report

November 2015

Assessment of the Receiving Environment for Alliance Lorneville's Treated Wastewater Discharge

Submitted to:
Alliance Group Ltd

fresh water solutions
environmental consultants

Executive Summary

Background

Alliance Group Limited will lodge applications for new resource consents to discharge treated wastewater from its Lorneville Plant (the Plant) to the Makarewa River in 2015. The discharge from the Plant includes wastewater from the slaughter, further processing, rendering and fellmongery operations along with human wastewater generated on site and from Wallacetown. Wastewater is treated onsite via physical, anaerobic and aerobic treatment systems followed by discharge to the Makarewa River. Work associated with the assessment of the current and possible future discharges on the Makarewa River, Oreti River and New River Estuary began in 2012 and has included the following:

- Environmental data review and monitoring plan preparation.
- New River Estuary nutrient and sediment load estimates.
- Aquatic plant, benthic invertebrate and fish surveys in summer 2013, spring 2013 (off season) and summer 2014.
- Mixing zone assessment in summer 2014.

Study Methods

This report outlines the methods used for the study followed by a general description of the receiving environments. The report describes the current discharge characteristics, water quality and mixing and receiving environment ecological and recreation values.

The data review undertaken in late 2012 identified some gaps and resulted in an expansion of the compliance discharge and river water quality monitoring programme. Additions to the programme included increasing the range of parameters, sampling sites and sampling frequency to ensure that all relevant effects could be assessed using comprehensive datasets and to allow comparisons against relevant national and Southland Regional Council (SRC) guidelines and limits.

The monitoring plan was presented to stakeholders and the SRC during a site visit and meeting. Stakeholders and the SRC were invited to comment on the proposed monitoring plan and make suggestions for alternative or additional assessments. Stakeholders and SRC provided useful feedback and endorsed the proposed monitoring plan with no additional survey work added.

Alliance undertakes regular compliance water quality monitoring at three sites: Bridge Site (upstream of the discharge), 350 m downstream of the discharge and at the Boundary Site (1,200 m downstream of the discharge). A very large volume of data collected from these sites between December 2001 and May 2014 has been analysed, summarised and presented in this report.

Four biological monitoring sites (Sites U1, U2 above the zone of influence of the discharge) and D1 and D2 within the zone of influence from the discharge and within the mixing zone) were selected on the Makarewa River and sampled in early March 2013, November 2013, February 2014 and March 2014. In addition, samples of whitebait caught from the Makarewa River in the vicinity of the discharge between 17 August and 4 November 2013 were collected from fishermen and identified.

The Plant’s discharge point is located near the upper end of the tidally influenced section of the river. There is a decreasing gradient of tidal influence from Site D1 to Site U2. The tide affects river level and water velocity but not salinity. Site U1 near the Wallacetown-

Lorneville Highway Bridge is unaffected by the tidal cycle. The changes that occur in an upstream direction between Sites D1 and U2 include an increase in coarse substrate, an increase in riffle habitat, decreased macrophyte cover and decreased river water level variation. The tidal cycle and river profile and flow conditions means that the area within which mixing takes place, at low river flow and low tide extends some 200 m downstream of the discharge while near the high tide the mixing zone extends from approximately 200 m downstream , with incomplete mixing 200 m upstream of the discharge.

Consideration was given to biological surveys in the lower Makarewa River beyond the mixing zone and in the lower Oreti River. The confounding effects of the tidal influence and other catchment scale effects would have meant that monitoring further downstream was unlikely to provide additional insight into the effects of the discharge and for this reason biological sampling was not undertaken in the lower Makarewa River or Oreti River.

The New River Estuary is regularly and comprehensively monitored by Invercargill City Council (ICC) and SRC and additional sampling of the estuary was not recommended by Freshwater Solutions (2013). Instead reliance has been placed on the ICC and SRC work.

The Receiving Environment

The Plant discharges to the Makarewa River 4.4 km downstream of the Wallacetown-Lorneville Highway Bridge and 5 km upstream of the confluence between the Makarewa River and Oreti River. The Makarewa/Oreti River confluence is approximately 14 km upstream of the New River Estuary.

The Makarewa River drains a 991 km^2 catchment that has been fully developed for agriculture with the exception of a small portion of the headwaters on the south-western flanks of the Hokonui Hills. The upper Makarewa River (above Wallacetown) is characterised by high nutrients, low visual clarity, low Amm-N concentrations, high faecal indicator bacteria counts, water temperatures suitable for protecting river ecosystem health, MCI scores at the Wallacetown-Lorneville Highway Bridge that are indicative of ‘fair’ water quality and low fish diversity in the upper reaches due to the high level of modification within the catchment.

The lower Makarewa River (below Wallacetown) has also been modified by historical river drainage and flood protection works. Makarewa River water and sediment quality, in the region of the Alliance Plant i.e immediately upstream and in the river downstream of the Plant, is characterised by high nutrient concentrations, high faecal indicator bacteria counts, low visual clarity, high Amm-N concentrations, generally moderate but occasionally low summer dissolved oxygen concentrations, and pH that is suitable for supporting healthy biological communities. The benthic invertebrate and aquatic plant communities in the lower Makarewa River change in response to the substrate, channel gradient, water velocity, tidal influence and water quality. Fine sediment cover increases and gravel and cobble cover decreases, thus decreasing the suitability of the habitat for a range of benthic invertebrate taxa such as *Deleatidium* and freshwater mussels. Key features of the biological communities in the Makarewa River immediately above and below the Plant discharge is the dominance of macrophytes, water and habitat tolerant benthic invertebrate taxa and a diverse fish community. The Makarewa River also supports a locally significant brown trout fishery that receives low-moderate use.

New River Estuary is a large, shallow ‘tidal lagoon’ estuary, situated at the confluence between the Oreti River and Waihopai River. The estuary forms part of the Awarua Plains Wetland complex. Its catchment largely consists of agricultural land, but it is also subject to stormwater and wastewater discharges from Invercargill City. Overall, the available data indicates that large parts of New River Estuary remain in reasonable condition, but a significant and increasing proportion of the estuary is seriously impacted by fine sediments and elevated nutrient concentrations. The New River Estuary supports high ecological values including a diverse bird fauna and freshwater and marine fish populations. The estuary provides important spawning and rearing habitat for fish. The estuary also provides game bird hunting, fishing, bird-watching, power boating, rowing, bathing, walking and picnicking opportunities.

Existing Discharge Quality

On no occasion during the monitoring period (December 2001 and June 2014) was the consent discharge volume limit exceeded.

The median pH and conductivity of the discharge in the monitoring period was 8.2 and 1.9 mS/m respectively. There have been minor exceedances of the 300 g/m^3 maximum total suspended solids (TSS) limit.

The median total nitrogen (TN) concentration in the discharge was 110 g/m^3. Discharge TN is dominated by ammoniacal nitrogen (Amm-N). The median TN load in the discharge was 1,320 kg/day. The median TP concentration in the discharge was 11 g/m^3 and the median total phosphorus (TP) load in the discharge was 140 kg/day. The major proportion of TP is present as dissolved reactive phosphorus (DRP).

The median biochemical oxygen demand (BOD) concentration in the discharge was 16 g/m^3 and the median BOD load was 120 kg/day.

The median faecal coliform (FC) concentration in the discharge was 3,100 MPN/100mL and the median FC load was 4.5 x 10^{11} MPN/day. The median *Escherichia coli* (*E. coli*) concentration in the discharge was 2,400 cfu/100mL and the median E. coli load was 3.6 x 10^{11} cfu/day.

Existing River Water Quality

There is little difference in river temperature between the Bridge Site, the 350 m Site and the Boundary Site. There is a slight increase in pH downstream of the discharge, although on no occasion was the pH at the 350 m Site outside the pH range stipulated in the consent (6.0–9.0). Dissolved oxygen (DO) at the 350 m Site was slightly less than that at the Bridge Site for 79% of the time. However, the DO consent condition state that 'DO concentration of the receiving waters beyond 350 m of the point of discharge shall be consistently maintained at not less than 6 g/m^3'. This was met at all times. Class D Standards require DO not to be reduced below 5 g/m^3 and this condition was met 99.7% of the time.

The existing consent conditions require river water clarity not to be reduced by more than 20% at the 350 m Site compared with the Bridge Site. There was a consistent reduction in water clarity at the 350 m Site and a greater than 20% reduction for 20% of the time. This exceedence of the current consent limit brings into question the efficacy of the approach taken to the management of water clarity within the existing consent conditions given the ambient water quality characteristics of the Makarewa River. This is addressed further in the main body of this report.

The median TN concentration at the Bridge Site was 1.3 g/m^3 and was predominately comprised of organic nitrogen and TON. There was a significant increase in TN at the 350 m Site and the Boundary Site. The composition of TN at the downstream sites was dominated by Amm-N. The consent contains two Amm-N conditions, both of which were met to a high degree of compliance (i.e., >99%).

The median TP concentration at the Bridge Site was 0.067 g/m^3 and increased to 0.49 g/m^3

and 0.32 g/m^3 at the 350 m Site and the Boundary Site respectively.

Median faecal coliform (FC) counts were lower at the downstream 350 m Site compared to the Bridge Site on 56% of sampling occasions.

Water quality at the site located just upstream of the confluence with the Oreti River was similar to that at the Boundary Site with respect to physico-chemical parameters. Nutrient concentrations recorded upstream of the confluence with the Oreti River were however lower than at the Boundary Site.

River sediment at sites upstream and downstream of the discharge showed elevated nutrient concentrations in the immediate vicinity of the discharge (100–200 m) and at a site 1.5 km downstream.

Makarewa River Habitat

The in-stream habitat in the vicinity and downstream of the discharge reflects the low gradient, tidal and highly modified nature of the lower Makarewa River. In-stream habitat also reflects the gradient of influence that natural factors such as tide, channel gradient and morphology has between upstream and downstream sites. Sites D1 and D2 were characterised by a large (1.0–1.5 m) difference in river water level and water velocity (0.0–1.2 m/s) between low and high tide. There is a slight change in river water level (0.1 m) and velocity between low and high tide at Site U2.

The Makarewa River downstream of the discharge is a meandering low gradient river characterised by soft river bed and bank sediments. The gently flowing run and pool habitat is dominated by submerged macrophytes and has a riparian zone comprising grazed and rank pasture grasses.

Makarewa River Aquatic Plant Community

The lack of periphyton at Sites D1 and D2 is reflective of the unsuitable nature of the habitat which is characterised by fine substrate and macrophytes beds. The MfE (2000) periphyton cover guidelines were exceeded at Site U1 in the November 2013 and February 2014 surveys. The MfE (2000) guideline for long filamentous green algae cover was exceeded at Site U2 (downstream of the Wallacetown-Lorneville Highway Bridge) during the February 2014 survey.

Total macrophyte cover was lower at Site U1 across all four surveys (range 5–22%) compared to Site U2 (range 35–85%), Site D1 (range 50–88%) and Site D2 (50–85%) and shows that there was a significant increase in macrophyte cover between the most upstream site (Site U1) and the most downstream site (Site D1).

The submerged and surface reaching rooted macrophyte community recorded during the February 2014 survey was dominated by introduced species that can reach nuisance levels including *Potomogeton crispus* (curly pondweed) and the native species *Potomogeton ochreatus* (blunt pondweed).

Total macrophyte cover exceeded the MfE (2012) recommended provisional guidelines of ≤50% cover of river bed area or river surface area at Sites U2, D1 and D2 in March 2013 and November 2013. Total macrophyte cover also exceeded the MfE (2012) recommended provisional guidelines at Sites D1 and D2 in February 2014.

Makarewa River Benthic Invertebrate Community

The benthic invertebrate community was dominated by water and habitat tolerant taxa at all sites during all three surveys and was characteristic of depositional enviromnments. The benthic invertebrate composition at Site D1 varied across the three surveys with crustaceans dominant in March 2014, worms dominant in November 2013 and molluscs dominant in March 2013. The depositional, soft-bottom tidal habitat is likely to exclude koura and mussels from large portions of the lower Makarewa River.

Key features of the benthic invertebrate community at Site D1 were the high numbers of cladocerans and hydra in March 2013 and March 2014 (most likely derived from wastewater treatment ponds), the absence of *Deleatidium* mayflies (prefer clean, fast flowing stony bed rivers) and the presence of clean water caddisfly taxa that can tolerate low water velocity. In contrast, the community recorded at Site D2 remained stable across the three surveys with crustaceans, worms and molluscs dominating the community.

When assessed in combination, benthic invertebrate index scores indicate that community health was lower at Sites D1 and D2 when compared to upstream sites in March 2013 and March 2014. Benthic invertebrate index scores during the off season were lower at upstream and downstream sites when compared with index scores during the processing season and potetentially indicates generally poorer water quality both upstream and downstream. There was no clear trend in index scores in November 2013 between upstream and downstream sites. When assessed in combination, benthic invertebrate index scores indicate that invertebrate community health was lower at Sites D1 and D2 compared to upstream sites in November 2013. Benthic invertebrate communities recorded from Sites D1 and D2 in November 2013 (when no was discharge occurring) were similar to the downstream communities in March 2013 and 2014 when the discharge was occurring. Supporting the conclusion that factors other than water quality are shaping the communities at downstream sites.

Makarewa River Fish Community

The Makarewa River supports high native fish diversity despite its highly modified state and includes five species with an ‘At Risk-Declining’ conservation status (Goodman et al. 2014). The most commonly occurring and abundant fish species in the vicinity of the discharge are shortfin eels and common bully.

The lower Makarewa River and lower Oreti River support very productive shortfin eel, and to a lesser extent, longfin eel fisheries. Despite historical channelisation and modification of habitat in the lower Makarewa River this section provides very good eel habitat, and in particular, the extensive macrophyte beds that provide important cover for shortfin eels.

Some of the native fish found in the Makarewa River use the lower Makarewa River as a migratory pathway to upstream adult habitat (e.g., koaro and banded kokopu). Other species such as inanga, shortfin eels, trout and black flounder use the lower Makarewa River to feed and grow. Most upstream juvenile fish migration in the lower Makarewa River occurs when there is low discharge loads occurring from the Plant. The Makarewa River downstream of the Plant provides habitat for adult brown trout but is unsuitable as spawning/rearing habitat due to the lack of gravel substrate and riffle habitat.

Table of Contents

Index to Tables

Index to Figures

Appendices

1.0 Introduction

1.1 Background

Alliance Group Limited (Alliance) will lodge applications for new resource consents to discharge treated wastewater (the discharge) from its Lorneville Plant (the Plant) to the Makarewa River in 2015. The discharge from the Plant includes wastewater from the slaughter, further processing, rendering and fellmongery operations along with human wastewater generated on site and from Wallacetown. Wastewater is treated onsite via physical, anaerobic and aerobic treatment systems followed by discharge to the Makarewa River (PDP 2013).

Work associated with the assessment of the current and possible future discharges on the Makarewa River, Oreti River and New River Estuary began in 2012. The work has included the following key assessments:

- Environmental data review and monitoring plan preparation (Freshwater Solutions 2013).
- New River Estuary nutrient and sediment load estimates (Robertson and Steven 2013).
- Aquatic plant, benthic invertebrate and fish surveys in summer 2013, spring 2013 (off season) and summer 2014.
- Mixing zone assessment in summer 2014 (Freshwater Solutions 2015).

Freshwater Solutions (2013) provided a preliminary review of the catchment wide hydrology, water quality and ecology of the Makarewa River, lower Oreti River and New River Estuary, reviewed relevant sediment water quality and ecology data collected under the existing treated wastewater discharge consent (Discharge Permit 92195), identified information gaps and set out a monitoring plan.

Robertson and Stevens (2013) described and assessed the nutrient loads entering the New River Estuary using the Catchment Land Use for Environmental Sustainability model (CLUES 10.1). The report summarised and presented the point and diffuse sources of total nitrogen (TN), total phosphorus (TP) and total suspended solids (TSS) to the estuary and estimated the Plant’s contribution to the Makarewa River and New River Estuary. Robertson and Stevens (2013) is included in full in Appendix 6.

Freshwater Solutions (2015) presented and described the results of a mixing zone assessment based on a survey of the river in March 2014 at low river flow and during an outgoing and incoming tide using an Acoustic Doppler Current Profiler and global positioning system. The draft report was reviewed by Dr Kit Rutherford and his comments/suggestions incorporated into the final report. Freshwater Solutions (2015) is included in full in Appendix 5.

This report builds on the previous assessments and includes all discharge and river water quality, sediment quality and biological data available at the completion of the 2013/2014 processing season. These previous assessments exclude assessing matters relevant to iwi which are being dealt with separately. This report updates the October 2014 report by including additional data and commentary following a review by Ryder and Associates Ltd in August 2015.

1.2 Report Structure

This report first sets out a summary of the methods used for the study followed by a general description of the receiving environments (upper Makarewa River, lower Makarewa River, lower Oreti River and New River Estuary). The report then goes on to describe in detail the current discharge characteristics, quality and mixing and current ecology and recreational values. The report is presented in the following sections:

Section 2: Summary of the methods used to collect, analyse and assess the data.

Section 3: Description of the receiving environment.

Section 4: Description of the discharge characteristics and quality and mixing of the discharge with the Makarewa River.

Section 5: Description of the Makarewa River water and sediment quality upstream and downstream of the discharge.

Section 6: Description of the ecology of the lower Makarewa River upstream and downstream of the discharge.

Section 7: Report references.

2.0 Assessment Methods

2.1 Makarewa River

The data review undertaken in late 2012 and presented in Freshwater Solutions (2013) identified some gaps and resulted in an expansion of the compliance discharge and river water quality monitoring programme. The additions to the programme included increasing the range of parameters, sampling sites and sampling frequency to ensure that all relevant effects could be assessed using comprehensive datasets and compared against relevant Southland Regional Council (SRC) and national guidelines and limits.

The monitoring plan was presented to stakeholders and the SRC during a site visit and meeting. Stakeholders and the SRC were invited to comment on the proposed monitoring plan and make suggestions for alternative or additional assessments. Stakeholders and SRC provided useful feedback and endorsed the proposed plan and no additional survey work was added. The full description of the methodology used in the various assessments is presented in Appendix 1 and is summarised below.

Alliance undertakes regular compliance water quality monitoring at three sites: Bridge Site (upstream of the discharge), 350 m downstream of the discharge and at the Boundary Site (1,200 m downstream of the discharge) (Figure 2). A very large volume of data collected from these sites between December 2001 and May 2014 has been summarised and presented.

Alliance also collected additional water quality data from the discharge, river compliance monitoring sites (Bridge Site, 350 m Site and Boundary Site) and a site immediately upstream of the confluence with the Oreti River to allow the nature and extent of the discharge effects to be fully assessed. Additional water quality sampling was also undertaken by Alliance at some of the biological monitoring sites (Sites U2, D1 and D2) to determine possible cause and effect relationships between the discharge and biological communities. Water samples were also collected from the boiler ditch (into which the treated wastewater is discharged) and Tomoporakau Stream that enters the Makarewa River on the true right bank approximately 200 m upstream of the Boundary Site in 2013 and 2014 to assess the relative contributions of these two tributaries to water quality in the lower Makarewa River.

Four biological monitoring sites were selected on the Makarewa River and sampled in early March 2013, November 2013, February 2014 and March 2014. A summary of the surveys undertaken at each site on each sampling occasion is presented in Table 1. The native fish survey on 8 March 2013 was a net and trap survey of pool and run habitat. The native fish survey on 12 March 2014 was an electric fishing survey of riffle habitat. In addition, samples of whitebait caught from the Makarewa River in the vicinity of the discharge between 17 August and 4 November 2013 were collected from fishermen and identified.

The Plant's discharge point is located near the upper end of the tidally influenced section of the river. There is a decreasing gradient of tidal influence from Site D1 to Site U2 (Figure 2). The tide affects river level and water velocity but not salinity. Site U1 near the Wallacetown Bridge is unaffected by the tidal cycle.

The changes that occur in an upstream direction between Sites D1 and U2 include an increase in coarse substrate, increase in riffle habitat, decreased macrophyte cover and decreased river water level variation. The tidal cycle, river profile and flow conditions means that the area within which mixing takes place at low river flow and low tide extends some 200 m downstream of the discharge while near the high tide the mixing zone extends from approximately 200 m downstream, with incomplete mixing 200 m upstream of the discharge (Appendix 5).

Table 1: Summary of biological assessments.

Survey date	Total periphyton cover	Total macrophyte cover	Macrophyte species cover	Benthic invertebrates	Native fish
8 March 2013	Y	Y	N	Y	Y+
7 November 2013	Y	Y	N	Y	N
6 February 2014	Y	Y	Y*	N	N
12 March 2014	Y*	Y*	N	Y*	Y*+

Note: * = Site U2 (up) was included in the March 2014 survey. + = Site U1 was excluded from the fish surveys.

The very limited amount of riffle habitat, preferred by water and habitat sensitive benthic invertebrates, downstream of the discharge, differences in the physical habitat, tidal influence and the extent of the mixing zone made it impossible to select benthic invertebrate and aquatic plant monitoring sites upstream and downstream that have similar sets of physical habitat conditions. As a result separating out the effects that habitat and water quality have on the ecology of the river is difficult.

A standard study design for assessing the effects of a discharge to a river would typically involve surveying two (or three) sites upstream and two (or three) sites downstream of the mixing zone. Sites would normally be carefully selected in order to minimise the potential for habitat conditions to influence survey results to ensure that effects associated with the discharge can more readily be identified and quantified. The location of the discharge prevented such a design being used due to the significant changes of habitat upstream and downstream of the discharge as a result of the gradient of influence from the tide.

Site D1 has the only riffle habitat suitable for sampling benthic invertebrates using a quantitative method (Surber sampler) and surveying periphyton and macrophytes downstream of the discharge. Site D1 is only accessible at low river flow (<4 m^3/s) and low tide, is approximately 100–200 m downstream of the discharge and is within the discharge mixing zone (see Appendix 5). In order to ensure a balanced statistical design a second ‘effects’ site (Site D2) with suitable habitat was selected 70 m upstream of the discharge and within the mixing zone during the incoming tide (see Appendix 5). The effects sites (Sites D1 and D2) are therefore both located within the mixing zone. The aquatic plant and benthic invertebrate results from these sites therefore occur where we would expect to see effects of the effects of the discharge.

Sites U2, and U2 up, approximately 2 km upstream of the discharge, are beyond the influence of the discharge and where the effect of the tide on habitat conditions and water level variations is minor (approximately 0.1 m between low and high tide compared to 1.0–1.5 m at Sites D1 and D2). Site U1 is approximately 300 m downstream of the Wallacetown Bridge. This site was selected because it is monitored annually by SRC and has a good long term benthic invertebrate dataset with which to compare results (Figure 1, Appendix 1).

The assessment of recreational values of the Makarewa River was based on a desktop assessment and including information gathered from SRC, DOC and Southland Fish and Game and the National angler survey. Following comments by the reviewer Freshwater Solutions understands Alliance is seeking to gather more specific information about the recreational values of the lower Makarewa River.

2.2 Oreti River and New River Estuary

Consideration was given to biological surveys in the lower Makarewa, beyond the mixing zone and in the lower Oreti Rivers. The confounding effects of the tidal influence and other catchment scale effects would have meant that monitoring further downstream was unlikely to provide additional insight into the effects of the discharge and for this reason biological sampling was not undertaken in the lower Makarewa River or Oreti River.

The New River Estuary is regularly and comprehensively monitored by Invercargill City Council (ICC) and SRC and additional sampling of the estuary was not recommended by Freshwater Solutions (2013). Instead the approach to assessing the effect of the discharge on the New River Estuary has been to rely on the work of ICC and SRC, and use the Catchment Land Use for Environmental Sustainability (CLUES) model to determine the proportion of nutrients in the estuary that are discharged by the Plant compared to other point and diffuse nutrient sources (see Robertson and Stevens 2013).

The assessment of recreational values of the lower Oreti River and New River Estuary was based on a desktop assessment and including information gathered from SRC, DOC and Southland Fish and Game and the National angler survey. Following comments by the reviewer Freshwater Solutions understands Alliance is seeking to gather more specific information about the recreational values of the lower Makarewa River.

3.0 Receiving Environment

3.1 Introduction

The Plant discharges to the Makarewa River 4.4 km downstream of the Wallacetown-Lorneville Highway Bridge and 5 km upstream of the confluence with the Oreti River. The Makarewa/Oreti River confluence is approximately 14 km upstream of the New River Estuary; a tidal lagoon that is open to the ocean at the eastern end of Oreti Beach (Figure 1 and Figure 2). The following section describes the receiving environment including the Makarewa River, lower Oreti River and the New River Estuary.

3.2 Upper Makarewa River

Management and Land Use

For the purposes of this description the upper Makarewa River is defined as the reach upstream of the Wallacetown-Lorneville Highway Bridge. The Makarewa River drains a 991 km^2 catchment that, apart from a small portion of the headwaters on the south western flanks of the Hokonui Hills, has been fully developed for agriculture. Major upper catchment tributaries include the Hedgehope Stream, Otapiri Stream, Dunsdale Stream and Tussock Creek. Gold Creek joins the Makarewa River in the middle of the catchment.

Hydrology

The Makarewa River flow is gauged at Counsell Road approximately 15 km upstream of the Plant by the SRC. The reliable portion of flow record for the Counsell Road Site (1982–2012) was assessed and summary statistics prepared by Aqualinc Research Ltd in 2013. The key flow statistics calculated were:

- Mean: 15.67 m^3/s.
- Median: 7.65 m^3/s.
- Minimum: 0.80 m^3/s.
- Maximum: 586 m^3/s.
- 7 day Mean Annual Low Flow: 1.75 m^3/s.
- 3 x annual median flow (FRE3): 22.95 m^3/s (using a five day interval between events to be recorded separately).

The mean number of FRE3 events/year and the mean number of 20+ day, 30+ day, 40+ day, 50+ day, 75+ day and 100+ day accrual periods/year (period between FRE3 events) are presented Table 2.

The number of FRE3 sized flow events/year has ranged from 7 in 2003 to 22 in 1995. The average accrual period ranged from 52 days in 2003 to 17 days in 1995. The accrual period record shows that there has been at least one 40+ day accrual period each year between 1982 and 2012. The frequency of longer accrual periods >50+ days is more variable with between zero and three accrual periods exceeding 50+ days/year between 1982 and 2012. These results highlight that, like many other lowland Southland rivers the Makarewa River regularly experiences accrual periods that allow proliferation of algal growths.

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Figure 1: Topographical map of lower Makarewa River, Oreti River and the New River Estuary.

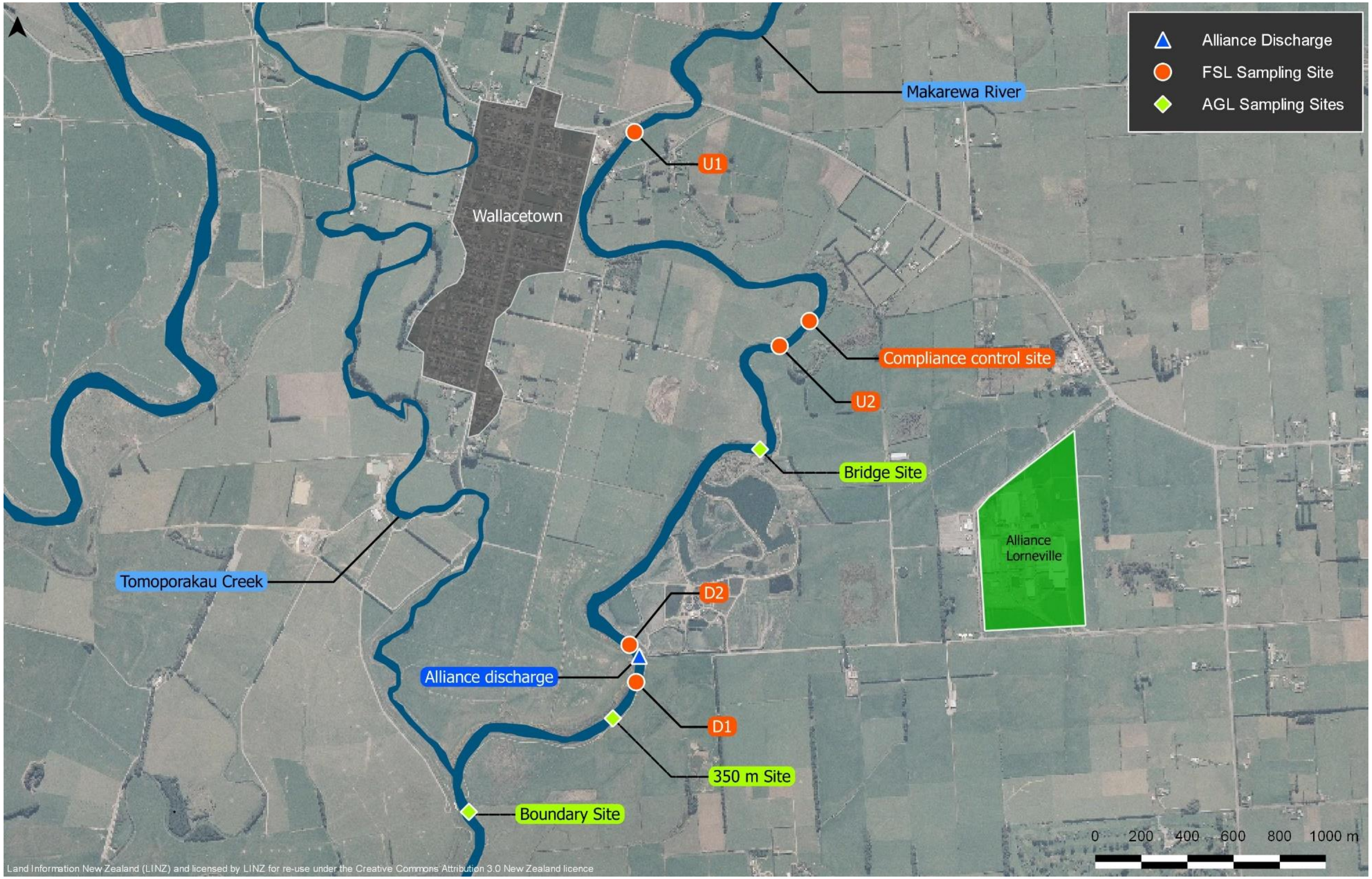

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Figure 2: Aerial map of lower Makarewa River, Oreti River and the New River Estuary.

Table 2: Makarewa River FRE3 and accrual periods.

Year	FRE3 events/y	Days of accrual					
		20+ days	30+ day	40+ days	50+ days	75+ days	100+ days
1982	17	6	6	3	1	0	0
1983	14	4	2	1	1	0	0
1984	19	4	3	1	1	1	1
1985	8	5	3	2	2	1	0
1986	11	4	4	2	2	2	2
1987	17	6	2	1	1	0	0
1988	17	7	5	1	0	0	0
1989	11	6	5	3	1	1	1
1990	8	4	4	3	2	1	0
1991	17	6	6	4	2	1	0
1992	16	7	1	1	1	0	0
1993	15	7	5	2	2	0	0
1994	15	4	1	1	1	0	0
1995	22	5	3	3	3	1	1
1996	16	5	2	1	1	1	1
1997	20	5	3	2	1	0	0
1998	19	6	3	3	0	0	0
1999	13	6	3	2	1	1	0
2000	13	7	5	4	1	1	0
2001	15	7	3	1	1	1	1
2002	12	6	2	1	1	1	1
2003	7	3	2	1	1	1	1
2004	17	6	3	2	2	1	1
2005	15	7	3	3	1	0	0
2006	14	9	5	2	1	0	0
2007	11	5	4	2	1	0	0
2008	14	4	2	2	2	1	1
2009	8	4	4	3	2	1	1
2010	16	8	5	4	2	1	1
2011	18	5	3	1	1	0	0
2012	14	4	3	3	3	1	0
Minimum	**7**	**3**	**1**	**1**	**0**	**0**	**0**
Maximum	**22**	**9**	**6**	**4**	**3**	**2**	**2**
Mean	**14.5**	**5.5**	**3.4**	**2.1**	**1.4**	**0.6**	**0.4**

Water Quality

SRC has monitored water quality at Lora Gorge Road and at Wallacetown since 2000. Both monitoring sites are classified by SRC as 'lowland soft bed' waterways. The Wallacetown Site is approximately 4.5 km upstream of the discharge point. The Lora Gorge Road site is approximately 70 km upstream of the discharge point.

The following key points summarise the water quality data collected by SRC on the Makarewa River between 2005 and 2010 (see SRC 2012):

- The Lora Gorge Road site has breached the dissolved reactive phosphorus (DRP) guideline of <0.01 g/m^3 (median 0.016 g/m^3, range <0.004–0.1 g/m^3) used in SRC (2012) on 87% of sampling occasions while the Wallacetown Site has breached the limit on 85% of sampling occasions (median 0.017 g/m^3, range <0.005–0.230 g/m^3).
- The Lora Gorge Road site has not breached the nitrate-nitrite guideline (<1.7 g/m^3) used in SRC (2012) while the Wallacetown Site has breached the limit on 25% of sampling occasions (median 0.96 g/m^3, range <0.160–4.18 g/m^3).
- The Lora Gorge Road and Wallacetown sites have not breached the unionised ammonia guideline (<0.034 g/m^3) used in SRC (2012).
- The Lora Gorge Road site has breached the visual clarity guideline (>1.6 m) used in SRC (2012) on 35% of sampling occasions (median 1.06 m, range 0.08–2.26 m) while the Wallacetown Site has breached the guideline on 50% of sampling occasions (median 0.79 m, range 0.28–1.34 m).
- The Lora Gorge Road site has breached the faecal bacteria guideline (<1,000 cfu/100 mL) used in SRC (2012) on 28% of sampling occasions (median 470, range 40–50,000) while the Wallacetown Site has breached the guideline on 27% of sampling occasions(median 50, range 30–39,000).
- The Lora Gorge Road and Wallacetown sites have not breached the temperature guideline (<23°C) used in SRC (2012).
- The Lora Gorge Road site has not breached the temperature guideline used in SRC (2012) for trout spawning areas (<11°C) while the Wallacetown Site has breached the limit on 2% of sampling occasions.

The SRC water quality results show that the upper Makarewa River is characterised by elevated nutrient and in particular DRP concentrations (>0.01 g/m^3), low visual clarity (<1.6 m), low unionised ammonia (Amm-N) concentrations (<0.034 g/m^3) and river water temperatures that are suitable for protecting river ecosystem health.

Ecology

SRC has monitored periphyton and benthic invertebrates at King Road, Wallacetown and at the Winton-Hedgehope Road since 2000. All three monitoring sites are classified by SRC as 'lowland soft bed' waterways. The Wallacetown Site is approximately 4.5 km upstream of the discharge point. The Winton-Hedgehope Road site is approximately 35 km upstream of the discharge point. The King Road site is approximately 55 km upstream of the discharge point.

The following key points summarise the ecology data collected by SRC on the Makarewa River between 2005 and 2014 (SRC 2012 and unpublished SRC data):

- The median Macroinvertebrate Community Index (MCI) scores, a measure of organic enrichment and benthic invertebrate community health in stony bed rivers, at Kings Road, Winton-Hedgehope Road and Wallacetown Bridge were 103, 81 and 89 respectively.

- The MCI scores at Kings Road and Wallacetown Bridge exceeded the >80 guideline used in SRC (2012) on 100% of sampling occasions. The MCI score at the Winton-Hedgehope Site did not meet the MCI guideline of >80 used in SRC (2012) on 40% of sampling occasions between 2000 and 2010.
- The chlorophyll-*a* level, a measure of nutrient conditions, at Kings Road, Winton-Hedgehope Road and Wallacetown Bridge exceeded the <120 mg/m^2 guideline used in SRC 2012 on 40%, 80% and 100% of occasions respectively.
- The Wallacetown Site is the only site of the 78 sites monitored by SRC to exceed the chlorophyll-*a* guideline used in SRC (2012) on 100% of occasions between 2000 and 2010.
- The periphyton Ash Free Dry Weight (AFDW) level, a measure of nutrient conditions, at Kings Road, Winton-Hedgehope Road and Wallacetown Bridge exceeded the <35 g/m^2 guideline used in SRC (2012) on 20%, 20% and 25% of occasions respectively.

The MCI score at Kings Road in 2011 was 93 (2012 – 2014 was not supplied by Environment Southland and was therefore not available for this site at the time of preparing this report), at the Wallacetown Bridge Site MCI scores in 2011 and 2013 were 84 and 87 respectively (2014 was not available for this site at the time of preparing this report) and MCI scores on the Makarewa upstream of the Hedgehope confluence (new site) in 2011, 2013 and 2014 were 88, 94 and 89 respectively. Overall the more recent MCI scores for the three SRC monitored sites are similar to those reported for the period 2000 – 2010.

SRC has monitored fish at Kings Road in the upper Makarewa River annually since 2007/2008 (SRC 2008). The key results from fish surveys to date are:

- Longfin eel, upland bully, brown trout and freshwater crayfish have been recorded on at least one of the three sampling occasions.
- The Integrated Biological Index (IBI) score, which is a measure of the overall health of the fish community at Kings Road in the upper Makarewa River is low and has ranged from 24 to 30. The most recent IBI score (24) placed the Kings Road site eleventh out of the twelve sites surveyed by SRC.

The SRC ecology monitoring results show that the upper Makarewa River is characterised by low-moderate benthic invertebrate community health and organic enrichment (median MCI scores ranging from 81–103), regular exceedance of periphyton chlorophyll-*a* and occasional exceedance of the periphyton AFDW guidelines and is reflective of the elevated nutrients concentrations, the modified nature of the river and highly developed nature of the catchment.

Recreation

The upper Makarewa River catchment provides a range of recreational values but the most significant is likely to be brown trout angling. The national angling survey results recorded that 3,610 ± 670, 1,910 ± 610, 1,940 ± 670 angler days were spent fishing the Makarewa River in the 1994/1995, 2001/2002 and 2007/2008 season respectively. The angler usage in the 2007/2008 season ranked the river below the Mataura River (40,260 ± 3,600), Oreti River (21,850 ± 2,040), Aparima River (7,730 ± 1,120), Waiau River (18,540 ± 2,290) and ahead of the Waihopai River (370 ± 210). The National angler survey data does not separate out use in the upper and lower Makarewa River (NIWA 2009). The Southland Fish and Game Council information on angler access points indicates that there are 12 angler access points in the upper Makarewa River including one on the Otapiri Stream, one on the Dunsdale Stream and four on the Hedgehope Stream.

Further information about the recreational use and values of the Makarewa River is currently been collected.

3.3 Lower Makarewa River

Management and Land Use

For the purposes of this description the lower Makarewa River is defined as the reach between the Wallacetown-Lorneville Highway Bridge and the Oreti River. The Tomoporakau Creek joins the lower river downstream of the Plant. The lower river is the most heavily modified section within the Makarewa River catchment and has been modified through historical river drainage and flood protection works. Water quality has been influenced by the cumulative effects of land use within the catchment. The lower Makarewa River is actively managed to reduce the impacts of large floods and to protect Wallacetown, Lorneville, the Plant and surrounding agricultural land.

Hydrology

The river flow of the lower Makarewa River is very similar to the gauged section at Counsell Road. The Counsell Road flow gauge data is likely to slightly (≤5%) underestimate the river flow at the Plant's discharge point (Brydon Hughes pers. comm.).

The key feature of the hydrology of the lower Makarewa River is the influence of the tide which alters river water level, depth and velocity but does not alter salinity. The Makarewa River is a low gradient river surrounding by low lying land and the flow is held up and the flow direction reversed by the incoming tide (see Appendix 5). There is a decreasing gradient in the influence from the incoming tide between the Oreti River confluence and approximately 2.2 km upstream of the Plant's discharge. In the approximately 1.2 km reach downstream of the Plants discharge the river level increases by over 1.0–1.5 m compared to an increase in waterlevel of approximately 0.1 m at a point 2.2 km upstream of the discharge. At times of low river flow water flows upstream during incoming tides from a point approximately 250 m upstream of the discharge down to and including the Oreti River.

Water and Sediment Quality

Water quality monitoring data collected upstream and downstream of the discharge from the Plant indicates the lower Makarewa River water quality is characterised by elevated nutrient concentrations that can result in nuisance algal growths, high faecal indicator bacteria counts (>1,000 cfu/100 mL), low visual clarity (<1.6 m), moderate-high ammoniacal nitrogen (Amm-N) concentrations (typically 2.5–7.5 g/m^3), generally moderate but occasionally low summer time DO concentrations (typically 5–9 g/m^3) and river water temperatures and pH that are suitable for supporting healthy biological communities.

Sediment quality in 2002 and 2014 at sites upstream and downstream of the discharge showed elevated nutrient concentrations in the immediate vicinity of the discharge and 1.5 km downstream. A detailed description of the discharge and river water and sediment quality above and below the discharge is provided in Sections 4 and 5.

Ecology

The benthic invertebrate and aquatic plant communities in the lower Makarewa River change in response to the substrate, channel gradient, water velocity, tidal influence and water quality changes that occur downstream of the Wallacetown-Lorneville Highway Bridge. Key features of the biological communities in the lower Makarewa River are:

- The aquatic plant community near the Wallacetown-Lorneville Highway Bridge is dominated by algal mats and filamentous green algae and regularly exceed the MfE (2000) periphyton cover and biomass guidelines.
- Nuisance algal growths such as cyanobacteria mats have been recorded in the lower Makarewa River at the Wallacetown-Lorneville Highway Bridge during stable summer low flows. *Didymosphenia geminate* (Didymo) is not present in the river (Cawthron 2010).
- The aquatic plant community within the section of the river influenced by the tide is dominated by macrophtyes.
- The invertebrate community is dominated by water quality tolerant taxa with a higher proportion of sensitive taxa upstream of the discharge and beyond the influence of the tide.
- MCI scores upstream of the discharge are either slightly above or below the SRC guideline of >80. MCI scores downstream of the discharge are below the SRC guideline of >80 (SRC 2012).
- A native fish community dominated by common bully and shortfin eels with a seasonal run of inanga, smelt, koaro, banded kokopu, giant kokopu and lamprey.

Recreation

The lower Makarewa River provides a range of recreational values but the most significant are likely to be whitebaiting and game bird hunting.

The lower Makarewa River supports a brown trout fishery. The extent of the use of the lower Makarewa River by trout anglers is unknown. There is an unknown proportion of the anglers recorded as fishing the Makarewa River in the national angling survey results that are likely to fish the lower Makarewa River. The Southland Fish and Game Council information on angler access points indicates that there are three angler accesses in the lower Makarewa River, one at the Wallacetown-Lorneville Highway Bridge and two at Wallacetown at the ends of Collean Road and Clyde Streets. Southland Fish and Game recommend that anglers bait fish in the lower Makarewa River. Given the poor access to the lower Makarewa River and the abundance of popular and productive fisheries nearby in the Mataura, Aparima and Oreti Rivers the angler use of the lower Makarewa River is expected to be limited to occasional use by local anglers.

The lower Makarewa River does attract whitebaiters who fish using handheld nets and nets erected on temporary stands.

The extent of the use of the lower Makarewa River by game bird hunters is unknown but given the high number of ducks that frequent the river it is expected that hunters that live along or near the lower river do hunt ducks.

Further information about the recreational use and values of the lower Makarewa River is currently been collected.

3.4 Lower Oreti River

Hydrology

The lower Oreti River catchment downstream of Wallacetown has a maximum elevation of approximately 640 m. The lower Oreti River is characterised by a single channel and point bar dominated gravel-bed reach in the area between the Branxholme Railway Bridge and the Riverton-Wallacetown Highway Bridge (Ryder Consulting 2001). Further downstream, the Oreti River naturally meanders within a single channel characterised by a series of long runs, shallow pools and occasional riffles. The river is constrained between steep banks (Kingett Mitchell 2002) with few riffles.

Mean rainfall in the Oreti River catchment varies from 2,500 mm/year in the headwaters to 750 mm/year at Lumsden. The key findings from the analysis of hydrology in the Oreti River based on flow data from the Wallacetown recorder were:

- Mean flow = 39.9 m^3/s.
- Median flow = 27.6 m^3/s.
- Minimum flow = 2.6 m^3/s.
- 7 Day Mean Annual Low Flow = 7.4 m^3/s.
- FRE3 (number of flow events/year exceeding three times annual median flow) = 8.9 (using a 5 day interval between events to be recorded separately).

Analysis of monthly and annual flow patterns showed that the lowest river flows occurred in December, February, March and April and the highest flows in winter and spring.

Water Quality

SRC has monitored water quality on the Oreti River at the Riverton-Wallacetown Highway Bridge since 2000. The site is classified by SRC as a 'lowland hard bed' waterway. The site is approximately 10 km upstream of the confluence with the Makarewa River. The following key points summarise the water quality data collected by SRC on the Oreti River at the Riverton-Wallacetown Highway Bridge between 2005 and 2010 (SRC 2012):

- The DRP limit used by SRC (2012) of <0.01 g/m^3 was breached on 14% of sampling occasions between 2005 and 2010 (median 0.006 g/m^3, range 0.002–0.063 g/m^3).
- The nitrate-nitrite limit (<1.7 g/m^3) used by SRC (2012) was breached on 24% of sampling occasions between 2005 and 2010 (median 0.85 g/m^3, range 0.44–2.9 g/m^3).
- The Amm-N limit (0.034 g/m^3) used by SRC (2012) was not breached between 2005 and 2010.
- The visual clarity limit (>1.6 m) used by SRC (2012) was breached on 26% of sampling occasions between 2005 and 2010 (median 1.5 m, range 0.06–5.0 m).
- The faecal bacteria limit (<1,000 cfu/100mL) used by SRC (2012) was breached on 18% of sampling occasions between 2005 and 2010 (median 210 cfu/100mL, range 6–24,000 cfu/100mL).
- The temperature and trout spawning temperature limits (<23°C and <11°C respectively) used by SRC (2012) were breached on 2% of sampling occasions between 2005 and 2010.

The SRC water quality results show that the Oreti River approximately 10 km upstream of the Makarewa River confluence is characterised by moderate nutrient concentrations (>0.01 g/m^3 DRP and Nitrate-N concentrations <2.9 g/m^3) moderate-low visual clarity (median <1.6 m), low unionised ammonia concentrations (<0.034 g/m^3) and river water temperatures that are suitable for protecting river ecosystem health.

Ecology

The lower Oreti River naturally meanders within a single channel characterised by a series of long runs, shallow pools and occasional riffles. River bed sediments are dominated by coarse sands (Kingett Mitchell 2002). The following key points summarise the ecology data collected by SRC on the Oreti River at the Wallacetown Bridge between 2005 and 2010:

- The median MCI score at Wallacetown Bridge was 95 and exceeded the SRC lowland hard bottom site guideline of >90 on all sampling occasions.
- Nuisance algal growths such as cyanobacteria mats occur in the Oreti River during stable summer low flows. Didymo is present in the Oreti River but is not understood to form extensive mats in the lower river.
- The median MCI score at the Wallacetown site decreased from 101 (between 1996 and 2004) to 95 (between 2005 and 2010) and is most likely attributed to upstream land use intensification over this period.
- The chlorophyll-*a* level at Wallacetown Bridge exceeded the MfE (2000) <120 mg/m^2 guideline on 40% of occasions.
- The AFDW level at Wallacetown Bridge met the MfE (2000) <35 g/m^2 guideline on all sampling occasions.

The MCI scores recorded at the Wallcetown Bridge between 2011 – 2014 ranged from 91 – 100 and remained above the SRC lowland hard bottom site guideline of >90 on all sampling occasions.

The SRC ecology monitoring results show that the lower Oreti River is characterised by moderate benthic invertebrate community health and organic enrichment (median MCI score for 2005 - 2010 = 95), regular exceedance (40%) of periphyton chlorophyll-*a* but no exceedance of the periphyton AFDW guidelines. The biological results from the lower Oreti River are reflective of the elevated nutrient concentrations, and the increasingly developed nature of the catchment.

The Oreti River supports a healthy native fish fauna classed as being ‘good quality’ based on the Fish IBI score (Wairesearch 2010). A total of 12 fish species had been recorded in the Oreti River catchment up until 2005 (Kingett Mitchell 2002). In addition to the species recorded prior to 2005, Freshwater Solutions confirmed the presence of two new native fish species including banded kokopu and giant kokopu in the Makarewa River.

Fish surveys and the New Zealand Freshwater Fish Database (NZFFDB) show that the Oreti River supports moderate to high native fish diversity including six species with an ‘At Risk-Declining’ conservation status (longfin eel, koaro, giant kokopu, banded kokopu, redfin bully and lamprey) and one species with a ‘Threatened-Nationally vulnerable’ conservation status (lamprey) (Goodman et al. 2014).

Recreation

Kingett Mitchell (2002) reported that the only detailed recreational survey carried out in the

Oreti River catchment was undertaken in 1974–1975. The key finding from the survey was that a large number of recreational users downstream of Wallacetown were classified as ‘onlookers’ (66%) followed by boating (12%), picnicking (9%), swimming (8%) and angling (5%). White baiting is popular along the tidal reach of the Oreti River as is duck shooting (Kingett Mitchell 2002).

The Oreti River supports a nationally significant brown trout fishery that receives moderate-high use (21,850 angler days in the 2007/2008 fishing season) with approximately 75% of use occurring downstream of Lumsden. By comparison, the Mataura River had 48,490 angler days in the 2007/2008 season. The Oreti River was the seventh most heavily fished river out of the 33 rivers surveyed during the 2007/2008 national angler survey (NIWA 2009).

Further information about the recreational use and values of the lower Oreti River is currently been collected.

3.5 New River Estuary

Setting and Physical Features

New River Estuary is a relatively large (4,600 ha), shallow (mean depth of around 2 m) ‘tidal lagoon’ estuary, situated at the confluence of the Oreti and Waihopai Rivers. The Estuary forms part of the Awarua Plains Wetland Complex. Its catchment largely consists of agricultural land, but it is also subject to stormwater and wastewater discharges from Invercargill City (Robertson and Stevens 2013).

Large areas of the Waihopai Arm have been affected by drainage and reclamation, but the broader estuary still contains a range of habitats including extensive mudflats, seagrass and relatively large saltmarsh areas (Robertson and Stevens 2013). Most of the estuary has a sandy substrate (75% of the un-vegetated intertidal area), but soft and very soft mud substrates also cover a relatively large proportion of the inlet (24%), particularly: in or near natural settlement areas in the Waihopai arm and Daffodil Bay; along the banks of the upper Oreti and Waihopai Rivers; and among rushland in the east of the estuary. Measured sedimentation rates in the Waihopai arm are high, with average rates of >10 mm/year since the 1960’s and >40 mm/year between 2007 and 2012 (Stevens and Robertson 2012).

Water Quality

SRC began to sample the New River Estuary water quality in 2012. ICC has monitored water quality twice monthly in the New Estuary since 1991 at eight sites and analysed samples for the following parameters:

- Faecal coliforms (FC) and *E. coli*.
- Ammoniacal-N (Amm-N).
- Nitrate nitrogen (NO_3-N).
- Total phosphorus (TP).
- Dissolved reactive phosphorus (DRP).
- Chlorophyll-*a*.
- Temperature.
- pH.
- DO.

The results of three (Dunns Road, Sandy Bay and Waihopai Arm) of the eight sites monitored by ICC are presented in SRC (2012). The following key points summarise the water quality data collected by ICC at Dunns Road and Sandy Bay between 2005 and 2010:

- The DRP guideline (0.01 g/m^3) used by SRC (2012) was breached on 50–75% of sampling occasions at Dunns Road and >75% at Sandy Point of sampling occasions between 2005 and 2010.
- The TP guideline (0.033 g/m^3) used by SRC (2012) was breached on 50–75% of sampling occasions at Dunns Road and >75% at Sandy Point of sampling occasions between 2005 and 2010.
- The Amm-N guideline (0.91 g/m^3) used by SRC (2012) was breached on <10% of sampling occasions between 2005 and 2010.
- The chlorophyll-*a* guideline (0.004 g/m^3) used by SRC (2012) was breached on 25–49% of sampling occasions at Dunns Road and 11–24% of sampling occasions at Sandy Point of sampling occasions between 2005 and 2010.

The results of the ICC monitoring show that the New River Estuary at Sandy Bay and Dunns Road is characterised by high nutrient concentrations and moderate chlorophyll-*a* concentrations. Most of the nutrient load within the New River Estuary comes from diffuse sources within the wider Oreti River catchment (Appendix 6).

Ecology

The New River Estuary supports high ecological values including a diverse bird fauna (74 water bird species) and freshwater and marine fish populations. Fish include five species of flatfish, eels, brown trout, smelt, whitebait and giant kokopu. The estuary provides important spawning and rearing habitat for marine and freshwater fish including whitebait species and has the highest usage of trans-equatorial shorebirds of all Southland estuaries.

The majority of the estuary is well flushed and largely remains free of nuisance macroalgae. However, parts of the estuary are severely affected by nutrients. Around 10.6% of its area is covered with high to very high percentages of nuisance macroalgae, with the dominant species being the red alga *Gracilaria chilensis* and the green alga *Ulva intestinalis*. Both species are known to respond positively to elevated nutrient concentrations. The most extensive growths occur in the Waihopai Arm, at Bushy Point and in Daffodil Bay, where significant and worsening problems are being caused by rotting macroalgae and poorly oxygenated, sulfide rich sediments.

In Daffodil Bay, macroalgae growth is limiting the natural removal of mud by reducing wave induced re-suspension, and as a consequence, sediments are becoming deeper, softer, and muddier in that area. Rotting macroalgae is releasing organic matter and nutrients into the sediments, reducing oxygenation and fuelling the growth of sulfide bacteria on the sediment surface. This is indicative of toxic conditions in which few animals can survive (Stevens and Robertson 2012). In the Waihopai Arm, Stevens and Robertson (2012) indicate that sediment conditions are so degraded that even the nuisance macroalgae are now dying off due to over-enrichment. Underlying sediments at Bushy Point were still mostly sandy and relatively well oxygenated in 2012, but deposition of muds over an area of around 27 ha, was providing an early warning of deteriorating conditions.

In 2012, around 8% of the estuary was classified as having gross eutrophic conditions, due to the combination of high sediment mud content, shallow redox potential discontinuity

(RPD) depths, elevated nutrient and organic concentrations, the displacement of invertebrates sensitive to organic enrichment, and high macroalgal growth (>50% cover). A trend of worsening conditions since 2001 was also noted. Seagrass cover has also decreased by around 41% since 2001, with greatest losses occurring in the Waihopai Arm (Stevens and Robertson 2012). Stevens and Robertson (2012) note that gross eutrophic conditions should not be present in estuaries like New River, which have short water residence times, and conclude that this is clear signal that the assimilative capacity of the estuary is being exceeded.

Overall, the available data indicates that large parts of New River Estuary remain in reasonable condition, but a significant and increasing proportion of the estuary is seriously impacted by fine sediments and elevated nutrient concentrations, primarily from diffuse sources.

Recreation

The New River Estuary is located on the edge of Invercargill City and provides a wide range of recreational values and opportunities including:

- Game bird hunting.
- Fishing.
- Bird watching.
- Power boating.
- Sea Scouts.
- Water skiing
- Rowing.
- Bathing.
- Walking.
- Photography.
- Horse riding.
- Mountain biking.
- Picnicking.

Public access to the estuary is good particularly around the Sandy Point Domain where several walking, horse riding and mountain bike tracks provide access to the lower Oreti River, the Oreti Arm of the New River Estuary and Daffodil and Whalers Bays on the southern edge of the estuary.

The Waihopai Rowing Club and Invercargill Rowing Club use the lower Oreti River along with the Southland Powerboat Club.

Further information about the recreational use and values of the lower Oreti River is currently been collected.

Summary

The Makarewa River drains a 991 km^2 catchment that, apart from a small portion of the headwaters on the south-western flanks of the Hokonui Hills, has been fully developed for agriculture. The Makarewa River above Wallacetown is characterised by high nutrients and in particular DRP concentrations, low visual clarity, low Amm-N concentrations, high levels of faecal coliforms, water temperatures suitable for protecting river ecosystem health, a median MCI score at the Wallacetown Bridge of 87 (indicative of ‘fair’ water quality) and low fish diversity in the upper reaches due to the high level of modification within the catchment.

The Makarewa River below Wallacetown has been modified by historical river drainage and flood protection works with the lower approximately 10 km of the river strongly influenced by the tide. There is a decreasing gradient in the influence from the incoming tide between the Oreti River confluence and approximately 2.2 km upstream of the Plant’s discharge.

Makarewa River water and sediment quality, immediately upstream and the river downstream of the Plant is characterised by high nutrient concentrations, high faecal indicator bacteria counts, low visual clarity, high Amm-N concentrations, generally moderate but occasionally low summer time dissolved oxygen concentrations and pH that are suitable for supporting healthy biological communities. The benthic invertebrate and aquatic plant communities in the lower Makarewa River change in response to the substrate, channel gradient, water velocity, tidal influence and water quality. Key features of the biological communities in the Makarewa River immediately above and in the river below the Plant discharge is the dominance of macrophytes and water and habitat tolerant benthic invertebrate taxa and a diverse fish community. The Makarewa River also supports a locally significant brown trout fishery that receives low-moderate use.

The Oreti River approximately 10 km upstream of the Makarewa River confluence is characterised by a gravel dominated substrate, moderate nutrient concentrations, moderate-low visual clarity, low Amm-N concentrations, water temperatures suitable for protecting river ecosystem health, a median MCI score of 95 (‘fair’ water quality), the presence of nuisance algal growths such as cyanobacteria mats during stable summer low flows and a healthy native fish fauna including six species with an ‘At Risk-Declining’ conservation status. A study in the late 1970s classified a large number of recreational users downstream of Wallacetown as ‘onlookers’ followed by boating, picnicking, swimming and angling. The Oreti River also supports a nationally significant brown trout fishery that receives moderate-high use.

New River Estuary is a large, shallow ‘tidal lagoon’ estuary, situated at the confluence of the Oreti and Waihopai Rivers. The estuary forms part of the Awarua Plains Wetland complex. Its catchment largely consists of agricultural land, but it is also subject to stormwater and wastewater discharges from Invercargill City. The estuary contains a range of habitats including extensive mudflats, seagrass and relatively large saltmarsh areas. Overall, the available data indicates that large parts of New River Estuary remain in reasonable condition, but a significant and increasing proportion of the estuary is seriously impacted by fine sediments and elevated nutrient concentrations. The New River Estuary supports high ecological values including a diverse bird fauna and freshwater and marine fish populations. The estuary provides important spawning and rearing habitat for fish. The estuary provides a wide range of recreational opportunities including game bird hunting, fishing, bird-watching, power boating, rowing, bathing, walking and picnicking.

Further information about the recreational use and values of the lower Makarewa and Oreti Rivers and the New River Estuary is currently been collected.

4.0 Discharge Quality and Characteristics

4.1 Discharge Characteristics

The main discharge period typically starts about two weeks after commencement of the processing season and after the wastewater treatment pond levels have increased. The discharge is not continuous during the processing season and is closed at times during the season. The main discharge period typically ceases about four weeks after the processing season finishes but discharge may continue to occur intermittently. The start and end dates of the discharge for the last 13 seasons are shown in Table 3. The current season (2013/2014) discharge was ongoing at the time of preparing this report.

Alliance manages the discharge to ensure it complies with its existing consent conditions and at times of low river flow during summer months Alliance is able to reduce or occasionally hold the discharge for periods of up to 15 days (assuming the wastewater treatment pond levels are low). During extended periods of very low river flow Alliance's consent allows it to discharge wastewater to land for temporary storage under emergency provisions. This could occur during a summer drought when farmers are forced to de-stock their farms and for animal welfare reasons stock must continue to be killed. The emergency discharge provisions have not been used over the past 13 years.

Table 3: Discharge period between December 2001 and June 2014 for each season.

Season	Start	End
2001/02	11 December 2001	27 May 2002
2002/03	8 October 2002	28 July 2003
2003/04	3 November 2003	6 July 2004
2004/05	14 December 2004	11 August 2005
2005/06	4 October 2005	28 August 2006
2006/07	17 October 2006	14 September 2007
2007/08	30 October 2007	16 July 2008
2008/09	7 October 2008	18 September 2009
2009/10	30 November 2009	16 September 2010
2010/11	1 November 2010	26 July 2011
2011/12	11 October 2011	13 September 2012
2012/13	24 October 2012	20 September 2013
2013/14	6 December 2013	25 June 2014

4.2 Discharge Volumes

This section presents the discharge volume and water quality data for the period between December 2001 and June 2014. Typical data values and distributions of the parameters in such a large data set are best understood in terms of the 50th percentile, 5th percentiles and 95th percentiles. The medians and ranges discussed in the following sections refer to these statistics, although minima and maxima are also presented for reasons of completeness.

Alliance's consent requires that the discharge from Pond 6 not exceed 22,730 m^3/day. The median discharge for the period between December 2001 and June 2014 was 12,195 m^3/day (5%-ile-95%-ile: 4,853–18,927 m^3/day) (Figure 3 and Table 4); it should be noted that Alliance do not measure instantaneous discharge rates. On no occasion has the consent limit for discharge volume been exceeded.

The lowest seasonal daily median was in 2008/2009 (10,091 m^3/day) and the highest in 2010/2011 (14,416 m^3/day).

4.3 Discharge Quality

This section presents discharge quality for a physico-chemical and microbiological parameters, nutrients and metals/metalloids. A sample analytical report from Watercare, which is an IANZ accredited laboratory, is presented in Appendix 7. This report also provides the analyte detection limits.

Physico-chemical Parameters

The median pH of the discharge was 8.2 (5%-ile-95%-ile: 7.7–8.8). There was no apparent trend in seasonal median pH. The minimum seasonal median occurred in 2001/2002 (pH = 7.8) and the highest in 2007/2008 (pH = 8.4) (

Table 5).

The median conductivity of the discharge was 1.9 mS/m (5%-ile-95%-ile: 0.96–3.5 mS/m) (

Table 5). The seasonal median conductivity between 2001/2002 and 2005/2006 seasons was 2.9–3.0 mS/m. Following this there was a marked reduction in the seasonal median conductivity between 2006/2007 and 2011/2012 from 1.8 to 1.5 mS/m. However, in 2012/2013 the maximum seasonal median was recorded at 3.4 mS/m.

The median Total Suspended Solids (TSS) concentration in the discharge was 50 g/m^3 (5%-ile-95%-ile: 13–190 g/m^3) (Table 6). The consent requires the TSS concentration in the discharge from Pond 6 not exceed 300 g/m^3, with an additional condition that TSS concentrations 'consistently maintained' at or less than 200 g/m^3; 'consistently maintained being defined as 80% of any five consecutive samples. The TSS concentration in the discharge exceeded the 300 g/m^3 limit on four occasions between December 2001 and June 2014. The discharge has been fully compliant with the secondary TSS consent condition. The maximum seasonal median TSS concentration occurred in 2007/2008 (105 g/m^3) and the lowest occurring in the recent 2013/2014 season (23 g/m^3) (Figure 4).

