Whangārei WWTP Consent Application

Water quality and public health risk assessment

Whangārei District Council

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→ The Power of Commitment

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Executive Summary

The Whangārei wastewater treatment plant (WWTP) discharges into the Limeburners (Hāhā) Creek, which is a tributary of the Hātea River. To support the consenting of the Whangārei WWTP treated wastewater discharge, an assessment of effects on the surface water, sediment, ecological conditions, and risk to public health has been carried out. Consideration has also been given to climate change and emerging contaminants and their potential effects on the receiving water environment. The purpose of this report is to present the findings of the assessment, describe how an adaptive approach to management of the WWTP will minimise further effects, and outline the proposed monitoring considered necessary to implement the adaptive approach.

Water quality assessment

The Proposed Northland Regional Plan (PNRP July 2021 – Appeals version) designates Limeburners (Hāhā) Creek, to its confluence with the Hātea River at the Port Road bridge, as a zone of reasonable mixing for a major discharge. As such, the water quality within this mixing zone is not required to meet the coastal water quality standards for the Hātea River prescribed in the PNRP, Policy H.3.3 (PNRP Table 22); however acute toxicity effects must be avoided (PNRP Policy D4.4).

Review of the PNRP water quality criteria has highlighted that while they may be appropriate for management of average conditions across the whole of the Hatea River, the methodology for developing them makes them inappropriate for managing water quality at discrete locations. As such, the standards are not considered to be meaningfully protective of water quality with respect to the WWTP discharge.

The water quality assessment is based on a review of Limeburners (Hāhā) Creek and Hātea River water quality information from Northland Regional Council's (NRC) state of the environment monitoring and 4Sight Consulting Water Quality Monitoring Report (4Sight, 2021a). The results indicate the Limeburners (Hāhā) Creek has elevated concentrations of nitrogen and phosphorous due in part to the WWTP discharge. These elevated concentrations intermittently influence the water quality of the Hātea River at the confluence of the two water bodies. Under typical flow conditions the concentration of nutrients at the Limeburners (Hāhā) Creek confluence with Hātea River is generally similar with that of the Waiarohia monitoring location, suggesting upstream catchment sources of nutrients also influence conditions in the Hātea River. Similarly, intermittent increases in nutrient discharges from the Limeburners (Hāhā) Creek are also noted from the Waiarohia canal, further demonstrating the influence of catchment activities on the receiving Hātea River.

It is concluded that mixing of the Limeburners (Hāhā) Creek flow within the Hātea River occurs rapidly and significant dilution within the river occurs downstream of the confluence with Limeburners (Hāhā) Creek. Even during periods of high discharge flows from the WWTP, or during periods of lower flow in the Hātea River due to tidal conditions, the influence of the Limeburners (Hāhā) Creek discharge on downstream water quality is considered minor, owing to the mixing and dilution that occurs within the river.

A nutrient balance was developed to assist in understanding the influence of WWTP discharges on the nutrient load within the Hātea River. The calculated percentage of nutrient mass contributed by the Limeburners (Hāhā) Creek to the Hātea River at the downstream Kissing Point monitoring location are outlined in, Table 1.

Table 1 Percentage of Limeburners (Hāhā) Creek load on total downstream load

Parameter	Limeburners (Hāhā) Creek contribution to Kissing Point nutrient load	
	Summer	Winter
Total Nitrogen	25% - 40%	15% - 25%
Total Phosphorous	25% - 50%	15% - 30%
Ammoniacal Nitrogen	15% - 35%	10% - 20%
Total Inorganic Nitrogen	20% - 55%	10% - 30%

Note: Values rounded to the nearest 5%

Key water quality assessment findings with regards to water quality are:

- Concentrations of nutrients and other indicator parameters of treated wastewater accumulate within Limeburners (Hāhā) Creek during the incoming tide, mixing with inflowing marine waters. On the turning tide mixed water flows to Hātea River where it is rapidly diluted. Intermittently elevated ammoniacal nitrogen concentrations within Limeburners (Hāhā) Creek are not considered to have a meaningful ecotoxicity effect as tidal flushing ensures such periods are short lived and only tolerant species have been identified in areas influenced by the WWTP. As such, effects within Limeburners (Hāhā) Creek are considered to be less than minor.
- The Hātea River is slightly to moderately eutrophic, but while the WWTP contributes a notable nutrient load to the river, this nutrient addition is not exacerbating the trophic state of the river, as indicated by the dissolved oxygen and chlorophyll-a concentrations. This is due to the high flushing rates. Effects to Hātea River water quality associated with the WWTP discharge are therefore considered to be minor.
- Due to the difference in sampling regimes, climate variables and the influence of the tide, there is uncertainty around the changes in water quality over time. The highly dynamic nature of the Hātea River mean that water quality is continuously changing and there are numerous influences on water quality.

To provide a robust benchmark for the effects of the WWTP discharge on the receiving water quality, a period of intensive monitoring will be implemented. Findings from this monitoring are intended to provide the basis for assessing change over time and managing discharges.

Sediment Assessment

The Limeburners (Hāhā) Creek, designated as a mixing zone, is not required to meet the coastal sediment quality guidelines for benthic sediment quality prescribed in the PNRP, Policy H.3.4 (Table 23). However, acute toxicity effects must be avoided.

The sediment assessment undertaken is based on a review of Limeburners (Hāhā) Creek and Hātea River sediment quality information from NRC state of the environment monitoring, as well as survey results by 4Sight Consulting presented in their Ecological Baseline Report (2020) and the Marine Ecology Assessment Report (2021b). The results of their investigations indicate that the intertidal sediment of Limeburners (Hāhā) Creek and the Hātea River is fine grained, dominated by mud fractions and very fine sand. The results also indicate the WWTP's influence on sediment quality is predominantly as accumulation of phosphorous in the shallow sediment, with influence being moderate in the Limeburners (Hāhā) Creek and low in the receiving Hātea River environment. The WWTP is also not considered to contribute meaningfully to the sediment load, with the treatment processes and use of artificial wetlands effective at managing the sediment discharge.

Sediment quality can influence aquatic health and ecology. The NRC monitoring indicates phosphorous, and nitrogen bound to sediment in the Hātea River and Limeburners (Hāhā) Creek is also attributed to catchment sources, yet the levels of phosphorous within the sediment does not appear to influence the benthic macroinvertebrate communities in the Limeburners (Hāhā) Creek. The metal concentrations in sediments are all relatively stable and attributed to catchment source, with no noticeable effects resulting from WWTP discharges.

Review of available sediment monitoring information indicates that while the WWTP discharges may be contributing to the accumulation of phosphorous in the shallow sediment, catchment sources are also likely contributing to this accumulation. Regardless of the source of phosphorous, the results show there is only a minor effect on the sediment quality in the receiving Hātea River environment.

No acute toxicity effects attributable to sediment contaminant concentrations were identified. However, the excessive presence of fine sediment within the Hātea River environment is considered to adversely influence the water quality and contribute to the eutrophic conditions.

Public health risk assessment

Water contaminated by human, or animal excreta, may contain a range of pathogenic micro-organisms, such as viruses, bacteria and protozoa. These organisms pose a health hazard where accidental ingestion of these micro-organisms occurs such as during ingestion of impacted water during recreational activities or the consumption of shellfish collected from impacted waters. While the Whangārei WWTP disinfects all wastewater prior to discharge to the wetlands, the treated wastewater has a residual active pathogen load that on discharge to the environment can increase the risk of infection for users of the receiving waterbody.

As a highly disturbed tidal creek, heavily influenced by catchment run-off, recreational use of the Hātea River is expected to be limited to secondary contact, such as is associated with boating and wading. Swimming within the Hātea River and shellfish gathering is not promoted. Likewise, as Limeburners (Hāhā) Creek is designated a mixing zone in the PNRP, it is unlikely Limeburners (Hāhā) Creek is used for recreation or shellfish gathering. Correspondingly there is no public health monitoring in place in Limeburners (Hāhā) Creek, and the Hātea River is only monitored for micro-organisms during routine monthly surveys of water quality. Downstream, the Whangārei Harbour is used extensively for recreational purposes, including both primary and secondary contact, and for shellfish gathering.

The public health risk assessment considered the Hātea River enterococci and faecal coliform data, and the recreational monitoring carried out by NRC at Onerahi Beach. The assessment found pathogen concentrations in the Hātea River are typically greatest at the Town Basin and decrease with distance downstream, indicating upstream catchment sources dominate the average microbiological water quality in the Hātea River.

Between 2011 and 2016 enterococci monitoring included sampling immediately after significant rainfall events. Over this period the 95^{th} percentile concentrations at the Limeburners (Hāhā) Creek and Hātea River confluence were occasionally greater than concentrations upstream indicating an influence on pathogen concentrations from the WWTP discharge during high flow conditions. Outside of the high flow events the WWTP influence on concentration is considered small compared to background catchment sources.

Enterococci concentration and faecal coliform count are generally lower at the downstream monitoring locations, such as Kissing Point, reinforcing the interpretation that mixing and tidal flushing significantly reduces the influence of upstream sources, including the WWTP, on the water quality. In 2011 upgrades to the WWTP UV disinfection process saw a desired reduction in risk to public health. In the context of the accepted recreational use of the receiving environment, and as supported by ongoing public health monitoring, the public health risk presented by the WWTP discharge is assessed to be minor.

Climate change and emerging contaminants

The wastewater sector in New Zealand is widely vulnerable to the effects of climate change. The effects of climate change are hard to quantify and predict, especially given the rate of change is unknown. The application of the adaptive approach for management of the WWTP will allow regular consideration of resilience against possible climate change challenges and the effect these will have on the receiving environment and associate values.

Emerging contaminants are chemicals, which can be manmade or naturally occurring, and are resilient to degradation and can be toxic to living organisms. Emerging contaminants are not monitored and are often chemicals that are new or already exist, but to date the risk to human health and/or the environment has not been quantified. The potential effect of emerging contaminants is unknown and difficult to predict, however, it is anticipated over time that limits regarding different emerging contaminants will be introduced in New Zealand and / or the wastewater sector. The use of the adaptive approach for WWTP management provides the flexibility to manage the potential effects of emerging contaminants.

Adaptive approach for management

Adaptive pathways planning provides guidance on how to develop a future plant that is adaptive and flexible to change as the future unfolds. Adaptive pathway planning is a practical approach that has been developed in recent years in response to the need to plan for long term and potentially uncertain futures.

The adaptive approach in the context of receiving environment management requires the following:

1. Identification of relevant drivers for which deviation from current environmental conditions, resulting from WWTP influence, would warrant WWTP improvements.
2. Identification of an appropriate metric or indicator representative of each driver and the influence the WWTP discharge has on it.
3. Determination of the trigger level or means of identifying when deviation from current conditions occurs.
4. Determination of the actions required to be undertaken in response to the confirmed deviation from current conditions.
5. Implementation of monitoring, validation and appropriate analysis to detect when the trigger occurs.
6. Regular review of the above to accommodate additional knowledge and/or change in desired outcomes.

This adaptive approach to managing the receiving environment is proposed to be detailed within a Receiving Environment Management Plan (REMP), with the REMP supporting the Adaptive Management Plan by providing the means of confirming when receiving environment drivers require WWTP improvement, as shown in Figure 1.

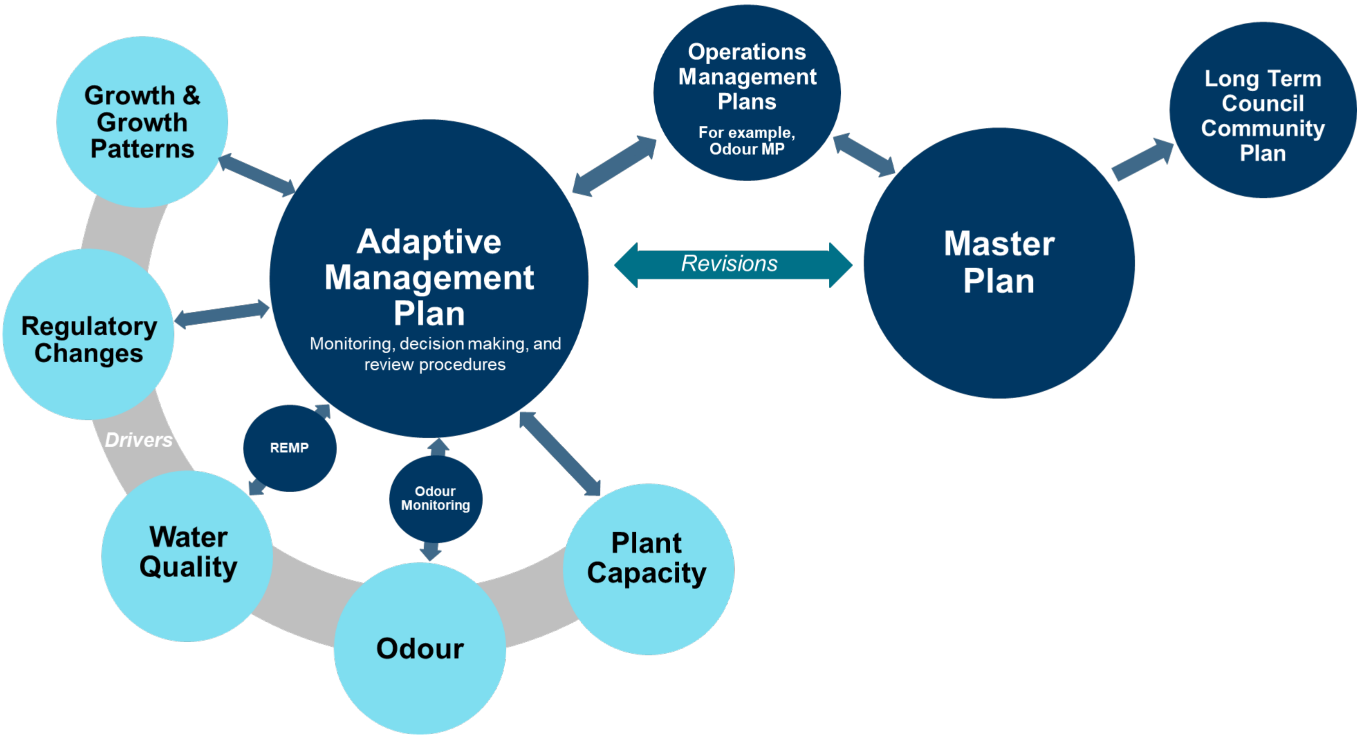

Figure 1 Adaptive Drivers and Management Documents

Management of receiving environment effects

The drivers for improving the WWTP discharges related to the receiving environment is proposed to align with the intent of the PNRP, being no further degradation of the Hātea River. The introduction of future regulations may also influence the treatment requirements and act as a potential driver for WWTP improvement under the adaptive plan.

The assessment has identified the key aspects of the receiving environment that may be influenced by the WWTP discharge and provides a benchmark for the current level of effects, Table 2.

Under the adaptive plan future increased impact in these areas, which indicates the WWTP is having a greater influence on the receiving environment than under current conditions, is considered a driver for improvements to the WWTP discharge.

In addition to understanding the receiving environment and using metrics for monitoring changing conditions, the quality and amount of treated wastewater being discharged to the marine environment are also relevant as key performance criteria of the WWTP. Understanding of changing WWTP discharge provides context for interpreting changes in the receiving environment.

Table 2 Receiving environment drivers and metrics

Driver	Description	Location	Medium	Metrics
Water quality	Aquatic ecosystem health as indicated by trophic state	1) Hātea River – Confluence with Limeburners (Hāhā) Creek 2) WWTP – Wetland discharge	Water	Total nitrogen Inorganic N Total phosphorus TSS Clarity Chlorophyll-a
Ecotoxicity	Contaminant concentrations in water and sediment that	1) Limeburners (Hāhā) Creek – in the vicinity of WWTP mixing	Water & Sediment	Water: Ammonia

Driver	Description	Location	Medium	Metrics
	cause acute toxicity to ecology	2) Hātea River – Confluence with Limeburners (Hāhā) Creek		Sediment: Heavy metals
Public health risk	Risk of infection from public use of the receiving environment for shellfish gathering and swimming	1) Hātea River – Confluence with Limeburners (Hāhā) Creek 2) WWTP – UV treatment outlet 3) Upper Harbor - Onerahi	Water	Enterococci Faecal coliforms
Emerging contaminants	Greater understanding of contaminant toxicity and introduction of new environmental regulations and criteria.	1) Limeburners (Hāhā) Creek 2) Hātea River – Confluence with Limeburners (Hāhā) Creek 3) WWTP – Wetland discharge 4) Upper Harbour – as needed	Water Sediment	Regulations

To manage influence of the WWTP on the receiving environment, effects triggers have been defined for each of the key drivers to identify when the receiving environment is deviating from current conditions. In the event of trigger level exceedance, a series of responses are proposed:

Step 1 - Reporting of the exceedance to NRC and relevant stakeholders.

Step 2 - Actions and assessment to validate that the inferred degradation in receiving environment condition is a result of WWTP discharges.

Step 3 - Assessment to determine whether the trigger level is appropriate and is appropriately reflective of a degrading receiving environment.

Step 4 - Determination of the appropriate WWTP operational changes and/or process upgrades required to respond to the receiving environment degradation.

Step 5 - NRC and stakeholder reporting of the proposed WWTP changes in the context of the adaptive pathways planning approach.

Step 6 - Implementation of the appropriate adaptive WWTP changes.

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Glossary

Abbreviation	Term
AmmN	Ammoniacal nitrogen
ANZECC	Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000)
ANZG	Australian and New Zealand guidelines for fresh and marine water quality (2018)
BOD_5	5-day Biochemical Oxygen Demand
CFU/100 mL	Colony forming units per 100 mL
CSSI	Compound specific stable isotope
E. Coli	*Escherichia coli*
ETI	Estuary Trophic Index
US	Upstream
DS	Downstream
g/m^3	Grams per metre cubed
Ha	Area unit - Hectare
ISQG – low trigger	Interim sediment quality guideline
Kg/day	Mass unit - Kilograms per day
kW	Energy/power unit - KiloWatts
m^3/day	Cubic Meters per Day
mWs/cm^2	milli-Watt seconds per square centimeter
MBR	Membrane Bioreactor
MoH	Ministry of Health
MfE	Ministry for Environment
MPN/100 mL	Most probable number per 100 mL
mg/L	Milligrams per Litre
ML	Volume unit - Mega Litres
ML/d	Flow unit - Mega Litres per Day, 1 ML/d = 1000 m^3/day
NIWA	National Institute of Water and Atmospheric Research
NES	National Environmental Standard
NRC	Northland Regional Council
NTU	Nephelometric Turbidity unit
PFU/100 L	Plaque forming units per 100 litres.
PNRP	Proposed Northland Regional Plan (Appeals Version) 2021
REMP	Receiving environment management plan
SOE	State of Environment
t/km2/yr	Tonnes per kilometre square per year
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total suspended sediment
UV	Ultra-Violet
QMRA	Quantitative Microbial Risk Assessment
WDC	Whāngarei District Council
WWTP	Wastewater Treatment Plant

Abbreviation	Term
ZCAA	Zero Carbon Amendment Act
%tile	Percentile

1. Introduction

1.1 Introduction

GHD Limited (GHD) has been engaged by Whangārei District Council (WDC) to carry out an assessment of effects to surface water quality and sediment quality, and a public health risk assessment to support consenting of the Whangārei wastewater treatment plant (WWTP) treated wastewater discharge. The WWTP discharges to Limeburners (Hāhā) Creek, which flows to the Hātea River and, ultimately, the Whangārei Harbour.

Proposed changes to the WWTP to accommodate the needs of various drivers, such as increased capacity in response to population growth, climate change and additional treatment in response to regulatory requirements, are proposed to be undertaken as needed and in an adaptive manner. These upgrades and change to the WWTP discharge are presented in the WWTP Master Plan (a living document to be regularly reviewed).

In addition to effects to water, sediment and risks to public, this report summarises the ecological conditions present in the discharge environment, which have been benchmarked by environmental consultants 4Sight Consulting, and the potential effects of climate change and emerging contaminants.

This report presents the findings of the receiving water environmental assessments undertaken, describes how an adaptive approach to management of the WWTP will minimise further effects to the receiving environment and public health over the term of consent, and outlines the proposed monitoring considered necessary to implement the adaptive approach being taken.

1.2 Background

WDC hold resource consent to discharge treated wastewater from its Kioreroa Road WWTP to Limeburners (Hāhā) Creek[1], which flows into the Hātea River and Upper Whangārei Harbour. The existing consent is due to expire in April 2022 and WDC are seeking to re-consent the discharge.

The Proposed Northland Regional Plan (PNRP) outlines receiving environment criteria, which were developed by Northland Regional Council (NRC) with the intent of ensuring no further degradation of the marine environment, including the Hātea River.

WDC have adopted an Adaptive Pathways Planning approach to the consenting of the WWTP to provide for a range of future uncertainties and develop flexible long-term strategies that allow for adaptive responses to different plausible futures or outcomes. This approach aims to address the considerable uncertainty in future conditions and requirements by keeping options and timing of WWTP improvement open through the production of an Adaptive Plan. The adaptive approach relies on establishing trigger points for specific drivers to upgrade the WWTP.

The quality of treated wastewater being discharged to the marine environment is a key performance criteria of the WWTP. The driver for improving the WWTP discharges related to the receiving environment is proposed to align with the intent of the PNRP, being no further degradation of the Hātea River. The introduction of future regulations may also influence the treatment requirements and act as a potential driver for further WWTP improvements under the adaptive plan.

GHD have undertaken this study to:

1. Characterise the current receiving environment and the influence the WWTP has on this environment.
2. Consider the risks to the environment and public health in the context of the current regulatory requirements.
3. Determine an appropriate approach to monitoring and management of effects to the environment, such that the intent of the PNRP is achieved.

1.3 Purpose of this report

The purpose of this report is to provide an assessment of effects on the environment of the Whangārei WWTP to surface water quality and sediment quality, and risk to public health to support consenting of the discharge of

[1] Also known as the Hāhā, which means luscious and anecdotally was known historically to be abundant in kaimoana.

treated wastewater to Limeburners (Hāhā) Creek. To fulfill this requirement the report has been structured as follows:

– Detail the WWTP current discharge and environmental setting, including relevant water quality criteria and compliance requirements, with an overview of relevant assessments of the receiving environment and an introduction to the concept of adaptive pathway planning (Section 2).
– Review of existing monitoring data in Limeburners (Hāhā) Creek, the Hātea River and upper Harbour to develop an understanding of the hydrodynamics (Section 3), water quality (Section 4), sediment quality and ecology (Section 5) of the existing receiving environment.
– Compare the current receiving environment condition to the relevant water quality criteria and compliance requirements (Section 3 to Section 5).
– Review of the Hātea River microbiological water quality and microbiological water quality criteria to characterise the existing receiving environment public health risks (Section 6).
– Detail the potential effects of climate change and emerging contaminants on the existing receiving environment (Section 7 and Section 8).
– Provide recommendations for monitoring and management of WWTP discharges and effects to the receiving environment, via the adaptive pathway plan for the WWTP to mitigate adverse effects to the receiving environment (Section 9).
– Provide recommendations to support maintenance and improvement of the receiving environment (Section 10).

1.4 Scope and limitations

This report: has been prepared by GHD for Whangārei District Council and may only be used and relied on by Whangārei District Council for the purpose agreed between GHD and the Whangārei District Council as set out Section 1.3 of this report.

GHD otherwise disclaims responsibility to any person other than Whangārei District Council arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Whangārei District Council and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

2. WWTP discharge and environmental setting

2.1 WWTP setting and discharge

Wastewater from the Whangārei city is treated at the Whangārei WWTP located on Kioreroa Road adjacent to Limeburners (Hāhā) Creek. The WWTP discharges treated wastewater into two constructed wetlands (Wetland 1 and 2), prior to discharging to Limeburners (Hāhā) Creek (Figure 2). The Creek has a predominantly urbanised catchment, with numerous industrial activities present. In the lower reaches, and at the locations of the wetland discharges, mangroves are present on tidal mud flats. The flow direction of the creek at the location of the discharges is dictated by the tide, with water levels fluctuating by approximately 2 m at the confluence with the Hātea River of which Limeburners (Hāhā) Creek is a tributary.

The Hātea River flows from the north-east of Whangārei southwards and into the northern head of the Whangārei Harbour (as shown in Figure 2 and Figure 12). The river forms part of the Upper Whangārei Harbour, with the upper reaches including the Whangārei town basin, and contributing urban tributaries such as the Waiarohia Canal. The Hātea River is the receptor of wastewater and stormwater discharges from Whangārei City and upstream catchments.

The Whangārei Harbour, into which the Hātea River discharges, is a drowned river valley estuary covering approximately 95 km^2 (NIWA, 2009). The main navigation channel is on the northern side of the Harbour with depths ranging from 15 –31 m with extensive intertidal mudflats to the south.

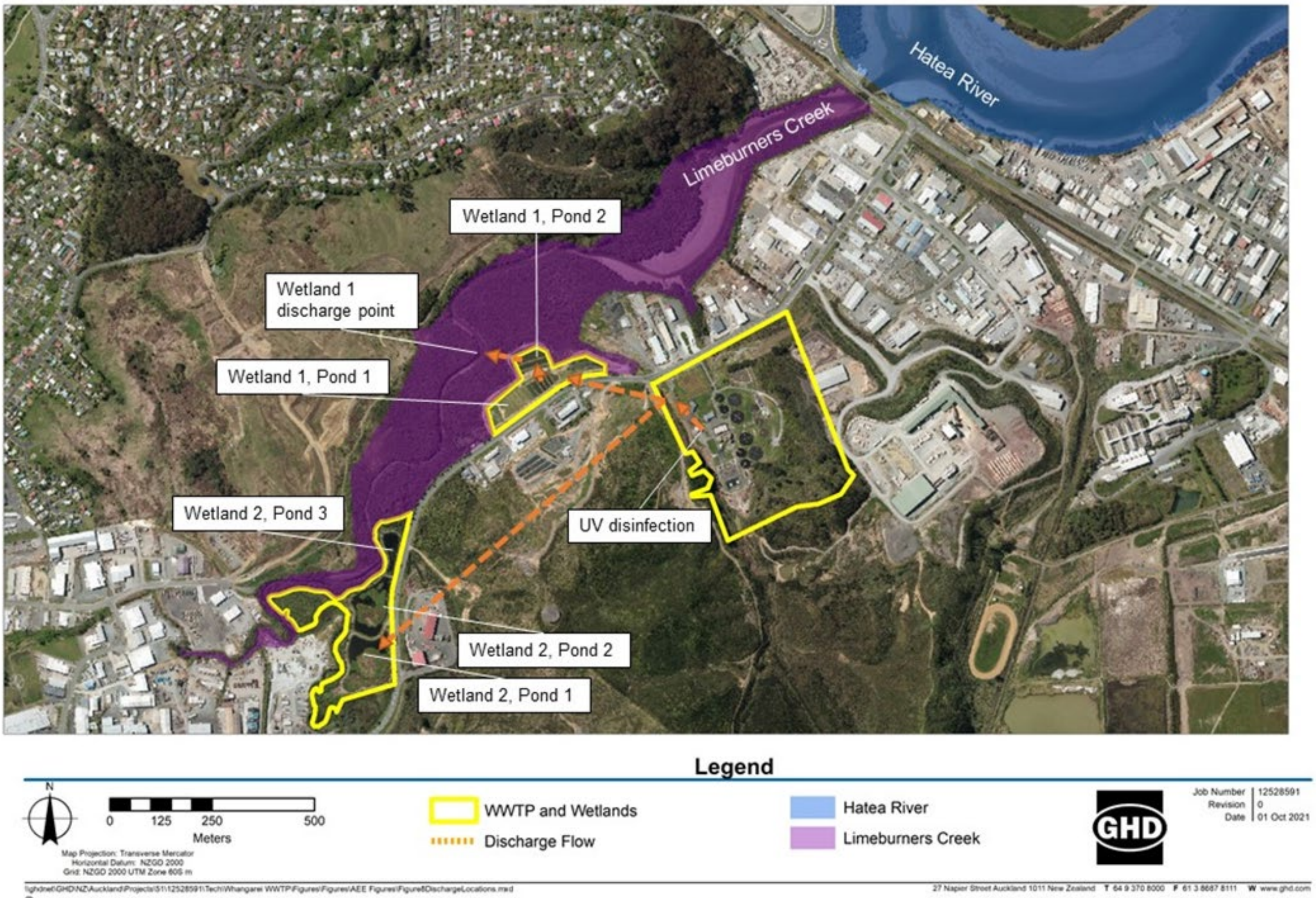

Figure 2 Map of site area, with Hātea River shaded blue and Limeburners (Hāhā) Creek shaded purple.

2.1.1 Climate

Rainfall data from the NIWA weather station, located 4 km southeast of the site at the Whangārei Aerodrome, indicates that average annual rainfall is approximately 1200 mm (calculated for the period 2010 – 2020). Typically, spring and winter months (March-September) record the greatest amount of rainfall, while summer and autumn months (August-February) are typically drier. Figure 3 illustrates recent daily rainfall.

2.1.2 Tides

The mean tidal range in the Hātea River is 1.7 m during neap tides, to 2.3 m during spring tides (NIWA, 2009). Tidal flushing of the Hātea River is variable, with flushing reduced inland of the Limeburners (Hāhā) Creek confluence owing to shallower bathymetry and the greater pressure imposed by inflowing freshwater. This is discussed in more detail in Section 3.

2.1.3 WWTP discharge

The current resource consent for Whangārei's WWTP discharge allows a maximum discharge of 140,000 m^3/day. WWTP daily average discharge volumes are illustrated in Figure 3, compared to daily rainfall. As a function of inflow and infiltration into the wastewater network, rates of wastewater inflow to the WWTP increase during rain events. Correspondingly, discharge rates increase during such events. This is particularly noticeable during the 1 in 500 rainfall event that occurred in July 2020. The influence of higher inflows results in portions of flow receiving a reduced level of treatment and a shorter residence time in the wetlands prior to discharge. Over the past 10 years development of two online storage tanks at Hātea and Tarewa, and upgrades to Okara Park Pump Station and associated trunk main have been established to minimise raw sewage overflows into the receiving environment. This has increased the storm event inflows into the plant and was one of the drivers of the increased limits as part of the 2011 change to the existing WWTP consent.

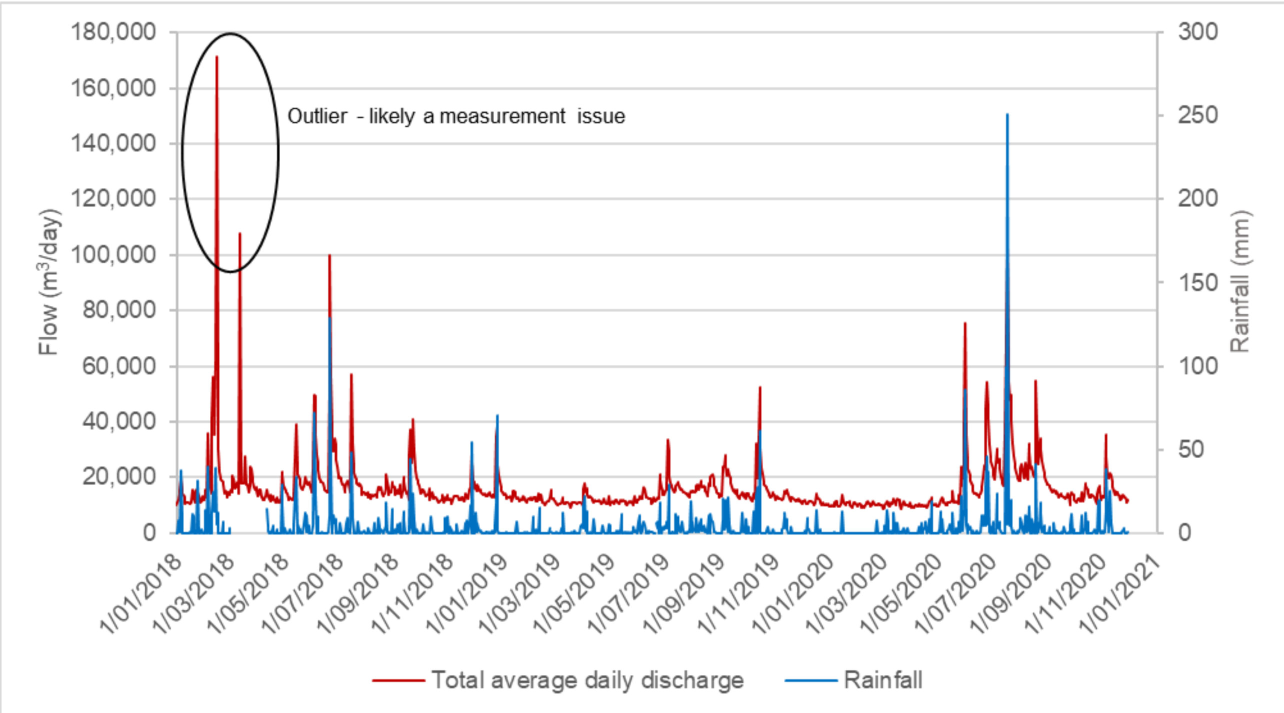

Figure 3 WWTP discharge and daily rainfall at Whāngarei Aerodrome (01/01/2018-30/11/2020)

Currently consented quality limits for treated wastewater are dependent upon the rate of discharge, as outlined in Table 3. The current consent also contains conditions related to UV treatment performance. For flows up to 30,400 m^3/d a minimum UV dose (10-minute average) of 30 milli-Watt seconds per square centimeter (mWs/cm^2) is required at all times. Flows in excess of 30,400 m^3/d, including flows above 57,400 m^3/d (referred to in the consent as "Extreme Wet Weather Flows") require a minimum UV dose (10 mins average) of 40 mWs/cm^2.

Previous work undertaken by NIWA (2011) demonstrated that disinfection of treated wastewater by UV treatment would assist in achieving a reduction in public health risk from consumption of shellfish collected from Onerahi during wet weather events. To achieve the modelled improvement in water quality, UV system providers were consulted to determine an appropriate UV dosage which was adopted as condition of consent.

As further surety of treatment, the resource consent includes limits on Extreme Wet Weather Flows of 1,500 colony forming units (CFU)/100 mL and 3,000 CFU100 mL for Median and 90th percentile E. Coli concentrations, respectively, and at least a 1.5 order of magnitude (i.e., 1.5 logarithm) reduction in the concentration of F-specific bacteriophage and culturable rotavirus when compared to untreated wastewater that enters the plant.

Table 3 Consent limits for treated wastewater

	Conditions based on daily discharge volume			
	Up to 21,000 m^3/day "Normal Daily Flow"	**21,000 to 30,400 m^3/day "Medium Wet Weather Flows"**	**30,400 to 57,400 m^3/day "High Wet Weather Flows"**	**57,400 to 140,000 m^3/day "Extreme Wet Weather Flows"**
BOD_5 (mg/L) - 50%ile/Median	15	20	25	
BOD_5 (kg/day) - Median	300	-	-	
BOD_5 (kg/day) - 90 %ile	500	-	-	
TSS (mg/L) - Median	15	25	25	
TSS (kg/day) - Median	300	-	-	
TSS (kg/day) - 90%ile	500	-	-	
Ammonia (mg/L as N) - Median	5	10	15	
Minimum UV dose (mWs/cm^2) – 10 minutes average	30		40	

2.1.4 WWTP treatment performance

Table 4 outlines the historical performance (July 17 to November 19) when operating below 21,000 m^3/day and compares this against data collected through a more intensive sampling programme when operation was below 21,000 m^3/day, implemented in late 2020. Based on the Plant Assessment carried out by GHD, it is understood the plant operates at below 21,000 m^3/d approximately 90 percent of the time (GHD, 2021b). The consent compliance for the historical plant performance is based on collection of 15 samples for every three months. Table 2 shows that plant performance based on the recent 2020 data, does not meet the median consent concentration limits for BOD_5, TSS, and ammoniacal nitrogen. It is understood from the Operations staff that there was an incident of illegal dumping in December 2020 which explains why the TSS result was considerably higher than the consent limit during this month. Elevated BOD_5 can also be attributed to solids spikes in the final effluent, explaining the exceedance in BOD_5.

In addition, a review of the plant effluent data from October to December 2020 indicated there had been recent deterioration of the plant performance with regards to the biological treatment, due to an extreme wet weather event (flooding) in July 2020 (Table 5). Nonetheless, the treatment plant has performed well throughout the past few years, particularly with respect to medium (21,000 to 30,400 m^3/day) and high flow conditions (30,400 to 57,400 m^3/day) described in the 6 monthly resource consent monitoring. Further details regarding the long-term performance of the plant are available in the Plant Assessment Report (GHD, 2021b).

To further support understanding of disinfection, monitoring of treated wastewater for Enterovirus (culture), commonly associated with gastrointestinal illness, has been carried out since 2015. Average Enterovirus levels over this period are in the order of 7 plaque forming units (PFU)/100 L, with maximum concentration of 30 PFU/100 L. Where untreated sewage may have enterovirus levels in the many thousands of PFU/L, the concentrations detected indicate that disinfection is effectively reducing the active virus load.

Table 4 Comparison of current (late 2020) and historical plant performance (July 2017 to November 2019) at flows <21,000 m³/d.

Determinant	Current Consent Limit for Flows <21 MLD		Historical Performance Jul 17 to Nov 19		Recent Plant Effluent Results Oct to Dec 20 (7 weeks)
	Median	90%tile	Median	90%tile	Median
BOD_5 (mg/L)	15	-	12	25	19
BOD_5 (kg/day)	300	500	178	340	239
TSS (mg/L)	15	-	18	32	38
TSS (kg/day)	300	500	274	483	432
Ammonia-N (mg/L as N)	5	-	4.2	11.1	9.0
TN (mg/L as N)	-	-	30*	37.2	31*
TP (mg/L as P)	-	-	3.6**	4.2	4.4**

** Number of TN samples between 2017 to 2019 and Oct to Dec 2020 were 25 and 6, respectively.*

*** Number of TP samples between 2017 to 2019 and Oct to Dec 2020 were 4 and 6, respectively.*

Table 5 Plant effluent (October – December 2020) results

Parameter	Average concentration (mg/L)	Sampling date range	No. samples
TSS	38	27/10/20 – 17/12/20	13
BOD_5	20	27/10/20 – 18/12/20	13
AmmN	7.7	25/10/20 – 17/12/20	13
TN	31	29/10/20 – 9/12/20	11 – *composite and grab samples*
TP	4.6	29/10/20 – 9/12/20	6
Faecal coliform	Median – 8727 (CFU/100 mL)*	29/10/20 – 17/12/20	11
E. Coli	Median – 4106 (MPN/100 mL)**	03/11/20 – 09/12/20	5

** Colony forming units per 100 mL (CFU/100 L)*

*** Most probable number per 100 mL (MPN/100 mL)*

2.1.5 Wetland performance

The wetlands provide further treatment to wastewater prior to discharge to Limeburners (Hāhā) Creek, through settlement of sediment, oxidation in exposed water areas and assimilation of nutrients by the floating wetland vegetation. Analysis of final effluent at the treatment plant compared to the final effluent at the wetlands from November 2020 to April 2021 indicates that there is:

– Removal of total suspended sediment through the wetlands.
– A reduction in biological oxygen demand through the wetlands.
– Net removal of nitrogen through the wetlands.
– Net removal of phosphorous through the wetlands.

It is important to note the efficiency of the wetland performance will be dependent on the volume of flow passing through, but the indication here is the wetlands do provide further polishing of the final treated effluent from the WWTP. This assessment is only indicative due to the limited temporal scale of the recent data set.

Table 6 Wetland effluent results (November 2020 to April 2021)

Parameter	Average concentration (mg/L)			Number of samples		
	Final Effluent	Wetland 1	Wetland 2	Final Effluent	Wetland 1	Wetland 2
TSS	26	5	6	34	27	27
BOD_5	16	4	4	32	27	27
AmmN	5.1	2.6	2.4	34	27	27
TN	36	25	22	18	25	25
TP	5.3	4.9	4.9	19	25	25

2.2 Regulatory setting

2.2.1 PNRP – water quality

The NRC Proposed Regional Plan (PNRP, Appeals version August 2020) combines regional air, land, water and coastal guidelines in accordance with the Resource Management Act 1991 (RMA).

In developing updated water quality criteria NRC classified the marine ecosystems being monitored in its regional programmes based on the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000) guideline classification system (NRC, 2017). This provided ecosystem classifications from Condition 1 (high ecological value) to Condition 3 (low ecological value). The Hātea River was classified as the regions only Condition 3 ecosystem, in recognition of its highly disturbed ecosystem and generally poor water quality.

The coastal water quality standards (Policy H.3.3 in the PNRP) includes separate criteria for the Hātea River, to accommodate the low ecological value to the ecosystem relative to other Northland coastal ecosystems. The relevant parameters and guideline values to this study are discussed in Section 4.

The PNRP designates Limeburners (Hāhā) Creek (to its confluence with the Hātea River at the Port Road bridge) as a zone of reasonable mixing for a major discharge and that the quality of Limeburners (Hāhā) Creek is not required to meet the standards for the Hātea River; however, the quality of water within the mixing zone should not cause acute toxicity.

In addition, sediment quality criteria are also in the PNRP. This contaminant concentration criteria, has been adopted in the assessment of effects to ecology of Limeburners (Hāhā) Creek and Hātea River carried out by 4Sight (2020 and 2021b).

2.2.2 Public health requirements

Exposure of the public to pathogens sourced from the WWTP discharge has the potential to result in illness. The water quality requirements to be protective of public health are dependent upon the means of exposure. In the context of the WWTP discharge into Limeburners (Hāhā) Creek and impacts to the Hātea River and the Whangārei Harbour, the primary means of exposure to wastewater derived pathogens is through recreational activities and consumption of sea food. For potential exposure to pathogens during swimming and from shellfish gathering, water quality limits are outlined in the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas by the Ministry for the Environment (MfE, 2003).

The PNRP also provide criteria for Enterococci, reflecting use of the water for secondary contact purposes such as wading. This limited recreational use reflects the disturbed environment and catchment contributions to the river.

The guideline values and public health risk assessment are discussed in Section 6.

2.2.3 Generic water quality and sediment criteria - ANZECC

Water quality threshold levels for protection of New Zealand freshwater and marine environments are provided in the ANZECC guidelines, (ANZECC, 2000) and Australian & New Zealand guidelines for fresh and marine water quality (ANZG,2018).While these guideline values provide generic context for water quality, they do not necessarily reflect thresholds to protect local ecology; particularly where local ecology has adapted in response to long term influences on water quality, such as the WWTP discharge. The ANZECC water quality thresholds are not considered within the current and proposed NRP, with location and context specific limits instead being provided for the Hātea River. For this reason, ANZECC water quality thresholds are not considered further.

2.3 Relevant assessments

Previous studies have been undertaken to progress the understanding of the potential effects of the WWTP discharge on the receiving environment. The reports considered relevant to the assessment are outlined below. Assessments prepared to support consenting in 2011 also informed subsequent plant upgrades and improvements to the network.

– NIWA – dispersion model (2009, 2010, 2011a)
  - The Hātea River hydrodynamics have been previously assessed by NIWA (2009, 2010 and 2011) using DHI MIKE3 software to simulate the hydrodynamics and contaminant dispersion within the Whangārei Harbour from the WWTP discharge. Modelling included estimated WWTP load discharges and a variety of wet and dry weather freshwater input scenarios.
  - The model results suggested that upgrading the WWTP would not significantly reduce enterococci levels in the Upper Whangārei Harbour, particularly in Limeburners (Hāhā) Creek and the Hātea River; however, the bacterial plume impacts at lower harbour locations past Parua Bay would be reduced. The report indicated that the model had some significant limitations around not incorporating adequate representation of the initial dilution or flow data of Limeburners (Hāhā) Creek.

– NIWA – Predictions of human health effects (2011b)
  - NIWA conducted a quantitative microbial risk assessment of human pathogens being discharged into the Hātea River and Upper Whangārei Harbour and the illness risk faced by swimming and shellfish-consumers. The modelling included 72 different scenarios, comprising various degrees of wastewater treatment and storage.
  - The assessment estimated the risk of illness from undertaking activities in the harbour at two nominated locations the Hātea River confluence with Limeburners (Hāhā) Creek (considered a secondary contact site only activities) and Kaiwaka Point (Onerahi) (considered a potential recreational location for swimmers and secondary contact as well as a potential shellfish gathering location). NIWA determined what would constitute an “acceptable” or “good” beach quality at these sites in accordance with MfE/MoH (2003) national water quality standards. This recognises that all-natural water bodies have a small health risk associated with contact recreation or shellfish gathering. The threshold for the investigation was a 5% probability that a person was exposed to an infectious dose, with a probability less than 5% deemed as acceptable.
  - The Quantitative Microbial Risk Assessment (QMRA) assessment concluded that:
    – Under all scenarios, including a high flow by-pass regime (that is no longer in use), the risks to users of the upper Whangārei Harbour for contact recreation purposes, including swimming, are acceptable both in summer and in winter.
    – Under all scenarios, the risks to persons collecting shellfish below Kaiwaka Point (Onerahi) are acceptable in summer, but not during winter.
    – Achieving acceptable limits in relation to shellfish consumption at Kaiwaka Point required a reduction in the load of pathogens from both the WWTP during high flow events and from wastewater network overflows. Improvement in background freshwater quality was also identified as being needed to reduce public health risk during high flow events, as it contributed a high proportion of the pathogen load.

– 4Sight – water quality monitoring (2021a) (Appendix B), ecological baseline survey (2020) (Appendix C) and marine ecology assessment (2021b) (Appendix D.
  - Water quality and sediment samples were collected at a variety of locations across Limeburners (Hāhā) Creek, Awaroa Creek and the Hātea River on a monthly basis over a period commencing January 2020 to characterise the WWTP discharge receiving environment. In total 12 water quality sampling rounds

were completed, and two sediment and ecology baseline surveys were conducted. Snapshot water quality samples were also collected during the baseline sediment and ecology surveys.

- Water quality sampling in Limeburners (Hāhā) Creek reported elevated concentrations of ammonia, exceeding the acute toxicity threshold, chlorophyll-a, nitrogen and phosphorous (compared to the PNRP criteria). The sediment samples in Limeburners (Hāhā) Creek indicated elevated concentrations of chlorophyll-a and phosphorous. In comparison to nearby locations the results indicate 'reasonable mixing' appears to have been achieved within the designated mixing zone. Generally, the water quality gradient appears to show an increase in quality from upstream to downstream locations.
- The reports concluded that the water quality, sediment quality and benthic ecology in the upper Hātea River has degraded to some extent due to multiple diffuse and point source discharges throughout the wider catchment. The WWTP discharge should be considered one of the influencers; however, the WWTP does not appear to have a dominating effect on the environment outside of Limeburners (Hāhā) Creek.

2.4 Adaptive pathways planning approach to WWTP improvement

Adaptive pathways planning provides guidance on how to develop a future plant that is adaptive and flexible to change as the future unfolds, and avoid redundant infrastructure being built. This approach helps embed adaptive responses into the short-medium actions that need to be taken, and leaves options open for the future if needed. Adaptive pathway planning is a practical approach that has been developed in recent years in response to the need to plan for long term and potentially uncertain futures. The adaptive pathway planning framework is shown in Figure 4.

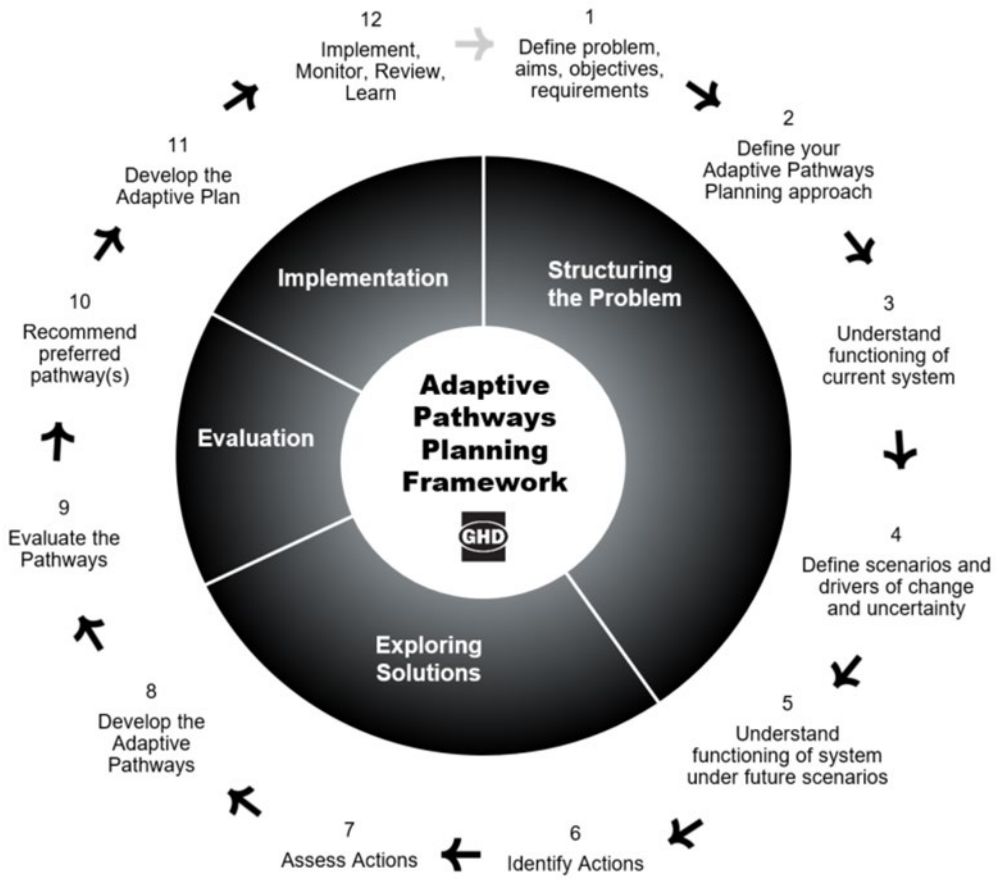

Figure 4 Dynamic adaptive pathway planning framework.

Over the planning horizon of a WWTP there is uncertainty associated with regulations and discharge requirements, future growth, demand for recycled water and requirements for stabilised biosolids. This is in addition to a wider range of unknowns associated with societal perspectives, environmental state, cultural heritage, politics, technology, and the economy. The adaptive pathway planning approach for a WWTP identifies that there is considerable uncertainty in the timing and structure of future work.

Based on analysis of available data, the adaptive pathway planning approach defines:

– Target implementation for future works based on projected trends. Implementation of future work will be in response to triggered needs, not a fixed timeframe. Timeframes will be estimated based on the current understanding of trends which will be regularly reviewed and updated.
– Considers the combined effect of future “disruptors” that could result in the works being brought forward in time, delayed, or the preferred high-level strategic pathway being changed.

The key concepts for adaptive planning are summarised in Table 7, with examples.

Table 7 Adaptive planning key concepts

Concept	Description	Example
Driver	A factor that has a significant influence on the need for WWTP upgrade works.	*NES Standard introduction*
Implementation point	The point at which upgrade works are predicted to be required in response to a driver.	*New primary clarifier required when population reaches 70,000 EP (Peak wet weather flow (PWWF) > 1,320 L/s).*
Lead time	The time prior to the implementation point required for final concept preparation, construction and commissioning work, considering uncertainty once a decision has been made.	*Primary clarifier may take five years to design, construct, and commission.*
Trigger point	The point that “lead time” commences to achieve implementation at an appropriate time. Determined in relation to a particular driver(s).	*The PWWF is approaching 1,320 L/s and may exceed this limit in five years.*
Uncertainties	Uncertainties may require the works to be completed sooner or later.	*Additional or lower than expected growth in the catchment resulting in higher or lower PWWF.*
Pathway	Logical progression of upgrade works and initiatives that reflect a single or series of upgrades made in response to particular driver(s). Pathways considers: – The benefits of the preceding works. – Next step for WWTP upgrade/augmentation.	*MBR upgrade to the activated sludge plant after new aeration tanks have been constructed.*

As part of the adaptive approach, the WWTP influence will be monitored to detect when to implement improvements over time to ensure no further degradation of water quality in the upper harbour, in line with the intent of the PNRP. It is expected that WWTP performance and the receiving environment will be monitored and managed with greater scrutiny than under previous resource consents to ensure that the improvements are made before meaningful degradation of the upper harbour occurs.

2.5 Assessment approach

The assessment of effects to water quality encompasses the influence of WWTP discharges on ecosystem and human health outcomes within the receiving environment, including:

– Potential ecotoxicity for aquatic and benthic ecology.
– Impacts on broader aquatic ecosystem health, such as trophic state.
– Risks to users of the receiving environment.

The following sections outline the approach to assessing these matters.

2.5.1 Water quality assessment (Sections 3 and 4)

The water quality assessment to support implementation of the adaptive management plan for improvements focusses on characterising the influence of the WWTP discharge on the receiving environment, to provide a baseline for managing future discharges so as to not degrade the environment further.

The assessment took the following approach in determining the influence of WWTP discharges on the environment:

1. Review of hydrology and dynamics characterisation of Limeburners (Hāhā) Creek and Hātea River to define flow contribution to the receiving environment.
2. Determination of existing water quality in the receiving environment through use of the long-term NRC state of the environment water quality monitoring data.
3. Differentiation of the catchment and WWTP influences on water quality and how these have changed over time.
4. Development of a nutrient water balance model to estimate the contribution of nutrient discharges to the receiving environment.
5. Interpretation of current WWTP effects on water quality, consideration of the PNRP water quality criteria and other water quality criteria to provide context for the current receiving environment conditions.

2.5.2 Sediment assessment (Section 5)

In understanding the existing influence of the WWTP discharge on the environment, effects to sediment quality are also assessed. The sediment assessment took the following approach:

1. Review of NRC sediment monitoring information for the Hātea River and the results of sediment monitoring carried out by 4Sight Consulting (4Sight, 2020).
2. Consideration of sediment contaminant distribution and indicators of WWTP influence.
3. Interpretation of current sediment quality, consideration of the PNRP water quality criteria and other sediment quality criteria to provide context for the current receiving environment conditions.

2.5.3 Public health risk assessment (Section 6)

A public health risk assessment has been carried out, leveraging previous detailed works by NIWA in 2011, to understand the extent to which pathogens sourced from the WWTP discharge may be presenting a risk to users of the Hātea River and downstream marine environment. The public health assessment took the following approach:

1. Review of local activities and identification of potential public activities that may constitute an exposure risk.
2. Review WWTP influence on pathogen levels in water, through review of NRC water quality results for the Hātea River and WDC public health monitoring results at the nearest swimming beach.
3. Review of the assumptions and validity of the existing public health risk assessment (NIWA, 2011) relative to the current WWTP discharge and conditions.
4. Review of treatment plant performance and assessment of risk to public health presented by the WWTP discharge.

2.5.4 Climate change and emerging contaminants (Sections 7 and 8)

Climate change has the potential to change the WWTP discharge, and the resulting effects to the environment and public health risks associated with the discharge. How climate change may change the discharge and resulting effects has been assessed in a qualitative manner. The assessment considers the following:

1. How climate change may influence rainfall and result in changes to discharge volumes and occurrence of peak discharge events.
2. How sea level rise may influence the receiving environment, local ecology and public use of the aquatic environment.

3. How the changes in discharge and environment may result in changes to the relative influence of the WWTP discharge on the environment and risk to public health.

Consideration is also given to the relevance of emerging contaminants in the assessment of effects to water quality and public health risk. Emerging contaminants being those naturally occurring, or synthetic contaminants which are currently unmonitored and unregulated, but have the potential to adversely influence ecosystems or human health. Many of these have beneficial use such as pharmaceuticals and personal care products, but the body of knowledge to reliably assess the risks presented by them and impose limits may not exist.

2.5.5 Management of receiving environment effects (Section 9)

The proposed approach to management of effects to the receiving environment considers the means by which monitoring can be undertaken to ensure that no further degradation of the receiving environment occurs. The recommended approach considers the following:

– Defining receiving environment drivers for WWTP improvement.
– Defining triggers for each of the drivers.
– Defining a response process in the event of trigger exceedance.
– Providing recommendations regarding monitoring and reporting of effects to the receiving environment.

3. Hydrology and hydrodynamics

3.1 Water Body Catchments

3.1.1 Hātea River catchments

The Hātea River receives road run-off and stormwater from Whangārei city and is the receiving environment for the Whangārei WWTP and a number of industrial and agricultural discharges. The shoreline and hydrology of the river has been significantly altered by saltmarsh drainage and reclamation for urban development.

The catchments that contribute to the Hātea River at the confluence with Limeburners (Hāhā) Creek include the Hātea Catchment (approximately 4,470 Ha of predominantly rural landuse), Whangārei City Catchment (of predominantly general urban landuse) and Waiarohia Catchment (approximately 1,890 Ha of mixed rural and general urban landuse).

Within the Whangārei City and Waiarohia catchments stormwater is expected to be impacted by the range of typical urban contaminant sources, industrial discharges, and intermittent wet weather and blockage related wastewater network overflows. These impact upon water and sediment quality of the Hātea River, with NRC water quality monitoring indicating that the five monitoring sites in the Hātea River (refer to Figure 12) have the lowest water quality of all 42 State of the Environment coastal water quality sites within Northland (Griffiths, 2015). Council's sediment and estuary monitoring programmes have also recorded elevated concentrations of nutrients and metal contaminants in the river sediment (Griffiths, 2014). These contaminant sources, which contribute to the contaminant load of surface water are referred to as catchment sources in this assessment and excludes the Whangārei WWTP.

3.1.2 Limeburners (Hāhā) Creek Catchment

The Limeburners (Hāhā) Creek catchment (approximately 1,280 Ha) includes rural, commercial, industrial, and quarrying landuse activities. As with the other urbanised catchments of Whangārei, these catchment sources of contaminants impact upon the water quality of Limeburners (Hāhā) Creek, with catchment influence on water quality expected to be generally consistent with those of the Waiarohia Creek.

The wetlands into which the WWTP discharges are located downgradient of the majority of catchment sources, and within the intertidal zone of the creek, Figure 2.

3.2 Hātea River and Limeburners (Hāhā) Creek hydrodynamics

The hydrodynamics of the Hātea River and its interaction with Limeburners (Hāhā) Creek are complex and includes a mixing zone influenced by catchment freshwater run-off, changes in water level, tidal flow direction and salinity induced stratification. To support understanding of the processes and degree of mixing of waters a number of studies have been carried out, with these described below.

3.2.1 Hydrodynamic modelling – NIWA 2009-2011

Hydrodynamic and dispersion modelling of the Hātea River and Whangārei Harbour was carried out by NIWA between 2009-2011, primarily to assess the potential dispersion of microbial contaminants, contaminant spills, run-off and stormwater discharges to the Harbour. The model was calibrated and verified using field data (NIWA, 2009).

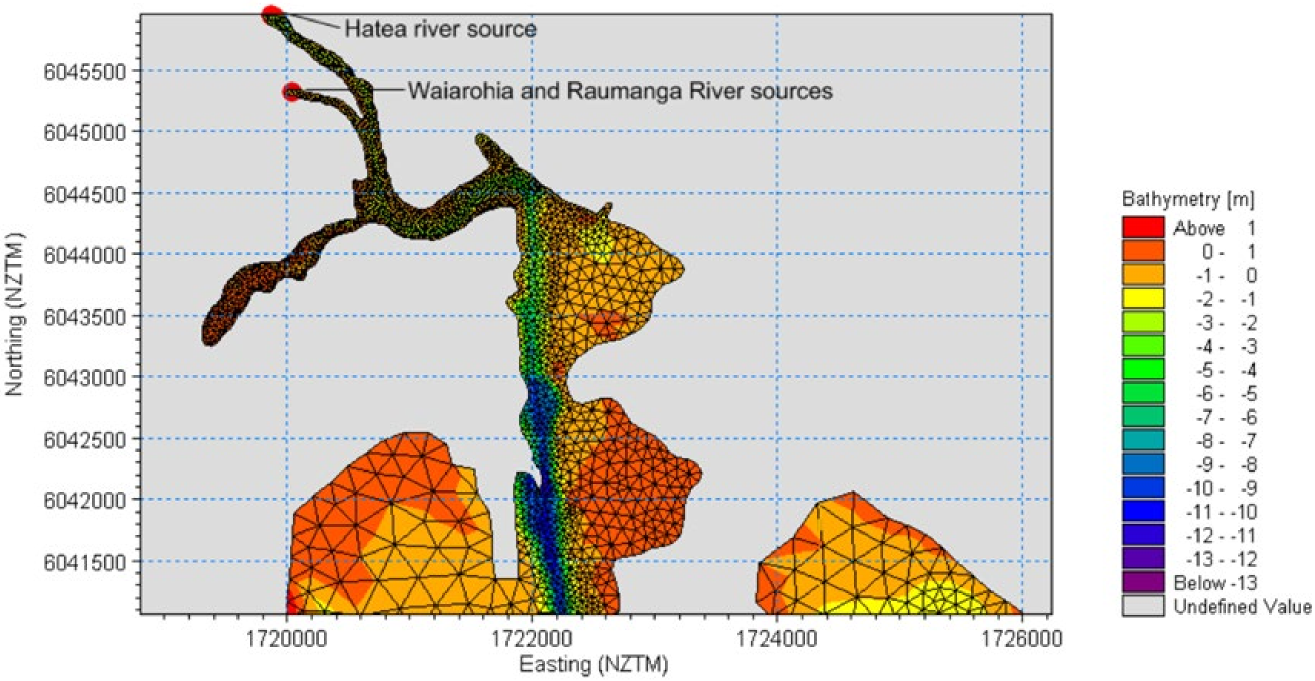

Figure 5 Model mesh in the upper extent of the Whangārei Harbour (NIWA, 2009)

Modelling reinforced the understanding of the tidal drivers for mixing of freshwater and saline water within the Hātea River. Tidal data collected at the mouth of the Hātea River between 2015 - 2020, indicate that the river water level fluctuates between approximately 0.2 – 3.4 m above mean sea level (AMSL). During high tide saline water from Whangārei Harbour extends up the Hātea River, constraining the flow of freshwater and reducing mixing. During low tide, water freshens as the saline water recedes from the Hātea River and the upper sections of the river and creeks drain into the lower Hātea River. Figure 6 illustrates the modelled salinity within the Hātea River during low and high tide.

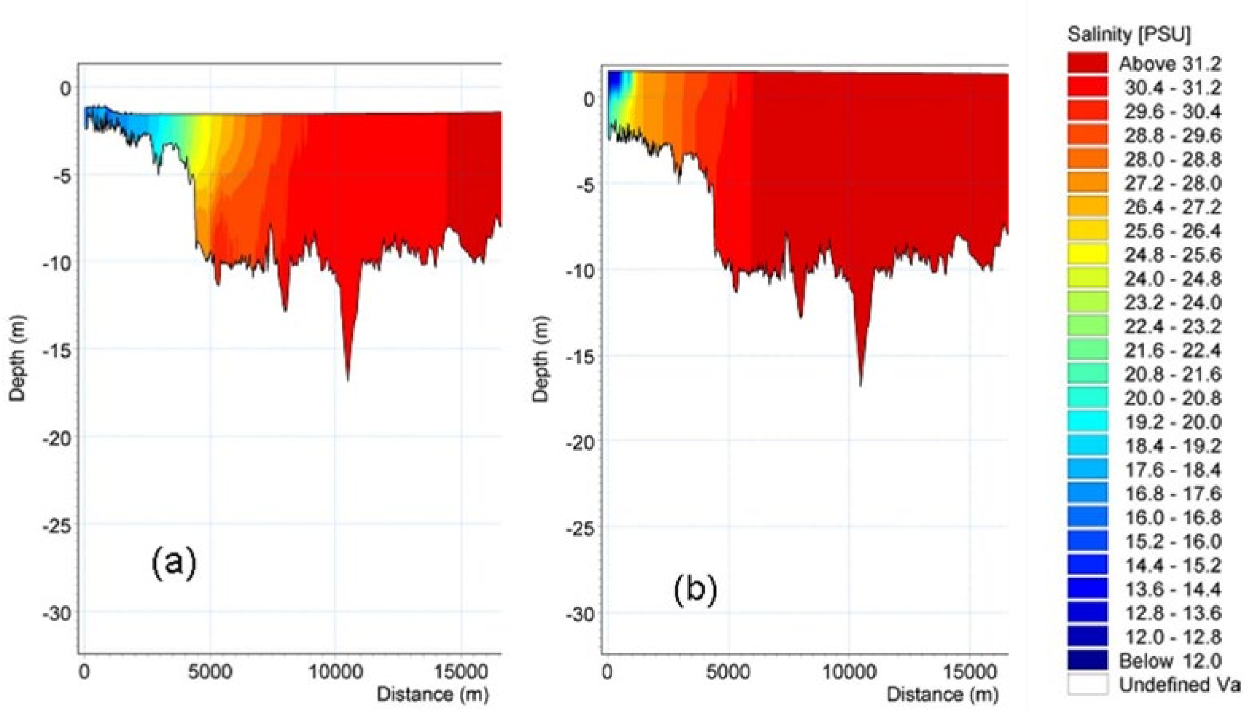

Figure 6 Modelled salinity with the Hātea River during low water (a) and high water (b) (NIWA, 2009)

A range of flow conditions and scenarios were assessed by NIWA, including under different WWTP discharge conditions and storm events, which included extreme flow bypass from the WWTP[2]. The findings were used to undertake a public health risk assessment to support WWTP optioneering and a resource consent application to vary the previous consent in 2011. This is discussed in more detail in Section 6 (Public health risk assessment).

3.2.2 Dye tracer test - 1987

The NIWA hydrodynamic model (Section 3.2.1) also made use of information gathered during dye tracer testing, carried out in 1987, to understand the dispersion of contaminant plumes moving down the Hātea River from the Town Basin on an outgoing tide. NIWA reported that the model calibrated well to the apparent dispersion. Aerial imagery collected during the test provides a visual reference for plume migration and an indication of the relatively minor influence that flow from Limeburners (Hāhā) Creek has on the Hātea River at the time of testing, as indicated by an absence or dilution of dye at the confluence. It is assumed that the test was undertaken on the outgoing tide.

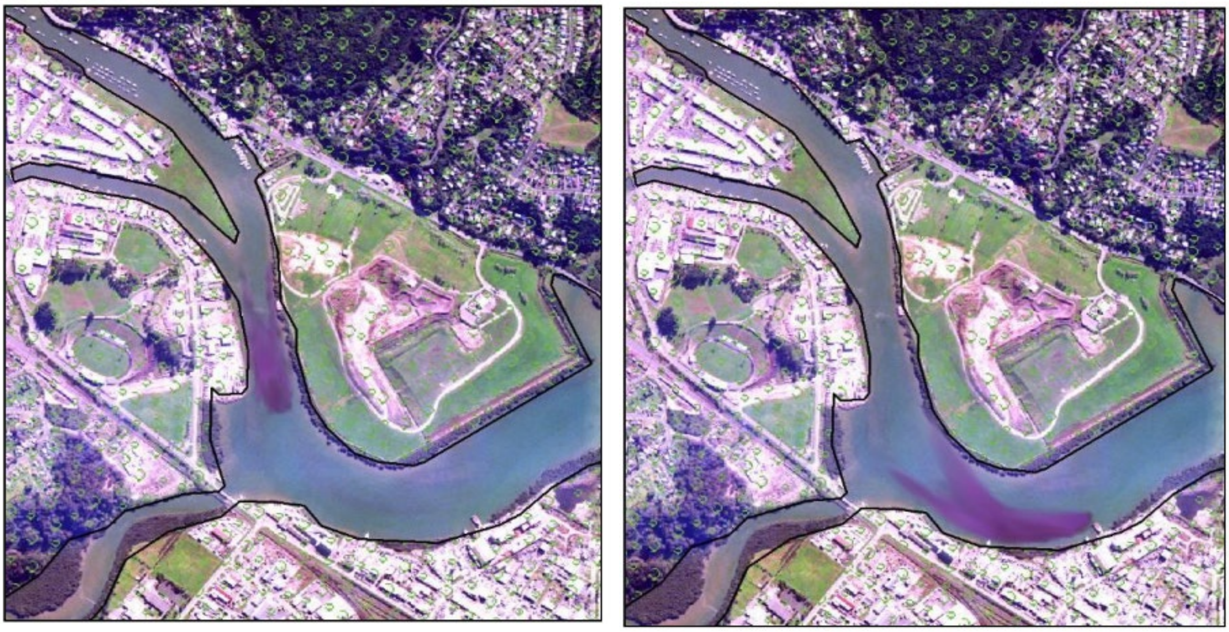

Figure 7 Aerial photos with dye tracer (coloured purple) excursion interpreted from oblique aerial photos (NIWA, 2010)

3.2.3 NRC continuous monitoring – 2019

Continuous monitoring of physical parameters dissolved oxygen (DO), salinity, pH and temperature was conducted by NRC at the confluence of Limeburners (Hāhā) Creek and the Hātea River, from 27 February to 12 March 2019. Monitoring comprised a multiparameter sonde affixed to a buoy, providing monitoring at a fixed depth of water. The results further demonstrate the dynamic nature of conditions at this location.

Figure 8 to Figure 11 illustrate the physical parameters over the monitoring period, with the influence of tide evident in the measured conditions. Review of the monitoring results indicates the following:

– Salinity fluctuates by between 10-40% between high and low tides, depending on timing relative to the spring tide cycle. This provides an indication of marine water movement into and out of the Hātea River at the Limeburners (Hāhā) Creek monitoring location, and dilution and mixing that occurs as a function of the tide.
– Temperature increases of approximately two degrees centigrade occur between night time and day time, and approximately one-degree centigrade fluctuation occurring between high and low tide, with higher temperatures occurring as a function of greater freshwater inflow.

[2] Now UV disinfected.

- Lower DO is associated with low tide and greater freshwater contribution, with this ranging from 4-6 mg/L during low tide, with the lowest values associated with the low Spring tide conditions. High tide has more consistent DO conditions between 8-9 mg/L. Low DO suggests periods of stagnation.
- The influence of rainfall, stormwater and run-off is evident by increased turbidity, low salinity, and very low DO, as recorded in response to approximately 15 mm of rainfall on 8 March 2019. Notably larger influence is expected during more significant rainfall events.

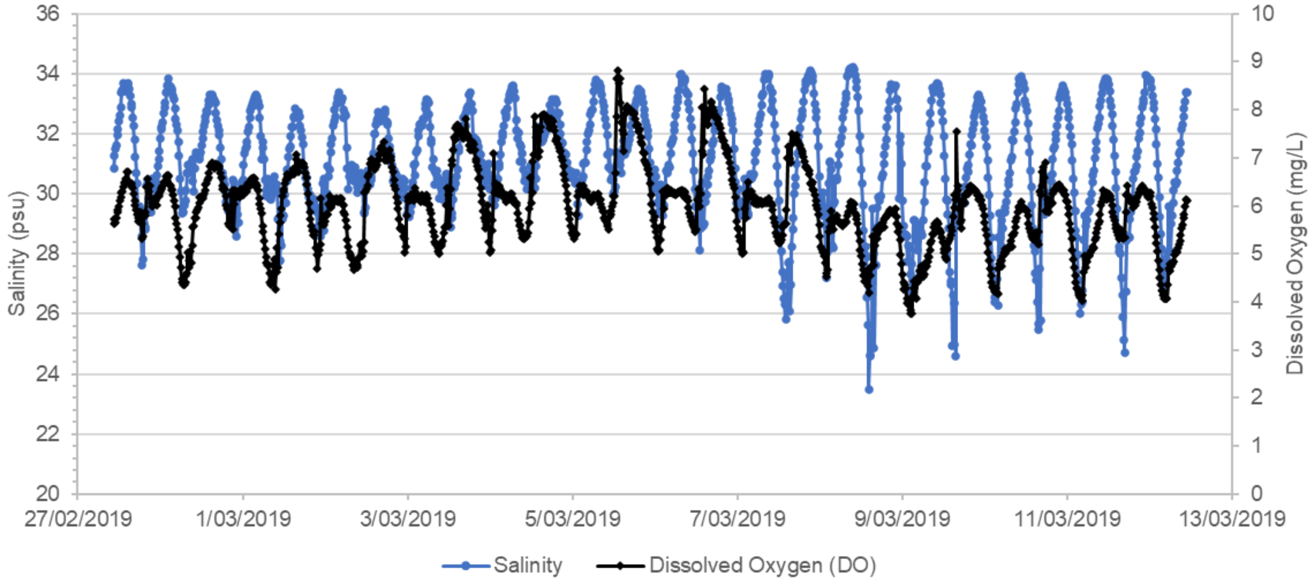

***Figure 8	Salinity and dissolved oxygen concentrations at Limeburners (Hāhā) Creek***

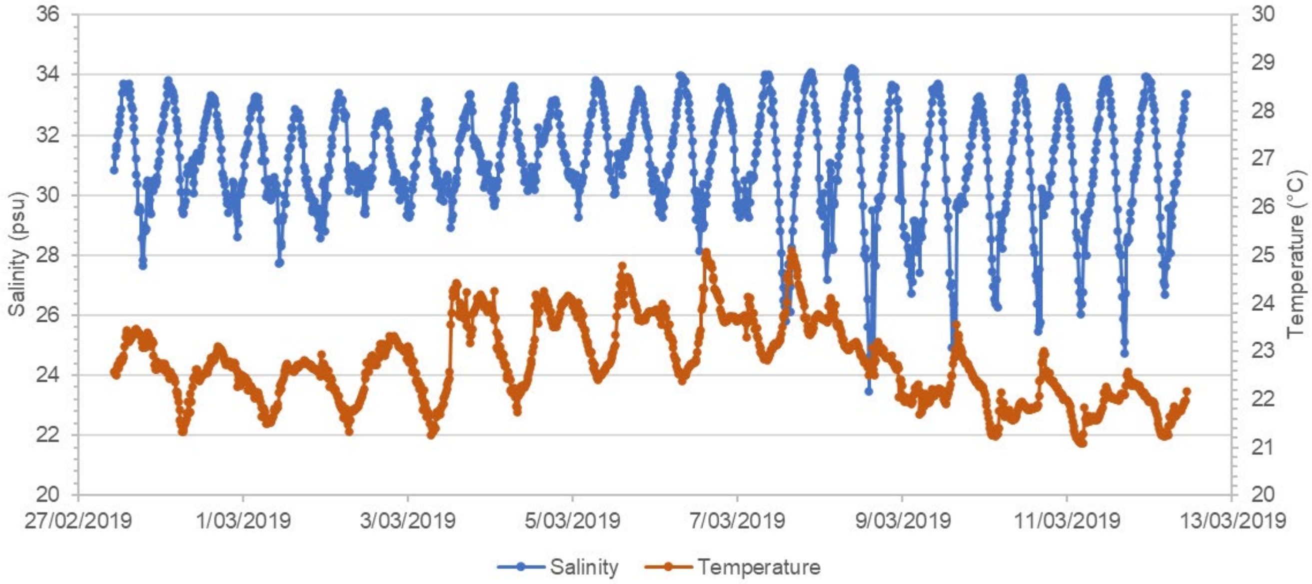

***Figure 9	Salinity concentration and temperature at Limeburners (Hāhā) Creek***

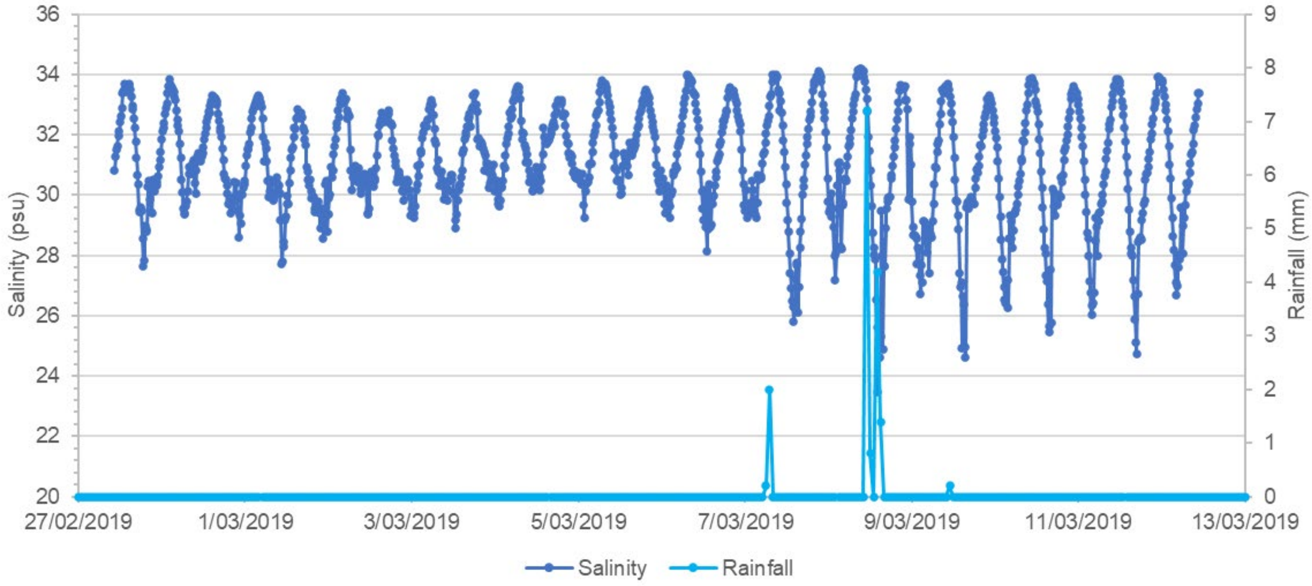

Figure 10 Salinity concentration at Limeburners (Hāhā) Creek and hourly rainfall at the WWTP

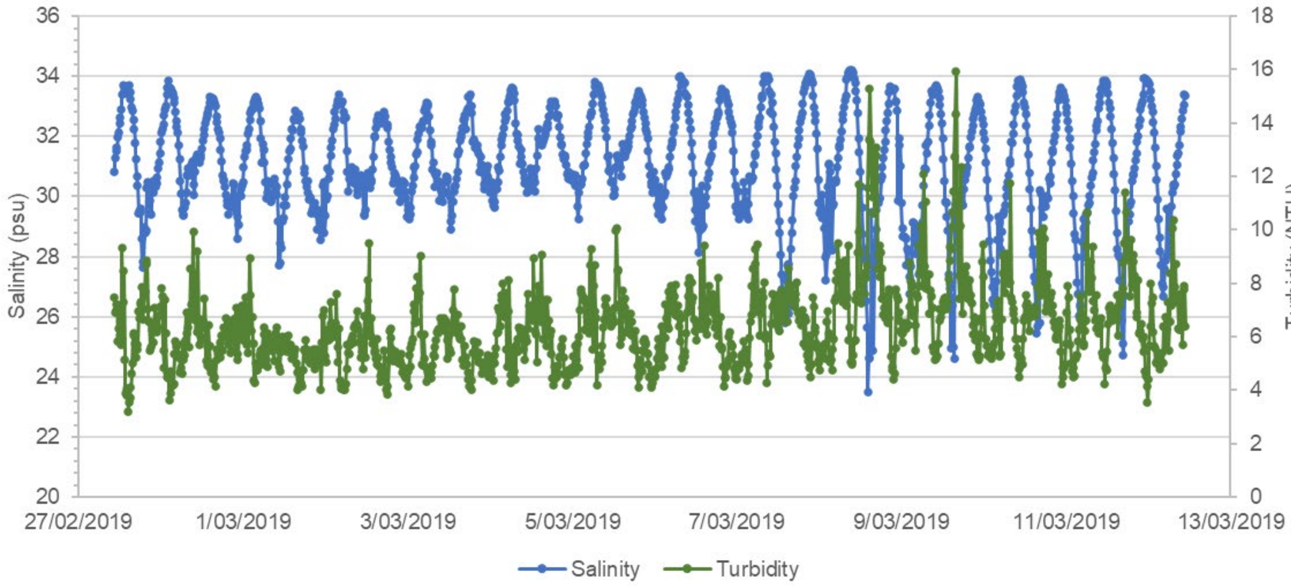

Figure 11 Salinity concentration and turbidity at Limeburners (Hāhā) Creek.

Review of the available modelling and continuous monitoring results suggests that the influence of freshwater and treated wastewater from Limeburners (Hāhā) Creek is most influential on water quality of the Hātea River at Port Road bridge at low tide.

3.2.4 NRC state of the environment monitoring

Monthly monitoring at five of the six monitoring locations within the Hātea River (refer Figure 12), undertaken by NRC from 2010 provide long-term supporting information for hydrodynamics and mixing of treated wastewater. Figure 13 outlines the range of salinity results measured at each of the monitoring locations. The measured salinity indicates the following:

– Increasing influence of marine water, and mixing between freshwater and marine water, moving downstream from the Town Basin to Kissing Point monitoring locations. Differences between Kissing Point and Lower Hātea locations are less notable, reflecting a limited freshwater input downstream of Kissing Point.

- Under typical conditions, freshwater makes up a minor proportion of the water composition at the Limeburners (Hāhā) Creek monitoring location.
- During peak rainfall events the Hātea River can be effectively flushed of marine water from the Town Basin, as far down as the Waiarohia monitoring location. However due to the influence of the Harbour, even during extreme events some mixing of marine water is expected to occur at the Limeburners (Hāhā) Creek monitoring location.
- During peak tidal events, droughts and/or with storm surge, the Hātea River may predominantly comprise marine water.

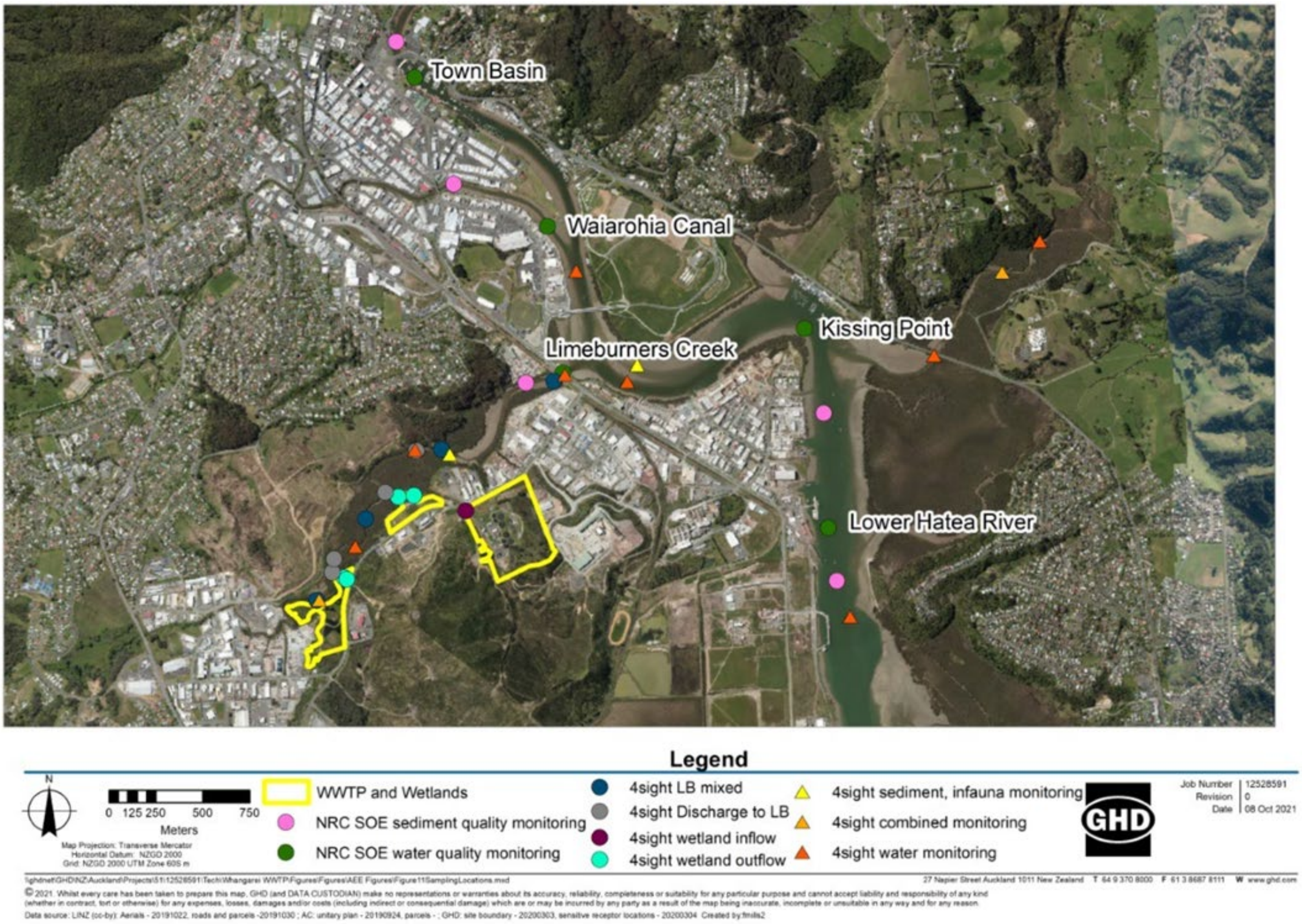

Figure 12 State of the environment (SOE), and 4Sight Consultant monitoring locations

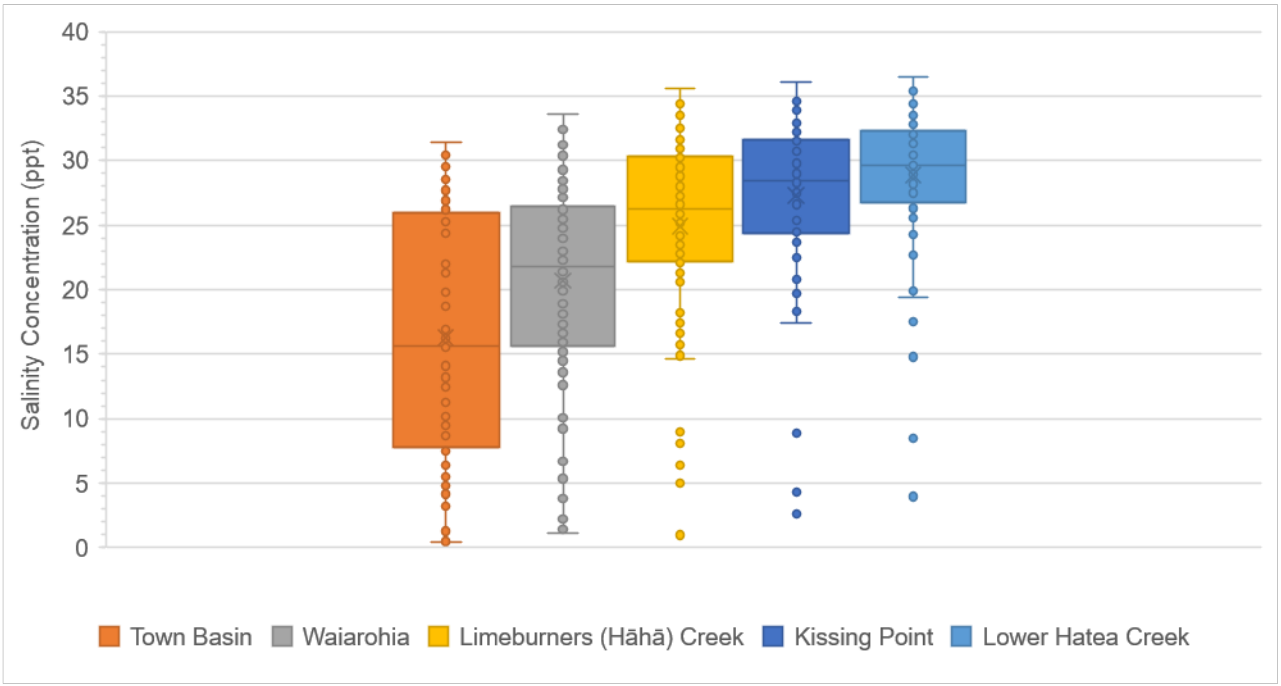

Figure 13 Salinity data (2010-2020)

Review of the NRC monitoring information suggests that marine water is the dominant component of Hātea River water at the Limeburners monitoring location, with the contribution of freshwater from Limeburners (Hāhā) Creek being small relative to the upstream Hātea River flow and the contribution of marine water coming from the Whangārei Harbour.

3.2.5 Limeburners (Hāhā) Creek monitoring - Whangārei District Council 2020-2021

Investigation of water and sediment quality, and the ecology of Limeburners (Hāhā) Creek has been carried out by environmental consultants 4Sight Consulting in order to provide an understanding of nearfield effects of WWTP discharges into the Limeburners (Hāhā) Creek mixing zone.

This included collection of water quality samples along the creek on the turning high tide as water began flowing towards the Hātea River. Sample locations were positioned upgradient of the WWTP, within the zone of discharge from the wetlands and downgradient of the WWTP. Samples were also collected from overflow points of both Wetland 1 and Wetland 2.

Sediment sampling was carried out on the banks of Limeburners (Hāhā) Creek at low tide, whilst survey of marine and benthic ecology was carried out along the creek and extending into the Hātea River where the two water bodies mix.

For water quality and sediment sampling locations, refer to Figure 12 or Appendix A of the 4Sight Baseline Ecological Survey report (2020) in Appendix C.

The influence of the WWTP discharge on sample water quality, as indicated by nitrogen and dissolved phosphorous concentrations, was found to be greatest upstream of the discharge areas and progressively decreasing towards the Hātea River. The findings indicate that treated wastewater is flowing upstream during the incoming tide and accumulating within the creek channel until the tide turns, at which time flow towards the Hātea river is initiated. There is then a period of time when the accumulated freshwater volume discharges to the Hātea River, with salinity decreasing during this period.

The greatest influence on Limeburners (Hāhā) Creek water quality is expected to occur at high tide, with this reflecting the time of the greatest accumulation of treated wastewater within this immediate receiving environment. In contrast, the greatest influence of the WWTP on the Hātea River is expected towards low tide when there has been a period of flow from the treated wastewater discharge to the river. This interpretation is consistent with the findings of the NRC continuous monitoring (refer to Section 3.2.3).

The varying hydrodynamic conditions are expected to result in pulses of treated wastewater flow to the Hātea River, with dilution occurring at the confluence of the water bodies, and some backflow of river water occurring on the incoming tide.

