Pōrangahau Wastewater Treatment Plant Discharge Water Quality Assessment

Prepared for Central Hawkes Bay District Council
Prepared by Beca Limited
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Contents

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Action	Name	Signed	Date
Prepared by	Lucas Everitt Sarah Blair		22 February 2021
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on behalf of	Beca Limited		

Executive Summary

A water quality report was undertaken to assess the effects of the Pōrangahau Wastewater Treatment Plant (WWTP) discharge on the Pōrangahau River, Hawkes Bay. The Pōrangahau WWTP consists of a single oxidation pond with a baffle system. It discharges initially to a small farm drain before flowing into the Pōrangahau River approximately 600 m downstream of the Pōrangahau Township and about 10 km upstream of the river's discharge to the Pacific Ocean.

This investigation included a review of relevant historical reports related to the last consenting phase in 2009, analysis of measured water quality data and an assessment of the effects of continuation of the discharge for six years, in which time a land application treatment system would be planned, consented and constructed. Water quality data was assessed based on summary statistics from points upstream and downstream of the WWTP discharge as well as a mass-balance downstream prediction methodology.

The Pōrangahau River can be considered saline at the point of discharge, with upstream flow common on an incoming tide. Despite this recurring 'negative' flow, historic dye tracer studies have shown that discharge from the WWTP is generally downstream, even on the incoming tide (due to localised eddying effects). This highlights the general complexity of the river flow at the point of discharge; a function of tidal processes, the bathymetry of the riverbed and nearby structures that disrupt the river flow.

Measurable differences in both sediment quality and benthic biota communities have historically been noted between the point of discharge and further downstream. However, the difference between the two sites is considered to be related to the salinity gradient rather than the WWTP discharge.

Water quality monitoring carried out by Central Hawkes Bay District Council (CHBDC) upstream of the discharge point demonstrate that the Pōrangahau River has generally elevated nutrient concentrations. Water quality parameters with medians above ANZECC[1] physical and chemical (PC) stressor values for warm, dry low-elevation rivers include total phosphorus, dissolved reactive phosphorus, and total nitrogen.

Monthly water quality and flow data over the last five years was reviewed in this report. Total nitrogen, total phosphorus and dissolved reactive phosphorus were found to be in exceedance of their relevant ANZECC PC stressor guidelines upstream of the discharge point. Measured comparisons of median contaminant concentrations downstream of the WWTP discharge indicate an increase in faecal coliforms and total ammoniacal nitrogen to concentrations above their relevant guidelines.

Desktop mass-balance calculations allowed for a prediction of contaminant concentrations from the existing WWTP discharge under median and low-flow conditions. The discharge from the WWTP is predicted to cause a low effect linked to small increases for most of the nutrient and microbiological contaminant concentrations in the Pōrangahau River downstream of the discharge during median flow conditions.

At times of low river flows, the increase in faecal coliforms and ammoniacal nitrogen are predicted to exceed relevant guideline values (using desktop mass-balance predictions). This is predicted to result in moderate adverse effect on downstream faecal coliform and ammoniacal nitrogen water quality concentrations at times of low flow. The downstream ammoniacal nitrogen concentration remains well below relevant toxicity guideline values and only the PC guideline value is exceeded.

However, based on historical monitoring, the discharge does not appear to result in the formation of excessive plant, algae and slime growths in the Pōrangahau River relative to upstream. For faecal coliforms,

[1] Australian and New Zealand Environment and Conservation Council (ANZECC), 2018. *Australian and New Zealand Guidelines for Fresh and Marine Water*.

it is noted that recreational activities occur some distance downstream at the Bridge Rd bridge and that further dilution will occur between the point of discharge and these downstream recreational areas.

The effects associated with the continued discharge of treated wastewater (for up to six more years) to the Pōrangahau River are equivalent to the effects associated with the existing discharge, based on the following assumptions:

- No notable population increase for Pōrangahau over the next six years
- Existing average and maximum daily discharge flow rates will remain stable
- Climate change is not considered as an influencing factor due to the short time period

Overall, no significant adverse water quality effects are predicted to occur with the continued discharge of treated wastewater to the Pōrangahau River.

Recommendations from this report include the potential to:

- Undertake further assessment of the stormwater infiltration potential of the Pōrangahau WWTP system and develop measures to reduce infiltration and the associated likelihood of a heavy rainfall, non-compliance event.
- Further water quality monitoring during low river flow conditions for parameters of concern, including:
  - Flow rates
  - Enterococci
  - Faecal coliforms
  - E. Coli
- Additionally, a dye tracer release study could be undertaken at point of discharge in low flow conditions to better understand the discharge plume in low flow conditions and verify the mixing dynamics and plume movement.

1 Introduction

1.1 Background

Central Hawke's Bay District Council (CHBDC) holds resource consent to discharge treated wastewater from Pōrangahau Wastewater Treatment Plant (WWTP) to the Pōrangahau River. Resource consent for the discharge of treated wastewater was granted by the Hawke's Bay Regional Council (HBRC) in October 2009 and will expire on 31 May 2021.

The Pōrangahau WWTP services the community of Pōrangahau (approx. 97 households) and consists of a single oxidation pond. Discharge is to a small farm drain which flows into the Pōrangahau River 600 m downstream of Pōrangahau township and approximately 4 km upstream of the Beach Road Bridge. Historical reports indicate this stretch of river is dominated by tidal influences with generally low baseflow conditions.

A second WWTP services the settlement of Te Paerahi, predominantly a summer holiday destination. The Te Paerahi WWTP is a single oxidation pond with a baffle system. Treated wastewater from Te Paerahi WWTP is passed through a covered polishing area and effluent channel before being discharged land within the sand dunes. HBRC granted the resource consent for Te Paerahi WWTP on 14th of May 2012 (Consent No. DP030234) to discharge treated domestic wastewater from the Te Paerahi oxidation pond into or onto land. The consent expires 31 May 2021. Te Paerahi WWTP is located approximately 500 m north of the end of Te Paerahi Road, Pōrangahau Beach.

The Te Paerahi WWTP does not discharge directly into the Pōrangahau River. A separate report (Beca, 2021, P:D.60) assesses water quality effects associated with the Te Paerahi WWTP.

The current Pōrangahau WWTP consent has conditions relating to volume, organic load (BOD_5), suspended solids and pH. There are no conditions set for nutrient concentrations (nitrogen and phosphorus) or microbiological quality. Further conditions include regular monitoring of the WWTP discharge, as well as at downstream and upstream monitoring locations. The CHBDC produces an annual monitoring and compliance report that shows the Pōrangahau WWTP is compliant with the existing consent conditions with the exception of two ex-tropical cyclone events in 2017 that caused the WWTP to exceed its discharge volume limits.

Recent investigations have been made to identify a long list of treatment and discharge options. The findings are detailed in the 'Te Paerahi and Pōrangahau Options Report' (2020) prepared by Beca. Engagement work undertaken by CHBDC indicates a clear community preference for land treatment of wastewater. CHBDC is currently working through the options assessment process and staging considerations for a land treatment scheme. This will take some time to work through and for these reasons, CHBDC seeks to continue the existing discharge for up to six years whilst the new discharge scheme is conceptualised, consented, designed, constructed and commissioned. This report therefore also assesses the effects of continuing the existing discharge in the transition period, for a period of up to six years.

1.2 Purpose of this Report

This report is set out in the following sections:

- A description of the receiving environment of the Pōrangahau River;
- A review of background information on the Pōrangahau WWTP including investigations undertaken for the previous consent;
- A review of existing water quality data from HBRC to assess the current state of the receiving environment of the Pōrangahau River;

- A review of existing WWTP treated wastewater data and CHBDC water quality monitoring results from the Pōrangahau River;
- An assessment of effects of the existing discharge on the water quality of the Pōrangahau River;
- An assessment of effects of the continuation of the existing discharge for up to six years; and
- Commentary on monitoring and mitigation options for the continuation of the existing discharge.

2 Description of the Environment

2.1 Catchment Overview

The Pōrangahau River catchment is approximately 705 km^2 and located in the south-eastern corner of the Hawke's Bay Region (Figure 1)[2]. The Pōrangahau River is known locally to Māori as the Tāurekaitai River[3]. The catchment is constrained by a series of low hill country (~400 m above sea level) and stretches inland from the coast to Flemington, north to Blackhead Beach and south to the Hawke's Bay – Manawatu-Wanganui Regional boundary.

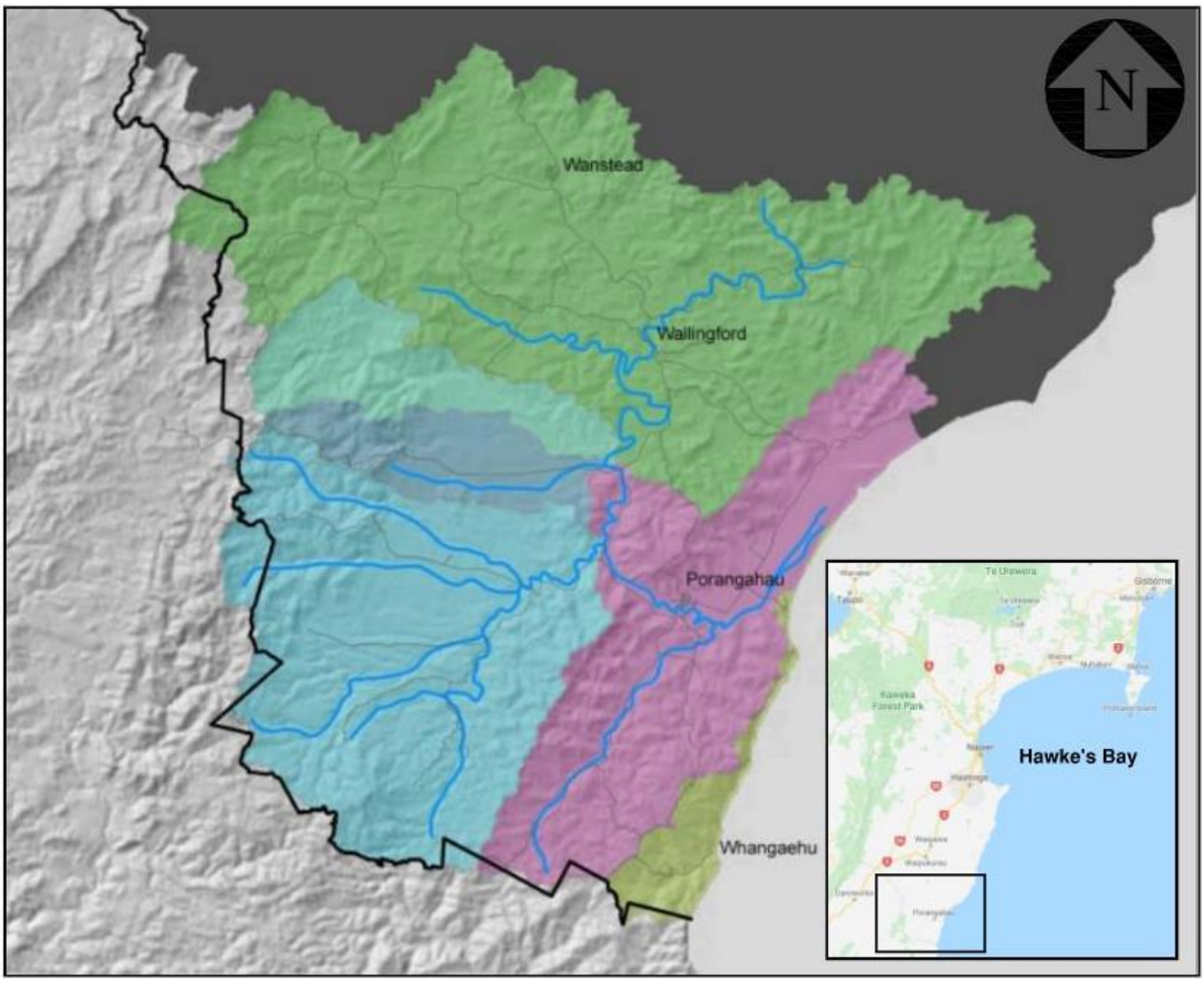

Figure 1. Pōrangahau River catchment zone and sub-catchments[4]. Inset - Location of catchment in Hawke's Bay Region.

Land use in the Pōrangahau River catchment is predominantly sheep and beef farming. A small amount of forestry, deer, cropping and one vineyard are also present in the catchment[2].

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[2] Taylor D. & Strang T, (2009). *Porangahau Township Oxidation Pond Discharge Mixing Study*. Opus.

[3] Hawke's Bay Regional Council. *Outstanding Water Bodies Assessment - Pōrangahau River*. https://www.hbrc.govt.nz/assets/Document-Library/Outstanding-Water-Bodies/3.-Secondary-Assessments/Porangahau-River.pdf

[4] Reed C. & Ide G. (2012). *Hawke's Bay Catchment Zone Profiles*. Hawke's Bay Regional Council Strategic Development Group. SD 12/08. HBRC Plan No. 4337

Pōrangahau is the largest town in the catchment, with a population just under 200 permanent residents according to the 2013 census[5]. The area experiences a significant influx of summer residents, particularly at Te Paerahi Beach which sits on the coast directly south of the Pōrangahau River mouth.

The Pōrangahau WWTP consists of a single oxidation pond approximately 600 m south-east of the Pōrangahau township. It discharges treated wastewater to the Pōrangahau River adjacent to the pond. Wastewater generated by the Te Paerahi settlement is treated by the Te Paerahi WWTP that discharges to land north-east of the settlement (Figure 2).

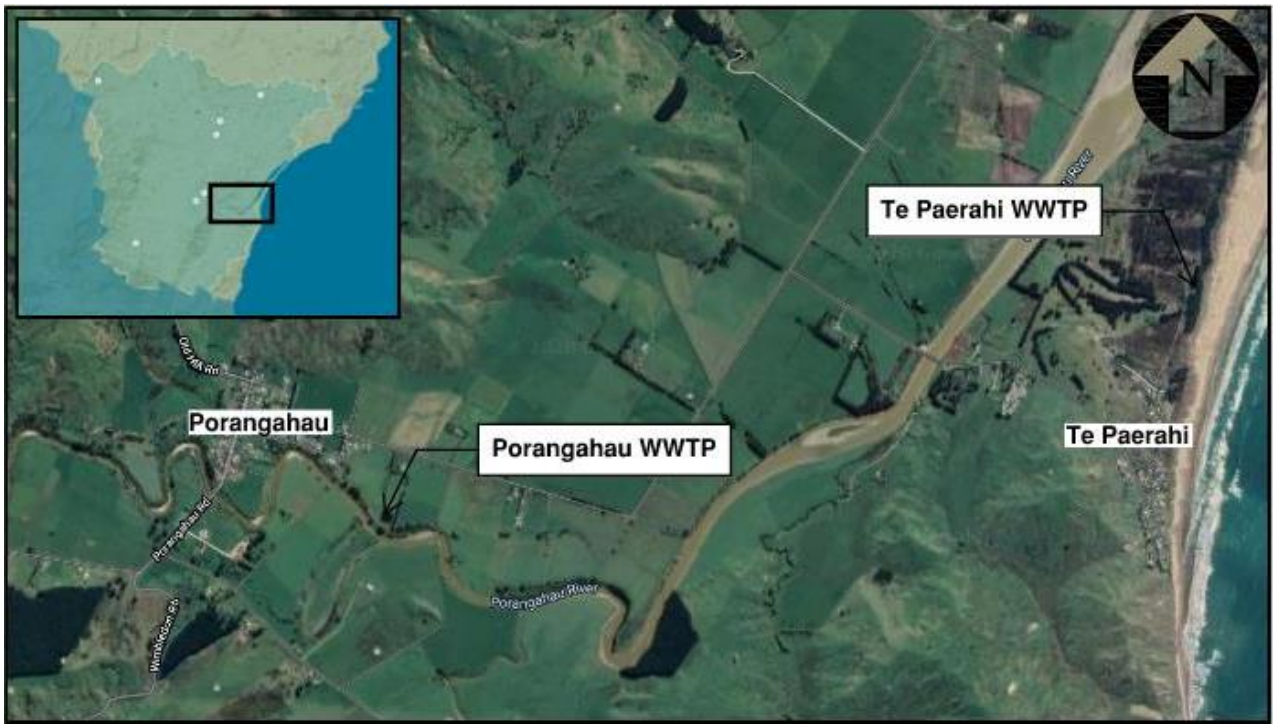

Figure 2. Location of WWTP that service Pōrangahau and Te Paerahi settlements. Inset – Pōrangahau River catchment.

2.1.1 Climate

The climate in Central Hawke's Bay is significantly influenced by the mountain ranges to the west. The ranges provide a sheltering effect from the predominantly westerly winds, which affect the climate patterns in New Zealand. This results in a temperate climate with lower than average rainfall. In summer, droughts are not uncommon, and this has a significant influence on the waterways in Central Hawke's Bay[6].

The climate at Pōrangahau is influenced by the coast and the hills behind and can result in higher intensity rainfall patterns than other parts of Central Hawke's Bay. Rainfall in the eastern hill country is moderate with typically 1200mm per year in the lower areas to over 2200mm in the higher country. The catchment is prone to prolonged summer dry spells[4].

2.1.2 Geology and soils

The Pōrangahau River catchment is underlain by predominantly soft marine sedimentary rocks from the Palliser (lower) and Mangatu (Wanstead Formation) Groups. These are characterised by interbedded graded sandstone and mudstone, massive concretionary mudstone and massive sandstone. These basement rocks are overtopped by early quaternary alluvium and colluvium that makes up the moderate hill country in the

[5] Stats NZ (2018) 2013 Census Data - http://archive.stats.govt.nz/Census/2013-census.aspx#gsc.tab=0

[6] Staff R. (2007) Porangahau Wastewater Treatment and Disposal Resource Consent Application – Assessment of Environmental Effects. Opus.

upper reaches of the catchment[7]. Soils are generally fertile, but erosion prone. There are areas of low elevation flat land, including alluvial terraces[2].

2.2 Pōrangahau River

2.2.1 Sensitivity of the Pōrangahau River Receiving Environment

Identified water quality issues for the Pōrangahau River – upstream of WWTP discharge – include poor visual clarity, elevated bacterial levels nutrient enrichment, periphyton growths, impairment of macroinvertebrate community health and poor bacteriological quality[2]. These issues, identified from data prior to 2012, are noted to be a function of diffuse agricultural runoff being the major contributor of dissolved nutrients and bacterial contamination[4].

The Pōrangahau River has been previously classified as a "phosphorus limited" environment, such that there is more nitrogen (N) present than can be used. Consequently, the addition of more soluble phosphorus (P) will tend to stimulate weed (macrophyte) growth when river flow and temperature conditions are favourable to it.

2.2.2 Hydrology

The flow in the Pōrangahau River is subject to extremes. HBRC monitor flow conditions at Saleyards Bridge, approximately 6 km upstream of WWTP discharge. The median flow is 1.312 m^3/s, the highest flow recorded is 456 m^3/s and low flows of nil are not uncommon. Very low flows are recorded in summer, with flows of less than 0.1 m^3/s common[8]. Table 1 gives some statistics based on HBRC flow monitoring of the Pōrangahau River at Saleyards Bridge.

Table 1. Flow (m^3/s) in the Pōrangahau River at Saleyards Bridge

			% of time flow is less than				
Min	Max	Mean	5%	25%	Median	75%	95%
0.01	455.79	7.25	0.02	0.21	1.31	4.79	21.16

The section of the Pōrangahau River around the WWTP discharge is strongly influenced by the tides with a measured difference between high and low tide of approximately 0.5 m[9]. This tidal influence is stronger during late summer when the contributing flows from the river catchment can decrease below 100 L/s. The tidal interchange of water in this section of the river is therefore more significant in the context of the wastewater discharge than the base river flow. The river is considered typically saline at the point of discharge under background, low flow conditions[2].

2.2.3 River Water Quality

HBRC monitor water quality at the Kate's Quarry location, approximately 5.6 km upstream of the discharge point. CHBDC also monitor at this location as well as 200 m upstream and 200 m downstream of the WWTP discharge as required under the conditions of the current consent (Figure 3).

[7] Heron D. W. (custodian) (2014) *Geological Map of New Zealand 1:250 000*. Institute of Geological & Nuclear Sciences

[8] Hawke's Bay Regional Council (2020) *River Levels and Flows* - https://www.hbrc.govt.nz/environment/river-levels/

[9] Hamill K. (2012) *Porangahau River Estuary Ecological Investigation, April 2012.* Opus.

Figure 3. HBRC and CHBDC Water quality monitoring locations along the lower Pōrangahau River. Pōrangahau WWTP is shown as red square.

A summary of recent water quality results for the Pōrangahau River at the Kate's Quarry monitoring location, upstream of the WWTP discharge, is presented in Table 2.

Table 2. HBRC Water quality monitoring results from Kate's Quarry (5.6km upstream of discharge point). Approx. 60 samples taken monthly between 2014 and 2019.

Parameter[1]	5%	Median	95%	Stressor[3]	Trigger
pH	7.63	8.1	8.32	7.27 – 7.8	
E.coli (cfu/100ml)	27	150	3500	261-550[4]	>550[5]
Faecal Coliforms (cfu/100ml)	23.5	165	**5195**	200[6]	
Total Phosphorus (mg/L)	0.0039	0.019	0.138	0.023	
Dissolved Reactive Phosphorus (mg/L)	0.0005	0.005	0.043	0.007	
Nitrate Nitrogen (mg/L)	0.00212	0.107	0.597	0.195	2.4[7] / 3.5[8]
Total Nitrogen (mg/L)	0.23	0.39	1.352	0.281	
Total Ammoniacal Nitrogen (mg/L)	0.003	0.003	0.033	0.017	0.24[7]
Suspended Solids (mg/L)	0.5	4.7	220	300[6]	
$cBOD_5$ (mg/L)	0.50	0.5	3.00		
Dissolved Oxygen (ppm)[2]	5.622	9.64	12.086	80%[6]	

Note: Orange highlight indicates the ANZECC chemical and physical stressor trigger[3] MAC Grade C[4] are exceeded, red highlight indicates the ANZECC toxicity trigger[3], MAC Grade D[5] or the national bottom line guidelines[7,8] are exceeded and **bold text** indicates the regional river guidelines are exceeded[6].

[1] Data is from HBRC dataset (July 2014-June 2019) unless otherwise stated.

[2] Data is from CHBDC dataset (July 2014-June 2019).

[3] All parameters are ANZECC (REC) default guideline values (DGVs) for physical and chemical (PC) stressor values for Warm Dry Low-elevation classification, except where otherwise stated

[4] MfE Microbiological Assessment Category for Freshwater Grade C

[5] MfE Microbiological Assessment Category for Freshwater Grade D

[6] Hawke's Bay Regional Resource Management Plan (republished as at 1 October 2015). Note that the faecal coliform surface water guideline value represents the concentration of contaminant in the water body that should not be exceeded after reasonable mixing

[7] National Policy Statement for Freshwater Management (NPS-FM) – Attribute State B, 95% species protection level (annual median)

A summary of recent water quality results for the Pōrangahau River 200 m upstream of the WWTP discharge is presented in Table 3. Samples are taken on the outflow tide and can therefore be assumed background conditions with no influence from the WWTP.

Table 3. CHBDC Water quality monitoring results from 200 m upstream of discharge point. Approx. 60 samples taken monthly between 2014 and 2019.

Parameter1	5%	Median	95%	Stressor[3]	Trigger
pH	7.63	8.1	8.32	7.27 – 7.8	
E.coli (CFU/100ml)	2	108	2218	261-550[4]	>550[5]
Faecal Coliforms (CFU/100ml)	4.4	120	**2380**	200[6]	
Enterococci (enterococci/100ml)	2.6	44	405	201-500[4]	>500[5]
Total Phosphorus (mg/L)	0.024	0.055	0.161	0.023	
Dissolved Reactive Phosphorus (mg/L)	0.003	0.023	0.055	0.007	
Nitrate Nitrogen + Nitrite Nitrogen (mg/L)	0.005	0.005	0.339	0.195	2.4[7] / 3.5[8]
Total Nitrogen (mg/L)	0.41	0.66	4.22	0.281	
Total Ammoniacal Nitrogen (mg/L)	0.005	0.005	0.04	0.017	0.24[7]
Suspended Solids (mg/L)	3	31	168	300[6]	
$cBOD_5$ (mg/L)	0.5	1	3		
Dissolved Oxygen (ppm)	7.54	9.16	11.63	80%[6]	

Note: Orange highlight indicates the ANZECC chemical and physical stressor trigger[3] MAC Grade C[4] are exceeded, red highlight indicates the ANZECC toxicity trigger[9], MAC Grade D[5] or the national bottom line guidelines[7,8] are exceeded and **bold text** indicates the regional river guidelines are exceeded[6].

[1] Data is from CHBDC dataset (July 2014-June 2019).

[2] Data is from HBRC dataset (July 2014-June 2019) unless otherwise stated.

[3] All parameters are ANZECC (REC) default guideline values (DGVs) for physical and chemical (PC) stressor values for Warm Dry Low-elevation classification, except where otherwise stated

[4] MfE Microbiological Assessment Category for Freshwater Grade C

[5] MfE Microbiological Assessment Category for Freshwater Grade D

[6] Hawke's Bay Regional Resource Management Plan (republished as at 1 October 2015). Note that the faecal coliform surface water guideline value represents the concentration of contaminant in the water body that should not be exceeded after reasonable mixing.

[7] National Policy Statement for Freshwater Management (NPS-FM) – Attribute State B, 95% species protection level (annual median)

[8] National Policy Statement for Freshwater Management (NPS-FM) – Attribute State B, 95% species protection level (annual maximum)

This water quality summary indicates that the Pōrangahau River is nutrient enriched and that water quality worsens slightly the further downstream (between the Kate's Quarry and upstream sites). The median values of Total Phosphorus (TP), Dissolved Reactive Phosphorus (DRP) and Total Nitrogen (TN) at the 200 m upstream site are above their respective ANZECC trigger values which indicates a consistent contribution of these nutrients exists in the upstream catchment. Diffuse agricultural runoff is assumed to be the major contributor of dissolved nutrients and bacterial contamination.

Elevated bacteria levels (*E.Coli* and faecal coliforms) upstream of the discharge appear to be a significant issue, however both parameters reduce further downstream. The bacteria concentrations only exceed trigger values at the 95th percentile of the datasets; this infers that higher bacterial concentrations are related to higher river flow events. As such it is likely the concentrations of *E.coli* and faecal coliforms (FC) are below trigger values for most of the time (this can be seen in the lower median values).

2.2.4 National Policy Statement for Freshwater Management

A new National Policy Statement for Freshwater Management (NPS:FM) was brought into effect on 3 September 2020. The main objective (OBJ2.1(1)) of the new NPS:FM (2020) states:

- The objective of this National Policy Statement is to ensure that natural and physical resources are managed in a way that prioritises:
  - First, the health and well-being of water bodies and freshwater ecosystems;
  - Second, the health needs of people (such as drinking water);

- Third, the ability of people and communities to provide for their social, economic, and cultural well-being, now and in the future.

HBRC are implementing the NPS:FM through a series of plan changes to their Regional Resource Management Plan on a catchment by catchment basis. This includes implementing the National Objectives Framework (NOF) by identifying values, and setting environmental outcomes and target attribute states, for freshwater management units within each catchment. The Pōrangahau catchment has not been subject to a plan change yet, with proposed timeframes for the proposed plan change estimated no later than 2024[10].

An HBRC report[11] addressing the state and trends in river water quality and ecology in the Pōrangahau catchment was prepared in 2016 using monitoring data collected during the 2004 – 2013 period as part of regular State of the Environment monitoring. Data from the Kate's Quarry monitoring site was compared to the now superseded NPS:FM 2014 attribute states and found that E.coli, nitrate (toxicity), and ammonia (toxicity) were within mainly the 'A' attribute state (good water quality).

However, an assessment of the baseline water quality of the Pōrangahau River against the NPS:FM 2020 attribute states, based on more recent available water quality data, is set out below. The five-year medians and 95th percentiles, measured at the 200m upstream monitoring location (Figure 3), are compared against the NPS:FM 2020 attribute states in Table 20. It is apparent from this assessment that the Pōrangahau River should be classified as a 'degraded water body' as it does not meet the NPS:FM national bottom line standards for microbiological contaminants (*E. coli*) and dissolved reactive phosphorus.

Table 4. Attribute Band classification of parameters measured 200 m upstream of the discharge.

Parameter	Median	Band	95%	Band	Overall Band
E.coli (CFU/100ml) [1]	96	A	1644	D	D
Dissolved Reactive Phosphorus (mg/L) [2]	0.023	D	0.055	D	D
Nitrate Nitrogen + Nitrite Nitrogen (mg/L) [3]	0.005	A	0.339	A	A
Total Ammoniacal Nitrogen (mg/L) [4]	0.005	A	0.04	A	A

Note - Attribute Bands are assessed against the National Policy Statement for Freshwater Management (NPS-FM 2020) – Attribute States Annual Median and Annual Maximum (95%). The lower band of the Median and 95th percentile dictates the Overall Band for that parameter.
[1] Values assessed against NPS:FM (2020), Appendix 2A, Table 9 – *Escherichia coli (E. coli)*
[2] Values assessed against NPS:FM (2020), Appendix 2B, Table 20 – Dissolved Reactive Phosphorus
[3] Values assessed against NPS:FM (2020), Appendix 2A, Table 6 – Nitrate (Toxicity)
[4] Values assessed against NPS:FM (2020), Appendix 2A, Table 5 – Ammonia (Toxicity)

2.2.5 Stream Ecology

Previous investigations have classified water quality adjacent to and upstream of the WWTP discharge as generally poor, with an MCI score of 80[4]. This is indicative of habitat of low quality for freshwater macro-invertebrates. The degradation was attributed to the soft and silty tidally influenced riverbed rather than pollution effects. In fact, an improvement in MCI score was observed downstream of the WWTP discharge (MCI - 92), which led to the conclusion that the ecology of the river is not adversely affected by the WWTP discharge. Despite this, the estuarine waters downstream of the WWTP discharge (approximately 4km) have been classified as "good" to "very good" based on the estuarine biotic indicators[7].

[10] HBRC, 2018. Minutes from the Meeting of the Regional Planning Committee, Wednesday 31 October 2018.

[11] HBRC, 2016. *Porangahau and Southern Coastal Catchments – State and Trends of River Water Quality and Ecology.* HBRC Report No. RM16-07-4786.

2.2.6 Proposed Plan Change 7 – Outstanding Water Bodies

The Pōrangahau River and Estuary have been designated as outstanding water bodies (OWB) by HBRC under Proposed Plan Change 7 (PPC7, also; Outstanding Water Bodies Plan Change). PPC7 aims to provide a framework which prescribes a high level of protection for these water bodies in future plan making.

> *"The water bodies identified in the Outstanding Water Bodies Plan Change are the 'best of the best' within the region, featuring an exceptional cultural, spiritual, recreation, natural character, landscape geology, or ecology value which is remarkable in Hawke's Bay."*[12]

The Pōrangahau River and Estuary were identified as outstanding natural water bodies due to their ecological, significant landscape, cultural and spiritual values. In general, the Pōrangahau River is culturally significant for the people of Heretaunga Tamatea and in particular, Ngati Kere.

The Pōrangahau Estuary, approximately 8 km downstream of the Pōrangahau WWTP discharge, and river were important pre-European settlements. Rich in archaeological sites, the area provided the first authenticated records of moa hunter occupation in the North Island. Vast shell middens are situated in the dune systems, and pa sites occur at either end of the estuary. At various times the people of Pōrangahau built and occupied at least 19 pa.

The Pōrangahau Estuary is listed as an Area of Significant Conservation Value by Hawke's Bay Regional Council. This also identifies significant cultural values around mahinga kai sites and states that 20 fishing sites existed between Pōrangahau township and the sea.

2.2.7 Ngati Kere interests and expectations for the rohe moana (coastal area)

A report[13], undertaken by the Ngati Kere community research and review teams, the Department of Conservation and the Ministry for the Environment, presents a commentary on modern management systems in the coastal area and their alignment to historical Maori management systems and applies to the coastal environment in the Pōrangahau estuary and beach.

Ngāti Kere, a recognised hapū within Central Hawke's Bay, of which Pōrangahau is the main township where descendants of Keretipiwhakairo (Kere) still reside. The depletion of important species was noted to be of great concern to Ngati Kere. Mana for the hapū is maintained in the ability to share in the abundance of kaimoana. Excessive takes and wastage are considered to be causing significant impacts on the natural ecosystem, as are coastal developments such as subdivision and housing, within the Ngati Kere Rohe.

Greater responsibility for monitoring indicator species by Ngati Kere hapū was emphasised in the report, with the overall aim to formulate a transparent decision-making process that can be actively and consistently practiced by everybody in order to sustain te Mauri o Ngati Kere.

The report concludes that through monitoring, communities are able to take greater responsibility for stewardship of their local environment while enhancing their capacity to contribute more effectively to management of coastal eco-systems. By achieving goals, communities can develop a sense of ownership that will be rewarding to all and to future generations. The vision of Ngāti Kere members is that the kaimoana as known now, and as has been known to be, is readily available for future generations in abundance, along with access to traditional fishing grounds and places of gathering.

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[12] HBRC (2021) *About Outstanding Water Bodies – Plan Change 7*. URL: https://www.hbrc.govt.nz/hawkes-bay/projects/outstanding-water-bodies/

[13] Wakefield, A. and Walker, L (2005). *Maori methods and indicators for marine protection – Ngati Kere interests and expectations for the rohe moana*. Prepared for Ngati Kere, Department of Conservation and Ministry for the Environment.

2.2.8 Recreational use

There are several known recreational uses of the Pōrangahau River downstream from the Pōrangahau WWTP that have been identified as a result of feedback from the community obtained during engagement sessions on recreational areas (as shown in Figure 4), including:

- Boat access and swimming near the Beach Road bridge;
- Fishing and whitebaiting approximately 0.5km upstream of the bridge;
- Shellfish gathering in the Pōrangahau estuary.

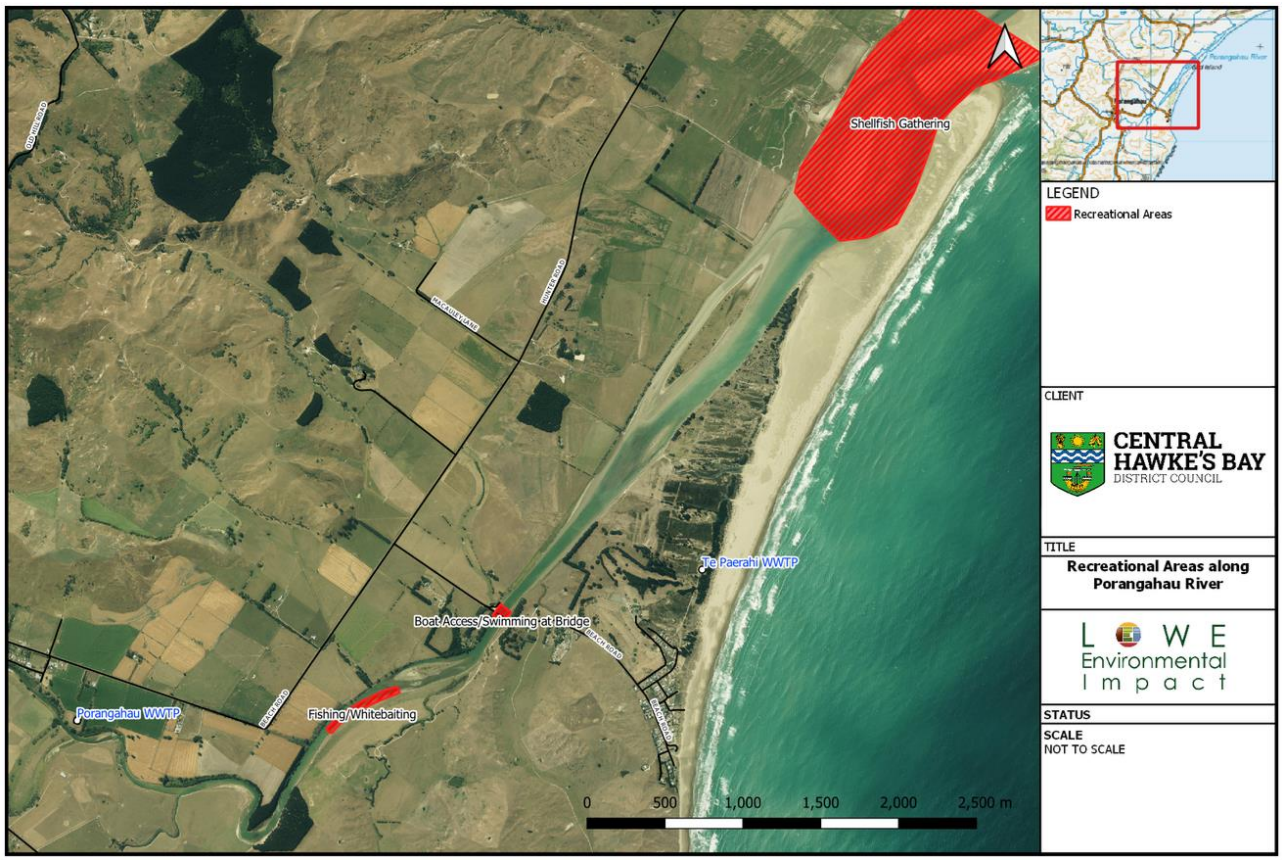

Figure 4. Known recreational uses of the Pōrangahau River downstream from the Pōrangahau WWTP (source: Lowe Environmental Impact, 2021).

2.3 Existing Wastewater Treatment System

2.3.1 Site Location

The Pōrangahau Township wastewater system is located approximately 250 metres from the end of Jones Street, around 50 metres from the Pōrangahau River (Figure 5). The adjoining land use is predominantly pastoral. It discharges through a strainer basket to a gravel filter into a farm drain which discharges to a tidally influenced reach of the Pōrangahau River.

Figure 5. Pōrangahau WWTP location (arial picture taken from Google Maps)

The system consists of a single oxidation pond approximately 0.3 ha in size. The WWTP services 96 properties with an estimated population of 270 contributing to the sewerage scheme. The wastewater received at the WWTP is predominantly of domestic origin. There are no significant trade waste discharges identified in the Pōrangahau Township.