The median TSS load in the discharge for the entire monitoring period was 580 kg/day (5%-ile-95%-ile: 150–2,000 kg/day); the maximum seasonal median TSS load was 1,040 kg/day in 2001/2002 and the minimum was 262 kg/day in 2012/2013 and 2013/2014 (Table 6).

Nutrients

The median TN concentration in the discharge was 110 g/m^3 (5%-ile-95%-ile: 29–160 g/m^3) (Table 7). The dominant nitrogen species was Amm-N (median = 96 g/m^3; 5%-ile-95%-ile: 17–150 g/m^3), which typically comprised approximately 87% of TN (median value). Total Organic Nitrogen (TON) (median = 0.88 g/m^3; 5%-ile-95%-ile: 0.10–14 g/m^3) typically comprised only approximately 1% of TN (median), with the remaining 12% (by difference) being Total Organic Nitrogen (TON). The median TN load in the discharge for the entire monitoring period was 1,320 kg/day (5%-ile-95%-ile: 250–2,380 kg/day); the maximum seasonal median TN load was 1,820 kg/day in the current 2013/2014 season and the minimum was 930 kg/day in 2003/2004 (Table 8).

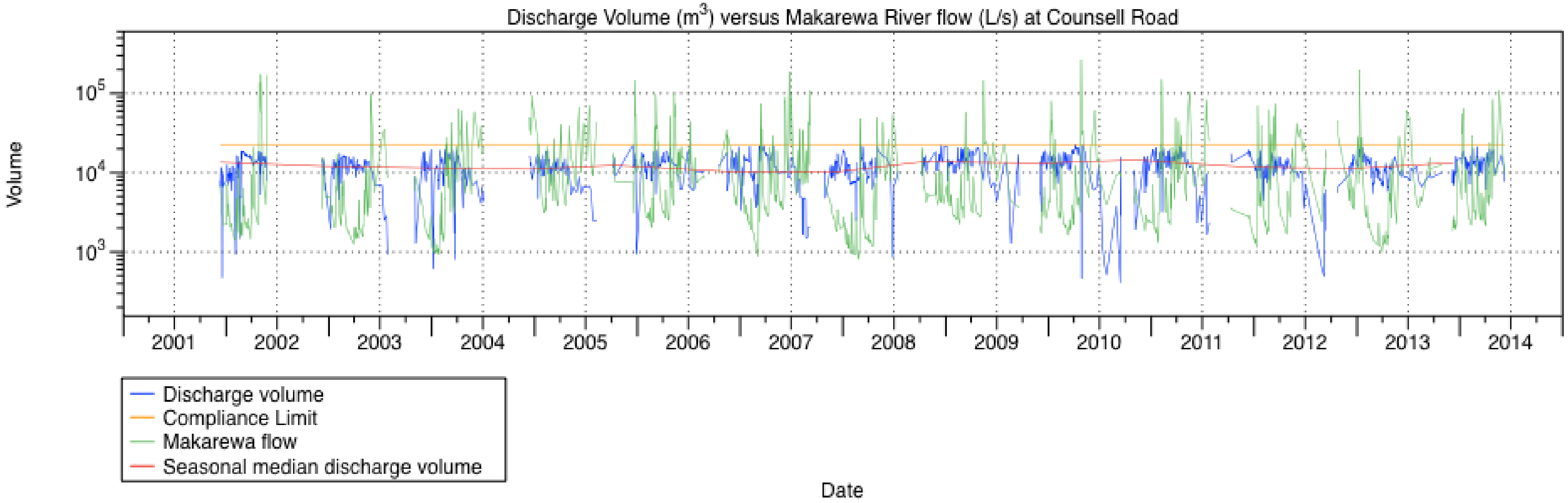

Figure 3: Discharge volumes between December 2001 and June 2014.

Table 4: Summary of daily discharge volumes between December 2001 and June 2014.

	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2001/14
Med.	13,533	12,094	11,512	11,097	12,392	10,266	10,091	13,740	13,144	14,416	11,748	11,252	13,280	12,195
Min.	472	921	612	2501	933	1524	845	1,288	408	1,649	491	5,480	6,171	408
Max.	18,928	17,477	19,742	18,520	22,133	22,239	22,519	22,442	22,727	21,399	19,414	21,163	21,105	22.727
5%-ile	6116	6722	3622	5,560	6,040	2,057	7,023	7,842	3,398	3,737	4,840	6,640	7,592	4,853
95%-ile	17,845	15,939	18,271	16,326	19,059	20,583	18,135	20,117	20,383	19,279	17,600	18,444	18,883	18,927
N	146	157	132	93	171	252	145	145	127	108	109	133	115	1,833

Note: all units m^3.

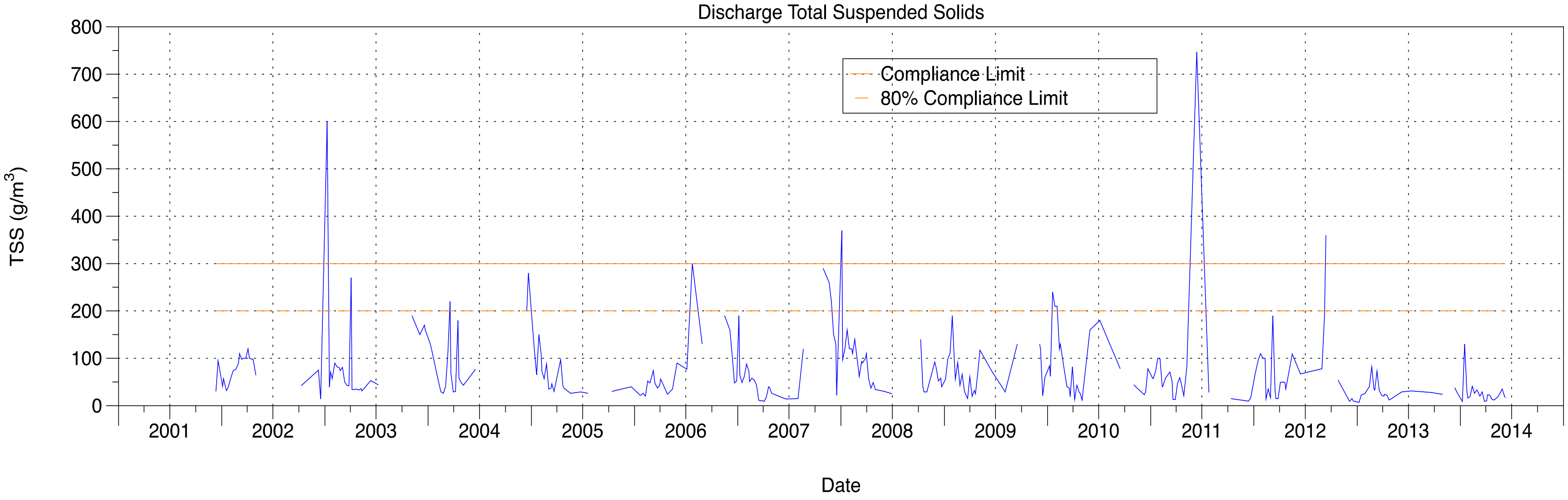

Figure 4: Discharge TSS concentration between December 2001 and September 2013.

Table 5: **Summary of discharge pH, EC and TSS concentrations between December 2001 and June 2014.**

	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2001/14
pH														
Med.	7.8	8.0	8.2	8.4	8.4	8.1	8.4	8.2	8.2	8.1	8.3	8.0	8.1	8.2
Min.	6.4	7.0	7.9	7.2	7.9	7.5	7.8	7.1	6.0	7.4	7.2	7.0	7.2	6.0
Max.	8.6	8.4	9.7	9.0	9.1	9.6	9.6	9.1	9.8	8.9	9.3	9.2	8.3	9.8
5%-ile	7.4	7.8	8.0	7.8	8.0	7.7	7.9	7.9	7.8	7.8	7.7	7.5	7.7	7.7
95%-ile	8.2	8.3	9.5	8.9	8.9	8.9	9.2	8.8	8.8	8.7	8.8	8.5	8.3	8.8
N	120	138	132	93	107	135	145	145	127	107	109	133	115	1606
Conductivity														
Med.	3.0	3.0	2.9	2.9	3.0	1.8	1.7	1.6	1.6	1.5	1.5	3.4	3.0	1.9
Min.	0.54	1.1	0.97	1.0	0.32	0.51	0.74	0.86	0.63	0.31	0.59	0.87	1.0	0.31
Max.	3.4	3.5	3.4	3.7	3.6	2.4	2.3	1.9	2.0	1.9	3.0	4.1	3.7	4.1
5%-ile	0.67	1.2	1.0	1.3	0.53	1.3	0.93	1.1	0.81	0.68	0.70	1.3	1.7	0.96
95%-ile	3.3	3.4	3.1	3.6	3.2	2.1	1.9	1.9	1.9	1.8	2.0	4.0	3.4	3.5
N	119	140	132	92	108	135	145	145	127	107	109	133	115	1607
TSS														
Med.	84	47	69	57	45	51	105	56	78	51	50	26	23	50
Min.	30	14	26	26	20	9.0	22	15	12	13	9.6	6.8	8.8	6.8
Max.	120	600	220	280	300	190	370	190	240	750	360	82	130	750
5%-ile	32	31	29	26	22	10	26	23	14	14	14	9.1	9.2	13
95%-ile	110	240	190	210	100	180	280	140	210	100	190	71	40	190
N	20	24	21	19	20	27	26	31	25	23	25	23	25	309

Note: pH, pH units; conductivity, mS/m; TSS, g/m^3. pH and conductivity measured daily, TSS measured weekly.

Table 6: Summary of discharge TSS and BOD loads between December 2001 and June 2014.

	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2001/14
TSS														
Med.	1040	570	570	840	540	590	970	740	750	800	560	260	260	580
Min.	110	120	120	160	280	120	170	270	49	49	49	85	66	49
Max.	1960	3400	2490	3190	1880	3400	6720	2200	3160	1720	2220	1030	2110	6720
5%-ile	230	310	250	170	399	159	269	369	289	200	140	94	130	150
95%-ile	1680	3020	1900	2910	1500	2640	3210	1760	1850	1480	1820	800	620	1980
N	20	24	21	19	20	27	26	31	25	23	25	23	25	309
BOD														
Med.	280	200	190	170	230	300	410	250	210	150	140	100	120	200
Min.	25	62	24	11	50	100	66	82	11	11	13	21	32	11
Max.	790	660	500	700	710	770	1820	680	680	450	410	400	270	1820
5%-ile	62	76	56	46	110	110	190	150	100	72	45	34	52	51
95%-ile	510	510	430	470	490	740	1500	620	650	350	280	330	240	650
N	20	24	23	19	21	24	24	31	25	23	25	23	25	307

Note: all units kg/day. TSS and BOD measured weekly; discharge loads are calculated based on weekly data and the discharge volume on the day TSS and BOD were measured.

The median TP concentration in the discharge was 11 g/m^3 (5%-ile-95%-ile: 6.0–16 g/m^3) and the median DRP concentration in the discharge was 9.0 g/m^3 (5%-ile-95%-ile: 3.0–14 g/m^3) (Table 9). DRP typically comprised 81% of TP (median). The median TP load in the discharge for the entire monitoring period was 140 kg/day (5%-ile-95%-ile: 43–250 kg/day); the maximum seasonal median TP load was 170 kg/day in the 2005/2006 and 2012/2013 seasons, and the minimum was 100 kg/day in 2003/2004 (Table 10).

The median BOD concentration in the discharge was 16 g/m^3 (5%-ile-95%-ile: 6.2–45 g/m^3) (Table 9, Figure 5). The median BOD load in the discharge for the entire monitoring period was 120 kg/day (5%-ile-95%-ile: 51–650 kg/day); the maximum seasonal median BOD load was 410 kg/day in 2007/2008 and the minimum was 100 kg/day in 2012/2013 (Table 6).

Microbiology

The median FC concentration in the discharge was 3,100 MPN/100mL (5%-ile-95%-ile: 93–67,100 MPN/100mL) (Table 11). The median FC load in the discharge for the entire monitoring period was 4.5 x 10^{11} MPN/day (5%-ile-95%-ile: 9.3 x 10^{9}–8.6 x 10^{12} MPN/day); the maximum seasonal median FC load was 1.0 x 10^{12} MPN/day in 2009/2010 and the minimum was 1.0 x 10^{11} MPN/day in 2011/2012 (Table 12).

Alliance began to analyse *E. coli* in the discharge in October 2013. The median *E. coli* concentration in the discharge was 2,400 cfu/100 mL (5%-ile-95%-ile: 100–27,600 cfu/100mL). The median *E. coli* load was 3.6 x 10^{11} cfu/day (5%-ile-95%-ile: 1.0 x 10^{10}–3.8 x 10^{12} cfu/day).

Other Parameters

Analysis of a comprehensive suite of metals/metalloids in the discharge was undertaken on 30 January 2014 and 13 February 2014 during a typical operational period. The full analytical data is presented in Appendix 2. For each of the two samples collected the metals/metalloids that were reported above the analytical detection limit were:

- Aluminium: 1.38, 1.40 g/m^3.
- Barium: 0.019, 0.015 g/m^3.
- Boron: 0.44, 0.27 g/m^3.
- Calcium: 51, 48 g/m^3.
- Iron: 2.4, 2.2 g/m^3.
- Magnesium: 6.4, 5.7 g/m^3.
- Manganese: 0.21, 0.15 g/m^3.
- Potassium: 66, 68 g/m^3.
- Rubidium: 0.17, 0.17 g/m^3.
- Sodium: 330, 330 g/m^3.
- Strontium: 0.11, 0.11 g/m^3.

The most notable feature of these discharge results is the presence of the alkali and alkaline earth metals calcium, magnesium, potassium and sodium, which are associated with meat processing wastes, and aluminium which is used in the wastewater treatment system.

Table 7: Summary of discharge Amm-N, TON and TN concentrations between December 2001 and June 2014.

	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2001/14
Amm-N														
Med.	100	110	100	100	92	77	92	80	84	80	97	149	130	96
Min.	22	2.5	1.0	2.8	17	1.9	1.8	7.0	6.2	6.2	11	8.8	18	1.0
Max.	140	150	140	150	130	150	200	120	110	120	130	190	150	200
5%-ile	28	14	2.1	21	31	32	24	13	14	12	19	25	62	17
95%-ile	140	130	130	140	120	110	150	110	110	110	120	190	150	150
N	120	140	131	92	108	134	144	145	127	107	109	133	115	1605
TON														
Med.	2.6	3.7	0.97	1.4	0.93	1.5	5.3	0.79	0.86	0.47	0.34	0.49	0.32	0.88
Min.	0.13	0.13	0.24	0.17	0.059	0.091	0.070	0.040	0.058	<0.005	0.023	0.023	0.030	<0.005
Max.	9.4	22	2.1	9.8	3.8	39	24	16	8.8	2.2	1.6	1.7	14	39
5%-ile	0.53	0.27	0.39	0.30	0.15	0.24	0.31	0.25	0.11	0.13	0.07	0.056	0.061	0.10
95%-ile	9.2	20	1.9	7.6	3.5	34	20	6.0	5.3	1.6	1.0	1.1	0.86	14
N	20	24	23	20	21	27	26	44	25	23	25	23	25	326
TN														
Med.	120	130	110	110	110	91	110	110	110	85	110	160	140	110
Min.	35	12	16	23	46	16	25	35	23	20	18	14	21	12
Max.	150	160	150	160	150	140	150	150	130	150	150	220	160	220
5%-ile	37	14	22	45	51	45	32	38	30	20	36	29	72	29
95%-ile	140	150	140	150	130	130	130	140	130	130	130	210	160	160
N	19	23	22	20	21	27	26	30	25	23	25	23	25	309

Note: all units g/m^3. Amm-N measured daily, TON and TN measured weekly.

Table 8: Summary of discharge Amm-N, TON and TN loads between December 2001 and June 2014.

	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2001/14
Amm-N														
Med.	1430	1250	920	1170	1160	1040	900	1040	1050	1060	1060	1510	1780	1160
Min.	11	29	5.3	43	31	15	19	69	5.3	5.3	14	59	181	5.3
Max.	2450	2070	2360	1950	2270	1980	3250	2510	2390	2420	1820	2470	2990	3250
5%-ile	250	74	17	110	330	230	230	160	64	99	160	240	580	130
95%-ile	1990	1880	2110	1750	1880	1710	2340	2070	2040	1920	1640	2130	2500	2070
N	120	140	131	92	109	134	144	145	127	107	109	133	115	1605
TON														
Med.	24	46	11	15	10	19	65	11	13	5.8	3.6	5.0	3.6	10
Min.	0.90	1.1	0.48	2.2	0.53	0.93	1.1	0.55	0.43	0.11	0.27	0.29	0.20	0.11
Max.	170	300	30	170	77	640	200	190	96	31	20	20	220	640
5%-ile	4.2	2.5	1.3	2.8	1.7	2.4	3.2	4.1	0.78	0.54	0.49	0.63	0.71	0.91
95%-ile	150	250	23	110	62	550	160	98	82	28	11	12	12	160
N	20	24	23	20	21	27	26	44	25	23	25	23	25	326
TN														
Med.	1610	1430	930	1190	1460	1060	950	1390	1370	1480	1110	1450	1820	1320
Min.	160	110	27	370	490	250	270	450	27	27	29	91	210	27
Max.	2400	2320	2750	2120	2640	2640	2820	2640	2500	1920	2120	2460	2960	2960
5%-ile	280	190	200	470	530	330	360	540	190	250	270	290	570	250
95%-ile	2330	2070	2380	1920	2350	2430	2020	2410	2430	1910	1740	2150	2680	2380
N	19	23	22	20	21	27	26	30	25	23	25	23	25	309

Note: all units kg/day. Amm-N, TON and TN measured weekly; discharge loads are calculated based on weekly data and the discharge volume on the day Amm-N, TON and TN were measured.

Table 9: Summary of discharge DRP, TP and BOD concentrations between December 2001 and June 2014.

	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2001/14
DRP														
Med.	9.9	11	9.9	8.8	9.4	7.9	8.7	7.6	8.4	6.8	8.6	13	9.9	9.0
Min.	3.7	2.1	2.7	0.13	4.1	2.9	2.3	2.9	2.4	1.9	1.5	3.8	5.3	0.13
Max.	12	14	15	14	12	12	13	12	11	14	12	17	19	19
5%-ile	7.7	2.9	2.9	1.5	5.1	3.5	3.0	4.0	2.9	2.3	3.8	3.8	5.7	3.0
95%-ile	12	14	13	14	12	11	11	11	11	11	12	15	15	14
N	20	24	23	16	21	27	26	31	25	23	25	23	25	309
TP														
Med.	11	14	11	11	12	11	12	11	11	8.9	12	13	13	11
Min.	5.3	2.5	6.6	5.9	6.7	5.6	6.5	5.1	5.3	2.8	3.9	4.2	6.7	2.5
Max.	15	16	16	14	15	14	15	17	13	17	19	54	21	54
5%-ile	9.3	3.7	6.8	7.0	8.4	5.8	6.8	5.6	6.1	5.1	5.0	5.8	7.9	6.0
95%-ile	14	16	16	14	15	13	14	14	13	13	15	21	18	16
N	20	24	22	20	21	27	26	31	25	23	24	23	25	311
BOD														
Med.	21	18	15	17	18	25	36	21	22	12	13	12	10	16
Min.	7.0	9.0	9.0	1.0	6.3	9.0	10	8.8	7.0	5.0	3.8	2.0	4.7	1.0
Max.	47	48	53	44	40	40	100	58	52	33	67	35	17	100
5%-ile	8.0	10	10	6.4	8.0	12	20	11	8.4	5.4	5.1	2.6	5.2	6.2
95%-ile	33	35	49	31	30	38	93	44	47	30	34	28	15	45
N	20	24	23	19	21	24	24	31	25	23	25	23	24	307

Note: all units g/m^3. DRP, TP and BOD measured weekly.

Table 10: Summary of discharge DRP and TP loads between December 2001 and June 2014.

	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2001/14
DRP														
Med.	120	130	110	95	130	97	94	100	110	110	98	110	130	110
Min.	16	20	7.0	1.8	26	18	24	34	8.1	4.4	4.0	27	44	1.8
Max.	210	210	240	150	220	210	240	220	250	170	160	180	310	310
5%-ile	34	31	21	24	30	30	33	44	16	11	14	36	62	26
95%-ile	180	200	210	150	190	200	170	190	200	160	150	160	270	200
N	20	24	22	16	21	27	26	31	25	23	25	23	25	308
TP														
Med.	140	150	100	120	170	140	120	150	140	140	120	170	160	140
Min.	20	22	14	51	42	33	50	46	20	16	44	40	54	14
Max.	260	240	280	170	250	260	220	290	300	210	200	410	340	410
5%-ile	49	45	22	56	45	42	60	61	31	18	51	45	76	43
95%-ile	220	230	230	160	230	260	210	250	220	210	200	200	320	250
N	20	24	22	16	21	27	26	31	25	23	24	23	25	307

Note: all units kg/day. DRP and TP measured weekly; discharge loads are calculated based on weekly data and the discharge volume on the day DRP and TP were measured.

Table 11: **Summary of discharge FC and *E. coli* concentrations between December 2001 and June 2014.**

	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2001/14
FC														
Med.	3000	5000	3000	5000	3000	4700	4400	6000	5700	1900	1400	1600	3000	3100
Min.	80	80	220	90	400	50	90	70	100	60	10	50	96	10
Max.	24000	160000	30000	90000	240000	17000	330000	820000	56000	1300000	130000	18000	49000	1300000
5%-ile	120	340	310	280	800	110	440	96	220	130	34	81	120	93
95%-ile	17000	4700	17000	81000	160000	15000	58000	130000	41000	69000	75000	12000	29000	67000
N	19	23	23	19	21	27	26	31	25	23	25	23	25	310
E. coli														
Med.	-	-	-	-	-	-	-	-	-	-	-	-	2400	2400
Min.	-	-	-	-	-	-	-	-	-	-	-	-	92	92
Max.	-	-	-	-	-	-	-	-	-	-	-	-	35000	35000
5%-ile	-	-	-	-	-	-	-	-	-	-	-	-	100	100
95%-ile	-	-	-	-	-	-	-	-	-	-	-	-	27600	27600
N	-	-	-	-	-	-	-	-	-	-	-	-	25	25

Note: FC, MPN/100mL; *E. coli*, cfu/100mL. FC and *E.coli* measured weekly.

Table 12: Summary of discharge FC and *E. coli* loads between December 2001 and June 2014.

	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2001/14
FC														
Med.	$2.4x10^{11}$	$6.7x10^{11}$	$4.4x10^{11}$	$5.9x10^{11}$	$4.8x10^{11}$	$4.7x10^{11}$	$5.6x10^{11}$	$8.2x10^{11}$	$1.0x10^{12}$	$2.3x10^{11}$	$1.0x10^{11}$	$1.4x10^{11}$	$4.2x10^{11}$	$4.5x10^{11}$
Min.	$5.6x10^{9}$	$5.5x10^{9}$	$1.7x10^{10}$	$1.4x10^{10}$	$6.9x10^{10}$	$2.4x10^{9}$	$9.6x10^{9}$	$8.9x10^{9}$	$3.2x10^{9}$	$7.0x10^{9}$	$6.3x10^{7}$	$4.7x10^{9}$	$1.0x10^{10}$	6.3410^{7}
Max.	$3.3x10^{12}$	$9.1x10^{12}$	$4.6x10^{12}$	$8.7x10^{12}$	$4.9x10^{13}$	$3.0x10^{12}$	$5.1x10^{13}$	$8.8x10^{13}$	$1.3x10^{13}$	$1.8x10^{14}$	$1.4x10^{13}$	$2.0x10^{12}$	$5.0x10^{12}$	$1.8x10^{14}$
5%-ile	$9.2x10^{9}$	$1.0x10^{10}$	$2.3x10^{10}$	$3.7x10^{10}$	$6.9x10^{10}$	$1.4x10^{10}$	$3.7x10^{10}$	$1.3x10^{10}$	$1.6x10^{10}$	$7.6x10^{9}$	$6.2x10^{9}$	$6.1x10^{9}$	$1.4x10^{10}$	$9.3x10^{9}$
95%-ile	$2.3x10^{12}$	$6.5x10^{12}$	$1.5x10^{12}$	$8.7x10^{12}$	$1.5x10^{13}$	$2.7x10^{12}$	$9.5x10^{12}$	$1.6x10^{13}$	$6.8x10^{12}$	$9.5x10^{12}$	$9.4x10^{12}$	$1.1x10^{12}$	$3.9x10^{12}$	$8.6x10^{12}$
N	19	24	23	19	21	27	26	31	25	23	25	23	25	311
E. coli														
Med.	-	-	-	-	-	-	-	-	-	-	-	-	$3.6x10^{11}$	$3.6x10^{11}$
Min.	-	-	-	-	-	-	-	-	-	-	-	-	$8.2x10^{9}$	$8.2x10^{9}$
Max.	-	-	-	-	-	-	-	-	-	-	-	-	$4.7x10^{12}$	$4.7x10^{12}$
5%-ile	-	-	-	-	-	-	-	-	-	-	-	-	$1.0x10^{10}$	$1.0x10^{10}$
95%-ile	-	-	-	-	-	-	-	-	-	-	-	-	$3.8x10^{12}$	$3.8x10^{12}$
N	-	-	-	-	-	-	-	-	-	-	-	-	25	25

Note: FC, MPN/day; *E. coli*, cfu/day. FC and *E. Coli* measured weekly; discharge loads are calculated based on weekly data and the discharge volume on the day FC and *E. Coli* were measured.

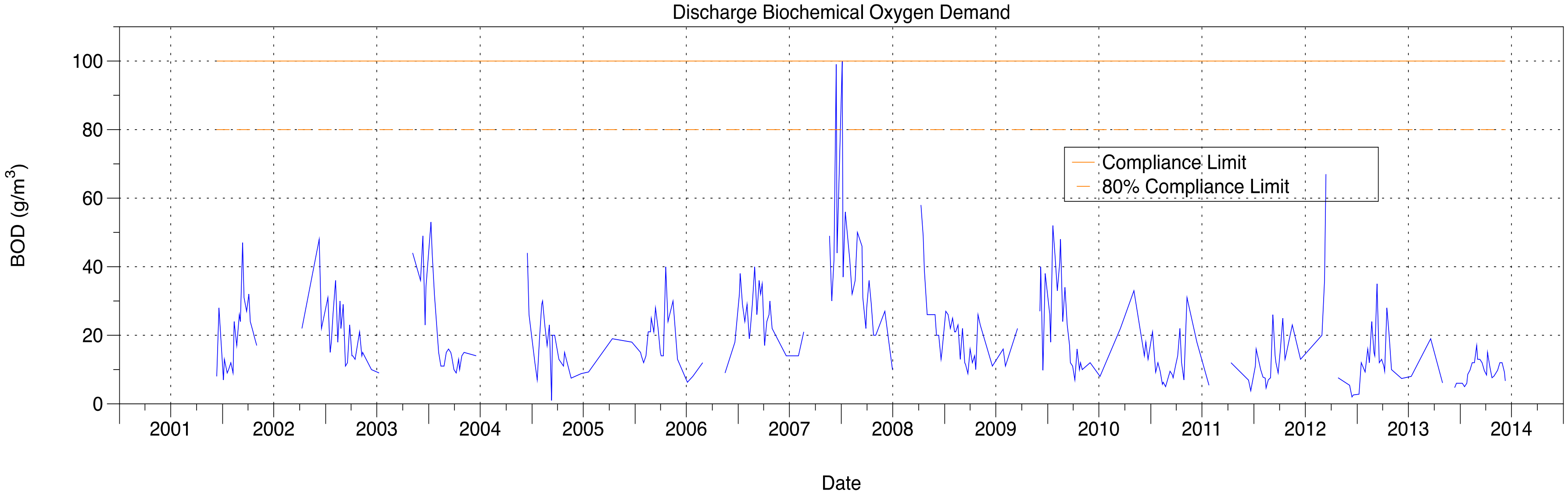

Figure 5: Discharge BOD concentrations between December 2001 and June 2014.

4.4 Mixing of the Discharge

A reach survey to assess river flow during low tide and high tide conditions was conducted by NIWA and Freshwater Solutions on the Makarewa River on 14 March 2014. River cross section profiles and depth averaged velocity data was collected by taking an Acoustic Doppler Current Profiler coupled with a Global Positioning System (GPS) across the river. Positional accuracy was achieved by using a Real Time Kinematic GPS.

At the same time as the flow survey, up to five grab samples of river water were collected at transects denoted both at the surface and at 0.6 m below the surface (if the river depth was sufficient). The determination of sodium concentrations was used to facilitate an assessment of mixing of the discharge.

Mixing of the discharge was not assessed under high flow conditions. Freshwater Solutions (2015) reported the findings of the flow survey and mixing assessment, and the report is provided in Appendix 5. The key findings of the mixing assessment were:

- At low river flow and near low tide conditions the discharge appears well mixed transversely at the river surface 200 m downstream of the discharge.
- At low river flow and near high tide conditions the discharge appears well mixed at the river surface and at depth from 200 m downstream of the discharge, although the river is flowing upstream. Under the same flow and tidal conditions the discharge is not fully mixed either transversally at the river surface or vertically at 200 m upstream of the discharge.

Summary

On no occasion during the monitoring period (December 2001 and June 2014) was the consent discharge volume limit exceeded.

The median pH of the discharge in the monitoring period was 8.2; no trend in pH was apparent. The median conductivity in the monitoring period was 1.9 mS/m; some seasonal trends in conductivity are evident. The consent requires that TSS concentration in the discharge does not exceed 300 g/m^3, with an additional condition that TSS concentrations are ‘consistently maintained’ at or less than 200 g/m^3. There have been minor exceedances of the 300 g/m^3 limit and no exceedances of the secondary TSS consent condition.

The median TN concentration in the discharge was 110 g/m^3; discharge TN is dominated by Amm-N. The median TN load in the discharge was 1,320 kg/day. The median TP concentration in the discharge was 11 g/m^3 and the median TP load in the discharge was 140 kg/day. The clear proportion of TP is present in a soluble form (DRP). The median BOD concentration in the discharge was 16 g/m^3 and the median BOD load was 120 kg/day.

The median FC concentration in the discharge was 3,100 MPN/100mL and the median FC load was 4.5 x 10^{11} MPN/day. There has also been a limited amount of *E. coli* analysis done on the discharge. The median *E. coli* concentration in the discharge was 2,400 cfu/100 mL and the median *E. coli* load was 3.6 x 10^{11} cfu/day.

At low river flow and near low tide conditions the discharge appears well mixed transversely at the river surface 200 m downstream of the discharge. At low river flow and near high tide conditions the discharge appears well mixed at the river surface and at depth from 200 m downstream of the discharge, although the river is flowing upstream. Under the same flow and tidal conditions the discharge is not fully mixed either transversally at the river surface or vertically at 200 m upstream of the discharge (Freshwater Solutions 2015).

5.0 River Water and Sediment Quality and Characteristics

5.1 Current Standards

The water quality parameters monitored by Alliance and the associated resource consent compliance limits along with the water quality standards and guidelines used by SRC for the Makarewa River, ANZECC (2000) guidelines for fresh and marine water and the NPS (2014) limits are presented in Table 13 and

Table 14. The rest of this section summarises Alliance's monitoring records of water and sediment quality.

5.2 Makarewa River Water Quality

A large amount of Bridge, 350 m and Boundary Site data was available for the period between December 2001 and June 2014 (Tables 1–14, Appendix 2). The data values are described in the following sections in terms of the 50th percentile, 5th percentiles and 95th percentiles, and ranges.

In addition to the regular river monitoring at the 350 m, a sonde with temperature, conductivity, pH and dissolved oxygen (DO) probes was deployed at this site between 6 February and 12 June 2014. DO data was only valid from 6 February to 20 February due to DO probe failure. Sonde data is also described in the following section.

Physico-chemical Parameters

The 5%-ile-95%-ile temperature at the Bridge Site was 7.0–18.8°C (median 13.9°C), and was similar at the 350 m Site (7.0–19.1°C, median 13.9°C) and the Boundary Site (6.9–19.1°C, median 14.0°C) (Table 1, Appendix 2). Alliance's consent stipulates that Class D Standards apply for the Makarewa River, namely 'the natural water temperature shall not be changed by more than 3 degrees Celsius'. This requirement was not met on two occasions; 8 January 2004 when the temperature at the Bridge Site was 16.4°C, but was 19.6°C at the 350 m Site, and 16 April 2014 when the temperature at the Bridge Site was 7.0°C, but was 11.2°C at the 350 m Site (Figure 6).

Temperature data from the sonde at the 350 m downstream site between 6 February and 20 June 2014 is presented in Figure 7 and ranged from 5.1 in late May to 20.7°C on 20 February 2014. The maximum daily range in temperature during this period was 4.1°C on 26 February 2014.

The 5%-ile-95%-ile Makarewa River pH was 6.5–7.6 (median 7.2) at the Bridge Site, 6.7–7.7 (median 7.3) at the 350 m Site and 6.8–7.7 (median 7.3) at the Boundary Site (Table 2, Appendix 2). Summary statistics indicate a slight increase in pH downstream of the discharge. A direct comparison of pH at the Bridge Site and 350 m Site confirms this; indicating the pH at the 350 m Site was greater than that at the Bridge Site 65% of the time. The Class D Standards stipulate 'pH shall be within the range 6–9 except when due to natural causes'; on no occasion was the pH at the 350 m Site outside this range (Figure 8).

The pH data from the sonde is presented in Figure 9 and Figure 10 and are in good agreement with the daily pH values (Figure 8). Alliance monitors pH in the river early in the morning (typically 9 am) which captures the lower river DO concentrations, and this typically coincides with the lowest daily pH values as evidenced by the diurnal pH pattern at the 350 m Site, although the diurnal spread of pH is not large (median 0.38).

The discharge results in a slight increase in the Makarewa River conductivity at the 350 m Site and the increase is also evident at the Boundary Site (Table 3, Appendix 2 and Figure 11). There is no consent requirement relating to conductivity.

Table 13: Water quality monitoring parameters and guidelines.

Parameter	SRC Freshwater Regional Standard/Guideline	Freshwater ANZECC (2000) Guideline	Monitored by Alliance	Consent Limit	Marine Regional Standard/ Guideline	Marine ANZECC (2000) Guideline	NPS (2014)
Temperature* (°C)	<23 and <3 change when ambient is ≤16 and <1 change when ambient is ≥16	-	Yes	<3 change	-	-	-
Electrical Conductivity** (µS/cm)	-	-	Yes	-	-	-	-
Dissolved oxygen*	>80%	98–105%	Yes	>5 g/m^3 100% of samples >6 g/m^3 >96% of samples	-	-	>5.0 (summer 7 day mean minimum)* >4.0 (summer 1 day mean minimum)*
Clarity (m) * & ***	>1.3 (at river flows below median)	>0.8	Yes	No conspicuous change (<20% decrease from upstream)	-	-	-
Colour***	-	-	Yes#	No conspicuous change	-	-	-
Films, scums and foams***	-	-	Yes#	No production of any conspicuous grease, films, scums, foams of floatable or suspendable material	-	-	-
pH * & ****	6.5–9.0 and no change that causes loss of biodiversity.	7.2–7.8	Yes	6.0–9.0	-	-	-
Turbidity (NTU) * & ***	-	<5.6	No	-	-	-	-
TSS (g/m^3) * & ***	-	-	No	-	-	-	-

Note: Based on temperature of 20°C and pH 8. NPS nitrate-N and ammonoiacal-N are toxicity guidelines. ANZECC (2000) total oxidised-N, ammoniacal-N, total nitrogen, dissolved reactive phosphorus and total phosphorus guidelines are stressor trigger values for New Zealand lowland rivers. # monitoring limited to 2012 – 2014 period. * = life supporting capacity, ** = general water quality, *** = aesethetics, **** = toxicity, ***** = human health.

Table 14: Water quality monitoring parameters and guidelines.

Parameter	SRC Freshwater Regional Standard/Guideline	Freshwater ANZECC (2000) Guideline	Monitored by Alliance	Consent Limit	Marine Regional Standard/ Guideline	Marine ANZECC (2000) Guideline	NPS (2014) Bottom Line
Biochemical oxygen demand (g/m^3)*	-	-	Yes	-	-	-	-
Soluble Biochemical oxygen demand (g/m^3)*	-	-	Yes	-	-	-	-
Nitrate-nitrite nitrogen (g/m^3)*	-	-	Yes	-	-	-	-
Nitrate (g/m^3)* and ****	-	-	-	-	-	-	≤6.9 (annual median) ≤9.8 (annual 95%)
Ammoniacal nitrogen (g/m^3)* and ****	<0.9	<0.021	Yes	Refer to Condition f in consent	-	0.91	≤1.3 (annual median) ≤2.4 (annual maximum)
Total nitrogen (g/m^3)*	-	<0.614	Yes	-	-	-	-
Total oxidised nitrogen*	-	<0.444	Yes	-	-	-	-
Dissolved reactive phosphorus (g/m^3)*	-	<0.010	Yes	-	-	-	-
Total phosphorus*	-	<0.033	Yes	-	-	-	-
Faecal coliforms (CFU/100 mL)*****	<1,000	-	Yes	-	Median <14/ 100 mL and 10% of samples in a season <43/100 mL	-	-
E. coli (CFU/100 mL)*****	-	-	Yes#	-	-	-	< 1,000 (annual median)
Chlorophyll *a* (mg/L)*	-	-	No	-	-	0.004	-

Note: Based on temperature of 20°C and pH 8. NPS nitrate-N and ammonoiacal-N are toxicity guidelines. ANZECC (2000) total oxidised-N, ammoniacal-N, total nitrogen, dissolved reactive phosphorus and total phosphorus guidelines are stressor trigger values for New Zealand lowland rivers. # monitoring limited to 2012 – 2014 period. * = life supporting capacity, ** = general water quality, *** = aesethetics, **** = toxicity , ***** = human health.

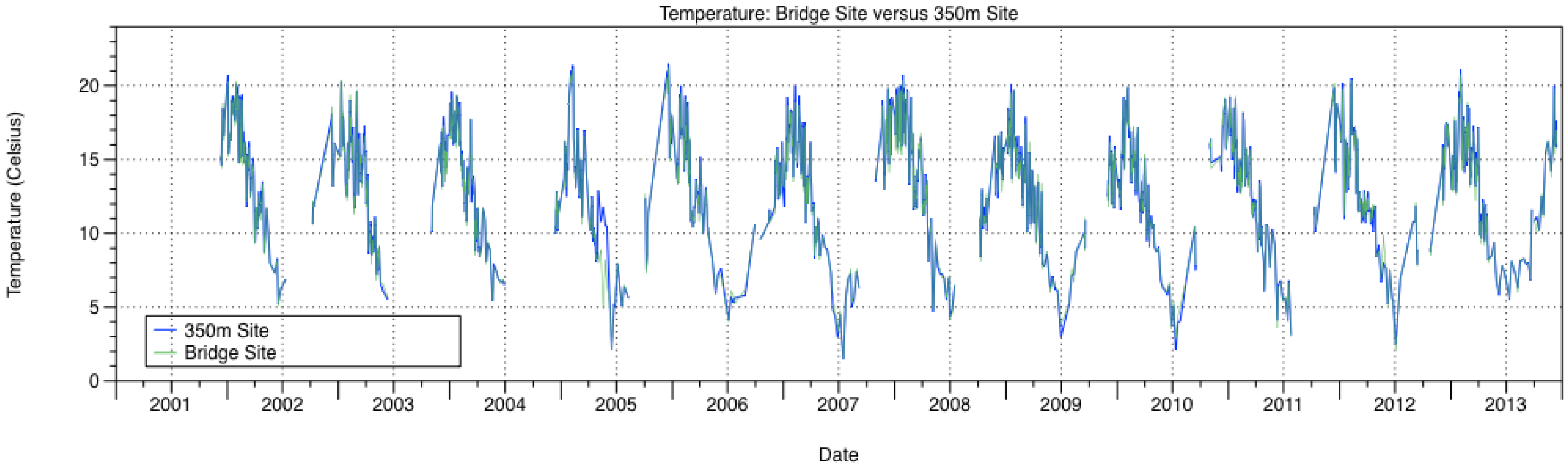

Figure 6: Water temperature at the Bridge and 350 m Sites between December 2001 and June 2014.

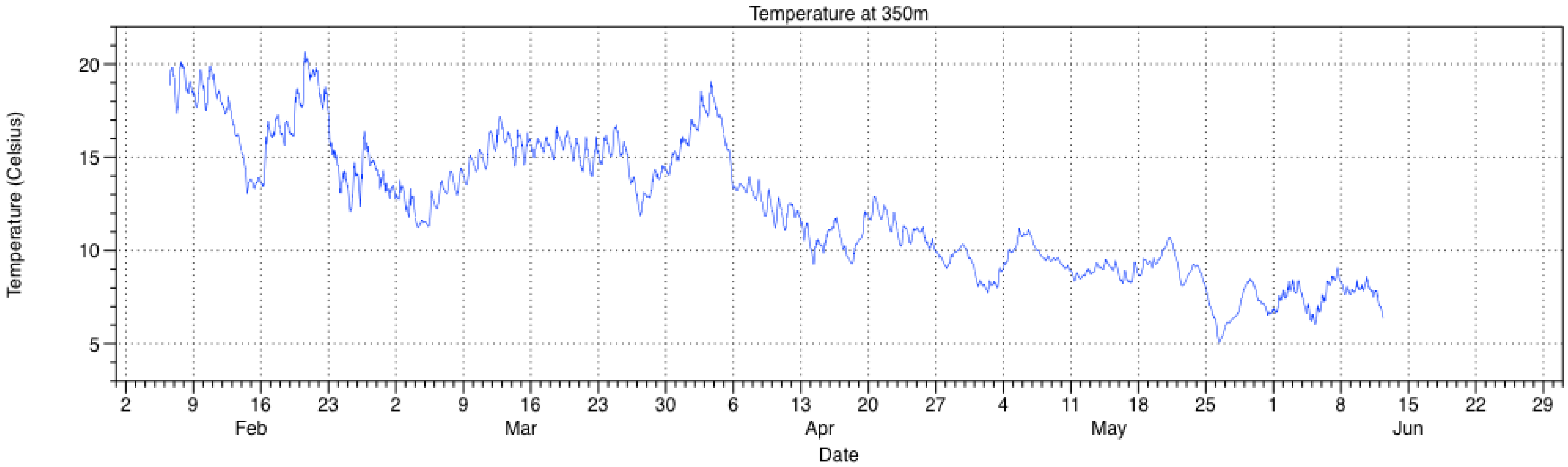

Figure 7: Continuous temperature at the 350 m Site between December 2001 and June 2014.

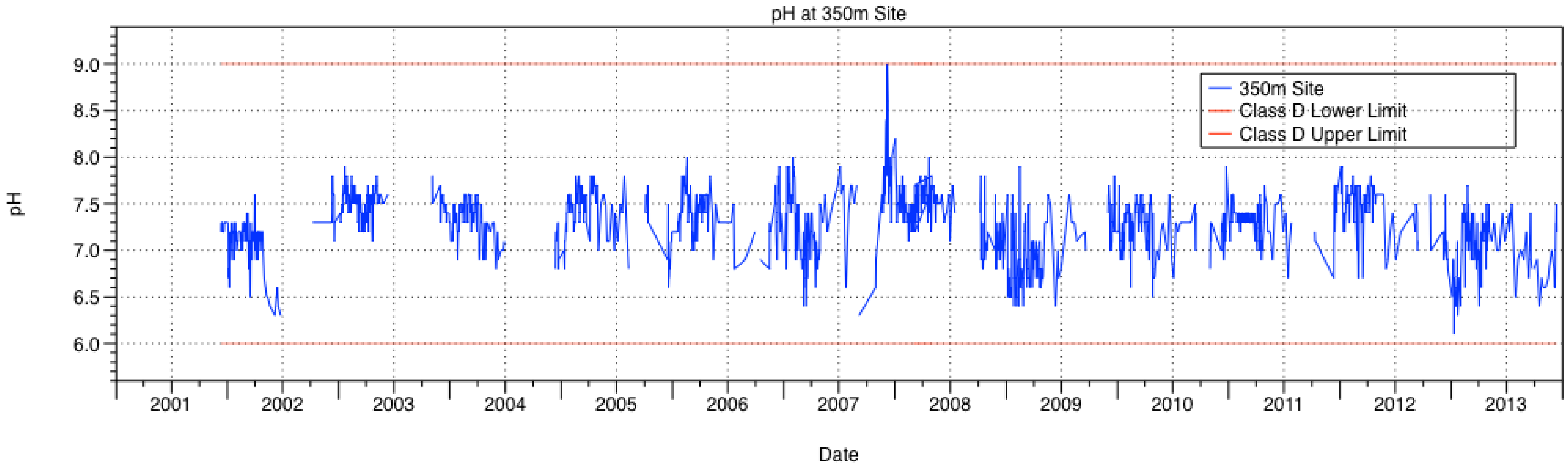

Figure 8: pH at the 350 m Site between December 2001 and June 2014.

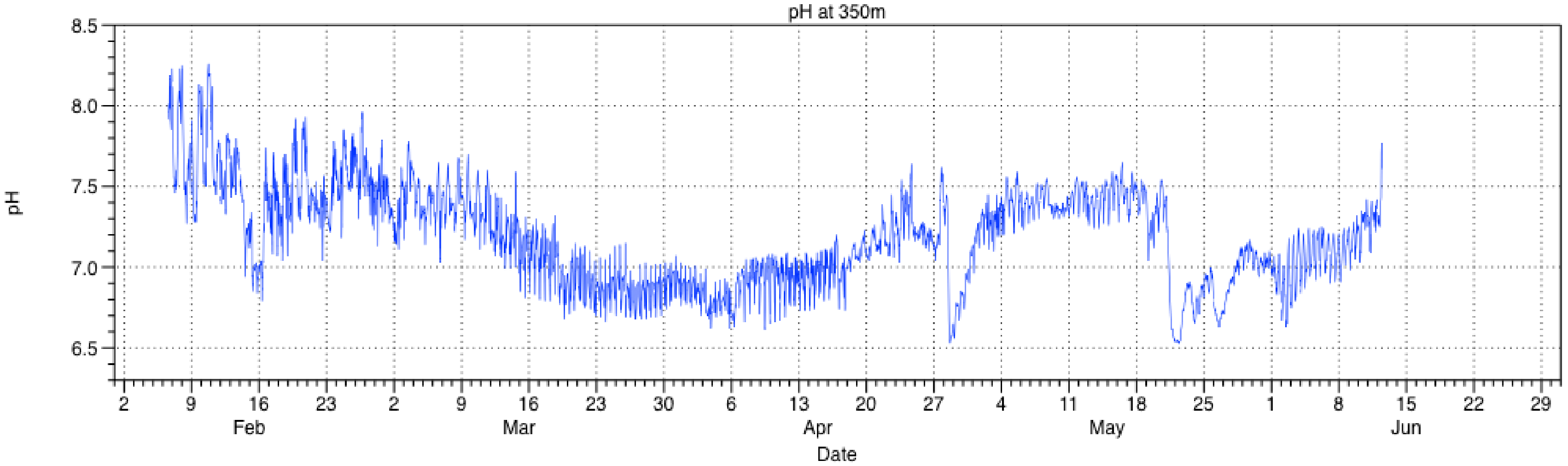

Figure 9: Continuous pH at 350 m Site between 6 February 2014 and 20 June 2014.

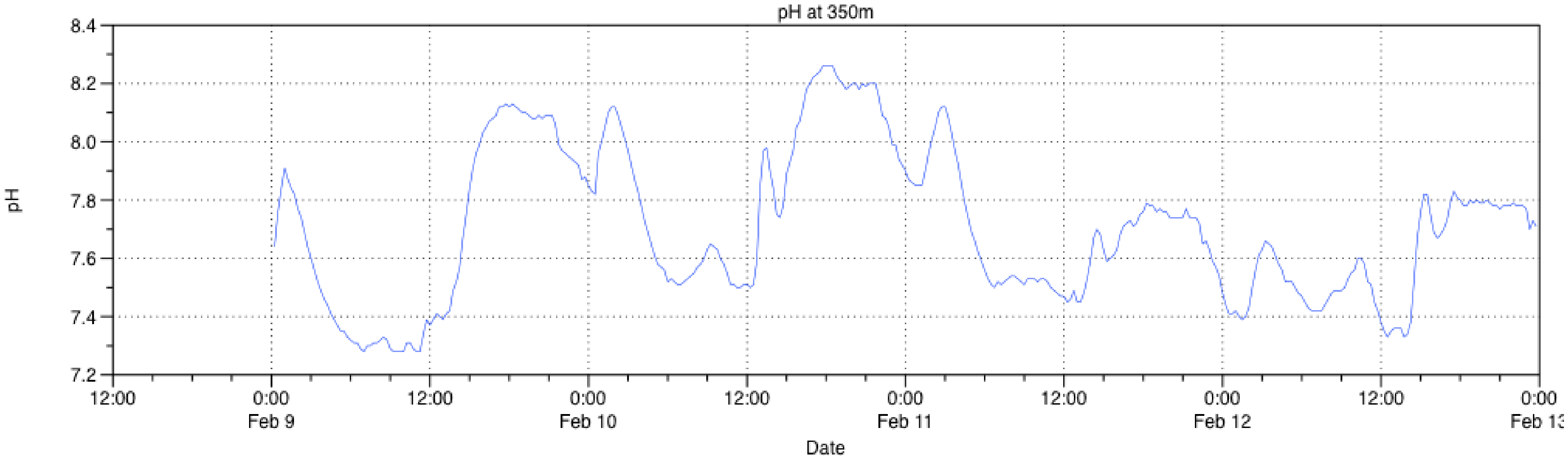

Figure 10: Continuous pH at 350 m Site between 9th and 13th February 2014.

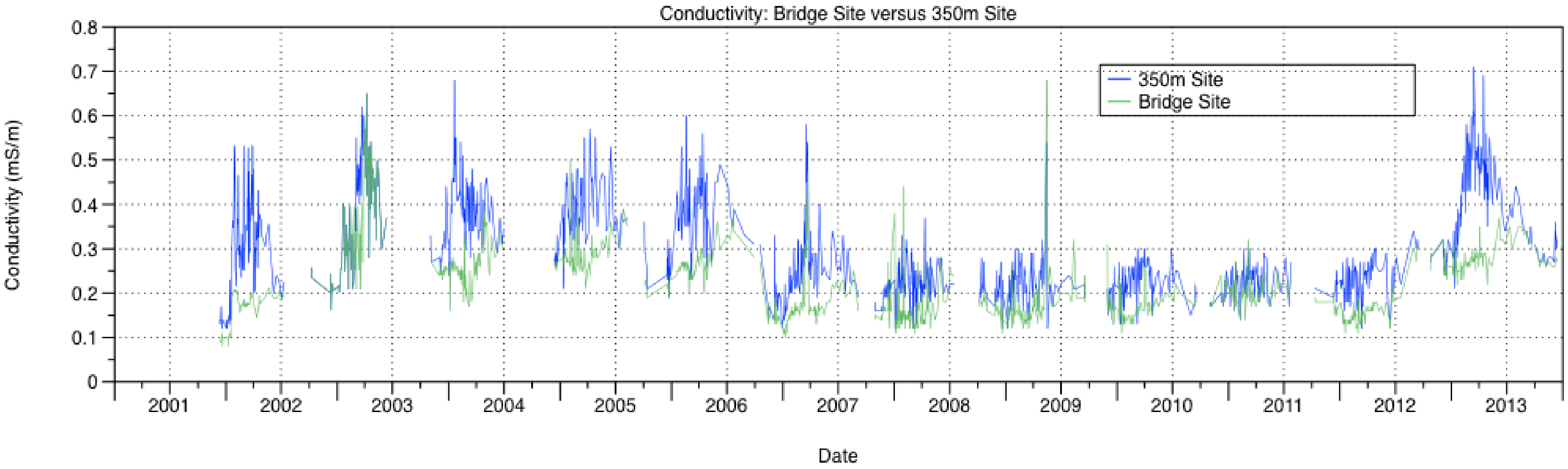

Figure 11: Conductivity at the Bridge Site and 350 m Site between December 2001 and June 2014.

Following the 2005/2006 season conductivity in the Makarewa River decreased at the Bridge Site upstream of the discharge and both downstream sites. The lower conductivities in the river were maintained until the end of the 2012 season, but in 2013 they returned to pre-2007 levels (Figure 11). Comparison of river conductivities downstream of the discharge with mass loadings of parameters that are well defined due to regular analysis (e.g., Amm-N) indicates the downstream trends in conductivity are well correlated to discharge mass loads.

Conductivity data at 350 m from the sonde is in good agreement with that obtained from daily monitoring (median 0.27 mS/m, range 0.12–0.48 mS/m) (Figure 12).

The 5%-ile-95%-ile DO at the Bridge Site was 7.1–12 g/m^3 (median 9.5 g/m^3), 6.6–11 g/m^3 (median 9.0 g/m^3) at the 350 m Site, and 6.4–11 g/m^3 (median 8.7 g/m^3) at the Boundary Site (Table 4, Appendix 2). Direct comparison of DO at the Bridge Site and the 350m Site indicates the DO at the 350 m Site was less than that at the Bridge Site 79% of the time. The consent states 'the dissolved oxygen concentration of the receiving waters beyond 200 m of the point of discharge shall be consistently maintained at not less than 6 g/m^3', where 'consistently maintained' means for 96% of samples taken in any year. This requirement was met for all years.

In addition the Class D Standards require dissolved oxygen not to be reduced below 5 g/m^3. This condition was not met on 6 out of 1,631 occasions monitored from December 2001–June 2014 (Figure 13). These occasions were as follows:

- 24 January 2002: discharge = 12,115 m^3, mean daily river flow = 1.8 m^3/s.
- 18 February 2002: discharge = 11,704 m^3, mean daily river flow = 1.9 m^3/s.
- 21 February 2007: discharge = 9,260 m^3, mean daily river flow = 1.5 m^3/s.
- 22 February 2007: discharge = 5,665 m^3, mean daily river flow = 1.4 m^3/s.
- 3 March 2007: discharge = 7,109 m^3, mean daily river flow = 1.1 m^3/s.
- 24 March 2013: discharge = 8,112 m^3, mean daily river flow = 2.5 m^3/s.

DO data from the sonde is shown in Figure 14 and indicates a clear diurnal pattern. The median DO over the period of sonde deployment was 8.9 g/m^3 (range 7.3–12 g/m^3).

The consent requires river water clarity (measured as clarity tube distance) not be reduced below 20% at the 350 m Site compared with the Bridge Site. The current consent limit is only applicable to clear water rivers that are managed for bathing (MfE 1994) and is not appropriate for the lower Makarewa River which is not a clear water river and is not used for bathing. A more appropriate clarity change limit for the lower Makarewa River is the 33–50% change as described in MfE (1994). The 5%-ile-95%-ile black disc clarity was 16–240 cm (median 45 cm) at the Bridge Site, 15–190 cm (median 39 cm) at the 350 m Site and 16–59 cm (median 38 cm) at the Boundary Site (Table 5, Appendix 2 and Figure 15). The clarity was reduced by more than 20% at the 350 m Site compared with the Bridge Site on 53 of the 321 occasions measured (17%).

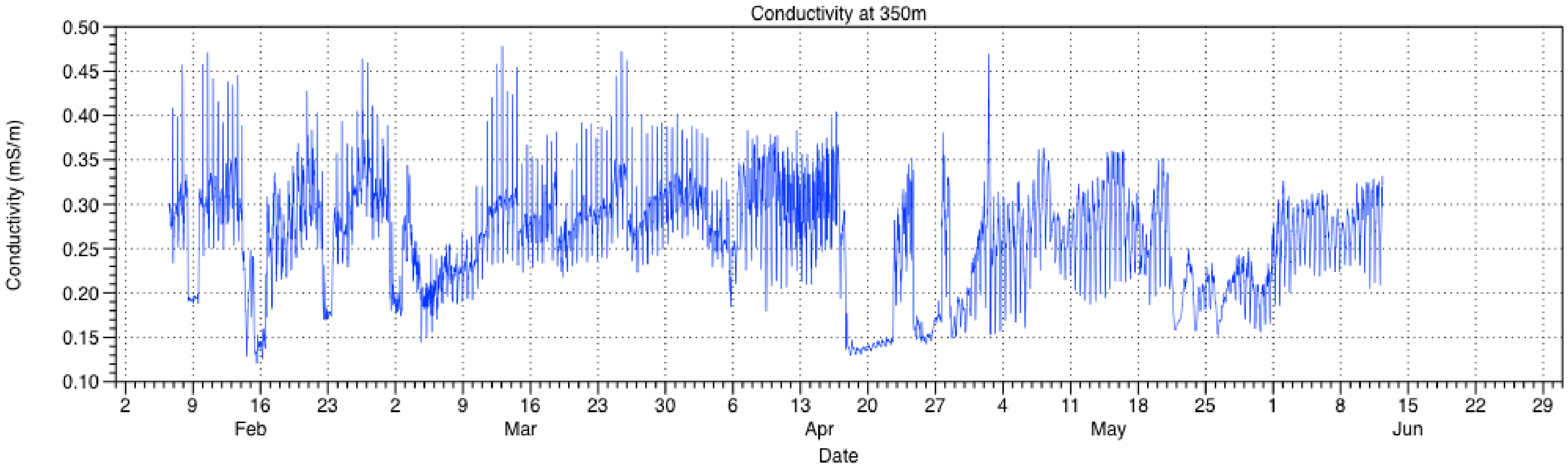

Figure 12: Continuous conductivity at the 350 m Site between 6 February 2014 and 20 June 2014.

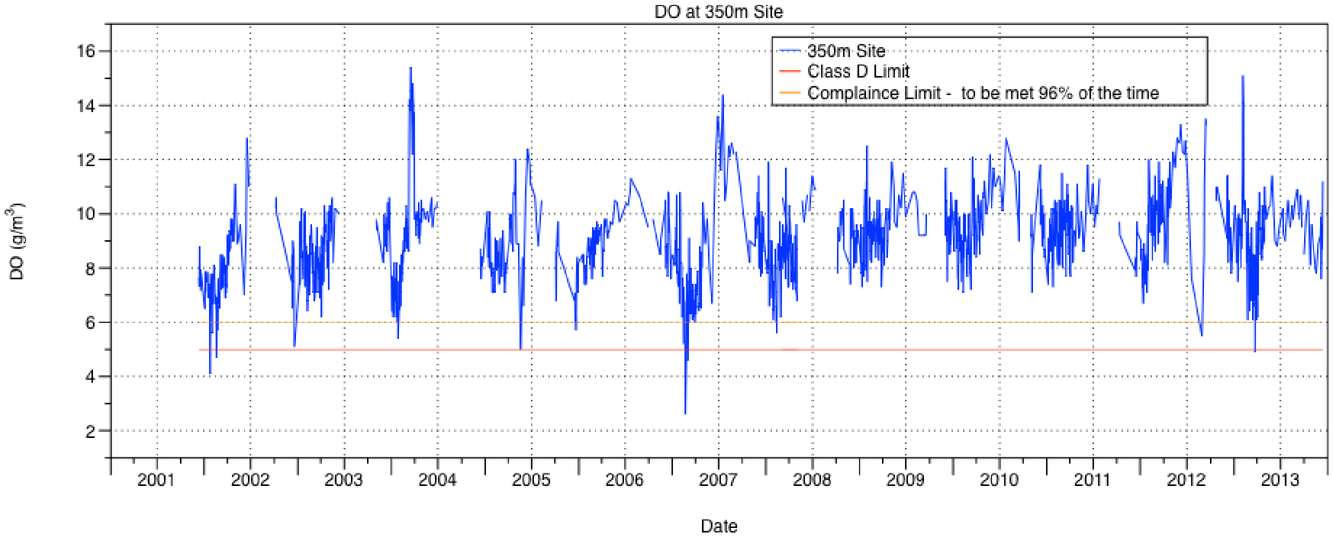

Figure 13: DO at the 350 m Site between December 2001 and June 2014.

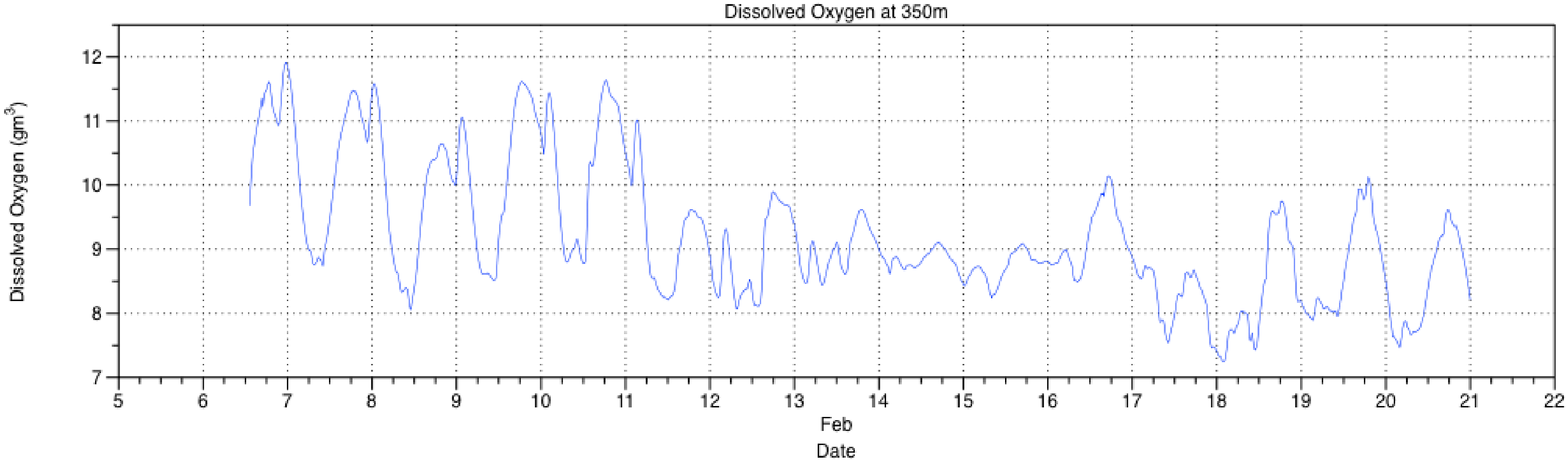

Figure 14: Continuous DO at 350 m Site between 6 February 2014 and 21 February 2014.

