THE WEST COAST
REGIONAL COUNCIL

State of the Environment Report

West Coast Surface Water Quality

April 2015

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State of the Environment Technical Report 14001

April 2015

Prepared by:

Jonny Horrox	West Coast Regional Council
Emma Chaney	West Coast Regional Council
Ashton Eaves	West Coast Regional Council

Reviewed and approved for release by:

Michael Meehan
Planning and Environmental Manager
West Coast Regional Council

Chris Ingle
Chief Executive Officer
West Coast Regional Council

Executive Summary

This report summarises results from the West Coast Regional Council Surface Water Quality Monitoring Program, for data up until 2014. This program assesses surface water quality state and trends at selected sites primarily where human impacts/pressures occur.

From 1996 to 2014, 43 sites were sampled for physical, chemical, and bacteriological water quality attributes, as well as periphyton and macroinvertebrate communities. Sites were sampled four to six times per year. Eight of these were paired sites, with one site upstream and one downstream. Data from an additional five sites that were part of NIWA's National River Water Quality Network were analysed. Other data included in this report came from the West Coast Regional Council Contact Recreation water quality program. This consisted of 17 sites (in 2014). The Council also monitors the water quality in Lake Brunner.

This report is intended to identify differences in water quality state, and changes in water quality over time at the various sites. Individual water quality attributes were compared with guidelines.

State of water quality in the West Coast Region

Previous analysis has shown that waterways in indigenous forest dominated catchments had better water quality than those in pasture catchments, which is consistent with other parts of the country. Streams where acidity, metals, and metal precipitates occurred, resulting from acid mine drainage, had significantly reduced stream health. Sediment alone from mining operations, if significant, can also reduce stream health. But sediment had less impact when not combined with acid mine drainage.

Comparison of individual water quality attributes to guidelines and benchmarks indicated a broad range of results among sites. The National Policy Statement for Freshwater Management (NPS-FM) was introduced in 2014. This contained the National Objectives Framework (NOF), which has been applied to a range of lake and river water quality attributes. In general, lake and river attributes covered by the NOF scored well (e.g. A), and were well above national bottom lines.

Invertebrate indices suggested that approximately half of the sites had MCI and SQMCI scores indicative of slight to un-impacted water quality, with the bottom quarter consistently having moderate to poor water quality. Nuisance periphyton growths have been infrequent for most sites. Often substantial nitrogen is not combined with sufficient phosphorus levels for nuisance periphyton growth. The West Coast's cool wet climate is also likely to be a factor limiting nuisance algal growth.

Sites at West Coast lakes have been the most suitable for swimming. Coastal beach sites were often good, with some exceptions. River sites had the most exceedances of bathing water quality guidelines. Rivers are affected by run-off, generated by rain events, which transport pathogen indicator bacteria from land to water. Health risk to swimmers during and after rain events is normally higher at all sites.

Trends in West Coast water quality

Attributes important to aquatic ecosystems (turbidity, clarity, ammonia), and human health (*E. coli*) improved at many Council monitoring sites. A reduction in ammonia was also evident over the last ten years at West Coast NIWA monitoring sites. Better environmental performance of activities within monitored catchments may have contributed to these improvements.

Four out of five NIWA sites had deteriorating trends for turbidity, assumed to be driven by an increase in suspended material. NIWA sites are on much larger rivers than those monitored by council. They encompass much larger catchments and a greater number of anthropogenic activities. Nitrates increased at many NIWA and Council sites, indicating an intensification in agricultural land use.

Lake Brunner

Lake Brunner currently remains in an oligotrophic (low nutrient) state, safe for swimming and other recreational activities. Water quality has declined since 1992. In the past when data from the entire record (1992-2014) has been analysed, there have been important deteriorating trends for a number of parameters.

From 2001 to 2014, only nitrate and total nitrogen has an increasing trend. Total nitrogen, driven by increasing nitrate, has also increased in the lakes tributaries. Increasing nitrate is most likely a result of agricultural activity. Dissolved nitrogen is easily leached and nitrogen from all sources is likely to leach in abundance given the catchment’s wet climate. It should be noted that Lake Brunner is phosphorus limited. So an increase in nitrate is unlikely to affect lake biology without an accompanying increase in phosphorus.

Water quality in Cashmere Bay is poorer than water in the center of the lake. This is due to a different suite of physical features between the two areas. Nitrate increased (deteriorated) in Cashmere Bay but clarity improved. Despite increasingly long periods of low oxygen at the bottom, phosphorus and subsequent phytoplankton proliferations have not been observed in Cashmere Bay.

Statement of data verification and liability

The West Coast Regional Council recognises the importance of good quality data. This fourth comprehensive surface water quality technical report provides interpretation of results from the West Coast Regional Council Surface Water Quality Monitoring Program and is a summary of relevant information available at the time the report was produced.