2.3.2 Relevant Consent Limit Conditions

In accordance with the provisions of the Resource Management Act 1991 (RMA), and subject to its conditions, the Hawke's Bay Regional Council granted the resource consent on the 22nd of October 2009 (Consent No. DP030233W) for CHBDC to discharge treated domestic wastewater from the Pōrangahau oxidation pond into or onto the land (via soakage) in circumstances where that contaminant may enter water.

Details of the resource consent:

- Effluent to be discharge – Treated domestic
- Rate of discharge – the average daily volume does not exceed 130 m^3/day for more than 50% of the time nor 415 m^3/day for more than 5% of the time over any 12 months period
- Consent duration – expires 31 May 2021

The discharge consent outlines the following conditions:

- General – outlines the physical works to be undertaken on the plant
- Performance – the following treated wastewater quality parameters Table 5 apply over any 12-month period:

Table 5. Pōrangahau WWTP discharge consent conditions

Parameter	50th Percentile	90th/95th Percentile
Average daily flow (ADF)	130 m^3/day	415 m^3/day – 95th
Instantaneous flow	1.5 L/sec	4.8 L/sec – 95th
Carbonaceous Biochemical Oxygen Demand – 5 day ($cBOD_5$)	30 mg/L	60 mg/L 90th
Total Suspended Solids (TSS)	50 mg/L	90 mg/L 90th
pH	6.5 – 9	

The 50th percentile standards above are deemed to be breached if more than 16 samples taken over any 12-month period exceeded the consent condition values. The 90th percentile standards are deemed to be breached if more than 5 samples are taken over any 12-month period exceed the values. pH is deemed to be breached if any sample taken is outside of the range.

2.3.3 Current System Performance

Flows from the system are monitored by CHBDC as part of the current consent conditions. The 'Te Paerahi and Pōrangahau Options Report (Beca, 2020) provides a full summary over the last nine years of consistent compliance for the Pōrangahau WWTP across all consent conditions.

The median flow, recorded daily between July 2014 and June 2019, was 94 m^3/day with a range of 0 m^3/day to 1700 m^3/day. Typical flow rates are given in Table 6.

Table 6. Pōrangahau WWTP discharge (m^3/day) from outlet[14]

			% of time flow is less than				
Min	Max	Mean	5%	25%	Median	75%	95%
0.00	1710.7	138.3	32.8	51.3	94.0	161.0	367.9

Treated wastewater quality monitoring of the WWTP discharge is presented in Table 7. Treated wastewater quality samples are collected once every two weeks. The consent conditions require monitoring for $cBOD_5$, TSS and pH. CHBDC monitor these parameters along with a full suite of other water quality parameters. The parameter concentrations presented below represent the discharge prior to discharge to the Pōrangahau River.

[14] CHBDC, (2020). Porangahau DP030233W – Quality Monitoring and Wastewater Outflow Charts

Table 7. Treated wastewater quality monitoring results of the Pōrangahau WWTP discharge: July 2014 to June 2019[8].

Parameter	5%	Median	95%
pH	7.4	7.8	8.6
E.coli (cfu/100ml)	48.5	2150	38,800
Faecal Coliforms (cfu/100ml)	310	7,000	101,500
Total Phosphorus (mg/L)	1.0	1.9	3.2
Dissolved Reactive Phosphorus (mg/L)	0.5	1.3	2.3
Total Nitrogen (mg/L)	7.9	12.7	19.9
Total Ammoniacal Nitrogen (mg/L)	2.3	7.3	14.7
Suspended Solids (mg/L)	3	29	91
$cBOD_5$ (mg/L)	3	18	41
Dissolved Oxygen (ppm)	0.3	2.8	10.6

The consent compliance data for 2018-2019 (July) is summarised in Table 8 below:

Table 8. Pōrangahau Discharge consent compliance for the year July 2018 to June 2019.

Parameter	Consent Value	Permitted Exceedance	Actual Exceedance	Maximum Value	Compliance
Instantaneous flow (L/sec)					
50th percentile	<1.5	<50% time	0 or 28.97%	-	Yes
90th percentile	<4.8	<5% time	0 or 1.71%		
ADF (m^3/day)					
50th percentile	<130	<50% time	136 d or 37%	-	Yes
90th percentile	<415	<5% time	9 d or 2.4%		
Unfiltered $cBOD_5$ (mg/L)				52	
50th percentile	<30	<16/26	8/26		Yes
90th percentile	<60	<5/26	0/26		
TSS (mg/L)				126	
50th percentile	<50	<16/26	7/26		Yes
90th percentile	<90	<5/26	4/26		
pH	6.5-9	0/26	0/26	7.4-8.8	Yes

Over the past 12-month period Pōrangahau WWTP met all discharge conditions. Over the nine-year period that data has been provided for, $cBOD_5$, TSS concentrations and pH have not breached the consent compliance limits. With respect to the discharge limit conditions, the ADF 90th percentile limit (415 m^3/day) was exceeded and non-compliant for the 2017/18 hydrological year. This exceedance was due to large volumes of rainfall during winter and spring, including two ex-tropical-cyclone events.

2.4 Summary

The Pōrangahau River drains a catchment of approximately 705 km^2 in the south-eastern corner of Hawkes Bay. The catchment is mostly low-lying hills that flatten to pasture near the ocean. Pastoral agricultural land uses are present in the catchment with sheep and beef farming prevalent.

The climate in the area is warm and dry, prone to long dry spells in the summer as well as heavy rainfall events in the winter. The Pōrangahau River reflects this by having a generally low baseflow and a flashy response to rainfall events.

The Pōrangahau River, upstream of the WWTP discharge, has consistently elevated levels of nutrients (nitrogen and phosphorus) while microbial contaminants (*E.coli* and Faecal coliforms) occasionally exceed trigger values.

The Pōrangahau WWTP discharge is at a point of largely saline waters and has discharge conditions based on flow volumes, $cBOD_5$, TSS and pH. The discharge over the last decade has been compliant with all conditions except the average daily flow 90th percentile limits (>415 m^3/day <5% of the year) throughout 2017 and 2018.

3 Historic Resource Consent Application Documents

A number of investigations exist that relate to the discharge of treated wastewater to the Pōrangahau River. These investigations were undertaken to support the application of the current consent, granted in 2013. The documents reviewed for this report include:

- Pōrangahau Wastewater Treatment and Disposal Resource Consent Application – Assessment of Environmental Effects (2007) by Opus;
- Pōrangahau Township Oxidation Pond Discharge Mixing Study (2009) by Opus;
- Pōrangahau WWTP resource consent hearing: statement of evidence by Murray Grant Webby (2009);
- Pōrangahau River Estuary Ecological Investigation (2012) by Opus.

Each of these reports is briefly summarised below and referred to as footnote references throughout the rest of this document where applicable. The 2009 Mixing Study and the 2012 Estuary Ecological Investigation are provided in Appendices A and B respectively.

3.1 Pōrangahau Wastewater Treatment and Disposal Resource Consent Application – Assessment of Environmental Effects (Opus, 2007)

3.1.1 Scope

This Assessment of Environmental Effects (AEE) report considered the effects of the discharge of treated wastewater from the pond system on the Pōrangahau River in consideration of the requirements under the HBRC Regional Resource Management Plan (HBRC RRMP) and outlines the effects of the discharge as well as the most efficient means of mitigating these effects.

3.1.2 Methods

This report assessed the environmental effects of the discharge on the Pōrangahau River with a focus on water quality, stream ecology, recreational use and cultural considerations. A full description of the existing environment as well as the wastewater treatment system was also provided.

The proposed discharge was also assessed against the relevant regional and national statutory framework. A consultation process including local iwi and other stakeholders was carried out to consider the best options for the WWTP moving forward.

3.1.3 Conclusion

The water quality upstream of the WWTP discharge point in the Pōrangahau River was characterised to be relatively poor due to the upstream agricultural catchment and high magnitude rainfall events that contrasted to the generally low baseflow background conditions of the river.

A combination of factors resulted in the conclusion that the effects of the WWTP discharge on the Pōrangahau River were less than minor, these factors include:

- Significant dilution factor, even at low flows due to the small discharge from the WWTP; and
- The treated wastewater discharge was deemed to add a relatively small load of nutrients to the Pōrangahau River compared to the concentrations in the River itself.

The effects on stream ecology was considered minor as the entire section of the Pōrangahau River (upstream and downstream) was classified by Macro-invertebrate Community Index (MCI) analysis as having degraded water quality (MCI < 100).

The river was understood to be in use by fishermen, kayakers and passive recreation users, predominantly upstream of the WWTP discharge. Shellfish collection at the mouth of the river was also noted as having

occurred. The presence of silt and weeds in and around the river made the location undesirable for swimming.

The are no cultural sites of significance in the vicinity of the WWTP, however it is acknowledged that protecting the mauri (life-force) and sustaining the health of the river is of vital importance. Local iwi had raised concerns over the health of the river.

Following the consultation process, this AEE presented a range of options for improving water quality outcomes in the Pōrangahau River. This included proposed treatment improvements, namely the installation of a baffle pond and a wetland. With the provision of these installations, the effects on the environment of the Pōrangahau WWTP discharge were considered to be less than minor.

In accordance with suggestions made in the AEE, a baffle was constructed in 2010, after the discharge consent was granted. The suggestion to construct a wetland was not fulfilled and the additional consent for construction of a wetland has since expired.

3.2 Pōrangahau Township Oxidation Pond Discharge Mixing Study (Opus, 2009)

3.2.1 Scope

The 2009 mixing study was undertaken to consider the extent of effects of WWTP discharge on the water quality in the Pōrangahau River. The study was conducted in response to a Section 92 request for additional information made by the HBRC on the 11th September 2008. This information was considered critical due to the tidal nature of the river, proximity of recreational sites and accessibility of the river to the public.

3.2.2 Methods

This report presented measured data from two site investigations which aimed to develop an understanding of the basic mixing characteristics of the river by undertaking mixing and dilution tracer studies for the Pōrangahau River. Investigations included general observations of river cross-sections, typical velocities, salinity profile and tide levels as well as a tracer dye analysis discharged with treated wastewater to understand the dispersion path of the treated wastewater plume.

3.2.3 Results

The 2009 mixing study found that the Pōrangahau River was of an estuarine nature at the point of WWTP discharge, with tides more dominant due to the generally low flow of the river. The salinity of the river at the point of discharge was typically 27 parts per thousand (ppt). This indicates that the receiving waters for the treated wastewater discharge are largely saline under low-flow conditions. In accordance with the 2007 AEE, overall river water quality, regardless of WWTP discharge, was deemed to be poor due to upstream diffuse agricultural activities.

The tidal influence around the discharge point was apparent, with negative (upstream) flow measured on the incoming tide at the 400 m upstream monitoring location. However, the largest overall flows were measured 300 m downstream of the discharge point, this indicates that the tidal influence reduces between the downstream and upstream monitoring locations.

Despite the noticeable upstream flow on the incoming tide, dye tracer analyses showed that treated wastewater discharge was largely in the downstream direction on during all tidal phases. This was attributed to the existence of nearby sand banks and riparian structures that disrupt a uniform flow regime.

With respect to treated wastewater mixing with the river flow, the overall concentrations of each contaminant indicator in the mixing zone (within 200 m of the discharge) was predominantly influenced by the volume and quality of the incoming river flow. The quality of the WWTP discharge was deemed to be a secondary

influence on the overall quality of the river due to the comparatively low volumes of the oxidation pond discharge.

The dilution and mixing study observations found that there was a 1,000 times dilution factor at the point of reasonable mixing, approximately 200 m downstream of the WWTP discharge (Figure 6; Opus, 2009). The tidal nature of the river means that contaminants sometimes travel upstream depending on the tidal cycle and therefore the point of reasonable mixing was also defined to be 200 m upstream of the WWTP discharge point (on the flood tide).

Figure 6. Sketch of dye plume created on outgoing tide[15]

The effect of the discharge on water quality progressively reduces downstream due to the treated wastewater becoming fully mixed, and the increasing influence of dilution. Under normal flow conditions it was determined to take about 1.5 tidal cycles for a parcel of treated wastewater to reach the Beach Road Bridge (3.9 km below the discharge).

3.2.4 Conclusion

The 2009 mixing study deduced that achieving HBRC RRMP guideline limits for the background FC and DRP within the treated wastewater mixing zone will be difficult without taking into consideration the upstream water quality. Further, the study included a recommendation that any resource consent conditions relating to water quality at the boundaries of the mixing zone need to be expressed relative to the background concentration of the parameters in the incoming river flow. Discharge conditions for $cBOD_5$ and TSS were included in the consent as was monitoring upstream and downstream of the WWTP discharge.

3.3 Pōrangahau WWTP resource consent hearing: statement of evidence by Murray Grant Webby (Webby, 2009)

As part of the Pōrangahau WWTP consent hearing, Murray Webby (chartered professional engineer specialising in hydraulic engineering) was engaged by CHBDC to provide a technical overview of river mixing investigations carried out for the Pōrangahau River for the purpose of evaluating the impact of the effluent discharge from the Pōrangahau WWTP. This included providing further evidence around the Opus, 2009 mixing study. In summary, his evidence concluded:

[15] Taylor D. & Strang T. (2009) *Porangahau Township Oxidation Pond Discharge Mixing Study*. Opus.

- The dye mixing test on the outgoing tide showed substantial dilution of the effluent discharge plume downstream of the discharge point with a dilution factor of greater than 1000 being achieved within 200 m downstream
- It was also inferred that substantial dilution may also have occurred in the upstream direction on an incoming tide due to the much higher flow velocities and spiralling motion of the flow round the bend immediately upstream of the effluent discharge point (although there were no measurements to support this)
- The water quality measurements on the outgoing tide indicated that the effluent discharge had no measurable effect on the water quality in the river on the day of the dye test conducted as part of the Opus 2009 study
- Some potential was noted for a measurable increase in faecal coliform concentrations downstream of the discharge point under worst-case conditions (low river flows or higher discharge concentrations)
- The Porangahau River at the effluent discharge point is strongly influenced by the tidal inflows from the sea
- The primary influence on the water quality of the estuarine zone in the Porangahau River is the volume and quality of the inflow from the upstream catchment. The quality of the effluent discharge from the Porangahau WWTP is only a secondary influence (unless the effluent quality is extremely poor) due to the low volumes of the effluent discharge relative to the tidal flushing volumes.

Further water quality monitoring was recommended as conditions of consent.

3.4 Pōrangahau River Estuary Ecological Investigation (Opus, 2012)

3.4.1 Scope

This report was an investigation into the effects of the discharge on the biota in the vicinity of the discharge as a consent requirement.

3.4.2 Methodology

Benthic biota and sediment chemistry were sampled at two sites on the Pōrangahau River estuary – downstream of the WWTP discharge and at the Pōrangahau Beach Road Bridge. The Beach Road Bridge site provided a ‘pseudo-control’ in a distance from impact’ study design despite noting significant environmental differences between the two sites, namely salinity gradient.

Monitoring methods were focused on assessing the influence of the Pōrangahau WWTP discharge on eutrophication and toxic contaminants in the receiving river environment. Sampling of sediments and benthic biota was undertaken during low tide at two downstream locations. With the further downstream location being labelled as the control site.

Sampling was carried out with respect to three main aspects; physical and chemical analysis; epifauna and microalgae; and infauna (animals living within the sediments).

3.4.3 Results

At both sites most abiotic sediment variables indicated either ‘good’ or ‘very good’ ecological condition and all the results for metals were less than the ANZECC (2000) Interim Sediment Quality Guidelines (ISQG)-low, which means we would not expect any adverse effects on aquatic life due to the values measured. Redox Potential Discontinuity (RPD) depth at the Beach Road Bridge Site rated ‘fair’.

There were differences in sediment quality between sites. There was moderate to strong evidence that sediments at the WWTP site had more chlorophyll a (2.5 times more), organic carbon, nitrogen, arsenic, cadmium, lead nickel and zinc compared to sediment at the Beach Road Bridge site. However, the beach road bridge site had more copper in the sediment.

The benthic invertebrate community at both sites indicated ‘moderate disturbance’ (based on the AMBI score). There was no significant difference in the taxa richness or the AMBI score between the two sites.

Biological diversity was relatively poor at both sites with species abundance dominated by a couple of species. The WWTP treatment site had a higher diversity, due to additional freshwater taxa. Total abundance of taxa was greater at the Beach Road Bridge site.

3.4.4 Conclusion

Overall, there were measurable differences between the two sites in both sediment quality and benthic biota community. The site closest to the WWTP had measurably higher sediment concentrations of nitrogen, carbon, arsenic, cadmium, lead zinc and chlorophyll a, some of these variables may be related to the WWTP discharge while others (e.g. arsenic) are more likely to be other sources.

While measurable differences between the two sites were found, the sediment quality at both sites corresponded to an estuarine condition of ‘good’ to ‘very good’. The concentrations of contaminants were low in terms of both effects and also relative to other NZ estuaries. None of the differences in sediment quality or downstream water quality were sufficient to account for differences in the benthic community; instead biological differences between the two sites were more likely to be related to the salinity gradient as an influence of the strong tidal actions rather than the WWTP discharge.

3.5 Summary

In summary, the historic reports above indicate that the Pōrangahau WWTP discharge has a relatively minor effect on the environmental condition of the Pōrangahau River and downstream estuary. The Pōrangahau River itself is characterised as nutrient-enriched due the agricultural nature of the upstream catchment. Downstream of the WWTP discharge, the River is classified as estuarine and exhibits ‘good’ to ‘very good’ estuarine characteristics.

The results of water quality monitoring of the Pōrangahau River upstream and downstream of the WWTP found that only total ammonia (NH_4-N), FC and DRP were higher downstream of the WWTP. All sites had total ammonia concentrations well within (more than 10 times lower) ANZECC guidelines to avoid chronic toxic effects on aquatic life.

While the WWTP could be the reason for increased downstream concentrations of FC, DRP and ammoniacal nitrogen (NH_4-N), concentrations upstream are already elevated for these parameters, in some cases above the ANZECC guidelines. Alternative point source pollution factors were identified as potential contributors to the degraded water quality in the Pōrangahau River. These include; a boat ramp on the true right bank downstream of the WWTP discharge, an abandoned timber mill site on the true right bank opposite from the WWTP discharge, and waterfowl observed along the true left bank just downstream of the WWTP discharge.

4 Assessment of Effects of the Existing Discharge of Treated Wastewater

4.1 Introduction

This section describes an assessment of effects of the existing discharge of the treated wastewater discharge on the water quality of the Pōrangahau River. The effects are evaluated for the current discharge, based on both measured and predicted results. The measured effects use monitoring data from both upstream and downstream of the discharge to obtain a direct assessment of changes in water quality within the Pōrangahau River. The predicted effect is based on a combination of measured and estimated treated wastewater and receiving water flows and contaminant concentrations.

4.2 Assessment Criteria

4.2.1 Water Quality Criteria

Effects of the WWTP discharge on the water quality of the Pōrangahau River will be made against a range of relevant guidelines. Available guidelines include those from the HBRC Regional Resource Management Plan (HBRC RRMP), the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2018), the Ministry for the Environment National Policy Statement for Freshwater Management (NPS-FM), the Ministry for the Environment Microbiological Assessment Categories (MAC) and the New Zealand Guidelines for Recreational Water Quality (Ministry for the Environment, 2003).

ANZECC present a preferred hierarchy of types of guideline values for water quality indicators. This hierarchy prioritises site-specific and/or local guidelines over regional and national guidelines. The assessment criteria for this report takes guidance from this preferred hierarchy.

Trigger values indicate that there is a ‘potential risk’ of adverse effects at a site. Trigger values are defined by the 80th percentile of indicators that are harmful at high values and/or the 20th percentile of indicators that cause problems at low values.

ANZECC (2018/2000) chemical and physical stressor and trigger values for the Pōrangahau River were identified using the River Environmental Classification (REC). The REC accounts for a range of natural factors that influence water quality (e.g., climate, topography and geology) and is widely used to study water quality patterns in New Zealand. The lower Pōrangahau River is classified as ‘Warm Dry Low-elevation’ by the REC database. Where applicable, REC (New Zealand) default guideline values (DGVs) for physical and chemical (PC) stressors are presented in Table 9 below, along with guidelines for different water quality parameters where relevant.

Table 9. Water quality assessment criteria

Parameter	HBRC RMP[1]	ANZECC Stressor[2]	MAC[3]	NPS-FM[4]
pH		7.27 – 7.8		
E.coli (CFU/100ml)			261-550 / >550[5]	
Faecal Coliforms (CFU/100ml)	200			
Enterococci (CFU/100ml)			>500[5]	
Total Phosphorus (mg/L)		0.023		
Dissolved Reactive Phosphorus (mg/L)		0.007		
Total Nitrogen (mg/L		0.281		
Total Ammoniacal Nitrogen (mg/L)	0.1	0.017		0.24
Suspended Solids (mg/L)	50	4.6		
$cBOD_5$ (mg/L)				
Dissolved Oxygen (%)	80%	82-100		
Conductivity (uS/cm)		86		
Nitrate + Nitrite Nitrogen (mg/L)		0.195		2.4 / 3.5[6]
Turbidity (NTU)		4.2		

[1] Hawke's Bay Regional Resource Management Plan – Republished as at 1 October 2015

[2] ANZECC chemical and physical stressor trigger values, except where otherwise stated

[3] All parameters are ANZECC (REC) default guideline values (DGVs) for physical and chemical (PC) stressor values for Warm Dry Low-elevation classification, except where otherwise stated

[4] National Policy Statement for Freshwater Management (NPS-FM) – Attribute State B, 95% species protection level (annual median), except where otherwise stated

[5] MfE Microbiological Assessment Category for Freshwater Grade D

[6] National Policy Statement for Freshwater Management (NPS-FM) – Attribute State B, 95% species protection level (annual maximum)

4.2.2 Measured Downstream Trends Analysis

Water quality data collected by CHBDC over the last decade at Kate's Quarry, 200 m upstream of the WWTP discharge and 200 m downstream of the WWTP discharge, allows for a downstream trend analysis of parameters. Assessing a significant difference of means between sampling locations upstream and downstream of the WWTP discharge enables the measured assessment of effects of the WWTP discharge on river water quality.

The means of 12 parameters (July 2014 to June 2019) were compared using a one-way T-test analysis at the 5% significance interval using the NIWA time trends software. The dataset at Kate's Quarry was compared to the 200 m upstream dataset and 200 m upstream dataset was subsequently compared to the 200 m downstream dataset. An initial comparison of the HBRC and CHBDC data at Kate's Quarry was undertaken.

4.2.3 Mass Balance Methodology

Contaminant concentrations downstream of the proposed WWTP discharge were predicted using mass balance calculations. The mass balance calculation is based on inputs from:

- The contaminant concentrations of the existing discharge based upon monthly monitoring between 2014 and 2020;
- The median background water quality in the Pōrangahau River upstream of the discharge; and
- Dilutions available based on proposed discharge volumes and the flow records of the Pōrangahau River.

The predicted water contaminant concentration (C_x) at the receiving water downstream of discharge is given by Equation 1:

$$C_x = \frac{(C_d - C_b)}{TD + 1} + C_b$$

Where C_d is the contaminant concentration of treated wastewater; C_b is the background contaminant concentration in the receiving environment; and TD id the total dilution.

The total dilution factor assumes full mixing when the discharge plume is evenly mixed across the full width of the receiving waters. Higher contaminant concentrations will occur within the discharge plume close to the point of discharge. The proposed reasonable mixing zone is discussed in Section 4.2.4.

The mass balance calculations for the predicted water quality downstream of the discharge in the Pōrangahau River are run under a worst-case low-flow scenario as well as a standard median flow scenario.

4.2.4 Reasonable Mixing

The RMA (1991) requires that any standards imposed through classification of waters or under Section 107 of the RMA should be met "after reasonable mixing". This implies the existence of a zone in which the underlying standards need not be met. The RMA however stops short of giving clear guidance about what constitutes reasonable mixing. It may be implied that the area of water required for "reasonable mixing" should be minimised and any adverse effects within the "reasonable mixing zone" should not frustrate the management objectives for the waters.

Policy 72 in Section 5.4.6 **(a)** of the Hawke's Bay Regional Resource Management Plan states that:

> *For the purposes of this Regional Plan, "reasonable mixing in surface water" of contaminants in surface water will generally be considered to have occurred as follows:*
>
> *a. In relation to flowing surface water bodies, at whichever of the following is the least:*
>
> *i. A distance 200 metres downstream of the point of discharge*
>
> *ii. A distance equal to seven times the bed width of the surface water body, but which shall not be less than 50 metres, or*
>
> *iii. The distance downstream at which mixing of contaminants has occurred across the full width of the surface water body, but which shall not be less than 50 metres.*
>
> *Alternatively, for activities that are subject to resource consents, "reasonable mixing" may be determined on a case by case basis through the resource consent process*.

The mixing study, described in Section 3.2, determined that the dilution of the treated wastewater plume was estimated to be in the range of 1000-3000 fold at the end of a 200 m long mixing zone. Dilution estimations for the mass-balance measurements supported a dilution factor of 1000 fold during normal flow conditions.

For the purposes of this report, the point of reasonable mixing is understood to be 200 m upstream and downstream of the WWTP discharge.

4.3 Measured Effects on Pōrangahau River

As discussed in Section 4.2.2, HBRC maintain a water quality monitoring station at Kate's Quarry, upstream of the township that provides monthly data on a number of water quality parameters. CHBDC also carry out monthly monitoring at Kate's Quarry, 200 m upstream and 200 m downstream of the Pōrangahau WWTP discharge point as part of consent conditions.

The following section presents analysis from a five-year record of measured water quality parameters collected at the three monitoring locations.

4.3.1 Measured downstream trends

A statistical comparison of means was carried out between the two Kate's Quarry datasets (HBRC and CHBDC) to ensure the consistency of data. The CHBDC dataset at Kate's Quarry is not significantly different compared to the HBRC dataset at Kate's Quarry for any parameters, thus validating the CHBDC dataset.

The means of the CHBDC datasets at the three monitoring locations were then compared to assess any significant downstream changes and determine whether the Pōrangahau WWTP could be resulting in significant changes in downstream water quality.

Comparison of datasets between Kate's Quarry and the 200 m upstream locations showed that there was a significant change in water quality between the two sites across almost every parameter analysed. This indicates there is a trend of degrading water quality further downstream independent of the WWTP discharge.

Table 10 presents the downstream comparison of means between the CHBDC monitored locations 200 m upstream and 200 m downstream of the WWTP discharge for all available parameters. Matching letters indicate no significant differences between the two datasets; different letters indicate a statistically significant difference.

Table 10. Dataset comparison of 12 water quality parameters - One-way T-Test at 5% significance.

Analyte	200m Upstream (CHBDC)	200m Downstream (CHBDC)	Statistical difference*
$cBOD_5$	A	A	
E.Coli	A	A	
Enterococci	A	B	
Faecal Coliforms	A	A	
Suspended Solids	A	B	
Turbidity	A	A	
Total Ammoniacal N	A	B	
Total N	A	A	
Nitrate + Nitrite N	A	B	
Total Kjeldahl N	A	A	
Total P	A	B	
DRP	A	B	

*Purple shading indicates a statistical difference in analyte concentrations is observed between the 200 m upstream and 200 m downstream monitoring points.

From the analysis carried out above, the following conclusion can be made: Enterococci, Suspended Solids, Total Ammoniacal Nitrogen, Nitrate + Nitrite N, Total Phosphorus and Dissolved Reactive Phosphorus show significant differences between the 200 m upstream and 200 m downstream monitoring locations. Summary statistics on these datasets, as well as FC, are presented below along with box plots comparing the sites at Kate's Quarry, 200 m upstream and 200 m downstream.

i. Enterococci

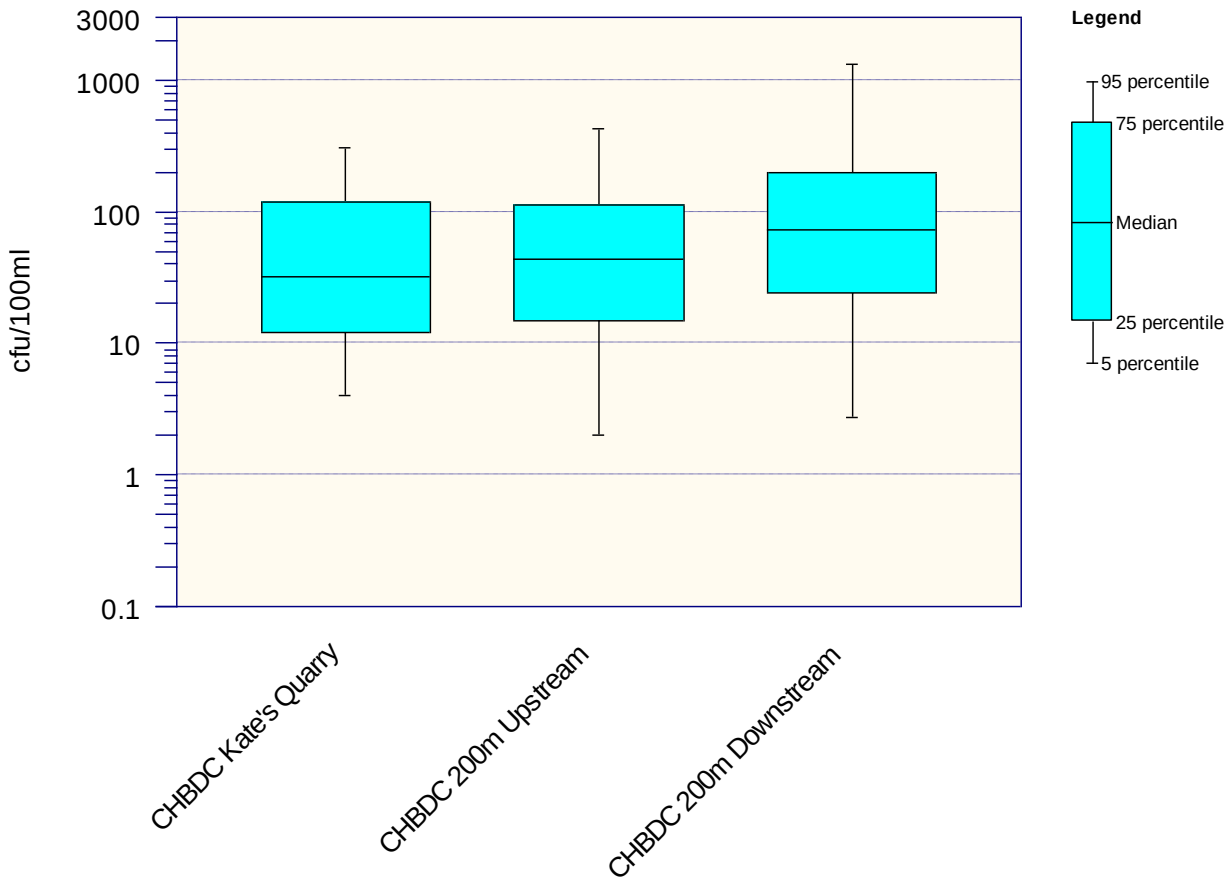

Figure 7. CHBDC Enterococci Monitoring Data Boxplot

Table 11. CHBDC Enterococci Monitoring Data Summary

Location	Sample Size	Min	5%	Median	Mean	95%	Max
Kate's Quarry (CHBDC)	57	2	4	32	82	280	680
200m Upstream (CHBDC)	57	2	2	44	102	430	720
200m Downstream (CHBDC)	57	2	4	72	225	928	2,700

ii. Faecal Coliforms

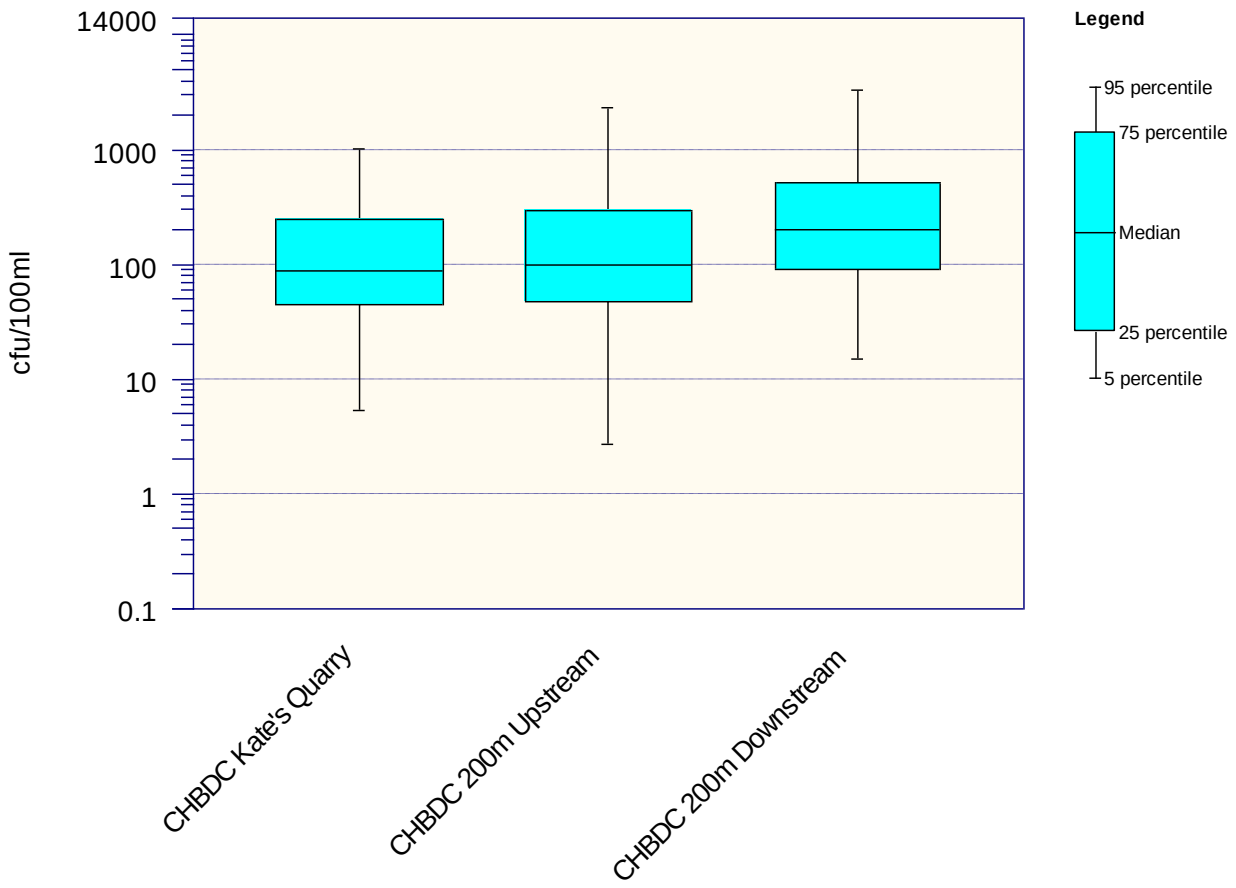

Figure 8. CHBDC Faecal Coliform Monitoring Data Boxplot

Table 12. CHBDC Faecal Coliform Monitoring Data Summary

Location	Sample Size	Min	5%	Median	Mean	95%	Max
Kate's Quarry (HBRC)	61	10	24	165	2972	5195	65,000
Kate's Quarry (CHBDC)	57	2	7	88	336	996	5,600
200m Upstream (CHBDC)	57	< 1	4	120	560	2380	13,200
200m Downstream (CHBDC)	57	2	18	200	655	3080	5,600

iii. Total Suspended Solids

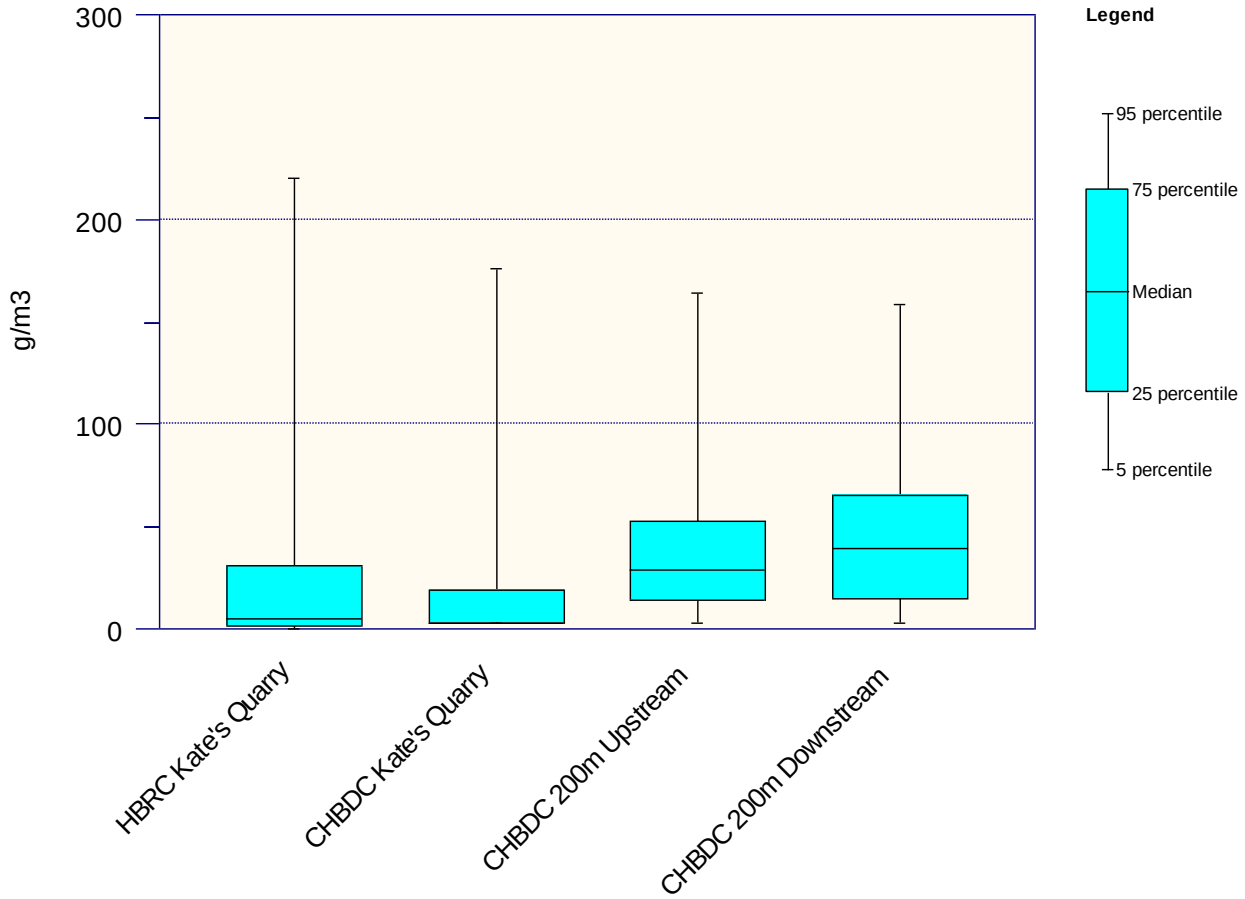

Figure 9. CHBDC Total Suspended Solids Monitoring Data Boxplot

Table 13. CHBDC Total Suspended Solids Monitoring Data Summary

Location	Sample Size	Min	5%	Median	Mean	95%	Max
Kates Quarry (HBRC)	61	<0.50	0.5	4	54	220	1,370
Kate's Quarry (CHBDC)	57	3	3	3	29	176	284
200m Upstream (CHBDC)	57	3	3	29	44	164	238
200m Downstream (CHBDC)	57	0	3	39	49	159	181