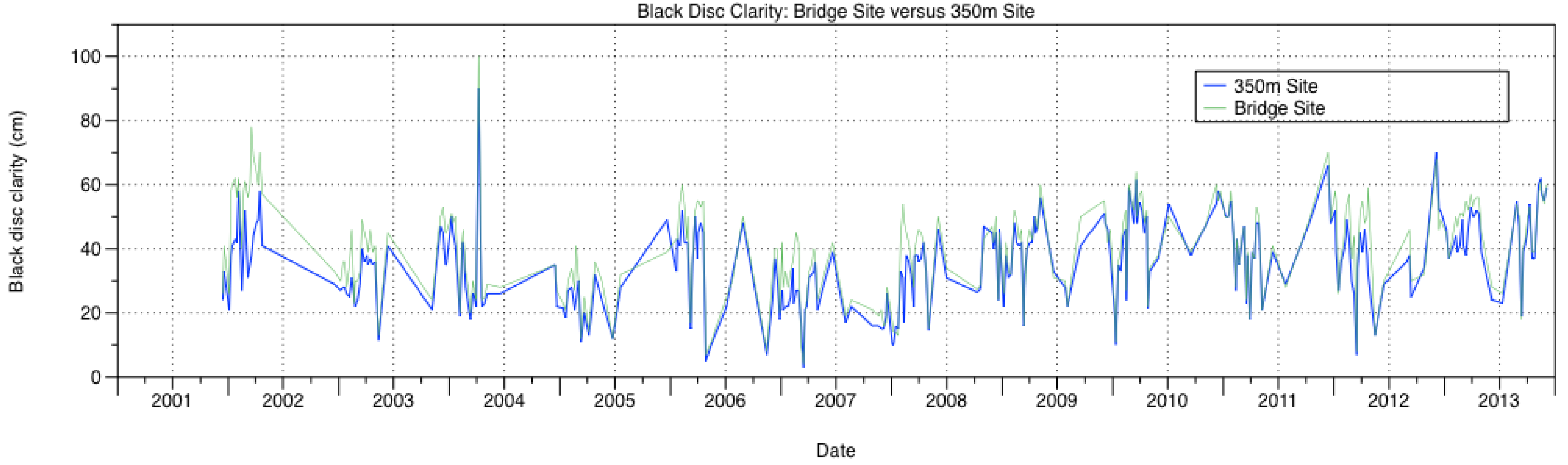

Figure 15: Clarity at the Boundary and 350 m Sites between December 2001 and June 2014.

Colour

Hue and brightness are the main attributes used to describe water colour (MfE 1994), which is well characterised by the Munsell system (Davies-Colley & Nagels 1999). Between 10 March 2014 and 23 April 2014 Alliance conducted a series of Munsell colour measurements at its three regular monitoring sites. Flow conditions in the Makarewa River (Counsell Road) during the duration of the colour assessment were lower than the long term median flow (2000-2014 = 4.4 m^3/s) 62% of the time, and ranged from 2.144 m^3/s to 23.91 m^3/s (median, 3.689 m^3/s) (Table 15).

The water colour at all three sites was predominantly 10Y (30) 8/2 (pale greenish yellow) at all sites on the majority of occasions and only differed at sites downstream of the discharge compared with the Bridge Site on two occasions; on both occasions the colour difference was 2.5 points on the Munsell scale.

Table 15: Munsell colour results from 2014.

Date	Munsell Colour			Discharge Volume	River Flow (m^3/s)
	Bridge Site	350 m Site	Boundary Site		
10/03/14	10Y (30) 8/2	10Y (30) 8/2	10Y (30) 8/2	9039	3.633
11/03/14	10Y (30) 8/2	10Y (30) 8/2	10Y (30) 8/2	12039	3.289
12/03/14	2.5Y (32.5) 8/2	10Y (30) 8/2	10Y (30) 8/2	13562	3.053
13/03/14	10Y (30) 8/2	10Y (30) 8/2	10Y (30) 8/2	14429	2.888
20/03/14	10Y (30) 8/2	7.5Y (27.5) 8/2	10Y (30) 8/2	13154	3.689
21/03/14	10Y (30) 8/2	10Y (30) 8/2	10Y (30) 8/2	12867	3.055
26/03/14	10Y (30) 8/2	10Y (30) 8/2	10Y (30) 8/2	14673	4.876
31/03/14	10Y (30) 8/2	10Y (30) 8/2	10Y (30) 8/2	14296	2.389
1/04/14	10Y (30) 8/2	10Y (30) 8/2	10Y (30) 8/2	12483	2.307
2/04/14	10Y (30) 8/2	10Y (30) 8/2	10Y (30) 8/2	12274	2.264
3/04/14	10Y (30) 8/2	10Y (30) 8/2	10Y (30) 8/2	11002	2.166
4/04/14	10Y (30) 8/2	10Y (30) 8/2	10Y (30) 8/2	6640	2.144
7/04/14	5Y (25) 8/2	5Y (25) 8/2	5Y (25) 8/2	16143	9.699
8/04/14	7.5Y (27.5) 8/2	7.5Y (27.5) 8/2	7.5Y (27.5) 8/2	17748	7.818
9/04/14	10Y (30) 8/2	10Y (30) 8/2	10Y (30) 8/2	16266	6.173
10/04/14	10Y (30) 8/2	10Y (30) 8/2	10Y (30) 8/2	15799	4.975
14/04/14	10Y (30) 8/2	10Y (30) 8/2	10Y (30) 8/2	11958	4.334
15/04/14	10Y (30) 8/2	10Y (30) 8/2	10Y (30) 8/2	15261	3.88
16/04/14	10Y (30) 8/2	10Y (30) 8/2	10Y (30) 8/2	14568	11.466
17/04/14	5Y (25) 8/2	5Y (25) 8/2	5Y (25) 8/2	19957	23.91
23/04/14	10Y (30) 8/2	10Y (30) 8/2	10Y (30) 8/2	13493	4.819

Foams and Scums

Alliance made 35 visual assessments of foams, scums and floatable material between 28 April 2013 and 18 December 2013. Freshwater Solutions made visual assessments of foams, scums and floatable material during biological surveys on 7 and 8 March 2013, 7 November 2013, 6 February 2014, 12 March 2014 and during the mixing zone assessment on 14 March 2014.

The first three observations during April and May 2013 were made when the discharge was occurring and on one occasion a small amount of foam was observed at the discharge point, on one occasion foam was observed 400 m downstream and on one occasion no foam was observed.

Of the 12 observations in July, August and September four recorded no foam of which three were when the discharge was closed, seven recorded foam within the mixing zone of which two were when the discharge was closed and one recorded foam at the Boundary Site. It is not known what the cause of the foam in the river was during periods without discharge but the formation of foams in rivers is known to occur naturally at times.

The first four observations in October 2013 were prior to the discharge starting and no foams or scums were observed. On 30 October 2013, after the start of the discharge foam was observed at the discharge point and close to the true left bank as far as 400 m downstream of the discharge. The discharge was closed during the four observations in November 2013 and foam was observed at the discharge point on two of those occasions.

Daily observations were made between 6 and 18 December 2013 (the first 11 days of the discharge in the 2013/2014 season). Of the 11 observations foam was recorded within the mixing zone on six occasions, one recorded foam at the Boundary Site and four recorded no foam.

Foam was observed on one of the five observations made during biological surveys and the mixing zone assessments in 2013 and 2014.

Overall the observations made during the 2012/2013 and 2013/2014 seasons indicates that foams and scums are visible in the river with and without the discharge but that generally foam and scum is limited to the mixing zone. Results indicate that there may need to be additional management measures applied to the discharge to avoid the generation of conspicuous foams or scums beyond the zone of reasonable mixing.

Nutrients

The 5%-ile-95%-ile total nitrogen concentrations in the Makarewa River at the Bridge Site was 0.76–3.5 g/m^3 (median 1.3 g/m^3) (Table 6, Appendix 2 and Figure 16). The composition of TN was 0.029–0.39 g/m^3 (median 0.072 g/m^3) Amm-N, 0.28–2.0 g/m^3 (median 0.66 g/m^3) TON (Table 7, Appendix 2) and, by difference 0.090–1.2 g/m^3 (median 0.50 g/m^3) organic nitrogen (Org-N); based on median concentrations this is an Amm-N : TON : Org-N ratio of 1.0 : 9.2 : 6.9. 5%-ile-95%-ile dissolved inorganic nitrogen (DIN) concentrations were 0.36–2.3 g/m^3 (median 0.82 g/m^3) (Table 8, Appendix 2 and Figure 17).

At the 350 m Site, 5%-ile-95%-ile TN concentrations were 1.7–10 g/m^3 (median 5.3 g/m^3) (Table 6, Appendix 2 and Figure 16) and the composition of TN was 0.32–9.1 g/m^3 (median 3.9 g/m^3) Amm-N, 0.42–2.2 g/m^3 (median 0.90 g/m^3) TON (Table 7, Appendix 2) and, by difference, 0.17–2.3 g/m^3 (median 0.81 g/m^3) Org-N; this is an Amm-N : TON : Org-N ratio of 4.8 : 1.1 : 1.0. 5%-ile-95%-ile DIN concentrations were 1.3–9.3 g/m^3 (median 4.4 g/m^3) (Table 8, Appendix 2 and Figure 17).

At the Boundary Site, 5%-ile-95%-ile TN concentrations were 1.5–9.8 g/m^3 (median 3.8 g/m^3) (Table 6, Appendix 2). The composition of TN was 0.23–8.1 g/m^3 (median 2.5 g/m^3) Amm-N, 0.43–2.1 g/m^3 (median 0.94 g/m^3) TON (Table 7, Appendix 2) and, by difference, 0.16–1.9 g/m^3 (median 0.70 g/m^3) Org-N; this is an Amm-N : TON : Org-N ratio of 3.6 : 1.3 : 1.0. 5%-ile-95%-ile DIN concentrations were 1.2–8.9 g/m^3 (median 3.1 g/m^3) (Table 8, Appendix 2).

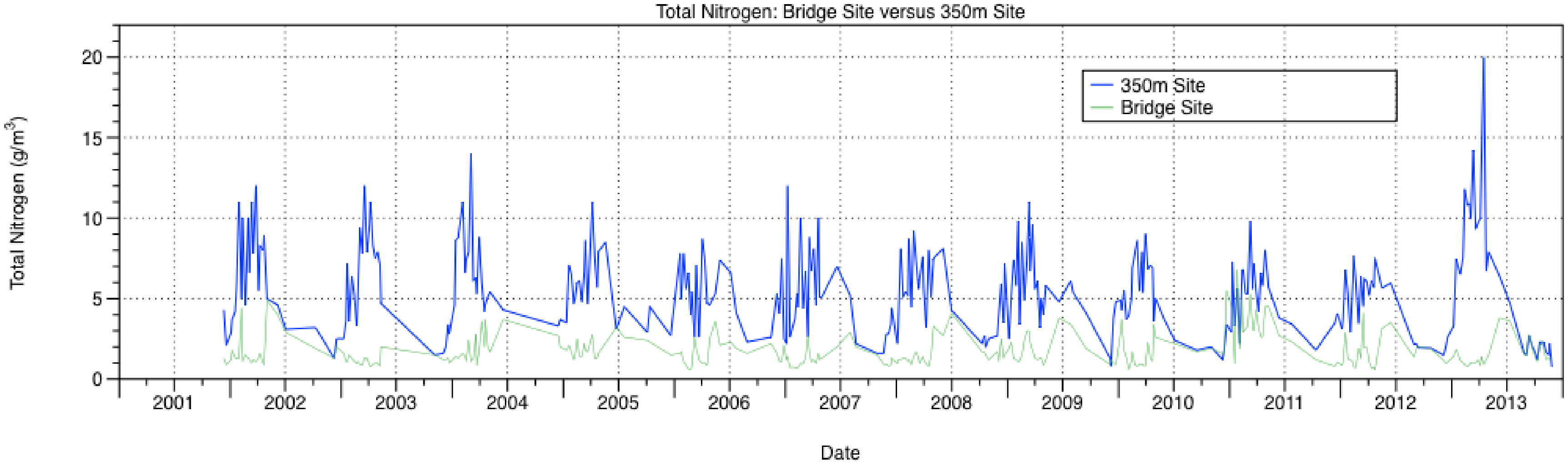

Figure 16: TN at the Bridge and 350 m Sites between December 2001 and June 2014.

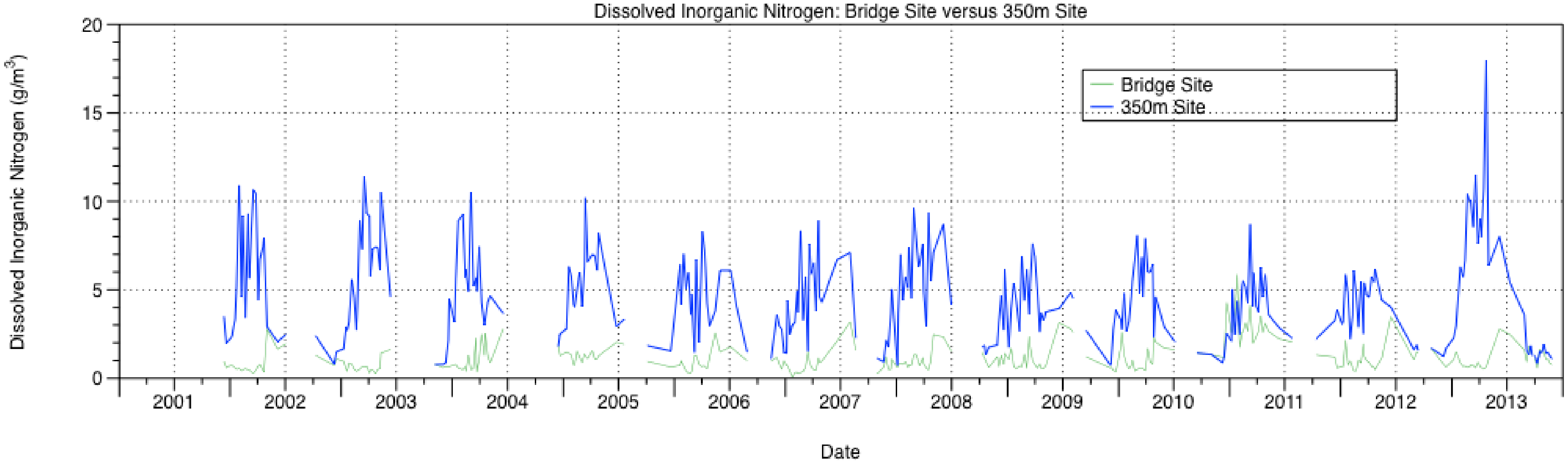

Figure 17: DIN at the Bridge and 350 m Sites between December 2001 and June 2014.

The consent contains two Amm-N conditions, one to be met in the first two years of the consent and the other for the remaining term of the consent. For the first two years of the consent the receiving water was not to exceed 0.11 g/m^3 unionised ammonia, or any five consecutive samples (taken on different days) exceed a median unionised ammonia concentration of 0.08 g/m^3. Both of these conditions were met with the exception of one occasion in March 2003 when the concentration was 0.15 g/m^3. Following the first two years of the consent the Amm-N condition reverted to the 1984 USEPA acute criteria, which are pH and temperature dependant and summarised in a table in the consent. This condition was not met on 12 out of 1,374 occasions between November 2003 and June 2014, most recently in April 2013 (Table 9, Appendix 2 and Figure 18 and Figure 19).

There is a large, almost daily, dataset of Amm-N concentrations in the discharge that indicates Alliance has contributed a median Amm-N load of 153 tonnes/season to the Makarewa River. The highest seasonal Amm-N loads of approximately 180–190 tonnes/season occurred in 2001/2002, 2002/2003, 2005/2006 and 2012/2013 (Figure 20). The significance of ammoniacal-N loading to the receiving environment are covered later in the report, both under direct effects of ammoniacal-N (toxicity effects) and also under the effects of TN (nutrient effects).

Based on Amm-N in the discharge consistently accounting for approximately 85% of TN discharged, Alliance has contributed a median TN load of approximately 170 tonnes/season to the Makarewa River. NIWA (2013) reports the TN load from the discharge is 448.1 tonnes/year, but this appears to be erroneously calculated based on the discharge occurring daily throughout the year. And based on TN data alone, Robertson and Stevens (2013) estimated the annual TN load for the 2011/2012 season was 256 tonnes, which is consistent with the long-term median load calculated here.

The monitoring record for the Makarewa River upstream of the discharge (Bridge Site) is also limited to weekly data for TN, hence there are 326 data points between December 2001 and June 2014. Based on the TN data and the daily flow record at Counsell Road, the estimated median daily TN load is 431 kg/d (or 157 tonnes/year).

Hence, downstream of the Alliance discharge the median contribution of TN to the Makarewa River between 2001 and 2014 was approximately 53% of the total river load. Based on data from selected seasons Robertson and Stevens (2013), estimated that the mean annual load of TN to the New River Estuary is approximately 4,531 tonnes/year (Robertson and Stevens 2013). Accordingly, this would mean the contribution of the Plant to the load in the New River Estuary is approximately 3.8%.

5%-ile-95%-ile total phosphorus concentrations at the Bridge Site were 0.032–0.29 g/m^3 (median 0.067 g/m^3) (Table 10, Appendix 2 and Figure 21), and DRP concentrations were 0.008–0.12 g/m^3 (median 0.027 g/m^3). When compared on a daily basis, DRP was 40% of TP as a median. At the 350 m Site 5%-ile-95%-ile TP concentrations were 0.084–1.1 g/m^3 (median 0.49 g/m^3), and 5%-ile-95%-ile DRP concentrations were 0.031–0.84 g/m^3 (median 0.35 g/m^3) (Table 11, Appendix 2 and Figure 22). When compared on a daily basis, DRP was 75% of TP as a median. There is no consent limit for TP or DRP. At the Boundary Site 5%-ile-95%-ile TP concentrations were 0.071–1.0 g/m^3 (median 0.32 g/m^3) (Table 10, Appendix 2), and DRP concentrations were 0.023–0.77 g/m^3 (median 0.22 g/m^3) (Table 11, Appendix 2). When calculated on a daily basis, DRP was 71% of TP as a median.

The BOD results are included in this section as BOD is a nutrient. The median BOD concentration at the Bridge Site between December 2001 and June 2014 was <2 g/m^3 and 5%-ile to 95%-ile was <1 g/m^3 to <2 g/m^3. A similar pattern was observed at the 350m and Boundary Sites where the median BOD was <2 g/ m^3 and 5%-ile to 95%-ile was <1 g/m^3 to 2 g/m^3 (Table 12, Appendix 2).

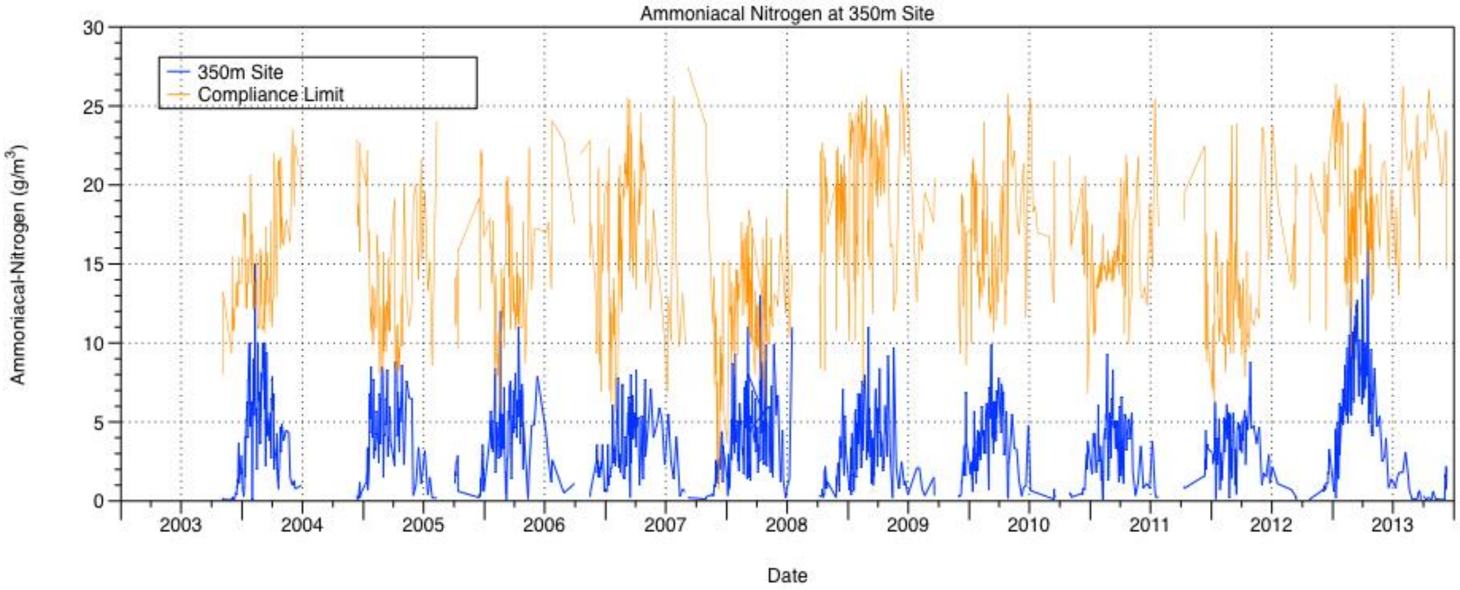

Figure 18: Amm-N concentration at the 350 m Site between December 2003 and June 2014.

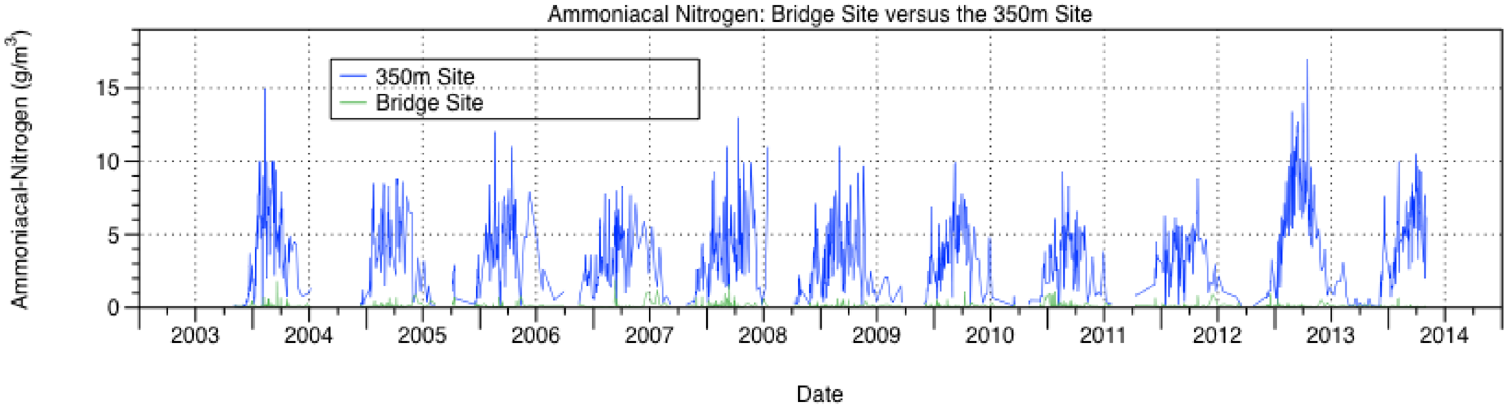

Figure 19: Amm-N concentration at the Bridge and 350 m Site between December 2003 and June 2014.

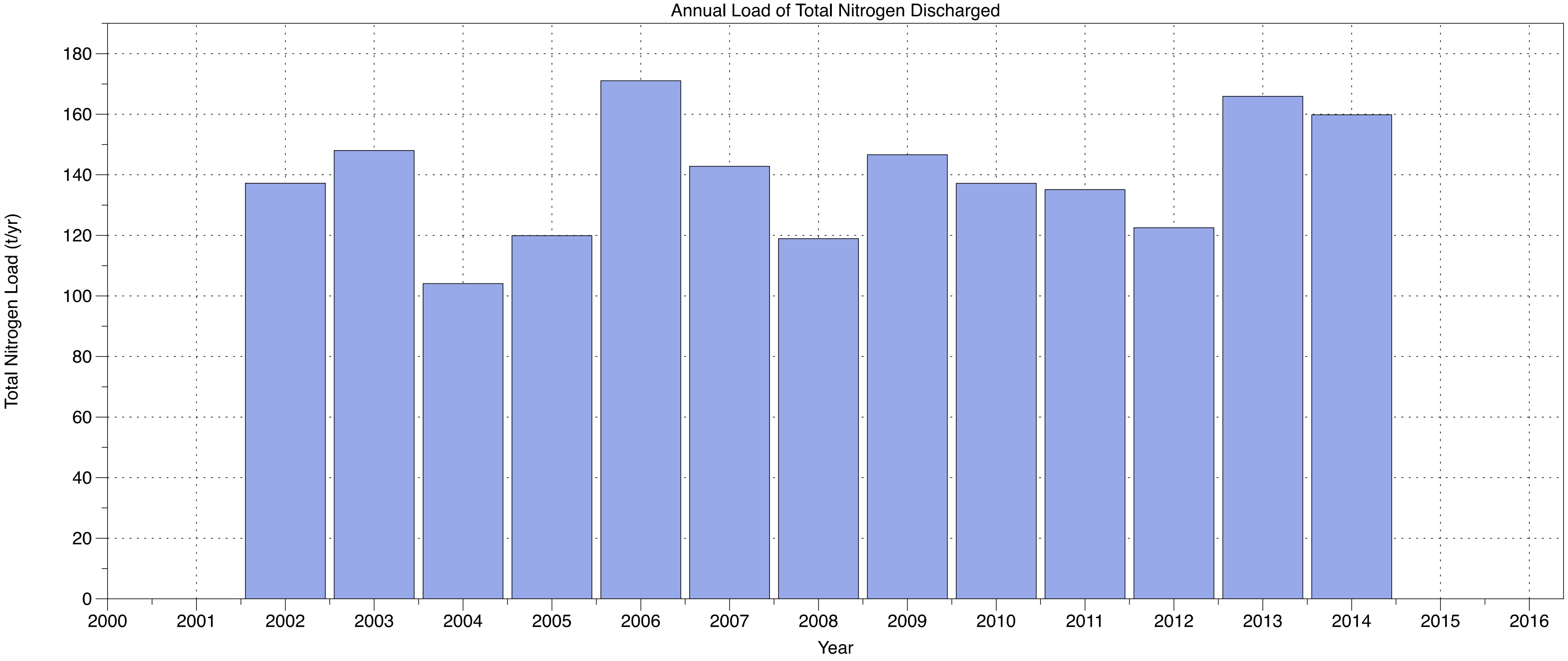

Figure 20: Discharge Amm-N loads between December 2001 and June 2014.

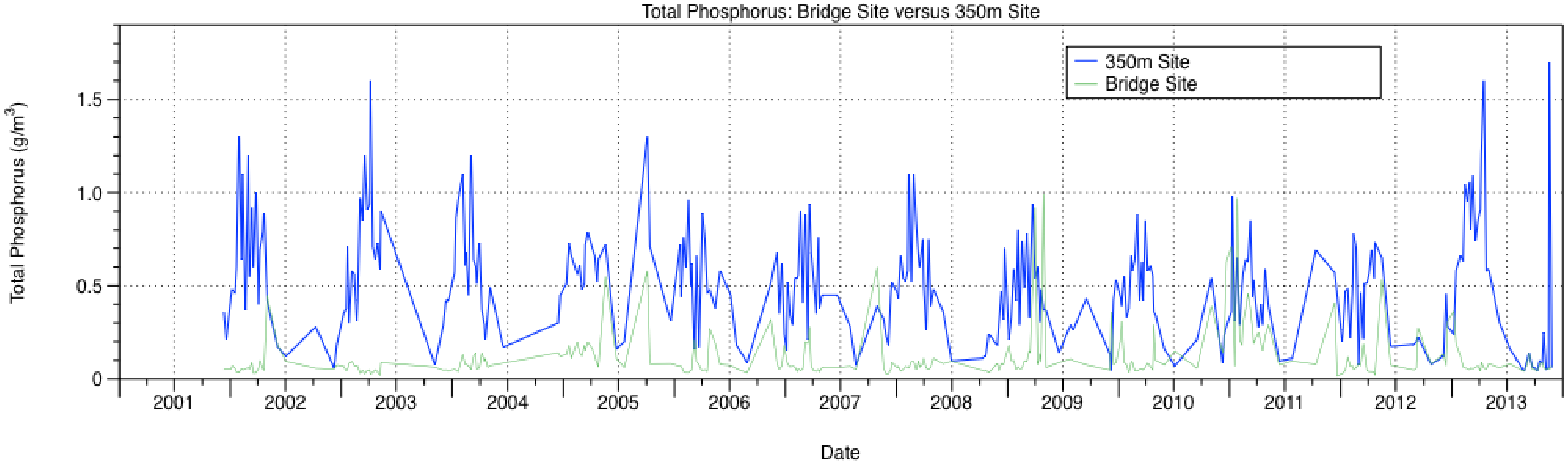

Figure 21: TP concentration at the Bridge and 350 m Sites between December 2001 and June 2014.

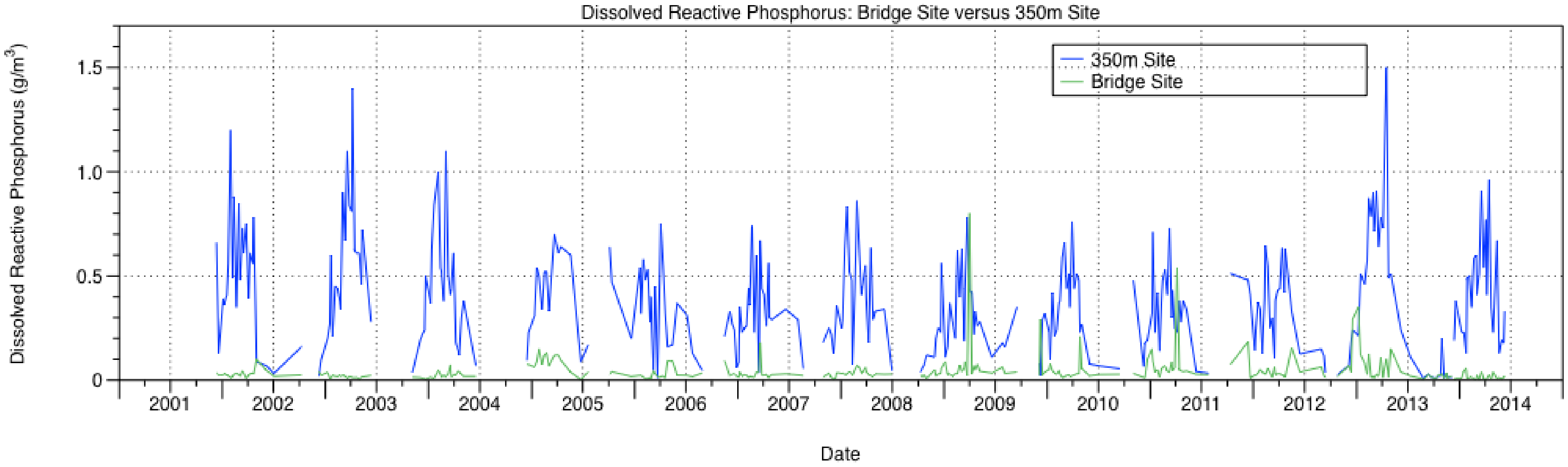

Figure 22: DRP concentration at the Bridge and 350 m Sites between December 2001 and June 2014.

Median concentrations of TP increased from 0.067 g/m^3 (Bridge Site) to 0.49 g/m^3 (350 m Site) and then decreased to 0.32 g/m^3 (Boundary Site) (Figure 21). A similar pattern was observed for DRP where the respective median concentrations were 0.027, 0.35 and 0.22 g/m^3. The greater proportion of DRP relative to TP downstream of the discharge is a fair reflection of the composition of the discharge, which is 81% DRP, whereas it is evident that phosphorus in the Makarewa River upstream of the discharge (40% of which is DRP) is more strongly associated with particulates and linked to nutrient run-off.

The median TP load in the discharge for the entire monitoring period was 140 kg/day (5%-ile-95%-ile: 43–250 kg/day) on days when discharge occurred. Like TN, TP is not measured daily on the discharge, hence it is only possible to estimate the median seasonal TP load as 18.4 tonnes/season based on 130 days of discharge per season. NIWA (2013) reports the TP load from the discharge is 48.8 tonnes/year but, again, this figure appears incorrectly based on the discharge occurring daily throughout the year.

The magnitude of seasonal TP loads mirrors that observed for Amm-N loads, i.e., highest loads in 2001/2002, 2002/2003, 2005/2006, 2012/2013 and 2013/2014, following the 2005/2006 season but prior to the 2012/2013 season (Figure 23).

Monitoring of the Makarewa River at the Bridge Site is based on weekly data for TP; based on this data and the daily flow record at Counsell Road, the estimated median daily TP load is 23.7 kg/d, or 8.6 tonnes/year. Hence, downstream of the discharge the median contribution of TP to the Makarewa River between 2001 and 2014 was approximately 68.1% of the total river TP load. According to Robertson and Stevens (2013) the mean annual load of TP to the New River Estuary is approximately 370 tonnes/year Robertson and Stevens (2013). Hence, the contribution from Plant to the New River estuary is approximately 5.0%.

Microbiology

Although the consent does not contain any condition relating to FC, the Regional Water Plan for Southland stipulates a FC limit of 1,000 MPN/100mL for lowland surface water bodies (excluding popular bathing sites). Between December 2001 and June 2014 the FC counts at the Bridge Site (median = 1,500 MPN/100mL) and the 350 m Site (median = 1,300 MPN/100mL) were consistently similar, but were lower at the Boundary Site (median = 885 MPN/100 mL) (Table 13, Appendix 2 and Figure 24) with median FC counts lower at the 350 m Site compared to the Bridge Site on 56% of sampling occasions. The annual median FC count was higher at the Bridge Site compared to the 350 m Site on 8 out of the 14 years analysed (Appendix 2).

Monitoring from March 2013 to June 2014 has indicated median *E. coli* concentrations of 500, 700 and 480 cfu/100 mL at the Bridge, 350 m and Boundary Sites, respectively (Figure 25). Hence, this typically defines the Makarewa River in the vicinity of the Alliance discharge as Microbiological Assessment Category C (261–550 *E. coli*/100mL, MfE/MoH, 2003).

A frequency analysis of Makarewa River water quality with respect to the MfE/MoH microbiological assessment category definitions for those sites in the vicinity of the discharge, as well as related sites monitored by Alliance, is presented in Table 16. The MfE/MOH Category D limit of < 550 cfu/100 ml was exceeded at the Bridge Site on 22 out 0f 47 sampling occasions while at the 350 m Site it was exceeded on 24 out of 47 sampling occasions.

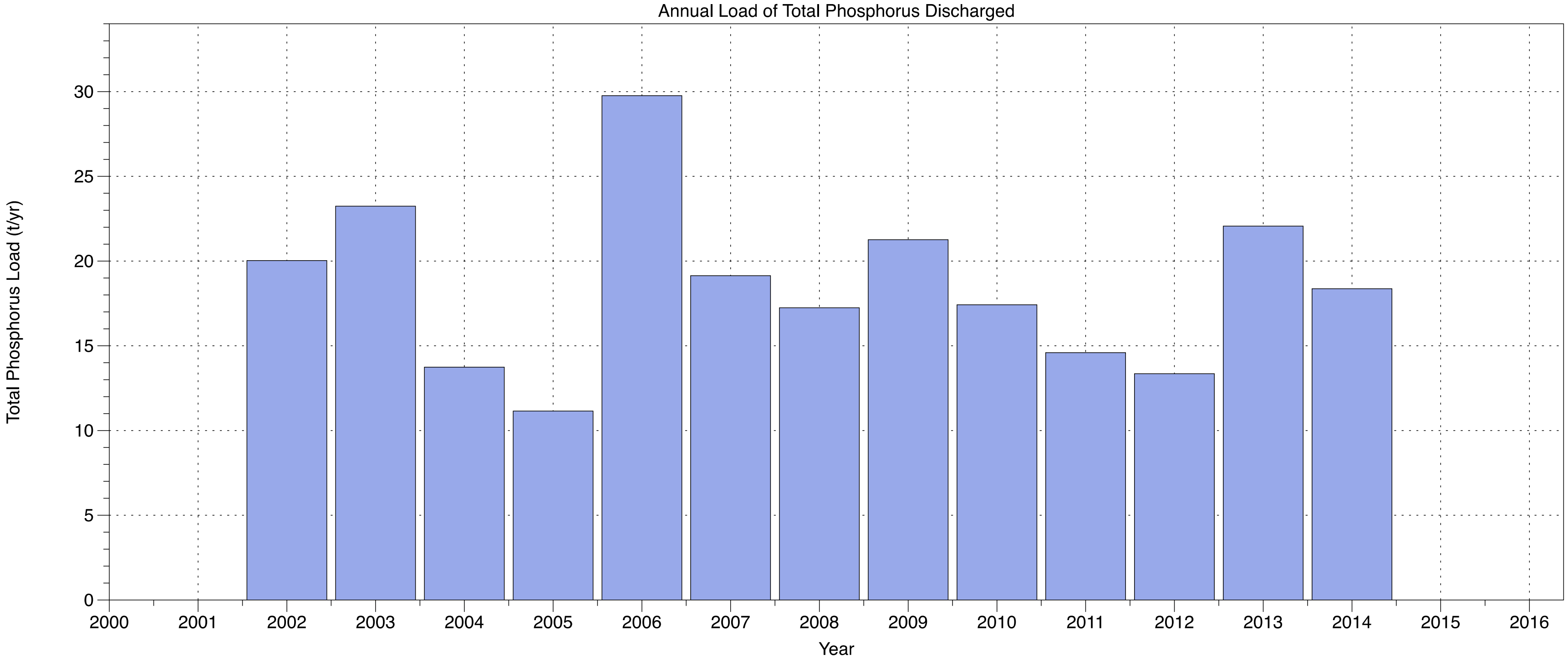

Figure 23: Discharge TP loads between December 2001 and June 2014.

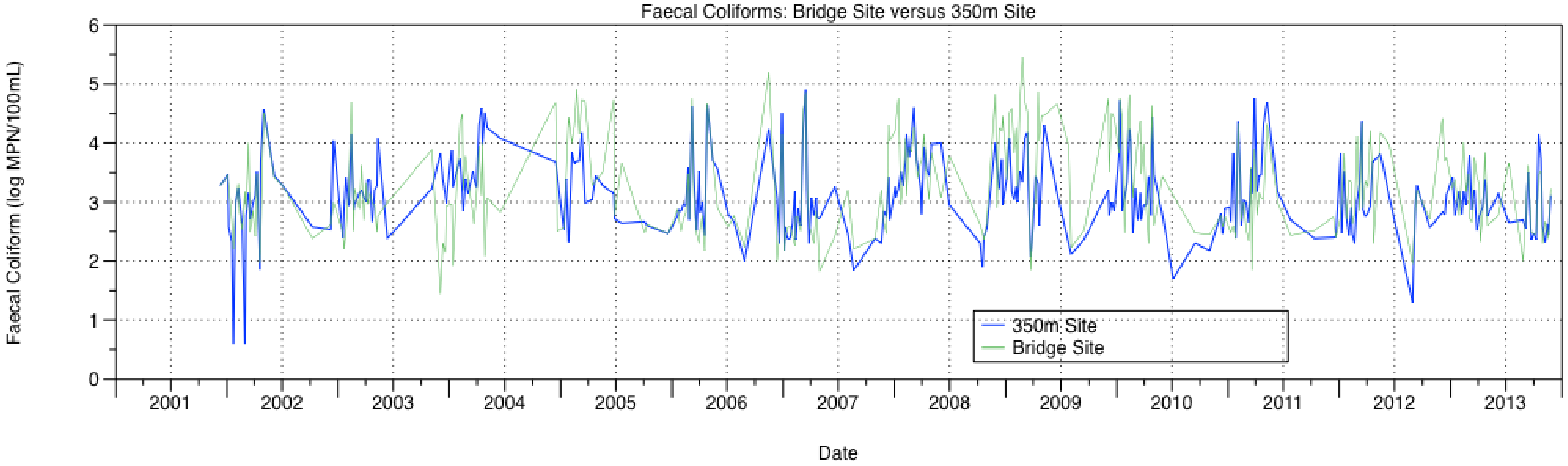

Figure 24: FC counts at the Bridge and 350 m Sites between December 2001 and June 2014.

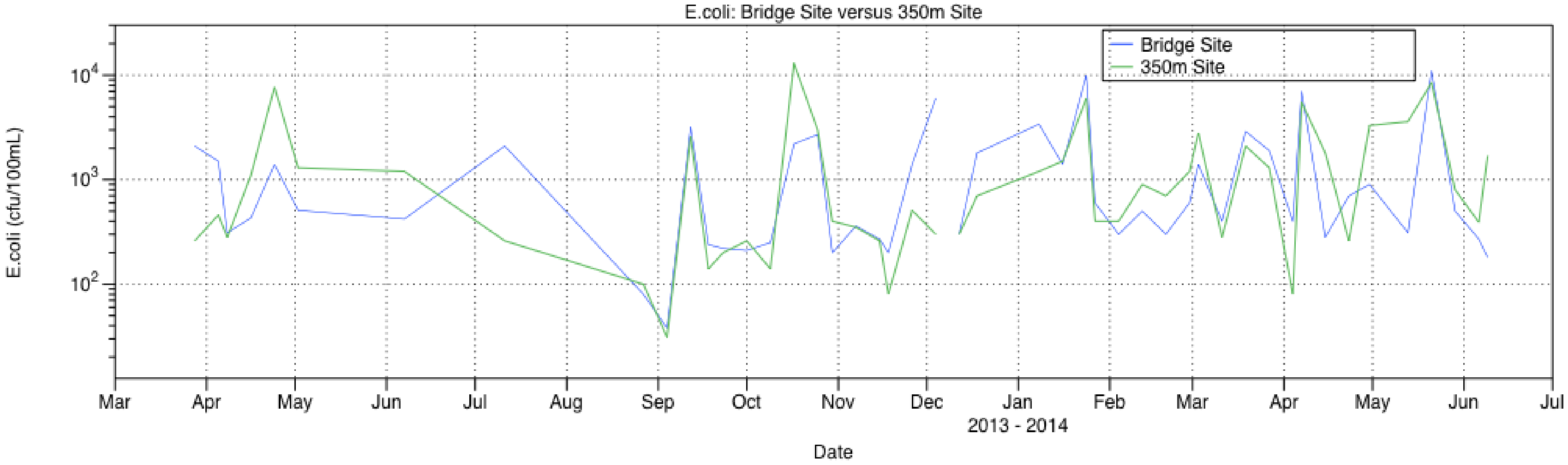

Figure 25: E. coli counts at the Bridge and 350 m Sites between December 2001 and June 2014.

Table 16: MfE/MoH microbiological assessment category definitions for Makarewa River and related sites.

MoH/MfE Category	N	A (≤130 cfu/100 mL)	B (131–260 cfu/100 mL)	C (261–550 cfu/100 mL)	D (>550 cfu/100 mL)
Site U2	22 (19)	1 (1)	2 (0)	5 (4)	14 (14)
Bridge Site	47 (29)	2 (0)	7 (1)	16 (11)	22 (17)
Site D2	22 (19)	2 (1)	3 (2)	5 (5)	12 (11)
Site D1	22 (19)	1 (0)	2 (1)	6 (5)	13 (13)
350 m DS Site	47 (29)	4 (2)	8 (3)	11 (9)	24 (15)
Boundary Site	47 (29)	3 (1)	13 (7)	12 (9)	19 (12)
Makarewa-Oreti River confluence	22 (19)	1 (0)	5 (3)	4 (4)	12 (12)
Tomoporakau Stream	3 (3)	0 (0)	0 (0)	3 (3)	0 (0)

Note: N = number of samples, number is parentheses = occurrences during the bathing season (November-April).

Biological Monitoring Site and Lower Makarewa River Water Quality

Alliance collected water quality data from Sites D1, D2, U2 and the lower Makarewa River at the confluence with the Oreti River between August 2013 and June 2014 in order to assess differences in nutrient concentrations and indicator bacteria counts between compliance monitoring sites (Bridge, 350 m and Boundary Sites), biological monitoring sites (Sites U2, D1 and D2) and the lower Makarewa just upstream of the Oreti River.

Data for U2, D1, D2 and the lower Makarewa River at the confluence with the Oreti River are summarised in Tables 15–18, Appendix 2. At Site U2 the physico-chemical parameters (temperature, pH and conductivity) closely matched that at the Bridge Site, although median DO concentrations were higher at Site U2 (11 g/m^3 compared with 10 g/m^3 at the Bridge Site between 2013 and 2014). Median TN and TP concentrations were marginally lower at Site U2 than at the Bridge Site. Faecal coliform and *E. coli* counts at Site U2 were similar to the Bridge Site.

The water quality at Site D2 (immediately upstream of the discharge) was closely matched to that of the Bridge Site. Likewise, the water quality at Site D1 (150 m downstream of the discharge) was closely matched to that of the 350 m Site.

The water quality at the site just upstream of the confluence with the Oreti River was similar to that of the Boundary Site with respect to physico-chemical parameters with the exception of conductivity which was lower; the median conductivity was 0.27 mS/m compared with 0.32 mS/m at the Boundary Site over the sampling period. TN and TP median concentrations upstream of the confluence with the Oreti River were lower than at the Boundary Site over the sampling period (2.4 g/m^3 compared with 3.7 g/m^3 and 0.16 g/m^3 compared with 0.32 g/m^3, respectively). BOD concentrations, FC counts and *E. coli* counts were similar at the site at the confluence with the Oreti River and the Boundary Site.

Boiler Ditch and Tomoporakau Stream Water Quality

Alliance also collected water quality samples from the boiler ditch and the Tomoporakau Stream between mid-December 2013 and late January 2014 to assess what contribution this streams makes to the nutrient loads in the discharge. The boiler ditch and Tomoporakau Stream water quality is not tabulated due to lack of data (three data points) but is described in this section.

The boiler ditch receives the discharge approximately 30 m upstream of its confluence with the Makarewa River the Tomoporakau Stream joins the Makarewa River between the 350m Site and the Boundary Site.

The boiler ditch water quality was characterised by low DO (2.0–3.9 g/m^3), high nutrients: TN, 3.8–6.3 g/m^3; TP, 0.24–0.60 g/m^3; and BOD, <6–31 g/m^3. Microbiological counts were moderate: FC, 1300–6000 MPN/100mL; *E. coli*, 400–3000 cfu/100mL.

The Tomoporakau Stream water quality was characterised by moderate DO (6.2–7.3 g/m^3), high nutrients: TN, 2.5–4.4 g/m^3; TP, 0.03–0.56 g/m^3; and low BOD, <2–3 g/m^3. Microbiological counts were moderate: FC, 500–700 MPN/100mL; *E. coli*, 500 cfu/100mL.

5.3 Makarewa River Sediment Quality

River sediment sample textures, nutrient concentrations and total organic carbon, TN and TP in the <63 mm fraction for the 2002 and June 2014 surveys are presented in Table 17 and Table 18. A survey of sediment quality in 2002 by Kingett Mitchell Ltd at sites upstream and downstream of the Alliance discharge showed elevated nutrient concentrations in the immediate vicinity of the discharge (100–200 m) (Kingett Mitchell 2002).

The 2014 survey results indicate a similar pattern. There is an increase in all parameters downstream of the Alliance discharge including TP, TN Amm-N and TOC.

Compared with sediment from near the Wallacetown Bridge, where the river channel gradient is higher, there is a trend to greater silt immediately downstream of the discharge, and greater sand and less gravel immediately upstream of the discharge in 2014.

There are some notable differences in the sediment grain sizes between the 2002 and 2014 surveys. Sediments 100 m and 200 m upstream and downstream of the discharge contained relatively greater proportions of sand and less gravel in 2014 than in 2002.

ANZECC has not derived sediment nutrient guidelines, but according to the condition ratings developed by for Southland estuaries (e.g., Robertson & Stevens, 2013), Makarewa River sediments are rated as very good for TOC (<1%) at all sites sampled in 2014. For TN upstream sites in 2014 are rated as very good (<0.05%) and downstream sites in 2014 are rated as good (0.05–0.2%).

Table 17: Sediment texture characteristics at Makarewa River sites.

Location	% <0.63 mm		% <2 mm		% >2 mm	
	2002	2014	2002	2014	2002	2014
Upstream 2 km	4.1	3.4	79.9	54.4	16.0	42.3
Upstream 150 m	10.7	0.8	42.3	95.4	22.0	3.7
Upstream 100 m	5.3	3.8	72.9	89.1	47.0	7.2
Downstream 100 m	4.6	4.5	30.7	43.5	65.0	52.0
Downstream 200 m	7.0	10.3	24.7	55.3	69.0	34.4
Downstream 1.5 km	6.2	12.2	94.1	88.7	<0.1	0.3

Table 18: Summary of sediment nutrient concentrations at Makarewa River sites.

Location	TOC%		TN%		Amm-N (mg/Kg)		TP (mg/Kg)		Olsens P (mg/Kg)	
	2002	2014	2002	2014	2002	2014	2002	2014	2002	2014
Upstream 2 km	0.29	0.32	<0.05	<0.05	8	<5	391	410	7	10
Upstream 150 m	0.22	0.20	<0.05	<0.05	9	<5	514	350	11	12
Upstream 100 m	1.10	0.32	0.11	<0.05	13	8	500	420	11	15
Downstream 100 m	0.52	0.89	0.07	0.09	34	43	728	940	26	47
Downstream 200 m	1.08	0.75	0.13	0.09	34	50	787	540	33	38
Downstream 1.5 km	0.26	0.72	<0.05	0.06	13	22	442	630	13	29

Summary

A comparison of Makarewa River temperature data indicates there is little difference between the Bridge Site, the 350 m Site and the Boundary Site. Alliance's consent stipulates that Class D Standards apply for the Makarewa River, namely 'the natural water temperature shall not be changed by more than 3°C'. This requirement was not met on two occasions between December 2001 and June 2014.

The summary statistics indicate a slight increase in pH downstream of the discharge. On no occasion was the pH at the 350 m Site outside the pH range stipulated in the consent (6.0–9.0). pH data from the sonde indicated a typical diurnal pH pattern, however at the 350m Site the median pH spread (0.38) was not large.

DO at the 350 m Site was slightly less than that at the Bridge Site 79% of the time, but the DO consent condition, that 'DO concentration of the receiving waters beyond 350 m of the point of discharge shall be consistently maintained at not less than 6 g/m^3', was fully met. Class D Standards require DO not to be reduced below 5 g/m^3 and this condition was met 99.7% of the time. DO data from the sonde during a summer low flow period indicated a clear diurnal pattern; the DO range was 7.3–12 g/m^3.

The consent requires river water clarity tube not be reduced below 20% at the 350 m Site compared with the Bridge Site. There was a consistent reduction in water clarity at the 350 m Site and a greater than 20% reduction 20% of the time in exceedence of the current consent limit. The 20% change in clarity within the current consent is for manging clear water rivers used for bathing. The appropriate water clarity change limit for the Makarewa River is 33–50%.

The median TN concentration at the Bridge Site was 1.3 g/m^3 and was predominately comprised of organic nitrogen and TON. There was a significant increase in TN at the 350 m Site (median 5.3 g/m^3) and the Boundary Site (3.8 g/m^3). The composition of TN at the downstream sites was dominated by Amm-N. The consent contains two Amm-N conditions, both of which were met to a high degree (>99%) of compliance.

The median TP concentration at the Bridge Site was 0.067 g/m^3 and increased to 0.49 g/m^3 and 0.32 g/m^3 at the 350 m Site and the Boundary Site, respectively. TP upstream was more associated with particulates (60%) than the downstream sites (25–29%).

The SRC Regional Water Plan FC limit is <1,000 MPN/100mL for lowland surface water bodies (excluding popular bathing sites). Median FC counts exceeded this limit at the Bridge Site and 350m Site but not at the Boundary Site. Median FC counts were lower at the 350 m Site compared to the Bridge Site on 56% of sampling occasions. The annual median FC count was higher at the Bridge Site compared to the 350m Site on 8 out of the 14 years analysed.

At Site U2 the physico-chemical parameters, nutrient concentrations, and microbiological parameters closely matched that at the Bridge Site; likewise the water quality at Site D1 closely matched to that of the 350 m Site. The water quality at the site just upstream of the confluence with the Oreti River was similar to that of the Boundary Site with respect to physico-chemical parameters but nutrient concentrations upstream of the confluence with the Oreti River were lower than at the Boundary Site.

River sediment at sites upstream and downstream of the discharge showed elevated nutrient concentrations in the immediate vicinity of the discharge (100–200 m) and at a site 1.5 km downstream.

6.0 Makarewa River Ecology

6.1 In-stream Habitat

In-stream habitat in the vicinity and downstream of the discharge reflects the low gradient, tidal and highly modified nature of the lower Makarewa River. In-stream habitat also reflects the gradient of influence that tide, channel gradient and morphology has between the upstream and downstream sites. Figure 26 to Figure 28 show a view of each of the biological monitoring sites during the summer 2013, spring 2013 and summer 2014 surveys.

Sites D1 and D2 were characterised by a large (1.0–1.5 m) difference in river water level and water velocity 0–1.2 m/s) between low and high tide. There is a slight change in river water level (0.1 m) and velocity between low and high tide at Sites U1 and U2. Mean riffle width at Site D1 and D2 on the November 2013 survey ranged from 30–40 m while the mean width at upstream sites was 25 m. Mean riffle depth was similar among sites ranging from 0.20–0.24 m at Site U1 to 0.31–0.43 m at Site U2. Mean riffle water velocity reflected the channel gradient with Site D2 having water velocities that were lower compared to the other sites (Table 19).

All sites have a U shaped channel that is characterised by relatively uniform depth across the river. Site U1 had the coarsest substrate with 40% cobble and 60% gravels, Sites U2 and Site D2 were dominated by gravels (90%) with some sand (10%) while Site D1 had 60–100% gravels and 20% cobbles. The finer substrate and lower water velocity at Sites D1 and D2 provide habitat that is much less suited to mayflies such as *Deleatidium* and caddisflies that prefer coarser substrate and higher water velocity. Substrate embeddedness, a measure of sediment deposition, was higher at Site D1 (30%) compared to the other sites (10%) and is reflective of the lower energy environment at that site.

Table 19: Stream habitat during summer 2013, spring 2013 and summer 2014 surveys.

Parameter	Site U1	Site U2	Site D2	Site D1
Site length (m)	100	100	100	100
Wetted width (m)	25	25	40	30
Mean riffle depth (m)	0.20, 0.24,0.22	0.31, 0.37, 0.43	0.3, 0.26, 0.28	0.24, 0.32, 0.42
Mean riffle velocity (m/s)	1.1, 1.0, 1.4	0.88, 1.1, 0.5	0.52, 0.40, 0.35	1.0, 0.55, 1.2
% Riffle,% run,% pool	Ri20, Ru40, P 40	Ri30, Ru40, P30	Ri30, Ru35, P35	Ru40, P40, Ri20
Riffle, run, pool channel shape	U	U	U	U
Riffle% substrate size classes	G 60, C 20 G 60, C 40 G 60, C 40	G 100 G 80, C 20 G 80, C 20	G 90, Sa 10 G 90, Sa 10 G 100	G 60, Sa 40 G 80, C 20 G 80, C 20
% embeddedness	10, 10, 10	10, 10, 10	30, 30, 30	10, 10, 10
Substrate compactness	Low, low, low	Low, low, low	Low, low, low	Low, low, low
Scouring	Mod, mod, mod	Mod, mod, mod	Low, low, low	Low, low. low

Note: Riffle velocity and depth is the mean of 3–6 readings, Ri = riffle, Ru = run, P = pool, G = gravel, C = cobble, Sa = sand. Channel shape, substrate classes, embeddedeness, compactness and scouring were visually assessed.

Spring 2013 Summer 2013 Summer 2014

Figure 26: View of Site U1 during the spring 2013, summer 2013 and summer 2014 biological surveys.

Spring 2013 Summer 2013 Summer 2014

Figure 27: View of Site U2 during the spring 2013, summer 2013 and summer 2014 biological surveys.


Spring 2013

Summer 2013

Summer 2014

Figure 28: View of Site D2 during the spring 2013, summer 2013 and summer 2014 biological surveys.


Spring 2013

Summer 2013

Summer 2014

Figure 29: View of Site D1 during the spring 2013, summer 2013 and summer 2014 biological surveys.

Physico-chemical conditions and water clarity was similar among sites during the March 2013 and March 2014 surveys. Noteworthy features of the physico-chemical results was the lower DO concentration at Site D1 and higher conductivity and salinity recorded at Site D1 reflecting the influence of the discharge (Table 20).

Table 20: Stream physico-chemical data for the summer 2013, and summer 2014 surveys.

Parameter	Site U1	Site U2	Site D2	Site D1
Date/time	8 March, 12pm	8 March, 10 am	8 March, 10am	8 March, 8am
Clarity (m)	0.91	>1.0	0.91	0.85
Temperature (°C)	15.6	15.0	15.5	15.6
Dissolved oxygen (g/m^3)	9.9	9.2	9.2	8.6
pH (pH units)	7.52	7.29	7.28	7.72
Conductivity (µS/cm)	170	170	177	306
Salinity	0.10	0.10	0.10	0.18
Date/time	14 March, 1 pm	14 March, 6 pm	14 March, 7 pm	14 March, 8 pm
Clarity (m)	>1.0	NR	NR	0.85
Temperature (°C)	16.0	17.3	17.1	17.1
Dissolved oxygen (g/m^3)	9.7	10.7	10.7	8.6
pH (pH units)	7.71	7.96	7.97	7.96
Conductivity (µS/cm)	113	115	115	280
Salinity	0.06	0.06	0.06	0.16

Note: Clarity = measured with a clarity tube.

The tidally influenced section of the lower Makarewa River, downstream of the discharge mixing zone, is a meandering low gradient river characterised by soft river bed and bank sediments and gently flowing run and pool habitat dominated by submerged macrophytes. The lower Makarewa River is strongly influenced by the tide and has been heavily modified by flood control works and agriculture. The depositional nature of the tidally influenced lower Makarewa River means that thick silt and mud is very common. The riparian zone comprises grazed and rank pasture grasses (Figure 30).

Figure 31 shows a view of the Makarewa River immediately upstream of the confluence with the Oreti River. Figure 32 shows a view of the Oreti River immediately downstream of the confluence with the Makarewa River.

Figure 30: View of the Makarewa River approximately 600 m downstream of the discharge.

Figure 31: View of the Makarewa River immediately upstream of the confluence with the Oreti River.

Figure 32: View of the Oreti River immediately downstream of the confluence with the Makarewa River.

Summary

The in-stream habitat in the vicinity and downstream of the discharge reflected the low gradient, tidal and highly modified nature of the lower Makarewa River. In-stream habitat also reflects the gradient of influence that tide, channel gradient and morphology has between the upstream and downstream sites. Sites D1 and D2 were characterised by a large (1.0–1.5 m) difference in river water level and water velocity (0.0–1.2 m/s) between low and high tide. There was a slight change in river water level (0.1 m) and velocity between low and high tide at Site U2.

All sites have a U shaped channel that is characterised by relatively uniform depth across the river. Site U1 has the coarsest substrate, followed by Sites U2 and Site D1 and then Site D2.

The Makarewa River, downstream of the discharge is a meandering low gradient river characterised by soft river bed and bank sediments and gently flowing run and pool habitat dominated by submerged macrophytes. The lower Makarewa River is strongly influenced by the tide and has been heavily modified by flood control works and agriculture. The riparian zone comprises grazed and rank pasture grasses.

6.2 Aquatic Plants

March 2010 Survey

A survey of the periphyton community was undertaken at two sites upstream (one approximately 200 m upstream and one site approximately 2 km upstream) and one site approximately 200 m downstream of the discharge in March 2010 (Golder 2010). The following summarises the key results from the March 2010 survey:

- Periphyton cover was below the MfE (2000) guidelines (<60% >0.3 cm thick) at all sites.
- Periphyton Ash Free Dry Weight (AFDW) and chlorophyll-*a* exceeded the MfE (2000) guideline for the protection of trout habitat (<35 g/m^2) at the site downstream of the discharge.
- Periphyton chlorophyll-*a* exceeded the MfE (2000) guideline for the protection of benthic biodiversity (<50 mg/m^2) at the downstream site and also at the site 2 km upstream of the discharge.
- Periphyton autotrophic index scores were high at all three sites but below the level that is indicative of organic enrichment.

The MfE (2000) periphyton guidelines were based on a survey of riffles in 30 clear water, cobble-bed rivers. Site U1 is the only site in the Golder (2010) survey to which the MfE (2000) guidelines can be directly applied. Site U2 (approximately 80 m upstream from Site D2 in the current study) and Site D1 have habitat conditions (poor clarity, tidal influenced, deeper, slow flowing, fine gravel dominated substrate) that fit them into the macrophyte dominated community category to which the MfE (2000) guidelines cannot be readily applied (MfE 2012).

Golder (2010) also reported on the composition of the periphyton community stating that:

A total of 60 taxa were identified across all sites sampled in March 2010, with the periphyton community being dominated by diatoms (48 taxa). Fifteen of these taxa were found exclusively at either or both of the sites upstream of the discharge and six taxa were found exclusively at the site downstream. The diatom species Melosira varians, was recorded at all three sampling sites in March 2010 and on average was recorded as 'common' at these sites. Melosira varians is found throughout New Zealand in slow to medium flowing rivers and can dominate in moderately enriched conditions, and has been reported as both a clean water and moderately pollution species. Oedogonium sp. was recorded as being dominant at Site U1 and Site U2 in March 2010. This genus is common and widespread and is normally associated with fairly enriched conditions and stable low flows. The cyanobacteria Phormidium spp. was recorded as dominant at Site D1 downstream of the discharge, and is also common throughout New Zealand and can become especially abundant in highly conductive waters (MfE 2000).

2013/2014 Surveys

There was insufficient algal material on substrate at Sites D1, D2 during the March 2013, November 2013, February 2014 and March 2014 surveys to allow samples to be collected and Chlorophyll-*a* and AFDW analysis to be undertaken. The lack of algal material at Sites D1 and D2 during the surveys is reflective of the unsuitable nature of the habitat for supporting periphyton growths which include deep, slow flowing habitat, poor water clarity and fine substrate. The habitat conditions at Sites D1 and D2 are much more suited to supporting a macrophyte dominated aquatic plant community.