Data collection and management systems follow systematic quality control procedures. International Accreditation New Zealand laboratories carried out sample analysis, excluding field analysis. When possible expert staff have been involved in each stage of the monitoring process.

While every attempt has been made to ensure the accuracy of the data and information presented, the West Coast Regional Council does not accept any liability for the accuracy of the information. It is the responsibility of the user to ensure the appropriate use of any data or information from the text, tables or figures. Not all available data or information is presented in the report. Only information considered reliable, of good quality, and of most importance to the readers has been included.

Acknowledgements

The following people and organisations are acknowledged for their efforts, which contributed to this report and the data contained in it:

- Staff of the West Coast Regional Council.
- National Institute of Water and Atmospheric Research: Piet Verburg, Rob Davies-Colley, Paul Lambert, Pete Mason, Mike O'Driscoll, and John Porteous.
- Bill Dyck and Envirolink.
- Hill Labs for laboratory analysis of water samples.

Table of Contents

1 Introduction

1.1 Rationale

The West Coast Region is renowned for its natural and physical attributes, including its lakes, rivers, and coastal areas. It is also renowned for its wet climate - something that has played an important role over time to help form the unique features we see today.

Under the Resource Management Act 1991 the West Coast Regional Council is required to monitor the overall state of the region's environment. This monitoring is important because it helps the Regional Council and the West Coast community to gauge the state of environmental quality and how it changes over time. The Regional Council monitors the quality of the Coast's key natural and physical resources regularly using a range of scientific techniques. Surface water quality is the main focus of this report. This monitoring allows us to make better decisions on how we manage the West Coast's water resources. It also provides information to measure how effective our policies are i.e. if water quality is improving, stable, or deteriorating.

The Regional Council will prepare a State of the Environment (SOE) report every three years to provide information about the quality of the West Coast's water resources. This technical report synthesises information from the Regional Council surface water quality monitoring program, as well as monitoring data provided by the National Institute of Atmospheric Research (NIWA). Separate technical reports are produced to discuss the state of the West Coast's groundwater, hydrology, and air quality.

1.2 The monitoring program

The Surface Water Quality Monitoring Program (monitoring program) has involved the collection of data on water quality, periphyton (algae on the stream bottom) and stream invertebrates from selected rivers and streams since the mid-nineties. Additional information has also been collected during the Council's contact recreation surveys and as part of scientific studies carried out in the West Coast region. Detailed specifications of the Regional Council sampling program are provided in Section 5.1 and 5.2. The National Institute of Water and Atmospheric Research's (NIWA)'s National River Water Quality Network has five sites within the West Coast region that have been sampled monthly since 1989, and data from this program is incorporated into analysis presented in this report. Lake Brunner is a particular area of focus where monitoring is conducted at a range of sites in the lake and its tributaries as part of the monitoring program.

An outline of analyses used in this report, and methods and explanations of some of the measurements and guidelines associated with the monitoring program used to assess water quality, are provided in Sections 5.3 & 5.4. Maps showing the location of monitoring program sites are provided in Section 1.3.

Aims of the West Coast monitoring program are:

- To determine the quality of surface waters in the West Coast region in reference to accepted standards (for public health, recreational, and ecological values).

- To identify short and long term trends in water quality.

- To identify environmental effects and compare to relevant guidelines and standards. .

- To understand the nature of surface water quality problems/issues in order to provide information that enables defensible management responses to be enacted. Such responses include seeking reviews to Regional Council resource management plans, regulations, and resource consent conditions.

- To identify new issues and monitoring requirements.

- To identify factors that cause change in surface water quality (i.e. impact monitoring).

The monitoring program was designed to achieve these aims. However, the program must work within a number of constraints. Given the resources available, quarterly sampling is undertaken. Sampling only occurs at base flow so very little is known about water quality after rain or flood flow conditions. For the Contact Recreation Water Quality Monitoring Program, sites are sampled twice-monthly from November-March, during base flow and non-rainfall periods. While information from the monitoring program will give clues as to the cause of poor water quality, it is often only after intensive sampling within a catchment that clear conclusions of cause and effect relating to specific land-use activities can be drawn. Such follow-up investigations are undertaken on a prioritised basis.

The program targets areas where the most significant human pressures, such as point source discharges, exist or are suspected, while maintaining a few sites in low impact and pristine areas for reference. A number of sites form upstream/downstream pairs on the same waterway – the upper site having the purpose of being a water quality reference for a site downstream. Sites in the program were chosen to try to achieve a balance within and between the following criteria:

(a) Geographical spread throughout the West Coast region;

(b) Range of waterway sizes represented (from large main-stem rivers to small creeks);

(c) Range of different environmental pressures represented at different sites;

(d) In areas with high human use (such as for recreation or drinking) or significant ecological values.