iv. Total Ammoniacal Nitrogen

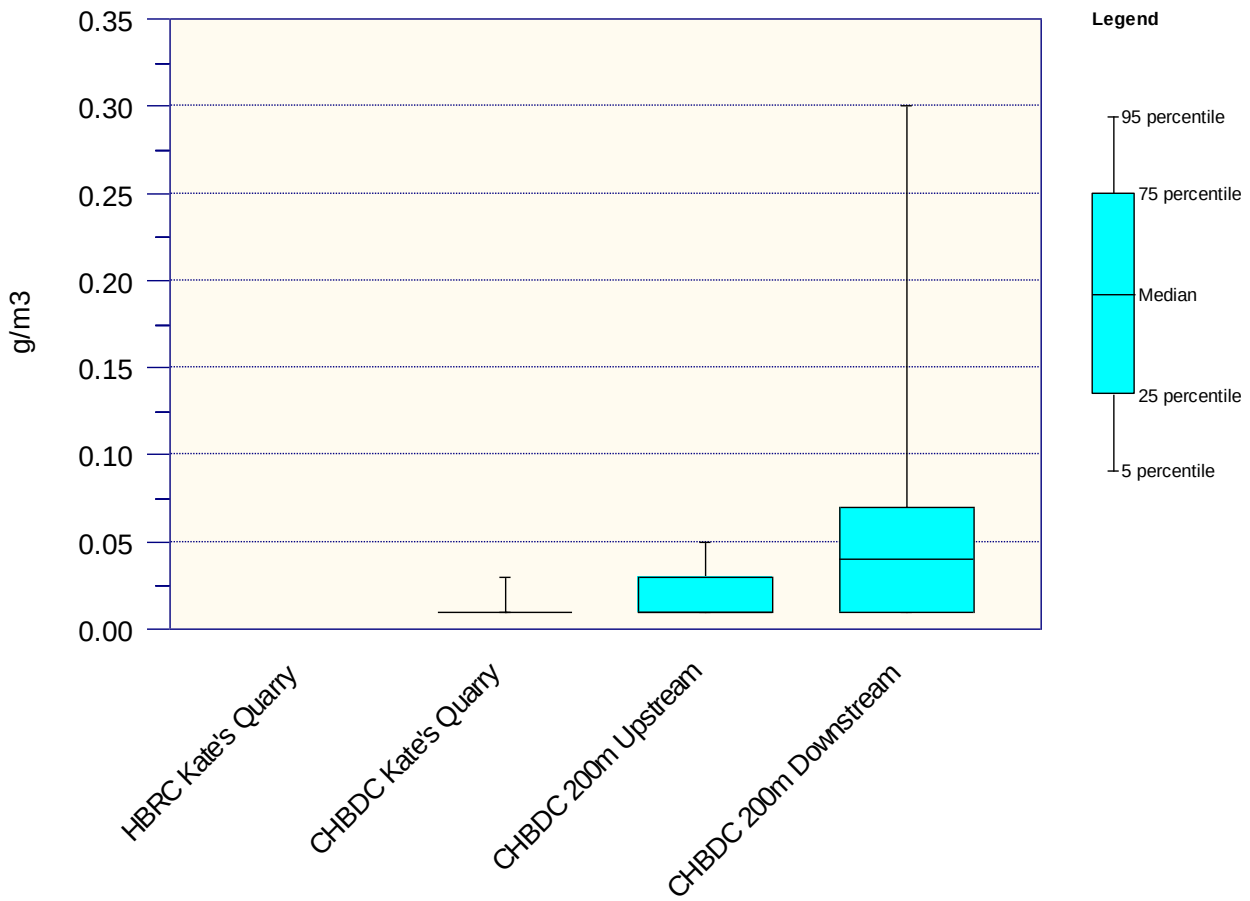

Figure 10. CHBDC Total Ammoniacal Nitrogen Monitoring Data Boxplot

Table 14. CHBDC Total Ammoniacal Nitrogen Monitoring Data Summary

Location	Sample Size	Min	5%	Median	Mean	95%	Max
Kates Quarry (HBRC)	61	<0.01	0.00	<0.01	0.01	0.02	0.03
Kate's Quarry (CHBDC)	57	0.01	0.01	0.01	0.01	0.03	0.06
200m Upstream (CHBDC)	57	0.01	0.01	0.01	0.20	0.05	0.28
200m Downstream (CHBDC)	57	0.01	0.01	0.04	0.11	0.30	1.63

v. Nitrate and Nitrite Nitrogen

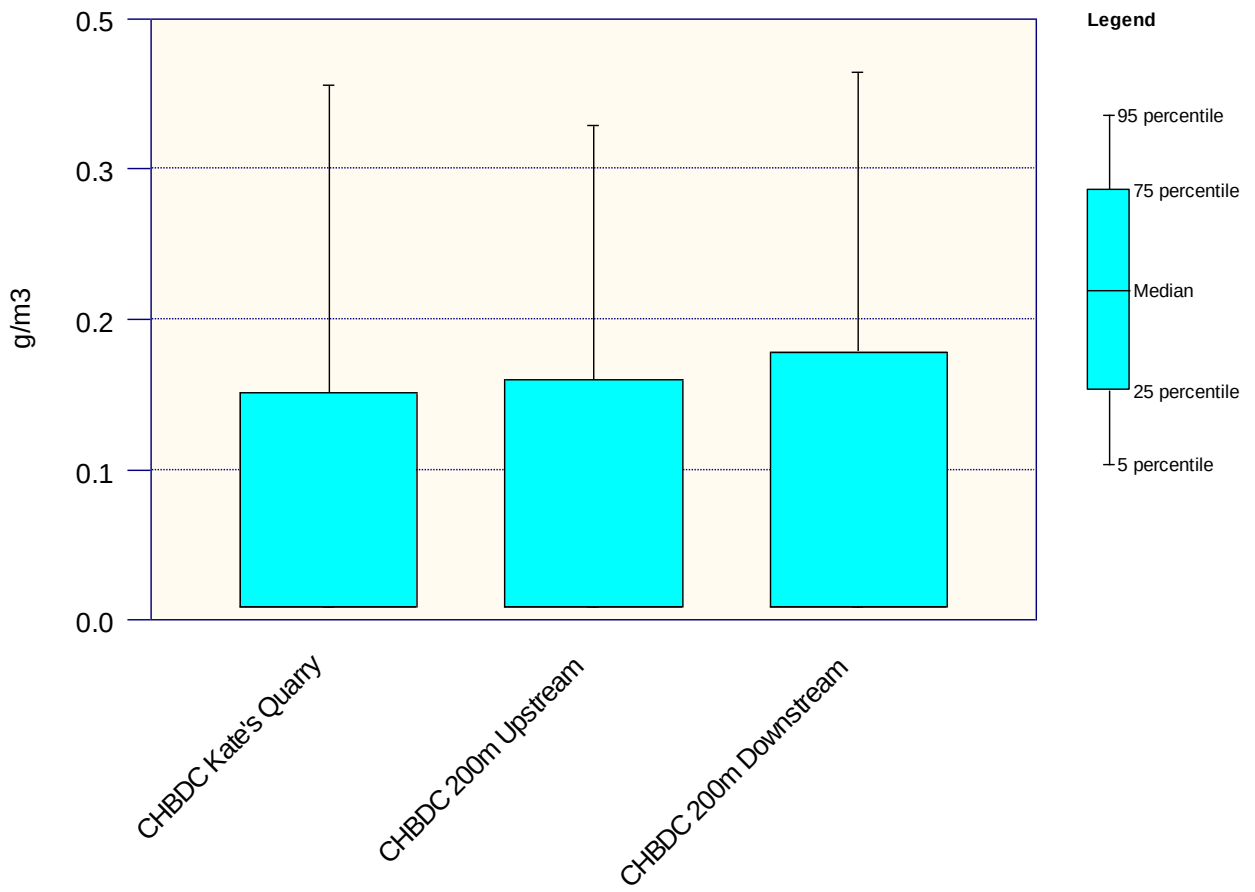

Figure 11. CHBDC Nitrate and Nitrite Nitrogen Monitoring Data Boxplot

Table 15. CHBDC Nitrate and Nitrite Nitrogen Monitoring Data Summary

Location	Sample Size	Min	5%	Median	Mean	95%	Max
Kate's Quarry (CHBDC)	57	0.01	0.01	0.01	0.10	0.37	0.63
200m Upstream (CHBDC)	57	0.01	0.01	0.01	0.10	0.35	0.65
200m Downstream (CHBDC)	57	0.01	0.01	0.01	0.11	0.40	1.00

vi. Total Phosphorus

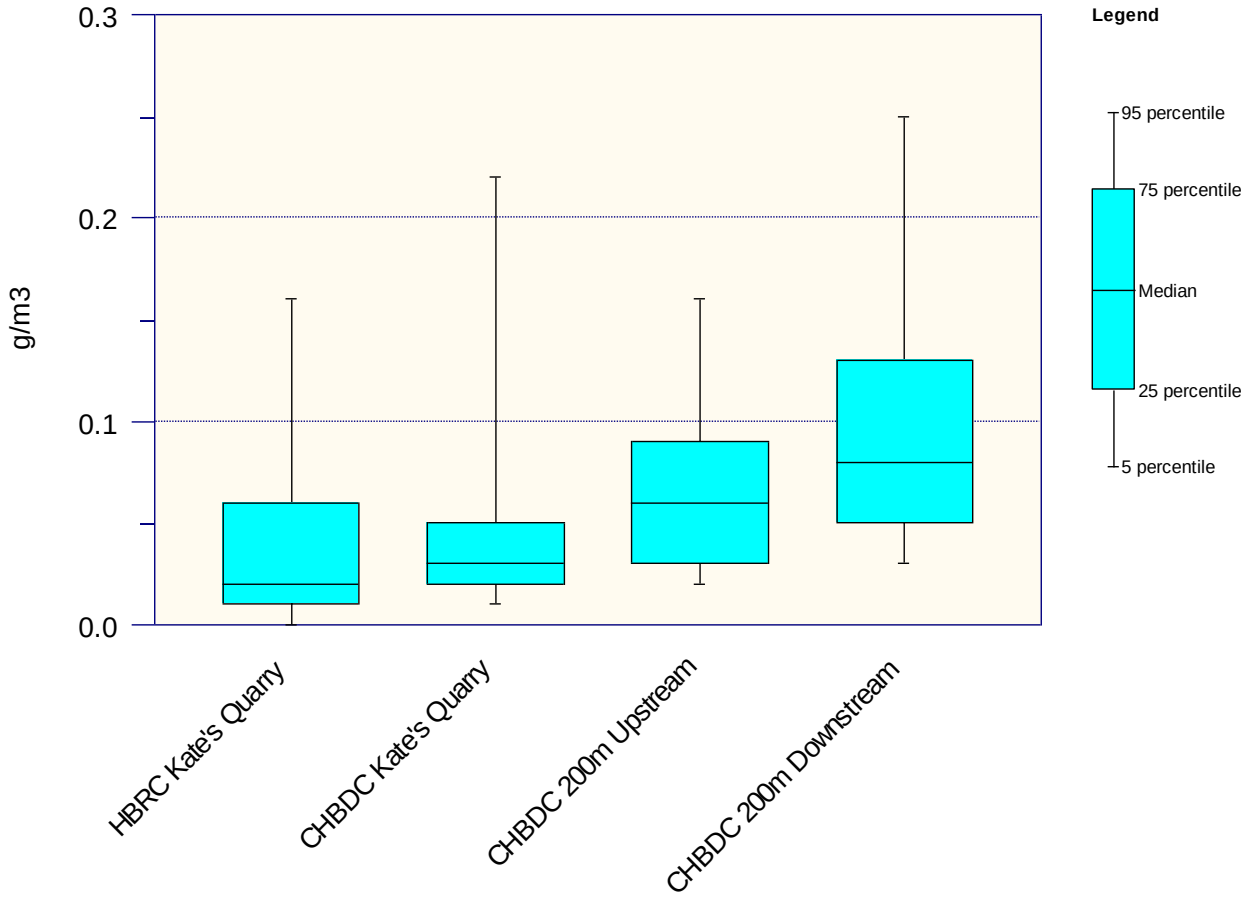

Figure 12. CHBDC Total Phosphorus Monitoring Data Boxplot

Table 16. CHBDC Total Phosphorus Monitoring Data Summary

Location	Sample Size	Min	5%	Median	Mean	95%	Max
Kates Quarry (HBRC)	61	<0.00	0.00	0.02	0.05	0.16	0.69
Kate's Quarry (CHBDC)	57	0.01	0.01	0.03	0.05	0.22	0.37
200m Upstream (CHBDC)	57	0.02	0.02	0.06	0.07	0.16	0.29
200m Downstream (CHBDC)	57	0.02	0.03	0.08	0.11	0.25	0.75

vii. Dissolved Reactive Phosphorus

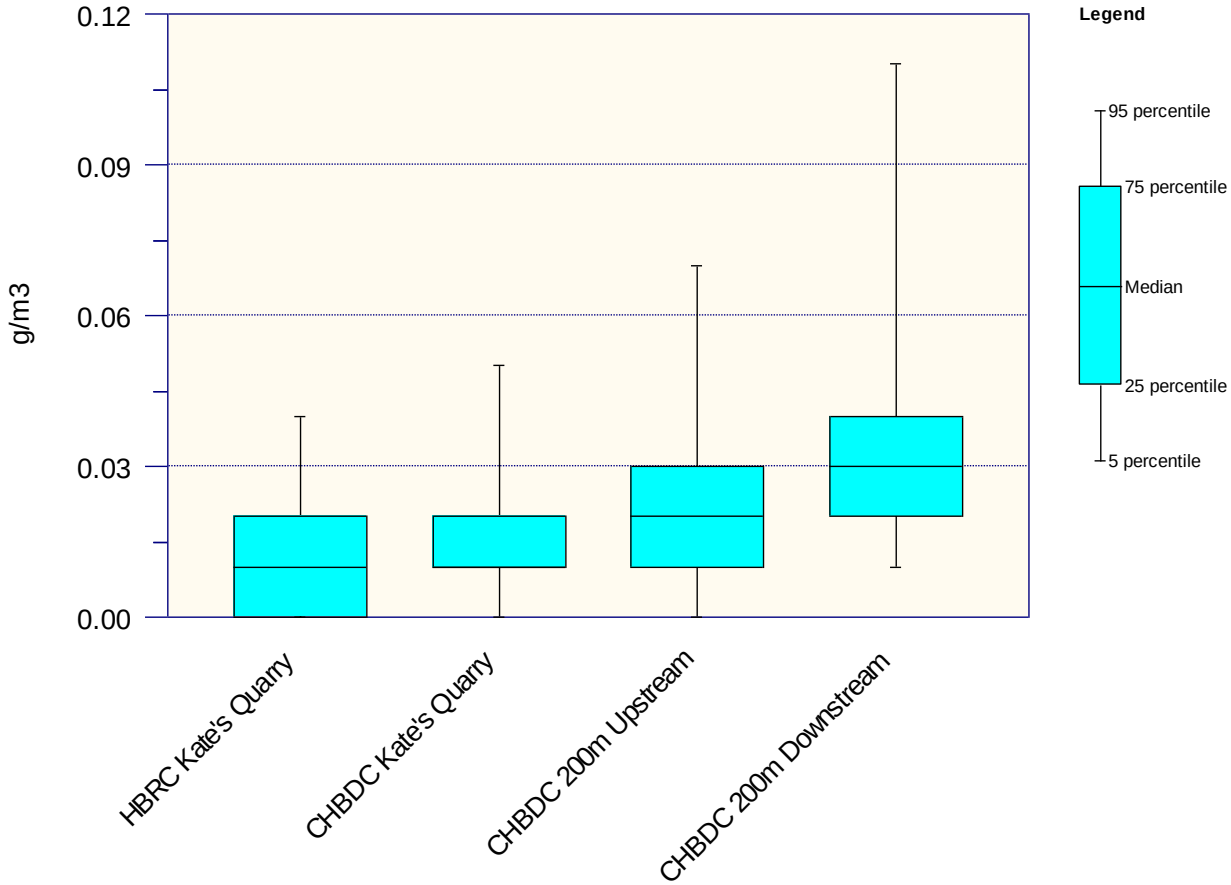

Figure 13. CHBDC Dissolved Reactive Phosphorus Monitoring Data Boxplot

Table 17. CHBDC Dissolved Reactive Phosphorus Monitoring Data Summary

Location	Sample Size	Min	5%	Median	Mean	95%	Max
Kates Quarry (HBRC)	61	<0.00	0.00	0.01	<0.00	0.04	0.07
Kate's Quarry (CHBDC)	57	0.00	0.00	0.01	0.02	0.05	0.07
200m Upstream (CHBDC)	57	0.00	0.00	0.02	0.02	0.07	0.19
200m Downstream (CHBDC)	57	0.00	0.01	0.03	0.04	0.11	0.33

4.3.2 Comparison of Upstream and Downstream Monitoring Locations

A comparison of sites directly upstream (200 m) and downstream (200 m) of the discharge point to the Pōrangahau River is provided in Table 18**,** showing the range and median difference directly upstream and downstream of the discharge. A positive difference represents an increase at the downstream location, while a negative difference represents a decrease downstream.

The difference between upstream and downstream water quality is shown in terms of the absolute differences in medians (units), and as a percentage of the upstream (%).

It is important to note that a number of parameters, including nutrients (e.g. TN, TP and DRP) and pH are already elevated above the ANZECC chemical and physical stressor trigger values upstream of the Pōrangahau WWTP discharge point. These elevated nutrient concentrations reflect the agricultural nature of the upstream catchment and sediment bound phosphorus.

Table 18. Summary of background water quality in the Pōrangahau River directly upstream and downstream of the discharge point

Parameter[1]	Upstream 200 m		Downstream 200m		Change in Median		Stressor[3]	Trigger
	Median	Range	Median	Range	Units	%		
pH	8.10	7.4-8.3	8.0	7.7-8.2	-0.1	-1%	7.27-7.8	
E.Coli (CFU/100ml)	108	2.0-13000.0	212	2.0-6000.0	104	96%	261-550[4]	>550[5]
FC (CFU/100ml)	120	0.5-13200.0	**220**	2.0-6800.0	100	83%	200[6]	
TSS	31	3-238	39	0.011-294	8	25.8%	50[6]	
TP (mg/L)	0.06	0.02-0.29	0.08	0.02-0.75	0.02	33%	0.023	
DRP (mg/L)	0.02	0.0-0.19	0.03	0.0-0.33	0.01	50%	0.007	
TN (mg/L)	0.66	0.41-11.61	0.69	0.41-6.07	0.03	5%	0.281	
NO_2+NO_3 N	0.005	0.005-0.65	0.01	0.005-0.64	0.005	100%	0.195	3.5[8]
NH_4-N (mg/L)	0.01	0.01-0.28	0.04	0.01-1.63	0.03	300%	0.017	0.24[7]
$cBOD_5$ (mg/L)	1.00	0.5-1.0	1.00	0.5-3.0	0	0%		
DO (ppm)[2]	9.16	7.31-12.43	9.70	7.44-927.0	0.54	6%	80%[6]	

Note: Orange highlight indicates the ANZECC chemical and physical stressor trigger[3] MAC Grade C[4] are exceeded, red highlight indicates the ANZECC toxicity trigger[9], MAC Grade D[5] or the national bottom line guidelines[7,8] are exceeded and **bold text** indicates the regional river guidelines are exceeded[6].

[1] Data is from CHBDC dataset (July 2014-June 2019) unless otherwise stated.

[2] Data is from HBRC dataset (July 2014-June 2019).

[3] All parameters are ANZECC (REC) default guideline values (DGVs) for physical and chemical (PC) stressor values for Warm Dry Low-elevation classification, except where otherwise stated

[4] MfE Microbiological Assessment Category for Freshwater Grade C

[5] MfE Microbiological Assessment Category for Freshwater Grade D

[6] Hawke's Bay Regional Resource Management Plan – Republished as at 1 October 2015

[7] National Policy Statement for Freshwater Management (NPS-FM) – Attribute State B, ammonia toxicity (NH_4-N) 95% species protection level (annual median)

All parameters sampled showed a large variation in values recorded both upstream and downstream with a large variation in range between the difference in concentrations upstream and downstream. It is likely that the fluctuation in concentrations recorded are related to seasonal variation in flow and also tidal influence.

From the analysis carried out above, the following conclusions are made:

- Total Ammoniacal nitrogen (NH_4-N) increases downstream of the discharge and is elevated above the ANZECC stressor trigger but well below the NPS:FM toxicity guideline value for 95% protection of species level by an order of magnitude.
- Total phosphorus (TP) and dissolved reactive phosphorus (DRP) increase moderately downstream of the discharge and are elevated above the ANZECC chemical and physical stressor trigger values. The upstream phosphorus concentrations are already elevated above the ANZECC guidelines upstream of the discharge.
- *Escherichia coli* (*E.coli*) and Faecal Coliforms (FC) increase downstream of the discharge point. FC is elevated above the HBRC RRMP Pōrangahau River guidelines.

- Suspended Solids (SS) increase moderately downstream of the discharge point but remains below the HBRC RRMP guidelines for the Pōrangahau River.

4.3.3 Summary

In general, nitrogen (ammoniacal), phosphorus, suspended solids and microbiological contaminants (*E.coli* and FC) show moderate to strong evidence for an increase downstream of the discharge point. The downstream increasing concentrations of NH_4-N, TP, DRP and SS are part of an increasing trend upstream of the discharge point (i.e. significant increase between Kate's Quarry and 200 m upstream). The upstream concentrations of TP, DRP and TN are already above ANZECC chemical and physical stressor guidelines and downstream increases are minor (within an order of magnitude).

NH_4-N is the only parameter that exhibits a large enough downstream increase to exceed the ANZECC chemical and physical stressor guidelines, but it is well below the NPS:FM toxicity trigger for protection of 95% of species.

While percentage increases in median concentrations for *E.coli* and FC between upstream and downstream monitoring locations are present, a t-test comparison of the upstream and downstream datasets shows they are not significantly different at the 5% confidence interval. Despite this, it should be noted that the median concentration of FC is above the HBRC RRMP guidelines downstream of the WWTP discharge.

Overall, the analysis of the monitoring data reveals that multiple strong increases in contaminant concentrations were measured downstream of the discharge, however this could be seen as a continuing trend of diffuse rural contaminant discharge to the river system and not solely related to the discharge from the Pōrangahau WWTP. Total ammoniacal nitrogen is the only contaminant that exhibits a strong increase downstream of the WWTP to exceed the ANZECC guidelines. TP, TN and DRP concentrations are above the ANZECC guidelines upstream of the WWTP.

4.4 Predicted Water Quality downstream of Discharge on the Pōrangahau River

4.4.1 Effects under Average River Flow Conditions

Predicted water quality affects were assessed using a standard mass-balance approach as described in Section 4.2.3. This approach utilises measured data and existing flow records to inform the potential concentrations of water quality parameters following reasonable mixing. The mass-balance method was carried out for two scenarios. The first scenario is normal flow conditions that would be expected most of the time. The second assessment simulates a 'worst-case', low-flow scenario by calculating the mean annual low flow (MALF) of the Pōrangahau River while still assuming a median flow input of treated wastewater from the WWTP.

Assessment of predicted changes in key contaminant concentrations in the Pōrangahau River downstream of the wastewater discharge under average annual stream flow conditions are summarised in Table 19 below.

The predicted effects of the wastewater discharge are based on a number of assumptions including:

- River flow of 1,312 L/s (1.312 m^3/s) in the Pōrangahau River upstream of the discharge was calculated based on HBRC flow data (Pōrangahau at Saleyards Bridge);
- The treated wastewater discharge flow was the median daily discharge volume of 93.9 m^3/day (0.00108 m^3/s) based on existing CHBDC records (2015-2019);
- The treated wastewater contaminant concentrations are medians calculated from the monitoring data collected from the outlet between July 2014 and June 2019, with the exception of the toxicants, total ammoniacal nitrogen (NH_4-N) and nitrate-N (NO_3-N) , which used the 95th percentile;

- Pōrangahau River contaminant concentrations are medians calculated from monitoring data collected from CHBDC monitoring site 200 m upstream of the WWTP discharge collected between July 2014 and June 2019; and
- The contaminants will be reasonably mixed at 200 m downstream from the discharge, as informed by the 2012 Mixing Study.

Dilution is estimated to be 1200 fold under median flow conditions[16].

Table 19. Predicted downstream contaminant concentrations - Median flow dilution (1200 x) within Pōrangahau River

Parameter	Unit	Discharge	Upstream	Downstream	Change
$cBOD_5$	mg/L	18.000	1.000	1.014	1%
TSS	mg/L	29.000	31.000	30.998	0%
NH_4-N	g/m3	14.700	0.010	0.022	122%
NO_2+NO_3-N	mg/L	0.920	0.005	0.006	15%
TN	g/m3	13.000	0.660	0.670	2%
TP	g/m3	2	0.055	0.057	3%
Enterococci	cfu/100ml	1700	44	45	3%
E.Coli	cfu/100ml	2150	108	110	2%
FC	cfu/100ml	8090	120	127	6%

Note: Orange highlight indicates the ANZECC chemical and physical stressor trigger or MAC Grade D is exceeded, red highlight indicates the ANZECC toxicity trigger is exceeded, red text indicates the national bottom line guidelines are exceeded and **bold text** indicates the regional river guidelines are exceeded (See Table 8).

The assessment indicates that, under normal stream flow conditions:

- The WWTP discharge is predicted to cause a moderate percentage increase in the concentration of NH_4-N in the Pōrangahau River downstream of the discharge (noting that in absolute terms, the concentration increase is fairly small and well below the NPS:FM toxicity guideline for protection of 95% of species). Concentrations are predicted to be slightly elevated above ANZECC chemical and physical stressor trigger guidelines.
- Total nitrogen (TN), total phosphorus (TP), *E.coli*, *Enterococci* and faecal coliforms (FC) are predicted have a minor increase downstream of the WWTP. TN and TP concentrations are already above the ANZECC chemical and physical stressor trigger guidelines upstream of the WWTP. *E.coli*, *Enterococci* and FC concentrations are predicted to remain below the MfE Microbiological Assessment Category for Freshwater (Grade C) and regional river guidelines despite the predicted increase.
- Very minor or no change is predicted for suspended solids (TSS) and biological oxygen demand ($cBOD_5$).

Based on these predictions, it appears that the Pōrangahau WWTP discharge would be expected to cause a less than minor increase in nutrient concentrations in the Pōrangahau River water quality during median (normal) flow conditions.

4.4.2 Effects during Low Stream Flow Conditions

Worst case effects for WWTP discharges typically occur in summer, when a combination of higher stream water temperature and low stream flow results in lower contaminant dilutions and greater stress on aquatic life. These effects can be noticeable in nutrient-enriched rural waterways such as the Pōrangahau River.

The Pōrangahau River low stream flow rate is based on the estimated seven-day mean annual low flow (MALF) value of 42.9 L/s (0.0429 m^3/s) at Saleyards Bridge (July 2014-June 2019) provided by HBRC. Other assumptions (contaminant concentrations and wastewater median daily discharge volume) remain the same

[16] (River flow / Wastewater flow) + 1 - (1.312 / 0.00109) + 1 = 1207.4

as in Section 4.4.1. The results of the predicted changes in water quality during low stream flow conditions are provided in Table 20. Dilution is estimated to be 40 fold under MALF conditions[17].

Table 20. Predicted downstream contaminant concentrations - Low flow dilution (40x) within the Pōrangahau River

Parameter	Unit	Discharge	Upstream	Downstream	Change
$cBOD_5$	mg/L	18	1	1.4	42%
SS	mg/L	29	31	30.95	0%
NH_4-N	g/m^3	14.700	0.010	0.373	3632%
NO_2+NO_3 N	mg/L	0.920	0.005	0.028	452%
TN	g/m^3	13.000	0.660	0.965	46%
TP	g/m^3	2.000	0.055	0.103	87%
Enterococci	cfu/100ml	1700	44	85	93%
E.Coli	cfu/100 mL	2150	108	158	47%
FC	cfu/100ml	8090	120	**317**	164%

Note: Orange highlight indicates the ANZECC chemical and physical stressor trigger or MAC Grade D is exceeded, red highlight indicates the ANZECC toxicity trigger is exceeded, red text indicates the national bottom line guidelines are exceeded and **bold text** indicates the regional river guidelines are exceeded (See Table 8).

The assessment indicates that, under low (MALF) stream flow conditions:

- The WWTP discharge is predicted to cause a major increase in the concentration of NH_4-N in the Pōrangahau River downstream of the discharge with concentrations predicted to be elevated above ANZECC chemical and physical stressor trigger guidelines. The predicted concentration of NH_4-N remains below the NPS:FM toxicity trigger value for 95% protection.
- The WWTP discharge is predicted to cause moderate increase in the concentrations of FC and Enterococci in the Pōrangahau River downstream of the discharge with FC concentrations predicted to be elevated above HBRC RRMP river guidelines for the Pōrangahau River.
- A major increase in the concentration of NO_2+NO_3 N is predicted downstream of the WWTP discharge point but will remain below the ANZECC chemical and physical stressor trigger guidelines downstream of the WWTP.
- A moderate increase in the concentration of total phosphorus (TP) is predicted downstream of the WWTP discharge point. TP concentrations are already above the ANZECC chemical and physical stressor trigger guidelines upstream of the WWTP.
- Biological oxygen demand ($cBOD_5$), total nitrogen (TN) and *E.coli* are predicted to have a low increase downstream of the WWTP. TN concentrations are already above the ANZECC chemical and physical stressor trigger guidelines upstream of the WWTP. *E.coli* is predicted to remain below the MfE Microbiological Assessment Category for Freshwater (Grade C) despite the predicted increase.
- No change is predicted for suspended solids (SS).

Based on these predictions, it appears that the Pōrangahau WWTP discharge would be expected to cause a moderate increase in nutrient and microbiological contaminant concentrations in the Pōrangahau River water quality during low-flow conditions. In particular, NH_4-N is predicted to exceed ANZECC chemical and physical stressor trigger guidelines and FC is predicted to exceed the regional river guidelines. While the increase is likely to be moderate during very low flows, it would not occur for an extended period of time. It is noted that the ecological survey conducted by Opus in 2012 did not observe substantial increase in undesirable biological growth (macro algae) downstream[15].

[17] (River flow$_{MALF}$ / Wastewater flow) + 1 - (0.0429 / 0.00109) + 1 = 40.4

4.5 Implications of varying tidal and flow regimes

Numerous reports have indicated that the Pōrangahau River at the point of treated wastewater discharge is dominated by a saline environment with a significant tidal influence. On a rising tide, river flow at the point of WWTP discharge is usually reversed. This is mostly due to the low-background flow of the Pōrangahau River. Therefore, any downstream effects identified should be extrapolated to at least 200 m upstream of the WWTP discharge point. Additionally, the modelled residence time for one parcel of treated wastewater to be discharged from the estuary is understood to take approximately 1.5 tidal cycles – based on the tracer study.

4.6 Summary of effects of the current discharge

In summary, the assessment of the effects of the current discharge on the Pōrangahau River was undertaken based on approaches by measurement and prediction. The assessment results indicate that:

- The water quality of the Pōrangahau River is highly impacted by the agricultural nature of the upstream catchment. The river is nutrient enriched, as shown by the elevated nitrogen and phosphorus concentrations upstream of the discharge point. Upstream nutrient concentrations of TN, TP and DRP are already elevated above the ANZECC guidelines prior to the point of discharge.
- Based upon water quality monitoring results from the Pōrangahau River , the treated wastewater discharge is currently causing a minor increase in nutrient and microbiological contaminant concentrations in the Pōrangahau River downstream of the discharge.
- The discharge does not appear to result in the formation of excessive plant, algae and slime growths in the Pōrangahau River relative to upstream.
- The predictions based on mass balance calculations suggest that the wastewater discharge would be expected to cause a moderate increase in nutrient and faecal coliform concentrations in the Pōrangahau River water quality during low flow conditions and a less than minor increase during median flow conditions. In particular, the increase in faecal coliforms and NH_4-N are predicted to exceed relevant guideline values during low flow scenarios.

Overall, it is considered there are no significant adverse effects to the water quality of the Pōrangahau River from the wastewater discharge. The analysis of the monitoring data reveals that multiple increases in contaminant concentrations were measured downstream of the discharge. Total ammoniacal nitrogen and faecal coliforms exhibit strong increases downstream of the WWTP to exceed the ANZECC and regional river guidelines. TP, TN and DRP concentrations are above the ANZECC guidelines upstream of the WWTP.

5 Assessment of Effects of the Future Discharge of Treated Wastewater

5.1 Proposed continued discharge

Engagement work undertaken by CHBDC indicates a clear community preference for land treatment of wastewater. CHBDC is currently working through the options assessment process and staging considerations for a land treatment scheme. This will take some time to work through and for these reasons, CHBDC seeks to continue the existing discharge of treated wastewater to the Pōrangahau River in the transition period (for up to six years) whilst the new discharge scheme is conceptualised, consented, designed, constructed and commissioned.

5.2 Summary of existing discharge

From the assessment of the existing discharge above (Section 4), the current effects of the WWTP discharge on the Pōrangahau River are measurable, albeit small. Nutrient concentrations are elevated in the river upstream of the discharge (TN, N_2, TP and DRP) and exhibit a small concentration increase downstream of the WWTP discharge with the greatest effects modelled during the lowest flows in the river.

Downstream parameters of note include faecal coliforms and total ammoniacal nitrogen. Faecal coliforms are generally elevated above the HBRC RRMP trigger values (but only under modelled low flow conditions), while total ammoniacal nitrogen joins total nitrogen, nitrate nitrogen, total phosphorus and dissolved reactive phosphorus in exceeding ANZECC stressor guidelines.

With respect to the compliance of the discharge to current consent conditions, $cBOD_5$, TSS concentrations and pH have not breached the consent compliance limits for the nine-year period that data has been provided for. In terms of the discharge limit conditions, the average daily volume (of wastewater discharged from the pond) 95th percentile limit (415 m^3/day) was exceeded and considered non-compliant for the 2017/18 hydrological year. This exceedance was due to large volumes of rainfall during winter and spring, including two ex-tropical-cyclone events. Conversely, at times of extreme low flow, potential modelled contaminants of concern include bacterial indicators where the downstream monitoring has shown the HBRC guidelines are exceeded. Whilst this increase is predicted as a result of the desktop analysis, actually monitoring downstream of the discharge has not detected the same magnitude of increase. The predicted downstream bacterial concentrations at times of low flow can therefore be considered as a conservative worst case assessment.

Overall, this assessment found no significant adverse effects to the water quality of the Pōrangahau River from the wastewater discharge and it is likely that these effects will continue for the six year period.

5.3 Summary of effects of continued discharge

The effects associated with the continued discharge of treated wastewater (for up to six more years) to the Pōrangahau River are equivalent to the effects associated with the existing discharge, based on the following assumptions:

- No notable population increase for Pōrangahau over the next six years
- Existing average and maximum daily discharge flow rates will remain stable
- Climate change is not considered as an influencing factor due to the short time period

Overall, no significant adverse water quality effects are associated with the continued discharge of wastewater to the Pōrangahau River during a short-term transition period. The continued effects of the discharge can be considered to be low for all contaminants, with the exception of faecal coliforms and

ammoniacal nitrogen exhibiting a moderate concentration increase above relevant guideline levels during low river flow events.

6 Monitoring and Mitigation

6.1 Current monitoring regime

With respect to water quality of the Pōrangahau River, the current consent conditions stipulate that CHBDC monitor the following parameters, monthly, at three locations (Kate's Quarry, 200 m upstream and 200 m downstream) along the Pōrangahau River:

- Unfiltered $cBOD_5$
- Total Ammoniacal Nitrogen
- Nitrate
- Total Kjeldahl Nitrogen
- Total Phosphorus
- Soluble Reactive Phosphorus
- Suspended Solids
- pH
- E. Coli
- Enterococci

The current consent conditions also stipulated the following field measurements at the 200 m upstream and 200 m downstream sampling sites on a monthly basis:

- Colour (Munsell colour scale)
- Turbidity
- Dissolved oxygen
- Conductivity
- Temperature
- Clarity (black disc method)

Monitoring of the influent untreated wastewater is undertaken once every 14 days, along with continuous flow measurements of inflow and discharge.

6.2 Recommendations for future monitoring

It is recommended, based on the information from this report and the previous mixing studies, that the 200 m defined mixing zone is a suitable classification. As such, the current monitoring at 200 m upstream and 200 m downstream is considered fit for purpose in understanding the effects of the discharge on the Pōrangahau River. Monitoring at Kate's Quarry allows for a comparison of the background water quality in the upstream Pōrangahau River.

