/21	2			
		3			
		4			

NOTES

The stratification lines represent the approximate boundary between soil types and the transition may be gradual.

PROJECT: RAVENSDOWN LTD.
LOCATION: Nos. 165 and 195 Waitangi Road, Awatoto, Napier
PROJECT NO.: BGS292-01

METHOD: Hydraulic Excavator
CONTRACTOR: Wrightson

LOGGED: AJ
DATE LOGGED: 02/09/21
PLOTTED: AJ

BAY GEOLOGICAL SERVICES LTD
m: +64 27 501 4984

TEST PIT LOG

TEST PIT No. 02 RL (m):
GRID REF (NZTM): E1936763, N5614506
SHEET: 1 OF 1 Fig. No. C-2

C3: Ravensdown Test Pit No. 1

C4: Ravensdown Test Pit No. 1

C5: Ravensdown Test Pit No. 2

C6: Ravensdown Test Pit No. 2

C7 Ravensdown Test Pit No. 2

APPENDIX D

Surrounding Shallow Wells Bore Logs

(HBRC)

D1. Well No. 5840

HAWKE'S BAY REGIONAL COUNCIL

Well 5840

IDENTIFICATION

WQ Site:	
Easting:	1936657.403
Northing:	5614135.319
Method:	Hand-held GPS
Address:	201 WAITANGI ROAD, AWATOTO

WELL INFORMATION

Drill date:	25/06/2008
Driller:	Honnor Drilling Limited
Casing Diameter (mm):	50
Bore Depth (m)	6
Well Depth (m):	5.95
Screen top (m):	
Screen bottom (m):	
Open hole top (m):	
Open hole bottom (m):	
Water level access:	Yes

Bore Consents

Consent Id	LU080252B
Consent Type	Bore consent
Use One	Exploratory Drilling
Use Two	Environmental Purposes

Aquifer Information

Inital Water Level	0
Aquifer Condition	Unconfined
Aquifer Lithology	Sand

Bore Log (m)

Lithology	TOPSOIL with clay
From Depth	0
To Depth	4

Lithology	blue SAND
From Depth	4
To Depth	6

D2. Well No. 5841

HAWKE'S BAY REGIONAL COUNCIL

Well 5841

IDENTIFICATION

WQ Site:	
Easting:	1936874.684
Northing:	5613933.193
Method:	Hand-held GPS
Address:	201 WAITANGI ROAD, AWATOTO

WELL INFORMATION

Drill date:	24/06/2008
Driller:	Honnor Drilling Limited
Casing Diameter (mm):	50
Bore Depth (m)	6
Well Depth (m):	5.69
Screen top (m):	
Screen bottom (m):	
Open hole top (m):	
Open hole bottom (m):	
Water level access:	Yes

Bore Consents

Consent Id	LU080253B
Consent Type	Bore consent
Use One	Exploratory Drilling
Use Two	Environmental Purposes

Aquifer Information

Inital Water Level	-2
Aquifer Condition	Unconfined
Aquifer Lithology	Gravels

Bore Log (m)

Lithology	TOPSOIL with clay
From Depth	0
To Depth	4

Lithology	fine blue GRAVEL
From Depth	4
To Depth	6

D3. Well No. 5839

HAWKE'S BAY REGIONAL COUNCIL

Well 5839

IDENTIFICATION

WQ Site:	
Easting:	1936664.499
Northing:	5613860.049
Method:	Hand-held GPS
Address:	201 WAITANGI RD, AWATOTO

WELL INFORMATION

Drill date:	25/06/2008
Driller:	Honnor Drilling Limited
Casing Diameter (mm):	50
Bore Depth (m)	6
Well Depth (m):	5.94
Screen top (m):	
Screen bottom (m):	
Open hole top (m):	
Open hole bottom (m):	
Water level access:	Yes

Bore Consents

Consent Id	LU080251B
Consent Type	Bore consent
Use One	Exploratory Drilling
Use Two	Environmental Purposes

Aquifer Information

Inital Water Level	-1
Aquifer Condition	Unconfined
Aquifer Lithology	Sand

Bore Log (m)

Lithology	TOPSOIL with clay
From Depth	0
To Depth	4

Lithology	fine blue SAND with gravel
From Depth	4
To Depth	6

D4. Well No. 5901

Well 5901

HAWKE'S BAY REGIONAL COUNCIL

IDENTIFICATION

WQ Site:	
Easting:	1937051.96
Northing:	5613620.943
Method:	Map estimate
Address:	SH2 WAITANGI BRIDGE