In order to address its aims while working within the constraints mentioned above, design of the monitoring program involved careful choice of indicators (measures) of water quality, sites, and methods. In addition to the intrinsic ecological values of waterways the issue of water quality is also related to community values. Therefore, the choice of environmental indicators may differ between monitoring sites with different values. For example, one reach of river may be highly valued as a fishery resource, but may be seldom used for swimming, while another may be popular for swimming. In this example water clarity, ammonia and macroinvertebrates would be the most important indicators for a river valued for its fishery, but faecal bacteria (*E. coli* and faecal coliforms), which are indicators of potential human disease, would be the most crucial indicators at sites valued for contact recreation. Indicators were, therefore, chosen partly to reflect community values, as well as to be consistent (as far as practical) with indicators recommended by the New Zealand Ministry for the Environment and other government affiliated agencies in charge of setting guidelines and regulations.

This report begins with an analysis of the state of West Coast surface water quality, followed by an assessment of surface water quality trends. A separate section covers state and trends of surface water quality in the Lake Brunner catchment. Supporting information can be found in the appendices including: site maps; explanations of the monitoring program structure, analytical methods, guidelines, and the basic science around water quality attributes; and presentation of more detailed analysis.

1.3 Location of surface water quality monitoring sites

The following maps show the location of surface water quality monitoring sites in the West Coast Region. Yellow points indicate West Coast Regional Council surface water quality monitoring sites; blue points indicate West Coast Regional Council contact recreation water quality monitoring sites; and pink points indicate NIWA surface water quality monitoring sites.

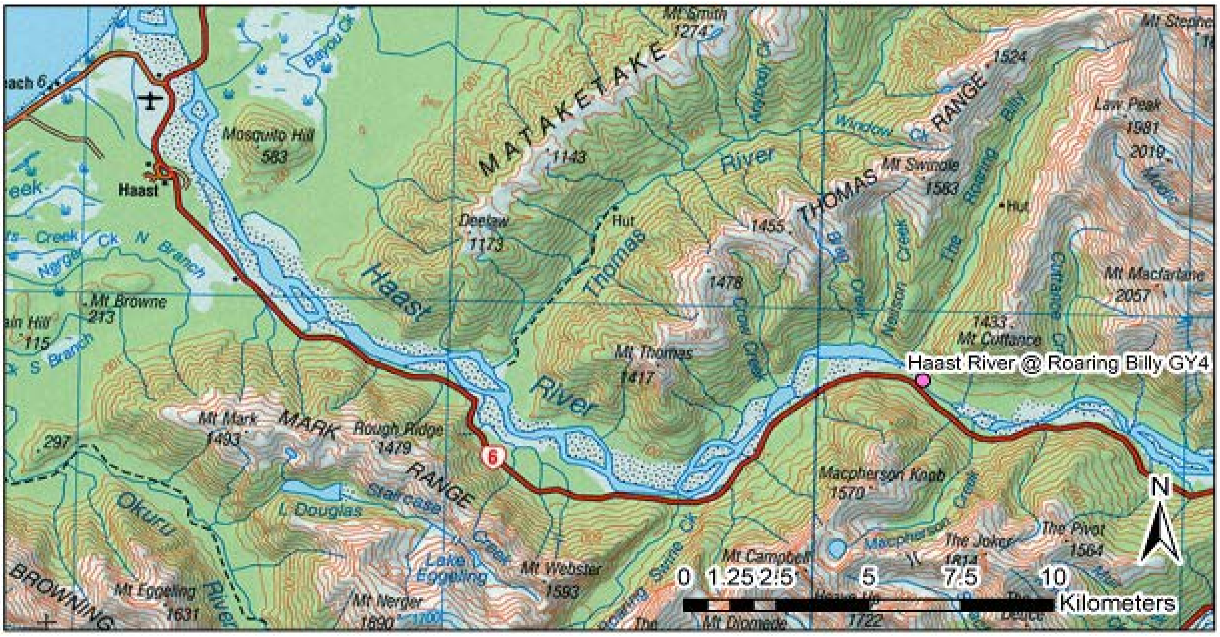

Figure 1 Site location map for Haast area.