Periphyton and total macrophyte cover results from the March 2013, November 2013, February 2014 and March 2014 surveys are presented in Figure 33 to Figure 36. The survey results show that Site U1 differed from the other sites on all four sampling occasions with a greater cover of thick mats and long filamentous green algae compared to the thin films and macrophyte dominated community at Sites U2, U2 (up), and D2 (upstream of the discharge) and at Site D1, downstream of the discharge. The MfE (2000) periphyton diatom cover guideline of <60% >0.03 cm thick, was exceeded at Site U1 in the November 2013 and the MfE (2000) guideline for long filaments (<30%, >2 cm) was also exceeded at Site U1 in the February 2014 survey. The MfE (2000) long filamentous green algae cover guideline was exceeded at Site U2 in the February 2014 survey.

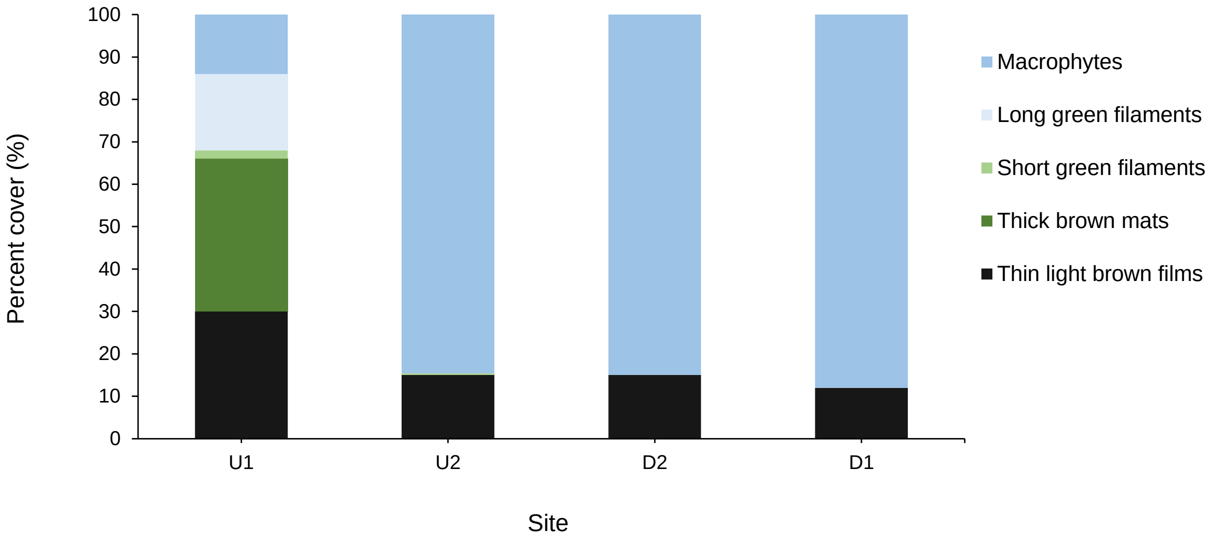

Figure 33: Periphyton and macrophyte cover in March 2013 survey.

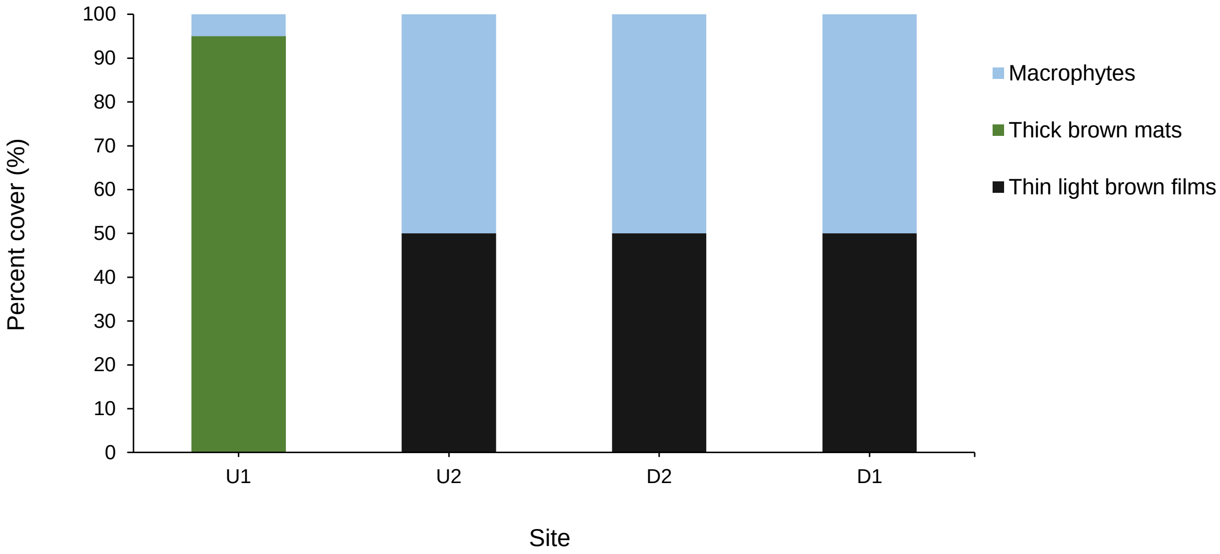

Figure 34: Periphyton and macrophyte cover in November 2013 survey.

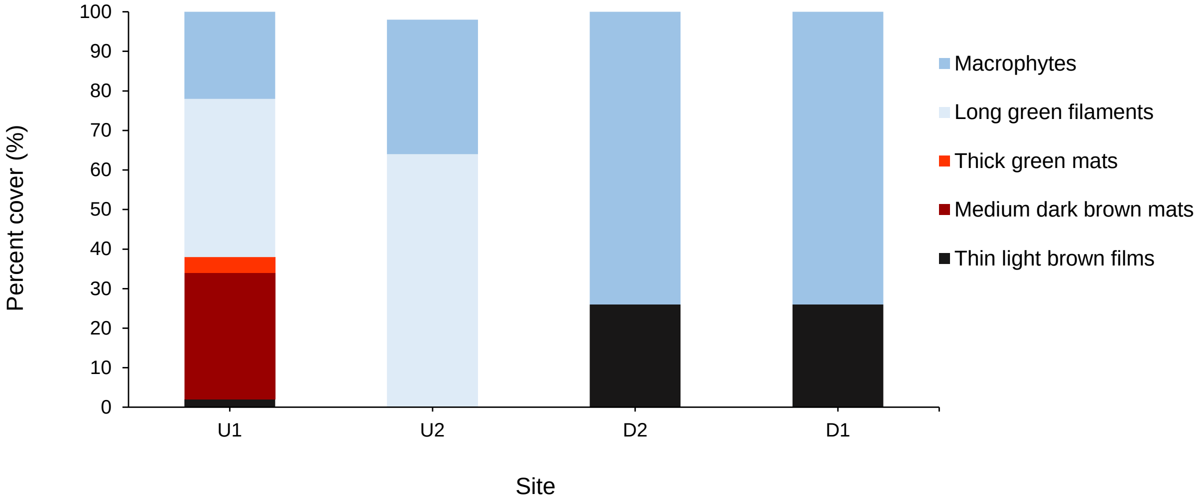

Figure 35: Periphyton and macrophyte cover in February 2014 survey.

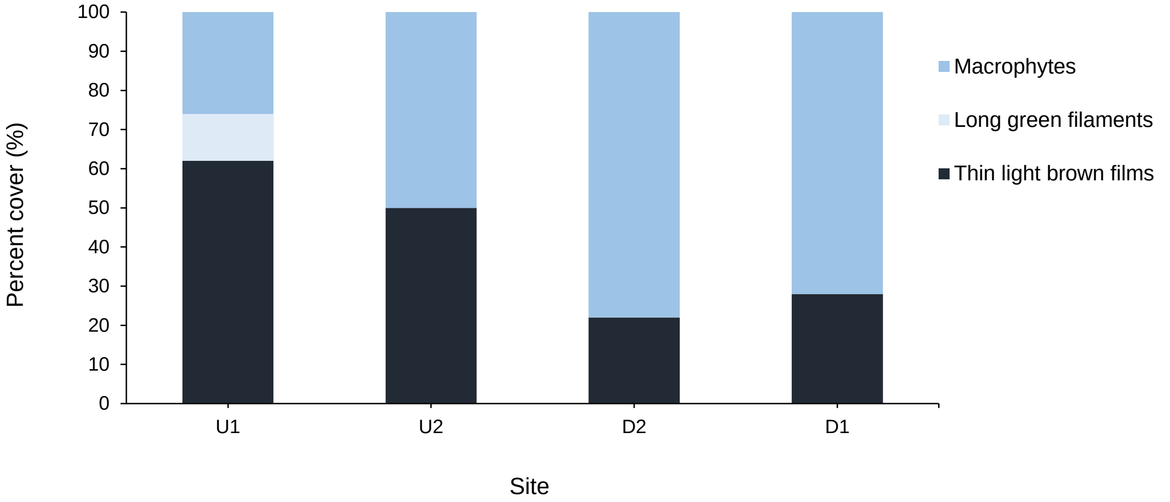

Figure 36: Periphyton and macrophyte cover in March 2014 survey.

Total macrophyte cover was lower at Site U1 across all 4 surveys (range 5–22%) compared to Site U2 (range 35–85%), Site D1 (range 50–88%) and Site D2 (50–85%) and shows that there is a significant increase in macrophyte cover between the most upstream site (Site U1) and the most downstream site (Site D1). Total macrophyte cover at Site U2, which is on the upstream boundary of the influence of the tide, was similar to the downstream sites in the March 2013 (85% cover) and November 2013 (≤50% cover) but was lower in February 2014 (35% cover) compared to downstream sites in February 2014 (70–76% cover). Total macrophyte cover was greater during summer surveys (March 2013, February 2014 and March 2014) compared to spring (November 2013).

The submerged (sub) and surface reaching (sur) rooted macrophyte community during the February 2014 survey was dominated by an introduced species that can reach nuisance levels - *Potomogeton crispus* (curly pondweed), with patches of native species *Potomogeton ochreatus* (blunt pondweed) and *Myriophyllum triphylllum* (mis identified as hornwort in previous report version, pending confirmation after further sampling) (Figure 37). Total macrophyte cover exceeded the MfE (2012) recommended provisional guidelines of ≤50% cover of river bed area or river surface area at Site U2 (upstream of discharge), Site D1 (150 m downstream of discharge) and Site D2 (70 m upstream of discharge) in March 2013 and November 2013. Total macrophyte cover also exceeded the MfE (2012) recommended provisional guidelines at Sites D1 and D2 in February 2014.

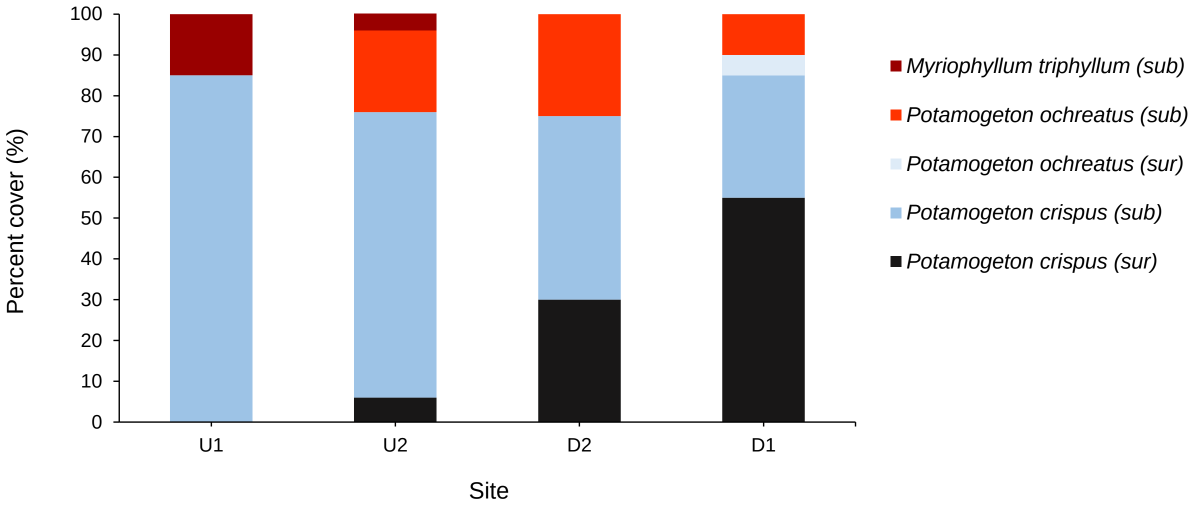

Figure 37: Macrophyte community composition in February 2014 survey.

Summary

There was insufficient algal material on substrate at Sites D1, D2 during surveys in 2013–2014 to allow samples to be collected and chlorophyll-*a* and AFDW analysis to be done. The lack of algae at Sites D1 and D2 is reflective of the unsuitable nature of the habitat for supporting periphyton.

Periphyton cover results from Site U1 (upstream of the discharge) differed from the other sites on all 4 sampling occasions with a greater cover of thick mats and long filamentous green algae compared to the thin films and macrophyte dominated community at Sites U2, U2 up, D2 (upstream of the discharge) and Site D1 (downstream of the discharge). The MfE (2000) periphyton cover guidelines were exceeded at Site U1 in the November 2013 and February 2014 surveys. The MfE (2000) long filamentous green algae cover guideline was exceeded at Site U2 (downstream of the Wallacetown Highway Bridge) in the February 2014 survey.

Total macrophyte cover was lower at Site U1 across all 4 surveys (range 5–22%) compared to Site U2 (range 35–85%), Site D1 (range 50–88%) and Site D2 (50–85%) and shows that there is a significant increase in macrophyte cover between the most upstream site (Site U1) and the most downstream site (Site D1).

The submerged and surface reaching rooted macrophyte community during the February 2014 survey was dominated by an introduced species that can reach nuisance levels including *Potomogeton crispus* (curly pondweed) and the native species *Potomogeton ochreatus* (blunt pondweed).

Total macrophyte cover exceeded the MfE (2012) recommended provisional guidelines of ≤50% cover of river bed area or river surface area at Sites U2, D1 and D2 in March 2013 and November 2013. Total macrophyte cover also exceeded the MfE (2012) recommended provisional guidelines at Sites D1 and D2 in February 2014.

6.3 Benthic Invertebrates

Introduction

Due to the difficulties in controlling for differences in habitat among sites associated with the tidal nature of the section of riverbed surveyed the best method of assessing the effect of the discharge is to compare the results at individual sites over the four surveys (three when the discharge was occurring and one without the discharge). The following section describes the results of each of the surveys separately and then analyses the results from each site among the surveys. A summary of statistical analyses results is presented in Appendix 4.

March 2010 Survey

A survey of the benthic invertebrate community was undertaken at two sites upstream (one approximately 200 m upstream and one site approximately 2 km upstream) and one site approximately 200 m downstream of the discharge in March 2010 Golder (2010). The following summarises the key results from the March 2010 survey:

- The invertebrate community was dominated by water quality and habitat tolerant taxa at all three sites but there was a higher proportion of sensitive taxa at the site 2 km upstream.
- MCI scores were low (range 60–83 at all three sites) with the lowest MCI recorded downstream of the discharge being below the SRC guideline of >80.
- The benthic invertebrate community at the Wallacetown Bridge site monitored by SRC was healthier compared to the sites immediately upstream and downstream of the discharge.

Golder (2010) stated that:

> *Macroinvertebrate composition at Site U1 was dominated by oligochaete worms (43%) and Diptera larvae (24%) in March 2010. In comparison, Site U2 was dominated by equal proportions of molluscs (30%), especially the snail Potamopyrgus, and Crustacea (30%), which consisted almost entirely of amphipods. Ephemeroptera, in particular the common mayfly Deleatidium, were found only at sites upstream of the discharge. Macroinvertebrate composition at Site D1 downstream of the discharge was dominated by oligochaete worms (38%). Other dominant groups recorded at Site D1 were Platyhelminthes (flat worms).*

Community Composition

March 2013 Survey

The benthic invertebrate community composition in March 2013 was similar at the upstream sites (Sites U1 and U2) and was dominated by caddisflies (trichopterans), molluscs (snails), worms (oligochaetes) and dipterans. The dominant taxa groups at Sites D1 and D2 in March 2013 were molluscs, crustaceans and worms, all water and habitat tolerant groups that prefer slow flowing weedy habitat (Figure 38). Mayflies (Ephemeroptera) made up a small percentage of the community at upstream sites. Mayflies made up a very small percentage of total abundance at Site D2 and were absent from Site D1 in March 2013 where habitat is not suited to this group (Figure 38).

Key features of the benthic invertebrate community at Site D1 in March 2013 was the high numbers of cladocerans and *Hydra* which are most likely to have come from Alliance's wastewater treatment ponds and the presence of a single damsel fly larvae (the only one recorded at any of the sites across the three surveys) which is indicative of the slow flowing and weedy habitat, adjacent to the small area of cobble substrate sampled at Site D1. Other notable features of the community at Site D1 were the absence of *Deleatidium*, which is a mayfly that prefers stony, clean fast flowing habitat and is intolerant of slow water velocities and the presence of two cased caddis taxa (*Pycnocentrodes* and *Pycnocentria*) that are typically found in clean water habitat and that can tolerate lower water velocities (Appendix 2).

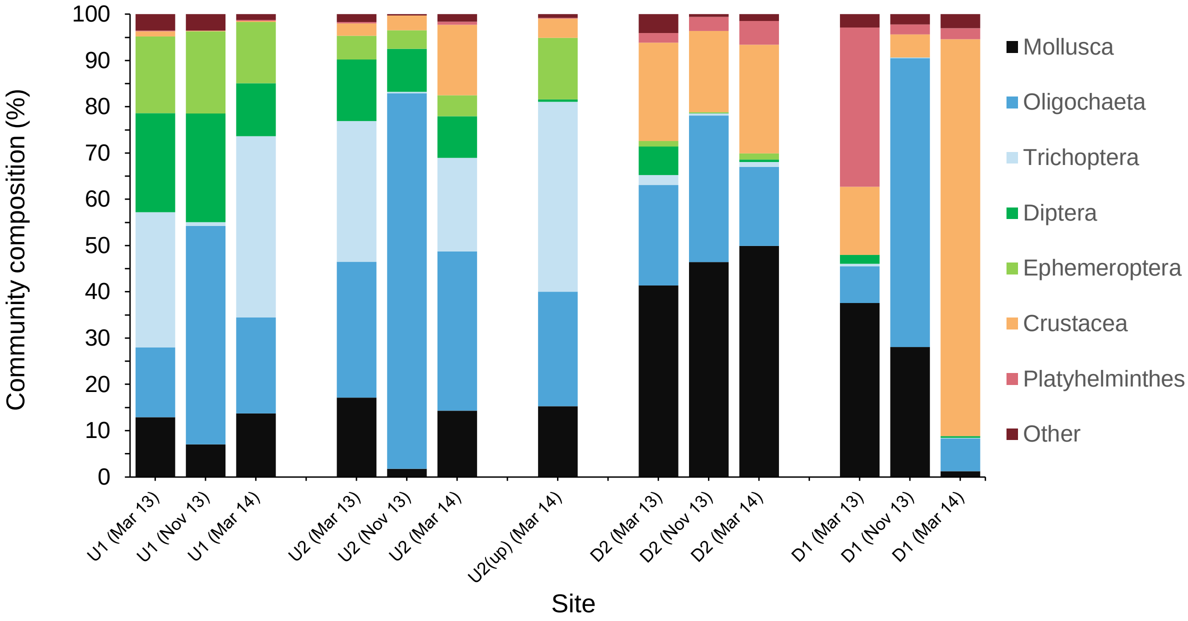

Figure 38: Relative abundance of major taxa groups in March 2013, November 2013 and March 2014.

November 2013 Survey

The benthic invertebrate community survey in November 2013 was undertaken during the Alliance off season and following a period of approximately two months without treated wastewater being discharged. The primary objective of the November 2013 survey was to determine whether invertebrate community health improved during the off season.

The dominant taxa group across all the sites was oligochaetes, a water and habitat quality tolerant group, reflective of poor water and habitat quality among sites (Figure 38). Molluscs were the next most dominant group at downstream sites and are reflective of the low water velocity environment in the lower river. Ephemeroptera made up a small proportion of total abundance at upstream sites but were absent or in very low numbers at downstream sites. Diptera made up 26% of total abundance at Site U1 and reflecting the extensive long green filamentous algal cover. Crustacea abundance increased in a downstream direction reflecting the increased tidal effects on water velocity and habitat in a downstream direction and the proximity to the wastewater treatment ponds.

Key features of the benthic invertebrate community at Site D1 in November 2013 were the absence of cladocerans and hydra (due to the lack of the wastewater discharge) and the absence of *Deleatidium*, and caddisflies such as *Pycnocentrodes* and *Pycnocentria* that prefer clean water (Appendix 2).

March 2014

The invertebrate community in March 2014 was similar at Site U1 and U2 up and was dominated by caddisflies (trichopterans), molluscs (snails) and worms. The dominant taxa group at Sites D1 in March 2014 were crustaceans (86%) while at Site D2 the dominant groups were molluscs (50%), crustaceans (23%) and worms (17%) (Figure 38). Mayflies made up a small percentage (5–13%) of the community at upstream sites and were absent at Site D1 and made up 1% of the community at Site D2 in March (Figure 38).

The benthic community composition at Site U1 in March 2013 and March 2014 was broadly similar. The benthic community composition at Site U2 in March 2013 and March 2014 was also broadly similar. The key change in invertebrate community composition at the upstream sites across the 3 surveys was the large increase in the relative abundance of worms in the November 2013 survey.

The benthic invertebrate composition at Site D1 varied across the three surveys with crustaceans (cladocera) dominant (86%) in March 2014, worms dominant (62%) in November 2013 and molluscs dominant (38%) in March 2013. Key features of the benthic invertebrate community at Site D1 in March 2014 were the high numbers of cladocerans and hydra, the absence of *Deleatidium* and very low abundance of clean water caddisflies (e.g., *Pycnocentrodes* and *Pycnocentria*; Appendix 2) and was reflective of the unsuitable nature of the habitat at Site D1.

In contrast the community composition at Site D2 remained stable across the three surveys with crustaceans (range 18–23%), worms (range 17–32%) and molluscs (range 41–50%) dominating the community (Figure 38) and also reflected the unsuitable nature of the habitat at Site D2 for supporting habitat sensitive taxa.

Large Crustaceans and Freshwater Mussels

In addition to benthic macroinvertebrate sampling of riffle habitats freshwater crayfish (koura) and shrimps were surveyed during fish surveys in March 2013 and March 2014. A single freshwater shrimp (*Paratya*) was recorded at the downstream site (1 km downstream from the discharge) during the March 2013 survey. A single Paratya and koura were also recorded at Site U2 (up) during the electric fishing survey in March 2014.

Freshwater mussels have declined throughout New Zealand’s rivers due to a range of factors including sedimentation, eutrophication and a decline in native fish numbers. Several searches for freshwater mussels were carried out between the Wallacetown Bridge and the confluence of the Makarewa and Oreti Rivers during the biological surveys in summer 2013, spring 2013 and summer 2014. River bed and bank searches failed to find any live mussels. Several mussel shells or shell fragments were found on the river bank beneath the Wallacetown Bridge and at Site U2 but no shells or shell fragments were located downstream of the discharge. Some trout fishermen use mussels as bait and it is possible that the shells found beneath the Wallacetown Bridge and at Site U2, may have been discarded by fishermen or deposited by birds.

Freshwater Solutions contacted DOC, SRC, Keith Hamill, a former SRC freshwater biologist and Dr Greg Ryder who has surveyed Southland’s rivers extensively including the Makarewa River. DOC, SRC, Keith Hamill and Dr Ryder all said they had not seen freshwater mussels in the Makarewa River, although none had specifically searched for them. Freshwater mussels tend to be patchily distributed and difficult to find particularly in rivers with poor clarity such as the Makarewa River. Based on the available information it appears very unlikely that mussels exist in the tidally influenced section and a large proportion of the wider Makarewa River catchment.

Total Taxa Number

Mean taxa number was similar (p >0.05) at upstream and downstream sites in March 2013 and ranged from 16.4 ± 1.3 at Site D1 to 18.0 ± 0.6 at Site U1 (Figure 39). Mean taxa number was lower in November 2013 compared to March 2013 and ranged from 6 ± 0.2 at Site U2 and 13 ± 2 at Site U1 (Figure 39). Taxa number decreased from 13 ± 2 at Site U1 to 6 ± 0.2 at Site U2 in the November 2013 survey (p <0.5). Taxa number overall in November 2013 was higher at downstream sites compared to upstream sites (p <0.05).

Mean taxa number increased in March 2014 compared to November 2013 and ranged from 10 ± 0.7 at Site D1 to 19 ± 0.8 at Site U2 (up). Mean taxa number at Sites U1 and U2 had recovered in March 2014 to March 2013 levels after a decrease in taxa number at these sites in November 2013. The mean taxa number at Site D1 in March 2014 remained at the same level recorded in November 2013.

Overall mean taxa number varied at all sites among the three surveys (with and without the discharge). If the discharge was a significant factor determining taxa number then it is expected that taxa number at downstream sites would have increased in the survey when the discharge was not occurring. The mean taxa number results among the three surveys indicate that factors other than the discharge such as high flow events were exerting an influence on mean taxa number.

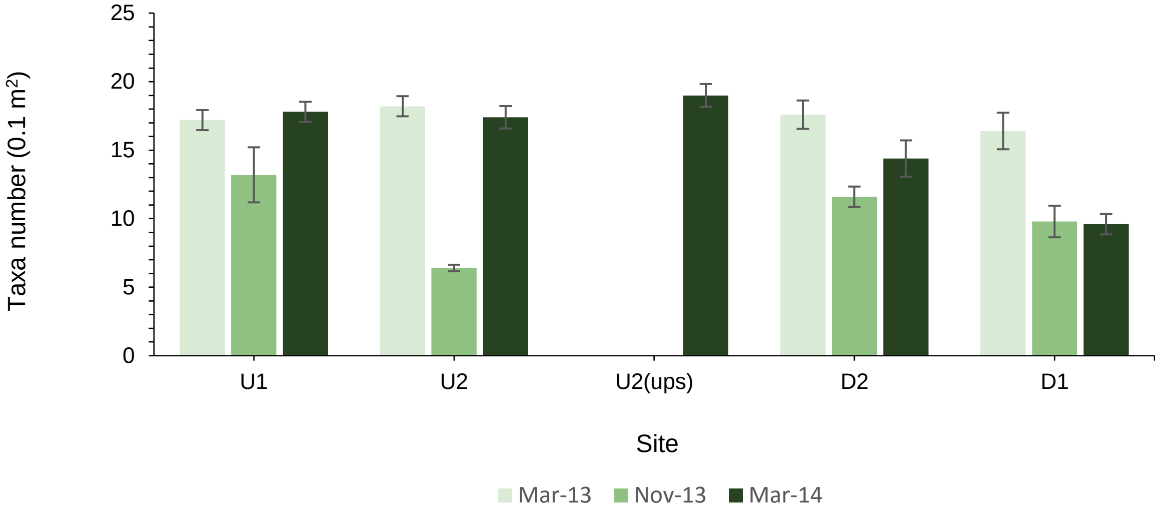

Figure 39: Mean (± 1 S.E.) taxa number recorded during the March 2013, November 2013 and March 2014 surveys.

EPT Taxa Number

Mean EPT taxa number was higher at upstream sites compared to downstream sites (p <0.05) in March 2013 and ranged from 3.2 ± 0.6 at Site D1 to 7.6 ± 0.2 at Site U2 (Figure 40). EPT taxa number was also lower in November 2013 compared to March 2013 and ranged from 1 ± 0.3 at Site D1 and 5 ± 1 at Site U1 (Figure 40). The EPT taxa number decreased from 5 ± 1 at Site U1 to 1 ± 0.2 at Site U2. Overall mean EPT number was lower at downstream sites compared to upstream sites.

EPT taxa number increased in March 2014 compared to November 2013 at all sites except Site D1 and ranged from 0.6 ± 0.2 at Site D1 to 6.4 ± 0.2 at Site U2 (up). Mean EPT taxa number at Sites U1 and U2 had recovered in March 2014 to March 2013 levels after a decrease in EPT taxa number at these sites in November 2013. The mean EPT taxa number at Site D1 in March 2014 was slightly below the level recorded in November 2013.

There was just a slight increase in mean EPT taxa number at Site D2 in March 2014 (3.0 ± 0.5) from November 2013 (2.2 ± 0.7) (Figure 40).

Collectively the mean EPT taxa results varied at all sites among the three surveys (with and without the discharge) indicating that factors other than the discharge such as reach scale habitat differences, high flow events and season were exerting an influence on the number of water and habitat sensitive EPT taxa (Figure 40).

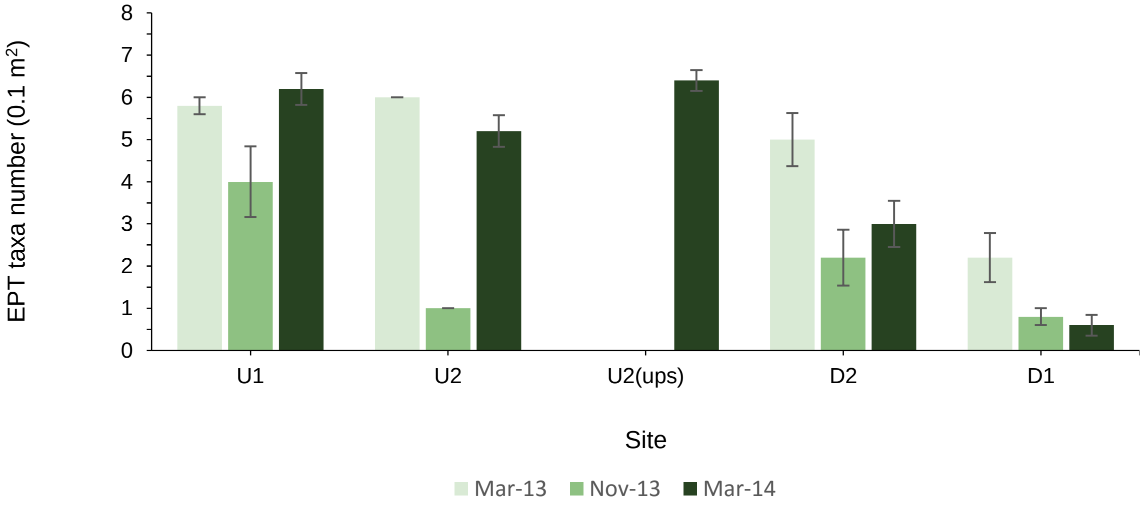

Figure 40: Mean (± 1 S.E.) EPT taxa number recorded during the March 2013, November 2013 and March 2014 surveys.

Deleatidium Abundance

Mean *Deleatidium* was lower in November 2013 compared to March 2013 ranging from 0 individuals at Site D1 and 89 ± 30 individuals at Site U1 (Figure 41). *Deleatidium* abundance decreased between Sites U1 and D1 and increased slightly at Site D2. *Deleatidium* abundance overall was higher at upstream sites compared to downstream sites ($p < 0.05$). *Deleatidium* abundance at Site D1 did not increase in November 2013 suggesting that habitat (substrate and water depth and velocity in particular) is likely to be the key factor in the absence of this taxa from this site.

Mean *Deleatidium* abundance increased in March 2014 compared to November 2013 at all sites except Site D1 and ranged from 0 individuals at Site D1 to 150 ± 35 individuals at Site U2. Mean *Deleatidium* abundance at Sites U1 and U2 had recovered in March 2014 to be close to the March 2013 levels after a decrease in *Deleatidium* abundance at these sites in November 2013. The *Deleatidium* abundance at Site D1 in March 2014 remained at 0 individuals across all three surveys. There was an increase in mean *Deleatidium* abundance at Site D2 in March 2014 (14 ± 5 individuals) from November 2013 (2 ± 1 individuals) (Figure 41). Mean *Deleatidium* abundance in March 2014 among the upstream sites (Site U1 and U2) was significantly higher compared to downstream sites (Sites D1 and D2) in March 2014 ($p < 0.05$) and is reflective of the suitability of the habitat for this taxa at upstream vs downstream sites.

Viewed together the results three surveys indicate that *Deleatidium* sp. abundance varied at all sites during the surveys with (March 2013 and 2014) and without (November 2013) the discharge. Habitat factors such as water depth and velocity associated with the influence of the tide, high flow events and season appear to exert a stronger influence on *Deleatidium* sp. abundance in the lower Makarewa River than the discharge (Figure 41).

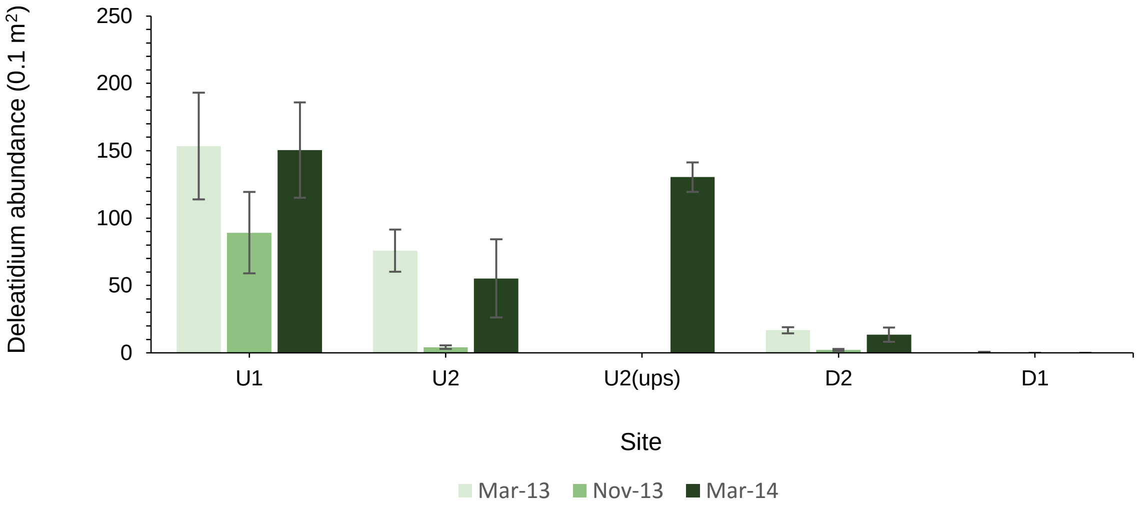

Figure 41: Mean (± 1 S.E.) *Deleatidium* abundance recorded during the March 2013, November 2013 and March 2014 surveys.

Oligochaete Abundance

Mean abundance of water and habitat quality tolerant oligochaetes was higher at upstream sites compared to downstream sites (p <0.05) in March 2013 and ranged from 151 ± 41 individuals at Site U1 to 414 ± 59 individuals at Site U2 (Figure 42).

Oligochaete abundance was higher at Sites D1 and U1 in November 2013 compared to March 2013. Oligochaete abundance was lower at Site U2 in November 2013 compared to March 2013 (Figure 42). Oligochaete abundance was higher at Sites U1 and U2 in March 2014 compared to November 2013.

Oligochaete abundance was lower at Sites D1 and D2 in March 2014 compared to November 2013 (Figure 42). The pattern in oligochaete abundance varied widely among sites across the three surveys with abundance increasing at Site U1 and decreasing at Site D2 across the surveys while at Sites U2 and D1 abundance was very low and very high respectively in November 2013 (Figure 42).

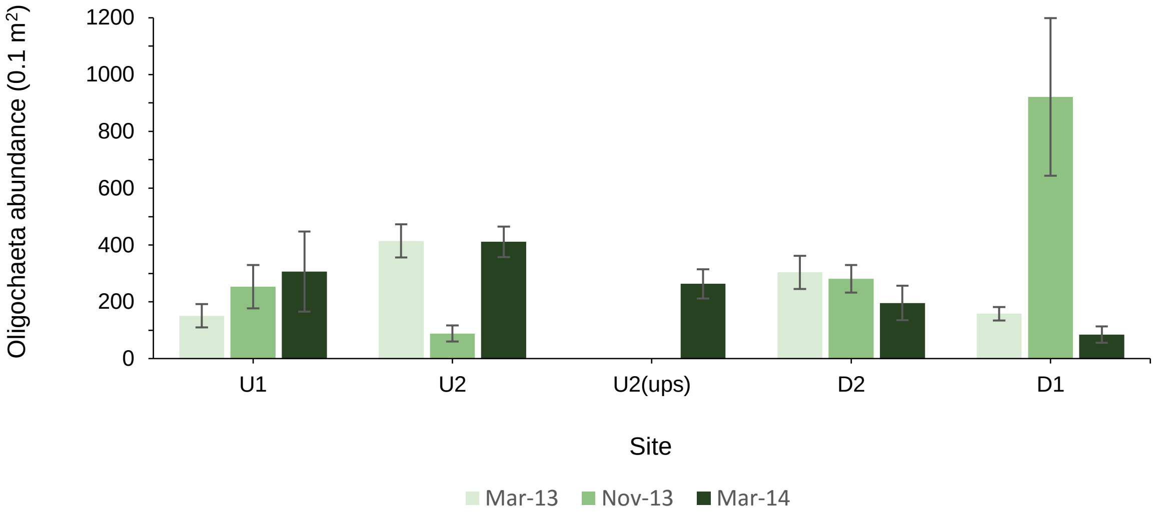

Figure 42: Mean (± 1 S.E.) oligochaete abundance recorded during the March 2013, November 2013 and March 2014 surveys.

Viewed together the results of three surveys indicate that oligochaete abundance varied at all sites during the surveys with (March 2013 and 2014) and without (November 2013) the discharge and in particular at Site U2 and Site D1 with habitat and factors other than the discharge clearly exerting a strong influence on oligochaete abundance (Figure 42).

Percent EPT

Mean %EPT in March 2013 and ranged from 1.0 ± 0 at Site D2 to 44 ± 2 at Site U1 (Figure 43) and added further evidence that the upstream sites provided better water and habitat conditions for water and habitat sensitive EPT taxa compared to downstream sites.

Mean %EPT was also lower in November 2013 compared to March 2013 and ranged from 19 ± 5 at Site U1 and 4 ± 1 at Site U2 (Figure 43). Percent EPT decreased between Sites U1 and U2 and mirrors the decrease in total taxa and EPT taxa number between the upstream sites. Percent EPT scores were lower overall at downstream sites compared to upstream sites ($p < 0.05$).

Mean %EPT increased in March 2014 compared to November 2013 at all sites except Site D1 and ranged from 0 at Site D1 to 52 ± 4 at Site U1. Mean %EPT at Sites U1 and U2 had recovered in March 2014 to be close to the March 2013 levels after a decrease in %EPT at these sites in November 2013.

The %EPT at Site D1 and Site D2 remained at 0 and <2% respectively across all three surveys (Figure 43). %EPT results among the three surveys indicate that %EPT varied at at upstream sites but remained at similar low levels at downstream sites among the surveys with and without the discharge. Results across the three surveys indicate that habitat and a range of factors other than the discharge are likely to play a key role in the %EPT within the invertebrate community upstream and downstream of the discharge (Figure 43).

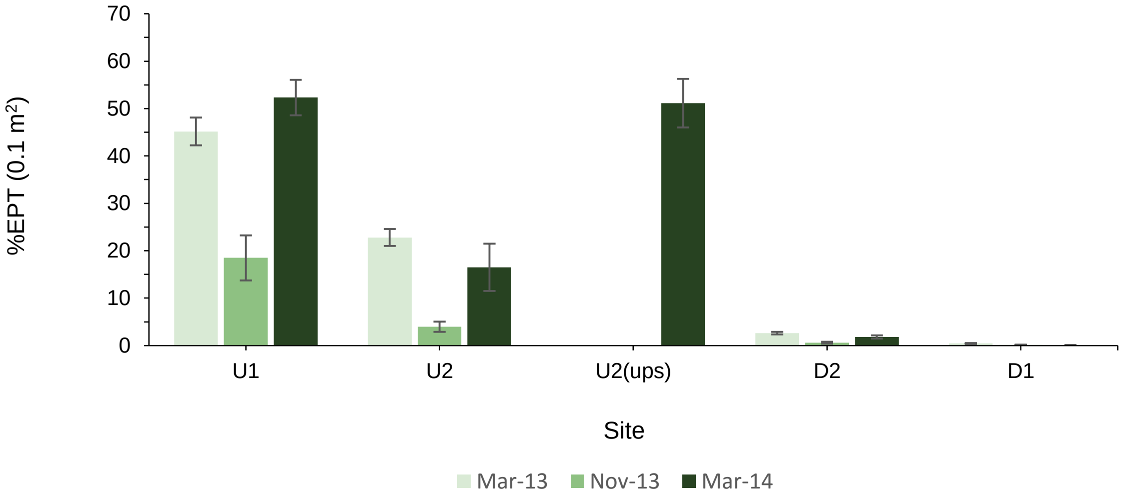

Figure 43: Mean (± 1 S.E.) %EPT recorded during the March 2013, November 2013 and March 2014 surveys.

MCI Scores

The MCI was developed to assess benthic invertebrate communities in soft and hard bottom flowing waters and its use and interpretation in the tidally influenced section of the Makarewa River needs to be done with considerable caution. Mean MCI scores ranged from 76.0 ± 0.1 at Sites D1 and D2 to 84 ± 0.1 at Site U1 during the March 2013 survey (Figure 44). The MCI scores in March 2013 at Sites D1 and D2 placed them in the poor water quality class and were below the SRC guideline of >80. The MCI scores at Sites U1 and U2 in March 2013 placed them in the 'fair' water quality class. The MCI score at Site U1 was similar to that reported by SRC for that site. The MCI scores at Site U2, Site D1 and Site D2 were similar to that recorded in March 2010 by Golder (2010).

The mean MCI scores in November 2013 ranged from 66.0 ± 2 at Site D1 and 83 ± 4 at Site D2 and were similar to March 2013 (Figure 44). The MCI scores at Sites D1 and U2 in November 2013 placed them in the 'poor' water quality class and were below the SRC guideline of >80. The MCI scores at Sites U1 and D2, in November 2013, placed them in the 'fair' water quality class. The MCI score at Site U1 was similar to that reported by SRC for that site.

The mean MCI score increased slightly at upstream sites but remained similar at downstream sites between the November 2013 and March 2014 surveys. MCI scores, in March 2014, ranged from 68.0 ± 2 at Site D1 and 88 ± 2 at Site U1 and were similar to March 2013 (Figure 44). The MCI scores at Site D1 in March 2014 placed it in the 'poor' water quality class and below the SRC guideline of >80. The MCI scores at Sites U1, U2, U2 up and D2 placed them in the 'fair' water quality class.

The MCI score at Site U1 was similar to that reported by SRC for that site. Mean MCI scores remained little changed at Site U1, U2 and D2 across the three surveys while at Site D1 there was a slight decline in MCI scores between March 2013, November 2013 and March 2014 (Figure 44).

Mean MCI scores remained reasonably similar at each site among surveys reflecting the nature of the MCI index which is a composite score based on the presence or absence of water and habitat tolerant and sensitive taxa.

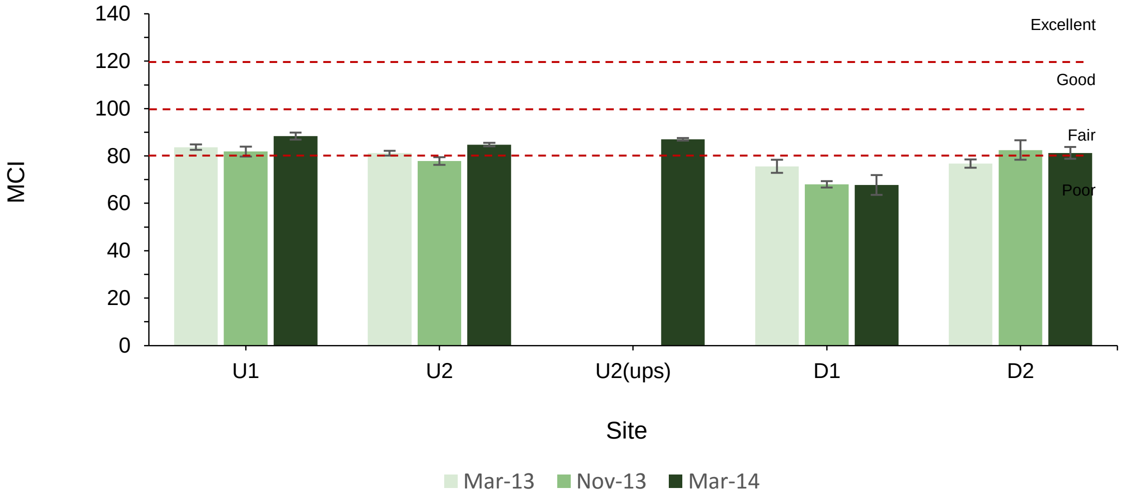

Figure 44: Mean (± 1 S.E.) MCI scores recorded during the March 2013, November 2013 and March 2014 surveys.

QMCI Scores

The same caution that is recommended in using and interpreting MCI scores applies equally to QMCI scores. Mean QMCI scores in March 2013 ranged from 3.2 ± 0.2 at Site U2 to 4.2 ± 0.1 at Site U1 (Figure 45). QMCI scores at Sites U2, D1 and D2 placed them in the 'poor' water quality class. The QMCI score at Site U1 placed it in the 'fair' quality class. The March 2013 QMCI scores, overall, indicated that the benthic invertebrate community was dominated by water and habitat tolerant taxa at all sites.

Mean QMCI scores matched the %EPT and EPT taxa numbers and were lower in November 2013 compared to March 2013 ranging from 1.6 ± 0.1 at Site U2 and 3.2 ± 0.2 at Site D2 and placing all sites in the 'poor' water quality class (Figure 45).

Mean QMCI scores increased in March 2014 compared to November 2013 at all sites and ranged from 3.1 ± 0.2 at Site U2 to 4.6 ± 0.1 at Site D1. Mean QMCI scores had recovered in March 2014 to March 2013 levels or higher at all sites after a decrease in November 2013. The QMCI scores in March 2014 placed Sites U1, U2 up and D1 in the 'fair' water quality class and Sites U2 and D2 in the 'poor' water quality class (Figure 45).

QMCI results among the three surveys varied at at all sites except Site D2 indiacting that habitat plays a key role in the QMCI upstream and downstream of the discharge (Figure 45).

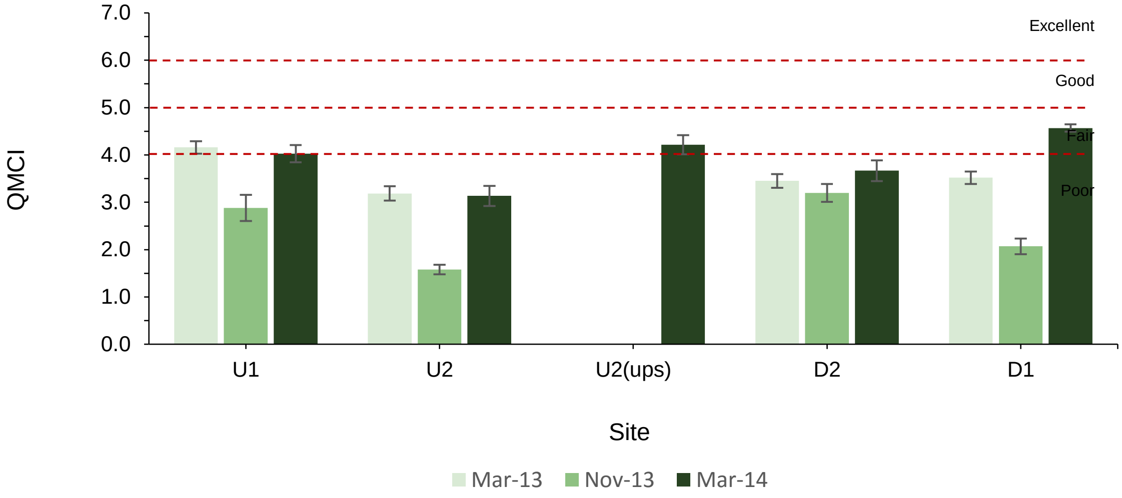

Figure 45: Mean (± 1 S.E.) QMCI scores recorded during the March 2013, November 2013 and March 2014 surveys.

Biological Index Scores among the Surveys

Averaged across the three surveys downstream sites surveyed during discharge periods (March 2013 and March 2014) had higher total taxa number compared to downstream sites during the non-discharge survey in November 2013 ($p < 0.05$) (Figure 39).

EPT taxa and %EPT were similiar across the three surveys with no significant differences in EPT taxa or %EPT determined between discharge surveys (March 2013 and March 2014) and the non-discharge survey in November 2013 ($p < 0.05$) (Figure 40 and Figure 43).

MCI scores and *Deleatidium* abundance at downstream sites were similar across the three surveys ($p > 0.05$) but scores were significantly higher at Site D2 compared to Site D1 ($p < 0.05$) (Figure 41 and Figure 44). QMCI score at Site D1 in March 2014 was significantly higher compared to all other sample date/site combinations ($p < 0.05$) (Figure 45) as a result of a large number of moderately sensitive cladocerans, presumably from the wastewater ponds (QMCI score = 5). The QMCI score was significantly lower at Site D1 in November 2013 (during the off season) compared to the other site/date combinations ($p < 0.05$) and when cladocerans were absent due to the lack of discharge (Figure 45).

The pattern in biological indices for Sites U1, U2, U2 up, D1 and D2 in March 2013, November 2013 and March 2014 are shown on nMDS ordinations differentiated by site

(Figure 46) and location (Figure 47). Three groups were identified by CLUSTER analysis and shown on each nMDS. Samples within each group had a suite of biological index values that were more similar to each other than those in other groups.

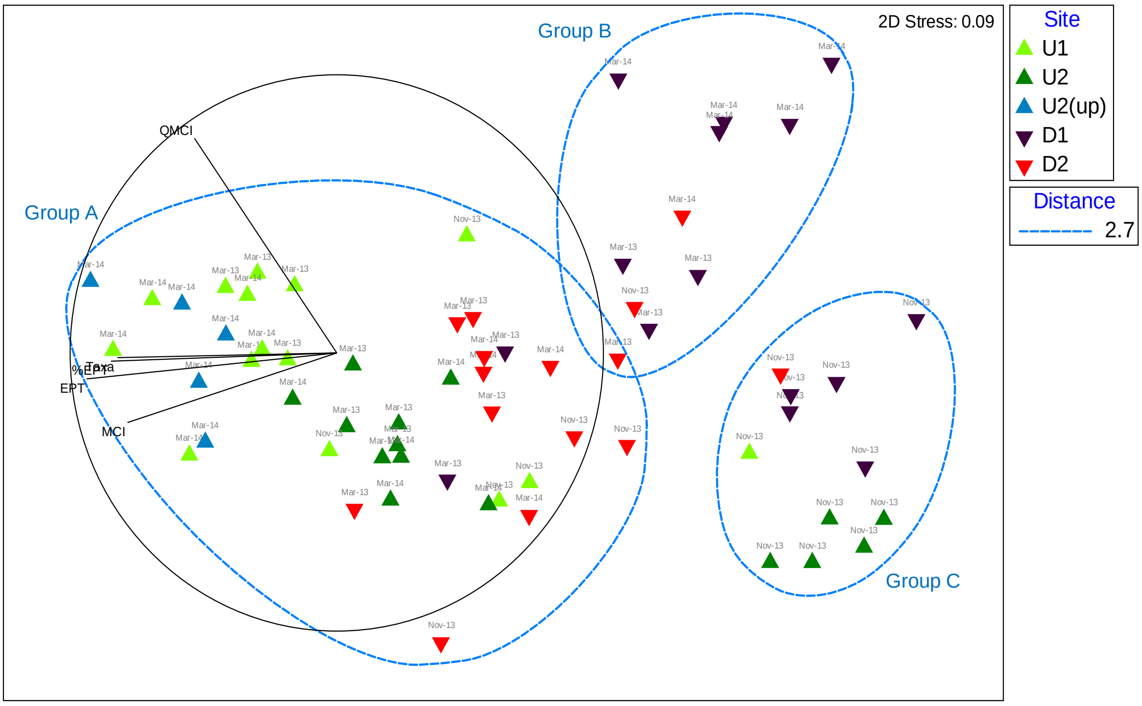

Figure 46: nMDS showing the pattern in biological indices for sites with samples differentiated by site (U1, U2, U2(up), D1 and D2).

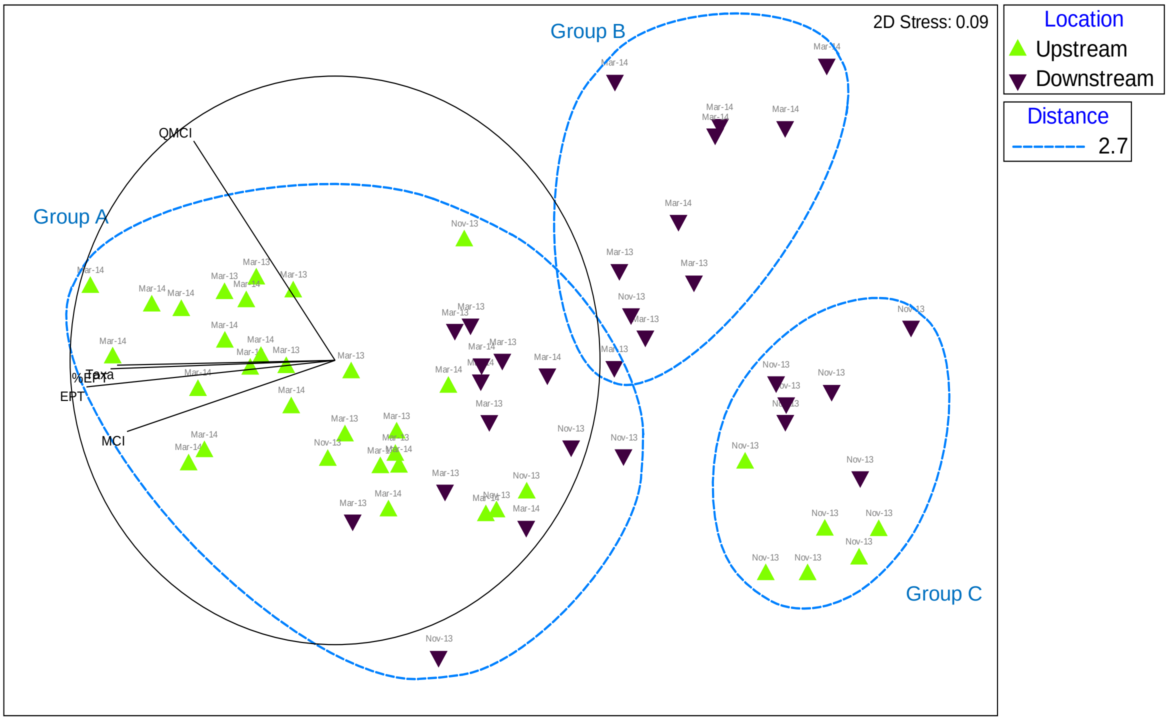

Figure 47: nMDS showing the pattern in biological indices for sites with samples differentiated by location (upstream vs. downstream).

The two-way ANOSIM procedure with sites nested within location identified minor separation of sites by biological index values (Global R = 0.2377; Figure 46) but clear separation between upstream and downstream locations (Global R = 0.667; Figure 47). Group A is the largest group with upstream Sites U1, U2 and U2 up in March 2013 and 2014 and some D2 replicates from all surveys. Group B comprised mostly downstream Site D1 samples for March 2013 and 2014. Group C included mostly upstream Site U2 and downstream Site D1 samples in November 2013.

There was a general left to right downstream shift in biological index values along Axis 1 (x-axis) with the exception of Group C in the lower right of the nMDS comprising upstream sites. There was also a shift in biological index values from bottom to top along Axis 2 (y-axis). EPT taxa, percent EPT, taxa number and MCI were strongly negatively correlated with Axis 1 (r_s = 0.938, -0.847, -0.8227 and -0.785 respectively). EPT taxa number, %EPT and total taxa number were closely linked as indicated by the direction and magnitude of the vectors shown on the nMDS. QMCI was strongly negatively correlated with Axis 2 (r_s = -0.7718) and explains the separation of Group C samples comprising upstream and downstream sites in November 2013 (lower region of nMDS) and Group B samples including mostly downstream Site D1 samples in March 2014 (upper region of nMDS).

ANOSIM results and the nMDS ordination of biological index values by location (Figure 47) showed clear separation between upstream and downstream locations. Higher total taxa number, EPT taxa number, %EPT and MCI scores were typically associated with upstream sites with the exception of values at the upstream Site U2 in November 2013, which had low biological index values with samples plotted amongst downstream sites. Interestingly, QMCI score separates downstream Site D1 samples in March 2014 out from other downstream samples that are plotted within Groups A and C and indicates that, although other indices were low, QMCI scores were relatively high on this occasion at this site.

Community Patterns among the Surveys

The invertebrate community pattern between Sites U1, U2, U2 up, D1 and D2 in March 2013, November 2013 and March 2014 are presented with site as the differentiating factor (Figure 48) and with date as the differentiating factor (Figure 49). Taxa contributing to community similarity at sites are shown as vectors (arrows). Sites within each group had communities that were more similar to each other than those in other groups.

The ANOSIM procedure identified minor separation of site communities (Global R = 0.308) but clear separation between upstream and downstream communities (Global R = 0.833). There was a downstream shift in communities along Axis 1 (x-axis) from left to right on the nMDS with upstream Sites U1 and U2 plotted to the left and downstream sites plotted to the right. Group A samples comprised those at upstream Sites U1, U2 and U2 up in March 2013 and March 2014. Group B samples included downstream Sites D1 and D2 in March 2013, November 2013 and March 2014.

The communities recorded from downstream Sites D1 and D2 in November 2013, when there was no discharge occurring, were similar to the downstream communities in March 2013 and 2014 when the discharge was occurring. This result indicates factors other than discharge water quality may be shaping the communities at downstream sites. Group C communities are located to the lower left of the nMDS and includes Site U2 and two replicates from Site U1 in November 2013.

Upstream communities were characterised by caddisflies (*Pycnocentrodes* and *Pycnocentria*), mayfly (*Deleatidium*) and chironomids (Orthocladiinae and Tanytarsini). There was a downstream shift in taxa contributing to ‘within site’ similarity to *Potamopyrgus* snails, *Paracalliope* (amphipods), Platyhelminthes and Cladocera, which represent a suite of taxa more typical of still water environments.

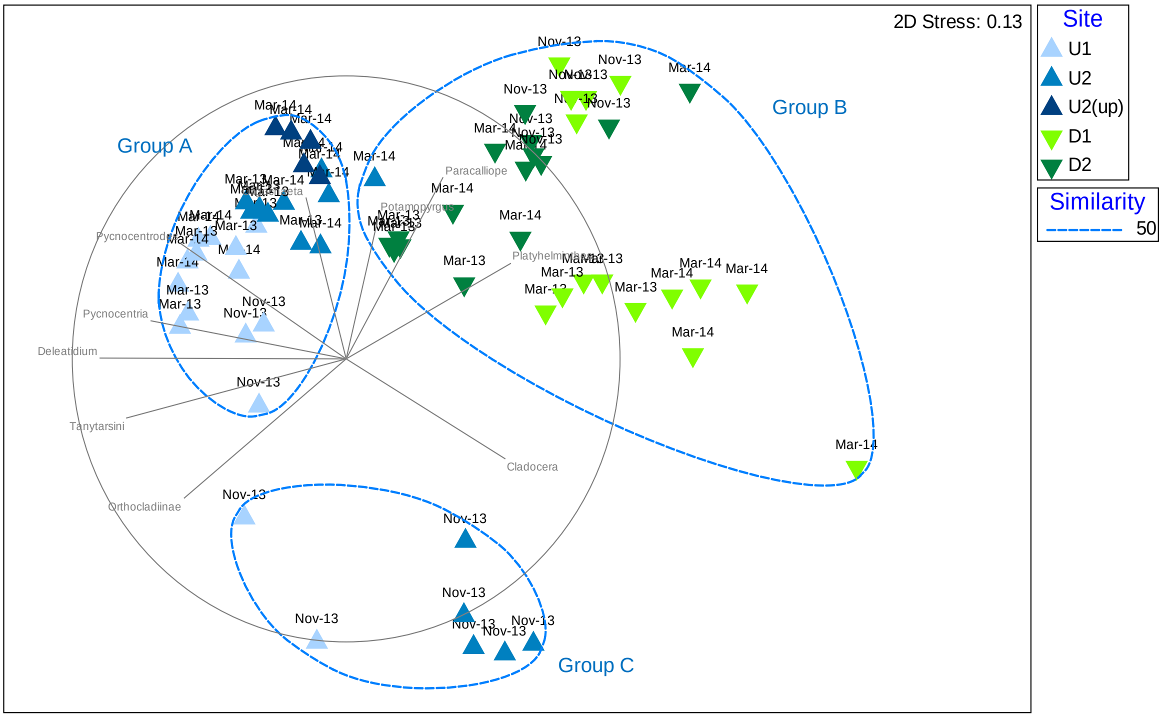

Figure 48: nMDS showing the community pattern with samples differentiated by site.