Although modelled analysis indicates some contaminants increase to concentrations above their relevant trigger levels during low flow conditions, there is no current data set to support this evidence. As such, it is recommended that grab sampling be undertaken for parameters of concern. Sampling would be undertaken on an outgoing tide, at the three defined monitoring locations, when the Pōrangahau River is flowing at or below the Mean Annual Low Flow (MALF) of 42.9 L/s, including:

- Flow rates
- Enterococci
- Faecal coliforms
- E. Coli

Additionally, a dye tracer release study could be undertaken at point of discharge in low flow conditions to better understand the discharge plume in low flow conditions (the existing 2009 mixing study was conducted in average flow conditions) and verify the mixing dynamics and plume movement.

6.3 Mitigation Options

Mitigation of the existing discharge, beyond the transition of discharge to land within six years' time, is not considered necessary. However, the Stormwater Infiltration Management Plan (required under previous consent condition 6) was last updated in 2010 and is due for an update. Previous consent compliance reports[18] observed that there were increases in outflow which could be attributed to infiltration during recent reporting periods. CHBDC highlighted that pump station hours, as well as inflow and infiltration investigations during rain events would continue to be used as tools for monitoring infiltration and inflow into the Pōrangahau network. Dedicated time and resourcing are planned to further study and understand inflow and infiltration in all the town networks in the 2020/2021 compliance year[19]. Updating the Stormwater Infiltration Management Plan to address potential inflow and infiltration issues may add storage capacity and hence treatment retention time to the existing WWTP, thereby better enabling compliance with discharge requirements.

[18] CHBDC, 2019. *Porangahau Oxidation Pond Annual Compliance Report – Year ending 30 June 2019.*

[19] CHBDC, 2020. *July 2019 to June 2020 Annual Compliance Report – Porangahau*.

7 Conclusions

The Pōrangahau WWTP discharge of treated wastewater is predicted to increase concentrations of nutrients and microbiological contaminants in the Pōrangahau River downstream of the discharge point. Increased downstream concentrations are relatively minor downstream of the WWTP at median flow levels, but effects become moderate in low-flow scenarios.

Median concentrations of total nitrogen, nitrate, total phosphorus and dissolved reactive phosphorus were found to be elevated above relevant guidelines upstream of the WWTP discharge. The most notable effects of the WWTP discharge are an increase in total ammoniacal nitrogen and faecal coliforms, which exceed relevant water quality guidelines downstream of the WWTP discharge in the measured and modelled analysis in this report.

The effects associated with the continued discharge of treated wastewater (for up to six more years) to the Pōrangahau River are equivalent to the effects associated with the existing discharge, based on the following assumptions:

- No notable population increase for Pōrangahau over the next six years
- Existing average and maximum daily discharge flow rates will remain stable
- Climate change is not considered as an influencing factor due to the short time period

Overall, no significant adverse water quality effects are associated with the continued discharge of treated wastewater to the Pōrangahau River.

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Porangahau Township Oxidation Pond Discharge Mixing Study

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Contents

1 Introduction

This mixing study was completed to consider the effect of the Porangahau Township oxidation pond discharge on the water quality in the Porangahau River. The study was conducted in response to the section 92 request for additional information made by the Hawkes Bay Regional Council on the 11th September 2008. The additional information is for a consent application to renew existing discharge consent DP030233W. The information is considered critical due to the tidal nature of the river, proximity of recreational sites and accessibility of the river to the public.

The section 92 request required that a study be undertaken to determine the extent and profile of the effluent plume in comparison to the mixing zone criteria and water quality guidelines set out in the Regional Resource Management Plan.

2 Oxidation Pond Discharge

The existing oxidation pond is located at Map Reference NZMS Series260 V24 176 936. Key characteristics of the discharge relevant for this assessment are:

- The treated effluent from the oxidation pond discharges to the river via a small stormwater drain. This drain is approximately 300-500mm wide and enters the Porangahau River on the true left bank approximately 600m downstream of the township-see Figure 1.

Figure 1 – (left) Effluent discharge channel / stormwater drain, (right) Discharge point to Porangahau River

- Dry weather flows are typically between 40 and 60m^3/day, while the maximum wet weather flow is estimated at 710m^3/day based on previous modelling work (SKM, 2003). The high wet weather flow is a result of stormwater entry to the wastewater reticulation. This flow regime is expected to remain for the foreseeable future as the population of Porangahau township is relatively stable.

- The quality of the effluent is summarised in Table 1 below.

Table 1 – Effluent Quality Porangahau Township

Parameter	25th Percentile	Median	90th Percentile
BOD_5 (g/m^3) [1]	12	20	36
Suspended Solids ((g/m^3)) [1]	16	35	90
Faecal Coliforms (CFU/100ml) [1]	3125	7700	29000
pH[1]	7.5	7.9	8.7
Dissolved Oxygen ((g/m^3)) [1]	1.4	3.6	15.9
Flow (l/s) [2]	0.8	1.2	2.7
Nitrogen (ammoniacal-g/m^3)[3]	5.8	5.9	6.8
Phosphorus (reactive-g/m^3)[3]	2.5	3.1	4.8

Notes:
1. Based on monthly monitoring results from Dec 02 - Aug 08
2. Based on daily monitoring results from Jan 07-December 08
3. Based on monthly monitoring results between Dec02 – Feb 03

- A resource consent application has been submitted for the construction of a wetland to provide a polishing stage for the effluent prior to discharge. The proposed wetland is not expected to significantly affect the quality of the effluent. Further information on the proposed wetland is given in Porangahau Township Wastewater Treatment Plant: Wetland Application (Opus 2008).

3 Receiving Environment

The Porangahau River is approximately 45 km long. Its catchment is 705km^2 consisting of predominately hill country farming. Flows in the river are very peaky, with the river rising and falling rapidly due to rainfall. In both summer and winter a number of periods of no flow are recorded at the gauging site. Table 2 gives some statistics based on the 28 year flow record.

Table 2 – Flow (l/s) in the Porangahau River

Minimum	Maximum	Mean	% of the time flow is less than					
			10%	25%	Median	75%	90%	95%
0	1,405,098	6,000	35	116	1,025	4,000	10,750	22,750

There is no flow gauging site on the Porangahau River. However there is a gauging site upstream at Wallingford in the Taurekaitai Stream, a tributary of the Porangahau River, approximately 12km from Porangahau Township and with a catchment of 283km^2. We have adjusted the flows from the Wallingford site by scaling according to catchment area. This gave a conversion factor of 2.5x that has been used for the above calculations

The section of the Porangahau River around the oxidation pond discharge is very strongly influenced by the tides with a measured difference between high and low tide of approximately 0.5m at both site visits (26th March and 3rd October). This tidal influence is

especially strong during late summer when the contributing flows from the river can decrease below 100 l/s.

The Porangahau River is used for white baiting during the season (mid August to late November). There are no other particular uses of the River at this location; however it is reasonable to assume that some contact recreation will occur (e.g. kayaking, water skiing, swimming etc).

Water quality upstream of the discharge point in the Porangahau River is expected to be relatively poor due to the agricultural catchment and peaky nature of the flows indicating significant overland flow with minimal detention. This is reflected in the monitoring results given in Table 3.

Table 3 – Water Quality monitoring results from Kate's Quarry, 5.6km upstream of the discharge point. Approx 80 samples taken intermittently between 1988 and 2002.

Parameter	Mean	Median	Minimum	Maximum
BOD_5 (mg/L) [1]	1.26	1	1	2
Suspended Solids (mg/L)	109	18.5	1	982
Faecal Coliforms (CFU/100ml) [2]	2106	280	49	32000
Dissolved Oxygen (%)[2]	93.7	96.4	66.2	121
pH	8	8	5.83	8.5
Dissolved Reactive Phosphorus (mg/L)	0.014	0.01	0	0.05
Ammoniacal-N (mg/L)	0.048	0.023	0	0.65

[1] Record extends from 1988-1997 and is very patchy
[2] Record extends from 1997-2002

The oxidation pond discharge is approximately 4.2 km upstream of the Beach Road Bridge and downstream estuary, as shown in Figure 2. There are sediment bars located roughly 1km upstream of the bridge, and these influence the tidal response and flows in the river.

Figure 2 – Position of oxidation pond relative to estuary, ocean and sediments bars/weirs

4 Previous Sampling of River Water Quality around Discharge

A sampling set of river water quality was completed over the summers of 2002 and 2003, and this provides results that are directly relevant to the mixing characteristics and dilution in the stream. Samples were taken from the river both above and below the oxidation pond discharge, with sites located at 100m upstream, 50m upstream, 50m downstream and 140m downstream. The time of sampling was also recorded, enabling the results to be interpreted relative to the tidal cycle. Results from this sampling set are discussed in Section 8.

5 Methods

5.1 Preliminary Approach and Programme of Investigations

A preliminary site investigation was completed on 26th March 2008 to obtain basic site data about the river cross-sections, typical velocities, salinity profile and tide levels upstream and downstream of the oxidation pond discharge. The purpose of the investigation was to develop an understanding of the basic mixing characteristics of the river to enable a methodology to be developed for the tracer studies.

Mixing and Dilution Tracer studies were carried out on 3rd October 2008 to observe the movement of a continuous flow of dye discharged with the effluent and give an understanding of the dispersion path of the effluent plume. The methodology for the tracer studies was agreed with Hawkes Bay Regional Council as being appropriate for the tidally influenced river, and is described in letter correspondence (Strang, 2008). Any departures from agreed methodology are identified below.

5.2 Preliminary Investigations

On 26th March 2008 between 08:30 and 17:00 hours, river cross-sections were taken at the point of discharge, 200m upstream, 400m upstream, 150m downstream and 300m downstream. A GPS unit with base-station was used to record the levels and co-ordinates. The datum for the survey was Hawkes Bay Regional Council datum, which measures approximately 10m elevation at mean sea level. The cross-section at the oxidation pond is presented in Figure 3, and a scale drawing has been included in Appendix A.

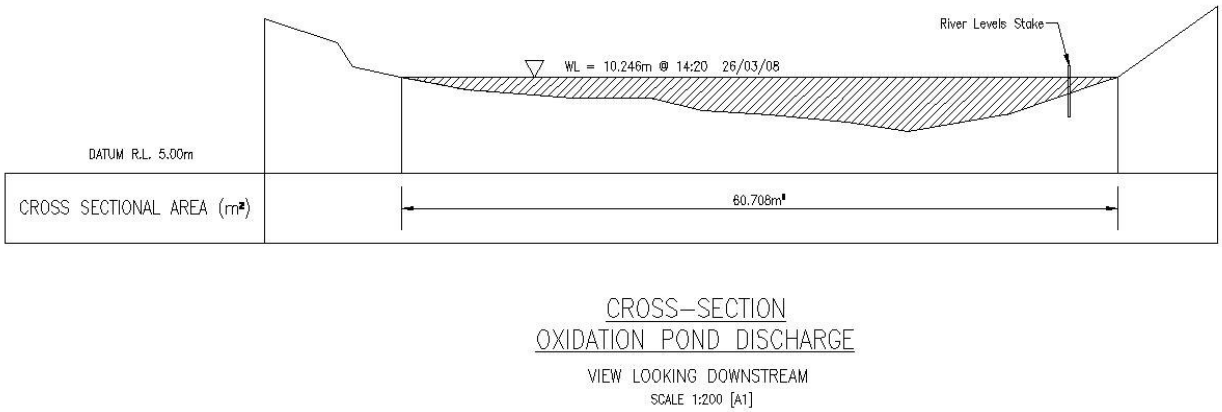

Figure 3 – Cross-section at point of discharge (not to scale) - note additional cross sections are in Appendix A.

Tide level measurements at the point of discharge were made by driving a stake into the river and measuring the water level at intervals throughout the day. A tidal variation of 0.5m was recorded, and this compares to an estimated 1.1m tidal range at the Porangahau River mouth for this day (from www.niwa.co.nz). The tidal range appeared to be slightly offset.

The salinity of the river was recorded at hourly intervals throughout the day for the point of discharge, 400m upstream and 300m downstream. Measurements were taken at ¼ width, ½ width and ¾ width, recording at 0.25m depth increments from 0.5m deep to the base of the river. Results indicated that salinity was constant over the cross sections and depth of flow, typically measuring around 27 parts per thousand (ppt). This can be compared to the salinity the water in the Porangahau estuary – measured at 32.5 ppt (Beach Road Bridge at approximately 5pm) and the average salinity of seawater at 35 ppt.

Velocities were measured in the same locations as for salinity, using a current meter and taking the average of five measurements at different depths at each location. The flow velocities were very low and difficult to measure. A peak flow of around 0.5m/s was measured in the upstream direction on the flood tide, with a peak flow of 0.3m/s in the downstream direction on the ebb tide. Velocity measurements may have been influenced

by wind, and for practical purposes there was very little difference between flood tide and ebb tide values.

Environmental conditions for the preliminary site investigation (26 March 2008) were fine but windy. The Taurekaitai Stream at Wallingford gauging station had recorded zero flow (data from Hawkes Bay Regional Council) continuously for several months prior to the investigation, indicating that flows in the Porangahau River would have been low. The Porangahau River may have collected minor inflows from other (ungauged) downstream tributaries.

5.3 Water Quality and Dilution Measurements/Tracer Studies

On 3rd October 2008, two separate releases of tracer were carried out, the first on the incoming tide (2.5-1.5 hrs before high tide) and the second on the outgoing tide (45min to 4 hrs after high tide). The initial proposal to release a third tracer during high tide conditions was abandoned, since there was not sufficient time to clear the colour prior to beginning the next test.

The discharge from the oxidation pond on the 3rd October was recorded as 0.5 l/s on the Central Hawkes Bay District Council flow monitoring system. The flow in the Porangahau river was approximately 0.7 m^3/s, based on the flow at the gauging site at Wallingford and scaling for catchments as discussed earlier.

Environmental conditions on 3rd October 2008 were fine but with a strong westerly wind (generally downstream towards the sea). Flow on the day was recorded as 0.28m^3/s at the Taurekaitai at Wallingford gauging station, indicating an estimated flow of 0.7m^3/s in the Porangahau River based on the scaling factor of 2.5 as discussed in Section 3. The average velocity (due to river flow with mean water levels and ignoring tidal influence) was calculated to be 0.01 m/s.

For each tracer test release, a continuous stream of diluted Rhodamine WT Dye was released for thirty minutes into the stormwater drain that carries the discharge from the oxidation ponds to the Porangahau River. Approximately 20 litres was injected, using a mariotte bottle to achieve a constant rate. The tracer meandered its way down the stormwater drain, with the first traces of colour reaching the river discharge point about 10 minutes after injection. By 15 minutes after injection, the effluent was a dark pink colour and three replicate samples were taken to indicate concentrations in the plume prior to dilution with river water. A sample of clean river water was taken prior to injection and used as a control.

The colour in the plume was left to build for around 15 minutes after the first colour was seen in the river before the plume was followed slowly downstream. Samples were taken from the surface at the middle of the plume and at the left and right edges, trying to always stay in approximately the middle of the long plume that moved gradually down the river. A kayak was used to access the deeper areas. Rhodamine WT dye samples were kept in a dark cool container prior to being couriered to Watercare Laboratories in Auckland for spectrofluorometric analysis.

Water quality samples were taken at points both upstream and downstream of the discharge. Samples were taken during ebb tide, starting with the upstream samples and then gradually moving downstream. Samples were cooled with ice and transferred to a portable fridge for transport back to the office and courier to Hills Laboratories in Hamilton. Samples were analysed for faecal coliforms, E coli, dissolved reactive phosphorus, ammonia nitrogen and total suspended solids. Sampling locations and tidal positions are summarised in Section 4.4. Essentially these water quality measurements are of the background water quality for the upstream catchment

5.4 Summary of Velocity, Water Quality and Dilution Measurements

Table 4 summarises the velocity, water quality and dilution measurements that were taken for both the preliminary investigations and tracer study investigations.

Table 4 - Summary of Measurements

Time after high tide	Distance from discharge														
	-1300	-1000	-400	0	1	30	70	100	150	200	300	400	600	1000	1500
-02:20				DC (x3)	DC (L,C,R)						V				
-01:50			V		V	DC (C,R)									
-01:25											V				
-01:05					V		DC (L,C,R)								
-00:30			V												
-00:15											V				
00:00			V		V										
00:40			V	DC (x3)	DC(C,R) V						V				
01:10								DC(L,C,R)							
01:50	WQ (2xL,2xR)	WQ (2xL,2xR)													
02:10									DC(L,C)		V				
02:40			V		V										
03:30										WQ (C,R)		WQ (L,R) DC (L,C,R)	WQ (L,C,R) DC (L,R)		
04:00											V			WQ (L,R)	WQ (L,R)
04:35					V										
05:40				W Q											

Key

V= velocity
DC = dye conc
WQ = water quality
L = left
C = centre
R = right

6 Results

6.1 Tide Levels

The difference between high tide and low tide is about 500mm during periods of relatively low flow. The tidal peak at the oxidation ponds is approximately 1 hour after the peak at the river mouth as shown by Figure 4.

Figure 4 also shows that it takes a significantly shorter time for the tide to rise (2-3 hours) than to fall (6hours). This pattern was also reflected during the dye injection investigations (Figure 5). What happens in the three hours between low tide and the tide rising are unclear due to a lack of data.

The much shorter time for the tide to rise than fall at the discharge point suggests that the river has a series of sediment bars downstream that form hydraulic controls (or broad crested weirs) between pools. These "weirs" are drowned at high tide, allowing a rapid inflow of water. The volume of water from the incoming tide is then distributed over the long tidally-influenced section of the river before slowly discharging to the downstream reaches as the tide goes out. This is consistent with observations of sandbars approximately 1km upstream (south) of the Beach Rd Bridge- refer Figure 2.

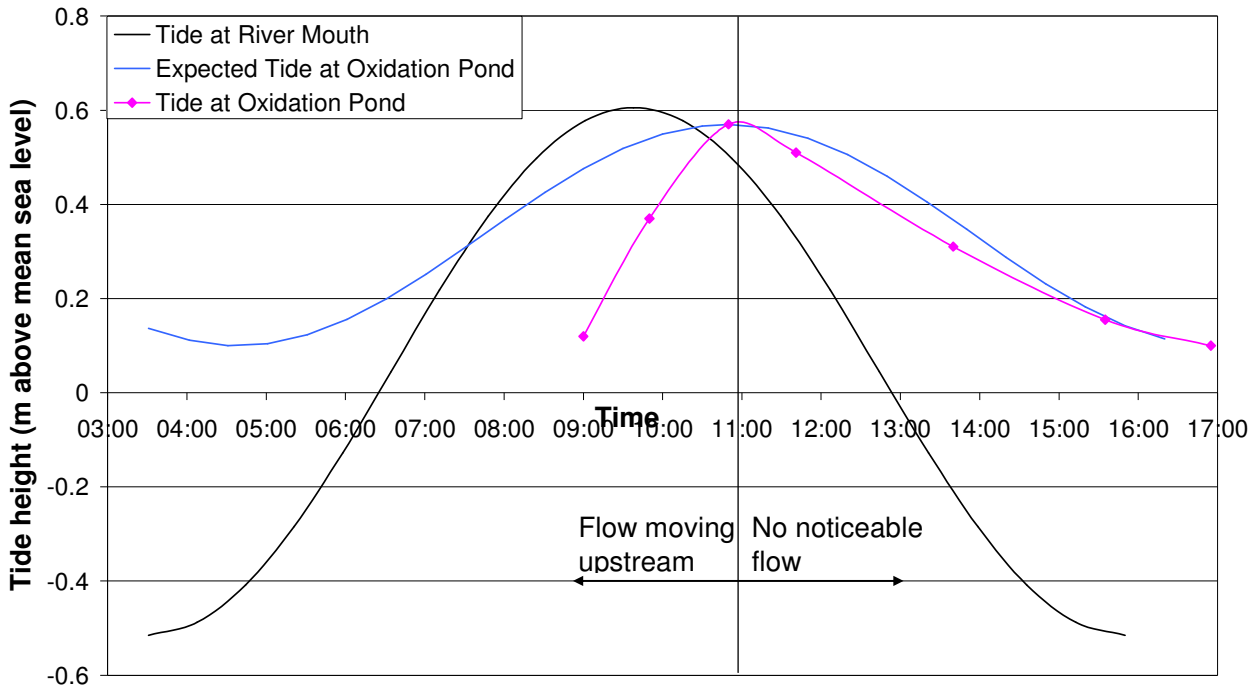

Figure 4 – Tide Height at the Porangahau River Mouth and at the Oxidation Pond (26 March 2008)

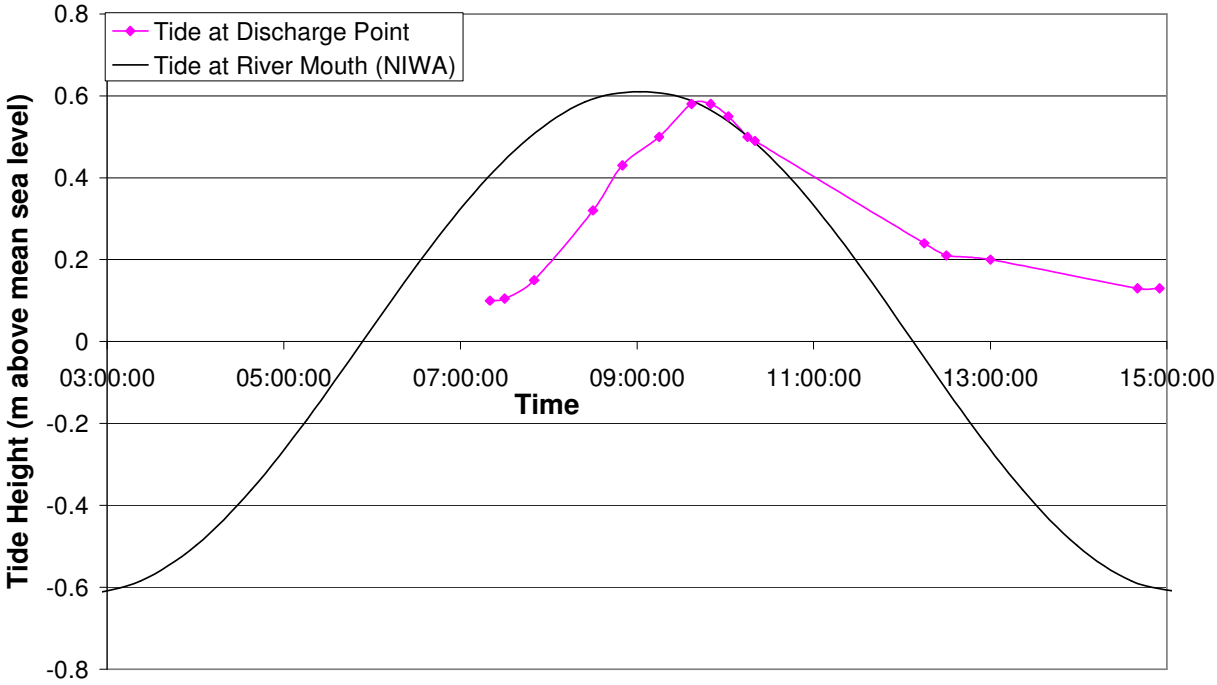

Figure 5 – Tide height at the Porangahau River Mouth and at the Oxidation Pond (3 Oct 2008)

6.2 Velocity and Flow

As a result of the much quicker rising tide than falling, the velocity in the river during rising tide was much stronger than that experienced on the falling tide. This is illustrated by Figures 6, 7 and 8 which show the tide height and velocity measured in the river. The negative velocities indicate flow upstream. The graphs illustrate how significantly higher velocities were measured on the incoming tide for two hours before high tide than during the out going tide when velocities in general were too small to measure. Figure 9 shows where the velocities were measured.

As described in the methodology section, the velocities were found by using a current meter and taking the average of 5 flows measured at different depths at each location. The LHS readings were taken at ¼ of the way across the river on the left hand side. The middle readings were taken at the middle of the channel and the RHS readings at ¼ of the way across the river from the right.

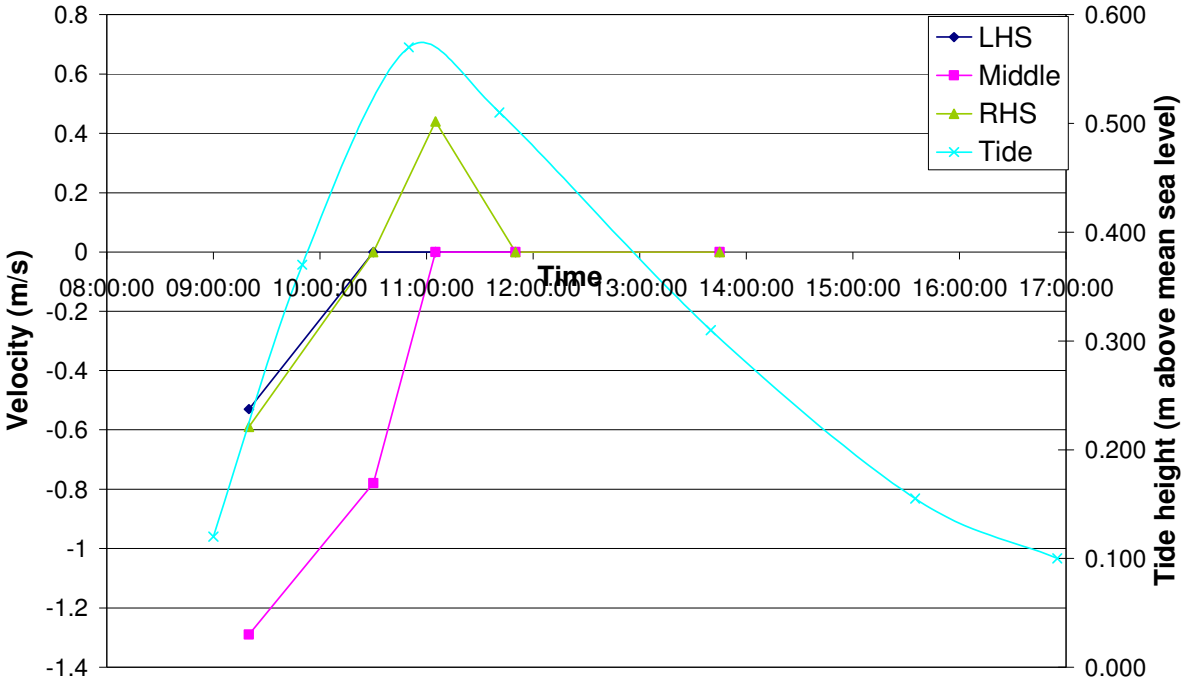

Figure 6 – Current Velocity and Tide Height 400m Upstream of Discharge

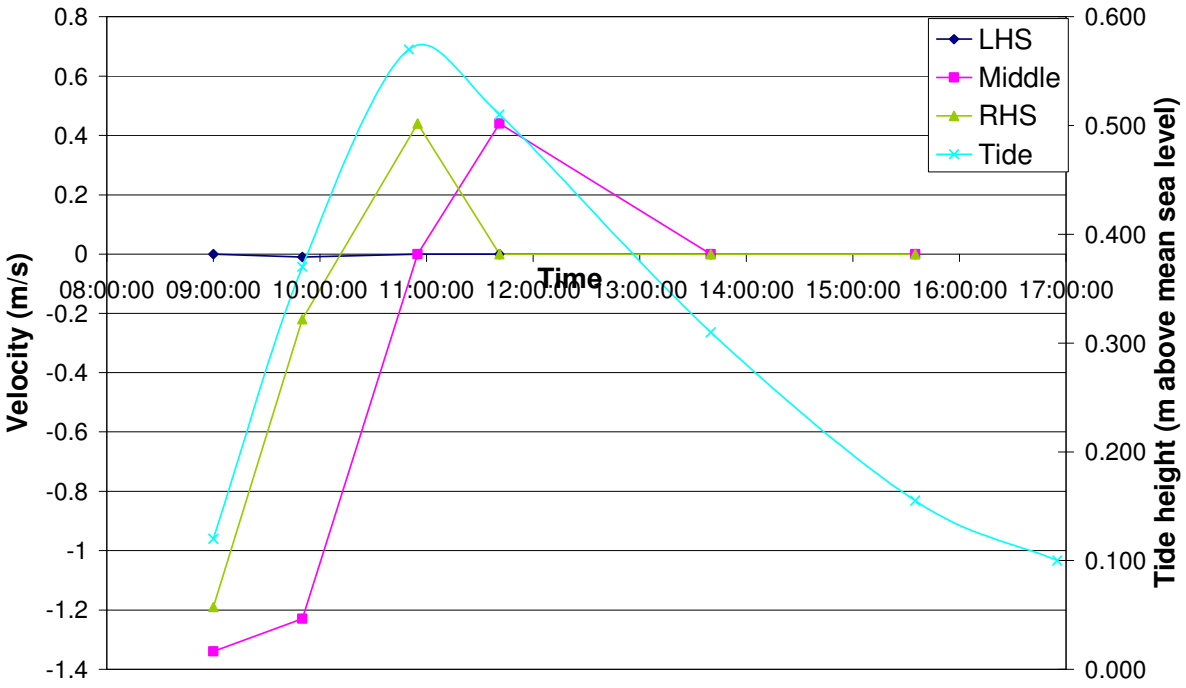

Figure 7 – Current Velocity and Tide Height at Effluent Discharge Point

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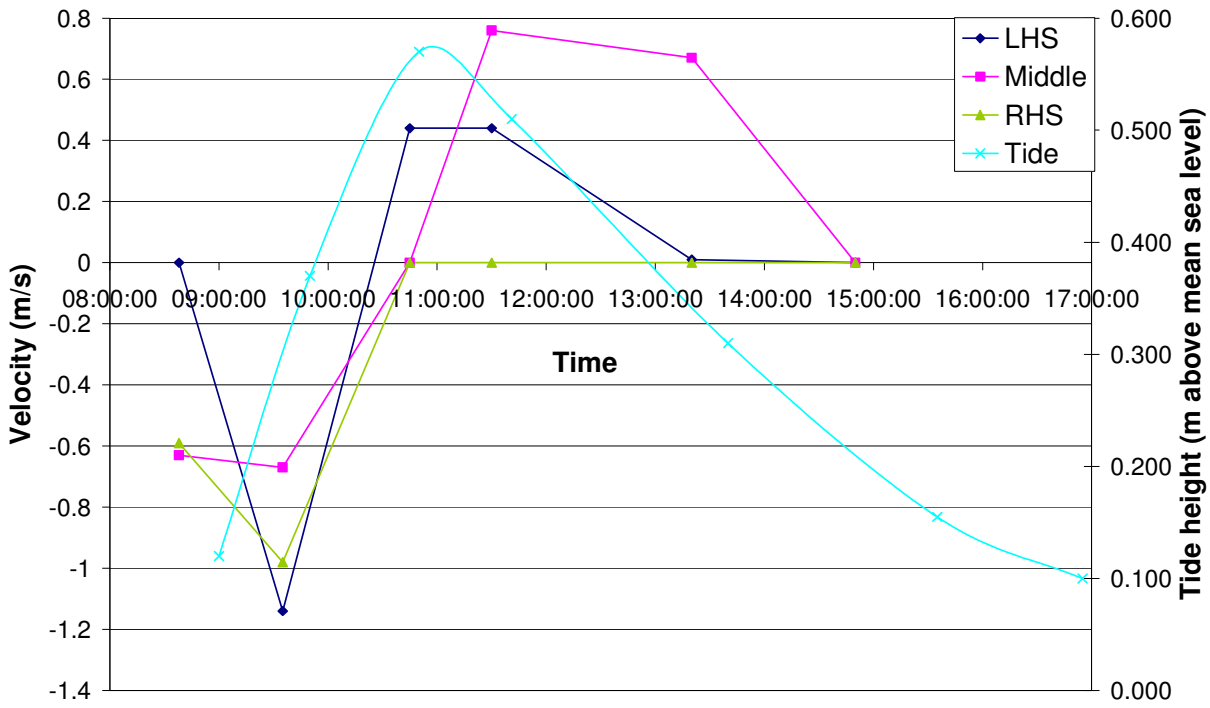

Figure 8 - Current Velocity and Tide Height 300m Downstream of Discharge

Figure 9 – Location of cross sections and velocity measurements

Converting these velocities to flow gives Figure 10. This shows that the flow in the river is significantly affected by the tides with flows of up to -18m3/s on the rising tide and 8m3/s on the falling tide. The results also indicate the tidal influence is starting to reduce significantly around the area of the ponds. This is illustrated by the largest flows being experienced at the 300m down stream site and significantly smaller flows being measured at the 400m upstream site.

The flows in Figure 10 were found by taking the velocity in each third of the river and multiplying by the area of that segment of river, adjusted to account for tide height then adding the three flows to obtain a total flow.

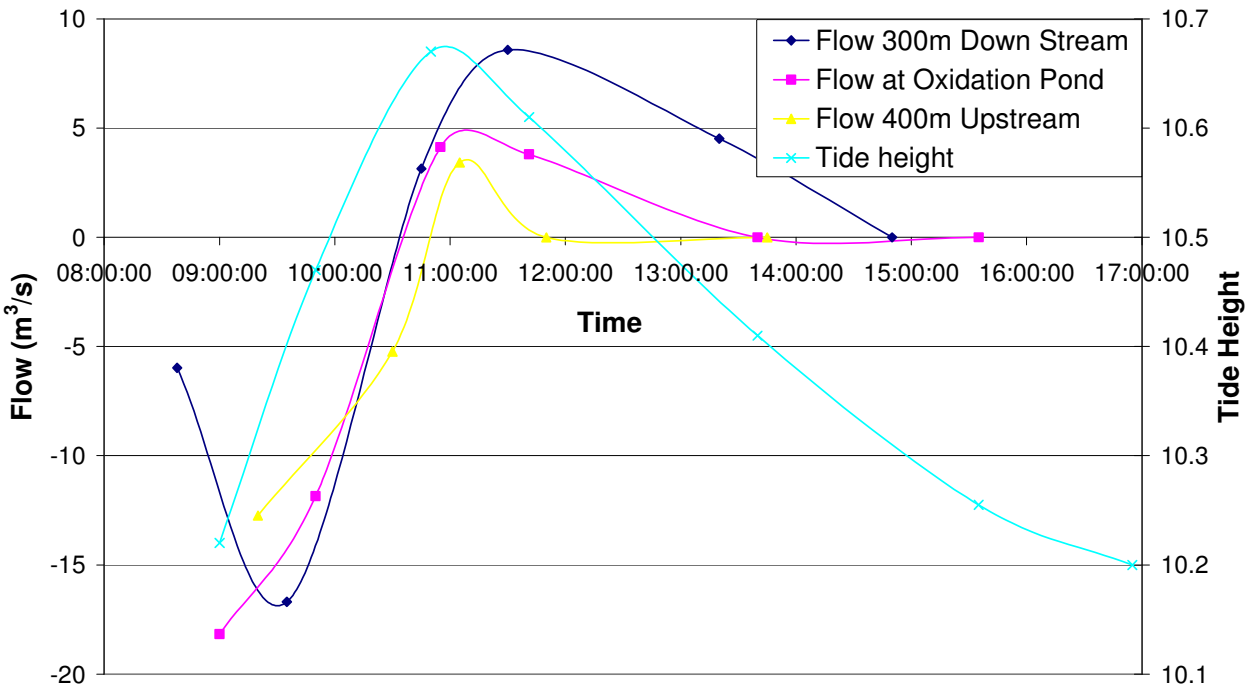

Figure 10 – Flow in the Porangahau River and Tide Height (negative flow indicates upstream flow)

6.3 Salinity Measurements

The salinity of the river water at the point of effluent discharge was only slightly less than that measured at the Porangahau lagoon.

This confirms that the receiving waters for the effluent discharge are largely saline under low flow conditions. As the effluent discharge is freshwater the density difference between the effluent and the water means that the effluent plume will behave as a buoyant surface jet. However the shallowness of the river at the point of discharge will negate much of this

effect. This is reinforced by observations which indicate that the plume mixes of the full depth fairly rapidly.

6.4 Water Quality Investigations

During the site visit on 3 October 2008 the water upstream and down stream of the discharge was tested for total suspended solids, total ammoniacal nitrogen, dissolved reactive phosphorus, faecal coliforms and E. coli. All samples were taken on the outgoing tide, moving from upstream to downstream to provide a "snapshot" of concentrations. These samples are essentially background concentrations as most samples were taken from outside the effluent plume. The results of this testing are shown in Figures 11, 12, 13 and 14. From these results a number of patterns are evident:

- The total suspended solids are relatively low on both sides of the river above the discharge then peak at between 600m (RHS) and 1000m (LHS). The peak concentrations are much higher than the suspended solids concentration of the oxidation pond discharge (measured at 13 g/m^3 on the day of the study with median values around 35 g/m^3) and are well downstream of the discharge point. The high suspended solids could be a result of localised sediment disturbance or possibly a secondary source of contamination.

- Ammoniacal nitrogen levels are very low, and mostly under the detection limit of 0.01 g/m^3. There is a very small spike above the detection limit at 400m (LHS) and 600m (RHS), however the levels are still very close to the detection limit. The samples indicate that background concentrations of ammonia were low.

- The results for Faecal coliforms and E. coli are very close, both in trend and in overall numbers. The general trend indicates a declining concentration the further downstream you move. Concentrations are very low and well below guideline levels. There is a slight dip in the concentrations at 400m which provides further support that the small suspended solids and ammonia "spikes" are unlikely to have been caused by the oxidation pond, since there is no corresponding Faecal coliform or E.coli "spike".

- The results from the phosphorus monitoring are not shown as they were always under the detection limit of 0.004g/ m^3, indicating low background concentrations of phosphorus and showing no detectable effect from the oxidation pond discharge.