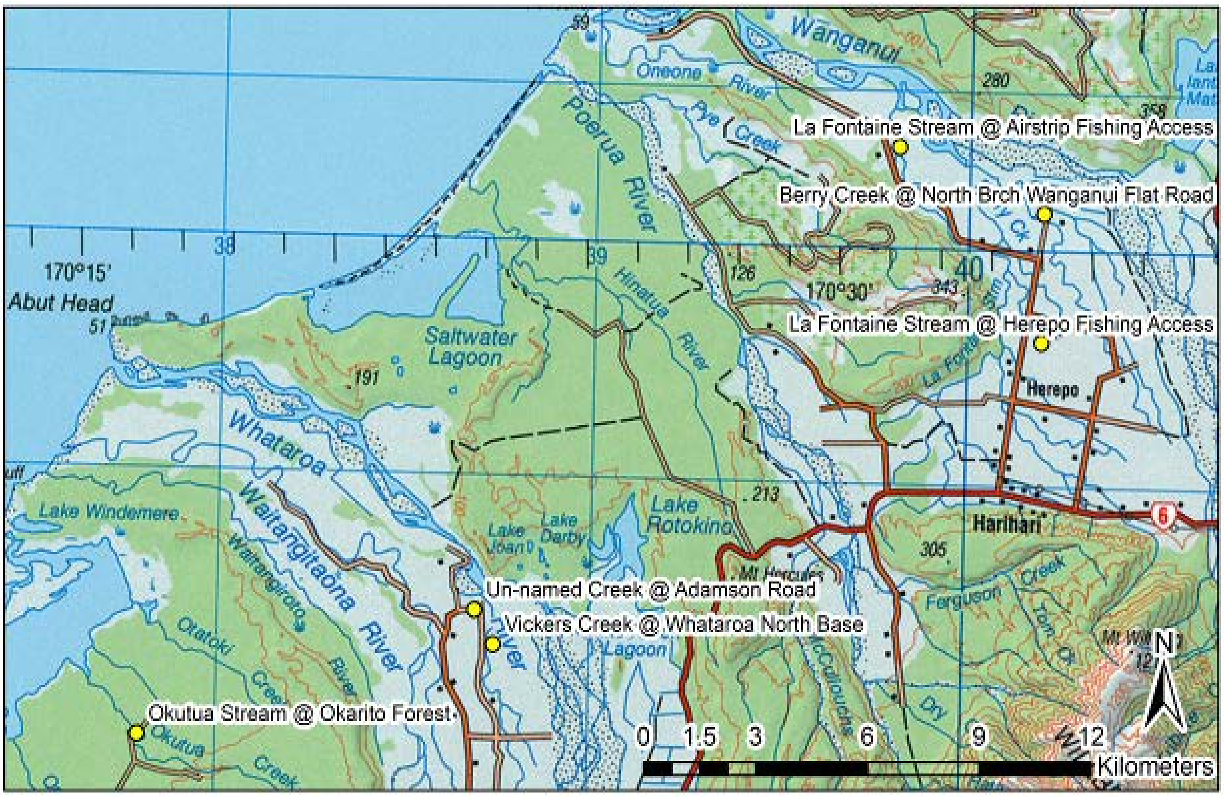

Figure 2 Site location map for Whataroa and Hari Hari areas

Figure 3 Site location map for Hokitika area.

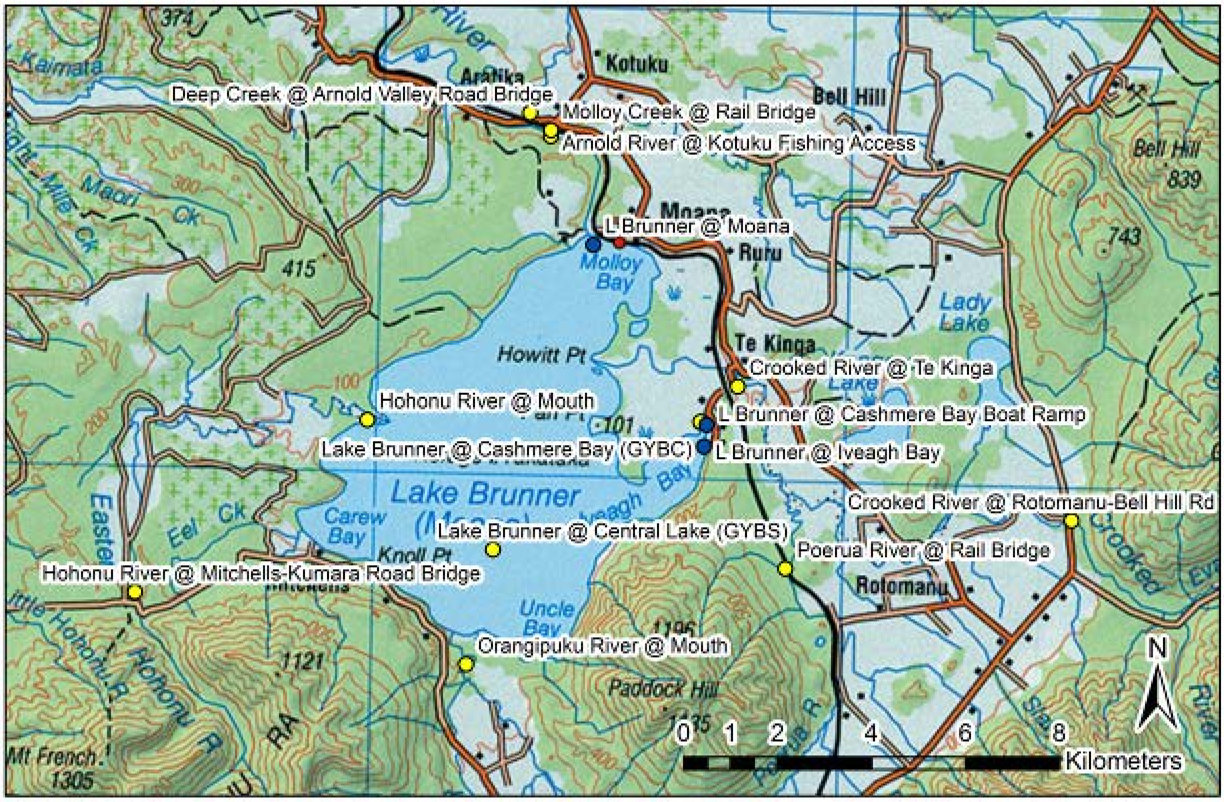

Figure 4 Site location map for Lake Brunner area.