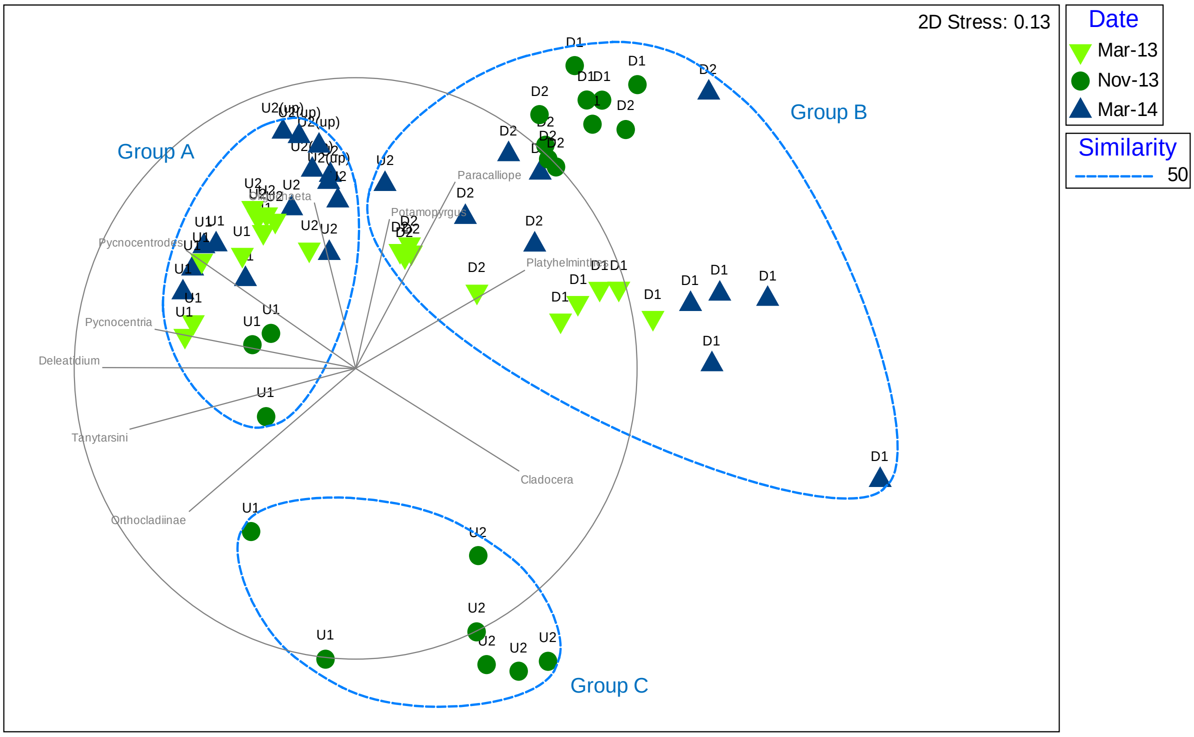

Figure 49: nMDS showing the community pattern with samples differentiated by year.

Community Patterns at Each Site among Surveys

Site D1

The invertebrate community pattern at Site D1 in March 2013, November 2013 and March 2014 is presented in Figure 50. Communities recorded at Site D1 in March 2013, November 2013 and March 2014 displayed little overlap with replicate samples collected on each occasion being grouped together at the 70% level of similarity. Clear separation of the communities in each month is also evident on the nMDS. The ANOSIM procedure confirmed there were significant differences in the communities recorded at this site on each occasion (range: R = 0.948–1.00).

Taxa contributing most to the similarity between replicates at Site D1 in March 2013 were *Potamopyrgus*, Platyhelminthes, Oligochaeta and Cladocera (explaining 56% of community similarity). This compares with Cladocera and Oligochaeta in March 2014 (explaining 50% of community similarity) and Oligochaeta, *Potamopyrgus* and *Paracalliope* in November 2013 (explaining 64% of similarity). Taxa explaining most of the within site similarity on each sampling occasion were pollution tolerant taxa that are common in sluggish flowing degraded rivers with high submerged macrophyte cover (Figure 50).

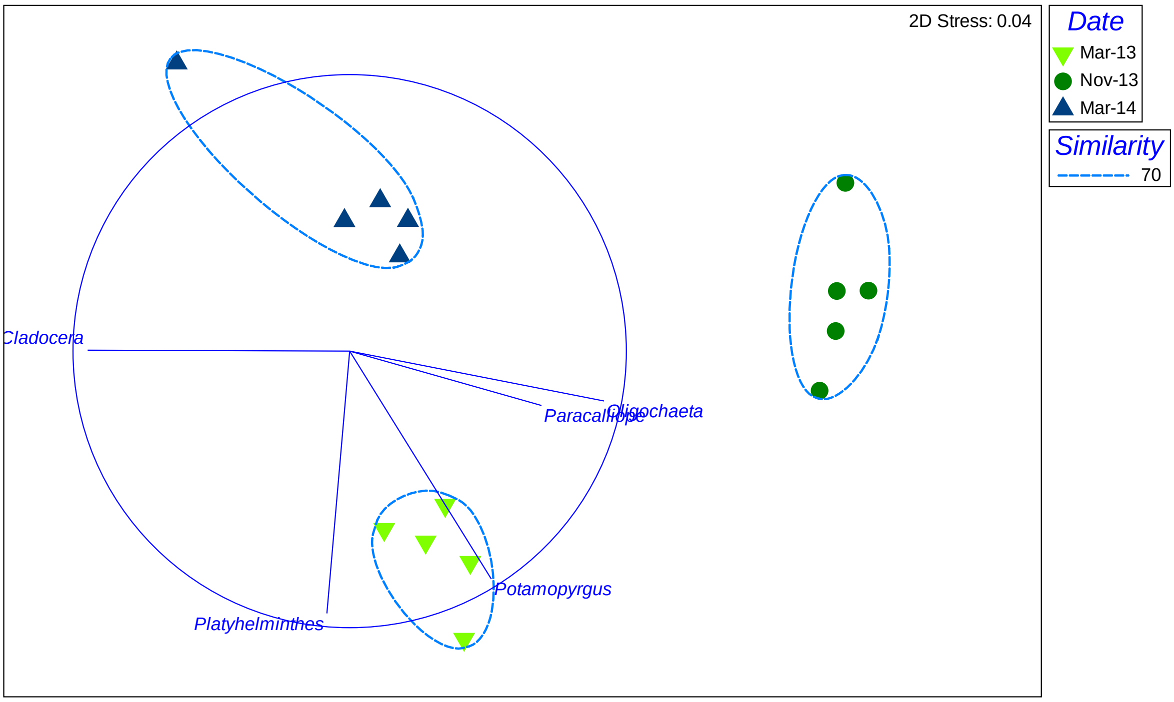

Figure 50: nMDS for Site D1 showing the community pattern with samples differentiated by year.

Site D2

The invertebrate community pattern at Site D2 in March 2013, November 2013 and March 2014 is presented in Figure 51. Communities recorded at Site D2 in March 2014 and November 2013 displayed some overlap as shown on the nMDS and in ANOSIM results (R = 0.380). There were differences with some overlap between the communities recorded in March 2013 and March 2014 (R = 0.556). The communities recorded in March 2013 and November 2013 were however well separated (R = 1.0). There was also some within site variability in the community recorded at Site D2 in March 2014 with replicate samples split into three groups at the 70% level of similarity as shown on the nMDS.

The three taxa contributing most to within site similarity at Site D2 during each of the three surveys were *Potamopyrgus*, Oligochaeta and *Paracalliope* (explaining 41%, 57% and 71% respectively). The lower contribution that this suite of three taxa provided to within site similarity in March 2013 may explain why the community was separated out from the communities in November 2013 and March 2014. Each of the three taxa only contributed between 13% and 15% in March 2013 compared with between 15% and 25% in November 2013 and March 2014. The pattern in the March 2013 community was also influenced by Orthocladiinae (9%) and Hydra (8%) whilst Platyhelminthes also contributed to within site similarity in November 2013 (13%) and March 2014 (12%) (Figure 51).

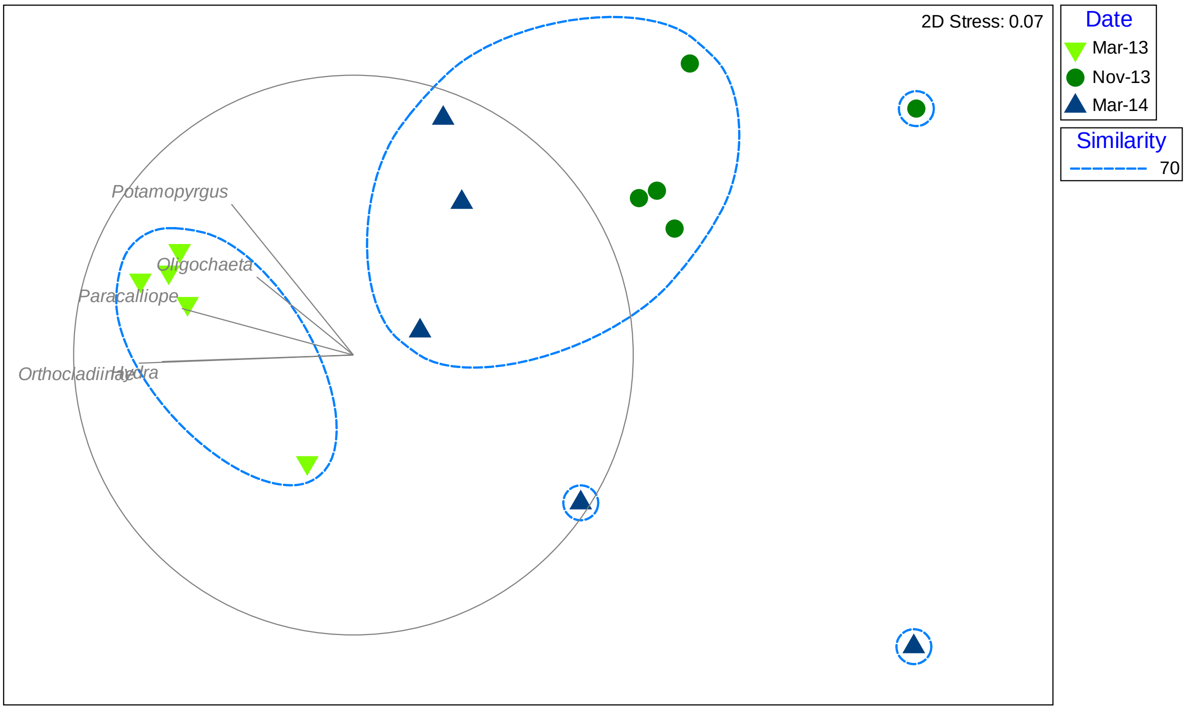

Figure 51: nMDS for Site D2 showing the community pattern with samples differentiated by year.

Site U1

The invertebrate community pattern at Site U1 in March 2013, November 2013 and March 2014 is presented in Figure 52. Communities recorded at Site U1 over the three surveys were separated into three groups at the 70% level of similarity. Replicate samples in March 2013 and 2014 were grouped together with ANOSIM showing some overlap (R = 0.492). The community recorded in November 2013 was different to that in March 2013 and 2014 with ANOSIM showing clear differences between March 2013 (R = 0.644) and March 2014 (R = 0.708). There was also variability between November 2013 replicates as indicated on the nMDS that samples were split into two groups.

The three taxa contributing most to within site similarity at Site U1 over the three surveys were *Aoteapsyche*, *Deleatidium* and Oligochaeta in March 2013 (explaining 33%), *Aoteapsyche*, Oligochaeta and *Potamopyrgus* in March 2014 (explaining 35%) and Oligochaeta, *Deleatidium* and Orthocladiinae (explaining 60%). Pollution tolerant

Oligochaeta and Orthocladiinae explained relatively high proportions of the within site similarity at Site U1 in November 2013 (24% and 17% respectively) when compared with March 2013 (12% and 11%) and March 2014 (11% and 5%) (Figure 52).

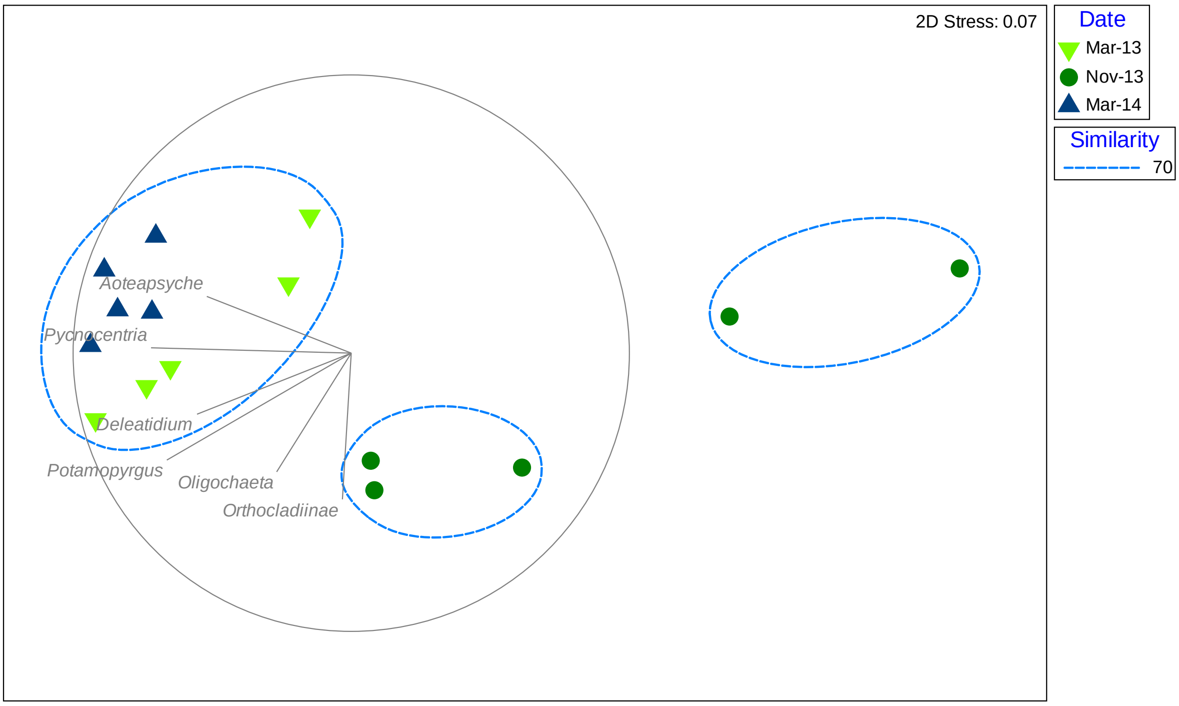

Figure 52: nMDS for Site U1 showing the community pattern with samples differentiated by year.

Site U2

The invertebrate community pattern at Site U2 in March 2013, November 2013 and March 2014 is presented in Figure 53. Communities recorded at Site U2 over the three surveys were separated into two well separated groups at the 70% level of similarity as shown in the nMDS. March 2013 and 2014 replicate samples make up one group located to the right along Axis 1 and November 2013 samples located to the left. ANOSIM confirms clear separation between November 2013 community and those in March 2013 and 2014 (R = 1.0) and some overlap but clear differences between the communities in March 2013 and 2014 (R = 0.592).

The three taxa contributing most to within site similarity at Site U2 during the March 2013 survey were Oligochaeta, *Potamopyrgus* and Oxyethira (explaining 32%). A similar suite of three taxa explained within site similarity in March 2014 including Oligochaeta, *Paracalliope* and *Potamopyrgus* (explaining 37%). Clear separation of the community in November 2013 from March 2013 and 2014 can be explained by the influence that Oligochaeta and Orthocladiinae had on explaining within site similarity at Site U2 in November 2013 (explaining 46% and 18% respectively) (Figure 53).

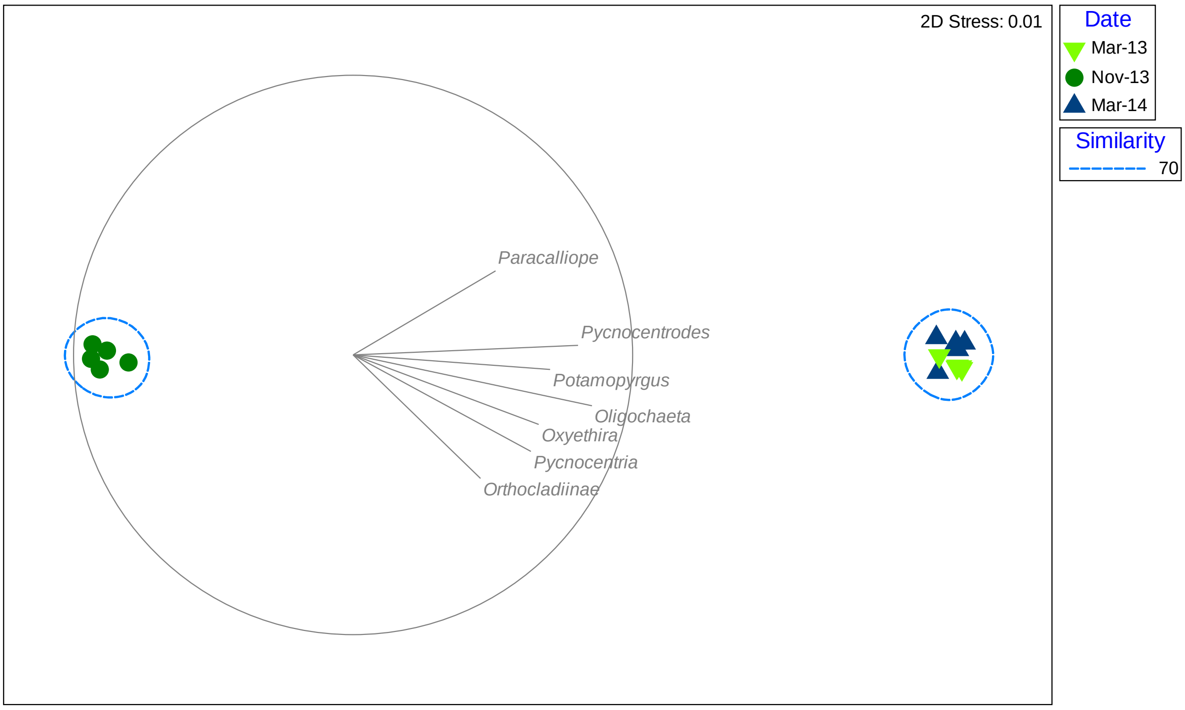

Figure 53: **nMDS for Site U2 showing the community pattern with samples differentiated by year.**

Overall the taxa explaining most of the within site similarity on each sampling occasion at Sites D1, D2 and U2 were pollution tolerant taxa that are common in sluggish flowing degraded rivers with high submerged macrophyte cover. At Site U1 within site similarity on each sampling occasion was explained by a mixture of water and habitat tolerant and sensitive taxa.

Community Patterns and Environmental Variables

The BIOENV procedure was used to identify the suite of factors that most explain the macroinvertebrate community pattern. Mean community data and environmental parameters (habitat variables, Amm-N, DRP and DIN) measured at Sites U2, D1 and D2 during the November 2013 and March 2014 surveys (shown as vectors) are presented on an nMDS (Figure 54). Amm-N, DRP and DIN concentrations are median values calculated from data for the month prior to each survey (November 2013: n = 2; March 2014: n = 6).

Dates presented represent occasions when macroinvertebrates were sampled with matching water quality data available at each site. Vectors indicate the direction and magnitude of the Pearson correlation coefficients between habitat parameters and nMDS axes and are used to indicate possible relationships between macroinvertebrate community structure and environmental variables.

The BIOENV procedure identified filamentous algae cover (%), macrophyte cover (%) and Amm-N concentrations as the factors that most likely explain the macroinvertebrate community pattern observed in the nMDS (r = 0.804) (Figure 54). Figure 54 shows the community recorded at Site U2 in November 2013 was most closely associated with filamentous algae cover. Downstream Sites D1 and D2 in November 2013 and March 2014 were most associated with macrophyte cover.

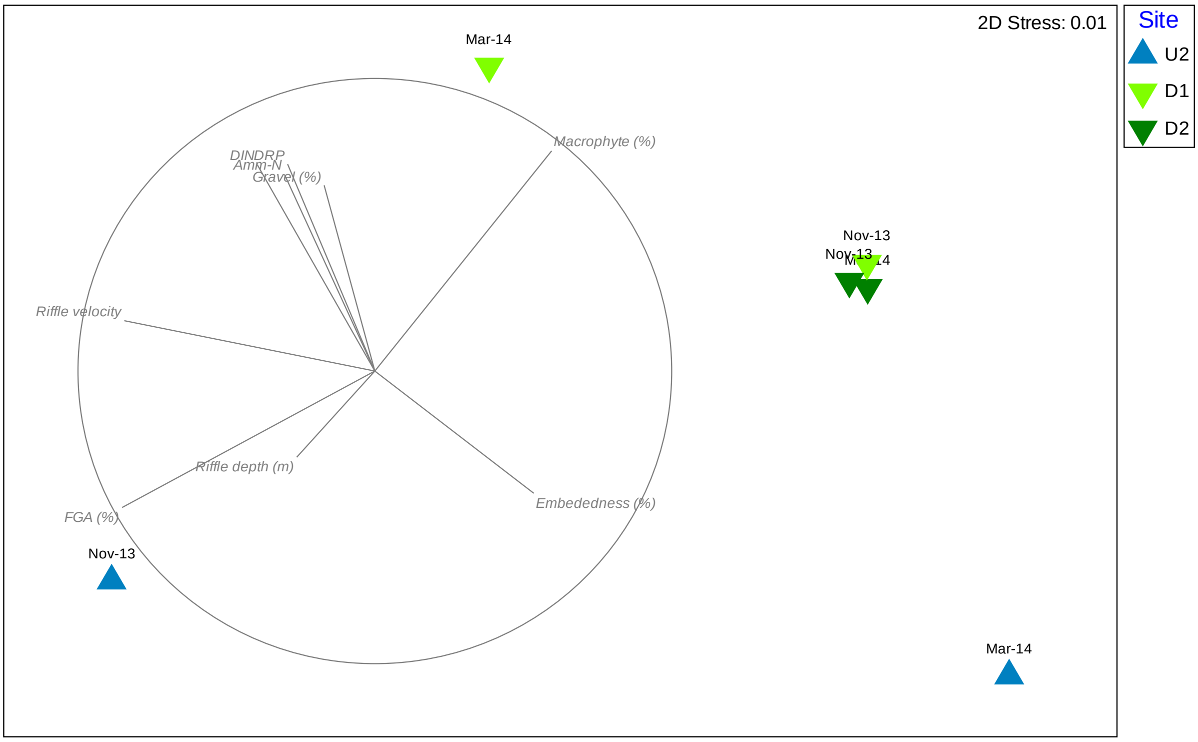

Figure 54: **nMDS showing the mean community pattern at Sites U2, D1 and D2 in November 2013 and March 2014.**

Summary

The benthic invertebrate community was dominated by water and habitat quality tolerant taxa at all sites during all three surveys. The benthic invertebrate composition at Site D1 varied across the three surveys with crustaceans dominant in March 2014, worms dominant in November 2013 and molluscs dominant in March 2013. Key features of the benthic invertebrate community at Site D1, within the downstream mixing zone, were the high numbers of cladocerans and hydra in March 2013 and March 2014 which are most likely to have come from the wastewater treatment ponds, the absence of *Deleatidium* which prefer clean, fast flowing stony bed rivers and the presence of ‘clean water’ caddisfly taxa that tolerate low water velocity. In contrast the community composition at Site D2, within the upstream mixing zone, remained stable across the three surveys with crustaceans, worms and molluscs dominating the community.

When assessed in combination, the benthic invertebrate indices scores indicate that invertebrate community health was lower at Sites D1 and D2 compared to upstream sites in March 2013 and March 2014.

The benthic invertebrate indices scores during the off season, in November 2013, were lower at upstream and downstream sites compared to March 2013 and March 2014 during the processing season. There was no clear trend in indices scores, in November 2013, between upstream and downstream sites. When assessed in combination the benthic invertebrate indices scores indicate that invertebrate community health was lower at Sites D1 and D2 compared to upstream sites in November 2013. This decline in invertebrate community health is likely to be due to a decline in the suitability of habitat for supporting sensitive taxa such as mayflies and caddisflies which generally prefer shallow cobble bed, fast flowing habitats.

The invertebrate communities recorded from downstream Sites D1 and D2 in November 2013, when there was no discharge occurring, were similar to the downstream communities in March 2013 and 2014 when the discharge was occurring indicating that factors other than discharge water quality may be shaping the communities at downstream sites. Upstream communities were characterised by caddisfly taxa, mayfly taxa and chironomids. There was a downstream shift in in the community to taxa such as snails, amphipods, Platyhelminthes and Cladocera, which prefer macrophyte dominated still water environments.

Sites D1 and D2 in November 2013 and March 2014 were most associated with macrophyte cover while the community at Site D1 in March 2014 was also also less strongly associated with higher Amm-N, DIN and DRP concentrations.

Unsuitable habitat is likely to exclude koura and mussels from large portions of the Makarewa River.

6.4 Native Fish

Makarewa River Catchment

SRC has monitored fish at King Road in the upper Makarewa River annually since 2007-2008 (SRC 2008). The key results from SRC fish surveys to date are longfin eel, upland bully, brown trout and koura have been recorded on at least one of the three sampling occasions. The Fish IBI score, which is a measure of the overall health of the fish community is low and has ranged from 24–30. The most recent Fish IBI score (24) placed the Kings Road site eleventh out of the twelve sites surveyed.

The NZFFDB has records from the Makarewa River for:

- Longfin eel.
- Shortfin eel.
- Lamprey.
- Common bully.
- Upland bully.
- Inanga.
- Galaxiid (unidentified).
- Black flounder.
- Brown trout.
- Koura.

March 2013 Net and Trap Survey

The fish survey using fyke nets and minnow traps 1 km upstream and 1 km downstream of the discharge aimed at describing the resident fish population utilising pool and run habitat was undertaken in March 2013.

The following species were recorded:

- Longfin eel.
- Shortfin eel.
- *Paratya* (shrimp).
- Common bully.

A total of 22 longfin eels ranging in size from 370–700 mm were captured in three fyke nets and 23 common bully ranging in size from 10–50 mm were caught in six minnow traps at the upstream site. A total of two longfin eels ranging in size from 550–600 mm and three shortfin eels ranging in size from 400–500 mm were captured in three fyke nets and seven common bully ranging in size from 10–40 mm were caught in six minnow traps at the downstream site. All fish appeared healthy.

Spring 2013 Whitebait Survey

The Makarewa River supports a small whitebait fishery with several local residents fishing the river in the vicinity of the discharge on a regular basis. Other fish species either caught or observed during fishing trips by Mr Casey and Mr Wishart during the whitebait catch survey included smelt, trout, perch and eels. Both fishermen said that smelt numbers tend to increase in October and November towards the tail end of the whitebait season.

Samples collected in August and September were almost completely made up of inanga. Banded kokopu, giant kokopu and koaro were identified from samples collected in mid-October-early November. The samples were dominated by inanga (85%) followed by banded kokopu (6%), giant kokopu (3%) and koaro (1%). Smelt made up the remaining 5% of samples. The whitebait survey has confirmed the presence of three new native fish species; banded kokopu, giant kokopu and koaro in the Makarewa River.

Summer 2014 Electric Fishing Survey

The most abundant and widespread species in the summer 2014 survey of riffle and run habitat was common bully, followed by shortfin eels (Table 21).

Juvenile migratory lamprey were captured at three of the four sites while adult inanga, adult brown trout, koura and shrimp were recorded in low numbers at a single site. Common bully were particularly abundant amongst river edge macrophytes that provide important cover from eels and trout.

Table 21: Summary of summer 2014 fish and large invertebrate survey results.

Common name	Scientific name	Site U2	Site U2 (up)	Site D2	Site D1
Common bully	*Gobiomorphus cotidianus*	30	>50	>100	>100
Lamprey	*Geotria australis*	-	3	5	5
Shortfin eel	*Anguilla australis*	3	5	10	10
Inanga	*Galaxias maculatus*	3	-	-	-
Flounder	*Rhombosolea retiaria*	-	1	-	-
Koura	*Paranephrops* sp.	-	1	-	-
Shrimp	*Paratya* sp.	-	1	-	-
Brown trout	*Salmo trutta*	-	-	1	-

Native Fish Values and Migration

Conservation Status

The fish surveys and NZFFDB records show that the lower Makarewa River supports moderate to high native fish diversity despite its highly modified state including five species; longfin eel, koaro, giant kokopu, banded kokopu and lamprey with an ‘At Risk-Declining’ conservation status (Goodman et al. 2014). The Southland Region Fish IBI score for the site immediately upstream and downstream of the discharge was 58 placing both sites in the ‘excellent’ class (Wairesearch 2010).

Eels

The lower Makarewa and lower Oreti Rivers support very productive shortfin eel and to a lesser extent longfin eel fisheries with up to six commercial fishermen operating in the area (Victor Thompson pers. comm.). Adult Shortfin eels migrate from the New River Estuary in spring and summer and drop back to the estuary in winter months. Despite the historical channelisation and modification of habitat in the lower Makarewa River the river provides very good eel habitat. Longfin eels are territorial and burrow into the river bank and river bed sediments while the extensive macrophyte beds provide important cover for shortfin eels (Victor Thompson pers. comm.). Juvenile longfin and shortfin eels are likely to migrate up the lower Makarewa River in summer while adults are likely to migrate downstream in summer and autumn during the period of greatest discharge loads (Table 22). Shortfin eels tend to take residence in the lower reaches and longfin eels well up the river.

Inanga

The lower Makarewa and Oreti Rivers are popular and at times productive whitebait fisheries. As with other whitebait runs around the country by far the most abundant species is inanga. Inanga is a diadromous species that spawn in the tidal zone near estuaries in autumn. Juvenile inanga are likely to migrate up the lower Makarewa River between August and November, spanning the period when there is typically low or no discharge (Table 22) and with peak migrations occurring a few days after floods in early spring. Larval inanga are expected to be washed downstream of the inanga spawning areas well downstream of the discharge between March and August (Table 22).

Adult inanga continue to shoal and occupy a range of freshwater habitats including pools and backwaters but preferring habitat upstream of the tidal influence (McDowall 1990). Juvenile inanga are likely to be an important seasonal food source for large eels and adult trout in the lower Makarewa River.

Large Galaxiids

Based on the results of the survey of whitebait fishermen juvenile galaxiid species in the whitebait run found in the Makarewa River (banded kokopu, giant kokopu and koaro) appear to migrate up the lower Makarewa River between September and November and when wastewater is typically discharged in low volumes (Table 22). Adult banded kokopu and koaro prefer swiftly flowing rivers with plenty of in-stream and riparian cover while giant kokopu require plenty of in stream cover from logs, tree roots and vegetation (McDowall 1990). Juvenile giant kokopu, koaro and banded kokopu are therefore not expected to remain in the lower river and instead it is expected that they migrate to the headwaters of the river where there is some remnant giant kokopu, banded kokopu and koaro habitat in the streams within the Hokonui Hills. Juvenile kokopu can be an important food source for large eels and adult trout.

Smelt

Juvenile smelt migrate up the lower Makarewa River at the tail end of the whitebait run and and when discharge volumes typically still low (Table 22). Smelt are likely to spend up to a year in the Makarewa River before spawning on sand banks and sand bars in the lower Oreti River. Juvenile smelt are also likely to be an important seasonal food source for large eels and adult trout in the lower Makarewa River.

Lamprey

Lamprey begin life in freshwater where juveniles live in burrows in muddy/sandy backwaters and along river margins and filter feed on microorganisms (McDowall 1990). After approximately 4–5 years, adult lamprey begin to migrate to sea in late winter early spring when there is typically no or little discharge (Table 22).

Common Bully

Juvenile common bully typically migrate from estuaries into freshwater to spawn in summer and the larvae are then washed out to sea in spring (McDowall 1990) (Table 22). Common bully have a varied diet and will consume mayflies, chironomids and caddisflies. Common bully can be an important food source for large eels and adult trout and was the most abundant species recorded during a fish survey upstream and downstream of the discharge.

Table 22: Migratory periods for migratory fish found in the Makarewa River.

Common name	Life stage	Direction	Peak migration period	Discharge load
Longfin eel	Glass eel	Up (as far as estuary)	Aug - Oct	low
	Juvenile	Up	Dec - Mar	med - high
	Adult	Down	Mar - May	high
Shortfin eel	Glass eel	Up (as far as estuary)	Sept - Nov	low
	Juvenile	Up	Dec - Mar	med - high
	Adult	Down	Feb - May	med - high
Lamprey	Juvenile	Down	Aug	low
	Adult	Up	Jan - Dec	low, med, high
Common bully	Juvenile	Up	Dec - Mar	med
	Larvae	Down	Oct - Nov	low
Inanga	Juvenile	Up	Aug - Nov	low
	Larvae	Down	Mar - Aug	high - low
Smelt	Juvenile	Up	Sept - Oct	low
	Larvae	Down	Apr - Jun	high - med
Giant kokopu	Juvenile	Up	Oct - Dec	low - med
	Larvae	Down	May - Sept	high - low
Banded kokopu	Juvenile	Up	Sep - Oct	low
	Larvae	Down	Jun - Jul	high
Koaro	Juvenile	Up	Sept - Oct	low
	Larvae	Down	May - Jun	high
Brown trout	Adult	Up	Dec - May	med - high
	Juvenile	Down	Jan - Dec	low, med, high

Note: Migration periods are for the full range of months identified in MPI (2015).

Trout Values

The Makarewa River, downstream of the Plant, provides habitat for adult brown trout but is unsuitable as spawning or rearing habitat due to the lack of suitable gravel substrate and riffle habitat.

Brown trout are primarily visual feeders (Cawthron 2006) although they are capable of capturing koura and small fish such as bullies and whitebait in turbid waters. It is likely that the adult brown trout population fluctuates throughout the year as trout move up from the New River Estuary and lower Oreti River in spring chasing whitebait and drop down into the lower Oreti River and New River Estuary in summer to avoid the elevated river water temperatures that can occur in the lower Makarewa River during summer months.

Adult trout were observed foraging along the river margins, rising to consume emerging or terrestrial insects or chasing inanga, downstream of the discharge, during the summer 2013, spring 2013, summer 2014 surveys. Adult sea run trout are expected to move through the lower Makarewa River and take up residence in the upper Makarewa River in spring and summer would typically be moving past the discharge when loads are med – high (Table 22).

Summary

The Makarewa River supports high native fish diversity despite its highly modified state including five species; longfin eel, koaro, giant kokopu, banded kokopu and lamprey with an ‘At Risk-Declining’ conservation status (see Goodman et al. 2014). The most commonly occurring and abundant fish species in the vicinity of the discharge are shortfin eels and common bully.

The lower Makarewa and lower Oreti Rivers support very productive shortfin and to a lesser extent longfin eel fisheries. Despite the historical channelisation and modification of habitat in the lower Makarewa River the river provides very good eel habitat and in particular the extensive macrophyte beds provide important cover for shortfin eels. Some of the native fish found in the Makarewa River use the lower Makarewa River as a migratory path to adult habitat while others such as inanga, shortfin eels, trout and black flounder use the lower Makarewa River to feed and grow.

The Makarewa River downstream of the Plant provides habitat for adult brown trout but is unsuitable as spawning/rearing habitat due to the lack of gravel substrate and riffle habitat.

Most juvenile fish migration in the lower Makarewa River occurs when discharge loads from the plant are low (late winter – late spring).

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Report Signature Page

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Appendix 1 – Study Methodology

Appendix 2 – Water Quality Summary Tables

Appendix 3 – Benthic Invertebrate Data

Appendix 4 – Statistical Analysis Results

Appendix 5 – Mixing Zone Assessment Report

Appendix 6 – New River Estuary CLUES Report

Appendix 7 – Laboratory Analysis Report

APPENDIX 1

Study Methods

Existing Compliance Water Quality Monitoring

Alliance currently monitors water quality at the Pipe Bridge upstream of the discharge, 350 m downstream of the discharge and 1.2 km downstream of the discharge (Boundary Site) (Figure 1). Samples are collected daily and analysed for:

- Electrical conductivity.
- pH.
- Temperature.
- Dissolved oxygen.
- Percent dissolved oxygen saturation.
- Total ammoniacal nitrogen.

Samples are collected weekly and analysed for:

- Electrical conductivity.
- pH.
- Temperature.
- Dissolved oxygen.
- Percent dissolved oxygen saturation.
- Total ammoniacal nitrogen.
- Total nitrogen.
- Total oxidised nitrogen.
- Total phosphorus.
- Dissolved reactive phosphorus.
- Carbonaceous BOD.
- Soluble carbonaceous BOD.
- Faecal coliforms.
- Black disk distance (clarity tube).

All sample analysis is currently undertaken Watercare Laboratory Services in Invercargill and its predessor accredited laboratories.

Water Quality Sampling Sites

Makarewa River

Alliance compliance monitoring data collected from the Bridge Site (upstream of the discharge), 350 m downstream of the discharge and at the Boundary Site (1,200 m downstream of the discharge) (Figure 1) between December 2001 and June 2014 has been summarised and presented.

Alliance also collected additional water quality data from the discharge, river compliance monitoring sites (Bridge, 350 m and Boundary Sites) and a site immediately upstream of the confluence with the Oreti River, biological monitoring sites (Sites U2, D1 and D2 only), the boiler ditch and Tomoporakau Stream that enters the Makarewa River on the true right bank approximately 200 m upstream of the Boundary Site. The additional water quality data collected to support the resource consent application will be presented and assessed in the final effects assessment report (unpublished report).

Ecology Sampling Sites

Makarewa River

Four biological monitoring sites were selected on the Makarewa River and were sampled in early March 2013, November 2013, February 2014. A fifth sampling site (Site U2 up) was added to the March 2014 survey in order to add another upstream site with more similar habiat conditions to Sites D1 and D2 and provide a ‘’balanced’’ sampling design (Site U2 + Site U2 up vs Site D1 and Site D2) for statistigal analysis of the data. A summary of the surveys undertaken at each site on each sampling occasion are presented in Table 1. The native fish survey on 8 March 2013 was a net and trap survey of pool and run habitat. The native fish survey on 12 March 2014 was an electric fishing survey of riffle habitat. In addition to the native fish survey samples of whitebait caught from the Makarewa River in the vicinity of the discharge, between 17 August and 4 November 2013 were collected from fishermen.

The Plant’s discharge point is located near the upper end of the tidally influenced section of the river. There is a decreasing gradient of tidal influence from Site D1 to Site U2 (Figure 1). Site U1 near the Wallacetown Bridge is unaffected by the tidal cycle which affects river level and water velocity but does not change the salinity of the river.

The changes that occur in an upstream direction between Sites D1 and U2 include an increase in coarse substrate, an increase in riffle habitat, decreased macrophyte cover and decreased river water level variation. The tidal cycle and river profile and flow conditions means that the mixing zone, at low river flow and low tide extends some 200 m downstream of the discharge while near the high tide the mixing zone extends from approximately 200 m downstream to 200 m upstream of the discharge (see Appendix 3).

Table 1: Summary of biological assessments.

Survey Date	Periphyton cover	Macrophyte Cover	Macrophyte species cover	Benthic invertebrates	Native fish
8 March 2013	Y	Y	N	Y	Y+#
7 November 2013	Y	Y	N	Y	N
6 February 2014	Y	Y	Y*	N	N
12 March 2014	Y*	Y*	N	Y*	Y*#

Note: * = Site U2 (up) was included in the March 2014 survey. + 1 site – 1 km downstream and 1 site – 1 km upstream of the discharge surveyed. # = Site U1 excluded from the March 2013 and 2014 fish surveys.

The limited amount of suitable habitat downstream of the discharge, differences in the physical habitat, tidal influence and the extent of the mixing zone made it impossible to select biological monitoring sites upstream and downstream that have similar sets of physical habitat conditions. As a result separating out the effects that habitat and water quality have on the ecology of the river is difficult.

A standard study design for assessing the effects of a discharge to a river would typically involve surveying 2 or 3 sites upstream and 2 or 3 sites downstream of the mixing zone. Sites would normally be carefully selected in order to minimise the potential for habitat conditions to influence survey results to ensure that effects associated with the discharge can more readily be identified and quantified. Unfortunately the location of the discharge prevented such a design been used.

Site D1 has only suitable riffle habitat for sampling benthic invertebrates using a quantitative method (Surber sampler) and surveying periphyton and macrophytes downstream of the discharge. Site D1 is only accessible at low river flow (<4 m^3/s) and low tide, is approximately 100-200 m downstream of the discharge and is within the discharge mixing zone (see Appendix 3). In order to ensure a balanced statistical design a second ‘effects’ site (Site D2) with suitable habitat was selected 70 m upstream of the discharge and within the mixing zone during the incoming tide (see Appendix 3). The effects sites (Sites D1 and D2) are therefore both located within the mixing zone. The aquatic plant and benthic invertebrate results from these sites therefore provide the ‘worst case’ assessment of the effects of the discharge.

Sites U2, approximately 2 km upstream of the discharge, is beyond the influence of the discharge and where the effect of the tide on habitat conditions and water level variations is minor (approximately 100 mm between low and high tide). Ideally Site U2 would have been located closer to Site D2 but there are no riffle areas to provide equivalent sampling conditons in the section of river between Site U2 and Site D2. Site U1 is approximately 300 m downstream of the Wallacetown Bridge. This site was selected because it is monitored annually by Southland Regional Council (SRC) and has a good long term benthic invertebrate dataset with which to compare results (Figure 1).

Oreti River and New River Estuary Sampling Sites

Consideration was given to biological monitoring in the lower Makarewa and Oreti Rivers. The confounding effects of the tidal influence and other catchment scale effects would have meant that monitoring further down the river was unlikely to provide additional insight into the effects of the discharge and for this reason biological sampling was not undertaken in the lower Makarewa or Oreti Rivers.

The New River Estuary is regularly and comprehensively monitored by Invercargill City Council and SRC and additional sampling of the estuary was not recommended by Freshwater Solutions (2013). Instead the approach to assessing the effect of the Lorneville discharge on the New River Estuary has been to use the Catchment Land Use for Environmental Sustainability (CLUES) model to determine the proportion of nutrients in the estuary that are discharged by the Lorneville Plant compared to other point and diffuse nutrient sources (see Wriggle 2013).

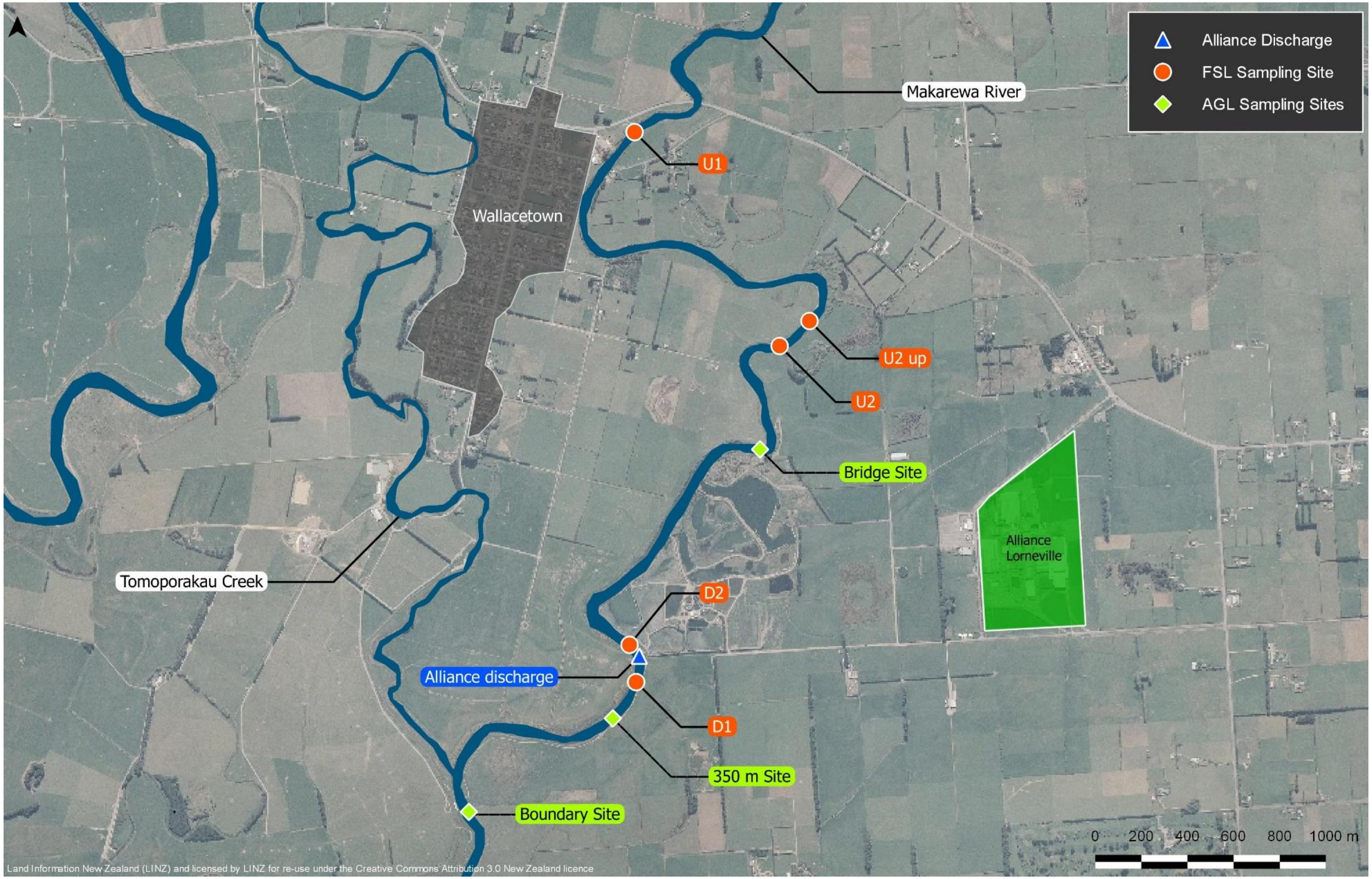

Figure 1: **Sampling Locations.**

In-stream Habitat

Component P2b of Protocol P2 from Harding et al. (2009) were used to assess in-stream and riparian habitat at each biological monitoring site and involved the collection of percent substrate composition, embeddedness, compactness, scour and deposition zones and organic matter within each of the riffles from which periphyton and benthic invertebrate samples were collected. All habitat features were visually assessed. Substrate characteristics and organic matter can influence periphyton, macrophyte and benthic invertebrate communities and data on these attributes was collected to assist in the interpretation of biological survey results.

Periphyton

Visual Assessment

Periphyton and macrophyte cover and composition assessments were made at each biological monitoring site using the Rapid Assessment Method (RAM 1) of MfE (2000). Periphyton cover was recorded from 10 points along 5 transects within the run (gentle riffle) from which quantitative periphyton and benthic macroinvertebrate samples were collected. Results were compared with the MfE (2000) periphyton guidelines for diatom and filamentous green algae cover (Table 2) and MfE (2012).

Ash Free Dry Weight and Chlorophyll-*a*

The intention was to collect five replicate periphyton samples at each site. Each replicate was to be collected by randomly selecting 3 rocks and scraping a total area of 0.0085 m^2 using a scalpel blade. There was insufficient periphyton at downstream sites in March 2013, November 2013, February 2014 and March 2014 due to the small size of the substrate (fine gravels mostly) to allow a sample that would have provided realiable AFDW or chlorophyll-*a* results.

Table 2: MfE (2000) guidelines for periphyton growing in gravel/cobble bed streams.

In-stream Values	Diatoms	Filamentous algae
Aesthetic/recreation (period 1 Nov–30 April)		
Maximum cover of visible stream bed	60% >0.3 cm thick	30% >2 cm long
Maximum AFDW (g/m^2)	N/A	35
Maximum chlorophyll-*a* (mg/m^2)	N/A	120
Benthic biodiversity		
Maximum chlorophyll-*a* (mg/m^2)	50	50
Trout habitat and angling		
Maximum cover of whole stream bed	N/A	30% >2 cm long
Maximum AFDW (g/m^2)	35	35
Maximum chlorophyll-*a* (mg/m^2)	200	120

Macrophytes

Total macrophyte cover was surveyed in March 2013, November 2013, February 2014 and March 2014. Macrophyte species composition was also assessed in February 2014 (Table 1). Total percent cover and the coverage of the major surface reaching and sub-surface species was assessed at 10 points across 5 transects using the survey methodology advocated by the Waikato Regional Council (Collier et al. 2007). Macrophyte cover was assessed against the MfE (2012) recommended provisional guidelines (Table 3).

Table 3: MfE (2012) recommended provisional macrophyte guidelines.

Nuisance threshold	Purpose
≤50% channel volume/cross sectional area	Ecological condition, flow conveyance, recreation
≤50% surface cover	Aesthetics, recreation

Benthic Macroinvertebrates

Sample Collection and Processing

Five benthic macroinvertebrate samples were collected from Sites U1, U2, D1 and D2, on each sampling occasion (March 2013, November 2013 and March 2014), using a 0.1 m^2 area Surber sampler with 500 µm net mesh recommended by Stark et al. (2001). Samples were preserved in 70% ethanol and sent to the laboratory for identification by an experienced taxonomist using Protocol P3 from Stark et al. (2001).

Data Analysis

Benthic macroinvertebrate taxa number, EPT taxa number, %EPT, Macroinvertebrate Community Index (MCI), Quantitative Macroinvertebrate Community Index (QMCI), *Deleatidium* and oligochaete abundance were calculated and were used to assess macroinvertebrate community health, habitat and water quality. Biological index data was graphed showing sites (U1, U2, D2 and D1) by sampling occasion (March 2013, November 2013 and March 2014). Error bars shown on graphs are standard error bars (± 1 S.E.).

- *Taxa Number.* This is a measure of the overall health of the benthic macroinvertebrate community and habitat and water quality. Generally the higher the taxa number the healthier the waterway. The number of taxa present at a site can be highly variable and can respond to a large number of factors and can therefore fluctuate widely depending on sampling effort (Stark and Maxted 2007).
- *Quantitative Macroinvertebrate Community Index (QMCI).* The QMCI is used for measuring stream health and in particular organic enrichment. Individual taxon scores range from 1 (insensitive) to 10 (highly sensitive). QMCI quality classes are presented in Table 3 (Stark and Maxted 2007).
- *Macroinvertebrate Community Index (MCI).* The MCI is used for measuring stream health and in particular organic enrichment. Individual taxon scores range from 1 (insensitive) to 10 (highly sensitive). Community MCI quality classes are presented in Table 3 (Stark and Maxted 2007).
- *Deleatidium Abundance. Deleatidium* is a water and habitat sensitive mayfly that

occurs very commonly in rivers throughout Southland and is used as an indicator of a change in water and habitat quality.

- *Oligochaete Abundance.* Oligochaetes (worms) are water and habitat tolerant taxa that thrive in organic rich environments and is used as an indicator of a change in water and habitat quality.
- *EPT Taxa Number.* This is another measure of the overall health of the benthic macroinvertebrate community and habitat and water quality. A benthic macroinvertebrate community that has a higher number of water and habitat sensitive taxa from the groups Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) (EPT) indicates a healthier waterway.
- *%EPT.* This is another measure of the overall health of the benthic macroinvertebrate community and habitat and water quality. A benthic macroinvertebrate community that has a higher percentage of water and habitat sensitive taxa from the EPT groups indicates a healthier waterway.

Table 4: MCI and QMCI quality classes.

Quality class	MCI	QMCI
Excellent	>119	>5.99
Good	100–119	5.00–5.99
Fair	80–99	4.00–4.99
Poor	<80	<4.00

Within Survey Statistical Analysis

Within survey analysis was undertaken to provide a site by time focussed analysis. Statistical analysis of benthic macroinvertebrate data from biological monitoring sites sampled in March 2013, November 2013 and March 2014 was carried out using the following variables: number of taxa, EPT taxa number, percentage EPT taxa, *Deleatidium* abundance, oligochaete abundance, MCI score and QMCI scores.

All variables were checked for normality using a Shapiro Wilks W-test prior to formal comparisons. Where data was determined to depart from expected normality they were checked for lognormal distribution and analysed using an nlog(x+1) transformation. If data was determined to not fit the normal or lognormal distributions they were analysed using nonparametric methods (e.g., Wilcoxon/Kruskal Wallis tests).

Differences between sites and locations were analysed using nested ANOVA techniques, with sites nested within location and Tukey’s HSD mean comparison methods. All statistical significance was determined at the 0.05 level, with marginal differences being reported for p-values falling between 0.10 and 0.05. All analyses were undertaken using JMP statistical software (SAS Institute 2003, vers. 5.0.1.2).

Pooled Survey Statistical Analysis

Pooled analyses was undertaken to take into account all the variation in sampling design and cut it back to key questions regarding environmental trends and specifically to determine differences among surveys with and without the discharge. The pooled analysis takes mean values with a larger sample size (n) and looks for bold trends as opposed to potential one off results from smaller sample sizes that may disrupt the ‘bigger picture’.

The sampling design was such that there were two locations for comparison (i.e., upstream and downstream), with each with two sites nested within each location (i.e., U1, U2, D1, and D2 respectively). Each of the sites had five independent replicate samples (i.e., 1–5). Samples were collected during 3 sample periods: March 2013, November 2013, and March 2014. There was no discharge operating during the November 2013 sampling period (off season). This gave a total of 20 samples during each sampling period, or 60 samples in total available for analysis.

In addition to the analysing upstream and downstream sites a separate analysis of downstream sites alone across the three surveys was carried out. The downstream location had 2 sites nested within it (i.e., downstream 1, and downstream 2). Each of the sites had five independent replicate samples (i.e., 1–5). Samples were collected during 3 sample periods: March 2013, November 2013, and March 2014. There was no discharge operating during the November 2013 sampling period (off season). This gave a total of 10 samples during each sampling period, or 30 samples in total available for analysis.

For the analysis all variables were checked for normality using a Shapiro Wilks W-test prior to formal comparisons. Where data was determined to depart from expected normality they were checked for lognormal distribution. The MCI scores were determined to be normally distributed and standard nested ANOVA techniques were used. The total taxa, EPT taxa number, %EPT, QMCI scores, Oligochaete abundance and *Deleatidium* abundance data were determined to not fit the normal or lognormal distributions and were therefore analysed using nonparametric methods (e.g., Wilcoxon/Kruskal Wallis tests).

Differences between sites and locations were analysed using nested ANOVA techniques (whereby sites were nested within location). Differences between sites and locations between sampling dates were performed using reverse selection methods. A simplified analysis of mean discharge vs non-discharge sampling periods was also performed. Tukey's HSD mean comparison methods were used to determine differences where appropriate. All statistical significance was determined at the 0.05 level, with marginal differences being reported for p-values falling between 0.10 and 0.05. All analyses were undertaken using JMP statistical software (SAS Institute 2003, vers. 5.0.1.2).

nMDS Analysis

Multivariate statistical analysis was performed on the macroinvertebrate community dataset, biological indices, habitat parameters and selected river water quality parameters. The macroinvertebrate community dataset included Sites U1, U2, U2 (up), D1 and D2 in March 2013, November 2013 and March 2014. Water quality data was available for Sites U2, D1 and D2 for November 2013 and March 2014. Multivariate statistical analyses were performed using PRIMER 6.1.14. The following multivariate statistical procedures were performed on data:

- **Non-metric multidimensional scaling (nMDS)** – the relative proximity of sites on nMDS ordinations indicates how similar communities are to each other. Points that are closer together represent samples that have a greater similarity in species composition (Clarke and Gorley 2006). The nMDS ordinations of community data were constructed from Bray-Curtis similarity matrices after log(x+1) transformation. The nMDS of community biological indices was constructed from normalised data and Euclidean distance. Ordinations are presented with 'site' or 'date' as the factor.
- **Hierarchical Cluster analysis (CLUSTER)** – identifies groups of samples that are most similar to each other at a given level of similarity (Bray-Curtis similarity for community data or Euclidean distance for biological indices). Groups identified by

CLUSTER analysis are shown on nMDS ordinations and labelled Group A, B, C, etc.

- **Species contributing to Similarity (SIMPER)** – identifies taxa contributing most to similarities and differences between macroinvertebrate communities. SIMPER analysis was performed on community data with 'site' as the factor. The cut-off for cumulative percent contribution to the community pattern was the 50% level of Bray-Curtis similarity. Taxa identified in SIMPER are shown on nMDS ordinations as vectors (arrows). Vectors show the direction and magnitude of the Pearson correlation coefficients between taxa and nMDS Axis 1 (x-axis) and Axis 2 (y-axis).
- **Analysis of similarities (ANOSIM)** – analogous to ANOVA and tests for significant differences 'within' and 'between' community factors (site and date). The output is a global R-value that tests for overall differences between samples and pairwise comparison R-values that tests for differences between paired sites. R-values range between 0 and 1 and can be interpreted as follows; R>0.75 indicates a community is well separated, R>0.5 indicates clear differences but some overlap and R<0.25 indicates the communities are barely different (Clarke and Gorley 2006).
- **BIO-ENV** –used to identify the suite of environmental factors that most explained the macroinvertebrate community pattern. Dataset limited to sites and dates where environmental data was available (i.e., Sites U2, D1 and D2; environmental parameters included habitat, variables, Ammoniacal-N, DRP and DIN). Environmental data was normalised prior to analysis.

Native Fish

Summer 2013 Survey

The objective of the summer 2013 fish survey was to qualitatively assess the presence or absence of native fish in pool and run habitat 1 km upstream and 1 km downstream of the discharge. The upstream and downstream sites were located outside of the discharge mixing zone (see Appendix 5). Three baited standard commercial fyke nets fitted with exclusion devices to prevent predation and three un-baited rectangular soft mesh minnow traps were set overnight at each site on 7 March 2013 (downstream of discharge) and 8 March 2013 (upstream of discharge). Nets and traps were cleared the next day and fish were identified, measured and returned to the river unharmed.

Whitebait Survey

The aim of the whitebait survey was to identify which species are found in the whitebait run and to provide further data on which to base the assessment of the native fish values of the river. Two regular whitebait fisherman near the Alliance discharge – George Wishart and Mo Casey provided a total of 10 samples of whitebait for identification between 17 August 2013 and 4 November 2013. The total weight of individual catches from which whitebait samples were collected ranged from ½ lb to 3 lb's (Mo Casey and George Wishart pers. comm.). Samples ranged from 24–75 individuals and were identified by Charles Mitchell an expert in whitebait identification.

Summer 2014 Survey

The objective of the summer 2014 fish survey was to qualitatively assess the presence or absence of native fish in riffle and run habitat at 2 sites upstream (Site U2 and U2 up) and 2 sites influenced by the discharge (Sites D1 and D2). The downstream sites were located within the discharge mixing zone (see Appendix 5). The river was too deep and slow flowing to allow electric fishing at sites below Site D1.

A qualitative survey of riffle and run habitat at Sites U2, U2 up, D1 and D2 was undertaken on 13 March 2014 using a 12V back pack electric fishing machine (EFM) to determine the presence or absence of fish. The survey was undertaken using a single pass fishing method with fish stunned and captured in a pole net or EFM operator held dip net. Approximately 625 m^2 of habitat was fished at each site. All fish were identified and returned to the river unharmed.

Recreational Values

The recreational values of the Makarewa River, Lower Oreti River and New River Estuary were assessed using published reports and information found on the New Zealand Fish Game, Department of Conservation, SRC and the Invercargill City Council websites (searched in June 2014).

APPENDIX 2

Water Quality Summary Tables

Table 1: Summary of Makarewa River temperature data between December 2001 and June 2014.

	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2001/14
Bridge														
Med.	14.8	13.8	14.0	13.0	13.3	13.9	15.3	13.7	13.5	13.9	12.3	13.8	14.0	13.9
Min.	5.1	5.6	5.4	2.1	4.0	1.5	4.2	3.8	2.9	3.4	2.1	5.6	7.0	1.5
Max.	20.3	20.4	19.4	21.1	21.2	18.9	20.4	19.7	19.9	19.1	20.4	20.8	19.8	21.2
5%-ile	8.8	8.1	7.8	5.5	6.7	5.8	7.2	7.1	6.3	6.2	7.2	7.2	8.4	7.0
95%-ile	19.1	18.2	18.4	20.4	19.5	18.3	19.4	17.6	18.6	18.4	19.4	17.8	17.4	18.8
N	127	136	131	93	112	134	145	145	127	110	109	147	114	1630
350 m														
Med.	15.0	14.2	14.1	13.3	13.4	14.0	15.8	13.6	13.4	13.9	12.7	14.1	14.1	13.9
Min.	5.2	5.5	4.8	2.1	4.1	1.5	4.3	3.0	2.1	3.1	2.5	5.5	7.6	1.5
Max.	20.7	20.3	19.6	21.4	21.5	20.0	20.7	20.1	19.9	19.2	20.5	21.1	20.0	21.5
5%-ile	8.9	8.4	7.7	5.8	6.6	5.4	7	7.2	6.2	6.3	7.2	7.2	8.5	7.0
95%-ile	19.3	18.1	18.6	20.7	19.7	18.4	19.6	17.9	18.5	18.4	19.4	18.3	17.8	19.1
N	127	136	132	94	112	135	153	145	127	110	109	147	113	1640
Boundary														
Med.	14.9	14.1	14.3	13.3	13.5	14.2	15.5	13.8	13.5	14.1	12.6	14.3	14.3	14.0
Min.	5.2	5.5	4.9	2.0	4.2	1.5	4.6	3.0	2.4	3.0	2.1	5.6	7.5	1.5
Max.	20.5	20.5	19.6	21.5	21.4	19.7	20.9	19.8	20.3	19.4	20.7	21.2	20.1	21.5
5%-ile	8.9	8.3	7.6	5.6	6.9	5.6	6.9	7.0	6.2	6.2	7.1	7.2	8.7	6.9
95%-ile	19.2	18.3	18.6	20.6	19.7	19.0	19.8	17.8	18.7	18.6	19.4	18.1	18.0	19.1
N	127	136	132	94	112	135	153	145	127	110	109	147	113	1640

Note: units °C

Table 2: Summary of Makarewa River pH data between December 2001 and June 2014.

	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2001/14
Bridge														
Med.	6.9	7.5	7.2	7.3	7.2	7.1	7.3	6.8	7.2	7.2	7.2	7.0	7.1	7.2
Min.	5.4	6.9	6.7	6.7	6.4	6.2	6.5	6.1	6.4	6.5	6.5	6.2	6.6	5.4
Max.	8.1	7.9	7.8	7.7	7.8	7.9	7.8	7.9	7.7	7.5	7.6	7.7	7.5	8.1
5%-ile	6.0	7.2	6.9	6.8	6.8	6.6	7	6.4	6.7	6.7	6.8	6.3	6.8	6.5
95%-ile	7.3	7.7	7.4	7.5	7.6	7.7	7.6	7.5	7.5	7.5	7.5	7.3	7.3	7.6
N	127	136	131	93	112	134	146	145	127	110	109	147	114	1631
350 m														
Med.	7.1	7.5	7.4	7.5	7.4	7.2	7.5	6.9	7.3	7.3	7.5	7.0	7.3	7.3
Min.	6.3	7.1	6.8	6.8	6.6	6.3	6.6	6.4	6.5	6.7	6.7	6.1	6.6	6.1
Max.	7.6	7.9	7.8	7.8	8.0	8.0	9.0	7.9	7.8	7.9	7.9	7.7	7.6	9.0
5%-ile	6.5	7.2	6.9	6.9	6.8	6.7	7.2	6.5	6.9	7.0	6.9	6.5	6.8	6.7
95%-ile	7.3	7.7	7.6	7.8	7.8	7.8	8.0	7.6	7.6	7.6	7.8	7.5	7.4	7.7
N	127	136	132	94	112	135	154	145	127	110	109	147	113	1641
Boundary														
Med.	7.2	7.5	7.3	7.4	7.3	7.2	7.5	7.1	7.3	7.3	7.5	7.0	7.2	7.3
Min.	6.4	6.9	6.8	6.8	6.7	6.4	6.6	6.4	6.5	6.6	6.6	6.1	6.6	6.1
Max.	7.6	7.7	7.7	7.9	8.0	8.0	8.8	8.0	7.9	7.9	8.1	7.5	7.7	8.8
5%-ile	6.8	7.2	7.0	7.0	6.9	6.8	7.3	6.6	6.7	7.1	7.0	6.5	6.9	6.8
95%-ile	7.4	7.7	7.6	7.6	7.7	7.7	8.0	7.5	7.6	7.5	7.7	7.4	7.5	7.7
N	127	136	132	94	112	135	154	145	127	110	109	147	113	1641

Table 3: Summary of Makarewa River Electrical Conductivity data between December 2001 and June 2014.