WELL INFORMATION

Drill date:	19/12/2008
Driller:	WARMINGTON DRILLING
Casing Diameter (mm):	100
Bore Depth (m)	27.45
Well Depth (m):	27
Screen top (m):	5
Screen bottom (m):	7
Open hole top (m):	
Open hole bottom (m):	
Water level access:	Unknown

Bore Consents

Consent Id	LU080479B
Consent Type	Bore consent
Use One	Exploratory Drilling
Use Two	Environmental Purposes

Aquifer Information

Inital Water Level	
Aquifer Condition	Unknown
Aquifer Lithology	Other

Bore Log (m)

Lithology	grey SAND with silt
From Depth	0
To Depth	3
Lithology	grey SAND with gravel
From Depth	3
To Depth	11
Lithology	grey SAND
From Depth	11
To Depth	25
Lithology	grey CLAY with silt
From Depth	25
To Depth	27

D5. Well No. 5902

Well 5902

HAWKE'S BAY REGIONAL COUNCIL

IDENTIFICATION

WQ Site:	
Easting:	1937051.97
Northing:	5613590.914
Method:	Map estimate
Address:	SH2, WAITANGI BRIDGE

WELL INFORMATION

Drill date:	22/12/2008
Driller:	WARMINGTON DRILLING
Casing Diameter (mm):	100
Bore Depth (m)	27.5
Well Depth (m):	27
Screen top (m):	5
Screen bottom (m):	7
Open hole top (m):	
Open hole bottom (m):	
Water level access:	Unknown

Bore Consents

Consent Id	LU080480B
Consent Type	Bore consent
Use One	Exploratory Drilling
Use Two	Environmental Purposes

Aquifer Information

Inital Water Level	
Aquifer Condition	Unknown
Aquifer Lithology	Other

Bore Log (m)

Lithology	grey SAND with gravel/sand/silt
From Depth	0
To Depth	3

Lithology	grey SILT
From Depth	3
To Depth	4

Lithology	grey GRAVEL with sand
From Depth	4
To Depth	10

Lithology	grey SILT
From Depth	10
To Depth	14

Lithology	grey SAND with silt
From Depth	14

D6. Well No. 5902 (cont.)

To Depth	19
Lithology	grey SAND
From Depth	19
To Depth	26
Lithology	grey SILT with clay
From Depth	26
To Depth	28

D7. Well No. 5027

HAWKE'S BAY REGIONAL COUNCIL

Well 5027

IDENTIFICATION

WQ Site:	
Easting:	1936549.827
Northing:	5615563.697
Method:	Map estimate
Address:	855 WAITANGI RD, AWATOTO

WELL INFORMATION

Drill date:	03/09/2003
Driller:	Baylis Brothers Limited
Casing Diameter (mm):	50
Bore Depth (m)	18
Well Depth (m):	18
Screen top (m):	16.3
Screen bottom (m):	18
Open hole top (m):	
Open hole bottom (m):	
Water level access:	Unknown

Bore Consents

Consent Id	LU030411B
Consent Type	Bore consent
Use One	Exploratory Drilling
Use Two	Environmental Purposes

Aquifer Information

Inital Water Level	
Aquifer Condition	Flowing confined
Aquifer Lithology	Sand

Bore Log (m)

Lithology	brown SILT (soft)
From Depth	0
To Depth	0

Lithology	fine grey SAND (loose)
From Depth	0
To Depth	1

Lithology	SAND (lost cone)
From Depth	1
To Depth	2

Lithology	SAND
From Depth	2
To Depth	2

Lithology	grey SILT with sand/shell (soft)
From Depth	2

D8. Well No. 5027 (cont.)