Water quality findings and the influence of the WWTP on the Hātea River water quality is discussed in detail in Section 4.

4. Water quality baseline

4.1 PNRP water quality criteria

The PNRP water quality criteria for the Hātea River (Table 8) are provided as receiving water criteria to be protective of further degradation of the river ecosystem health and to manage public health risks. As outlined in Section 2, the adopted criteria are intended to reflect the highly modified nature of the river.

Table 8 PNRP water quality guideline values (PNRP August 2020 - Policy H.3.3 - Water quality standards for ecosystem health in coastal waters, contact recreation and shellfish consumption)

Attribute	Unit	Compliance metric	Hātea River guideline value
Dissolved oxygen	mg/L	Annual median	>6.2
		Minimum	4.6
Temperature	°C	Maximum change	3
pH	Unitless	Annual minimum - maximum	7.0 – 8.5
Turbidity	NTU	Annual median	<7.5
Secchi depth	m	Annual median	>0.8
Chlorophyll-a	mg/L	Annual median	<0.003
Total phosphorus	mg/L	Annual median	<0.119
Total nitrogen	mg/L	Annual median	<0.860
Nitrite-nitrate nitrogen	mg/L	Annual median	<0.580
Ammoniacal nitrogen	mg/L	Annual median	<0.099
Copper	mg/L	Maximum	0.0013
Lead	mg/L	Maximum	0.0044
Zinc	mg/L	Maximum	0.015
Enterococci	MPN/100 mL	Annual 95th percentile	<500

4.1.1 PNRP criteria derivation methodology

The criteria for the Hātea River were derived from water quality data collected at the six monitoring sites in the Hātea River (NRC, 2017). Criteria for parameters indicative of physical and trophic state were derived statistically, as a percentile of the monitoring data. The adopted percentile was typically the $80^{th}/20^{th}$, except where NRC considered that the 80th percentile "appears to be too relaxed when compared to median values for the six sites in the Hātea River delta". This is the case for:

– Total phosphorus - 70th percentile adopted.
– Nitrate-nitrite nitrogen - 75th percentile of monitoring data adopted.
– Ammoniacal nitrogen - 70th percentile adopted.
– Total Nitrogen – unclear.

For metal contaminants, the more conservative threshold ANZECC 2000 value for protection of 95% marine water species was adopted, rather than the 90% or 80% species protection value recommended by ANZECC.

The compliance metric for water quality in the Hātea River are outlined in Table 8 and are summarised as follows:

– Trophic state indicators - physical parameters, nutrients and chlorophyll-a - annual median.
– Acute ecosystem influence - physical state and toxicants - threshold limits (maximum/minimum).

– Public health risk – annual 95th percentile.

4.1.2 PNRP water quality criteria as a discharge criteria

A limitation of using a median value from across six sampling locations is that the adopted criteria (70-80th percentile) is not reflective of the distribution of monitoring results at any of the individual monitoring sites. As an improvement in water quality moving downstream in the Hātea River is typically evident, the criteria are less protective of change at downstream locations than upstream locations. Comparison of the individual criteria against the median of each monitoring location was carried out during development of the criteria, but no further statistical analysis is apparent to understand the likelihood of exceedance of criteria at a monitoring site in any particular year. Section 4.3.2 outlines the historical occurrence of exceedance of the PNRP criteria at each monitoring location. Without an understanding of the statistical distribution of data (e.g. normal, log-normal, etc.) there remains uncertainty regarding the probability of exceeding the criteria at each location or as an aggregate of the six monitoring sites.

Given the variable nature of the water quality in any given year, another limitation of the criteria is the duration over which repeat exceedance of the criteria must occur in order to reflect true degradation of the water quality and to also be attributed to WWTP discharges. Assuming no changes to catchment or WWTP discharges, exceedance of the criteria can be expected at an unknown frequency due to the variability of climatic conditions and timing of sampling relative to rainfall events. For example, if a sample is collected at low tide within 24 hours of a high rainfall event, it is hard to compare this to a sample collected at high tide after weeks of on-going dry conditions. Consistency of sampling (depth in the water column, at the same point in the tide) and a detailed commentary associated with the current and recent climate conditions is paramount to help understand the variable nature of water quality. A number of years of criteria exceedance may be needed before degradation in water quality can be proven in a statistically robust manner.

In general, the PNRP criteria for parameters that influence trophic state are considered only relevant if used in reviewing water quality across the whole of the Hātea River, rather than at specific locations. Additionally, it is the frequency that the criteria are exceeded that provides an indication of whether conditions are changing. Given these constraints and the limitations of the dataset used to develop the criteria, it is considered that the PNRP water quality criteria are not likely to be suitable as a means of determining receiving environment degradation as a function of the WWTP discharges. An alternative approach using of preliminary triggers, that will be refined through intensive monitoring, is outlined Section 9

Section 4.3 below provides an illustrative comparison of the Hātea River water quality against the PNRP.

4.2 Limeburners (Hāhā) Creek water quality

To characterise the water quality of Limeburners (Hāhā) Creek, 4Sight Consulting were engaged to carry out monthly water quality sampling at various locations along Limeburners (Hāhā) Creek. Sampling was carried out from January 2020 to February 2021. Samples were collected from:

– The discharge from the WWTP to each of the treatment wetlands (Outflow).
– The discharges from the wetlands to the mangrove forest (Wetland).
– The discharges into Limeburners (Hāhā) Creek.
– Locations throughout Limeburners (Hāhā) Creek including before, during, and after the mixing and dilution with the WWTP discharges.

4Sight generally collected samples on the outgoing tide, normally within 1 – 3 hours following high tide. The water quality analysis was summarised in a report by 4Sight (2021a), refer to Appendix B, and the results are replicated below (Figure 14).

To provide context 4Sight compared the results to the Hātea River PNRP water quality criteria (Table 8) and the ammonia acute toxicity value from the ANZECC 2000 guidelines[3]. The results were summarised as follows (4Sight, 2021a):

[3] The ANZECC (2000) acute toxicity guidelines values are 0.91 mg/L for marine waters and 0.90 mg/L for freshwater. 4Sight use the marine guideline value.

– At least half of the sampling occasions recorded ammonia concentrations at all sampling locations within the acute guideline levels for ammonia toxicity. Ammonia concentrations generally exceeded the acute toxicity guidelines from June to October 2020.
– Dissolved oxygen and pH was within the PNRP water quality criteria at the mouth of Limeburners (Hāhā) Creek. Dissolved oxygen levels were also lower in the Wetlands than the Outflow, likely due to the high CBOD levels in the Outflow.
– Chlorophyll-a and nutrients frequently exceeded the PNRP water quality criteria, with the median concentrations higher than the water quality standards. During summer the nutrient concentrations were lower, but chlorophyll-a was still elevated indicating uptake by high levels of phytoplankton.
– The median total nitrogen concentrations of the Outflow and Wetlands samples were significantly higher than the Limeburners (Hāhā) Creek discharge, upper and lower sites. The median total phosphorous concentrations were within a similar range at the Outflow and Wetlands locations. The median concentration at these locations was higher than the median at the discharge location and upper Limeburners (Hāhā) Creek location. The median total phosphorous concentration was lowest at the lower Limeburners (Hāhā) Creek location.
– Enterococci concentrations were variable and had similar medians across sampling sites.
– Turbidity levels were within the PNRP water quality criteria on four out of 12 occasions. The total suspended solids median concentration was elevated at the discharge and Limeburners (Hāhā) Creek upper and lower locations, compared to the Outflow and Wetlands. This is likely a result of the freshwater from the wetland mixing with marine water causing particle resuspension.
– Overall, there were marked differences between the water quality in the Outflow and Wetlands sites in comparison to the Limeburners (Hāhā) Creek, particularly with regards to nutrients and CBOD, which was shown to reduce from the Outflow to Limeburners (Hāhā) Creek.

  However, improvements throughout the post-treatment mixing zone were not observed for all parameters, with total suspended solids being lower in the Outflow than in Limeburners (Hāhā) Creek.

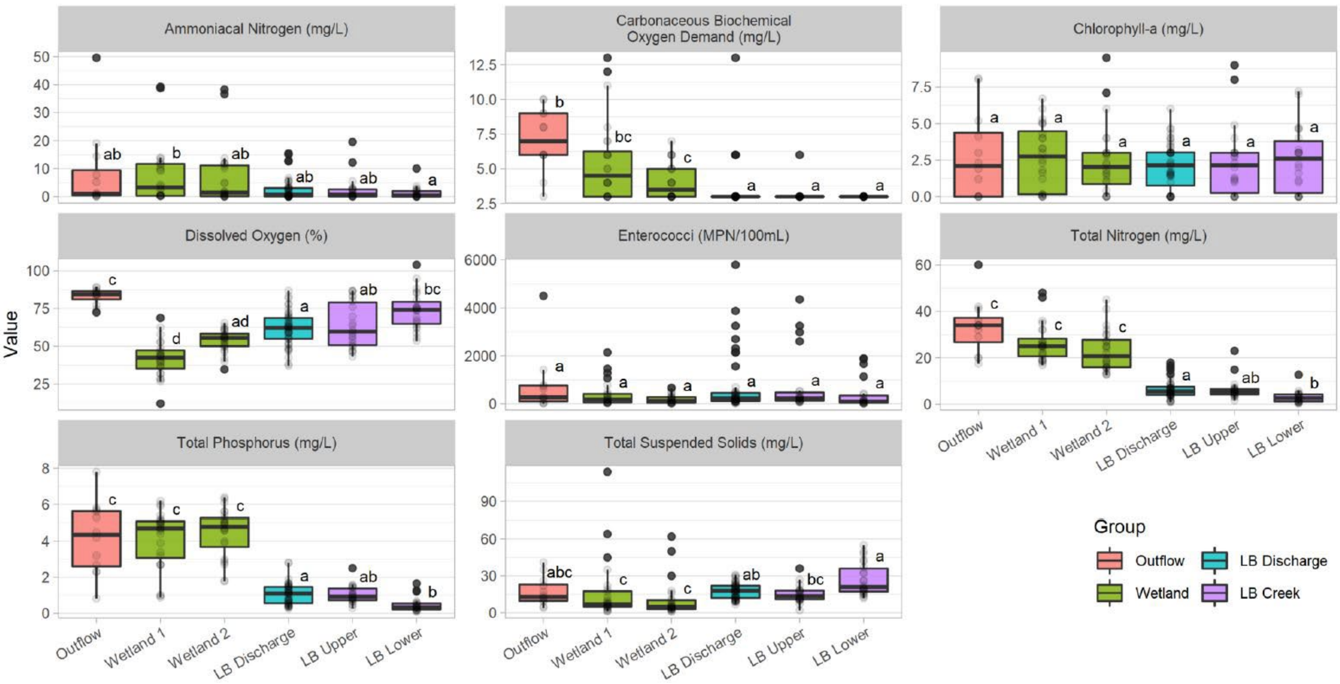

Figure 14 Water quality results, taken from 4Sight (2021a). Note the letters above each boxplot indicate the statistical significance from a Kruskal-Wallace test.

The 4Sight report concluded the WWTP discharge via Limeburners (Hāhā) Creek into the Hātea River is one of the ecological stressors in the upper Hātea environment. In addition, the report concludes the water quality of upper Limeburners (Hāhā) Creek is reflective of the WWTP discharge having an influence on Limeburners (Hāhā) Creek.

Considering the sampling was being conducted within 1 – 3 hours following high tide this is not considered to be unexpected, as the incoming tide reverses flow in the creek carrying the discharges from the WWTP up Limeburners (Hāhā) Creek. Treated wastewater discharged during this period is captured within the creek, mixing with saline water from Hātea River and any freshwater flowing from up-catchment. The mixed water is then drawn out to the Hātea River environment during the outgoing tide.

The water quality results reported by 4Sight are therefore reflective of the advancing high tide 'drawing' the WWTP discharges upstream. It is assumed during periods of low tide, when the upper Limeburners (Hāhā) Creek predominantly comprises freshwater, the water quality would differ from that of the Limeburners (Hāhā) Creek WWTP discharge location.

Limeburners (Hāhā) Creek is designated as a mixing zone, therefore the water quality of the Creek does not need to meet the Hātea River PNRP water quality guideline values. The results indicate the discharge is resulting in elevated concentrations of ammoniacal nitrogen and reduction in dissolved oxygen in the Limeburners (Hāhā) Creek. The reasonable mixing zone is improving the dissolved oxygen concentration towards the mouth of Limeburners (Hāhā) Creek as a function of mixing with river water. The SOE monitoring (detailed in 4.3.1) demonstrates the mixing zone may also be improving the ammonia downstream at the confluence with the Hātea River. Additional monitoring is required to understand dynamic nature of water quality within the creek (see Section 9)

Given the many years of discharge to the creek, it is expected that the aquatic and benthic ecology present comprises those species relatively tolerant to the periodically elevated ammonia concentrations and low dissolved oxygen. This is discussed in more detail in Section 5.

Analysis into the quality of the sediment in Limeburners (Hāhā) Creek was also undertaken by 4Sight and is summarised later in Section 5.2.1.

4.3 Hātea River water quality

4.3.1 NRC state of the environment monitoring

Water samples have been collected along the Hātea River (Figure 12) as part of State of the Environment (SOE) monitoring undertaken by NRC since 2000. For the purposes of this assessment, data collected from 2010-2020 has been reviewed, with this encompassing the period in which changes to the WWTP discharge were made, including:

1. Desludging Wetland 1 and installation of floating vegetation structures.
2. Discharge of all flows through the wetlands rather than diverting extreme flows directly to Limeburners (Hāhā) Creek.
3. Upgrade of UV treatment providing disinfection to all flows from the plant.

Monitoring prior to 2018 has been carried out every two months from January to November (six per year), with monthly monitoring subsequently undertaken. Statistical analysis of years preceding 2018, including determination of median concentrations, is therefore less robust than recent years. It is also noted that the results are expected to demonstrate variability in water quality owing to the timing of sampling with respect to tide. Regardless, the SOE dataset provides a reasonable long-term record from which the variability in water quality due to catchment influence and changes with the WWTP discharge can be assessed. The data set also provides understanding of the likely extent of the Limeburners (Hāhā) Creek mixing zone within the Hātea River.

NRC monitor the water samples for the following parameters:

- Dissolved oxygen
- Temperature
- Depth
- pH

– Turbidity
– Chlorophyll-a
– Total phosphorous
– Total nitrogen
– Nitrate-nitrite nitrogen
– Ammoniacal nitrogen
– Enterococci

4.3.2 Water quality variability

To provide a baseline for water quality of the Hātea River and influence of the WWTP, the variability in water quality across the SOE monitoring locations has been considered using typical statistical measures. Assessment for each parameter monitored as part of the NRC SOE monitoring between 2010-2020 is provided below. For total nitrogen, analysis results are only available for the period 2016-2020.

Total nitrogen

Figure 15 provides the distribution of total nitrogen concentrations at each SOE monitoring location, with Figure 16 providing annual median comparison to the PNRP criteria for total nitrogen.

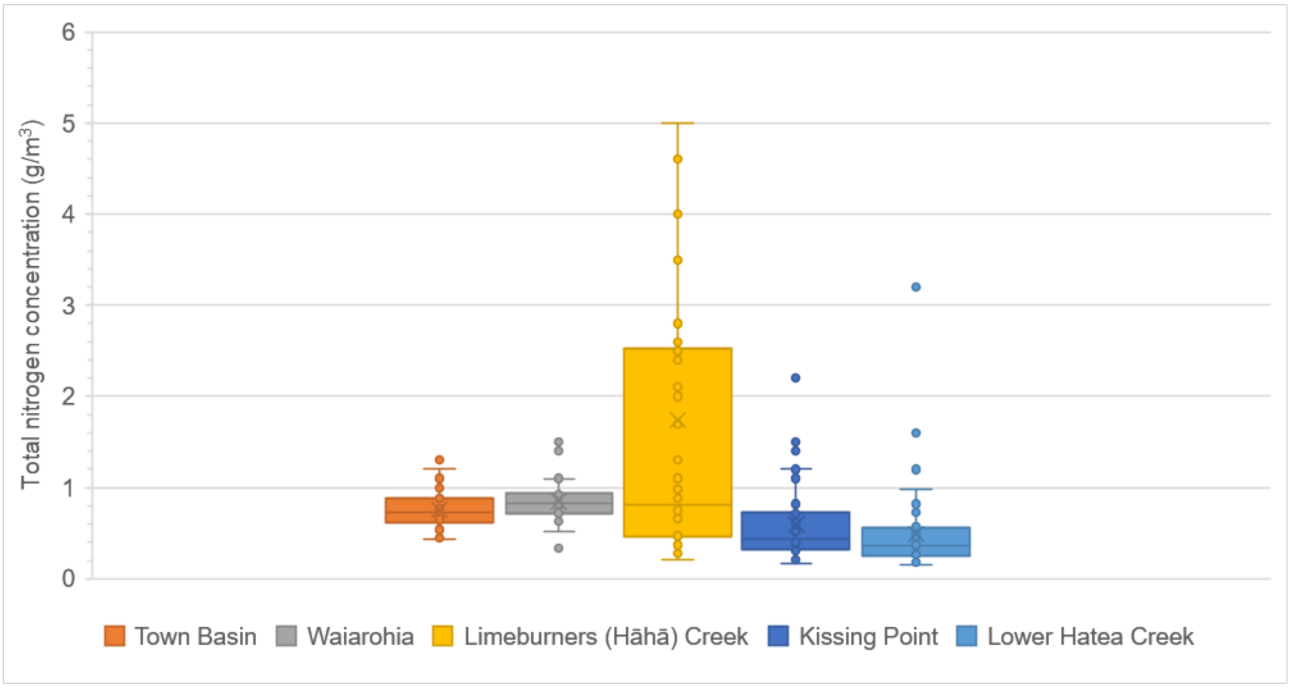

Figure 15 Distribution of total nitrogen concentrations at SOE monitoring sites

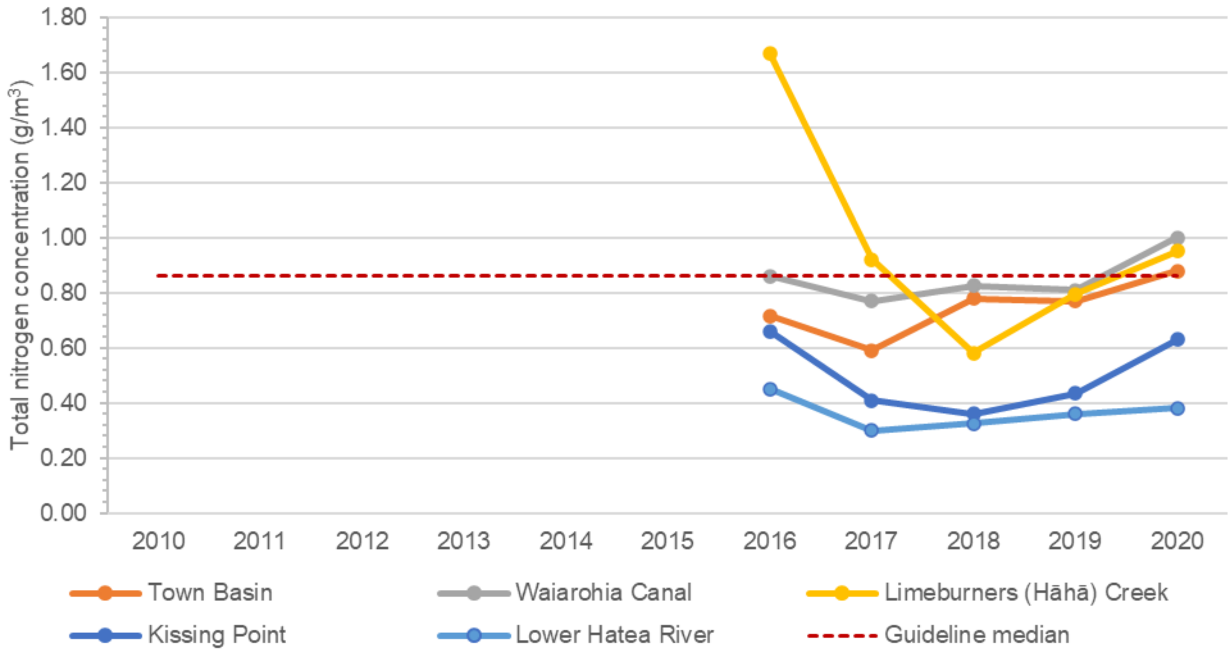

Figure 16 Total Nitrogen annual median at each SOE monitoring site compared against PNRP criteria

Review of available sample results since 2016 indicates that while the long term median total nitrogen at Limeburners (Hāhā) Creek is approximately equivalent to that at Waiarohia and the Town Basin, there is a notable difference in statistical distribution. There is a high variability in the upper end of concentrations at Limeburners (Hāhā) Creek, with the distribution of results skewed. These intermittent periods of elevated nitrogen concentration are most likely attributed to the less frequent periods of high flow WWTP discharge.

When considering the concentrations of individual years, excluding 2016 and 2017 during which only six samples were collected annually, the periods of high WWTP discharge are sufficiently infrequent to not influence the median total nitrogen concentration. Notably, the annual median for total nitrogen has been lower at the Limeburners location than the Waiarohia location for the period 2018-2020. Also noteworthy is that the 2020 annual median concentrations for the Town Basin, Waiarohia and Limeburners (Hāhā) Creek locations have all exceeded the PNRP water criteria.

Nitrite-Nitrate Nitrogen

Figure 17 provides the distribution of nitrite-nitrate nitrogen concentrations at each SOE monitoring location, with Figure 18 providing annual median comparison to the PNRP criteria for nitrite-nitrate nitrogen.

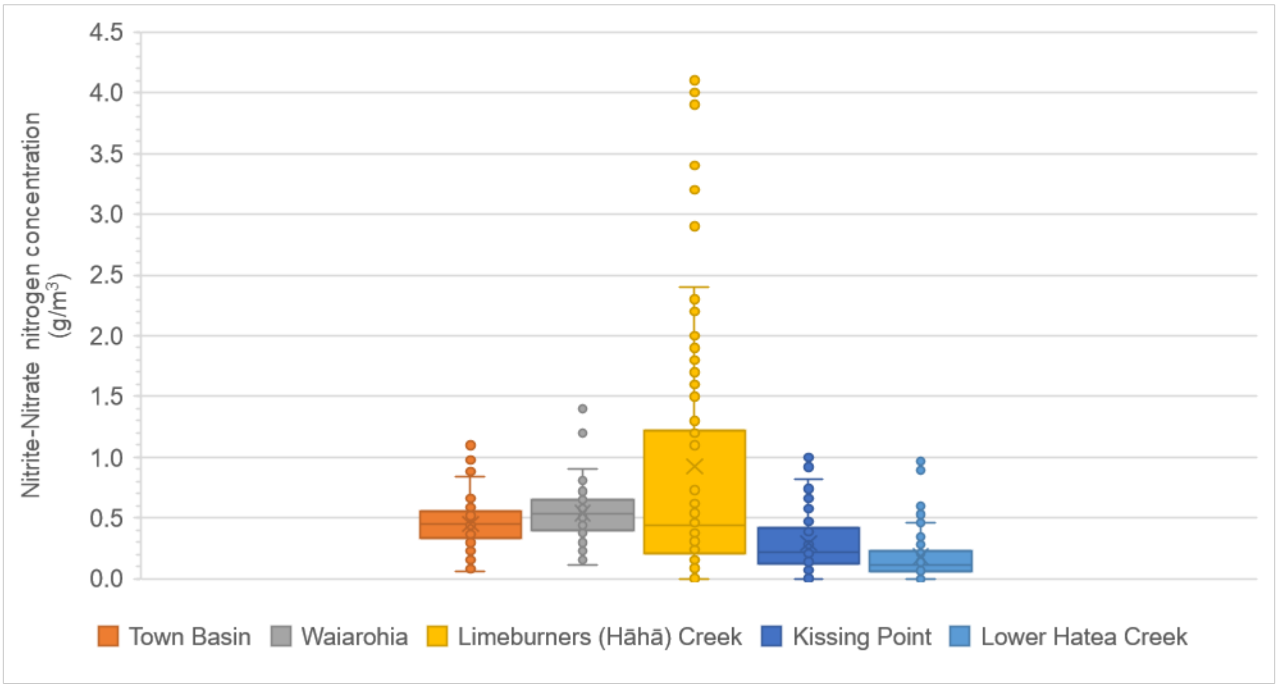

Figure 17 Distribution of nitrite-nitrate nitrogen concentrations at SOE monitoring sites

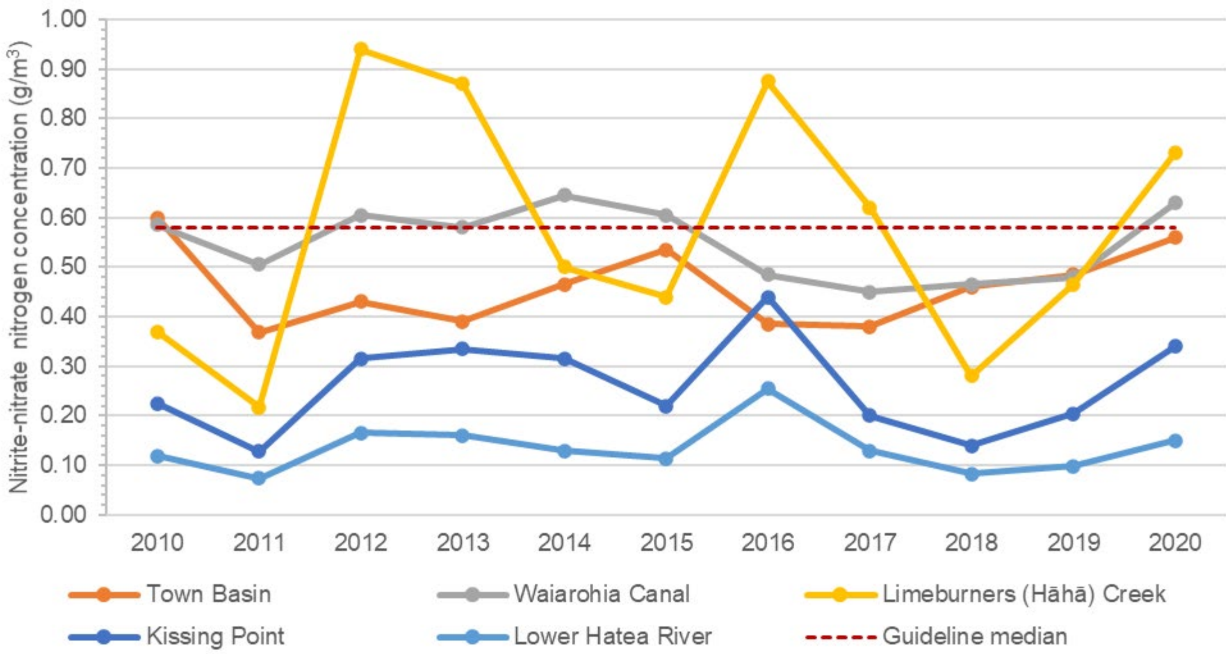

Figure 18 Nitrite-nitrate nitrogen annual median at each SOE monitoring site compared against PNRP criteria

Nitrite-nitrate nitrogen concentration in the Hātea River follow a similar trend and distribution to that of the total nitrogen concentrations. Nitrite-nitrate nitrogen is formed through the oxidation of nitrogen compounds and represents a considerable portion of total nitrogen. The long-term median nitrite-nitrate nitrogen concentration at Limeburners (Hāhā) Creek is approximately equivalent to that of the Town Basin and Waiarohia Canal locations, with a notable difference in statistical distribution of the higher concentrations at Limeburners (Hāhā) Creek. The intermittent increases in concentration at this location are considered to result from periods of high flow discharge from the WWTP. Waiarohia Canal and Limeburners (Hāhā) Creek have exceeded the PNRP guideline median value on several occasions between 2010 and 2020.

Total Phosphorous

Figure 19 provides the distribution of total phosphorous concentrations at each SOE monitoring location, with Figure 20 providing annual median comparison to the PNRP criteria for total phosphorous.

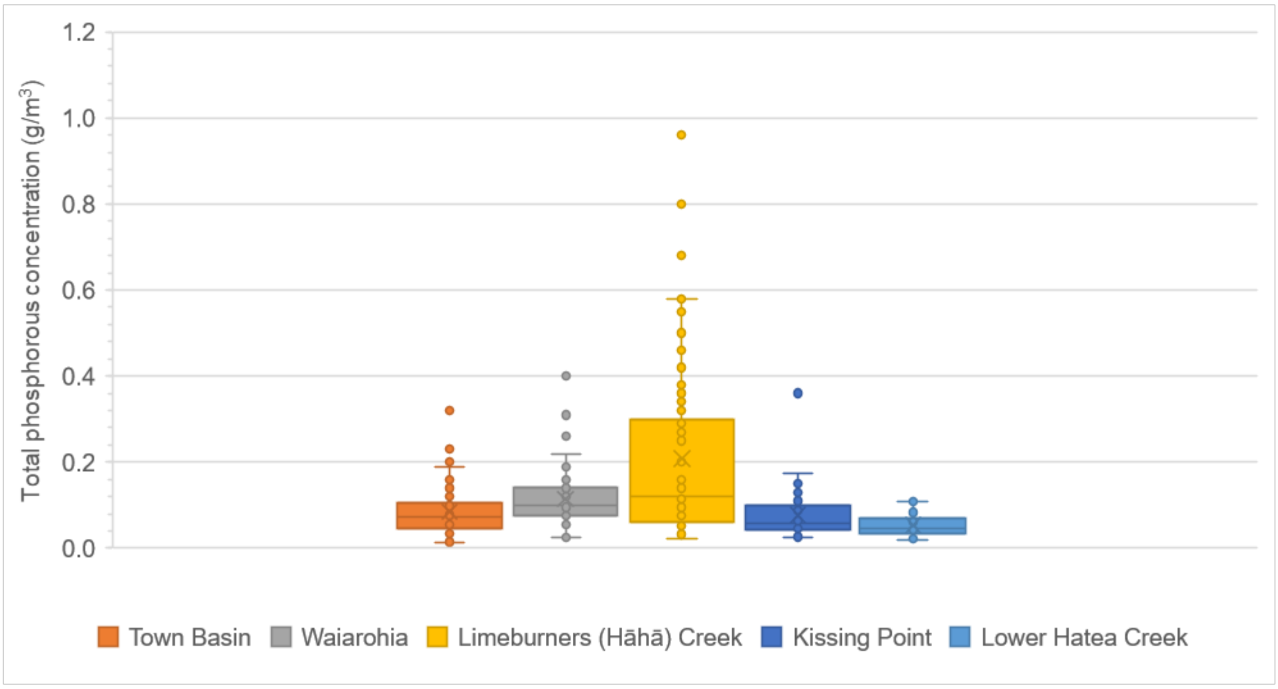

Figure 19 Distribution of total phosphorus concentrations at SOE monitoring sites

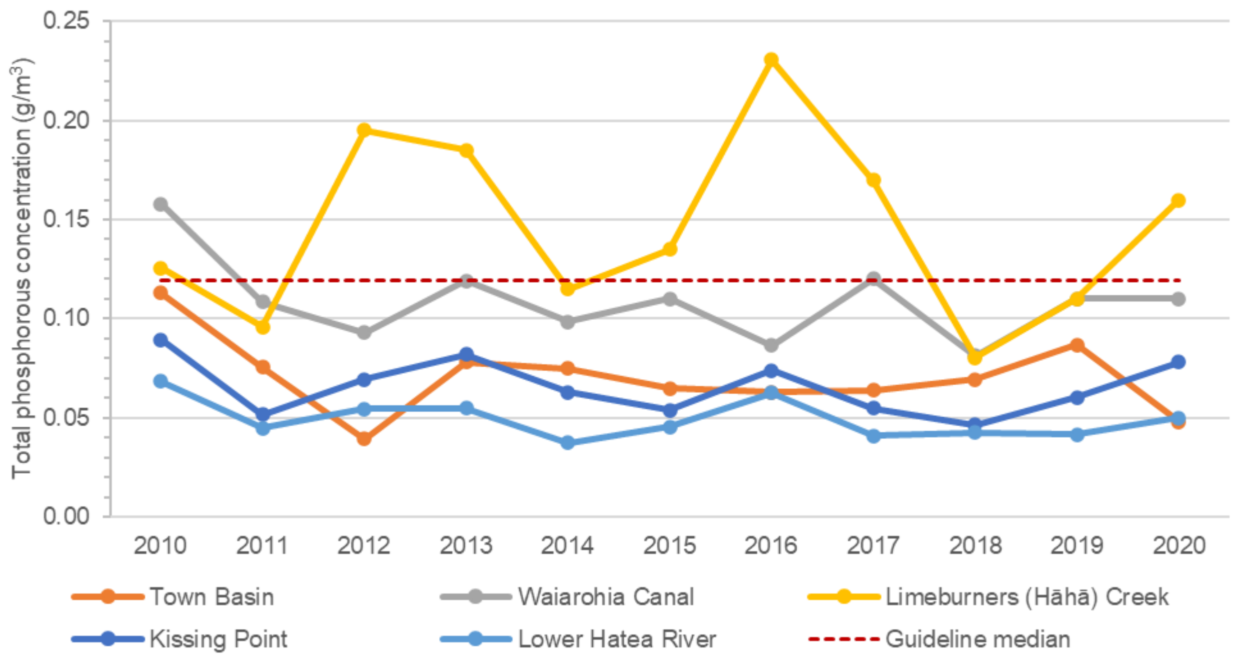

Figure 20 Total phosphorus annual median at each SOE monitoring site compared against PNRP criteria

In a similar manner to total nitrogen, total phosphorous concentrations at the Limeburners (Hāhā) Creek monitoring location show the greatest variability in the upper ranges of the measured concentrations. Annual median concentrations for both the Waiarohia and Limeburners (Hāhā) Creek have routinely exceeded the PNRP criteria, including prior to 2017 when the proposed criteria were derived.

The greater potential for accumulation of sediment and the more industrialised catchment activities of the Waiarohia and Limeburners (Hāhā) Creeks relative to the Town Basin, is considered likely to provide the greater background concentration of total phosphorous in these water bodies. The periodic increase in WWTP influence at the Limeburners (Hāhā) Creek location is typically consistent with the occurrence of elevated total nitrogen. This supports the inference that the less frequent periods of elevated phosphorous concentrations are likely to be attributable to high flow discharges from the WWTP.

Ammoniacal Nitrogen

Figure 21 provides the distribution of ammoniacal concentrations at each SOE monitoring location, with Figure 22 providing annual median comparison to the PNRP criteria for ammoniacal nitrogen.

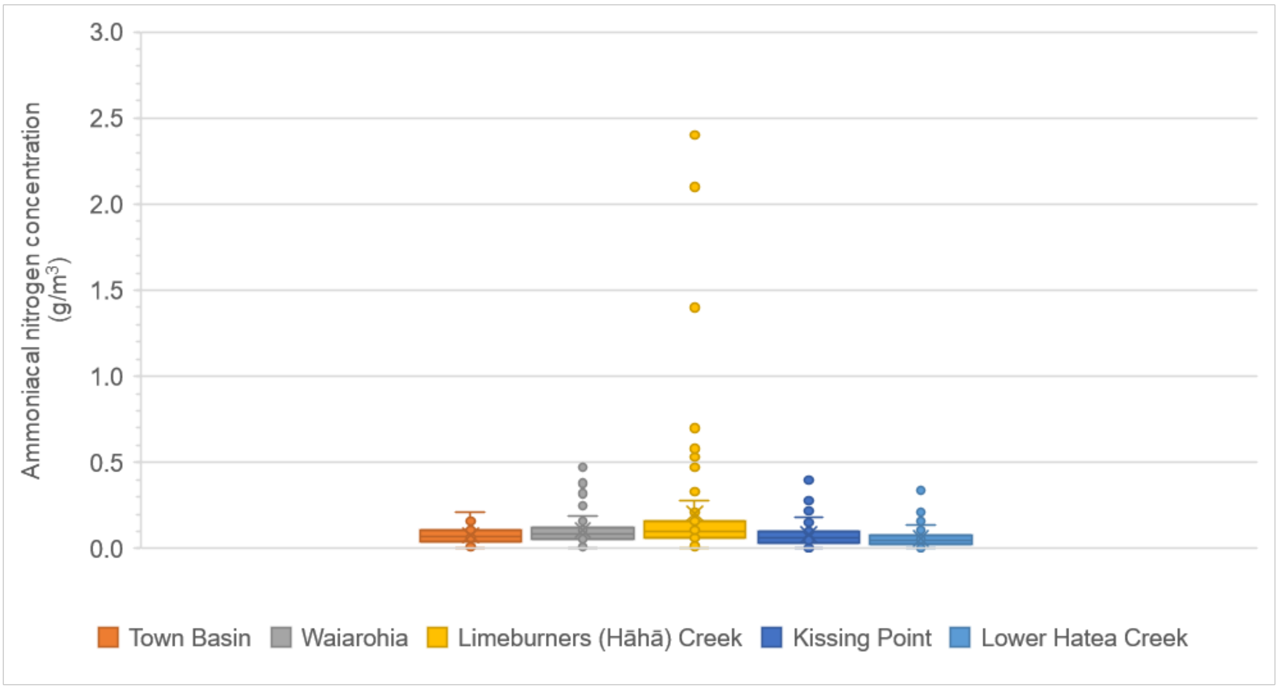

Figure 21 Distribution of ammoniacal nitrogen concentrations at SOE monitoring sites

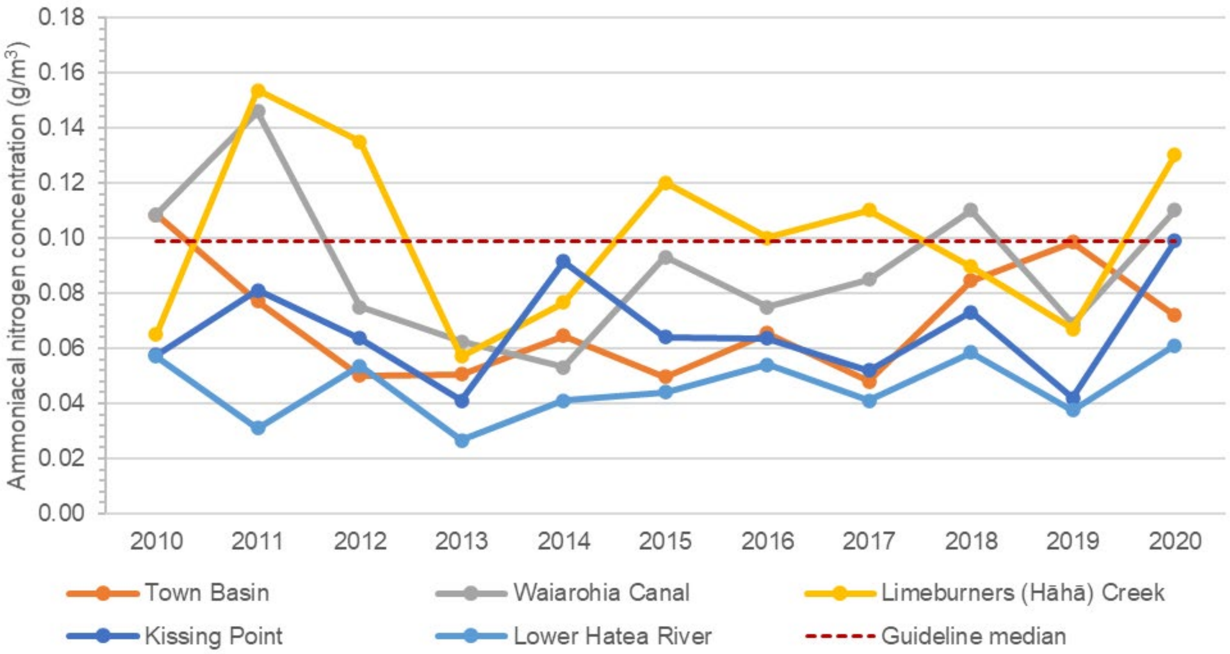

Figure 22 Ammoniacal nitrogen annual median at each SOE monitoring site compared against PNRP criteria

Present in the marine environment primarily as ammonium, ammoniacal nitrogen comprises approximately 10% of the total nitrogen concentrations measured in the Hātea River.

Peak concentrations of ammoniacal nitrogen are typically observed in the Waiarohia Canal and Limeburners (Hāhā) Creeks, with catchment sources considered to be influential on water quality. Elevated ammoniacal nitrogen at the Limeburners location do not consistently correlate with total nitrogen, nitrite-nitrate nitrogen or total phosphorous, which are considered indicative of the WWTP discharge. This would suggest that the WWTP discharge is unlikely to be the primary source of variation in the ammoniacal nitrogen concentrations. With changes in temperature or dissolved oxygen of the water bodies, or discharges from benthic sediment may contribute to the variability of ammoniacal nitrogen.

The ammonia concentrations recorded in the Limeburners (Hāhā) Creek monitoring, carried out by 4Sight Consulting, Section 4.1.2, suggests that there are acute toxicity issues within the Limeburners (Hāhā) Creek. To better understand what is causing the acute ammonia concentrations and the variability in ammoniacal nitrogen in the Hātea River at the confluence with Limeburners (Hāhā) Creek additional monitoring is required. As such a routine, high resolution sampling regime is required at the WWTP and Limeburners (Hāhā) Creek, which is proposed and detailed in Section 9.

Annual median concentrations of ammoniacal nitrogen at downstream monitoring locations (Kissing Point and Lower Hātea) are typically below the PNRP criteria, while those at the Town Basin, Waiarohia and Limeburners (Hāhā) Creek locations demonstrate frequent exceedances.

Chlorophyll-a

Chlorophyll-a concentration is an indicator of algal growth (biomass) and together with transparency (Secchi disk depth) and nutrient concentrations is used as a measure of the trophic status of water bodies. In this respect Chlorophyll-a provides an understanding of whether the water body is degrading (eutrophic) due to the nutrient load. Poor flushing and increased transparency can also result in elevated Chlorophyll-a. Where phytoplankton, such as Chlorophyll-a proliferate, the decay of large amounts of biomass can lead to oxygen consumption and hypoxic conditions that can be toxic to the local ecosystem.

In marine ecosystems, and where salinity strongly fluctuates, the relationship between nutrients and biomass is complicated and correlation between nutrient input and algal growth cannot always be established. Typically, nitrogen is the limiting nutrient in marine environments.

Figure 23 provides the distribution of Chlorophyll-a concentrations at each SOE monitoring location, with Figure 24 providing annual median comparison to the PNRP criteria for Chlorophyll-a.

Chlorophyll-a concentrations are relatively consistent across the Hātea River, with the greatest concentrations over the period of monitoring typically occurring in the Town Basin and Waiarohia monitoring locations. This is thought to be a reflection of the lower rate of water flushing that occurs in these upstream locations and, potentially, the lower salinity at such times. Notably, Chlorophyll-a concentrations at the Limeburners (Hāhā) Creek monitoring location are consistently below the PNRP and do not appear to be influenced by the WWTP discharge, with this likely to be due to the greater flushing that occurs in this, and downstream parts of, the Hātea River.

Concentrations of Chlorophyll-a in the Hātea River are expected to reflect a moderate eutrophic state[4], as indicated by the New Zealand Estuary Trophic Index (ETI) developed by NIWA. However, macroalgae abundance may provide a better indicator of trophic state in the Hātea River owing to the extent of intertidal areas and reasonable degree of flushing that occurs in the river.

Nitrogen is typically the limiting nutrient for phytoplankton growth in estuaries.

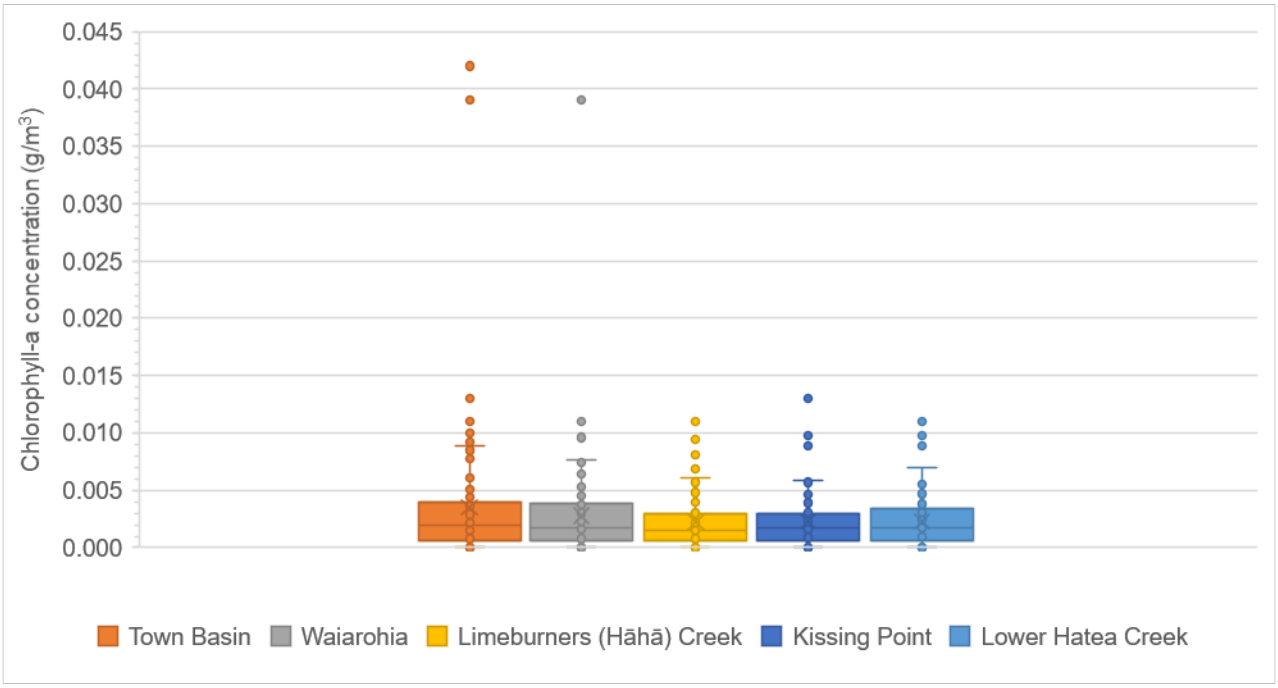

Figure 23 Distribution of chlorophyll-a concentrations at SOE monitoring sites

[4] A eutrophic water body is typically abundant in nutrients and has high rates of productivity. This frequently results in oxygen depletion below the surface layer of the waterbody (ANZECC, 2000).

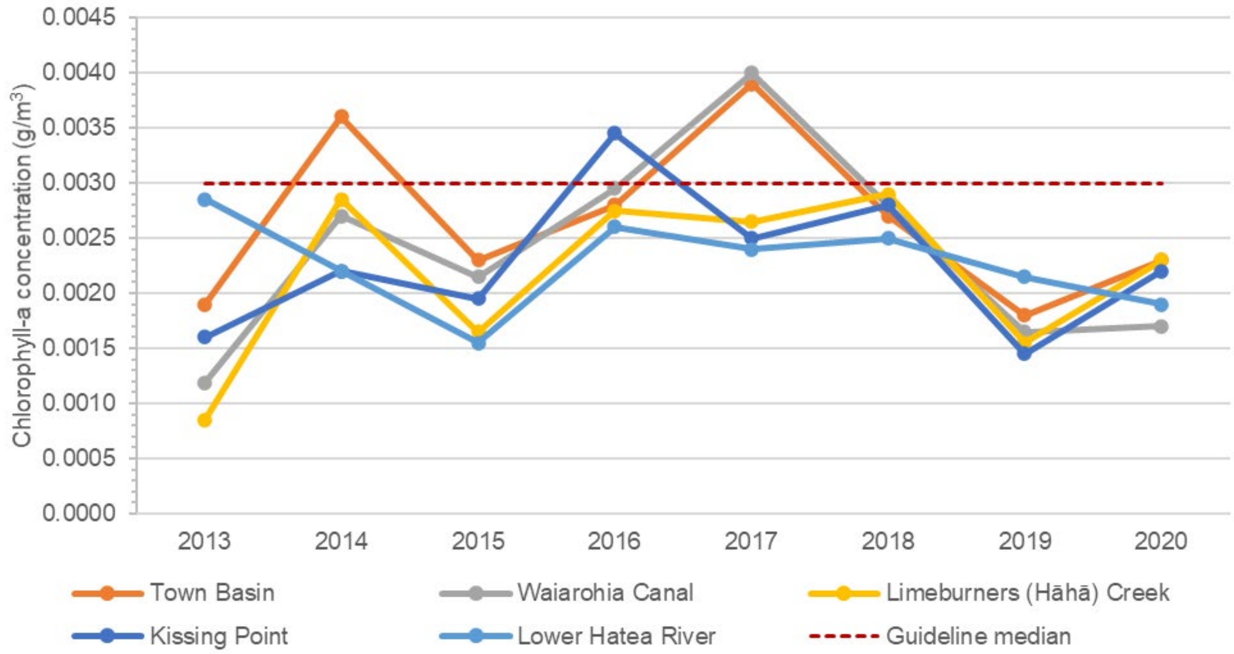

Figure 24 Chlorophyll-a annual median at each SOE monitoring site compared against PNRP criteria

Dissolved oxygen

Figure 25 provides the distribution of dissolved oxygen concentrations at each SOE monitoring location, with Figure 26 providing annual median comparison to the PNRP criteria.

The distribution of dissolved oxygen between sample locations across the full monitoring period mimics that of chlorophyll-a. The correlation between biomass and dissolved oxygen is common, with oxygen consumed through the microbial degradation of organic matter.

While historically dissolved oxygen has dropped below 5 g/m^3 on a small number of occasions (a general threshold considered to be required to sustain a healthy marine ecosystem), oxygen levels have been consistently above 6 g/m^3 for the past 10 years. Notably, the annual median dissolved oxygen data from the NRC SOE monitoring indicates levels have not dropped below the PNRP criteria of 6.2 g/m^3

The annual median dissolved oxygen data from the NRC SOE monitoring at Limeburners (Hāhā) Creek supports the results of the 4Sight monitoring (Section 4.2) that dissolved oxygen levels are considered appropriate at the mouth of Limeburners (Hāhā) Creek. This does not help determine what the source of low dissolved oxygen is within the creek and thus further monitoring is required, see Section 9.

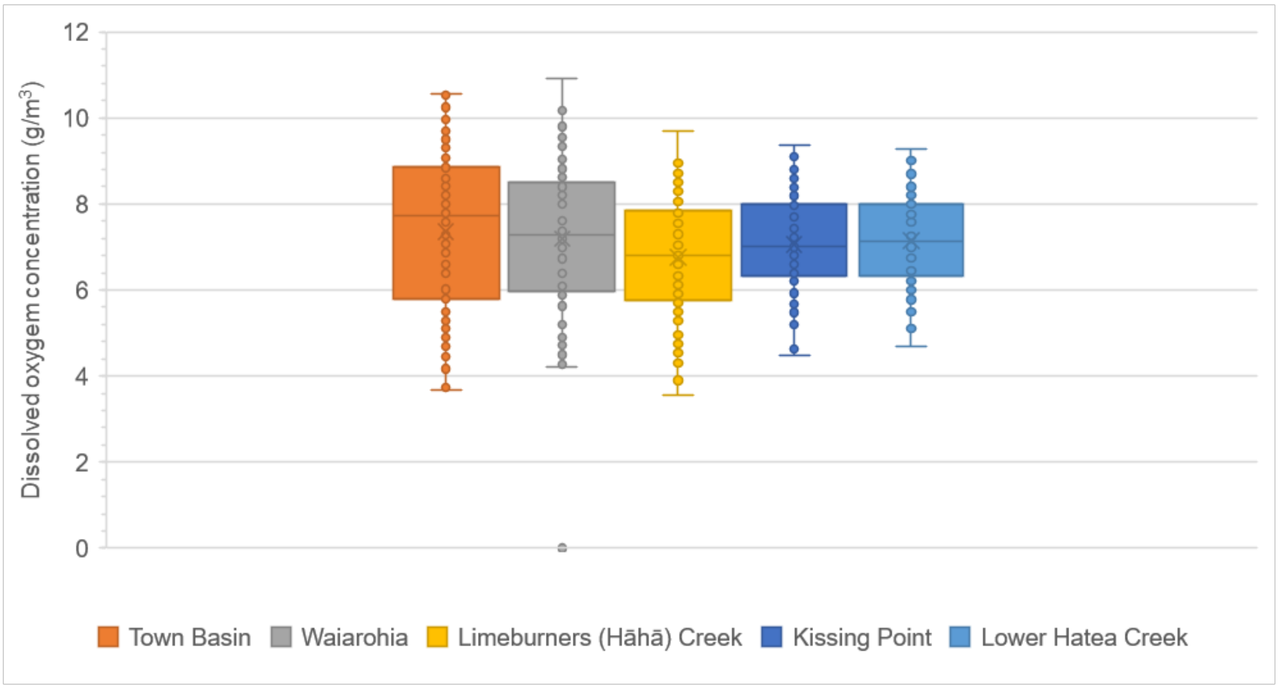

Figure 25 ***Distribution of dissolved Oxygen concentrations at SOE monitoring sites***

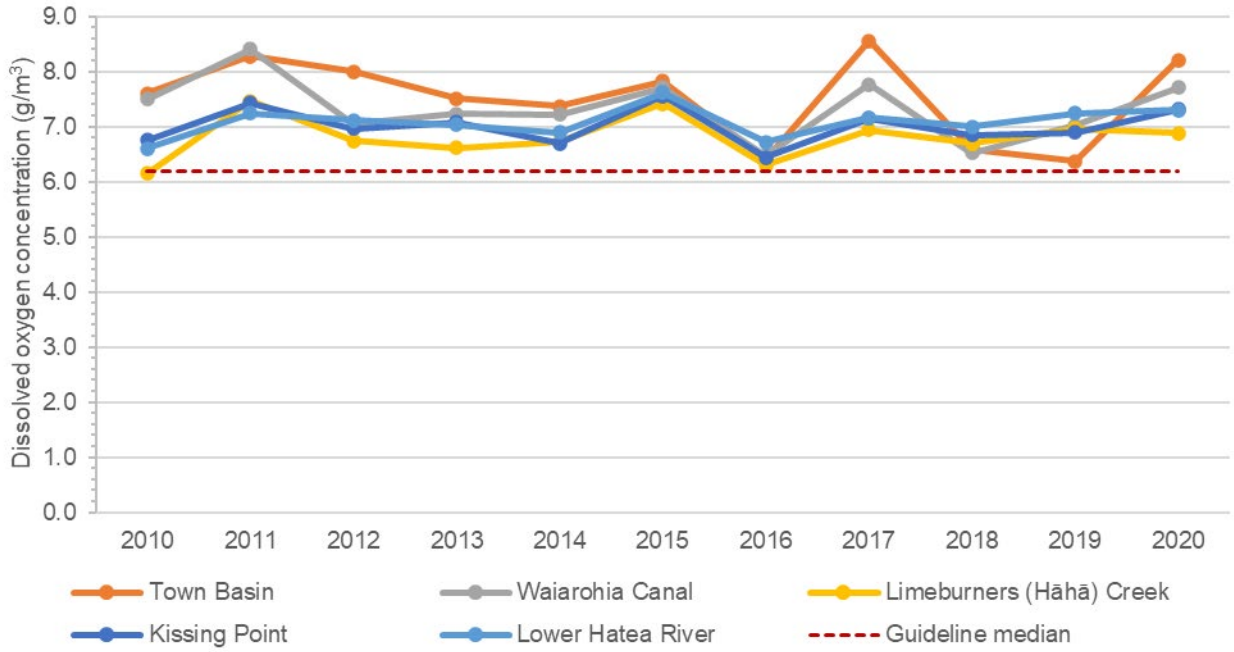

Figure 26 ***Dissolved Oxygen annual median at each SOE monitoring site compared against PNRP criteria***

Transparency

The ability for light to pass through the water is an indicator for the trophic state of a water body where the proliferation of algae can impact upon visibility. It is also a function of the turbidity of the water resulting from fine sediment, which can influence ecosystem health and recreational use of water. Transparency is measured by Secchi Disc, as 'm' of water depth through which the disc is visible.

Figure 27 provides the distribution of Secchi depth at each SOE monitoring location, with Figure 28 providing annual median comparison to the PNRP criteria.

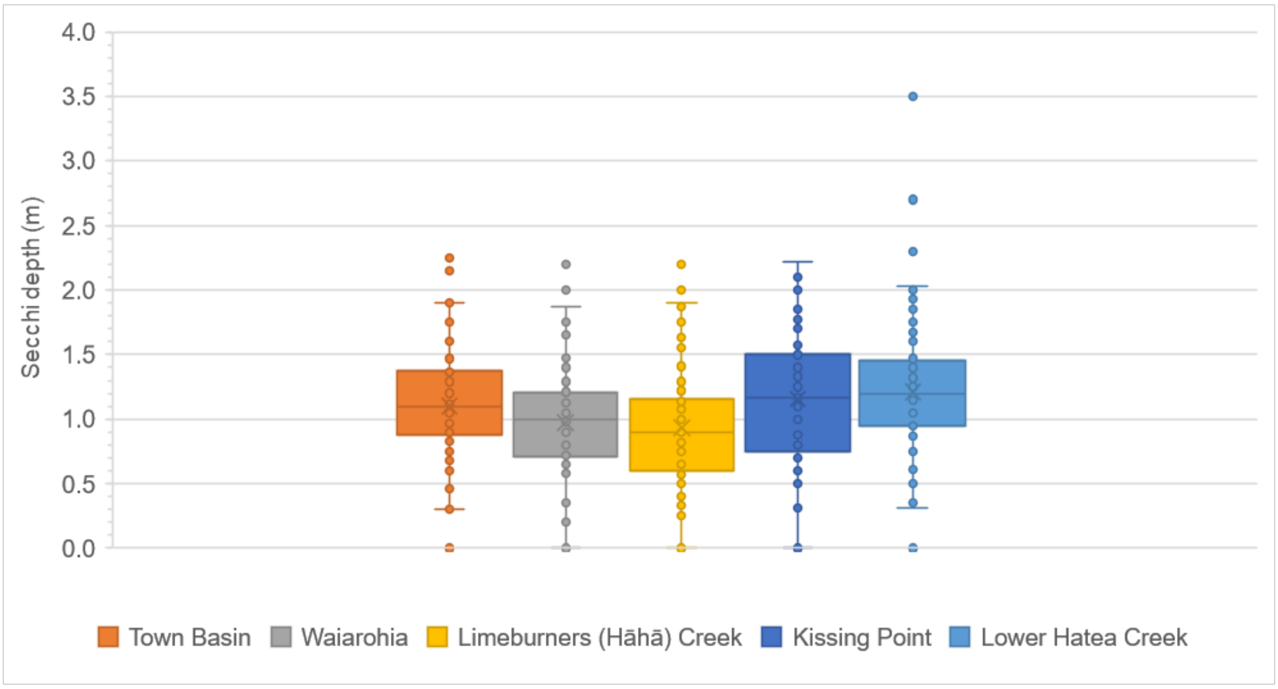

Figure 27 ***Distribution of Secchi Depth at SOE monitoring sites***

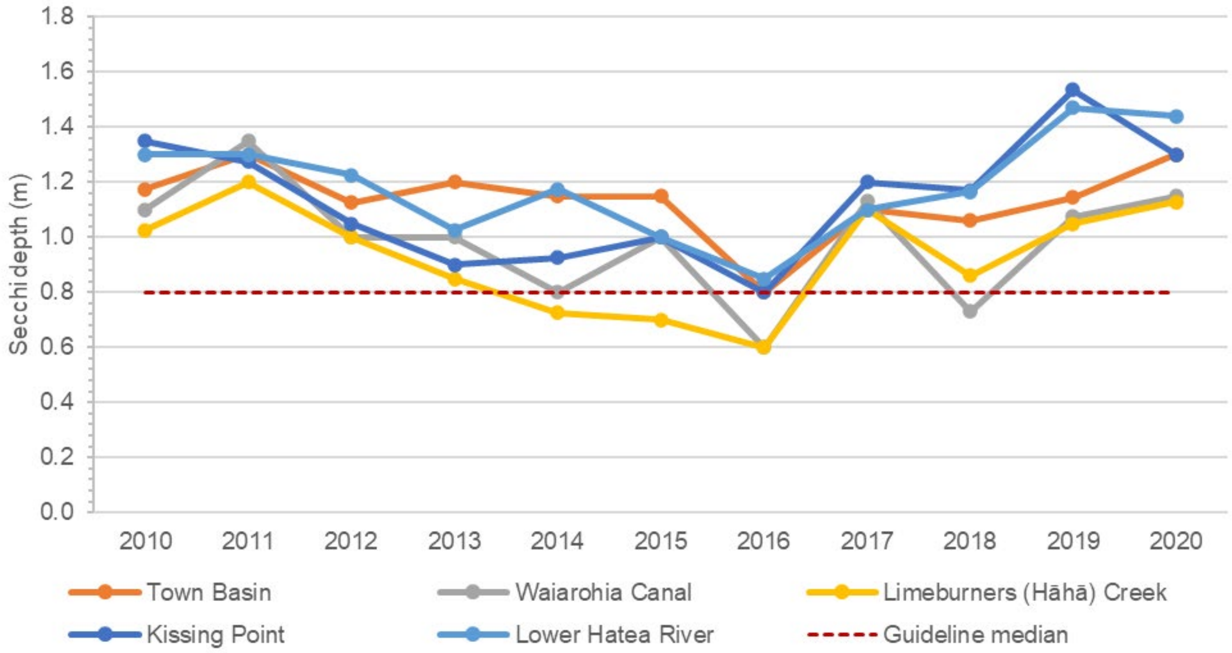

Figure 28 ***Secchi depth annual median at each SOE monitoring site compared against PNRP criteria***

Transparency in the Hātea River is typical of a disturbed shallow estuarine environment, with the lowest visibility typically evident in the Limeburners (Hāhā) Creek area. Visibility does not follow the same distribution as measured for chlorophyl-a, suggesting that fine sediment (mud) is more likely to be influencing visibility than phytoplankton growth. Notably, visibility appears to be influenced in both of the shallow Waiarohia and Limeburners estuarine creeks in a similar manner, suggesting that the urban catchment is a source of fine sediment that is influential on visibility.

The improved visibility downstream of Limeburners (Hāhā) Creek is expected to be the result of increased tidal flushing and a reduced catchment influence closer to the mouth of the Hātea River.

pH

Review of NRC monitoring data indicates that pH values of the Hātea River are considered typical of an estuarine environment (within pH 7.5 – 8.5). The median and individual pH values are within the PNRP water quality guidelines.

Temperature

Temperature is found to be typically consistent along the length of the Hātea River. The annual average median temperatures ranged from 15 to 19°C at all monitoring locations.

Salinity

The range of salinity measured in the Hātea River is discussed in Section 3.2.4. In summary, all locations are predominately marine water. Rain events and tide greatly influence salinity in the upper parts of the river (Town Basin and Waiarohia Creek), with tidal flushing greatest at the Limeburners (Hāhā) Creek monitoring location.

Metals

Total copper and total zinc have been monitored in the Hātea River since 2015 and total lead was monitored between 2015 and 2017. The concentration of total copper exceeds the PNRP water quality maximum criteria at most monitoring sites, with higher elevations noted at the Town Basin, Waiarohia Canal and Limeburners (Hāhā) Creek locations. It is important to note the allowable maximum concentration is 0.0013 mg/L for copper, and prior to August 2019 the detection limit associated with the copper analysis was 0.002 mg/L. Consequently, there is a portion of results prior to August 2019 which exceed the allowable limit by being at or below laboratory analysis detection limit.

The zinc concentrations at Town Basin, Waiarohia Canal and Limeburners (Hāhā) Creek have occasionally exceeded the PNRP water quality criteria, with the concentration reducing towards the lower Hātea River site with increased flushing.

Both copper and zinc are likely to be present at elevated concentrations due to stormwater from industrial and urban catchments. This is further supported by the conclusions from the 4Sight (2020 Ecological Baseline Report, which highlighted all metals assessed in the sediment samples were below the PNRP sediment quality guidelines, yet elevated concentrations were recorded at Town Basin (refer to 5.2.1).

During 2015 and 2016 the concentrations of lead were consistently recorded below the allowable PNRP water quality criteria, with a singular exception in May 2016 at Waiarohia Canal.

4.4 WWTP influence on Hātea River water quality

The results from the NRC SOE data indicates that the discharge from Limeburners (Hāhā) Creek has elevated concentrations of nitrogen and phosphorous due to the WWTP discharges, with this intermittently influencing the water quality of the Hātea River at the confluence of the two water bodies. Key points relating to the influence of the WWTP discharge on Hātea River water quality are as follows:

- The mixing of wastewater discharges with other freshwater sources and marine water is considered to occur to a great extent within Limeburners (Hāhā) Creek.
- Under typical flow conditions, concentrations of nitrogen from Limeburners (Hāhā) Creek are generally consistent with, or better than, those recorded at the Waiarohia monitoring location. This demonstrates the notable catchment source of nitrogen in the Hātea River derived from upstream catchment sources.
- The intermittent increases in nutrient discharges from Limeburners (Hāhā) Creek result in annual median water quality at the Limeburners (Hāhā) Creek monitoring location exceeding the PNRP criteria for nutrients at a greater frequency than other monitoring locations. However, catchment influences evident at the Waiarohia location also result in intermittent exceedance of the criteria, demonstrating that the Hātea River has a notable background nutrient load due to catchment activities.
- While periods of high flow WWTP discharge from Limeburners (Hāhā) Creek influences the water quality at the immediate location of mixing with the Hātea River, as reflected by the Limeburners (Hāhā) Creek monitoring location, this only has a minor influence on water quality further downstream. This suggests that

mixing within the Hātea River occurs rapidly and that significant dilution of WWTP discharges and flushing of the Hātea River occurs downstream of Limeburners (Hāhā) Creek.

– The relationship between elevated phosphorous and degraded visibility at the Limeburners (Hāhā) Creek monitoring location is consistent with the greater influence of fine sediment (mud) discharging from Limeburners (Hāhā) Creek. Similarly, although more subdued, influence on the Hātea River from the Waiarohia Creek demonstrates that catchment sources also contribute a meaningful phosphorous load to the river. Correlated to nitrogen, phosphorus is intermittently elevated during WWTP high flow events.
– The trophic state of the Hātea River is expected to be less influenced by the discharges from the WWTP compared to upstream catchment sources, as indicated by the dissolved oxygen and chlorophyll-a concentrations. This is likely due to the increased flushing in the downstream areas of the upper harbour, including Limeburners (Hāhā) Creek monitoring location, relative to the Town Basin and Waiarohia locations. It is noted that even during periods of high nutrient load due to WWTP peak flows, the high rates of flushing of the river in the vicinity of the Limeburners (Hāhā) Creek Monitoring location appear to limit excessive phytoplankton growth.
– There is a need for a high-resolution regular monitoring regime, which considers climatic influences, tidal cycles and what is occurring at the WWTP to determine if the WWTP is causing toxicity issues in Limeburners (Hāhā) Creek, with respect to ammonia and dissolved oxygen. The proposed monitoring outlined as part of the adaptive management approach (Section 9) aims to address this

4.4.1 Nutrient balance approach

A simplistic nutrient balance was developed to support the understanding of nutrient load and relative contribution of nutrients to the Hātea River from Limeburners (Hāhā) Creek relative to upstream sources. The total nitrogen, total phosphorous, ammoniacal nitrogen and total inorganic nitrogen (calculated by summing nitrite/nitrate nitrogen and ammoniacal nitrogen) were assessed using the SOE data from 2010 to 2020, with these considered to be key analytes when determining the influence of the WWTP on the receiving environment.

The nutrient loads were determined at each of the SOE monitoring points by multiplying the calculated yearly median concentrations by the flow. Flows for Town Basin, Waiarohia Canal and Limeburners (Hāhā) Creek were adopted from the NIWA study (NIWA, 2011b)[5], which splits flows into seasonal low flow (summer) and high flow (winter) as presented in Table 9. The flow at Kissing Point was calculated by summing the upstream flows.

Table 9 Adopted flow volumes (m^3/s)

Town Basin		Waiarohia Canal		Limeburners (Hāhā) Creek		Kissing Point	
Summer flow	Winter flow	Summer flow	Winter flow	Summer flow	Winter flow	Summer flow	Winter flow
1.0	60.0	0.5	50.0	0.3	12.0	1.8	122.0

The nutrient loads were calculated using the following formula:

$$Load\ (\frac{kg}{day}) = Concentration\ \left(\frac{g}{m^3}\right) x\ Flow\ (\frac{m^3}{s})$$

4.4.2 Nutrient balance results

Calculated loads

Based on the adopted flow regime and the annual median concentrations for the period 2010-2020 at each location, the mass loads for nutrients during summer and winter were calculated. The range of results are provided in Table 10, and the yearly calculated values are included in Appendix A.

From the estimated mass loads the percentage of nutrients contributed by discharge from Limeburners (Hāhā) Creek to downstream water quality was calculated, with the range of results provided in Table 11.

[5] Note that the flows used in the NIWA (2011b) model were monitored only at Town Basin and Waiarohia Canal, whereas the flows from Limeburners (Hāhā) Creek were nominal values. The report indicated that not knowing the actual flow of Limeburners (Hāhā) Creek was a major limitation of the model.

Table 10 Calculated nutrient loads

Parameter	Town Basin (kg/day)		Waiarohia Canal (kg/day)		Limeburners (Hāhā) Creek (kg/day)		Kissing Point (kg/day)	
	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
Total Nitrogen	51 – 76	3992 – 5184	33 – 43	3326 – 4320	15 – 43	601 – 1731	56 – 103	3795 – 6957
Total Phosphorous	3 – 10	425 – 819	4 – 7	354 – 683	2 – 6	83 – 239	7 – 14	490 - 943
Ammoniacal Nitrogen	4 – 9	275 – 757	2 – 6	229 – 631	1 – 4	59 – 159	6 – 15	432 – 1044
Total Inorganic Nitrogen	37 – 57	2722 – 4044	23 – 34	2268 – 3370	9 – 32	362 – 1275	37 – 76	2498 – 5160

Table 11 Percentage of Limeburners (Hāhā) Creek load on total downstream load

Parameter	Limeburners (Hāhā) Creek contribution to Kissing Point nutrient load	
	Summer	Winter
Total Nitrogen	25% - 40%	15% - 25%
Total Phosphorous	25% - 50%	15% - 30%
Ammoniacal Nitrogen	15% - 35%	10% - 20%
Total Inorganic Nitrogen	20% - 55%	10% - 30%

Note: Values rounded to the nearest 5%

Mass balance validation

As a validation of predicted mass loads, a total upstream load was calculated by summing the calculated loads at the three upstream monitoring locations (Town Basin, Waiarohia Canal and Limeburners (Hāhā) Creek), to predict the mass load at Kissing Point (located downstream from the three upstream locations).

The total upstream (US) load was calculated by:

$$US\ Load\ \left(\frac{kg}{day}\right) = Town\ Basin\ Load + Waiarohia\ Canal\ Load + Limeburners\ Creek\ Load$$

A predicted concentration for Kissing Point was then calculated, using the cumulative flow of the upstream contributors, and compared to the annual median concentrations for Kissing Point measured by NRC (Table 12).

Table 12 Validation check

Parameter	Back-calculated median concentration		Kissing Point median concentration
	Summer	Winter	Sample results
Total nitrogen (g/m^3)	0.79	0.81	0.44
Total phosphorus (g/m^3)	0.089	0.110	0.063
Ammoniacal nitrogen (g/m^3)	0.074	0.088	0.064
Total inorganic nitrogen (g/m^3)	0.59	0.67	0.32

The NRC sample concentrations are similar to the calculated concentrations, with some over prediction of mass load. This is likely due to the following factors contributing to measured concentrations being less than predicted:

– Partial mixing.
– Attenuation processes.
– The inferred flow rate at Kissing Point (inferred using the sum of the upstream locations; a higher flow rate would result in a decreased concentration).

Given the similarity in predicted concentrations (within the same order of magnitude) the mass balance developed from the adopted flow rates is considered sufficiently accurate to provide a comparative understanding of the various contributing sources influencing water quality in the Hātea River.

4.4.3 WWTP Impacts to Water Quality

While the nutrient load within the Hātea River is considered to be high, and the WWTP contributes in a measurable way to this, long term monitoring indicates that Hātea River water quality and the local ecosystem is unlikely to be meaningfully influenced by discharges from the WWTP. Upstream and local catchment phytoplankton, DO and visibility measurements demonstrate a baseline consistent with a disturbed environment, but these conditions are not interpreted to be further degraded by the WWTP discharges. Fine sediment within the river in particular appears to be having the most meaningful influence on the ecosystem of the Hātea River.

The intermittent influence of the WWTP during periods of high flow discharges does, however, result in short periods of decline of Hātea River water quality. The occurrence of elevated nutrient concentrations in the vicinity of the Limeburners (Hāhā) Creek) confluence with the river at such times is considered to provide the most meaningful indication of how the WWTP affects water quality. Given the short duration (days at most and coinciding with high catchment discharges from rain events), such events are not considered to meaningfully influence the general condition of the river.

5. Sediment quality

5.1 NRC sediment monitoring

Since 2010 NRC have monitored sediment metal concentrations, and sediment total organic carbon, nitrogen, and phosphorous content in the Whangārei Harbour. The 2016 Coastal Sediment Monitoring Programme Report (NRC 2016) summarised the results between 2010 - 2016, with monitoring undertaken every two years. The NRC monitoring collects surface samples from the top 2 cm of sediment at the SOE monitoring locations throughout the Whangārei Harbour (Figure 12). The 2016 report summarised the results from this monitoring as follows:

- Copper concentrations are highest at the Upper Hātea River and the Waiarohia Canal, where they were recorded to exceed the ANZECC ISQG-low effect trigger in 2016. These two monitoring locations have consistently recorded the highest concentrations of copper since 2010, while concentrations tend to decrease from the Hātea River to the entrance of the Harbour.
- Zinc and lead follow a similar trend to copper, with the highest concentrations recorded at the Upper Hātea River and the Waiarohia Canal. The zinc concentrations at these two sites exceeded the ANZECC-ISQG-low trigger level in 2016. No exceedance was recorded for lead.
- Chromium concentrations were all recorded below the ANZECC ISQG-low effect trigger level, with the highest concentrations located at Upper Hātea River and the Waiarohia Canal. Chromium concentrations were also observed to decrease towards the Harbour.
- Nickel was analysed from 2012 onward and has consistently been below its respective trigger level, following a similar trend as chromium.
- Cadmium was also consistently below its respective trigger level with many monitoring locations reporting concentrations below the analytical detection limit. Cadmium follows a similar trend to chromium with the highest concentrations recorded at the Upper Hātea River and Limeburners (Hāhā) Creek and decreasing towards the Harbour.
- The concentrations of all metals are relatively stable at most sites with no significant increases or decreases observed. Given the Hātea River flows through the city of Whangārei the metal concentrations are likely attributed to road runoff, stormwater discharges, industrial discharges, and leachates from landfill sites. The higher concentrations noted in the Hātea are also consistent with these monitoring locations being in depositional tidal creek environments, where there is a higher proportion of mud. The results from the Whangārei Harbour indicated there is a strong correlation between mud presence and metal concentrations.
- Overall, relatively low concentrations of metal contaminants were recorded at Limeburners (Hāhā) Creek.
- The highest total organic carbon content was recorded in the Waiarohia Canal, Upper Hātea River and Limeburners (Hāhā) Creek in 2016, with these monitoring locations being classified as ‘enriched’ in total organic carbon. NRC note that across the sampling period the concentration of total organic carbon has increased noticeably at the Upper Harbour sites.
- The highest total nitrogen concentration was recorded at the Waiarohia Canal in 2016, with concentrations in the Upper Hātea River and Limeburners (Hāhā) Creek noted to be elevated in comparison to the Harbour. The highest total phosphorous concentration in the sediment samples was recorded at the Upper Hātea River, Waiarohia Canal and Limeburners (Hāhā) Creek in 2016.
- Like total organic carbon, a strong correlation was established between nitrogen and phosphorous concentrations and the presence of mud. Noticeable decreases in the nitrogen and phosphorous concentrations at Limeburners (Hāhā) Creek were also reported across the monitoring period.

The results of the NRC sediment monitoring indicate that from 2010 to 2016 the WWTP discharges to the Limeburners (Hāhā) Creek were not having a considerable impact on the receiving environment, with the metal and nutrient concentrations likely derived from catchment sources. The elevated or enriched concentrations compared to the downstream monitoring locations were also correlated to the high content of mud at these locations.

5.2 Limeburners (Hāhā) Creek and Hātea River sediment monitoring

5.2.1 4Sight monitoring

During March 2019 and February 2020 4Sight carried out sediment and ecological surveys to characterise the nearby environment of the WWTP. The surveys included broad-scale habitat mapping, fine-scale ecology sampling and water quality analysis, as detailed in the 4Sight Ecological Baseline Report (2020) and the Marine Ecology Assessment Report (2021b), attached in Appendix C and Appendix D respectively.

Sediment samples were collected within the Hātea River, Limeburners (Hāhā) Creek and Awaroa Canal and were compared against the PNRP Coastal Sediment Quality Guidelines (PNRP, 2020) to assess the ecosystem health of the environment. Sample locations are shown in Figure 29 (and Figure 12). The guideline values are listed in Table 13.

Table 13 Coastal sediment quality guidelines (PNRP, 2020)

Attribute	Unit	Compliance metric	Hātea River guideline value
Copper	mg/kg	Maximum	65
Lead			50
Zinc			200
Chromium			80
Nickel			21
Cadmium			1.5

The 4Sight (2021b) report characterised the intertidal sediment at each site as fine grained with the dominant size fractions being mud, fine sand, and very fine sand. Of note, the upper Limeburners (Hāhā) Creek sample comprised approximately 25% gravel, and the Hātea River had the lowest proportion of mud, reflecting the higher energy environment at these sampling locations.

The 4Sight (2020) report concluded all sites reported metal concentrations that were within the PNRP sediment quality guidelines. The total organic carbon concentration in the sediment was substantially higher at the Hātea River monitoring location compared to the other sites, reflecting the high mud content noted at this location at the time of sampling; this is consistent with the findings of NRC monitoring.

Chlorophyll-a concentrations were recorded to be elevated at the lower Limeburners (Hāhā) Creek monitoring location, compared to the upstream site, whereas the total phosphorous concentration in the sediment was markedly higher at the upstream Limeburners site compared to the downstream site and that of the Awaroa and Hātea. The sediment total nitrogen concentrations were similar at each location, and the redox measurements were highly variable with no significant difference noted between sites.

Overall, the 4Sight reports (2020; 2021b) concluded the high total organic carbon content is reflective of a moderate to high stress environment for benthic organisms, and nutrient enrichment is reflected by the high chlorophyll-a concentrations recorded. The influence the WWTP has on the overall sediment quality is further detailed in Section 5.3.

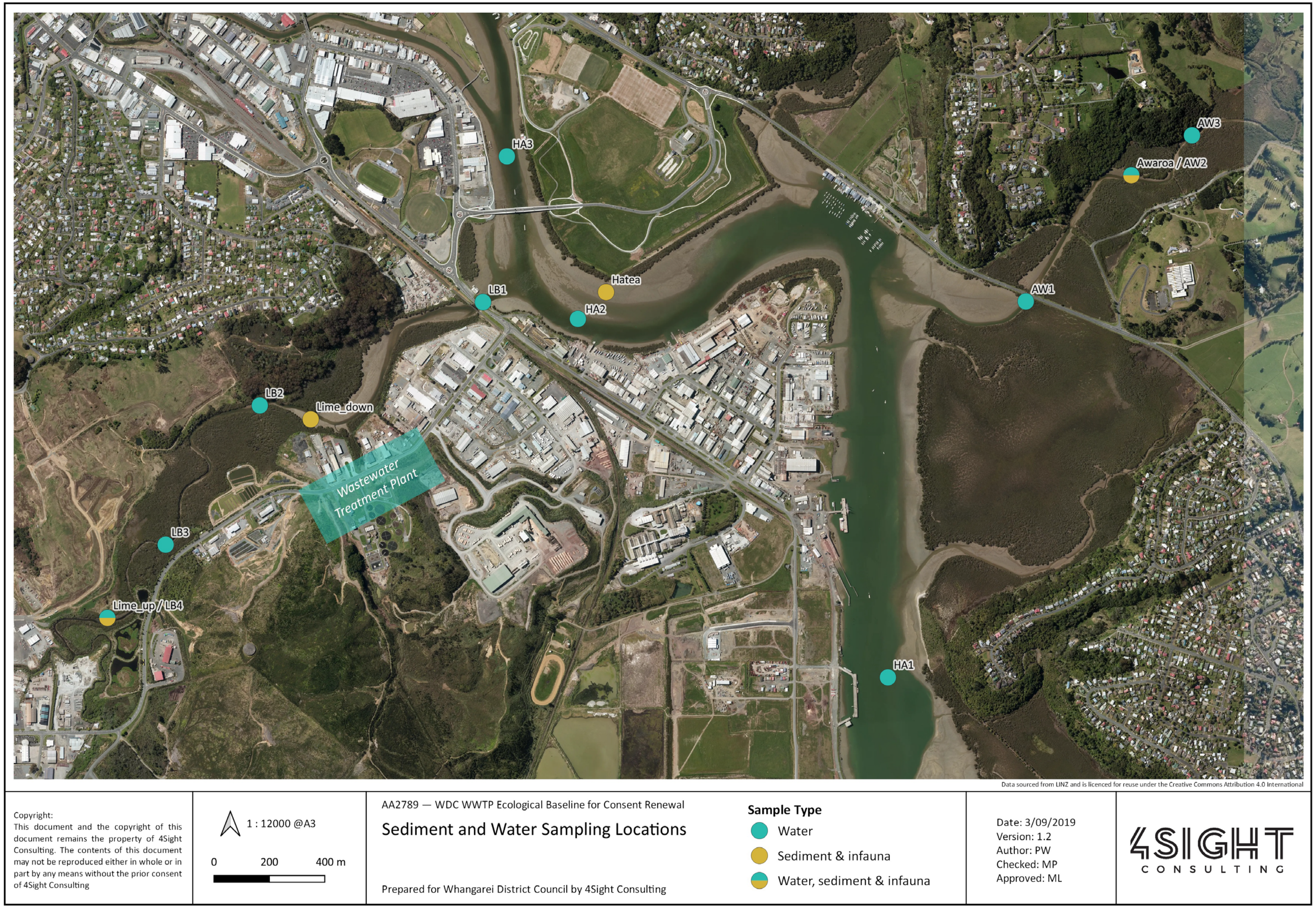

Figure 29 4Sight sediment and water sampling locations (4Sight, 2020; 2021b).

5.2.2 Benthic macroinvertebrate communities

Benthic macroinvertebrate communities are an indicator of the ecosystem health in estuarine systems as they respond to environmental stressors. The 4Sight reports (2020 and 2021) summarises the results of the benthic macroinvertebrate community surveys in terms of whole community indices: richness, abundance, and diversity. In general, they conclude the communities were typical of a moderately impacted environment, with low species richness and diversity indexes.

The Hātea River site had an even spread of taxa distribution but the fewest individual species. The most abundant species noted was polychaete worms of the genera *Arcidea* and *Prinonospio.* Additionally, a mud tolerant polychaete worm was present and the invasive Asian date mussel was also present in high abundance. Overall, 25 taxa were sampled, and 743 individuals collected, of which five species accounted for 69% of the total abundance. The communities found were reflective of a dynamic environment with a variety of habitat types and nutrient conditions.

The upstream Limeburners (Hāhā) Creek surveys identified an estuarine snail, unique to this site due to its tolerance of environmental extremes such as changes in salinity. The most abundant species was the polychaete worm from the *Nereididae* family, also present was oligochaete worms, amphipods, which are mud tolerant, and a singular stalk-eyed mud-crab. Overall, there were 19 different taxa sampled, 724 individuals collected, and one species accounted for 75% of the total abundance.

The surveys at the downstream Limeburners (Hāhā) Creek site identified the oligochaete worm as the most abundant species, followed by the polychaete worm of the family *Spinoidae*. Mud tolerant polychaete worms of a different family, amphipods and stalk-eyed mud-crabs were also identified. Overall, there were 24 different taxa sampled, 1,643 individuals collected, and the three main species found accounted for 74% of total abundance. The differences noted between the upstream and downstream site are reflective of the different physical conditions including substrate and salinity.

At the Awaroa reference site the most abundant species was also the oligochaete worms. Polychaete worms were also present, and mud tolerant polychaete worms, amphipods and the stalk-eyed mud-crab were also identified. Overall, 28 taxa were sampled, 1,220 individuals were recorded, and two species accounted for 70% of the total abundance. The abundances, richness and diversity measures are similar to the Limeburners (Hāhā) Creek downstream site, suggesting the Limeburners (Hāhā) Creek is atypical for the estuarine location.

5.2.3 Sedimentation

In 2013 NIWA investigated the historical rates of sediment accumulation and sediment sources in the Whangārei Harbour, (NIWA 2013) on behalf of NRC. This work included collection of sediment cores, radioisotope dating, 3-dimensional hydrodynamic HD and particle-tracking modelling and catchment sediment yield calculations. The results of the mud-transport modelling indicated most of the fine silt discharged to the harbour was through the Hātea, Oaika and Mangapai rivers, with the fine silt deposited close to the sources on the intertidal flats in the Upper Harbour. Under flood flows, 1 year return period and 10- year return period, the model simulations indicated increased deposition of fine sediment in the Upper Harbour extending to the intertidal flats in the middle reaches of the Harbour.

The radioisotope analysis and x-radiographs assisted in the determination of sediment accumulation rates. In the samples from the Hātea arm of the Harbour the data was consistent with frequent physical reworking of bed sediments by waves (NIWA, 2013). The long-term average specific sediment yield from the collective catchments draining to the Upper Harbour was estimated at approximately 138 $t/km^2/yr$, plus or minus 28 $t/km^2/yr$, which was within the range of values estimated for the major sub-catchments using the NIWA WRENZ model. The NIWA WRENZ model estimated the sediment yield from the Hātea at 122 $t/km^2/yr$ (NIWA, 2013). These values are moderate to high for the Northland area.

The detailed assessment of the Hātea River by NIWA noted significant differences in the Compound Specific Stable Isotope (CSSI) signatures in sediment samples. To further understand these differences the Hātea River was assessed as upper and lower sections, separated at Mair Park. The results showed the percentage of sediment each sub-catchment contributed to the River:

– 9% from the upper Hātea River.

- 3% from Awaroa and Waioneone Creeks.
- 31% from Limeburners (Hāhā) Creek.
- 56% from the Raumanga Stream system (including Waiarohia Canal).

The low proportion of sediment contribution from the upper Hātea River was assumed to be a result of the thickness of the sediment layer sampled and the lack of recent deposition events. A deeper analysis of the sediment from the Raumanga Stream identified that the majority of the sediment was derived from sub-soil erosion, with 90% of the sediment contributed from Limeburners (Hāhā) Creek also from this source.

5.3 WWTP influence on sediment quality

The results of the NRC and 4Sight sediment monitoring has highlighted the WWTP influence on sediment quality is moderate in the Limeburners (Hāhā) Creek and low in the receiving Hātea River environment. The influence of WWTP discharge on sediment in the Limeburners (Hāhā) Creek is predominantly evident as the accumulation of phosphorous in the shallow sediment (4Sight 2021b). Phosphorous has a high affinity for adsorbing to fine sediment, therefore the dissolved phosphorous and the phosphorous bound sediment from the WWTP discharge are likely to act as additional sources of phosphorus. Phosphorous concentrations in the two Limeburners (Hāhā) Creek sample locations were elevated compared to the reference Awaroa and Hātea River sites indicating the influence of the WWTP discharges on phosphorous are limited to the Limeburners (Hāhā) Creek, with the tide carrying discharges upstream as well as downstream. The NRC monitoring indicated phosphorous and nitrogen bound to sediment in the Hātea River and Limeburners (Hāhā) Creek was also attributed to catchment sources. Additionally, the levels of phosphorous within the sediment did not appear to influence the benthic macroinvertebrate communities in the Limeburners (Hāhā) Creek.

Like phosphorous, metals also typically partition strongly to sediments and precipitate from freshwater on mixing with marine water. The metal concentrations in sediments from the 4Sight monitoring (2020 and 2021b) were all recorded below the PNRP metal guideline values. The NRC 2016 monitoring concluded metal concentrations were relatively stable at most sites and attributed to catchment sources, with no noticeable WWTP effects. Both studies also attributed the high total organic carbon concentrations to catchment sources in the Upper Hātea River and Limeburners (Hāhā) Creek, and the presence of mud in the intertidal flats. Metal concentrations in sediment recorded below quality limits, indicate that soluble metal concentrations in the water column are unlikely to be elevated

The influence of the WWTP discharge on sediment in the Limeburners (Hāhā) Creek is predominantly evident as the accumulation of phosphorus in shallow sediment, with this considered to represent a relatively minor influence on overall sediment quality. The WWTP is not considered to contribute meaningfully to the generation of sediment or the deposition of potentially toxic trace elements.

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6. Public health risk assessment

6.1 Public health concerns

Water contaminated by human or animal excreta may contain a range of pathogenic micro-organisms, such as viruses, bacteria and protozoa. These organisms may pose a health hazard when the water is used for recreational activities, as the water could be swallowed, inhaled, or come in contact with ears, nasal passages, mucous membranes or cuts in the skin, providing a potential pathway for pathogens to enter the body (MfE, 2003).

Many occurrences of infection are asymptomatic. Where infection does result in ill-health, the effects from exposure are typically minor and short-lived. Gastro-enteritis and respiratory issues are the most commonly exhibited health effects. However, there is the potential for more serious diseases to be contracted, such as hepatitis A, giardiasis, cryptosporidiosis, campylobacteriosis and salmonellosis (Philip, 1991).

While the Whangārei WWTP UV disinfects all wastewater prior to discharge to the wetlands, the treated wastewater has a residual active pathogen load that on discharge to the environment can increase the risk of infection for users of the water body.

6.2 Water quality criteria for public health

Public health requirements pertaining to this study include guidelines for swimming and shellfish gathering, which are outlined in the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas by the Ministry for the Environment (MfE, 2003).