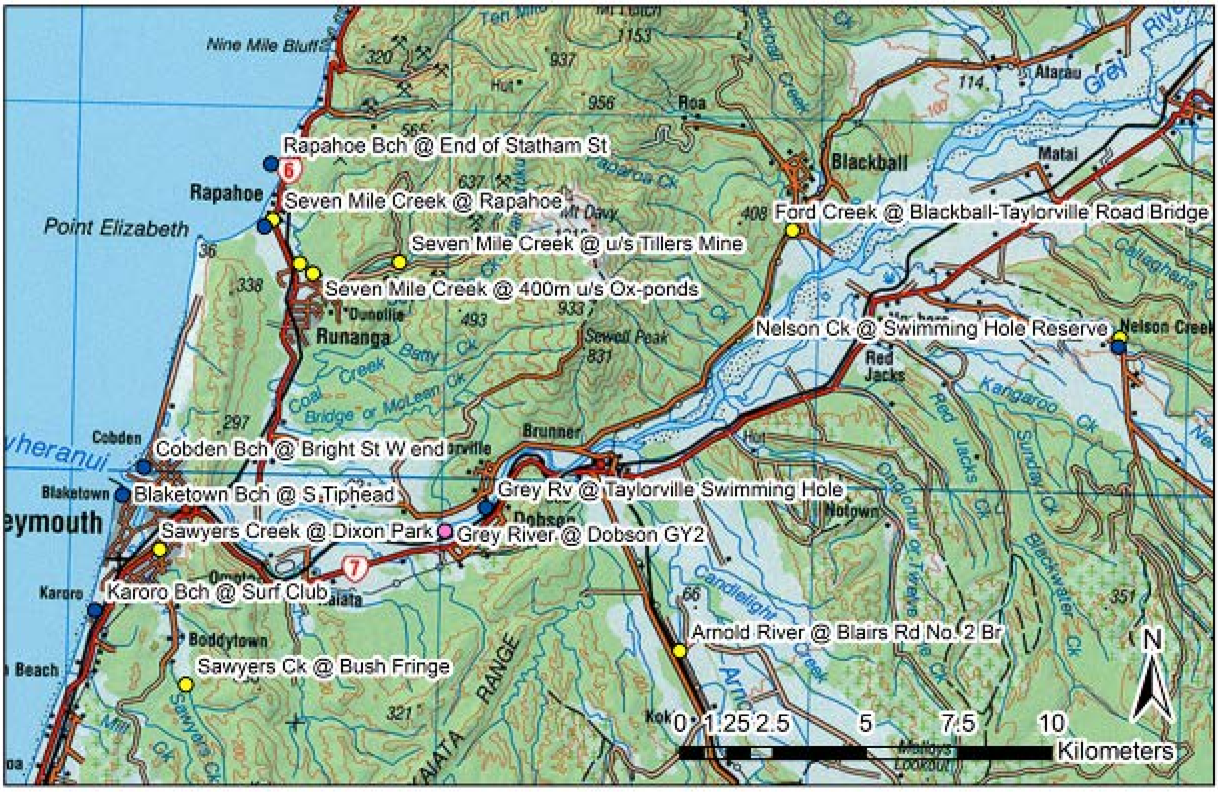

Figure 5 Site location map for Greymouth area.