	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2001/14
Bridge														
Med.	0.18	0.24	0.25	0.27	0.26	0.16	0.15	0.16	0.16	0.16	0.16	0.27	0.26	0.19
Min.	0.08	0.13	0.16	0.21	0.19	0.10	0.11	0.11	0.11	0.11	0.11	0.22	0.21	0.080
Max.	0.21	0.38	0.38	0.50	0.37	0.47	0.44	0.68	0.31	0.23	0.31	0.37	0.34	0.68
5%-ile	0.093	0.15	0.18	0.25	0.20	0.13	0.12	0.13	0.13	0.13	0.13	0.24	0.23	0.13
95%-ile	0.20	0.30	0.33	0.35	0.31	0.31	0.26	0.21	0.21	0.20	0.25	0.35	0.30	0.30
N	127	136	131	93	112	134	145	145	127	110	109	147	114	1630
350 m														
Med.	0.31	0.40	0.38	0.39	0.37	0.23	0.21	0.21	0.22	0.22	0.23	0.43	0.38	0.28
Min.	0.12	0.16	0.24	0.21	0.19	0.12	0.12	0.12	0.13	0.14	0.12	0.21	0.22	0.12
Max.	0.53	0.65	0.68	0.57	0.60	0.58	0.37	0.54	0.30	0.30	0.34	0.71	0.50	0.71
5%-ile	0.13	0.21	0.27	0.28	0.23	0.16	0.16	0.16	0.16	0.17	0.16	0.27	0.30	0.17
95%-ile	0.48	0.55	0.49	0.51	0.48	0.42	0.29	0.28	0.28	0.28	0.30	0.58	0.46	0.50
N	127	136	132	94	112	135	152	145	127	110	109	147	113	1639
Boundary														
Med.	0.29	0.36	0.32	0.33	0.33	0.21	0.22	0.20	0.20	0.19	0.20	0.37	0.33	0.26
Min.	0.08	0.16	0.23	0.24	0.20	0.12	0.10	0.10	0.11	0.14	0.10	0.21	0.21	0.08
Max.	0.52	0.62	0.54	0.47	0.52	0.54	0.43	0.60	0.31	0.32	0.32	0.64	0.46	0.64
5%-ile	0.11	0.20	0.26	0.26	0.23	0.15	0.16	0.15	0.14	0.16	0.15	0.26	0.27	0.16
95%-ile	0.46	0.54	0.50	0.43	0.40	0.40	0.30	0.29	0.28	0.25	0.30	0.56	0.41	0.47
N	127	136	132	94	112	135	152	145	127	110	109	147	113	1639

Note: units mS/m

Table 4: Summary of Makarewa River Dissolved Oxygen data between December 2001 and June 2014.

	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2001/14
Bridge														
Med.	8.5	9.5	9.5	9.0	9.1	8.0	8.5	9.9	10	10	10	10	10	9.5
Min.	5.5	5.2	6.4	6.8	5.9	5.8	6.3	7.2	7.9	8.0	5.9	7.5	7.9	5.2
Max.	12	12	17	13	11	16	14	14	15	14	15	14	14	17
5%-ile	7.1	7.5	6.9	7.2	6.5	6.5	7.0	8.3	8.5	9.0	7.8	8.4	8.7	7.1
95%-ile	10	11	15	12	11	13	11	12	13	12	13	12	12	12
N	127	136	131	91	112	134	145	145	127	110	109	147	114	1628
350 m														
Med.	7.7	8.5	9.4	8.5	8.8	7.9	8.3	9.4	9.5	9.4	9.7	9.3	9.7	9.0
Min.	4.1	5.1	5.4	5.0	5.7	2.6	5.6	7.3	7.1	7.1	5.5	4.9	6.1	2.6
Max.	13	11	15	12	11	14	12	13	13	12	14	15	12	15
5%-ile	6.4	6.8	6.4	7.1	6.8	6.0	6.5	7.8	7.6	7.9	7.3	6.7	8.0	6.6
95%-ile	9.8	10	14	11	10	12	11	11	12	11	13	11	11	11
N	127	135	132	94	112	135	145	145	127	110	109	147	113	1631
Boundary														
Med.	7.6	8.0	9.4	8.6	8.8	7.8	8.2	9.0	9.3	9.5	9.4	8.7	9.5	8.7
Min.	6.0	4.2	4.7	6.9	5.0	2.4	6.0	6.8	7.5	7.0	5.6	4.1	6.0	2.4
Max.	15	11	16	13	11	16	11	12	13	12	14	15	12	16
5%-ile	6.3	6.5	6.4	7.2	6.6	5.6	6.3	7.5	8.0	7.8	7.1	6.0	7.0	6.4
95%-ile	9.4	10	14	11	10	12	11	11	12	12	12	11	11	11
N	127	136	132	94	112	135	145	145	127	110	109	147	113	1632

Note: units g/m^3

Table 5: Summary of Makarewa River Black Disc data between December 2001 and June 2014.

	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2001/14
Bridge														
Med.	60	36	48	260	50	33	34	43	48	50	48	50	55	45
Min.	26	13	20	12	7	4	13	16	11	18	8	18	13	4
Max.	78	345	310	410	180	45	54	60	64	60	70	68	65	410
5%-ile	26	23	20	27	11	9	14	23	20	21	16	28	26	16
95%-ile	71	49	289	368	117	42	50	51	60	58	59	60	63	240
N	19	21	23	18	22	26	26	31	25	24	25	37	24	321
350 m														
Med.	41	30	42	213	42	24	24	40	46	44	38	46	53	39
Min.	21	12	18	12	5	3	10	16	10	18	7	19	15	3
Max.	58	180	260	350	150	39	46	56	62	58	66	70	61	350
5%-ile	24	22	19	19	10	10	11	22	19	21	15	24	23	15
95%-ile	58	41	259	325	107	37	41	49	58	56	51	60	60	190
N	19	22	23	18	22	26	26	31	25	24	25	37	24	322
Boundary														
Med.	41	31	27	24	41	28	25	40	44	44	41	47	54	38
Min.	19	13	22	13	5	3	12	18	10	18	7	18	15	3
Max.	59	44	80	37	52	41	48	62	63	60	65	72	61	80
5%-ile	22	25	22	14	9	9	15	22	20	21	15	24	24	16
95%-ile	52	39	50	34	49	39	38	48	59	58	52	60	60	59
N	19	21	22	18	22	25	26	31	25	24	25	37	24	319

Note: units cm

Table 6: Summary of Makarewa River Total Nitrogen data between December 2001 and June 2014.

	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2013/14
Bridge														
Med.	1.3	1.1	1.4	1.8	1.6	1.2	1.2	1.5	1.2	1.4	1.2	1.2	1.1	1.3
Min.	0.89	0.78	0.85	1.2	0.60	0.71	0.79	0.87	0.60	0.70	0.57	0.79	0.65	0.57
Max.	4.9	3.0	3.7	3.2	3.6	2.9	4.1	3.8	3.7	4.0	4.1	3.8	4.3	4.9
5%-ile	0.91	0.83	1.0	1.3	0.66	0.72	0.83	1.1	0.81	0.74	0.69	0.88	0.75	0.76
95%-ile	4.4	2.0	3.7	2.8	2.6	2.6	3.2	3.3	3.3	3.7	3.4	3.0	3.3	3.5
N	22	23	23	19	22	26	26	31	25	24	25	36	24	326
350 m														
Med.	5.7	6.4	5.4	5.9	5.3	5.1	5.2	5.2	5.0	5.4	5.3	3.0	6.0	5.3
Min.	2.1	1.3	1.5	3.1	2.3	2.2	1.6	2.0	0.82	1.2	1.8	0.75	3.1	0.75
Max.	12	12	14.	11	8.7	12	9.2	11	9.0	9.8	7.7	20	10	20
5%-ile	2.9	2.5	1.6	3.3	2.6	2.3	1.8	2.4	1.4	1.8	2.0	1.1	3.3	1.7
95%-ile	11	11	11	8.7	7.8	10	8.6	9.7	8.5	7.9	7.4	13	9.5	10
N	22	23	23	20	23	26	26	31	25	24	25	36	24	328
Boundary														
Med.	4.8	4.8	3.8	3.4	3.8	3.5	4.7	4.1	3.6	3.1	3.9	2.6	4.0	3.8
Min.	1.2	1.4	1.5	2.3	1.7	1.5	1.5	1.8	0.80	0.95	1.6	0.59	2.4	0.59
Max.	13	14	10	8.3	10	16	9.1	12	7.8	6.8	7.1	15	12	16
5%-ile	1.9	2.0	1.5	2.3	1.9	2.0	1.8	2.1	1.7	1.52	1.8	1.0	2.6	1.5
95%-ile	11	14	9.0	5.7	9.4	6.3	8.3	7.8	6.5	5.5	6.3	11	6.4	9.8
N	22	23	23	20	23	26	26	31	25	24	25	37	24	329

Note: units g/m^3

Table 7: Summary of Makarewa River Total Oxidised Nitrogen data between December 2001 and June 2014.

	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2001/14
Bridge														
Med.	0.48	0.48	0.62	1.1	0.73	0.66	0.45	0.73	0.64	0.68	0.83	0.80	0.49	0.66
Min.	0.25	0.18	0.29	0.53	0.20	0.030	0.12	0.31	0.21	0.36	0.25	0.37	0.25	0.030
Max.	2.5	1.5	2.7	1.8	2.0	3.0	2.3	2.9	2.2	1.9	2.6	2.6	2.0	3.0
5%-ile	0.29	0.23	0.30	0.62	0.27	0.22	0.26	0.42	0.23	0.40	0.31	0.39	0.31	0.28
95%-ile	1.8	1.3	2.4	1.7	1.7	1.3	1.8	2.5	2.0	1.7	2.0	1.8	1.9	2.0
N	22	23	23	20	23	26	26	31	25	24	25	37	24	329
350 m														
Med.	0.87	0.89	0.78	1.3	0.76	1.1	0.86	0.88	0.81	0.88	0.84	1.2	0.63	0.90
Min.	0.40	0.47	0.26	0.77	0.30	0.40	0.40	0.44	0.34	0.35	0.44	0.34	0.30	0.26
Max.	2.7	3.4	2.8	1.9	2.0	3.5	3.3	2.9	2.2	2.0	2.5	2.5	2.0	3.5
5%-ile	0.45	0.50	0.41	0.83	0.38	0.49	0.46	0.48	0.36	0.39	0.48	0.51	0.34	0.42
95%-ile	2.0	1.7	2.4	1.9	1.7	2.9	2.2	2.6	1.9	1.9	2.1	2.2	1.9	2.2
N	22	23	23	20	23	26	26	31	25	24	25	36	24	328
Boundary														
Med.	0.97	0.89	0.78	1.2	0.93	1.1	0.98	0.83	0.89	0.83	0.83	1.3	0.69	0.94
Min.	0.45	0.37	0.24	0.84	0.36	0.41	0.43	0.040	0.35	0.36	0.43	0.53	0.17	0.040
Max.	2.7	2.0	2.8	1.9	4.3	3.4	3.3	3.0	2.1	1.9	2.6	2.8	2.0	4.3
5%-ile	0.56	0.46	0.26	0.86	0.43	0.52	0.52	0.36	0.39	0.40	0.54	0.54	0.30	0.43
95%-ile	2.0	1.9	2.4	1.8	2.0	2.7	2.3	2.4	2.0	1.7	2.1	2.4	1.9	2.1
N	22	23	23	20	23	26	26	31	25	24	25	37	24	329

Note: units g/m^3

Table 8: Summary of Makarewa River Dissolved Inorganic Nitrogen data between December 2001 and June 2014.

	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2001/14
Bridge														
Med.	0.55	0.54	0.76	1.3	0.78	0.71	0.79	0.98	0.79	1.2	0.98	0.91	0.57	0.82
Min.	0.28	0.27	0.36	0.73	0.29	0.061	0.24	0.53	0.36	0.64	0.40	0.52	0.30	0.061
Max.	2.8	1.6	2.8	2.0	2.6	3.2	2.5	3.1	2.6	2.1	3.5	2.8	2.2	3.5
5%-ile	0.33	0.30	0.40	0.75	0.31	0.26	0.47	0.55	0.41	0.70	0.44	0.57	0.36	0.36
95%-ile	1.9	1.4	2.5	2.0	1.8	2.0	2.1	2.7	2.3	2.1	2.1	2.0	2.0	2.3
N	22	23	23	20	23	26	26	31	25	24	25	37	24	329
350 m														
Med.	4.9	5.6	4.7	5.9	4.2	3.8	5.1	3.9	4.6	4.1	4.0	2.6	5.3	4.4
Min.	2.0	0.80	0.77	1.8	1.5	1.1	0.74	1.3	0.75	0.88	1.6	0.42	2.5	0.42
Max.	11	11	11	10	8.3	8.9	9.6	7.6	8.1	8.7	6.2	18	9.8	18
5%-ile	2.1	1.5	0.80	2.5	1.5	1.4	0.98	1.7	0.92	1.2	1.7	1.0	2.7	1.3
95%-ile	11	10	9.2	8.5	7.1	8.1	9.2	7.2	7.7	6.2	6.0	11	8.7	9.3
N	22	23	23	20	23	26	26	31	25	24	25	36	24	328
Boundary														
Med.	3.8	3.8	3.0	3.0	3.0	2.9	4.4	3.3	2.6	2.6	3.2	1.8	3.3	3.1
Min.	1.6	0.92	0.74	1.6	1.1	0.98	0.73	1.2	0.50	1.2	1.5	0.63	1.8	0.50
Max.	11	15	9.3	7.6	9.4	14	8.9	11	7.3	5.9	6.7	13	8.4	15
5%-ile	1.6	1.2	0.76	2.0	1.2	1.1	0.94	1.5	1.0	1.2	1.5	1.1	2.1	1.2
95%-ile	11	11	6.9	6.5	9.0	5.4	7.8	7.2	5.5	4.2	4.8	11	5.6	8.9
N	22	23	23	20	23	26	26	31	25	24	25	37	24	329

Note: units g/m^3

Table 9: Summary of Makarewa River Ammoniacal Nitrogen data between December 2001 and June 2014.

	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2001/14
Bridge														
Med.	0.055	0.076	0.087	0.10	0.062	0.051	0.091	0.069	0.068	0.094	0.063	0.080	0.060	0.072
Min.	0.014	0.028	0.023	0.036	0.014	0.017	0.0090	0.005	0.014	0.015	0.015	0.024	0.030	0.005
Max.	0.81	1.4	1.8	0.88	0.77	1.9	1.6	0.61	1.1	1.1	0.92	0.93	0.63	1.9
5%-ile	0.031	0.042	0.038	0.058	0.020	0.023	0.031	0.033	0.031	0.018	0.023	0.035	0.037	0.029
95%-ile	0.16	0.22	0.45	0.47	0.42	0.77	0.59	0.35	0.31	0.52	0.37	0.24	0.14	0.39
N	128	136	131	93	112	133	144	144	127	110	109	147	114	1628
350 m														
Med.	4.7	5.3	4.4	4.1	3.7	3.0	3.6	2.7	3.3	3.1	3.5	5.4	5.1	3.9
Min.	0.16	0.099	0.061	0.093	0.061	0.21	0.12	0.17	0.12	0.095	0.13	0.060	0.70	0.060
Max.	15	22	15	8.8	12	8.3	13	11	9.9	9.3	8.8	17	11	22
5%-ile	0.99	0.38	0.16	0.22	0.48	0.59	0.68	0.35	0.30	0.32	0.34	0.12	1.5	0.32
95%-ile	9.7	11	9.7	8.4	7.6	6.9	8.7	7.3	7.2	6.1	5.7	12	9.3	9.1
N	128	136	132	94	112	133	152	145	127	110	109	146	113	1637
Boundary														
Med.	3.1	4.2	2.3	2.1	2.3	2.0	3.2	2.1	1.8	1.8	2.2	3.6	3.4	2.5
Min.	0.027	0.076	0.076	0.074	0.053	0.14	0.098	0.17	0.053	0.072	0.040	0.060	0.37	0.027
Max.	10	13	10	7.1	8.5	11	12	13	9.3	11	8.1	14	13	14
5%-ile	0.56	0.29	0.15	0.18	0.24	0.33	0.51	0.31	0.18	0.26	0.25	0.11	0.69	0.23
95%-ile	9	10	7.9	5.5	5.3	4.3	6.7	7.4	6.7	4.1	4.9	11	6.5	8.1
N	128	135	132	92	111	133	151	145	127	110	109	147	113	1633

Note: units g/m^3

Table 10: Summary of Makarewa River Total Phosphorus data between December 2001 and June 2014.

	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2001/14
Bridge														
Med.	0.054	0.049	0.063	0.14	0.067	0.064	0.063	0.087	0.075	0.088	0.059	0.061	0.060	0.067
Min.	0.031	0.019	0.019	0.060	0.032	0.037	0.027	0.034	0.032	0.024	0.015	0.040	0.030	0.015
Max.	0.45	0.094	0.14	0.55	0.58	0.32	0.60	0.99	0.36	0.58	0.53	0.36	0.23	0.99
5%-ile	0.033	0.026	0.038	0.063	0.033	0.039	0.032	0.042	0.042	0.031	0.023	0.040	0.042	0.032
95%-ile	0.18	0.087	0.14	0.25	0.26	0.26	0.11	0.72	0.31	0.41	0.38	0.21	0.14	0.29
N	21	23	23	18	23	26	26	31	25	24	25	37	24	326
350 m														
Med.	0.58	0.59	0.50	0.54	0.58	0.49	0.52	0.37	0.42	0.40	0.48	0.29	0.54	0.49
Min.	0.12	0.057	0.075	0.16	0.086	0.072	0.096	0.11	0.045	0.083	0.074	0.040	0.21	0.040
Max.	1.3	1.6	1.2	0.79	1.3	0.94	1.1	0.94	0.88	1.0	0.78	1.7	1.1	1.7
5%-ile	0.17	0.19	0.17	0.20	0.16	0.17	0.19	0.12	0.080	0.097	0.18	0.048	0.22	0.084
95%-ile	1.2	1.2	1.1	0.73	0.95	0.90	1.0	0.79	0.81	0.82	0.73	1.3	1.1	1.1
N	22	23	22	20	23	26	26	31	25	24	25	36	24	327
Boundary														
Med.	0.40	0.41	0.35	0.28	0.37	0.31	0.42	0.32	0.26	0.24	0.35	0.16	0.32	0.32
Min.	0.051	0.057	0.088	0.080	0.045	0.058	0.17	0.094	0.033	0.068	0.092	0.040	0.12	0.033
Max.	1.2	1.5	1.9	0.81	1.2	1.5	1.0	1.0	0.71	0.97	1.7	1.1	0.85	1.9
5%-ile	0.082	0.14	0.11	0.099	0.097	0.093	0.19	0.12	0.062	0.077	0.14	0.050	0.13	0.071
95%-ile	1.2	1.2	0.99	0.77	0.92	0.59	0.97	0.92	0.61	0.70	0.64	0.94	0.73	1.0
N	22	23	22	20	23	26	26	31	25	24	25	37	24	328

Note: units g/m^3

Table 11: Summary of Makarewa River Dissolved Reactive Phosphorus data between December 2001 and June 2014.

	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2001/14
Bridge														
Med.	0.027	0.018	0.019	0.088	0.019	0.024	0.031	0.032	0.028	0.050	0.031	0.023	0.008	0.027
Min.	0.009	0.005	0.005	0.003	0.005	0.011	0.007	0.008	0.012	0.013	0.010	0.005	<0.005	<0.005
Max.	0.10	0.042	0.074	0.15	0.092	0.18	0.070	0.80	0.29	0.54	0.18	0.35	0.055	0.80
5%-ile	0.011	0.009	0.007	0.033	0.007	0.013	0.013	0.018	0.016	0.014	0.012	0.008	0.003	0.008
95%-ile	0.047	0.037	0.048	0.13	0.086	0.080	0.062	0.089	0.18	0.14	0.14	0.18	0.044	0.12
N	22	23	23	18	23	26	26	31	25	24	25	37	24	324
350 m														
Med.	0.53	0.46	0.38	0.44	0.37	0.29	0.38	0.25	0.32	0.33	0.38	0.21	0.40	0.35
Min.	0.033	0.019	0.036	0.087	0.011	0.035	0.045	0.038	0.023	0.033	0.036	0.006	0.13	0.006
Max.	1.2	1.4	1.1	0.70	0.75	0.74	0.86	0.78	0.76	0.73	0.65	1.5	0.96	1.5
5%-ile	0.070	0.10	0.075	0.092	0.047	0.056	0.088	0.066	0.058	0.045	0.11	0.009	0.14	0.031
95%-ile	0.88	1.1	0.98	0.66	0.63	0.65	0.79	0.64	0.65	0.68	0.63	0.92	0.89	0.84
N	22	23	23	16	23	26	26	31	25	24	25	36	24	324
Boundary														
Med.	0.365	0.310	0.220	0.210	0.210	0.195	0.285	0.220	0.170	0.155	0.223	0.110	0.26	0.22
Min.	0.026	0.018	0.003	0.036	0.045	0.027	0.031	0.044	0.017	0.030	0.022	0.006	0.013	0.003
Max.	0.94	1.1	0.97	0.69	0.92	1.1	0.78	0.91	0.57	0.62	1.3	0.99	0.66	1.3
5%-ile	0.070	0.055	0.044	0.047	0.050	0.057	0.053	0.050	0.035	0.040	0.053	0.0090	0.032	0.023
95%-ile	0.93	0.95	0.58	0.67	0.70	0.46	0.74	0.69	0.50	0.46	0.61	0.89	0.62	0.77
N	22	23	23	17	23	26	26	31	25	24	25	37	24	326

Note: units g/m^3

Table 12: Summary of Makarewa River soluble Biochemical Oxygen Demand data between December 2001 and June 2014.

	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2001/14
Bridge														
Med.	<1	1	1	<2	<2	<2	1	<2	<2	<2	<2	<2	<2	<2
Min.	<1	<1	<1	<2	<2	<2	1	<2	<2	<2	<2	<2	<2	<1
Max.	1	2	1	2	3	6	2	2	4	9	6	5	<2	9
5%-ile	<1	<1	<1	<2	<2	<2	1	<2	<2	<2	<2	<2	<2	<1
95%-ile	1	2	1	<2	<2	4	1	2	2	8	3	2	<2	<2
N	22	22	24	20	22	25	26	30	25	24	25	37	24	326
350 m														
Med.	<1	1	<1	<2	<2	<2	1	<2	<2	<2	<2	<2	<2	<2
Min.	<1	<1	<1	<2	<2	<2	<1	<2	<2	<2	<2	<2	<2	<1
Max.	2	2	1	3	5	4	4	6	4	3	4	4	<2	6
5%-ile	<1	<1	<1	<2	<2	<2	1	<2	<2	<2	<2	<2	<2	<1
95%-ile	2	2	<1	2	4	3	2	2	3	<2	3	2	<2	2
N	22	23	23	20	22	26	26	30	25	24	25	37	24	327
Boundary														
Med.	<1	1	<1	<2	<2	<2	1	<2	<2	<2	<2	<2	<2	<2
Min.	<1	<1	<1	<2	<2	<2	<1	<2	<2	<2	<2	<2	<2	<1
Max.	2	2	1	<2	3	7	15	5	3	8	6	<2	<2	15
5%-ile	<1	<1	<1	<2	<2	<2	1	<2	<2	<2	<1	<2	<2	<1
95%-ile	2	1	<1	<2	<2	4	5	3	2	6	2	<2	<2	2
N	22	23	23	20	22	25	26	30	25	24	24	37	24	325

Note: total BOD in 2007/2008, units g/m^3.

Table 13: Summary of Makarewa River Faecal Coliforms data between December 2001 and June 2014.

	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2001/14
Bridge														
Med.	870	880	1200	10000	530	380	5600	11000	9600	4600	1050	1500	800	1500
Min.	93	160	28	320	150	67	240	70	200	70	90	100	180	28
Max.	33000	50000	31000	81000	56000	160000	56000	280000	65000	24000	22000	26000	17000	280000
5%-ile	160	247	85	360	173	113	330	200	300	230	210	208	280	170
95%-ile	10000	7350	22000	59400	42840	61250	23000	70000	56800	18605	15800	9400	11280	49900
N	21	23	21	17	23	26	26	31	25	24	25	37	24	323
350 m														
Med.	1100	1200	2600	2650	690	575	2700	1700	1000	1245	800	630	1650	1300
Min.	4	240	700	210	100	69	200	80	50	150	20	210	270	4
Max.	37000	14000	39000	91000	45000	79000	40000	20000	52000	56000	23500	14000	14000	91000
5%-ile	4	259	1003	334	272	163	305	125	220	256	208	230	288	200
95%-ile	4900	11900	31700	18800	37410	28500	14000	13500	25000	45995	6660	5675	8730	20000
95%-ile	21	23	23	20	23	26	26	31	25	24	25	36	24	327
Boundary														
Med.	745	830	1800	2050	640	415	2400	1100	850	580	690	550	950	885
Min.	7	170	260	340	67	100	190	50	200	70	30	100	200	7
Max.	38000	7700	31000	7700	46000	79000	10000	62000	46000	21200	24000	5400	10000	79000
5%-ile	8	188	500	407	240	120	260	80	200	223	166	136	252	140
95%-ile	25650	3510	17600	7225	38470	25000	8250	10900	35050	18795	12960	3380	8095	14525
N	20	23	23	20	23	26	26	31	24	24	25	37	24	326

Note: units MPN/100mL

Table 14: Summary of Makarewa River *E. coli* data between October 2012 and June 2014.

	2012/13	2013/14	2001/14
Bridge			
Med.	430	550	500
Min.	38	180	38
Max.	3200	11000	11000
5%-ile	63	200	190
95%-ile	2540	8050	6700
N	13	34	47
350 m			
Med.	280	750	700
Min.	31	80	31
Max.	7700	13000	13000
5%-ile	72	120	86
95%-ile	4640	6875	7190
95%-ile	13	34	47
Boundary			
Med.	230	505	480
Min.	14	80	14
Max.	3700	9000	9000
5%-ile	84	200	130
95%-ile	2140	5075	3640
N	13	34	47

Note: units cfu/100mL

Table 15: Summary of Water Quality data at Site U2 August 2013 to April 2014.

	DO	Temp	pH	Cond	Clarity	Amm-N	TN	TON	DIN	TP	DRP	FC	*E. coli*	Sol BOD
med	11.3	13.4	7.1	0.27	55	0.060	1.0	0.52	0.59	0.050	0.0075	800	750	<2.0
min	8.5	8.3	6.4	0.23	25	0.040	0.69	0.27	0.34	0.040	<0.005	50	50	<2.0
max	13.1	18.0	7.4	0.33	65	0.27	3.0	1.9	2.0	0.13	0.069	28000	19000	<2.0
5%-ile	9.4	9.5	6.7	0.23	39.1	0.040	0.74	0.28	0.36	0.040	<0.005	191	152.5	<2.0
95%-ile	12.1	17.2	7.3	0.30	62.8	0.21	2.1	1.5	1.6	0.11	0.055	19950	15800	<2.0
N	22	22	22	22	22	22	22	22	22	22	22	22	22	22

Table 16: Summary of Water Quality data at Site D2 August 2013 to April 2014.

	DO	Temp	pH	Cond	Clarity	Amm-N	TN	TON	DIN	TP	DRP	FC	*E. coli*	Sol BOD
med	10	13.5	7.2	0.27	54	0.090	1.0	0.51	0.77	0.070	0.008	640	605	<2.0
min	7.8	8.4	6.5	0.23	23	0.040	0.68	0.21	0.26	0.030	<0.005	130	70	<2.0
max	12	18.2	7.5	0.35	61	2.4	3.4	1.9	2.8	0.89	0.27	75000	6900	<2.0
5%-ile	7.9	9.7	6.8	0.23	39	0.050	0.74	0.27	0.35	0.040	<0.005	194	133	<2.0
95%-ile	12	17.6	7.4	0.32	60	2.2	3.3	1.6	2.7	0.35	0.2	6900	6740	<2.0
N	22	22	22	22	22	22	22	22	22	22	21	22	22	22

Table 17: Summary of Water Quality data at Site D1 August 2013 to April 2014.

	DO	Temp	pH	Cond	Clarity	Amm-N	TN	TON	DIN	TP	DRP	FC	*E. coli*	Sol BOD
med	10	13.5	7.3	0.36	54	4.1	5.1	0.65	4.8	0.51	0.37	900	760	<2.0
min	6.6	8.3	6.5	0.26	23	0.080	1.0	0.26	0.71	0.050	0.005	120	80	<2.0
max	12	18.4	7.6	0.49	64	10	11	1.9	10	1.2	1.0	15000	8000	<2.0
5	8.3	9.6	6.8	0.27	39	0.084	1.6	0.28	1.5	0.051	0.013	200	162	<2.0
95	12	17.6	7.5	0.45	60	8.2	8.8	1.5	8.8	1	0.90	7850	5890	<2.0
N	22.0	22.0	22.0	22.00	22	22.000	22	22	22	22	22	22	22	22

Table 18: Summary of Water Quality data at Makarewa River – Oreti River confluence Site August 2013 to April 2014.

	DO	Temp	pH	Cond	Clarity	Amm-N	TN	TON	DIN	TP	DRP	FC	*E. coli*	Sol BOD
med	10	13.6	7.3	0.27	54	1.0	2.4	0.88	2.2	0.16	0.15	675	615	<2.0
min	6.1	8.9	6.6	0.17	21	0.020	1.1	0.5	1.1	0.020	<0.005	60	40	<2.0
max	13	19.6	7.7	0.33	81	3.3	4.6	2.0	4.0	0.50	0.40	12000	10000	<2.0
5	8.5	9.9	6.9	0.19	32	0.051	1.1	0.56	1.1	0.021	0.0029	191.5	152.5	<2.0
95	12	18.6	7.5	0.31	65	3.0	4.3	1.7	3.9	0.40	0.33	8360	8235	<2.0
N	22.0	22.0	22.0	22.00	22	22.000	22	22	22	22	22	22	22	21

APPENDIX 3

Benthic Invertebrate Data

		March 2014																											
		U1					U2					U2(up)					D1					D2				
Taxa	MCI	U1a	U1b	U1c	U1d	U1e	U2a	U2b	U2c	U2d	U2e	U2a(up)	U2b(up)	U2c(up)	U2d(up)	U2e(up)	D1a	D1b	D1c	D1d	D1e	D2a	D2b	D2c	D2d	D2e
Ephemeroptera																															
Austroclima	9			1	1																										
Deleatidium	8	224	52	140	236	100	160	23	3	76	14	148	92	148	144	120						30	4	11	2	21
Plecoptera																															
Acroperla	5																														
Trichoptera																															
Aoteapsyche	4	928	164	312	216	300	9	2	3		7	8	11	6	4	1						1				1
Hudsonema	6	1	2	2			4			6	1	7	5	10	8	48										
Hydrobiosis	5	12	8	12	5	10	2		2	2	6	1		2		2										
Oecetis	6												1		1	1										
Olinga	9																									
Oxyethira	2	1			1		48	36	132	52	288	12	32	14	23	96		3	1		1	1	4		2	12
Paroxyethira	2																									
Psilochorema	8	1											1													
Pycnocentria	7	96	96	56	40	48	68	16	8	32	8	36	40	52	44	32	1					3	6	1		2
Pycnocentrodes	5	48	68	56	40	12	212	100	32	84	104	300	136	560	220	484		1	1			2	7	3		4
Odonata																										
Xanthocnemis	5																									
Megaloptera																										
Archichauliodes	7	1																								
Coleoptera																										
Elmidae	6	8	12	5	4	8	3	2	1	6	3	2	1	4	1	3							1			1
Scirtidae	8																					1		1		
Staphylinidae	5											1														
Diptera																										
Aphrophila	5	15	10	9	4	16	1		1	1	6	1	1													
Austrosimulium	3			5	2						2															
Chironomidae	2																									
Chironomus	1																				1					
Empididae	3																									
Harrisius	6					1																				
Molophilus	5																									
Muscidae	3		1									1	1													
Orthocladiinae	2	32	8	8	7	40	1	5	92	20	112		4	1	3	1		8	2	1	7			3	1	6
Polypedilum	3																									
Tanypodinae	5																									
Tanytarsini	3	416	36	76	12	148	36	2	124	32	184		5	2		5					1			2		2
Lepidoptera																										
Hygraula	4																									
Crustacea																										
Amphipoda	5						1	3		20	20	2	2	1	4	2								8	4	2
Cladocera	5																784	1056	756	632	1296			13		
Ostracoda	3											1	1		2	7						2	34	2		
Paracalliope	5	5	1	1	5	1	52	136	200	144	344	20	28	33	52	56	3	6	18	25	92	392	184	96	51	276
Acarina	5																									
Mollusca																										
Gyraulus	3																									
Physa	3									1					1					1		2				
Potamopyrgus	4	224	224	116	48	140	324	168	44	84	236	124	204	164	112	132	1	13	21	11	16	1240	1424	272	54	404
Sphaeriidae	3	2	16	4	4	4						1	1		1	1			1			5	1			
Oligochaeta	1	864	184	148	232	104	436	208	440	524	448	100	240	308	252	416	30	71	66	60	196	308	192	340	3	136
Hirudinea	3																									
Plychaeta							12	12	3	15	2	2	2	3	1	3	2	5	6	6	5	3	3	1	4	6
Platyhelminthes	3	3	1	1	6		24	3	1	10	3		6	2				14	20	42	61	136	156	7	7	48
Nematoda	3	5	5	6	5		1	1	12	3	15	4	1	4	4	5						1				2
Nemertea	3		3		4	1																1				1
Coelenterata																										
Hydra	3									1							17	14	20	55	13	2	17	2	1	5
Bryozoa																										

		March 2013																			
		U1					U2					D1					D2				
Taxa	MCI	U1a	U1b	U1c	U1d	U1e	U2a	U2b	U2c	U2d	U2e	D1a	D1b	D1c	D1d	D1e	D2a	D2b	D2c	D2d	D2e
Ephemeroptera																					
Austroclima	9																				
Deleatidium	8	176	280	160	112	39	108	88	96	19	68	1				1	10	23	18	14	19
Plecoptera																					
Acroperla	5																				
Trichoptera																					
Aoteapsyche	4	152	116	236	96	56	36	15	40	5	19							2	14	8	3
Hudsonema	6	1	28	20	1		3	11	7	2	5	2					1		1		1
Hydrobiosis	5	10	5	12	13	9	2	1	1	2	7							2		1	1
Oecetis	6																				
Olinga	9																				
Oxyethira	2	2	7	2	6	4	96	152	240	104	316	1	2	3	2	2	5	5	6	19	5
Paroxyethira	2						1	1		1											
Psilochorema	8																				1
Pycnocentria	7	30	120	120	76	17	96	92	76	44	140	3	5	1	7	13	4	13	15	14	13
Pycnocentrodes	5	5	72	60	44	13	160	120	160	56	168	5			2	4		8	4	4	4
Odonata																					
Xanthocnemis	5											1									
Megaloptera																					
Archichauliodes	7																				
Coleoptera																					
Elmidae	6	6	40	7	37	6	40	13	24	4	28	7	1	5	10	8		2	1	5	3
Scirtidae	8											33		1		1					
Staphylinidae	5																				
Diptera																					
Aphrophila	5		2	4	1	1					2										
Austrosimulium	3	2								1											
Chironomidae	2																				
Chironomus	1											5	14	14	2	1	1	1	1	4	2
Empididae	3																				
Harrisius	6																				
Molophilus	5				1																
Muscidae	3		1	1		1			1	1	1										
Orthocladiinae	2	156	64	320	68	51	48	264	280	44	52	60	10	23	5	48	14	60	104	104	51
Polypedilum	3								1												
Tanypodinae	5																				
Tanytarsini	3	20	28	140	56	29	24	48	112	44	52	3			2		4	64	40	24	8
Lepidoptera																					
Hygraula	4															1				1	
Crustacea																					
Amphipoda	5				1																
Cladocera	5											63	72	92	572	724					
Ostracoda	3						1					1		1				3	3	1	
Paracalliope	5		44	1	19	1	56	40	40	23	18	24	11	52	18	15	136	608	284	132	592
Acarina	5										1										
Mollusca																					
Gyraulus	3								1												
Physa	3		1	3				1	1		2	12	7	7	4	3	2	6		8	9
Potamopyrgus	4	8	256	164	268	11	336	144	304	68	444	624	540	456	1000	1000	132	1000	592	688	1000
Sphaeriidae	3	1	2		2							9	3	2	11	18			1	2	
Oligochaeta	1	132	256	224	116	27	372	468	576	220	436	184	64	188	184	172	216	284	456	148	416
Hirudinea	3											1									
Plychaeta																					
Platyhelminthes	3	1	5	2				3	3	5	3	1000	364	888	484	556	10	56	48	30	15
Nematoda	3	3	14	8	21	8	3	1	8	1	1			1			1	2		3	1
Nemertea	3								1												
Coelenterata																					
Hydra	3									2		23	72	44	16	14	34	72	112	32	15
Bryozoa																					

		Nov 2013																			
		U1					U2					D1					D2				
Taxa	MCI	U1a	U1b	U1c	U1d	U1e	U2a	U2b	U2c	U2d	U2e	D1a	D1b	D1c	D1d	D1e	D2a	D2b	D2c	D2d	D2e
Ephemeroptera																					
Austroclima	9																				
Deleatidium	8	196	55	18	104	73	1	3	2	7	8						4	2		4	1
Plecoptera																					
Acroperla	5				1																
Trichoptera																					
Aoteapsyche	4	2	1		1	2															
Hudsonema	6	4	1			3															1
Hydrobiosis	5	3			1	1															
Oecetis	6															1	1				
Olinga	9	1																			
Oxyethira	2	2	2			2			1					2			3	1		1	
Paroxyethira	2																				
Psilochorema	8																				
Pycnocentria	7	2	1																		1
Pycnocentrodes	5					2							3	1	2		1	3		2	13
Odonata																					
Xanthocnemis	5																				
Megaloptera																					
Archichauliodes	7																				
Coleoptera																					
Elmidae	6	2	1			6											1	3	3	3	1
Scirtidae	8																				
Staphylinidae	5																				
Diptera																					
Aphrophila	5	2	1	1	1	5															
Austrosimulium	3	4	3			2															
Chironomidae	2																	1			
Chironomus	1																				
Empididae	3		1																		
Harrisius	6							1													
Molophilus	5																				
Muscidae	3																				
Orthocladiinae	2	164	156	12	30	176	6	12	2	15	4			1				1			
Polypedilum	3																				
Tanypodinae	5			1										1					1	1	1
Tanytarsini	3	72	32	2	10	92	1	1		1											
Lepidoptera																					
Hygraula	4																				
Crustacea																					
Amphipoda	5																				
Cladocera	5																				
Ostracoda	3													1				1	1		
Paracalliope	5	2	1			1	2	3	2	8	2	112	64	140	56	18	236	168	62	236	160
Acarina	5									1			1	1							
Mollusca																					
Gyraulus	3																				
Physa	3																			1	
Potamopyrgus	4	168	25		2	116	1	1	1	5	2	608	404	696	320	64	444	936	128	228	868
Sphaeriidae	3	4				2						15	35	12	16	3	2	1	3		16
Oligochaeta	1	312	236	64	148	508	56	41	63	196	87	824	732	2000	616	436	440	236	200	344	184
Hirudinea	3												1		1	1					
Plychaeta												10	39	6	8	22	3	3		1	4
Platyhelminthes	3					1						56	11	104	16	8	45	72	8	25	18
Nematoda	3	23	15	9	7	4					1	11	5	2	3	2	1				
Nemertea	3																				
Coelenterata																					
Hydra	3																				
Bryozoa														1			1		1		

APPENDIX 4

Statistical Analysis Results

March 2013

Nested Analysis

Response Number of Taxa

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	6.550000	2.18333	0.4772
Error	16	73.200000	4.57500	Prob > F
C. Total	19	79.750000		0.7026

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Location	1	1	2.4500000	0.5355	0.4749
Site[Location]	2	2	4.1000000	0.4481	0.6466

Response Oligochaetes

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	239708.55	79902.9	7.0333
Error	16	181770.40	11360.6	Prob > F
C. Total	19	421478.95		0.0031

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Location	1	1	13261.25	1.1673	0.2960
Site[Location]	2	2	226447.30	9.9663	0.0015

Site[Location]

Least Squares Means Table

Level	Least Sq Mean	Std Error
[Downstream]1	158.40000	47.666865
[Downstream]2	304.00000	47.666865
[Upstream]1	151.00000	47.666865
[Upstream]2	414.40000	47.666865

LSMeans Differences Tukey HSD

Level			Least Sq Mean
[Upstream]2	A		414.40000
[Downstream]2	A	B	304.00000
[Downstream]1		B	158.40000
[Upstream]1		B	151.00000

Levels not connected by same letter are significantly different

Response MCI

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	241.40254	80.4675	5.8967
Error	16	218.33797	13.6461	Prob > F
C. Total	19	459.74050		0.0066

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Location	1	1	227.45458	16.6681	0.0009
Site[Location]	2	2	13.94796	0.5111	0.6093

Response QMCI

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	2.5529569	0.850986	8.5696
Error	16	1.5888454	0.099303	Prob > F
C. Total	19	4.1418023		0.0013

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Location	1	1	0.1755793	1.7681	0.2023
Site[Location]	2	2	2.3773776	11.9703	0.0007

Location

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
Downstream	3.4852747	0.09965081	3.48527
Upstream	3.6726670	0.09965081	3.67267

Site[Location]

Least Squares Means Table

Level	Least Sq Mean	Std Error
[Downstream]1	3.5199523	0.14092752
[Downstream]2	3.4505972	0.14092752
[Upstream]1	4.1590159	0.14092752
[Upstream]2	3.1863182	0.14092752

LSMeans Differences Tukey HSD

Level			Least Sq Mean
[Upstream]1	A		4.1590159
[Downstream]1		B	3.5199523
[Downstream]2		B	3.4505972
[Upstream]2		B	3.1863182

Levels not connected by same letter are significantly different

Non Parametric Tests

Oneway Analysis of EPT Taxa By Location

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Downstream	10	4.50000	1.77951	0.56273	3.2270	5.7730
Upstream	10	7.20000	0.63246	0.20000	6.7476	7.6524

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Downstream	10	60.5	6.0500	-3.420
Upstream	10	149.5	14.9500	3.420

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
149.5	3.41995	0.0006

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
11.9634	1	0.0005

Oneway Analysis of Deleatidium By Location

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Downstream	10	8.600	9.2640	2.930	1.973	15.23
Upstream	10	114.600	75.5119	23.879	60.582	168.62

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Downstream	10	56.5	5.6500	-3.637
Upstream	10	153.5	15.3500	3.637

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
153.5	3.63667	0.0003

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
13.5023	1	0.0002

November 2013

Nested Analysis

Response Number of Taxa

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	127.75000	42.5833	5.6778
Error	16	120.00000	7.5000	Prob > F
C. Total	19	247.75000		0.0076

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Location	1	1	4.05000	0.5400	0.4731
Site[Location]	2	2	123.70000	8.2467	0.0035

Location

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
downstream	10.700000	0.86602540	10.7000
upstream	9.800000	0.86602540	9.8000

Site[Location]

Least Squares Means Table

Level	Least Sq Mean	Std Error
[downstream]1	9.800000	1.2247449
[downstream]2	11.600000	1.2247449
[upstream]1	13.200000	1.2247449
[upstream]2	6.400000	1.2247449

LSMeans Differences Tukey HSD

Level			Least Sq Mean
[upstream]1	A		13.200000
[downstream]2	A		11.600000
[downstream]1	A	B	9.800000
[upstream]2		B	6.400000

Levels not connected by same letter are significantly different

Response %EPT

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	1132.2145	377.405	12.9565
Error	16	466.0574	29.129	Prob > F
C. Total	19	1598.2719		0.0002

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Location	1	1	611.84783	21.0051	0.0003
Site[Location]	2	2	520.36669	8.9322	0.0025

Location

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
downstream	0.397644	1.7067098	0.3976
upstream	11.459722	1.7067098	11.4597

Site[Location]

Least Squares Means Table

Level	Least Sq Mean	Std Error
[downstream]1	0.141119	2.4136522

Level	Least Sq Mean	Std Error
[downstream]2	0.654168	2.4136522
[upstream]1	18.668804	2.4136522
[upstream]2	4.250640	2.4136522

LSMeans Differences Tukey HSD

Level			Least Sq Mean
[upstream]1	A		18.668804
[upstream]2		B	4.250640
[downstream]2		B	0.654168
[downstream]1		B	0.141119

Levels not connected by same letter are significantly different

Response MCI

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	895.8098	298.603	8.8082
Error	16	542.4110	33.901	Prob > F
C. Total	19	1438.2208		0.0011

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Location	1	1	164.23192	4.8445	0.0428
Site[Location]	2	2	731.57785	10.7900	0.0011

Location

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
downstream	74.143333	1.8412140	74.1433
upstream	79.874510	1.8412140	79.8745

Site[Location]

Least Squares Means Table

Level	Least Sq Mean	Std Error
[downstream]1	65.820000	2.6038698
[downstream]2	82.466667	2.6038698
[upstream]1	81.844258	2.6038698
[upstream]2	77.904762	2.6038698

LSMeans Differences Tukey HSD

Level			Least Sq Mean
[downstream]2	A		82.466667
[upstream]1	A		81.844258
[upstream]2	A		77.904762
[downstream]1		B	65.820000

Levels not connected by same letter are significantly different

Response QMCI

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	8.204915	2.73497	14.7211
Error	16	2.972566	0.18579	Prob > F
C. Total	19	11.177481		<.0001

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Location	1	1	0.8203529	4.4156	0.0518
Site[Location]	2	2	7.3845621	19.8739	<.0001

Location

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
downstream	2.6348372	0.13630310	2.63484
upstream	2.2297809	0.13630310	2.22978

Site[Location]

Least Squares Means Table

Level	Least Sq Mean	Std Error
[downstream]1	2.0719212	0.19276169
[downstream]2	3.1977531	0.19276169
[upstream]1	2.8790743	0.19276169
[upstream]2	1.5804876	0.19276169

LSMeans Differences Tukey HSD

Level			Least Sq Mean
[downstream]2	A		3.1977531
[upstream]1	A		2.8790743
[downstream]1		B	2.0719212
[upstream]2		B	1.5804876

Levels not connected by same letter are significantly different

Response Ln(EPT#taxa+1)

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	2.9945081	0.998169	4.1914
Error	16	3.8103951	0.238150	Prob > F
C. Total	19	6.8049032		0.0228

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Location	1	1	0.3980089	1.6713	0.2144
Site[Location]	2	2	2.5964992	5.4514	0.0157

Location

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
downstream	0.9169518	0.15432100	0.91695
upstream	1.1990897	0.15432100	1.19909

Site[Location]

Least Squares Means Table

Level	Least Sq Mean	Std Error
[downstream]1	0.6356108	0.21824284
[downstream]2	1.1982929	0.21824284
[upstream]1	1.6239393	0.21824284
[upstream]2	0.7742402	0.21824284

LSMeans Differences Tukey HSD

Level			Least Sq Mean
[upstream]1	A		1.6239393
[downstream]2	A	B	1.1982929
[upstream]2	A	B	0.7742402
[downstream]1		B	0.6356108

Levels not connected by same letter are significantly different

Response ln(EPT#ind+1)

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	33.165561	11.0552	16.6112
Error	16	10.648445	0.6655	Prob > F
C. Total	19	43.814006		<.0001

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Location	1	1	12.069954	18.1359	0.0006
Site[Location]	2	2	21.095607	15.8488	0.0002

Location

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
downstream	1.3725498	0.25797826	1.37255
upstream	2.9262521	0.25797826	2.92625

Site[Location]

Least Squares Means Table

Level	Least Sq Mean	Std Error
[downstream]1	0.9128696	0.36483635
[downstream]2	1.8322300	0.36483635
[upstream]1	4.3040238	0.36483635
[upstream]2	1.5484804	0.36483635

LSMeans Differences Tukey HSD

Level			Least Sq Mean
[upstream]1	A		4.3040238
[downstream]2		B	1.8322300
[upstream]2		B	1.5484804
[downstream]1		B	0.9128696

Levels not connected by same letter are significantly different

Non Parametric Tests

variable=%EPT

Oneway Analysis of number By Location

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
downstream	10	0.3976	0.4197	0.1327	0.0974	0.698
upstream	10	11.4597	10.4607	3.3080	3.9766	18.943

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
downstream	10	55	5.5000	-3.743
upstream	10	155	15.5000	3.743

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
155	3.74326	0.0002

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
14.2965	1	0.0002

variable=Deleatidium

Oneway Analysis of number By Location

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
downstream	10	1.1000	1.6633	0.526	-0.090	2.290
upstream	10	46.7000	63.4456	20.063	1.314	92.086

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
downstream	10	63	6.3000	-3.183
upstream	10	147	14.7000	3.183

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
147	3.18290	0.0015

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
10.3765	1	0.0013

variable=Oligochaetes

Oneway Analysis of number By Location

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
downstream	10	601.200	538.664	170.34	215.86	986.54
upstream	10	171.100	148.744	47.04	64.69	277.51

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
downstream	10	142.5	14.2500	2.798
upstream	10	67.5	6.7500	-2.798

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
67.5	-2.79799	0.0051

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
8.0418	1	0.0046

March 2014

Nested Analysis

Response QMCI Value

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Loc	1	1	0.6322788	3.6765	0.0696
site[Loc]	3	3	5.3722894	10.4128	0.0002

Loc

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
downstream	4.1176498	0.13114010	4.11765
upstream	3.7930272	0.10707544	3.79303

site[Loc]

Least Squares Means Table

Level	Least Sq Mean	Std Error
[downstream]3	4.5690305	0.18546010
[downstream]4	3.6662690	0.18546010
[upstream]1	4.0288716	0.18546010
[upstream]2	3.1349500	0.18546010
[upstream]2a	4.2152600	0.18546010

LSMeans Differences Tukey HSD

Level				Least Sq Mean
[downstream]3	A			4.5690305
[upstream]2a	A	B		4.2152600
[upstream]1	A	B		4.0288716
[downstream]4		B	C	3.6662690
[upstream]2			C	3.1349500

Levels not connected by same letter are significantly different

Non Parametric Tests

Oneway Analysis of Number of Taxa By Loc

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
downstream	10	12.0000	0.80470	10.335	13.665
upstream	15	18.0667	0.65703	16.707	19.426

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
downstream	10	63	6.3000	-3.728
upstream	15	262	17.4667	3.728

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
63	-3.72840	0.0002

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
14.1108	1	0.0002

Oneway Analysis of EPT Taxa By Loc

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
downstream	10	2.50000	0.41406	1.6434	3.3566
upstream	15	6.73333	0.33808	6.0340	7.4327

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
downstream	10	57	5.7000	-4.084
upstream	15	268	17.8667	4.084

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
57	-4.08410	<.0001

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
16.9107	1	<.0001

Oneway Analysis of %EPT By Loc

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
downstream	10	1.2879	3.9998	-6.99	9.562
upstream	15	43.8066	3.2658	37.05	50.562

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
downstream	10	55	5.5000	-4.133
upstream	15	270	18.0000	4.133

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
55	-4.13252	<.0001

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
17.3077	1	<.0001

Oneway Analysis of Deleatidium By Loc

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
downstream	10	6.800	17.514	-29.43	43.03
upstream	15	112.000	14.300	82.42	141.58

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
downstream	10	62	6.2000	-3.759
upstream	15	263	17.5333	3.759

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
62	-3.75944	0.0002

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
14.3435	1	0.0002

Oneway Analysis of Oligochaetes By Loc

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
downstream	10	140.200	54.632	27.19	253.21
upstream	15	326.933	44.607	234.66	419.21

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
downstream	10	82.5	8.2500	-2.608
upstream	15	242.5	16.1667	2.608

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
82.5	-2.60759	0.0091

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
6.9450	1	0.0084

Oneway Analysis of MCI Value By Loc

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
downstream	10	74.5488	2.1056	70.193	78.905
upstream	15	86.7303	1.7192	83.174	90.287

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
downstream	10	68	6.8000	-3.413
upstream	15	257	17.1333	3.413

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
68	-3.41272	0.0006

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
11.8368	1	0.0006

Oneway Analysis of Number of Taxa By site

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	5	17.8000	0.91869	15.884	19.716
2	5	17.4000	0.91869	15.484	19.316
2a	5	19.0000	0.91869	17.084	20.916
3	5	9.6000	0.91869	7.684	11.516
4	5	14.4000	0.91869	12.484	16.316

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
1	5	85	17.0000	1.339
2	5	79.5	15.9000	0.961
2a	5	97.5	19.5000	2.197
3	5	17.5	3.5000	-3.227
4	5	45.5	9.1000	-1.305

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
16.2314	4	0.0027

Small sample sizes. Refer to statistical tables for tests, rather than large-sample approximations.

Oneway Analysis of EPT Taxa By site

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	5	6.60000	0.43359	5.6955	7.5045
2	5	6.20000	0.43359	5.2955	7.1045
2a	5	7.40000	0.43359	6.4955	8.3045
3	5	1.20000	0.43359	0.2955	2.1045
4	5	3.80000	0.43359	2.8955	4.7045

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
1	5	86.5	17.3000	1.449
2	5	76.5	15.3000	0.759
2a	5	105	21.0000	2.725
3	5	16	3.2000	-3.346
4	5	41	8.2000	-1.621

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
19.6931	4	0.0006

Small sample sizes. Refer to statistical tables for tests, rather than large-sample approximations.

Oneway Analysis of EPT individuals By site

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	5	657.800	90.655	468.7	846.90
2	5	308.000	90.655	118.9	497.10
2a	5	570.000	90.655	380.9	759.10
3	5	1.600	90.655	-187.5	190.70
4	5	23.400	90.655	-165.7	212.50

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
1	5	101	20.2000	2.413
2	5	71	14.2000	0.374
2a	5	98	19.6000	2.209
3	5	15.5	3.1000	-3.330
4	5	39.5	7.9000	-1.699

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
20.4028	4	0.0004

Small sample sizes. Refer to statistical tables for tests, rather than large-sample approximations.

Oneway Analysis of %EPT By site

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	5	52.3645	3.0353	46.03	58.696
2	5	24.7085	3.0353	18.38	31.040
2a	5	54.3466	3.0353	48.02	60.678
3	5	0.1467	3.0353	-6.18	6.478
4	5	2.4290	3.0353	-3.90	8.761

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
1	5	101	20.2000	2.412
2	5	65	13.0000	0.034
2a	5	104	20.8000	2.616
3	5	15	3.0000	-3.363
4	5	40	8.0000	-1.664

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
21.9397	4	0.0002

Small sample sizes. Refer to statistical tables for tests, rather than large-sample approximations.

Oneway Analysis of Deleatidium By site

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	5	150.400	21.188	106.2	194.60
2	5	55.200	21.188	11.0	99.40
2a	5	130.400	21.188	86.2	174.60
3	5	0.000	21.188	-44.2	44.20
4	5	13.600	21.188	-30.6	57.80

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
1	5	99	19.8000	2.285
2	5	67	13.4000	0.102
2a	5	97	19.4000	2.149
3	5	15	3.0000	-3.377
4	5	47	9.4000	-1.194

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
18.6416	4	0.0009

Small sample sizes. Refer to statistical tables for tests, rather than large-sample approximations.

Oneway Analysis of Oligochaetes By site

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	5	306.400	77.306	145.1	467.66
2	5	411.200	77.306	249.9	572.46
2a	5	263.200	77.306	101.9	424.46
3	5	84.600	77.306	-76.7	245.86
4	5	195.800	77.306	34.5	357.06

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
1	5	65	13.0000	0.034
2	5	103	20.6000	2.548
2a	5	74.5	14.9000	0.612
3	5	26	5.2000	-2.616
4	5	56.5	11.3000	-0.544

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
11.5521	4	0.0210

Small sample sizes. Refer to statistical tables for tests, rather than large-sample approximations.

Oneway Analysis of MCI Value By site

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	5	88.3462	2.3059	83.536	93.156
2	5	84.7832	2.3059	79.973	89.593
2a	5	87.0614	2.3059	82.251	91.871
3	5	67.8000	2.3059	62.990	72.610
4	5	81.2976	2.3059	76.488	86.108

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
1	5	98.5	19.7000	2.243
2	5	65.5	13.1000	-0.000
2a	5	93	18.6000	1.869
3	5	19.5	3.9000	-3.058
4	5	48.5	9.7000	-1.087

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
15.7007	4	0.0034

Small sample sizes. Refer to statistical tables for tests, rather than large-sample approximations.