As monitoring and assessment of risk for individual pathogens that cause ill health is impractical, indicator microorganisms are used which indirectly reflect the level of pathogens within water. For marine waters the preferred indicator for risk during recreational exposure is Enterococci. The MfE guidelines describe the use of a sanitary inspection category (very low to very high) to reflect the likelihood that pathogens represent human faecal contamination of water, with this rating together with the enterococci count determining the suitability of the water for recreational use (very good to very poor).

For potential risk to public health through the ingestion of shellfish from a coastal area, faecal coliform count is used as an indicator of pathogens in water. The PNRP criteria have consideration for these guidelines and different exposure scenarios, as follows:

- Enterococci criteria for the Hātea River is intended to maintain a microbiological category of ‘C’ (refer to Table 15), reflecting a water quality suitable for secondary contact (such as wading and kayaking).
- Shellfish gathering is not provided for in the Hātea River and other tidal creeks.
- Criteria for estuaries, which includes the Whangārei Harbour into which the Hātea River discharges, includes Enterococci criteria intended to maintain a microbiological category of ‘B’, reflecting water quality suitable for primary (swimming) and secondary contact during recreation.
- Criteria for estuaries includes criteria for Faecal Coliforms, assuming shellfish gathering activities will be occurring.

Limeburners (Hāhā) Creek, designated as a mixing zone for industrial discharges, does not have specific water quality criteria under the PNRP.

While addressed at a screening level through the application of the criteria above, the public health risk specific to viruses were assessed at a location specific level through a quantitative microbial risk assessment (QMRA) undertaken by NIWA in 2011 (refer Section 2.3). Such assessments bring together the exposure-response (also referred to as the dose-response) for viruses predominantly responsible for ill health where people are exposed to contaminated water. The assessments also estimate exposure based on source virus concentrations, physical processes of movement and dilution, and predictions of rates of virus inactivation (such as by exposure to sunlight).

The four basic steps of a QMRA typically include (Haas, Rose, and Gerba 1999):

- Hazard identification

- Exposure assessment
- Dose-response analysis
- Risk characterization

The NIWA QMRA in 2011 considered both wet weather and dry weather discharges of wastewater from the Whangārei WWTP and wider wastewater network, including extreme flow by-pass from the WWTP to Limeburners (Hāhā) Creek. The findings of this assessment were used to inform additional disinfection requirements (UV treatment) for such flow events. The illness threshold assessed, consistent with a "good" grading, was to present up to 5% risk of gastrointestinal illness over the bathing season, consistent with the recommendations from the World Health Organisation (WHO, 2003).

Recent review of national microbiological water quality guidelines for marine recreational areas undertaken by NIWA (2019) has suggested that Enterococci remains an appropriate indicator for risks to public health outside of the mixing zone for treated wastewater discharges (typically >500 m from the point of discharge). For recreational areas closer to the point of discharge, the QMRA approach was considered to remain the appropriate method of assessing risk to recreational users of the area.

6.3 Pathogen exposure and monitoring programmes

As a highly disturbed tidal creek heavily influenced by catchment run-off, public use of the Hātea River is expected to be limited to secondary contact associated with boating and wading. Swimming within the Hātea River and shellfish gathering is uncommon and not promoted. Correspondingly, there is no public health monitoring programme in place for microbiological contamination in the Upper Hātea River zone, with the SOE monitoring of water quality by NRC (Section 3.2.4) providing the long-term understanding of pathogen levels in this receiving environment.

Downstream of the Hātea River, the Whangārei Harbour is used extensively for recreational purposes, including both primary and secondary contact, and for shellfish gathering.

NRC monitors several of Northland's popular swimming spots for enterococci each summer to check that the water is suitable for recreational activities. The recreational swimming period typically starts in December and ends in March, and the programme includes weekly sampling. When elevated levels of pathogens are detected, monitoring is carried out at increased frequency until conditions improve. In general, water quality is suitable for swimming at most of the open coastal beaches because of dilution and tidal flushing, however, areas near freshwater systems often observe periods of elevated pathogen levels.

The nearest swimming area to the WWTP is located at Onerahi beach, immediately downstream of the Hātea River in the Whangārei Harbour. Onerahi is a popular swimming and kayaking spot for residents, and NRC collects samples across the swimming season for enterococci analysis.

Potential use of Limeburners (Hāhā) Creek for recreation or shellfish gathering is unlikely, with the use of the creek as a mixing zone recognised in the mixing zone designation provided by the PNRP.

This public health risk assessment considers the Hātea River and Onerahi Beach as the receiving environments for the above exposure scenarios and is consistent with the approach adopted in the 2011 QMRA.

6.4 Hātea River microbiological water quality

The current water pathogen levels and influence of the WWTP and catchment sources have been assessed for in the following manner:

1. The SOE water quality data (2010 – 2020) collected in the Hātea River for enterococci concentrations have been assessed against the PNRP criteria and public health guidelines (MfE, 2003). Comparison between monitoring locations has been carried out to provide an understanding of the influence of the WWTP on pathogen levels in the Hātea River and to inform a broad assessment of public health risk associated with recreational use of the river.
2. The results of the public health monitoring programme at Onerahi Beach have been assessed to identify variability in pathogen levels over a short timeframe in response to wet weather flow events, and to inform public health risk for recreational activities and shellfish gathering.

The assessment of WWTP treatment performance in the context of the QMRA findings is outlined in Section 6.4.4.

6.4.1 Hātea River Enterococci

The distribution of enterococci concentration results for SOE monitoring in the Hātea River are presented in Figure 30. The results are presented without peak concentrations in Figure 31, to provide a clearer representation of the range of typical concentrations.

Pathogen concentrations in the Hātea River are typically greatest at the Town Basin and decrease with distance downstream. Monitoring at the Waiarohia Canal, considered representative of a tidal creek and catchment similar to the Limeburners (Hāhā) Creek, records Enterococci concentrations greater than at the downstream confluence with Limeburners (Hāhā) Creek. These notably elevated microbiological concentrations upstream of Limeburners (Hāhā) Creek indicate that catchment sources dominate the average microbiological water quality within the Hātea River.

The significant dilution and tidal flushing of the Hātea River downstream of Limeburners (Hāhā) Creek, evident in nutrient concentrations, is likewise evident in the relatively low Enterococci concentrations predominantly occurring at the Kissing Point and Lower Hātea monitoring locations. The average reduction in annual median concentration from the Limeburners (Hāhā) Creek confluence to Kissing Point is in the order of 50%.

Significant increases in Enterococci concentrations up to approximately two order of magnitude change are evident at all locations. These events have generally low occurrence and reflect the influence of notable rain events, which generate catchment run-off and an increase in discharge volume from the WWTP.

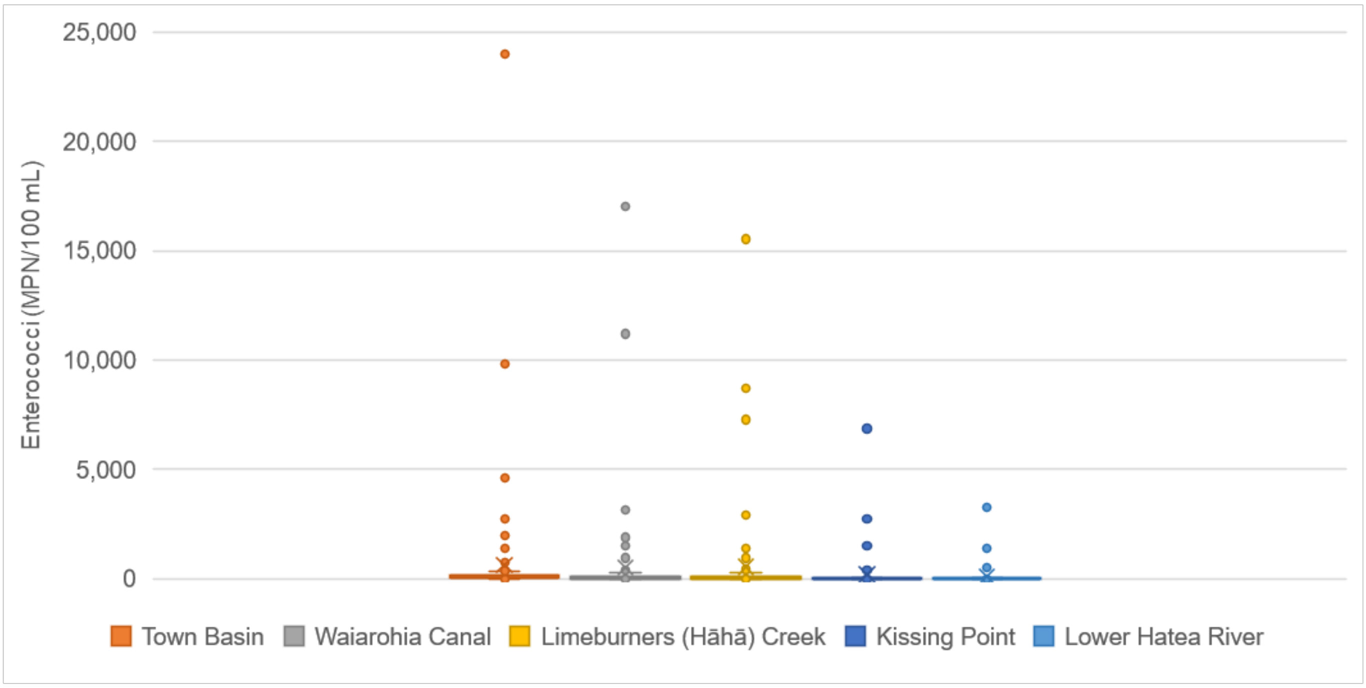

Figure 30 Enterococci values (2010-2020)

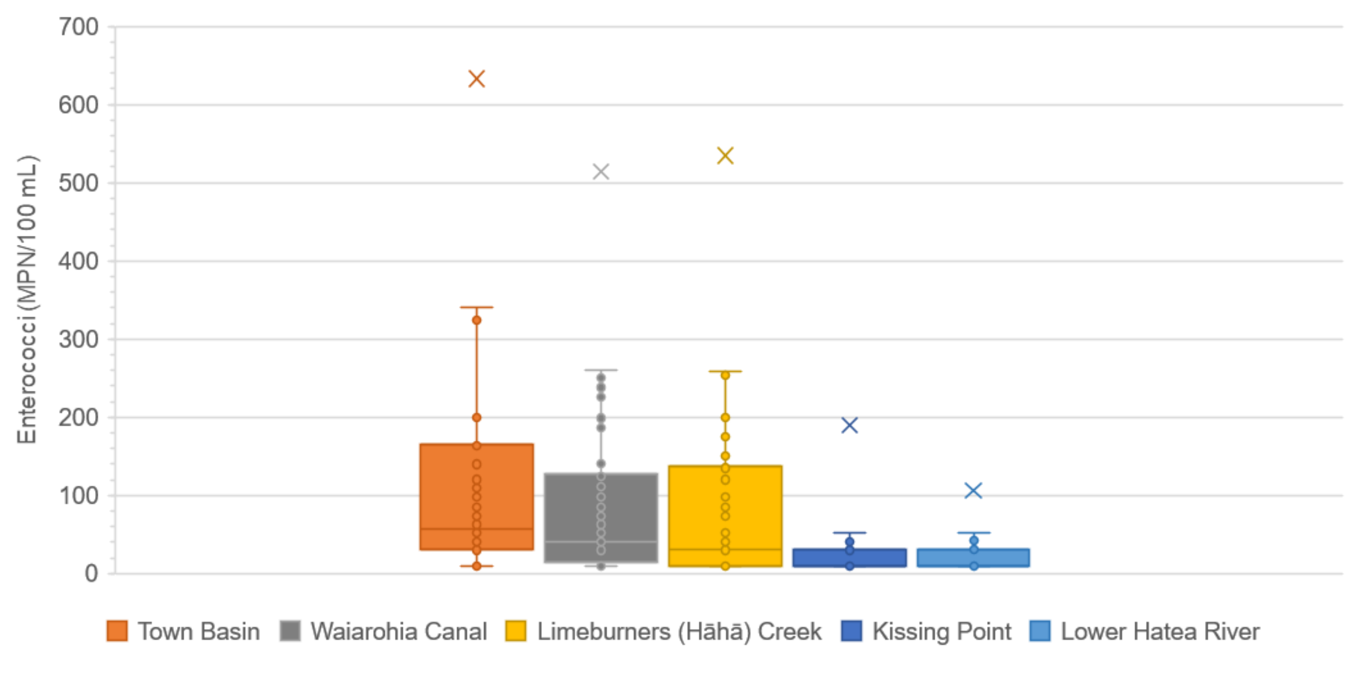

Figure 31 Enterococci values (2010-2020) – high concentration outliers not shown

Comparison to guideline values

Enterococci concentrations for the period 2010-2020, with comparison against the PNRP (2020), are provided in Table 14, with the values representing the 95th percentile of measurements obtained during these years.

Monitoring during the years 2011 and 2016 included the sampling immediately after significant rainfall events (approximately 60 mm within 48 hours) with the 95th percentile results for these years capturing the elevated concentrations associated with these events. Over the period of monitoring, Enterococci 95%ile concentrations at the Limeburners (Hāhā) Creek confluence were only greater than those of the upstream monitoring locations during these years. The influence of the WWTP discharge during these high flow discharge events is considered likely to be the cause of these elevated microbiological loads. Outside of such high flow events, the influence of the WWTP is considered to be relatively small compared to the background influence of catchment pathogen sources.

Table 14 Enterococci 95th percentile (95%ile) concentrations (bold values show guideline exceedance)

Year	Enterococci 95%ile Concentration (MPN / 100 mL)					
	PNRP (2020) Guideline value	Town Basin	Waiarohia Canal	Limeburners (Hāhā) Creek	Kissing Point	Lower Hātea
2010	**500**	386	200	123	70	106
2011		**7378**	**8424**	**11656**	**2069**	456
2012		366	383	**828**	416	363
2013		83	114	95	25	18
2014		150	180	118	10	36
2015		362	**869**	479	255	187
2016		**2161**	**2466**	**5516**	**5178**	**2452**
2017		**651**	115	48	20	20
2018		411	**1070**	**1045**	**1040**	**921**
2019		**1373**	**652**	**688**	420	131
2020		**14300**	**9450**	**5800**	10	275

The Microbial Assessment Category definitions provided in MfE (2003)[6] are outlined in Table 15. In isolation the grading does not explicitly indicate risk of recreational use of the water. However, they are considered to provide a meaningful indication of useability of the waters for high exposure recreation activities, such as swimming.

To provide a basic screening of conditions within the Hātea River, the annual 95th percentile results for Enterococci concentrations for each monitoring location have been graded against these criteria, with the comparison illustrated in Figure 32.

Table 15 Microbiological assessment category definitions for marine waters

Grade	Unit	Compliance metric	Guideline value
A	Enterococci/100 mL	95th percentile across annual swimming season	<40
B			41-200
C			201-500
D			>500

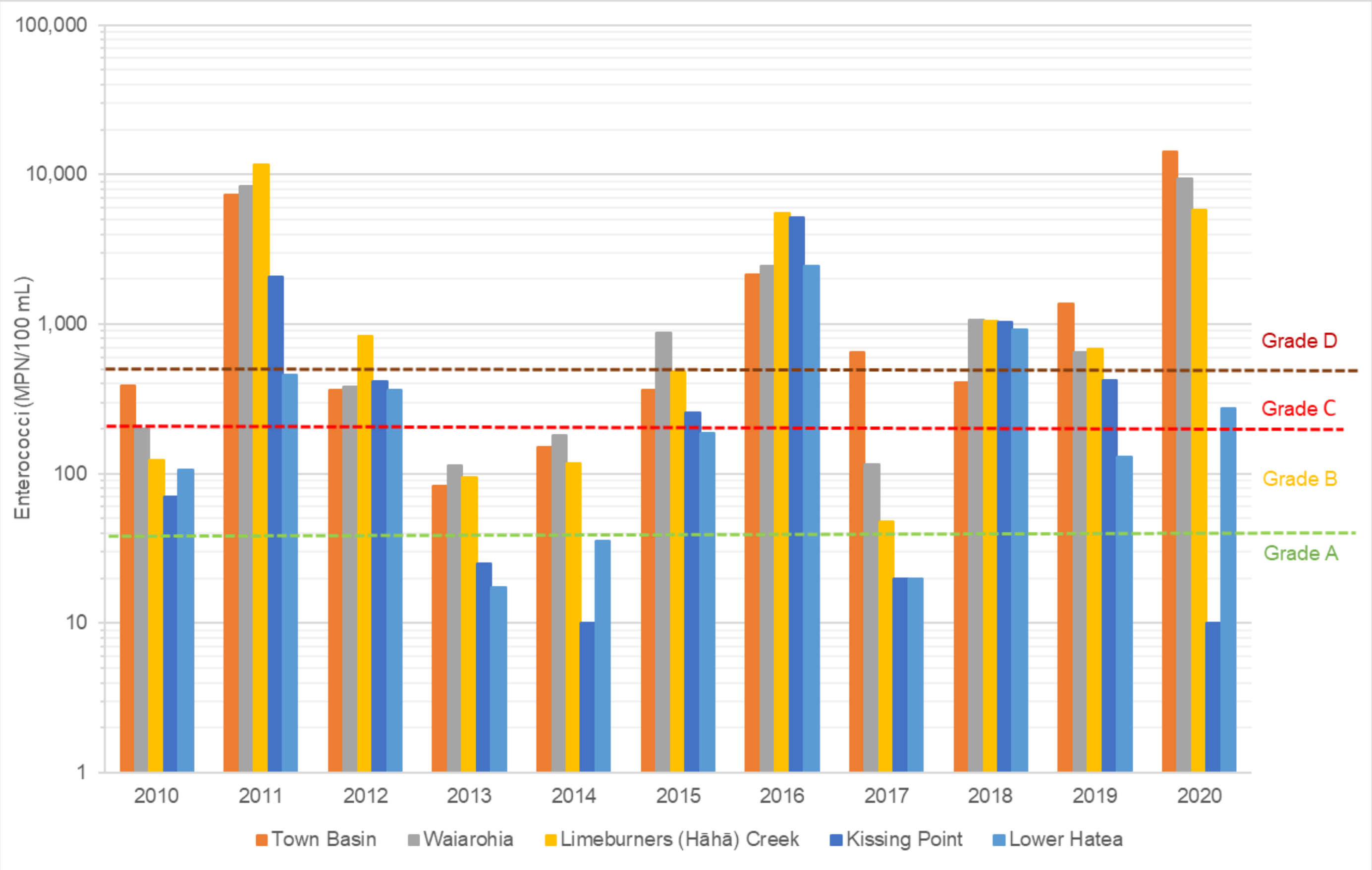

Figure 32 Enterococci annual 95%ile (2010-2020)

The results of the grading system indicates that the Lower Hātea monitoring locations are generally Grade A or B, with those years in which results are influenced by notable run-off events the annual grades are skewed towards C or D. This is considered to be a function of sampling frequency, rather than notable degradation in conditions throughout those years.

The upstream locations, including Limeburners (Hāhā) Creek, demonstrate general conditions in the range of Grade B-D, with the occurrence of lower water quality more typical. These areas are likely to be influenced more readily by rainfall events, resulting in more frequent increases in Enterococci load.

[6] Note that the guideline states more than 20 samples should be collected across the recreational period, and more than 100 samples over five years. The dataset used in this assessment generally had only 6 samples over the entire year.

It is noted that the grading suggested by MfE is to use a minimum of 20 samples across the recreational period, representing approximately weekly monitoring. The 6-12 samples collected during annual SOE monitoring, whilst providing spatial comparison and indication of likely influence of the WWTP on the Hātea River, does not provide sufficient temporal resolution to accurately represent conditions during the bathing season.

6.4.2 Faecal coliforms assessment

Existing environment

The faecal coliform data used in the analysis was collected at each of the SOE monitoring locations from 2010 – 2020. A box plot was created, shown in Figure 33, to indicate the maximum, minimum and median concentrations. The graph was replicated without elevated outlier concentrations as Figure 34, to provide clearer illustration of typical concentrations.

The locations at Town Basin and Limeburners (Hāhā) Creek have the greatest range and median faecal coliform concentrations for the monitoring period, suggesting that both upstream catchment sources and the WWTP are providing a contribution of faecal coliforms to the Hātea River. This differs to some extent to the interpretation for Enterococci, for which the catchment sources are considered to be the dominant contributor of microbial contaminants to the river. This is evident through the lower concentrations noted at Waiarohai Canal. Given the variability of potential microbial sources within the urban catchments represented by the Town Basin, Waiarohia and Limeburners (Hāhā) Creek monitoring locations, it is not unsurprising that differences in the relative contribution of different indicator microbes occurs between monitoring locations.

The downstream locations at Kissing Point and Lower Hātea do, however, consistently record lower faecal coliform counts than upstream locations. This reinforces the interpretation that mixing and tidal flushing significantly reduces the influence of upstream microbial sources, including the WWTP, on water quality.

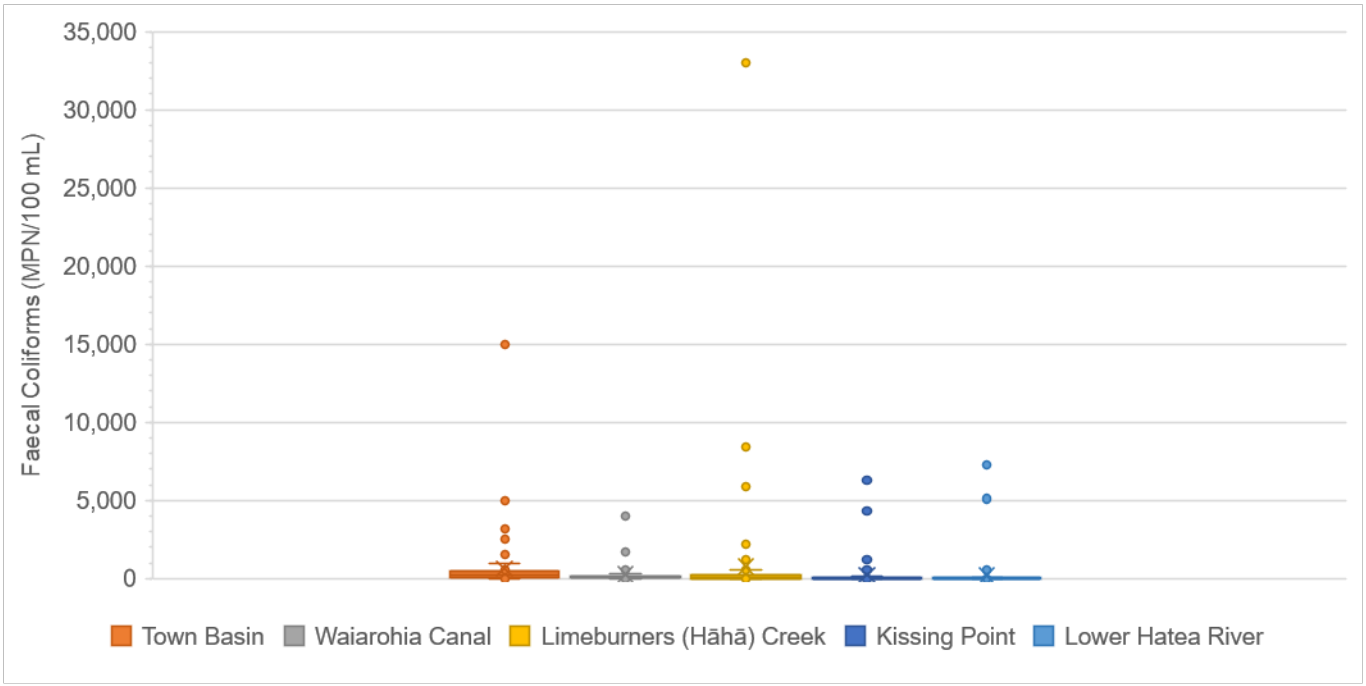

Figure 33 Faecal Coliforms (2010-2020)

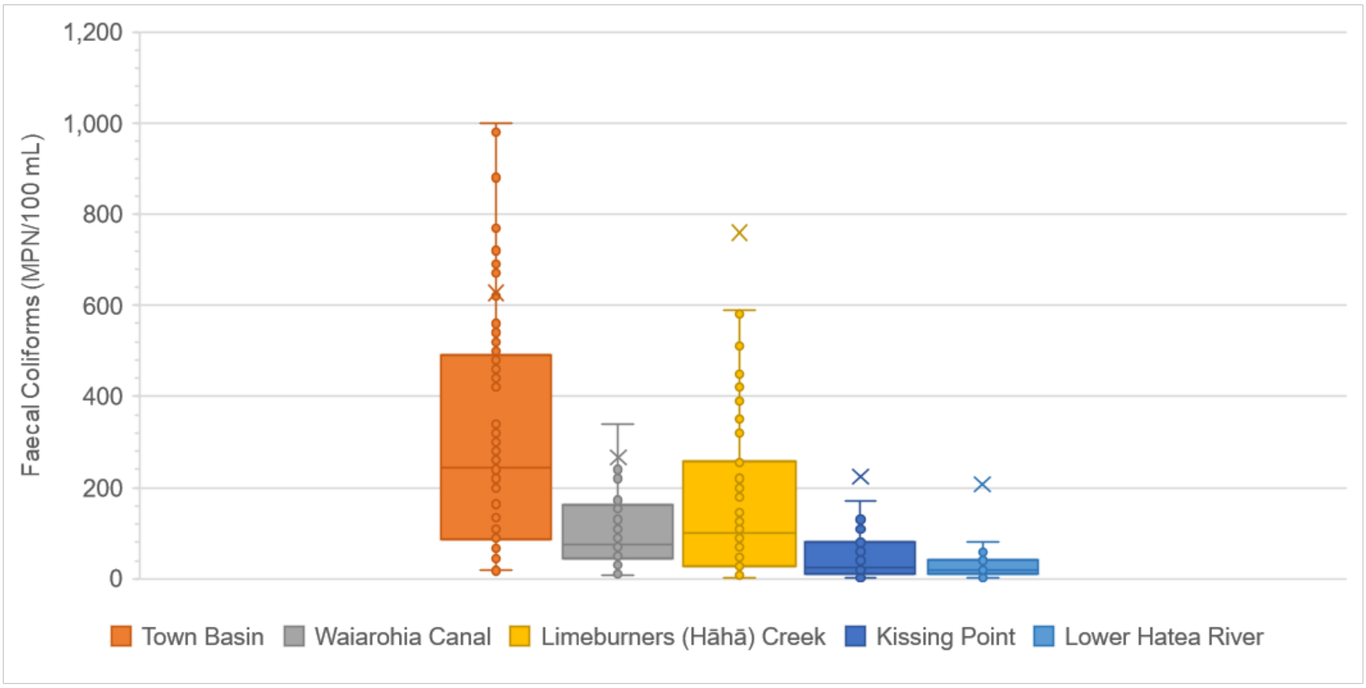

Figure 34 Faecal Coliforms (2010-2020) – elevated outliers not shown

Comparison to guideline values

The faecal coliform concentrations for samples collected during SOE monitoring between 2010-2020 were compared against the guideline values for Recreational Shellfish-gathering Bacteriological Guideline Values (MfE, 2003), to provide an indication of the extent to which catchment and WWTP microbial contaminant sources may influence public health risk associated with recreational activities in the Hātea River. The guideline values utilise both median conditions across the monitoring period and the upper range of faecal coliform concentrations to represent the periodic influence of intermittent activities (such as run-off) on public health risk from consuming gathered shellfish. Compliance with these guidelines alone does not guarantee that shellfish grown in waters will be safe, rather these should be used as a management tool to measure any changes from prevailing conditions. The guideline values are provided in Table 16, with comparison to the monitoring results provided in Table 17, and illustrated in Figure 35.

Table 16 Faecal Coliforms guideline values

Unit	Compliance metric	Guideline value
Faecal Coliform - Most Probable Number (MPN) / 100 mL	Median across shellfish-gathering season	>14
	No more than 10% of samples across shellfish-gathering season	>43

It is noted that the assessment used annual medians (across 12 months), based on six to 12 samples, whereas the guidelines suggest that a sufficient number of samples should be gathered throughout the shellfish-gathering season to provide reasonable statistical power in test for compliance. As the assessment used a low sample count, as well as samples being collected outside of the recreational period, the calculated metrics are used only as a general representation of conditions and suitability for shellfish gathering.

The results suggest that shellfish gathering should only occur, if at all, at the downstream locations near Kissing Point and Lower Hātea, due to the upstream locations consistently exceeding the guideline values. However, the downstream locations also record multiple exceedances above the 14 MPN/100 mL guideline value; therefore, the 10% of samples exceeding 43 MPN/100 mL across the seasonal guideline should be observed. Across the monitoring period at the Lower Hātea monitoring locations, there has been only one exceedance of this value, which occurred in 2016 (46 MPN/100 mL).

Table 17 Annual median Faecal Coliform and guidelines value

Year	Guideline value (MPN/100 mL)		Annual Median Faecal Coliform Concentration				
	Median	No more than 10% of samples	Town Basin	Waiarohia Canal	Limeburners (Hāhā) Creek	Kissing Point	Lower Hātea
2010	14	43	230	120	104	34	20
2011			140	73	35	16	10
2012			322	115	115	20	24
2013			89	48	135	37	9
2014			60	71	100	28	14
2015			163	70	140	19	18
2016			405	115	184	126	46
2017			109	45	90	10	10
2018			330	210	50	20	24
2019			270	140	40	14	15
2020			540	440	200	66	40

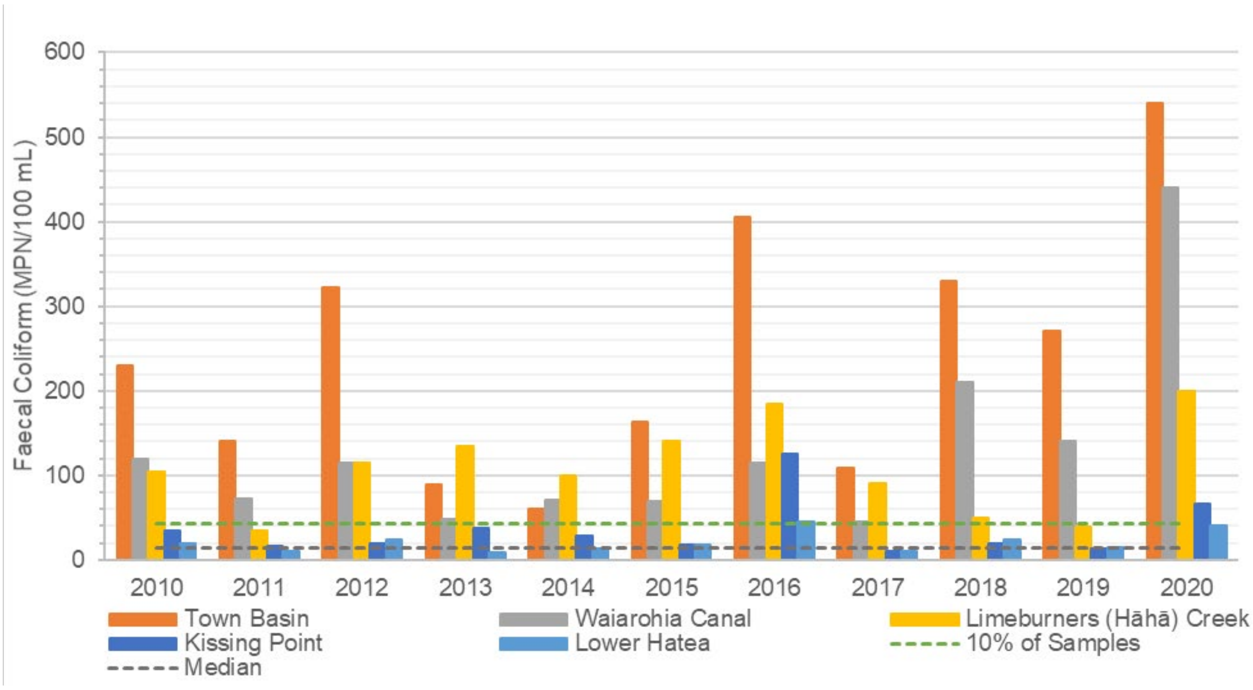

Figure 35 Annual median Faecal Coliforms (2010-2020)

6.4.3 Recreational period monitoring of Onerahi Beach

The NRC sample results for the period of 2014 – 2020 at Onerahi foreshore, representing monitoring for five recreational periods, are illustrated in Figure 36. Over this monitoring period microbial concentrations have predominantly been sufficiently low as to represent a very low risk of infection during swimming. There have been multiple exceedances of 'Alert levels' (Enterococci concentration greater than 140 MPN/100 mL), with such concentrations still considered to reflect an acceptable level of risk during swimming. Five exceedances of 'Action levels' (Enterococci concentration greater than 280 MPN/100 mL) were recorded over the period, resulting in temporary warning signs being erected.

Samples collected on a number of days following intense rainfall events recorded relatively low concentrations, providing an indication of the period of time required to achieve adequate flushing of impacted water from the vicinity of Onerahi. For example, sampling at Onerahi was carried out six days following the 71 mm rainfall event on 25 December 2018, with the recorded Enterococci concentration of 41 MPN/100 mL relatively low compared to periods when sampling occurred closer to the time of rainfall.

In contrast, exceedances at Onerahi have recently occurred following relatively modest rainfall events. For example, exceedance of the Action level occurred on 24 February 2020 (13,000 MPN/100 mL) and 2 March 2020 (1,300 MPN/100 mL), with these occurring after a prolonged dry period of more than a month and immediately preceded by a period of rainfall (8 mm on 23 February 2020).

Figure 37 presents the monitoring results in the Hātea River and at Onerahi over the 2017-2018 recreational period. During this time monitoring at Onerahi recorded four relatively elevated sample results (greater than 100 MPN/100 mL). These peaks were not detected within the less frequent monitoring occurring at the downstream monitoring locations of the Hātea River. Whilst the relative lack of correlation with Onerahi monitoring data to Hātea River data is considered to primarily be the result of sampling frequency, it does suggest the following:

– Elevated levels of Enterococci in the Hātea River, resulting from discharges during rainfall events, are rapidly flushed from the river.
– It is likely that other sources of microbial contamination closer to Onerahi are influencing water quality at this location. Indications of this include the occurrence of high Enterococci concentrations at Onerahi during relatively dry periods, when the influence of urban catchment sources and the WWTP are at their lowest. Local sources of microbial contamination of water at Onerahi beach may include local accidental wastewater discharges, port discharges and/or marine wastewater discharges, such as from boats and ships.

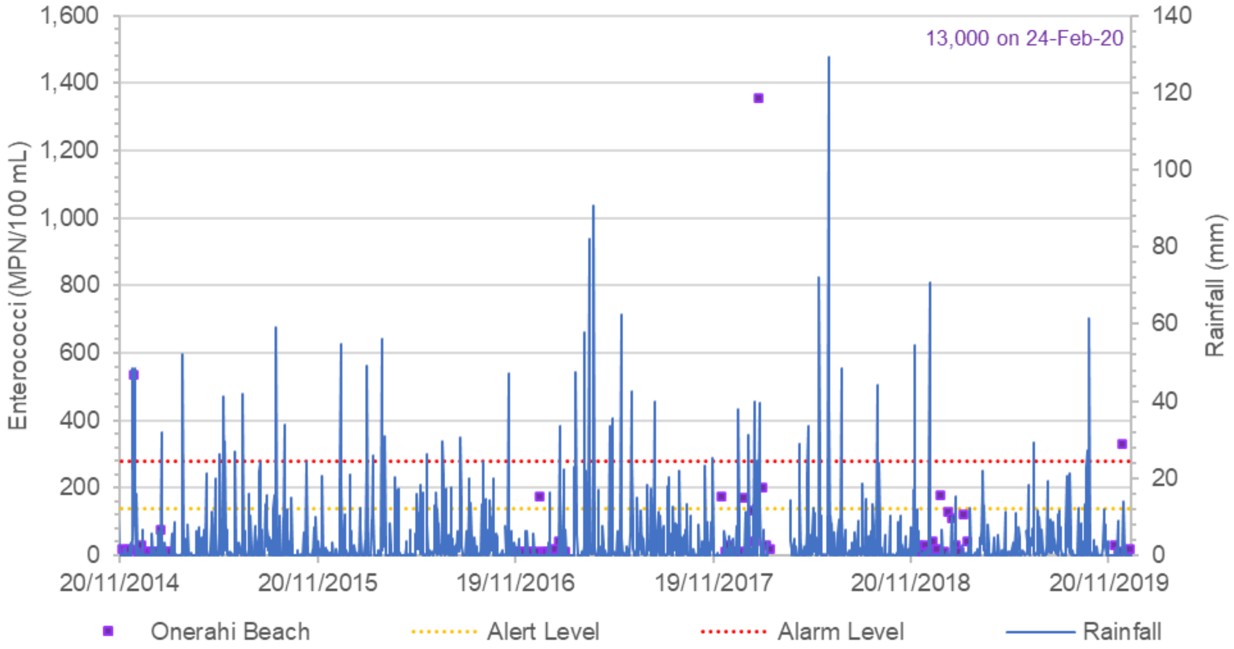

Figure 36 Onerahi Beach (2014-2019) Enterococci results and daily rainfall.

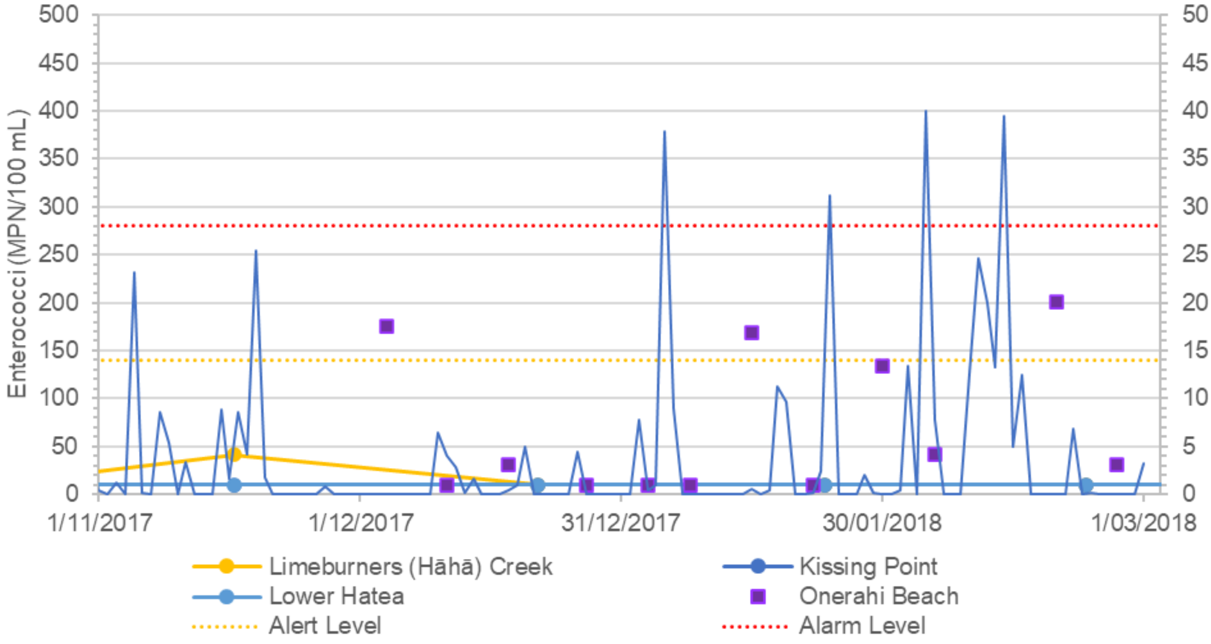

Figure 37 Onerahi Beach (2017-2019) Enterococci results and daily rainfall.

6.4.4 Wastewater disinfection

The disinfection performance of the WWTP is summarised in Section 2.1.5 and described in detail in the Plant Assessment Report (GHD, 2021b). In summary, the level of disinfection is considered to have been appropriate for the past five years. However, recent increases in TSS are considered to have decreased the efficiency of the UV treatment, resulting in a small decrease in the level of disinfection being achieved. This is reflected by elevated E.Coli levels greater than 3,000 MPN/100 ml. Regardless, monitoring of Enterovirus in treated wastewater has indicated that the desired level of virus reduction is likely being achieved, with a maximum level of 30 PFU/100L.

6.5 Public health risk assessment

The exposure assessment carried out by NIWA in 2011 considered the rates of microbial contaminants ingested during water recreational activities and from shellfish consumption. A one-dimensional model was used to predict virus and indicator bacterium concentrations in water in the Hātea River (confluence with Limeburners (Hāhā) Creek) and in water and shellfish at Onerahi beach, under both wet and dry weather conditions. Both time-varying and season-varying rates of inactivation of rotovirus and faecal coliform indicator bacterium was applied in the model to predict the total consumption of these microbes, with dose response curves applied to determine the risk of infection.

The assumptions regarding exposure for these indicators of illness associated with faecal pathogen contaminants is considered to remain appropriate for the environmental and discharge setting.

The model uses the rotovirus dose-response model as representative of all pathogenic viruses related to gastrointestinal illness. Use of dose-response relationships for other virus groups related to such illness, including the Enterovirus and Norovirus, were not considered. Given the evolving nature of the risk assessment approach and uncertainty related to infection rates, the use of the rotovirus in the model is considered appropriately conservative as a means of predicting potential risk.

The findings of the 2011 assessment are considered to be appropriately conservative for managing the public health risk and discharges from the WWTP. The upgrade of the UV disinfection process, undertaken in response to the 2011 public health risk assessment, was to achieve a 1.5 log reduction in rotovirus levels under high flow events. To achieve this a UV dose of >40 mWs/cm^2 was required for flows greater than 30,400 m^3/day, with this predicted to achieve a median E.Coli level of 1,500 MPN/100mL and 90%ile of 3,000 MPN/100mL, as an indicator for pathogen disinfection.

With implementation of these works the desired reduction in risk to public health is expected to have been achieved. Subsequent improvements to the network to reduce overflows is likewise expected to have reduced the risk to users of the receiving environment. In the context of the accepted recreational use of the receiving environment, and as supported by review of NRC and public health monitoring data outlined in Section 6.4, the public health risk presented by the WWTP discharge is considered to be no more than minor.

To ensure the desired level of disinfection can be maintained, treatment augmentation works are proposed as the first phase of adaptive upgrades to the WWTP. Ongoing monitoring of treated effluent is proposed to identify when further adaptation of the plant is needed to ensure public health risks are effectively managed.

7. Climate change and its potential effects

The wastewater sector in New Zealand is widely vulnerable to the effects of climate change. The potential effects of climate change on the wastewater sector can be described as direct effects and indirect effects, with direct effects having an impact on the physical functionality and operation of wastewater facilities and networks, whilst indirect effects influence the wider components of the sector, including, but not limited to, quality of influent and effluent, conservation drivers, influence on the environment and process efficiencies.

In 2016 NIWA published the Northland Region climate change projections and implications (NIWA, 2016). This report surmised:

- Average annual temperatures in Northland are expected to increase by 0.7 to 1.1°C by 2040 and 0.7 to 3.1°C by 2090.
- Precipitation projections indicate less rainfall for eastern parts of Northland in spring by 2040 and significant decreases in precipitation by 2090, with up to a 20% decrease in spring precipitation and up to a 10% decrease in summer and autumn.
- The frequency of heavy rainfall events is projected to decrease across the Northland Region and drought frequency is projected to increase by 7% by 2040 and 10% by 2090.
- Sea level rise scenarios project approximately 0.5 m increase by 2090, with higher mean sea levels expected.

Each of these changes to the climate will influence the Whangārei WWTP directly and indirectly. For example, sea level rise is predicted to have an impact on communities in coastal areas and habitats within estuaries due to changes in tidal range, duration and frequency of high tides, greater influence on storm inundation and coastal erosion, and sediment redistribution (NIWA, 2016). Given the proximity of the Whangārei WWTP to the coast and a tidally influenced Creek, sea level rise and storm surges also increase the risk for infrastructure damage through inundation and corrosion (GHD *et al.* ,2020).

Increases in sea level will lead to a shift in the hydrodynamics of the Hātea River and Limeburners (Hāhā) Creek, by influencing the mixing of freshwater and marine water. In conjunction with the expected increase in drought conditions and reduced rainfall, it is likely the freshwater component of the Limeburners (Hāhā) Creek and Hātea River will reduce, changing current estuarine ecosystems. Reduced rainfall and increasing drought conditions will also lead to reduced runoff of contaminants during dry weather but cause an influx of contaminant runoff during periods of precipitation after pro-longed dry conditions. The same response is anticipated through urban catchment runoff and through the stormwater systems.

Increases in temperature and drought frequency are predicted to slow the overall flow of water in wastewater systems, leading to build up of solids in the network or reduced quality of the waste. Factors such as these, combined with increasing restrictions on discharge quality, higher levels of protection for receiving environments, already stressed by climate change factors, and performance improvement standards to reduce the use of energy and production of greenhouse gas emissions, leads to a broad horizon of potential effects which are difficult to predict and plan for.

In addition, with growing knowledge regarding the potential effects of climate change there has been a surge in climate change related legislative changes. The Zero Carbon Amendment Act (ZCAA) in New Zealand sets out the 2050 domestic emission target. The ZCAA also sets out the requirement for an Emission Reduction Plan. Both the emissions targets and the Emission Reduction Plan requirement will impact the wastewater sector through the development of sector-specific policies and strategies to reduce emissions, increase removal efficiencies, and set out standards for adapting to the effects of climate change.

The rate of change is unknown, with many climate change variables and more regional specific data and monitoring needed to aid in quantifying climate change effects. Response to climate change effects will need to be location specific, flexible, and adaptive. The application of the Adaptive Pathway Planning approach has the ability to build in resilience against possible climate change effects, whilst also building an understanding of the local climate change effects through the application of more frequent, robust monitoring.

8. Emerging contaminants and their potential effects

Similar to climate change, emerging contaminants have the potential to cause effects on the wastewater sector and therefore the Whangārei WWTP. Emerging contaminants are chemicals, which can be manmade or naturally occurring, and are resilient to degradation, therefore accumulate in environmental areas, and can be toxic to living organisms. Emerging contaminants are not monitored and are often chemicals that are new or already exist, but to date the risk to human health and/or the environment has not been quantified. The majority of emerging contaminants are organic chemicals. Emerging contaminants include, but are not limited to, industrial chemicals, personal care products and medicines.

Multiple sources of emerging contaminants have been identified, including solid waste disposal, landfill leachate discharges, atmospheric deposition, agricultural waste, wastewater and stormwater discharges. Wastewater discharges in particular are considered to be a significant source (Tremblay *et al.* 2011), with municipal wastewater systems flagged as a major source of emerging contaminants, due to the nature of the waste they receive and centralisation of contaminants into a single discharge. Wastewater primarily contains human waste, which can contain pharmaceuticals and hormones from personal care products, and industrial waste, which can have an array of different compounds and chemicals. The treatment process at a WWTP is not always designed to remove many of the emerging contaminants and these may pass through the treatment plant to the receiving environment (Tremblay *et al.,* 2011).

Emerging contaminants are a concern largely due to the uncertainty of the influence they may have on contributing to adverse effects on human and ecological health. Research has found that a number of emerging contaminants have the potential to interfere with reproductive and immune systems of humans and animals. Emerging contaminants that are delivered to aquatic ecosystems have the potential to shift the ecosystem into a toxic state for some organisms, leading to a shift in the species present and the overall health of the receiving environment. Additionally, persistent bioaccumulating contaminants can have a wider influence by effecting the food chain. This has been identified as a concern in New Zealand where the ability to collect fish and shellfish for human consumption has significant cultural value.

Although the knowledge and research regarding emerging contaminants has considerably grown in the last decade, the ability to directly correlate exposure to effects leaves uncertainty regarding whether regulation of particular contaminants is required. There is currently little guidance and no legislative requirements around emerging contaminants and their discharge to receiving environments in New Zealand. It is anticipated over time that this situation will change and regulations and limits regarding different emerging contaminants will be introduced in New Zealand and / or the wastewater sector. The use of an Adaptive Pathway Planning approach provides the flexibility to manage the potential effects of emerging contaminants. New contaminants, limits and monitoring requirements can be adopted through the regular review process built into the Adaptive Management Plan. This will help determine when WWTP upgrades may be required to address the removal of particular emerging contaminants during the treatment process, or if changes to processes are required to reduce emerging contaminants reaching the receiving environment.

9. Adaptive Management Plan for receiving environment protection

9.1 Adaptive management approach

Augmentation of the WWTP as outlined in the Master Plan (GHD, 2021), is proposed to provide improvements to meet current treatment expectations regarding the discharge. Subsequent to this, WDC are proposing to implement improvements over time to ensure no further degradation of the upper harbour water quality, in line with the intent of the PNRP. As part of the adaptive approach, the WWTP influence will be monitored to detect when these improvements are no longer adequate to maintain the health of the receiving environment, at which point additional upgrade works will be initiated. It is expected that WWTP performance and the receiving environment will be monitored and managed with greater scrutiny than under previous resource consents to ensure that the improvements are made before meaningful degradation of the upper harbour occurs.

The adaptive approach in the context of receiving environment management requires the following:

1. Identification of relevant drivers for which deviation from current conditions, resulting from WWTP influence, would warrant WWTP improvements.
2. Identification of an appropriate metric or indicator representative of each driver and the influence the WWTP discharge has on it.
3. Determination of the trigger, or means of identifying, when deviation from current conditions occurs.
4. Determination of the required actions to be undertaken in response to the confirmed deviation from current conditions.
5. Implementation of monitoring, validation and appropriate analysis to detect when the trigger occurs.
6. Regular review of the above to accommodate additional knowledge and/or change in desired outcomes.

This adaptive approach to managing the receiving environment is proposed to be detailed within a Receiving Environment Management Plan (REMP), with this to include:

- Drivers and adopted metrics.
- Triggers reflective of deviation from current conditions and the methodology used to determine these.
- Contingency actions for compliance and implementation of the adaptive WWTP improvements.
- Monitoring requirements.
- Data management, interpretation and reporting requirements.
- Responsibilities.

The REMP will support an Adaptive Management Plan by providing the means of confirming when receiving environment drivers require WWTP improvement. Figure 38 illustrates the relationship between the REMP and the other key aspects of the proposed adaptive approach.

The following section outlines the proposed adaptive management approach with respect to the receiving environment.

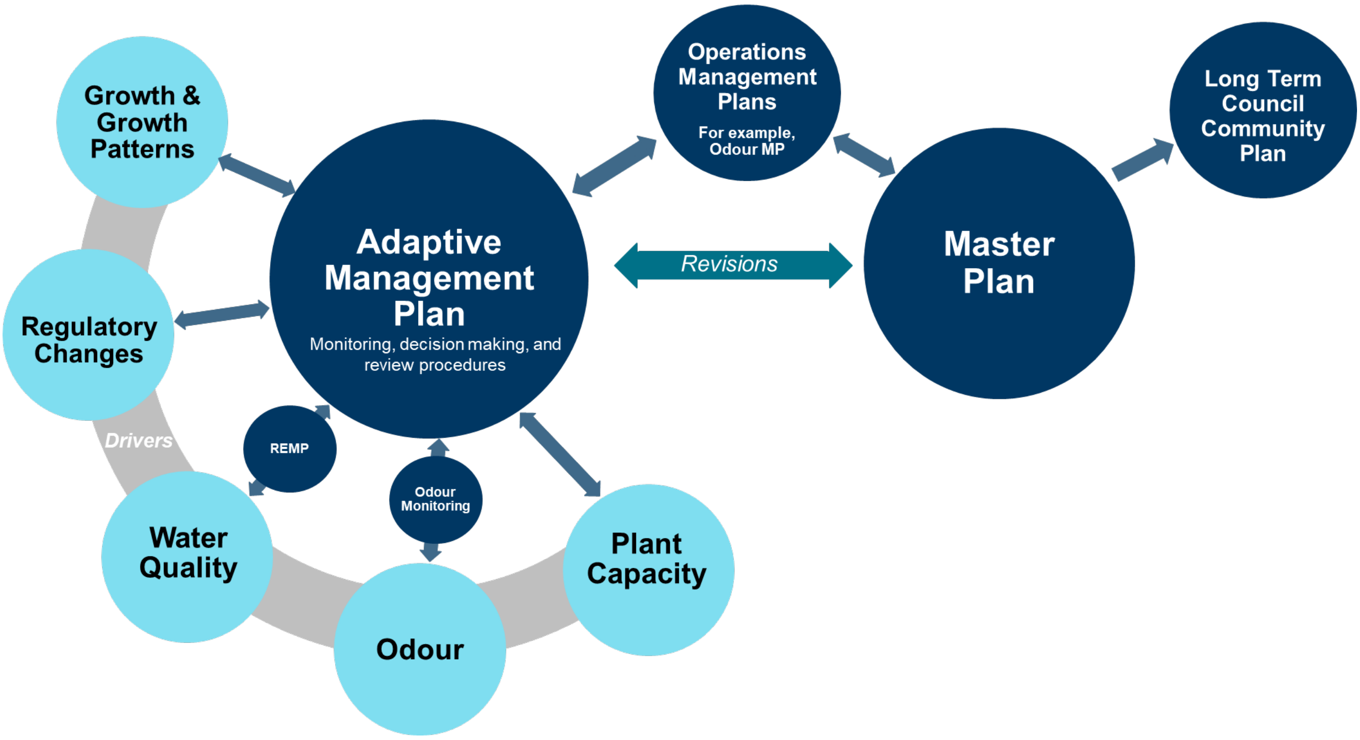

Figure 38 Adaptive Drivers and Management Documents

9.2 Receiving environment drivers for upgrade

Assessment has identified the key aspects of the receiving environment that may be influenced by the WWTP discharge and provides a benchmark for the current level of effects. Under the adaptive plan future increased impact in these areas, which indicates the WWTP is having a greater influence on the receiving environment than under current conditions, is considered a driver for improvements to the WWTP discharge. Table 18 outlines the proposed drivers, descriptions, locations and monitoring/regulation metrics.

The drivers and associated monitoring locations and regulation metrics will be refined through the REMP as a comprehensive understanding of the metrics is developed. For example, as a better understanding of the dissolved oxygen concentrations and the associated cause of these concentrations is established in Limeburners (Hāhā) Creek this metric will be included.

Table 18 Receiving environment drivers and metrics

Driver	Description	Location	Medium	Metrics
Water quality	Aquatic ecosystem health as indicated by trophic state	3) Hātea River – Confluence with Limeburners (Hāhā) Creek 4) WWTP – Wetland discharge	Water	Total nitrogen Inorganic N Total phosphorus TSS Clarity Chlorophyll-a
Ecotoxicity	Contaminant concentrations in water and sediment that cause acute toxicity to ecology	3) Limeburners (Hāhā) Creek – in the vicinity of WWTP mixing 4) Hātea River – Confluence with Limeburners (Hāhā) Creek	Water & Sediment	Water: Ammonia Sediment: Heavy metals
Public health risk	Risk of infection from public use of the receiving	4) Hātea River – Confluence with	Water	Enterococci Faecal coliforms

Driver	Description	Location	Medium	Metrics
	environment for shellfish gathering and swimming	Limeburners (Hāhā) Creek 5) WWTP – treatment 6) Upper Harbor - Onerahi		
Emerging contaminants	Greater understanding of contaminant toxicity and introduction of new environmental regulations and criteria.	5) Limeburners (Hāhā) Creek 6) Hātea River – Confluence with Limeburners (Hāhā) Creek 7) WWTP – Wetland discharge 8) Upper Harbour – as needed	Water Sediment	Regulations

9.3 Receiving environment triggers

Preliminary receiving environment triggers have been defined for each of the adaptation drivers as a means of identifying when the receiving environment is deviating from the current conditions, potentially as a result of WWTP discharges. These triggers will be refined and updated following the outcomes of the monitoring detailed in in step 3 of the proposed monitoring, outlined in Section 9.3.1 below. The proposed triggers are recommended to include:

1. Trigger levels as threshold limits for each driver, over which a change in environmental conditions may be occurring.
2. Statistical confirmation of trends to 95% confidence, identifying long term changes not readily detected by other means.
3. WWTP discharge trigger levels (threshold mass discharge) as a means of validating whether detected changes are likely related to the WWTP discharge.

Triggers for each of the proposed drivers are detailed in the following sections.

9.3.1 Water quality

The PNRP water quality criteria for the Hātea River are not proposed to be used as trigger levels for water quality, as these do not provide a basis for detecting change from current conditions associated with the WWTP discharge.

To accommodate the intent of the PNRP water quality criteria as a measure intended to be protective of further degradation of the Hātea River, the following is proposed for managing the WWTP discharge:

1. Implementation of preliminary water quality trigger levels developed from the existing data set for the Hātea River.
2. Implementation of preliminary WWTP mass discharge trigger levels from the existing data set for the wetlands.
3. Undertake a one-year period of intensive monitoring of WWTP discharges and the receiving environment to provide a comprehensive dataset for trigger level refinement. This will also help link the current information to certain drivers (i.e., are the low ammonia levels in Limeburners (Hāhā) Creek a result of the current WWTP discharges).
4. Develop long term trigger levels from the refined dataset and implement a long-term monitoring programme.
5. Undertake periodic statistical analysis of WWTP discharge and receiving environment water quality data to detect potential trends of receiving environment degradation.
6. Undertake periodic review of trigger levels and methodology for development.

Available information from monitoring and investigations completed to date demonstrates the highly dynamic nature of the receiving environment. While the relative influence of the WWTP on the receiving environment can be predicted from the investigations, there are gaps in the knowledge of how water quality varies in the short term as a function of tidal hydrodynamics, run-off events and even seasonality. In the absence of a dataset that adequately represents the variability of the natural environment, trigger levels will have a relatively high degree of uncertainty in how conservative they are i.e. it's unclear whether they will provide adequate long-term protection or be overly conservative and result in initiation of WWTP upgrades long before they are needed. For this reason, trigger levels based on the currently available information are proposed to be preliminary only.

To provide a sufficiently robust dataset from which to develop long term water quality trigger levels a period of intensive monitoring and analysis is proposed to be undertaken over a minimum of a full year. This monitoring will characterise the temporal and spatial variability of water quality in high detail in the vicinity of the proposed monitoring locations. From this data, the long-term monitoring programme and trigger levels will be determined.

The REMP will outline the preliminary trigger levels and requirements for the intensive monitoring programme and proposed methodology for developing the long-term water quality trigger levels. And once developed the REMP will be updated to reflect the long-term water quality trigger levels.

9.3.2 Ecotoxicity

The acute influence of discharges on the receiving environment is proposed to be managed through implementation of the Australian and New Zealand guidelines for fresh and marine water quality (ANZG, 2018) threshold criteria for water and sediment as trigger levels for typical contaminant concentrations. The proposed criteria include the use of 80% level of protection for aquatic species, which is appropriate for the disturbed nature of the immediate receiving environments in Limeburners (Hāhā) Creek and the Hātea River. This approach is considered to be consistent with the intent of the PNRP to maintain conditions and the approach for degraded ecosystems outlined in ANZECC (2000).

For sediment, the ISQC outlined in the PNRP and presently used by NRC in routine sediment surveys is considered appropriate. Unlike water quality, sediment contaminant concentrations are not expected to be highly dynamic. Additionally, the WWTP discharges are not inferred to have a notable influence on sediment contaminant concentrations. As such the regular sediment surveys presently being undertaken by NRC are considered appropriate for receiving environment sediment monitoring.

9.3.3 Public health risk

Due to the multiple sources of pathogens in the receiving environment, the primary control on public health risk due to WWTP discharges is the degree of disinfection wastewater receives prior to discharge. Previous assessments have related public health risk to an appropriate level of disinfection, and it is considered that this remains appropriate in the context of the receiving environment. Disinfection efficiency is proposed to continue as a trigger level for managing public health risk.

The existing use of MfE water quality criteria appropriate for recreational use and shellfish gathering at Onerahi beach, are also considered to remain appropriate for protection of current and expected future use of the area. The current programme of monitoring during periods of recreational use has been successful in identifying periods of elevated pathogen levels at this location, although these are attributed to sources other than the WWTP.

Within the Hātea River the MfE Enterococci limit for secondary contact, consistent with the PNRP criteria, is proposed as a preliminary trigger level. A long-term trigger level is proposed to be developed in the vicinity of the confluence with Limeburners (Hāhā) Creek, in the same manner as the water quality trigger levels, to assist in detecting degradation of the receiving environment should it occur.

9.3.4 Emerging contaminants

While monitoring and management of effects to the receiving environment consider contaminants currently understood to have potential implications for public and environmental health, routine review of the adaptive management plan for the WWTP and associated REMP provides the opportunity for amendments to trigger levels. This will include identification of regulations relating to new or emerging contaminants. Given the lack of benchmark for any newly introduced contaminant criteria, a programme of investigation would be undertaken to first characterise risk to the receiving environment and/or to public health. The findings would be used to inform the need for adaptation of the WWTP. The REMP would also be updated to reflect the required level of monitoring and trigger level associated with the new contaminant.

9.3.5 Preliminary Trigger Levels

The preliminary proposed trigger levels are presented in Table 19.

Table 19 Preliminary proposed triggers

<table>
<tr><th>Driver</th><th>Location</th><th>Medium (compliance metric)</th><th>Metric</th><th>Preliminary Trigger</th><th>Description</th></tr>
<tr><td rowspan="11">Water quality</td><td rowspan="5">Hātea River (appropriate location to be defined)</td><td rowspan="5">Water (maximum concentration)</td><td>Total Nitrogen</td><td>6.3 g/m^3</td><td rowspan="5">Derived from NRC SOE monitoring data (2010 to 2020). Refer to Appendix E for details.</td></tr>
<tr><td>Inorganic Nitrogen</td><td>4.1 g/m^3</td></tr>
<tr><td>Total Phosphorous</td><td>1.0 g/m^3</td></tr>
<tr><td>TSS</td><td>45 g/m^3</td></tr>
<tr><td>Chlorophyll-a</td><td>0.011 g/m^3</td></tr>
<tr><td rowspan="6">WWTP Wetland discharge</td><td rowspan="6">Water (upper quartile mass)</td><td rowspan="2">Total nitrogen</td><td>360 kg/d
(flows <15,000 m^3/d)</td><td rowspan="6">Derived from wetland effluence discharge monitoring. Refer to Appendix E for details.</td></tr>
<tr><td>550 kg/d
(flows > 15,000 m^3/d)</td></tr>
<tr><td>Total Phosphorous</td><td>80 kg/d</td></tr>
<tr><td rowspan="3">TSS</td><td>100 kg/d
(flows < 20,000 m^3/d)</td></tr>
<tr><td>350 kg/d
(flows >20,000 m^3/d)</td></tr>
<tr></tr>
<tr><td rowspan="4">Ecotoxicity</td><td rowspan="2">Limeburners (Hāhā) Creek</td><td></td><td>Ammonia</td><td>19.5 g/m^3</td><td>Derived from 4Sight monitoring in the Limeburners (Hāhā) Creek from January 2020 – January 2021.</td></tr>
<tr><td>Sediment (maximum concentration)</td><td>Heavy metals (maximum concentration)</td><td>Copper: 65 mg/kg
Lead: 50 mg/kg
Zinc: 200 mg/kg
Chromium: 80 mg/kg
Nickel: 21 mg/kg
Cadmium: 1.5 mg/kg</td><td>As per the coastal sediment quality guidelines in the PNRP and presently used by NRC in routine sediment surveys.</td></tr>
<tr><td rowspan="2">Hātea River</td><td>Water (max concentration)</td><td>Ammonia</td><td>2.4 g/m^3</td><td>Derived from NRC SOE monitoring data (2010 to 2020). Refer to Appendix E for details.</td></tr>
<tr><td>Sediment (maximum concentration)</td><td>Heavy metals (maximum concentration)</td><td>Copper: 65 mg/kg
Lead: 50 mg/kg
Zinc: 200 mg/kg
Chromium: 80 mg/kg
Nickel: 21 mg/kg
Cadmium: 1.5 mg/kg</td><td>As per the coastal sediment quality guidelines in the PNRP and presently used by NRC in routine sediment surveys.</td></tr>
<tr><td>Public health risk</td><td>Hātea River</td><td>Water</td><td>Enterococci (annual 95th percentile)</td><td>≤500 enterococci/100mL</td><td>As per the coastal water quality standards in the PNRP.</td></tr>
</table>

Driver	Location	Medium (compliance metric)	Metric	Preliminary Trigger	Description
	Upper Harbour	Water	Enterococci (95th percentile during swimming season)	As per the values outlined in Table 15	As per the Microbial Assessment Category definitions provided in MfE (2003).
			Faecal Coliform (median and no more than 10%)	As per the values outlined in Table 16	As per the Recreational Shellfish-gathering Bacteriological Guideline Values (MfE, 2003).

9.4 Receiving environment adaptive responses

Trigger level exceedance will result in a series of responses, including the following steps:

Step 1 - Reporting of the exceedance to NRC and relevant stakeholders.

Step 2 - Actions and assessment to validate that the inferred degradation in receiving environment condition is a result of WWTP discharges.

Step 3 - Assessment to determine whether the trigger level is appropriate and is appropriately reflective of a degrading receiving environment.

Step 4 - Determination of the appropriate WWTP operational changes and/or process upgrades required to respond to the receiving environment degradation. Depending on the scale of changes proposed, engagement with stakeholders and iwi may be necessary at this point where multiple options may be needing consideration.

Step 5 - NRC and stakeholder reporting of the proposed WWTP changes in the context of the adaptive pathways planning approach through updates to the Operations Management Plan (in terms of operation changes proposed) or Master Plan (in terms of proposed upgrade options).

Step 6 - Implementation of the appropriate WWTP changes.

The required responses to confirm that conditions are changing will be provided in the REMP, while the approach to determining and implementing WWTP changes will be provided in the Adaptive Management Plan.

Assessment steps are included in the process to ensure that actions taken are appropriate, given the highly dynamic environment and other significant contaminant sources contributing to the receiving environment. This stepwise process is also expected to accommodate the use of the preliminary trigger levels for monitoring discharges, during the period of intensive monitoring. For these preliminary trigger levels, the monitoring results will allow determination of appropriate trigger levels (Step 3 above).

At the conclusion of each of the above steps, recommendations regarding changes to the REMP may be made by WDC for consideration by relevant stakeholders. Additionally, the ongoing appropriateness of the responses will be considered during regular review of the Adaptive Management Plan and the REMP.

9.5 Proposed monitoring

The specifics of the intensive monitoring to be undertaken to inform development of long-term trigger levels is to be outlined in the REMP. However, monitoring during this period for the purpose of monitoring against the preliminary trigger levels is recommended to be undertaken as discussed in the following sections.

9.5.1 Receiving Environment Monitoring

1. Monitoring in the receiving environment is recommended to be carried out on a weekly basis at the following monitoring locations:
    a. Limeburners (Hāhā) Creek downstream of Wetland 1 discharge.

b. Hātea River at the confluence with Limeburners (Hāhā) Creek.

2. Monitoring should be carried out on the outgoing tide, between 4 to 5 hours after high tide.
3. The minimum recommended parameters for weekly monitoring include:
   - Water level
   - Dissolved oxygen
   - Salinity
   - pH
   - Temperature
   - Total nitrogen
   - Total phosphorous
   - Dissolved reactive phosphorous
   - Ammoniacal-N
   - Inorganic-N
   - Enterococci
   - Faecal Coliforms
   - TSS
   - Secchi Disk depth
   - Chlorophyll-a
4. Monitoring of pathogens in the broader Hātea River and Onerahi Beach, for public health risk purposes, is presently being carried out by NRC for state of the environment purposes and by WDC. No changes to the current monitoring programmes are proposed, with these considered adequate to identify public health risk associated with recreational use in these areas.

9.5.2 WWTP discharge monitoring

Monitoring of the discharge from Wetland 1 and 2 is recommended to be carried out for the following parameters:

Daily

– Discharge volume
– Turbidity
– pH
– Temperature

Weekly

– Total nitrogen
– Total phosphorous
– Dissolved reactive phosphorous
– Ammoniacal-nitrogen
– Inorganic-nitrogen
– cBOD
– Enteroccoci
– Faecal Coliforms
– TSS

10. Conclusion and Recommendations

10.1 Summary

The current resource consent for discharge of wastewater from Whangārei's WWTP allows up to 140,000 m^3/day of treated wastewater to be discharged to Limeburners (Hāhā) Creek from two constructed wetlands (Wetland 1 and 2). Under typical conditions the discharge is in the order of <20,000 m^3/day.

The PNRP includes water quality criteria for the Hātea River as a means of maintaining water quality at current levels with no further persistent degradation. While the criteria outlined in the PNRP are not considered appropriate as a means of managing the effects of the WWTP discharge, the intent of the PNRP has been adopted in:

1. Characterising the current receiving environment conditions and the influence of the WWTP.
2. Recommending an approach to managing the effects of the WWTP such that no further degradation of the Hātea River occurs.

In the context of this assessment, degradation is considered to be defined by statistically demonstrated deviation from the current water quality, ecotoxicity, sediment conditions and public health risk, as a result of WWTP discharges.

Assessment of the current effects of discharges from the WWTP on the receiving environment have highlighted the following key findings:

Limeburners (Hāhā) Creek water quality

– Limeburners (Hāhā) Creek, a designated mixing zone, reflects the influence of an urbanised and industrial catchment, and is degraded relative to pristine tidal creeks in the Northland Region.
– Fluctuation of water levels in the Hātea River results in flow in Limeburners (Hāhā) Creek changing direction with tide. Wastewater discharge occurring during the incoming tide accumulates within the creek, mixing with saline water from Hātea River and freshwater flowing from the creek catchment. On the outgoing tide the mixed water discharges to the Hātea River as a relatively mixed volume of water.
– Water quality within Limeburners (Hāhā) Creek demonstrates the influence of wastewater discharge, with elevated concentrations of nutrients and indicators of wastewater, such as ammonia, being frequently recorded.
– Discharges of treated wastewater are not considered to be resulting in acute toxicity issues for local ecology, as the ecosystem has adapted to be tolerant to the conditions.

Hātea River water quality

The below key points are made with respect to the influence of the wastewater discharge on the Hātea River, identified as the primary receiving environment to wastewater discharge:

– Under typical flow conditions, concentrations of nitrogen from Limeburners (Hāhā) Creek are generally consistent with, or better than, those recorded at the Waiarohia monitoring location. This demonstrates the notable catchment source of nitrogen in the Hātea River derived from upstream sources.
– The intermittent increases in nutrient discharges from Limeburners (Hāhā) Creek result in annual median water quality at the Limeburners (Hāhā) Creek monitoring location exceeding the PNRP criteria for nutrients at a greater frequency than other monitoring locations. However, catchment influences evident at the Waiarohia location do also result in intermittent exceedance of the criteria, demonstrating that the Hātea River has a notable background nutrient load due to catchment activities.
– While periods of high flow WWTP discharge from Limeburners (Hāhā) Creek influences the water quality at the immediate location of mixing with the Hātea River, as reflected by the Limeburners (Hāhā) Creek monitoring location, this only has a minor influence on water quality further downstream. This suggests that mixing within the Hātea River occurs rapidly and that significant dilution of WWTP discharges and flushing of the Hātea River occurs downstream of Limeburners (Hāhā) Creek.

- The trophic state of the Hātea River is expected to be less influenced by the discharges from the WWTP compared to upstream catchment sources, as indicated by the dissolved oxygen and chlorophyll-a concentrations. This is likely due to relatively high rates of flushing downstream of the Town Basin.
- The relatively high sediment load of the river, resulting from catchment sources, appears to have the most significant influence on the receiving environment ecosystem, with mud content influencing both sediment and water clarity.
- Discharge of treated wastewater is having a minor effect on the current water quality of the Hātea River with regards to nutrients. This is evident in the occasional exceedances noted at the confluence of Limeburners (Hāhā) Creek and the Hātea River. Due to the degree of mixing this effect does not continue downstream.

Sediment and ecology

The results of the NRC sediment monitoring indicate that from 2010 to 2016 the WWTP discharges to the Limeburners (Hāhā) Creek were not having a considerable impact on the receiving environment, with the metal concentrations likely linked to catchment sources. Elevated phosphorous concentrations in sediment are, however, expected to result from the wastewater discharge, however the existing benthic ecology is considered to be tolerant to such conditions. Elevated or enriched concentrations of contaminants identified at monitoring sites in the Hātea River are typically correlated to the high content of mud at these locations, suggesting that adsorption reactions limit the mobility of these catchment sourced contaminants.

Detailed investigation of the benthic ecology identified that communities were typical of a moderately impacted environment, with low species richness and diversity indexes. The communities recorded also reflected the dynamic nature of the tidal setting and catchments, with a variety of habitat types and nutrient conditions. Differences were identified between upstream and downstream locations in Limeburners (Hāhā) Creek, reflecting the different physical conditions, including substrate and salinity. The abundance, richness and diversity measures of the Limeburners (Hāhā) Creek downstream site were found to be generally consistent with that of the Awaroa reference site, suggesting the influence of the WWTP discharges on the benthic ecology was likely to be limited.

Public health risk assessment

Assessment of available data indicates that Enterococci concentrations, providing a proxy for risk of infection due to viruses from wastewater, were recorded to be greater following heavy rainfall events at the confluence of Limeburners (Hāhā) Creek and Hātea River when compared to upstream monitoring locations. The WWTP discharge during these high flow discharge events is considered likely to be the cause of these elevated microbiological loads, however catchment sources are anticipated to provide a relatively high baseline contribution. The elevated levels of Enterococci are expected to be rapidly flushed from the river following these events.

Outside of such high flow events, the influence of the WWTP is considered to be relatively small compared to the background influence of catchment pathogen sources. Downstream of Limeburners (Hāhā) Creek, and outside of periods following rainfall events, water within the Hātea River is typically acceptable for secondary contact and meets the PNRP criteria. Upstream locations influenced by the urban catchment indicate greater degradation.

At Onerahi, the nearest swimming and shellfish gathering location, conditions are typically acceptable for both activities (PNRP criteria). However, monitoring during summer periods has resulted in intermittent alerts for elevated microbiological levels and occasional closure of the beach. Such occurrences do not appear to correlate with the occurrence of elevated pathogen levels in the Hātea River: It is likely that other sources of microbial contamination closer to Onerahi are influencing water quality at this location, such as local accidental wastewater discharges, port discharges and/or marine wastewater discharges, such as from boats and ships.

The receiving environment conditions remain consistent with those assessed by NIWA during the 2011 QMRA. While knowledge of public health risks presented by pathogens has progressed in some areas since the QMRA was undertaken, the assumptions of the assessment are still considered to remain appropriate for managing risks to public health from the WWTP discharge.

Testing of treated wastewater for viruses typically responsible for gastrointestinal infection has demonstrated that disinfection is adequate to manage public health risks. However, monitoring over a longer timeframe has shown that disinfection efficiency, as indicated by E.Coli and TSS levels, has recently been lower than previously proposed to reduce pathogen levels. To address the potential for reduced levels of disinfection WDC will be undertaking WWTP augmentation works to reduce TSS and improve the performance of disinfection. It is understood that these works will be completed by 2025 and will provide a net improvement in water quality and reduced risk to public health.

10.2 Recommendations

It is recommended that the approach to managing effects to the receiving environment from the WWTP be structured to achieve the intent of the PNRP, with no further degradation of the Hātea River or broader increase in risk to the environment or public health.

The following are recommended to be undertaken by WDC to support management of effects to the receiving environment:

1. A preliminary receiving environment monitoring plan (REMP) be developed, detailing:
   a. Receiving environment drivers for WWTP upgrade and metrics for monitoring.
   b. Triggers reflective of deviation from current conditions and the methodology used to determine these.
   c. Contingency actions for compliance and implementation of the adaptive WWTP improvements.
   d. Monitoring requirements.
   e. Data management, interpretation and reporting requirements.
   f. Responsibilities.

   The preliminary REMP should incorporate the proposed preliminary trigger levels (Table 19), to be implemented until such time as additional information is available to inform development of long-term trigger levels and a monitoring programme.
2. Further water quality investigations, including high resolution and continuous monitoring of physical and water quality conditions, should be undertaken to characterise the influence of the dynamic setting on water quality in Limeburners (Hāhā) Creek and the Hātea River. To assist in providing a comparable, reliable dataset, this investigation should confirm:
   a. The locations for intensive monitoring to characterise the dynamic processes.
   b. The frequency and timing of intensive monitoring to standardise conditions as much as practicable.
3. A one-year period of intensive monitoring of the receiving environment and WWTP discharges. The monitoring should be sufficient to characterise the broad range of receiving environment conditions and WWTP discharges and how these change in response to weather, climate and other dynamic influences.
4. Finalisation of the long-term REMP, including:
   a. Analysis of collected receiving environment and WWTP discharge data.
   b. Review of preliminary triggers and refinement of trigger levels.
   c. Development of a long-term monitoring programme adequate to detect degradation of the receiving environment as a result of WWTP discharges.
   d. Confirm the appropriate reporting and responses to trigger level exceedance, including the escalation of decision making for WWTP improvement.
   e. Preparation of a technical assessment, detailing the findings of intensive monitoring and basis for the proposed REMP approach, for approval by NRC and stakeholders.
5. Implementation of the long term REMP, with regular reviews in line with those for the Adaptive Management Plan.

As a key aspect of implementing adaptive management of the activity, it is recommended that a condition of consent be included in the WWTP discharge consent requiring implementation of the Preliminary REMP and the subsequent Long-Term REMP.

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Appendices

Appendix A

Annual nutrient loads

Table A.1 Calculated median total nitrogen concentrations

Year	Nitrogen Median Concentration (g/m^3)					
	Guideline value	Town Basin	Waiarohia Canal	Limeburners (Hāhā) Creek	Kissing Point	Lower Hātea
2010	0.86	-	-	-	-	-
2011		-	-	-	-	-
2012		-	-	-	-	-
2013		-	-	-	-	-
2014		-	-	-	-	-
2015		-	-	-	-	-
2016		0.72	0.86	1.67	0.66	0.45
2017		0.59	0.77	0.92	0.41	0.30
2018		0.78	0.83	0.58	0.36	0.33
2019		0.77	0.81	0.80	0.44	0.36
2020		0.88	1.00	0.95	0.63	0.38

Table A.2 Calculated median phosphorus concentrations

Year	Nitrogen median concentration (g/m^3)					
	Guideline value	Town Basin	Waiarohia Canal	Limeburners (Hāhā) Creek	Kissing Point	Lower Hātea
2010	0.119	0.113	0.158	0.126	0.090	0.069
2011		0.076	0.109	0.096	0.052	0.045
2012		0.040	0.093	0.195	0.070	0.055
2013		0.078	0.119	0.185	0.082	0.055
2014		0.075	0.099	0.115	0.063	0.038
2015		0.065	0.110	0.135	0.054	0.046
2016		0.063	0.087	0.231	0.074	0.063
2017		0.064	0.120	0.170	0.055	0.041
2018		0.070	0.082	0.081	0.047	0.043
2019		0.087	0.110	0.110	0.061	0.042
2020		0.048	0.110	0.160	0.078	0.050

Table A.3 Calculated median ammoniacal nitrogen concentrations

Year	Ammoniacal Nitrogen median concentration (g/m^3)					
	Guideline value	Town Basin	Waiarohia Canal	Limeburners (Hāhā) Creek	Kissing Point	Lower Hātea
2010	0.099	0.11	0.11	0.07	0.06	0.06
2011		0.08	0.15	0.15	0.08	0.03
2012		0.05	0.08	0.14	0.06	0.05
2013		0.05	0.06	0.06	0.04	0.03
2014		0.06	0.05	0.08	0.09	0.05
2015		0.05	0.09	0.12	0.06	0.04
2016		0.07	0.08	0.10	0.06	0.05
2017		0.05	0.09	0.12	0.06	0.04
2018		0.08	0.12	0.09	0.07	0.06
2019		0.10	0.07	0.07	0.04	0.04
2020		0.07	0.11	0.13	0.10	0.06

Table A.4 Calculated median total inorganic nitrogen concentrations

Year	Total Inorganic Nitrogen median concentration (g/m^3)					
	Guideline value	Town Basin	Waiarohia Canal	Limeburners (Hāhā) Creek	Kissing Point	Lower Hātea
2010	N/A	0.63	0.77	0.51	0.28	0.19
2011		0.48	0.64	0.59	0.27	0.12
2012		0.46	0.68	1.23	0.38	0.22
2013		0.46	0.65	0.94	0.39	0.22
2014		0.51	0.68	0.53	0.38	0.19
2015		0.60	0.69	0.52	0.32	0.16
2016		0.48	0.60	0.98	0.49	0.30
2017		0.43	0.54	0.77	0.25	0.21
2018		0.54	0.60	0.35	0.24	0.16
2019		0.63	0.53	0.50	0.27	0.23
2020		0.66	0.78	0.87	0.36	0.21

Appendix B

4Sight, Water Quality Monitoring Report, 2021

4SIGHT
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Whangarei
District Council

WHANGAREI WASTEWATER TREATMENT PLANT: WATER QUALITY MONITORING REPORT (2020–2021)

For Whangarei District Council

March 2021

REPORT INFORMATION AND QUALITY CONTROL

Prepared for:	Hai Nguyen Whangarei District Council	

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1 INTRODUCTION

Whangarei District Council (WDC) hold consents to discharge treated wastewater from the WDC Wastewater Treatment Plant (WWTP) into Limeburners Creek. The consents required for this activity will expire in April 2022. It is anticipated that WDC will lodge applications for new consents in late 2021.

4Sight Consulting Ltd (4Sight) was commissioned by WDC to conduct monthly water sampling at locations between the WWTP post-treatment wetlands and the tidal discharge of Limeburners creek to the Hātea River. The purpose of this sampling is to characterise the water quality at various locations to understand how it changes in the environment after it has been discharged from the WWTP.

Treated wastewater is discharged into two treatment wetlands, each of which flows through a dense mangrove forest and deep muddy channels before discharging into Limeburners Creek. The Proposed Northland Regional Plan[1] designates Limeburners Creek as a 'mixing zone for major discharges', which is a continuation of the status Limeburners Creek has held since the inception of the WWTP. Consequently, the water quality in Limeburners Creek is not required to meet the water quality standards for the Hātea River coastal water quality management unit identified in the plan. The discharge from Limeburners Creek, however, should not cause water quality in the Hātea River to exceed the designated water quality standards after the 'reasonable mixing' it is deemed to have received in the Creek.

This report presents the findings of monthly water sampling conducted from January 2020 to February 2021. Samples were analysed for a broad range of water quality parameters to capture a snapshot of the water quality at the WWTP outflow, treatment wetlands, discharge into Limeburners Creek, and the discharge of Limeburners Creek into the Hātea River.

2 METHODS

The approach for conducting monthly water quality sampling is described in this section, including monitoring locations, timing, water quality parameters, and data analysis.

2.1 Monitoring Locations

The following locations were sampled monthly, where possible, to assess the change in water quality of the treated wastewater as it passes through the treatment wetland into Limeburners Creek and finally into the Hātea River. This equates to four distinct parts of the post-treatment process that are described in this section and referred to as sampling groups herein:

1) Discharge from the WWTP into each of the two treatment wetlands (Outflow);
2) Discharges from the treatment wetlands into the mangrove forest (Wetland);
3) Discharges into Limeburners Creek (LB Discharge); and
4) Water quality throughout Limeburners Creek. Before, during, and after mixing and diluting with the WWTP discharge (LB Creek).

The locations of these features are shown in Figure 1 and a map showing each of the monitoring locations is presented in Appendix A.

Samples from the WWTP Outflow and treatment wetlands were collected on foot. Samples from Limeburners Creek were collected from a boat.

[1] 'PNRP'; Appeals Version, June 2020.

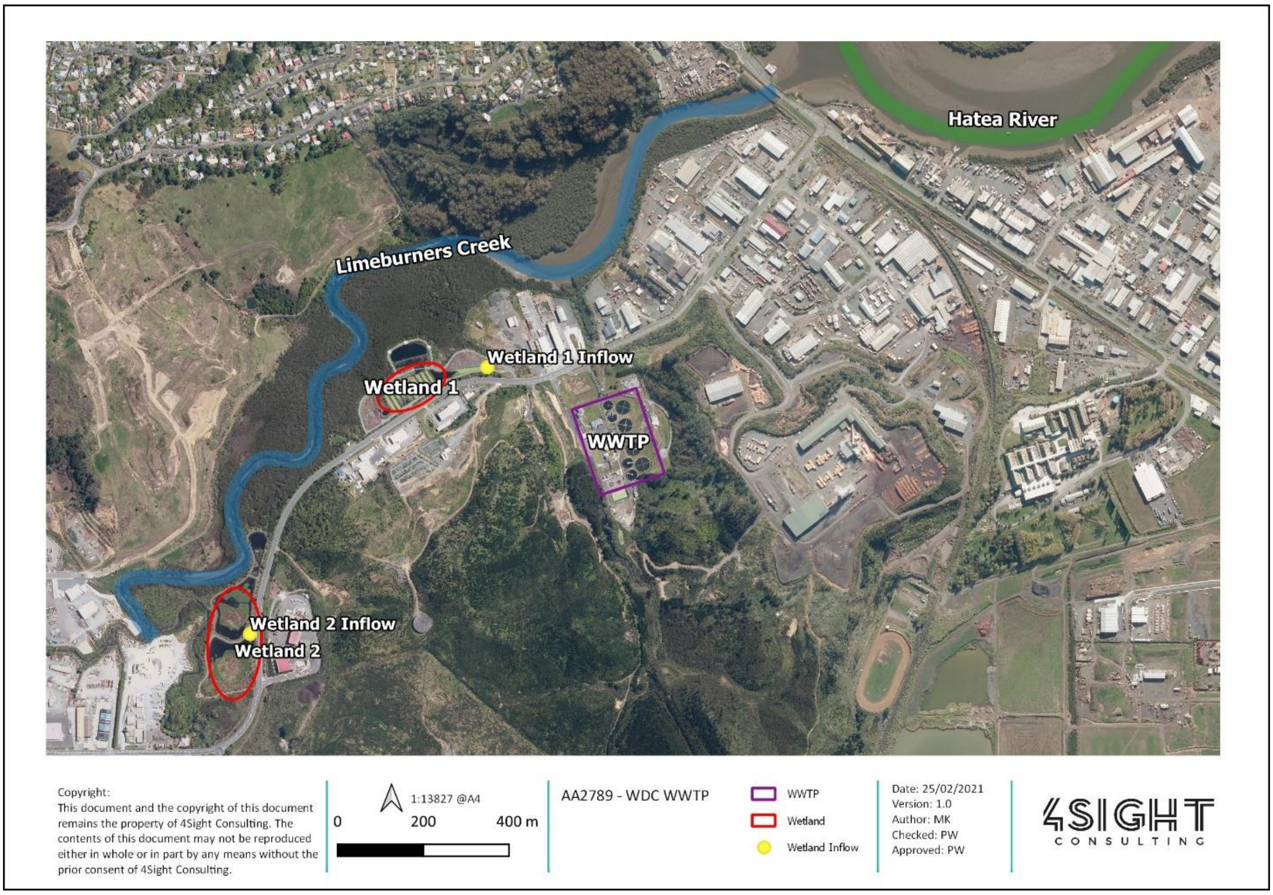

Figure 1: Key locations associated with WWTP discharge.

2.1.1 WWTP Outflow

Water samples were collected from the main outflow from the WWTP, which flows into each of the two treatment wetlands. This serves as an assessment of the quality of the discharge leaving the WWTP and a baseline to assess how water quality changes throughout each treatment wetland.

2.1.2 Treatment Wetland Outflow

Water samples were collected from two representative outflows from each treatment wetland. Results from these locations can be compared to the WWTP outflow to assess the effect each treatment wetland has on the treated wastewater.

2.1.3 Discharge into Limeburners Creek

Water samples were collected from the main points where the flow from the treatment wetlands through the mangrove forest becomes confluent before it enters the Limeburners Creek main channel.

These monitoring locations will serve two purposes:

1) Showing how water quality changes, if at all, after flowing through the mangrove forest; and

2) Identifying the quality of the discharge water before it mixes with the main tidal body of the Limeburners Creek.

2.1.4 Mixed Sites within Limeburners Creek

Four locations along Limeburners Creek were monitored to assess 'background' water quality and how water quality in the creek changes as it mixes with the WWTP discharges. The four locations are:

1) Upstream of all WWTP discharges ('background');

2) Downstream of Treatment Wetland 1;

3) Downstream of Treatment Wetland 2; and

4) Mouth of Limeburners Creek.

Although sampling was carried out after high tide on the first half of the ebb tide, the previous flood tide is likely to have conveyed WWTP discharges well up the Limeburners Creek. At the time of sampling on the ebb tide, there may still have been residual WWTP discharge influences on so called 'background' water quality.

2.2 Time and Frequency

Samples were collected monthly from January 2020 to February 2021, where possible. During this period, there were two situations whereby samples could not be collected in their respective month. Firstly, samples could not be collected in March or April 2020 because of the country being in COVID-19 Alert Level 4. Secondly, for the February 2021 sampling round, samples were only collected at the Outflow and Wetland locations. Technical issues with the boat meant that samples could not be collected from Limeburners Discharge or Limeburners Creek on this occasion. Overall, 11 samples were collected from all Limeburners Discharge and Limeburners Creek sites (January 2020 to January 2021, incl.) and 12 samples from the Wetland Inflow and Outflow sites (January 2020 to February 2021, incl.). The sampling schedule is summarised in Table 1.

Table 1: Sampling schedule.

Period	Sites Sampled
January – February 2020	All sites
March – April 2020	No sampling due to COVID19 alert level 4
May 2020 – January 2021	All sites
February 2021	WWTP Outflow and Wetland sites

Limeburners Creek is tidal and, therefore, water quality is influenced by the state of the tide. For this assessment, samples were collected on the outgoing (ebb) tide, generally between one and three hours after high tide. This tidal state was chosen to focus on the water quality in Limeburners Creek rather than the incoming Hātea River and Whangārei Harbour water; however, estuarine environments are complex and so there will always be influences from freshwater and marine sources, and additionally in Limeburners Creek, the WWTP discharge.

2.3 Water Quality Parameters

A broad suite of water quality parameters was measured in all samples to characterise the water quality; the complete list of parameters is outlined in Table 2. Collectively, these parameters are indicators of the ecological health of the environment and provide a comparative basis for assessing water quality against published guidelines.