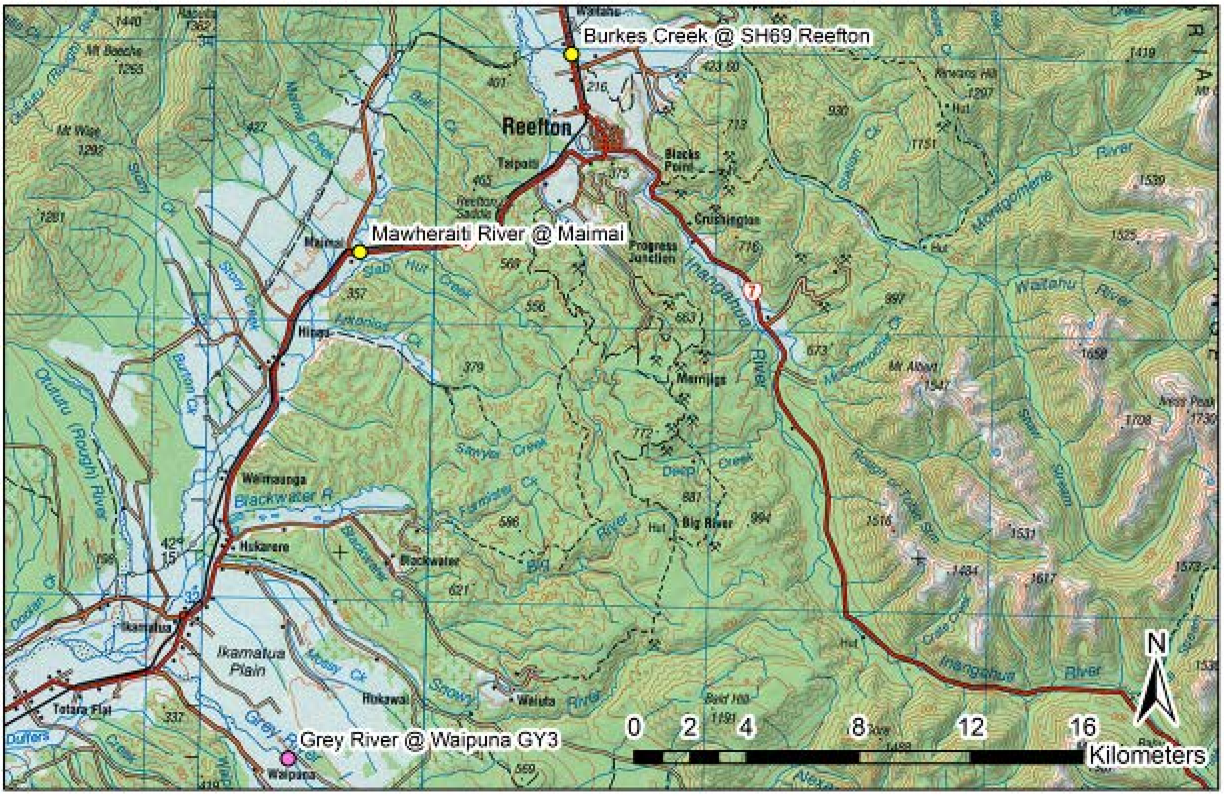

Figure 6 Site location map for Reefton area.

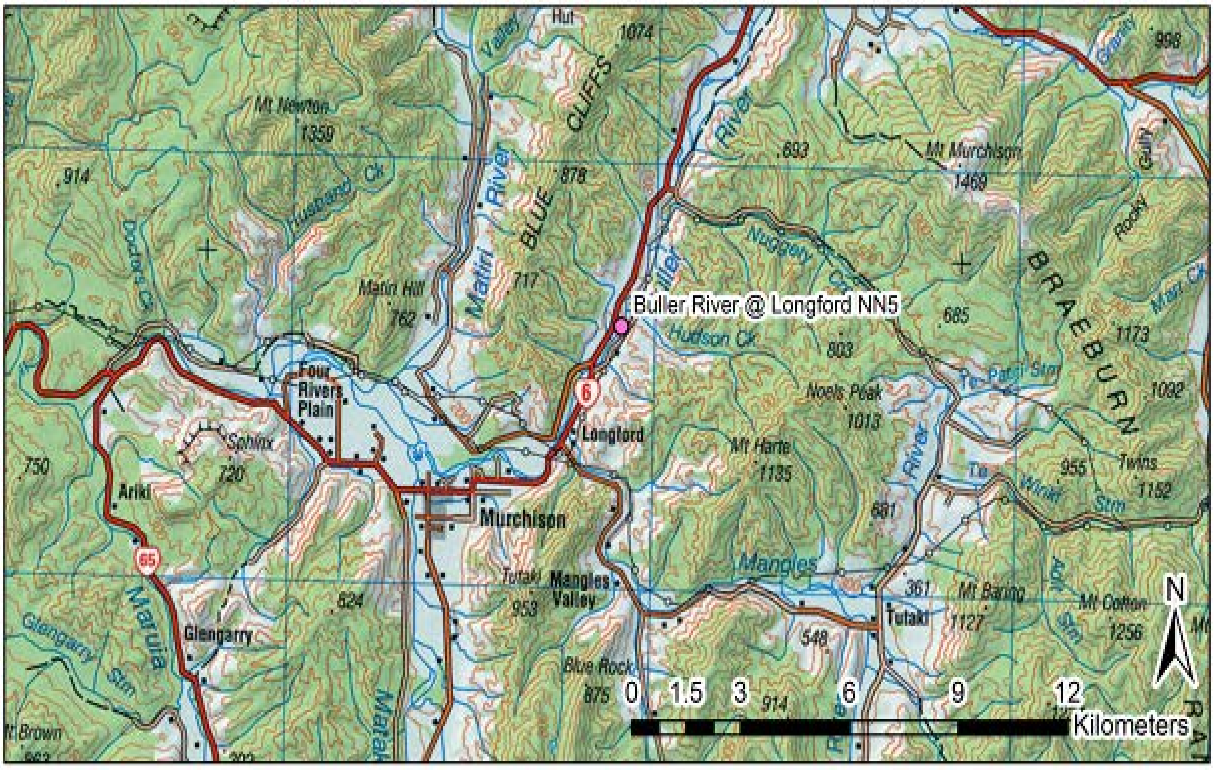

Figure 7 Site location map for Murchison area.