Effluent quality on 3 October 2008 was high, and below 25th percentile values for most components

Parameter	Effluent Quality on 3 October 2008
Suspended Solids (g/m^3)	13
Faecal Coliforms (CFU/100ml) [1]	420
EColi (CFU/100ml)	250
Nitrogen (ammoniacal – g/m^3)	5.6
Phosphorus (reactive – g/m^3)	1.4

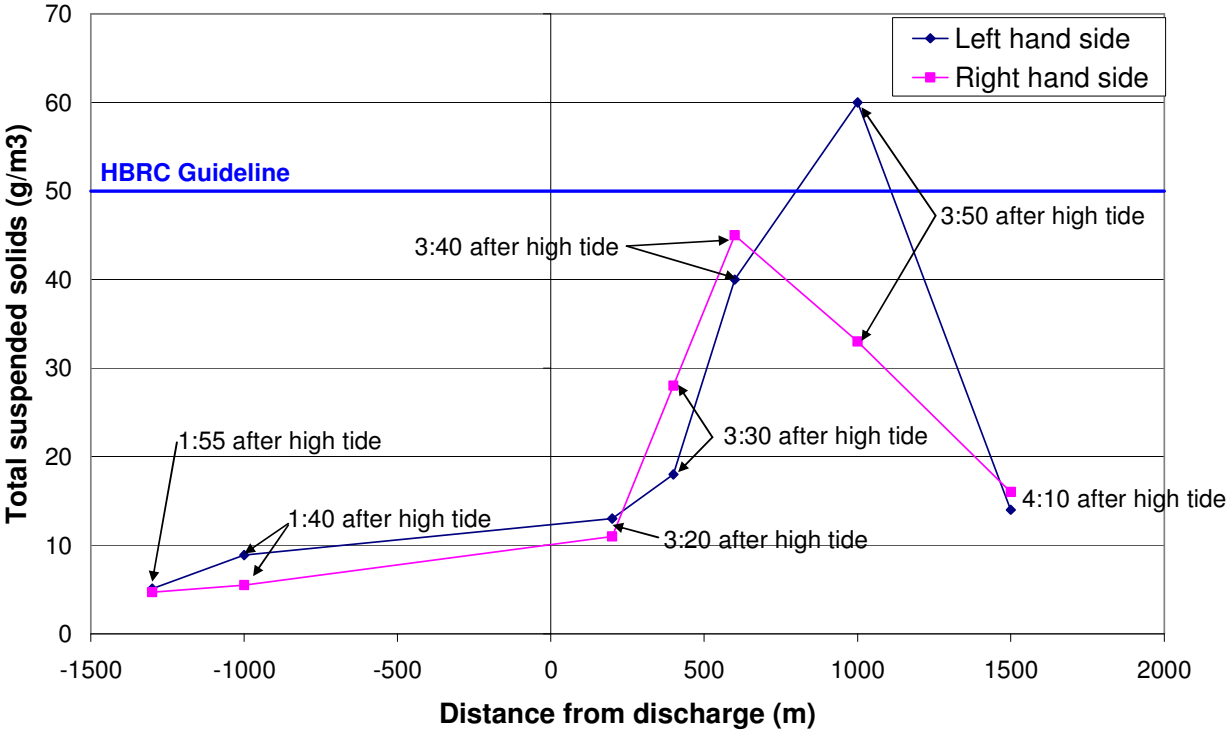

Figure 11 – Suspended solids in the Porangahau River up and down stream of the discharge

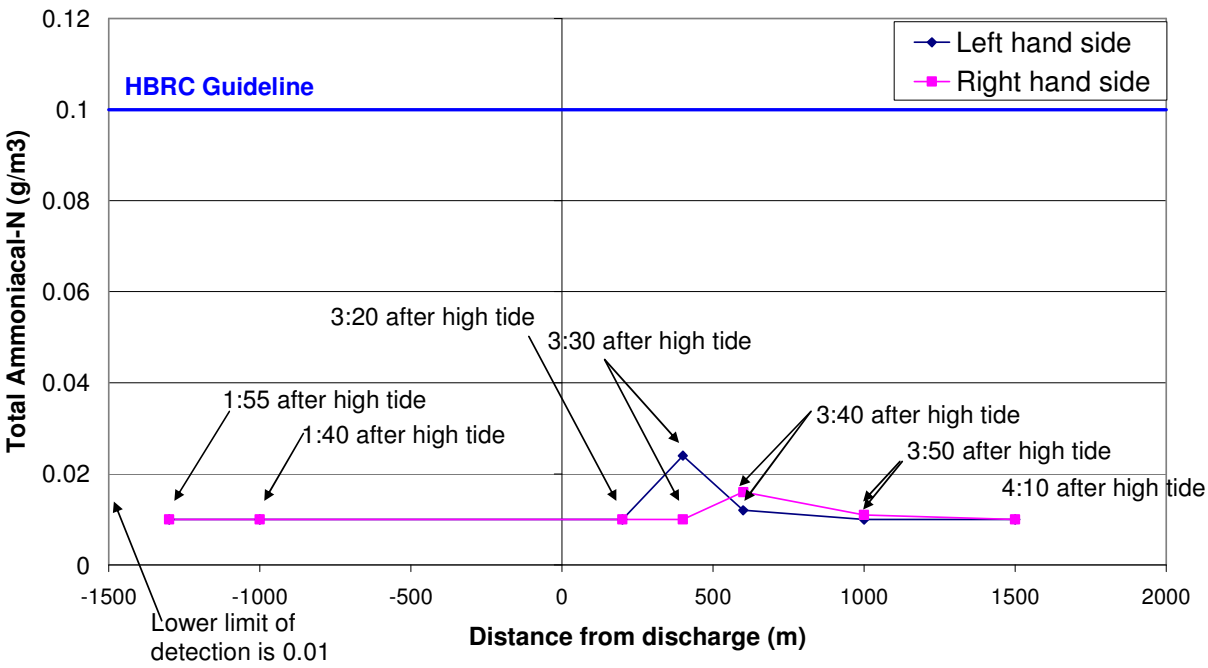

Figure 12 – Total Ammoniacal-N in the Porangahau River up and downstream of the discharge

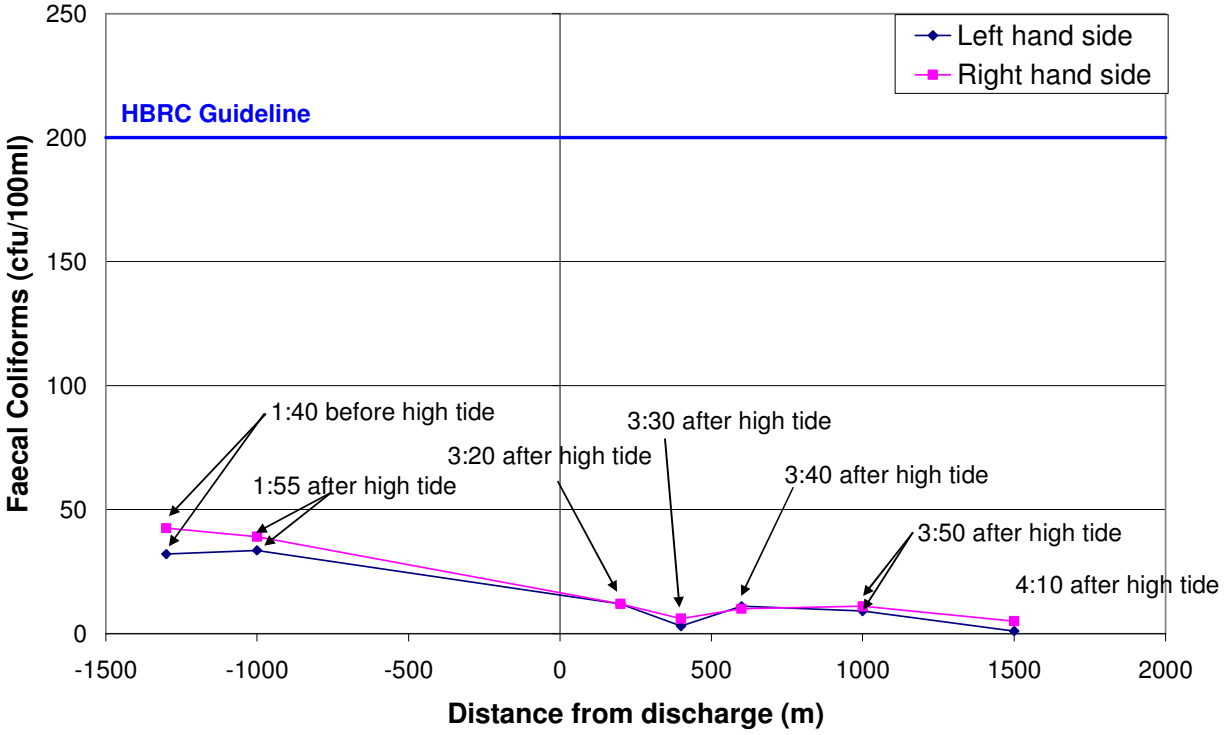

Figure 13 – Faecal Coliforms in the Porangahau River up and downstream of the discharge

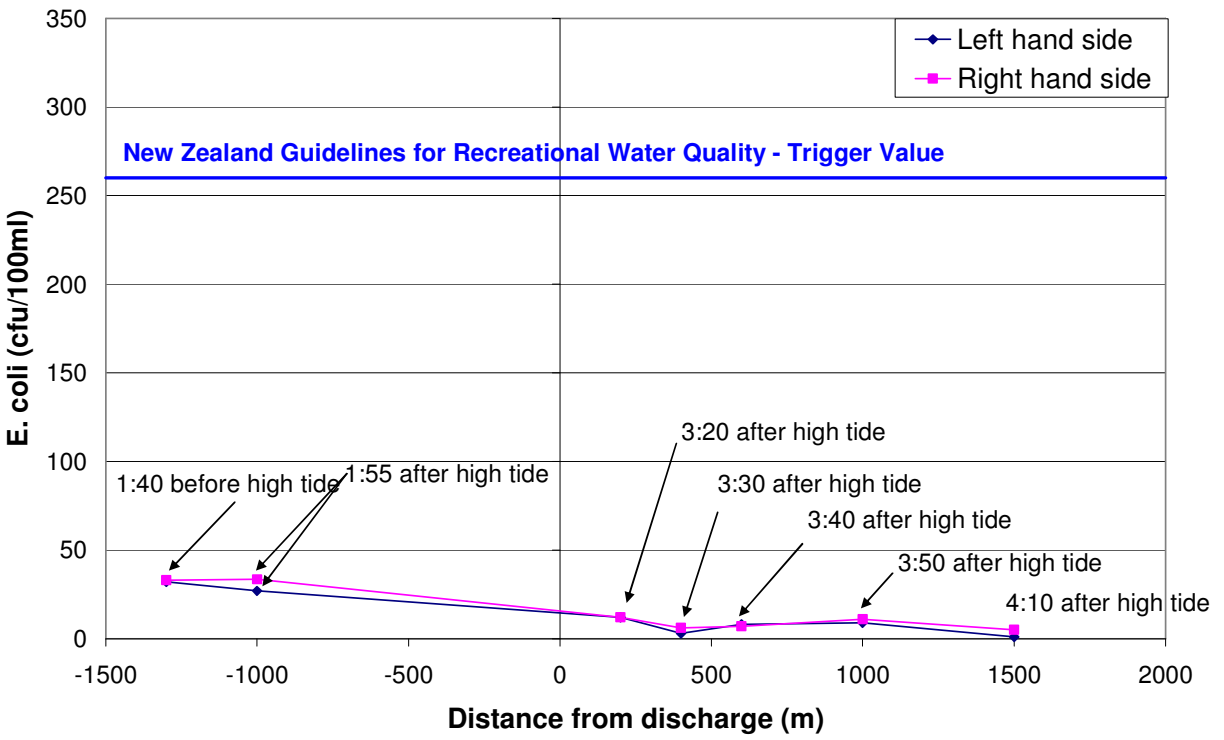

Figure 14– E. coli in the Porangahau River up and downstream of the discharge

6.5 Dye injection and sampling

Two separate releases of tracer were carried out, the first on the incoming tide (2.5-1.5 hrs before high tide) and the second on the outgoing tide (45min to 4 hrs after high tide). For each release, a continuous stream of Rhodamine Dye was released for thirty minutes into the stormwater drain that carries the discharge from the oxidation ponds to the Porangahau River. The plume was then followed downstream and samples were taken from the centre, the left and the right of the plume.

The majority of the plume moved downstream in both releases, despite the first release being on the incoming tide. It is thought that this is due to the effect of secondary currents occurring at the bank of the river (i.e. the main tidal flow travels upstream at the centre of the river but flow at the edges is downstream). It is unclear if this phenomenon would occur during all high tides as the flow and bank shape changes. However if it does occur at all flows it indicates that the bank-side discharge may have a reduced impact over a discharge in the centre of the river as the discharge always flows downstream and so contaminants will not accumulate during successive tide cycles.

Visual observations indicate the plume had a distinct tendency to follow the left bank as shown in Figures 15, 16 and 18. Observations also indicate that the mixing is highly dependant on bank geometry. This is shown in figure 18 by the way the plume experiences significant transverse diffusion at the first sand groin the plume encounters (as indicated by the sudden widening of the plume just upstream of the obstruction). It is also indicated by the rapid diffusion that is evident in Figure 19 as the river turns the corner and the plume rapidly spreads laterally.

During both releases a small amount of dye moved upstream as shown by Figure 15 and Figure 17. This is believed to be due to small eddies formed at the bank of the river by obstructions to the flow. In the incoming tide case by the exposed sand groin, in the outgoing tide case by the wharf 20m upstream of the discharge.

The dye plume was clearly visible up until around 150m downstream where the plume rapidly diffused transversely to cover approximately half the river width before being diluted beyond visual observation, as shown by Figure 20 and 21. The point at which the dye was no longer visible was between 150m and 200m downstream.

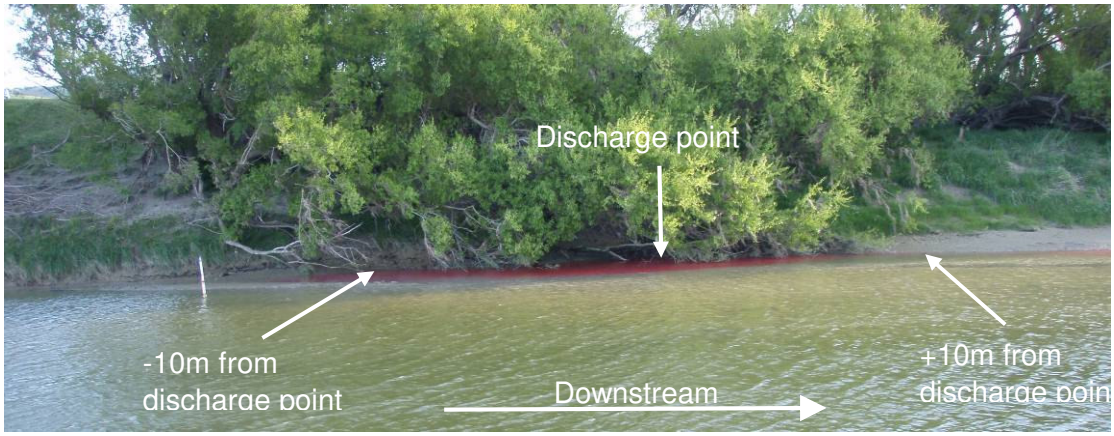

Figure 15 – Rhodamine Dye plume on incoming tide -10 to 10m from discharge point Taken at 7:50, 2hrs before high tide, 35min after release of dye)

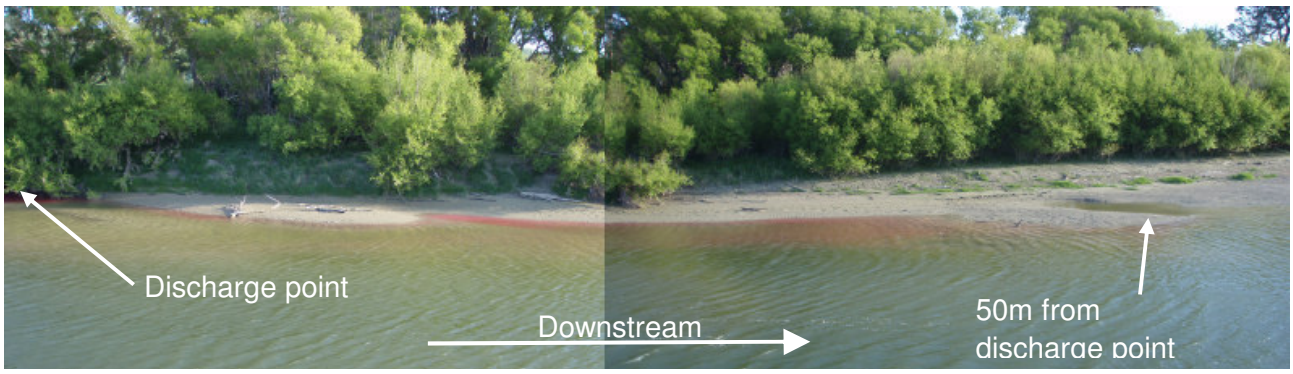

Figure 16 – Rhodamine Dye plume on incoming tide, 0 to 50m from discharge point. Taken at 7:50, 2hrs before high tide, 35min after release of dye.

Figure 17 – Rhodamine Dye plume on outgoing tide, -20m to 0m from discharge point. Taken at 10:50, 1hr after high tide, 20min after release of dye.

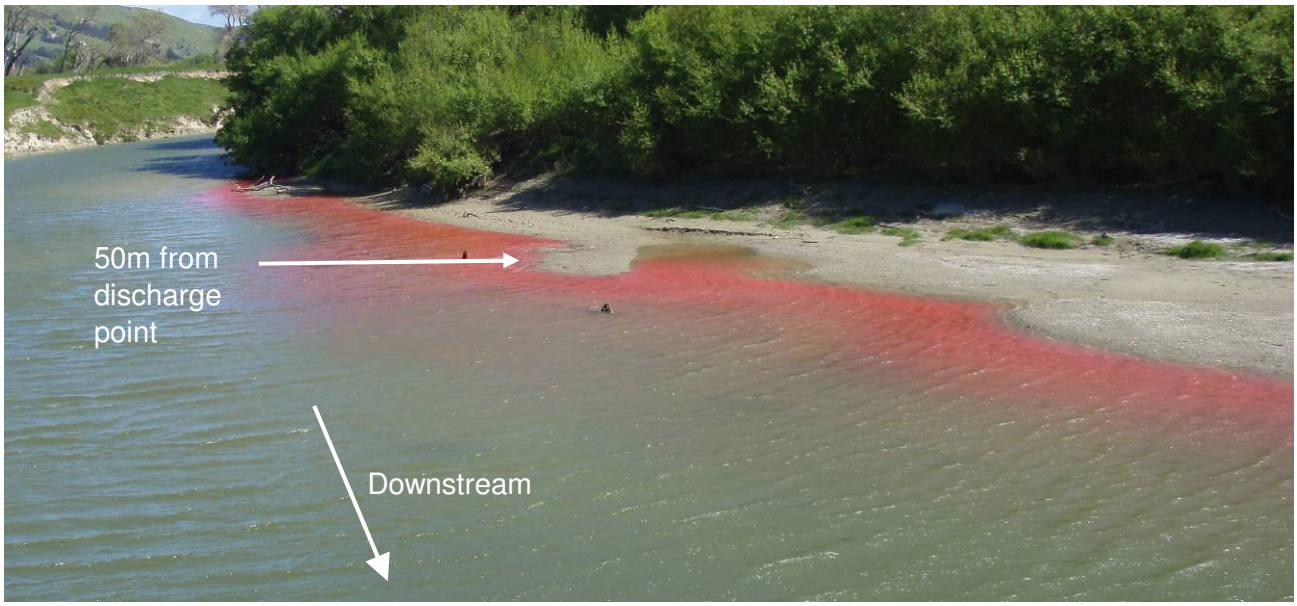

Figure 18 - Rhodamine dye plume on outgoing tide, 0 to 100m from discharge point. Taken at 11:30, 1hr 40min after high tide, 1hr after release of dye.

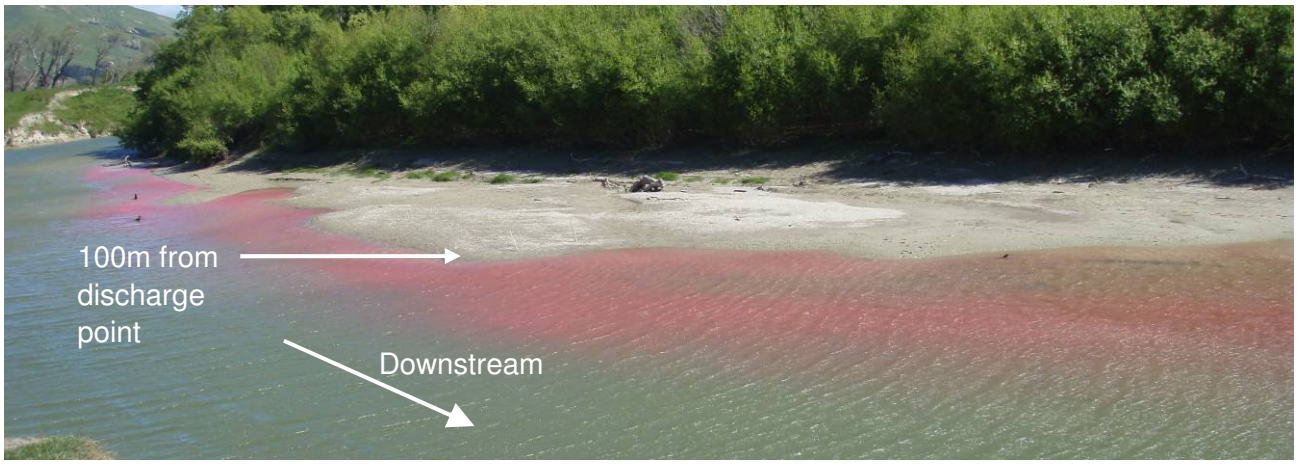

Figure 19 - Rhodamine dye plume on outgoing tide, 0 to 150m from discharge point. Taken at 11:50, 2hrs after high tide, 1hr 20min after release of dye.

Figure 20 - Rhodamine dye plume on outgoing tide, 150 to 300m from discharge point.

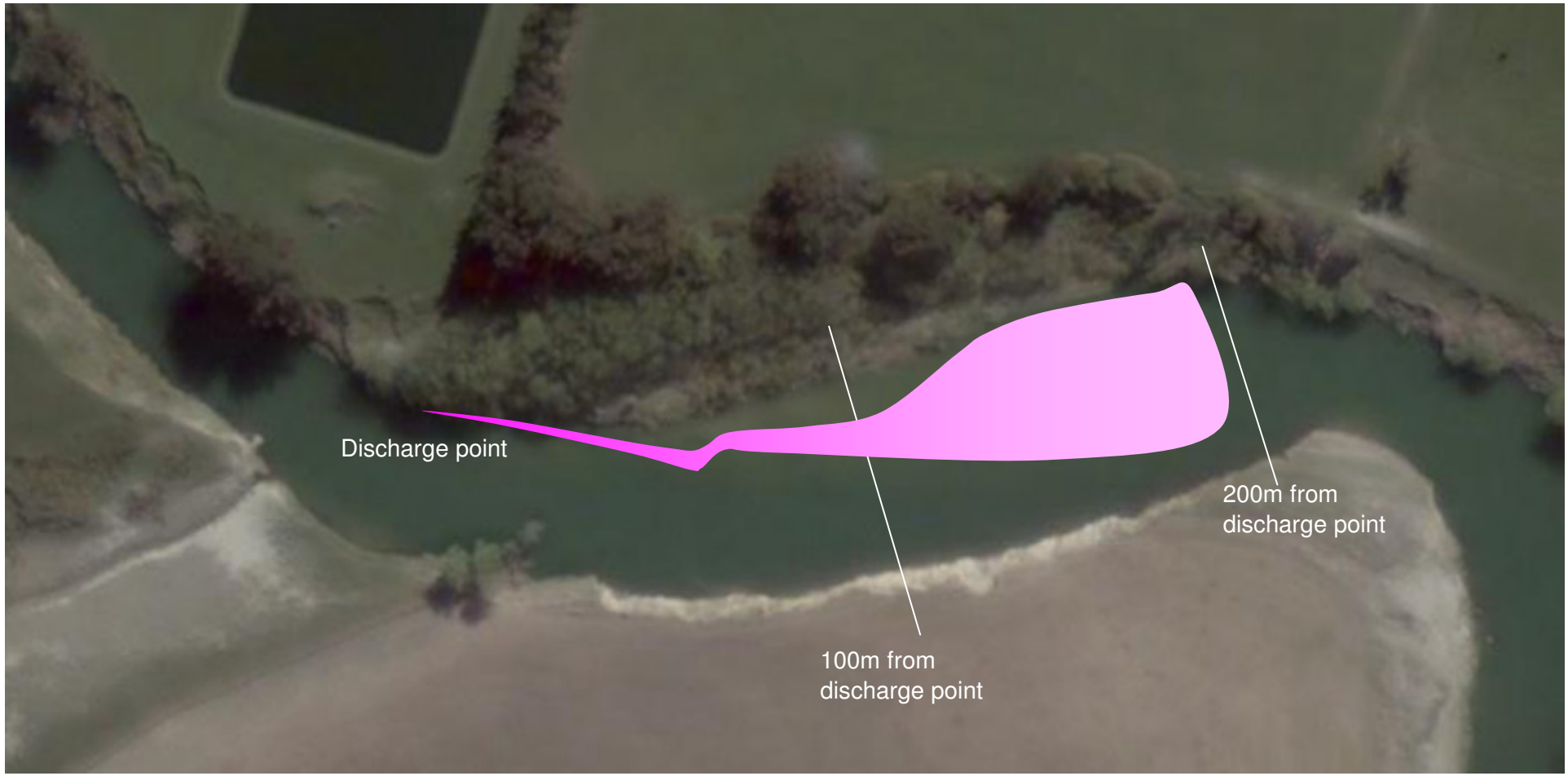

Figure 21 – Sketch of the Rhodamine dye plume created on the outgoing tide.

As part of the dye tracer study samples were taken at the centre, left edge and right edge of the plume and tested for dye concentration. The results from this sampling are shown in Table 5 and 6 and Figure 22.

Table 5 – Rhodamine dye dilution on incoming tide

Time	Tide	Distance from Discharge (m)	Distance / River Width	Rhodamine Dye Concentrations (ug/l)			Dilution
				Left	Centre	Right	
07.15	low/incoming	0	0	14100	16600	15650	1
07.30	incoming	1	0.03	1030	2680	329	5.8
08.00	incoming	30	0.78		296	137	52
08:45	incoming	70	1.8	30	49	<0.5	315

Table 6 – Rhodamine dye dilution on outgoing tide

Time	Tide	Distance from Discharge (m)	Distance / River Width	Rhodamine Dye Concentrations (ug/l)			Dilution
				Left	Centre	Right	
10.30	high/outgoing	0	0	88600	95300	89900	1
10.30	high/outgoing	1	0.03		2060	4900	19
11.00	outgoing	5	0.13		458		199
11.30	outgoing	100	2.6	213	392	161	233
12.00	outgoing	150	3.8	43	96		951
13.20	outgoing	400	10.3	14	5	5	6519
13.30	outgoing	600	15.4	9		10	9127

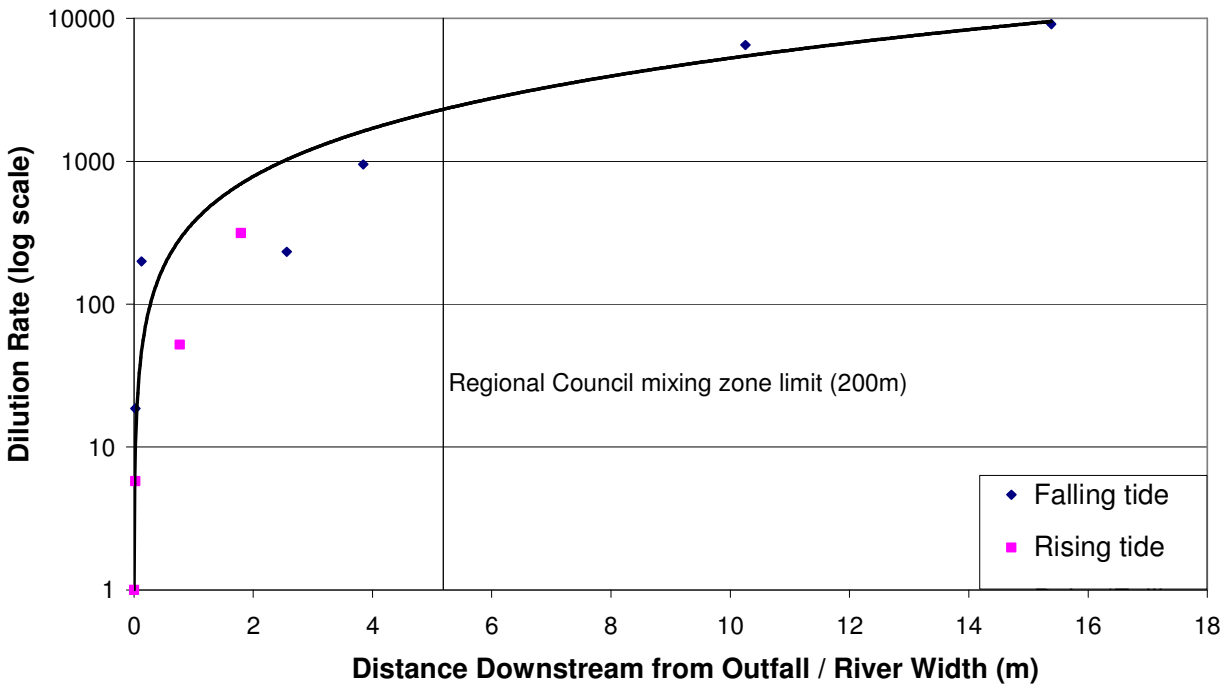

Figure 22 – Dilution of Rhodamine Dye against distance downstream (Note: highest dye concentration at each point used)

Using the results from the graph in figure 22 gives a dilution at 200m in excess of 1000x. Applying a 1000x dilution to the average and maximum effluent quality and assuming the background concentration of contaminants is negligible gives the concentration of contaminants in the effluent plume shown in Table 7.

Table 7 – Expected water quality in the effluent plume 200m downstream of the discharge point assuming negligible river inflow contaminant concentrations.

Parameter	Effluent Quality		Expected water quality 200m down stream of discharge point	
	Mean	Maximum	Mean	Maximum
BOD_5 (mg/L)	24.3	69	0.024	0.069
Suspended Solids (mg/L)	44.2	140	0.044	0.14
Faecal Coliforms (cfu/100ml)	10740	73000	10	73
E. coli (cfu/100ml)	250[1]		0.25	
Ammoniacal –N (mg/L)	5.8[2]	7.0	0.0058	0.0070
DRP (mg/L)	3.4[2]	4.8	0.0034	0.0048

[1] Value based on single measurement taken on the 3/10/08 as part of the dye mixing study as there are no long term monitoring results for this parameter.
[2.] Values based on limited monitoring between Dec02 and Feb03.

7 Water Quality Guidelines

The effects of the discharge on water quality in the Porangahau River will be assessed by Hawke's Bay Regional Council (HBRC) against commonly used guidelines. Available guidelines include those from the HBRC Resource Management Plan, the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZEEC, 2000) and the New Zealand Guidelines for Recreational Water Quality (Ministry for the Environment, 2003). These are summarised in Table 8 below for different water quality parameters.

Table 8 – Water Quality Guidelines and Trigger Values

Parameter	HBRC Resource Management Plan	ANZECC NZ Freshwater (Trigger Values)[1]	ANZECC SE Australia Estuarine (Trigger Values)	Guidelines for Recreational WQ
DO (%)	80%	98-105%	80-110%	
Suspended solids (mg/l)	50			
Faecal coliforms (CFU/100ml)	200			
E. coli (CFU/100ml)				260(alert)/550(action)
NH4+(mg/l)	0.1	0.021	0.015	
DRP (mg/l)	0.015	0.01	0.01	

[1]. Trigger values for slightly disturbed lowland river.

Note that the ANZECC values given in Table 8 are trigger values meaning that, if the values are exceeded, then further investigation work should be initiated to understand the sources and reasons for the high contaminant concentrations. There is no expectation that the monitored water quality should remain continuously below trigger values.

If the expected contaminant concentrations in Table 7 are compared with the guideline values given in Table 8, then it can be seen that all the contaminant concentrations are significantly less than any of the guideline or trigger values after 200m (assuming negligible river inflow concentrations of contaminants). However this interpretation applies strictly to the effluent discharge, river inflow, tidal and wind conditions that occurred on the day of the dye mixing tests (3 October 2008). The background concentrations of different tracer contaminants under a much wider range of boundary conditions are examined in Section 9 with the aid of a tidal mixing analysis assuming classic plume behaviour in the tidal affected river.

8 Comparison with Previous River Water Monitoring

Monitoring of river water quality over the summers of 2002 and 2003 can be compared to the results of the dye tracer study. The river water quality measurements were taken on 9 occasions from sites 100m upstream, 50m upstream, 50m downstream and 140m downstream. For comparison, samples were characterised relative to the tidal cycle, as presented in Table 9.

Table 9 Characterisation of Previous Sampling relative to Tidal Cycle

Date of Sampling	Time Taken	Tide at River Mouth	Estimated Point in Tidal Cycle at Oxidation Pond[1]	Assumed Characteristic	Flow in River [2] (m^3/s)
6/11/02	4.20pm	LT 1.10pm HT 7:19pm	4:00 before HT	Incoming tide	0.25
13/11/02	12.40pm	LT 1.13am HT 7:35pm	1:35 before HT	Incoming tide	0.13
19/11/02	10.00am	HT 5.39am LT 11:45am	3:15 after HT	Outgoing tide	1.75
27/11/02	11.20am	LT 5:12am HT 11:35am	1:10 before HT	Incoming tide	2.0
4/12/02	10.15am	HT 5.40am LT 11:54am	2:40 before LT	Outgoing tide	0.75
11/12/02	12.40pm	HT 11:51am LT 6:13pm	0:10 before HT	High tide	0.75
28/01/03	12.30pm	LT 8:29am HT 2:37pm	1:10 after HT	Outgoing tide	0.01
20/03/03	11.00am	HT 7:33am LT 1:50pm	2:10 after HT	Outgoing tide	0.12

[1]. Assuming 1 hr delay between tide cycle at river mouth and oxidation pond
[2] Based on flows from Taurekaitai at Wallingford gauging station, scaled by 2.5 to estimate Porangahau flows

The results from the sampling have been presented in Figures 23, 24, 25 and 26 for the incoming tide, and Figures 27, 28, 29 and 30 for the outgoing tide. The figures have the following characteristics:

- Even on the incoming tide, increased concentrations of ammonia and dissolved reactive phosphorus are observed downstream of the discharge, which is consistent with the results of the tracer study.
- Results for faecal coliforms[1] are highly variable, and perhaps indicative of the large variation of faecal coliform numbers in the river system – refer to monitoring results for Kate's Quarry in Section 3.
- Faecal coliform results taken on the incoming tide (Figure 25) show one occasion when concentrations were above the guideline of 200 cfu/100ml at 140m downstream, although noting that there is still 60m available for further dilution prior to the 200m recommended mixing zone.
- Faecal coliform concentrations taken on the outgoing tide (Figure 29) show that concentrations are generally above guideline levels; however concentrations at 140m downstream are similar to or below concentrations at 100m upstream, indicating that the high concentrations are likely due to high background levels in the river.
- Concentrations of ammoniacal nitrogen, dissolved reactive phosphorus and suspended solids are generally below guideline levels by 140m downstream of the discharge point. An exception to this is the result for 19/11/02 which shows dissolved reactive phosphorus levels approximately double the guideline level – however in this case a minor 2x dilution would be sufficient to achieve the guideline level and there is still 60m of river available to achieve this.

[1] Note that faecal coliform data may be influenced by receiving water salinity – refer to footnote on page 31..