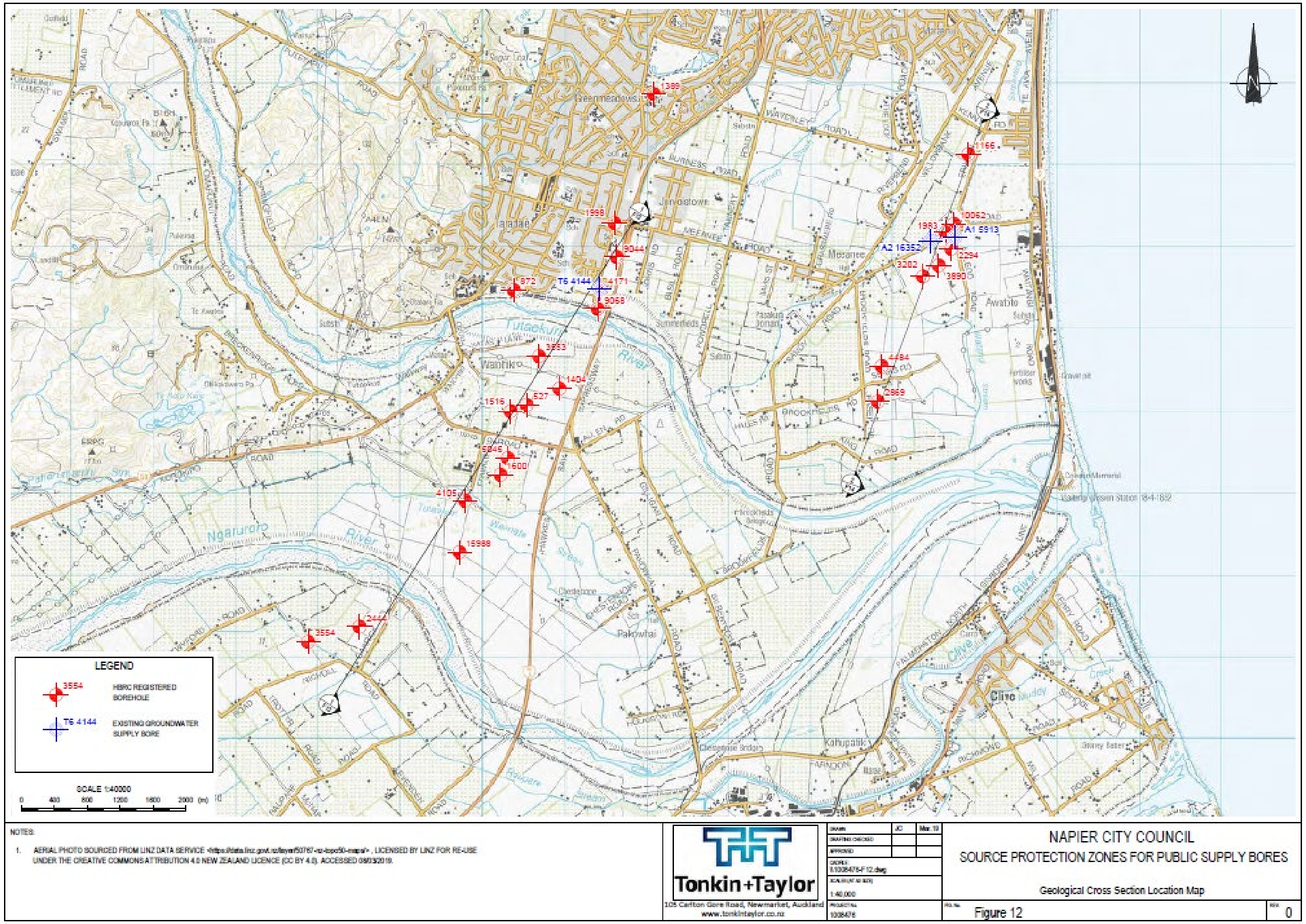
To Depth	2
Lithology	grey SILT (soft)
From Depth	2
To Depth	3
Lithology	grey SAND with silt (lost cone)
From Depth	3
To Depth	4
Lithology	fine grey SAND (band of brown organic at 5.72m)
From Depth	4
To Depth	6
Lithology	fine grey SAND
From Depth	6
To Depth	9
Lithology	grey SILT with shell (soft)
From Depth	9
To Depth	10
Lithology	fine grey SAND (silt and sand bands)
From Depth	10
To Depth	12
Lithology	fine grey SAND
From Depth	12
To Depth	14
Lithology	grey SAND with silt (flowing)
From Depth	14
To Depth	16
Lithology	SAND with silt (banded)
From Depth	16
To Depth	18

APPENDIX E

Well Correlation Map

(Tonkin and Taylor, 2019)

E1. Tonkin and Taylor (2019) map displaying Taradale (1) and Awatoto (2) well correlation sections.



E2. Tonkin and Taylor (2019) well correlation 2-2'.