Figure 8 Site location map for Westport area

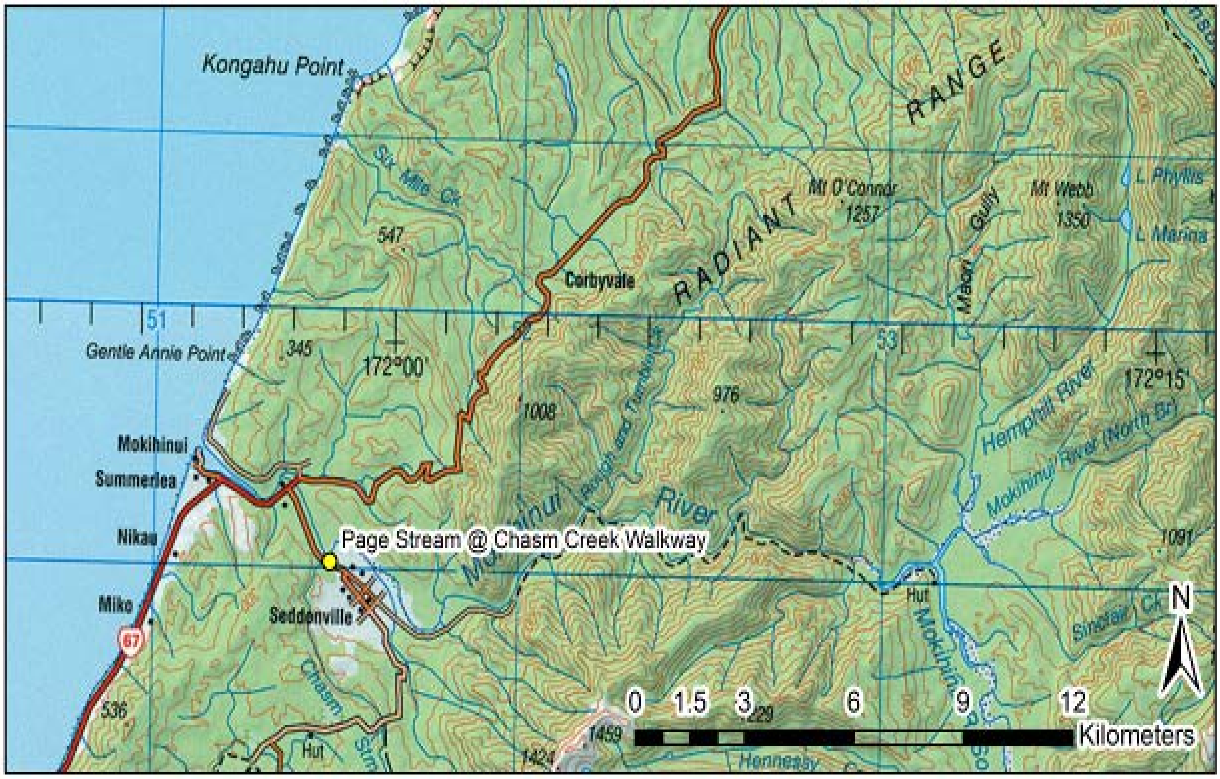

Figure 9 Site location map for Mokihinui area.