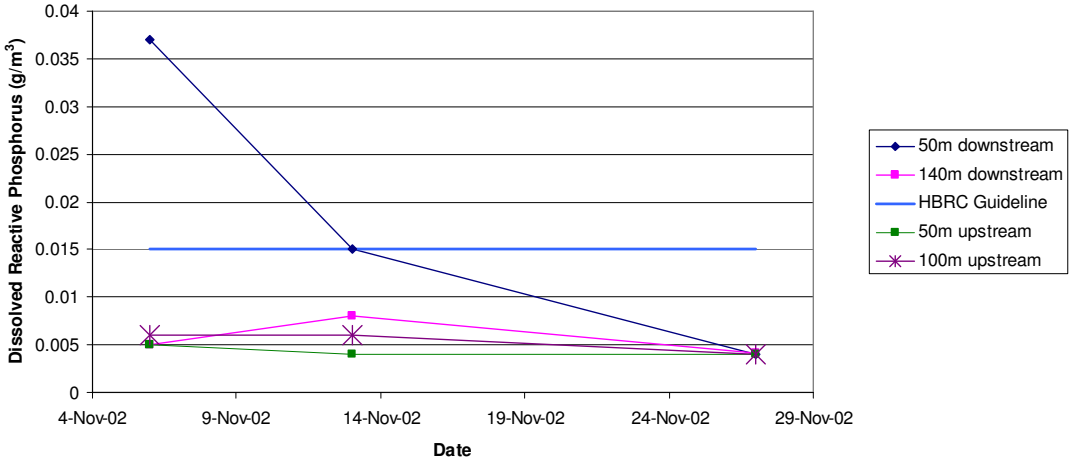

Figure 23 – Dissolved reactive phosphorus concentration sampling on incoming tide

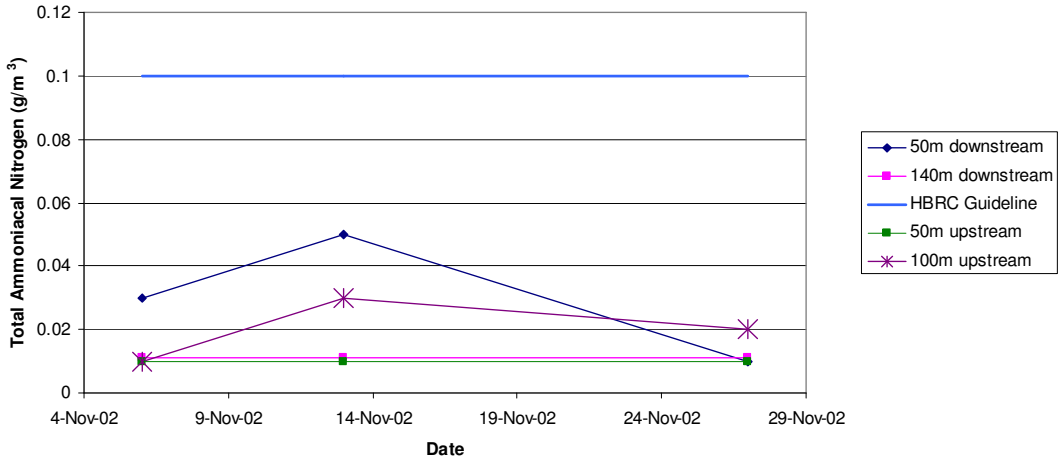

Figure 24 –Total ammoniacal nitrogen sampling on incoming tide

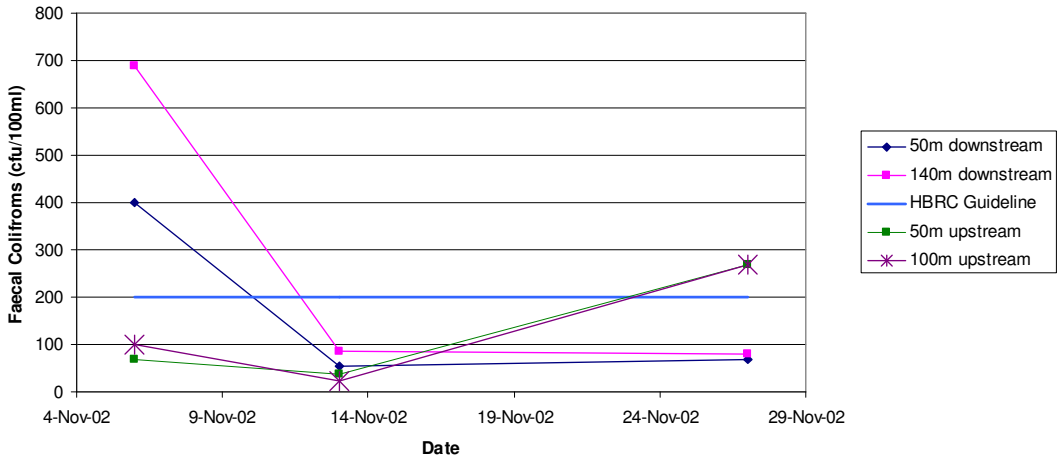

Figure 25 –Faecal Coliform concentration sampling on incoming tide

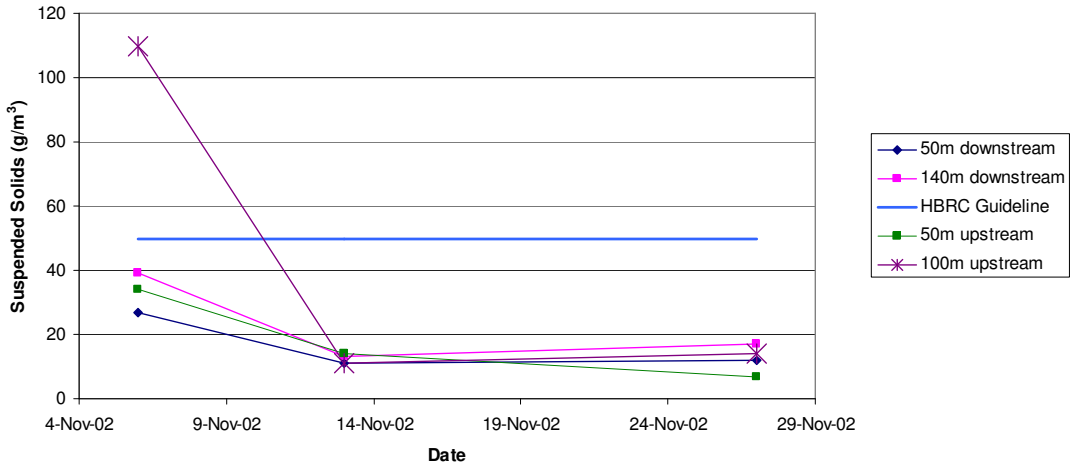

Figure 26 –Suspended solids concentration on incoming tide

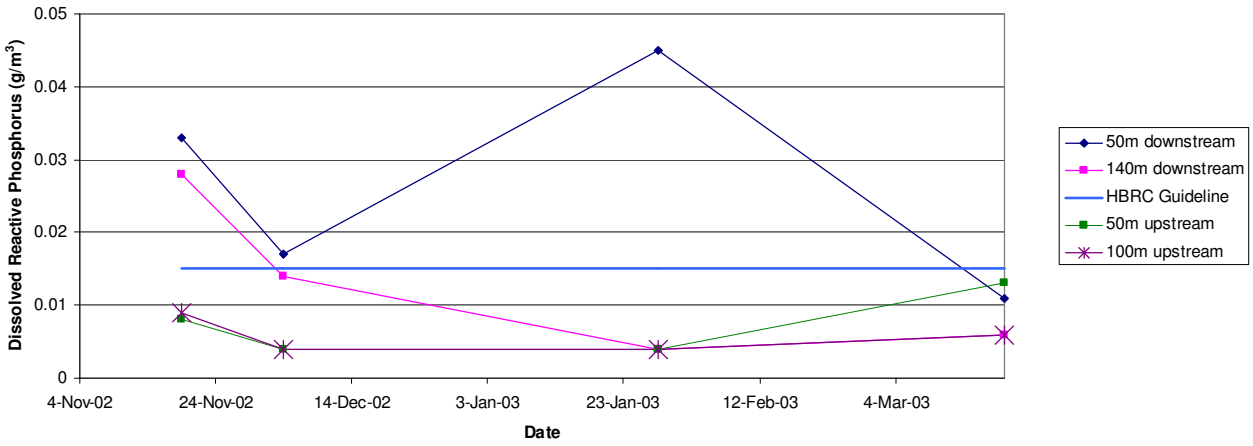

Figure 27 –Dissolved reactive phosphorus concentration on outgoing tide

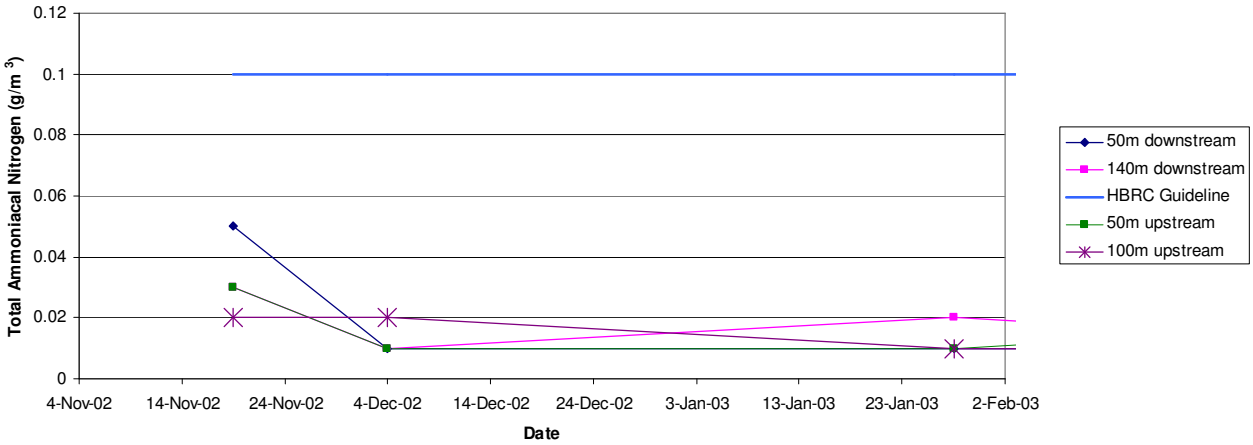

Figure 28 –Ammonia nitrogen concentration on outgoing tide

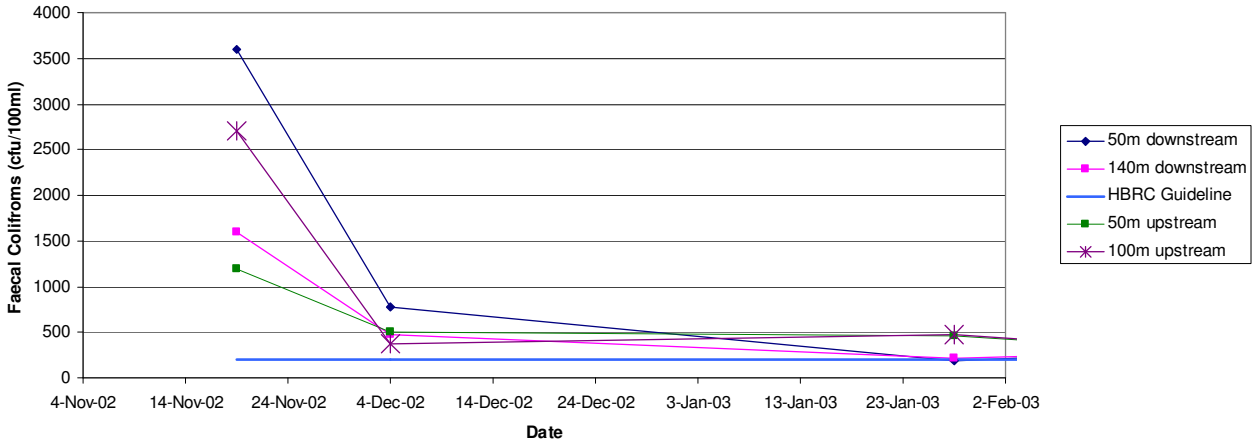

Figure 29 –Faecal coliform concentration on outgoing tide

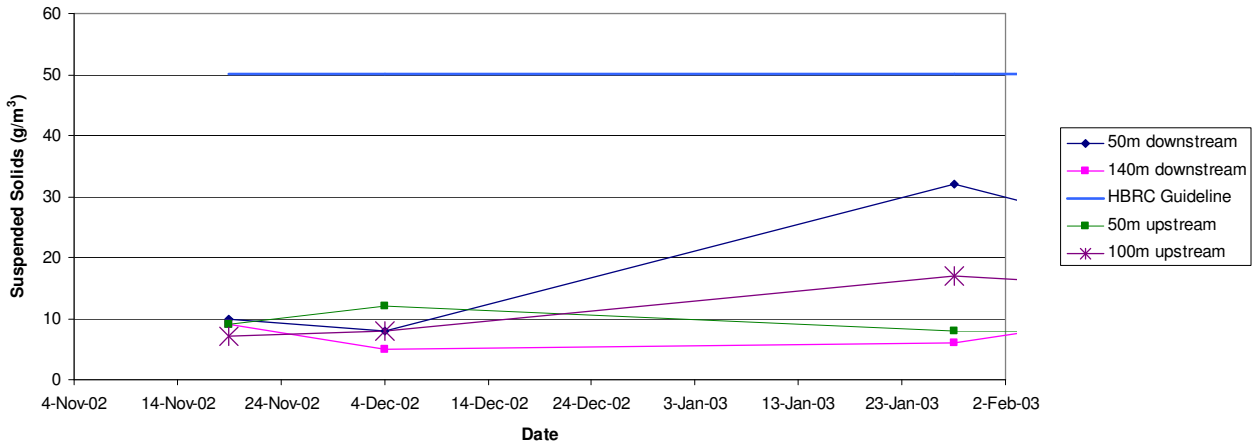

Figure 30 –Suspended solids concentration on outgoing tide

9 Tidal Mixing Analysis

9.1 Introduction

The observation from the dye mixing tests (Section 6) that the effluent plume for the oxidation pond outlet moved downstream during an incoming (flood) tide as well as during an outgoing (ebb) tide was a surprising result. It was counter-intuitive to the expected flow behaviour in an estuarine situation. It is not known whether this observed plume behaviour would also occur during a flood tide under different river inflow and wind conditions.

For this reason a tidal mixing analysis was carried out based on the premise that, under flood tide conditions, the effluent plume would exhibit the normal expected behaviour and be directed upstream, while under ebb tide conditions the plume would be directed downstream. Under either condition, the plume would be expected to mix over the full depth of the river within a few metres of the discharge point and over the full width of the river within 200-300m of the discharge point.

The purpose of the tidal mixing analysis was

- to determine the relative influence of the two primary components[2] of contaminant concentration (the river flow component and the effluent discharge component) to the total background in the effluent discharge mixing zone taking account of tidal flushing; and
- to gain an appreciation of the likely magnitude of the total background contaminant concentration in the mixing zone given typical values of quantities and concentrations for the two contributing components.

9.2 Tidal Prism Model

Initially a tidal prism model was set up and calibrated against the measured salinity data from the preliminary investigations on 26 March 2008.

The model was very crude as only limited river cross-section information was available and this was confined to the area immediately upstream and downstream of the effluent discharge point. However based on this limited data, the river downstream to the Beach Road Bridge was approximated as a rectangular-shaped channel 40m wide. The approximate dimensions of the lagoon downstream of this bridge were inferred from the NZMS 260 series topographic map Sheet V24. At the effluent discharge point, the tidal range was assumed to be 0.1-0.6m relative to mean sea level (based on the tidal measurements from the preliminary investigations and the dye mixing tests), while in the lagoon, it was assumed to be -0.6m to +0.6m relative to mean sea level based on tide level predictions.

[2] Note that there may be other secondary factors (such as stormwater inflows, groundwater seepage and biological activity) which could influence background concentration in the mixing zone. The influence of these factors has been assumed to be minor and they have therefore been ignored in the tidal mixing analysis.

The tidal prism model was successfully calibrated to within 1 ppt of the measured salinity values of 27 ppt at the effluent discharge point and 32.5 ppt at the Beach Road Bridge with an open sea value of 35 ppt as a downstream boundary condition. The model calibration indicated that the estuary was very well mixed with a net freshwater inflow (from the river and the oxidation pond) of approximately 0.3 m^3/s on 26 March 2008 (this is predominantly sourced from the upstream river as the effluent flow is very low). This is consistent with the flow record from the Taurakaitai at Wallingford flow gauging station upstream from which it was inferred that the river flow entering the estuary on 26 March 2008 would have been very low.

9.3 Estimation of Background Contaminant Concentrations Using Tidal Prism Model

The upstream segment of the tidal prism model was used to estimate the background concentration in the effluent mixing zone of both biological and chemical tracers (faecal coliforms[3], dissolved reactive phosphorous and ammoniacal nitrogen) based on the premise that the distribution of background tracer concentration downstream to the sea reflected the distribution of salinity deficit predicted by the model. The effluent mixing zone was assumed to fully occupy the upstream segment of the model which extended roughly 400m upstream and 200m downstream of the effluent discharge point. The tracer contaminants were assumed to be fully mixed within the contained volume of this segment.

Figure 31 shows a near-continuous effluent flow record for the period April 2007 to March 2008. This has been taken to be roughly indicative of the range of flows over a full year. Table 10 summarises the flow statistics for the period of record.

Table 10 – Porangahau oxidation pond effluent discharge (l/s) (April 2007 – March 2008)

Minimum	Mean	Maximum	% of the time flow is less than					
			10%	25%	50%	75%	90%	95%
0.19	1.18	11.4	0.45	0.66	1.02	1.49	2.00	2.34

For the purposes of the tidal mixing zone analysis, a range of effluent flows from 0.2 to 5 l/s was considered.

[3] The Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (Ministry for Environment June 2003) note that for salt water the preferred indicator organism is enterococci (Section D2), not E coli (which is the one for fresh water). This is because E. coli are affected by the salt and die off faster than in fresh water, making them an unreliable indicator. However on Page D1 it is noted that for oxidation pond discharges, E. coli should be used because enterococci are damaged by the pond and are therefore not a reliable indicator. Enterococci can also come from runoff from densely vegetated catchment areas so that it is best not to rely on this indicator only as then there is a risk of overestimating the concentration in the river. It appears therefore that both E. coli (or faecal coliforms) and enterococci have limitations as indicators in this context. For the purposes of the mixing zone analysis, we have used faecal coliforms and other chemical tracers as indicators of contaminant concentration.

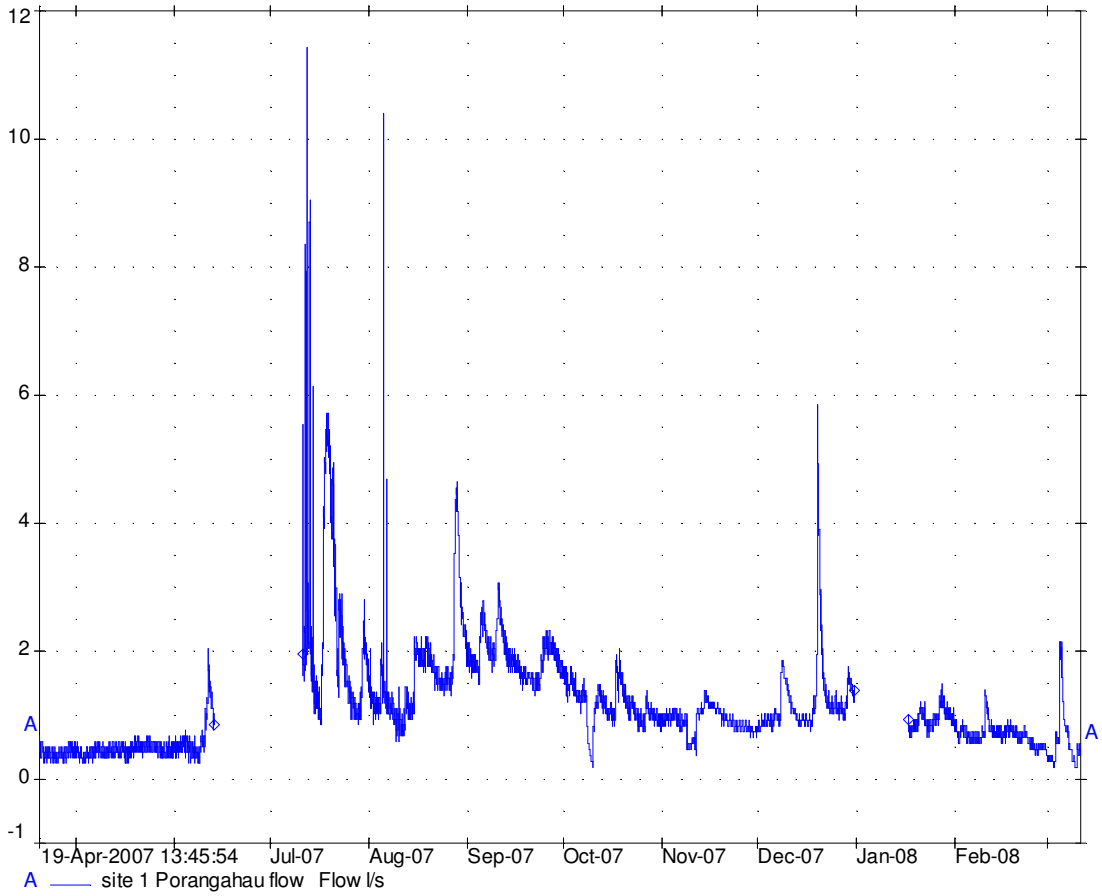

Figure 31 Porangahau oxidation pond effluent discharge (April 2007 – March 2008)

Table 11 summarises the range of faecal coliform (FC), dissolved reactive phosphorus (DRP) and ammoniacal-N (NH_4-N) concentrations in the oxidation pond effluent assumed for the tidal mixing zone analysis based on the summary of measured data in Table 1.

Table 11 Ranges of effluent tracer concentrations assumed for tidal mixing analysis

Tracer	Unit	Tracer Concentration Range
Faecal coliforms (FC)	CFU/100ml	1,000-30,000 (10 and 90 percentile values)
Dissolved reactive phosphorus (DRP)	mg/l	2-5 (minimum and maximum values)
Ammoniacal-nitrogen (NH_4-N)	mg/l	4-7 (minimum and maximum values)

The assumed range of FC concentrations in Table 11 is based on data from about 70 monthly samples measured over the period December 2002 to August 2008. The assumed ranges of DRP and NH_4-N concentrations are based on only a very limited number of samples taken over the five month period from December 2002 to April 2003.

For the purposes of the analysis, river flows of 0.3 and 1 m^3/s were considered based on the inferred flow on 26 March 2008 (the date of the preliminary field investigations) and the inferred median river flow value (refer Table 2).

The following approximate median tracer concentration values were also assumed for the upstream river based on data for approximately 80 intermittent samples taken at Kate's Quarry, 5.6 km upstream of the effluent discharge point, over the period 1988-2002.

- Faecal coliforms 300 CFU/100ml
- Dissolved reactive phosphorus 0.01 mg/l
- Ammoniacal-nitrogen 0.023 mg/l

These values were taken as being indicative of the quality of the water normally flowing into the upstream end of the estuary. For comparison purposes, zero tracer concentration values were also considered.

9.4 Results of Tidal Mixing Analysis

Figures 32-34 show predicted background FC concentrations in the effluent mixing zone as a function of effluent flow and quality for the following cases:

- river flow 0.3 m^3/s (26 March 2008 flow), river FC concentration 0 CFU/100ml
- river flow 0.3 m^3/s (26 March 2008 flow), river FC concentration 300 CFU/100ml (approximate median value from limited upstream sampling)
- river flow 1 m^3/s (median flow value inferred from upstream tributary flow record), river FC concentration 300 CFU/100ml (approximate median value from limited upstream sampling)

These figures illustrate the sensitivity of the background concentration in the effluent mixing zone to the quantity and quality of the incoming river flow. The HBRC Resource Management Plan guideline value for FC concentration is 200 CFU/100ml (Table 8). The results of this analysis suggest that the component of the background FC concentration contributed by the incoming river flow would need to substantially lower than 300 CFU/100ml if this guideline was to be met. Achieving a consistent and reduced effluent quality has some effect on background concentrations in the mixing zone but, due to the low volumes of the oxidation pond discharge; this is only a secondary influence.

To achieve the 200 CFU/100ml guideline value for FC concentration at the boundaries of the effluent mixing zone for the 90 percentile effluent flow value of 2 l/s, the FC concentration in an incoming river flow of 0.3 m^3/s would need to be lower than about:

- 210 CFU/100ml assuming an effluent FC concentration of 10,000 CFU/100ml
- 80 CFU/100ml assuming an effluent FC concentration of 30,000 CFU/100ml

It needs to be emphasised that the predictions shown in Figures 32-34 are based on the assumption of a river FC concentration of 300 CFU/100ml. In contrast the FC concentrations measured upstream of the effluent discharge point during the dye mixing tests on 3 October 2008 were of the order of 40-50 CFU/100ml (when the effluent flow was 0.5 l/s and FC concentration 420 CFU/100ml). If this measured upstream FC concentration value is taken as indicative of the river inflow FC concentration (rather than the median FC value of the 2002-2003 measurements as assumed for the model predictions in Figures 32-34) and applied to this to the tidal mixing model for river inflows of 0.3 m^3/s and 1 m^3/s, then the resulting predictions of background FC concentration in the effluent mixing zone are given in Figures 35 and 36 respectively. These results indicate that the HBRC Resource Management Plan FC concentration guideline value of 200 CFU/100ml could be met for a substantial proportion of the time:

- for a river inflow of 0.3 m^3/s and the 90th percentile effluent discharge value of 2 l/s, the effluent FC concentration would need to be at least 30000 CFU/100ml for the HBRC Resource Management Plan guideline value of 200 CFU/100ml to be exceeded; or
- for a river inflow of 1 m^3/s and the 90th percentile effluent discharge value of 2 l/s, the effluent FC concentration would need to be at least 20000 CFU/100ml for the HBRC Resource Management Plan guideline value of 200 CFU/100ml to be exceeded

Figures 32-36 demonstrate that the primary influence on background tracer concentration in the effluent mixing zone is the component of tracer concentration contributed by the river inflow. The component of tracer concentration contributed by the effluent discharge is generally fairly small (unless the effluent tracer concentration is extremely high) due to the low volumes of the oxidation pond discharge.

Inspection of the measured monthly effluent FC concentration values for the December 2002 to August 2008 period indicates that they are highly variable with no particular pattern. It may therefore be difficult to achieve a consistently low FC concentration with the oxidation pond discharge.

The results of the tidal mixing analysis highlight the need for:

- monitoring background concentrations of indicator tracers at each end of the effluent mixing zone (upstream and downstream of the effluent discharge point) **and** upstream of the tidally affected reach of the river; and
- any resource consent conditions relating to water quality at the boundaries of the mixing zone to be expressed relative to the background concentration of the indicator tracers in the incoming river flow.

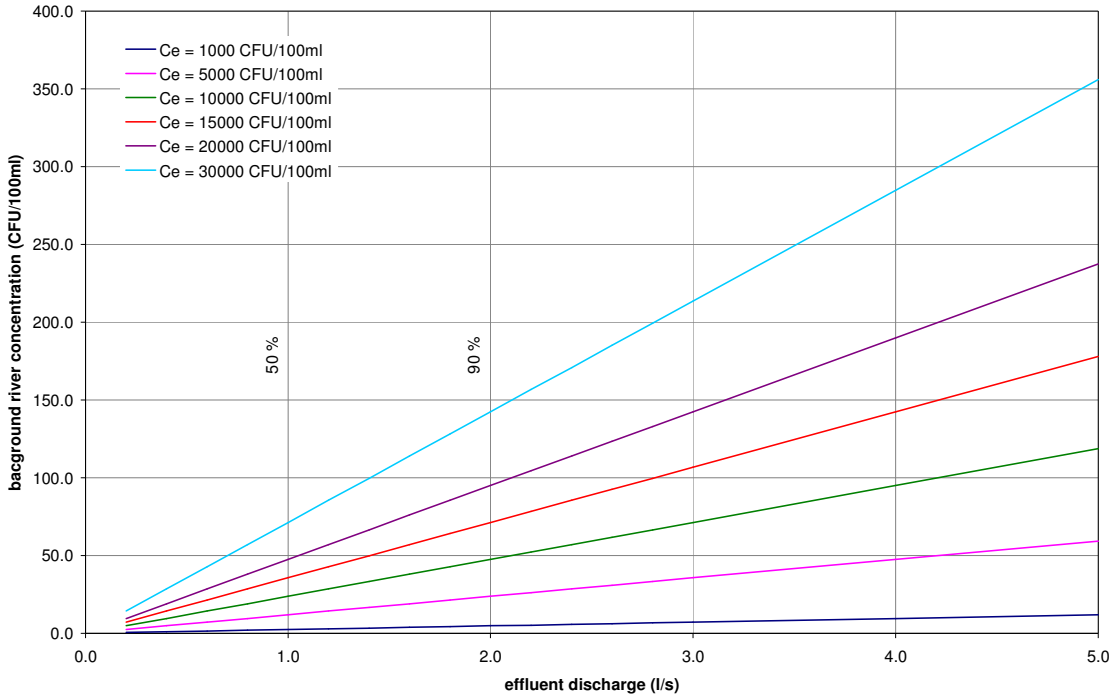

Figure 32 Background FC concentration as a function of effluent discharge and quality (river flow 0.3 m^3/s, river FC concentration 0 CFU/100ml)

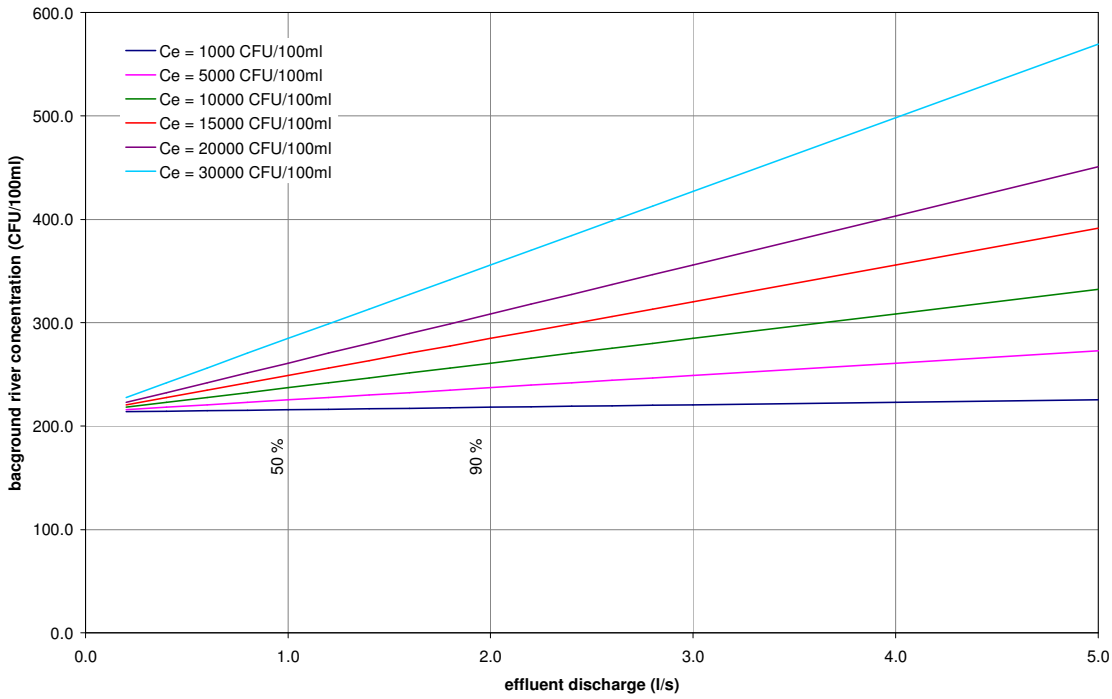

Figure 33 Background FC concentration as a function of effluent discharge and quality (river flow 0.3 m^3/s, river FC concentration 300 CFU/100ml)

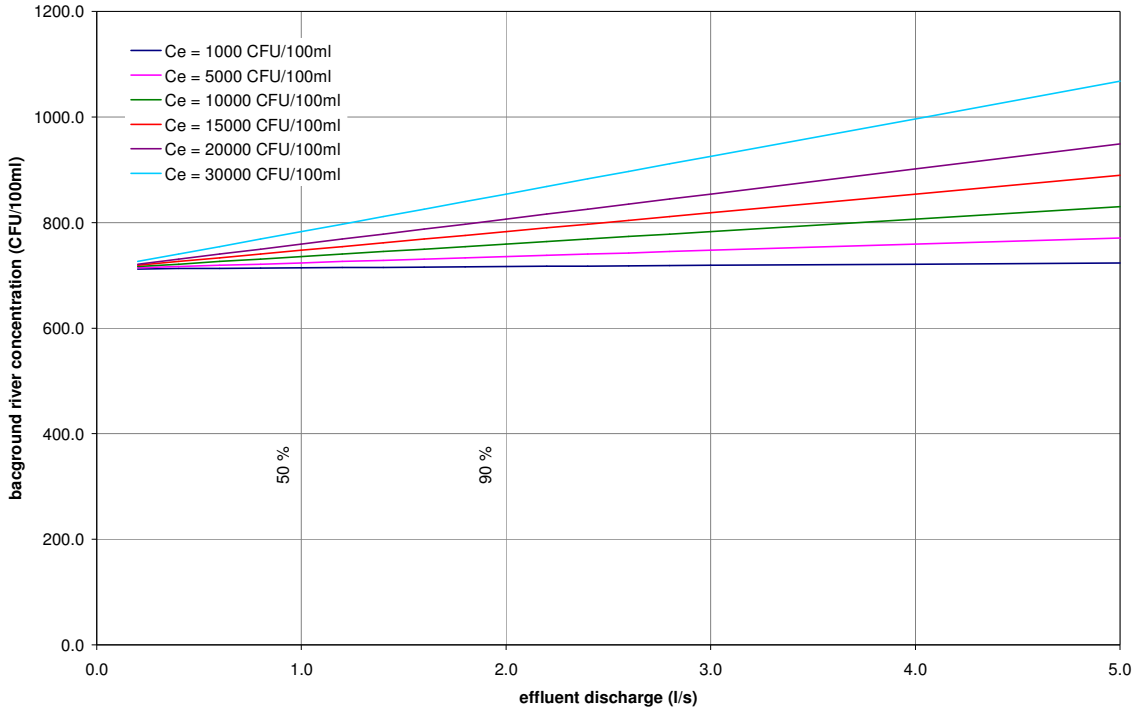

Figure 34 Background FC concentration as a function of effluent discharge and quality (river flow 1 m^3/s, river FC concentration 300 CFU/100ml)

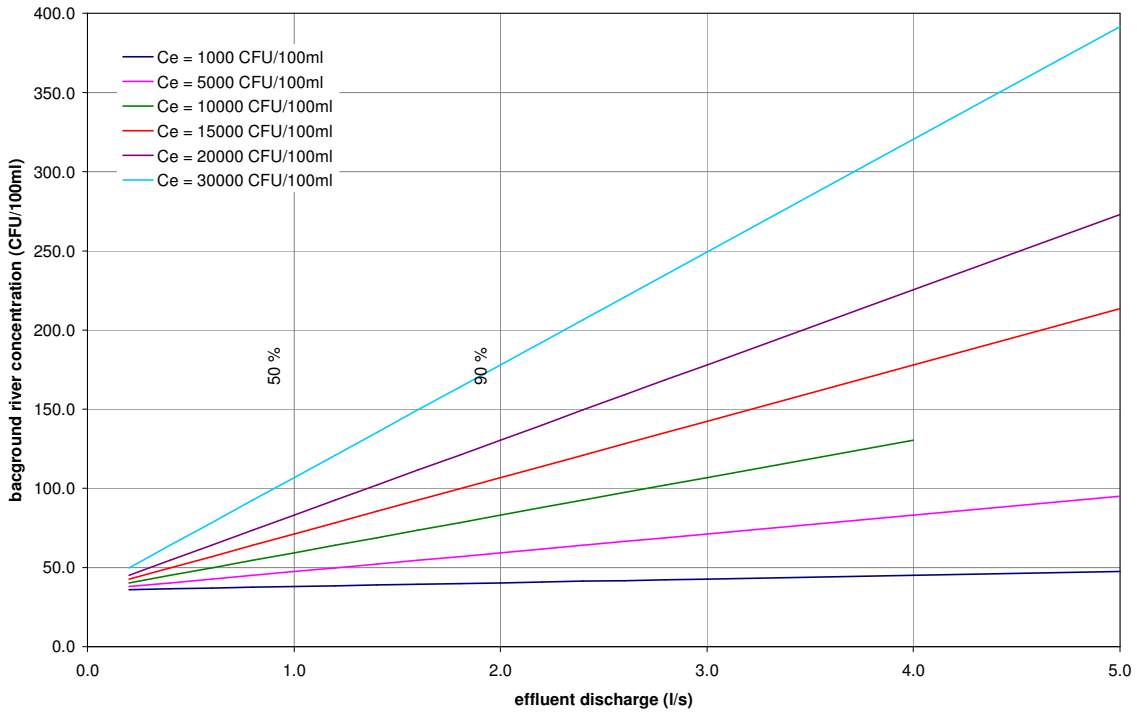

Figure 35 Background FC concentration as a function of effluent discharge and quality (river flow 0.3 m^3/s, river FC concentration 50 CFU/100ml)

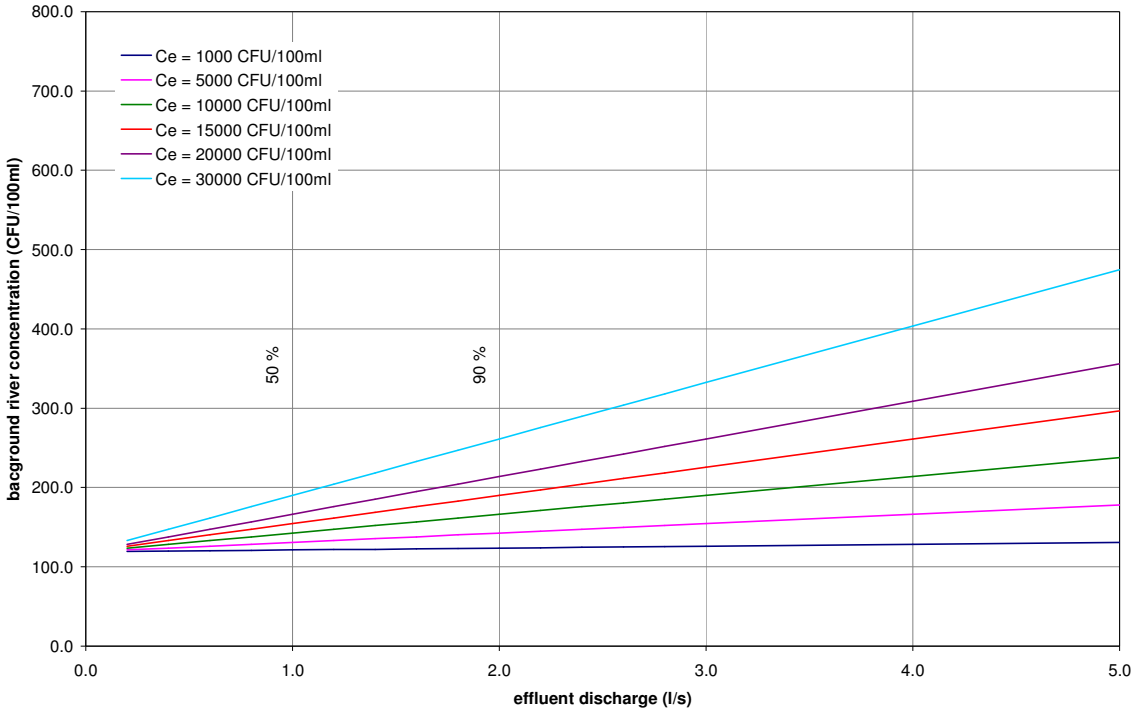

Figure 36 Background FC concentration as a function of effluent discharge and quality (river flow 1 m^3/s, river FC concentration 50 CFU/100ml)