Table 2: Summary of water quality parameters and their purpose

Parameter	Description
Temperature	Overarching parameter that influences other measurements. Elevated temperatures can also be a stressor to aquatic organisms.
Salinity	A measure of the total salt content of the water and indicates the extent of dilution and mixing with oceanic water from Whangarei Harbour.
Dissolved oxygen saturation	The amount of oxygen dissolved in the water.
pH	An indicator of the overall state of water chemistry in terms of how acidic the water is. Overly high or low values may have adverse effects on aquatic organisms.
Turbidity	A measure of water clarity. Closely linked with total suspended solids.
Total suspended solids	The measure of suspended material in the water. Closely linked with turbidity.
Total nitrogen	Measures of the total nitrogen and phosphorus in the water. Excess nutrients may fuel nuisance algal growth.
Total phosphorus	
Nitrate + nitrite nitrogen (Total oxidised nitrogen)	Components of the total nitrogen and phosphorus pools that are readily used by aquatic plants. Excess concentrations of these components may fuel nuisance algal growth. High concentrations may be toxic to aquatic animals.
Total ammoniacal nitrogen	
Dissolved reactive phosphorus	
Chlorophyll-a	A proxy for phytoplankton biomass, which is an indicator of nutrient enrichment (eutrophication) and overall estuarine health.
Biological oxygen demand (cBOD5)	The amount of dissolved oxygen needed by aerobic biological organisms to break down organic material present. High values can decrease the dissolved oxygen saturation in the water.
Enterococci	Measures of faecal bacteria. High levels increase the risk to human health (swimming and shellfish-gathering).
Escherichia coli	
Faecal coliforms	

2.4 Data Analysis

Based on an initial inspection of data, a subset of water quality parameters was selected for further analysis and discussion. There are two reasons for selecting a subset of the measured parameters for analysis. Firstly, some parameters are important to measure as supporting parameters, such as pH and temperature, to help explain other parameters but are not necessarily key indicators or likely to be influenced by the WWTP. Secondly, a range of nutrient species were measured (e.g., total, nitrate-nitrite nitrogen, and ammoniacal nitrogen), which is important to assess the potential ecological effects. Initial inspection revealed similar patterns among the various nutrient species and so, instead, total nitrogen and phosphorus are used as the primary indicators of nitrogen and phosphorus levels and total ammoniacal nitrogen is included to assess for potential toxicity effects.

The following key parameters are analysed and discussed in further detail:

- Carbonaceous biochemical oxygen demand (CBOD);
- Chlorophyll-a;
- Dissolved oxygen (% saturation);
- Enterococci;
- Total ammoniacal nitrogen;

- Total nitrogen;
- Total phosphorus; and
- Total suspended solids;

A conservative approach was taken for the statistical analysis of results that were less than the laboratory level of reporting. Such values were assumed to be equal to the level of reporting (e.g., <3 mg/L CBOD = 3 mg/L).

Non-parametric statistical methods were used to assess significant differences. The Wilcoxon signed-rank test was used where two groups were being compared and a Kruskal–Wallis test for comparing more than two groups. Where tests were statistically significant, a Dunn's test of multiple comparisons was used to determine the ranking of sites within groups.

2.4.1 Site Grouping

Similar sites were grouped for the purpose of statistical analysis to increase the statistical power (Table 3).

Table 3: Site groups

Site Name	Group Name
Wetland Inflow / WWTP Outflow	Outflow
Wetland 1 Outlet 1	Wetland 1
Wetland 1 Outlet 2	
Wetland 2 Outlet 3	Wetland 2
Wetland 2 Outlet 4	
LB Discharge 1	LB Discharge
LB Discharge 2	
LB Discharge 3	
LB Discharge 4	
LB Upper	LB Upper
LB Mid	
LB Lower	LB Lower
LB Mouth	

2.4.2 Seasonality

Differences in water quality among seasons were assessed by grouping data into climatic seasons (e.g., summer = December, January, February). The statistical significance of any differences was determined using a Kruskal–Wallis test and, where significant, followed by Dunn's test of multiple comparisons to determine the ranking of sites within groups.

2.4.3 Guideline Values

To report results in an appropriate context, they are compared to relevant guidelines. Such guidelines are outlined below.

2.4.3.1 NRC Coastal Water Quality Standards

The Proposed Northland Regional Plan coastal water quality standards provide relevant water quality standards for the Hātea River (Table 4). As noted previously, water quality in Limeburners Creek is not required to meet these standards, however, the discharge from Limeburners Creek should not cause water quality in the Hātea River to exceed them.

Table 4: Northland Regional Council coastal water quality standards (Proposed regional plan, Policy H.3.3, Table 22).

Attribute	Unit	Compliance Metric	Hātea River Standard
Dissolved oxygen	mg/L	Annual median	>6.2
Temperature	°C	Maximum change	3
pH	NA	Annual minimum and annual maximum	7.0–8.5
Turbidity	NTU	Annual median	<7.5
Chlorophyll-a	mg/L	Annual median	<0.003
Total phosphorus	mg/L	Annual median	<0.119
Total nitrogen	mg/L	Annual median	<0.860
Nitrate-nitrite nitrogen (total oxidisable nitrogen)	mg/L	Annual median	<0.580
Ammoniacal nitrogen	mg/L	Annual median	<0.099
Enterococci	Enterococci/100mL	Annual 95^{th} percentile	≤500

2.4.3.2 Ammonia Toxicity

The toxicity of ammonia is dependent on pH and temperature. To assess the potential toxicity, ammonia measurements were normalised to pH 8.0, which is in alignment with the most recent ammonia toxicity guidelines (ANZECC, 2000). The guideline value is slightly higher in marine waters (0.91 mg/L) than in freshwater (0.90 mg/L). Because the focus of this assessment is on Limeburners Creek, the marine guideline value has been used for all sites for consistency.

3 RESULTS

Monthly water quality samples were analysed to assess:

- Whether there were any differences between the treatment wetlands;
- How water quality changes from the WWTP Outflow to the Limeburners Creek discharge;
- The potential toxicity of ammonia;
- Concentrations of various water quality parameters measured at Limeburners Mouth and how they compare to NRC water quality standards; and
- Whether there are any seasonal effects.

Summaries of the results are presented in this section. Plots of all data are presented in Appendix B and the laboratory reports are in Appendix C.

3.1 Differences Between Treatment Wetlands

The two treatment wetlands each receive the same water from the WWTP. Wetland 2 receives 10,000 m^3 per day and the remaining treated wastewater is discharged to Wetland 1. Wetland 1 has plants growing in it, which are occasionally cut and removed; Wetland 2 does not. The following results show the findings of a water quality assessment at the discharge points of each of the wetlands to determine whether there are any differences in the water quality between the wetlands.

The median dissolved oxygen saturation in Wetland 2 (56%) is statistically significantly higher than in Wetland 1 (44%).[2] No other differences were statistically significant; however, the water quality in Wetland 1 was generally more variable and had higher median total nitrogen and enterococci concentrations than Wetland 2.

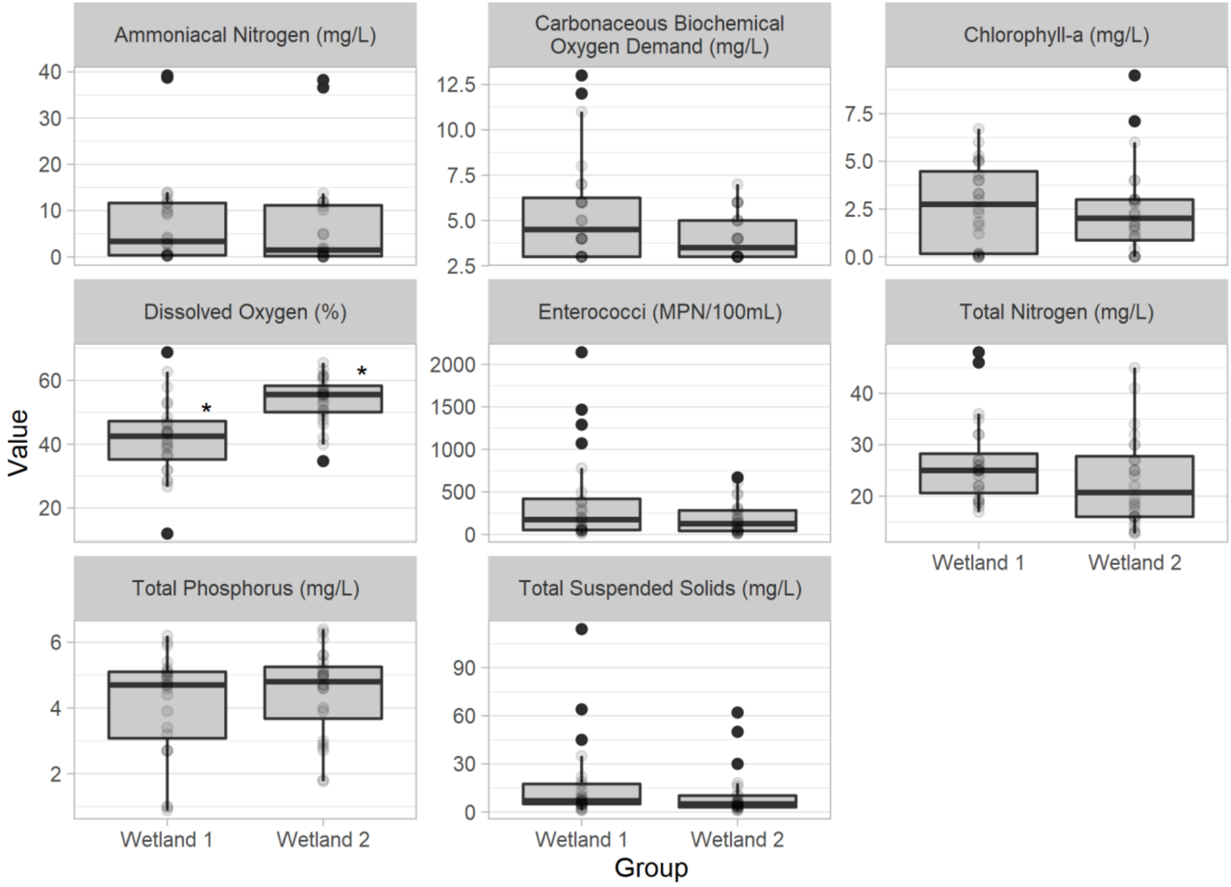

Figure 2: Comparison of key water quality measurements between the two treatment wetlands. Statistically significant differences are indicated by a star above the boxplot. Note that one high result in Wetland 1 for enterococci was excluded from the plot (but not statistical analyses) to make the remaining information visible.

3.2 Changes in Water Quality Between the WWTP Outflow and the Hātea River

It was anticipated that water quality would change notably in the treated wastewater as it flowed from the treatment wetlands into a dense mangrove forest, through deep, muddy channels, and into Limeburners Creek before being discharged into the Hātea River. The differences through this process are assessed in this section and visually represented in Figure 3.

Overall, results for the analysed water quality parameters were highly variable. On at least two occasions, results for most parameters were highly elevated (more than 1.5 times the interquartile range [the box of the boxplot]). The highest results were measured in October 2020 (Appendix B). WDC informed 4Sight that they were aware of some issues in the plant around September 2020, which may explain some of these elevated results.

[2] Kruskal-Wallis rank sum test: p-value = 0.002.

3.2.1 Ammonia

Ammonia concentrations were generally higher in the WWTP Outflow and treatment wetlands, but such differences were not statistically significant for all sites. The median ammonia concentrations were lower and similar in LB Discharge and both LB Upper and Lower groups.

3.2.2 CBOD

The median CBOD concentration was highest in the WWTP Outflow. On occasion, CBOD concentrations were higher in Wetland 1 than in the Outflow. CBOD concentrations in LB Discharge and LB Upper and Lower were all similarly low and generally below the laboratory level of reporting.

3.2.3 Chlorophyll-a

Chlorophyll-a concentrations were equally variable and had similar medians for all groups.

3.2.4 Dissolved Oxygen

Median dissolved oxygen concentrations were highest in the WWTP Outflow. This is likely a result of the treatment and aeration process. Dissolved oxygen concentrations notably declined in the treatment wetlands and increased throughout the Limeburners Creek mixing zone before being discharged into the Hātea River. At Limeburners Mouth, the median dissolved oxygen concentration was still lower than that in the WWTP Outflow.

3.2.5 Enterococci

In general, enterococci concentrations were equally variable and had similar medians for all groups.

3.2.6 Total Nitrogen

The median total nitrogen concentration decreased in each group from the WWTP Outflow to LB Lower. Outflow and Wetlands 1 and 2 were statistically significantly higher than LB Discharge and LB Upper and Lower.

3.2.7 Total Phosphorus

Median total phosphorus concentrations were similar and high in the Outflow and Wetlands 1 and 2. Concentrations were lower at LB Discharge and LB Upper and decreased further at LB Lower.

3.2.8 Total Suspended Solids

The median total suspended solid concentration decreased slightly from the WWTP Outflow to the treatment wetlands, however, such difference was not statistically significant. Concentrations increased in LB Discharge and LB Upper and Lower; this is likely a result of the freshwater from the treatment wetlands mixing with estuarine waters causing particles to be resuspended.

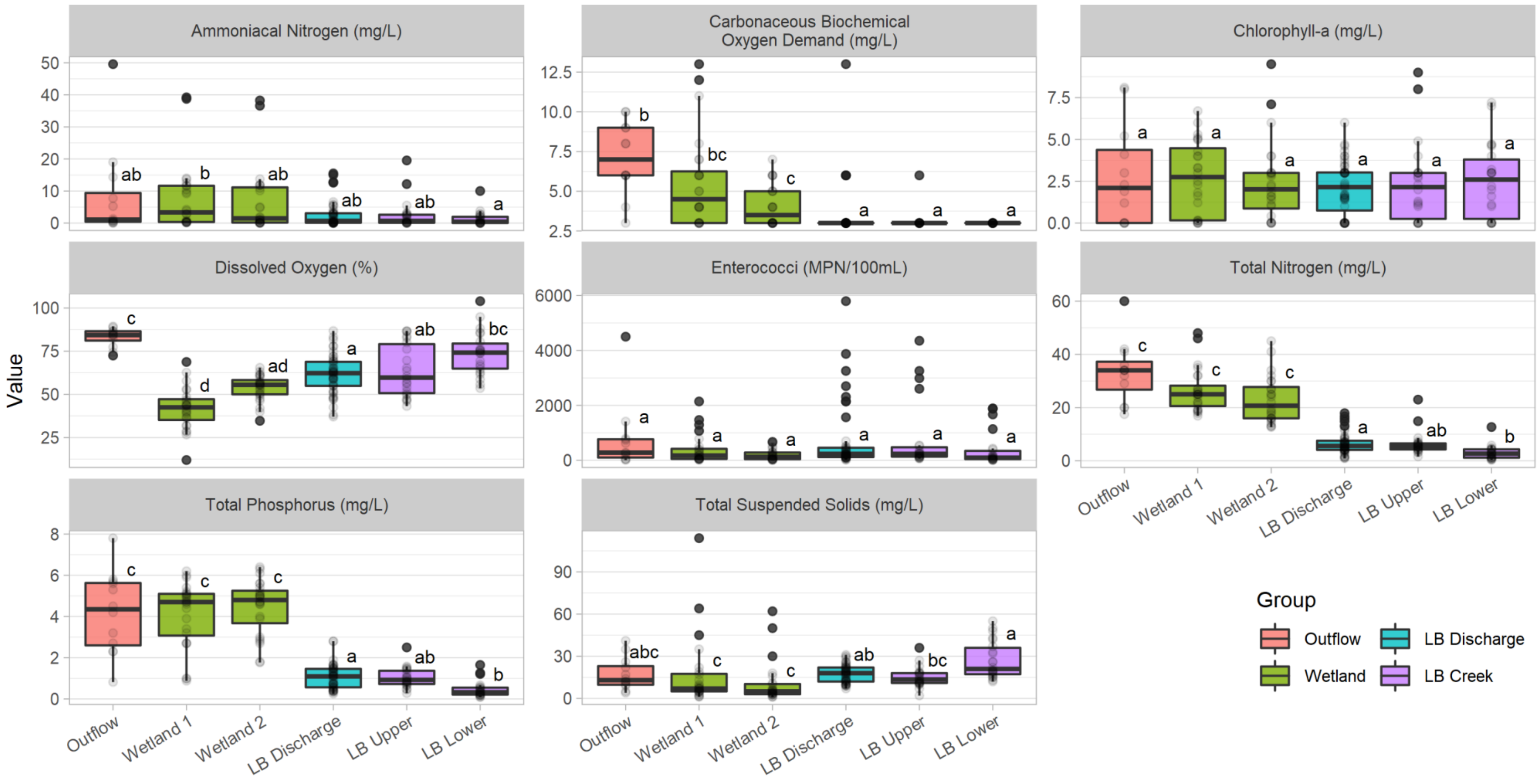

Figure 3: Summary of key water quality measurements from the WWTP discharge through to the final discharge of Limeburners Creek into the Hātea River. Letters above each boxplot indicate the statistical significance from a Kruskal–Wallace test.

3.2.9 Multivariate Analysis

Multivariate analysis allows all the parameters described above to be analysed simultaneously and to be used to identify key parameters that differentiate sites. It is a useful way to visualise the magnitude of the difference between sites, if any.

The PC1 axis describes 34% of the variation in the dataset. This is mostly due to changes in CBOD and nutrients (total phosphorus and nitrogen, and ammoniacal nitrogen). That is, the wetland and outflow sites are positioned further to the left of the plot, which indicates higher levels of nutrients and CBOD. One point for Outflow is positioned in the far bottom-left of the plot. Such large separation from the rest of the data is due to the high enterococci and nutrient concentrations measured in October 2020. LB Discharge and LB Upper and Lower are further to the right of the plot, indicating lower concentrations of these parameters. This is in agreement with the individual parameter results presented in the previous section.

The PC2 axis describes 17% of the variation in the dataset. The spread on this axis is predominantly described by changes in enterococci, ammonia, and dissolved oxygen concentrations. The spread of points on this axis appears to reflect the monthly variation, rather than differences due to locations and exposure to the WWTP discharge.

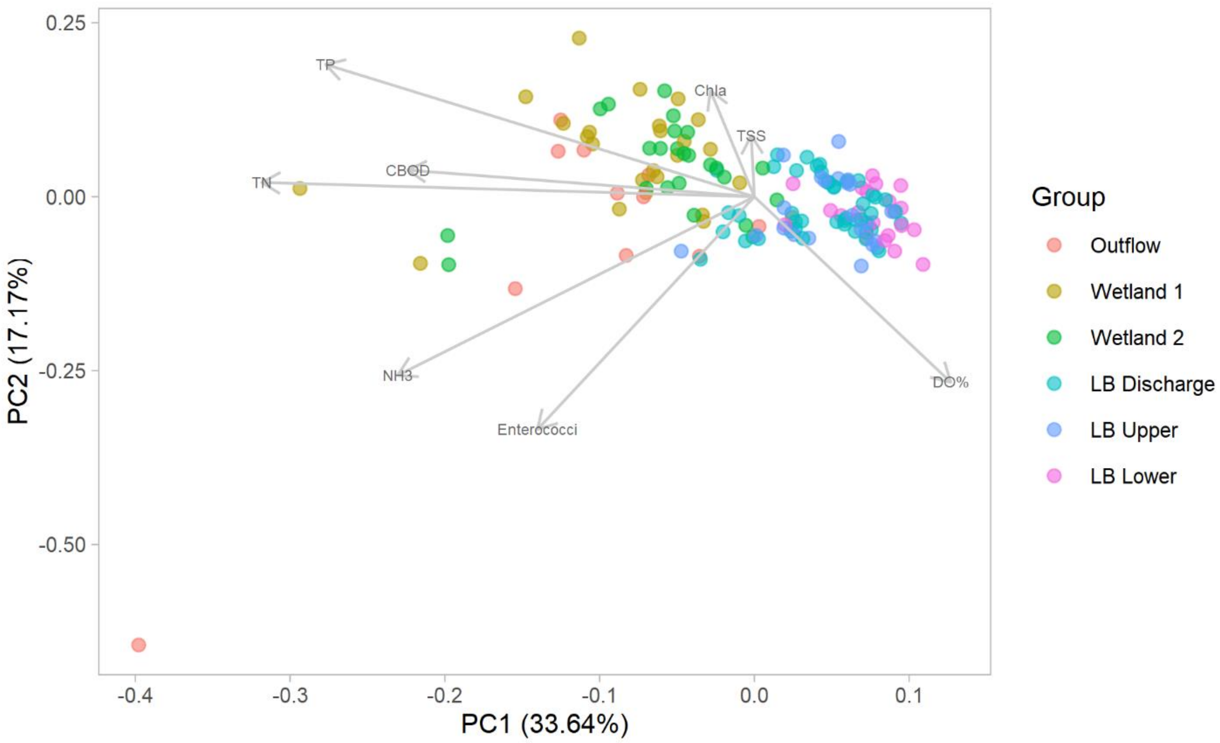

Figure 4: Principal component analysis of key water quality parameters.

3.3 Ammonia (Toxicity)

Ammonia concentrations at all sites were within the chronic guideline value on at least half of the sampling occasions. However, concentrations generally exceeded the chronic guideline value from June to October. On such occasions, concentrations were approximately 5–10 times higher than the guideline value in the outflow and treatment wetlands and 1.5–2 times higher in Limeburners Creek.

Samples collected on 1 October 2020 had the highest concentrations at all sites, which was notably higher than all other results. On this occasion, concentrations were up to 38 times higher than the chronic guideline value at the Outflow, 10 times higher in Limeburners Creek, and 2 times higher at Limeburners Mouth.

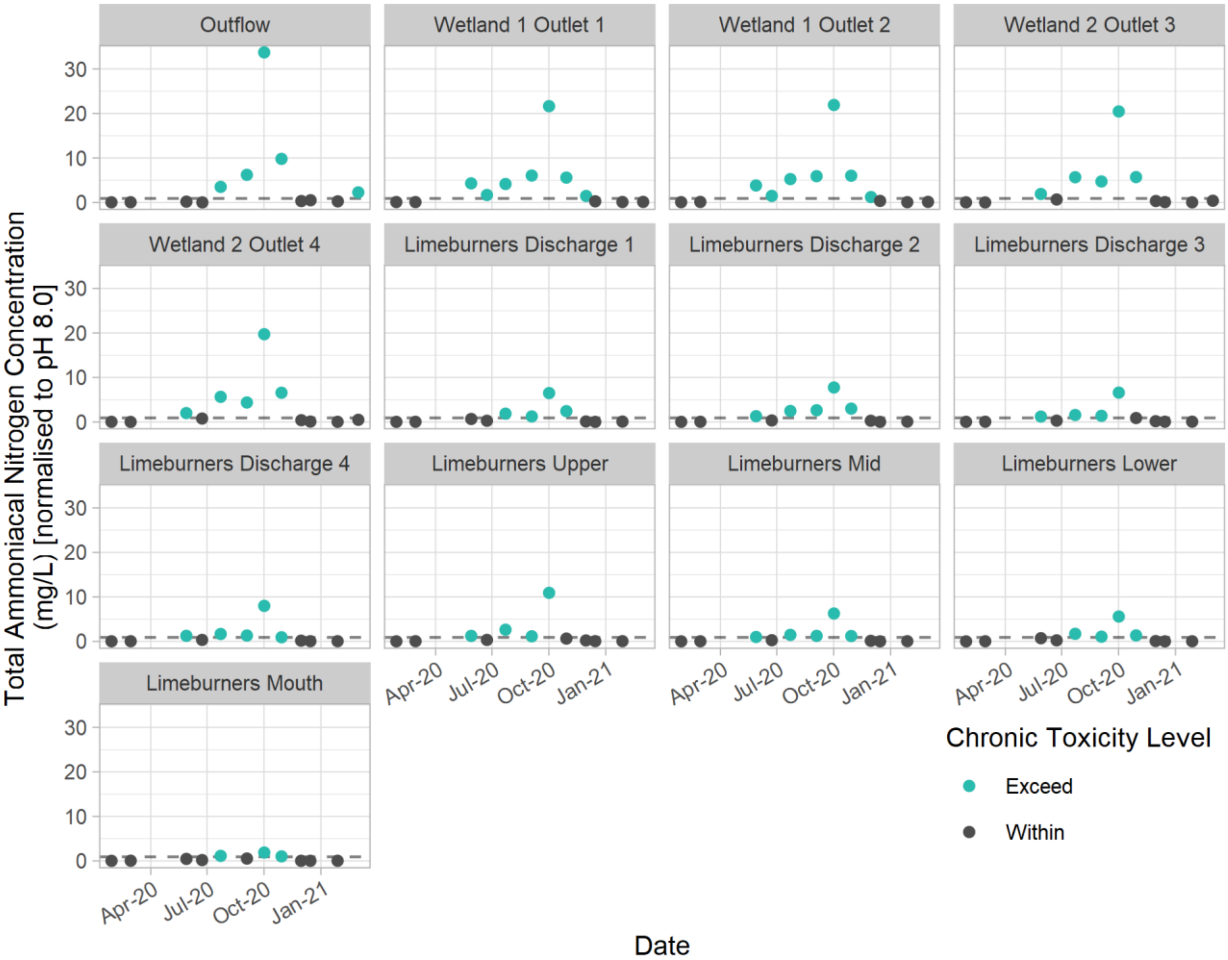

Figure 5: Total ammoniacal nitrogen concentrations measured at each location and adjusted to pH 8.0. The dashed horizontal line indicates the marine chronic toxicity guideline value (0.91 mg/L; ANZECC (2000)).

3.4 Discharge from Limeburners Creek into the Hātea River

As noted in the introduction, Limeburners Creek is designated as a 'mixing zone for major discharges', which is a continuation of the status Limeburners Creek has held since the inception of the WWTP. Therefore, the water quality in Limeburners Creek is not required to meet the water quality standards for the Hātea River coastal water quality management unit. Results from Limeburners Mouth have been compared to the coastal water quality standards for the Hātea River coastal water quality management unit to place them in context, however (Table 5).

It is important to note that all guidelines used in this section are for ecosystem health. The guideline value for ammonia used in this section is an order of magnitude lower (more conservative) than in the section addressing potential toxicity above.

The sampling conducted for this study was not intended to be compliance monitoring. However, the WWTP consent Condition 15 lists some water quality limits at Limeburners Creek as measured at the Port Road Bridge, which also provide a useful reference for the sampling results. The Limeburners Mouth location monitored for this dataset is very similar to that of the NRC consent monitoring location. The consent limits are higher and less conservative than those in the coastal water quality standards for pH, dissolved oxygen, and ammonia: pH range is 6.9–9.0; oxygen saturation must be >80%; the ammonia standard is for toxicity (0.91 mg/L at pH 8.0 and high salinity water), which is described in the previous section (3.3). The Enterococci consent limit is lower and more conservative than the coastal water quality standard (median 136 enterococci/100 mL; single sample 277 enterococci/100 mL).

WDC informed 4Sight that they were aware of some issues in the plant around September and December 2020, which may explain some of the elevated results in those months.

Dissolved oxygen saturation and pH were the only parameters that were always within the coastal water quality standards. Since the standards are more conservative (more restrictive) than the consent limits, results were also within the limits for these parameters (median dissolved oxygen was 84.4%).

Chlorophyll-a and nutrients (total nitrogen, nitrate-nitrite nitrogen, and total phosphorus) exceeded the water quality standards more often than not. Consequently, the median concentration of each of these parameters was higher than the water quality standard.

Chlorophyll-a concentrations were lowest during the coolest months (June–September). From November 2020 to January 2021, nutrient concentrations were within the water quality standard, however, chlorophyll-a still exceeded the standard. Such low nutrient concentrations could result from uptake by the high levels of phytoplankton, as indicated by the elevated chlorophyll-a concentrations.

Enterococci concentrations were within the coastal water quality standards on all but two sampling occasions; note, however, that the standard is for the 95th percentile of the data. On such occasions, the concentrations were 2.3 and 3.3 times greater than the water quality standard. Because of the two relatively high exceedances, the 95th percentile of the data exceeded the standard value even though the median concentration was relatively low at 41 enterococci/100 mL. When compared to consent condition 15(g), the median enterococci concentration of 41 enterococci/100 mL was within the consent limit, and two of the 11 results were greater than the single sample limit of 277 enterococci/100 mL.

Turbidity levels were within the water quality standards on four out of 12 sampling occasions. The highest concentration (13.4 NTU) was 1.8 times greater than the standard.

Table 5: Proposed Northland Regional Plan coastal water quality standards and summary of monthly sampling at the mouth of Limeburners Creek. Highlighted cells indicate an exceedance of the standard.

Attribute	Unit	Compliance Metric	Hātea River Standard	Limeburners Mouth
Dissolved oxygen	mg/L	Annual median	>6.2	6.54
Temperature	°C	Maximum change	3	NA
pH	NA	Annual minimum and annual maximum	7.0–8.5	7.4–7.9
Turbidity	NTU	Annual median	<7.5	5.76
Chlorophyll-a	mg/L	Annual median	<0.003	3
Total phosphorus	mg/L	Annual median	<0.119	0.21
Total nitrogen	mg/L	Annual median	<0.860	1.6
Nitrate-nitrite nitrogen (total oxidisable nitrogen)	mg/L	Annual median	<0.580	0.81
Ammoniacal nitrogen	mg/L	Annual median	<0.099	0.32
Enterococci	Enterococci/100mL	Annual 95th percentile	≤500	1,643

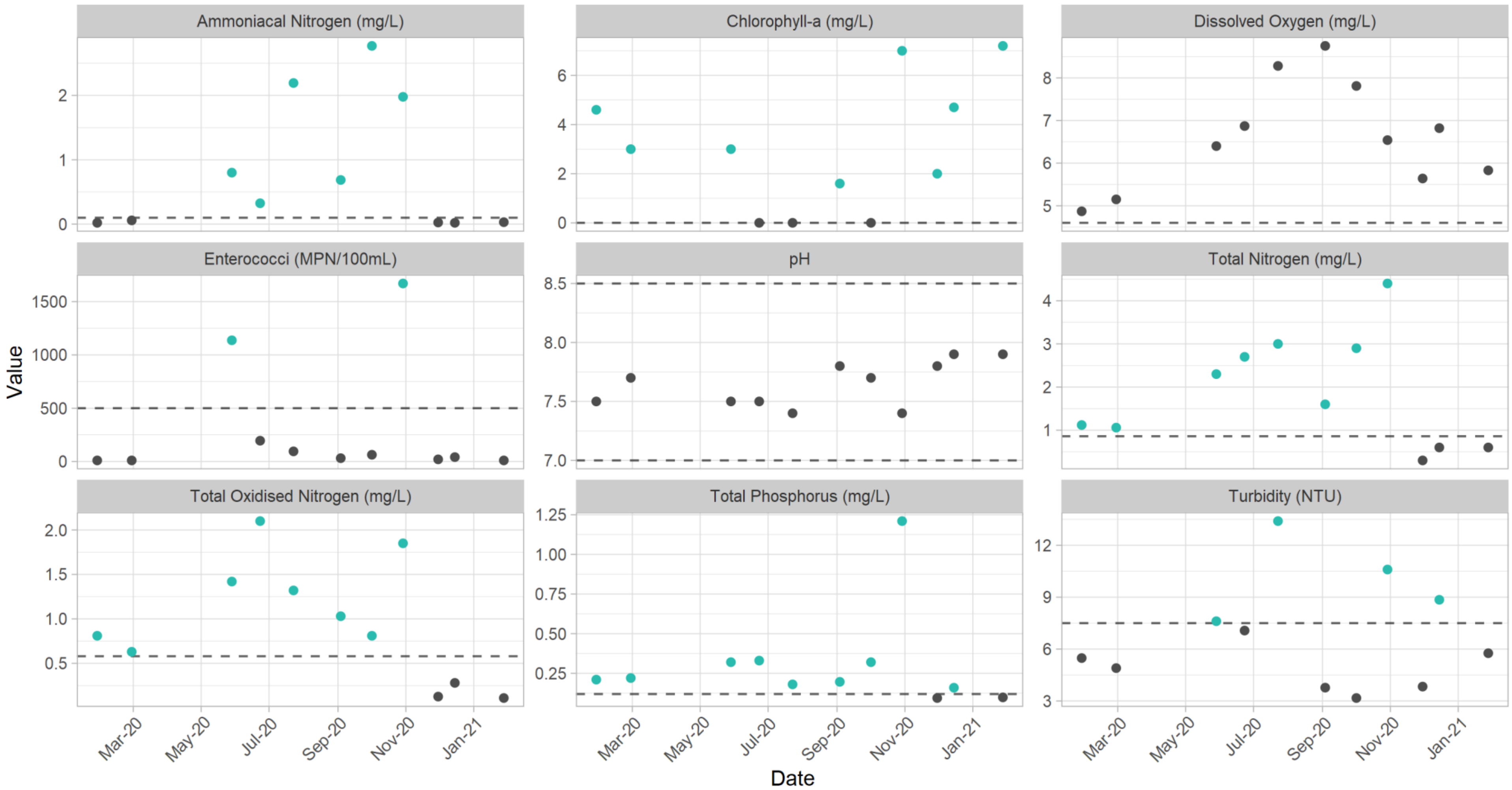

Figure 6: Water quality parameters measured from January 2020 to March 2021 at the mouth of Limeburners Creek that have a water quality standard in the NRC Proposed Regional Plan (dashed horizontal line). Exceedances of the standard are highlighted in green. Temperature was excluded because the standard is a deviation from background values.

3.5 Seasonal Effects

Differences in water quality among climatic seasons were assessed for each group and each of the key water quality parameters. There were insufficient data points for the Outfall site to conduct the statistical analyses, however, the data were still included in the boxplots for completeness and visual comparison (Appendix D).

In winter, chlorophyll-a concentrations were much lower than during other seasons. Ammonia concentrations were similarly at their lowest for all sites. Total nitrogen and total phosphorus concentrations were slightly lower in winter in the treatment wetlands, but such differences were not statistically significant in LB Discharge, Upper, or Lower.

Ammonia concentrations were the lowest in summer and similarly high during the other seasons.

Enterococci concentrations were highly variable and so there were very few statistically significant differences. In general, the median enterococci concentration was highest in autumn and lowest in summer in the LB Discharge, Upper, and Lower sites.

There were no statistically significant differences among seasons for CBOD and total suspended solids. There were generally no significant differences among seasons for dissolved oxygen, except for a small difference between winter (slightly higher) and spring/summer at the LB Discharge sites.

4 DISCUSSION

There were marked differences between the water quality in the Outflow and Wetland sites compared to the sites in Limeburners Creek, most notably for nutrient (total nitrogen and phosphorus and ammoniacal nitrogen) and CBOD parameters. Each of these parameters reduced substantially from the Outflow to the Limeburners Creek sites after flowing through the mangrove forest and mixing with the water in Limeburners Creek.

Improvements were not seen for all water quality parameters throughout the post-treatment mixing zone. Total suspended solids, for example, was lower in the Outflow than it was in Limeburners Creek (all sites). This is unsurprising, however, as it is well understood that turbidity and suspended solids concentrations increase at freshwater–marine interfaces due to the mixing and resuspension of particles and the precipitation of dissolved chemical species due to salinity changes.

Chlorophyll-a and enterococci concentrations were variable throughout the mixing zone from the Outflow to Limeburners Creek mouth and there were no significant differences among the sites.

Chlorophyll-a concentrations were lowest during the coolest months (June–September). During summer, chlorophyll-a concentrations remained high at all locations, whereas nutrient concentrations were lower relative to other seasons in Limeburners Creek. Nutrient concentrations at Outflow were not substantially lower during this time, with the exception of ammoniacal nitrogen. This suggests that nutrient concentrations may have decreased due to the uptake of nutrients by phytoplankton growth during summer.

Dissolved oxygen levels were lower in the treatment wetlands than they were in the Outflow. Such decreases are likely a consequence of the high CBOD levels in the outflow. The microbial degradation of organic matter is a highly oxygen-consuming process and the oxygen supply in the slow-moving waters of the treatment wetlands appears to be lower than the oxygen requirements of these processes. In the treatment wetlands, most of the oxygen is likely to be supplied by diffusion from the air. The flow of water over weirs and faster flow through the mangrove forest likely aid reoxygenation of the water, which is seen by increases in oxygen between the treatment wetlands and Limeburners Discharge sites. Oxygen levels further increase after mixing with the waters of Limeburners Creek.

The water quality at Limeburners Discharge sites was similar to that at Limeburners Upper sites. This suggests that the discharge had already mixed with water from Limeburners Creek. Samples could be collected from further upstream in the mangrove forest to increase the level of detail of water quality changes throughout the process, however, this would add further logistical difficulties and sampling time due to limited accessibility. The current sampling approach is sufficient to assess the change in water quality from the WWTP discharge to the discharge from Limeburners Creek into the Hātea River.

Ammonia concentrations at Limeburners Mouth exceeded the chronic toxicity guideline value on 3 out of 6 sampling occasions between May and October. The highest exceedance was twice that of the guideline value.[3] Further up Limeburners Creek at the Lower, Mid, and Upper sites, ammonia concentrations exceeded the guideline value on four to five occasions out of six by up to 12 times. This indicates that for six months of the year, ammonia within the mixing zone, may act as a stressor for some aquatic organisms. The extent of such effects is dependent on the length of time a species remains in Limeburners Creek and the tolerance of such species to ammonia. After mixing with the Hātea River, ammonia levels appear to decrease substantially such that they are within the Hātea water quality management unit coastal water quality standard, which is an order of magnitude lower than the toxicity guideline value.[4]

Nutrients and chlorophyll-a concentrations often exceed the regional plan Hātea River water quality standards at the mouth of Limeburners Creek. As noted clearly throughout this report, results were compared to these standards to put them in context, however, Limeburners Creek is designated as a 'mixing zone for major discharges', which is a continuation of the status Limeburners Creek has held since the inception of the WWTP. Therefore, the water quality in Limeburners Creek is not required to meet the water quality standards for the Hātea River coastal water quality management unit. It may be expected, however, that concentrations at the mouth of Limeburners Creek are within, or very close to the Hātea water quality management unit coastal water quality standards. Previous sampling by 4Sight and NRC shows that locations on the Hātea River near the mouth of Limeburners Creek are generally within the NRC coastal water quality standards and that there were no obvious 'step changes' in water quality.[5] The contribution of the WWTP discharge via Limeburners Creek into the Hātea River is one of many ecological stressors in the upper Hātea environment. On this basis, it appears that reasonable mixing of the WWTP discharge has occurred within Limeburners Creek so that water quality in the Hātea River does not exceed the required standards.

5 CONCLUSIONS

- There were substantial reductions in the concentration of nutrients (total ammonia and phosphorus and ammoniacal nitrogen) and CBOD from the WWTP Outflow to the mouth of Limeburners Creek.
- Turbidity was higher in Limeburners Creek than in the Outflow or treatment wetlands. Increases in turbidity/suspended solids are common at freshwater/marine interfaces where particles can be resuspended and dissolved chemical species precipitated out due to salinity changes.
- There were no notable differences in chlorophyll-a or enterococci concentrations among all sites.
- Dissolved oxygen concentrations decreased in the treatment wetlands compared to the WWTP outflow. This is likely a result of the high CBOD of the WWTP discharge and the relatively slow-moving waters in the treatment wetlands. Oxygen concentrations subsequently increase beyond the treatment wetlands and within the Limeburners Creek mixing zone.
- During summer, chlorophyll-a concentrations remained high and nutrient concentrations decreased. Such a decrease in nutrients could be a result of the uptake of nutrients by phytoplankton growth.
- Ammonia concentrations at Limeburners Mouth exceeded the chronic toxicity guideline value on three out of six sampling occasions between May and October. Ammonia concentrations appear to decrease markedly after mixing with the Hātea River such that they comply with the Hātea water quality management unit coastal water quality standard, which is an order of magnitude lower than the toxicity guideline.
- Nutrient and chlorophyll-a concentrations at Limeburners Mouth frequently exceed the NRC coastal water quality standards. Limeburners Creek is designated as a mixing zone and, therefore, water quality is not required to meet this standard.
- The contribution of the WWTP discharge via Limeburners Creek into the Hātea River is one of many ecological stressors in the upper Hātea environment. Additional monitoring by 4Sight and NRC have shown that water

[3] Maximum concentration of 1.88 mg/L [at pH 8.0] on 1/10/2020.

[4] Wilson, P. 2020. Whangarei Wastewater Treatment Plant: Baseline Ecological Survey 2020. 4Sight Report prepared for Whangarei District Council. 36 p.

[5] Wilson, P. 2020. Whangarei Wastewater Treatment Plant: Baseline Ecological Survey 2020. 4Sight Report prepared for Whangarei District Council. 36 p.

quality in the Hātea River near the moth of Limeburners Creek is typically within the coastal water quality standard and that there are no ‘step changes’ in water quality near the confluence of Limeburners Creek and the Hātea River. Based on this, the discharge from Limeburners Creek does not appear to be causing the Hātea River to exceed the required water quality standards.

Appendix A:

Water Quality Monitoring Locations

1 : 5000 @A3

0 100 200 m

AA2789 - WDC WWTP

Water Quality Monitoring Locations

Prepared for Whangarei District Council by 4Sight Consulting

- Wetland Inflow
- Wetland Outflow
- Discharge to LB
- LB Mixed

Date: 11/03/2021
Version:1.0
Author: PW
Checked: MP
Approved: MP

4SIGHT CONSULTING

Appendix B:

Scatter Plots of All Water Quality Data

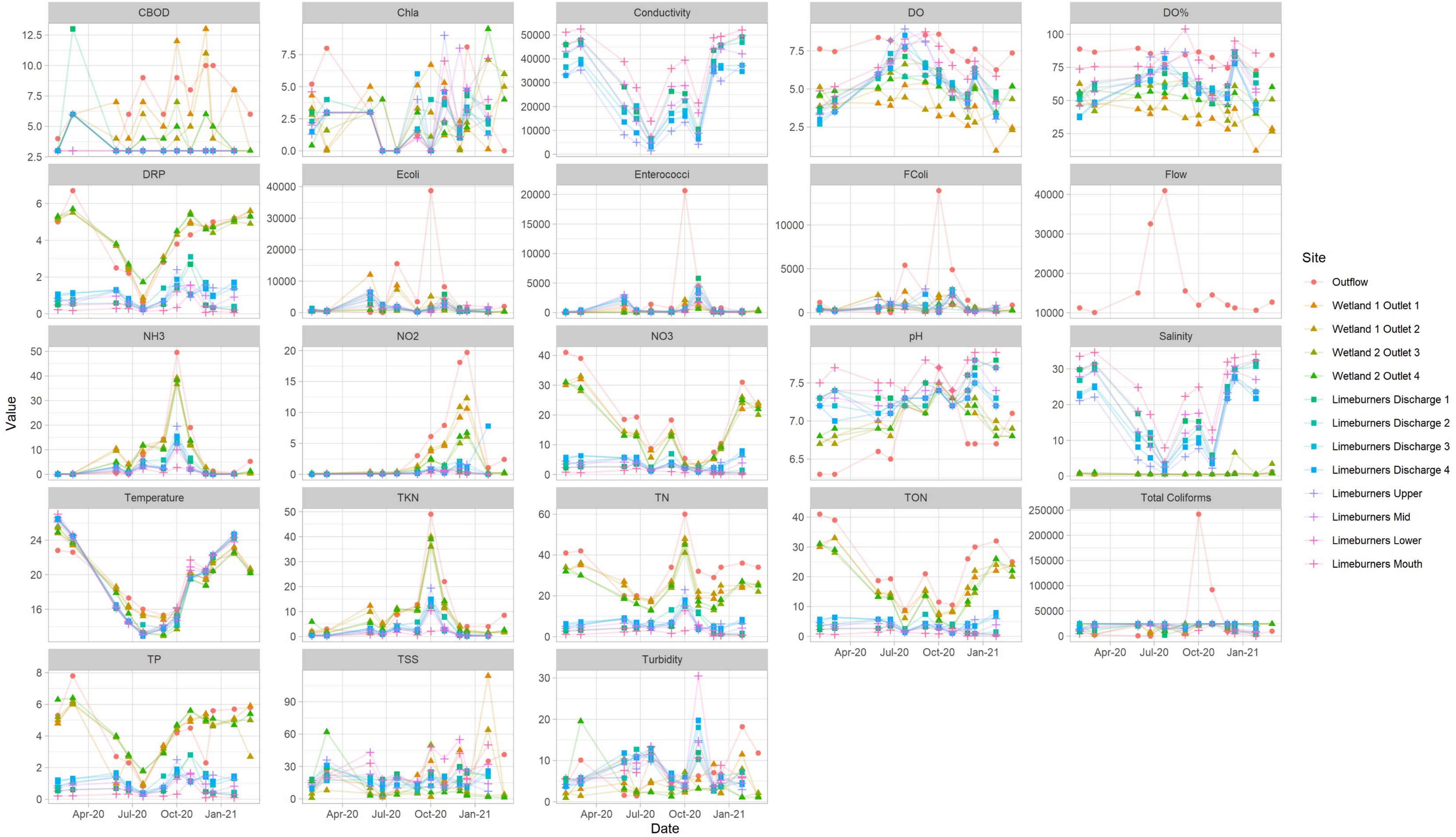

Figure B1: Scatter plots of all water quality data.

Appendix C:

Laboratory Reports

Whangarei District Laboratory
79 Kioreroa Road, Private Bag 9023, Whangarei 0148, New Zealand
P +64 9 430 4220 E wdclaboratory@wdc.govt.nz
www.wdc.govt.nz

Hai Hguyen
WDC Wastewater Treatment
Kioreroa Rd
Private Bag 9023
Whangarei

Laboratory Analysis Report

Sample Information

Batch	2001B183
Site Name	Limeburners Creek Water Quality
Customer Reference	
Sampled By	.Customer
Sample Received	29/01/2020 11:53 AM

Results

Sample Reference		Wetland Inflow	Wetland 1 Outlet 1	Wetland 1 Outlet 2	Wetland 2 Outlet 3
Secondary Reference		ca	da	db	dc
Notes					
Our Reference		20010700	20010701	20010702	20010703
Sample Collection		28/01/2020 10:38 AM	28/01/2020 11:11 AM	28/01/2020 11:03 AM	28/01/2020 11:34 AM
Ammonia (ISE LR)					
Reported Result	mg/L	**0.126**	**0.262**	**0.191**	**0.090**
Chlorophyll a (Trace).					
Reported Result	mg/L	**0.0052**	**0.043**	**0.033**	**0.0028**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**1071**	**591**	**368**	**228**
Total Coliforms					
Reported Result	MPN/100mL	**11199**	**>24196**	**>24196**	**>24196**
Enterococci (97w)					
Reported Result	MPN/100mL	**160**	**199**	**41**	**41**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**1172**	**600**	**340**	**230**
Flow (m3/d)					
reported result	m3/d	**11233**	**-**	**-**	**-**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**41.000**	**30.000**	**31.000**	**31.000**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**0.059**	**0.140**	**0.15**	**0.101**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**2.1**	**2.0**	**1.64**	**1.45**
Nitrogen (Total Oxidised)	mg/L	**41**	**30**	**31**	**31**
Nitrogen (Total)	mg/L	**41**	**32**	**32**	**34**
Oxygen (% Dissolved)					
Reported Result	%	**88.8**	**46.8**	**62.7**	**55.8**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**7.63**	**3.87**	**5.12**	**4.53**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**4**	**<3**	**<3**	**<3**
pH					
Reported Result	pH Units	**6.3**	**6.7**	**6.8**	**6.7**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**5.0**	**5.3**	**5.1**	**5.2**
Phosphorus (Total Trace).					
Reported Result	mg/L	**5.3**	**4.8**	**5.0**	**5.2**
Salinity					
Reported Result	ppt	**0.8**	**0.8**	**<0.5**	**0.8**
Solids (Suspended)					
Reported Result	mg/L	**9**	**5**	**5**	**<1.0**
Temperature Field					
Reported Result	°C	**22.8**	**24.8**	**25.4**	**25.6**
Turbidity					
Reported Result	NTU	**3.97**	**2.04**	**2.13**	**0.972**

Sample Reference		Wetland 2 Outlet 4	Limeburners Discharge 1	Limeburners Discharge 2	Limeburners Discharge 3
Secondary Reference		de	ea	eb	ec
Notes					
Our Reference		20010704	20010705	20010706	20010707
Sample Collection		28/01/2020 11:43 AM	28/01/2020 1:44 PM	28/01/2020 1:37 PM	28/01/2020 1:14 PM
Ammonia (ISE LR)					
Reported Result	mg/L	**0.092**	**0.051**	**0.054**	**0.075**
Chlorophyll a (Trace).					
Reported Result	mg/L	**0.42**	**0.0030**	**0.0023**	**0.0015**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**529**	**1002**	**1388**	**512**
Total Coliforms					
Reported Result	MPN/100mL	**>24196**	**8164**	**14136**	**>24196**
Conductivity Field					
Reported Result	µs/cm	**-**	**46004**	**41578**	**36534**
Enterococci (97w)					
Reported Result	MPN/100mL	**142**	**73**	**14**	**183**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**460**	**380**	**609**	**350**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**31.000**	**2.300**	**3.600**	**5.800**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**0.105**	**0.027**	**0.035**	**0.056**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**5.9**	**0.41**	**0.46**	**0.51**
Nitrogen (Total Oxidised)	mg/L	**31**	**2.3**	**3.7**	**5.8**
Nitrogen (Total)	mg/L	**32**	**2.8**	**4.1**	**6.3**
Oxygen (% Dissolved)					
Reported Result	%	**56.1**	**54.8**	**50.8**	**38.2**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**4.62**	**3.72**	**3.51**	**2.71**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**<3**	**<3**	**<3**	**<3**
pH					
Reported Result	pH Units	**6.8**	**7.3**	**7.3**	**7.2**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**5.3**	**0.49**	**0.72**	**1.07**
Phosphorus (Total Trace).					
Reported Result	mg/L	**6.3**	**0.55**	**0.77**	**1.21**
Salinity					
Reported Result	ppt	**0.8**	**29.8**	**26.8**	**23.1**
Solids (Suspended)					
Reported Result	mg/L	**16**	**18**	**9**	**10**
Temperature Field					
Reported Result	°C	**24.9**	**26.5**	**26.4**	**26.4**
Turbidity					
Reported Result	NTU	**3.91**	**5.60**	**4.74**	**4.05**

Sample Reference		Limeburners Discharge 4	Limeburners Upper	Limeburners Mid	Limeburners Lower
Secondary Reference		ed	fa	fb	fd
Notes					
Our Reference		20010708	20010709	20010710	20010711
Sample Collection		28/01/2020 1:04 PM	28/01/2020 12:49 PM	28/01/2020 1:27 PM	28/01/2020 1:58 PM
Ammonia (ISE LR)					
Reported Result	mg/L	**0.072**	**0.050**	**0.041**	**<0.02**
Chlorophyll a (Trace).					
Reported Result	mg/L	**0.0015**	**0.0013**	**0.0020**	**0.0022**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**657**	**320**	**892**	**914**
Total Coliforms					
Reported Result	MPN/100mL	**14136**	**14136**	**12033**	**9804**
Conductivity Field					
Reported Result	µs/cm	**33085**	**33324**	**43108**	**46166**
Enterococci (97w)					
Reported Result	MPN/100mL	**121**	**95**	**161**	**85**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**400**	**200**	**500**	**370**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**5.300**	**4.500**	**3.500**	**2.300**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**0.053**	**0.052**	**0.037**	**0.027**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**0.59**	**0.40**	**0.43**	**0.37**
Nitrogen (Total Oxidised)	mg/L	**5.3**	**4.6**	**3.5**	**2.3**
Nitrogen (Total)	mg/L	**5.9**	**5.0**	**3.9**	**2.7**
Oxygen (% Dissolved)					
Reported Result	%	**37.1**	**46.1**	**49.6**	**55.8**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**2.99**	**3.32**	**3.42**	**3.78**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**<3**	**<3**	**<3**	**<3**
pH					
Reported Result	pH Units	**7.2**	**7.2**	**7.3**	**7.3**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**0.98**	**0.85**	**0.69**	**0.48**
Phosphorus (Total Trace).					
Reported Result	mg/L	**1.12**	**0.86**	**0.71**	**0.52**
Salinity					
Reported Result	ppt	**22.4**	**21.1**	**27.8**	**29.9**
Solids (Suspended)					
Reported Result	mg/L	**10**	**13**	**11**	**17**
Temperature Field					
Reported Result	°C	**26.5**	**26.1**	**26.3**	**26.6**
Turbidity					
Reported Result	NTU	**3.75**	**3.35**	**4.20**	**5.67**

Sample Reference		Limeburners Mouth
Secondary Reference		fd
Notes		
Our Reference		20010712
Sample Collection		28/01/2020 2:06 PM
Ammonia (ISE LR)		
Reported Result	mg/L	**<0.02**
Chlorophyll a (Trace).		
Reported Result	mg/L	**0.0046**
Escherichia coli (E. coli)		
Reported Result	MPN/100mL	**679**
Total Coliforms		
Reported Result	MPN/100mL	**4884**
Conductivity Field		
Reported Result	µs/cm	**51149**
Enterococci (97w)		
Reported Result	MPN/100mL	**10**
Faecal Coliform (Presumptive)		
Reported Result	cfu/100mL	**200**
Nitrogen (Nitrate Trace).		
Reported Result	mg/L	**0.790**
Nitrogen (Nitrite Trace).		
Reported Result	mg/L	**0.0125**
Nitrogen (Total Trace).		
Nitrogen (Total Kjeldahl)	mg/L	**0.31**
Nitrogen (Total Oxidised)	mg/L	**0.81**
Nitrogen (Total)	mg/L	**1.12**
Oxygen (% Dissolved)		
Reported Result	%	**73.7**
Oxygen (Field Dissolved)		
Reported Result	mg/L	**4.87**
Oxygen Demand (Carbonaceous Biochemical)		
Reported Result	mg/L	**<3**
pH		
Reported Result	pH Units	**7.5**
Phosphorus (Dissolved Reactive).		
Reported Result	mg/L	**0.22**
Phosphorus (Total Trace).		
Reported Result	mg/L	**0.21**
Salinity		
Reported Result	ppt	**33.5**
Solids (Suspended)		
Reported Result	mg/L	**15**
Temperature Field		
Reported Result	°C	**27.0**
Turbidity		
Reported Result	NTU	**5.48**

Test Method Information

Method	*Reference*	*Method Type*
Salinity	APHA 2520 B	Not Accredited
pH	APHA Section 4500 H+ B	IANZ
Solids (Suspended)	APHA Section 2540 D	IANZ
Phosphorus (Dissolved Reactive).	APHA 4500 P E	Subcontracted
Faecal Coliform (Presumptive)	APHA section 9222D	IANZ
Enterococci (97w)	APHA 9230 D	IANZ
Escherichia coli (E. coli)	APHA Section 9223 B (Colilert)	IANZ
Total Coliforms	APHA Section 9223 B (Colilert)	IANZ
Oxygen Demand (Carbonaceous Biochemical)	APHA Section 5210B	IANZ
Temperature Field	APHA 2550 B	IANZ
Oxygen (% Dissolved)	APHA Section 4500 E	Not Accredited
Flow (m3/d)	NA	Not Accredited
Nitrogen (Nitrate Trace).	APHA 4500NO3 I	Subcontracted
Nitrogen (Nitrite Trace).	APHA 4500NO3 I	Subcontracted
Nitrogen (Total Trace).	Calc:TKN+TON	Subcontracted
Phosphorus (Total Trace).	APHA 4500P E	Subcontracted
Oxygen (Field Dissolved)	APHA Section 4500 E	Not Accredited
Ammonia (ISE LR)	APHA Section 4500-N D	IANZ
Turbidity	ISO7027-1:2016	IANZ
Chlorophyll a (Trace).	APHA 10200 H Fluorometer	Subcontracted
Conductivity Field	APHA 2510 B	IANZ

End of Report

Results are based on sample(s) as received, every effort is made to ensure these results are accurate. This report may not be reproduced except in full, without written consent of the signatory. Analysis is certified correct by the Key Technical Personnel.

Signed Lois H Howe Lois Howe

Reported 10/02/2020 3:40 PM

IANZ ACCREDITED LABORATORY

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The tests specified in this report have been performed in accordance with IANZ terms of accreditation.

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Laboratory Analysis Report

Sample Information

Batch	2101B179
Site Name	Limeburners Creek Water Quality
Customer Reference	
Sampled By	.Customer
Sample Received	28/01/2021 12:14 PM

Results

Sample Reference		Wetland Inflow	Wetland 1 Outlet 1	Wetland 1 Outlet 2	Wetland 2 Outlet 3
Secondary Reference		ca	da	db	dc
Notes					
Our Reference		21010694	21010695	21010696	21010697
Sample Collection		28/01/2021 8:00 AM			
Ammonia (ISE LR)					
Reported Result	mg/L	**0.677**	**0.274**	**0.165**	**0.094**
Chlorophyll a (Trace).					
Reported Result	mg/L	**0.023**	**0.127**	**0.025**	**0.0071**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**520**	**121**	**74**	**86**
Total Coliforms					
Reported Result	MPN/100mL	**3255**	**>24196**	**>24196**	**>24196**
Enterococci (97w)					
Reported Result	MPN/100mL	**259**	**10**	**63**	**121**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**280**	**260**	**200**	**127**
Flow (m3/d)					
reported result	m3/d	**10626**	**-**	**-**	**-**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**31**	**22**	**24**	**26**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**1.07**	**0.28**	**0.195**	**0.176**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**4.0**	**1.65**	**1.62**	**1.32**
Nitrogen (Total Oxidised)	mg/L	**32**	**22**	**24**	**26**
Nitrogen (Total)	mg/L	**36**	**24**	**25**	**27**
Oxygen (% Dissolved)					
Reported Result	%	**72.5**	**12.0**	**40.2**	**49.3**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**6.26**	**0.94**	**3.47**	**4.28**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**8**	**8**	**3**	**<3**
pH					
Reported Result	pH Units	**6.7**	**6.8**	**7.0**	**6.9**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**5.2**	**5.1**	**5.2**	**5.0**
Phosphorus (Total Trace).					
Reported Result	mg/L	**5.7**	**5.1**	**5.0**	**5.0**
Salinity					
Reported Result	ppt	**0.5**	**0.5**	**0.5**	**0.5**
Solids (Suspended)					
Reported Result	mg/L	**35**	**114**	**64**	**3**
Temperature Field					
Reported Result	°C	**22.9**	**23.2**	**23.2**	**22.4**
Turbidity					
Reported Result	NTU	**18.2**	**11.5**	**7.93**	**1.15**

Sample Reference		Wetland 2 Outlet 4	Limeburners Discharge 1	Limeburners Discharge 2	Limeburners Discharge 3
Secondary Reference		de	ea	eb	ec
Notes					
Our Reference		21010698	21010699	21010700	21010701
Sample Collection					
Ammonia (ISE LR)					
Reported Result	mg/L	**0.084**	**0.113**	**0.111**	**0.129**
Chlorophyll a (Trace).					
Reported Result	mg/L	**0.0095**	**0.0034**	**0.0021**	**0.0014**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**84**	**1223**	**1031**	**311**
Total Coliforms					
Reported Result	MPN/100mL	**>24196**	**2909**	**8664**	**17329**
Conductivity Field					
Reported Result	µs/cm	**-**	**49200**	**46900**	**37300**
Enterococci (97w)					
Reported Result	MPN/100mL	**132**	**74**	**30**	**199**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**100**	**590**	**600**	**190**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**25**	**0.62**	**1.48**	**6.7**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**0.188**	**0.0100**	**0.0162**	**0.045**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**1.34**	**0.2**	**0.2**	**0.5**
Nitrogen (Total Oxidised)	mg/L	**26**	**0.63**	**1.50**	**6.7**
Nitrogen (Total)	mg/L	**27**	**0.9**	**1.7**	**7.2**
Oxygen (% Dissolved)					
Reported Result	%	**39.9**	**69.3**	**63.3**	**47.1**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**3.43**	**4.79**	**4.43**	**3.41**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**<3**	**<3**	**<3**	**<3**
pH					
Reported Result	pH Units	**6.8**	**7.8**	**7.7**	**7.3**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**5.1**	**0.22**	**0.40**	**1.40**
Phosphorus (Total Trace).					
Reported Result	mg/L	**4.7**	**0.25**	**0.44**	**1.30**
Salinity					
Reported Result	ppt	**0.5**	**32.1**	**30.7**	**23.6**
Solids (Suspended)					
Reported Result	mg/L	**2**	**22**	**21**	**23**
Temperature Field					
Reported Result	°C	**22.6**	**24.2**	**24.3**	**24.5**
Turbidity					
Reported Result	NTU	**1.01**	**7.10**	**7.36**	**4.62**

Sample Reference		Limeburners Discharge 4	Limeburners Upper	Limeburners Mid	Limeburners Lower
Secondary Reference		ed	fa	fb	fd
Notes					
Our Reference		21010702	21010703	21010704	21010705
Sample Collection					
Ammonia (ISE LR)					
Reported Result	mg/L	**0.108**	**0.129**	**0.095**	**0.055**
Chlorophyll a (Trace).					
Reported Result	mg/L	**0.0024**	**0.0012**	**0.0027**	**0.0040**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**367**	**230**	**1388**	**1780**
Total Coliforms					
Reported Result	MPN/100mL	**>24196**	**19863**	**9208**	**7270**
Conductivity Field					
Reported Result	µs/cm	**34700**	**37200**	**42100**	**49600**
Enterococci (97w)					
Reported Result	MPN/100mL	**259**	**249**	**86**	**98**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**240**	**140**	**830**	**520**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**7.9**	**5.9**	**3.9**	**0.54**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**7.8**	**0.049**	**0.031**	**0.0099**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**0.5**	**0.4**	**0.3**	**0.3**
Nitrogen (Total Oxidised)	mg/L	**7.9**	**5.9**	**3.9**	**0.55**
Nitrogen (Total)	mg/L	**8.3**	**6.4**	**4.2**	**0.8**
Oxygen (% Dissolved)					
Reported Result	%	**42.5**	**43.2**	**56.2**	**58.7**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**3.15**	**3.02**	**4.02**	**4.13**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**<3**	**<3**	**<3**	**<3**
pH					
Reported Result	pH Units	**7.2**	**7.2**	**7.4**	**7.7**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**1.71**	**1.36**	**0.91**	**0.196**
Phosphorus (Total Trace).					
Reported Result	mg/L	**1.46**	**1.24**	**0.82**	**0.28**
Salinity					
Reported Result	ppt	**21.7**	**23.6**	**27.0**	**32.3**
Solids (Suspended)					
Reported Result	mg/L	**26**	**7**	**14**	**32**
Temperature Field					
Reported Result	°C	**24.7**	**24.7**	**24.3**	**23.8**
Turbidity					
Reported Result	NTU	**4.22**	**2.94**	**4.50**	**6.07**

Sample Reference		Limeburners Mouth
Secondary Reference		fd
Notes		
Our Reference		21010706
Sample Collection		
Ammonia (ISE LR)		
Reported Result	mg/L	**0.030**
Chlorophyll a (Trace).		
Reported Result	mg/L	**0.0072**
Escherichia coli (E. coli)		
Reported Result	MPN/100mL	**97**
Total Coliforms		
Reported Result	MPN/100mL	**512**
Conductivity Field		
Reported Result	µs/cm	**52100**
Enterococci (97w)		
Reported Result	MPN/100mL	**<10**
Faecal Coliform (Presumptive)		
Reported Result	cfu/100mL	**50**
Nitrogen (Nitrate Trace).		
Reported Result	mg/L	**0.107**
Nitrogen (Nitrite Trace).		
Reported Result	mg/L	**0.0035**
Nitrogen (Total Trace).		
Nitrogen (Total Kjeldahl)	mg/L	**0.5**
Nitrogen (Total Oxidised)	mg/L	**0.110**
Nitrogen (Total)	mg/L	**0.6**
Oxygen (% Dissolved)		
Reported Result	%	**85.8**
Oxygen (Field Dissolved)		
Reported Result	mg/L	**5.83**
Oxygen Demand (Carbonaceous Biochemical)		
Reported Result	mg/L	**<3**
pH		
Reported Result	pH Units	**7.9**
Phosphorus (Dissolved Reactive).		
Reported Result	mg/L	**0.068**
Phosphorus (Total Trace).		
Reported Result	mg/L	**0.098**
Salinity		
Reported Result	ppt	**34.1**
Solids (Suspended)		
Reported Result	mg/L	**50**
Temperature Field		
Reported Result	°C	**24.3**
Turbidity		
Reported Result	NTU	**5.76**

Test Method Information

Method	*Reference*	*Method Type*
Chlorophyll a (Trace).	APHA 10200 H Fluorometer	Subcontracted
Ammonia (ISE LR)	APHA Section 4500-N D	IANZ
Turbidity	ISO7027-1:2016	IANZ
Phosphorus (Total Trace).	APHA 4500P E	Subcontracted
Oxygen (Field Dissolved)	APHA Section 4500 E	Not Accredited
Nitrogen (Nitrite Trace).	APHA 4500NO3 I	Subcontracted
Nitrogen (Total Trace).	Calc:TKN+TON	Subcontracted
Flow (m3/d)	NA	Not Accredited
Nitrogen (Nitrate Trace).	APHA 4500NO3 I	Subcontracted
Oxygen (% Dissolved)	APHA Section 4500 E	Not Accredited
Temperature Field	APHA 2550 B	IANZ
Salinity	APHA 2520 B	Not Accredited
Total Coliforms	APHA Section 9223 B (Colilert)	IANZ
Oxygen Demand (Carbonaceous Biochemical)	APHA Section 5210B	IANZ
Enterococci (97w)	APHA 9230 D	IANZ
Escherichia coli (E. coli)	APHA Section 9223 B (Colilert)	IANZ
Phosphorus (Dissolved Reactive).	APHA 4500 P E	Subcontracted
Faecal Coliform (Presumptive)	APHA section 9222D	IANZ
pH	APHA Section 4500 H+ B	IANZ
Solids (Suspended)	APHA Section 2540 D	IANZ
Conductivity Field	APHA 2510 B	IANZ

End of Report

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Signed Lois Howe

Reported 12/02/2021 3:34 PM

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Hai Hguyen
WDC Wastewater Treatment
Kioreroa Rd
Private Bag 9023
Whangarei

Laboratory Analysis Report

Sample Information

Batch	2012B117
Site Name	Limeburners Creek Water Quality
Customer Reference	
Sampled By	.Customer
Sample Received	15/12/2020 3:22 PM

Results

Sample Reference		Wetland Inflow	Wetland 1 Outlet 1	Wetland 1 Outlet 2	Wetland 2 Outlet 3
Secondary Reference		ca	da	db	dc
Notes					
Our Reference		20120390	20120391	20120392	20120393
Sample Collection		15/12/2020 8:00 AM			
Ammonia (ISE LR)					
Reported Result	mg/L	**1.327**	**0.608**	**0.807**	**0.168**
Chlorophyll a (Trace).					
Reported Result	mg/L	**0.0081**	**0.0182**	**0.0163**	**0.022**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**1483**	**369**	**657**	**933**
Total Coliforms					
Reported Result	MPN/100mL	**9208**	**>24196**	**>24196**	**>24196**
Enterococci (97w)					
Reported Result	MPN/100mL	**794**	**52**	**161**	**228**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**600**	**320**	**600**	**570**
Flow (m3/d)					
reported result	m3/d	**11244**	**-**	**-**	**-**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**10.4**	**9.2**	**9.9**	**8.5**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**19.7**	**10.6**	**12.3**	**6.1**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**4.0**	**2.2**	**2.6**	**1.40**
Nitrogen (Total Oxidised)	mg/L	**30**	**19.8**	**22**	**14.6**
Nitrogen (Total)	mg/L	**34**	**22**	**25**	**16.0**
Oxygen (% Dissolved)					
Reported Result	%	**84.3**	**43.6**	**31.8**	**61.0**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**7.62**	**3.86**	**2.80**	**5.17**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**10**	**4**	**4**	**5**
pH					
Reported Result	pH Units	**6.7**	**7.1**	**7.1**	**7.3**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**5.0**	**4.8**	**4.7**	**4.4**
Phosphorus (Total Trace).					
Reported Result	mg/L	**5.6**	**4.7**	**4.7**	**4.6**
Salinity					
Reported Result	ppt	**0.8**	**0.6**	**0.7**	**6.5**
Solids (Suspended)					
Reported Result	mg/L	**12**	**4**	**7**	**5**
Temperature Field					
Reported Result	°C	**20.4**	**21.3**	**21.3**	**21.6**
Turbidity					
Reported Result	NTU	**6.69**	**2.19**	**2.06**	**3.55**

Sample Reference		Wetland 2 Outlet 4	Limeburners Discharge 1	Limeburners Discharge 2	Limeburners Discharge 3
Secondary Reference		de	ea	eb	ec
Notes					
Our Reference		20120394	20120395	20120396	20120397
Sample Collection					
Ammonia (ISE LR)					
Reported Result	mg/L	**0.186**	**0.027**	**<0.02**	**0.092**
Chlorophyll a (Trace).					
Reported Result	mg/L	**0.0184**	**0.0043**	**0.0031**	**0.0034**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**323**	**780**	**696**	**520**
Total Coliforms					
Reported Result	MPN/100mL	**>24196**	**14136**	**8164**	**>24196**
Conductivity Field					
Reported Result	µs/cm	**-**	**45700**	**45500**	**37100**
Enterococci (97w)					
Reported Result	MPN/100mL	**187**	**85**	**96**	**161**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**450**	**210**	**210**	**200**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**9.3**	**0.64**	**0.65**	**2.3**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**6.7**	**0.27**	**0.23**	**1.04**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**2.0**	**0.2**	**0.3**	**0.5**
Nitrogen (Total Oxidised)	mg/L	**16.1**	**0.91**	**0.89**	**3.4**
Nitrogen (Total)	mg/L	**18.1**	**1.2**	**1.2**	**3.8**
Oxygen (% Dissolved)					
Reported Result	%	**55.6**	**83.3**	**86.8**	**77.9**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**5.00**	**6.09**	**6.35**	**5.79**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**5**	**<3**	**<3**	**<3**
pH					
Reported Result	pH Units	**7.2**	**7.7**	**7.8**	**7.5**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**4.7**	**0.34**	**0.34**	**0.94**
Phosphorus (Total Trace).					
Reported Result	mg/L	**5.1**	**0.38**	**0.39**	**0.91**
Salinity					
Reported Result	ppt	**0.6**	**29.8**	**29.9**	**27.9**
Solids (Suspended)					
Reported Result	mg/L	**3**	**24**	**26**	**10**
Temperature Field					
Reported Result	°C	**20.4**	**22.0**	**22.2**	**22.3**
Turbidity					
Reported Result	NTU	**4.21**	**6.14**	**3.61**	**3.66**

Sample Reference		Limeburners Discharge 4	Limeburners Upper	Limeburners Mid	Limeburners Lower
Secondary Reference		ed	fa	fb	fd
Notes					
Our Reference		20120398	20120399	20120400	20120401
Sample Collection					
Ammonia (ISE LR)					
Reported Result	mg/L	**0.080**	**0.110**	**<0.02**	**<0.02**
Chlorophyll a (Trace).					
Reported Result	mg/L	**0.0047**	**0.0028**	**0.0049**	**0.0032**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**422**	**450**	**381**	**2352**
Total Coliforms					
Reported Result	MPN/100mL	**>24196**	**>24196**	**14136**	**10462**
Conductivity Field					
Reported Result	µs/cm	**36100**	**30700**	**44100**	**46100**
Enterococci (97w)					
Reported Result	MPN/100mL	**211**	**336**	**109**	**156**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**130**	**300**	**60**	**154**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**2.5**	**4.0**	**0.87**	**0.62**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**1.12**	**1.60**	**0.39**	**0.34**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**0.4**	**0.6**	**0.3**	**0.3**
Nitrogen (Total Oxidised)	mg/L	**3.6**	**5.6**	**1.26**	**0.96**
Nitrogen (Total)	mg/L	**4.1**	**6.2**	**1.6**	**1.3**
Oxygen (% Dissolved)					
Reported Result	%	**77.9**	**80.1**	**83.7**	**88.2**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**5.85**	**5.98**	**6.16**	**6.40**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**<3**	**<3**	**<3**	**<3**
pH					
Reported Result	pH Units	**7.6**	**7.5**	**7.8**	**7.8**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**1.00**	**1.41**	**0.41**	**0.33**
Phosphorus (Total Trace).					
Reported Result	mg/L	**1.13**	**1.53**	**0.47**	**0.39**
Salinity					
Reported Result	ppt	**27.3**	**26.8**	**29.3**	**30.8**
Solids (Suspended)					
Reported Result	mg/L	**11**	**14**	**18**	**26**
Temperature Field					
Reported Result	°C	**22.3**	**22.3**	**22.3**	**22.3**
Turbidity					
Reported Result	NTU	**5.76**	**6.65**	**4.56**	**5.21**

Sample Reference		Limeburners Mouth
Secondary Reference		fd
Notes		
Our Reference		20120402
Sample Collection		
Ammonia (ISE LR)		
Reported Result	mg/L	**<0.02**
Chlorophyll a (Trace).		
Reported Result	mg/L	**0.0047**
Escherichia coli (E. coli)		
Reported Result	MPN/100mL	**608**
Total Coliforms		
Reported Result	MPN/100mL	**5172**
Conductivity Field		
Reported Result	µs/cm	**49400**
Enterococci (97w)		
Reported Result	MPN/100mL	**41**
Faecal Coliform (Presumptive)		
Reported Result	cfu/100mL	**90**
Nitrogen (Nitrate Trace).		
Reported Result	mg/L	**0.192**
Nitrogen (Nitrite Trace).		
Reported Result	mg/L	**0.088**
Nitrogen (Total Trace).		
Nitrogen (Total Kjeldahl)	mg/L	**0.4**
Nitrogen (Total Oxidised)	mg/L	**0.28**
Nitrogen (Total)	mg/L	**0.6**
Oxygen (% Dissolved)		
Reported Result	%	**94.9**
Oxygen (Field Dissolved)		
Reported Result	mg/L	**6.82**
Oxygen Demand (Carbonaceous Biochemical)		
Reported Result	mg/L	**<3**
pH		
Reported Result	pH Units	**7.9**
Phosphorus (Dissolved Reactive).		
Reported Result	mg/L	**0.125**
Phosphorus (Total Trace).		
Reported Result	mg/L	**0.159**
Salinity		
Reported Result	ppt	**33.1**
Solids (Suspended)		
Reported Result	mg/L	**19**
Temperature Field		
Reported Result	°C	**22.2**
Turbidity		
Reported Result	NTU	**8.85**

Test Method Information

Method	*Reference*	*Method Type*
Chlorophyll a (Trace).	APHA 10200 H Fluorometer	Subcontracted
Ammonia (ISE LR)	APHA Section 4500-N D	IANZ
Turbidity	ISO7027-1:2016	IANZ
Phosphorus (Total Trace).	APHA 4500P E	Subcontracted
Oxygen (Field Dissolved)	APHA Section 4500 E	Not Accredited
Nitrogen (Nitrite Trace).	APHA 4500NO3 I	Subcontracted
Nitrogen (Total Trace).	Calc:TKN+TON	Subcontracted
Flow (m3/d)	NA	Not Accredited
Nitrogen (Nitrate Trace).	APHA 4500NO3 I	Subcontracted
Oxygen (% Dissolved)	APHA Section 4500 E	Not Accredited
Temperature Field	APHA 2550 B	IANZ
Salinity	APHA 2520 B	Not Accredited
Total Coliforms	APHA Section 9223 B (Colilert)	IANZ
Oxygen Demand (Carbonaceous Biochemical)	APHA Section 5210B	IANZ
Enterococci (97w)	APHA 9230 D	IANZ
Escherichia coli (E. coli)	APHA Section 9223 B (Colilert)	IANZ
Phosphorus (Dissolved Reactive).	APHA 4500 P E	Subcontracted
Faecal Coliform (Presumptive)	APHA section 9222D	IANZ
pH	APHA Section 4500 H+ B	IANZ
Solids (Suspended)	APHA Section 2540 D	IANZ
Conductivity Field	APHA 2510 B	IANZ

End of Report

Results are based on sample(s) as received, every effort is made to ensure these results are accurate. This report may not be reproduced except in full, without written consent of the signatory. Analysis is certified correct by the Key Technical Personnel. Dates of testing are available on request. Please contact the laboratory for more information.

Signed Jeremy Taylor

Reported 7/01/2021 11:52 AM

IANZ ACCREDITED LABORATORY

This Laboratory is accredited by International Accreditation New Zealand.
The tests specified in this report have been performed in accordance with IANZ terms of accreditation.

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Laboratory Analysis Report

Sample Information

Batch	2011B231
Site Name	Limeburners Creek Water Quality
Customer Reference	
Sampled By	.Customer
Sample Received	30/11/2020 11:14 AM

Results

Sample Reference		Wetland Inflow	Wetland 1 Outlet 1	Wetland 1 Outlet 2	Wetland 2 Outlet 3
Secondary Reference		ca	da	db	dc
Notes			Vegetation in sample		
Our Reference		20110723	20110724	20110725	20110726
Sample Collection		30/11/2020 8:30 AM	30/11/2020 8:47 AM	30/11/2020 8:53 AM	30/11/2020 9:10 AM
Ammonia (ISE LR)					
Reported Result	mg/L	**0.850**	**2.847**	**2.818**	**0.726**
Chlorophyll a (Trace).					
Reported Result	mg/L	**0.0019**	**0.17**	**0.0023**	**0.030**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**1674**	**315**	**465**	**203**
Total Coliforms					
Reported Result	MPN/100mL	**9208**	**>24196**	**14136**	**>24196**
Enterococci (97w)					
Reported Result	MPN/100mL	**624**	**187**	**52**	**173**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**1409**	**480**	**400**	**220**
Flow (m3/d)					
reported result	m3/d	**11957**	**-**	**-**	**-**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**7.5**	**5.1**	**5.4**	**5.6**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**18.1**	**9.2**	**10.9**	**5.0**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**3.1**	**4.3**	**4.3**	**2.3**
Nitrogen (Total Oxidised)	mg/L	**26**	**14.3**	**16.3**	**10.6**
Nitrogen (Total)	mg/L	**29**	**18.6**	**21**	**12.9**
Oxygen (% Dissolved)					
Reported Result	%	**74.4**	**28.2**	**41.6**	**34.7**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**6.82**	**2.57**	**3.80**	**3.12**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**10**	**13**	**11**	**6**
pH					
Reported Result	pH Units	**6.7**	**7.4**	**7.1**	**7.2**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**4.7**	**4.7**	**4.7**	**4.6**
Phosphorus (Total Trace).					
Reported Result	mg/L	**2.3**	**5.4**	**5.2**	**4.9**
Salinity					
Reported Result	ppt	**0.5**	**0.5**	**<0.5**	**0.5**
Solids (Suspended)					
Reported Result	mg/L	**17**	**45**	**10**	**18**
Temperature Field					
Reported Result	°C	**19.6**	**19.5**	**19.4**	**18.8**
Turbidity					
Reported Result	NTU	**7.05**	**9.08**	**3.08**	**2.52**

Sample Reference		Wetland 2 Outlet 4	Limeburners Discharge 1	Limeburners Discharge 2	Limeburners Discharge 3
Secondary Reference		de	ea	eb	ec
Notes					
Our Reference		20110727	20110728	20110729	20110730
Sample Collection		30/11/2020 9:14 AM			
Ammonia (ISE LR)					
Reported Result	mg/L	**0.913**	**0.178**	**0.524**	**0.354**
Chlorophyll a (Trace).					
Reported Result	mg/L	**0.0102**	**0.0014**	**0.0017**	**0.0015**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**246**	**1403**	**738**	**425**
Total Coliforms					
Reported Result	MPN/100mL	**>24196**	**17329**	**>24196**	**>24196**
Conductivity Field					
Reported Result	µs/cm	**-**	**43609**	**38868**	**36789**
Enterococci (97w)					
Reported Result	MPN/100mL	**305**	**121**	**199**	**281**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**260**	**230**	**360**	**250**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**5.7**	**0.60**	**1.93**	**2.4**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**6.1**	**0.51**	**2.1**	**1.85**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**2.4**	**0.4**	**1.1**	**0.8**
Nitrogen (Total Oxidised)	mg/L	**11.7**	**1.11**	**4.1**	**4.3**
Nitrogen (Total)	mg/L	**14.1**	**1.5**	**5.2**	**5.1**
Oxygen (% Dissolved)					
Reported Result	%	**46.3**	**61.1**	**55.0**	**52.1**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**4.33**	**4.66**	**4.32**	**4.09**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**6**	**<3**	**<3**	**<3**
pH					
Reported Result	pH Units	**7.1**	**7.6**	**7.4**	**7.3**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**4.6**	**0.47**	**1.46**	**1.69**
Phosphorus (Total Trace).					
Reported Result	mg/L	**5.0**	**0.48**	**1.62**	**1.54**
Salinity					
Reported Result	ppt	**0.5**	**23.4**	**25.0**	**23.6**
Solids (Suspended)					
Reported Result	mg/L	**7**	**30**	**19**	**16**
Temperature Field					
Reported Result	°C	**18.7**	**20.3**	**20.2**	**20.4**
Turbidity					
Reported Result	NTU	**3.30**	**3.61**	**2.90**	**2.63**

Sample Reference		Limeburners Discharge 4	Limeburners Upper	Limeburners Mid	Limeburners Lower
Secondary Reference		ed	fa	fb	fd
Notes					
Our Reference		20110731	20110732	20110733	20110734
Sample Collection					
Ammonia (ISE LR)					
Reported Result	mg/L	**0.352**	**0.452**	**0.256**	**0.130**
Chlorophyll a (Trace).					
Reported Result	mg/L	**0.0010**	**0.0011**	**0.0008**	**0.0011**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**411**	**355**	**829**	**837**
Total Coliforms					
Reported Result	MPN/100mL	**24196**	**>24196**	**24196**	**>24196**
Conductivity Field					
Reported Result	µs/cm	**34525**	**34067**	**36642**	**44050**
Enterococci (97w)					
Reported Result	MPN/100mL	**241**	**259**	**75**	**52**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**340**	**270**	**200**	**127**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**2.0**	**2.3**	**1.41**	**0.53**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**1.49**	**1.74**	**0.98**	**0.43**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**0.7**	**0.9**	**0.7**	**0.3**
Nitrogen (Total Oxidised)	mg/L	**3.5**	**4.0**	**2.4**	**0.96**
Nitrogen (Total)	mg/L	**4.2**	**5.0**	**3.1**	**1.3**
Oxygen (% Dissolved)					
Reported Result	%	**51.4**	**46.9**	**54.1**	**61.7**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**4.07**	**3.73**	**4.23**	**4.68**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**<3**	**<3**	**<3**	**<3**
pH					
Reported Result	pH Units	**7.3**	**7.3**	**7.4**	**7.6**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**1.37**	**1.57**	**0.99**	**0.42**
Phosphorus (Total Trace).					
Reported Result	mg/L	**1.41**	**1.45**	**0.96**	**0.44**
Salinity					
Reported Result	ppt	**21.7**	**21.4**	**23.3**	**28.5**
Solids (Suspended)					
Reported Result	mg/L	**13**	**11**	**27**	**55**
Temperature Field					
Reported Result	°C	**20.5**	**20.3**	**20.3**	**20.4**
Turbidity					
Reported Result	NTU	**3.54**	**2.91**	**3.64**	**3.86**

Sample Reference		Limeburners Mouth
Secondary Reference		fd
Notes		
Our Reference		20110735
Sample Collection		
Ammonia (ISE LR)		
Reported Result	mg/L	**0.025**
Chlorophyll a (Trace).		
Reported Result	mg/L	**0.0020**
Escherichia coli (E. coli)		
Reported Result	MPN/100mL	**933**
Total Coliforms		
Reported Result	MPN/100mL	**9208**
Conductivity Field		
Reported Result	µs/cm	**48810**
Enterococci (97w)		
Reported Result	MPN/100mL	**20**
Faecal Coliform (Presumptive)		
Reported Result	cfu/100mL	**81**
Nitrogen (Nitrate Trace).		
Reported Result	mg/L	**0.084**
Nitrogen (Nitrite Trace).		
Reported Result	mg/L	**0.043**
Nitrogen (Total Trace).		
Nitrogen (Total Kjeldahl)	mg/L	**<0.2**
Nitrogen (Total Oxidised)	mg/L	**0.126**
Nitrogen (Total)	mg/L	**0.3**
Oxygen (% Dissolved)		
Reported Result	%	**76.3**
Oxygen (Field Dissolved)		
Reported Result	mg/L	**5.64**
Oxygen Demand (Carbonaceous Biochemical)		
Reported Result	mg/L	**<3**
pH		
Reported Result	pH Units	**7.8**
Phosphorus (Dissolved Reactive).		
Reported Result	mg/L	**0.076**
Phosphorus (Total Trace).		
Reported Result	mg/L	**0.094**
Salinity		
Reported Result	ppt	**31.9**
Solids (Suspended)		
Reported Result	mg/L	**42**
Temperature Field		
Reported Result	°C	**20.6**
Turbidity		
Reported Result	NTU	**3.83**

Test Method Information

Method	*Reference*	*Method Type*
Chlorophyll a (Trace).	APHA 10200 H Fluorometer	Subcontracted
Ammonia (ISE LR)	APHA Section 4500-N D	IANZ
Turbidity	ISO7027-1:2016	IANZ
Phosphorus (Total Trace).	APHA 4500P E	Subcontracted
Oxygen (Field Dissolved)	APHA Section 4500 E	Not Accredited
Nitrogen (Nitrite Trace).	APHA 4500NO3 I	Subcontracted
Nitrogen (Total Trace).	Calc:TKN+TON	Subcontracted
Flow (m3/d)	NA	Not Accredited
Nitrogen (Nitrate Trace).	APHA 4500NO3 I	Subcontracted
Oxygen (% Dissolved)	APHA Section 4500 E	Not Accredited
Salinity	APHA 2520 B	Not Accredited
Temperature Field	APHA 2550 B	IANZ
Total Coliforms	APHA Section 9223 B (Colilert)	IANZ
Oxygen Demand (Carbonaceous Biochemical)	APHA Section 5210B	IANZ
Escherichia coli (E. coli)	APHA Section 9223 B (Colilert)	IANZ
Enterococci (97w)	APHA 9230 D	IANZ
Phosphorus (Dissolved Reactive).	APHA 4500 P E	Subcontracted
Faecal Coliform (Presumptive)	APHA section 9222D	IANZ
pH	APHA Section 4500 H+ B	IANZ
Solids (Suspended)	APHA Section 2540 D	IANZ
Conductivity Field	APHA 2510 B	IANZ

End of Report

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Signed Lois Howe

Reported 15/12/2020 2:39 PM

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Hai Hguyen
WDC Wastewater Treatment
Kioreroa Rd
Private Bag 9023
Whangarei

Laboratory Analysis Report

Sample Information

Batch	2009B014
Site Name	Limeburners Creek Water Quality
Customer Reference	
Sampled By	.Customer
Sample Received	3/09/2020 1:16 PM

Results

Sample Reference		Wetland Inflow	Wetland 1 Outlet 1	Wetland 1 Outlet 2	Wetland 2 Outlet 3
Secondary Reference		ca	da	db	dc
Notes					
Our Reference		20090042	20090043	20090044	20090045
Sample Collection		3/09/2020 8:09 AM	3/09/2020 8:27 AM	3/09/2020 8:32 AM	3/09/2020 8:50 AM
Ammonia (ISE LR)					
Reported Result	mg/L	**14.350**	**13.980**	**13.650**	**10.920**
Chlorophyll a (Trace).					
Reported Result	mg/L	**0.0012**	**0.0051**	**0.0033**	**0.0016**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**3450**	**816**	**327**	**548**
Total Coliforms					
Reported Result	MPN/100mL	**19180**	**7270**	**4106**	**>24196**
Enterococci (97w)					
Reported Result	MPN/100mL	**738**	**52**	**52**	**52**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**2100**	**410**	**340**	**280**
Flow (m3/d)					
reported result	m3/d	**15534**	**-**	**-**	**-**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**18.3**	**13.9**	**14.2**	**12.7**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**3.0**	**1.32**	**1.24**	**0.83**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**12.8**	**12.2**	**10.3**	**10.4**
Nitrogen (Total Oxidised)	mg/L	**21**	**15.2**	**15.5**	**13.5**
Nitrogen (Total)	mg/L	**34**	**27**	**26**	**24**
Oxygen (% Dissolved)					
Reported Result	%	**84.4**	**68.8**	**36.8**	**65.5**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**8.54**	**5.40**	**3.65**	**6.68**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**6**	**5**	**3**	**4**
pH					
Reported Result	pH Units	**7.1**	**7.1**	**7.1**	**7.1**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**2.8**	**3.1**	**3.1**	**2.9**
Phosphorus (Total Trace).					
Reported Result	mg/L	**3.2**	**3.4**	**3.2**	**3.0**
Salinity					
Reported Result	ppt	**<0.5**	**<0.5**	**<0.5**	**<0.5**
Solids (Suspended)					
Reported Result	mg/L	**10**	**22**	**6**	**5**
Temperature Field					
Reported Result	°C	**15.3**	**14.8**	**15.2**	**12.9**
Turbidity					
Reported Result	NTU	**4.47**	**5.94**	**3.32**	**2.25**