Pooled Survey Statistical Analysis

Nested Analysis

Response MCI

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Site[Location]	2	2	792.94977	12.2484	<.0001
Location	1	1	869.98178	26.8766	<.0001

Site[Location]

Least Squares Means Table

Level	Least Sq Mean	Std Error
[Downstream]D1	70.478861	1.4690015
[Downstream]D2	80.202605	1.4690015
[Upstream]U1	84.627910	1.4690015
[Upstream]U2	81.284943	1.4690015

LSMeans Differences Tukey HSD

Level			Least Sq Mean
[Upstream]U1	A		84.627910
[Upstream]U2	A		81.284943
[Downstream]D2	A		80.202605
[Downstream]D1		B	70.478861

Levels not connected by same letter are significantly different

Location

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
Downstream	75.340733	1.0387409	75.3407
Upstream	82.956427	1.0387409	82.9564

Non Parametric Tests

Oneway Analysis of Taxa By Date

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Mar-13	20	17.3500	0.73717	15.874	18.826
Mar-14	20	14.8000	0.73717	13.324	16.276
Nov-13	20	10.2500	0.73717	8.774	11.726

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Mar-13	20	861	43.0500	3.944
Mar-14	20	660.5	33.0250	0.787
Nov-13	20	308.5	15.4250	-4.739

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
25.8492	2	<.0001

Oneway Analysis of EPT By Date

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Mar-13	20	4.75000	0.44278	3.8634	5.6366
Mar-14	20	3.75000	0.44278	2.8634	4.6366
Nov-13	20	2.00000	0.44278	1.1134	2.8866

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Mar-13	20	802.5	40.1250	3.067
Mar-14	20	641.5	32.0750	0.495
Nov-13	20	386	19.3000	-3.570

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
15.0107	2	0.0006

Oneway Analysis of %EPT By Date

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Mar-13	20	17.7464	3.9702	9.796	25.696
Mar-14	20	17.6728	3.9702	9.723	25.623
Nov-13	20	5.7935	3.9702	-2.157	13.744

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Mar-13	20	714	35.7000	1.623
Mar-14	20	640	32.0000	0.463
Nov-13	20	476	23.8000	-2.094

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
4.8656	2	0.0878

Oneway Analysis of QMCI By Date

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Mar-13	20	3.57907	0.14336	3.2920	3.8662
Mar-14	20	3.84978	0.14336	3.5627	4.1369
Nov-13	20	2.43231	0.14336	2.1452	2.7194

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Mar-13	20	707	35.3500	1.513
Mar-14	20	834	41.7000	3.505
Nov-13	20	289	14.4500	-5.026

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
26.6600	2	<.0001

Oneway Analysis of Oligo By Date

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Mar-13	20	256.950	66.222	124.34	389.56
Mar-14	20	249.500	66.222	116.89	382.11
Nov-13	20	386.150	66.222	253.54	518.76

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Mar-13	20	609.5	30.4750	0.000
Mar-14	20	555.5	27.7750	-0.847
Nov-13	20	665	33.2500	0.855

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.9835	2	0.6116

Oneway Analysis of Del By Date

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Mar-13	20	61.6000	15.293	30.98	92.224
Mar-14	20	54.8000	15.293	24.18	85.424
Nov-13	20	23.9000	15.293	-6.72	54.524

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Mar-13	20	712.5	35.6250	1.610
Mar-14	20	643.5	32.1750	0.521
Nov-13	20	474	23.7000	-2.139

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
5.0051	2	0.0819

Oneway Analysis of Taxa By Site

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
D1	15	11.9333	1.0941	9.742	14.125
D2	15	14.5333	1.0941	12.342	16.725
U1	15	16.0667	1.0941	13.875	18.258
U2	15	14.0000	1.0941	11.808	16.192

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
D1	15	320.5	21.3667	-2.339
D2	15	464	30.9333	0.103
U1	15	570	38.0000	1.919
U2	15	475.5	31.7000	0.300

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
7.0034	3	0.0718

Oneway Analysis of EPT By Site

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
D1	15	1.20000	0.44490	0.3088	2.0912
D2	15	3.40000	0.44490	2.5088	4.2912
U1	15	5.33333	0.44490	4.4421	6.2246
U2	15	4.06667	0.44490	3.1754	4.9579

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
D1	15	200	13.3333	-4.470
D2	15	436.5	29.1000	-0.357
U1	15	666.5	44.4333	3.626
U2	15	527	35.1333	1.200

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
26.1470	3	<.0001

Oneway Analysis of %EPT By Site

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
D1	15	0.2037	2.5809	-4.97	5.374
D2	15	1.6664	2.5809	-3.50	6.836
U1	15	38.6737	2.5809	33.50	43.844
U2	15	14.4065	2.5809	9.24	19.577

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
D1	15	139.5	9.3000	-5.421
D2	15	340.5	22.7000	-1.989
U1	15	767	51.1333	5.276
U2	15	583	38.8667	2.134

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
49.4899	3	<.0001

Oneway Analysis of QMCI By Site

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
D1	15	3.38697	0.20921	2.9679	3.8061
D2	15	3.43834	0.20921	3.0192	3.8574
U1	15	3.68899	0.20921	3.2699	4.1081
U2	15	2.63392	0.20921	2.2148	3.0530

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
D1	15	499	33.2667	0.700
D2	15	484	32.2667	0.444
U1	15	584	38.9333	2.151
U2	15	263	17.5333	-3.312

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
12.2966	3	0.0064

Oneway Analysis of Oligo By Site

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
D1	15	388.200	77.424	233.10	543.30
D2	15	260.200	77.424	105.10	415.30
U1	15	237.000	77.424	81.90	392.10
U2	15	304.733	77.424	149.63	459.83

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
D1	15	433	28.8667	-0.410
D2	15	482.5	32.1667	0.418
U1	15	402.5	26.8333	-0.931
U2	15	512	34.1333	0.922

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
1.5792	3	0.6641

Oneway Analysis of Del By Site

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
D1	15	0.133	12.167	-24.2	24.51
D2	15	10.867	12.167	-13.5	35.24
U1	15	131.000	12.167	106.6	155.37
U2	15	45.067	12.167	20.7	69.44

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
D1	15	130.5	8.7000	-5.611
D2	15	414	27.6000	-0.739
U1	15	753	50.2000	5.070
U2	15	532.5	35.5000	1.280

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
44.6968	3	<.0001

Oneway Analysis of Taxa By Discharge

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
discharge	40	16.0750	0.54319	14.988	17.162
no discharge	20	10.2500	0.76818	8.712	11.788

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
discharge	40	1521.5	38.0375	4.739
no discharge	20	308.5	15.4250	-4.739

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
308.5	-4.73853	<.0001

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
22.5283	1	<.0001

Oneway Analysis of EPT By Discharge

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
discharge	40	4.25000	0.31725	3.6150	4.8850
no discharge	20	2.00000	0.44866	1.1019	2.8981

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
discharge	40	1444	36.1000	3.570
no discharge	20	386	19.3000	-3.570

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
386	-3.57049	0.0004

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
12.8055	1	0.0003

Oneway Analysis of %EPT By Discharge

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
discharge	40	17.7096	2.7830	12.14	23.280
no discharge	20	5.7935	3.9358	-2.08	13.672

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
discharge	40	1354	33.8500	2.094
no discharge	20	476	23.8000	-2.094

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
476	-2.09374	0.0363

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
4.4166	1	0.0356

Oneway Analysis of QMCI By Discharge

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
discharge	40	3.71443	0.10206	3.5101	3.9187
no discharge	20	2.43231	0.14433	2.1434	2.7212

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
discharge	40	1541	38.5250	5.026
no discharge	20	289	14.4500	-5.026

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
289	-5.02584	<.0001

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
25.3380	1	<.0001

Oneway Analysis of Oligo By Discharge

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
discharge	40	253.225	46.423	160.30	346.15
no discharge	20	386.150	65.652	254.73	517.57

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
discharge	40	1165	29.1250	-0.855
no discharge	20	665	33.2500	0.855

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
665	0.85489	0.3926

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.7443	1	0.3883

Oneway Analysis of Del By Discharge

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
discharge	40	58.2000	10.730	36.72	79.678
no discharge	20	23.9000	15.174	-6.47	54.274

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
discharge	40	1356	33.9000	2.139
no discharge	20	474	23.7000	-2.139

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
474	-2.13909	0.0324

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
4.6095	1	0.0318

Oneway Analysis of Taxa By Location

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Downstream	30	13.2333	0.79087	11.650	14.816
Upstream	30	15.0333	0.79087	13.450	16.616

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Downstream	30	784.5	26.1500	-1.929
Upstream	30	1045.5	34.8500	1.929

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
1045.5	1.92950	0.0537

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
3.7516	1	0.0528

Oneway Analysis of EPT By Location

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Downstream	30	2.30000	0.35119	1.5970	3.0030
Upstream	30	4.70000	0.35119	3.9970	5.4030

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Downstream	30	636.5	21.2167	-4.187
Upstream	30	1193.5	39.7833	4.187

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
1193.5	4.18716	<.0001

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
17.5954	1	<.0001

Oneway Analysis of %EPT By Location

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Downstream	30	0.9350	2.4007	-3.87	5.740
Upstream	30	26.5401	2.4007	21.73	31.346

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Downstream	30	480	16.0000	-6.425
Upstream	30	1350	45.0000	6.425

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
1350	6.42473	<.0001

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
41.3722	1	<.0001

Oneway Analysis of QMCI By Location

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Downstream	30	3.41265	0.16106	3.0903	3.7350
Upstream	30	3.16145	0.16106	2.8391	3.4838

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Downstream	30	983	32.7667	0.998
Upstream	30	847	28.2333	-0.998

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
847	-0.99795	0.3183

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
1.0107	1	0.3147

Oneway Analysis of Oligo By Location

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Downstream	30	324.200	54.629	214.85	433.55
Upstream	30	270.867	54.629	161.52	380.22

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Downstream	30	915.5	30.5167	-0.000
Upstream	30	914.5	30.4833	0.000

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
914.5	0.00000	1.0000

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.0001	1	0.9941

Oneway Analysis of Del By Location

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Downstream	30	5.5000	10.188	-14.89	25.89
Upstream	30	88.0333	10.188	67.64	108.43

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Downstream	30	544.5	18.1500	-5.507
Upstream	30	1285.5	42.8500	5.507

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
1285.5	5.50701	<.0001

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
30.4091	1	<.0001

APPENDIX 5

Mixing Zone Assessment Report

report

November 2015

Lorneville Mixing Zone Assessment

Submitted to:
Alliance Group Ltd

Table of Contents

Index of Tables

1.0 Introduction

As part of an assessment of the effects of its treated wastewater discharge to the Makarewa River Alliance Group Limited (Alliance) has requested Freshwater Solutions Ltd undertake a discharge mixing zone assessment.

The mixing zone in the section of the Makarewa River where the discharge occurs is influenced by a strong tidal flushing effect but it the river does not become saline during the flush tide; salinity in the mixing zone ranged from 0.13 to 0.17 ppt during the survey. The proposed initial approach to this mixing zone assessment was to track the discharge sodium concentration 'signature' during summer low river flows and peak, or near peak, discharge volumes. It was also decided that river bed profile and water velocity data at regularly spaced transects would be collected at the same time as sodium sample gathering. Channel profile and water velocity data was used to assist this initial assessment and are also key CORMIX model inputs, should CORMIX modelling be required.

Hence, the objective of this assessment was to assess the vertical, lateral and longitudinal wastewater mixing characteristics during low river flow and low tide/high tide conditions.

The results of the mixing zone assessment may also help identify any zones of non-compliance and the potential for the discharge to cause adverse effects within the mixing zone and to assess the need for any modifications to the discharge structure.

2.0 Methodology

A reach survey to assess river flow during low tide and high tide conditions was conducted by NIWA and Freshwater Solutions on the Makarewa River on 14 March 2014. River cross section profiles and depth averaged velocity (DAV) data was collected by taking an Acoustic Doppler Current Profiler coupled with a Global Positioning System (ADCP/GPS) across the river. Positional accuracy was achieved by using a Real Time Kinematic (RTK) GPS.

The cross sections were taken at the sites listed in Table 1; the time, tidal conditions and calculated river flows are also presented. The mean flows reported under high tide conditions were highly variable and replicate measurements made even just several minutes apart were found to differ by up to a factor of 2.3. Hence these flows have not been used in mixing calculations.

At the same time as the flow survey, up to five grab samples of river water were collected at transects denoted T1–T5, both at the surface and at 0.6 m below the surface (if the river depth was sufficient). These samples were sent to Hill Laboratories to determine sodium concentrations to be used in the assessment of mixing of the discharge. In addition, triplicate samples of the discharge water were collected on the day of the survey and also analysed for sodium.

The sodium and river profile and flow data is presented graphically. The data for the low tide survey is presented with the true right bank as the right bank looking downstream. The data for the high tide survey has the true right bank reversed as this reflects the actual direction of flow (upstream) that occurs during the flush tide. Nevertheless, the transect denoted T1 is always closest to the river bank from which the discharge occurs.

Table 1: Makarewa River flow assessment – sites and river conditions.

Site	Time	Tidal Conditions	Mean Flow[a]
Upstream 50 m	7:43 - 7:50	Low tide + 37 min	3.1 m^3/s
Downstream 50 m	7:58 - 8:02	Low tide + 52 min	3.5 m^3/s
Downstream 200 m	8:13 - 8:16	Low tide + 67 min	3.1 m^3/s
Downstream 500 m	8:27 - 8:36	Low tide + 81 min	3.5 m^3/s
Downstream 800 m	8:42 - 8:45	Low tide + 96 min	3.4 m^3/s
Downstream 1200 m	9:00 - 9:05	Low tide + 114 min	3.4 m^3/s
Upstream 200 m	14:03 - 14:06	High tide + 57 min	0.0 m^3/s
Upstream 50 m	13:40 - 13:43	High tide + 34 min	0.2 m^3/s
Downstream 50 m	13:22 - 13:25	High tide + 14 min	-2.7 m^3/s
Downstream 200 m	13:05 - 13:08	High tide – 3 min	-2.7 m^3/s
Downstream 500 m	12:44 - 12:48	High tide – 22 min	-6.3 m^3/s
Downstream 800 m	12:27 - 12:32	High tide – 31 min	-7.9 m^3/s
Downstream 1,200 m	12:04 - 12:10	High tide – 64 min	-12.0 m^3/s

Note: [a] Calculated based on cross sectional and DAV data; negative flows indicate river flowing upstream; low tide at Oreti Beach 7:06, high tide at Oreti Beach 13:08.

3.0 Results

The results of the survey and sodium analyses are presented in Table 2 and Table 3. Under low tide conditions the concentration of sodium upstream of the discharge (average 15 g/m^3), the river flow upstream of the discharge (3.1 m^3/s), the wastewater concentration of sodium (average 337 g/m^3), and the wastewater discharge rate recording on the day of the survey (13,244 m^3/d) can be used to estimate the fully mixed sodium concentration downstream of the discharge, which is 30 ± 3 g/m^3. Hence, downstream sodium concentrations less than 27 g/m^3 and greater 33 g/m^3 represent zones of incomplete mixing.

Estimates of the degree of discharge mixing, under high tide conditions are far less straightforward. At the time of the survey the visual extent of the tidal influence coincided approximately with the furthest upstream sampling point, which was 200 m upstream of the discharge – hence the field observation that the discharge plume at times appeared 'upstream' of the discharge point. In addition, the tidal effect was such that a section of near static flow occurred up to approximately 200 m downstream of the discharge point; downstream of this it was clearly apparent that the Makarewa River 'flowed backwards.

Table 2: Sodium concentrations for the wastewater and Makarewa River transects.

Wastewater					
Sodium (g/m^3)	350	320	340		
Makarewa River					
Low Tide	**T1**	**T2**	**T3**	**T4**	**T5**
US 50-S sodium (g/m^3)	15	15	14	15	15
DS 50-S sodium (g/m^3)	42	27	17	21	16
DS 50-D sodium (g/m^3)	-	26	33	29	31
DS 200-S sodium (g/m^3)	30	30	32	31	31[a]
DS 500-S sodium (g/m^3)	30	31	32	31	31
DS 500-D sodium (g/m^3)	-	31	31	-	
DS 800-S sodium (g/m^3)	29	31[a]	31	31	31
DS 800-D sodium (g/m^3)	-	30	32	31	-
DS 1200-S sodium (g/m^3)	28	29	28	29	29
DS 1200-D sodium (g/m^3)	-	30	29	29	-
High Tide	**T1**	**T2**	**T3**	**T4**	**T5**
US 200-S sodium (g/m^3)	41	31	25	31	23
US 200-D sodium (g/m^3)	40	28	23	31	27
US 50-S sodium (g/m^3)	39	38	42	47	41
US 50-D sodium (g/m^3)	37	38	41	46	42
DS 50-S sodium (g/m^3)	31	32	31	34	35
DS 50-D sodium (g/m^3)	32	32	32	33	35
DS 200-S sodium (g/m^3)	33	32	31	31	32
DS 200-D sodium (g/m^3)	33	32	31	32	32
DS 500-S sodium (g/m^3)	31	31	32	32	32
DS 500-D sodium (g/m^3)	34	32	31	31	32[a]
DS 800-S	31	31	30	29	30
DS 800-D	32	29	30	29	30
DS 1200-S	27	27	29	26	26
DS 1200-D	27	27	28	-	-

Note: US = upstream, DS = downstream, S = surface sample, D = sample at 0.6m, [a]average of two replicates.

Table 3: **Summary of Makarewa River depth averaged velocities.**

Low Tide	Min	5%-ile	Median	95%-ile	Max
US 50 m	0.53	0.73	5.5	16.5	17.4
DS 50 m	7.1	7.4	13.5	19.5	19.5
DS 200 m	4.2	4.4	19.9	41.7	46.7
DS 500 m	8.6	10.8	19.9	28.6	29.7
DS 800 m	2.1	3.5	15.2	21.9	24.0
DS 1,200 m	2.5	3.2	11.2	13.7	14.4
High Tide					
US 200 m	0.2	0.3	3.6	5.6	7.2
US 50 m	0.8	1.1	2.9	8.6	11.1
DS 50 m	-2.3	-2.8	-5.3	-9.1	-9.9
DS 200 m	-3.5	-3.9	-6.7	-10.1	-11.1
DS 500 m	-2.6	-3.6	-10.3	-13.8	-14.4
DS 800 m	-3.6	-5.1	-10.8	-14.4	-15.3
DS 1,200 m	-5.8	-8.9	-20.2	-23.4	-23.8

Note: All data cm/s, US = upstream, DS = downstream, negative velocities indicate river flowing upstream.

River sodium concentrations are presented against a cross sectional profile of the river and are colour coded on the river cross-section figures presented below.

- Blue: <27 g/m^3 (not fully mixed – low tide conditions only).
- Green: 27–33 g/m^3 (fully mixed – low tide conditions only).
- Red: >33 g/m^3 (not fully mixed – low tide conditions only).

It should be noted the colour-coded concentrations are applicable to those figures for the low tide conditions only. The same colour coding is used in the figures for the high tide conditions as well, but this is just for purposes of comparison with the low tide since a full assessment of vertical mixing under high tide conditions is not possible.

Makarewa River Upstream 50 m – Low Tide

At low tide, 50 m upstream of the discharge, the river was slower flowing (<10 cm/s) downstream across the majority of the river. There was a 5 m section that had higher velocity at the true right bank (10–17 cm/s) (Figure 1). Sodium concentrations, at the 50 m upstream cross section were uniform (approximately 15 g/m^3) at the surface (Figure 2).

Figure 1: **Depth averaged velocities at 50 m upstream cross section at high tide.**

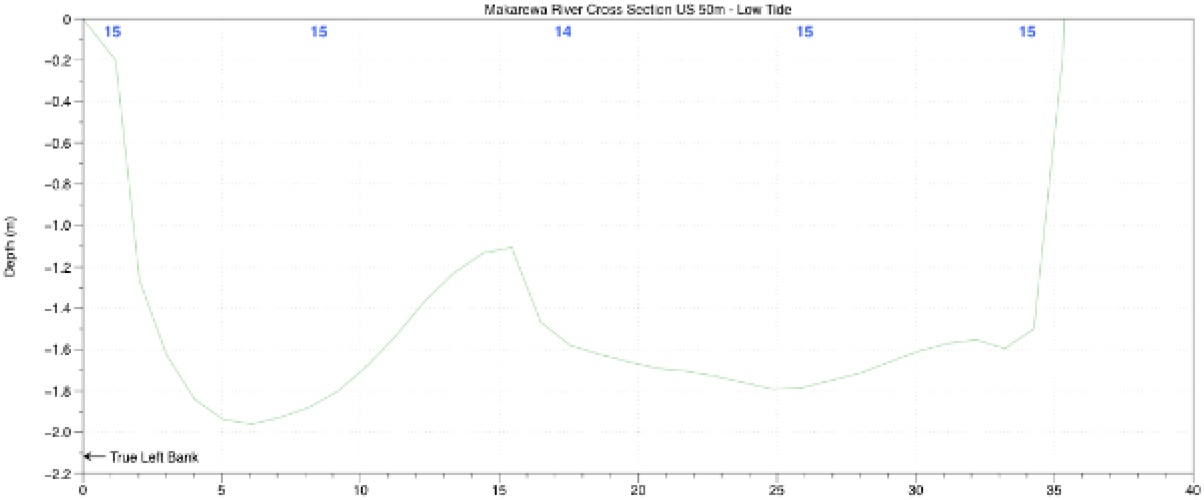

Figure 2: **Salinity profile results at 50 m upstream cross section at high tide.**

Makarewa River downstream 50 m – Low Tide

At low tide, 50 m downstream of the discharge, the river was flowing downstream at 11–20 cm/s on the true left bank to approximately the middle of the river as the discharge joined, but slower flowing (7–10 cm/s) from approximately the middle of the river toward the true right bank (Figure 3).

Figure 3: Depth averaged velocities at 50 m upstream cross section at low tide.

Sodium concentrations, at the 50 m downstream cross section, were elevated in the higher flowing section toward the true left bank at the surface (42 g/m^3) but more uniform (29 –33 g/m^3) and indicative of approximately full mixing at a depth of 0.6 m from approximately the middle of the river toward the true right bank. At the surface, from approximately the middle of the river toward the true right bank, sodium concentrations were only slightly elevated (16–21 g/m^3) compared with upstream concentrations, indicating little mixing of the discharge at the surface (Figure 4).

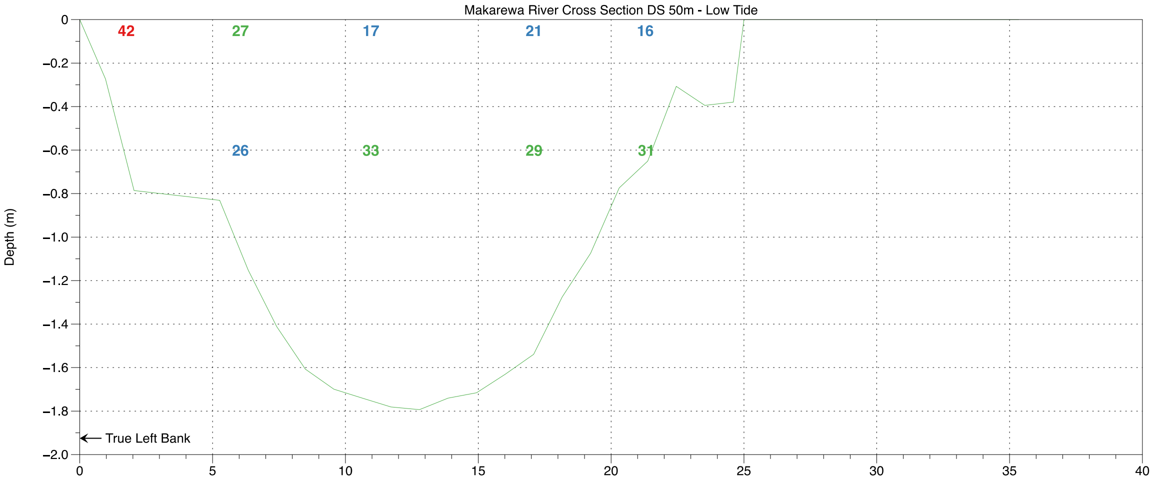

Figure 4: Salinity profile results at 50 m upstream cross section at low tide.

Makarewa River downstream 200 m – Low Tide

At the 200 m downstream cross section, at low tide the river was highest flowing (11–47 cm/s) in the middle and slower flowing (4–10 cm/s) toward the banks (Figure 5). The river was too shallow to sample at depth at 200 m downstream cross section, but sodium concentrations were uniform at the surface (30–32 g/m^3) (Figure 6). Based on the estimated theoretical fully mixed sodium concentration at this site (27–33 g/m^3) the discharge was fully mixed across the channel at the surface at 200 m.

Figure 5: Depth averaged velocities at 200 m downstream cross section at low tide.

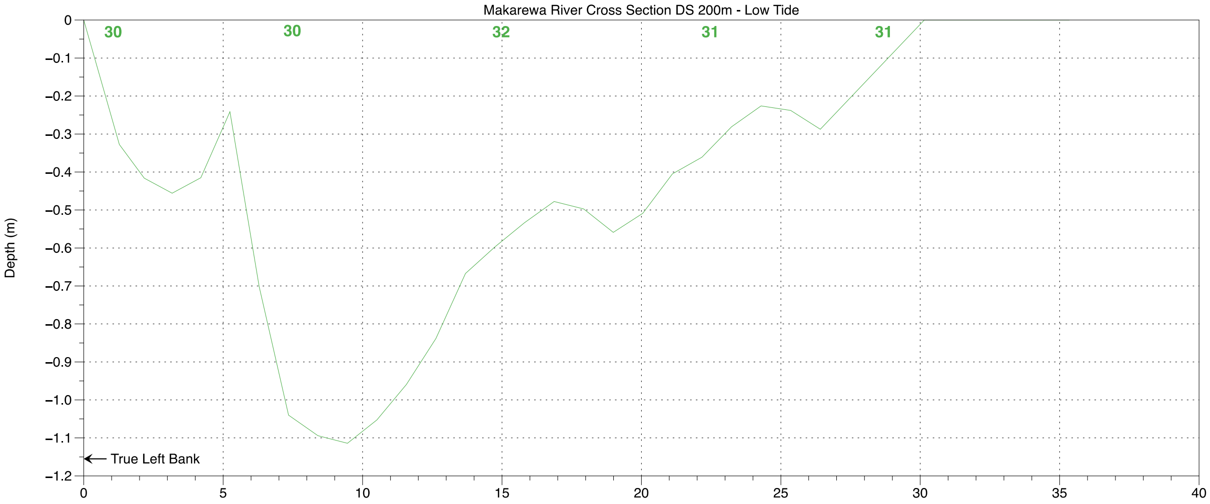

Figure 6: Salinity profile results at 200 m downstream cross section at low tide.

Makarewa River downstream 500 m and 800 m – Low Tide

At low tide at the 500 m and 800 m cross sections the river was highest flowing (>10 cm/s) in the middle and slower flowing (4–10 cm/s) toward the banks (Figures 7 and 9). At 500 m sodium concentrations were uniform at the surface and at a depth of 0.6m (30–32 g/m^3) Figure 8). An analogous situation was observed at the 800 m downstream cross section (29–32 g/m^3), albeit with a trend toward slightly lower sodium concentrations (Figure 10). Hence, at 500 m and 800 m the discharge appears fully mixed at the surface across the channel and at a depth of 0.6 m.

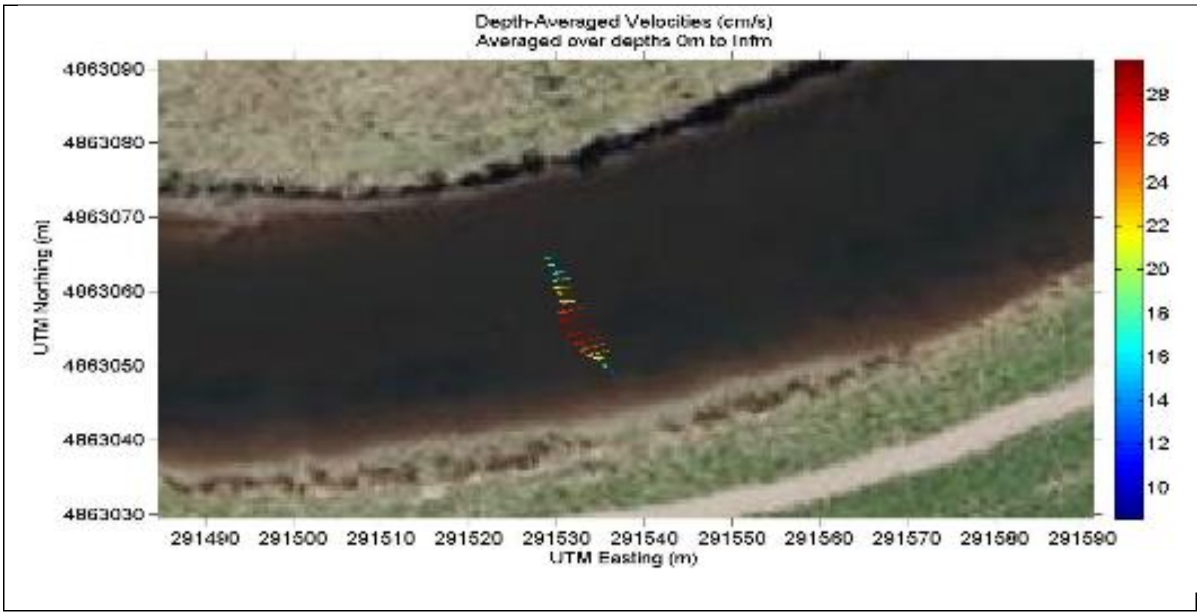

Figure 7: Depth averaged velocities at 500 m downstream cross section at low tide.

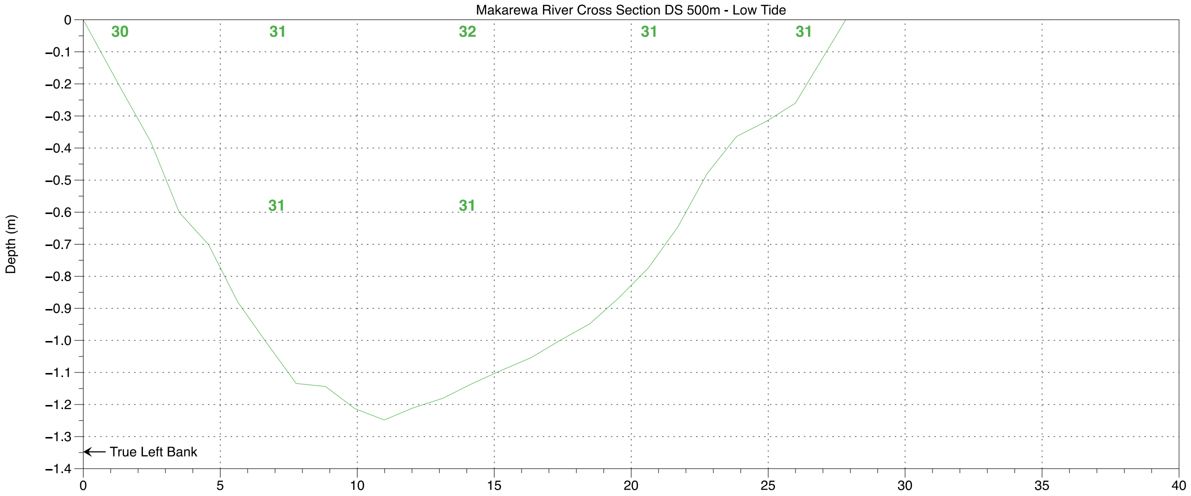

Figure 8: Salinity profile results at 500 m downstream cross section at low tide.

Figure 9: Depth averaged velocities at 800 m downstream cross section at low tide.

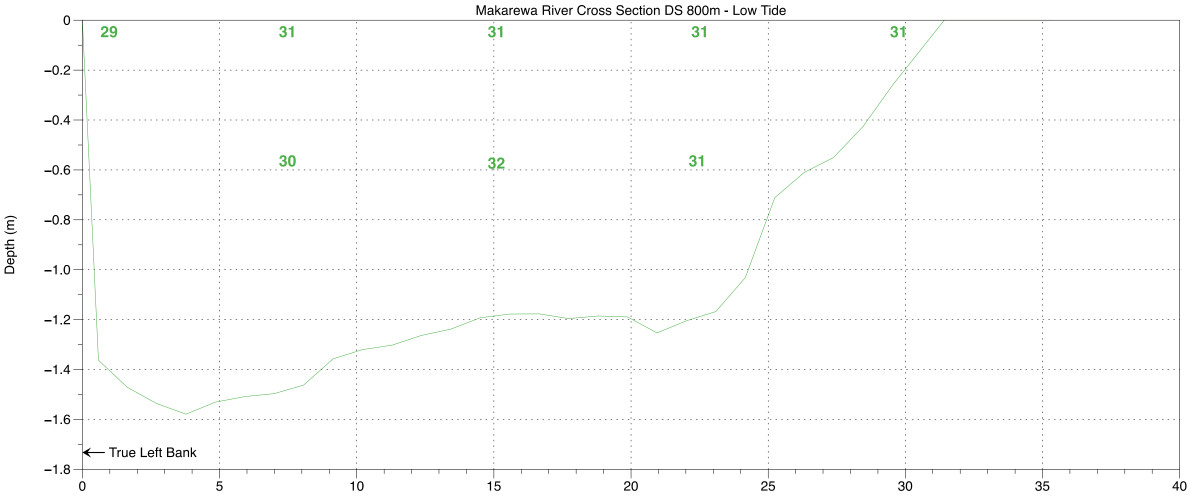

Figure 10: Salinity profile results at 800 m downstream cross section at low tide.

Makarewa River downstream 1,200 m – Low Tide

At low tide a similar pattern to the 500 m and 800 m cross sections is seen at 1,200 m cross section but the river was generally slower flowing. The highest flowing sections were 10–24 cm/s and the slower flowing sections were 3–10 cm/s (Figure 11). Sodium concentrations, at the 1,200 m downstream cross section, at the surface (28–29 g/m^3) and at a depth of 0.6 m (29–30 g/m^3) indicated the discharge was fully mixed (Figure 12).

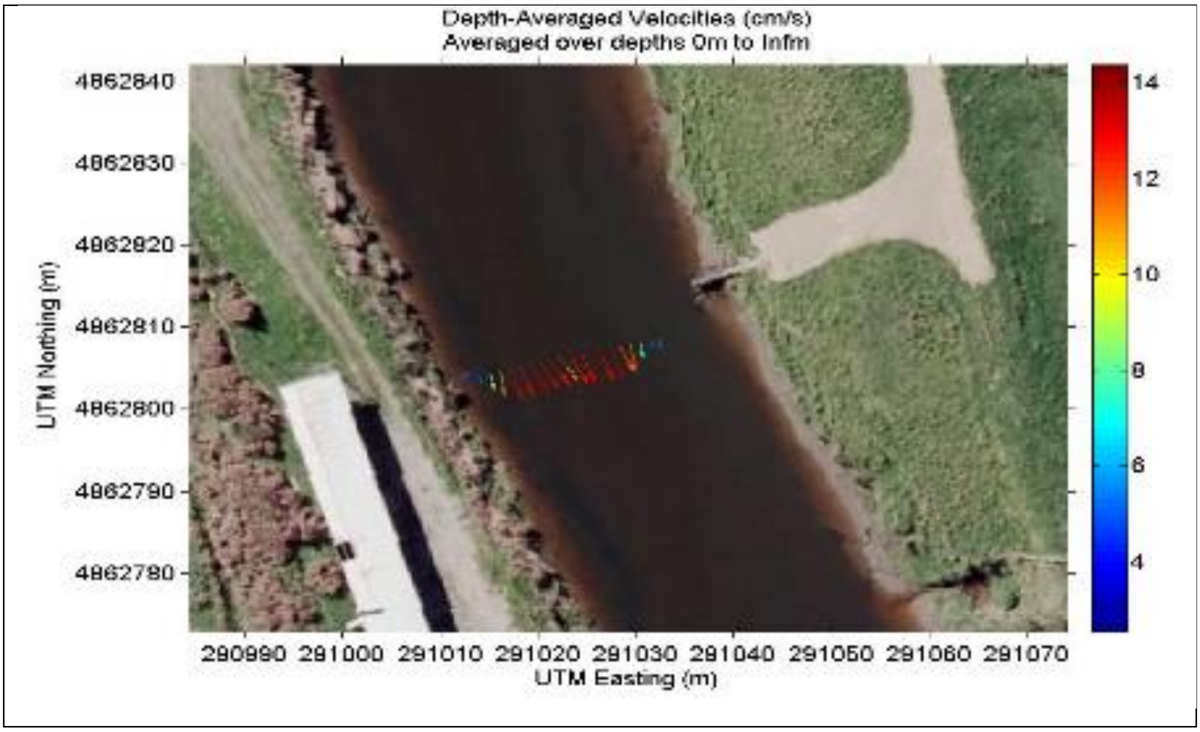

Figure 11: Depth averaged velocities at 1,200 m downstream cross section at low tide.

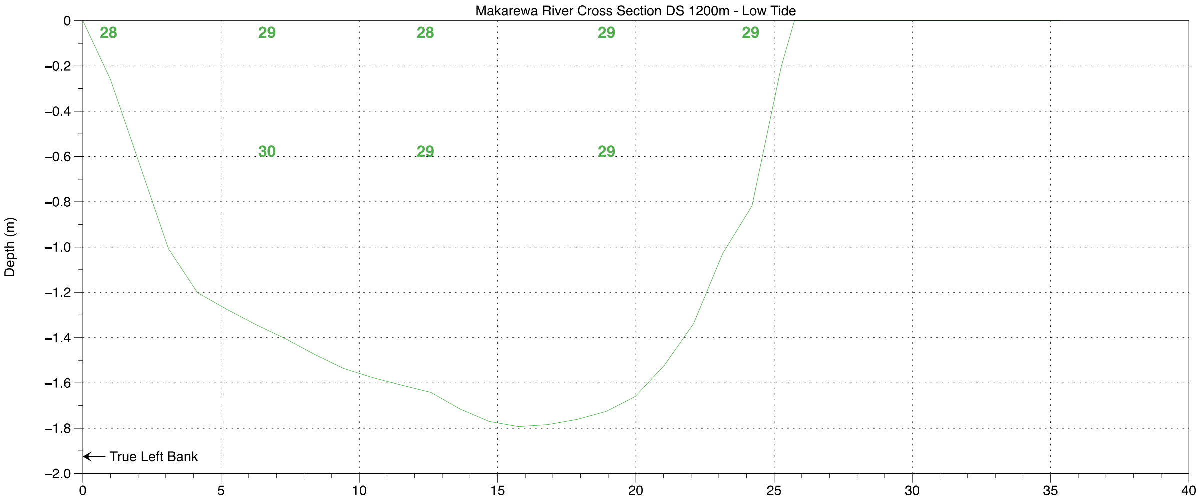

Figure 12: Salinity profile results at 1,200 m downstream cross section at low tide.

Makarewa River upstream 200 m – High Tide

At high tide and 200 m upstream of the discharge, the vast proportion of the river was flowing downstream at <6 cm/s. A faster flowing (>7 cm/s) section was observed on the true right bank. Also of note is the thin band of upstream flow at >7 cm/s at the true left bank (Figure 13).

Figure 13: Depth averaged velocities at 200 m upstream cross section at high tide.

Here, elevated concentrations of sodium were observed at the surface and at a depth of 0.6 m on the true left bank, indicating the position of the discharge plume. The remainder of the cross section of the river shows pockets of well mixed discharge at the surface and at 0.6 m depth that have flowed upstream, combined with other pockets of fresher river water from upstream

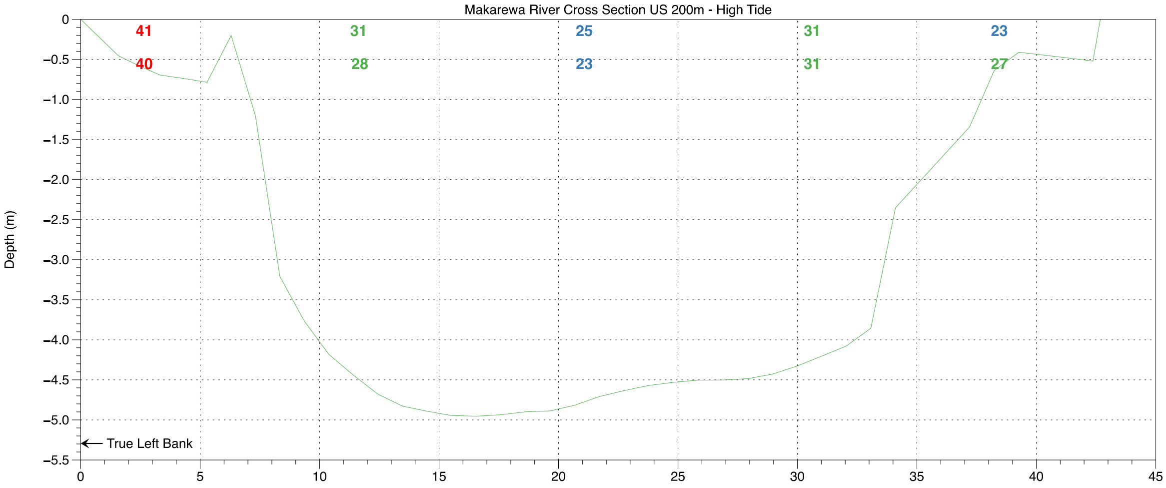

Figure 14: Salinity profile results at 200 m upstream cross section at high tide.

Makarewa River upstream 50 m – High Tide

The river was flowing quite rapidly downstream (>10 cm/s) in a small section of the river on the true left bank at the 50 m upstream cross section. The remainder of the river was almost static or slowly flowing upstream (Figure 15). Based on sodium concentrations at the surface and at 0.6 m depth, this section of the river shows incompletely mixed discharge that has spread across the width of the river, possibly sitting on top of previously well mixed river water that has returned with the incoming river flow (Figure 16).

Figure 15: Depth averaged velocities at 50 m upstream cross section at high tide.

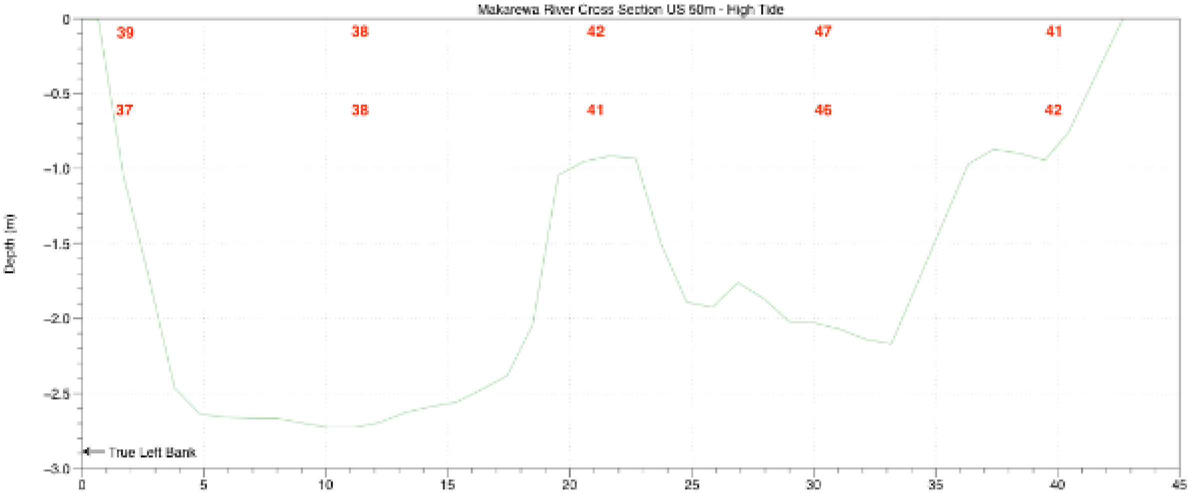

Figure 16: Salinity profile results at 50 m upstream cross section at high tide.

Makarewa River downstream 50 m – High Tide

At the 50 m downstream cross section the river was flowing upstream at 5–10 cm/s with the tidal influence being greatest toward the extreme true left bank which is now defined as the opposite side of the river to which the discharge occurs. The river was flowing downstream only in a small cross-section that appeared to be in the discharge plume (Figure 17). It is likely that the majority of the discharge plume at the 50 m downstream cross section was being pushed back upstream, but sodium concentrations indicate that the discharge prior to the tide turning was well mixed at the surface and at a depth of 0.6 m (Figure 18).

Figure 17: Depth averaged velocities at 50 m downstream cross section at high tide.

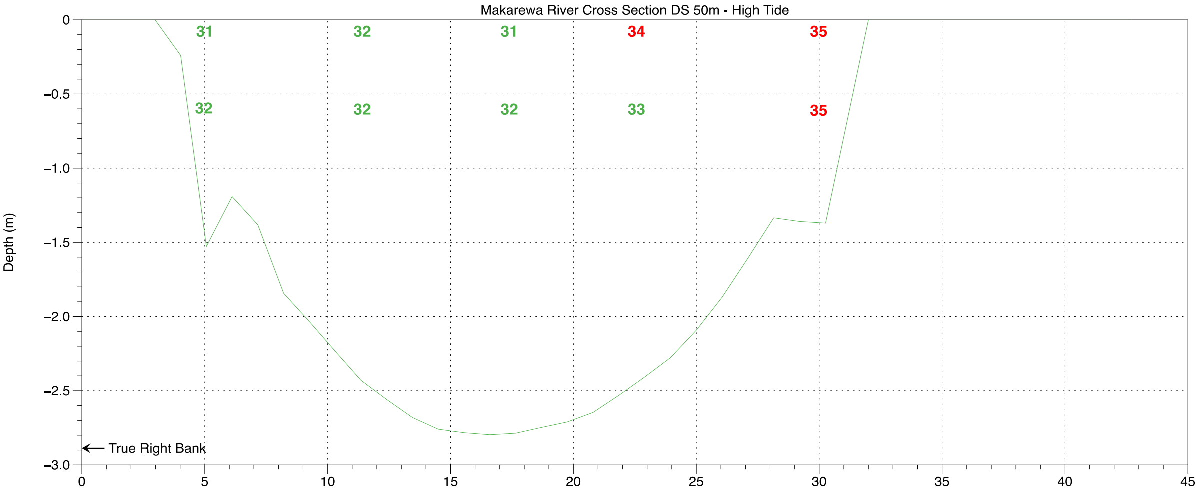

Figure 18: Salinity profile results at 50 m downstream cross section at high tide.

Makarewa River downstream 200 m – High Tide

At the 200 m downstream cross section the river flow was upstream at 6–11 cm/s with the tidal influence clearly evident (Figure 19). Although the discharge plume at the time of sampling at this site was being held upstream, sodium concentrations from discharges before the tide had turned indicate the discharge was well mixed at the surface and at a depth of 0.6 m (Figure 20).

Figure 19: Depth averaged velocities at 200 m downstream cross section at high tide.

Figure 20: Salinity profile results at 200 m downstream cross section at high tide.

Makarewa River downstream 500 m – 1,200 m – High Tide

At the 500 m, 800 m and 1,200 m downstream cross sections the river flow was upstream with the tidal influence being greatest across the centre of the river, but less toward the river banks. Flows at 500 m and 800 m downstream cross sections were similar (average 10–11 cm/s) but significantly faster at 1,200 m downstream: (average 20 cm/s) (Figures 21, 23 and 25). Sodium concentrations at the 500 m, 800 m, and 1,200 m downstream cross sections indicated near complete mixing of the discharge had occurred before the tide had turned (Figures 22, 24 and 26).

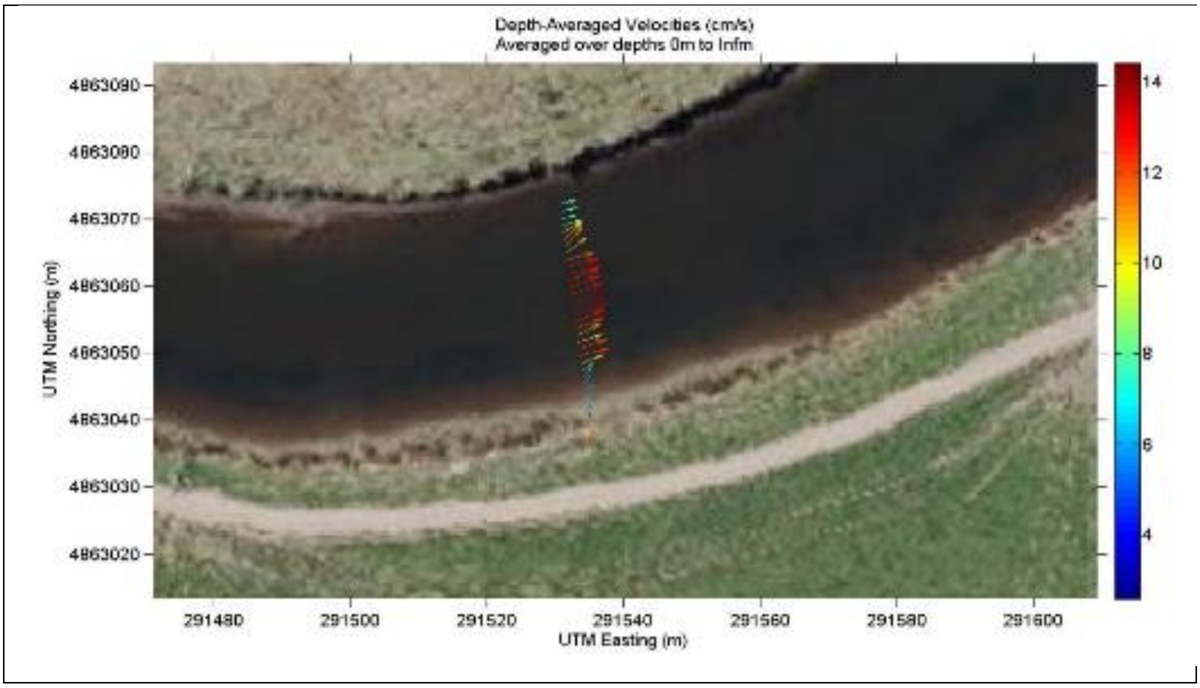

Figure 21: Depth averaged velocities at 500 m downstream cross section at high tide.

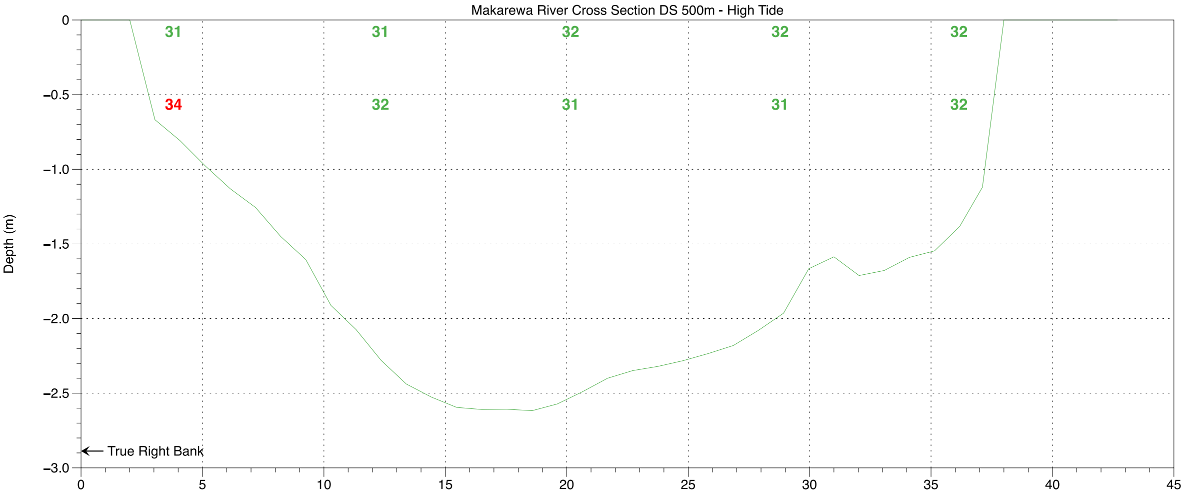

Figure 22: Salinity profile results at 500 m downstream cross section at high tide.

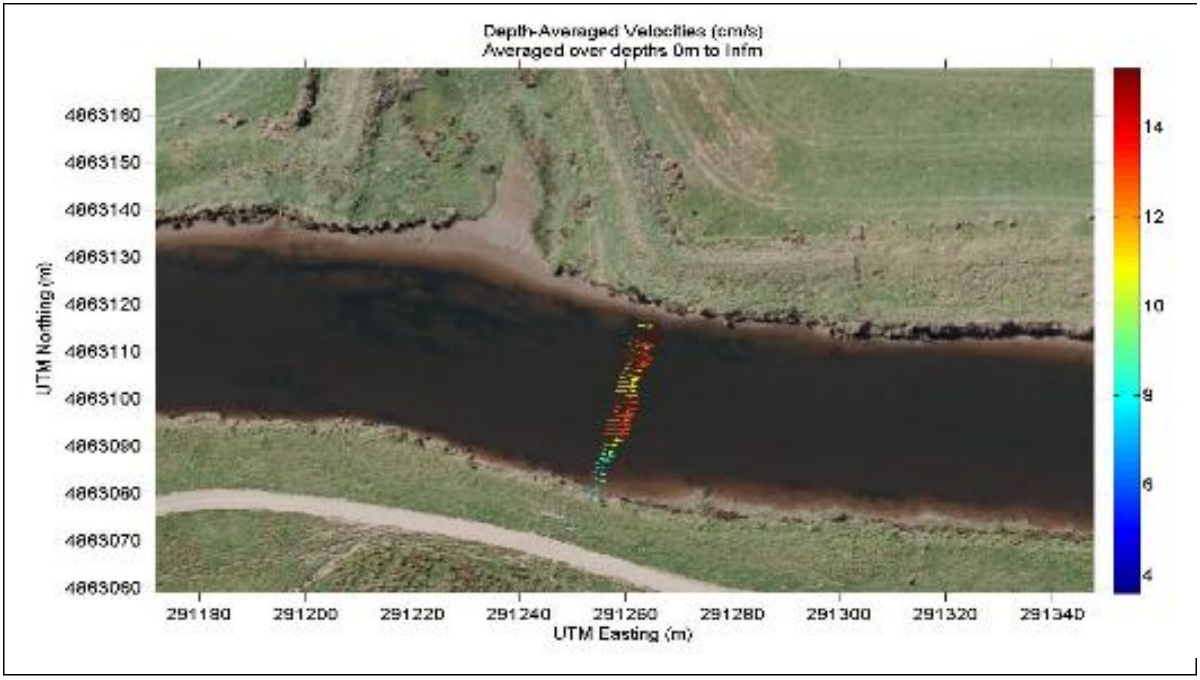

Figure 23: Depth averaged velocities at 800 m downstream cross section at high tide.

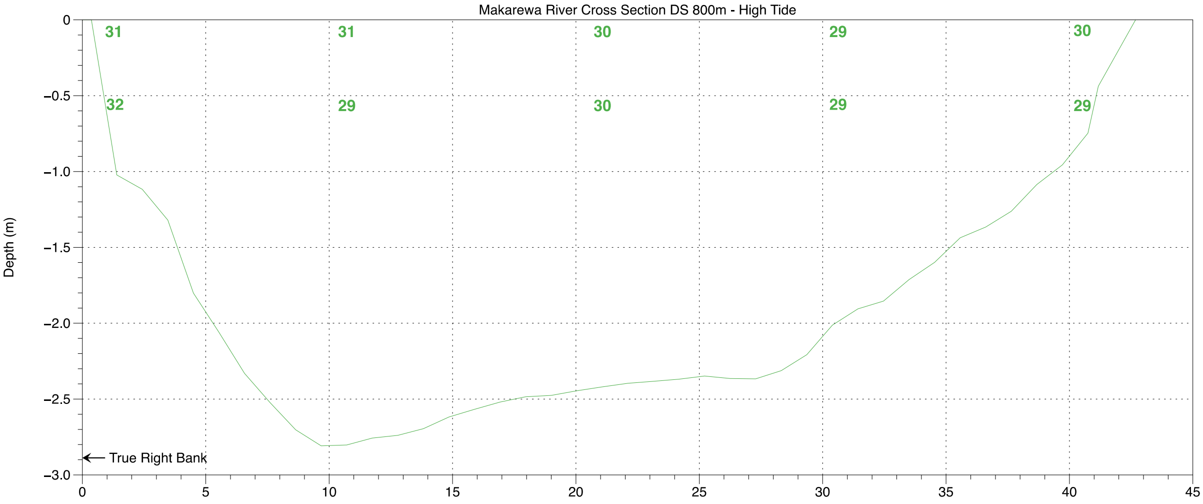

Figure 24: Salinity profile results at 800 m downstream cross section at high tide.

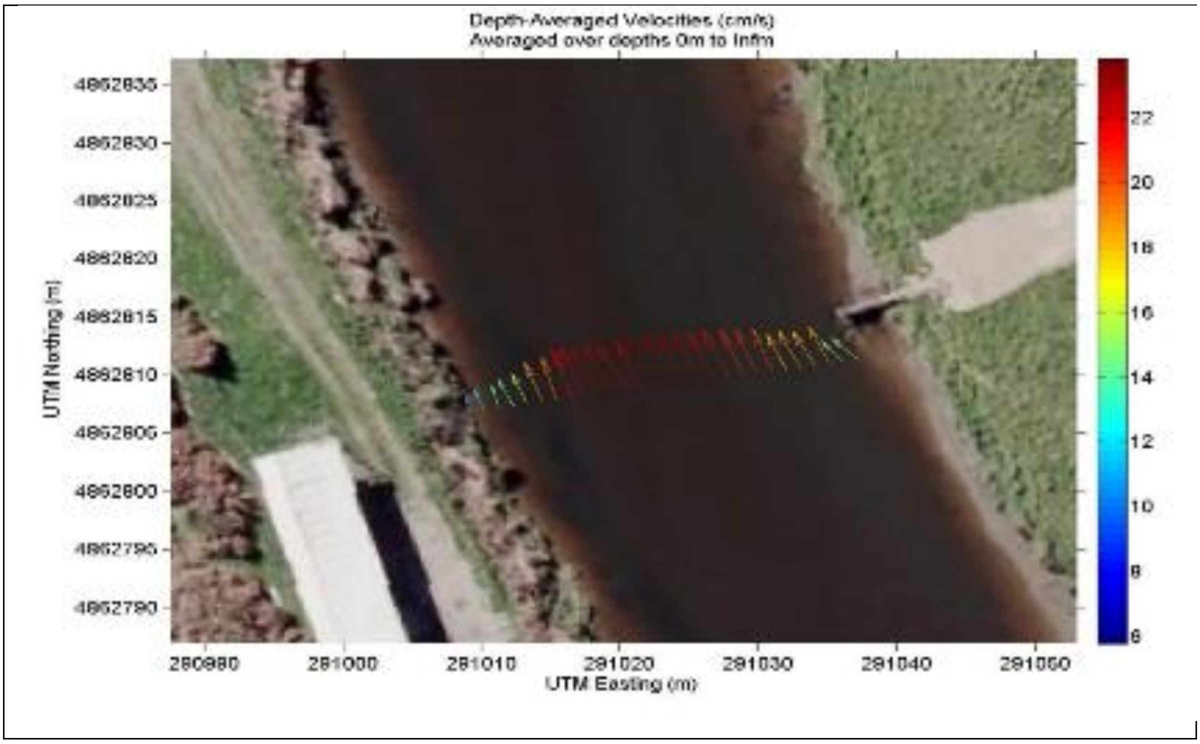

Figure 25: Depth averaged velocities at 1,200 m downstream cross section at high tide.

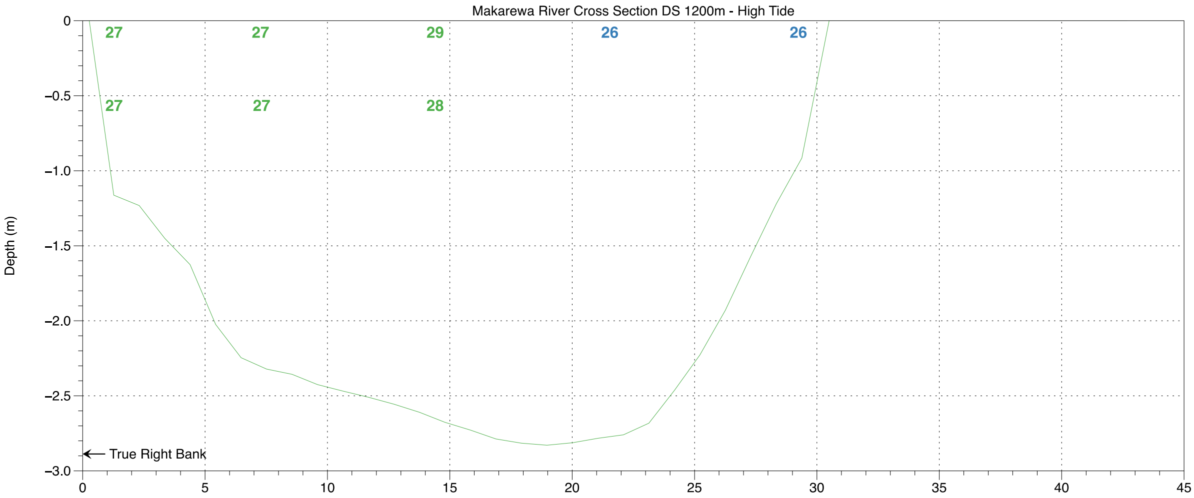

Figure 26: Salinity profile results at 1,200 m downstream cross section at high tide.

4.0 Discussion

This mixing zone assessment tracked the discharge sodium concentrations during low river flows at near peak discharge volumes, under both at high and low tidal conditions. The key findings from this assessment were:

- At low river flow and near low tide conditions the discharge appears well mixed transversely at the river surface 200 m downstream of the discharge.
- At low river flow and near high tide conditions the discharge appears well mixed at the river surface and at depth from 200 m downstream of the discharge, although the river is flowing 'backwards'. However, under the same flow and tidal conditions the discharge is not fully mixed either transversally at the river surface or vertically at 200 m upstream of the discharge.

No detailed modelling of the discharge plume was undertaken as part of this assessment. However, a simple plume model (using the USEPA plume simulation model Visual Plumes) indicated that under the low flow/low tide conditions observed during this survey, the discharge would hit the river bottom within the first 20 m downstream of the discharge point. The Visual Plumes output also indicated that such bottoming out of the discharge plume would result in a high degree of mixing within a short distance (50 m) of the discharge, and this is consistent with the findings of this assessment.

Visual Plumes is not sophisticated enough to enable modelling of the discharge plume under low river flow/high tide conditions. This assessment has found that scenario to be to complex, and it would require a CORMIX mixing zone model to gain a clear understanding of how the discharge plume behaves across the full range of high tide conditions.

This assessment shows that a range of discharge mixing conditions occur in the Makarewa River downstream of the discharge. The mixing is conventional under low flow and low tide conditions and the discharge appears well mixed from 200 m downstream of the discharge. Hence, it is unlikely any zones of non-compliance due to incomplete mixing would extend beyond this.

Similarly, under low flow and high tide conditions the discharge that occurred before the tide turned appears well mixed from 200 m downstream of the discharge point and it is, again, unlikely any zones of non-compliance due to incomplete mixing would extend downstream of this distance.

It is possible, however, that non-compliance with in-river criteria might occur due to incomplete mixing from 200 m downstream of the discharge point to 200 m upstream of the discharge point under low flow/high tide conditions. The degree of vertical mixing under these conditions was beyond the ability of this survey to assess. The results of the survey indicate that a mixing zone extending from 200 m upstream to 200 m downstream of the discharge is appropriate under low flow/low tide conditions but not under under low flow/high tide conditions.

Based on simple Visual Plumes modeling it is considered that modifications to the discharge structure will not result in greater mixing under low flow and low tide conditions, or under low flow and high tide conditions.

5.0 Summary

The vertical, lateral and longitudinal wastewater mixing characteristics of the Alliance discharge to the Makarewa River during low river flow and low tide/high tide conditions have been assessed based on data collected during reach survey conducted on 14 March 2014. The survey determined river cross section profiles and depth averaged velocities. Grab samples were collected at transects across the river and these were analysed for sodium.

The assessment found that under low river flow and both low and high tidal conditions, the discharge is well mixed from 200 m downstream of the discharge. Under low river flow and high tide conditions the discharge is pushed upstream of the discharge point, and a section of less well mixed discharge occurs from 200 m upstream to 200 m downstream. The results of the survey indicate that a mixing zone extending from 200 m upstream to 200 m downstream of the discharge is appropriate under low flow/low tide conditions but not under under low flow/high tide conditions.

Report Signature Page

Freshwater Solutions Ltd

R. Montgomerie

Richard Montgomerie

Director

APPENDIX 6

New River Estuary CLUES Report

coastalmanagement

New River Estuary

Preliminary Nutrient and Sediment Load Estimates 2012/13

Prepared
for
**Alliance
Group Ltd
10 October
2013**

New River Estuary

Preliminary Nutrient and Sediment Load Estimates
2012/13

Prepared for
Alliance Group Ltd

By

Barry Robertson and Leigh Stevens

Wriggle Limited, PO Box 1622, Nelson 7040, NZ. Ph 0275 417 935; 03 545 6315, 021 417 936, www.wriggle.co.nz

Contents

List of Figures

List of Tables

NEW RIVER ESTUARY: PRELIMINARY NUTRIENT AND SEDIMENT LOAD ESTIMATES

INTRODUCTION

In order to facilitate the assessment of the potential impact of wastewater discharges from the two meat processing factories (Alliance Makarewa and Lorneville) on the New River Estuary, the Alliance Group Limited contracted Wriggle Coastal Management to undertake a preliminary estimation of current nutrient loads to the estuary using existing modelling data. This is the subject of this report.

BACKGROUND TO NEW RIVER ESTUARY

The New River Estuary (Figure 1) is a large, modified "tidal lagoon" type estuary (area 4,600ha), that is open to the ocean at the east end of Oreti Beach. Situated at the confluence of the Oreti and Waihopai Rivers (mean flows 41 and 2.7 $m^3.s^{-1}$ respectively), it drains a primarily agricultural catchment (Figure 2) but also receives stormwater and wastewater discharges from Invercargill City and upstream point source inputs. The majority of the estuary is relatively well-flushed (<3 day residence time), given its relatively shallow mean depth (approximately 2m) and large area of intertidal flats (2,952ha). The estuary includes high value vegetated habitat in the form of tidal saltmarsh (464ha) and seagrass (64ha). Monitoring of the estuary condition by Environment Southland indicates a significant decline in estuary quality since 2001 (particularly over the last 5 years) as follows:

- 22% increase in area of soft muds.
- 44% loss of seagrass (particularly from the Waihopai Arm).
- Large expansion of the area of gross eutrophic conditions (signified by high nuisance macroalgal cover and muddy anoxic sediments) from 23ha in 2001 to 240ha in 2012.
- Large increase in the area of high density nuisance macroalgal cover from 1% of estuary in 2001 to 13% in 2013.
- Reduced abundance of pipi at fine scale monitoring sites.
- Excessive sedimentation rates.
- 100% increase in mud content of surface sediments in main body of estuary.