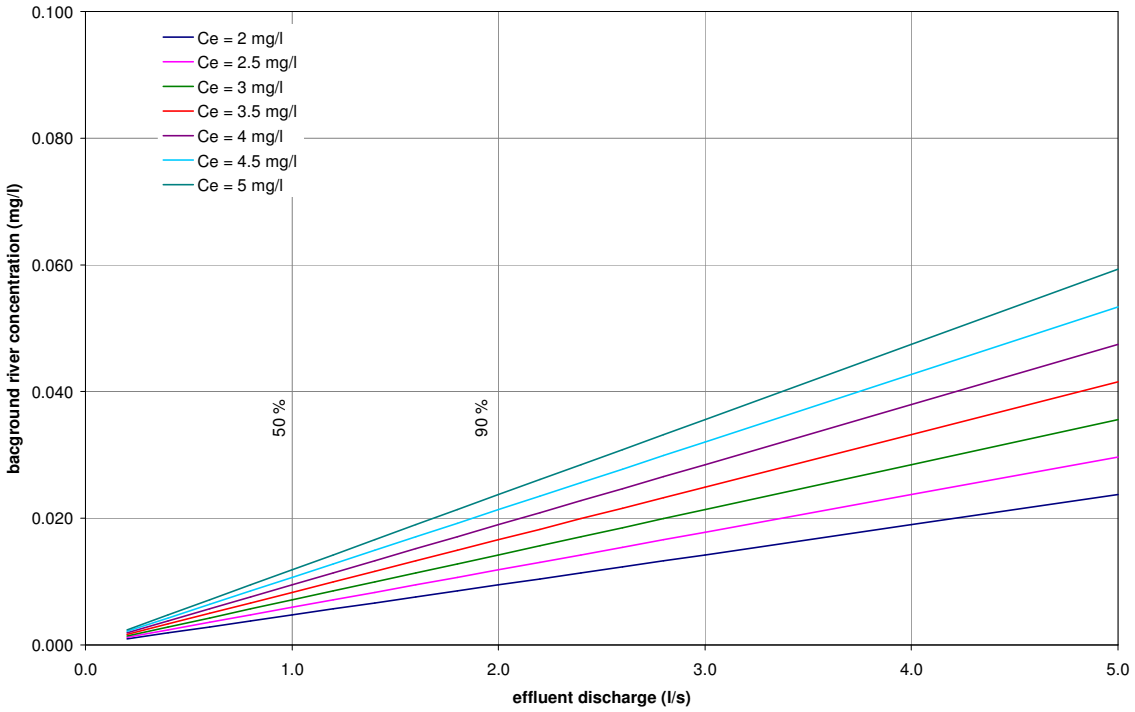

Figure 37 Background DRP concentration as a function of effluent discharge and quality (river flow 0.3 m^3/s, river DRP concentration 0 mg/l)

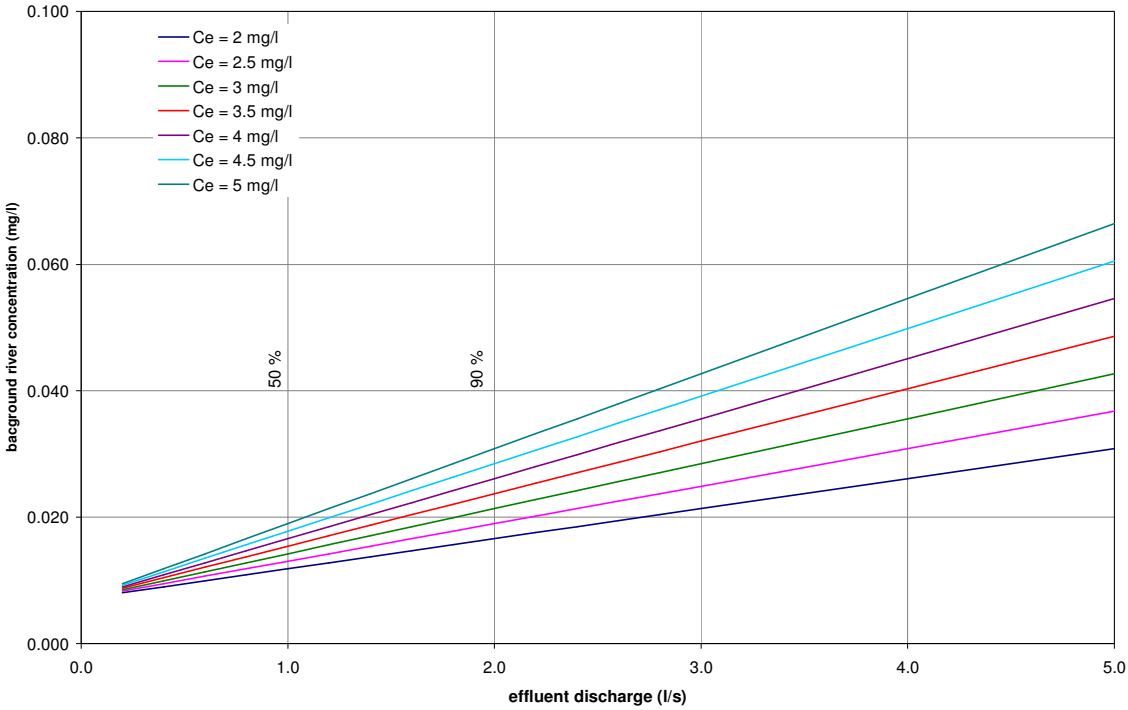

Figure 38 Background DRP concentration as a function of effluent discharge and quality (river flow 0.3 m^3/s, river DRP concentration 0.01 mg/l)

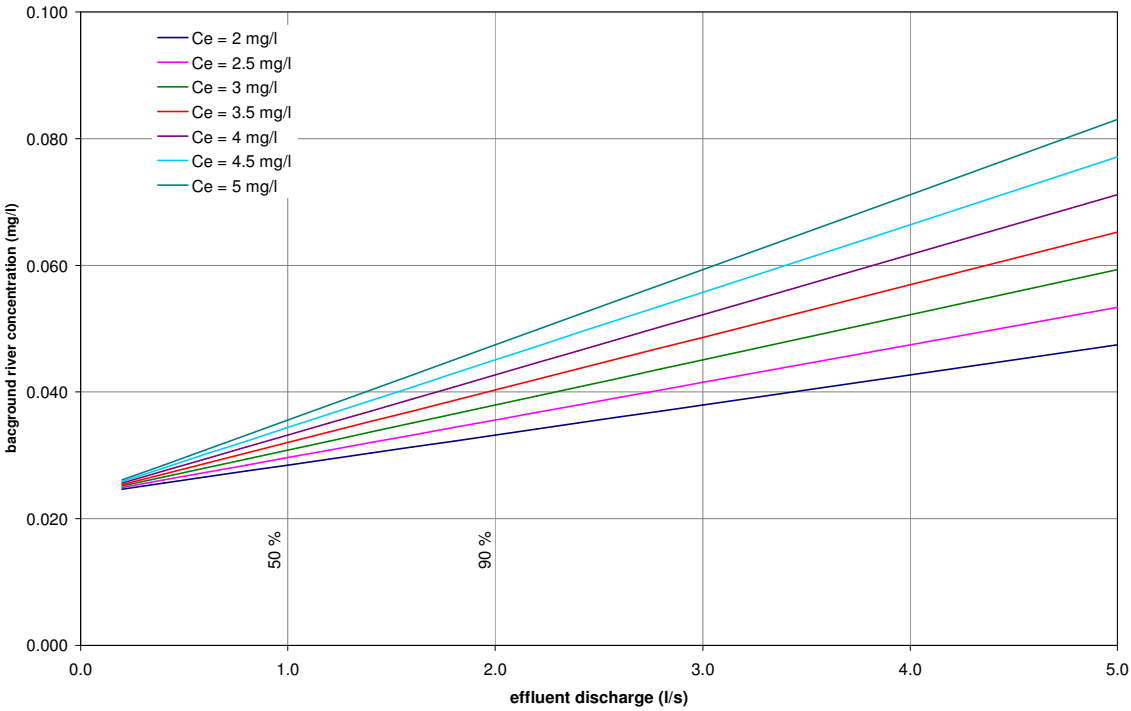

Figure 39 Background DRP concentration as a function of effluent discharge and quality (river flow 1 m^3/s, river DRP concentration 0.01 mg/l)

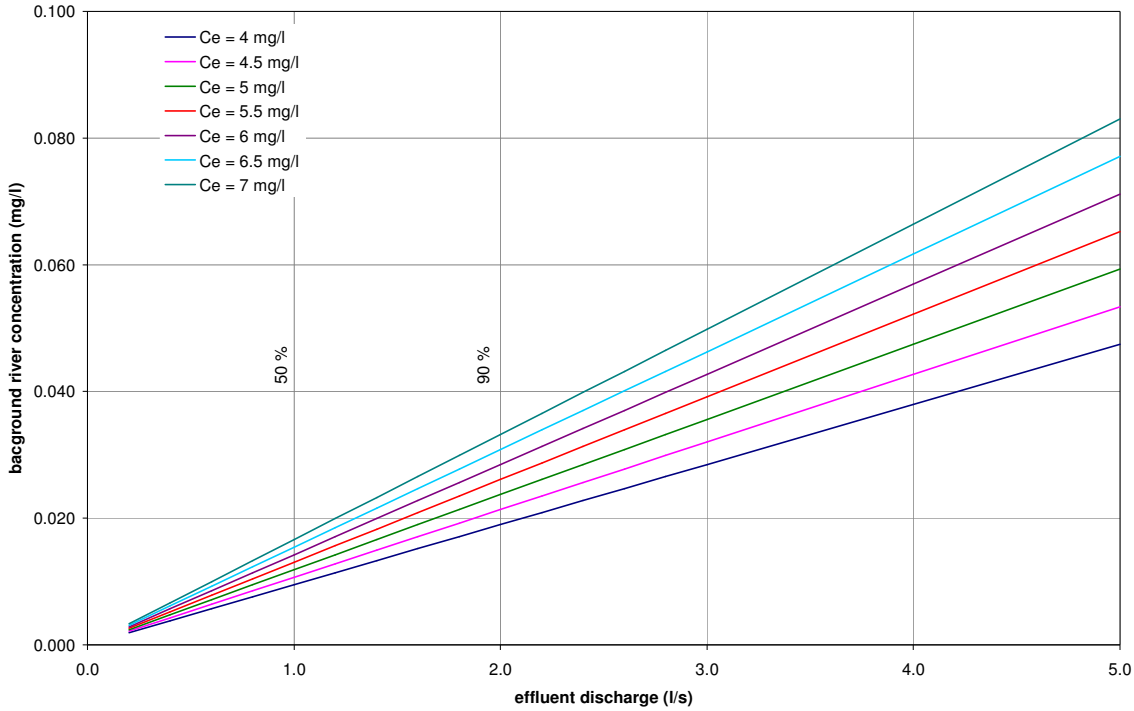

Figure 40 **Background NH_4-N concentration as a function of effluent discharge and quality (river flow 0.3 m^3/s, river NH_4-N concentration 0 mg/l)**

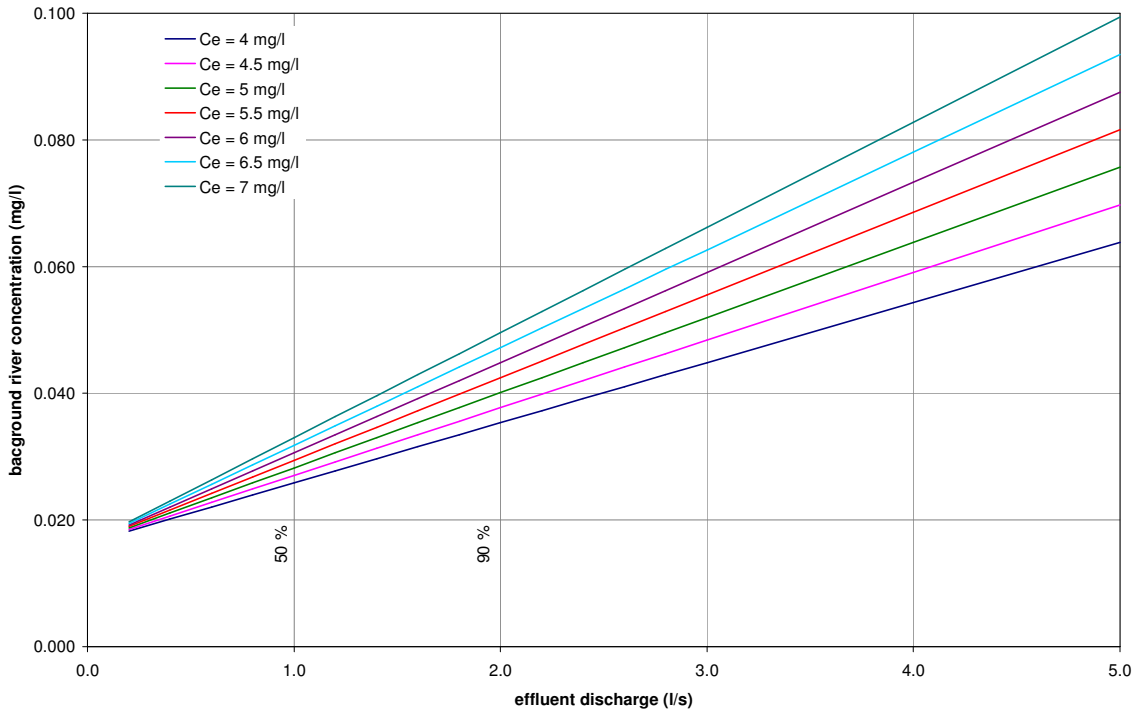

Figure 41 **Background NH_4-N concentration as a function of effluent discharge and quality (river flow 0.3 m^3/s, river NH_4-N concentration 0.023 mg/l)**

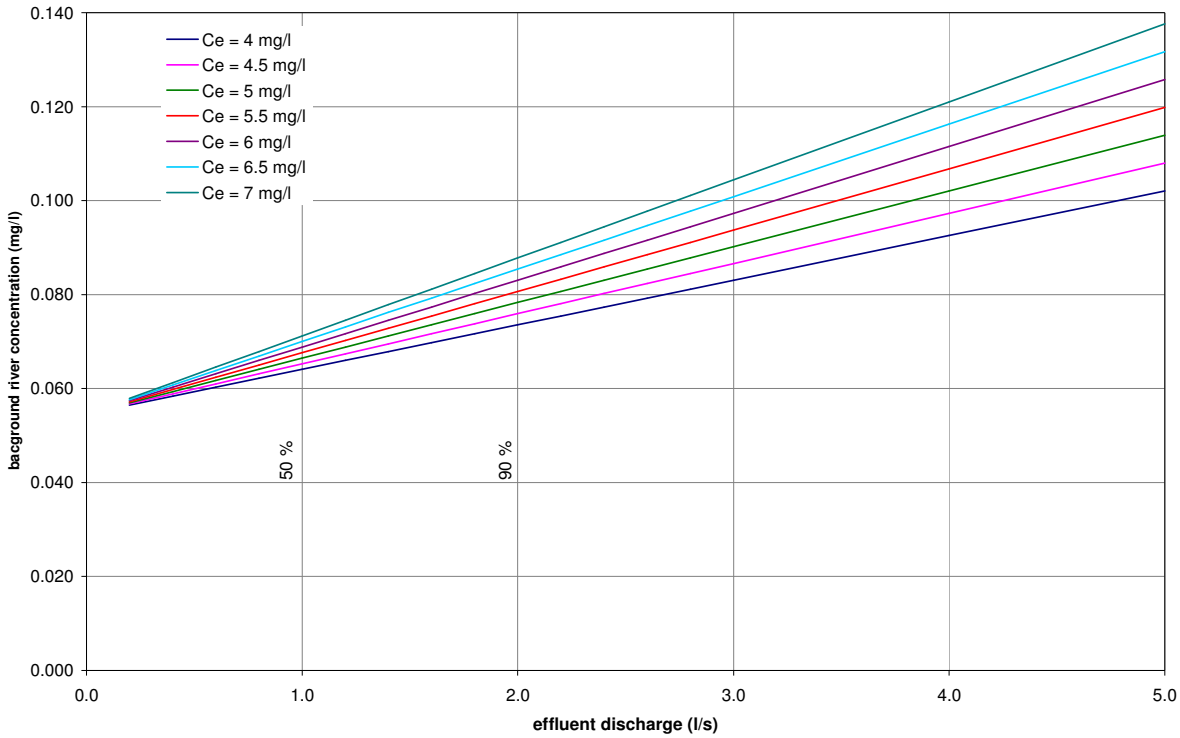

Figure 42 Background NH_4-N concentration as a function of effluent discharge and quality (river flow 1 m^3/s, river NH_4-N concentration 0.023 mg/l)

The location of any upstream water quality monitoring site needs to be outside the zone of tidal influence on the river flow. There must also not be any significant point sources of contaminant input between this monitoring site and the effluent mixing zone.

Figures 37-39 show predicted background dissolved reactive phosphorus (DRP) concentrations in the effluent mixing zone as a function of effluent flow and quality for the following cases:

- river flow 0.3 m^3/s (26 March 2008 flow), river DRP concentration 0 mg/l
- river flow 0.3 m^3/s (26 March 2008 flow), river DRP concentration 0.01 mg/l (approximate median value from limited upstream sampling)
- river flow 1 m^3/s (median flow value inferred from upstream tributary flow record), river DRP concentration 0.01 mg/l (approximate median value from limited upstream sampling)

These figures again highlight the sensitivity of the background DRP concentration in the mixing zone to the volume and quality of the incoming river flow. The HBRC Resource Management Plan specifies a guideline DRP limit of 0.015 mg/l (Table 8). Figures 35-37 indicate that this limit would be extremely difficult to achieve given the assumed DRP concentration for the incoming river flow which is based on very limited data.

Figures 40-42 show predicted background ammoniacal-nitrogen (NH_4-N) concentrations in the effluent mixing zone as a function of effluent flow and quality for the following cases:

- river flow 0.3 m^3/s (26 March 2008 flow), river NH_4-N concentration 0 mg/l
- river flow 0.3 m^3/s (26 March 2008 flow), river NH_4-N concentration 0.023 mg/l (approximate median value from limited upstream sampling)
- river flow 1 m^3/s (median flow value inferred from upstream tributary flow record), river NH_4-N concentration 0.023 mg/l (approximate median value from limited upstream sampling)

The HBRC Resource Management Plan specifies a guideline limit of 0.1 mg/l for NH_4-N. Figures 39 and 40 suggest that this guideline limit would be able to be achieved for much of the time beyond the effluent mixing zone given the range of river and effluent volumes and qualities. However it would be extremely difficult to achieve the ANZECC SE Australia trigger value of 0.015mg/l for NH_4-N beyond the effluent mixing zone.

10 Conclusions

Field Investigations

- At the time of study, the flow behaviour of the river at the point of effluent discharge was estuarine in nature and dominated by the ebb and flow of the tide. This is reflective of low flow conditions.
- The receiving environment in the Porangahau River for the oxidation pond discharge is essentially saline from tidal inflows with minor dilution by incoming river flows.
- The effluent discharge, being freshwater, will act as a buoyant surface plume discharging into a shallow cross-flow. However the shallowness of the water at the point of discharge reduces the effect of buoyancy and the plume rapidly becomes mixed over the full depth.
- On the day of the dye mixing tests, the bank-side discharge plume was observed to be directed downstream even on an incoming tide. This was inferred to be due to the effect of secondary recirculation currents induced by interaction of the incoming tidal flow and the morphological form of the river. It is not certain whether this observed plume behaviour would occur during a flood tide under different river inflow and wind conditions.
- The downstream dilution behaviour of the plume was observed to be very similar on an incoming and an outgoing tide under the low flow conditions on the day of the tests.
- The morphological form of the river downstream (with bank side dead zones, projecting sediment bar and bends) plays a significant role in promoting transverse diffusion and hence dilution of the effluent plume.
- While the location of dead zones along the banks and sediment bars may shift over time, these features will continue to characterise the morphological form of the river and influence the dilution behaviour of the effluent plume.
- Based on the results of the dye mixing tests the dilution of the effluent plume is estimated to be in range of 1000-3000 at the end of a 200m long mixing zone.

Tidal Mixing Analysis

- The background concentration of various indicator tracers in the effluent mixing zone induced by tidal flushing has two components: one component sourced from the upstream river flow and the other component sourced from the oxidation pond discharge.
- There is a distinct lack of long term water quality data for the incoming river flow.

- The background concentration of each contaminant indicator in the effluent mixing zone is predominantly influenced by the volume and quality of the incoming river flow. The quality of the effluent is a secondary influence only due to the very low volumes of the oxidation pond discharge.
- Achieving the HBRC Resource Management Plan guideline limits for background faecal coliform and dissolved reactive phosphorus within the effluent mixing zone will be extremely difficult if historic values on incoming water quality are indicative of current values. The Resource Management Plan guideline limit for background ammoniacal-nitrogen may be able to be achieved most of the time,
- Sites for future monitoring of background concentrations of contaminant indicators need to be established at the upstream and downstream ends of the effluent mixing zone and upstream of the tidally affected reach of the river.
- Any resource consent conditions relating to water quality at the boundaries of the mixing zone need to be expressed relative to the background concentration of the indicators in the incoming river flow

B

Appendix B – Pōrangahau River Estuary Ecological Investigation (2012) by Opus

DP030233W

Porangahau River Estuary Ecological Investigation, April 2012

Prepared for Central Hawkes Bay District Council

OPUS

River Lake Ltd

Porangahau River Estuary Ecological Investigation, April 2012

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Approved for Release By

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Contents

1 Introduction

1.1 Resource Consent Monitoring Requirements

Central Hawke's Bay District Council (CHBDC) holds resource consent to discharge treated wastewater from Porangahau wastewater treatment pond to the Porangahau River. Resource consent for the discharge of treated wastewater was granted by the Hawke's Bay Regional Council (HBRC) in October 2009. The resource consent includes a condition which requires monitoring, it states:

The consent holder shall undertake an investigation into the effects of the discharge on the biota in the vicinity of the discharge. Design of the investigation shall be submitted to the Council (Manager, Science) within 12 months of the commencement of consent. The investigation shall occur within 3 years of the commencement of the consent.

The investigation was developed by Hamill (2010) and approved by the HBRC. This report describes and discusses the results of this investigation.

1.2 Nature of the discharge environment

The Porangahau Wastewater Treatment Pond discharge enters the Porangahau River, via a drainage ditch on the true left bank. It is approximately 8.6 km upstream of the river mouth and about 1.7 km downstream of the Porangahau Road Bridge (see Figure 1.1). At the point of discharge, the Porangahau River has fairly sluggish flow velocities, an average depth of 1.0 – 1.4 metres and a tidal range of 0.5 metres compared to a 1.1 metre range at the Porangahau River mouth. Tidal water is fully mixed at the point of discharge so there is no salt wedge.

Evidence presented by Dr Webby at the Porangahau WWTP discharge consent hearing (2009) explains that the effluent plume hugs the true left bank before becoming reasonably mixed across the river at a distance of about 200m downstream (see Figure 1.2). On an incoming tide it is possible for the effluent plume to travel upstream. A zone of reasonable mixing was estimated to be 200m upstream and downstream of the discharge, with full mixing across the river occurring at a distance of about 400 m upstream and downstream of the discharge.

There was estimated to be about 1000 times dilution at the point of reasonable mixing 200m downstream. However, the tidal nature of the river means that contaminants discharged to this section of the river will be accumulated in the estuarine zone before being discharged to the open sea.

The effect of the discharge on water quality progressively reduces downstream due to the effluent becoming fully mixed, and the increasing influence of seawater dilution. Under normal flow conditions it takes about 1.5 tidal cycles for a parcel of effluent to reach the Beach Road Bridge (3.9 km below the discharge); at this point the median salinity is about 80% compared to about 55 % salinity at the discharge point (Hamill 2009).

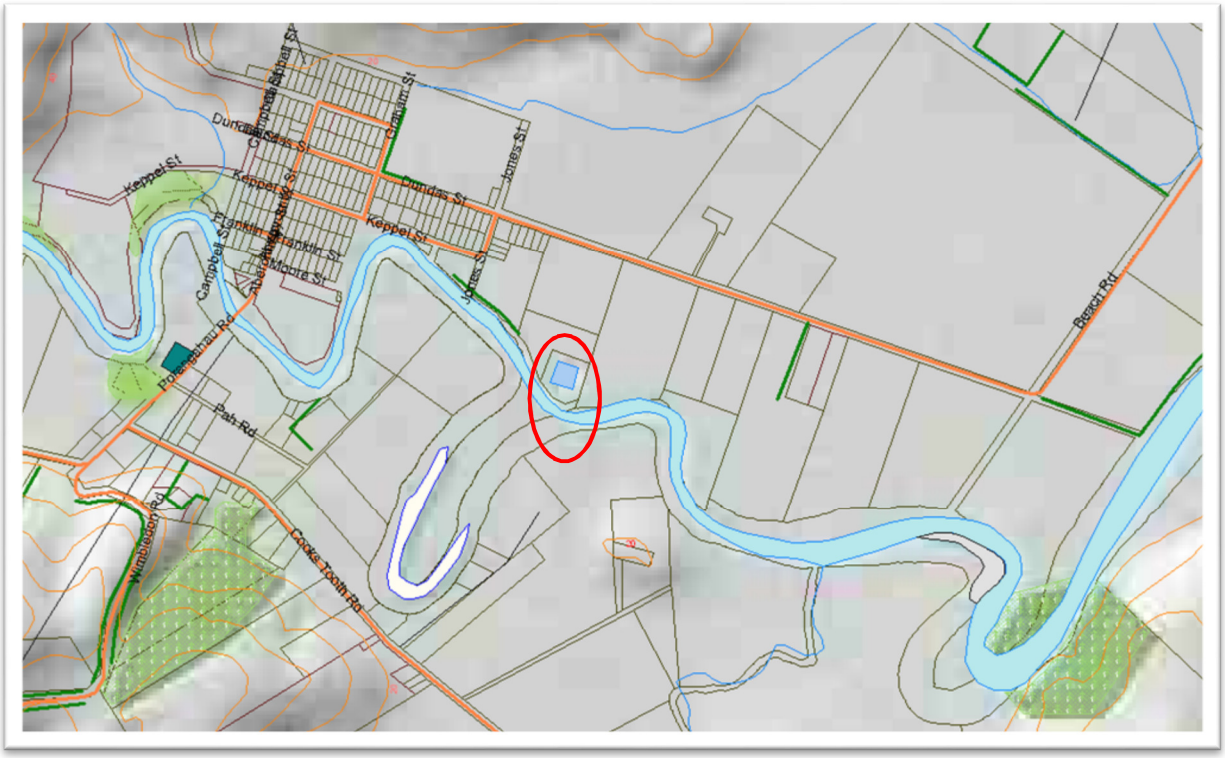

Figure 1.1: A map showing the location of the Porangahau Wastewater Treatment Pond and Porangahau Township.

Figure 1.2: Sketch of Porangahau township WWTP effluent discharge plume in Porangahau River on outgoing tide based on a visible dye trace. The white line indicates the distance 200m downstream of the discharge point.

2 Sampling Design and Method

2.1 Design principles

1.1.1 Control sites

To assess the effect of a discharge on the environment, ecological surveys should ideally be designed to have surveys 'before and after' at both 'impact and control sites' (i.e. BAIC design). Unfortunately this type of design is not always possible. In the case of the Porangahau wastewater treatment plant (WWPT) discharge we have an existing discharge (i.e. we can't do a 'before and after' study), in a transitional zone of the upper estuary / lower river (complicating an upstream downstream study design).

Monitoring upstream of the discharge was not considered suitable as a control site because of health and safety risks in sampling vertical banks in deep water, and the freshwater influence reducing the diversity of estuarine species at the site (see Hamill 2010). Instead, the investigation used a 'distance from impact' design, where the downstream site provided a 'control' based on it being further from the discharge and having much greater seawater dilution.

1.1.2 Monitoring

The monitoring methods were based on tools developed in the National Estuary Monitoring Protocol (Robertson et al. 2002) and extensions to the monitoring reported in Robertson and Stevens (2008). The monitoring was developed for State of Environment Monitoring (SOE) monitoring of estuaries and provides detailed information on indicators of chemical and biological condition of inter-tidal mudflats of low-mid water.

The key effects of the Porangahau WWTP that could influence the Porangahau River and estuary are eutrophication and toxic contaminants. Consequently, the sampling focused on:

- Redox profile of the sediment (depth of redox discontinuity profile in sediment);
- Organic and nutrient enrichment (total nitrogen, total phosphorus and total organic carbon in upper 2 cm of sediment, chlorophyll *a* in the top 0.5 cm of sediment);
- Contamination of the bottom sediments (indicator metals (cadmium, chromium, copper, nickel, lead and zinc) in replicate samples of top 2 cm of sediment);
- Biodiversity of bottom dwelling animals (number and type of animals living in the upper 15 cm of sediments (infauna in replicate cores) and on sediments (epifauna in 0.25m^2 replicate quadrates)).
- Nuisance macroalgae cover (% cover in 10 quadrates);
- Salinity and grain size (% mud, sand, silt) to help with interpretation of results.

2.2 Loaction and timing of monitoring

The sampling was undertaken during low tide on 25 April 2012. Flow in the Porangahau River was estimated by using flow data from the Taurekaitai Stream gauging station. At the time of sampling the Taurekaitai Stream was flowing at 681 l/s compared to its median flow of 433 l/s.

Sampling of sediments and benthic biota was undertaken at the following two sites:

Site name	location	upstream co-ordinates	downstream co-ordinates
d/s WWTP	150-200m downstream of the discharge on the true left bank	E2817837, N6093543 (rep 1)	E2817856, N6093569 (rep 10)
Beach Rd (control)	40m downstream of Beach Road Bridge (about 3.9km downstream of the discharge). Opposite boat ramp.	E2820431, N6094319 (rep 1)	E2820461, N6094366 (rep 6)

The location of the monitoring sites is indicated on Figure 2.1 and photographs of the sites shown in Figure 2.2 and Figure 2.3.

Figure 2.1: The location of the proposed monitoring sites.

Figure 2.2: Porangahau River 150m – 200m downstream of discharge. The numbers correspond to approximate plot location.

Figure 2.3: Porangahau River downstream Beach Road bridge. The numbers correspond to approximate plot location (plots 6 to 10 were closer to the water than plots 1 to 5).

2.3 Sampling method

At site d/s WWTP an area of about 5 x 60 metres was marked out along the estuarine margin of the river and divided into 10 equally sized plots. All plots were adjacent to the water's edge. Replicate 1 was at the upstream end of the plot and replicate 10 at the downstream end. At the Beach Rd Bridge site the plots 6 to 10 were closer to the water than plots 1 to 5 (see Figure 2.3).

Within each area 10 plots were selected and a random position defined within each plot. Within randomly selected areas from the plots the following sampling was undertaken:

Physical and chemical analysis (8 replicates)

- Collect one core (6 cm diameter) in 8 of the plots to a depth of 10cm and photograph alongside a ruler. Record colour, texture and average depth of Redox Discontinuity Profile (RDP).
- Use a 10 cm diameter PVC corer and plastic scraper to collect the top 2 cm of sediment from five cores. These were bulked into one sample (of about 250 g) for each of 8 plots for analysis; i.e. eight replicates from site below the discharge and eight replicates from the site below Beach Road Bridge.
- Store cool in a chilli bin and analysed at Hill Laboratories laboratory for:
  - Grain size distribution (% mud, sand, silt);
  - Total nitrogen (TN) and total phosphorus (TP);
  - Total organic carbon as a measure of organic content;
  - Trace metal contaminants, i.e. cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb) and zinc (Zn).
- Use a 10 cm diameter PVC corer to collect 5 sediment cores (to bulk) from each plot. Carefully collect the top 0.5 cm of sediment from each core and place in a dark container. Bulk five samples from each plot and repeat for eight plots to collect eight replicates per site. Transport in a cool, dark chilli bin and analyse this sample for chlorophyll *a* as a measure of microalgae. [1]
- Measure water salinity or electrical conductivity.

Epifauna and macroalgae (10 replicates)

- Identify and count all epifauna (surface dwelling animals) within a 0.25 m^2 quadrate in each of the 10 randomly selected areas at each site.
- Identify and estimate the percent cover of any visible macroalgae at each of 10 quadrates.

[1] This is a larger area than used by Roberson et al. (2002) in order to reduce spatial variability.

Infauna (animals living within the sediments) (8 replicates)

- Collect one core in each of the 8 plots to a depth of 15 cm using a 10 cm diameter PVC tube and place in a labelled plastic bag (i.e. 0.007853m^2 and 0.001178 m^3).
- Wash contents of each core through a 0.5mm nylon mesh and carefully return the remaining infauna to a plastic container with a water proof label and preserve in alcohol (e.g. 70% isopropyl alcohol).
- Transport to a laboratory for counting and identification by a marine ecology specialist - Rod Asher, Cawthron Institute.

2.4 Guidelines and statistical analysis

Guidelines

There is no formal criteria for rating the overall condition of estuaries in New Zealand, however Robinson and Stevens (2008) have developed interim indicators and ratings for estuaries based on the National Estuarine Monitoring Protocol (Robertson et al. 2002). The indicators include Redox Potential Discontinuity (RPD) layer, macrofauna (AZTI Marine Benthic Index), organic matter (total organic carbon), nutrients (total nitrogen and total phosphorus), and metals (Cd, Cr, Cu, Ni, Pb, Zn). These indices are rated on a scale of 'very good', 'good', 'fair', and 'poor'. For nutrient the ratings 'good', 'fair' and 'poor' correspond to 'low-mod enrichment', 'enriched' and 'very enriched'. The estuarine condition ranking for various parameters is summarised in Table 2.1.

Table 3: Summary of estuarine condition ranking (from Robinson and Stevens 2008)

Rating	Metals	TN (mg/kg)	TP (mg/kg)	TOC (%)	RDP (cm)	Macroalgae (% cover)	AMBI BC
Very good	<0.2 x ISQG-low	<500	<200	<1%	>10	<1%	unpolluted
Good	<ISQG-low	500-2000	200-500	1-2%	3-10	1-10%	Slightly polluted
Fair	<ISQG-high but >ISQG-low	2000-4000	500-1000	2-5%	1-3	10-50%	Moderately polluted
Poor	>ISQG-high	>4000	>1000	>5%	<1	>50%	Heavily polluted

Note: ISQG = Interim Sediment Quality Guidelines in the ANZECC (2000).

Biotic indices

Benthic invertebrates are often used as bioindicators to detect and monitor environmental changes, because of their rapid responses to natural and/or anthropogenic caused stress. They integrate water and sediment quality conditions over time. Indices commonly used in estuarine areas include the AMBI (Azti Marine Biotic Index, Borja et al., 2000) and the Shannon–Wiener index (H') (Pielou, 1975). These indices aim to separate impacted sites from undisturbed (reference) sites, but there are also influenced by natural variation such as salinity gradients. Zetler et al. (2007) compared the AMBI Shannon-Wiener index and the Benthic Quality Index

(BQI) across a salinity gradient in the Baltic Sea, and found that the AMBI was less sensitive to the salinity gradient, but none of the indices were well adjusted for use along a salinity gradient.

AZTI's Marine Biotic Index (AMBI)

The AZTI's Marine Biotic Index (AMBI) provides a classification of pollution or disturbance based on the composition of the estuarine benthic community. It is derived from the proportions of individual abundances in five ecological groups, which are related to the degree of sensitivity/tolerance to an environmental stress gradient. The model has been validated in both the northern and southern hemisphere and found to detect changes in the benthic community as a result of dredging, engineering works, sewage discharges and dumping of polluted waters (Borja et al 2000, Borja and Muxika 2005). It has also been applied to a number of estuaries in New Zealand (e.g. Robinson and Stevens 2008).

Borja and Muxika (2005) note while the AMBI is useful for detecting trends, its robustness is reduced when there is only a small number of taxa or individuals in samples (<3/replicate). The results should be interpreted with care if applied to naturally-stressed environments (e.g. dead leaves of Zostera beds naturally increasing organic matter content) or if applied to low salinity environments – which is the case in this study. Care is also needed if more than 20% of taxa in the samples have not been assigned to an ecological group.

The biotic index (BI) is derived from a biotic coefficient using (see Table x). The AMBI Biotic Coefficient (BC) is calculated using the following formula:

BC = {(0 x %GI) + (1.5 x %GII) + (3 x %GIII) + (4.5 x %GIV) + (6 x %GV)}/100

The calculation of the AMBI exclude all non-benthic invertebrate taxa and freshwater taxa.

The characteristics of the ecological groups (GI, GII, GIII, GIV, GV) are:

- Group I: Species very sensitive to organic enrichment and present under unpolluted conditions (initial state). They include the specialist carnivores and some deposit feeding tubicolous polychaetes.
- Group II. Species indifferent to enrichment, always present in low densities with non-significant variations with time (from initial state, to slight unbalance). These include suspension feeders, less selective carnivores and scavengers.
- Group III. Species tolerant to excess organic matter enrichment. These species may occur under normal conditions, but their populations are stimulated by organic richment (slight unbalance situations). They are surface deposit-feeding species, as tubicolous spionids.
- Group IV. Second-order opportunistic species (slight to pronounced unbalanced situations). Mainly small sized polychaetes: subsurface deposit-feeders, such as cirratulids.
- Group V. First-order opportunistic species (pronounced unbalanced situations). These are deposit feeders, which proliferate in reduced sediments.

Table 2.1: Summary of the BC and BI (from Bora et al. 2000).

Site pollution classification	Biotic Coefficient	Biotic index	Dominating ecological group	Benthic community health
Unpolluted	0:0< BC ≤0:2	0	I	Normal
Unpolluted	0:2< BC ≤1:2	1		Impoverished
Slightly polluted	1:2< BC ≤3:3	2	III	Unbalanced
Meanly polluted	3:3< BC ≤4:3	3	IV	Transitional to pollution
Meanly polluted	4:5< BC ≤5:0	4	IV-V	Polluted
Heavily polluted	5:0< BC ≤5:5	5		Transitional to heavy pollution
Heavily polluted	5:5< BC ≤6:0	6	V	Heavy polluted
Extremely polluted	Azoic	7	Azoic	Azoic

Shannon–Wiener index (H')

The Shannon–Wiener index (H') was calculated using the software package Primer v6 (Clarke and Warwick, 1994). In simple terms this is the weighted combination of the total number of species (richness) and the extent to which the total abundance is spread equally amongst the observed species (evenness). High values of H' are representative of more diverse communities. A community with only one species would have an H' value of 0. If the species are evenly distributed then the H' value would be high. The H' value tells us about not only the number of species but how the abundance of the species is distributed among all the species in the community.