Sample Reference		Wetland 2 Outlet 4	Limeburners Discharge 1	Limeburners Discharge 2	Limeburners Discharge 3
Secondary Reference		de	ea	eb	ec
Notes					
Our Reference		20090046	20090047	20090048	20090049
Sample Collection		3/09/2020 8:55 AM	3/09/2020 10:35 AM	3/09/2020 10:29 AM	3/09/2020 10:15 AM
Ammonia (ISE LR)					
Reported Result	mg/L	**10.110**	**2.225**	**5.811**	**2.882**
Chlorophyll a (Trace).					
Reported Result	mg/L	**0.003**	**0.0016**	**0.0016**	**0.0017**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**399**	**452**	**404**	**272**
Total Coliforms					
Reported Result	MPN/100mL	**24196**	**14136**	**19863**	**12997**
Conductivity Field					
Reported Result	µs/cm	**-**	**26400**	**17180**	**17090**
Enterococci (97w)					
Reported Result	MPN/100mL	**31**	**97**	**169**	**231**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**109**	**380**	**380**	**900**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**13.1**	**3.0**	**7.0**	**4.1**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**0.73**	**0.158**	**0.42**	**0.22**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**10.8**	**1.9**	**5.8**	**2.7**
Nitrogen (Total Oxidised)	mg/L	**13.8**	**3.2**	**7.4**	**4.3**
Nitrogen (Total)	mg/L	**25**	**5.0**	**13.1**	**7.0**
Oxygen (% Dissolved)					
Reported Result	%	**52.5**	**69.5**	**62.1**	**68.7**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**5.49**	**6.50**	**5.89**	**6.70**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**4**	**<3**	**<3**	**<3**
pH					
Reported Result	pH Units	**7.1**	**7.5**	**7.2**	**7.3**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**2.9**	**0.51**	**1.40**	**0.73**
Phosphorus (Total Trace).					
Reported Result	mg/L	**2.9**	**0.52**	**1.46**	**0.76**
Salinity					
Reported Result	ppt	**<0.5**	**15.4**	**10.0**	**9.9**
Solids (Suspended)					
Reported Result	mg/L	**11**	**12**	**7**	**9**
Temperature Field					
Reported Result	°C	**13.1**	**13.8**	**13.8**	**13.7**
Turbidity					
Reported Result	NTU	**1.29**	**5.69**	**3.29**	**5.49**

Sample Reference		Limeburners Discharge 4	Limeburners Upper	Limeburners Mid	Limeburners Lower
Secondary Reference		ed	fa	fb	fd
Notes					
Our Reference		20090050	20090051	20090052	20090053
Sample Collection		3/09/2020 10:08 AM	3/09/2020 10:02 AM	3/09/2020 10:20 AM	3/09/2020 10:42 AM
Ammonia (ISE LR)					
Reported Result	mg/L	**2.764**	**2.409**	**2.414**	**1.907**
Chlorophyll a (Trace).					
Reported Result	mg/L	**0.0006**	**0.0004**	**0.0010**	**0.0010**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**404**	**369**	**388**	**238**
Total Coliforms					
Reported Result	MPN/100mL	**15531**	**24196**	**15531**	**15531**
Conductivity Field					
Reported Result	µs/cm	**14110**	**9700**	**20500**	**28400**
Enterococci (97w)					
Reported Result	MPN/100mL	**243**	**228**	**134**	**161**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**2100**	**2700**	**854**	**260**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**3.9**	**3.7**	**3.7**	**2.7**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**0.21**	**0.183**	**0.195**	**0.141**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**2.8**	**2.9**	**2.1**	**1.6**
Nitrogen (Total Oxidised)	mg/L	**4.1**	**3.9**	**3.9**	**2.8**
Nitrogen (Total)	mg/L	**6.9**	**6.8**	**6.0**	**4.4**
Oxygen (% Dissolved)					
Reported Result	%	**65.2**	**86.5**	**86.5**	**62.8**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**6.41**	**8.07**	**8.15**	**5.85**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**<3**	**<3**	**<3**	**<3**
pH					
Reported Result	pH Units	**7.3**	**7.3**	**7.4**	**7.5**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**0.70**	**0.66**	**0.66**	**0.47**
Phosphorus (Total Trace).					
Reported Result	mg/L	**0.75**	**0.81**	**0.68**	**0.49**
Salinity					
Reported Result	ppt	**8.1**	**5.4**	**12.0**	**17.2**
Solids (Suspended)					
Reported Result	mg/L	**13**	**11**	**16**	**15**
Temperature Field					
Reported Result	°C	**13.8**	**14.2**	**13.8**	**13.6**
Turbidity					
Reported Result	NTU	**6.92**	**6.30**	**5.96**	**4.72**

Sample Reference		Limeburners Mouth
Secondary Reference		fd
Notes		
Our Reference		20090054
Sample Collection		3/09/2020 10:51 AM
Ammonia (ISE LR)		
Reported Result	mg/L	**0.686**
Chlorophyll a (Trace).		
Reported Result	mg/L	**0.0016**
Escherichia coli (E. coli)		
Reported Result	MPN/100mL	**135**
Total Coliforms		
Reported Result	MPN/100mL	**3448**
Conductivity Field		
Reported Result	µs/cm	**35900**
Enterococci (97w)		
Reported Result	MPN/100mL	**31**
Faecal Coliform (Presumptive)		
Reported Result	cfu/100mL	**81**
Nitrogen (Nitrate Trace).		
Reported Result	mg/L	**0.98**
Nitrogen (Nitrite Trace).		
Reported Result	mg/L	**0.049**
Nitrogen (Total Trace).		
Nitrogen (Total Kjeldahl)	mg/L	**0.6**
Nitrogen (Total Oxidised)	mg/L	**1.03**
Nitrogen (Total)	mg/L	**1.6**
Oxygen (% Dissolved)		
Reported Result	%	**104.0**
Oxygen (Field Dissolved)		
Reported Result	mg/L	**8.75**
Oxygen Demand (Carbonaceous Biochemical)		
Reported Result	mg/L	**<3**
pH		
Reported Result	pH Units	**7.8**
Phosphorus (Dissolved Reactive).		
Reported Result	mg/L	**0.177**
Phosphorus (Total Trace).		
Reported Result	mg/L	**0.196**
Salinity		
Reported Result	ppt	**22.3**
Solids (Suspended)		
Reported Result	mg/L	**16**
Temperature Field		
Reported Result	°C	**14.1**
Turbidity		
Reported Result	NTU	**3.77**

Test Method Information

Method	*Reference*	*Method Type*
Chlorophyll a (Trace).	APHA 10200 H Fluorometer	Subcontracted
Salinity	APHA 2520 B	Not Accredited
Ammonia (ISE LR)	APHA Section 4500-N D	IANZ
Turbidity	ISO7027-1:2016	IANZ
Nitrogen (Nitrite Trace).	APHA 4500NO3 I	Subcontracted
Nitrogen (Total Trace).	Calc:TKN+TON	Subcontracted
Phosphorus (Total Trace).	APHA 4500P E	Subcontracted
Oxygen (Field Dissolved)	APHA Section 4500 E	Not Accredited
Flow (m3/d)	NA	Not Accredited
Nitrogen (Nitrate Trace).	APHA 4500NO3 I	Subcontracted
Oxygen (% Dissolved)	APHA Section 4500 E	Not Accredited
Temperature Field	APHA 2550 B	IANZ
Total Coliforms	APHA Section 9223 B (Colilert)	IANZ
Oxygen Demand (Carbonaceous Biochemical)	APHA Section 5210B	IANZ
Enterococci (97w)	APHA 9230 D	IANZ
Escherichia coli (E. coli)	APHA Section 9223 B (Colilert)	IANZ
Phosphorus (Dissolved Reactive).	APHA 4500 P E	Subcontracted
Faecal Coliform (Presumptive)	APHA section 9222D	IANZ
pH	APHA Section 4500 H+ B	IANZ
Solids (Suspended)	APHA Section 2540 D	IANZ
Conductivity Field	APHA 2510 B	IANZ

End of Report

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Signed Lois H Howe Lois Howe

Reported 14/09/2020 3:51 PM

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Laboratory Analysis Report

Sample Information

Batch	2103B019
Site Name	Limeburners Creek Water Quality
Customer Reference	
Sampled By	.Customer
Sample Received	2/03/2021 3:13 PM

Results

Sample Reference		Wetland Inflow	Wetland 1 Outlet 1	Wetland 1 Outlet 2	Wetland 2 Outlet 3
Secondary Reference		ca	da	db	dc
Notes					
Our Reference		21030046	21030047	21030048	21030049
Sample Collection		2/03/2021 10:51 AM	2/03/2021 11:08 AM	2/03/2021 11:13 AM	2/03/2021 11:32 AM
Ammonia (ISE LR)					
Reported Result	mg/L	**5.255**	**0.345**	**0.361**	**0.980**
Chlorophyll a (Trace).					
Reported Result	mg/L	**<0.005**	**0.006**	**0.005**	**0.006**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**1968**	**448**	**285**	**428**
Total Coliforms					
Reported Result	MPN/100mL	**9804**	**>24196**	**24196**	**>24196**
Enterococci (97w)					
Reported Result	MPN/100mL	**279**	**301**	**272**	**464**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**850**	**280**	**250**	**310**
Flow (m3/d)					
reported result	m3/d	**12689**	**-**	**-**	**-**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**23**	**23**	**24**	**20**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**2.4**	**0.138**	**0.161**	**0.27**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**8.5**	**1.69**	**1.58**	**2.2**
Nitrogen (Total Oxidised)	mg/L	**25**	**24**	**24**	**20**
Nitrogen (Total)	mg/L	**34**	**25**	**26**	**22**
Oxygen (% Dissolved)					
Reported Result	%	**84.3**	**28.7**	**26.7**	**50.7**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**7.36**	**2.45**	**2.31**	**4.33**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**6**	**<3**	**<3**	**<3**
pH					
Reported Result	pH Units	**7.1**	**6.8**	**6.8**	**6.9**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**5.3**	**5.6**	**5.6**	**4.9**
Phosphorus (Total Trace).					
Reported Result	mg/L	**5.8**	**5.9**	**2.7**	**5.0**
Salinity					
Reported Result	ppt	**1.2**	**0.7**	**0.7**	**3.4**
Solids (Suspended)					
Reported Result	mg/L	**41**	**3**	**<1.2**	**4**
Temperature Field					
Reported Result	°C	**20.2**	**20.7**	**20.4**	**20.6**
Turbidity					
Reported Result	NTU	**11.8**	**1.07**	**1.40**	**2.13**

Sample Reference		Wetland 2 Outlet 4
Secondary Reference		de
Notes		
Our Reference		21030050
Sample Collection		2/03/2021 11:36 AM
Ammonia (ISE LR)		
Reported Result	mg/L	**1.254**
Chlorophyll a (Trace).		
Reported Result	mg/L	**0.004**
Escherichia coli (E. coli)		
Reported Result	MPN/100mL	**318**
Total Coliforms		
Reported Result	MPN/100mL	**>24196**
Enterococci (97w)		
Reported Result	MPN/100mL	**275**
Faecal Coliform (Presumptive)		
Reported Result	cfu/100mL	**250**
Nitrogen (Nitrate Trace).		
Reported Result	mg/L	**22**
Nitrogen (Nitrite Trace).		
Reported Result	mg/L	**0.25**
Nitrogen (Total Trace).		
Nitrogen (Total Kjeldahl)	mg/L	**2.6**
Nitrogen (Total Oxidised)	mg/L	**22**
Nitrogen (Total)	mg/L	**25**
Oxygen (% Dissolved)		
Reported Result	%	**60.1**
Oxygen (Field Dissolved)		
Reported Result	mg/L	**5.18**
Oxygen Demand (Carbonaceous Biochemical)		
Reported Result	mg/L	**<3**
pH		
Reported Result	pH Units	**6.8**
Phosphorus (Dissolved Reactive).		
Reported Result	mg/L	**5.3**
Phosphorus (Total Trace).		
Reported Result	mg/L	**5.4**
Salinity		
Reported Result	ppt	**0.9**
Solids (Suspended)		
Reported Result	mg/L	**<1.2**
Temperature Field		
Reported Result	°C	**20.2**
Turbidity		
Reported Result	NTU	**1.10**

Test Method Information

Method	*Reference*	*Method Type*
Salinity	APHA 2520 B	Not Accredited
pH	APHA Section 4500 H+ B	IANZ
Solids (Suspended)	APHA Section 2540 D	IANZ
Phosphorus (Dissolved Reactive).	APHA 4500 P E	Subcontracted
Faecal Coliform (Presumptive)	APHA section 9222D	IANZ
Enterococci (97w)	APHA 9230 D	IANZ
Escherichia coli (E. coli)	APHA Section 9223 B (Colilert)	IANZ
Total Coliforms	APHA Section 9223 B (Colilert)	IANZ
Oxygen Demand (Carbonaceous Biochemical)	APHA Section 5210B	IANZ
Temperature Field	APHA 2550 B	IANZ
Oxygen (% Dissolved)	APHA Section 4500 E	Not Accredited
Flow (m3/d)	NA	Not Accredited
Nitrogen (Nitrate Trace).	APHA 4500NO3 I	Subcontracted
Nitrogen (Nitrite Trace).	APHA 4500NO3 I	Subcontracted
Nitrogen (Total Trace).	Calc:TKN+TON	Subcontracted
Phosphorus (Total Trace).	APHA 4500P E	Subcontracted
Oxygen (Field Dissolved)	APHA Section 4500 E	Not Accredited
Ammonia (ISE LR)	APHA Section 4500-N D	IANZ
Turbidity	ISO7027-1:2016	IANZ
Chlorophyll a (Trace).	APHA 10200 H Fluorometer	Subcontracted

End of Report

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Signed Lois H Howe Lois Howe

Reported 12/03/2021 3:45 PM

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Private Bag 9023
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Laboratory Analysis Report

Sample Information

Batch	2002B306
Site Name	Limeburners Creek Water Quality
Customer Reference	
Sampled By	.Customer
Sample Received	28/02/2020 1:32 PM

Results

Sample Reference		Wetland Inflow	Wetland 1 Outlet 1	Wetland 1 Outlet 2	Wetland 2 Outlet 3
Secondary Reference		ca	da	db	dc
Notes					
Our Reference		20020843	20020844	20020845	20020846
Sample Collection		28/02/2020 11:25 AM			
Ammonia (ISE LR)					
Reported Result	mg/L	**0.167**	**0.234**	**0.332**	**0.023**
Chlorophyll a (Trace).					
Reported Result	mg/L	**0.008**	**0.138**	**0.020**	**0.016**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**355**	**345**	**404**	**269**
Total Coliforms					
Reported Result	MPN/100mL	**2282**	**>24196**	**>2420**	**>24196**
Enterococci (97w)					
Reported Result	MPN/100mL	**41**	**41**	**30**	**20**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**163**	**310**	**340**	**270**
Flow (m3/d)					
reported result	m3/d	**10062**	**-**	**-**	**-**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**39.000**	**32.000**	**33.000**	**28.000**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**0.088**	**0.172**	**0.158**	**0.122**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**3**	**2.1**	**2.2**	**1.31**
Nitrogen (Total Oxidised)	mg/L	**39**	**33**	**33**	**28**
Nitrogen (Total)	mg/L	**42**	**35**	**36**	**30**
Oxygen (% Dissolved)					
Reported Result	%	**86.5**	**48.5**	**46.0**	**42.0**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**7.46**	**4.12**	**3.87**	**3.58**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**6**	**<6**	**<6**	**<6**
pH					
Reported Result	pH Units	**6.3**	**6.8**	**6.7**	**6.8**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**6.7**	**5.5**	**5.5**	**5.5**
Phosphorus (Total Trace).					
Reported Result	mg/L	**7.8**	**6.2**	**6**	**6.1**
Salinity					
Reported Result	ppt	**<0.5**	**<0.5**	**<0.5**	**<0.5**
Solids (Suspended)					
Reported Result	mg/L	**26**	**19**	**8**	**30**
Temperature Field					
Reported Result	°C	**22.6**	**23.4**	**23.8**	**23.5**
Turbidity					
Reported Result	NTU	**10.1**	**3.07**	**1.46**	**5.37**

Sample Reference		Wetland 2 Outlet 4	Limeburners Discharge 1	Limeburners Discharge 2	Limeburners Discharge 3
Secondary Reference		de	ea	eb	ec
Notes					
Our Reference		20020847	20020848	20020849	20020850
Sample Collection					
Ammonia (ISE LR)					
Reported Result	mg/L	**<0.02**	**0.071**	**0.080**	**0.112**
Chlorophyll a (Trace).					
Reported Result	mg/L	**0.029**	**<0.003**	**0.004**	**<0.003**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**631**	**641**	**483**	**332**
Total Coliforms					
Reported Result	MPN/100mL	**>24196**	**11199**	**15531**	**>24196**
Conductivity Field					
Reported Result	μs/cm	**-**	**47815**	**45978**	**39719**
Enterococci (97w)					
Reported Result	MPN/100mL	**20**	**97**	**131**	**441**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**370**	**320**	**150**	**160**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**29.000**	**2.600**	**4.100**	**6.300**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**0.123**	**.026**	**0.032**	**0.048**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**1.59**	**0.31**	**0.41**	**0.44**
Nitrogen (Total Oxidised)	mg/L	**29**	**2.7**	**4.1**	**6.4**
Nitrogen (Total)	mg/L	**30**	**3.2**	**5.6**	**7.3**
Oxygen (% Dissolved)					
Reported Result	%	**57.7**	**62.8**	**59.6**	**48.7**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**4.88**	**4.39**	**4.20**	**3.51**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**<6**	**13**	**<6**	**<6**
pH					
Reported Result	pH Units	**6.9**	**7.4**	**7.4**	**7.2**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**5.7**	**0.54**	**0.77**	**1.14**
Phosphorus (Total Trace).					
Reported Result	mg/L	**6.4**	**0.61**	**1.09**	**1.28**
Salinity					
Reported Result	ppt	**1.0**	**31.2**	**29.8**	**25.2**
Solids (Suspended)					
Reported Result	mg/L	**62**	**29**	**22**	**17**
Temperature Field					
Reported Result	°C	**23.7**	**24.5**	**24.4**	**24.5**
Turbidity					
Reported Result	NTU	**19.5**	**5.26**	**5.85**	**4.31**

Sample Reference		Limeburners Discharge 4	Limeburners Upper	Limeburners Mid	Limeburners Lower
Secondary Reference		ed	fa	fb	fd
Notes					
Our Reference		20020851	20020852	20020853	20020854
Sample Collection					
Ammonia (ISE LR)					
Reported Result	mg/L	**0.108**	**0.096**	**0.065**	**0.071**
Chlorophyll a (Trace).					
Reported Result	mg/L	**<0.003**	**<0.003**	**<0.003**	**<0.003**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**329**	**266**	**363**	**642**
Total Coliforms					
Reported Result	MPN/100mL	**24196**	**24196**	**19863**	**17329**
Conductivity Field					
Reported Result	µs/cm	**37878**	**35281**	**45242**	**48112**
Enterococci (97w)					
Reported Result	MPN/100mL	**206**	**315**	**63**	**63**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**170**	**210**	**260**	**220**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**6.300**	**3.200**	**4.100**	**2.500**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**0.049**	**0.031**	**0.035**	**0.025**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**0.52**	**0.47**	**0.37**	**0.33**
Nitrogen (Total Oxidised)	mg/L	**6.3**	**3.2**	**4.1**	**2.5**
Nitrogen (Total)	mg/L	**6.5**	**5.8**	**4.5**	**3.1**
Oxygen (% Dissolved)					
Reported Result	%	**48.1**	**47.2**	**56.9**	**64.5**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**3.49**	**3.50**	**4.03**	**4.49**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**<6**	**<6**	**<3**	**<3**
pH					
Reported Result	pH Units	**7.0**	**7.4**	**7.3**	**7.4**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**1.10**	**0.58**	**0.76**	**0.47**
Phosphorus (Total Trace).					
Reported Result	mg/L	**1.31**	**1.02**	**0.89**	**0.60**
Salinity					
Reported Result	ppt	**24.8**	**22.1**	**29.2**	**31.4**
Solids (Suspended)					
Reported Result	mg/L	**31**	**36**	**19**	**22**
Temperature Field					
Reported Result	°C	**24.5**	**24.0**	**24.3**	**24.5**
Turbidity					
Reported Result	NTU	**5.36**	**4.57**	**5.82**	**5.52**

Sample Reference		Limeburners Mouth
Secondary Reference		fd
Notes		
Our Reference		20020855
Sample Collection		
Ammonia (ISE LR)		
Reported Result	mg/L	**0.058**
Chlorophyll a (Trace).		
Reported Result	mg/L	**<0.003**
Escherichia coli (E. coli)		
Reported Result	MPN/100mL	**468**
Total Coliforms		
Reported Result	MPN/100mL	**3873**
Conductivity Field		
Reported Result	µs/cm	**52536**
Enterococci (97w)		
Reported Result	MPN/100mL	**<10**
Faecal Coliform (Presumptive)		
Reported Result	cfu/100mL	**170**
Nitrogen (Nitrate Trace).		
Reported Result	mg/L	**0.610**
Nitrogen (Nitrite Trace).		
Reported Result	mg/L	**0.0109**
Nitrogen (Total Trace).		
Nitrogen (Total Kjeldahl)	mg/L	**0.23**
Nitrogen (Total Oxidised)	mg/L	**0.63**
Nitrogen (Total)	mg/L	**1.06**
Oxygen (% Dissolved)		
Reported Result	%	**75.6**
Oxygen (Field Dissolved)		
Reported Result	mg/L	**5.15**
Oxygen Demand (Carbonaceous Biochemical)		
Reported Result	mg/L	**<3**
pH		
Reported Result	pH Units	**7.7**
Phosphorus (Dissolved Reactive).		
Reported Result	mg/L	**0.181**
Phosphorus (Total Trace).		
Reported Result	mg/L	**0.22**
Salinity		
Reported Result	ppt	**34.6**
Solids (Suspended)		
Reported Result	mg/L	**20**
Temperature Field		
Reported Result	°C	**24.6**
Turbidity		
Reported Result	NTU	**4.90**

Test Method Information

Method	*Reference*	*Method Type*
Salinity	APHA 2520 B	Not Accredited
pH	APHA Section 4500 H+ B	IANZ
Solids (Suspended)	APHA Section 2540 D	IANZ
Phosphorus (Dissolved Reactive).	APHA 4500 P E	Subcontracted
Faecal Coliform (Presumptive)	APHA section 9222D	IANZ
Enterococci (97w)	APHA 9230 D	IANZ
Escherichia coli (E. coli)	APHA Section 9223 B (Colilert)	IANZ
Total Coliforms	APHA Section 9223 B (Colilert)	IANZ
Oxygen Demand (Carbonaceous Biochemical)	APHA Section 5210B	IANZ
Temperature Field	APHA 2550 B	IANZ
Oxygen (% Dissolved)	APHA Section 4500 E	Not Accredited
Flow (m3/d)	NA	Not Accredited
Nitrogen (Nitrate Trace).	APHA 4500NO3 I	Subcontracted
Nitrogen (Nitrite Trace).	APHA 4500NO3 I	Subcontracted
Nitrogen (Total Trace).	Calc:TKN+TON	Subcontracted
Phosphorus (Total Trace).	APHA 4500P E	Subcontracted
Oxygen (Field Dissolved)	APHA Section 4500 E	Not Accredited
Ammonia (ISE LR)	APHA Section 4500-N D	IANZ
Turbidity	ISO7027-1:2016	IANZ
Chlorophyll a (Trace).	APHA 10200 H Fluorometer	Subcontracted
Conductivity Field	APHA 2510 B	IANZ

End of Report

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Signed Lois N Howe Lois Howe

Reported 25/03/2020 11:13 AM

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Hai Hguyen
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Laboratory Analysis Report

Sample Information

Batch	2005B142
Site Name	Limeburners Creek Water Quality
Customer Reference	
Sampled By	.Customer
Sample Received	29/05/2020 9:26 AM

Results

Sample Reference		Wetland Inflow	Wetland 1 Outlet 1	Wetland 1 Outlet 2	Wetland 2 Outlet 3
Secondary Reference		ca	da	db	dc
Notes					
Our Reference		20050516	20050517	20050518	20050519
Sample Collection		28/05/2020 10:10 AM	28/05/2020 10:26 AM	28/05/2020 10:34 AM	28/05/2020 10:49 AM
Ammonia (ISE)					
Reported Result	mg/L	**<0.5**	**10.4**	**9.6**	**4.8**
Chlorophyll a (Trace).					
Reported Result	mg/L	**<0.003**	**0.005**	**0.004**	**<0.003**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**110**	**12033**	**6131**	**959**
Total Coliforms					
Reported Result	MPN/100mL	**512**	**>24196**	**24196**	**>24196**
Enterococci (97w)					
Reported Result	MPN/100mL	**41**	**780**	**393**	**75**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**45**	**>2000**	**>2000**	**610**
Flow (m3/d)					
reported result	m3/d	**15031**	**-**	**-**	**-**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**18.500**	**14.400**	**14.400**	**13.200**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**0.24**	**0.40**	**0.37**	**0.171**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**1.44**	**12.3**	**9.9**	**6.1**
Nitrogen (Total Oxidised)	mg/L	**18.7**	**14.9**	**14.8**	**13.4**
Nitrogen (Total)	mg/L	**20**	**27**	**25**	**19.4**
Oxygen (% Dissolved)					
Reported Result	%	**89.4**	**43.4**	**53.1**	**61.7**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**8.38**	**4.05**	**4.98**	**5.83**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**<3**	**7**	**4**	**3**
pH					
Reported Result	pH Units	**6.6**	**7.0**	**6.9**	**6.9**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**2.5**	**3.8**	**3.7**	**3.8**
Phosphorus (Total Trace).					
Reported Result	mg/L	**2.7**	**1.0**	**3.9**	**3.9**
Salinity					
Reported Result	ppt	**<0.5**	**0.6**	**<0.5**	**<0.5**
Solids (Suspended)					
Reported Result	mg/L	**4**	**13**	**5**	**10**
Temperature Field					
Reported Result	°C	**18.4**	**18.3**	**18.6**	**17.9**
Turbidity					
Reported Result	NTU	**1.56**	**4.55**	**2.74**	**10.4**

Sample Reference		Wetland 2 Outlet 4	Limeburners Discharge 1	Limeburners Discharge 2	Limeburners Discharge 3
Secondary Reference		de	ea	eb	ec
Notes					
Our Reference		20050520	20050521	20050522	20050523
Sample Collection		28/05/2020 10:55 AM	28/05/2020 1:50 PM	28/05/2020 1:42 PM	28/05/2020 1:27 PM
Ammonia (ISE)					
Reported Result	mg/L	**5.0**	**1.4**	**3.0**	**2.8**
Chlorophyll a (Trace).					
Reported Result	mg/L	**<0.003**	**<0.003**	**<0.003**	**<0.003**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**860**	**2603**	**5172**	**4360**
Total Coliforms					
Reported Result	MPN/100mL	**>24196**	**>24196**	**19863**	**>24196**
Conductivity Field					
Reported Result	µs/cm	**-**	**28330**	**19500**	**17612**
Enterococci (97w)					
Reported Result	MPN/100mL	**10**	**1565**	**2700**	**2142**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**630**	**350**	**680**	**440**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**13.000**	**2.700**	**5.700**	**5.600**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**0.175**	**0.049**	**0.102**	**0.093**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**5.4**	**1.5**	**3.3**	**2.7**
Nitrogen (Total Oxidised)	mg/L	**13.2**	**2.7**	**5.8**	**5.7**
Nitrogen (Total)	mg/L	**18.6**	**4.2**	**9.2**	**8.3**
Oxygen (% Dissolved)					
Reported Result	%	**53.6**	**67.6**	**62.9**	**63.5**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**5.08**	**5.99**	**5.69**	**5.83**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**<3**	**<3**	**<3**	**<3**
pH					
Reported Result	pH Units	**6.9**	**7.3**	**7.1**	**7.1**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**3.8**	**0.58**	**1.26**	**1.30**
Phosphorus (Total Trace).					
Reported Result	mg/L	**4.0**	**0.68**	**1.36**	**1.66**
Salinity					
Reported Result	ppt	**<0.5**	**17.5**	**11.8**	**10.4**
Solids (Suspended)					
Reported Result	mg/L	**3**	**17**	**20**	**18**
Temperature Field					
Reported Result	°C	**17.9**	**16.1**	**16.5**	**16.5**
Turbidity					
Reported Result	NTU	**3.22**	**9.51**	**5.77**	**9.59**

Sample Reference		Limeburners Discharge 4	Limeburners Upper	Limeburners Mid	Limeburners Lower
Secondary Reference		ed	fa	fb	fd
Notes					
Our Reference		20050524	20050525	20050526	20050527
Sample Collection		28/05/2020 1:19 PM	28/05/2020 1:09 PM	28/05/2020 1:35 PM	28/05/2020 1:55 PM
Ammonia (ISE LR)					
Reported Result	mg/L	**-**	**-**	**-**	**1.400**
Ammonia (ISE)					
Reported Result	mg/L	**2.9**	**3.0**	**2.2**	**1.4**
Chlorophyll a (Trace).					
Reported Result	mg/L	**<0.003**	**<0.003**	**<0.003**	**<0.003**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**6488**	**6867**	**5475**	**3873**
Total Coliforms					
Reported Result	MPN/100mL	**>24196**	**>24196**	**>24196**	**24196**
Conductivity Field					
Reported Result	µs/cm	**13535**	**8143**	**20250**	**29180**
Enterococci (97w)					
Reported Result	MPN/100mL	**2310**	**2603**	**2987**	**1892**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**600**	**1500**	**600**	**400**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**5.600**	**5.500**	**4.200**	**2.500**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**0.096**	**0.096**	**0.072**	**0.047**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**3.1**	**3.1**	**2.3**	**1.5**
Nitrogen (Total Oxidised)	mg/L	**5.7**	**5.5**	**4.3**	**2.6**
Nitrogen (Total)	mg/L	**8.8**	**8.6**	**6.6**	**4.1**
Oxygen (% Dissolved)					
Reported Result	%	**64.1**	**63.7**	**65.3**	**67.4**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**5.97**	**6.08**	**5.95**	**5.95**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**<3**	**<3**	**<3**	**<3**
pH					
Reported Result	pH Units	**7.1**	**7.0**	**7.2**	**7.4**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**1.29**	**1.24**	**0.96**	**0.55**
Phosphorus (Total Trace).					
Reported Result	mg/L	**1.498**	**1.41**	**1.05**	**0.67**
Salinity					
Reported Result	ppt	**8.1**	**4.5**	**12.3**	**18.1**
Solids (Suspended)					
Reported Result	mg/L	**14**	**12**	**23**	**43**
Temperature Field					
Reported Result	°C	**16.3**	**16.4**	**16.2**	**16.1**
Turbidity					
Reported Result	NTU	**11.8**	**10.4**	**9.20**	**5.91**

Sample Reference		Limeburners Mouth
Secondary Reference		fd
Notes		
Our Reference		20050528
Sample Collection		28/05/2020 2:00 PM
Ammonia (ISE)		
Reported Result	mg/L	**0.8**
Chlorophyll a (Trace).		
Reported Result	mg/L	**<0.003**
Escherichia coli (E. coli)		
Reported Result	MPN/100mL	**1850**
Total Coliforms		
Reported Result	MPN/100mL	**19863**
Conductivity Field		
Reported Result	µs/cm	**38800**
Enterococci (97w)		
Reported Result	MPN/100mL	**1137**
Faecal Coliform (Presumptive)		
Reported Result	cfu/100mL	**740**
Nitrogen (Nitrate Trace).		
Reported Result	mg/L	**1.390**
Nitrogen (Nitrite Trace).		
Reported Result	mg/L	**0.026**
Nitrogen (Total Trace).		
Nitrogen (Total Kjeldahl)	mg/L	**0.8**
Nitrogen (Total Oxidised)	mg/L	**1.42**
Nitrogen (Total)	mg/L	**2.3**
Oxygen (% Dissolved)		
Reported Result	%	**75.7**
Oxygen (Field Dissolved)		
Reported Result	mg/L	**6.40**
Oxygen Demand (Carbonaceous Biochemical)		
Reported Result	mg/L	**<3**
pH		
Reported Result	pH Units	**7.5**
Phosphorus (Dissolved Reactive).		
Reported Result	mg/L	**0.29**
Phosphorus (Total Trace).		
Reported Result	mg/L	**0.32**
Salinity		
Reported Result	ppt	**24.8**
Solids (Suspended)		
Reported Result	mg/L	**33**
Temperature Field		
Reported Result	°C	**16.2**
Turbidity		
Reported Result	NTU	**7.61**

Test Method Information

Method	*Reference*	*Method Type*
Salinity	APHA 2520 B	Not Accredited
pH	APHA Section 4500 H+ B	IANZ
Solids (Suspended)	APHA Section 2540 D	IANZ
Phosphorus (Dissolved Reactive).	APHA 4500 P E	Subcontracted
Faecal Coliform (Presumptive)	APHA section 9222D	IANZ
Enterococci (97w)	APHA 9230 D	IANZ
Escherichia coli (E. coli)	APHA Section 9223 B (Colilert)	IANZ
Total Coliforms	APHA Section 9223 B (Colilert)	IANZ
Oxygen Demand (Carbonaceous Biochemical)	APHA Section 5210B	IANZ
Temperature Field	APHA 2550 B	IANZ
Oxygen (% Dissolved)	APHA Section 4500 E	Not Accredited
Flow (m3/d)	NA	Not Accredited
Ammonia (ISE)	APHA Section 4500-NH3 D	IANZ
Nitrogen (Nitrate Trace).	APHA 4500NO3 I	Subcontracted
Nitrogen (Nitrite Trace).	APHA 4500NO3 I	Subcontracted
Nitrogen (Total Trace).	Calc:TKN+TON	Subcontracted
Phosphorus (Total Trace).	APHA 4500P E	Subcontracted
Oxygen (Field Dissolved)	APHA Section 4500 E	Not Accredited
Turbidity	ISO7027-1:2016	IANZ
Chlorophyll a (Trace).	APHA 10200 H Fluorometer	Subcontracted
Conductivity Field	APHA 2510 B	IANZ
Ammonia (ISE LR)	APHA Section 4500-N D	IANZ

End of Report

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Signed Lois Howe

Reported 5/06/2020 3:30 PM

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Hai Hguyen
WDC Wastewater Treatment
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Whangarei

Laboratory Analysis Report

Sample Information

Batch	2006B167
Site Name	Limeburners Creek Water Quality
Customer Reference	
Sampled By	.Customer
Sample Received	24/06/2020 2:19 PM

Results

Sample Reference		Wetland Inflow	Wetland 1 Outlet 1	Wetland 1 Outlet 2	Wetland 2 Outlet 3
Secondary Reference		ca	da	db	dc
Notes					
Our Reference		20060577	20060578	20060579	20060580
Sample Collection		23/06/2020 10:00 AM			
Ammonia (ISE LR)					
Reported Result	mg/L	**0.040**	**4.230**	**3.836**	**1.684**
Chlorophyll a (Trace).					
Reported Result	mg/L	**<0.003**	**0.004**	**<0.003**	**<0.003**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**20**	**1169**	**908**	**637**
Total Coliforms					
Reported Result	MPN/100mL	**97**	**8664**	**5172**	**>24196**
Enterococci (97w)					
Reported Result	MPN/100mL	**<10**	**85**	**98**	**41**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**10**	**620**	**460**	**450**
Flow (m3/d)					
reported result	m3/d	**32537**	**-**	**-**	**-**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**19.300**	**13.300**	**14.000**	**13.300**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**0.025**	**0.30**	**0.24**	**0.139**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**0.99**	**5.4**	**4.5**	**2.6**
Nitrogen (Total Oxidised)	mg/L	**19.3**	**13.6**	**14.3**	**13.4**
Nitrogen (Total)	mg/L	**20**	**19.1**	**18.8**	**16.0**
Oxygen (% Dissolved)					
Reported Result	%	**85.4**	**39.6**	**44.1**	**61.2**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**8.18**	**3.90**	**4.34**	**6.07**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**<6**	**4**	**<3**	**<3**
pH					
Reported Result	pH Units	**6.5**	**6.9**	**6.8**	**6.9**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**2.2**	**2.5**	**2.4**	**2.6**
Phosphorus (Total Trace).					
Reported Result	mg/L	**2.3**	**2.7**	**2.7**	**2.7**
Salinity					
Reported Result	ppt	**0.5**	**<0.5**	**<0.5**	**<0.5**
Solids (Suspended)					
Reported Result	mg/L	**5**	**5**	**<1.3**	**3**
Temperature Field					
Reported Result	°C	**17.3**	**16.2**	**16.4**	**15.5**
Turbidity					
Reported Result	NTU	**1.41**	**2.72**	**2.04**	**1.89**

Sample Reference		Wetland 2 Outlet 4	Limeburners Discharge 1	Limeburners Discharge 2	Limeburners Discharge 3
Secondary Reference		de	ea	eb	ec
Notes					
Our Reference		20060581	20060582	20060583	20060584
Sample Collection					
Ammonia (ISE LR)					
Reported Result	mg/L	**1.927**	**0.563**	**0.737**	**0.644**
Chlorophyll a (Trace).					
Reported Result	mg/L	**0.004**	**<0.003**	**<0.003**	**<0.003**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**450**	**1467**	**1956**	**1483**
Total Coliforms					
Reported Result	MPN/100mL	**>24196**	**>24196**	**>24196**	**>24196**
Conductivity Field					
Reported Result	µs/cm	**-**	**17760**	**14970**	**20368**
Enterococci (97w)					
Reported Result	MPN/100mL	**10**	**420**	**386**	**359**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**370**	**860**	**940**	**990**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**12.800**	**3.500**	**4.300**	**4.200**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**0.146**	**0.053**	**0.066**	**0.063**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**3.0**	**0.85**	**1.13**	**1.10**
Nitrogen (Total Oxidised)	mg/L	**12.9**	**3.5**	**4.4**	**4.3**
Nitrogen (Total)	mg/L	**15.9**	**4.3**	**5.6**	**5.0**
Oxygen (% Dissolved)					
Reported Result	%	**56.8**	**72.1**	**65.6**	**72.0**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**5.65**	**6.87**	**6.34**	**7.32**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**<3**	**<3**	**<3**	**<3**
pH					
Reported Result	pH Units	**6.9**	**7.3**	**7.2**	**7.2**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**2.7**	**0.48**	**0.61**	**0.61**
Phosphorus (Total Trace).					
Reported Result	mg/L	**2.8**	**0.57**	**0.72**	**0.72**
Salinity					
Reported Result	ppt	**<0.5**	**10.6**	**8.6**	**12.2**
Solids (Suspended)					
Reported Result	mg/L	**4**	**18**	**16**	**9**
Temperature Field					
Reported Result	°C	**15.5**	**14.5**	**14.5**	**14.5**
Turbidity					
Reported Result	NTU	**2.35**	**11.0**	**12.7**	**11.0**

Sample Reference		Limeburners Discharge 4	Limeburners Upper	Limeburners Mid	Limeburners Lower
Secondary Reference		ed	fa	fb	fd
Notes					
Our Reference		20060585	20060586	20060587	20060588
Sample Collection					
Ammonia (ISE LR)					
Reported Result	mg/L	**0.795**	**0.784**	**0.603**	**0.535**
Chlorophyll a (Trace).					
Reported Result	mg/L	**<0.003**	**<0.003**	**<0.003**	**<0.003**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**2603**	**2282**	**1376**	**1137**
Total Coliforms					
Reported Result	MPN/100mL	**>24196**	**24196**	**19863**	**>24196**
Conductivity Field					
Reported Result	μs/cm	**9010**	**5006**	**13774**	**19090**
Enterococci (97w)					
Reported Result	MPN/100mL	**364**	**135**	**197**	**393**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**1050**	**1290**	**1030**	**740**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**5.700**	**4.500**	**3.900**	**3.500**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**0.084**	**0.071**	**0.060**	**0.054**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**1.49**	**1.19**	**0.97**	**0.85**
Nitrogen (Total Oxidised)	mg/L	**5.8**	**4.6**	**4.0**	**3.5**
Nitrogen (Total)	mg/L	**6.9**	**5.4**	**5.1**	**4.4**
Oxygen (% Dissolved)					
Reported Result	%	**64.9**	**82.8**	**69.7**	**69.4**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**6.38**	**8.17**	**6.77**	**6.65**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**<3**	**<3**	**<3**	**<3**
pH					
Reported Result	pH Units	**7.1**	**7.1**	**7.2**	**7.2**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**0.83**	**0.66**	**0.55**	**0.47**
Phosphorus (Total Trace).					
Reported Result	mg/L	**0.98**	**0.77**	**0.64**	**0.56**
Salinity					
Reported Result	ppt	**5.1**	**2.7**	**8.1**	**11.2**
Solids (Suspended)					
Reported Result	mg/L	**13**	**<2.0**	**17**	**18**
Temperature Field					
Reported Result	°C	**14.6**	**14.6**	**14.4**	**14.5**
Turbidity					
Reported Result	NTU	**10.7**	**7.95**	**11.2**	**9.39**

Sample Reference		Limeburners Mouth
Secondary Reference		fd
Notes		
Our Reference		20060589
Sample Collection		
Ammonia (ISE LR)		
Reported Result	mg/L	**0.324**
Chlorophyll a (Trace).		
Reported Result	mg/L	**<0.003**
Escherichia coli (E. coli)		
Reported Result	MPN/100mL	**908**
Total Coliforms		
Reported Result	MPN/100mL	**24196**
Conductivity Field		
Reported Result	µs/cm	**27909**
Enterococci (97w)		
Reported Result	MPN/100mL	**195**
Faecal Coliform (Presumptive)		
Reported Result	cfu/100mL	**510**
Nitrogen (Nitrate Trace).		
Reported Result	mg/L	**2.000**
Nitrogen (Nitrite Trace).		
Reported Result	mg/L	**0.034**
Nitrogen (Total Trace).		
Nitrogen (Total Kjeldahl)	mg/L	**0.53**
Nitrogen (Total Oxidised)	mg/L	**2.1**
Nitrogen (Total)	mg/L	**2.7**
Oxygen (% Dissolved)		
Reported Result	%	**75.2**
Oxygen (Field Dissolved)		
Reported Result	mg/L	**6.87**
Oxygen Demand (Carbonaceous Biochemical)		
Reported Result	mg/L	**<3**
pH		
Reported Result	pH Units	**7.5**
Phosphorus (Dissolved Reactive).		
Reported Result	mg/L	**0.28**
Phosphorus (Total Trace).		
Reported Result	mg/L	**0.33**
Salinity		
Reported Result	ppt	**17.2**
Solids (Suspended)		
Reported Result	mg/L	**12**
Temperature Field		
Reported Result	°C	**14.3**
Turbidity		
Reported Result	NTU	**7.07**

Test Method Information

Method	*Reference*	*Method Type*
Salinity	APHA 2520 B	Not Accredited
pH	APHA Section 4500 H+ B	IANZ
Solids (Suspended)	APHA Section 2540 D	IANZ
Phosphorus (Dissolved Reactive).	APHA 4500 P E	Subcontracted
Faecal Coliform (Presumptive)	APHA section 9222D	IANZ
Enterococci (97w)	APHA 9230 D	IANZ
Escherichia coli (E. coli)	APHA Section 9223 B (Colilert)	IANZ
Total Coliforms	APHA Section 9223 B (Colilert)	IANZ
Oxygen Demand (Carbonaceous Biochemical)	APHA Section 5210B	IANZ
Temperature Field	APHA 2550 B	IANZ
Oxygen (% Dissolved)	APHA Section 4500 E	Not Accredited
Flow (m3/d)	NA	Not Accredited
Nitrogen (Nitrate Trace).	APHA 4500NO3 I	Subcontracted
Nitrogen (Nitrite Trace).	APHA 4500NO3 I	Subcontracted
Nitrogen (Total Trace).	Calc:TKN+TON	Subcontracted
Phosphorus (Total Trace).	APHA 4500P E	Subcontracted
Oxygen (Field Dissolved)	APHA Section 4500 E	Not Accredited
Ammonia (ISE LR)	APHA Section 4500-N D	IANZ
Turbidity	ISO7027-1:2016	IANZ
Chlorophyll a (Trace).	APHA 10200 H Fluorometer	Subcontracted
Conductivity Field	APHA 2510 B	IANZ

End of Report

Results are based on sample(s) as received, every effort is made to ensure these results are accurate. This report may not be reproduced except in full, without written consent of the signatory. Analysis is certified correct by the Key Technical Personnel. Dates of testing are available on request. Please contact the laboratory for more information.

Signed Lois N Howe Lois Howe

Reported 3/07/2020 1:12 PM

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Laboratory Analysis Report

Sample Information

Batch	2007B181
Site Name	Limeburners Creek Water Quality
Customer Reference	
Sampled By	
Sample Received	23/07/2020 4:15 PM

Results

Sample Reference		Wetland Inflow	Wetland 1 Outlet 1	Wetland 1 Outlet 2	Wetland 2 Outlet 3
Secondary Reference		ca	da	db	dc
Notes					
Our Reference		20070669	20070670	20070671	20070672
Sample Collection					
Ammonia (ISE LR)					
Reported Result	mg/L	**7.746**	**9.178**	**11.620**	**11.860**
Chlorophyll a (Trace).					
Reported Result	mg/L	**<0.003**	**<0.003**	**<0.003**	**<0.003**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**15531**	**8664**	**7270**	**556**
Total Coliforms					
Reported Result	MPN/100mL	**>24196**	**24196**	**17329**	**11199**
Enterococci (97w)					
Reported Result	MPN/100mL	**1414**	**496**	**377**	**52**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**5400**	**2400**	**1200**	**500**
Flow (m3/d)					
reported result	m3/d	**40947**	**-**	**-**	**-**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**8.700**	**8.100**	**5.700**	**1.670**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**0.106**	**0.43**	**0.40**	**0.27**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**8.7**	**9.4**	**10.8**	**11.3**
Nitrogen (Total Oxidised)	mg/L	**8.8**	**8.5**	**6.1**	**1.94**
Nitrogen (Total)	mg/L	**17.5**	**17.9**	**16.9**	**13.2**
Oxygen (% Dissolved)					
Reported Result	%	**77.4**	**52.6**	**44.1**	**63.3**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**7.60**	**5.25**	**4.45**	**6.63**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**9**	**7**	**6**	**4**
pH					
Reported Result	pH Units	**7.2**	**7.2**	**7.2**	**7.3**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**0.56**	**0.73**	**0.87**	**1.72**
Phosphorus (Total Trace).					
Reported Result	mg/L	**0.82**	**0.88**	**0.98**	**1.77**
Salinity					
Reported Result	ppt	**<0.5**	**<0.5**	**<0.5**	**<0.5**
Solids (Suspended)					
Reported Result	mg/L	**22**	**7**	**7**	**4**
Temperature Field					
Reported Result	°C	**16.0**	**15.5**	**15.2**	**13.3**
Turbidity					
Reported Result	NTU	**11.0**	**4.49**	**4.92**	**2.49**

Sample Reference		Wetland 2 Outlet 4	Limeburners Discharge 1	Limeburners Discharge 2	Limeburners Discharge 3
Secondary Reference		de	ea	eb	ec
Notes					
Our Reference		20070673	20070674	20070675	20070676
Sample Collection					
Ammonia (ISE LR)					
Reported Result	mg/L	**11.800**	**4.124**	**5.454**	**3.273**
Chlorophyll a (Trace).					
Reported Result	mg/L	**<0.003**	**<0.003**	**<0.003**	**<0.003**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**1043**	**1191**	**2014**	**1616**
Total Coliforms					
Reported Result	MPN/100mL	**9804**	**1733**	**>24196**	**>24196**
Conductivity Field					
Reported Result	µs/cm	**-**	**6598**	**4160**	**5520**
Enterococci (97w)					
Reported Result	MPN/100mL	**52**	**119**	**96**	**238**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**530**	**772**	**781**	**818**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**1.550**	**1.640**	**2.500**	**1.230**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**0.27**	**0.143**	**0.168**	**0.113**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**10.8**	**4.1**	**4.3**	**3.8**
Nitrogen (Total Oxidised)	mg/L	**1.82**	**1.78**	**2.6**	**1.34**
Nitrogen (Total)	mg/L	**12.7**	**6.4**	**6.9**	**5.1**
Oxygen (% Dissolved)					
Reported Result	%	**55.5**	**70.5**	**60.2**	**74.8**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**5.81**	**7.13**	**5.80**	**7.76**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**4**	**<3**	**<3**	**<3**
pH					
Reported Result	pH Units	**7.3**	**7.2**	**7.2**	**7.3**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**1.73**	**0.23**	**0.34**	**0.23**
Phosphorus (Total Trace).					
Reported Result	mg/L	**1.80**	**0.37**	**0.41**	**0.40**
Salinity					
Reported Result	ppt	**<0.5**	**3.5**	**2.2**	**3.0**
Solids (Suspended)					
Reported Result	mg/L	**4**	**23**	**19**	**19**
Temperature Field					
Reported Result	°C	**13.2**	**13.3**	**14.2**	**13.1**
Turbidity					
Reported Result	NTU	**2.27**	**11.5**	**10.1**	**12.9**

Sample Reference		Limeburners Discharge 4	Limeburners Upper	Limeburners Mid	Limeburners Lower
Secondary Reference		ed	fa	fb	fd
Notes					
Our Reference		20070677	20070678	20070679	20070680
Sample Collection					
Ammonia (ISE LR)					
Reported Result	mg/L	**3.488**	**5.507**	**3.070**	**3.780**
Chlorophyll a (Trace).					
Reported Result	mg/L	**<0.003**	**<0.003**	**<0.003**	**<0.003**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**1467**	**1616**	**2178**	**1850**
Total Coliforms					
Reported Result	MPN/100mL	**15531**	**>24196**	**>24196**	**15531**
Conductivity Field					
Reported Result	µs/cm	**3170**	**1450**	**4660**	**7220**
Enterococci (97w)					
Reported Result	MPN/100mL	**63**	**241**	**156**	**134**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**700**	**990**	**727**	**745**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**1.290**	**1.910**	**1.270**	**1.570**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**0.116**	**0.193**	**0.111**	**0.137**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**2.9**	**5.2**	**2.8**	**3.2**
Nitrogen (Total Oxidised)	mg/L	**1.41**	**2.1**	**1.38**	**1.71**
Nitrogen (Total)	mg/L	**4.3**	**7.3**	**4.1**	**4.9**
Oxygen (% Dissolved)					
Reported Result	%	**81.8**	**86.8**	**76.2**	**73.9**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**8.53**	**8.94**	**7.94**	**7.67**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**<3**	**<3**	**<3**	**<3**
pH					
Reported Result	pH Units	**7.3**	**7.3**	**7.3**	**7.2**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**0.23**	**0.33**	**0.23**	**0.23**
Phosphorus (Total Trace).					
Reported Result	mg/L	**0.32**	**0.47**	**0.28**	**0.30**
Salinity					
Reported Result	ppt	**1.6**	**0.7**	**2.5**	**3.9**
Solids (Suspended)					
Reported Result	mg/L	**13**	**10**	**18**	**20**
Temperature Field					
Reported Result	°C	**12.9**	**13.1**	**13.0**	**13.3**
Turbidity					
Reported Result	NTU	**10.9**	**9.84**	**11.5**	**13.2**

Sample Reference		Limeburners Mouth
Secondary Reference		fd
Notes		
Our Reference		20070681
Sample Collection		
Ammonia (ISE LR)		
Reported Result	mg/L	**2.193**
Chlorophyll a (Trace).		
Reported Result	mg/L	**<0.003**
Escherichia coli (E. coli)		
Reported Result	MPN/100mL	**1169**
Total Coliforms		
Reported Result	MPN/100mL	**19863**
Conductivity Field		
Reported Result	µs/cm	**13850**
Enterococci (97w)		
Reported Result	MPN/100mL	**95**
Faecal Coliform (Presumptive)		
Reported Result	cfu/100mL	**370**
Nitrogen (Nitrate Trace).		
Reported Result	mg/L	**1.240**
Nitrogen (Nitrite Trace).		
Reported Result	mg/L	**0.083**
Nitrogen (Total Trace).		
Nitrogen (Total Kjeldahl)	mg/L	**1.7**
Nitrogen (Total Oxidised)	mg/L	**1.32**
Nitrogen (Total)	mg/L	**3.0**
Oxygen (% Dissolved)		
Reported Result	%	**85.4**
Oxygen (Field Dissolved)		
Reported Result	mg/L	**8.28**
Oxygen Demand (Carbonaceous Biochemical)		
Reported Result	mg/L	**<3**
pH		
Reported Result	pH Units	**7.4**
Phosphorus (Dissolved Reactive).		
Reported Result	mg/L	**0.147**
Phosphorus (Total Trace).		
Reported Result	mg/L	**0.180**
Salinity		
Reported Result	ppt	**7.9**
Solids (Suspended)		
Reported Result	mg/L	**19**
Temperature Field		
Reported Result	°C	**13.4**
Turbidity		
Reported Result	NTU	**13.4**

Test Method Information

Method	*Reference*	*Method Type*
Salinity	APHA 2520 B	Not Accredited
pH	APHA Section 4500 H+ B	IANZ
Solids (Suspended)	APHA Section 2540 D	IANZ
Phosphorus (Dissolved Reactive).	APHA 4500 P E	Subcontracted
Faecal Coliform (Presumptive)	APHA section 9222D	IANZ
Enterococci (97w)	APHA 9230 D	IANZ
Escherichia coli (E. coli)	APHA Section 9223 B (Colilert)	IANZ
Total Coliforms	APHA Section 9223 B (Colilert)	IANZ
Oxygen Demand (Carbonaceous Biochemical)	APHA Section 5210B	IANZ
Temperature Field	APHA 2550 B	IANZ
Oxygen (% Dissolved)	APHA Section 4500 E	Not Accredited
Flow (m3/d)	NA	Not Accredited
Nitrogen (Nitrate Trace).	APHA 4500NO3 I	Subcontracted
Nitrogen (Nitrite Trace).	APHA 4500NO3 I	Subcontracted
Nitrogen (Total Trace).	Calc:TKN+TON	Subcontracted
Phosphorus (Total Trace).	APHA 4500P E	Subcontracted
Oxygen (Field Dissolved)	APHA Section 4500 E	Not Accredited
Ammonia (ISE LR)	APHA Section 4500-N D	IANZ
Turbidity	ISO7027-1:2016	IANZ
Chlorophyll a (Trace).	APHA 10200 H Fluorometer	Subcontracted
Conductivity Field	APHA 2510 B	IANZ

End of Report

Signed Lois N Howe Lois Howe

Reported 4/08/2020 10:44 AM

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Hai Hguyen
WDC Wastewater Treatment
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Whangarei

Laboratory Analysis Report

Sample Information

Batch	2010B001
Site Name	Limeburners Creek Water Quality
Customer Reference	
Sampled By	.Customer
Sample Received	1/10/2020 2:36 PM

Results

Sample Reference		Wetland Inflow	Wetland 1 Outlet 1	Wetland 1 Outlet 2	Wetland 2 Outlet 3
Secondary Reference		ca	da	db	dc
Notes			Vegetation in sample		vegetation in sample
Our Reference		20100001	20100002	20100003	20100004
Sample Collection		1/10/2020 8:30 AM	1/10/2020 8:38 AM	1/10/2020 8:45 AM	1/10/2020 8:58 AM
Ammonia (ISE LR)					
Reported Result	mg/L	**49.570**	**38.740**	**39.220**	**36.610**
Chlorophyll a (Trace).					
Reported Result	mg/L	**<0.003**	**0.067**	**0.003**	**0.011**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**38730**	**2489**	**5172**	**882**
Total Coliforms					
Reported Result	MPN/100mL	**>241960**	**>24196**	**>24196**	**19863**
Enterococci (97w)					
Reported Result	MPN/100mL	**20640**	**1467**	**2142**	**305**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**13909**	**1663**	**2000**	**260**
Flow (m3/d)					
reported result	m3/d	**11941**	**-**	**-**	**-**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**5.4**	**3.5**	**3.6**	**3.0**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**6.1**	**3.7**	**4.1**	**2.3**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**49**	**39**	**40**	**36**
Nitrogen (Total Oxidised)	mg/L	**11.5**	**7.1**	**7.7**	**5.2**
Nitrogen (Total)	mg/L	**60**	**46**	**48**	**41**
Oxygen (% Dissolved)					
Reported Result	%	**86.7**	**32.0**	**38.7**	**56.8**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**8.60**	**3.21**	**3.84**	**5.80**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**9**	**12**	**4**	**7**
pH					
Reported Result	pH Units	**7.7**	**7.5**	**7.5**	**7.5**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**3.8**	**4.3**	**4.3**	**4.5**
Phosphorus (Total Trace).					
Reported Result	mg/L	**4.2**	**4.6**	**4.4**	**4.6**
Salinity					
Reported Result	ppt	**0.6**	**0.5**	**0.5**	**0.5**
Solids (Suspended)					
Reported Result	mg/L	**12**	**35**	**<2.0**	**50**
Temperature Field					
Reported Result	°C	**15.9**	**15.2**	**15.5**	**13.7**
Turbidity					
Reported Result	NTU	**5.94**	**6.00**	**2.25**	**7.17**

Sample Reference		Wetland 2 Outlet 4	Limeburners Discharge 1	Limeburners Discharge 2	Limeburners Discharge 3
Secondary Reference		de	ea	eb	ec
Notes					
Our Reference		20100005	20100006	20100007	20100008
Sample Collection		1/10/2020 9:03 AM	1/10/2020 10:39 AM	1/10/2020 10:31 AM	1/10/2020 10:15 AM
Ammonia (ISE LR)					
Reported Result	mg/L	**38.240**	**12.590**	**15.030**	**12.790**
Chlorophyll a (Trace).					
Reported Result	mg/L	**0.020**	**<0.003**	**0.004**	**<0.003**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**1317**	**1211**	**1250**	**676**
Total Coliforms					
Reported Result	MPN/100mL	**>24196**	**>24196**	**>24196**	**>24196**
Conductivity Field					
Reported Result	µs/cm	**-**	**25400**	**22400**	**18280**
Enterococci (97w)					
Reported Result	MPN/100mL	**487**	**504**	**504**	**697**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**1000**	**500**	**540**	**310**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**3.0**	**1.97**	**2.0**	**1.95**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**2.5**	**0.70**	**0.80**	**0.74**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**39**	**12.1**	**13.9**	**13.1**
Nitrogen (Total Oxidised)	mg/L	**5.5**	**2.7**	**2.8**	**2.7**
Nitrogen (Total)	mg/L	**45**	**14.8**	**16.7**	**15.8**
Oxygen (% Dissolved)					
Reported Result	%	**50.3**	**62.5**	**58.8**	**59.2**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**5.16**	**6.26**	**5.89**	**5.45**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**5**	**<3**	**<3**	**<3**
pH					
Reported Result	pH Units	**7.4**	**7.4**	**7.4**	**7.4**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**4.5**	**1.41**	**1.54**	**1.52**
Phosphorus (Total Trace).					
Reported Result	mg/L	**4.7**	**1.50**	**1.63**	**1.68**
Salinity					
Reported Result	ppt	**0.5**	**15.3**	**13.5**	**10.7**
Solids (Suspended)					
Reported Result	mg/L	**6**	**22**	**25**	**12**
Temperature Field					
Reported Result	°C	**14.1**	**15.3**	**15.3**	**14.2**
Turbidity					
Reported Result	NTU	**2.74**	**3.38**	**3.46**	**4.01**

Sample Reference		Limeburners Discharge 4	Limeburners Upper	Limeburners Mid	Limeburners Lower
Secondary Reference		ed	fa	fb	fd
Notes					
Our Reference		20100009	20100010	20100011	20100012
Sample Collection		1/10/2020 10:10 AM	1/10/2020 10:06 AM	1/10/2020 10:24 AM	1/10/2020 10:44 AM
Ammonia (ISE LR)					
Reported Result	mg/L	**15.500**	**19.540**	**12.170**	**10.010**
Chlorophyll a (Trace).					
Reported Result	mg/L	**<0.003**	**<0.003**	**<0.003**	**<0.003**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**776**	**1553**	**663**	**759**
Total Coliforms					
Reported Result	MPN/100mL	**>24196**	**>24196**	**>24196**	**>24196**
Conductivity Field					
Reported Result	µs/cm	**16040**	**13410**	**23200**	**28800**
Enterococci (97w)					
Reported Result	MPN/100mL	**327**	**521**	**546**	**432**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**36**	**836**	**350**	**340**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**2.1**	**2.8**	**1.92**	**1.68**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**0.86**	**1.19**	**0.72**	**0.62**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**14.9**	**19.4**	**12.3**	**10.4**
Nitrogen (Total Oxidised)	mg/L	**3.0**	**4.0**	**2.6**	**2.3**
Nitrogen (Total)	mg/L	**17.9**	**23**	**14.9**	**12.7**
Oxygen (% Dissolved)					
Reported Result	%	**55.5**	**60.5**	**59.0**	**66.3**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**5.61**	**6.30**	**5.90**	**6.74**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**<3**	**<3**	**<3**	**<3**
pH					
Reported Result	pH Units	**7.4**	**7.5**	**7.4**	**7.5**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**1.88**	**2.4**	**1.50**	**1.20**
Phosphorus (Total Trace).					
Reported Result	mg/L	**1.89**	**2.5**	**1.48**	**1.26**
Salinity					
Reported Result	ppt	**9.3**	**7.7**	**13.9**	**17.6**
Solids (Suspended)					
Reported Result	mg/L	**19**	**11**	**18**	**48**
Temperature Field					
Reported Result	°C	**14.8**	**16.1**	**15.1**	**14.7**
Turbidity					
Reported Result	NTU	**5.98**	**3.51**	**3.97**	**4.64**

Sample Reference		Limeburners Mouth
Secondary Reference		fd
Notes		
Our Reference		20100013
Sample Collection		1/10/2020 10:55 AM
Ammonia (ISE LR)		
Reported Result	mg/L	**2.770**
Chlorophyll a (Trace).		
Reported Result	mg/L	**<0.003**
Escherichia coli (E. coli)		
Reported Result	MPN/100mL	**121**
Total Coliforms		
Reported Result	MPN/100mL	**11199**
Conductivity Field		
Reported Result	µs/cm	**39400**
Enterococci (97w)		
Reported Result	MPN/100mL	**63**
Faecal Coliform (Presumptive)		
Reported Result	cfu/100mL	**109**
Nitrogen (Nitrate Trace).		
Reported Result	mg/L	**0.61**
Nitrogen (Nitrite Trace).		
Reported Result	mg/L	**0.20**
Nitrogen (Total Trace).		
Nitrogen (Total Kjeldahl)	mg/L	**2.1**
Nitrogen (Total Oxidised)	mg/L	**0.81**
Nitrogen (Total)	mg/L	**2.9**
Oxygen (% Dissolved)		
Reported Result	%	**80.5**
Oxygen (Field Dissolved)		
Reported Result	mg/L	**7.81**
Oxygen Demand (Carbonaceous Biochemical)		
Reported Result	mg/L	**<3**
pH		
Reported Result	pH Units	**7.7**
Phosphorus (Dissolved Reactive).		
Reported Result	mg/L	**0.34**
Phosphorus (Total Trace).		
Reported Result	mg/L	**0.32**
Salinity		
Reported Result	ppt	**24.9**
Solids (Suspended)		
Reported Result	mg/L	**26**
Temperature Field		
Reported Result	°C	**16.2**
Turbidity		
Reported Result	NTU	**3.17**

Test Method Information

Method	*Reference*	*Method Type*
Chlorophyll a (Trace).	APHA 10200 H Fluorometer	Subcontracted
Ammonia (ISE LR)	APHA Section 4500-N D	IANZ
Turbidity	ISO7027-1:2016	IANZ
Phosphorus (Total Trace).	APHA 4500P E	Subcontracted
Oxygen (Field Dissolved)	APHA Section 4500 E	Not Accredited
Nitrogen (Nitrite Trace).	APHA 4500NO3 I	Subcontracted
Nitrogen (Total Trace).	Calc:TKN+TON	Subcontracted
Flow (m3/d)	NA	Not Accredited
Nitrogen (Nitrate Trace).	APHA 4500NO3 I	Subcontracted
Oxygen (% Dissolved)	APHA Section 4500 E	Not Accredited
Temperature Field	APHA 2550 B	IANZ
Salinity	APHA 2520 B	Not Accredited
Total Coliforms	APHA Section 9223 B (Colilert)	IANZ
Oxygen Demand (Carbonaceous Biochemical)	APHA Section 5210B	IANZ
Enterococci (97w)	APHA 9230 D	IANZ
Escherichia coli (E. coli)	APHA Section 9223 B (Colilert)	IANZ
Phosphorus (Dissolved Reactive).	APHA 4500 P E	Subcontracted
Faecal Coliform (Presumptive)	APHA section 9222D	IANZ
pH	APHA Section 4500 H+ B	IANZ
Solids (Suspended)	APHA Section 2540 D	IANZ
Conductivity Field	APHA 2510 B	IANZ

End of Report

Results are based on sample(s) as received, every effort is made to ensure these results are accurate. This report may not be reproduced except in full, without written consent of the signatory. Analysis is certified correct by the Key Technical Personnel. Dates of testing are available on request. Please contact the laboratory for more information.

Signed Lois Howe

Reported 8/10/2020 8:56 AM

This Laboratory is accredited by International Accreditation New Zealand.
The tests specified in this report have been performed in accordance with IANZ terms of accreditation.

Whangarei District Laboratory

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Hai Hguyen
WDC Wastewater Treatment
Kioreroa Rd
Private Bag 9023
Whangarei

Laboratory Analysis Report

Sample Information

Batch	2010B184
Site Name	Limeburners Creek Water Quality
Customer Reference	
Sampled By	.Customer
Sample Received	29/10/2020 12:01 PM

Results

Sample Reference		Wetland Inflow	Wetland 1 Outlet 1	Wetland 1 Outlet 2	Wetland 2 Outlet 3
Secondary Reference		ca	da	db	dc
Notes					
Our Reference		20100658	20100659	20100660	20100661
Sample Collection		29/10/2020 7:14 AM	29/10/2020 7:30 AM	29/10/2020 7:39 AM	29/10/2020 7:55 AM
Ammonia (ISE LR)					
Reported Result	mg/L	**19.010**	**11.690**	**12.570**	**11.920**
Chlorophyll a (Trace).					
Reported Result	mg/L	**0.0041**	**0.0053**	**0.0122**	**0.023**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**8200**	**3255**	**4352**	**670**
Total Coliforms					
Reported Result	MPN/100mL	**92080**	**>24196**	**>24196**	**>24196**
Enterococci (97w)					
Reported Result	MPN/100mL	**4500**	**1071**	**1291**	**613**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**4900**	**2100**	**1927**	**890**
Flow (m3/d)					
reported result	m3/d	**14525**	**-**	**-**	**-**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**2.6**	**3.5**	**3.6**	**1.81**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**7.9**	**4.6**	**4.9**	**1.43**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**22**	**11.3**	**13.3**	**11.9**
Nitrogen (Total Oxidised)	mg/L	**10.5**	**8.1**	**8.5**	**3.2**
Nitrogen (Total)	mg/L	**32**	**19.4**	**22**	**15.1**
Oxygen (% Dissolved)					
Reported Result	%	**82.4**	**36.3**	**57.9**	**54.8**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**7.47**	**3.28**	**5.25**	**5.01**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**8**	**6**	**5**	**3**
pH					
Reported Result	pH Units	**7.4**	**7.3**	**7.3**	**7.3**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**4.3**	**5.0**	**4.9**	**5.5**
Phosphorus (Total Trace).					
Reported Result	mg/L	**4.5**	**4.9**	**5.1**	**5.6**
Salinity					
Reported Result	ppt	**<0.5**	**<0.5**	**<0.5**	**<0.5**
Solids (Suspended)					
Reported Result	mg/L	**14**	**17**	**9**	**6**
Temperature Field					
Reported Result	°C	**20.0**	**20.2**	**20.3**	**19.5**
Turbidity					
Reported Result	NTU	**6.27**	**5.27**	**3.17**	**3.23**

Sample Reference		Wetland 2 Outlet 4	Limeburners Discharge 1	Limeburners Discharge 2	Limeburners Discharge 3
Secondary Reference		de	ea	eb	ec
Notes					
Our Reference		20100662	20100663	20100664	20100665
Sample Collection		29/10/2020 8:01 AM	29/10/2020 8:00 AM	29/10/2020 9:08 AM	29/10/2020 9:13 AM
Ammonia (ISE LR)					
Reported Result	mg/L	**13.720**	**5.362**	**6.610**	**1.952**
Chlorophyll a (Trace).					
Reported Result	mg/L	**0.0139**	**0.0022**	**0.0036**	**0.0038**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**1274**	**5794**	**3282**	**3076**
Total Coliforms					
Reported Result	MPN/100mL	**>24196**	**>24196**	**>24196**	**>24196**
Conductivity Field					
Reported Result	µs/cm	**-**	**10440**	**7610**	**8030**
Enterococci (97w)					
Reported Result	MPN/100mL	**670**	**5794**	**2143**	**3873**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**1081**	**-**	**2600**	**2100**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**1.76**	**2.5**	**2.7**	**0.94**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**1.34**	**0.97**	**1.40**	**0.25**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**14.2**	**7.8**	**8.0**	**2.3**
Nitrogen (Total Oxidised)	mg/L	**3.1**	**3.5**	**4.1**	**1.20**
Nitrogen (Total)	mg/L	**17.3**	**11.3**	**12.1**	**3.5**
Oxygen (% Dissolved)					
Reported Result	%	**47.6**	**47.5**	**58.7**	**59.2**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**4.37**	**4.39**	**5.34**	**5.41**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**3**	**<3**	**<3**	**<3**
pH					
Reported Result	pH Units	**7.3**	**7.2**	**7.2**	**7.2**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**5.4**	**2.7**	**3.1**	**1.07**
Phosphorus (Total Trace).					
Reported Result	mg/L	**5.6**	**2.8**	**2.8**	**1.10**
Salinity					
Reported Result	ppt	**<0.5**	**5.9**	**4.2**	**4.4**
Solids (Suspended)					
Reported Result	mg/L	**6**	**12**	**10**	**21**
Temperature Field					
Reported Result	°C	**19.5**	**19.7**	**19.5**	**19.5**
Turbidity					
Reported Result	NTU	**3.14**	**11.9**	**10.3**	**18.0**

Sample Reference		Limeburners Discharge 4	Limeburners Upper	Limeburners Mid	Limeburners Lower
Secondary Reference		ed	fa	fb	fd
Notes					
Our Reference		20100666	20100667	20100668	20100669
Sample Collection		29/10/2020 9:20 AM	29/10/2020 9:26 AM	29/10/2020 9:33 AM	29/10/2020 9:37 AM
Ammonia (ISE LR)					
Reported Result	mg/L	**2.064**	**1.414**	**2.674**	**2.823**
Chlorophyll a (Trace).					
Reported Result	mg/L	**0.0046**	**0.0009**	**0.0023**	**0.0047**
Escherichia coli (E. coli)					
Reported Result	MPN/100mL	**2098**	**1658**	**3076**	**4352**
Total Coliforms					
Reported Result	MPN/100mL	**>24196**	**>24196**	**>24196**	**>24196**
Conductivity Field					
Reported Result	µs/cm	**6440**	**4190**	**8840**	**17340**
Enterococci (97w)					
Reported Result	MPN/100mL	**3255**	**4352**	**3255**	**1872**
Faecal Coliform (Presumptive)					
Reported Result	cfu/100mL	**2100**	**2600**	**2000**	**1700**
Nitrogen (Nitrate Trace).					
Reported Result	mg/L	**0.81**	**0.81**	**1.29**	**2.0**
Nitrogen (Nitrite Trace).					
Reported Result	mg/L	**0.23**	**0.20**	**0.39**	**0.70**
Nitrogen (Total Trace).					
Nitrogen (Total Kjeldahl)	mg/L	**2.9**	**2.3**	**3.7**	**3.1**
Nitrogen (Total Oxidised)	mg/L	**1.05**	**1.02**	**1.68**	**2.7**
Nitrogen (Total)	mg/L	**4.0**	**3.3**	**5.4**	**5.8**
Oxygen (% Dissolved)					
Reported Result	%	**56.8**	**51.8**	**50.4**	**53.6**
Oxygen (Field Dissolved)					
Reported Result	mg/L	**5.20**	**4.83**	**4.56**	**4.81**
Oxygen Demand (Carbonaceous Biochemical)					
Reported Result	mg/L	**<3**	**<3**	**<3**	**<3**
pH					
Reported Result	pH Units	**7.2**	**7.2**	**7.2**	**7.3**
Phosphorus (Dissolved Reactive).					
Reported Result	mg/L	**1.01**	**0.92**	**1.55**	**1.56**
Phosphorus (Total Trace).					
Reported Result	mg/L	**1.16**	**1.08**	**1.58**	**1.65**
Salinity					
Reported Result	ppt	**3.5**	**2.2**	**4.9**	**10.1**
Solids (Suspended)					
Reported Result	mg/L	**20**	**10**	**12**	**37**
Temperature Field					
Reported Result	°C	**19.6**	**19.8**	**20.5**	**20.9**
Turbidity					
Reported Result	NTU	**19.7**	**14.8**	**14.4**	**30.5**

Sample Reference		Limeburners Mouth
Secondary Reference		fd
Notes		
Our Reference		20100670
Sample Collection		29/10/2020 9:52 AM
Ammonia (ISE LR)		
Reported Result	mg/L	**1.978**
Chlorophyll a (Trace).		
Reported Result	mg/L	**0.0070**
Escherichia coli (E. coli)		
Reported Result	MPN/100mL	**1789**
Total Coliforms		
Reported Result	MPN/100mL	**>24196**
Conductivity Field		
Reported Result	µs/cm	**21500**
Enterococci (97w)		
Reported Result	MPN/100mL	**1670**
Faecal Coliform (Presumptive)		
Reported Result	cfu/100mL	**972**
Nitrogen (Nitrate Trace).		
Reported Result	mg/L	**1.31**
Nitrogen (Nitrite Trace).		
Reported Result	mg/L	**0.54**
Nitrogen (Total Trace).		
Nitrogen (Total Kjeldahl)	mg/L	**2.5**
Nitrogen (Total Oxidised)	mg/L	**1.85**
Nitrogen (Total)	mg/L	**4.4**
Oxygen (% Dissolved)		
Reported Result	%	**74.5**
Oxygen (Field Dissolved)		
Reported Result	mg/L	**6.54**
Oxygen Demand (Carbonaceous Biochemical)		
Reported Result	mg/L	**<3**
pH		
Reported Result	pH Units	**7.4**
Phosphorus (Dissolved Reactive).		
Reported Result	mg/L	**1.12**
Phosphorus (Total Trace).		
Reported Result	mg/L	**1.21**
Salinity		
Reported Result	ppt	**12.9**
Solids (Suspended)		
Reported Result	mg/L	**13**
Temperature Field		
Reported Result	°C	**21.7**
Turbidity		
Reported Result	NTU	**10.6**

Test Method Information

Method	*Reference*	*Method Type*
Chlorophyll a (Trace).	APHA 10200 H Fluorometer	Subcontracted
Ammonia (ISE LR)	APHA Section 4500-N D	IANZ
Turbidity	ISO7027-1:2016	IANZ
Phosphorus (Total Trace).	APHA 4500P E	Subcontracted
Oxygen (Field Dissolved)	APHA Section 4500 E	Not Accredited
Nitrogen (Nitrite Trace).	APHA 4500NO3 I	Subcontracted
Nitrogen (Total Trace).	Calc:TKN+TON	Subcontracted
Flow (m3/d)	NA	Not Accredited
Nitrogen (Nitrate Trace).	APHA 4500NO3 I	Subcontracted
Temperature Field	APHA 2550 B	IANZ
Oxygen (% Dissolved)	APHA Section 4500 E	Not Accredited
Salinity	APHA 2520 B	Not Accredited
Total Coliforms	APHA Section 9223 B (Colilert)	IANZ
Oxygen Demand (Carbonaceous Biochemical)	APHA Section 5210B	IANZ
Enterococci (97w)	APHA 9230 D	IANZ
Escherichia coli (E. coli)	APHA Section 9223 B (Colilert)	IANZ
Phosphorus (Dissolved Reactive).	APHA 4500 P E	Subcontracted
Faecal Coliform (Presumptive)	APHA section 9222D	IANZ
pH	APHA Section 4500 H+ B	IANZ
Solids (Suspended)	APHA Section 2540 D	IANZ
Conductivity Field	APHA 2510 B	IANZ

End of Report

Signed Lois N Howe Lois Howe

Reported 16/11/2020 4:59 PM

IANZ ACCREDITED LABORATORY

This Laboratory is accredited by International Accreditation New Zealand.
The tests specified in this report have been performed in accordance with IANZ terms of accreditation.

Appendix D:

Seasonality Boxplots

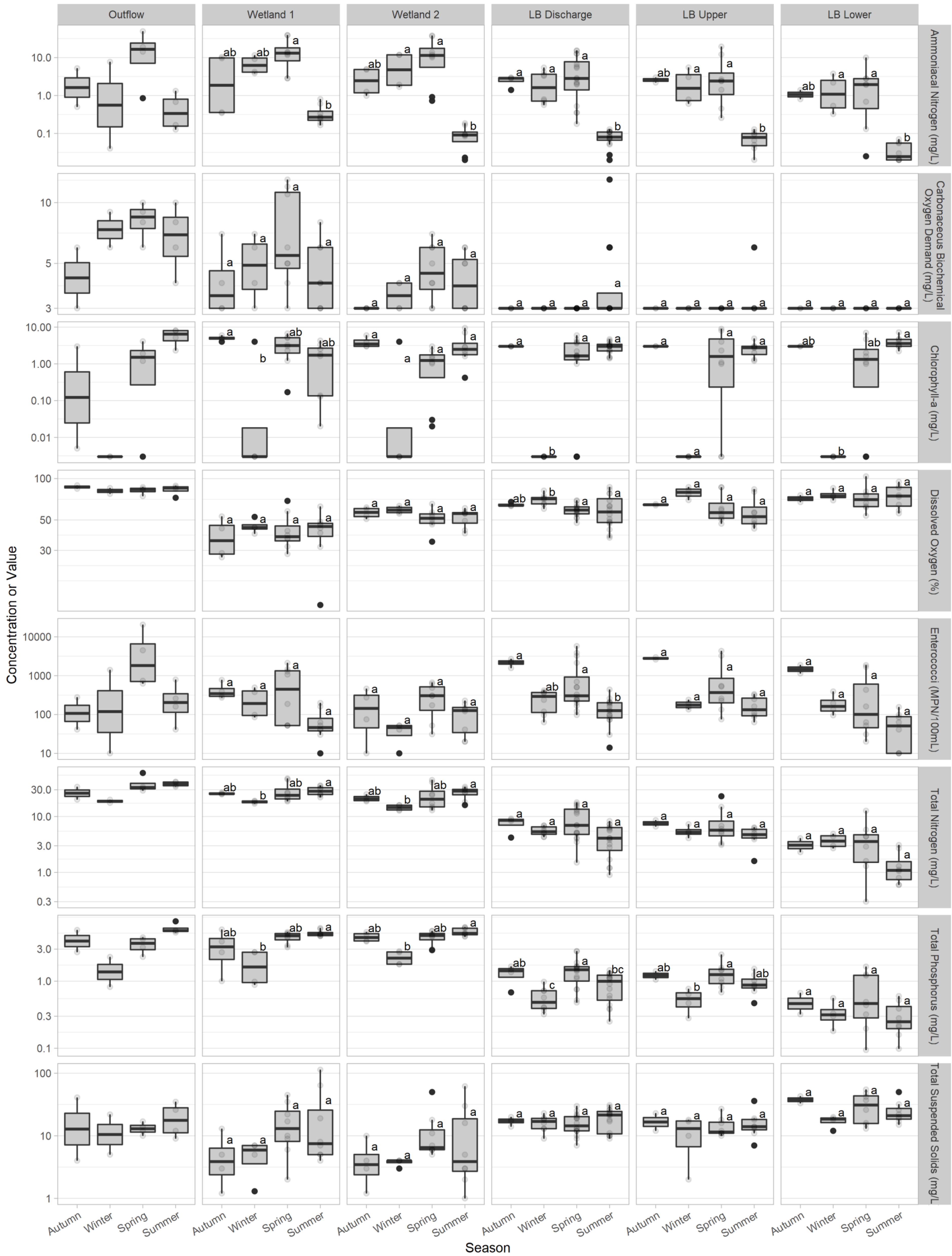

Figure C1: Boxplots of key water quality parameters by site and season. Note the log-scale on the x-axis. Letters above each box indicate statistical significance as determined by a Kruskal–Wallis test (Outflow was omitted due to limited data points).

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Appendix C

4Sight, Baseline Ecological Survey Report, 2020

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LAND. PEOPLE. WATER.

WHANGAREI WASTEWATER TREATMENT PLANT

For Whangarei District Council

Baseline Ecological Survey 2020

September 2020

REPORT INFORMATION AND QUALITY CONTROL

Prepared for:	Hai Nguyen Waste & Drainage Department Whangārei District Council	

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Reviewer:	Mark Poynter Principal Ecology Consultant	
Approved for Release:	Mark Poynter Principal Ecology Consultant	

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	1.0	4/11/2020

TOITŪ CARBON REDUCE ISO 14064-1 ORGANISATION

SITE SAFE MEMBER

Telarc. Registered Telarc Q-Base Code

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1 INTRODUCTION

Whangārei District Council ('WDC') hold consents to discharge treated wastewater from the Whangārei District Council Wastewater Treatment Plant ('WWTP') into Limeburners Creek (Figure 1). These consents will expire in April 2022. It is anticipated that WDC will lodge applications for new consents during late 2021.

Figure 1: Approximate location of the Whangārei District Council WWTP and the key rivers and creeks assessed in this report.

4Sight Consulting Ltd (4Sight) was commissioned by WDC to conduct a baseline ecological survey of Limeburners Creek, the nearby receiving environment, and a background (reference) site. The purpose of this survey is to characterise the WWTP discharge receiving environment to assess the effects of the discharge on sediment quality, water quality, and benthic ecology.

Surveys were conducted over two summers (March 2019 and February 2020) to provide sampling replication to understand the potential natural variability and heterogeneity of the environment and its ecology. Two surveys conducted during sequential years is insufficient to assess trends or change over time, so this has not been attempted here. Rather, differences between years have been interpreted within the context of expected natural variation relative to potential environmental gradients associated with the Limeburners Creek treated wastewater discharge.

Results from the first survey (2019) were reported by Wilson and Bone (2019). This report (2020) builds on the previous and further assesses the data to characterise the state of Limeburners Creek and the nearby receiving environment. The potential effects of the WWTP discharge on Limeburners Creek and the receiving environment are also briefly discussed in this report. This is a baseline technical report that will contribute to a formal assessment of ecological effects, which is yet to be prepared.

2 METHODS

This section describes the methods that were used to characterise the environment nearby the WWTP discharge, including broadscale habitat mapping, fine-scale benthic ecology assessments, and sediment and water quality in Limeburners Creek and surrounding areas.

2.1 Broad-scale habitat mapping

Broad-scale habitat mapping of Limeburners Creek was completed using methods adapted from the New Zealand National Estuarine Monitoring Protocol (NEMP; Robertson et al., 2002). Briefly, GIS referenced aerial photographs in GIS software were used to derive a broad outline of dominant habitat features. Ground-truthing of the aerial map and field identification of the dominant substrate and vegetation types was then completed over 19–20 March 2019 following the methods outlined in the NZ Estuarine Trophic Index (ETI) Tool 2 (Robertson et al., 2016). Habitat types were checked for accuracy during sampling on 18–19 February 2020. The map was subsequently updated and refined to produce a habitat map of the following estuary features within Limeburners Creek:

- Mangrove forest;
- Seagrass;
- Opportunistic (seasonal) macroalgae;
- Subtidal area; and
- Substrate types (e.g. soft mud, oyster reef, gravel-field, rock-field).

The area of the mapped estuary features were determined and their values compared to the numerical trophic threshold rating bands (A to D) defined in the ETI.

2.2 Fine-scale ecology

Fine-scale ecology sampling was completed according to the methods outlined in the NEMP (Robertson et al., 2002) and updates to this method described in the ETI Tool 2 (Robertson et al., 2016). These guidelines specify that fine-scale sampling sites must be representative of the estuarine area of interest and comprise low to mid intertidal flats that are unvegetated and not within the estuary channels.

Representative fine-scale sampling sites were selected based on initial reconnaissance surveys and following the first stage of broad-scale habitat mapping. We included two sites within Limeburners Creek (one upstream and one downstream of the WWTP discharges), one site in the Hātea River, and one site in the Awaroa Creek (Appendix A) to serve as an approximate reference or comparison site. It is important to note that because the Awaroa Creek site is relatively close to Limeburners Creek, it may be influenced by the WWTP discharge to some extent and may not serve as a true reference site. However, it is the best candidate for comparisons with Limeburners Creek in the upper Whangārei Harbour. At each site, a 50 × 5 m plot was established. An exception to this was at the Awaroa site, which had a slightly reduced 50 × 3 m plot due to the limited available intertidal area. Within each plot, 10 locations were selected using a random number generator. A cylindrical core (15 cm diameter by 15 cm length; volume 2.65 L) was taken from the sediment at each of these 10 random positions.

The intact core was transferred to a 500 µm mesh sieve sock and washed to remove the fine sediments from the infauna and debris. The remaining infauna and debris were transferred to a jar and preserved in an 80% ethanol/seawater solution. Samples were stained with Rose Bengal dye before extracting the infauna from the debris by experienced 4Sight staff. The extracted infauna samples were sent to the Cawthron Institute for taxonomic identification and enumeration.

2.3 Water quality

Discrete water samples were collected by 4Sight on 19–20 March 2019 and 19 February 2020 to gain a snapshot of water quality in Limeburners Creek, Hātea River, and Awaroa Creek (locations shown in Appendix A). Sampling was conducted approximately one hour after high tide. This is separate to monthly water quality sampling, also being conducted by 4Sight, that began in February 2020 to understand how water quality changes from the treatment wetlands, into Limeburners Creek, and the Hātea River. The results from the monthly water sampling will be analysed and reported separately. Sampling was conducted on the outgoing tide to focus on the discharge from Limeburners Creek, upper Hātea River, and Awaroa Creek rather than the incoming harbour water.

2.3.1 Guideline values

Where possible, measured values are assessed against the Coastal Water Quality Standards for the Hātea River in the NRC Proposed Regional Plan ('PNRP'; Appeals Version, June 2020; Table 1). The PNRP designates Limeburners Creek as a 'mixing zone for major discharges', which is a continuation of the status the Limeburners Creek has held since the inception of the WWTP. The water quality of Limeburners Creek is not required to meet the standards for the Hātea River coastal water quality management unit. The discharge from Limeburners Creek, however, should not cause water quality in the Hātea River to exceed the designated water quality standards after the 'reasonable mixing' it is deemed to have received in the Creek. It should be noted that most of the standards are annual medians and, therefore, assessing two discrete sampling occasions against these guidelines should be done so conservatively.

Table 1: Coastal water quality standards from the Proposed Northland Regional Plan (Appeal Version, June 2020) relevant for assessing results presented in this report.

Attribute	Unit	Compliance Metric	Hātea River
Dissolved Oxygen	mg/L	Annual median	>6.2
		Minimum	4.6
Temperature	°C	Maximum change	3
pH		Annual minimum and maximum	7.0–8.5
Turbidity	NTU	Annual median	<7.5
Chlorophyll-a	mg/L	Annual median	<0.003
Total phosphorus	mg/L	Annual median	<0.119
Total nitrogen	mg/L	Annual median	<0.860
Nitrite-nitrate nitrogen	mg/L	Annual median	<0.580
Ammoniacal nitrogen	mg/L	Annual median	<0.099

2.3.2 Discrete sampling

The following parameters were measured in the field at the time of sampling using a YSI ProDSS handheld instrument:

- Temperature,
- Salinity,
- Turbidity, and
- Dissolved oxygen.

Discrete water quality samples were collected and analysed at the laboratory for the following parameters:

- Turbidity,
- Total suspended sediment,
- Chlorophyll-a,
- Total nitrogen,
- Nitrate + nitrite nitrogen,
- Total ammoniacal nitrogen,
- Total phosphorus, and

- Dissolved reactive phosphorus.

Faecal bacteria measurements were omitted as they are included in the monthly water quality sampling that is being conducted by and will be reported separately by 4Sight.

2.3.3 High-frequency water quality measurements

High-frequency water quality measurements provide a detailed look at changes in the water column. This approach highlights the natural variation that occurs during each day that cannot be captured by discrete water quality sampling.

NRC deployed a water quality buoy in the Hātea River (in the town basin) from 17 January to 27 February 2019. The buoy was then moved to the mouth of Limeburners Creek, just upstream from the bridge from 27 February to 12 March 2019.

The following water quality parameters were measured every 15 minutes:

- Temperature,
- Salinity,
- Dissolved oxygen, and
- Turbidity.

2.4 Sediment quality

Sediments were sampled from four locations and analysed for a range of parameters to assess the ecosystem health of the environment (locations shown in Appendix A). The upper 2-cm of sediment was collected by 4Sight staff. Samples were chilled and couriered to the laboratory for analysis. This sediment depth broadly represents cumulative effects from the past 10 years. The actual period is determined by many mediating processes including bioturbation, tides and wave action, and other physical and chemical processes.

2.4.1 Guideline values and comparisons

Sediment quality results are analysed and put in context using two approaches. Firstly, where applicable, results are compared to the Coastal Sediment Quality Guidelines for the Hātea River in the Proposed Northland Regional Plan (Appeals Version, June 2020; Table 2).

The second approach is to compare the sediment results from Limeburners Creek with other nearby locations; these being the Hātea River downstream from Limeburners Creek and the Awaroa River. This approach allows gradients to be assessed and to determine if sediment quality in Limeburners Creek substantially differs from the other nearby locations. This may indicate the magnitude of any response to the WWTP discharges.

Table 2: Coastal sediment quality guidelines used to assess the results presented in this report. From the Proposed Northland Regional Plan (Appeals Version, June 2020).

Attribute	Unit	Compliance Metric	Hātea River
Copper	mg/kg	Maximum	65
Lead	mg/kg	Maximum	50
Zinc	mg/kg	Maximum	200
Chromium	mg/kg	Maximum	80
Nickel	mg/kg	Maximum	21
Cadmium	mg/kg	Maximum	1.5

2.4.2 Sampling and analysis

Composite samples (10 sub-samples each) were taken from three locations within the plot at each site described in Section 2.2 – Fine-scale Ecology. Sub-samples for each composite were collected along a transect running from the most low-shore extent of the plot to the high-shore extent (Figure 2). The three samples were collected from the upstream, mid, and downstream locations within each plot.