These issues of eutrophication and sedimentation, which are expected to detrimentally impact on fisheries and birdlife in the area, have been identified as major issues in the estuary since at least 1973 (Blakely 1973), with worsening conditions reported since 2007-8 (Robertson and Stevens 2012, Stevens and Robertson 2012). Such findings have triggered recommendations for a more detailed investigation of the estuary including; catchment nutrient and sediment load assessments, derivation of appropriate input load guidelines, and a review of existing condition information (Robertson and Stevens 2012). Environment Southland have recently contracted out this work, the bulk of which is expected to be completed in 2014. Preliminary investigations by the authors have identified;

- Nitrogen as the primary nutrient controlling the symptoms of eutrophication (primarily growth of nuisance macroalgae) in the estuary, and
- Areal nitrogen loading guidelines, to ensure a moderate trophic status, as likely to be in the range 50-100 $mgN.m^{-2}.d^{-1}$. based on input load versus estuary response data for a large number of NZ estuaries.

NEW RIVER ESTUARY: PRELIMINARY NUTRIENT AND SEDIMENT LOAD ESTIMATES

Figure 1. New River Estuary.

Waihopai Arm - Extensive macroalgal growth.

Waihopai Arm - Anoxic muds and decaying macroalgae.

Waihopai Arm gross eutrophic site.

Daffodil Bay gross eutrophic site.

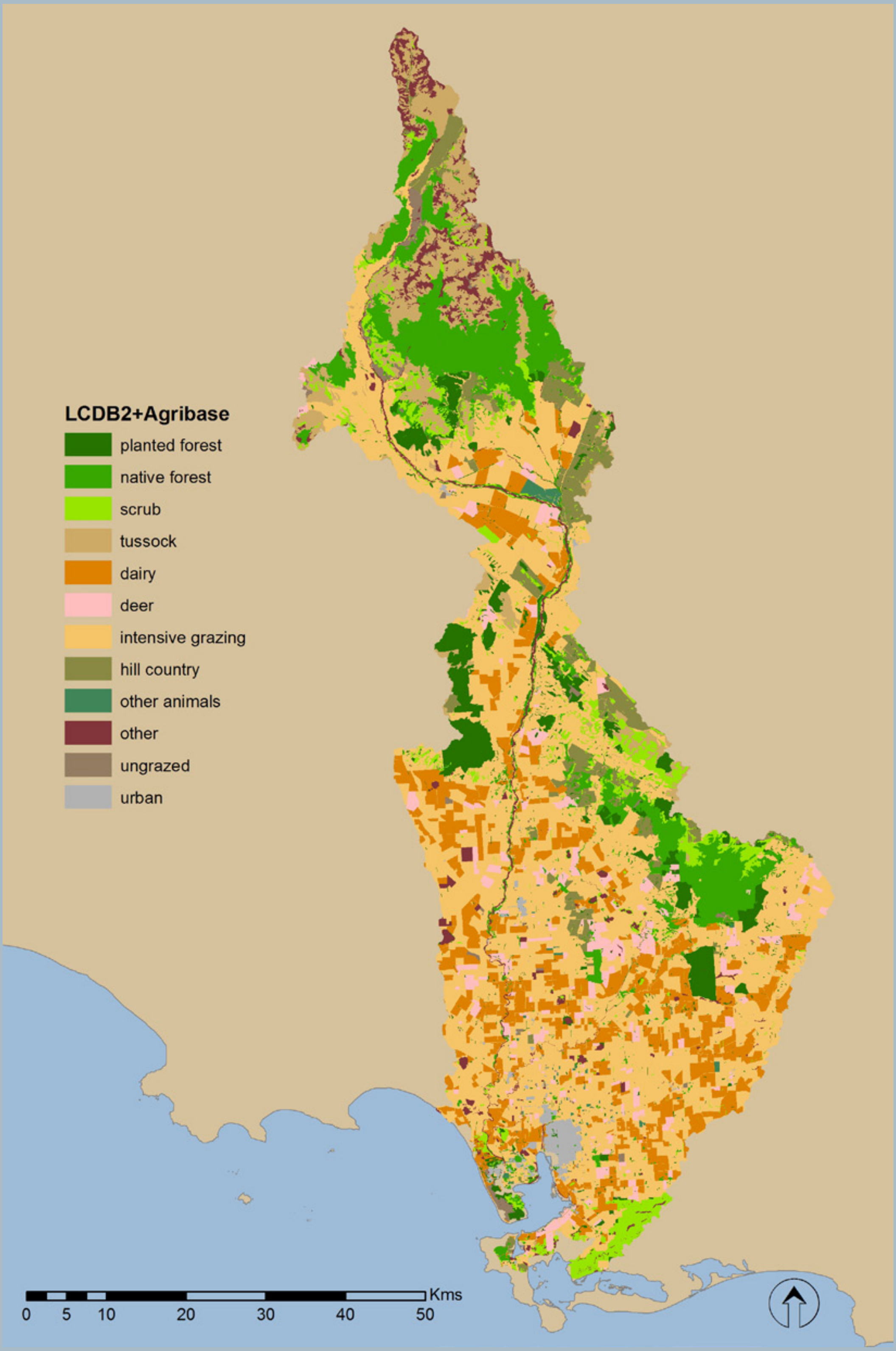

Figure 2. New River Estuary dominant catchment landuse - sourced from LCDB2 plus Agribase.

NEW RIVER ESTUARY: PRELIMINARY NUTRIENT AND SEDIMENT LOAD ESTIMATES

METHODS

The parameters used to assess nutrient and sediment loads to the estuary from point and non-point sources were as follows:

- Total Nitrogen (TN)
- Total Phosphorus (TP)
- Total Suspended Solids (TSS)

Point Source (PS) Loads

PS loads were estimated based on recent (2012-2013) consent monitoring data provided by Environment Southland (ES). Where monitoring data were insufficient (e.g. for small community wastewater discharges with relatively low expected loads), loads were estimated based on an assessment of expected wastewater characteristics from comparable treatment systems elsewhere.

Non Point Source Loads

In order to provide a preliminary assessment of the non-point source loads to New River Estuary, the Catchment Land Use for Environmental Sustainability model (CLUES 10.1) was used. CLUES is a modelling system for assessing the effects of land use change on water quality and socio-economic factors at a minimum scale of sub-catchments (~10 km^2 and above). CLUES was developed by NIWA in collaboration with Lincoln Ventures, Harris Consulting, AgResearch, HortResearch, Crop and Food Research, and Landcare Research for the Ministry of Agriculture and Forestry (MAF) and the Ministry for the Environment (MfE). CLUES couples a number of existing models within a GIS-platform and is provided to users as a front-end interface within ArcGIS.

POINT SOURCE DISCHARGES

INVERCARGILL CITY COUNCIL - CLIFTON WASTEWATER 2010

The Invercargill City Council (ICC) currently holds a resource consent to discharge treated wastewater direct to the Waihopai Arm in New River Estuary. The following data (Table 1) was provided by ICC in 2011 as part of their estuary monitoring report (Robertson and Stevens 2011).

Table 1. Clifton wastewater effluent loads to New River estuary.

Clifton Outfall 2010	Mean Flow (m^3/d)	Mean TN (mg/l)	Mean TP (mg/l)	Mean TSS (mg/l)		Mean Flow (m^3/yr)	Mean TN (t/yr)	Mean TP (t/yr)	Mean TSS (t/yr)
	20,500	24.2	5	19.9		7,482,500	181	37	149

POINT SOURCE DISCHARGES

PRIME RANGE MEATS LIMITED

Prime Range Meats Limited is a meat processing and rendering plant located on the banks of the Waikiwi Stream. The plant processes livestock for the local and export markets, as well as rendering the by-products generated at this and other meat processing companies. Prime Range Meats operate a wastewater treatment facility which discharges a maximum of 1500 m^3/day of treated wastewater to Waikiwi Stm, approximately 500 metres downstream of the West Plains Road Bridge. Table 2 below summarises ES consent data for the period Jan 2012-July 2013.

Table 2. Prime Range Meats Ltd wastewater effluent loads to Waikiwi Stream

Prime Range Meats Limited Wastewater Discharge	Mean (Range) Flow (m^3/d)	Mean (Range) TN (mg/l)	Mean TP (mg/l)	Mean TSS (mg/l)		Mean Flow (m^3/yr)	Mean TN (t/yr)	Mean TP (t/yr)	Mean TSS (t/yr)
	893 (92-1493)	160 (112-240)	21.7 (5.5-30.4)	18 (5-34)		326000	29.3	4	3.4

Note: the mean flow is calculated from more extensive data than the mean concentrations, therefore multiplying the mean flow by the mean concentration does not produce the mean load.

ALLIANCE LORNEVILLE

Alliance Lorneville is a meat processing and rendering plant located on the banks of the Makarewa River operated by Alliance Group Limited.. The company use approximately 34 hectares of ponds to treat the effluent generated from the activities at the plant and sewage from Wallacetown township. This extensive pond system discharges treated wastewater to the Makarewa River. Effluent volumes are greatest during the main season (December to June each year) and least during the period July to November. Table 3 below summarises ES consent data for the 2009-2012 period.

Table 3. Alliance Lorneville wastewater effluent loads to Makarewa R.

Alliance Lorneville	Period	Number of Discharge Days	Mean TN (t/yr)	Mean TP (t/yr)	Mean TSS (t/yr)
High Load Year	1 Sept 2009 to 30 Oct 2010	208	270	27	203
Medium Load Year	1 Sept 2010 to 30 Oct 2011	193	232	25	150
Low Load Year	1 Sept 2011 to 30 Oct 2012	174	184	22	120
TOTAL ANNUAL HIGH LOAD			**270**	**27**	**203**

Note: Consent monitoring data for the 3 years (Appendix 1 for details) shown in table were used to calculate the annual load. Calculation was as follows: (Effluent concentration x daily effluent flow) = daily load (kg/d). Daily loads were then averaged for the chosen period and the consequent mean daily load multiplied by days of discharge, to derive the estimated annual load.

ALLIANCE MAKAREWA

Alliance Makarewa is a primarily venison meat processing and rendering plant located on the banks of the Makarewa River operated by Alliance Group Limited. Effluent is treated and stored in a number of large treatment ponds and discharged to land, or to the Makarewa River during wet periods. Table 4 summarises ES consent data for the 2012-2013 period.

Table 4. Alliance Makarewa wastewater effluent loads to Makarewa R.

Alliance Makarewa 2012-2013	Mean TN (t/yr)	Mean TP (t/yr)	Mean TSS (t/yr)
TOTAL ANNUAL LOAD	15.3	1.9	7.9

Note: Consent monitoring data for the period March 2012 to July 2013 was used to calculate the annual load. Calculation was as follows: (Effluent concentration x daily effluent flow) = daily load (kg/d). Daily loads were then averaged for the chosen period and the consequent mean daily load multiplied by 54 days discharge/yr to derive the estimated annual load.

POINT SOURCE DISCHARGES

BLUE SKY MEATS LIMITED

Blue Sky Meats is a meat processing and rendering plant located near the Waihopai River operated by Blue Sky Meats Limited. Effluent is treated and discharged to land, but it is understood that much of the effluent leaches to a tributary of the Waihopai River. Therefore, a precautionary approach is taken in this load assessment and assumed that all the effluent reaches the river (Table 5).

Table 5. Blue Sky Meats Ltd wastewater effluent loads to Waihopai River.

Blue Sky Meats Ltd 2012-2013	Mean TN (t/yr)	Mean TP (t/yr)	Mean TSS (t/yr)
TOTAL ANNUAL LOAD NOTE: discharge is to land but a percentage leaches to water.	<361mg/l x effluent mean flow	<39mg/l x effluent mean flow	very low

Note: Consent monitoring data for the period April 2011 to June 2013 was used to calculate the annual load. Calculation was as follows: (Effluent concentration x daily effluent flow) = daily load (kg/d). Daily loads were then averaged for the chosen period and the consequent mean daily load multiplied by 365 to derive the estimated annual load.

SMALL COMMUNITY TREATED WASTEWATER DISCHARGES

A number of small community wastewater effluents discharge to the New River Estuary catchment (Table 6).

Table 6. Small community wastewater effluents in New River Estuary catchment.

Alliance Lorneville 2012-2013	Population	Mean TN (t/yr)	Mean TP (t/yr)	Mean TSS (t/yr)
Mossburn Wastewater	250 persons	0.7	0.2	2.0
Woodlands Wastewater	300 persons	0.8	0.3	2.4
Winton Wastewater	2500 persons	6.8	2.4	20.1
Lumsden Wastewater	500 persons	1.4	0.5	4.0
Browns Wastewater	<200 persons	0.5	0.2	1.6
Whitehouse Hotel	<200 persons	0.5	0.2	1.6

Raw Sewage has 23kgTSS/person/yr, 4.2 kgN/person/yr and 1.5 kgP/person/yr. Assuming 35% removal for secondary treatment of N and P (Elliot and Sorrell 2002 and actual monitoring data from Lumsden Wastewater) gives 2.7 kgN/yr/person and 1 kgP/yr/person. Assuming 65% removal of SS for secondary treatment gives 8 kgTSS/person/yr.

NON-POINT SOURCE DISCHARGES

Non-point source discharges to the New River Estuary originate from a number of sources within the catchment including:

- Overland flow (or surface runoff). That part of precipitation which flows overland to streams or directly to lakes. Overland flow is typically enriched in P (dissolved and particulate forms), sediment, faecal bacteria and ammonium-N, but little nitrate-N.
- Subsurface flow (or drainage). That part of precipitation which infiltrates the soil and moves to streams or lakes as ephemeral, shallow, perched or ground water flow. In contrast to overland flow, subsurface drainage is usually the dominant pathway involved in the transfer of mobile pollutants such as nitrate from soil to water. In agricultural landscapes, the downward movement (or leaching) of subsurface flow can be intercepted by artificial drainage systems such as mole-pipe drains. Much local and international research has documented how this artificial drainage pathway can also deliver significant quantities of less mobile pollutants such as P, sediment and faecal bacteria to surface waters. Preferential flow through macropores to mole-pipe systems are attributes that allow these soil-water transfers to occur.

The level of nutrients and suspended sediment transported in these discharges to rivers and subsequently to estuaries, is generally dependent on landuse. In 2012, landuse in the catchment was dominated by intensive pastoral and dairying (Figure 2, Table 7).

NON-POINT SOURCE DISCHARGES

Table 7. Landuse and areas for catchments draining to New River Estuary.

Catchment	Total ha	%	Oreti	Makarewa	Waikiwi	Otatara	Waihopai	Otepuni	Kingswell	Waimatua	Mokotua	Mokomoko	Whalers
dairy	106,010	27	53,543	25,719	3,023	425	11,614	584	216	2,142	8,629	97	20
deer	15,948	4	6,260	7,189	804	11	586	205	16	604	247	27	
hill	19,097	5	12,649	6,145		38						266	
intensive	122,171	31	56,932	41,975	10,308	876	4,913	1,684	904	4,215		364	
native	44,681	11	30,221	13,490	80	226	74	70	56	133		248	84
other	13,995	4	12,023	1,351	232	141	75	8	24	32		102	8
other animals	1,335	0	828	142	111	52	182	4	12	5			
planted forest	22,068	6	13,972	7,252	130	57	130	39	11	185		18	273
scrub	16,603	4	9,291	6,424	176	27	76	2	13	322		120	152
tussock	28,486	7	26,791	1,691			3						
ungrazed	3,716	1	2,735	346	75	22	54	64	11	32		1	377
urban	3,843	1	724	128	219	330	896	1,084	436	11		14	
Grand Total	397,953	100	225,970	111,851	15,157	2,204	18,603	3,743	1,701	7,680	8,876	1,256	913

* Areas from clipped land use LCDB2+agribase layer in CLUES and modified to account for increased area of dairying and reduced intensive pastoral since 2002. Area of dairying expansion was provided by ES.

The estimated loads from each catchment, using the CLUES model 10.1 (default setting), with modifications to account for the additional dairying in the catchments, and omitting point source discharges, are presented in Table 8 and Figures 3, 4 and 5. The estimates are presented as preliminary values with a likely 20-25% error, and it is recommended that estimates be re-evaluated in 2014 once validation monitoring data for the catchment has been assessed, and improvements to the CLUES model are undertaken.

Table 8. Non-point source discharges for catchments draining to New River Estuary

Non-Point Source Discharges to New River Estuary	Mean TN(t/yr)	Mean TP (t/yr)	Mean TSS (t/yr)
Oreti River (EXCLUDING Makarewa River and Waikiwi Stream)	1,807	132	115,555
Waikiwi Stream	20	4	1,131
Makarewa River	983	69	32,609
Otatara (all combined)	15	1	103
Waihopai River (EXCLUDING Otepuni Creek)	359	16	1,634
Otepuni Creek	23	1	259
Kingswell Creek	13	1	115
Waimatua (Duck Creek)	76	3	638
Mokotua Stream (including Waipaka Stream)	284	13	130
Mokomoko tributaries (all combined)	5	1	152
Whalers Bay	1	0	52
Total Non-Point Source Discharges to New River Estuary	3,398	233	152,000
Makarewa River above Alliance Makarewa Plant	828	60	28,000
Makarewa River above Alliance Lorneville Plant	914	64	29,000

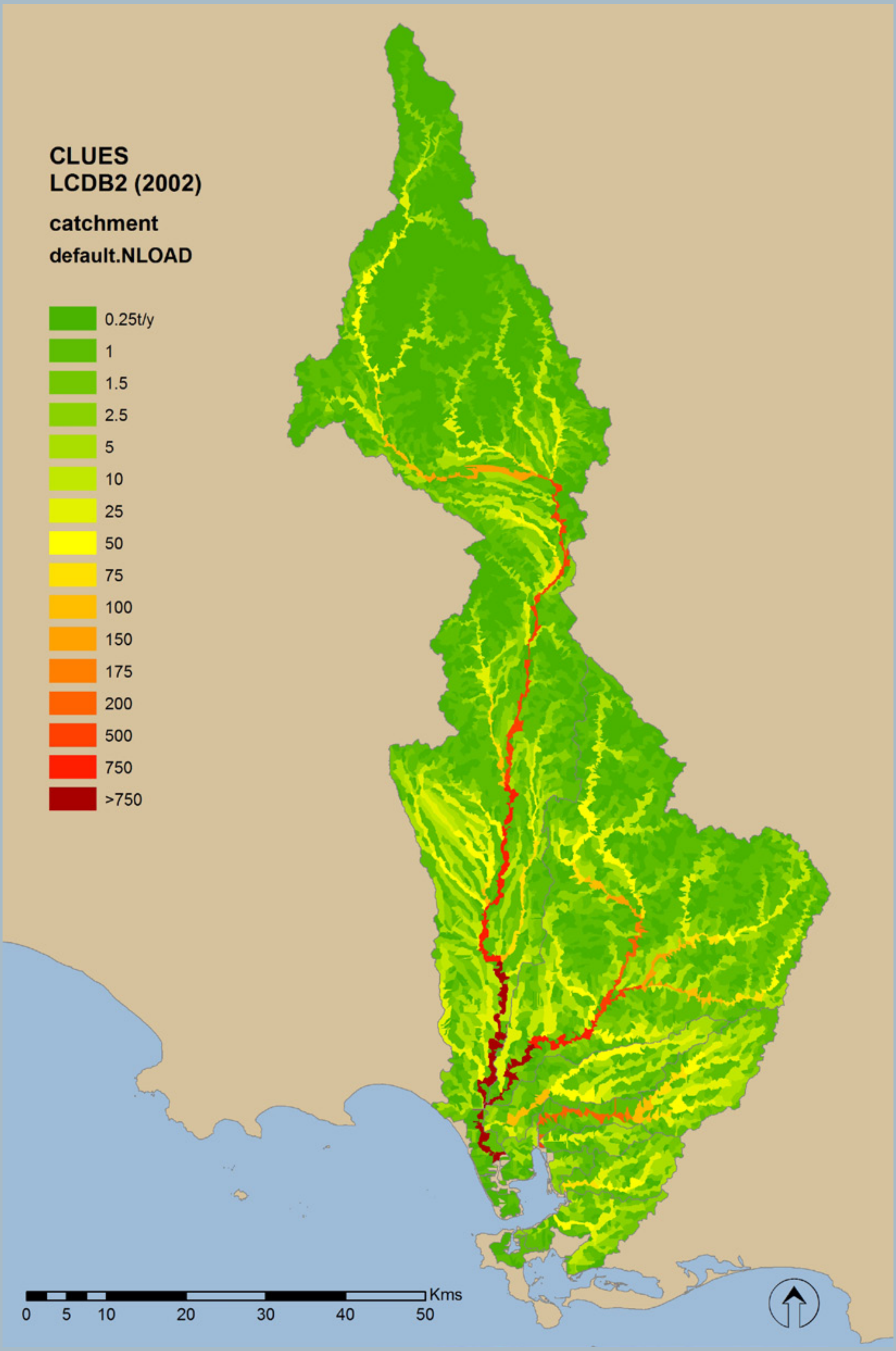

Figure 3. Estimated total nitrogen loads for New River Estuary catchment - (source CLUES model 10.1 default with point sources omitted). Note these outputs do not include the increased dairying load since 2002, included in Table 8.

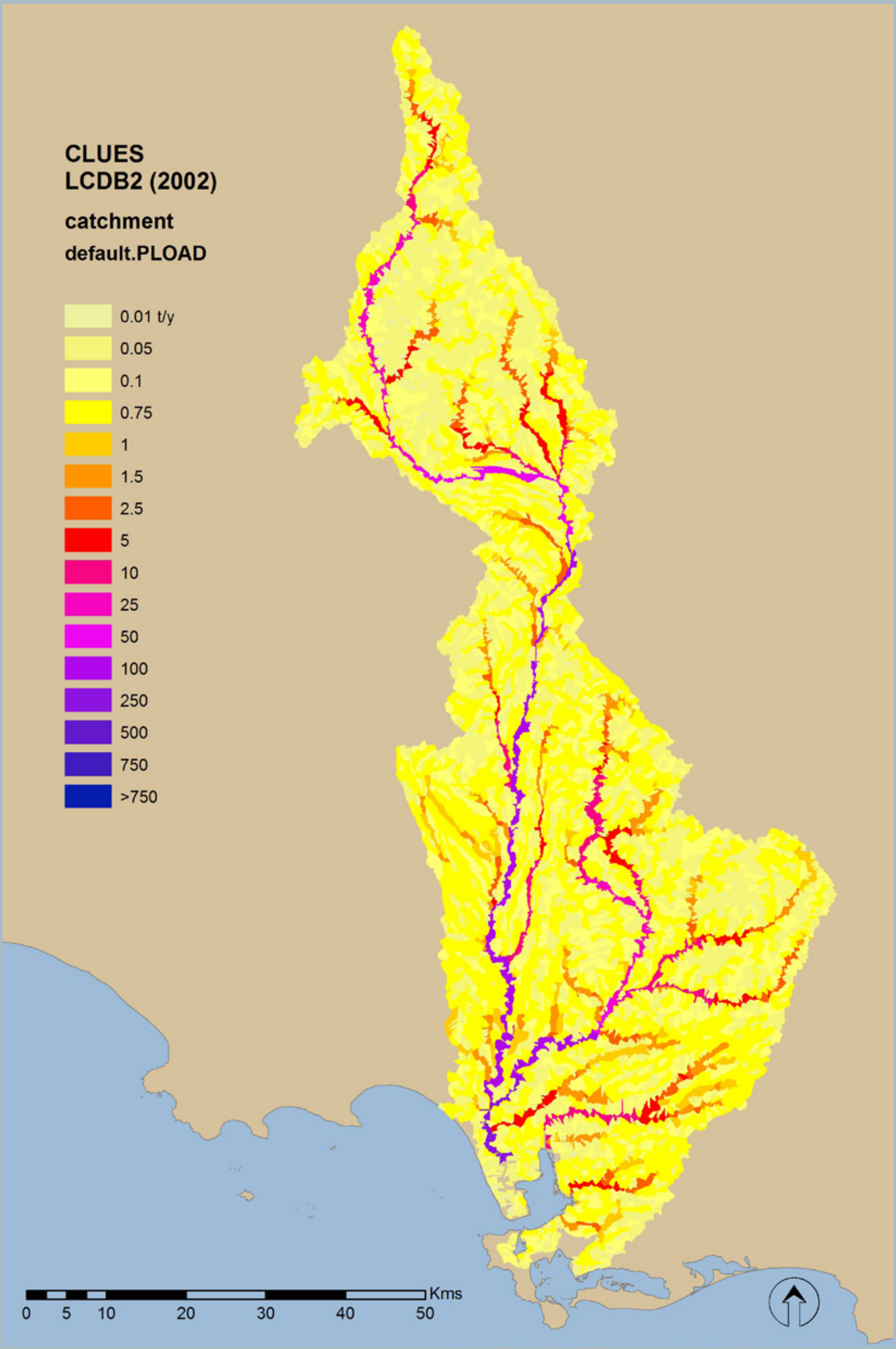

Figure 4. Estimated total phosphorus loads for New River Estuary catchment - (source CLUES model 10.1 default with point sources omitted). Note these outputs do not include the increased dairying load since 2002, included in Table 8.

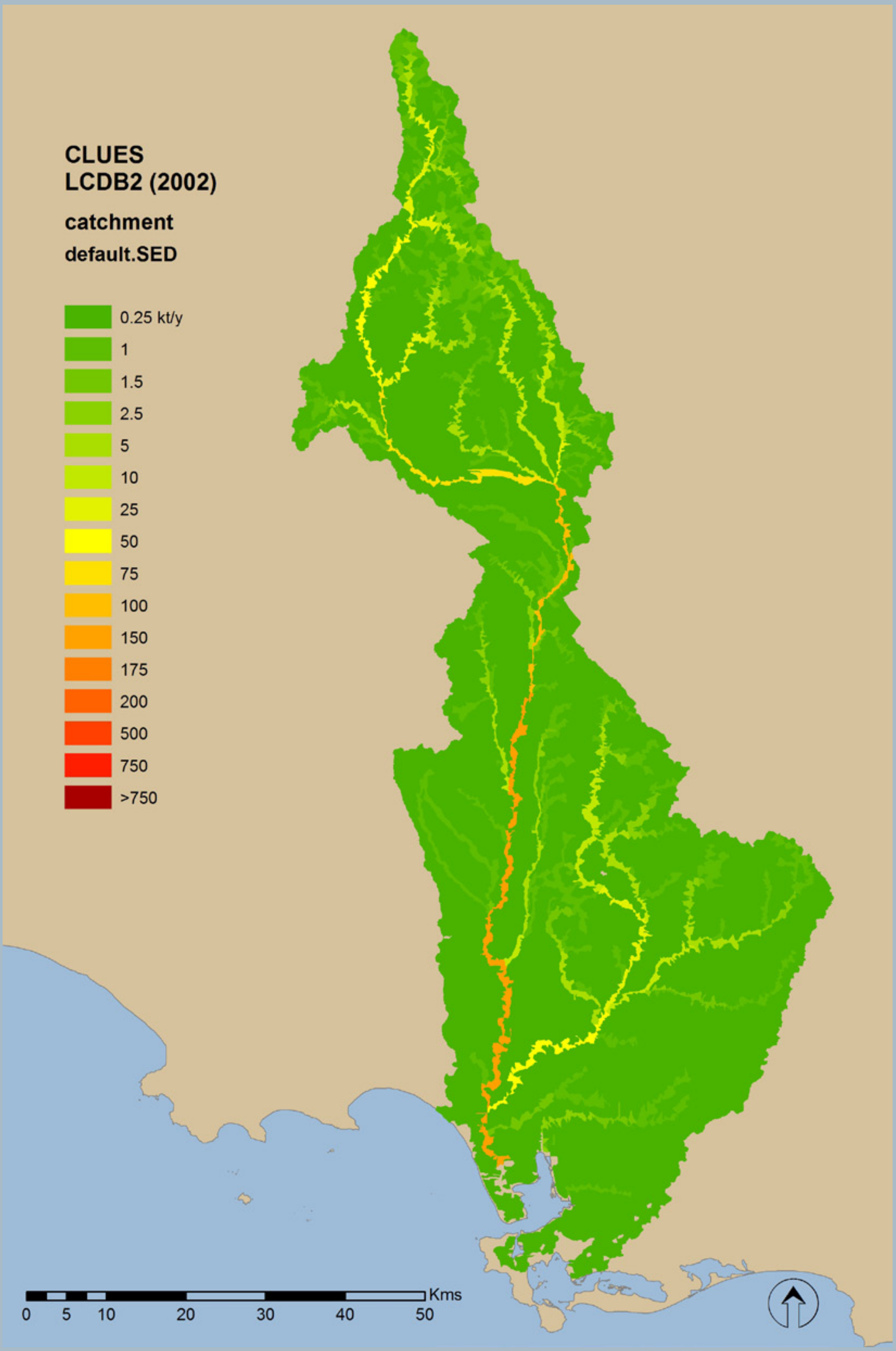

Figure 5. Estimated total sediment loads for New River Estuary catchment - (source CLUES model 10.1 default with point sources omitted). Note these outputs do not include the increased dairying load since 2002, included in Table 8.

COMBINED NON-POINT AND POINT SOURCE DISCHARGES

The combined estimated point and non-point source nitrogen and phosphorus discharges to the New River catchment and estuary for 2012 are presented in Figures 5 and 6. These figures show that the dominant sources of both N and P were the non-point source inputs to the Oreti and Makarewa catchments. The highest point source loads were from the various meat processing plants discharging to the Makarewa and Waihopai Rivers. Compared with the likely areal nitrogen loading guidelines to ensure a moderate trophic status for tidal lagoon estuaries (i.e. 50-100 mgN.m^{-2}.d^{-1}), the current estimated total areal N load to the estuary was excessive (i.e. 320 mgN.m^{-2}.d^{-1}).

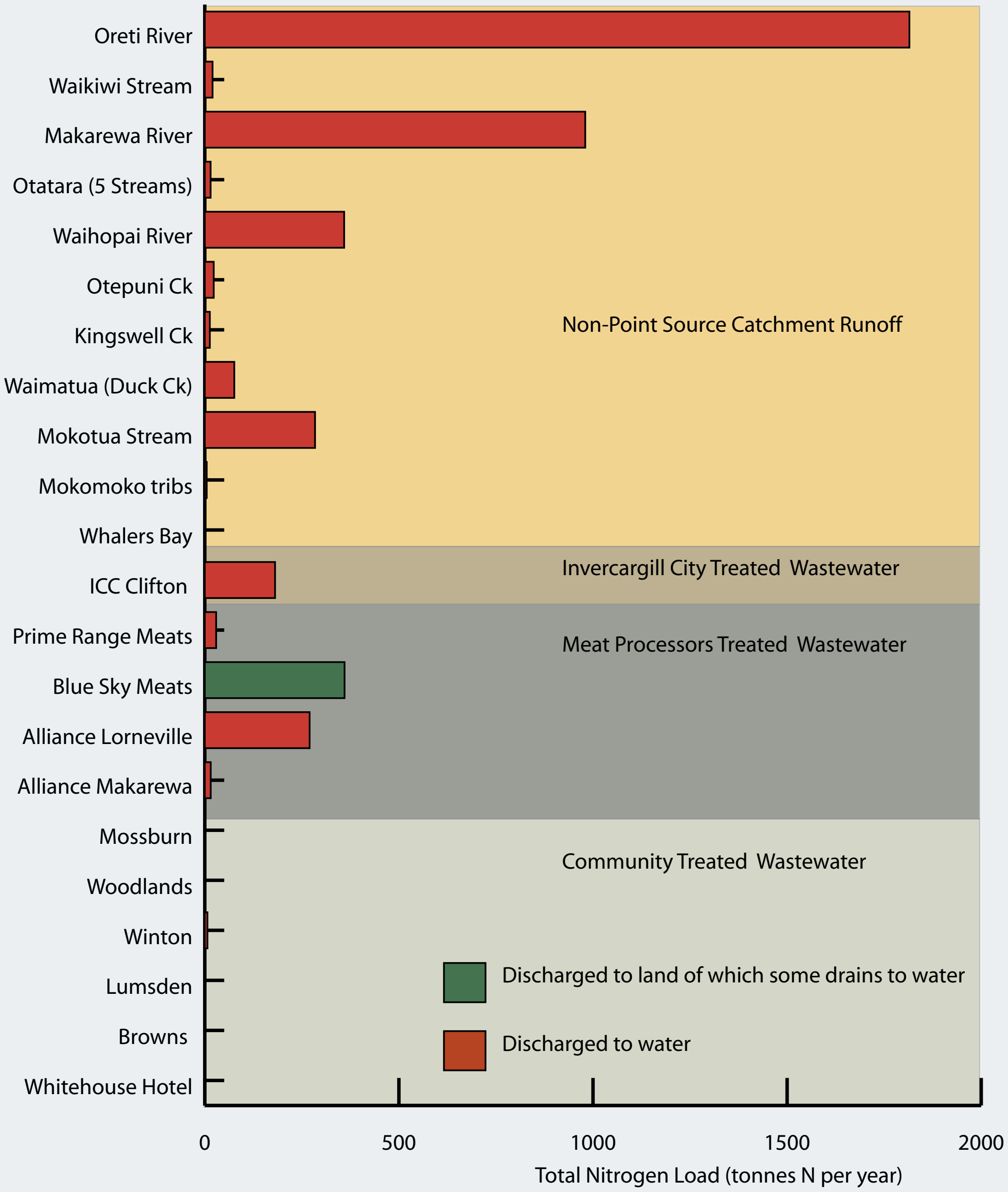

Figure 6. Estimated 2012 total nitrogen loads to New River Estuary from both catchment non-point and point source discharges. Note: used HIGH LOAD YEAR (2009/10) for Alliance Lorneville.

COMBINED NON-POINT AND POINT SOURCE DISCHARGES

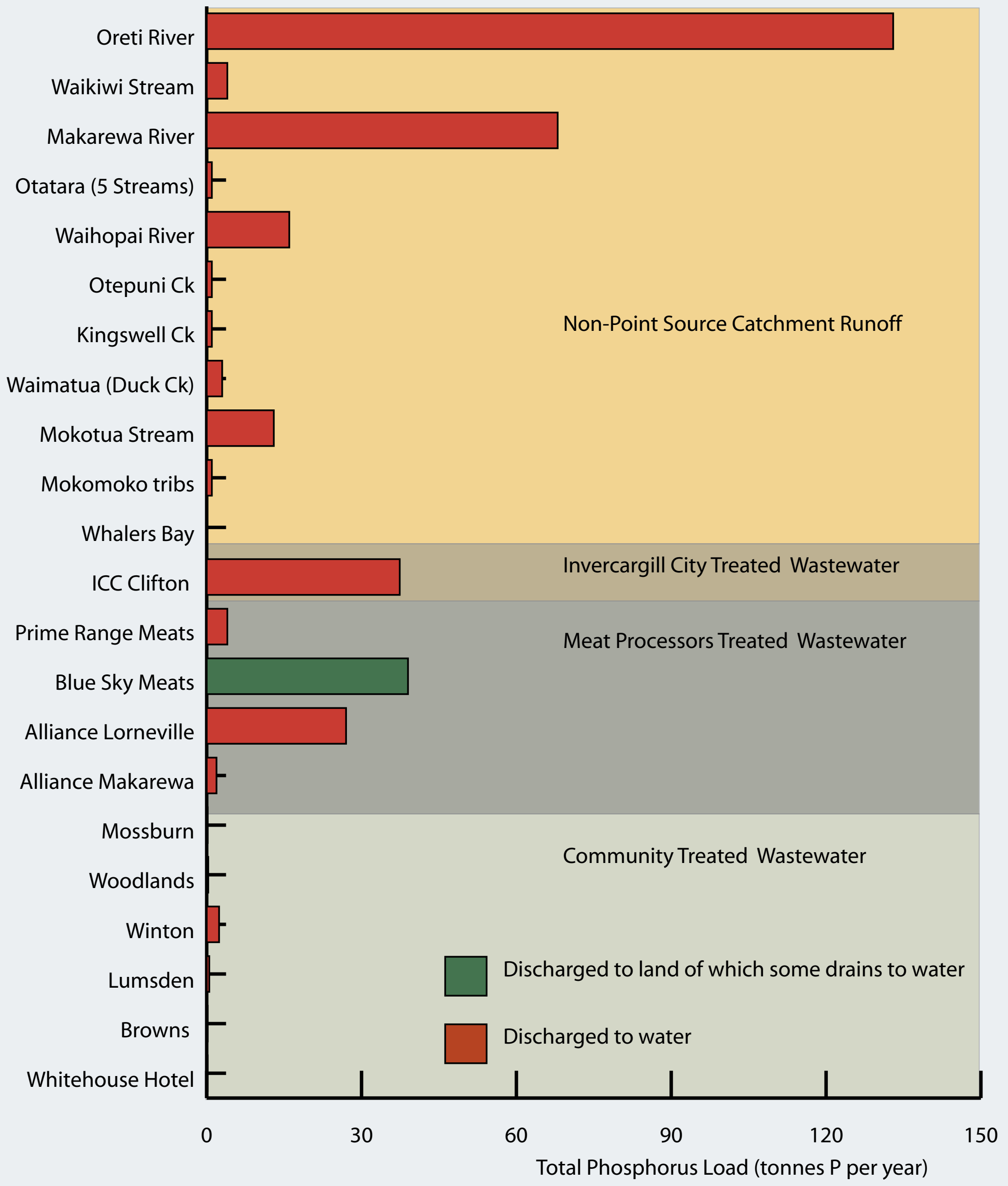

Figure 7. Estimated 2012 total phosphorus loads to New River Estuary from both catchment non-point and point source discharges. Note: used HIGH LOAD YEAR (2009/10) for Alliance Lorneville.

In conclusion, the contribution of the Alliance Lorneville discharge to the total estimated catchment loads of nitrogen, phosphorus and total suspended solids entering the New River Estuary in 2012 is estimated at approximately 6%, 8% and <0.1% respectively (Table 9). However, because the discharge does not include instream attenuation between the discharge point and the estuary, these values can be considered as overestimates.

Table 9. Total N, P and TSS loads draining to New River Estuary.

Discharge		Mean N Load (t/y)	Mean P Load (t/y)	Mean SS Load (t/y)	N % Contribution	P % Contribution	TSS % Contribution
Non Point Source Discharges Only (i.e. point sources to these catchments not included)	Oreti River	1815	133	115555	40.72%	37.56%	75.71%
	Waikiwi Stream	20	4	1131	0.45%	1.13%	0.74%
	Makarewa River	980	68	32609	21.99%	19.20%	21.37%
	Otatara (5 Streams)	15	1	103	0.34%	0.28%	0.07%
	Waihopai River	359	16	1634	8.05%	4.52%	1.07%
	Otepuni Ck	23	1	259	0.52%	0.28%	0.17%
	Kingswell Ck	13	1	115	0.29%	0.28%	0.08%
	Waimatua (Duck Ck)	76	3	638	1.71%	0.85%	0.42%
	Mokotua Stream	284	13	130	6.37%	3.67%	0.09%
	Mokomoko tribs	5	1	152	0.11%	0.28%	0.10%
	Whalers Bay	1	0	52	0.02%	0.00%	0.03%
Point Source Discharges	ICC Clifton	181	37.4	0.15	4.06%	10.56%	0.00%
	Prime Range Meats	29.3	4	3.4	0.66%	1.13%	0.00%
	Blue Sky Meats	360	39	0	8.08%	11.01%	0.00%
	Alliance Lorneville*	270	27	203	6.05%	7.62%	0.13%
	Alliance Makarewa	15.3	1.9	7.9	0.34%	0.54%	0.01%
	Mossburn	0.7	0.2	2	0.02%	0.06%	0.00%
	Woodlands	0.8	0.3	2.4	0.02%	0.08%	0.00%
	Winton	6.8	2.4	20.1	0.15%	0.68%	0.01%
	Lumsden	1.4	0.5	4	0.03%	0.14%	0.00%
	Browns	0.5	0.2	1.6	0.01%	0.06%	0.00%
	Whitehouse Hotel	0.5	0.2	1.6	0.01%	0.06%	0.00%
TOTAL		**4456**	**354**	**152624**	**100%**	**100%**	**100%**

* Used HIGH LOAD YEAR (2009/10) for Alliance Lorneville

References

Blakely, R.J. 1973. Sedimentation in the New River Estuary. Unpublished report prepared for the New River Estuary Technical Advisory Committee as a Bachelor of Engineering project report.

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APPENDIX 1. ALLIANCE LORNEVILLE WASTEWATER DATA

Alliance Lorneville 2009-10

No Days	Date	Discharge Volume [m3/day]	TN [g/m3]	TP [g/m3]	TSS [g/m3]	TN kg/d	TP kg/d	TSS kg/d
1	1-Dec-09	13783						
1	2-Dec-09	8320						
1	3-Dec-09	5249						
1	4-Dec-09	5710	29	5.3	130	166	30	742
1	7-Dec-09	3231	23	6.3	120	74	20	388
1	8-Dec-09	16390						
1	9-Dec-09	13762						
1	10-Dec-09	13133						
1	11-Dec-09	12524						
1	14-Dec-09	18281						
1	15-Dec-09	16473	58	8.2	21	955	135	346
1	16-Dec-09	14876						
1	17-Dec-09	13936						
1	18-Dec-09	13128						
1	21-Dec-09	19231						
1	22-Dec-09	17865						
1	23-Dec-09	17422	74	8.4	60	1289	146	1045
1	24-Dec-09	10788						
1	5-Jan-10	17439						
1	6-Jan-10	18330						
1	7-Jan-10	14325						
1	8-Jan-10	12833	62	7.1	84	796	91	1078
1	9-Jan-10	11179						
1	10-Jan-10	12018						
1	11-Jan-10	11461	70	7.4	62	802	85	711
1	12-Jan-10	16167						
1	13-Jan-10	15243						
1	14-Jan-10	14299						
1	15-Jan-10	14629						
1	16-Jan-10	15086						
1	17-Jan-10	17113						
1	18-Jan-10	11964						
1	19-Jan-10	13144	100	12	240	1314	158	3155
1	20-Jan-10	10664						
1	21-Jan-10	10832						
1	22-Jan-10	11732						
1	23-Jan-10	12488						
1	24-Jan-10	15683						
1	25-Jan-10	11827						
1	26-Jan-10	11624						
1	27-Jan-10	8884	110	12	210	977	107	1866
1	28-Jan-10	9298						
1	29-Jan-10	10786						
1	30-Jan-10	11717						
1	31-Jan-10	13378						
1	1-Feb-10	11489						
1	2-Feb-10	8277						
1	3-Feb-10	7303						
1	4-Feb-10	8519	110	12	210	937	102	1789
1	5-Feb-10	10524						
1	8-Feb-10	17465						
1	9-Feb-10	15383						
1	10-Feb-10	13473						
1	11-Feb-10	12299						
1	12-Feb-10	12625	110	12	120	1389	152	1515
1	13-Feb-10	11897						
1	14-Feb-10	13322						
1	15-Feb-10	12472	110	11	130	1372	137	1621
1	16-Feb-10	12220						
1	17-Feb-10	12121						
1	18-Feb-10	11502						
1	19-Feb-10	11470						
1	22-Feb-10	18214						
1	23-Feb-10	15583	120	11	100	1870	171	1558
1	24-Feb-10	14364						
1	25-Feb-10	12377						
1	26-Feb-10	12314						

APPENDIX 1. ALLIANCE LORNEVILLE WASTEWATER DATA

Alliance Lorneville 2009-10 (continued)

No Days	Date	Discharge Volume [m3/day]	TN [g/m3]	TP [g/m3]	TSS [g/m3]	TN kg/d	TP kg/d	TSS kg/d
1	1-Mar-10	17983						
1	2-Mar-10	16083						
1	3-Mar-10	14953	120	11	69	1794	164	1032
1	4-Mar-10	13847						
1	5-Mar-10	13035						
1	8-Mar-10	15969						
1	9-Mar-10	16868						
1	10-Mar-10	11823						
1	11-Mar-10	10956	127	13.1	40	1391	144	438
1	12-Mar-10	10870						
1	15-Mar-10	14418						
1	16-Mar-10	16977						
1	17-Mar-10	16074						
1	18-Mar-10	12056						
1	19-Mar-10	10830	130	9.6	37	1408	104	401
1	22-Mar-10	12185	120	11	19	1462	134	232
1	23-Mar-10	13981						
1	24-Mar-10	19372						
1	25-Mar-10	18243						
1	26-Mar-10	17655						
1	29-Mar-10	19669						
1	30-Mar-10	19135	118	12	82	2258	230	1569
1	31-Mar-10	17310						
1	1-Apr-10	17124						
1	7-Apr-10	22727	110	13	13	2500	295	295
1	8-Apr-10	21398						
1	9-Apr-10	19983						
1	12-Apr-10	20554						
1	13-Apr-10	20585						
1	14-Apr-10	18672						
1	15-Apr-10	17348	123	11	43	2134	191	746
1	16-Apr-10	16657						
1	19-Apr-10	20769						
1	20-Apr-10	19323						
1	21-Apr-10	17592						
1	22-Apr-10	16872						
1	23-Apr-10	16636	120	11	28	1996	183	466
1	27-Apr-10	12933	110	11	26	1423	142	336
1	28-Apr-10	458						
1	29-Apr-10	14720						
1	30-Apr-10	21364						
31	3-May-10	22457	110	7.8	12	2470	175	269
	10-May-10	18203						
	17-May-10	12070						
	24-May-10	10938						
	31-May-10	7966	110	7.2	160	876	57	1275
28	8-Jun-10	6195						
	14-Jun-10	6057						
	21-Jun-10	6602						
	28-Jun-10	12346						
28	5-Jul-10	5608	86	6.0	180	482	34	1009
	12-Jul-10	1115						
	19-Jul-10	669						
	26-Jul-10	516						
9	30-Aug-10	3789						
1	13-Sep-10	408						
1	14-Sep-10	15717						
1	15-Sep-10	7378	36	7.7	78	266	57	575
1	16-Sep-10	2892						
Total discharge days **208**						**Mean** **1296**	**Mean** **130**	**Mean** **978**

APPENDIX 1. ALLIANCE LORNEVILLE WASTEWATER DATA

Alliance Lorneville 2010-11

No Days	Date	Discharge Volume [m3/day]	TN [g/m3]	TP [g/m3]	TSS [g/m3]	TN kg/d	TP kg/d	TSS kg/d
1	1-Nov-10	9340						
1	2-Nov-10	10620	23	17	44	244	181	467
1	3-Nov-10	8989						
1	4-Nov-10	6669						
1	5-Nov-10	1896						
1	7-Dec-10	15995						
1	8-Dec-10	10567						
1	9-Dec-10	6523	20	2.8	23	130	18	150
1	10-Dec-10	5560						
1	14-Dec-10	14959	20	5.0	29	299	75	434
1	15-Dec-10	10994						
1	16-Dec-10	6693						
1	17-Dec-08	9875						
1	20-Dec-08	16155						
1	21-Dec-10	13540						
1	22-Dec-10	12452	53	6.1	78	660	76	971
1	23-Dec-10	10858						
1	24-Dec-10	10618						
1	6-Jan-11	19776						
1	7-Jan-11	16061	44	7.2	59	707	116	948
1	10-Jan-11	19221	58	9.1	57	1115	175	1096
1	11-Jan-11	16958						
1	12-Jan-11	15629						
1	13-Jan-11	14440						
1	14-Jan-11	13906						
1	17-Jan-11	18972						
1	18-Jan-11	20707	77	10	72	1594	207	1491
1	19-Jan-11	14391						
1	20-Jan-11	9774						
1	21-Jan-11	10285						
1	24-Jan-11	14716						
1	25-Jan-11	14484						
1	26-Jan-11	11261	85	12	100	957	135	1126
1	27-Jan-11	8622						
1	28-Jan-11	9958						
1	31-Jan-11	18142						
1	1-Feb-11	15269						
1	2-Feb-11	13623						
1	3-Feb-11	12236	79	6.6	99	967	81	1211
1	4-Feb-11	11085						
1	7-Feb-11	18847						
1	8-Feb-11	3164						
1	9-Feb-11	11439						
1	10-Feb-11	17693						
1	11-Feb-11	16265	83	7.8	40	1350	127	651
1	14-Feb-11	20180	83	9.7	42	1675	196	848
1	15-Feb-11	17425						
1	16-Feb-11	15442						
1	17-Feb-11	13759						
1	18-Feb-11	13004						
1	21-Feb-11	16197						
1	22-Feb-11	14236	96	12	58	1367	171	826
1	23-Feb-11	12659						
1	24-Feb-11	11798						
1	25-Feb-11	11737						
1	28-Feb-11	18881						

APPENDIX 1. ALLIANCE LORNEVILLE WASTEWATER DATA

Alliance Lorneville 2010-11 (continued)

No Days	Date	Discharge Volume [m3/day]	TN [g/m3]	TP [g/m3]	TSS [g/m3]	TN kg/d	TP kg/d	TSS kg/d
1	1-Mar-11							
1	2-Mar-11		120	13	40			
1	3-Mar-11	11919						
1	4-Mar-11	11881						
1	7-Mar-11	19310						
1	8-Mar-11	15186						
1	9-Mar-11	12738						
1	10-Mar-11	11013	151	12	71	1663	132	782
1	11-Mar-11	11124						
1	14-Mar-11	14299						
1	15-Mar-11	15798						
1	16-Mar-11	15568						
1	17-Mar-11	14707						
1	18-Mar-11	14233	115	9.8	51	1637	139	726
1	21-Mar-11	14958	117	9.0	13	1750	135	194
1	22-Mar-11	16336						
1	23-Mar-11	15338						
1	24-Mar-11	14630						
1	25-Mar-11	14185						
1	28-Mar-11	18238						
1	29-Mar-11	17188	111	12	13	1908	206	223
1	30-Mar-11	16208						
1	31-Mar-11	15321						
1	1-Apr-11	14112						
1	4-Apr-11	15952						
1	5-Apr-11	17369						
1	6-Apr-11	16225	110	8.9	48	1785	144	779
1	7-Apr-11	15124						
1	8-Apr-11	14620						
1	11-Apr-11	21399						
1	12-Apr-11	17270						
1	13-Apr-11	15844						
1	14-Apr-11	14889	129	8.3	59	1921	124	878
1	15-Apr-11	15629						
1	18-Apr-11	20825						
1	19-Apr-11	17541						
1	20-Apr-11	16758	112	8.3	45	1877	139	754
1	21-Apr-11	15538						
1	27-Apr-11	18327						
1	28-Apr-11	17213	101	8.4	21	1739	145	361
3	29-Apr-11	14999						
31	6-May-11	11474						
	9-May-11	14581	130	13	82	1895	190	1196
	17-May-11	11552						
	25-May-11	12463						
30	2-Jun-11	9360						
	10-Jun-11	6058						
	13-Jun-11	2308	108	8.9	747	249	21	1724
	21-Jun-11	5120						
	29-Jun-11	2389						
31	7-Jul-11	4800						
	15-Jul-11	9737						
	18-Jul-11	1649						
	26-Jul-11	2333	65	6.7	28	152	16	65
2	August							
Total discharge days **193**						**Mean** **1202**	**Mean** **128**	**Mean** **778**

APPENDIX 1. ALLIANCE LORNEVILLE WASTEWATER DATA

Alliance Lorneville 2011-12

No Days	Date	Discharge Volume [m3/day]	TN [g/m3]	TP [g/m3]	TSS [g/m3]	TN kg/d	TP kg/d	TSS kg/d
1	11-Oct-11	17391						
1	12-Oct-11	16403	18	12	15	295	197	246
1	13-Oct-11	13468						
1	12-Dec-11	17890						
1	13-Dec-11	19414	34	8.1	9.6	660	157	186
1	14-Dec-11	17491						
1	15-Dec-11	16454						
1	16-Dec-11	15750						
1	19-Dec-11	18667						
1	20-Dec-11	18503						
1	21-Dec-11	15847	54.76	7.3	16	868	116	254
1	22-Dec-11	15260						
1	4-Jan-12	12307						
1	5-Jan-12	10476						
1	6-Jan-12	11339	49.6	3.88	68	562	44	771
1	9-Jan-12	11405	62.5	4.65	76	713	53	867
1	10-Jan-12	10636						
1	11-Jan-12	8552						
1	12-Jan-12	8469						
1	13-Jan-12	8625						
1	14-Jan-12	14605						
1	15-Jan-12	13993						
1	16-Jan-12	15273						
1	17-Jan-12	12619	87.7	9.16	97	1107	116	1224
1	18-Jan-12	12822						
1	19-Jan-12	10744						
1	20-Jan-12	10526						
1	23-Jan-12	19057						
1	24-Jan-12	15303						
1	25-Jan-12	11938	116	13.9	110	1385	166	1313
1	26-Jan-12	8420						
1	27-Jan-12	9078						
1	30-Jan-12	10569						
1	31-Jan-12	12690						
1	1-Feb-12	10882						
1	2-Feb-12	7064	115	15.3	100	812	108	706
1	3-Feb-12	4423						
1	7-Feb-12	11306						
1	8-Feb-12	12031						
1	9-Feb-12	9993						
1	10-Feb-12	8408	114	14.1	100	959	119	841
1	13-Feb-12	9300	114	13.6	14	1060	126	130
1	14-Feb-12	12501						
1	15-Feb-12	10403						
1	16-Feb-12	8744						
1	17-Feb-12	7389						
1	20-Feb-12	12145						
1	21-Feb-12	12551	110	13.2	35	1381	166	439
1	22-Feb-12	10259						
1	23-Feb-12	8523						
1	24-Feb-12	8039						
1	27-Feb-12	13828						
1	28-Feb-12	16047						
1	29-Feb-12	14245	149	11.8	17	2123	168	242

APPENDIX 1. ALLIANCE LORNEVILLE WASTEWATER DATA

Alliance Lorneville 2011-12 (continued)

No Days	Date	Discharge Volume [m3/day]	TN [g/m3]	TP [g/m3]	TSS [g/m3]	TN kg/d	TP kg/d	TSS kg/d
1	1-Mar-12	14860						
1	2-Mar-12	14147						
1	5-Mar-12	17673						
1	6-Mar-12	16178						
1	7-Mar-12	13354						
1	8-Mar-12	10245	132	11.3	190	1352	116	1947
1	9-Mar-12	8989						
1	12-Mar-12	9892						
1	13-Mar-12	11268						
1	14-Mar-12	16005						
1	15-Mar-12	13822						
1	16-Mar-12	10107	105	9.25	32	1061	93	323
1	19-Mar-12	14292	101	11.1	15	1443	159	214
1	20-Mar-12	13543						
1	21-Mar-12	12684						
1	22-Mar-12	11067						
1	23-Mar-12	10561						
1	26-Mar-12	13418						
1	27-Mar-12	15809	102	12.0	15	1613	190	237
1	28-Mar-12	13933						
1	29-Mar-12	12617						
1	30-Mar-12	12115						
1	2-Apr-12	11748						
1	3-Apr-12	15755						
1	4-Apr-12	12777	112	11.9	49	1431	152	626
1	5-Apr-12	12694						
1	11-Apr-12	12690						
1	12-Apr-12	11123	111	15.5	50	1235	172	556
1	13-Apr-12	9206						
1	16-Apr-12	12620						
1	17-Apr-12	11439						
1	18-Apr-12	11092						
1	19-Apr-12	10950						
1	20-Apr-12	10745	123	10.8	49	1322	116	527
1	23-Apr-12	14282	124	11.8	35	1771	169	500
1	24-Apr-12	12680						
1	26-Apr-12	13798						
1	27-Apr-12	11374						
1	30-Apr-12	15242						
24	8-May-12	12477						
	16-May-12	10536	130	19.4	109	1370	204	1148
	24-May-12	10114						
32	1-Jun-12	10009						
	7-Jun-12	8443						
	14-Jun-12	10451	122	8.68	67	1275	91	700
	22-Jun-12	10007						
	25-Jun-12	3520						
19	3-Jul-12	7134						
	19-Jul-12	3462						
1	29-Aug-12	634	46.2	0.168	78	29	0	49
1	6-Sep-12	491						
1	7-Sep-12	5465	47.2	13.0	190	258	71	1038
1	11-Sep-12	1859						
1	12-Sep-12	6154	47.3	8.24	360	291	51	2215
1	13-Sep-12	5971						
Total discharge days **174**						**Mean** **1055**	**Mean** **125**	**Mean** **692**

APPENDIX 7

Laboratory Analysis Report

Watercare
Laboratory Services

	Auckland	**Invercargill**	**Queenstown**
	52 Aintree Ave,	142 Esk Street,	74 Glenda Drive,
	PO Box 107028,	PO Box 747,	PO Box 2614,
	Auckland Airport,	Invercargill, 9840	Wakatipu,
Tel:	(09) 539 7614	(03) 214 4040	(03) 409 0559
Fax:	(09) 539 7601	(03) 214 4041	

www.watercarelabs.co.nz
clientsupport@water.co.nz

Certificate of Analysis
Laboratory Reference:150921-001

Attention:	Frances Wise	*Final Report:*	**151845-0**
Client:	**ALLIANCE GROUP LTD**	*Report Issue Date:*	**14-Sep-2015**
Address:	**State Highway 99 RD 6, Invercargill, 9876**	*Received Date:*	**08-Sep-2015**
Client Reference:	**Lorneville Weekly**	*Sampled By:*	**Client**
Purchase Order:	**Not Supplied**	*Quote Reference :*	**1245**

Sample Details

		WATERS	WATERS	WATERS	WATERS
Lab Sample ID:		**150921-001-1**	**150921-001-2**	**150921-001-3**	**150921-001-4**
Client Sample ID:					
Sample Date/Time:		08/09/2015	08/09/2015	08/09/2015	08/09/2015
Description:		Pipe Bridge Weekly	200 Below Weekly	Boundary Weekly	Anaerobic Pond Weekly
General Testing					
Ammoniacal Nitrogen (as N)	mg/L	0.07	0.40	0.21	96
CBOD5	mg/L	<2.0	<2.0	<2.0	66
Dissolved CBOD5 (Glass Fibre Filtered)	mg/L	<2.0	<2.0	<2.0	-
Dissolved Reactive Phosphorus (as P)	mg/L	0.011	0.033	0.019	-
Total Kjeldahl Nitrogen (as N)	mg/L	-	-	-	110
Total Nitrogen (as N)	mg/L	1.7	2.0	1.9	-
Total Oxidised Nitrogen (as N)	mg/L	1.4	1.4	1.3	-
Total Phosphorus (as P)	mg/L	0.09	0.12	0.11	-
Total Suspended Solids	mg/L	-	-	-	34
Turbidity	NTU	22	23	23	-
Microbiology					
Escherichia coli by Membrane Filtration using NAMUG					
Escherichia coli (NAMUG)	cfu/100 mL	290	320	300	-
Faecal coliforms by Membrane Filtration					
Faecal coliforms	cfu/100 mL	300	380	320	-

Sample Details

		WATERS
Lab Sample ID:		**150921-001-5**
Client Sample ID:		
Sample Date/Time:		08/09/2015
Description:		Pond 6 Weekly
General Testing		
Ammoniacal Nitrogen (as N)	mg/L	34
CBOD5	mg/L	27
Dissolved Reactive Phosphorus (as P)	mg/L	2.5
Total Nitrogen (as N)	mg/L	41
Total Oxidised Nitrogen (as N)	mg/L	0.23
Total Phosphorus (as P)	mg/L	5.0
Total Suspended Solids	mg/L	120
Volatile Solids	mg/L	110
Microbiology		
Escherichia coli by Membrane Filtration using NAMUG		
Escherichia coli (NAMUG)	cfu/100 mL	130
Faecal coliforms by Membrane Filtration		
Faecal coliforms	cfu/100 mL	150

*Results marked with * are not accredited to International Accreditation New Zealand*

Where samples have been supplied by the client they are tested as received. A dash indicates no test performed.

Reference Methods

The sample(s) referred to in this report were analysed by the following method(s)

Analyte	Method Reference	MDL	Samples	Location
General Testing				
Ammoniacal Nitrogen (as N) by Colorimetry/Discrete Analyser	EPA 350.2	0.010 mg/L	All	Invercargill
Carbonaceous Biochemical Oxygen Demand, CBOD5 by Electrode	APHA (online edition) 5210 B	2 mg/L	All	Invercargill
Dissolved Carbonaceous Biochemical Oxygen Demand, CBOD5 (Gla	APHA (online edition) 5210 B	2 mg/L	1, 2, 3	Invercargill
Dissolved Reactive Phosphorus (as P) by Colorimetry/Discrete Analy	APHA (online edition) 4500-P E	0.005 mg/L	1, 2, 3, 5	Invercargill
Total Kjeldahl Nitrogen (as N) by Sulphuric Acid Digestion (with merc	APHA (online edition) 4500-N org A, D	2 mg/L	4	Auckland
Total Nitrogen (as N) by Persulphate Digestion and Colorimetry/Discr	APHA (online edition) 4500-P J, 4500-NO3 H	0.010 mg/L	1, 2, 3, 5	Invercargill
Total Oxidised Nitrogen (as N) by Colorimetry/Discrete Analyser	APHA (online edition) 4500-NO3 H	0.010 mg/L	1, 2, 3, 5	Invercargill
Total Phosphorus (as P) by Persulphate Digestion and Colorimetry/D	APHA (online edition) 4500-P B, J (modified)	0.010 mg/L	1, 2, 3, 5	Invercargill
Total Suspended Solids by Gravimetry	APHA (online edition) 2540 D	2.5 mg/L	4, 5	Invercargill
Turbidity by Nephelometry	APHA (online edition) 2130 B (modified)	0.1 NTU	1, 2, 3	Invercargill
Volatile Solids by Gravimetry	APHA (online edition) 2540 D	2.5 mg/L	5	Invercargill
Microbiology				
Escherichia coli by Membrane Filtration using NAMUG				
Escherichia coli (NAMUG)	APHA (online edition) 9222 G	2 cfu/100 mL	1, 2, 3, 5	Invercargill
Faecal coliforms by Membrane Filtration				
Faecal coliforms	APHA (online edition) 9222 D	2 cfu/100 mL	1, 2, 3, 5	Invercargill
Preparations				
Glass Fibre Filtration	APHA (online edition) 2540 C (Filtration)		1, 2, 3	Invercargill
Membrane Filtration (0.45 µm)	APHA (online edition) 4500-P B (preliminary filtration)		1, 2, 3, 5	Invercargill

The method detection limit (MDL) listed is the limit attainable in a relatively clean matrix. If dilutions are required for analysis the detection limit may be higher

Samples, with suitable preservation and stability of analytes, will be held by the laboratory for a period of two weeks after results have been reported, unless otherwise advised by the submitter.

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IANZ ACCREDITED LABORATORY

All tests reported herein have been performed in accordance with the laboratory's scope of accreditation

Report Signatory 14/09/2015

Tonia Bulling
KTP Signatory