Scores have been proposed for the Shannon–Wiener index for the purpose of identifying the ecological status of European marine sites (Zetler et al. 2007). These propose H'>4 = 'high', H'3-4 = 'good', H' 2-3 = 'moderate, H' 1-2 = 'poor', H'<1 = 'bad'.

Statistical analysis

The statistical significance of indices was assessed with a student t-test and an equivalence test using the software 'TimeTrends'. A difference was considered statistically significant if the *p*-value was <0.05.

Tests for equivalence and inequivalence were based on +/- 20% change compared to the control site. This recognises that habitats can seldom be perfectly matched and even small changes in habitat can impact on sediment quality and infauna composition.

Equivalence tests incorporate both testing of means (using a student t-test) and testing of a meaningful change (interval testing). One advantage of equivalence tests is that increasing the sampling effort may make it either more or less likely that an equivalence hypothesis will be rejected, unlike the statistical test where more data means that the hypothesis is more likely to be rejected.

Cluster analysis was performed on the data along with a similarity profile (SIMPROF) permutation test to identify any significant differences between clusters (i.e. *p*-value <0.05). Prior to cluster analysis biological data was transformed using a square root transformation

and a triangular similarity matrix created using Bray-Curtis; and environmental data was transformed using a square root transformation, normalised and a triangular resemblance matrix created using Euclidian distance.

To detect statistically significant differences in benthic invertebrate assemblages between sites a Permutational Multivariate Analysis of Variance test (PERMANOVA) was performed on the data using the software PERMANOVER for PRIMER (Anderson et al. 2008). This was done on the raw data of the square-root transformed Bray-Curtis similarity matrix.

3 Results

3.1 Sediment

The substrate at site 'd/s WWTP' consisted of about 2 to 3cm of brown mud over sand/small gravel near replicates 1 to 4, deepening to >15cm at replicates 5 to 10. Rotting vegetation was present at the interface of the mud and sand and the redox discontinuity depth ranged from 3 to 10 cm, but it was not defined where shallow mud overlaid sand/gravel (see Figure 3.1). There was no anoxic smell and the boundary layer was difficult to define. The footprints and faeces of sheep and waterfowl occurred over the site – acting as a potential source of faecal contamination and nutrients. Electrical conductivity in the river at the time of sampling was 545 µS/cm.

The substrate at site 'Beach Road bridge' was black/brown mud with a redox discontinuity depth of 0.7 to 2 cm (see Figure 3.1). Electrical conductivity in the river at the time of sampling was 10,390 µS/cm.

There was no significant difference in the % mud (<63 µm fraction) in the surface sediment between the sites so that results were not adjusted for mud content to improve comparability between sites. Not adjusting for %mud also allowed a direct comparison with the estuary condition rating criteria. The clay fraction (<3.9µm) was also similar between the sites (19.2 and 21.9% at Beach Road Bridge and WWTP respectively).

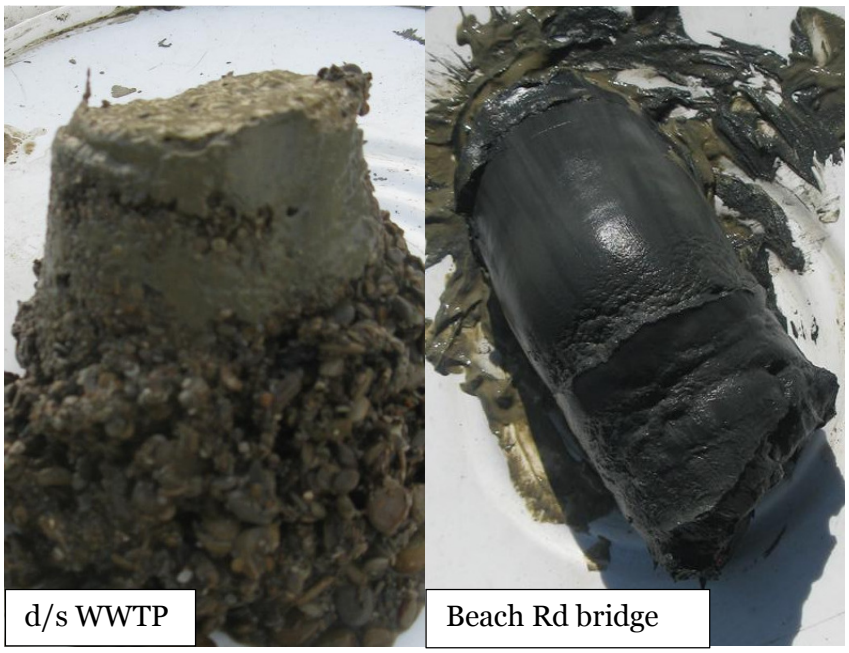

Figure 3.1: Sediment cores from Porangahau River estuary sites showing different sediment characteristics for sites: d/s WWTP (plot 1) and Beach Road Bridge (plot 1).

The results of sediment analysis are shown in Table 3.1 and statistical comparison of these results is shown in Table 3.2. The analysis was based on whole sample fractions and were not normalised to allow a direct comparison with the ANZECC (2000) guidelines and the condition rating in Robinson and Stevens (2008). With the exception of the Redox Potential Discontinuity (RPD) depth at the Bridge Site (rated 'fair'), all the sediment variables at both sites indicated either a 'good' or 'very good' condition rating (see Table 3.3). All the results for metal were less than the ANZECC (2000) Interim Sediment Quality Guidelines (ISQG)-low, which means we would expect no adverse effects on aquatic life from the values measured.

There were differences in sediment quality between sites. There was moderate to strong evidence that sediments at the WWTP site had more chlorophyll *a* (2.5 times more), organic carbon, nitrogen, arsenic, cadmium, lead and zinc compared to sediment at the B site. However the Beach Road bridge site had more copper in the sediment. There is a boat ramp on the opposite side of the river from this site and it is possible that some of the copper was due to anti-fouling paint or metal rubbed from boats. Alternatively it could be residual from the old sawmill operation (Section 3.3), although the upstream site (also understood to be below the sawmill) did not show elevated copper.

Table 3.1: Surface sediment quality in the Porangahau River estuary, April 2012.

Site	Chl a (mg/kg)	% mud (<63 um)	TOC (g/100g)	TP (mg/kg)	TN (mg/kg)	Arsenic (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Nickel (mg/kg)	Zinc (mg/kg)	RPD (cm)
Beach Rd Bridge 1	10.9	85.4	0.8	400	900	3.4	0.122	10.5	16.5	8.2	15.5	54	1
Beach Rd Bridge 2	10.6	93.2	0.85	420	1100	3.3	0.128	10.9	18.8	8.2	16.1	56	1.5
Beach Rd Bridge 3	9.6	84.6	0.83	420	1000	3.5	0.123	10.2	15.9	8	14.7	53	1.1
Beach Rd Bridge 4	15.3	89.8	0.69	390	800	3.1	0.109	8.9	13.6	7.4	13.3	48	1
Beach Rd Bridge 5	6.8	87.6	0.77	410	900	3.1	0.112	9.5	14.6	7.4	13.6	50	1
Beach Rd Bridge 6	7.3	83.7	0.71	400	900	3.5	0.1	8.2	12.8	7	12.4	47	0.7
Beach Rd Bridge 7	10.4	87.4	0.75	420	1000	3.9	0.118	9	14.3	7.9	14	53	1.2
Beach Rd Bridge 8	9.1	81.3	0.76	420	900	3.6	0.102	8.4	14.1	7.4	13.1	50	2
Porangahau WWTP 1	32.8	76.3	0.7	310	800	3.9	0.12	6.9	10.5	6.9	11.7	46	.
Porangahau WWTP 2	24	87.5	1.33	430	1400	3.9	0.184	9.5	12.8	9.2	14.8	59	.
Porangahau WWTP 3	6.4	90.5	1.3	440	1300	4.1	0.2	10.7	13.4	9.7	15.7	62	.
Porangahau WWTP 4	27.5	93.4	1.21	450	1500	4	0.187	10.5	13	9.3	15.3	61	.
Porangahau WWTP 5	36.5	87.7	0.92	440	1100	4.3	0.148	9.7	12.6	8.3	14.8	57	3
Porangahau WWTP 6	9	81.5	0.82	440	1100	4	0.134	9.5	12.4	8.3	14.8	54	3
Porangahau WWTP 7	8.4	86.4	0.94	420	1200	4.2	0.161	10.4	13.1	8.8	15.1	58	4
Porangahau WWTP 8	30.1	93.8	1.36	520	1700	4.7	0.197	12.2	14.4	10.3	17.1	68	10
ISQG-low / 'Good' rating			*2*	*500*	*2000*	*20*	*1.5*	*80*	*65*	*50*	*21*	*200*	
Beach Rd Bridge - median	10.0	86.4	0.77	415	900	3.45	0.115	9.3	14.5	7.7	13.8	51.5	1.1
WWTP - median	25.8	87.6	1.08	440	1250	4.05	0.173	10.1	12.9	9.0	15.0	58.5	3.5

Note

TP = total phosphorus, TOC = total organic carbon, TN = total nitrogen, Chl a = chlorophyll a, Phe a = pheophytin a, RDP= redox potential discontinuity

All metals are total recoverable in mg/kg dry weight.

Sediment sample = 0.0393m^2 x 2cm deep. Chl a sample = 0.0393m2 x 0.5cm deep

Table 3.2: Results of student t-test and equivalence test (+/- 20%)

Variable	t-test (*p*-value)	Equivalence test (evidence of a >20% difference)
% silt	ns	No practically important difference
TOC	0.006	Moderate evidence. Control less than impact
TP	ns	No practically important difference
TN	0.007	Moderate evidence. Control less than impact
Chl a	0.02	Strong evidence. Control less than impact
Arsenic	<0.001	Moderate evidence. Control less than impact
Cadmium	<0.001	Strong evidence. Control less than impact
Chromium	ns	No practically important difference
Copper	0.01	Moderate evidence. Control is greater than impact
Lead	0.01	Moderate evidence. Control less than impact
Nickel	ns	No practically important difference
Zinc	0.02	Moderate evidence. Control less than impact

ns = not significant

Table 3.3: Estuary condition rating for each site based on Robinson and Stevens (2008).

Indicator	WWTP site	Beach Rd Bridge
Redox Potential Discontinuity	Very good	Fair
Total Nitrogen	Low-moderate enrichment	Low-moderate enrichment
Total Phosphorus	Low-moderate enrichment	Low-moderate enrichment

Total Organic Carbon	Good	Very good
Macro algae	Very good	Very good
Metals		
As	Good	Very good
Cd	Very good	Very good
Cr	Very good	Very good
Cu	Very good	Good
Pb	Very good	Very good
Ni	Good	Good
Zn	Good	Good

3.2 Epifauna and Infauna

Epifauna

No macro algae was observed at either of the Porangahau River estuary sites which provides an estuary condition rating of 'very good' for this variable.

The epifauna observed in quadrates were mud snail (*Amphibola crenata*), tunnelling mud crab (*Helice crassa*) and the estuarine snail (*Potamopyrgus antipodarum*), crab holes were abundant at both sites (see Table 3.4 for densities). All the epifauna species observed in quadrates were also found in high densities within the cores taken for infauna.

Table 3.4: Epifauna from Porangahau River estuary sites

Species	common name	Beach Road mean /m2)	d/s WWTP mean /m2
Amphibola crenata	Mud snail	2	0
Crab holes		54.8	72.8
Helice crassa	Tunnelling mud crab	1.6	0
Potamopyrgus antipodarum	Esturine snail	28.8	1.2
Macro algae		0	0

3.2.1 Infauna

The AMBI scores indicated 'moderate disturbance' from both of the Porangahau estuary sites. There was no significant difference in the taxa richness or the AMBI score between the two sites (see Table 3.5, Table 3.6 and Figure 3.3), although the site downstream of the WWTP had a slightly higher (i.e. more impact) AMBI score. Care is needed interpreting the AMBI score from these sites because a large number (about three quarters) of the taxa were not assigned an AMBI score, including the two taxa found in highest abundance – *Paracorophium* amphipod and *Potamopyrgus* snail.

Biological diversity (Shannon-Weiner diversity) at the two sites was relatively poor with species abundance dominated by a couple of species (*Paracorophium* amphipod and *Potamopyrgus* snail). A statistical analysis of the results found that the site downstream of Porangahau WWTP had significantly more diversity (H') compared to the Beach Road Bridge site (see Table 3.5, Table 3.6 and Figure 3.2). This reflects the greater number of freshwater taxa rather than better ecological condition of the site. When freshwater taxa were excluded from the analysis the median

H' diversity was 1.25 and 1.36 for downstream WWTP and Beach Road Bridge respectively and the difference was not statistically significant (t-test p=0.14, equivalence test = 'inconclusive').

The total abundance of taxa was significantly higher at Beach Road Bridge site (see Table 3.5, Table 3.6), this was largely due to more of the freshwater amphipod *Paracorophium* sp.

The composition of the infauna samples reflected the transitional salinity gradient at the sites. Two predominantly freshwater species were found at the Beach Road Bridge site and eight freshwater species were found at the site downstream of the WWTP (see species shaded in blue in Table 3.6).

The SQMCI score for the freshwater species found at the site downstream of the WWTP was 103, which is higher than was typically found in the Porangahau River upstream of the town bridge (sampling from 2005 to 2012 found a range of 70 to 98 (Hamill 2012).

A cluster analysis using Brays-Curtis of the infauna community data with a similarity profile permutation test found that the infauna at the Bridge site and the WWTP site were significantly different from each other but replicates within sites could not be statistically differentiated (see Figure 3.4). Excluding freshwater species from the analysis resulted in the replicated WWTP 4 being grouped with the Beach Road Bridge sites.

A PERMANOVA test on the raw biological data from the square-root transformed Bray-Curtis similarity matrix found a statistically significant difference between the sites (p-value = 0.0002).

A best match analysis on all the data (using Euclidean distance for resemblance) found that much (correlation 0.89) of the differentiation between the sites was due to freshwater amphipods (more abundant at bridge site), copopods and *Chironomus* sp. midges (only found at the d/s WWTP site).

A cluster analysis using Euclidean distance of the abiotic variables did not find such a clear cut differentiation between the sites (see Figure 3.5). However, a PERMANOVA test on the raw abiotic data from the square-root transformed, normalised Euclidean distance similarity matrix found a statistically significant difference between the sites (p-value = 0.002).

There was a high degree of correlation between many of the variables sampled. The results of a Pearson correlation between the variables of both sites is shown in Appendix 1. Organic carbon was strongly correlated with total nitrogen, cadmium, lead and zinc. Total phosphorus was strongly correlated with total nitrogen and chromium. Interestingly copper was only weakly correlated with other variables. Surprisingly, the Shannon-Weiner Diversity had a relatively strong positive correlation with arsenic (0.77). A stepwise Spearman Rank regression (using Timetrends software) found that arsenic levels explained 56% of the variation in Shannon-Weiner Diversity.

Table 3.5: Summary statistics of Porangahau River estuary infauna and results of statistical comparison

Variable	Beach Rd Bridge median	Porangahau WWTP median	t-test	Equivalence test
No of Individuals /0.01m^3	1537	437	<0.001	Strong evidence Bridge > WWTP
No of Taxa (richness)	10	9.5	0.5	No practically important difference
Peilous_Evenness	0.41	0.675	<0.001	Strong evidence Bridge < WWTP
Shannon-Wiener_Diversity	0.92	1.51	0.003	Strong evidence Bridge < WWTP
Azti Marine Biotic Index (AMBI)	4.3	4.7	0.25	Inconclusive

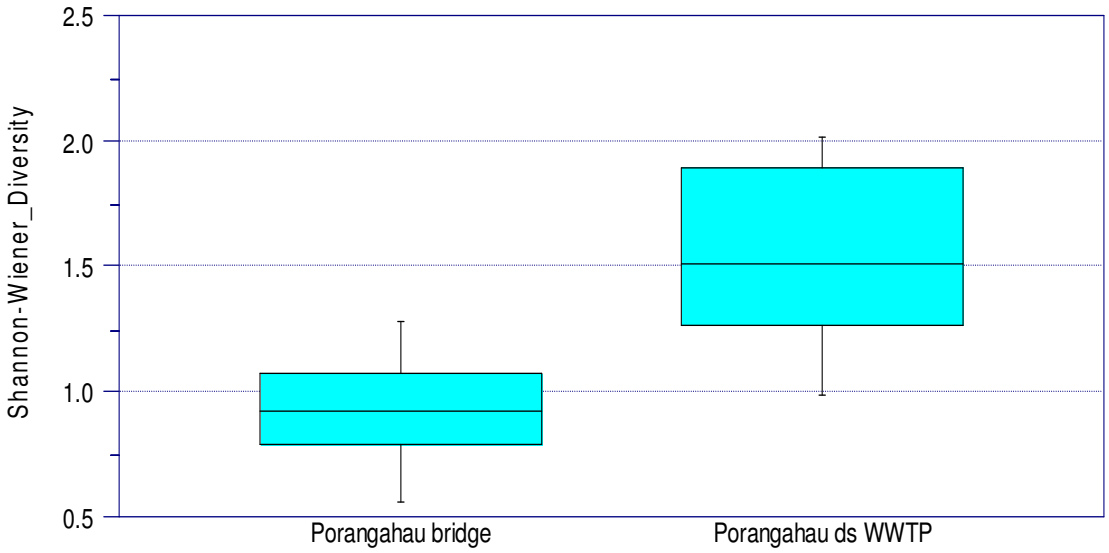

Figure 3.2: A significant difference in Shannon-Weiner diversity Index between the two Porangahau estuary sites.

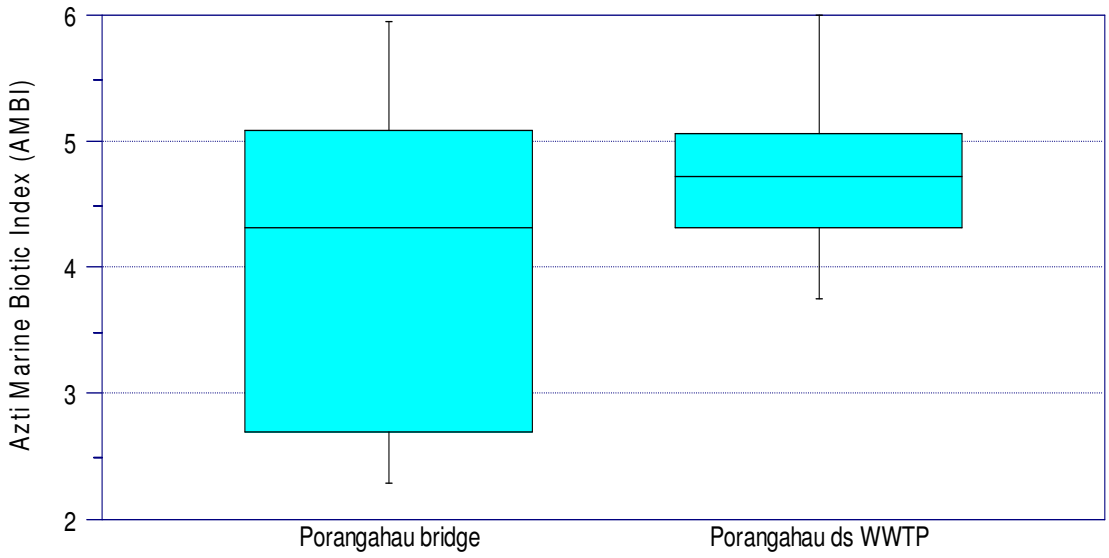

Figure 3.3: No significant difference in AMBI between the two Porangahau River estuary sites.

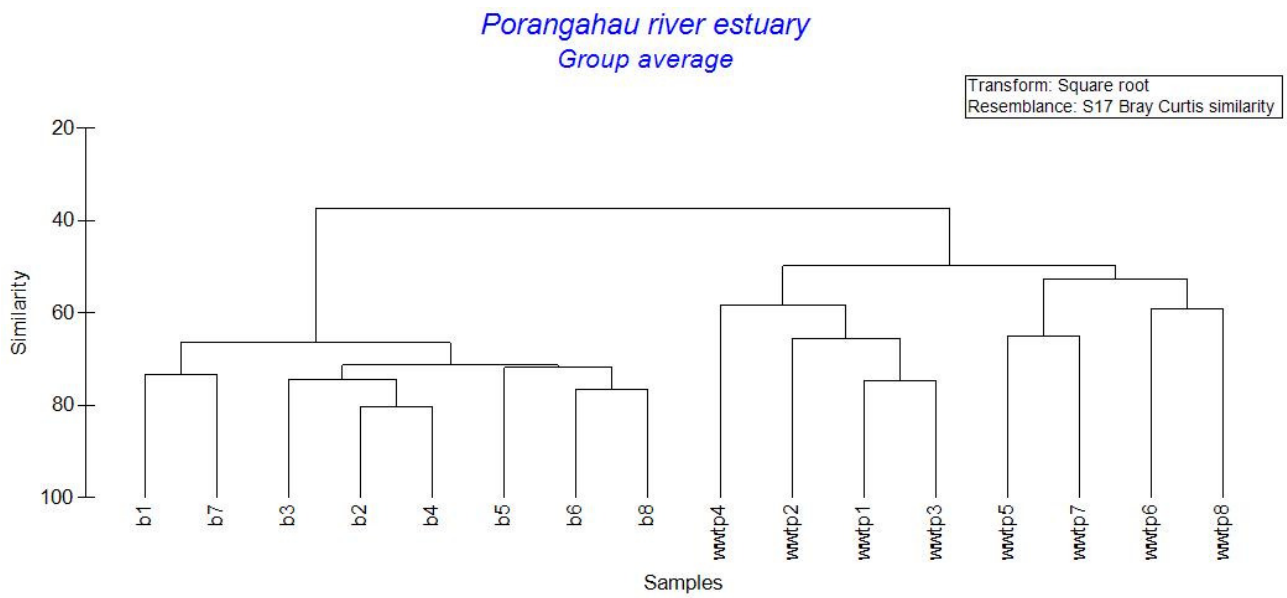

Figure 3.4: Dendrogram showing results of Brais-Curtis similarity analysis of biological data (data square-root transformed).

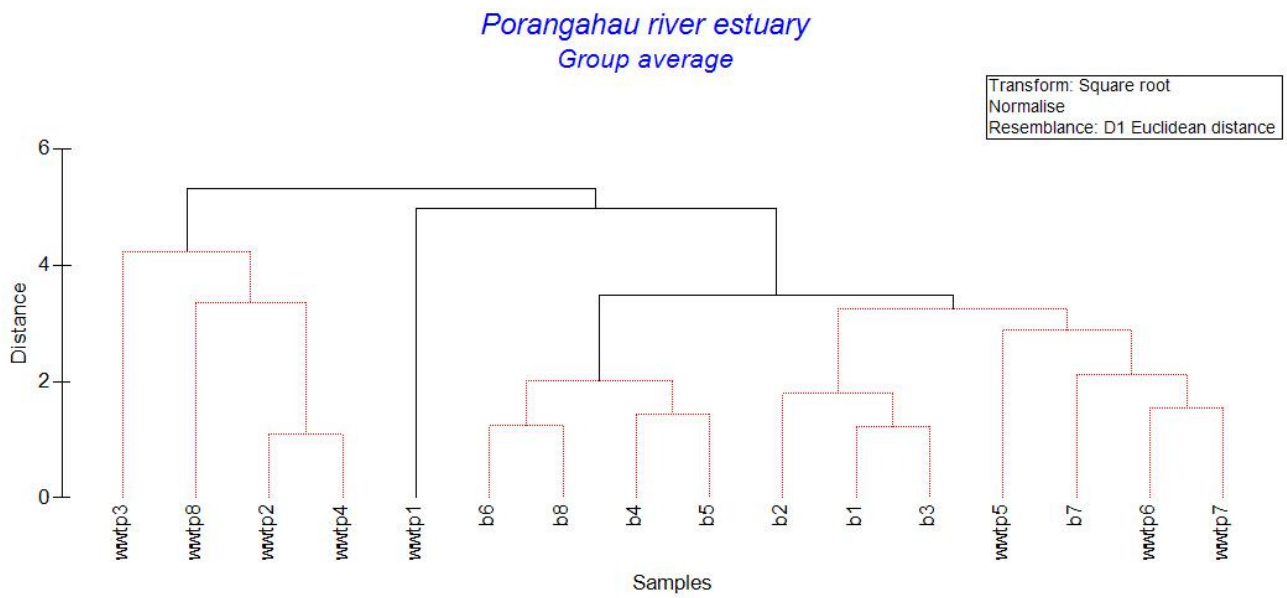

Figure 3.5: Dendrogram showing results of Euclidean distance similarity matrix of abiotic data (data square-root transformed and normalised). Clusters linked by red lines are not statistically significant.

Table 3.6: Infauna from Porangahau River estuary sites, April 2012

				Beach Road Bridge									Porangahau WWTP								
General Group	**Taxa**	**Common Name**	**AMBI Eco Group**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**mean**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**mean**
Platyhelminthes	Platyhelminthes	Flat Worm	II											1							
Nematoda	Nematoda	Roundworm	IV	1						1			2								
Gastropoda	Amphibola crenata	Mud Snail	na		1						2										
Gastropoda	Gyraulus sp.	Freshwater snail	na	1									1							1	
Gastropoda	Halopyrgus pupoides	Estuarine snail	na	1	1	5		2	4	1	1		2	4	3	1				1	
Gastropoda	Melanopsis sp.	Freshwater snail	na											1							
Gastropoda	Potamopyrgus antipodarum	Estuarine snail	na	38	25	16	7	9	25	28	39		31	19	35	6	17	14	53	25	
Bivalvia	Sphaeriidae	pea mussel	na	1	2	5				6	1										
Bivalvia	Xenostrobus securis	Little Black Mussel	na										1	1							
Oligochaeta	Oligochaeta	Oligochaete worms	V	2	4	53	10	2	3	1	24		3	7	2	2	1	5	8	1	
Polychaeta: Spionidae	Scolecolepides benhami	Polychaete worm	na					1		4										1	
Polychaeta: Nereidae	Nereidae (juvenile)	Rag worms	III		1	1	1	2	2	5	10		3	2	1	2		1		3	
Polychaeta: Nereidae	Ceratonereis sp.	Rag worm	III ?					3	4	3	3		3		1			1			
Polychaeta: Nereidae	Nicon aestuariensis	Rag worm	III ?	1	1	1	1		3					1							
Polychaeta: Lumbrineridae	Lumbrineridae	Polychaete worm	II														1				
Hirudinea	Hirudinea	Leeches	IV															2			
Crustacea	Herpetocypris pascheri	Seed shrimps	na										1					4	1	3	
Mysidacea	Mysidacea	Mysid shrimp	II	7	2		2		9	12											
Isopoda	Exosphaeroma chilensis	Isopod	na						1												
Isopoda	Sphaeroma quoyanum	Isopod	na														1	1		1	
Amphipoda	Phoxocephalidae	Amphipod (family)	III		1																
Amphipoda	Paracorophium sp.	Freshwater amphipod	na	83	134	188	163	131	197	113	203		3	1	1	32	3		1		
Amphipoda	Amphipoda indet.	Amphipod (family)	III															3			
Decapoda	Halicarcinus whitei	Pill-box Crab	na	4		1				1											
Decapoda	Helice crassa	Tunnelling Mud Crab	na			4	1	1													
Decapoda	Macrophthalmus hirtipes	Stalk-eyed Mud Crab	na						1	1	1										
Copepoda	Copepoda	Copepods	na														2	8	6	10	
Insecta	Dolichopodidae larvae	Small fly larvae	na	1	1	1	1										1	2	1		
Insecta	Chironomus sp.	Midge	na										2	7	6	7	4	23	3	4	
Odonata	Xanthocnemis	Damselfly	na											1		1		2		2	
Coleoptera	Elmidae	Riffle beetle	na											1		2				6	
Diptera	Tanytarsini	Non-biting midges	na																	3	
Trichoptera	Oxyethira	Axe-head caddis	na														1				
Trichoptera	Triplectides obsoletus	Caddis fly larvae	na															1			
	No of Individuals /0.01m^3			1188	1469	2334	1579	1282	2114	1494	2411	**1733.9**	424	390	416	450	263	569	620	518	**456.3**
	No of Taxa (richness)			11	11	10	8	8	10	12	9	**9.9**	10	12	7	8	9	13	7	13	**9.9**
	Peilous_Evenness			0.50	0.35	0.45	0.27	0.29	0.37	0.51	0.45	**0.40**	0.64	0.75	0.53	0.64	0.71	0.79	0.51	0.76	**0.67**
	Shannon-Wiener_Diversity			1.19	0.85	1.03	0.56	0.61	0.86	1.28	0.98	**0.92**	1.46	1.87	1.04	1.34	1.55	2.01	0.99	1.96	**1.53**
	Azti Marine Biotic Index (AMBI)			2.7	4.1	5.9	5.1	4.5	2.7	2.3	5.1	**4.1**	4.5	5.0	5.0	4.5	3.8	5.3	6.0	3.8	**4.7**
	Biotic Index (from Mean AMBI)			2	3	6	5	4	2	2	5	**3**	4	4	4	4	3	5	6	3	**4**
	BI Disturbance Clasification											**Moderately disturbed**									**Moderately disturbed**
	Not assigned (%)			72.7	63.6	80	62.5	75	70	66.7	77.8	**71**	73	75	71	75	78	77	86	85	**77**

Note: Shaded cells are freshwater species

3.3 Discharge quality

The results of water quality monitoring of the Porangahau River upstream and downstream of the WWTP were summarised and compared with previous results in Hamill (2012b). This found that only total ammonia (NH_4-N) and dissolved reactive phosphorus (DRP) were significantly higher downstream of the WWTP (Kruskal-Wallis test). All sites had total ammonia concentrations well within (more than 10 times lower than) ANZECC guidelines to avoid chronic toxic effects on aquatic life (see Table 3.6).

Total metals have been measured in the wastewater effluent since April 2011. The results of this sampling is shown in Table 3.7 and indicate particularly low concentrations of arsenic, chromium and nickel.

It seems unlikely that the small increases in nitrogen in the water column downstream of the WWTP can explain the increased concentration of TN in the downstream sediments. Other factors may also be playing a role such as the waterfowl observed at the WWTP site but not at the Beach Road Bridge site.

Similarly it is unlikely that the low concentrations of arsenic observed in the wastewater influent would account for an elevation (albeit small) in the sediments immediately downstream. There may be /have been other sources of arsenic and metal contaminants in the vicinity such as the now abandoned timber mill site on the true right bank opposite from the WWTP discharge.

Table 3.6: Median results of monthly sampling of the Porangahau River upstream and downstream of the waste water treatment plant.

Site	DO (g/m3)	cBOD5 g/m3	Enterococci cfu/100mL	E.coli cfu/100mL	FC cfu/100mL	pH	EC (mS/m)	Turbidity	TN (g/m3)	NH4-N (g/m3)	NNN (g/m3)	DRP (g/m3)	TP (g/m3)	TSS (g/m3)
Porangahau Rv us at Kates Quarry	9.37	0.75	55	117	245	8.1	54.85	2.73	0.608	0.007	0.015	0.009	0.027	6.5
Porangahau Rv 200m us	8.79	0.75	47.5	235	285	7.95	58.35	4.85	0.608	0.007	0.037	0.009	0.028	16.5
Porangahau Rv 200m ds	9.25	1	160	550	910	8	58.5	5.86	0.73	0.039	0.046	0.021	0.051	24
Pond discharge 2009 -2012		16	235	2200		7.9			10.7	6.03	0.1	1.13	1.865	31
Pond discharge 2002-2008		*20*			*7700*	*7.9*				*5.9*		*3.1*		*35*

Most variables had 29 monthly samples between November 2009 and January 2012

Table 3.7: Influent quality for Porangahau WWTP plant showing low concentrations of metals

Date	TN (mg/L)	NH4-N (mg/L)	TP (mg/L)	SRP (mg/L)	Total As (mg/L)	Total Cd (mg/L)	Total Cr (mg/L)	Total Cu (mg/L)	Total Pb (mg/L)	Total Hg (mg/L)	Total Ni (mg/L)	Total Zn (mg/L)
7-Apr-11	25.9	18.9	3.29	2.05	<0.002	<0.001	<0.001	0.04	<0.001	<0.001	0.002	0.03
26-Apr-11	29	18.6	6.67	4.98	<0.002	<0.001	<0.001	0.031	0.001	<0.001	<0.005	0.08
24-May-11	37.3	5.23	9.65	2.12	<0.002	<0.001	0.002	0.064	0.004	<0.001	<0.005	0.098
21-Jun-11	43.2	15.9	9.7	5.07	0.002	<0.001	0.004	0.099	0.006	<0.001	0.01	0.167
25-Oct-11	15.3	12.2	2.14	1.55	<0.002	<0.001	<0.001	0.024	0.001	<0.001	0.001	0.047
10-Apr-12	12.6	9.33	1.95	1.35	<0.002	<0.001	<0.001	0.021	<0.001	<0.001	0.002	0.034
26-Apr-12	27.8	17.4	4.14	2.64	<0.002	<0.001	<0.001	0.043	0.001	<0.001	<0.005	0.047
22-May-12	13.4	9.72	1.44	1.1	<0.002	<0.001	<0.001	0.021	<0.001	<0.001	0.002	0.02
23-Oct-12	18.5	14.7	1.99	1.51	<0.002	<0.001	<0.001	0.031	<0.001	<0.001	0.003	0.039
15-Jan-13	31.7	21.8	3.32	1.92	<0.002	<0.001	<0.001	0.055	<0.001	<0.001	0.002	0.047
median	26.85	15.30	3.31	1.99	<0.002	<0.001	<0.001	0.04	0.001	<0.001	0.003	0.05

4 Summary and conclusion

Benthic biota and sediment chemistry was sampled at two sites on the Porangahau River estuary – downstream of the WWTP discharge and at the Porangahau Beach Road Bridge. The Beach Road bridge site provided a 'pseudo-control' in a 'distance from impact' study design, but the two sites were also on a salinity gradient with electrical conductivity during low tide of 545 µS/cm 10,390 µS/cm at the WWTP site and the Beach Road Bridge site respectively.

At both sites most abiotic sediment variables indicated either a 'good' or 'very good' ecological condition and all the results for metals were less than the ANZECC (2000) Interim Sediment Quality Guidelines (ISQG)-low, which means we would not expect any adverse effects on aquatic life due to the values measured. Redox Potential Discontinuity (RPD) depth at the Beach Road Bridge site rated 'fair'.

There were differences in sediment quality between sites. There was moderate to strong evidence that sediments at the WWTP site had more chlorophyll *a* (2.5 times more), organic carbon, nitrogen, arsenic, cadmium, lead and zinc compared to sediment at the Beach Road Bridge site. However the Beach Road Bridge site had more copper in the sediment.

The benthic invertebrate community at both sites indicated 'moderate disturbance' (based on the AMBI score). There was no significant difference in the taxa richness or the AMBI score between the two sites.

Biological diversity was relatively poor at both sites with species abundance dominated by a couple of species (*Paracorophium* amphipod and *Potamopyrgus* snail). The WWTP site had significantly higher diversity, due in part to the additional freshwater taxa at the site. The total abundance of taxa was greater at the Beach Road Bridge site due to *Paracorophium* amphipods.

Cluster analysis and a PERMANOVA statistical test found a clear distinction between the biological communities between the two sites. The difference between the two sites was best explained by the Beach Road Bridge site having many more *Paracorophium* amphipods and no copopods or *Chironomus* sp. midges (both freshwater species). This suggests that the differences were more likely to be related to the salinity gradient rather than the WWTP discharge.

Overall, there were measureable differences between the two sites in both sediment quality and benthic biota community. The site closest to the WWTP had measurably higher sediment concentrations of nitrogen, carbon, arsenic, cadmium, lead zinc and chlorophyll *a,* some of these variables may be related to the WWTP discharge while others are more likely to be other sources (e.g. arsenic). While differences were found the sediment quality at both sites corresponded to an estuarine condition of 'good' to 'very good'. The concentrations of contaminants were low in terms of both effects and other NZ estuaries. None of the differences in sediment quality or downstream water quality were sufficient to account for differences in the benthic invertebrate community; instead biological differences between the two sites are more likely to be related to the salinity gradient.

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Appendix 1: Correlation between variables

Pearson correlation between variables (shaded cells have a correlation of > 0.8)

	TP	TOC	TN	Chl a	Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Zinc	Shannon-Wiener Diversity	No of Individuals	Richness	AMBI
T Phosphorus	**1.00**	0.68	**0.80**	0.07	0.53	0.62	**0.81**	0.24	0.79	0.79	**0.83**	0.39	-0.19	0.24	-0.01
Total Organic Carbon*		**1.00**	**0.93**	0.35	0.64	**0.96**	0.65	-0.08	**0.93**	0.69	**0.90**	0.51	-0.60	0.06	0.16
Total Nitrogen*			**1.00**	0.37	0.72	**0.92**	0.73	-0.02	**0.94**	0.76	**0.94**	0.58	-0.56	0.19	0.10
Chlorophyll a*				**1.00**	0.53	0.39	-0.02	-0.42	0.25	0.06	0.29	0.56	-0.59	0.16	-0.11
Arsenic					**1.00**	0.73	0.34	-0.44	0.69	0.44	0.71	0.75	-0.66	0.21	0.02
Cadmium						**1.00**	0.65	-0.17	**0.94**	0.70	**0.91**	0.52	-0.73	-0.02	0.21
Chromium							**1.00**	0.54	**0.83**	**0.97**	**0.86**	0.18	-0.26	0.10	0.06
Copper								**1.00**	0.08	0.50	0.14	-0.37	0.46	0.16	-0.16
Lead									**1.00**	**0.87**	**0.99**	0.51	-0.59	0.12	0.14
Nickel										**1.00**	**0.90**	0.34	-0.37	0.22	0.04
Zinc											**1.00**	0.50	-0.56	0.14	0.08
Shannon-Wiener Diversity												**1.00**	-0.61	0.67	-0.06
No of Individuals													**1.00**	-0.02	-0.07
Richness														**1.00**	-0.39

Pearson correlation between variables

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