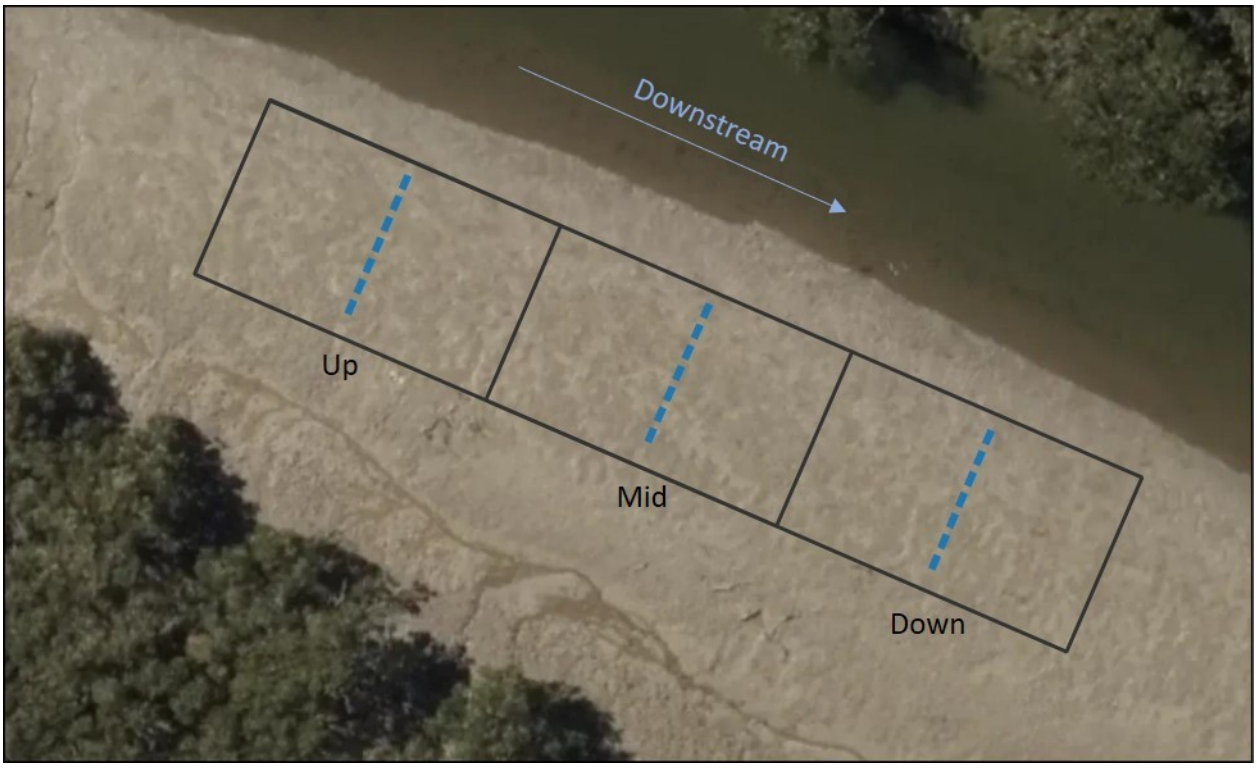

Figure 2: Example intertidal plot showing transects along which sediment sub-samples were collected to create each composite sample (blue dotted lines). The grey lines show the extent of the plot and lines breaking the plot into three equally spaced sections.

Samples were analysed at the laboratory for the following parameters:

- Total organic carbon,
- Total recoverable phosphorus,
- Total nitrogen,
- Sediment mud content,
- Chlorophyll-a,
- Total recoverable arsenic,
- Total recoverable cadmium,
- Total recoverable chromium,
- Total recoverable copper,
- Total recoverable lead,
- Total recoverable nickel, and
- Total recoverable zinc.

In addition to the laboratory-measured parameters, redox potential (mV at 1-cm depth) was measured in the field at the time of sampling.

2.5 Statistical analysis

To assess the current ecological state and determine if there were differences between the sampling sites, all collected benthic ecology, sediment quality, and water quality data were interrogated using a range of univariate and multivariate statistical approaches. Such approaches are described below.

2.5.1 Benthic macroinvertebrate data

Species richness, abundance and diversity metrics were calculated for each site. Additionally, an ordination plot was produced using non-Metric Multidimensional Scaling in the statistical software RStudio using the 'vegan' package. The analysis used Bray–Curtis dissimilarities with data >9 undergoing a Wisconsin double standardization and data >50 undergoing a square root transformation. A stable solution was reached through 9999 permutations of the data. Sample site was a fixed factor with four levels: Awaroa, Hātea, Lime_down and Lime_up. Year of sampling was a fixed factor with two levels: Year 2019 and Year 2020.

To test whether communities at different sites are significantly different from one another, a permutational multivariate analysis of variance (PERMANOVA) using Bray–Curtis distance matrices was performed using the command 'adonis' through 999 permutations. The number of permutations performed is a reflection of the number of computations required to ensure the capture of a 'best fit' model and is typical for this type of analysis. To check the assumption of homogeneity of multivariate dispersion, an analysis of variance was performed on the factor 'Site' using the command 'betadisper'.

To identify which species were significantly responsible for the differences and similarities in communities between sites and years, an indicator species analysis was performed in RStudio using the package *indicspecies* and the command 'multipatt' with 9999 permutations.

2.5.2 Water quality and sediment quality data

2.5.2.1 Univariate analyses

To have sufficient data points to conduct univariate analyses, water quality results were grouped by waterbody (i.e., Limeburners, Hātea, and Awaroa) and data from both years were combined. Sediment quality results were grouped by sampling site and data from both years were combined. Summary plots of results from each site and year are presented in Appendix B.

Raw data and log10 transformed data were tested for normality to determine whether parametric or non-parametric statistical analyses were the most appropriate. Not all parameters were normally distributed, even after being log-transformed and, therefore, non-parametric statistical methods were used.

To determine whether there were any statistically significant differences between groups for each parameter, a Kruskal–Wallace test was used (similar to the parametric ANOVA). Where statistically significant differences were identified, post-hoc Dunn tests were used to determine the ranking of the sites within each group. Statistically significant differences are denoted on each bar plot using letters; different letters indicate statistically significant differences.

2.5.2.2 Multivariate analyses

Data were further investigated using multivariate analyses. Principal Component Analysis (PCA) was used for water quality and sediment quality results. Before analysis, all parameters were log10 transformed. A log transformation was chosen to render the data as close to normally distributed as possible for modelling. This also prevents parameters with large result values from skewing analyses. Exploratory analyses indicated that the choice of transformation did not affect model outputs.

3 RESULTS AND DISCUSSION

3.1 Broad-scale habitat mapping

Limeburners Creek is an upper tidal arm of the Whangārei Harbour. The estuary is mangrove dominated and bordered by rural and industrial land. Two small patches of native forest border the true left bank near the estuary mouth. The total area of the Limeburners Creek estuary, including intertidal and subtidal components, is approximately 32.49 ha. The key estuary features are presented below (Table 3) and shown on a map in Appendix C.

Table 3: Calculated area of estuary features within Limeburners Creek based on broad-scale mapping.

Estuary feature	Total area (ha)	% of estuary	% of intertidal
Vegetation types			
Mangrove forest	23.8	73.4	81.6
Seagrass	Not present	N/A	N/A
Opportunistic Macroalgae	0.1	0.2	0.2
Substrate types			
Subtidal channel	3.3	10.1	N/A
Unvegetated intertidal	4.3	13.2	14.7
Soft Mud/Very soft mud (>25% mud content)	4.2	13.0	14.4
Cobble field	0.1	0.2	0.2
Rock field	0.03	0.1	0.1
Oyster reef	0.01	0.04	0.05
Oxygen depleted substrate	4.2	13.0	14.4

3.1.1 Mangrove forest

Mangrove forests are common in Northland estuaries and their areal extent has been increasing over the past 50 years (Lundquist et al., 2017). Mangrove expansion is typically associated with increased sediment inputs to the estuary. While the expansion of mangroves may have both real and perceived positive and negative effects, temperate mangrove forests are valuable and productive ecosystems and provide habitat for numerous bird and fish species (Morrisey et al., 2007). Mangroves are also known to interact with sedimentation processes, such as trapping fine sediments (Swales et al., 2015).

Mangroves may play an important role in nutrient cycling and eutrophication processes; however, this role is not well understood or documented for Northland estuaries. The ETI acknowledges that given that temperate mangroves occupy a similar location within estuaries to the area that gross nuisance macroalgal conditions typically occur. Considering the high mud retention capacity and effective oxygenation of sediments by mangroves, they may repress the response of macroalgae to nitrogen loads (Robertson et al., 2016). That is, the presence of mangroves in a location may inhibit or suppress macroalgal growth where it may typically be expected due to elevated nutrient levels.

While mangrove forests are likely to interact with estuarine nutrient inputs in some capacity, in Northland, mangroves occur in estuaries of varying trophic status from highly developed and nutrient-rich (such as Limeburners Creek) to relatively pristine, undeveloped, low-nutrient environments (such as Parengarenga and Rangaunu Harbours in the Far North). On that basis, the occurrence of mangrove forests appears not to be particularly sensitive to nutrient enrichment.

The intertidal mangrove stands in Limeburners Creek comprise the majority of the overall estuary area (23.84 ha, 73.6%) and likely play an important role in estuarine processes. They are unlikely to be adversely affected by nutrient inputs to Limeburners Creek and likely provide some positive effects such as being carbon sinks and using nutrients for growth.

3.1.2 Seagrass

No seagrass was identified in the Limeburners Creek. This is not surprising considering the sightly elevated levels of suspended sediment in the water and the relatively high mud content of the sediments – two factors that are detrimental to seagrass growth and survival.

3.1.3 Opportunistic macroalgae

The ETI identifies opportunistic macroalgae as the primary indicator for assessing estuary trophic state. This index, however, was primarily developed with data from lower North Island and South Island estuaries that do not have mangroves. As a result, macroalgae may not be the most suitable primary indicator of eutrophication in Limeburners Creek. Multiple lines of enquiry, for example, assessing sediment and water column nutrient and chlorophyll-a concentrations is likely to provide a more robust indicator of the nutrient status of Limeburners Creek.

Only small patches of macroalgae (0.05 ha. 0.16% of the estuary) were recorded in Limeburners Creek. The macroalgae quality status and trophic condition rating are determined according to methods outlined in the Opportunistic Macroalgae Blooming Tool ('OMBT'; Water Framework Directive - United Kingdom Advisory Group, 2014). The macroalgae % cover of the entire Limeburners Creek water body was recorded as 0.019%. As this is far below 5%, the OMBT specifies an Ecological Quality Rating of 0.8 (or 'High class'). This correlates with a trophic condition rating of 'A' based on the ETI scoring system (i.e. ecological communities such as bird, fish, seagrass, and macroinvertebrates are healthy and resilient; Robertson et al., 2016, p. 35). Such high rating contrasts with the elevated nutrient concentrations and sediment muddiness measured at the location and reinforces that using macroalgae as the primary trophic status is inappropriate in Limeburners Creek and the upper Hātea River.

3.1.4 Intertidal substrates (excluding mangrove forest)

The area of the estuary not dominated by mangroves consists of the subtidal channel (3.29 ha, 10.11%) and unvegetated intertidal substrates (4.29 ha 13.20%). The unvegetated intertidal substrates were dominated by soft mud (4.20 ha, 12.91% of the estuary), and minor amounts of cobble, rock, and oyster reef.

The areal extent of soft mud (substrate with mud content >%25) represents a supporting indicator for assessing estuary trophic state within the ETI. The areal extent of soft mud recorded in Limeburners Creek correlates with a trophic condition rating of 'C' (i.e. moderate stress on a number of aquatic organisms caused by the indicator exceeding preference levels for some species). Mud accumulation is typically associated with adverse estuary impacts.

3.1.5 Sediment oxygenation

Sediment oxygenation is a supporting indicator (still under development) in the ETI for assessing estuary trophic state. Depleted sediment oxygenation may have direct adverse impacts on resident macrofauna. As a result, impacts may also be exerted on higher trophic levels, e.g., birds and fish.

During the surveys reported on here, sediment oxygenation was assessed based on the mean redox potential (mV) at 1-cm depth at representative sites throughout the estuary. Scaling up measurements to the total area of soft mud habitat, the area of intertidal habitat within Limeburners Creek deemed to be 'oxygen-depleted' (i.e., exerting negative impacts on the resident macrofauna) was 4.20 ha (12.91% of the total estuary area). This corresponds with an ETI trophic condition rating of 'D' (i.e. significant, persistent stress on a range of aquatic organisms caused by the indicator exceeding tolerance levels).

3.2 Benthic macroinvertebrate community

Benthic macroinvertebrate communities are useful indicators of ecosystem health in NZ estuarine systems as they integrate the effects of environmental stressors in the benthic environment. The benthic macroinvertebrate communities at the sites sampled in the 2020 survey are assessed below based on whole community indices (richness, abundance, and diversity) and then related to the 2019 survey results. The relationship between macroinvertebrates and site locations has been analysed in further detail via multivariate statistical approaches with a two-year dataset.

3.2.1 Species richness, abundance, and diversity

The average species richness, abundance, and Shannon Weiner diversity index for each site in the 2020 sampling are presented in Table 4 and the 2019 results are presented in Table 5. The full data set for each sampling period is presented in Appendix D.

Table 4: Average species abundance, species richness and Shannon Weiner diversity for each site sampled in 2020. (core volume = 2.65 L).

2020				
	Awaroa	Hātea	Lime_down	Lime_up
Average Abundance/core	122	74.3	164.3	72.4
Average Richness/core	10.5	10.9	10.6	7.6
Shannon Weiner Diversity Index	1.48	1.8	1.43	1.31

Table 5: Average species abundance, species richness and Shannon Weiner diversity for each site sampled in 2019. (core volume = 2.65 L).

2019				
	Awaroa	Hātea	Lime_down	Lime_up
Average Abundance/core	99.4	113.5	102.8	67.6
Average Richness/core	9	12.4	10.6	7.8
Shannon Weiner Diversity Index	1.41	1.82	1.67	1.49

In general, the metrics and indices for the 2020 monitoring are typical of a 'moderately impacted' environment, which is shown by the relatively low species richness and diversity indexes. The Hātea had fewer individuals per core but supported the greatest average number of taxa and based on the diversity index, had the most even spread of taxa within its community distribution. The slightly higher diversity index for the Hātea site is consistent with expectations for a sampling site adjacent to the main channel and beyond the confines of the smaller estuarine arms. In contrast, the Limeburners Creek upstream site had the lowest scores across all measures, which may reflect the different physical conditions such as the cobble substrate and lower salinity in the water column at this more inland location. Limeburners Creek downstream site's abundance, richness, and diversity measures are all similar to the Awaroa 'reference site'. Collectively, these statistics on the macroinvertebrate community do not suggest that the Limeburners Creek is atypical for this upper estuarine location.

When comparing the results for average abundances, species richness and Shannon Wiener diversity scores between each year, there are differences at each site. When considering these differences over a two-year monitoring period, the results should be considered a reflection of the annual variation at these sites rather than a means of identifying any environmental change.

3.2.2 Abundance of individual species

3.2.2.1 Awaroa

At the Awaroa site, the most abundant species were infaunal deposit-feeding oligochaete worms. They accounted for 39.5% of individuals collected and were numerically dominant in most core samples. Polychaete worms of the family *Spionidae* were the next most abundant organisms accounting for 30.9% of individuals collected. *Spionids* are typically deposit feeders with some species capable of switching between deposit and suspension-feeding. A number of mud tolerant taxa were recorded including the polychaete worm *Scolecolepides benhami*, amphipods of the family *Corophiidae* and the stalk-eyed mud-crab *Macrophthalmus hirtipes.* A total of 28 taxa and 1220 individuals were recorded, but two species accounted for 70.4% of the total abundance. This pattern of diversity and dominance can indicate a response to organic enrichment.

3.2.2.2 Hātea

At the Hātea site, the most abundant species were polychaete worms of the genera *Aricidea* and *Prionospio*. *Aricidea sp*. are known to be sub-surface deposit feeders and bioturbators, while *Prionospio* are surface deposit feeders. Together they accounted for 32% of individuals collected. The mud tolerant polychaete worm *Heteromastus filiformis* was present only at the Hātea site. The invasive Asian date mussel (*Musculista senhousia*) was also present in high abundance, but only in two of the ten cores collected. Oligochaete worms were substantially less conspicuous at this site with only two individuals identified. There were 25 taxa sampled and 743 individuals collected, of which five species accounted for 69% of the total abundance. While the Hātea had a lower diversity and total number of individuals compared to the Awaroa, the community composition was more evenly distributed among a greater number of species. This can reflect a more dynamic environment that offers more variety of habitat type and nutrient conditions to support a greater number of species.

3.2.2.3 Lime_down

At the Lime_down site, the most abundant species were oligochaete worms which accounted for 37.6% of individuals collected. As with the Awaroa site, the next most common species were polychaete worms of the family *Spionidae*; those taxonomically unique with the polydorid complex, which accounted for 24.2% of individuals collected, and those of the genus *Prionospio* which accounted for 12.2% of individuals collected. Mud tolerant taxa included the polychaete worm *Scolecolepides benhami,* amphipods of the family *Corophiidae* and the stalk-eyed mud-crab *Macrophthalmus hirtipes*. While there were 24 different taxa sampled and 1643 individuals collected, three species accounted for 74% of the total abundance. As with the Awaroa site, the community composition was comparably diverse yet dominated by a few species, which can indicate a response to organic enrichment.

3.2.2.4 Lime_up

The estuarine snail *Potamopyrgus estuarinus* was identified and is unique to the Limeburners upstream site. A key feature of this species is its tolerance of environmental extremes including changes in salinity where it thrives in brackish mixing zones. The presence of this species is an indication that the Lime_up site is a distinctly different habitat due to tidal driven changes in salinity. At the Lime_up site the most abundant species is the polychaete worm from the family *Nereididae*, commonly named rag worm, with 324 individuals identified as juveniles and a further 219 identified as from the genus *Ceratonereis*. Given that only five individuals belonged to the two remaining *Nereididae* species, it is highly likely that most juveniles belonged to the genus *Ceratonereis.* Oligochaete worms were less conspicuous compared to the Limeburners downstream site. Other mud tolerant taxa present include the amphipods of the family *Corophiidae* and one individual stalk-eyed mud-crab *Macrophthalmus hirtipes*. While there were 19 different taxa sampled and 724 individuals collected, one species accounted for 75% of the total abundance. In general, the community composition was less diverse and even more truncated relative to the other sites.

3.2.3 Site differences

To assess whether there were significant differences in the community composition among sites, we used a non-metric multidimensional scaling and ordination plot (nMDS). Ordination summarizes community data by producing a low-dimensional ordination space in which similar species and samples are plotted close together, and dissimilar species and samples are placed far apart. It is used to describe relationships between species compositions and any intrinsic patterns that the data possess and can be displayed in a visual manner that is easy to interpret.

The ordination plot below shows the position of each core sample's taxonomic assemblage relative to one another based on the amount of dissimilarity between their species composition (i.e., how different the benthic community in one sample was to other samples). They are also linked to the site they were collected from and the year they were sampled by a black line tracing to the centre of their respective cluster. This interpretation of the data helps visualise what has been discussed in the results above.

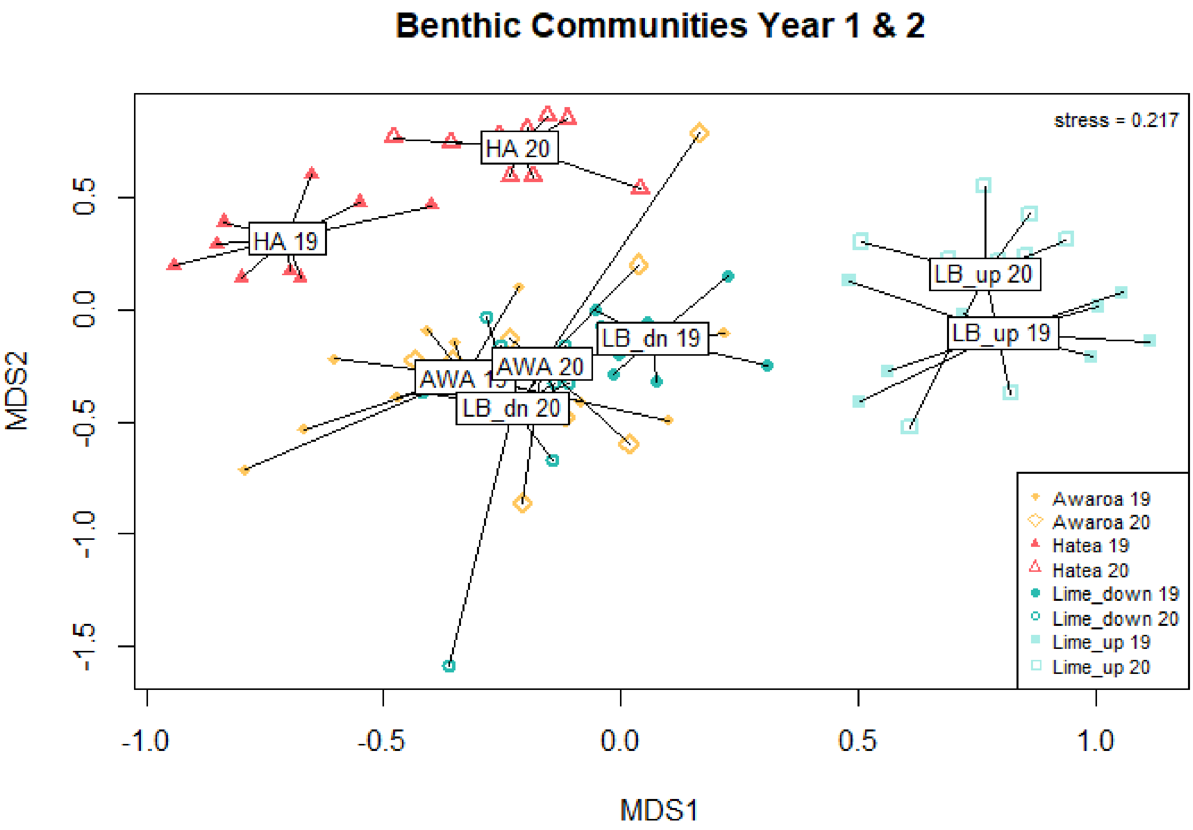

Figure 3: 2-dimensional ordination plot of the benthic communities sampled at each site in 2019 and 2020.

The results of the permutational multivariate analysis of variance (PERMANOVA[1]) indicated that the communities at each site are significantly different from one another. The species found in each core sample of each year at the Lime_down site are relatively similar, as the data points are clustered closely around the centre points (except one 2020 sample). Data points that overlap between yearly clusters indicate that those individual core samples from one year are similar in species composition to results from different years. Despite there being little overlap between core samples collected in 2019 and 2020, the closeness of their centre points is indicative of only a small difference in community composition, which we interpret to be natural variability.

The community composition identified on the intertidal zone of the Awaroa is similar to that identified in Lime_down, indicated by the data points being clustered closely around the centre points. However, the difference between the two sites is that the Awaroa samples collected in 2019 and 2020 largely overlap. This, coupled with the closeness of their centre points, indicates that the benthic community differed very little between years. The fact that the Lime_down clusters and the Awaroa clusters overlap with one another indicates that, overall, the benthic community composition at these two sites are very similar.

The greatest difference in community composition between the two sampling years is at the Hātea site where there is a distinct separation in data points. Within each sampling year, the species found in each core sample are relatively similar, indicated by the data points clustered closely around each centre point. However, in this case, the centre points for each year are far apart to the extent that the data points from each year do not overlap. This indicates that the benthic community composition is notably different between 2019 and 2020, which differs from the other sites. This suggests that the benthic community composition at Hātea is heterogeneous and results are highly influenced by the

[1] F = 8.673, R^2 = 0.457, and p = 0.001. The significance was confirmed by a test for the assumption of homogeneity of multivariate dispersion for the factor 'Site', p = 0.4368.

exact sampling locations. Despite such difference between sampling years, the benthic community composition was distinct from that of the other two sites in the analysis.

The communities sampled at Lime_up are relatively similar among each core sample of each year, indicated by the data points clustering closely around the centre points. There is also some noticeable overlap between results from 2019 and 2020m, indicating similar species compositions in some of the core samples between years. The closeness of their centre points is indicative of only a small difference in community composition between years.

These relationships over the monitoring period should be considered a reflection of the natural variation at these sites rather than major shifts in community structure given the period between surveys is just one year.

3.2.4 Key indicator species

Identifying indicator species is a useful way of observing which species are the most significant drivers of the relationships found between groups. The analysis (described in Section 2.5.1) identified that 28 of 54 species were significantly associated with one or more sites, meaning the remaining 26 species present could not be attributed to any specific site(s).

The communities at Hātea are substantially different from the other sites and between each sampling year. Therefore, a number of indicator species that characterise these differences would be expected. Such differences were found to be primarily the high abundances of the polychaete worms of the family *Paraonidae*[2] and *Nicon aestuariensis* in the 2019 communities. In the 2020 communities[3] polychaete worms *Perinereis sp*., and *Aricidea sp*., and the bivalve of the family *Nuculidae* accounted for much of the variability.

The Awaroa site has little variation in community composition between 2019 and 2020 so it is not surprising to see a species that is strongly and significantly associated with both years. The polychaete worm *Scolecolepides benhami* is an endemic surface deposit feeder that is found at all sites but is predominant in the mudflats of the Awaroa. It is this relative high abundance that singles it out as an indicator species.[4]

The taxonomic group Copepoda is strongly and significantly associated with the Lime_down site in both 2019 and 2020.[5] Copepods are small crustaceans, some of which are benthic-dwelling species that feed on benthic phytoplankton. They have been shown to be indicators of ecotoxicity in urban estuarine sediment with higher concentrations of pollutants reducing the success of breeding and survival (Charry et al., 2018). The relatively high abundances of Copepods at the Lime_down site suggest that pollutants are not having a substantial effect.

A clear feature of the ordination plot is the close association of groups between Awaroa 2019 and 2020, and Lime_down 2019 and 2020. The indicator species analysis identified the taxonomic group Oligochaetes as being strongly and significantly associated with these groups.[6] As previously discussed, oligochaetes accounted for 39.5% of the individuals sampled at the Awaroa site in 2020 and 37.6% of individuals sampled at the Lime_down site in 2020, demonstrating that they are the most prevalent taxa within these communities.

3.2.5 Comparison with NRC Estuary Monitoring Programme

The Northland Regional Council (NRC) Whangārei Harbour Estuary Monitoring Programme 2012 (Griffiths, 2012) presented data on intertidal infauna communities at 25 sites throughout the Whangārei Harbour (Figure 4). Seven of these sites (Hātea One – Hātea Five, Otaika Three, and Mangapai) are similarly muddy upper harbour sites, and broadly similar to the sites in the 4Sight surveys.

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[2] $p = 0.0001$

[3] Statistical analysis was used to confirm key species. 2019: *Paraonidae,* $p = 0.0001$; *Nicon aestuariensis,* $p = 0.0003$. 2020: *Perinereis sp,* $p = 0.0001$; *Aricidea sp*., $p = 0.0001$; *Nuculidae,* $p = 0.012$.

[4] *Scolecolepides benhami,* $p = 0.004$

[5] Copepoda, $p = 0.0006$

[6] Oligochaetes, $p = 0.0008$

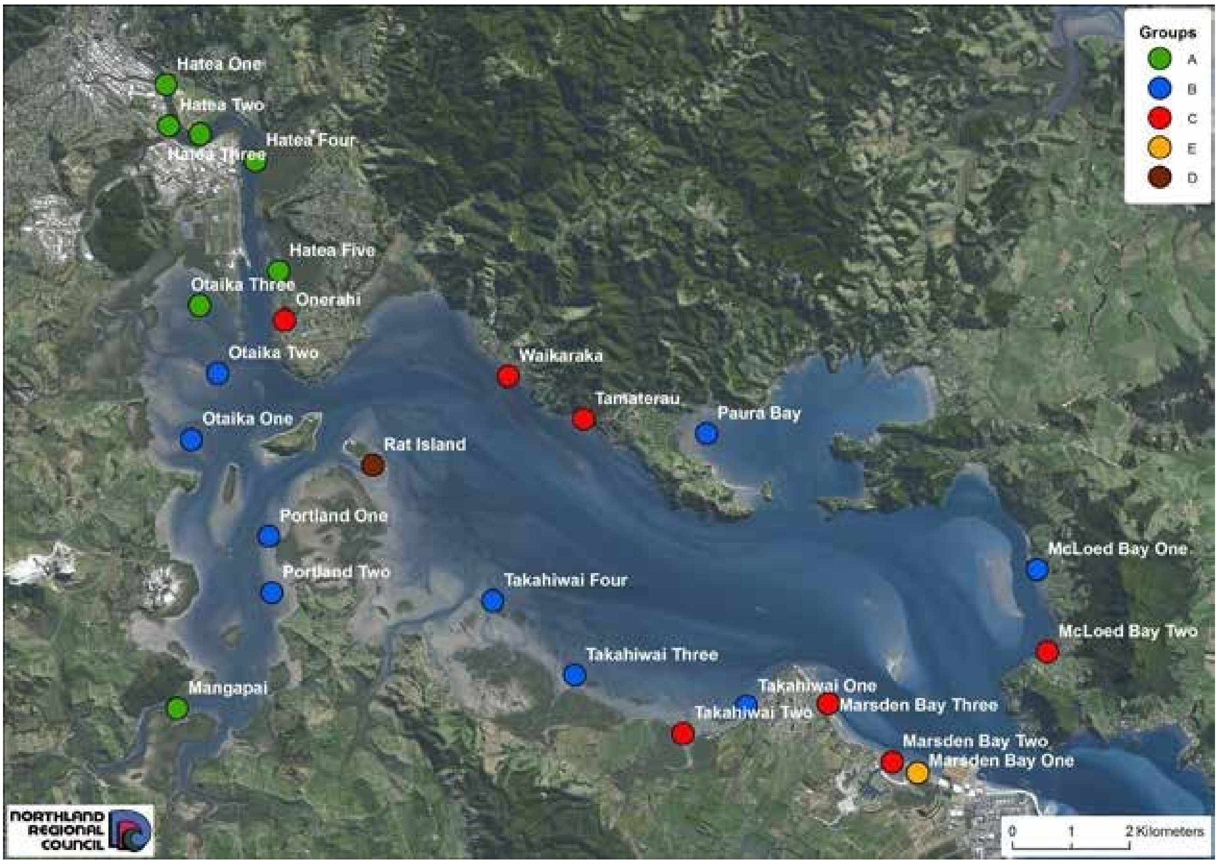

Figure 4: Location of ecological sampling sites in Whangārei Harbour from Whangārei Harbour Estuary Monitoring Programme 2012 (Griffiths 2012).

Given the similar location and habitat characteristics, a similar infauna community composition would be expected. It should be noted that although the NRC methods used the same core dimensions (15 cm diameter by 15 cm length cylindrical core (volume 2.65 L), results are taken from three cores per site, whereas results from the 4Sight surveys are based on ten cores per site.

In the NRC estuary monitoring report, analysis of the average linkage clustering of the species abundance data indicated that most of the samples could be separated into three main groups (Figure 4). The group of interest, Group A, corresponds to those sites located in sheltered tidal creek environments in the upper Harbour and are the most relatable to the results of this study.

Group A sites in the upper harbour tended to be dominated by polychaete worms and oligochaete worms which accounted for nearly 80% of all the individuals identified, with relatively few gastropods, crustaceans, and bivalves. The polychaete worms *Boccardia* (*Paraboccardia*) *syrtis*, *Prionospio yuriel*, *Capitella sp*. and oligochaete worms were particularly abundant and accounted for more than half of all individuals at these five sites. The data collected in the 4Sight surveys align closely with these NRC results as polychaete worms and oligochaete worms were also the most common benthic fauna sampled at all four sites.

The NRC results for Group A average 174 individuals collected per core at each site, however with the removal of the Mangapai site, which was located furthest from the upper Hātea, the average count was 127 individuals per core. The average count from the current survey is 96 individuals per core, and considering the slight differences in sampling locale, it can be said that there is little difference in the average abundance of individuals between the two studies. Group A sites had an average species richness of 17 taxa, whereas the 4Sight surveys had an average richness of 9.9 taxa. The average Shannon Weiner diversity index score for the Group A sites was 2.0, whereas in this study it was 1.5. These differences are a reflection of the average scores across all sites and given that in this survey three of the four sites are not located on the Hātea intertidal they are not directly comparable. However, they do provide context for an understanding of benthic communities on a broader upper harbour scale.

Overall, the species abundance, richness and Shannon Weiner Diversity scores recorded in 4Sight surveys are lower than recorded for the NRC Hātea sites. The lower values could be attributed to natural variation and heterogeneous distribution of benthic organisms on the intertidal flats. NRC conducted monitoring at the same time as 4Sight in 2019 and we observed that that NRC site was at a higher elevation (further from the low tide mark) than in this study. Further, the tidal arms sampled in this study perhaps have less potential to host as wide a range of macroinvertebrates than the larger intertidal area found in the Hātea River. There were similarities between the sites sampled in the current survey and the NRC Hātea sites in terms of the numerically dominant species recorded.

3.2.6 Potential effect of the WWTP discharge from Limeburners Creek on benthic communities

The sites Lime_up and Lime_down are upstream and downstream of the WWTP discharges. Because of the tidal influence at these locations, both sites will be exposed to the WWTP discharge at times. There were notable differences in the benthic communities at these two sites, with Lime_down having on average 226% more individuals and three more taxa per core, and a Shannon Wiener score 0.12 higher. This indicates a more populated, diverse and even benthic community at the downstream site. Such changes are most likely attributed to the differing habitat (cobbled mud upstream, soft mud downstream) and the strong freshwater influence causing large salinity gradients at the upstream site and not exposure to the WWTP discharge.

Further, Lime_down is likely exposed to greater volumes of the WWTP discharge than the upstream site, being at the mouth of Limeburners Creek. The benthic communities at the downstream site were very similar to those at the Awaroa site, which was used as a comparison away from Limeburners Creek. Such similarities between the two sites suggest that the WWTP discharge is not having a significant effect on the benthic communities at Lime_down. Likely, other environmental stressors, such as substrate muddiness, have a greater influence on the benthic community composition in the area.

NRC state of the environment data can also provide some insight into whether the discharge from Limeburners Creek is affecting the benthic ecology in the receiving environment as NRC sample over a much larger spatial scale than in this survey. Of relevance are results from locations further up the Hātea River near the Town Basin and further downstream in the Hātea River towards the Whangārei Harbour that were collected in 2016 (Griffiths, 2016). These sites are labelled Hātea One to Hātea Five (locations shown in Figure 4 of this report). The results presented by NRC from their multivariate analysis (nMDS plot) showed each of Hātea One to Hātea Five being grouped close together and distinct from other down-harbour locations in their analysis. This suggests that the sites measured along the Hātea River are relatively similar. The NRC analysis did not show any substantial differences at locations near the mouth of Limeburners Creek that could be attributed to the WWTP discharge.

Shannon Weiner diversity scores for the five NRC Hātea sites (Griffiths, 2016) show lower scores at sites Three and Four (refer below Table 6). These sites are located downstream of Limeburners Creek. Two factors suggest this is unlikely to be primarily a response to the discharge of Limeburners Creek:

Firstly, NRC's Hātea Two site, which is located at the mouth of Limeburners Creek and is potentially most exposed to the discharge, had the highest Shannon Weiner diversity score of the Hātea sites. This would not be consistent with or expected if the discharge from Limeburners Creek was having adverse effects.

Secondly, the sediment at Hātea Three and Four is very muddy. Sediment muddiness is known to have a significant (negative) effect on the benthic community composition (e.g., Pearson and Rosenberg, 1978; Clark et al., 2019). Benthic communities at these sites in the Hātea are more likely to be affected and governed by other dominant environmental stressors such as sedimentation than from the discharge from Limeburners Creek.

Table 6: Summary of benthic macroinvertebrate results from 2012 NRC state of the environment monitoring (Griffiths, 2012). Sites locations are shown in Figure 4.

Site Name	Species Richness	Number of Individuals	Shannon Weiner Diversity
Hātea One	17	108	2.31
Hātea Two	19	102	2.57
Hātea Three	16	273	1.92
Hātea Four	16	129	1.89
Hātea Five	15	72	2.13

3.3 Shellfish

No specific monitoring was conducted by 4Sight to assess shellfish in the area; however, shellfish populations were assessed by NRC in their state of the environment monitoring (Griffiths, 2012). The monitoring showed small populations of cockles (*Austrovenus stutchburyi*) and wedge shells (*Macomona liliana*) in the upper Hātea River and the mouth of Limeburners Creek. Most individuals were found in the Whangārei Harbour, rather than in the Hātea River. Oysters are known to be present in the soft muds near mangroves, including in Limeburners Creek. Three non-indigenous species were also identified primarily in subtidal areas. The three species were the bivalve *Theora lubrica*, Asian date mussel (*Musculista senhousia*), and Australian dog whelk (*Nassarius (Plicarcularia) burchardi*).

3.4 Water quality

Water quality varies throughout the day in response to the continually changing conditions, including rainfall, point source discharges, catchment runoff, tides, day/night cycles, mixing, and dilution. Results from the two discrete sampling occasions should be interpreted with appropriate caution as they are intended to supplement the collective knowledge of water quality for the area and the monthly water quality sampling that will be reported separately.

3.4.1 Discrete sampling

This section presents a high-level overview of the water quality in Limeburners Creek and surrounding areas based on two discrete sampling occasions that were undertaken during the baseline surveys in 2019 and 2020. For simplicity and to allow statistical analyses to be conducted by increasing the number of data in each group, data from both years (2019 and 2020) were combined and grouped by each waterbody (Limeburners Creek, Hātea River, and Awaroa Creek). Summaries of the data collected during 2019 and 2020 are shown below in Figure 5 and Figure 6 and discussed in the following sections. More detailed plots of results by year and site are presented in Appendix B and a copy of the laboratory results are in Appendix E.

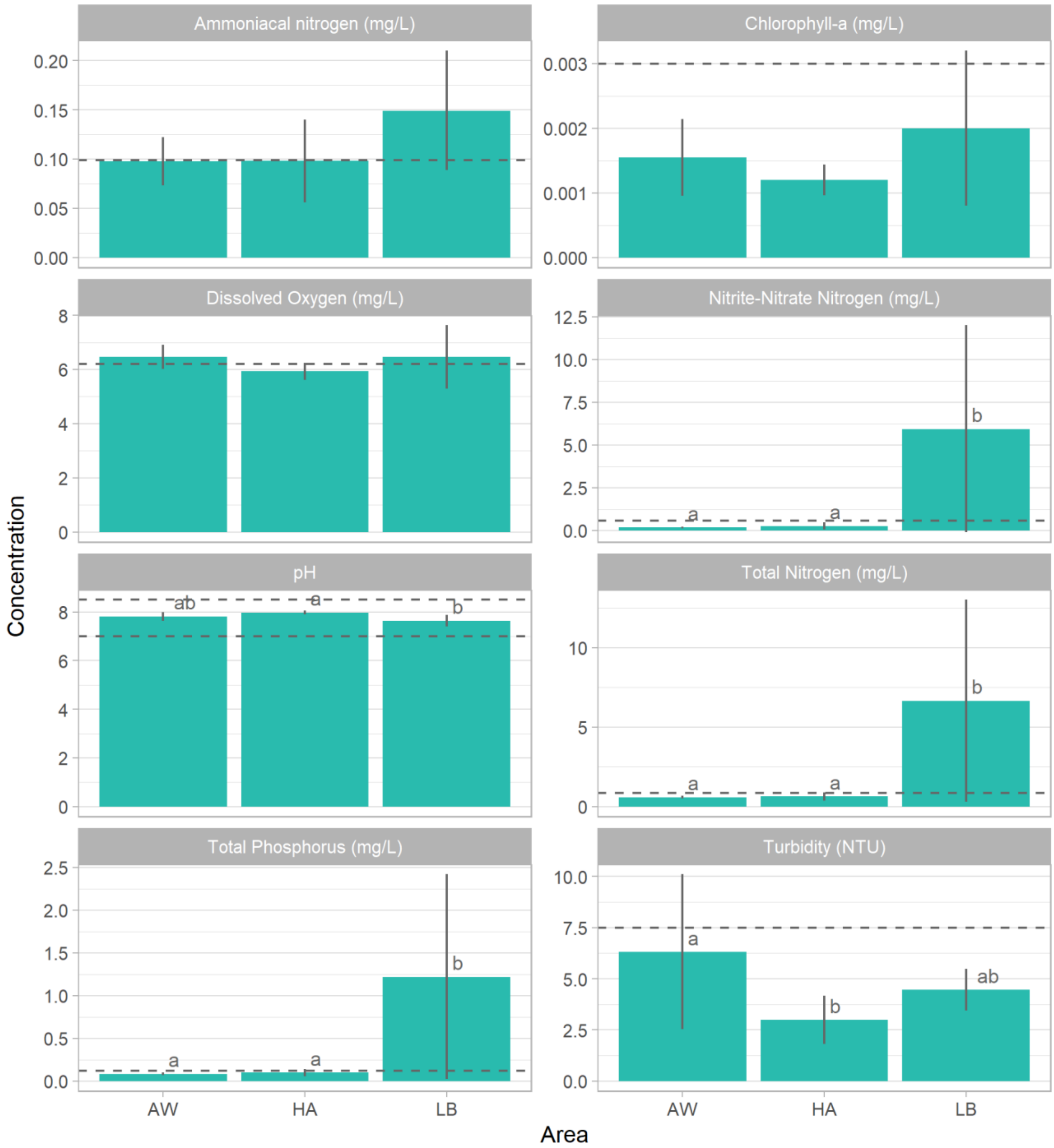

Figure 5: Mean water quality results by waterbody (area) from 2019 and 2020 snapshot water sampling for parameters with NRC standards. Error bars show the 95th percentile of the mean (n = 6 for AW and HA, n = 8 for LB). The NRC coastal water quality standard for the Hātea River is shown by the horizontal dotted line.

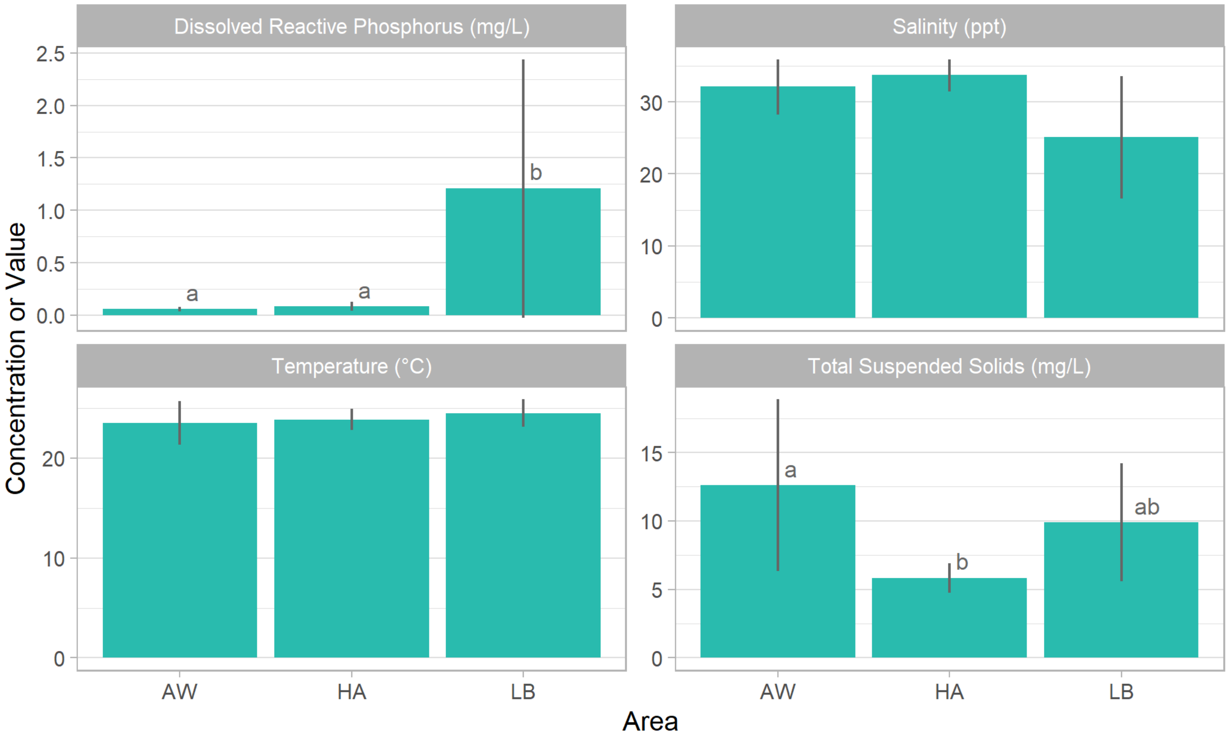

Figure 6: Mean water quality results by waterbody (area) from 2019 and 2020 snapshot water sampling for parameters with no NRC standards. Error bars show the 95th percentile of the mean (n = 6 for AW and HA, n = 8 for LB).

3.4.1.1 Nutrients

The mean value of all nutrient measurements[7] except for ammoniacal nitrogen was statistically significantly higher in Limeburners Creek than in the Hātea River and Awaroa Creek (Figure 5 and Figure 6).

The mean and median concentrations of ammoniacal nitrogen were higher in Limeburners Creek than the other locations but the variation in the results meant that these differences were not statistically significant. The variation in ammonia largely arises from concentrations being markedly higher at LB2 and lower at LB4 in 2019 than they were in 2020. Overall, mean ammonia concentrations were just below the NRC water quality standard (ecosystem health) in Awaroa Creek and Hātea River. A greater number of individual sites exceeded the water quality standard in 2020 than in 2019. This is likely related to the exact state of the tide that samples were collected, preceding and prevailing climatic conditions, or the nature of the discharge from the WWTP at the time.

Total nitrogen, nitrate-nitrite nitrogen, total phosphorus, and dissolved reactive phosphorus concentrations were all markedly higher in Limeburners Creek than at the other locations. This suggests that, although there are elevated nutrient concentrations in Limeburners Creek as a result of the WWTP discharge (which is expected given that it is the designated mixing zone for the discharge), there is sufficient mixing with and dilution from the Hātea River such that concentrations elevated above the required receiving water standards are not measured elsewhere.

Total phosphorus and dissolved reactive phosphorus concentrations were very similar in Limeburners Creek. Typically, dissolved reactive phosphorus concentrations are much lower than total phosphorus in estuaries as phosphorus is predominantly sediment-bound (e.g., Conley et al., 1995). Having such a large proportion of the total phosphorus pool comprising dissolved reactive phosphorus may be a factor of discharge from the WWTP treatment wetlands into Limeburners Creek and the typical elevation of dissolved reactive phosphorus concentrations in estuarine waters as sediment-bound phosphorus is desorbed. Further, because of chronic exposure to elevated phosphorus levels,

[7] For clarity, nutrient measurements include total nitrogen, total phosphorus, nitrate-nitrite nitrogen, ammoniacal nitrogen, and dissolved reactive phosphorus.

sediments in Limeburners creek may be saturated with phosphorus, which would inhibit the binding of phosphorus in the water column.

3.4.1.2 Ammonia (toxicity)

Ammoniacal nitrogen (NH_3 and NH_4^+), hereafter ammonia, contributes to the total nitrogen load, which can fuel excessive algal growth. Additionally, ammonia can be toxic to some species at elevated concentrations. The toxicity of ammonia is primarily attributed to the un-ionised NH_3 and this means that the toxicity is a factor of the ammonia concentration, temperature, and pH due to the equilibrium between NH_3 and NH_4^+.

To assess the potential toxicity of the measured ammonia concentrations, values were adjusted to pH 8.0 equivalents following the ANZG (2018) guidelines. This is a simplified approach that only corrects for the primary factor, pH. The adjusted ammonia concentrations were all well below the ANZG (2018) toxicant default guideline value, which indicates a low toxicity risk to marine organisms (Figure 7).[8]

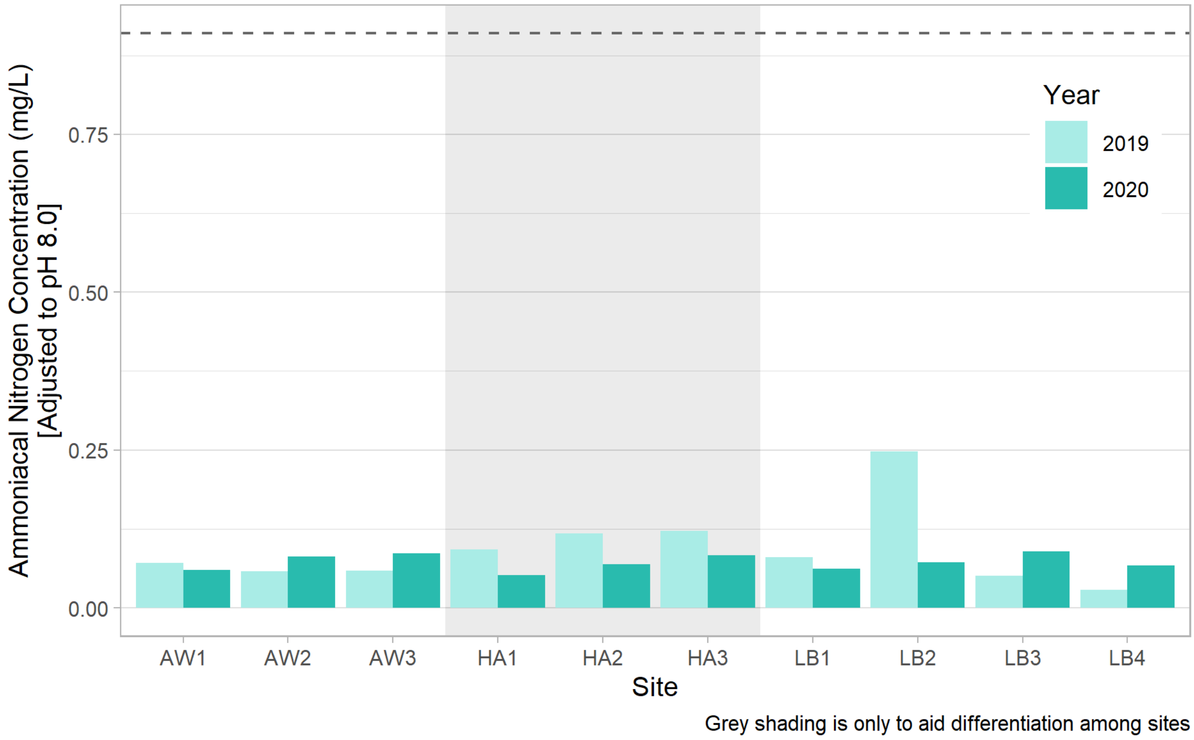

Figure 7: Ammoniacal nitrogen concentrations adjusted to pH 8.0 and compared against the ANZG (2018) toxicant default guideline value (dashed, horizontal line, 0.910 mg/L).

3.4.1.3 Chlorophyll-a

Chlorophyll-a is measured as a proxy for phytoplankton biomass. Elevated phytoplankton levels can indicate symptoms of nutrient enrichment (eutrophication). The mean and median concentrations of chlorophyll-a are higher in Limeburners Creek than the other two areas, but such differences are not statistically significant (Figure 5). The mean concentrations in all areas were below (that is, met) the NRC water quality standard. This indicates that, at the time of sampling, there was no excessive algal growth even though there were elevated nutrient levels within Limeburners Creek.

Two key water quality factors could inhibit algal growth within Limeburners Creek notwithstanding the availability of nutrients: 1) elevated levels of suspended sediment reduce the available light for algae to photosynthesise, and 2) the tidal flushing of Limeburners Creek may not provide sufficient time for algae to grow and accumulate within the Creek.

[8] A table showing all values is presented in Appendix B:.

The combination of these factors may be the reason why chlorophyll-a concentrations are less than may be expected in the nutrient-rich Limeburners Creek.

Mean chlorophyll-a concentrations were higher in Awaroa Creek than in the Hātea River, but less than in Limeburners Creek. As with Limeburners Creek, such differences in the mean chlorophyll-a concentrations were not statistically significant. Higher chlorophyll-a concentrations in the Awaroa Creek than in the Hātea River may be expected as it is reflective of a more sheltered estuarine arm than the larger, faster flowing Hātea River.

3.4.1.4 Dissolved oxygen

Mean dissolved oxygen concentrations were relatively similar in all areas and were generally close to the NRC water quality standard (Figure 5). The Hātea River was the only area to have oxygen concentrations that were consistently just below (that is, did not meet) the water quality standard The slightly lower oxygen concentrations in the Hātea River are not unexpected considering that it is in an upper estuarine setting and water temperatures were warm (>20 °C). This may also be reflective of wider catchment influences.

3.4.1.5 pH

Mean and individual pH values at all sites were within the NRC water quality standard range (Figure 5). In Limeburners Creek, the mean pH value was slightly lower (7.64) than in Awaroa Creek (7.82) or Hātea River (7.98). These results indicate that there are unlikely to be any adverse ecological effects arising from pH at these locations.

3.4.1.6 Turbidity and total suspended solids

Mean turbidity concentrations were below (met) the NRC water quality standard at all sites. There is no NRC water quality standard for total suspended solids, however, the mean concentrations followed the same pattern as turbidity as would be expected. Turbidity and suspended solids were highest in Awaroa Creek[9], followed by Limeburners Creek and Hātea River.

3.4.1.7 Temperature

There were no significant differences in the mean water temperatures at each site. Mean temperatures in 2020 were slightly higher (~25 °C) than they were in 2019 (~23 °C). This is most likely attributed to the 2020 samples being collected in February and the 2019 samples being collected in March.

3.4.1.8 Salinity

In general, the salinity in Awaroa Creek and Hātea River ranged from 28–35 ppt indicating a predominantly marine influence and indicate limited freshwater influence at the time of sampling. Limeburners Creek had a much wider range, with salinities in the most upstream site (LB4) being as low as 9 ppt, indicative of the strong freshwater influence at this location.

3.4.1.9 Multivariate analysis

Multivariate analysis allows all the parameters described above to be analysed simultaneously and used to identify key parameters that differentiate sites from one another and to visualise the magnitude of the difference between sites, if any.

The principal component analysis (PCA) shown in Figure 8 explains 91% of the variation in the data from the PC1-axis. This axis predominantly comprises the parameters total nitrogen, total phosphorus, nitrate-nitrite nitrogen, and dissolved reactive phosphorus (i.e., all nutrient parameters excluding ammonia). This indicates that these are the key drivers of difference among the sites measured here. The PC2-axis explains a further 5% of the variation using primarily turbidity, total suspended solids, chlorophyll-a and ammonia. In total, the PC1 and PC2 axes explain 96% of the variation in the data (i.e., the model explains the data well).

[9] Statistically significantly higher than Hātea River but not Limeburners Creek.

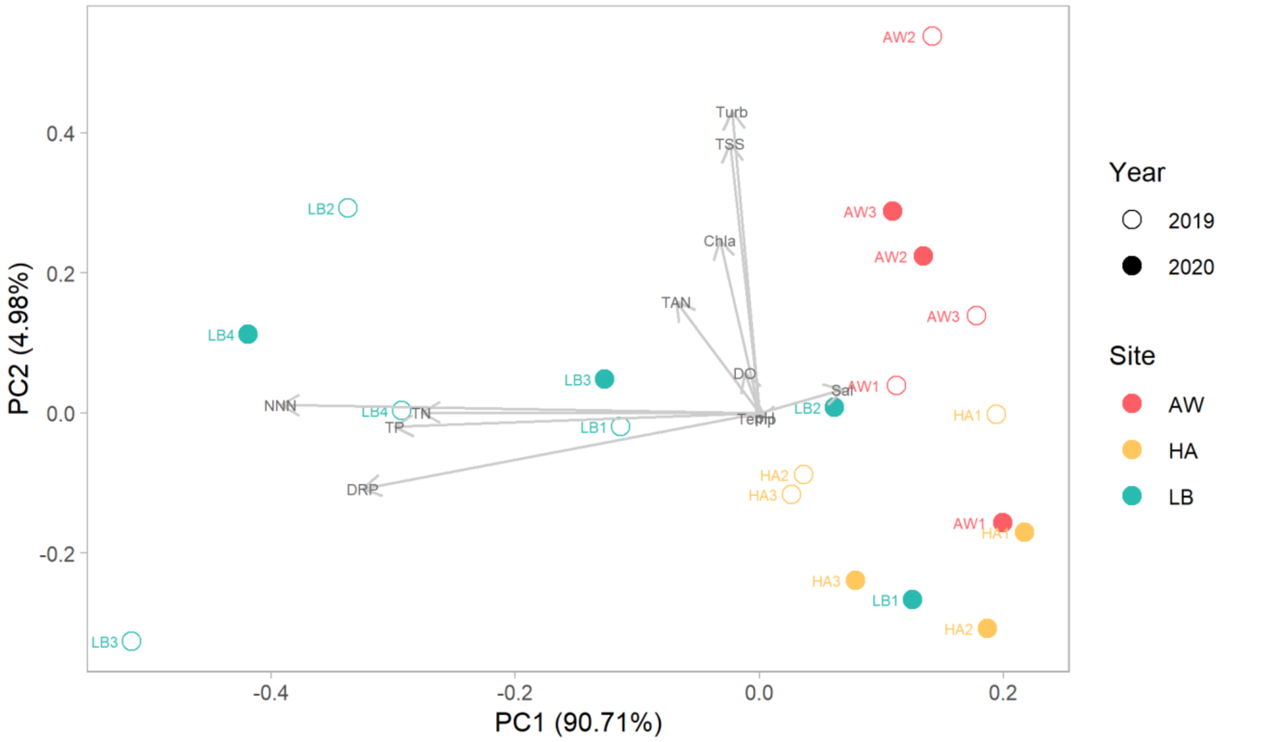

Figure 8: Principal Component Analysis (PCA) of water quality results. Samples from 2019 and 2020 were combined and analysed as one group. [NNN = nitrate-nitrite nitrogen, DRP = dissolved reactive phosphorus, TP = total phosphorus, TN = total nitrogen, Turb = turbidity, TSS = total suspended solids, Chla = chlorophyll-a, TAN = total ammoniacal nitrogen, DO = dissolved oxygen, Temp = water temperature, Sal = salinity]

As noted above, most of the variation in the data is explained by nutrient measurements, excluding ammonia. These primarily separate Limeburners Creek from Awaroa Creek and Hātea River along the PC1 axis. Sites further to the left of the plot have higher nutrient concentrations. This is most notable for sites in the upper reaches of Limeburners Creek (LB3 and LB4), which likely arises due to reduced flushing in this reach.

At times, nutrient concentrations at LB1 and LB2 were similar to those measured in the Hātea River. This is likely a reflection of the mixing and dilution of the WWTP discharge along Limeburners Creek. Water sampling was conducted during an outgoing tide so results should largely represent the contribution from Limeburners Creek rather than the Hātea River. The extent of the mixing and dilution, however, is dependent on the exact state of the tide that sampling was conducted and other hydrodynamic and climatic factors.

The Awaroa and Hātea sites had similar nutrient concentrations, indicated by the data points spanning a similar range along the PC1-axis. The two areas were able to be largely differentiated by the level of suspended solids/turbidity and chlorophyll-a concentrations, with Awaroa having higher concentrations of each of these on average than the Hātea. This may be expected due to the Awaroa being a shallow creek with muddy intertidal areas.

Overall, the PCA shows that nutrient concentrations, excluding ammonia, are responsible for the greatest differences among the three sites. Limeburners had the highest nutrient concentrations of the sites and was the most separated in the plot. At times, results from the lower reaches of Limeburners Creek (LB1 and LB2) were similar to results from the Hātea River. This suggests that, at times, the discharge from the WWTP is well mixed and diluted in the lower reaches of Limeburners Creek and the water quality at these locations is similar to that of the Hātea River.

3.4.1.10 Comparison with NRC state of the environment data

The most recent SOE report on coastal water quality that includes the Hātea River was published in 2015 (Griffiths, 2015). Multiple SOE locations are sampled along the Hātea River and at the mouth of Limeburners Creek that can be used for comparison with the results identified from the two discrete sampling occasions conducted for the 4Sight surveys (Figure 9).

Figure 9: Northland Regional Council (NRC) State of the Environment (SOE) water quality monitoring sites near the WWTP discharge in Limeburners Creek.

Limeburners Creek was the lowest-ranked site based on the Water Quality Index of all NRC coastal water quality monitoring locations; however, it ranked similarly to the upstream Waiarohia Canal, Upper Hātea River, and Town Basin sites. This indicates that, in general, the water quality in the upper Hātea River is degraded to some extent because of the multiple diffuse and point source discharges nearby and in the wider catchment. The WWTP discharge is one of those influences but it cannot readily be isolated from other stressors. While it will contribute to the cumulative effect on water quality, it appears not to have a dominating or preeminent effect on the upper harbour water quality.

Overall, the NRC SOE monitoring revealed similar water quality patterns in Limeburners Creek as the results from the 4Sight surveys. That is, Limeburners Creek has highly elevated levels of nutrients relative to the other monitoring locations. On balance, however, results for the upper Hātea River indicate impacted water quality as far upstream as the Town Basin and that water quality improves downstream towards the Whangārei Harbour. There are no obvious step-changes in the NRC SOE monitoring data at sites up or downstream of Limeburners Creek that would suggest that the discharge of the Limeburners Creek into the Hātea River is having a significant effect on water quality. The water quality in the Hātea river appears to be governed by cumulative effects from the wider catchment.

3.4.2 High-frequency water quality measurements

High-frequency water quality measurements in both Limeburners Creek and the Hātea River show the large, natural variation in water quality that occurs during each day (Figure 10 and 11) in response to day/night and high tide/low tide cycles.

There are no NRC water quality standards for dissolved oxygen (%) and so the values of 80–110% from the ANZECC guidelines[10] were used.

Turbidity measurements were typically below the NRC standard (10 NTU) unless there was also rainfall. The two highest turbidity readings in Limeburners Creek (8 and 9 March) coincide with the two lowest salinity measurements. About 12 mm rainfall was measured at the rainfall gauge in Whangārei on 8 March, which is the most likely explanation for the decreased salinity and increase in turbidity as rainfall washes sediment from the catchment into nearby waterways.

In general, the range of results for each parameter in Limeburners Creek was within the range of results for each respective parameter in the Hātea River. This means that the water quality (dissolved oxygen, turbidity, temperature, and salinity) at the mouth of Limeburners Creek was within a similar range as water quality measured in the Hātea River in the Town Basin.

The median dissolved oxygen concentration in the Hātea River (at the Town Basin; 67.2%) was lower than in Limeburners Creek (84.3%). Only 20% of dissolved oxygen measurements in the Hātea River fell within the ANZECC guideline range, whereas 58% of dissolved oxygen measurements were within the range in Limeburners Creek. That is, on average, the Hātea River had lower dissolved oxygen concentrations than the mouth of Limeburners Creek.

Based on these data, Limeburners Creek appears to maintain higher water quality, with regard to dissolved oxygen, temperature, and turbidity, than the wider Upper Hātea environment.

[10] ANZECC & ARMCANZ 2000, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

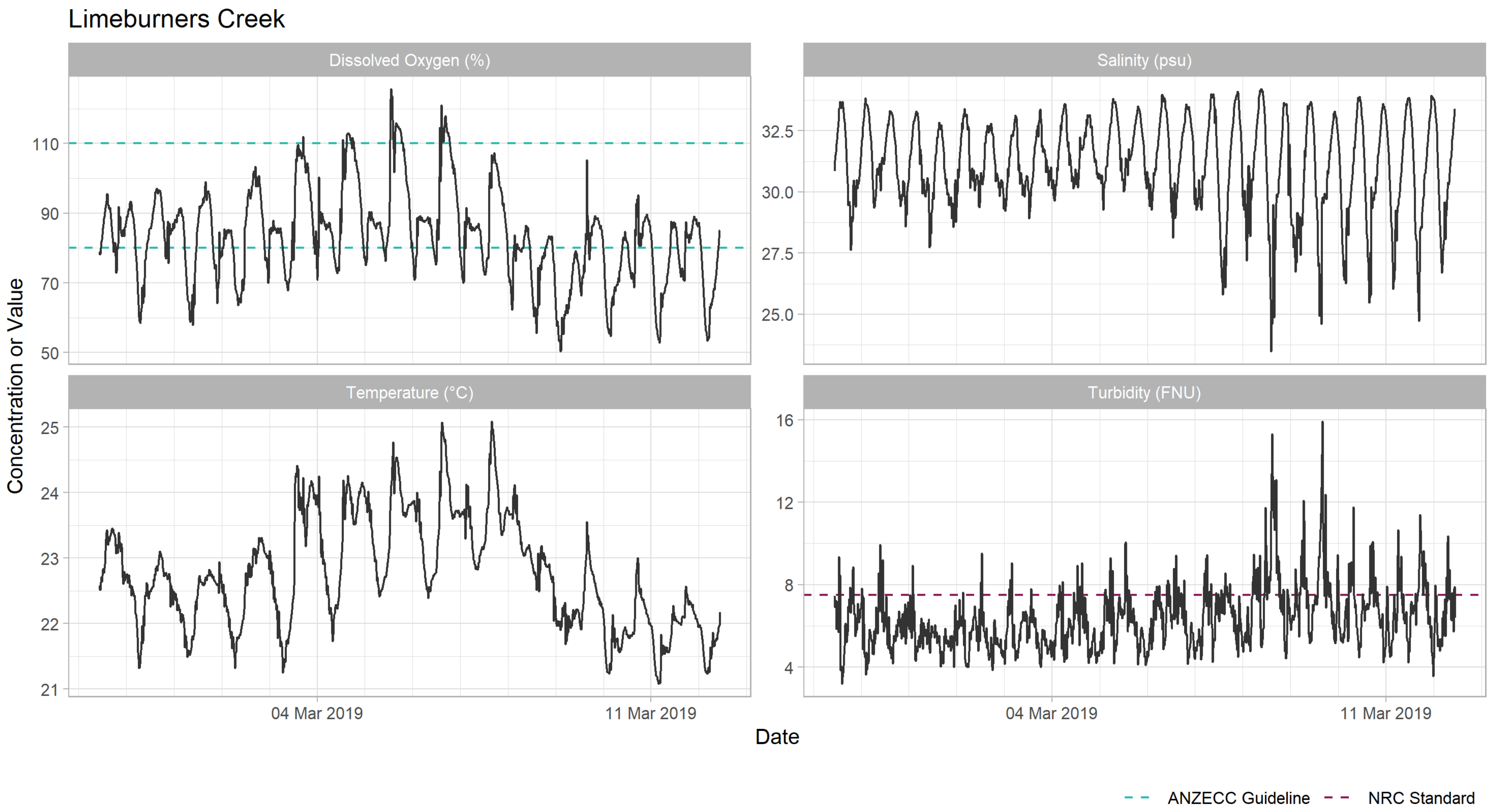

Figure 10: Water quality parameters measured by the NRC monitoring buoy at the mouth of Limeburners Creek

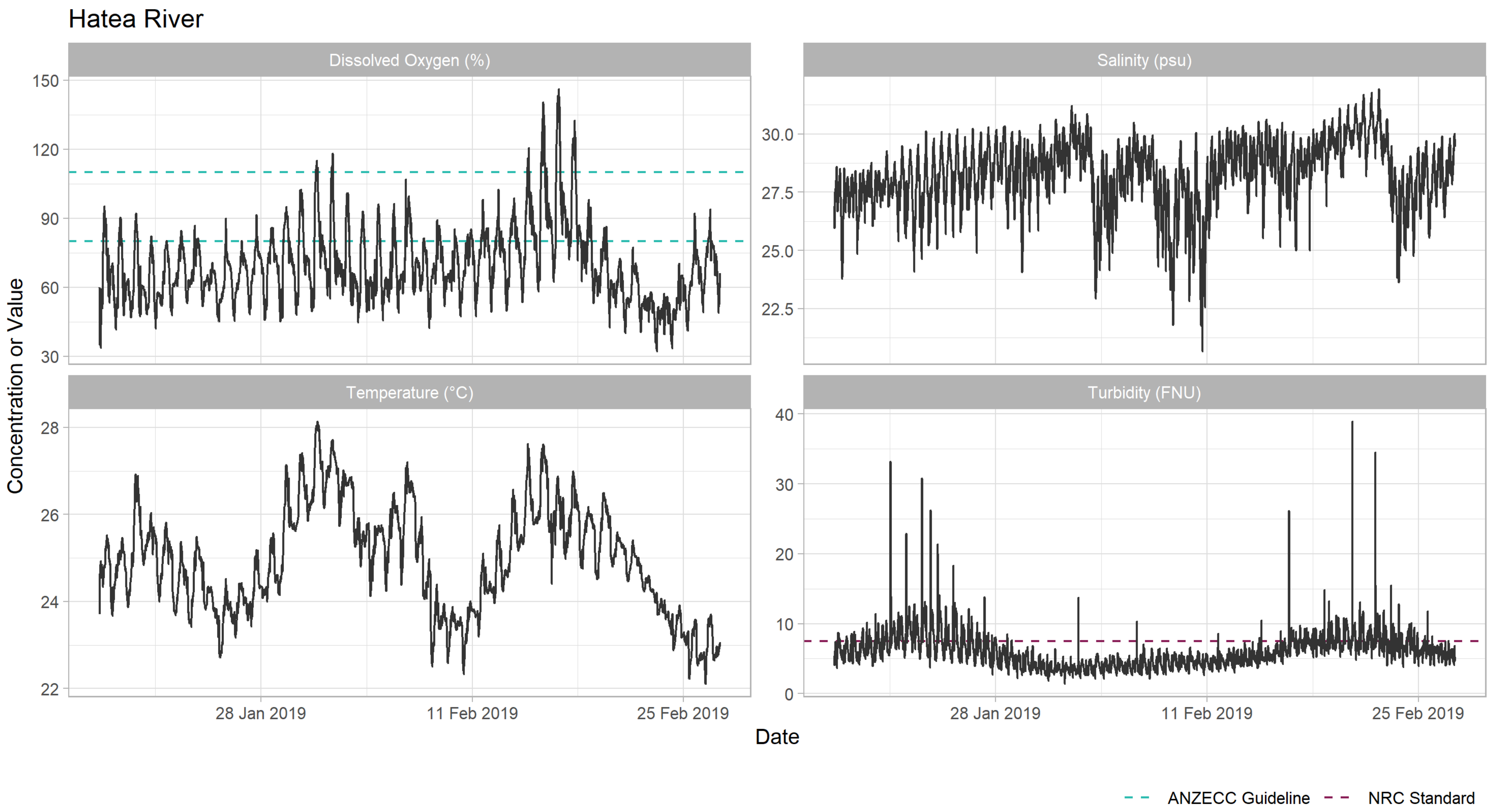

Figure 11: Water quality parameters measured by the NRC monitoring buoy in the Hātea River

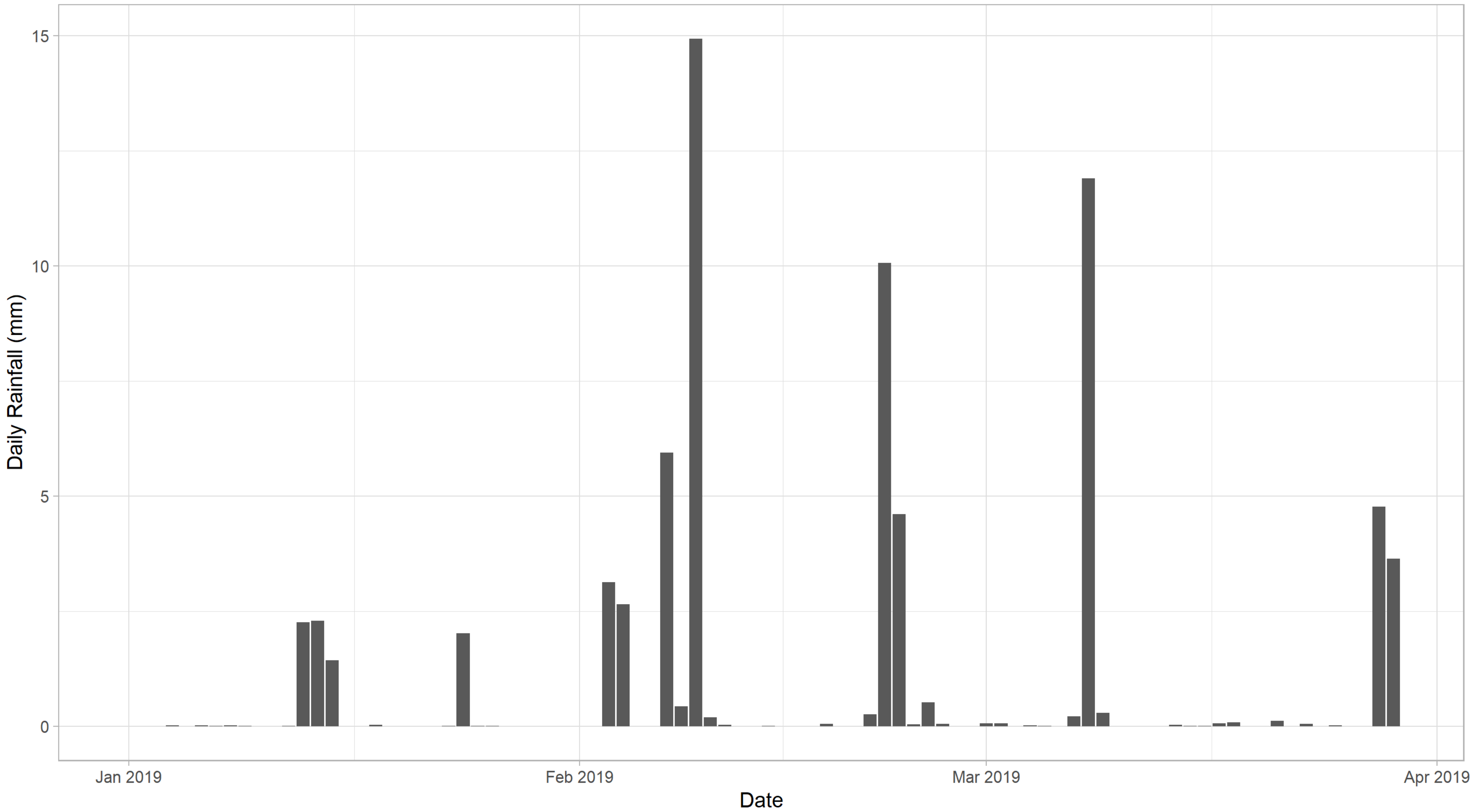

Figure 12: Daily rainfall measured by Northland Regional Council at Whangārei Air Shed at Robert Street.

3.4.3 Potential effect of the WWTP discharge on water quality in the Hātea River

Results from the 4Sight surveys and NRC SOE reports show clearly that Limeburners Creek has elevated nutrients levels as a result of the WWTP discharge. What is more difficult to discern, however, is the effect that the discharge of Limeburners Creek into the Hātea River is having on the receiving environment. The complexity is increased with the combination of ecological stressors (specifically, sediment and nutrients) from point source and diffuse sources in the upper Hātea River and wider catchment.

There are a number of factors that suggest that the discharge of Limeburners Creek into the Hātea River is not having a significant effect on the water quality in the receiving environment:

1) NRC SOE monitoring shows that the water quality at Limeburners Creek is similar to that measured upstream and downstream of Limeburners Creek; such similarities extend as far upstream as the Town Basin. It is important to note, however, that at least part of the discharge from Limeburners Creek during the latter part of the ebb tide is likely to pool in the Hātea and then move upstream during an incoming tide. This makes it difficult to determine whether reduced water quality in the Town Basin is a result (in part, or predominantly) of the discharge from Limeburners Creek.
2) The water quality parameters measured in the 4Sight surveys at the Hātea site, downstream from Limeburners Creek, were within the NRC coastal water quality standards. That is, the discharge from Limeburners Creek is not causing this site to exceed (not meet) the water quality standards.
3) Water quality measured by NRC along the Hātea River from the Town Basin to the Whangārei Harbour shows a general gradient of poorer water quality upstream and improved water quality downstream. There do not appear to be any 'step changes' in water quality in the Hātea River near Limeburners Creek that would indicate a significant effect.
4) Based on high-frequency data, Limeburners Creek appears to maintain higher water quality, with regard to dissolved oxygen, temperature, and turbidity, than the wider Upper Hātea environment.

3.5 Sediment quality

This section presents a high-level overview of the sediment quality in Limeburners Creek and surrounding areas based on the two sampling occasions that were undertaken during the baseline surveys in 2019 and 2020. For simplicity and to allow statistical analyses to be conducted by increasing the number of data in each group, data from both years (2019 and 2020) were combined. Summaries of the data collected during 2019 and 2020 are shown below in Figure 13 and Figure 14 and discussed in the following sections. More detailed plots of results by year are presented in Appendix B. Any differences in results between sampling years should be considered a reflection of the annual variation at these sites rather than a means of identifying any environmental change.

3.5.1 Metals

All sediment metal concentrations at all sites were below (met) the NRC coastal sediment quality standard (Figure 13). This indicates a low risk of toxicity to benthic organisms. This also indicates that there is no significant accumulation of metals from the WWTP discharge.

Arsenic and zinc had concentrations that were closest to the standard value. Mean arsenic concentrations were higher in Awaroa Creek and Hātea River than they were in Limeburners Creek. Zinc concentrations in Limeburners Creek were similar to those measured in the Hātea River.

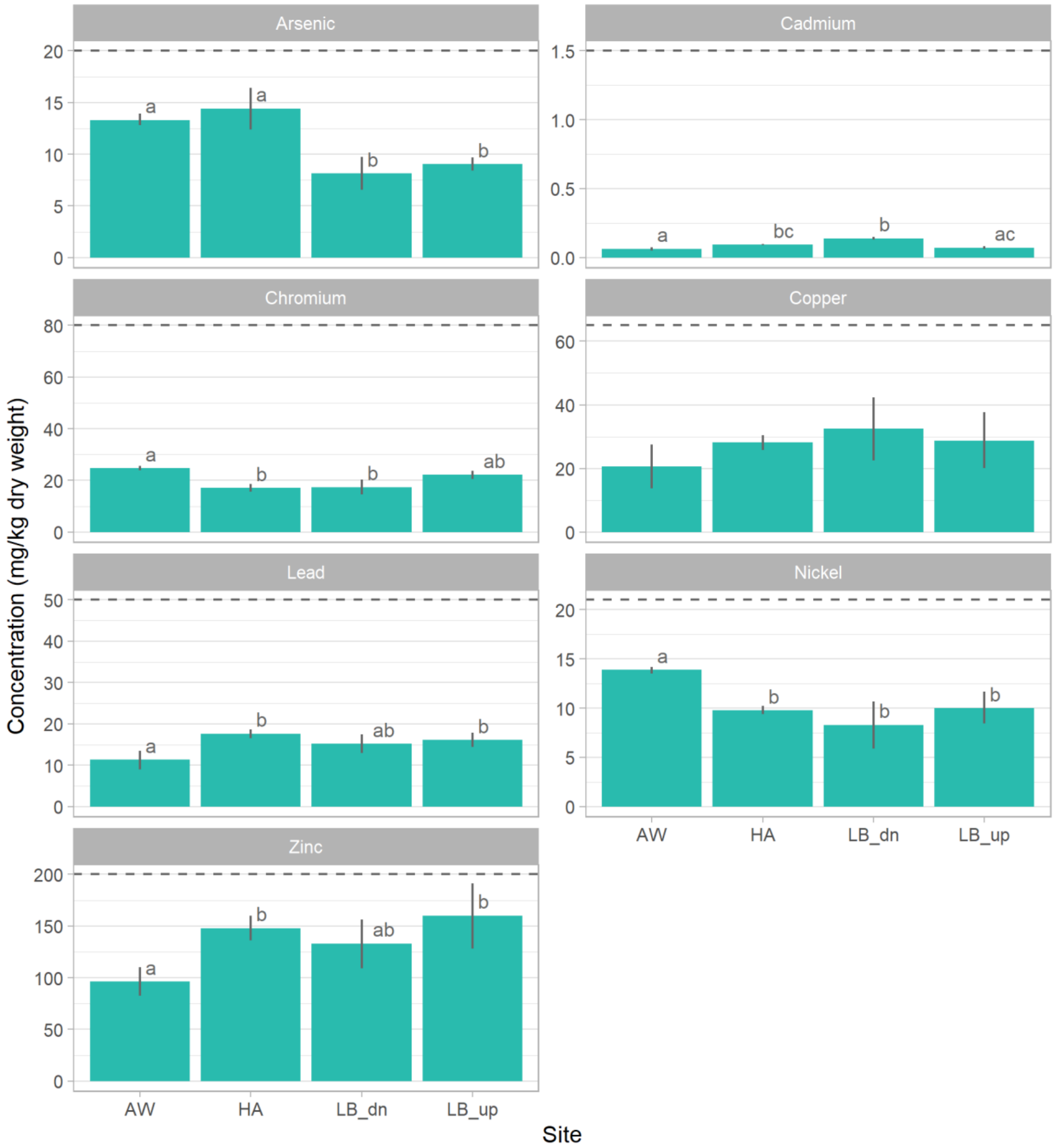

Figure 13: Mean sediment metal concentrations at each site collected during 2019 and 2020 field campaigns. Error bars show the 95% confidence interval of the mean (n = 6). The dashed, horizontal line denotes the NRC sediment quality guideline from the Proposed Northland Regional Plan (Appeals Version, June 2020).

3.5.2 Ecosystem health

The following sediment parameters do not have NRC coastal sediment quality standards. Where applicable, results are compared to the ETI tool 2 bands to put them in the context of ecosystem health.

3.5.2.1 Total recoverable phosphorus

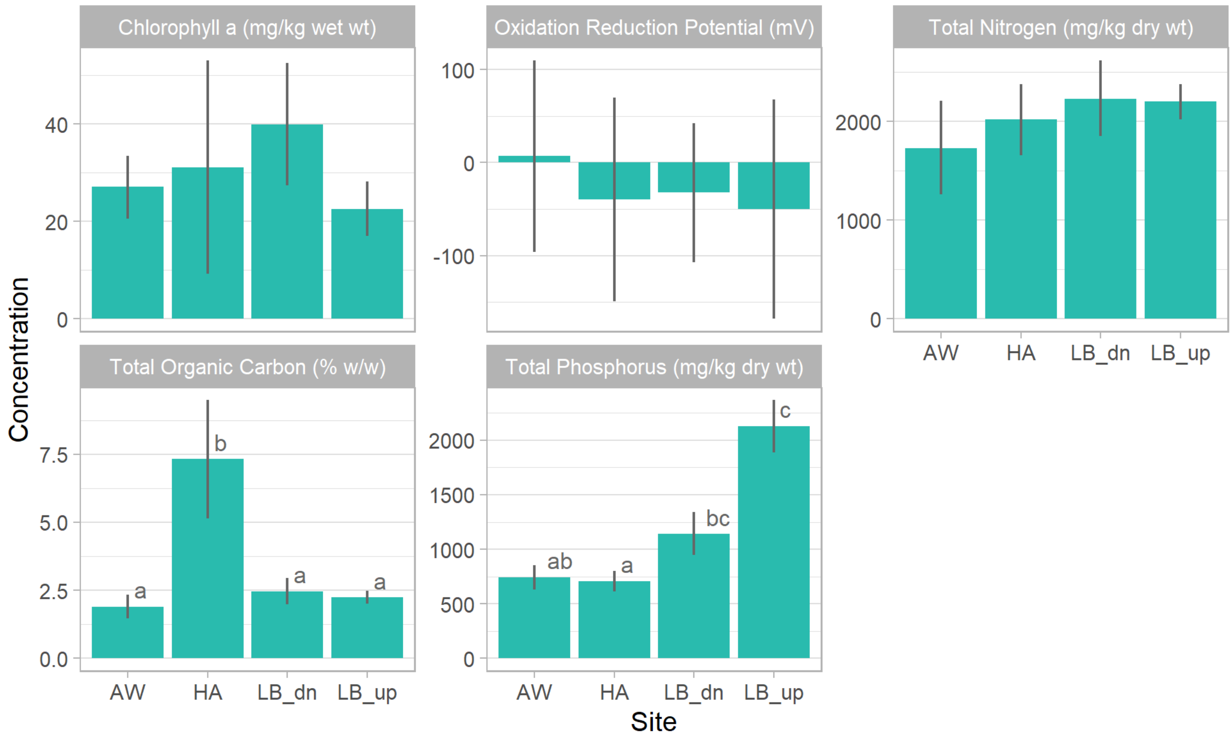

Figure 14: Mean sediment nutrient, organic carbon, and chlorophyll-a concentrations at each site collected during 2019 and 2020 field campaigns. Error bars show the 95% confidence interval of the mean (n = 6).

3.5.2.2 Total organic carbon

Sediment total organic carbon (TOC) was substantially higher at the Hātea site (mean ~7.5%) than at the Limeburners and Awaroa sites (mean ~2.5%). This is in agreement with the muddiness of the site, which was up to waist height when sampling. At low tide, the intertidal area at the Hātea site is expansive and appears to be a significant sediment deposition area within the river. The relatively low turbidity levels in Limeburners in combination with sediment TOC concentrations similar to that of the Awaroa Creek suggest that Limeburners Creek and the WWTP discharge do not significantly contribute towards TOC in the receiving environment.

Such high TOC contents place these sites in Band D of the ETI, which is described as having significant, persistent stress on a range of aquatic organisms. The elevated TOC levels appear to be characteristic of the upper Hātea River and have likely been in this state for many years. The benthic fauna that remain are necessarily tolerant toward sedimentation and muddy habitats.

3.5.2.3 Chlorophyll-a

Sediment chlorophyll-a results can be interpreted in a similar manner to water column measurements in that elevated levels can indicate symptoms of nutrient enrichment (eutrophication). Due to the variation among results, the mean chlorophyll-a concentrations were not statistically significantly different from each other.

The mean chlorophyll-a concentration was higher at Lime_down than at Lime_up. This may, in part, reflect the Lime_up site having a greater freshwater influence and, therefore, being less suitable for benthic algal growth. Lime_down may also be exposed to greater nutrient loads with greater volumes of water passing by this location and being located downstream of all discharge points from the mangrove forest into Limeburners Creek.

3.5.2.4 Total nitrogen

Sediment total nitrogen content was relatively similar at each location and there were no statistically significant differences in the mean concentrations. The mean concentration at Awaroa was slightly lower than the other sites. This places the Awaroa site in Band C of the ETI, whereas the other locations fall within Band D.

Interestingly, sediment nitrogen content is not elevated in Limeburners Creek any more than the other sites despite the elevated water-column nitrogen levels. It is possible that due to constant exposure to elevated nitrogen levels, the ability for sediment to bind nitrogen is inhibited.

In a similar manner to TOC discussed above, elevated sediment nutrient levels appear to be characteristic of the upper Hātea River and have not likely changed in recent years.

3.5.2.5 Total recoverable phosphorus

Sediment total phosphorus content was markedly higher at Lime_up than at Awaroa or Hātea. This is in agreement with the water quality results in that the highest phosphorus concentrations were measured in the most upstream sites of Limeburners Creek. This is likely a consequence of the high phosphorus concentration in the discharge from the WWTP into Limeburners Creek.

3.5.2.6 Oxidation-reduction potential

Oxidation-reduction potential ('redox') measurements were highly variable as indicated by the large error bars. Consequently, there were no statistically significant differences among the means of each site. Overall, Awaroa had the highest mean, albeit near 0 mV, indicating a slightly oxidising (better quality) sediment at 1-cm depth. The Hātea and Limeburners sites were similar to each other with redox values at 1-cm depth of about −50 mV. This indicates that, at this depth, sediment oxygen has been consumed and the sediment is anoxic. This is likely a result of the fine grain size and high organic carbon content of the sediment; oxygen diffuses poorly into fine sediments and the microbially-mediated breakdown of organic matter is a highly oxygen-consuming process.

3.5.3 Multivariate analysis

Multivariate analysis allows all the parameters described above to be analysed simultaneously and used to identify key parameters that differentiate sites and to visualise the magnitude of the difference between sites, if any.

The principal component analysis (PCA) shown in Figure 15 explains 38% of the variation in the data from the PC1-axis. This axis is dominated by TOC concentrations. The PC2-axis explains a further 30% of the variation using primarily total phosphorus. This indicates that sediment TOC and TP are the key drivers of difference among the sites measured here. All four sites were distinctly separated by the analysis.

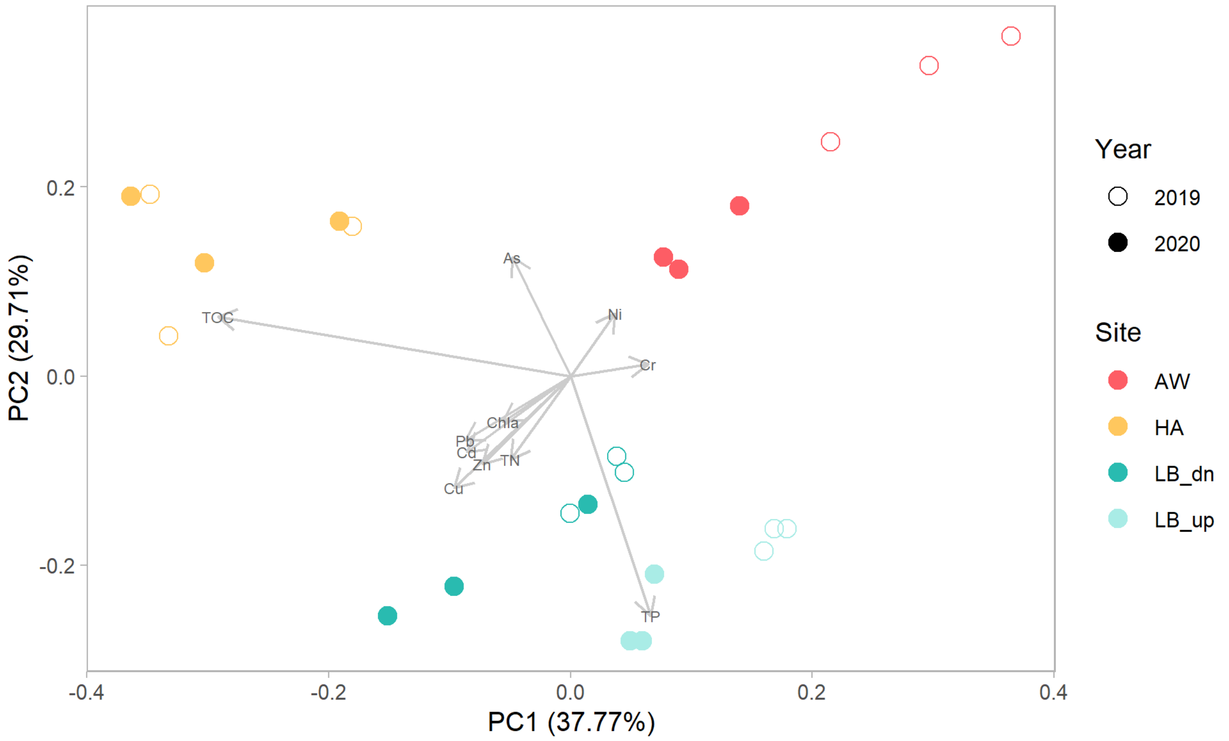

Figure 15: Principal Component Analysis (PCA) of intertidal sediment samples. Samples from 2019 and 2020 were combined and analysed as one dataset.

The Hātea River sites are separated on the left-hand side of the PCA plot from the other sites due to their substantially higher TOC levels. The position of the sites is similar for each sampling year, which indicates that the sediment properties were similar during each sampling occasion.

Both sites in Limeburners Creek are characterised by elevated total phosphorus levels, the upstream site more so than the downstream site. The Limeburners sites also had higher levels of chlorophyll-a, however, this had a relatively weak influence in the PCA. That is, although chlorophyll-a is slightly elevated in Limeburners Creek, total phosphorus was a better defining characteristic of the site in this analysis.

The Awaroa site is characterised by a number of parameters, namely lower TOC and total phosphorus and lower metal concentrations, except for nickel and chromium, than the other two sites. Results from 2019 are further towards the top-right of the plot than results for 2020. This is due to the 2019 samples, in general, having lower TOC, total phosphorus, and metal concentrations. The reasons for such differences between years is not clear, however, this could be a result of a deposition event that occurred between the two sampling occasions or due to natural variation and heterogeneity at the site.

3.5.4 Comparison with NRC state of the environment data

The most recent SOE report on coastal sediment quality that includes the Hātea River was published in 2016 (Bamford, 2016). Multiple locations are sampled along the Hātea River and at the mouth of Limeburners Creek that can be used as a comparison for the data collected in the 4Sight surveys (Figure 16).

1:40000 @A4
0 500 1,000 m

NRC SOE Sediment Quality Sites

Date: 04/09/2020
Version: 1.0
Author: PW
Checked: MP
Approved: ML

Figure 16: Northland Regional Council (NRC) State of the Environment (SOE) sediment quality monitoring sites near the WWTP discharge in Limeburners Creek.

In general, the sediment quality measurements presented by NRC in their SOE report are similar to those measured in this study. In the Hātea River from Limeburners Creek downstream, sediment metal concentrations are low and below the NRC coastal sediment quality guidelines. Upstream of Limeburners Creek at the Town Basin, however, metal concentrations are elevated, likely a result of the industrial and urban influence of this area.

The sampling conducted for this study revealed particularly high TOC concentrations at the Hātea site. This differed to the NRC SOE report; however, similarly high concentrations were reported further upstream at the Town Basin location. Higher concentrations measured by 4Sight may be a result of a recent deposition event or reflect the heterogeneity of the environment. In general, the upper Hātea River had elevated TOC concentrations that are indicative of an environment that is likely unsuitable for benthic species that are not mud-tolerant.

NRC identified elevated sediment phosphorus concentrations at the mouth of Limeburners and the other two sites further upstream to the Town Basin. This is in agreement with the particularly high sediment phosphorus concentrations measured in this study. Earlier in this report (Section 3.5.2.5), it was concluded that the high sediment phosphorus concentrations were likely a result of the WWTP discharge. Noting the high sediment phosphorus concentrations upstream, there may also be other catchment-derived sources of phosphorus in addition to the WWTP discharge.

4 CONCLUSIONS

4.1 Habitats

Limeburners Creek is dominated by a large mangrove forest and bordered by rural and industrial land. The intertidal areas of Limeburners Creek account for about 13% of the estuary's area and comprise predominantly soft mud and small, patchy areas of cobble, rock, and oyster reef.

Although the estuary has elevated nutrients, only small patches of macroalgae (0.16% of the estuary) were identified. This is, perhaps, lower than anticipated given the documented nutrient levels. It may reflect the efficacy of the treatment wetland as well as factors such as the role of mangroves and the flushing potential of the creek in removing nutrient and/or reducing it to levels that do not sustain macroalgal proliferation. There is also no indication that benthic microalgae, as reflected in the sediment chlorophyll-a data, is unusually elevated in Limeburners Creek relative to the other sites sampled in the upper harbour.

4.2 Benthic ecology

In general, all sites had appropriate species diversity for estuarine intertidal areas but were dominated by only a few of those species. This suggests some response to sedimentation and/or organic enrichment and may reflect the relatively high sediment content and total organic carbon that was measured at all site but most notably at Hātea.

NRC identified limited populations of shellfish on intertidal and subtidal areas of the Hātea River. These include a patchy distribution of small cockles and also several invasive exotic species.

Turbidity levels measured in Limeburners Creek were typical of the upper Hātea environment and were lower (improved water quality) than in Awaroa Creek and the Hātea River, at times. This suggests that Limeburners Creek is not contributing sediment disproportionately into the environment, relative to the other measured sites.

The benthic community composition data indicate that sedimentation and organic enrichment are key stressors in the upper Hātea environment, but the data does not indicate that these stressors are due to the WWTP discharge in Limeburners Creek. Rather, this is likely a result of wider scale catchment influences and a consequence of land-use change and urbanisation over time.

The benthic macroinvertebrate communities found at the downstream site in Limeburners Creek were very similar to those found at the Awaroa site, which was used as a reference or comparison site. Both sites were characterised by a comparatively high abundance of infaunal deposit-feeding oligochaete worms. This suggests that the WWTP discharge is not having a significant effect on the benthic macroinvertebrate communities and that the communities present are characteristic of the general upper Hātea environment.

A relatively high abundance of Copepods was identified at the downstream Limeburners Creek Site. These organisms are known to be susceptible to metal contaminants and their presence suggests that the current metal concentrations are not having a significant effect on the ecology. This is supported by the relatively low sediment metal concentrations (meeting the sediment quality standards) that were measured at all sites.

There were notable differences between the upstream and downstream Limeburners Creek sites. The upstream Limeburners site was the only site to have the estuarine snail, *Potamopyrgus estuarinus*. This species is tolerant of environmental extremes including changes in salinity, allowing it to survive in brackish mixing zones. The upstream site also had a cobbled habitat and had the lowest measured salinity at times. The benthic communities at this location reflect the differing habitat: specifically, differing sediment type and strong freshwater influence. Consequently, differences between the benthic communities at the two Limeburners sites are expected.

4.3 Water quality

The discharge of Limeburners Creek should not cause water quality in the Hātea River to exceed the designated water quality standards after the 'reasonable mixing' it is deemed to have received in the Creek. Although sampling conducted by 4Sight and NRC show that Limeburners Creek has elevated nutrient levels, nearby locations in the Hātea River are within the NRC coastal water quality standards. On this basis, 'reasonable mixing' appears to be achieved within the designated mixing zone.

Chlorophyll-a concentrations in Limeburners Creek were lower than might be anticipated due to the elevated nutrient levels. Algal growth may be mitigated by suspended sediment limiting the available light for growth and the tidal flushing of Limeburners Creek into the Hātea River. There may be insufficient time (i.e., low residence time) for substantial algal biomass to accumulate.

Overall, water quality measured along the Hātea River from the Town Basin to the Whangārei Harbour shows a general gradient of poorer water quality upstream and improved water quality downstream. There do not appear to be any ‘step changes’ in water quality in the Hātea River near Limeburners Creek that would indicate a significant effect due to the waters emanating from Limeburners Creek.

In this regard, the contribution of the WWTP discharge via Limeburners Creek into the Hātea River is one of many ecological stressors in the upper Hātea environment. We are not able to discern an effect that would distinguish the effects of the discharge from Limeburners from the other stressors in the upper Hātea.

4.4 Sediment quality

Overall, all sites had relatively high TOC and nutrient concentrations, which is indicative of an environment that provides moderate to high stress on benthic organisms. This is likely characteristic of the upper Hātea River environment and a consequence of land-use change and urbanisation over time. The benthic biota in this general area are likely to be resilient and tolerant towards the effects of sedimentation and organic enrichment. These communities are also likely to be naturally suppressed and limited by seasonal ambient conditions including wide variation in both dissolved oxygenation and water temperatures which can result in potentially stressful low oxygen levels and high temperatures.

The most notable difference in Limeburners Creek was the elevated levels of total phosphorus in the sediment. This is likely a combination of dissolved phosphorus from the WWTP discharge binding to sediments and from phosphorus-bound sediment from the discharge being deposited in Limeburners Creek. Consequently, sediments in Limeburners Creek are likely to act as an additional source of phosphorus.

Interestingly, sediment nitrogen concentrations were no more elevated in Limeburners Creek than they were at the other sites despite having elevated water-column nitrogen levels. The elevated sediment phosphorus concentrations do not appear to have a significant effect on the benthic macroinvertebrate communities. This is supported by the benthic communities in the downstream Limeburners site and Awaroa site having similar community compositions. Further, the other sites did not have substantially elevated sediment phosphorus levels relative to Limeburners Creek, which suggests that elevated levels of phosphorus in sediments is isolated to Limeburners Creek.

All sites, including Limeburners Creek, had metal concentrations that were within the NRC sediment quality guidelines. This is consistent with the presence of the metal-sensitive Copepods at the downstream Limeburners site.

4.5 Overall Conclusion

The discharge from the WWTP is discharged via treatment wetlands into Limeburner Creek, which is designated as a mixing zone. Consequently, nutrient levels are unsurprisingly elevated in the sediment and water in Limeburners Creek. Based on the data presented in this report, such elevated nutrients in Limeburners Creek don’t appear to significantly affect water quality, sediment quality, or benthic communities at nearby sites in the Hātea River.

In general, the water quality, sediment quality, and benthic ecology in the upper Hātea River are degraded to some extent because of the multiple diffuse and point source discharges nearby and in the wider catchment. The WWTP discharge is one of those influences but it cannot readily be isolated from other stressors. While it will contribute to the cumulative effect on the environment, it appears not to have a dominating or preeminent effect on the upper harbour environment outside that of Limeburners Creek.

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Appendix A:

Sampling Locations

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1 : 12000 @A3

0 200 400 m

AA2789 — WDC WWTP Ecological Baseline for Consent Renewal

Sediment and Water Sampling Locations

Prepared for Whangarei District Council by 4Sight Consulting

Sample Type

- Water
- Sediment & infauna
- Water, sediment & infauna

Date: 3/09/2019
Version: 1.2
Author: PW
Checked: MP
Approved: ML

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Appendix B:

Additional Water and Sediment Quality Plots and Tables

Figure B1: Snapshot water quality results from 2019 and 2020 samples for parameters with NRC guideline values.

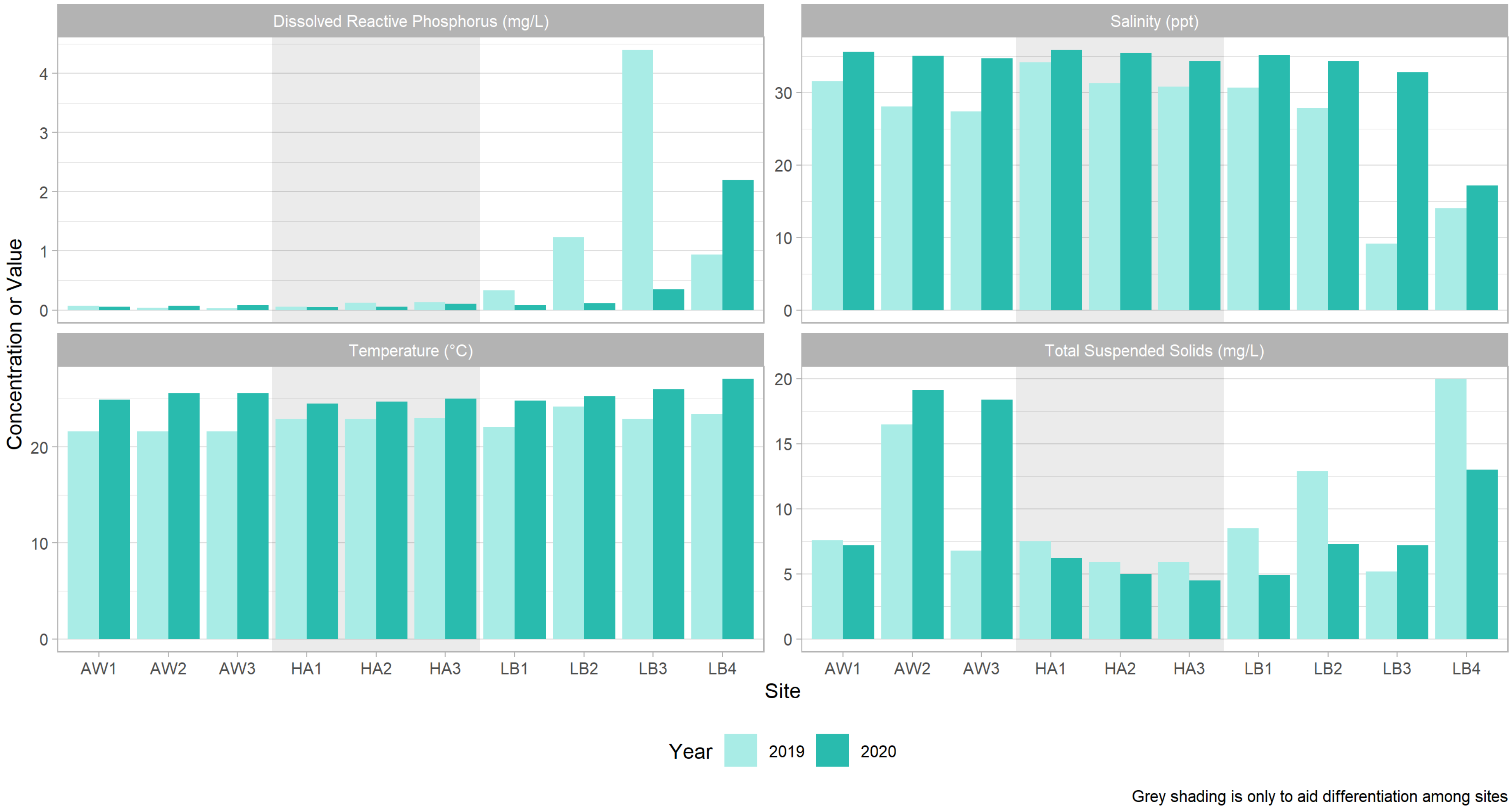


Figure B2: Snapshot water quality results from 2019 and 2020 samples for parameters with no NRC guideline values.

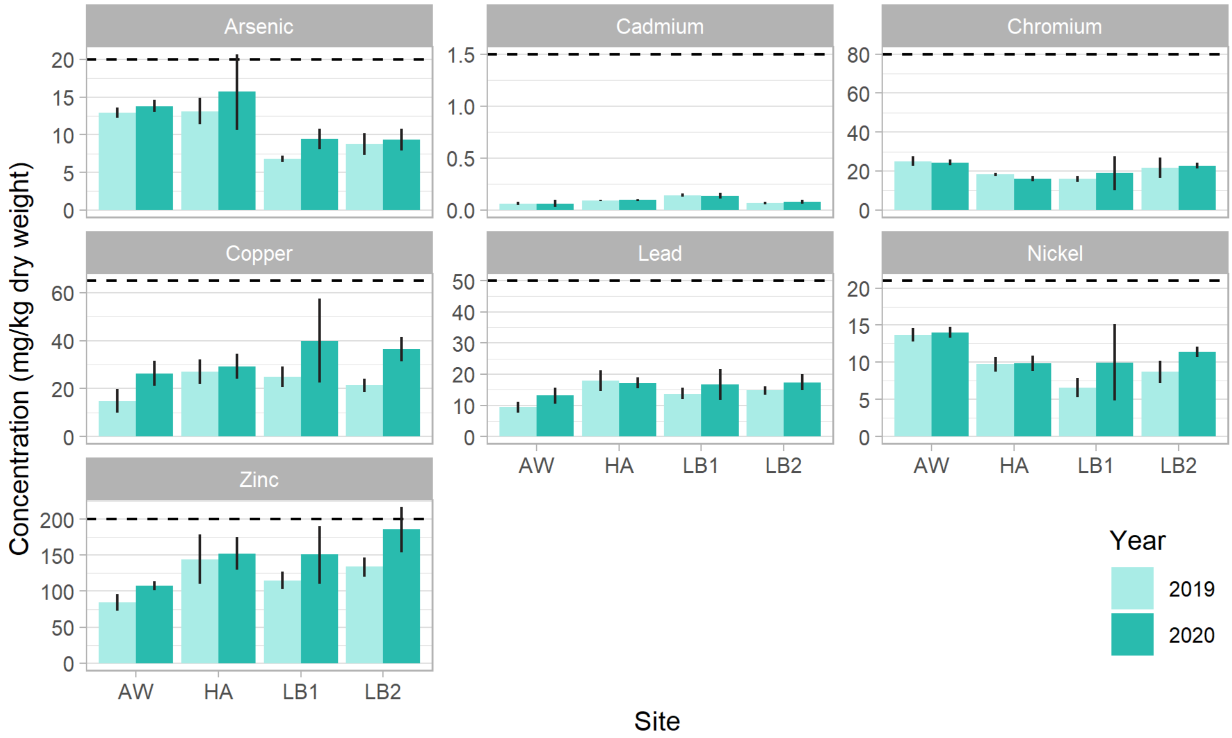


Figure B3: Sediment metal concentrations at each site collected during 2019 and 2020 field campaigns. Error bars show the 95% confidence interval of the mean (n = 3). The dashed, horizontal line denotes the ANZG (2018) default guideline value (DGV).

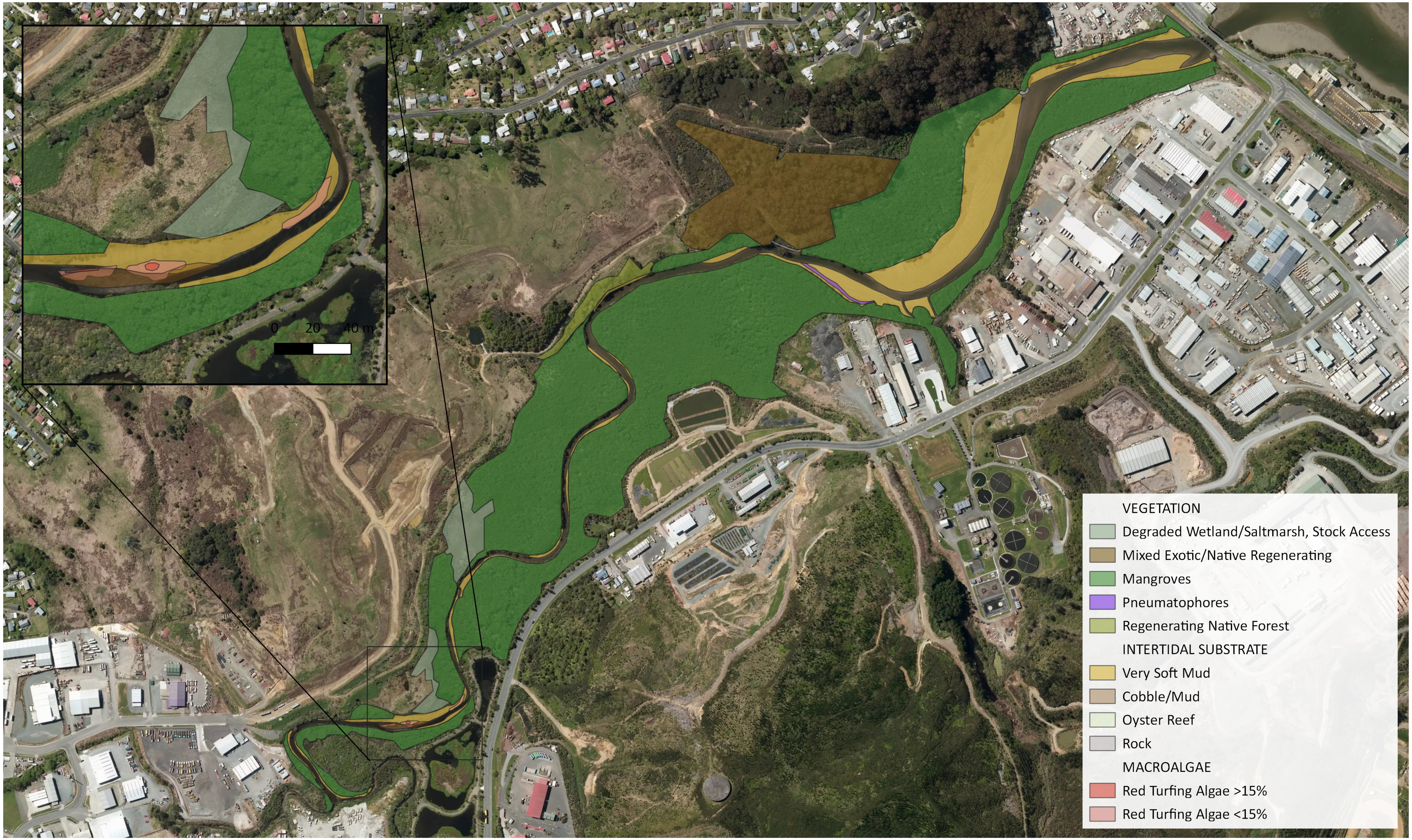
Table B1: Ammoniacal nitrogen concentrations adjusted to pH 8.0 to assess against the ANZG (2018) toxicant default guideline value.

Site	pH		Ammoniacal Nitrogen (mg/L)		Ammoniacal Nitrogen (adjusted to pH 8.0; mg/L)	
	2019	2020	2019	2020	2019	2020
AW1	7.78	8.01	0.103	0.060	0.071	0.060
AW2	7.62	7.97	0.118	0.081	0.058	0.081
AW3	7.60	7.91	0.119	0.104	0.059	0.086
HA1	8.12	7.99	0.076	0.052	0.093	0.052
HA2	7.94	7.96	0.143	0.069	0.118	0.069
HA3	7.92	7.92	0.148	0.101	0.122	0.083
LB1	7.74	7.92	0.138	0.075	0.081	0.062
LB2	7.87	7.84	0.300	0.104	0.248	0.072
LB3	7.45	7.78	0.138	0.130	0.050	0.090
LB4	7.21	7.29	0.100	0.210	0.028	0.067
ANZG (2018) toxicant default guideline value					**0.910**	

Figure B4: Sediment nutrient, organic carbon, and chlorophyll-a concentrations at each site collected during 2019 and 2020 field campaigns. Error bars show the 95% confidence interval of the mean (n = 3).

Appendix C:

Limeburners Creek Habitat Map



1 : 6000 @A3

0 100 200 m

AA2789 - WDC WWTP Ecological Baseline for Consent Renewal

Limeburners Creek Habitat Map

Prepared for Whangarei District Council by 4Sight Consulting

Date: 18/09/2019
Version: 1.1
Author: PW
Checked: MP
Approved: ML

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Appendix D:

Benthic Macroinvertebrate Results

Benthic Macroinvertebrates - 2019

General Group	Family	Genus	Taxa	Common Name	Feeding	AWA	AWA	AWA	AWA	AWA	AWA	AWA	AWA	AWA	AWA	HAT	HAT	HAT	HAT	HAT	HAT	HAT	HAT	HAT	HAT	LBL	LBL	LBL	LBL	LBL	LBL	LBL	LBL	LBL	LBL	LBU	LBU	LBU	LBU	LBU	LBU	LBU	LBU	LBU	LBU
Nemertea			Nemertea	Proboscis worms													1				1		1						1	1		1													
Gastropoda			Gastropoda operculum and body	Snails																																	1								
Gastropoda	Amphibolidae	Amphibola	Amphibola crenata	Mud Snail	Microalgal grazer																																							2	
Gastropoda	Nassariidae	Nassarius (Plicarcularia)	Nassarius (Plicarcularia) burchardi	Australian dog whelk																	1	1																							
Gastropoda	Hydrobiidae	Potamopyrgus	Potamopyrgus estuarinus	Estuarine snail	Microalgal & detrital grazer																														2			83	1		1	4	2	5	4
Bivalvia			Bivalvia indeterminable																					1																	1	1			
Bivalvia			Xenostrobus sp.										1		1													1								2		1		8		5		1	
Bivalvia	Lasaeidae	Arthritica	Arthritica sp.	Small bivalve	Infaunal deposit feeder						1		1	6	2	2				1	3		2	1	2							1		1	7	7		25	4	9	2	8		59	1
Bivalvia	Veneridae	Austrovenus	Austrovenus stutchburyi	Cockle; Huangi	Infaunal deposit feeder													1			1			3	1				1																
Bivalvia	Tellinidae	Macomona	Macomona liliana	Wedge shell Hanikura	Infaunal suspension feeder																	1																							
Bivalvia	Mytilidae	Musculista	Musculista senhousia															5			1			20	19	1		1														1		1	
Oligochaeta			Oligochaeta	Oligochaete worms	Infaunal deposit feeder	160	125	74	24	17	54	31	11	8	18		13	3				2	2	1	2	24	14	44	137	5	22	50	1	9	6		2						8	1	7
Polychaeta: Spionidae	Spionidae		Polydorid			15	15	16	1	6	39	8	5	12		99	23	23	38	165	8	32	10	12	23	3	2	26	2	2	10	2	1	6	1				1	5		1		5	
Polychaeta:			Nereididae indeterminable			6	3								1	2					1	1		2		8										1			1				1		
Polychaeta: Paraonidae	Paraonidae		Paraonidae		Infaunal deposit feeder	1		7		1			1	3		9	12	2	8	11	1	6	9	5	2																				
Polychaeta: Paraonidae	Paraonidae	Aricidea	Aricidea sp.													10	5		6	9	2	3		2	8																				
Polychaeta: Cossuridae	Cossuridae	Cossura	Cossura consimilis		Deposit feeder															2		1	1																						
Polychaeta: Spionidae	Spionidae	Prionospio	Prionospio sp.		Surface deposit feeder	7	71	7	32	31	1	2	1			47	26	5	86	93	10	32	10	7	7	17	41	11	3	10	10	51	1	7	10		1						1	1	2
Polychaeta: Spionidae	Spionidae	Scolecolepides	Scolecolepides benhami		Surface deposit feeder	1		1		1	2	8	3	17	1											2	7		1	2		1	1												
Polychaeta: Capitellidae	Capitellidae	Barantolla	Barantolla lepte														1	1				2	1																						
Polychaeta: Capitellidae	Capitellidae	Capitella	Capitella sp.		Infaunal deposit feeder	10				1	2	3				2	6	2	6	11	7	3				2	7	10	2	2	3	3	2	3	1										
Polychaeta: Capitellidae	Capitellidae	Heteromastus	Heteromastus filiformis		Infaunal deposit feeder											2	2		1	8	1	5																							
Polychaeta: Polynoidae	Polynoidae		Polynoidae	Scale worms	Infaunal carnivore				1							3		2		1	6	1						1		1			1												
Polychaeta: Nereididae	Nereididae		Nereididae (juvenile)		Omnivorous	6		3	1	3	1	6	25	11		2	2	1	2	5	2	1	9	8	8	23	6	13	22	13	18	21	4	3	31	22	7	40	7	26	18	39	2	27	15
Polychaeta: Nereididae	Nereididae	Ceratonereis	Ceratonereis sp.	Rag worm								3	4	1	3											20	68	19	5	13	30	14	28	16	7	2	26	2	8	29	8	1	3	30	15
Polychaeta: Nereididae	Nereididae	Nicon	Nicon aestuariensis		Omnivorous								2	3		1	4		4	3		15	6			1				1			2	1			1		2		2		3		1
Polychaeta: Nereididae	Nereididae	Perinereis	Perinereis sp.		Omnivorous	3				1	2			3	3	2		1		2	2		2		2	4			1		1			1											1
Polychaeta: Cirratulidae	Cirratulidae		Cirratulidae		Deposit feeder														1	1																									
Isopoda	Sphaeromatidae	Exosphaeroma	Exosphaeroma chilensis																																	2		6				1			
Amphipoda	Corophiidae		Corophiidae	Amphipod (family)		3							2													2		8		1						16	4	3		7		7		14	
Amphipoda			Amphipoda indet.	Amphipods								2																																	
Decapoda	Alpheidae	Alpheus	Alpheus socialis	Snapping Shrimp														1																											
Decapoda	Aristeidae	Aristaeomorpha	Aristaeomorpha foliacea																		1																								
Decapoda	Varunidae	Austrohelice	Austrohelice crassa	Tunnelling Mud Crab	Deposit feeder & scavenger	2					1	4	3	2	2													4	3	1		1		1			1								
Decapoda	Hymenosomatidae	Halicarcinus	Halicarcinus whitei	Pill-box Crab	Eats small organisms & weed																																								1
Decapoda	Macrophthalmidae	Hemiplax	Hemiplax hirtipes	Stalk-eyed Mud Crab	Deposit feeder & scavenger										1																		1	1											
Decapoda			Decapoda indeterminable	Decapoda							1			1																															
Copepoda			Copepoda	Copepods					5	1		1		1	1		2			1	1	1				1	2	2		4		1		1	2										
			Count: No of Individuals			**214**	**214**	**108**	**64**	**62**	**104**	**68**	**59**	**68**	**33**	**181**	**97**	**47**	**152**	**313**	**49**	**107**	**53**	**62**	**74**	**108**	**147**	**140**	**178**	**56**	**94**	**146**	**42**	**50**	**67**	**52**	**43**	**160**	**24**	**84**	**32**	**68**	**20**	**146**	**47**
			Count: No of Taxa			**11**	**4**	**6**	**6**	**9**	**10**	**10**	**12**	**12**	**10**	**12**	**12**	**12**	**9**	**14**	**17**	**16**	**11**	**11**	**10**	**13**	**8**	**12**	**11**	**13**	**7**	**11**	**10**	**12**	**9**	**7**	**8**	**7**	**7**	**6**	**6**	**10**	**7**	**11**	**9**

Benthic Macroinvertebrates - 2020

General Group	Family	Genus	Taxa	Common Name	Feeding	AWA	AWA	AWA	AWA	AWA	AWA	AWA	AWA	AWA	AWA	HAT	HAT	HAT	HAT	HAT	HAT	HAT	HAT	HAT	HAT	LBL	LBL	LBL	LBL	LBL	LBL	LBL	LBL	LBL	LBL	LBU	LBU	LBU	LBU	LBU	LBU	LBU	LBU	LBU	LBU
Anthozoa			Anthozoa	Anemones		1																						1							1		2	2					1	1	1
Anthozoa	Actiniidae	Anthopleura	Anthopleura hermaphroditica																																				3						
Nemertea			Nemertea	Proboscis worms			1									1				1	1																								
Gastropoda	Amphibolidae	Amphibola	Amphibola crenata	Mud Snail	Microalgal grazer		1																																						
Gastropoda	Hydrobiidae	Potamopyrgus	Potamopyrgus estuarinus	Estuarine snail	Microalgal & detrital grazer																															1	5	2			1		4	1	3
Gastropoda	Muricidae	Xymene	Xymene sp.																					1																					
Opisthobranchia			Opisthobranchia Unid.				1																																						
Bivalvia	Lasaeidae		Lasaeidae			1									1	2	4	4	1	2			7	6	4	4				1	1				3		3	3	5	4	3	6	1		5
Bivalvia	Nuculidae		Nuculidae														2																												
Bivalvia	Veneridae	Austrovenus	Austrovenus stutchburyi (0-5mm)	Cockle (0-5mm)	Infaunal deposit feeder																			1																					
Bivalvia	Veneridae	Austrovenus	Austrovenus stutchburyi (31+mm)	Cockle (>31mm)	Infaunal deposit feeder																		1																						
Bivalvia	Nuculidae	Linucula	Linucula hartvigiana	Nut Shell	Surface deposit & filter feeder													1				1	1																						
Bivalvia	Mactridae	Maorimactra	Maorimactra ordinaria																1		1																								
Bivalvia	Mytilidae	Musculista	Musculista senhousia														64								23														1			6	1		
Bivalvia	Ostreidae	Saccostrea	Saccostrea glomerata	Auckland rock oyster			4																																						
Bivalvia	Mytilidae	Xenostrobus	Xenostrobus securis	Little Black Mussel		1	1							2																1					1			1	5	2		23	3		3
Oligochaeta			Oligochaeta	Oligochaete worms	Infaunal deposit feeder	157	3	40	26	95	37	5	47	66	6	1	1									34	44	90	233	133	8	5	10	14	46	34		2		1				3	2
Polychaeta: Spionidae	Spionidae		Polydorid complex			154		34	11	68	44	57			9	2	2	4	1	3	4		2	1	20	37	106	33	83		34		16	44	44				2						
Polychaeta:						1																																							
Polychaeta: Paraonidae	Paraonidae		Paraonidae		Infaunal deposit feeder				2	1	2						2	1	3	1	1	2	5	2	12						1														
Polychaeta: Paraonidae	Paraonidae	Aricidea	Aricidea sp.													5	5	16	9	11	30	12	17	3	11	1																			
Polychaeta: Spionidae	Spionidae	Prionospio	Prionospio sp.		Surface deposit feeder	1	2		2	6	13	39	4	2		2	3	6	6	23	25	8	27	5	14	19	60	3	1	10	21		57	9	21										
Polychaeta: Spionidae	Spionidae	Scolecolepides	Scolecolepides benhami		Surface deposit feeder	5	1		5	2	5	4	2	13	6	2					1	2	2				2	3	7				1	2	1	1		1	3					1	
Polychaeta: Capitellidae	Capitellidae	Capitella	Capitella sp.		Infaunal deposit feeder	7		4		2	1	6		1												15	30	3	10	2	6		3	5	7										
Polychaeta: Capitellidae	Capitellidae	Heteromastus	Heteromastus filiformis		Infaunal deposit feeder														2	11	2		5	1																					
Polychaeta: Capitellidae	Capitellidae	Notomastus	Notomastus sp.		Infaunal deposit feeder													1																											
Polychaeta: Polynoidae	Polynoidae		Polynoidae	Scale worms	Infaunal carnivore					1		1		1										1	1						1														
Polychaeta: Nereididae	Nereididae		Nereididae (juvenile)		Omnivorous	1						10	2	1		15	3	10	14	3	5	12	9	16	9		6	2	11		1		3		2	13	15	28	96	41	22	17	15	28	49
Polychaeta: Nereididae	Nereididae	Ceratonereis	Ceratonereis sp.	Rag worm		5	3	1	1	3	1	2	2	3	1								1		1	1	1	4	13	1	7		1	15	1	12	17	8	41	26	4	59	18	15	19
Polychaeta: Nereididae	Nereididae	Nicon	Nicon aestuariensis		Omnivorous																												1					2					1		
Polychaeta: Nereididae	Nereididae	Perinereis	Perinereis sp.		Omnivorous	5	4			2		2	1		1	6	3	10	6	8	4	9	4	14	9		1	1	2					1	1			3							
Polychaeta: Glyceridae	Glyceridae		Glyceridae		Infaunal carnivore & deposit feeder																1				1																				
Polychaeta: Cirratulidae	Cirratulidae		Cirratulidae		Deposit feeder			1																																					
Arthropoda	Tipulidae		Tipulidae	Crane fly larvae			3																																						
Isopoda	Sphaeromatidae	Exosphaeroma	Exosphaeroma planulum																																									2	
Isopoda	Sphaeromatidae	Exosphaeroma	Exosphaeroma sp.																								3																		
Amphipoda	Corophiidae		Corophiidae	Amphipod (family)				1	57	3		22			3	1							61		30	4		3	2		18		10	6	12			1	3		1		1		2
Amphipoda	Melitidae		Melitidae	Amphipods																																1									
Amphipoda			Amphipoda indet.	Amphipods		1		2					1				1											8	2		4			1		1				1		5	2		
Decapoda	Varunidae	Austrohelice	Austrohelice crassa	Tunnelling Mud Crab	Deposit feeder & scavenger	10	5	8	3	7	3			2	6											2	3	12	7					4	5										
Decapoda	Hymenosomatidae	Halicarcinus	Halicarcinus whitei	Pill-box Crab	Eats small organisms & weed																												1												
Decapoda	Macrophthalmidae	Hemiplax	Hemiplax hirtipes	Stalk-eyed Mud Crab	Deposit feeder & scavenger		2				2		2				1	1	1	1	1	1			2								2				1								
Copepoda			Copepoda	Copepods		1			1		2	2			1											5	4	3	1	1	5		2	4											
Cirripedia	Balanidae	Austrominius	Austrominius modestus	Estuarine Barnacle	Filter feeder		2																				28			2															2
Diptera	Psychodidae		Psychodidae	moth fly																										1		74													
Ascidiacea			Ascidian (solitary)	Sea Squirts		1																																							
			Count: No of Individuals			**352**	**33**	**91**	**108**	**190**	**110**	**150**	**61**	**91**	**34**	**37**	**91**	**54**	**44**	**64**	**76**	**47**	**142**	**51**	**137**	**122**	**288**	**166**	**372**	**152**	**107**	**79**	**107**	**105**	**145**	**63**	**43**	**53**	**159**	**75**	**31**	**116**	**47**	**51**	**86**
			Count: No of Taxa			**16**	**14**	**8**	**9**	**11**	**10**	**11**	**8**	**9**	**9**	**10**	**12**	**10**	**10**	**10**	**12**	**8**	**13**	**11**	**13**	**10**	**12**	**13**	**12**	**9**	**12**	**2**	**12**	**11**	**13**	**7**	**6**	**11**	**9**	**6**	**5**	**6**	**10**	**7**	**9**

Appendix E:

Laboratory Results

Hill Laboratories
TRIED, TESTED AND TRUSTED

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Certificate of Analysis

SPv1

Client:	4SIGHT Consulting Limited	**Lab No:**	2144935
Contact:	Oliver Bone	**Date Received:**	20-Mar-2019
	C/- 4SIGHT Consulting Limited	**Date Reported:**	03-May-2019
	PO Box 402053	**Quote No:**	97960
	Tutukaka 0153	**Order No:**	AA2789
		Client Reference:	
		Submitted By:	Pete Wilson

Sample Type: Saline

Sample Name:		MM_Upstream 19-Mar-2019 11:58 am	MM_LB3 19-Mar-2019 2:35 pm	MM_LB2 19-Mar-2019 2:46 pm		
Lab Number:		2144935.1	2144935.2	2144935.3		
Individual Tests						
Turbidity*	NTU	4.2	3.5	6.3	-	-
Total Suspended Solids*	g/m^3	20	5.2	12.9	-	-
Total Nitrogen	g/m^3	5.9	23	7.2	-	-
Total Ammoniacal-N	g/m^3	0.100	0.138	0.30	-	-
Nitrite-N	g/m^3	0.049	0.054	0.048	-	-
Nitrate-N	g/m^3	5.0	21	6.2	-	-
Nitrate-N + Nitrite-N	g/m^3	5.1	21	6.3	-	-
Dissolved Reactive Phosphorus	g/m^3	0.94	4.4 #1	1.23	-	-
Total Phosphorus*	g/m^3	1.04	4.3 #1	1.32	-	-
Chlorophyll a*	g/m^3	0.0009	0.0013	0.0047	-	-

Sample Type: Sediment

Sample Name:		Sed_LB1_1 19-Mar-2019 1:01 pm	Sed_LB1_2 19-Mar-2019 1:14 pm	Sed_LB1_3 19-Mar-2019 1:30 pm	Sed_LB2_1 19-Mar-2019 2:50 pm	Sed_LB2_2 19-Mar-2019 2:59 pm
Lab Number:		2144935.4	2144935.5	2144935.6	2144935.7	2144935.8
Individual Tests						
Total Recoverable Phosphorus	mg/kg dry wt	950	1,000	1,130	1,900	1,980
Total Nitrogen*	g/100g dry wt	0.20	0.19	0.23	0.19	0.22
Total Organic Carbon*	g/100g dry wt	2.2	2.2	2.5	1.94	2.0
Chlorophyll a*	mg/kg as rcvd	27.8	29.5	30.5	30.6	26.1
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	6.9	6.6	6.9	8.4	8.4
Total Recoverable Cadmium	mg/kg dry wt	0.144	0.147	0.136	0.066	0.062
Total Recoverable Chromium	mg/kg dry wt	15.2	16.1	16.3	20	21
Total Recoverable Copper	mg/kg dry wt	24	24	27	22	20
Total Recoverable Lead	mg/kg dry wt	13.7	13.0	14.5	14.5	14.4
Total Recoverable Nickel	mg/kg dry wt	6.3	6.3	7.2	9.0	8.0
Total Recoverable Zinc	mg/kg dry wt	110	115	120	134	128

Sample Name:		Sed_LB2_3 19-Mar-2019 3:03 pm				
Lab Number:		2144935.9				
Individual Tests						
Total Recoverable Phosphorus	mg/kg dry wt	2,300	-	-	-	-
Total Nitrogen*	g/100g dry wt	0.22	-	-	-	-
Total Organic Carbon*	g/100g dry wt	2.2	-	-	-	-
Chlorophyll a*	mg/kg as rcvd	18.8	-	-	-	-

Sample Type: Sediment						
	Sample Name:	Sed_LB2_3 19-Mar-2019 3:03 pm				
	Lab Number:	2144935.9				
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	9.4	-	-	-	-
Total Recoverable Cadmium	mg/kg dry wt	0.070	-	-	-	-
Total Recoverable Chromium	mg/kg dry wt	24	-	-	-	-
Total Recoverable Copper	mg/kg dry wt	22	-	-	-	-
Total Recoverable Lead	mg/kg dry wt	15.4	-	-	-	-
Total Recoverable Nickel	mg/kg dry wt	9.1	-	-	-	-
Total Recoverable Zinc	mg/kg dry wt	139	-	-	-	-

Analyst's Comments

[#1] It has been noted that the result for Dissolved Reactive Phosphorus was greater than that for Total Phosphorus, but within the analytical variation of these methods.

Appendix No.1 - Chlorophyll A results

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Saline

Test	Method Description	Default Detection Limit	Sample No
Total Nitrogen Digestion	Caustic persulphate digestion. APHA 4500-N C 23rd ed. 2017.	-	1-3
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	1-3
Turbidity*	Saline sample. Analysis using a Hach 2100N, Turbidity meter. APHA 2130 B 23rd ed. 2017.	0.05 NTU	1-3
Total Suspended Solids*	Saline sample. Filtration of a 2L sample using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D (modified) 23rd ed. 2017.	0.5 g/m^3	1-3
Total Nitrogen	Alkaline persulphate digestion, automated Cd reduction/sulphanilamide colorimetry. APHA 4500-N C & 4500-$NO3^-$ I (modified) 23rd ed. 2017.	0.010 g/m^3	1-3
Total Ammoniacal-N	Saline sample. Phenol/hypochlorite colorimetry. Flow injection analyser. (NH4-N = NH4+-N + NH3-N). APHA 4500-NH_3 H 23rd ed. 2017.	0.005 g/m^3	1-3
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.0010 g/m^3	1-3
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	1-3
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.0010 g/m^3	1-3
Dissolved Reactive Phosphorus	Saline sample. Molybdenum blue colorimetry. Flow injection analyser. APHA 4500-P G 23rd ed. 2017.	0.0010 g/m^3	1-3
Total Phosphorus*	Total phosphorus digestion, ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P B & E (modified from manual analysis and also modified to include a reductant to reduce interference from any arsenic present in the sample) 23rd ed. 2017. NWASCO, Water & soil Miscellaneous Publication No. 38, 1982.	0.004 g/m^3	1-3
Chlorophyll a*	Acetone extraction. Fluorometer. APHA 10200 H (modified) 23rd ed. 2017.	0.0002 g/m^3	1-3

Sample Type: Sediment

Test	Method Description	Default Detection Limit	Sample No
Environmental Solids Sample Drying*	Air dried at 35°C Used for sample preparation. May contain a residual moisture content of 2-5%.	-	4-9
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	4-9
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level.	0.010 - 0.4 mg/kg dry wt	4-9
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	4-9

Sample Type: Sediment			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Recoverable Phosphorus	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt	4-9
Total Nitrogen*	Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	4-9
Total Organic Carbon*	Acid pretreatment to remove carbonates present followed by Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	4-9
Chlorophyll a*	Extraction with 95% Ethanol, Spectroscopy. Subcontracted to NIWA, Hamilton. In-house.	0.1 mg/kg as rcvd	4-9

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

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

This certificate of analysis must not be reproduced, except in full, without the written consent of the signatory.

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

NIWA
Taihoro Nukurangi

NIWA HAMILTON WATER QUALITY LABORATORY

CLIENT :	Hill Laboratories	LOT NUMBER :	2019000348	CHECKED :	DR
	28 Duke Street	SF NUMBER :	HM 8048	APPROVED :	MC
	Hamilton	JOB NUMBER :	HN19LAB/TEST	REPORT DATE :	2/05/2019

JOB : Purchase Order # 151561 Env SubNIWA 263

NIWA ID	***Client ID***	***Date Collected***	***Date Received***	***Chla µg/g***	***Phaeo µg/g***
HM1	2144935.4	20/03/2019	20/03/2019	27.8	20.6
HM2	2144935.5	20/03/2019	20/03/2019	29.5	20.4
HM3	2144935.6	20/03/2019	20/03/2019	30.5	22.3
HM4	2144935.7	20/03/2019	20/03/2019	30.6	39.8
HM5	2144935.8	20/03/2019	20/03/2019	26.1	37.9
HM6	2144935.9	20/03/2019	20/03/2019	18.8	20.8

A summary of methods used and detection limits is as follows.

Parameter	**Description**	**Detection Limit**	**Method**
Phaeophytin (Phaeo)	Extraction with 95% Ethanol, spectrometric measure.	0.1	In House
Chlorophyll a(Chla)	Extraction with 95% Ethanol, spectrometric measure.	0.1	In House

Samples are held at the laboratory for two months after reporting of results.
After this date they are discarded unless otherwise advised by the submitter.
These samples were analysed as received at the laboratory.

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Certificate of Analysis

Client:	4SIGHT Consulting Limited	**Lab No:**	2145849 SPv1
Contact:	Oliver Bone	**Date Received:**	21-Mar-2019
	C/- 4SIGHT Consulting Limited	**Date Reported:**	03-May-2019
	PO Box 402053	**Quote No:**	97960
	Tutukaka 0153	**Order No:**	AA2789
		Client Reference:	
		Submitted By:	Oliver Bone

Sample Type: Saline

Sample Name:		MM-LB-Mouth 20-Mar-2019 11:36 am	WQ-HA3 20-Mar-2019 11:40 am	WQ-HA2 20-Mar-2019 11:46 am	WQ-HA1 20-Mar-2019 11:55 am	WQ-AW1 20-Mar-2019 12:10 pm
Lab Number:		2145849.1	2145849.2	2145849.3	2145849.4	2145849.5
Individual Tests						
Turbidity*	NTU	4.9	3.4	3.9	4.4	4.5
Total Suspended Solids*	g/m³	8.5	5.9	5.9	7.5	7.6
Total Nitrogen	g/m³	1.90	0.92	0.86	0.38	0.64
Total Ammoniacal-N	g/m³	0.138	0.148	0.143	0.076	0.103
Nitrite-N	g/m³	0.0183	0.0115	0.0098	0.0048	0.0079
Nitrate-N	g/m³	1.37	0.49	0.44	0.103	0.23
Nitrate-N + Nitrite-N	g/m³	1.39	0.50	0.45	0.108	0.24
Dissolved Reactive Phosphorus	g/m³	0.33	0.128	0.124	0.051	0.069
Total Phosphorus*	g/m³	0.37	0.150	0.144	0.066	0.095
Chlorophyll a*	g/m³	0.0011	0.0010	0.0010	0.0011	0.0014

Sample Name:		WQ-AW2 20-Mar-2019 12:53 pm	WQ-AW3 20-Mar-2019 12:20 pm			
Lab Number:		2145849.6	2145849.7			
Individual Tests						
Turbidity*	NTU	13.1	5.5	-	-	-
Total Suspended Solids*	g/m³	16.5	6.8	-	-	-
Total Nitrogen	g/m³	0.63	0.56	-	-	-
Total Ammoniacal-N	g/m³	0.118	0.119	-	-	-
Nitrite-N	g/m³	0.0071	0.0066	-	-	-
Nitrate-N	g/m³	0.168	0.140	-	-	-
Nitrate-N + Nitrite-N	g/m³	0.175	0.146	-	-	-
Dissolved Reactive Phosphorus	g/m³	0.042	0.032	-	-	-
Total Phosphorus*	g/m³	0.083	0.067	-	-	-
Chlorophyll a*	g/m³	0.0026	0.0017	-	-	-

Sample Type: Sediment

Sample Name:		Sed-AW-1 20-Mar-2019 1:26 pm	Sed-AW-2 20-Mar-2019 1:36 pm	Sed-AW-3 20-Mar-2019 1:46 pm	Sed-HA1-1 20-Mar-2019 3:20 pm	Sed-HA1-2 20-Mar-2019 3:27 pm
Lab Number:		2145849.8	2145849.9	2145849.10	2145849.11	2145849.12
Individual Tests						
Total Recoverable Phosphorus	mg/kg dry wt	650	650	700	670	830
Total Nitrogen*	g/100g dry wt	0.12	0.13	0.16	0.17	0.25
Total Organic Carbon*	g/100g dry wt	1.38	1.59	1.77	4.9	7.6
Chlorophyll a*	mg/kg as rcvd	18.5	20.3	30.5	20.7	72.9

Sample Type: Sediment						
Sample Name:		Sed-AW-1 20-Mar-2019 1:26 pm	Sed-AW-2 20-Mar-2019 1:36 pm	Sed-AW-3 20-Mar-2019 1:46 pm	Sed-HA1-1 20-Mar-2019 3:20 pm	Sed-HA1-2 20-Mar-2019 3:27 pm
Lab Number:		2145849.8	2145849.9	2145849.10	2145849.11	2145849.12
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	12.8	12.7	13.2	13.9	12.5
Total Recoverable Cadmium	mg/kg dry wt	0.057	0.061	0.071	0.094	0.088
Total Recoverable Chromium	mg/kg dry wt	26	24	25	18.0	18.6
Total Recoverable Copper	mg/kg dry wt	13.0	14.6	16.9	25	29
Total Recoverable Lead	mg/kg dry wt	8.8	9.4	10.2	19.5	17.5
Total Recoverable Nickel	mg/kg dry wt	14.1	13.4	13.6	10.1	9.8
Total Recoverable Zinc	mg/kg dry wt	81	83	90	160	133

Sample Name:		Sed-HA1-3 20-Mar-2019 3:34 pm				
Lab Number:		2145849.13				
Individual Tests						
Total Recoverable Phosphorus	mg/kg dry wt	660	-	-	-	-
Total Nitrogen*	g/100g dry wt	0.22	-	-	-	-
Total Organic Carbon*	g/100g dry wt	10.2	-	-	-	-
Chlorophyll a*	mg/kg as rcvd	17.9	-	-	-	-
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	13.0	-	-	-	-
Total Recoverable Cadmium	mg/kg dry wt	0.091	-	-	-	-
Total Recoverable Chromium	mg/kg dry wt	18.2	-	-	-	-
Total Recoverable Copper	mg/kg dry wt	27	-	-	-	-
Total Recoverable Lead	mg/kg dry wt	17.0	-	-	-	-
Total Recoverable Nickel	mg/kg dry wt	9.3	-	-	-	-
Total Recoverable Zinc	mg/kg dry wt	140	-	-	-	-

Analyst's Comments

Appendix No.1 - Chlorophyll A results

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Saline			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Nitrogen Digestion	Caustic persulphate digestion. APHA 4500-N C 23rd ed. 2017.	-	1-7
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	1-7
Turbidity*	Saline sample. Analysis using a Hach 2100N, Turbidity meter. APHA 2130 B 23rd ed. 2017.	0.05 NTU	1-7
Total Suspended Solids*	Saline sample. Filtration of a 2L sample using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D (modified) 23rd ed. 2017.	0.5 g/m^3	1-7
Total Nitrogen	Alkaline persulphate digestion, automated Cd reduction/sulphanilamide colorimetry. APHA 4500-N C & 4500-$NO3^-$ I (modified) 23rd ed. 2017.	0.010 g/m^3	1-7
Total Ammoniacal-N	Saline sample. Phenol/hypochlorite colorimetry. Flow injection analyser. (NH4-N = NH4+-N + NH3-N). APHA 4500-NH_3 H 23rd ed. 2017.	0.005 g/m^3	1-7
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.0010 g/m^3	1-7
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	1-7
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.0010 g/m^3	1-7
Dissolved Reactive Phosphorus	Saline sample. Molybdenum blue colorimetry. Flow injection analyser. APHA 4500-P G 23rd ed. 2017.	0.0010 g/m^3	1-7

Sample Type: Saline

Test	Method Description	Default Detection Limit	Sample No
Total Phosphorus*	Total phosphorus digestion, ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P B & E (modified from manual analysis and also modified to include a reductant to reduce interference from any arsenic present in the sample) 23rd ed. 2017. NWASCO, Water & soil Miscellaneous Publication No. 38, 1982.	0.004 g/m^3	1-7
Chlorophyll a*	Acetone extraction. Fluorometer. APHA 10200 H (modified) 23rd ed. 2017.	0.0002 g/m^3	1-7

Sample Type: Sediment

Test	Method Description	Default Detection Limit	Sample No
Environmental Solids Sample Drying*	Air dried at 35°C Used for sample preparation. May contain a residual moisture content of 2-5%.	-	8-13
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	8-13
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level.	0.010 - 0.4 mg/kg dry wt	8-13
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	8-13
Total Recoverable Phosphorus	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt	8-13
Total Nitrogen*	Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	8-13
Total Organic Carbon*	Acid pretreatment to remove carbonates present followed by Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	8-13
Chlorophyll a*	Extraction with 95% Ethanol, Spectroscopy. Subcontracted to NIWA, Hamilton. In-house.	0.1 mg/kg as rcvd	8-13

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

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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

NIWA
Taihoro Nukurangi

NIWA HAMILTON WATER QUALITY LABORATORY

CLIENT :	Hill Laboratories	LOT NUMBER :	2019000357	CHECKED :	DR
	28 Duke Street	SF NUMBER :	HT 8055	APPROVED :	MC
	Hamilton	JOB NUMBER :	HN19LAB/TEST	REPORT DATE :	2/05/2019

JOB : Purchase Order # 151571 EnvSubNIWA 264

NIWA ID	***Client ID***	***Date Collected***	***Date Received***	***Chla µg/g***	***Phaeo µg/g***
HT1	2145849.8	20/03/2019	21/03/2019	18.5	15.7
HT2	2145849.9	20/03/2019	21/03/2019	20.3	15.7
HT3	2145849.10	20/03/2019	21/03/2019	30.5	20.8
HT4	2145849.11	20/03/2019	21/03/2019	20.7	23.8
HT5	2145849.12	20/03/2019	21/03/2019	72.9	54.8
HT6	2145849.13	20/03/2019	21/03/2019	17.9	15.9

A summary of methods used and detection limits is as follows.

Parameter	**Description**	**Detection Limit**	**Method**
Phaeophytin (Phaeo)	Extraction with 95% Ethanol, spectrometric measure.	0.1	In House
Chlorophyll a(Chla)	Extraction with 95% Ethanol, spectrometric measure.	0.1	In House

Samples are held at the laboratory for two months after reporting of results.
After this date they are discarded unless otherwise advised by the submitter.
These samples were analysed as received at the laboratory.

Hill Laboratories
TRIED, TESTED AND TRUSTED

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Certificate of Analysis

SPv1

Client:	4Sight Consulting Limited	**Lab No:**	2325896
Contact:	Pete Wilson	**Date Received:**	20-Feb-2020
	C/- 4Sight Consulting Limited	**Date Reported:**	01-May-2020
	PO Box 1420	**Quote No:**	97960
	Waikato Mail Centre	**Order No:**	AA2789
	Hamilton 3240	**Client Reference:**	
		Submitted By:	Pete Wilson

Sample Type: Saline

Sample Name:		AW1 19-Feb-2020 3:39 pm	AW2 19-Feb-2020 3:30 pm	AW3 19-Feb-2020 3:24 pm	HA1 19-Feb-2020 3:03 pm	HA2 19-Feb-2020 3:52 pm
Lab Number:		2325896.13	2325896.14	2325896.15	2325896.16	2325896.17
Individual Tests						
Turbidity*	NTU	2.6	5.5	6.6	2.6	1.34
Total Suspended Solids*	g/m³	7.2	19.1	18.4	6.2	5.0
Total Nitrogen	g/m³	0.46	0.59	0.67	0.41	0.47
Total Ammoniacal-N	g/m³	0.060	0.081	0.104	0.052	0.069
Nitrite-N	g/m³	0.0044	0.0060	0.0070	0.0039	0.0047
Nitrate-N	g/m³	0.088	0.155	0.187	0.076	0.103
Nitrate-N + Nitrite-N	g/m³	0.092	0.161	0.194	0.080	0.108
Dissolved Reactive Phosphorus	g/m³	0.053	0.072	0.081	0.047	0.056
Total Phosphorus*	g/m³	0.064	0.088	0.101	0.060	0.068
Chlorophyll a*	g/m³	0.0010	0.0012	0.0014	0.0012	0.0016

Sample Name:		HA3 19-Feb-2020 3:59 pm	LB1 19-Feb-2020 4:23 pm	LB2 19-Feb-2020 4:17 pm	LB3 19-Feb-2020 4:10 pm	LB4 19-Feb-2020 12:05 pm
Lab Number:		2325896.18	2325896.19	2325896.20	2325896.21	2325896.22
Individual Tests						
Turbidity*	NTU	2.3	2.6	4.4	3.9	5.9
Total Suspended Solids*	g/m³	4.5	4.9	7.3	7.2	13.0
Total Nitrogen	g/m³	0.76	0.62	0.79	2.3	11.5 #2
Total Ammoniacal-N	g/m³	0.101	0.075	0.104	0.130	0.21
Nitrite-N	g/m³	0.0083	0.0068	0.0089	0.0195	0.095
Nitrate-N	g/m³	0.30	0.193	0.32	1.51	11.5
Nitrate-N + Nitrite-N	g/m³	0.30	0.199	0.33	1.53	11.6 #2
Dissolved Reactive Phosphorus	g/m³	0.104	0.079	0.115	0.35 #1	2.2
Total Phosphorus*	g/m³	0.114	0.094	0.127	0.34 #1	2.2
Chlorophyll a*	g/m³	0.0013	0.0008	0.0015	0.0037	0.0020

Sample Type: Sediment

Sample Name:		AW_down 19-Feb-2020 9:55 am	AW_mid 19-Feb-2020 9:45 am	AW_up 19-Feb-2020 9:40 am	HA1_down 19-Feb-2020 10:45 am	HA1_mid 19-Feb-2020 10:50 am
Lab Number:		2325896.1	2325896.2	2325896.3	2325896.4	2325896.5
Individual Tests						
Total Recoverable Phosphorus	mg/kg dry wt	710	920	830	820	640
Total Nitrogen*	g/100g dry wt	0.18	0.23	0.22	0.22	0.16
Total Organic Carbon*	g/100g dry wt	1.89	2.4	2.4	7.8	4.9
Chlorophyll a*‡	mg/kg as rcvd	28.7	33.5	30.9	27.8	19.7

Sample Type: Sediment						
Sample Name:		AW_down 19-Feb-2020 9:55 am	AW_mid 19-Feb-2020 9:45 am	AW_up 19-Feb-2020 9:40 am	HA1_down 19-Feb-2020 10:45 am	HA1_mid 19-Feb-2020 10:50 am
Lab Number:		2325896.1	2325896.2	2325896.3	2325896.4	2325896.5
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	13.9	14.0	13.4	14.8	14.2
Total Recoverable Cadmium	mg/kg dry wt	0.078	0.050	0.058	0.092	0.092
Total Recoverable Chromium	mg/kg dry wt	24	25	24	15.8	16.6
Total Recoverable Copper	mg/kg dry wt	24	27	28	27	31
Total Recoverable Lead	mg/kg dry wt	11.9	13.8	13.5	16.4	17.7
Total Recoverable Nickel	mg/kg dry wt	14.2	13.7	14.2	9.5	10.3
Total Recoverable Zinc	mg/kg dry wt	105	108	110	142	159
7 Grain Sizes Profile as received*						
Dry Matter of Sieved Sample*	g/100g as rcvd	47	48	46	54	57
Fraction >/= 2 mm*	g/100g dry wt	< 0.1	< 0.1	0.1	15.3	10.6
Fraction < 2 mm, >/= 1 mm*	g/100g dry wt	0.2	0.2	0.2	6.0	4.0
Fraction < 1 mm, >/= 500 µm*	g/100g dry wt	0.5	0.5	0.5	3.4	2.0
Fraction < 500 µm, >/= 250 µm*	g/100g dry wt	1.9	1.9	1.6	2.3	2.0
Fraction < 250 µm, >/= 125 µm*	g/100g dry wt	13.9	8.3	8.6	14.4	14.2
Fraction < 125 µm, >/= 63 µm*	g/100g dry wt	29.9	21.5	21.5	28.7	34.0
Fraction < 63 µm*	g/100g dry wt	53.6	67.6	67.4	29.9	33.1

Sample Name:		HA1_up 19-Feb-2020 10:56 am	LB1_down 19-Feb-2020 8:40 am	LB1_mid 19-Feb-2020 9:00 am	LB1_up 19-Feb-2020 8:50 am	LB2_down 19-Feb-2020 10:10 am
Lab Number:		2325896.6	2325896.7	2325896.8	2325896.9	2325896.10
Individual Tests						
Total Recoverable Phosphorus	mg/kg dry wt	640	1,040	1,320	1,410	1,900
Total Nitrogen*	g/100g dry wt	0.19	0.19	0.25	0.28	0.22
Total Organic Carbon*	g/100g dry wt	8.5	1.94	2.8	3.2	2.4
Chlorophyll a*‡	mg/kg as rcvd	27.8	53.6	46.3	51.9	23.0
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	18.0	8.9	9.5	10.0	8.9
Total Recoverable Cadmium	mg/kg dry wt	0.099	0.123	0.145	0.142	0.071
Total Recoverable Chromium	mg/kg dry wt	15.5	15.1	22	19.8	22
Total Recoverable Copper	mg/kg dry wt	30	32	43	45	34
Total Recoverable Lead	mg/kg dry wt	17.6	14.4	17.6	18.0	16.5
Total Recoverable Nickel	mg/kg dry wt	9.7	7.7	11.7	10.5	11.5
Total Recoverable Zinc	mg/kg dry wt	156	132	158	162	174
7 Grain Sizes Profile as received*						
Dry Matter of Sieved Sample*	g/100g as rcvd	57	43	42	42	43
Fraction >/= 2 mm*	g/100g dry wt	11.5	0.2	0.2	< 0.1	14.5
Fraction < 2 mm, >/= 1 mm*	g/100g dry wt	5.3	0.2	0.2	0.2	3.8
Fraction < 1 mm, >/= 500 µm*	g/100g dry wt	2.6	0.7	0.6	0.5	3.0
Fraction < 500 µm, >/= 250 µm*	g/100g dry wt	2.6	6.3	3.2	3.4	3.0
Fraction < 250 µm, >/= 125 µm*	g/100g dry wt	14.4	20.9	15.9	14.8	5.6
Fraction < 125 µm, >/= 63 µm*	g/100g dry wt	31.1	17.1	21.0	19.9	11.0
Fraction < 63 µm*	g/100g dry wt	32.4	54.6	58.8	61.1	59.1

Sample Name:		LB2_mid 19-Feb-2020 10:15 am	LB2_up 19-Feb-2020 10:20 am			
Lab Number:		2325896.11	2325896.12			
Individual Tests						
Total Recoverable Phosphorus	mg/kg dry wt	2,400	2,300	-	-	-
Total Nitrogen*	g/100g dry wt	0.24	0.23	-	-	-
Total Organic Carbon*	g/100g dry wt	2.4	2.5	-	-	-
Chlorophyll a*‡	mg/kg as rcvd	21.5	15.5	-	-	-
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	10.0	9.1	-	-	-
Total Recoverable Cadmium	mg/kg dry wt	0.077	0.086	-	-	-

Sample Type: Sediment						
Sample Name:		LB2_mid 19-Feb-2020 10:15 am	LB2_up 19-Feb-2020 10:20 am			
Lab Number:		2325896.11	2325896.12			
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Chromium	mg/kg dry wt	23	23	-	-	-
Total Recoverable Copper	mg/kg dry wt	37	38	-	-	-
Total Recoverable Lead	mg/kg dry wt	17.2	18.5	-	-	-
Total Recoverable Nickel	mg/kg dry wt	11.1	11.6	-	-	-
Total Recoverable Zinc	mg/kg dry wt	184	199	-	-	-
7 Grain Sizes Profile as received*						
Dry Matter of Sieved Sample*	g/100g as rcvd	52	48	-	-	-
Fraction >/= 2 mm*	g/100g dry wt	43.9	22.1	-	-	-
Fraction < 2 mm, >/= 1 mm*	g/100g dry wt	4.7	4.4	-	-	-
Fraction < 1 mm, >/= 500 µm*	g/100g dry wt	3.2	4.3	-	-	-
Fraction < 500 µm, >/= 250 µm*	g/100g dry wt	3.8	5.6	-	-	-
Fraction < 250 µm, >/= 125 µm*	g/100g dry wt	4.1	6.2	-	-	-
Fraction < 125 µm, >/= 63 µm*	g/100g dry wt	4.1	6.8	-	-	-
Fraction < 63 µm*	g/100g dry wt	36.1	50.6	-	-	-

Analyst's Comments

‡ Analysis subcontracted to an external provider. Refer to the Summary of Methods section for more details.

#1 It has been noted that the result for Dissolved Reactive Phosphorus was greater than that for Total Phosphorus, but within the analytical variation of these methods.

#2 It has been noted that the result for Nitrate-N + Nitrite-N was greater than that for Total Nitrogen, but within the analytical variation of these methods.

Summary of Methods

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

Sample Type: Saline

Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Total Nitrogen Digestion	Caustic persulphate digestion. APHA 4500-N C 23rd ed. 2017.	-	13-22
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	13-22
Turbidity*	Saline sample. Analysis using a Hach 2100N, Turbidity meter. APHA 2130 B 23rd ed. 2017 (modified).	0.05 NTU	13-22
Total Suspended Solids*	Saline sample. Filtration of a 2L sample using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D (modified) 23rd ed. 2017.	0.5 g/m^3	13-22
Total Nitrogen	Alkaline persulphate digestion, automated Cd reduction/sulphanilamide colorimetry. APHA 4500-N C & 4500-$NO3^-$ I (modified) 23rd ed. 2017.	0.010 g/m^3	13-22
Total Ammoniacal-N	Saline sample. Phenol/hypochlorite colorimetry. Flow injection analyser. (NH4-N = NH4+-N + NH3-N). APHA 4500-NH_3 H 23rd ed. 2017.	0.005 g/m^3	13-22
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.0010 g/m^3	13-22
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	13-22
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.0010 g/m^3	13-22
Dissolved Reactive Phosphorus	Saline sample. Molybdenum blue colorimetry. Flow injection analyser. APHA 4500-P G 23rd ed. 2017.	0.0010 g/m^3	13-22
Total Phosphorus*	Total phosphorus digestion, ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P B & E (modified from manual analysis and also modified to include a reductant to reduce interference from any arsenic present in the sample) 23rd ed. 2017. NWASCO, Water & soil Miscellaneous Publication No. 38, 1982.	0.004 g/m^3	13-22
Chlorophyll a*	Acetone extraction. Fluorometer. APHA 10200 H (modified) 23rd ed. 2017.	0.0002 g/m^3	13-22

Sample Type: Sediment

Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Environmental Solids Sample Drying*	Air dried at 35°C Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-12
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-12
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1-12
Total Recoverable Phosphorus	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt	1-12
Total Nitrogen*	Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	1-12
Total Organic Carbon*	Acid pretreatment to remove carbonates present followed by Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	1-12
Chlorophyll a*	Extraction with 95% Ethanol, Spectroscopy. Subcontracted to NIWA, Hamilton. In-house.	0.1 mg/kg as rcvd	1-12
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level.	0.010 - 0.4 mg/kg dry wt	1-12
7 Grain Sizes Profile as received			
Dry Matter for Grainsize samples (sieved as received)*	Drying for 16 hours at 103°C, gravimetry (Free water removed before analysis).	0.10 g/100g as rcvd	1-12
Fraction >/= 2 mm*	Wet sieving with dispersant, as received, 2.00 mm sieve, gravimetry.	0.1 g/100g dry wt	1-12
Fraction < 2 mm, >/= 1 mm*	Wet sieving using dispersant, as received, 2.00 mm and 1.00 mm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-12
Fraction < 1 mm, >/= 500 µm*	Wet sieving using dispersant, as received, 1.00 mm and 500 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-12
Fraction < 500 µm, >/= 250 µm*	Wet sieving using dispersant, as received, 500 µm and 250 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-12
Fraction < 250 µm, >/= 125 µm*	Wet sieving using dispersant, as received, 250 µm and 125 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-12
Fraction < 125 µm, >/= 63 µm*	Wet sieving using dispersant, as received, 125 µm and 63 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-12
Fraction < 63 µm*	Wet sieving with dispersant, as received, 63 µm sieve, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-12

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

Dates of testing are available on request. Please contact the laboratory for more information.

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

Ara Heron BSc (Tech)
Client Services Manager - Environmental

www.4sight.consulting

Appendix D

4Sight, Marine Ecological Assessment, 2021

4SIGHT CONSULTING

LAND. PEOPLE. WATER.

Whangarei District Council

WHANGAREI WASTEWATER TREATMENT PLANT: MARINE ECOLOGICAL ASSESSMENT

For Whangarei District Council

July 2021

REPORT INFORMATION AND QUALITY CONTROL

Prepared for:	Hai Nguyen Waste & Drainage Department Whangārei District Council

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1 INTRODUCTION

1.1 Background

Whangārei District Council (‘WDC’ or ‘Council’) hold consents to discharge treated wastewater from the Whangārei Wastewater Treatment Plant (‘WWTP’) into Limeburners Creek (Figure 1). These consents will expire in April 2022, and it is anticipated that WDC will lodge applications for new consents during late 2021.

The Whangārei WWTP is located on Kioreroa Road and has the capacity to treat a wet weather flow of up to 125,000 m^3 per day. The existing consent allows for a discharge of up to 140,000 m^3 of treated wastewater per day, however, the estimated annual daily flow is much less than this at 15,000 m^3 per day.

Wastewater is treated by advanced secondary and tertiary treatment before being discharged into two treatment wetlands (Figure 1). Water from each of the wetlands is discharged via weirs into several deep, muddy channels that run through the dense mangrove forest into Limeburners Creek and then, after mixing, discharge into the Hātea River. The Proposed Northland Regional Plan (PNRP) designates Limeburners Creek as a ‘mixing zone for major discharges’, which is a continuation of the status the Limeburners Creek has held since the inception of the WWTP.

During wet weather, wastewater may be diverted to a bypass system and receive varying levels of treatment, depending on the flowrate, and UV disinfection before being discharged to the wetlands.

It is understood that treatment upgrades are proposed for the WWTP and that the quality of the discharge should be the same, but likely better, than the current discharge.

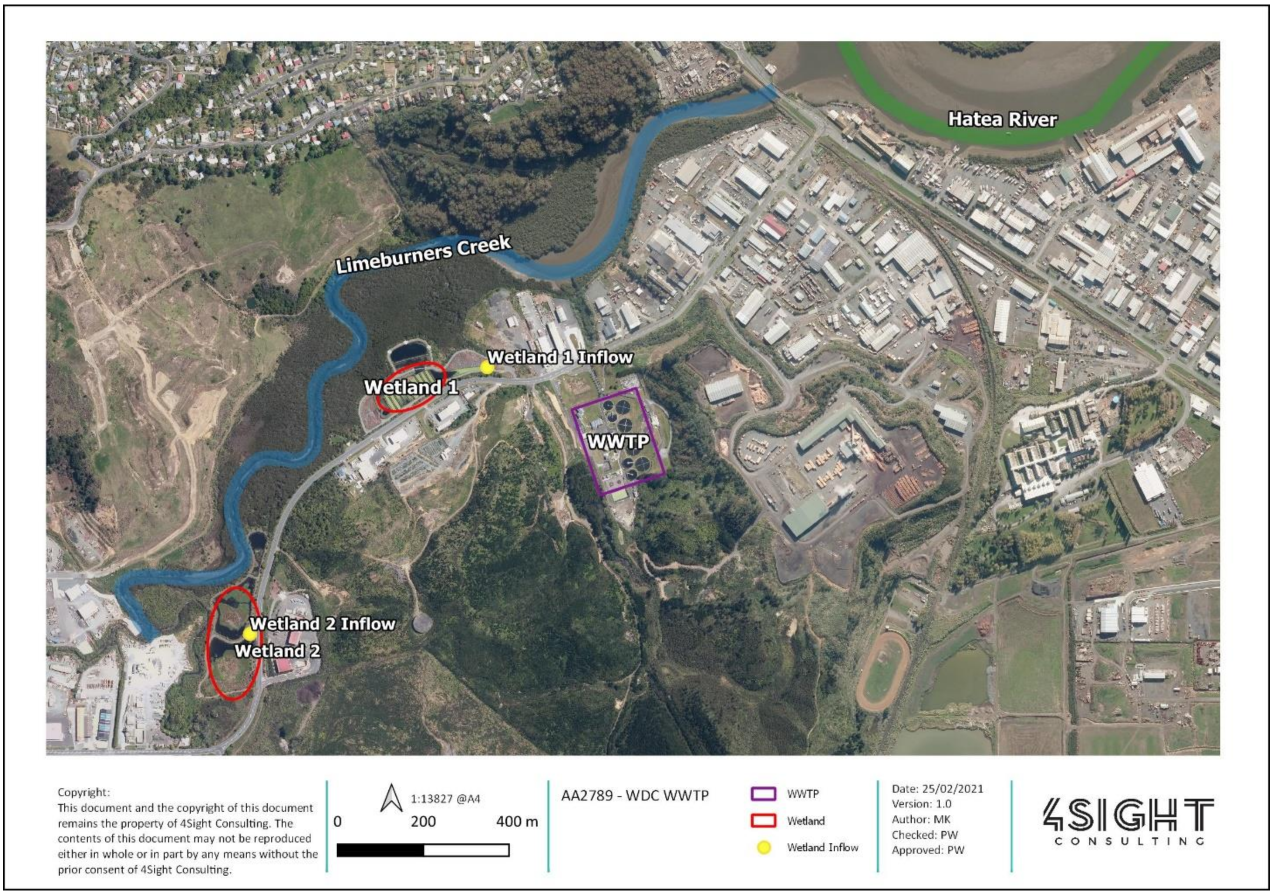

Figure 1: Key locations associated with the Whangārei WWTP.

1.2 Purpose of this report

4Sight Consulting Ltd (4Sight) was engaged by WDC to undertake an assessment of ecological effects to support the resource consent application. A conservative approach has been taken with this assessment where it has been assumed that the quality of the discharge remains the same as it is now. The scope of this assessment includes effects of the WWTP discharge in Limeburners Creek and the nearby receiving environment on:

- Coastal and marine habitats,
- Intertidal sediment quality,
- Benthic macroinvertebrates,
- Shellfish,
- Fish, and
- Birds.

Assessing the potential effects of the WWTP discharge on water quality is out of scope for this report as it is being reported by GHD.

2 METHODOLOGY

The following approach has been taken to carry out the assessment of ecological effects:

- Desktop review of available ecological data and reports;
- Two baseline surveys (2019 and 2020), including assessments of intertidal sediment, benthic macroinvertebrates, and vegetation; and
- An assessment of the effects of the WWTP discharge on the marine environment in Limeburners Creek and the nearby receiving environment.

2.1 Desktop review

Relevant publications, plans, and data relating to marine ecology in Limeburners Creek and the nearby receiving environment were reviewed. The review included the following sources:

- 4Sight monitoring plans and reports prepared for the Whangārei WWTP;
- Northland Regional Council monitoring reports;
- Proposed Northland Regional Plan (Appeals Version, June 2020);
- New Zealand eBird database (ebird.org/content/newzealand);
- New Zealand freshwater fish database (nzffdms.niwa.co.nz); and
- Other relevant published documents as referenced throughout the report.

2.2 Baseline surveys

4Sight was commissioned by WDC to conduct two baseline surveys to characterise Limeburners Creek, the nearby receiving environment, and a background (reference) site. Samples were collected from four locations and analysed for sediment quality and benthic macroinvertebrates (Figure 2). The purpose of these surveys was to characterise Limeburners Creek and the nearby receiving environment to assess the potential effects of the discharge on sediment quality, water quality, and benthic ecology. Surveys were conducted over two summers (March 2019 and February 2020) to provide sampling replication to understand the natural variability and heterogeneity of the environment and its ecology. The findings of these surveys are reported in 4Sight (2020) and are used in this report to inform the assessment of effects.

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WHANGAREI WWTP - ECOLOGICAL ASSESSMENT

SEDIMENT SAMPLING LOCATIONS

Prepared for Whangarei District Council by 4Sight Consulting

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Checked: MP
Approved: PW

Figure 2: Sediment sampling locations.

4Sight also conducted monthly water quality sampling from January 2020 to February 2021 to assess the quality of the WWTP discharge as it flowed through the treatment wetlands, into Limeburners Creek, and finally, into the Hātea River. The results are reported in 4Sight (2021); however, as noted earlier, the assessment in this report excludes the effects on water quality as they are being addressed by GHD.

The methods used during the baseline surveys to assess coastal vegetation, intertidal sediment quality, and benthic macroinvertebrates are described in detail in 4Sight (2020) and summarised in the following paragraphs.

Broad-scale habitat mapping in Limeburners Creek was conducted using aerial photographs in GIS software. Habitat types were ground-truthed during fieldwork in March 2019.

Fine-scale habitat mapping was conducted by collecting sediment samples from two locations in Limeburners Creek (upper and lower), a nearby location in the Hātea River, and from Awaroa Creek to serve as a reference site. From each location, 10 samples were collected with a cylindrical core (15 cm diameter by 15 cm length; volume 2.65 L) and the benthic macroinvertebrates were separated from the sediment and debris and identified by a taxonomist. Additionally, three composite samples (comprising 10 sub-samples each), were collected from each location to be analysed for sediment nutrients, metals, chlorophyll-a, total organic content, and grain size.

No specific surveys for shellfish, fish, or birds were conducted by 4Sight for this assessment. Instead, assessments of these components relied on information from the desktop review and from previous work in the area.

2.2.1 Sediment quality guidelines

Results for sediment metal concentrations were put into context by comparing them to the NRC Coastal Sediment Quality Guidelines for the Hātea River in the Proposed Northland Regional Plan (Table 1).

Table 1: Coastal sediment quality guidelines used to assess sediment quality results. From the Proposed Northland Regional Plan.

Attribute	Unit	Compliance Metric	Hātea River
Copper	mg/kg	Maximum	65
Lead	mg/kg	Maximum	50
Zinc	mg/kg	Maximum	200
Chromium	mg/kg	Maximum	80
Nickel	mg/kg	Maximum	21
Cadmium	mg/kg	Maximum	1.5

Sediment measurements for ecosystem health (e.g., organic content, and nutrients) do not have NRC coastal sediment quality standards. Where applicable, results are compared to the Estuarine Trophic Index (ETI) Tool 2 bands by Zeldis et al. (2017). The ETI Tool 2 does not include bands for total phosphorus, so the bands developed by Robertson and Stevens (2013) were used.

Table 2: Sediment quality guidelines for ecosystem health. From Zeldis et al. (2017) and Robertson and Stevens (2013).

Band	A	B	C	D
Narrative	No stress caused by the indicator on any aquatic organisms.	A minor stress on sensitive organisms caused by the indicator.	Moderate stress on a number of aquatic organisms caused by the indicator exceeding preference levels for some species and a risk of sensitive macroinvertebrate species being lost.	Significant, persistent stress on a range of aquatic organisms caused by the indicator exceeding tolerance levels. A likelihood of local extinctions of keystone species and loss of ecological integrity.
Total organic carbon (%; top 2 cm)	<0.5	0.5–1	>1–2	>2
Total nitrogen (mg/kg)	<250	250–1000	1000–2000	>2000
Total phosphorus (mg/kg)	<200	200–500	500–1000	>1000
Redox potential (mV; at 1 cm)	>100	100 to -50	-50 to -150	< -150

3 EXISTING ENVIRONMENT

This section briefly describes the state of the marine environment in Limeburners Creek and the nearby receiving environment of the WWTP discharge.

3.1 Coastal vegetation and habitats

Limeburners Creek is an upper tidal arm of the Whangārei Harbour. The estuary is mangrove dominated and bordered by rural and industrial land. Two small patches of native forest border the true left bank near the estuary mouth. The total area of the Limeburners Creek estuary, including intertidal and subtidal components, is approximately 32.49 ha.

The intertidal mangrove stands in Limeburners Creek comprise the majority of the overall estuary area (23.84 ha, 73.6%). There were only small patches of benthic algae observed during each survey. A map of the key habitats in Limeburners Creek is presented in Appendix A.

3.2 Intertidal sediment

Intertidal sediment was collected from four locations. Overall, the sediment at each site was typically fine-grained, had metal concentrations below the NRC sediment quality guidelines, and showed signs of nutrient enrichment. These aspects are described in more detail in the following sections.

3.2.1 Sediment grain size

In general, the sediments at each site were fine-grained. The dominant size fractions were typically mud, fine sand, and very fine sand (Figure 3). The sediment at the upper site in Limeburners Creek comprised about 25% gravel. Sediments from the Hātea River site had the lowest proportion of mud at about 25%; this likely reflects the higher energy and greater water flow in this location than at the others.

Laboratory results are presented in Appendix B.

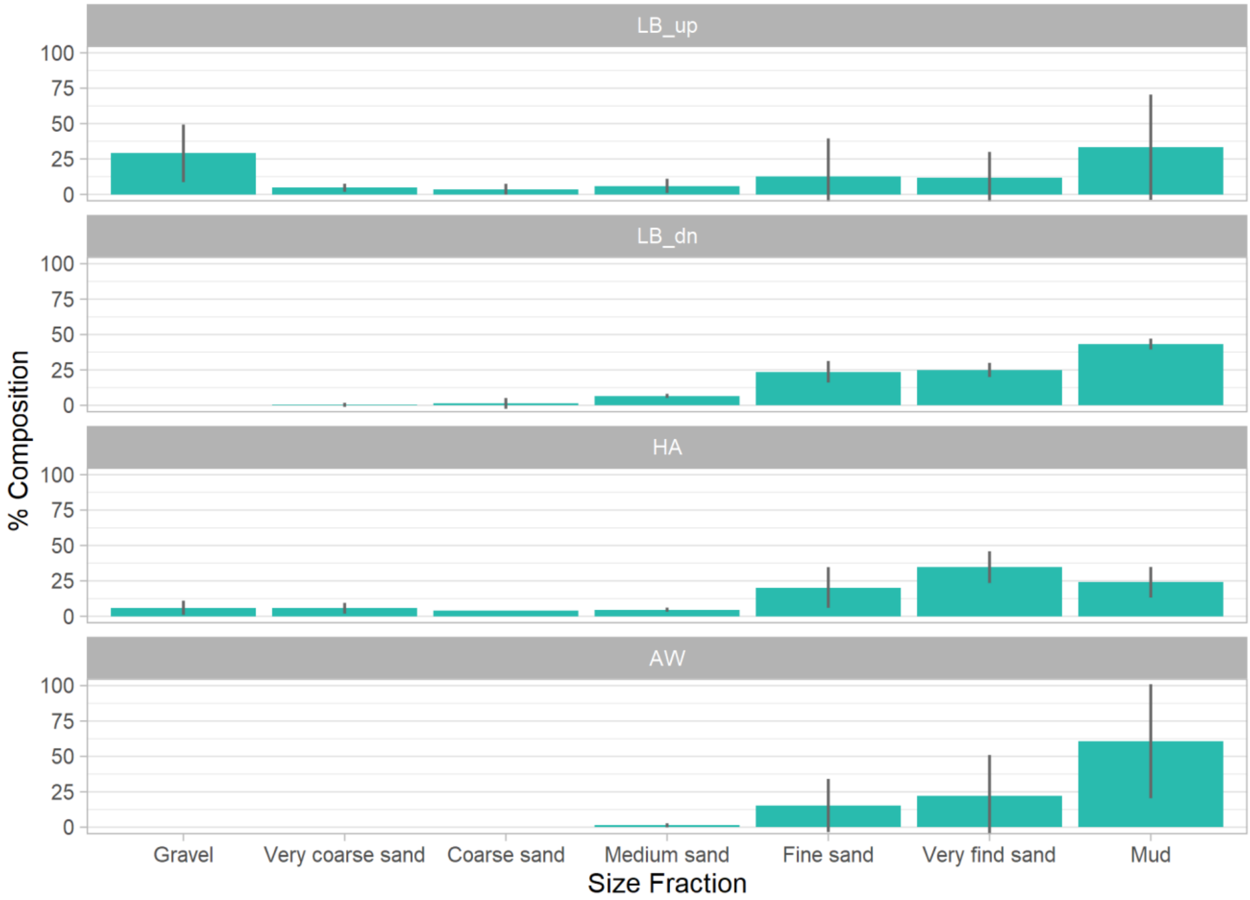

Figure 3: Mean sediment grain size at each site. Error bars show the 95% confidence interval of the mean (n = 3).

3.2.2 Metals

Heavy metals are naturally present in the environment but can cause adverse effects to benthic organisms at elevated concentrations. All sediment metal concentrations at all sites were below (met) the NRC coastal sediment quality standard (Figure 4). This indicates a low risk of toxicity to benthic organisms. This also suggests that there is no significant accumulation of metals in the sediments from the WWTP discharge. Laboratory results are presented in Appendix B.

Figure 4: Mean sediment metal concentrations at each site collected from combined 2019 and 2020 field campaigns. Error bars show the 95% confidence interval of the mean (n = 6). Letters above each bar denote the statistical significance of the difference; different letters indicate statistically significant differences. The dashed, horizontal line denotes the NRC sediment quality guideline from the Proposed Northland Regional Plan.

3.2.3 Ecosystem health

Overall, all sites had relatively high total organic carbon and nutrient concentrations, which is indicative of an environment that provides moderate to high stress on benthic organisms (Figure 5). Such nutrient enrichment is similarly reflected by relatively high chlorophyll-a concentrations at all sites. This is likely characteristic of the upper

Hātea River environment and a consequence of land-use change and urbanisation over time in general, with some additional enrichment in Limeburners Creek due to the WWTP discharge.

The most notable difference in Limeburners Creek to the other locations was the elevated levels of total phosphorus in the sediment. This is likely a combination of dissolved phosphorus from the WWTP discharge binding to sediments and from phosphorus-bound sediment from the discharge being deposited in Limeburners Creek. The most elevated sediment phosphorus concentration at LB_up could also suggest a potential upstream source of phosphorus.

Sediment nitrogen concentrations were no more elevated in Limeburners Creek than they were at the other sites despite having elevated water-column nitrogen levels.

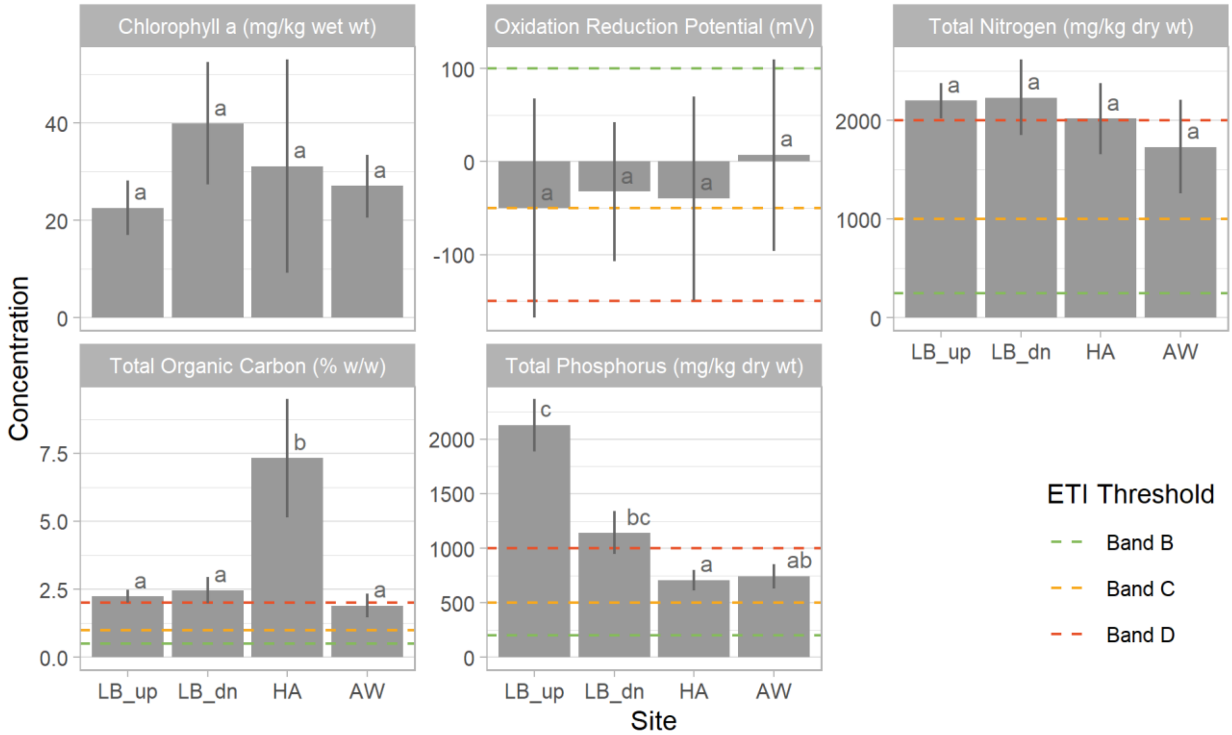

Figure 5: Mean sediment nutrient, organic carbon, and chlorophyll-a concentrations at each site from combined 2019 and 2020 field campaigns. Error bars show the 95% confidence interval of the mean (n = 6). Letters above each bar denote the statistical significance of the difference; different letters indicate statistically significant differences.

3.3 Benthic macroinvertebrates

In general, all sites had appropriate species diversity for estuarine intertidal areas but were dominated by only a few of those species. This is indicated by the high average abundance per core but relatively low average richness in Table 3. This suggests some response to sedimentation and/or organic enrichment and may reflect the relatively high sediment content and total organic carbon that was measured at all sites but most notably at the site on the Hātea River. For comparison, the Shannon-Weiner diversity scores from NRC state of the environment monitoring at the mouth of Limeburners Creek and near the same Hātea River site as in this study were 2.57 and 1.93, respectively.

Table 3: Average species abundance, species richness and Shannon Weiner diversity for each site sampled in 2020. (core volume = 2.65 L).

	2020			
	Lime_up	Lime_down	Hātea	Awaroa
Average Abundance per core	72.4	164.3	74.3	122
Average Richness per core	7.6	10.6	10.9	10.5
Shannon Weiner Diversity Index	1.31	1.43	1.8	1.48

The benthic community composition data indicate that sedimentation and organic enrichment are key stressors in the upper Hātea environment, but the data does not indicate that these stressors are due to the WWTP discharge in Limeburners Creek. Rather, this is likely a result of wider scale catchment influences and a consequence of land-use change and urbanisation over time.

The benthic macroinvertebrate communities found at the downstream site in Limeburners Creek were very similar to those found at the Awaroa Creek site, which was used as a reference or comparison site. This is indicated by the closeness of the points from these locations in the ordination plot shown in Figure 6. The plot separates points by how different the benthic communities are in each sample. Both sites were characterised by a comparatively high abundance of infaunal deposit-feeding oligochaete worms. This suggests that the WWTP discharge is not having a significant effect on the benthic macroinvertebrate communities and that the communities present are characteristic of the general upper Hātea environment.

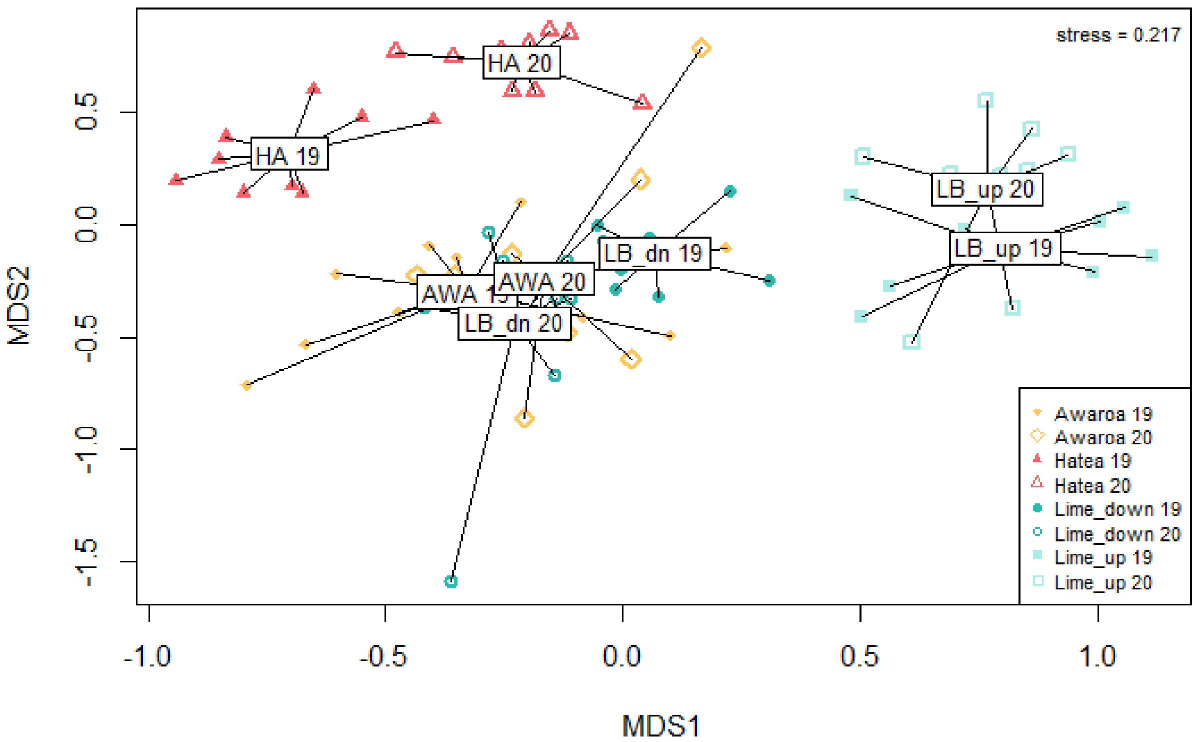

Figure 6: 2-dimensional ordination plot of the benthic communities sampled at each site in 2019 and 2020.

A relatively high abundance of Copepods was identified at the downstream Limeburners Creek Site. These organisms are known to be susceptible to metal contaminants and their presence suggests that the current metal concentrations are not having a significant effect on the ecology. This is supported by the relatively low sediment metal concentrations (meeting the sediment quality standards) that were measured at all sites.

There were notable differences between the upstream and downstream Limeburners Creek sites. The upstream Limeburners site was the only site to have the estuarine snail, *Potamopyrgus estuarinus*. This species is tolerant of environmental extremes including changes in salinity, allowing it to survive in brackish mixing zones. The upstream site also had a cobbled habitat and had the lowest measured salinity at times. The benthic communities at this location reflect the differing habitat: specifically, differing sediment type and strong freshwater influence. Consequently, differences between the benthic communities at the two Limeburners sites are expected.

Detailed results are presented in Appendix C.

3.4 Shellfish

Shellfish were not specifically monitored in the area by 4Sight for this assessment. Shellfish populations were assessed, however, by NRC in their state of the environment monitoring (Griffiths, 2012). The monitoring showed small populations of indigenous species, including cockles (*Austrovenus stutchburyi*) and wedge shells (*Macomona liliana*) in the upper Hātea River and the mouth of Limeburners Creek. Most individuals were found in the Whangārei Harbour, rather than in the Hātea River. This is likely due to their preference for sandier sediments. Oysters are known to be present in the soft muds near mangroves, including in Limeburners Creek. Three non-indigenous species were also identified primarily in subtidal areas of the Hātea River; the three species were the bivalve *Theora lubrica*, Asian date mussel (*Musculista senhousia*), and Australian dog whelk (*Nassarius* (*Plicarcularia*) *burchardi*).

3.5 Fish

Fish were not specifically surveyed for this assessment by 4Sight. Fish are likely to use the local estuary for feeding, shelter, spawning and as a migratory route. Fish species likely to use the area at one time or another include yelloweye mullet, grey mullet, flounders, piper, anchovy like fishes, kahawai, koheru, kingfish, snapper, trevally, parore, rays and small wrasses. These are common coastal and harbour species.

4Sight has sighted an eel (*Anguilla sp*.) and a bridled goby (*Arenigobius bifrenatus*) during previous works in the Hātea River, near the entrance to Limeburners Creek in 2016.

A search of the New Zealand freshwater fish database returned ten records for sites in the upper catchment, from headwater tributaries (Limeburners Creek and Te Waiiti Stream) that drain into the main Limeburners Creek and associated Hātea River. The fish records were collected in 2018, with shortfin eel (*Anguilla australis,* four records), banded kokopu (G*alaxias fasciatus,* four records) and longfin eel (*Anguilla dieffenbachia*, two records) recorded from these upper tributaries. These species are likely to pass through Limeburners Creek at different periods throughout the year.

Based on experience in these types of environments, other freshwater fish in the area at one time or another could potentially include common smelt (*Retropinna retropinna*), inanga (*Galaxias maculatus*) and possibly other whitebait species of this genus (koaro (G*alaxias brevipinnis*), giant kokopu (G*alaxias argenteus*), and shortjaw kōkopu (G*alaxias postvectis*)).

Freshwater fish species potentially within the area at different times of the year and their conservation status are described in Table 4.

Table 4: Freshwater fish species potentially within the area and their conservation status.

Scientific Name	**Common Name**	**Threat Status (Dunn et al., 2017)**
Galaxias postvectis	Shortjaw kokopu	Nationally Vulnerable
Galaxias argenteus	Giant kokopu	At Risk-Declining
Galaxias brevipinnis	Koaro	At Risk-Declining
Anguilla dieffenbachii	Longfin eel	At Risk-Declining
Galaxias maculatus	Inanga	At Risk-Declining
Anguilla australis	Shortfin eel	Not Threatened

Galaxias fasciatus	Banded kokopu	Not Threatened
Retropinna retropinna	Common smelt	Not Threatened
Arenigobius bifrenatus	Bridled goby	Introduced and Naturalised

3.6 Birds

Birds were not specifically surveyed for this assessment by 4Sight. The local mudflats and mangrove habitat offer soft shore habitats to a range of birdlife.

4Sight has sighted the following species in the vicinity during previous works on the Hātea River, near the entrance to Limeburners Creek in 2016, which are described in Table 5.

Table 5: Avifauna sighted near Limeburners Creek.

Scientific Name	Common Name	Threat Status (Robertson et al., 2017)
Hydropogne caspia	Caspian tern	Nationally Vulnerable
Gallirallus philippensis assimilis	Banded rail	At Risk-Declining
Larus novaehollandiae scopulinus	Red-billed gull	At Risk-Declining
Sterna striata striata	White-fronted tern	At Risk-Declining
Phalacrocorax varius varius	Pied shag	At Risk-Recovering
Haematopus unicolor	Variable oystercatcher	At Risk-Recovering
Phalacrocorax carbo novaehollandiae	Black shag	At Risk-Naturally Uncommon
Egretta novaehollandiae	White-faced heron	Not Threatened
Phalacrocorax melanoleucos brevirostris	Little shag	Not Threatened
Larus dominicanus dominicanus	Southern black-backed gull	Not Threatened
Porphyrio melanotus melanotus	Pukeko	Not Threatened
Todiramphus sanctus vagans	New Zealand kingfisher	Not Threatened
Vanellus miles novaehollandiae	Spur-winged plover	Not Threatened
Morus serrator	Australasian gannet	Not Threatened
Anas platyrhynchos	Mallard	Introduced and Naturalised

New Zealand eBird is a real-time, online checklist program that the birding community reports and accesses information about birds. Birds New Zealand launched eBird New Zealand in May 2008 after it was initiated in 2002 by the Cornell Lab of Ornithology and National Audubon Society. A review of the database showed that Limeburners Creek Wetlands was a particular hotspot for bird records. 29 bird species have been recorded since 2020, most of which are listed in Table 5, with the rest being common birdlife all of which are classed as native – not threatened or introduced and naturalised (e.g., species such as the New Zealand Fantail, European Starling, and Eurasian Blackbird).

4 ASSESSMENT OF POTENTIAL ECOLOGICAL EFFECTS

This section provides an assessment of the potential ecological effects of the WWTP discharge on Limeburners Creek and the nearby receiving environment.

4.1 Effects on coastal vegetation and habitats

Mangroves are the dominant vegetation in the receiving environment and are a common, indigenous species in northern New Zealand harbours. The physical and ecological drivers for mangrove habitats and their ecological role and value in an estuarine ecosystem has been reviewed by Morrisey, D. et al (2007). It is complex and variable and determined largely by site-specific factors which can include the age of the mangrove stand and the presence of other habitats such as saltmarsh and seagrass areas and intertidal flats. As a largely mature stand that has been exposed to the WWTP discharge for a long period, the mangroves and associated habitat in Limeburners Creek are unlikely to be sensitive to, or limited by, nutrient or suspended particulate inputs associated with the wastewater discharge from the wetlands. The habitat can be considered robust in this context.

The primary effect of the WWTP discharge on estuarine vegetation is inputs of nutrients and suspended material, which could result in the modification of habitats. Limeburners Creek and the nearby Hātea River already contain elevated levels of sediment nutrients, have elevated organic matter content, and generally comprise fine muds as a result of historic land clearance and catchment-wide land use change. These conditions have resulted in dominant coverage of mangrove forests, which have likely reached their near-maximum extent in Limeburners Creek and the nearby receiving environment. It is unlikely that the inputs from the WWTP will notably modify the nearby existing intertidal areas nor affect the extent of mangroves present.

Overall, we consider the effects of the WWTP discharge on vegetation and coastal habitats to be no more than low and likely negligible.

4.2 Effects on intertidal sediment quality

The greatest difference in the quality of intertidal sediments in Limeburners Creek compared to those of the Hātea River and Awaroa Creek, is the elevated total phosphorus levels. This is likely, in part, a result of the WWTP discharge, which was shown in 4Sight (2021) to have elevated phosphorus levels. There may also be potential upstream phosphorus sources but these require further investigation to conclude. The other sites did not have substantially elevated sediment phosphorus levels relative to Limeburners Creek, which suggests it is isolated to Limeburners Creek.

Such elevated levels of phosphorus will contribute to the already generally elevated sediment nutrient levels found in the upper Hātea area and could provide some additional stress to benthic organisms. However, as described in the next section (4.3), benthic macroinvertebrates are not notably different between the lower Limeburners Creek and Awaroa Creek sites, which suggests that the biota present are tolerant towards nutrient-enriched sediments.

The concentration of sediment metals at all sites was below the applicable NRC sediment quality guideline for the Hatea River Water Quality Management Unit from the Proposed Northland Regional Plan. This suggests that there is no significant accumulation of metals in the sediments from the WWTP discharge.

The WWTP is one of many potential contaminant sources in the Hātea River, however, it is a notable source of nutrients in Limeburners Creek. Consequently, we consider the effects of the WWTP discharge on intertidal sediments in Limeburners Creek to be moderate (that is, having a measurable effect but not substantially adverse) but in Hātea River and other nearby environments, we consider the effects to be low due to the additional dilution and dispersion that occurs. The effect on sediment quality within Limeburners Creek is consistent with expectations from its use as a mixing zone as provided for in the PNRP.

4.3 Effects on benthic macroinvertebrates

The two monitoring sites in Limeburners Creek, LB_up and LB_dn, are upstream and downstream of the WWTP discharges. Because of the tidal influence at these locations, both sites will be exposed to the WWTP discharge at times. There were notable differences in the benthic communities at these two sites, with LB_dn having on average 226% more individuals and three more taxa per core, and higher species diversity (Shannon Wiener score 0.12 higher). This indicates a more populated, diverse, and even benthic community at the downstream site. Such changes are most likely attributed to the differing habitat (cobbled mud upstream, soft mud downstream) and the strong freshwater influence causing large salinity gradients at the upstream site rather than a result of exposure to the WWTP discharge.

Further, LB_dn is likely exposed to greater volumes of the WWTP discharge than the upstream site, being closer to the mouth of Limeburners Creek. The benthic communities at the downstream site were very similar to those at the

Awaroa site, which was used as a comparison away from Limeburners Creek. Such similarities between the two sites suggest that the WWTP discharge is not having a significant effect on the benthic communities at LB_dn. Likely, other environmental stressors, such as substrate muddiness, have a greater influence on the benthic community composition in the area.

NRC state of the environment data can also provide some insight into whether the discharge from Limeburners Creek is affecting the benthic ecology in the receiving environment as NRC sample over a much larger spatial scale than in this survey. Of relevance are the results from locations further up the Hātea River near the Town Basin and further downstream in the Hātea River towards the Whangārei Harbour that were collected in 2012 (Griffiths, 2012). The results presented by NRC from their multivariate analysis (nMDS plot) showed each of the nearby sites on the Hātea River to be grouped close together and distinct from other down-harbour locations in their analysis. This indicates that the sites measured along the Hātea River are relatively similar. The NRC analysis did not show any substantial differences at locations near the mouth of Limeburners Creek that could be attributed to the WWTP discharge.

Overall, the effects of the WWTP discharge on benthic macroinvertebrate communities appear to be low.

4.4 Effects on shellfish

Shellfish species identified at the mouth of Limeburners Creek and the nearby Hātea River and known to be in the general area are low densities and mostly small cockles, wedge shells, and oysters. The cockles and oysters do not represent potentially harvestable edible species in this setting. The greatest influence on the abundance of these species in the area is likely to be that of the sediment quality, most notably the high proportion of mud. High sediment mud content generally results in fewer shellfish species.

Water quality monitoring showed relatively low concentrations of suspended solids or, at the least, concentrations that are unlikely to result in further increases in sediment mud content that may further suppress the shellfish community.

Sediment monitoring showed that metal concentrations were below concentrations known to cause chronic adverse effects on biota. This indicates that metal concentrations in the sediment are unlikely to have adverse effects on shellfish in Limeburners Creek or the nearby receiving environment.

Overall, we consider the effects of the WWTP discharge on nearby shellfish populations to be low.

4.5 Effects on fish

Fish use the local estuary for feeding, shelter, spawning, and in the case of diadromous freshwater species such as eels and at least one galaxiid species (banded kokopu), as a migratory route.

Upper estuarine environments such as Limeburners Creek can experience stressful conditions for resident biota and fish incidental to normal seasonality. For example, increased temperatures and reduced dissolved oxygen can occur during some summer conditions and create marginal conditions for fish. The discharge from the WWTP has the potential to exacerbate adverse conditions to which fish are potentially exposed at such times. However, fish are mobile and can move in and out of the estuarine arm with the tides, and or otherwise avoid or actively move away from the discharge.

One contaminant present in the discharge that has the potential to adversely affect fish is ammonia. However, monitoring conducted by 4Sight to date has shown that ammonia concentrations were below levels known to have chronic (or acute) toxicity effects on fish (4Sight, 2021).

Overall, we consider the potential effects of the WWTP discharge on fish species is likely to be low.

4.6 Effects on birds

Of the bird species recorded or considered to utilise the mangrove or soft shore habitat, only the Caspian tern is recognised as 'threatened' based on its conservation status, which is 'Nationally Vulnerable'. Six species are classed as 'at risk', three of which are declining, two recovering, and one as naturally uncommon.

Many bird species use the mangroves and adjacent tidal flats within Limeburners Creek and the surrounding area for feeding, nesting, and shelter. Birds could be affected by the WWTP discharge if it were to affect the bird's food sources (e.g., fish, shellfish, invertebrates), nesting and shelter (e.g., vegetation). There is the potential for the elevated nutrient concentrations from the WWTP to promote or sustain the abundance of invertebrates in intertidal sediments. This could be seen as a small, positive effect.

An additional, small positive effect from the WWTP is the treatment wetlands themselves. The wetlands provide additional habitat for birds.

The effects of the WWTP on vegetation, benthic macroinvertebrates, shellfish, and fish, which might be used by birds, have been assessed above to be low. Based on these assessments, the overall effect of the WWTP discharge on birds is likely to be low.

5 CONCLUSIONS AND RECOMMENDATIONS

Based on the information presented above, the following conclusions were developed regarding the potential effects of the WWTP discharge on Limeburners Creek and the nearby receiving environment.

- Coastal vegetation and habitats are unlikely to be affected by the WWTP discharge. As such, we consider the effects to be no more than low and likely negligible.
- The WWTP discharge is one of many potential contaminant sources in the upper Hātea River. The only notable effect the discharge appears to have on intertidal sediments is elevating the levels of sediment phosphorus in Limeburners Creek, however, such elevated levels are localised. There is also the possibility of upstream phosphorus sources, which would require investigation to determine their presence and/or contribution. Metals do not appear to be accumulating in sediments and are below sediment quality guidelines. Overall, we consider the effects of the WWTP on intertidal sediment to be moderate with Limeburners Creek and low in the nearby receiving environments.
- There were no notable differences between benthic macroinvertebrates at the downstream Limeburners Creek and Awaroa sites, which suggests that the WWTP is not having adverse effects on the benthic macroinvertebrate communities. We consider the effects on benthic macroinvertebrates to be low.
- Limited numbers of shellfish were identified near the mouth of Limeburners Creek. Metal concentrations in the water are unlikely to adversely affect these species. We consider the effects on shellfish to be low.
- Fish in the area will be highly mobile and can actively move away from the discharge. Ammonia concentrations in the discharge are also below levels known to have chronic adverse effects on fish. We consider the effects on fish to be low.
- The greatest effect the WWTP could have on birds is to affect their food sources (e.g., fish, shellfish, invertebrates) or habitats. The WWTP discharge does not appear to be affecting these and so we consider the effects on birds to be low. In addition, the treatment wetlands provide additional habitat for birds, which is a small, positive effect.
- Some consideration may also be warranted regarding potential sources of phosphorus in Limeburners Creek upstream of the WWTP. An investigation could be conducted to determine whether there are likely to be significant phosphorus sources in Limeburners Creek in addition to the WWTP discharge that may contribute to the elevated sediment phosphorus concentrations.

5.1 Monitoring recommendations

The following monitoring is recommended at the mouth of Limeburners Creek to identify long-term ecological changes or trends. The frequency and methodology of the monitoring are recommended to be the same as that conducted by NRC for regional state of the environment monitoring. Specifically:

- Continuation of intertidal sediment quality monitoring for total organic carbon, nutrients, heavy metals, and grain size; and
- Continuation of benthic macroinvertebrate monitoring.

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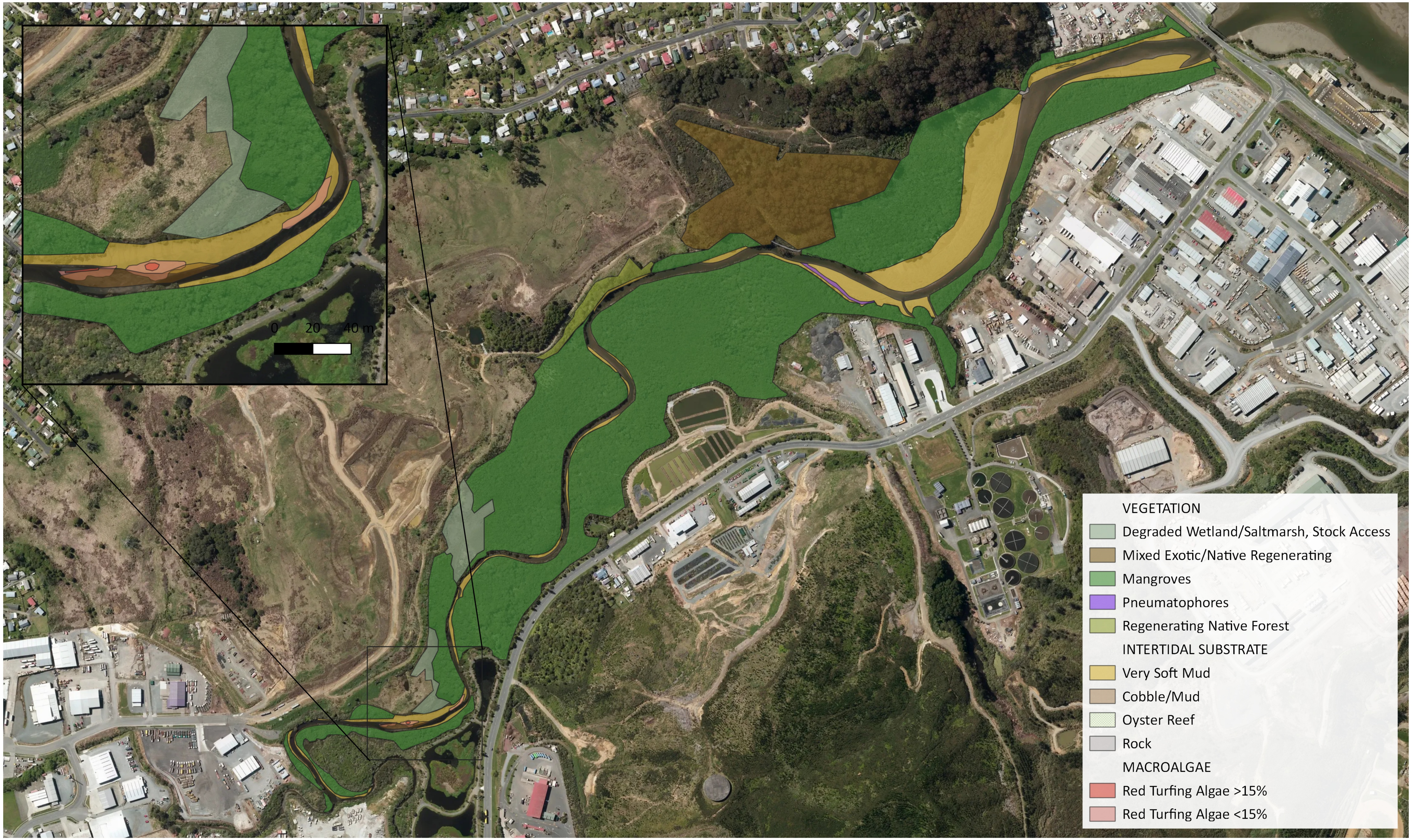
Appendix A

Limeburners Creek Habitat Map



1 : 6000 @A3

0 100 200 m

AA2789 - WDC WWTP Ecological Baseline for Consent Renewal

Limeburners Creek Habitat Map

Prepared for Whangarei District Council by 4Sight Consulting

Date: 18/09/2019
Version: 1.1
Author: PW
Checked: MP
Approved: ML

4SIGHT CONSULTING

Appendix B

Laboratory Results

Hill Laboratories
TRIED, TESTED AND TRUSTED

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

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T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis

SPv1

Client:	4SIGHT Consulting Limited	**Lab No:**	2144935
Contact:	Oliver Bone	**Date Received:**	20-Mar-2019
	C/- 4SIGHT Consulting Limited	**Date Reported:**	03-May-2019
	PO Box 402053	**Quote No:**	97960
	Tutukaka 0153	**Order No:**	AA2789
		Client Reference:	
		Submitted By:	Pete Wilson

Sample Type: Saline

Sample Name:		MM_Upstream 19-Mar-2019 11:58 am	MM_LB3 19-Mar-2019 2:35 pm	MM_LB2 19-Mar-2019 2:46 pm		
Lab Number:		2144935.1	2144935.2	2144935.3		
Individual Tests						
Turbidity*	NTU	4.2	3.5	6.3	-	-
Total Suspended Solids*	g/m³	20	5.2	12.9	-	-
Total Nitrogen	g/m³	5.9	23	7.2	-	-
Total Ammoniacal-N	g/m³	0.100	0.138	0.30	-	-
Nitrite-N	g/m³	0.049	0.054	0.048	-	-
Nitrate-N	g/m³	5.0	21	6.2	-	-
Nitrate-N + Nitrite-N	g/m³	5.1	21	6.3	-	-
Dissolved Reactive Phosphorus	g/m³	0.94	4.4 #1	1.23	-	-
Total Phosphorus*	g/m³	1.04	4.3 #1	1.32	-	-
Chlorophyll a*	g/m³	0.0009	0.0013	0.0047	-	-

Sample Type: Sediment

Sample Name:		Sed_LB1_1 19-Mar-2019 1:01 pm	Sed_LB1_2 19-Mar-2019 1:14 pm	Sed_LB1_3 19-Mar-2019 1:30 pm	Sed_LB2_1 19-Mar-2019 2:50 pm	Sed_LB2_2 19-Mar-2019 2:59 pm
Lab Number:		2144935.4	2144935.5	2144935.6	2144935.7	2144935.8
Individual Tests						
Total Recoverable Phosphorus	mg/kg dry wt	950	1,000	1,130	1,900	1,980
Total Nitrogen*	g/100g dry wt	0.20	0.19	0.23	0.19	0.22
Total Organic Carbon*	g/100g dry wt	2.2	2.2	2.5	1.94	2.0
Chlorophyll a*	mg/kg as rcvd	27.8	29.5	30.5	30.6	26.1
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	6.9	6.6	6.9	8.4	8.4
Total Recoverable Cadmium	mg/kg dry wt	0.144	0.147	0.136	0.066	0.062
Total Recoverable Chromium	mg/kg dry wt	15.2	16.1	16.3	20	21
Total Recoverable Copper	mg/kg dry wt	24	24	27	22	20
Total Recoverable Lead	mg/kg dry wt	13.7	13.0	14.5	14.5	14.4
Total Recoverable Nickel	mg/kg dry wt	6.3	6.3	7.2	9.0	8.0
Total Recoverable Zinc	mg/kg dry wt	110	115	120	134	128

Sample Name:		Sed_LB2_3 19-Mar-2019 3:03 pm				
Lab Number:		2144935.9				
Individual Tests						
Total Recoverable Phosphorus	mg/kg dry wt	2,300	-	-	-	-
Total Nitrogen*	g/100g dry wt	0.22	-	-	-	-
Total Organic Carbon*	g/100g dry wt	2.2	-	-	-	-
Chlorophyll a*	mg/kg as rcvd	18.8	-	-	-	-

Sample Type: Sediment						
Sample Name:		Sed_LB2_3 19-Mar-2019 3:03 pm				
Lab Number:		2144935.9				
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	9.4	-	-	-	-
Total Recoverable Cadmium	mg/kg dry wt	0.070	-	-	-	-
Total Recoverable Chromium	mg/kg dry wt	24	-	-	-	-
Total Recoverable Copper	mg/kg dry wt	22	-	-	-	-
Total Recoverable Lead	mg/kg dry wt	15.4	-	-	-	-
Total Recoverable Nickel	mg/kg dry wt	9.1	-	-	-	-
Total Recoverable Zinc	mg/kg dry wt	139	-	-	-	-

Analyst's Comments

[#1] It has been noted that the result for Dissolved Reactive Phosphorus was greater than that for Total Phosphorus, but within the analytical variation of these methods.

Appendix No.1 - Chlorophyll A results

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Saline

Test	Method Description	Default Detection Limit	Sample No
Total Nitrogen Digestion	Caustic persulphate digestion. APHA 4500-N C 23rd ed. 2017.	-	1-3
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	1-3
Turbidity*	Saline sample. Analysis using a Hach 2100N, Turbidity meter. APHA 2130 B 23rd ed. 2017.	0.05 NTU	1-3
Total Suspended Solids*	Saline sample. Filtration of a 2L sample using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D (modified) 23rd ed. 2017.	0.5 g/m^3	1-3
Total Nitrogen	Alkaline persulphate digestion, automated Cd reduction/sulphanilamide colorimetry. APHA 4500-N C & 4500-$NO3^-$ I (modified) 23rd ed. 2017.	0.010 g/m^3	1-3
Total Ammoniacal-N	Saline sample. Phenol/hypochlorite colorimetry. Flow injection analyser. (NH4-N = NH4+-N + NH3-N). APHA 4500-NH_3 H 23rd ed. 2017.	0.005 g/m^3	1-3
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.0010 g/m^3	1-3
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	1-3
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.0010 g/m^3	1-3
Dissolved Reactive Phosphorus	Saline sample. Molybdenum blue colorimetry. Flow injection analyser. APHA 4500-P G 23rd ed. 2017.	0.0010 g/m^3	1-3
Total Phosphorus*	Total phosphorus digestion, ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P B & E (modified from manual analysis and also modified to include a reductant to reduce interference from any arsenic present in the sample) 23rd ed. 2017. NWASCO, Water & soil Miscellaneous Publication No. 38, 1982.	0.004 g/m^3	1-3
Chlorophyll a*	Acetone extraction. Fluorometer. APHA 10200 H (modified) 23rd ed. 2017.	0.0002 g/m^3	1-3

Sample Type: Sediment

Test	Method Description	Default Detection Limit	Sample No
Environmental Solids Sample Drying*	Air dried at 35°C Used for sample preparation. May contain a residual moisture content of 2-5%.	-	4-9
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	4-9
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level.	0.010 - 0.4 mg/kg dry wt	4-9
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	4-9

Sample Type: Sediment			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Recoverable Phosphorus	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt	4-9
Total Nitrogen*	Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	4-9
Total Organic Carbon*	Acid pretreatment to remove carbonates present followed by Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	4-9
Chlorophyll a*	Extraction with 95% Ethanol, Spectroscopy. Subcontracted to NIWA, Hamilton. In-house.	0.1 mg/kg as rcvd	4-9

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

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

This certificate of analysis must not be reproduced, except in full, without the written consent of the signatory.

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

NIWA HAMILTON WATER QUALITY LABORATORY

CLIENT :	Hill Laboratories	LOT NUMBER :	2019000348	CHECKED :	DR
	28 Duke Street	SF NUMBER :	HM 8048	APPROVED :	MC
	Hamilton	JOB NUMBER :	HN19LAB/TEST	REPORT DATE :	2/05/2019

JOB : Purchase Order # 151561   Env SubNIWA 263

NIWA ID	***Client ID***	***Date Collected***	***Date Received***	***Chla µg/g***	***Phaeo µg/g***
HM1	2144935.4	20/03/2019	20/03/2019	27.8	20.6
HM2	2144935.5	20/03/2019	20/03/2019	29.5	20.4
HM3	2144935.6	20/03/2019	20/03/2019	30.5	22.3
HM4	2144935.7	20/03/2019	20/03/2019	30.6	39.8
HM5	2144935.8	20/03/2019	20/03/2019	26.1	37.9
HM6	2144935.9	20/03/2019	20/03/2019	18.8	20.8

A summary of methods used and detection limits is as follows.

Parameter	**Description**	**Detection Limit**	**Method**
Phaeophytin (Phaeo)	Extraction with 95% Ethanol, spectrometric measure.	0.1	In House
Chlorophyll a(Chla)	Extraction with 95% Ethanol, spectrometric measure.	0.1	In House

Samples are held at the laboratory for two months after reporting of results.
After this date they are discarded unless otherwise advised by the submitter.
These samples were analysed as received at the laboratory.

Hill Laboratories
TRIED, TESTED AND TRUSTED

R J Hill Laboratories Limited
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Certificate of Analysis

SPv1

Client:	4SIGHT Consulting Limited	**Lab No:**	2145849
Contact:	Oliver Bone	**Date Received:**	21-Mar-2019
	C/- 4SIGHT Consulting Limited	**Date Reported:**	03-May-2019
	PO Box 402053	**Quote No:**	97960
	Tutukaka 0153	**Order No:**	AA2789
		Client Reference:	
		Submitted By:	Oliver Bone

Sample Type: Saline

Sample Name:		MM-LB-Mouth 20-Mar-2019 11:36 am	WQ-HA3 20-Mar-2019 11:40 am	WQ-HA2 20-Mar-2019 11:46 am	WQ-HA1 20-Mar-2019 11:55 am	WQ-AW1 20-Mar-2019 12:10 pm
Lab Number:		2145849.1	2145849.2	2145849.3	2145849.4	2145849.5
Individual Tests						
Turbidity*	NTU	4.9	3.4	3.9	4.4	4.5
Total Suspended Solids*	g/m³	8.5	5.9	5.9	7.5	7.6
Total Nitrogen	g/m³	1.90	0.92	0.86	0.38	0.64
Total Ammoniacal-N	g/m³	0.138	0.148	0.143	0.076	0.103
Nitrite-N	g/m³	0.0183	0.0115	0.0098	0.0048	0.0079
Nitrate-N	g/m³	1.37	0.49	0.44	0.103	0.23
Nitrate-N + Nitrite-N	g/m³	1.39	0.50	0.45	0.108	0.24
Dissolved Reactive Phosphorus	g/m³	0.33	0.128	0.124	0.051	0.069
Total Phosphorus*	g/m³	0.37	0.150	0.144	0.066	0.095
Chlorophyll a*	g/m³	0.0011	0.0010	0.0010	0.0011	0.0014

Sample Name:		WQ-AW2 20-Mar-2019 12:53 pm	WQ-AW3 20-Mar-2019 12:20 pm			
Lab Number:		2145849.6	2145849.7			
Individual Tests						
Turbidity*	NTU	13.1	5.5	-	-	-
Total Suspended Solids*	g/m³	16.5	6.8	-	-	-
Total Nitrogen	g/m³	0.63	0.56	-	-	-
Total Ammoniacal-N	g/m³	0.118	0.119	-	-	-
Nitrite-N	g/m³	0.0071	0.0066	-	-	-
Nitrate-N	g/m³	0.168	0.140	-	-	-
Nitrate-N + Nitrite-N	g/m³	0.175	0.146	-	-	-
Dissolved Reactive Phosphorus	g/m³	0.042	0.032	-	-	-
Total Phosphorus*	g/m³	0.083	0.067	-	-	-
Chlorophyll a*	g/m³	0.0026	0.0017	-	-	-

Sample Type: Sediment

Sample Name:		Sed-AW-1 20-Mar-2019 1:26 pm	Sed-AW-2 20-Mar-2019 1:36 pm	Sed-AW-3 20-Mar-2019 1:46 pm	Sed-HA1-1 20-Mar-2019 3:20 pm	Sed-HA1-2 20-Mar-2019 3:27 pm
Lab Number:		2145849.8	2145849.9	2145849.10	2145849.11	2145849.12
Individual Tests						
Total Recoverable Phosphorus	mg/kg dry wt	650	650	700	670	830
Total Nitrogen*	g/100g dry wt	0.12	0.13	0.16	0.17	0.25
Total Organic Carbon*	g/100g dry wt	1.38	1.59	1.77	4.9	7.6
Chlorophyll a*	mg/kg as rcvd	18.5	20.3	30.5	20.7	72.9

Sample Type: Sediment						
Sample Name:		Sed-AW-1 20-Mar-2019 1:26 pm	Sed-AW-2 20-Mar-2019 1:36 pm	Sed-AW-3 20-Mar-2019 1:46 pm	Sed-HA1-1 20-Mar-2019 3:20 pm	Sed-HA1-2 20-Mar-2019 3:27 pm
Lab Number:		2145849.8	2145849.9	2145849.10	2145849.11	2145849.12
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	12.8	12.7	13.2	13.9	12.5
Total Recoverable Cadmium	mg/kg dry wt	0.057	0.061	0.071	0.094	0.088
Total Recoverable Chromium	mg/kg dry wt	26	24	25	18.0	18.6
Total Recoverable Copper	mg/kg dry wt	13.0	14.6	16.9	25	29
Total Recoverable Lead	mg/kg dry wt	8.8	9.4	10.2	19.5	17.5
Total Recoverable Nickel	mg/kg dry wt	14.1	13.4	13.6	10.1	9.8
Total Recoverable Zinc	mg/kg dry wt	81	83	90	160	133

Sample Name:		Sed-HA1-3 20-Mar-2019 3:34 pm				
Lab Number:		2145849.13				
Individual Tests						
Total Recoverable Phosphorus	mg/kg dry wt	660	-	-	-	-
Total Nitrogen*	g/100g dry wt	0.22	-	-	-	-
Total Organic Carbon*	g/100g dry wt	10.2	-	-	-	-
Chlorophyll a*	mg/kg as rcvd	17.9	-	-	-	-
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	13.0	-	-	-	-
Total Recoverable Cadmium	mg/kg dry wt	0.091	-	-	-	-
Total Recoverable Chromium	mg/kg dry wt	18.2	-	-	-	-
Total Recoverable Copper	mg/kg dry wt	27	-	-	-	-
Total Recoverable Lead	mg/kg dry wt	17.0	-	-	-	-
Total Recoverable Nickel	mg/kg dry wt	9.3	-	-	-	-
Total Recoverable Zinc	mg/kg dry wt	140	-	-	-	-

Analyst's Comments

Appendix No.1 - Chlorophyll A results

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Saline

Test	Method Description	Default Detection Limit	Sample No
Total Nitrogen Digestion	Caustic persulphate digestion. APHA 4500-N C 23rd ed. 2017.	-	1-7
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	1-7
Turbidity*	Saline sample. Analysis using a Hach 2100N, Turbidity meter. APHA 2130 B 23rd ed. 2017.	0.05 NTU	1-7
Total Suspended Solids*	Saline sample. Filtration of a 2L sample using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D (modified) 23rd ed. 2017.	0.5 g/m^3	1-7
Total Nitrogen	Alkaline persulphate digestion, automated Cd reduction/sulphanilamide colorimetry. APHA 4500-N C & 4500-$NO3^-$ I (modified) 23rd ed. 2017.	0.010 g/m^3	1-7
Total Ammoniacal-N	Saline sample. Phenol/hypochlorite colorimetry. Flow injection analyser. (NH4-N = NH4+-N + NH3-N). APHA 4500-NH_3 H 23rd ed. 2017.	0.005 g/m^3	1-7
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.0010 g/m^3	1-7
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	1-7
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.0010 g/m^3	1-7
Dissolved Reactive Phosphorus	Saline sample. Molybdenum blue colorimetry. Flow injection analyser. APHA 4500-P G 23rd ed. 2017.	0.0010 g/m^3	1-7

Sample Type: Saline			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Phosphorus*	Total phosphorus digestion, ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P B & E (modified from manual analysis and also modified to include a reductant to reduce interference from any arsenic present in the sample) 23rd ed. 2017. NWASCO, Water & soil Miscellaneous Publication No. 38, 1982.	0.004 g/m^3	1-7
Chlorophyll a*	Acetone extraction. Fluorometer. APHA 10200 H (modified) 23rd ed. 2017.	0.0002 g/m^3	1-7

Sample Type: Sediment			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Environmental Solids Sample Drying*	Air dried at 35°C Used for sample preparation. May contain a residual moisture content of 2-5%.	-	8-13
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	8-13
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level.	0.010 - 0.4 mg/kg dry wt	8-13
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	8-13
Total Recoverable Phosphorus	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt	8-13
Total Nitrogen*	Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	8-13
Total Organic Carbon*	Acid pretreatment to remove carbonates present followed by Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	8-13
Chlorophyll a*	Extraction with 95% Ethanol, Spectroscopy. Subcontracted to NIWA, Hamilton. In-house.	0.1 mg/kg as rcvd	8-13

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

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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

NIWA
Taihoro Nukurangi

NIWA HAMILTON WATER QUALITY LABORATORY

CLIENT : Hill Laboratories
28 Duke Street
Hamilton

LOT NUMBER : 2019000357
SF NUMBER : HT 8055
JOB NUMBER : HN19LAB/TEST

CHECKED : DR
APPROVED : MC
REPORT DATE : 2/05/2019

JOB : Purchase Order # 151571 EnvSubNIWA 264

NIWA ID	***Client ID***	***Date Collected***	***Date Received***	***Chla µg/g***	***Phaeo µg/g***
HT1	2145849.8	20/03/2019	21/03/2019	18.5	15.7
HT2	2145849.9	20/03/2019	21/03/2019	20.3	15.7
HT3	2145849.10	20/03/2019	21/03/2019	30.5	20.8
HT4	2145849.11	20/03/2019	21/03/2019	20.7	23.8
HT5	2145849.12	20/03/2019	21/03/2019	72.9	54.8
HT6	2145849.13	20/03/2019	21/03/2019	17.9	15.9

A summary of methods used and detection limits is as follows.

Parameter	**Description**	**Detection Limit**	**Method**
Phaeophytin (Phaeo)	Extraction with 95% Ethanol, spectrometric measure.	0.1	In House
Chlorophyll a(Chla)	Extraction with 95% Ethanol, spectrometric measure.	0.1	In House

Samples are held at the laboratory for two months after reporting of results.
After this date they are discarded unless otherwise advised by the submitter.
These samples were analysed as received at the laboratory.

Hill Laboratories
TRIED, TESTED AND TRUSTED

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Certificate of Analysis

SPv1

Client:	4Sight Consulting Limited	**Lab No:**	2325896
Contact:	Pete Wilson	**Date Received:**	20-Feb-2020
	C/- 4Sight Consulting Limited	**Date Reported:**	01-May-2020
	PO Box 1420	**Quote No:**	97960
	Waikato Mail Centre	**Order No:**	AA2789
	Hamilton 3240	**Client Reference:**	
		Submitted By:	Pete Wilson

Sample Type: Saline

Sample Name:		AW1 19-Feb-2020 3:39 pm	AW2 19-Feb-2020 3:30 pm	AW3 19-Feb-2020 3:24 pm	HA1 19-Feb-2020 3:03 pm	HA2 19-Feb-2020 3:52 pm
Lab Number:		2325896.13	2325896.14	2325896.15	2325896.16	2325896.17
Individual Tests						
Turbidity*	NTU	2.6	5.5	6.6	2.6	1.34
Total Suspended Solids*	g/m³	7.2	19.1	18.4	6.2	5.0
Total Nitrogen	g/m³	0.46	0.59	0.67	0.41	0.47
Total Ammoniacal-N	g/m³	0.060	0.081	0.104	0.052	0.069
Nitrite-N	g/m³	0.0044	0.0060	0.0070	0.0039	0.0047
Nitrate-N	g/m³	0.088	0.155	0.187	0.076	0.103
Nitrate-N + Nitrite-N	g/m³	0.092	0.161	0.194	0.080	0.108
Dissolved Reactive Phosphorus	g/m³	0.053	0.072	0.081	0.047	0.056
Total Phosphorus*	g/m³	0.064	0.088	0.101	0.060	0.068
Chlorophyll a*	g/m³	0.0010	0.0012	0.0014	0.0012	0.0016

Sample Name:		HA3 19-Feb-2020 3:59 pm	LB1 19-Feb-2020 4:23 pm	LB2 19-Feb-2020 4:17 pm	LB3 19-Feb-2020 4:10 pm	LB4 19-Feb-2020 12:05 pm
Lab Number:		2325896.18	2325896.19	2325896.20	2325896.21	2325896.22
Individual Tests						
Turbidity*	NTU	2.3	2.6	4.4	3.9	5.9
Total Suspended Solids*	g/m³	4.5	4.9	7.3	7.2	13.0
Total Nitrogen	g/m³	0.76	0.62	0.79	2.3	11.5 #2
Total Ammoniacal-N	g/m³	0.101	0.075	0.104	0.130	0.21
Nitrite-N	g/m³	0.0083	0.0068	0.0089	0.0195	0.095
Nitrate-N	g/m³	0.30	0.193	0.32	1.51	11.5
Nitrate-N + Nitrite-N	g/m³	0.30	0.199	0.33	1.53	11.6 #2
Dissolved Reactive Phosphorus	g/m³	0.104	0.079	0.115	0.35 #1	2.2
Total Phosphorus*	g/m³	0.114	0.094	0.127	0.34 #1	2.2
Chlorophyll a*	g/m³	0.0013	0.0008	0.0015	0.0037	0.0020

Sample Type: Sediment

Sample Name:		AW_down 19-Feb-2020 9:55 am	AW_mid 19-Feb-2020 9:45 am	AW_up 19-Feb-2020 9:40 am	HA1_down 19-Feb-2020 10:45 am	HA1_mid 19-Feb-2020 10:50 am
Lab Number:		2325896.1	2325896.2	2325896.3	2325896.4	2325896.5
Individual Tests						
Total Recoverable Phosphorus	mg/kg dry wt	710	920	830	820	640
Total Nitrogen*	g/100g dry wt	0.18	0.23	0.22	0.22	0.16
Total Organic Carbon*	g/100g dry wt	1.89	2.4	2.4	7.8	4.9
Chlorophyll a*‡	mg/kg as rcvd	28.7	33.5	30.9	27.8	19.7

Sample Type: Sediment						
Sample Name:		AW_down 19-Feb-2020 9:55 am	AW_mid 19-Feb-2020 9:45 am	AW_up 19-Feb-2020 9:40 am	HA1_down 19-Feb-2020 10:45 am	HA1_mid 19-Feb-2020 10:50 am
Lab Number:		2325896.1	2325896.2	2325896.3	2325896.4	2325896.5
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	13.9	14.0	13.4	14.8	14.2
Total Recoverable Cadmium	mg/kg dry wt	0.078	0.050	0.058	0.092	0.092
Total Recoverable Chromium	mg/kg dry wt	24	25	24	15.8	16.6
Total Recoverable Copper	mg/kg dry wt	24	27	28	27	31
Total Recoverable Lead	mg/kg dry wt	11.9	13.8	13.5	16.4	17.7
Total Recoverable Nickel	mg/kg dry wt	14.2	13.7	14.2	9.5	10.3
Total Recoverable Zinc	mg/kg dry wt	105	108	110	142	159
7 Grain Sizes Profile as received*						
Dry Matter of Sieved Sample*	g/100g as rcvd	47	48	46	54	57
Fraction >/= 2 mm*	g/100g dry wt	< 0.1	< 0.1	0.1	15.3	10.6
Fraction < 2 mm, >/= 1 mm*	g/100g dry wt	0.2	0.2	0.2	6.0	4.0
Fraction < 1 mm, >/= 500 µm*	g/100g dry wt	0.5	0.5	0.5	3.4	2.0
Fraction < 500 µm, >/= 250 µm*	g/100g dry wt	1.9	1.9	1.6	2.3	2.0
Fraction < 250 µm, >/= 125 µm*	g/100g dry wt	13.9	8.3	8.6	14.4	14.2
Fraction < 125 µm, >/= 63 µm*	g/100g dry wt	29.9	21.5	21.5	28.7	34.0
Fraction < 63 µm*	g/100g dry wt	53.6	67.6	67.4	29.9	33.1

Sample Name:		HA1_up 19-Feb-2020 10:56 am	LB1_down 19-Feb-2020 8:40 am	LB1_mid 19-Feb-2020 9:00 am	LB1_up 19-Feb-2020 8:50 am	LB2_down 19-Feb-2020 10:10 am
Lab Number:		2325896.6	2325896.7	2325896.8	2325896.9	2325896.10
Individual Tests						
Total Recoverable Phosphorus	mg/kg dry wt	640	1,040	1,320	1,410	1,900
Total Nitrogen*	g/100g dry wt	0.19	0.19	0.25	0.28	0.22
Total Organic Carbon*	g/100g dry wt	8.5	1.94	2.8	3.2	2.4
Chlorophyll a*‡	mg/kg as rcvd	27.8	53.6	46.3	51.9	23.0
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	18.0	8.9	9.5	10.0	8.9
Total Recoverable Cadmium	mg/kg dry wt	0.099	0.123	0.145	0.142	0.071
Total Recoverable Chromium	mg/kg dry wt	15.5	15.1	22	19.8	22
Total Recoverable Copper	mg/kg dry wt	30	32	43	45	34
Total Recoverable Lead	mg/kg dry wt	17.6	14.4	17.6	18.0	16.5
Total Recoverable Nickel	mg/kg dry wt	9.7	7.7	11.7	10.5	11.5
Total Recoverable Zinc	mg/kg dry wt	156	132	158	162	174
7 Grain Sizes Profile as received*						
Dry Matter of Sieved Sample*	g/100g as rcvd	57	43	42	42	43
Fraction >/= 2 mm*	g/100g dry wt	11.5	0.2	0.2	< 0.1	14.5
Fraction < 2 mm, >/= 1 mm*	g/100g dry wt	5.3	0.2	0.2	0.2	3.8
Fraction < 1 mm, >/= 500 µm*	g/100g dry wt	2.6	0.7	0.6	0.5	3.0
Fraction < 500 µm, >/= 250 µm*	g/100g dry wt	2.6	6.3	3.2	3.4	3.0
Fraction < 250 µm, >/= 125 µm*	g/100g dry wt	14.4	20.9	15.9	14.8	5.6
Fraction < 125 µm, >/= 63 µm*	g/100g dry wt	31.1	17.1	21.0	19.9	11.0
Fraction < 63 µm*	g/100g dry wt	32.4	54.6	58.8	61.1	59.1

Sample Name:		LB2_mid 19-Feb-2020 10:15 am	LB2_up 19-Feb-2020 10:20 am			
Lab Number:		2325896.11	2325896.12			
Individual Tests						
Total Recoverable Phosphorus	mg/kg dry wt	2,400	2,300	-	-	-
Total Nitrogen*	g/100g dry wt	0.24	0.23	-	-	-
Total Organic Carbon*	g/100g dry wt	2.4	2.5	-	-	-
Chlorophyll a*‡	mg/kg as rcvd	21.5	15.5	-	-	-
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	10.0	9.1	-	-	-
Total Recoverable Cadmium	mg/kg dry wt	0.077	0.086	-	-	-

Sample Type: Sediment						
Sample Name:		LB2_mid 19-Feb-2020 10:15 am	LB2_up 19-Feb-2020 10:20 am			
Lab Number:		2325896.11	2325896.12			
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Chromium	mg/kg dry wt	23	23	-	-	-
Total Recoverable Copper	mg/kg dry wt	37	38	-	-	-
Total Recoverable Lead	mg/kg dry wt	17.2	18.5	-	-	-
Total Recoverable Nickel	mg/kg dry wt	11.1	11.6	-	-	-
Total Recoverable Zinc	mg/kg dry wt	184	199	-	-	-
7 Grain Sizes Profile as received*						
Dry Matter of Sieved Sample*	g/100g as rcvd	52	48	-	-	-
Fraction >/= 2 mm*	g/100g dry wt	43.9	22.1	-	-	-
Fraction < 2 mm, >/= 1 mm*	g/100g dry wt	4.7	4.4	-	-	-
Fraction < 1 mm, >/= 500 µm*	g/100g dry wt	3.2	4.3	-	-	-
Fraction < 500 µm, >/= 250 µm*	g/100g dry wt	3.8	5.6	-	-	-
Fraction < 250 µm, >/= 125 µm*	g/100g dry wt	4.1	6.2	-	-	-
Fraction < 125 µm, >/= 63 µm*	g/100g dry wt	4.1	6.8	-	-	-
Fraction < 63 µm*	g/100g dry wt	36.1	50.6	-	-	-

Analyst's Comments

‡ Analysis subcontracted to an external provider. Refer to the Summary of Methods section for more details.

#1 It has been noted that the result for Dissolved Reactive Phosphorus was greater than that for Total Phosphorus, but within the analytical variation of these methods.

#2 It has been noted that the result for Nitrate-N + Nitrite-N was greater than that for Total Nitrogen, but within the analytical variation of these methods.

Summary of Methods

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

Sample Type: Saline

Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Total Nitrogen Digestion	Caustic persulphate digestion. APHA 4500-N C 23rd ed. 2017.	-	13-22
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	13-22
Turbidity*	Saline sample. Analysis using a Hach 2100N, Turbidity meter. APHA 2130 B 23rd ed. 2017 (modified).	0.05 NTU	13-22
Total Suspended Solids*	Saline sample. Filtration of a 2L sample using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D (modified) 23rd ed. 2017.	0.5 g/m^3	13-22
Total Nitrogen	Alkaline persulphate digestion, automated Cd reduction/sulphanilamide colorimetry. APHA 4500-N C & 4500-$NO3^-$ I (modified) 23rd ed. 2017.	0.010 g/m^3	13-22
Total Ammoniacal-N	Saline sample. Phenol/hypochlorite colorimetry. Flow injection analyser. (NH4-N = NH4+-N + NH3-N). APHA 4500-NH_3 H 23rd ed. 2017.	0.005 g/m^3	13-22
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.0010 g/m^3	13-22
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	13-22
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.0010 g/m^3	13-22
Dissolved Reactive Phosphorus	Saline sample. Molybdenum blue colorimetry. Flow injection analyser. APHA 4500-P G 23rd ed. 2017.	0.0010 g/m^3	13-22
Total Phosphorus*	Total phosphorus digestion, ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P B & E (modified from manual analysis and also modified to include a reductant to reduce interference from any arsenic present in the sample) 23rd ed. 2017. NWASCO, Water & soil Miscellaneous Publication No. 38, 1982.	0.004 g/m^3	13-22
Chlorophyll a*	Acetone extraction. Fluorometer. APHA 10200 H (modified) 23rd ed. 2017.	0.0002 g/m^3	13-22

Sample Type: Sediment			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Individual Tests			
Environmental Solids Sample Drying*	Air dried at 35°C Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-12
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-12
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1-12
Total Recoverable Phosphorus	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt	1-12
Total Nitrogen*	Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	1-12
Total Organic Carbon*	Acid pretreatment to remove carbonates present followed by Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	1-12
Chlorophyll a*	Extraction with 95% Ethanol, Spectroscopy. Subcontracted to NIWA, Hamilton. In-house.	0.1 mg/kg as rcvd	1-12
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level.	0.010 - 0.4 mg/kg dry wt	1-12
7 Grain Sizes Profile as received			
Dry Matter for Grainsize samples (sieved as received)*	Drying for 16 hours at 103°C, gravimetry (Free water removed before analysis).	0.10 g/100g as rcvd	1-12
Fraction >/= 2 mm*	Wet sieving with dispersant, as received, 2.00 mm sieve, gravimetry.	0.1 g/100g dry wt	1-12
Fraction < 2 mm, >/= 1 mm*	Wet sieving using dispersant, as received, 2.00 mm and 1.00 mm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-12
Fraction < 1 mm, >/= 500 µm*	Wet sieving using dispersant, as received, 1.00 mm and 500 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-12
Fraction < 500 µm, >/= 250 µm*	Wet sieving using dispersant, as received, 500 µm and 250 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-12
Fraction < 250 µm, >/= 125 µm*	Wet sieving using dispersant, as received, 250 µm and 125 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-12
Fraction < 125 µm, >/= 63 µm*	Wet sieving using dispersant, as received, 125 µm and 63 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-12
Fraction < 63 µm*	Wet sieving with dispersant, as received, 63 µm sieve, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-12

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

Dates of testing are available on request. Please contact the laboratory for more information.

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

Ara Heron BSc (Tech)
Client Services Manager - Environmental

Appendix C

Benthic Macroinvertebrate Data

Benthic Macroinvertebrates - 2019

General Group	Family	Genus	Taxa	Common Name	Feeding	AWA	AWA	AWA	AWA	AWA	AWA	AWA	AWA	AWA	AWA	HAT	HAT	HAT	HAT	HAT	HAT	HAT	HAT	HAT	HAT	LBL	LBL	LBL	LBL	LBL	LBL	LBL	LBL	LBL	LBL	LBU	LBU	LBU	LBU	LBU	LBU	LBU	LBU	LBU	LBU
Nemertea			Nemertea	Proboscis worms													1				1		1						1	1		1													
Gastropoda			Gastropoda operculum and body	Snails																																	1								
Gastropoda	Amphibolidae	Amphibola	Amphibola crenata	Mud Snail	Microalgal grazer																																							2	
Gastropoda	Nassariidae	Nassarius (Plicarcularia)	Nassarius (Plicarcularia) burchardi	Australian dog whelk																	1	1																							
Gastropoda	Hydrobiidae	Potamopyrgus	Potamopyrgus estuarinus	Estuarine snail	Microalgal & detrital grazer																														2			83	1		1	4	2	5	4
Bivalvia			Bivalvia indeterminable																					1																	1	1			
Bivalvia			Xenostrobus sp.										1		1													1								2		1		8		5		1	
Bivalvia	Lasaeidae	Arthritica	Arthritica sp.	Small bivalve	Infaunal deposit feeder						1		1	6	2	2				1	3		2	1	2							1		1	7	7		25	4	9	2	8		59	1
Bivalvia	Veneridae	Austrovenus	Austrovenus stutchburyi	Cockle; Huangi	Infaunal deposit feeder													1			1			3	1				1																
Bivalvia	Tellinidae	Macomona	Macomona liliana	Wedge shell Hanikura	Infaunal suspension feeder																	1																							
Bivalvia	Mytilidae	Musculista	Musculista senhousia															5			1			20	19	1		1														1		1	
Oligochaeta			Oligochaeta	Oligochaete worms	Infaunal deposit feeder	160	125	74	24	17	54	31	11	8	18		13	3				2	2	1	2	24	14	44	137	5	22	50	1	9	6		2						8	1	7
Polychaeta: Spionidae	Spionidae		Polydorid			15	15	16	1	6	39	8	5	12		99	23	23	38	165	8	32	10	12	23	3	2	26	2	2	10	2	1	6	1				1	5		1		5	
Polychaeta:			Nereididae indeterminable			6	3								1	2					1	1		2		8										1			1				1		
Polychaeta: Paraonidae	Paraonidae		Paraonidae		Infaunal deposit feeder	1		7		1			1	3		9	12	2	8	11	1	6	9	5	2																				
Polychaeta: Paraonidae	Paraonidae	Aricidea	Aricidea sp.													10	5		6	9	2	3		2	8																				
Polychaeta: Cossuridae	Cossuridae	Cossura	Cossura consimilis		Deposit feeder															2		1	1																						
Polychaeta: Spionidae	Spionidae	Prionospio	Prionospio sp.		Surface deposit feeder	7	71	7	32	31	1	2	1			47	26	5	86	93	10	32	10	7	7	17	41	11	3	10	10	51	1	7	10		1						1	1	2
Polychaeta: Spionidae	Spionidae	Scolecolepides	Scolecolepides benhami		Surface deposit feeder	1		1		1	2	8	3	17	1											2	7		1	2		1	1												
Polychaeta: Capitellidae	Capitellidae	Barantolla	Barantolla lepte														1	1				2	1																						
Polychaeta: Capitellidae	Capitellidae	Capitella	Capitella sp.		Infaunal deposit feeder	10				1	2	3				2	6	2	6	11	7	3				2	7	10	2	2	3	3	2	3	1										
Polychaeta: Capitellidae	Capitellidae	Heteromastus	Heteromastus filiformis		Infaunal deposit feeder											2	2		1	8	1	5																							
Polychaeta: Polynoidae	Polynoidae		Polynoidae	Scale worms	Infaunal carnivore				1							3		2		1	6	1						1		1			1												
Polychaeta: Nereididae	Nereididae		Nereididae (juvenile)		Omnivorous	6		3	1	3	1	6	25	11		2	2	1	2	5	2	1	9	8	8	23	6	13	22	13	18	21	4	3	31	22	7	40	7	26	18	39	2	27	15
Polychaeta: Nereididae	Nereididae	Ceratonereis	Ceratonereis sp.	Rag worm								3	4	1	3											20	68	19	5	13	30	14	28	16	7	2	26	2	8	29	8	1	3	30	15
Polychaeta: Nereididae	Nereididae	Nicon	Nicon aestuariensis		Omnivorous								2	3		1	4		4	3		15	6			1				1			2	1			1		2		2		3		1
Polychaeta: Nereididae	Nereididae	Perinereis	Perinereis sp.		Omnivorous	3				1	2			3	3	2		1		2	2		2		2	4			1		1			1											1
Polychaeta: Cirratulidae	Cirratulidae		Cirratulidae		Deposit feeder														1	1																									
Isopoda	Sphaeromatidae	Exosphaeroma	Exosphaeroma chilensis																																	2		6				1			
Amphipoda	Corophiidae		Corophiidae	Amphipod (family)		3							2													2		8		1						16	4	3		7		7		14	
Amphipoda			Amphipoda indet.	Amphipods								2																																	
Decapoda	Alpheidae	Alpheus	Alpheus socialis	Snapping Shrimp														1																											
Decapoda	Aristeidae	Aristaeomorpha	Aristaeomorpha foliacea																		1																								
Decapoda	Varunidae	Austrohelice	Austrohelice crassa	Tunnelling Mud Crab	Deposit feeder & scavenger	2					1	4	3	2	2													4	3	1		1		1			1								
Decapoda	Hymenosomatidae	Halicarcinus	Halicarcinus whitei	Pill-box Crab	Eats small organisms & weed																																								1
Decapoda	Macrophthalmidae	Hemiplax	Hemiplax hirtipes	Stalk-eyed Mud Crab	Deposit feeder & scavenger										1																		1	1											
Decapoda			Decapoda indeterminable	Decapoda							1			1																															
Copepoda			Copepoda	Copepods					5	1		1		1	1		2			1	1	1				1	2	2		4		1		1	2										
			Count: No of Individuals			**214**	**214**	**108**	**64**	**62**	**104**	**68**	**59**	**68**	**33**	**181**	**97**	**47**	**152**	**313**	**49**	**107**	**53**	**62**	**74**	**108**	**147**	**140**	**178**	**56**	**94**	**146**	**42**	**50**	**67**	**52**	**43**	**160**	**24**	**84**	**32**	**68**	**20**	**146**	**47**
			Count: No of Taxa			**11**	**4**	**6**	**6**	**9**	**10**	**10**	**12**	**12**	**10**	**12**	**12**	**12**	**9**	**14**	**17**	**16**	**11**	**11**	**10**	**13**	**8**	**12**	**11**	**13**	**7**	**11**	**10**	**12**	**9**	**7**	**8**	**7**	**7**	**6**	**6**	**10**	**7**	**11**	**9**

Benthic Macroinvertebrates - 2020

General Group	Family	Genus	Taxa	Common Name	Feeding	AWA	AWA	AWA	AWA	AWA	AWA	AWA	AWA	AWA	AWA	HAT	HAT	HAT	HAT	HAT	HAT	HAT	HAT	HAT	HAT	LBL	LBL	LBL	LBL	LBL	LBL	LBL	LBL	LBL	LBL	LBU	LBU	LBU	LBU	LBU	LBU	LBU	LBU	LBU	LBU
Anthozoa			Anthozoa	Anemones		1																						1							1		2	2					1	1	1
Anthozoa	Actiniidae	Anthopleura	Anthopleura hermaphroditica																																				3						
Nemertea			Nemertea	Proboscis worms			1									1				1	1																								
Gastropoda	Amphibolidae	Amphibola	Amphibola crenata	Mud Snail	Microalgal grazer		1																																						
Gastropoda	Hydrobiidae	Potamopyrgus	Potamopyrgus estuarinus	Estuarine snail	Microalgal & detrital grazer																															1	5	2			1		4	1	3
Gastropoda	Muricidae	Xymene	Xymene sp.																					1																					
Opisthobranchia			Opisthobranchia Unid.				1																																						
Bivalvia	Lasaeidae		Lasaeidae			1									1	2	4	4	1	2			7	6	4	4				1	1				3		3	3	5	4	3	6	1		5
Bivalvia	Nuculidae		Nuculidae														2																												
Bivalvia	Veneridae	Austrovenus	Austrovenus stutchburyi (0-5mm)	Cockle (0-5mm)	Infaunal deposit feeder																			1																					
Bivalvia	Veneridae	Austrovenus	Austrovenus stutchburyi (31+mm)	Cockle (>31mm)	Infaunal deposit feeder																		1																						
Bivalvia	Nuculidae	Linucula	Linucula hartvigiana	Nut Shell	Surface deposit & filter feeder													1				1	1																						
Bivalvia	Mactridae	Maorimactra	Maorimactra ordinaria																1		1																								
Bivalvia	Mytilidae	Musculista	Musculista senhousia														64								23														1			6	1		
Bivalvia	Ostreidae	Saccostrea	Saccostrea glomerata	Auckland rock oyster			4																																						
Bivalvia	Mytilidae	Xenostrobus	Xenostrobus securis	Little Black Mussel		1	1							2																1					1			1	5	2		23	3		3
Oligochaeta			Oligochaeta	Oligochaete worms	Infaunal deposit feeder	157	3	40	26	95	37	5	47	66	6	1	1									34	44	90	233	133	8	5	10	14	46	34		2		1				3	2
Polychaeta: Spionidae	Spionidae		Polydorid complex			154		34	11	68	44	57			9	2	2	4	1	3	4		2	1	20	37	106	33	83		34		16	44	44				2						
Polychaeta:						1																																							
Polychaeta: Paraonidae	Paraonidae		Paraonidae		Infaunal deposit feeder				2	1	2						2	1	3	1	1	2	5	2	12						1														
Polychaeta: Paraonidae	Paraonidae	Aricidea	Aricidea sp.													5	5	16	9	11	30	12	17	3	11	1																			
Polychaeta: Spionidae	Spionidae	Prionospio	Prionospio sp.		Surface deposit feeder	1	2		2	6	13	39	4	2		2	3	6	6	23	25	8	27	5	14	19	60	3	1	10	21		57	9	21										
Polychaeta: Spionidae	Spionidae	Scolecolepides	Scolecolepides benhami		Surface deposit feeder	5	1		5	2	5	4	2	13	6	2					1	2	2				2	3	7				1	2	1	1		1	3					1	
Polychaeta: Capitellidae	Capitellidae	Capitella	Capitella sp.		Infaunal deposit feeder	7		4		2	1	6		1												15	30	3	10	2	6		3	5	7										
Polychaeta: Capitellidae	Capitellidae	Heteromastus	Heteromastus filiformis		Infaunal deposit feeder														2	11	2		5	1																					
Polychaeta: Capitellidae	Capitellidae	Notomastus	Notomastus sp.		Infaunal deposit feeder													1																											
Polychaeta: Polynoidae	Polynoidae		Polynoidae	Scale worms	Infaunal carnivore					1		1		1										1	1						1														
Polychaeta: Nereididae	Nereididae		Nereididae (juvenile)		Omnivorous	1						10	2	1		15	3	10	14	3	5	12	9	16	9		6	2	11		1		3		2	13	15	28	96	41	22	17	15	28	49
Polychaeta: Nereididae	Nereididae	Ceratonereis	Ceratonereis sp.	Rag worm		5	3	1	1	3	1	2	2	3	1								1		1	1	1	4	13	1	7		1	15	1	12	17	8	41	26	4	59	18	15	19
Polychaeta: Nereididae	Nereididae	Nicon	Nicon aestuariensis		Omnivorous																												1					2					1		
Polychaeta: Nereididae	Nereididae	Perinereis	Perinereis sp.		Omnivorous	5	4			2		2	1		1	6	3	10	6	8	4	9	4	14	9		1	1	2					1	1			3							
Polychaeta: Glyceridae	Glyceridae		Glyceridae		Infaunal carnivore & deposit feeder																1				1																				
Polychaeta: Cirratulidae	Cirratulidae		Cirratulidae		Deposit feeder			1																																					
Arthropoda	Tipulidae		Tipulidae	Crane fly larvae			3																																						
Isopoda	Sphaeromatidae	Exosphaeroma	Exosphaeroma planulum																																									2	
Isopoda	Sphaeromatidae	Exosphaeroma	Exosphaeroma sp.																								3																		
Amphipoda	Corophiidae		Corophiidae	Amphipod (family)				1	57	3		22			3	1							61		30	4		3	2		18		10	6	12			1	3		1		1		2
Amphipoda	Melitidae		Melitidae	Amphipods																																1									
Amphipoda			Amphipoda indet.	Amphipods		1		2					1				1											8	2		4			1		1				1		5	2		
Decapoda	Varunidae	Austrohelice	Austrohelice crassa	Tunnelling Mud Crab	Deposit feeder & scavenger	10	5	8	3	7	3			2	6											2	3	12	7					4	5										
Decapoda	Hymenosomatidae	Halicarcinus	Halicarcinus whitei	Pill-box Crab	Eats small organisms & weed																												1												
Decapoda	Macrophthalmidae	Hemiplax	Hemiplax hirtipes	Stalk-eyed Mud Crab	Deposit feeder & scavenger		2				2		2				1	1	1	1	1	1			2								2				1								
Copepoda			Copepoda	Copepods		1			1		2	2			1											5	4	3	1	1	5		2	4											
Cirripedia	Balanidae	Austrominius	Austrominius modestus	Estuarine Barnacle	Filter feeder		2																				28			2															2
Diptera	Psychodidae		Psychodidae	moth fly																										1		74													
Ascidiacea			Ascidian (solitary)	Sea Squirts		1																																							
			Count: No of Individuals			**352**	**33**	**91**	**108**	**190**	**110**	**150**	**61**	**91**	**34**	**37**	**91**	**54**	**44**	**64**	**76**	**47**	**142**	**51**	**137**	**122**	**288**	**166**	**372**	**152**	**107**	**79**	**107**	**105**	**145**	**63**	**43**	**53**	**159**	**75**	**31**	**116**	**47**	**51**	**86**
			Count: No of Taxa			**16**	**14**	**8**	**9**	**11**	**10**	**11**	**8**	**9**	**9**	**10**	**12**	**10**	**10**	**10**	**12**	**8**	**13**	**11**	**13**	**10**	**12**	**13**	**12**	**9**	**12**	**2**	**12**	**11**	**13**	**7**	**6**	**11**	**9**	**6**	**5**	**6**	**10**	**7**	**9**

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Appendix E

Proposed adaption triggers

WWTP mass discharges

To determine the mass discharge loads from the wetlands, preliminary investigations considered calculating mass discharge loads for total nitrogen, total phosphorous, and total suspended sediment. All three of these constituents are monitored as concentrations from the wetland 1 and wetland 2 effluent discharge locations.

To calculate mass the flow from wetland 1 and wetland 2 was inferred using the total average daily flow from the final effluent discharge location from the WWTP. This flow was proportioned using the assumption 50% of flow goes to wetland 2, up to a maximum of 10 MLD, which is the maximum pumping capacity to wetland 2. Everything above and beyond that flows to wetland 1. Using the proportioned flow, mass discharge volumes were calculated.

Total nitrogen

Total nitrogen concentration has been monitored at both wetlands since November 2020, except for 2 additional samples collected from wetland 1 in 2015. On the other hand, ammonia concentrations have been monitored since 2015 onward at both locations. Using the ratio of ammonia to total nitrogen, the total nitrogen concentrations were inferred back to 2015 using the ammonia data. For each day where both ammonia and total nitrogen concentrations were recorded the ratio for ammonia to total nitrogen was calculated at wetland 1 and wetland 2. The average of these ratios was then taken, 0.13 at wetland 1 and 0.15 at wetland 2, and total nitrogen concentrations were back calculated for each day ammonia was recorded. This increased the total nitrogen data sets from approximately 25 data points to just over 300 data points, Figure E.1.

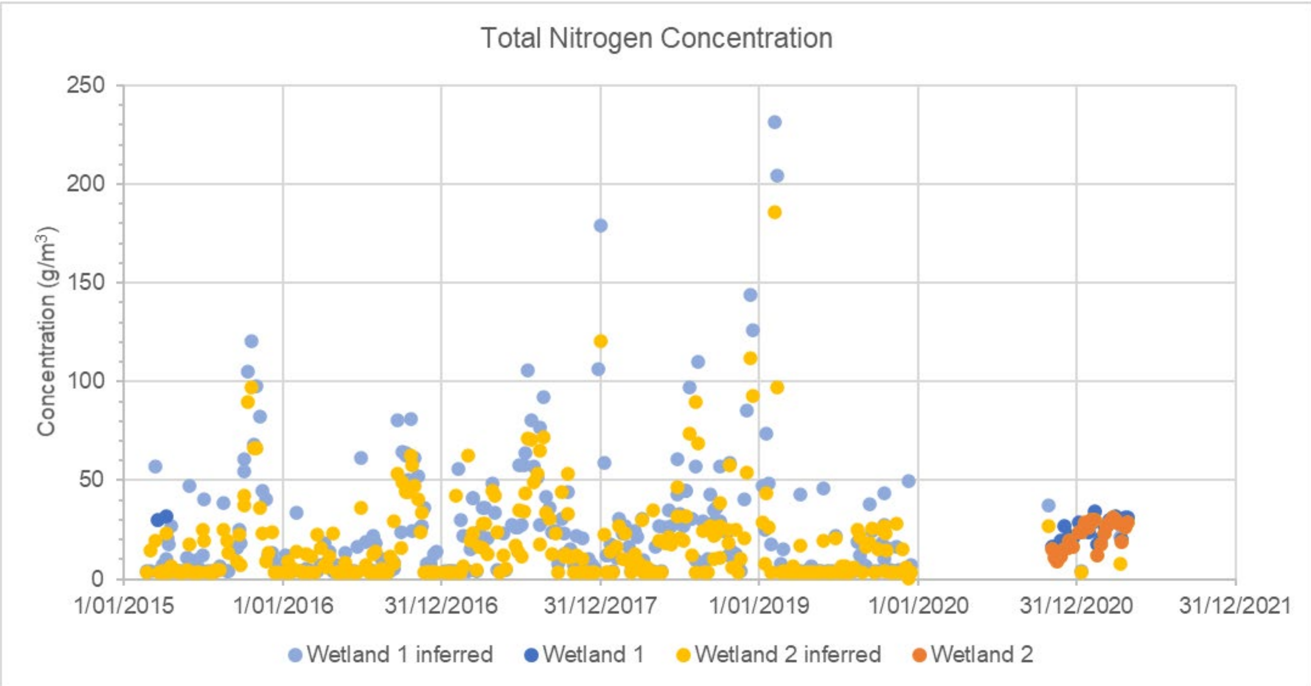

Figure E.1 Measured and inferred total nitrogen concentrations from wetland 1 and wetland 2.

Using the extended total nitrogen data sets and the proportioned flow data from the WWTP the mass was calculated for wetland 1 and 2. Due to uncertainties associated with the date of sample collection (not currently recorded), the gaps in the concentration data set and the inferred concentrations, extreme mass values were produced, ranging from 0 to >4900 kg/day, concluding this mass calculation approach is unfavorable for producing total nitrogen trigger levels.

As an alternative the inferred and measured total nitrogen concentrations were infilled to produce a continuous data set and plotted against flow, given there is more certainty associated with the total average daily flow data measured at the plant. The data set was infilled using the previously recorded concentration and then averaged over a rolling 7-day period. The concentration versus flow plot, Figure E.2, shows the concentrations. The concentrations have been broken up into two flow bands to address the differing range in discharge values: below 15,000 m^3/d and equal to or greater than 15,000 m^3/d.

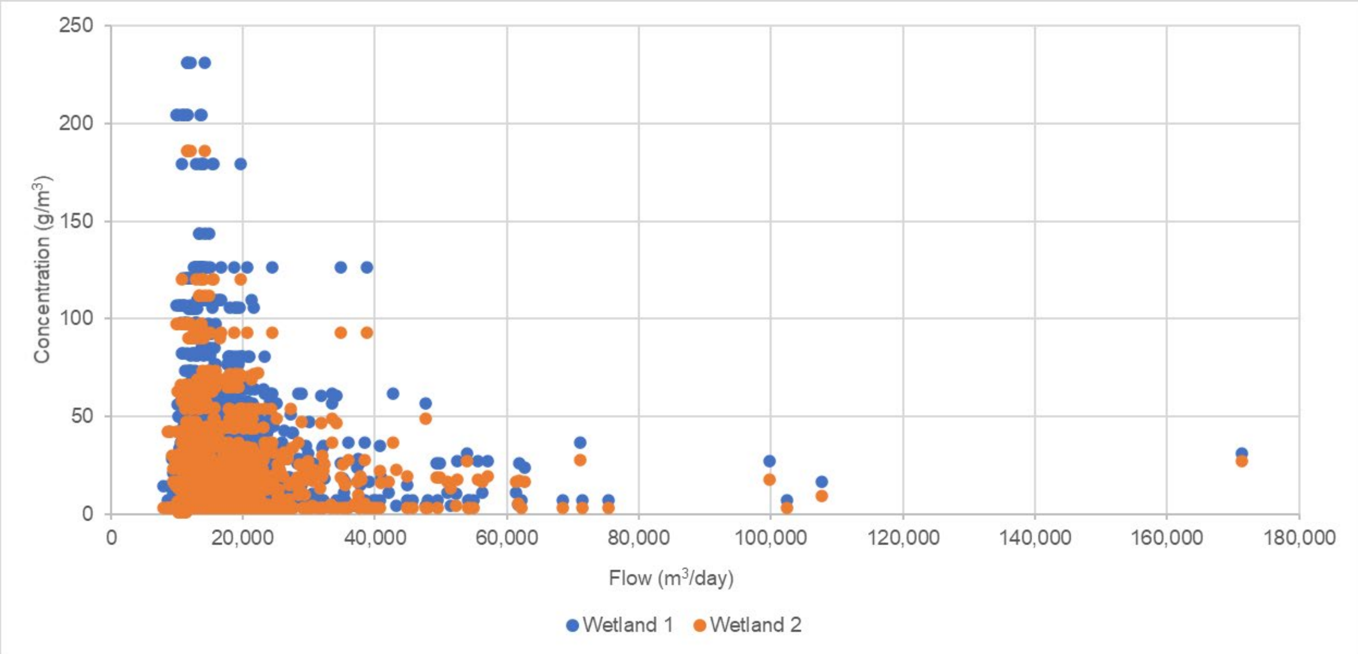

Figure E.2 Total nitrogen concentration of wetland 1 and wetland 2 plotted against flow, data from 2015 to April 2021.

Using these flow bands, the upper quartile of total nitrogen was calculated for each flow band from the wetlands data, Table E.1. Using the upper quartile concentration, the mass (kg/day) was calculated assuming the maximum of the flow band. It is proposed the calculated mass load for each flow band is applied as the preliminary adaptation trigger, for the time being. Once a better understanding of flow conditions and mass discharge from the wetlands is determined during the early part of the consent, it is recommended these values are revised.

Table E.5 Upper quartile total nitrogen concentration for 4 different flow bands.

Flow band (m^3/day)	Metric	Wetland TN effluent concentration(g/m^3)	Mass (kg/d) using max flow
<14,999	Upper quartile	24	360
> 15,000	Upper quartile	27	543*
** Using a flow rate of 20,000 m^3/day*			

Total phosphorous

Considering the limited total phosphorous concentration data, the existing total phosphorous concentrations for wetland 1 and wetland 2 were plotted against flow without any infilling of the data set, Figure E.3. From the available data there is no distinct grouping of concentrations against different volumes of flow, but there is a general decreasing in concentration trend with higher volumes of discharge. The upper quartile total phosphorous concentration from the wetlands was 5.3 g/m^3. Assuming a general maximum flow of 16,000 m^3/day, this would equate to a mass of 80 kg/day. Therefore, it is proposed a preliminary adaption trigger up to 80 kg/day of total phosphorous is applied until a better understanding of flow conditions and total phosphorous mass from the wetlands is determined, at which time, it is recommended this trigger value is revised.

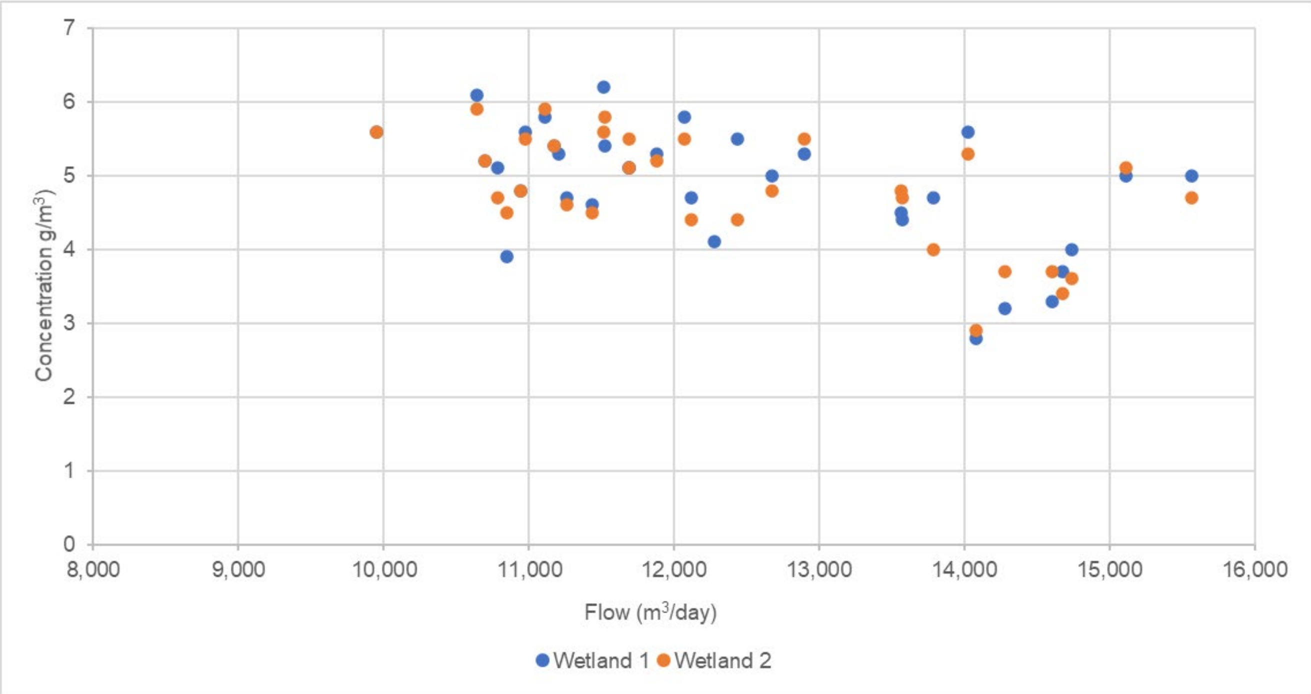

Figure E.3 Total phosphorous concentration of wetland 1 and wetland 2 plotted flow, data from 2015 to April 2021.

Total suspended sediment

Given the extent of total suspended sediment (TSS) data (from 2015 – 2021) the measured TSS concentrations were infilled to produce a continuous data set and plotted against flow, as per the above analysis, Figure E.4. The plot shows the concentrations can be broken up into three flow bands, less than 20,000 m^3/d, and > 20,0000 m^3/d. Using these flow bands, the upper quartile of TSS concentration is shown in Table E.2. Using the upper quartile concentration, the mass was calculated assuming the maximum of the flow band. It is proposed the calculated mass load for each flow band is applied as the preliminary adaptation trigger, for the time being. Once a better understanding of flow conditions and mass discharge from the wetlands is determined it is recommended these values are revised.

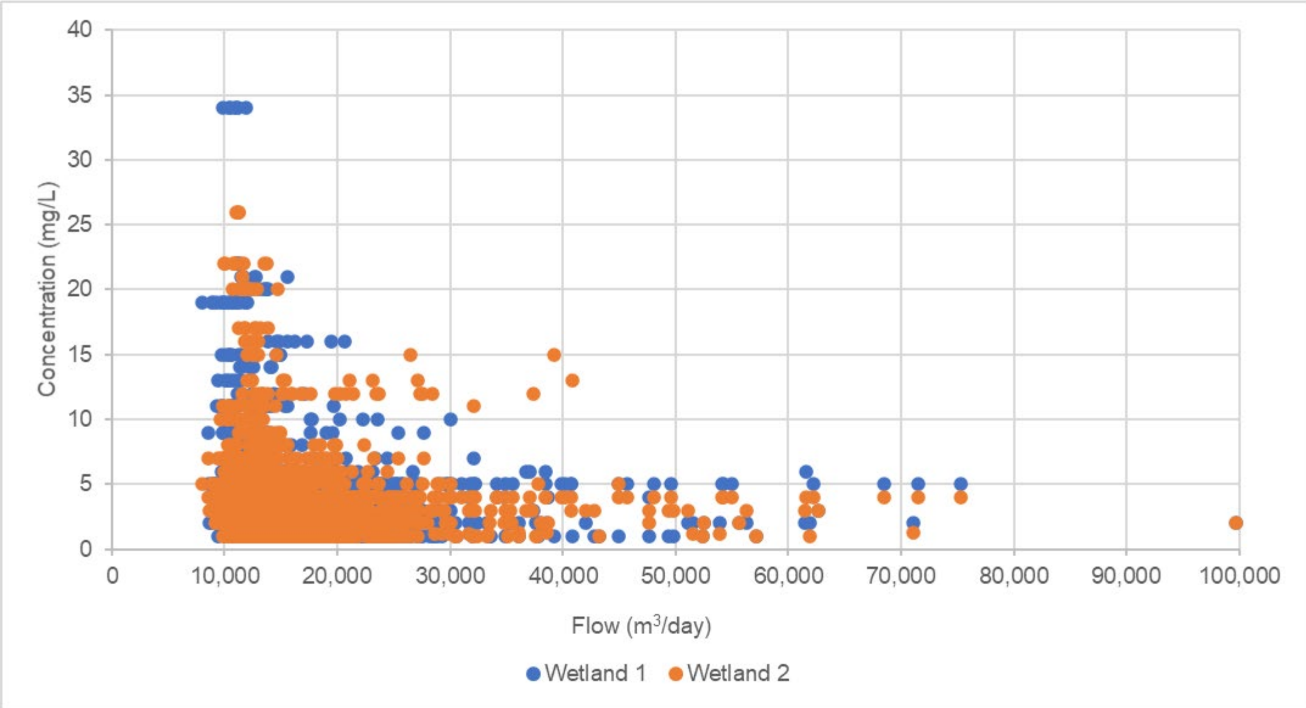

Figure E.4 Total suspended sediment (TSS) concentration of wetland 1 and wetland 2 plotted against flow, data from 2015 to April 202

Table E.6 Upper quartile total suspended sediment concentration for 3 different flow bands

Flow band (m^3/day)	Metric	Wetland TSS effluent concentration(g/m^3)	Mass (kg/d) using max flow
<19,999	Upper quartile	5	100
> 20,000	Upper quartile	4	350*
** Using a flow rate of 70,000 m³/day*			

Hātea River

It is proposed the Hātea River SoE monitoring location at Limeburners (Hāhā) Creek is used as a secondary adaption trigger location. Using the available Limeburners (Hāhā) Creek SoE monitoring data, from 2008 to 2020, detailed in Section 4.3.1, a review of the maximum concentrations during estimated low tide was carried out. During periods of low tide, or when the tide is out, close to being out, or has turned and is just starting to flow inland, constituent concentrations at the outlet of Limeburners (Hāhā) Creek are anticipated to be at their highest. Concentrations are anticipated to be high during low tide as the outward flow direction is expected to be carrying all discharges from the WWTP downstream and minimal mixing with marine water is occurring.

From a review of the data there was no clear relationship between the salinity values and the concentration of total nitrogen, total phosphorous, ammoniacal nitrogen, or nitrite-nitrate nitrogen. Conversely concentrations compared to depth from the boat showed a relationship between total phosphorous and ammoniacal nitrogen, with concentrations increasing as depth decreased. Depth measurements ranged from 0.3 m – 3.9 m. Therefore, assuming a halfway point of 2 m indicates the tide has turned and will be going out, the maximum value of each variable below 2 m was determined Table D.1.

Using these values preliminary trigger levels can be derived, Table D.1. The maximum total nitrogen concentration of 13 g/m^3, recorded in July 2020 (during flooding conditions), was considered an outlier with all other concentrations recorded below the next highest concentration 6.3 g/m^3. Considering this, a preliminary total nitrogen trigger level of 6.3 g/m^3 has been determined.

Table E.7 Limeburners (Hāhā) Creek SoE maximum concentration when depth (metres from the boat) is at or below 2 metres, and preliminary trigger levels.

Constituent (unit)	Maximum concentration (g/m^3)	Proposed compliance metric	Proposed trigger level (g/m^3)
Total nitrogen (g/m^3)	13.0	Maximum	6.3
Ammoniacal nitrogen (g/m^3)	2.4	Maximum	2.4
Nitrite-nitrate nitrogen (g/m^3)	4.1	Maximum	4.1
Total phosphorous (g/m^3)	1.0	Maximum	1.0
Total suspended sediment (g/m^3)	45	Maximum	45
Chlorophyll-a	0.011	Maximum	0.011

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