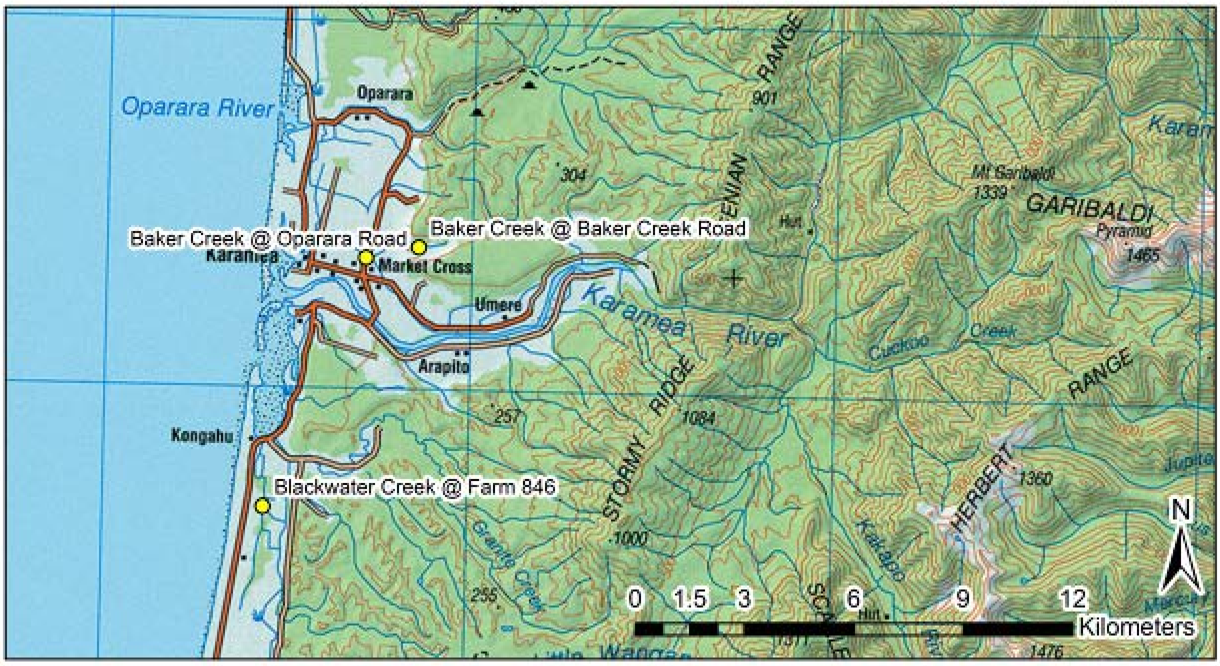

Figure 10 Site location map for Karamea area

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2 State of surface water quality on the West Coast

Summary of surface water quality state on the West Coast

Many of the conclusions drawn in the 2005 Surface Water Quality SOE report, using the REC framework, remain relevant. Due to the West Coast Region's topography and climate, water quality in larger waterways tends to fare better in the face of human induced environmental pressure in comparison to smaller waterways. Smaller streams in lowland areas are more susceptible to impact from human development. Spring fed streams, that are located on agricultural plains, form their own characteristic stream type. With a high base flow proportional to their catchment size (stemming from recharge from groundwater sources beyond their surface water catchment boundaries), water quality was often higher in spring fed streams than what might have been expected relative to the level of development in their catchment, although nitrates can be higher than in other stream types.

In 2008, using a combination of all water quality attributes, waterways in pasture-dominated catchments had poorer water quality than those in indigenous forest, which agreed with previous analyses in 2005. Several water quality attributes have been shown to have a strong relationship with the percentage of natural land cover in the catchment. These were faecal indicator bacteria, nitrogen and phosphorus concentrations, and invertebrate community structure (MCI & %EPT)(Horrox 2008). This was consistent with relationships still observed around New Zealand (Ballantine & Davies-Colley 2009).

Past and present mining can cause significant lowering of pH in areas where sufficient quantities of acid mine drainage occurred. When combined with high levels of dissolved and particulate metals, which often accompanied this source of acidity, significant negative effects on aquatic ecology have been observed. This was not apparent where mining occurred in non-acid forming rock types, although increased sediment from these activities has had an impact on stream ecology. The impacts of mining related sediment alone - from land disturbance opposed to metal precipitation - were not as substantial as when combined with acid mine drainage. It can be difficult to differentiate between impacts from current vs. historic mining.

It continues to be shown that overall water quality is poorer at downstream sites compared to those upstream of them in catchments impacted by human activities. This was evident when comparing paired upstream/downstream sites. However these comparisons indicate that upstream/downstream relationships for some water quality attributes are not simple. Factors such as increasing dilution and changes in habitat and flow regimes can have opposing effects on changing water quality. These intrinsic factors can cause either an apparent improvement for a particular variable, or in some cases, an apparent deterioration.

The National Policy Statement for Freshwater Management (NPS-FM) was introduced in 2014. This contained the National Objectives Framework (NOF), which has been applied to a range of lake and river water quality attributes. In general, lake and river attributes covered by the NOF scored well (e.g. A), and were well above national bottom lines (e.g. D).

Comparison of data for water quality attributes with their respective guidelines and benchmarks indicated a broad range of results among sites. Some sites rated poorly for many attributes, while other sites only rated poorly for some. The particular natural characteristics of a water body can mitigate or exacerbate anthropogenic effects, and are an important consideration when comparing water quality among sites.

Invertebrate indices suggested that approximately half of the sites had MCI and SQMCI scores indicative of slight to un-impacted water quality, with the bottom quarter consistently rating as having moderate to poor water quality. Nuisance periphyton growths have been infrequent at most sites. Often substantial nitrogen is not combined with sufficient phosphorus levels for nuisance periphyton growth to occur. The West Coast's cool wet climate is also likely to be a limiting factor.

Contact recreation sites at West Coast lakes have been the most suitable for swimming. Coastal beach sites were also good, with some recent exceptions. River sites exceedanced bathing water quality guidelines the most. Rivers are affected by run-off, generated by rain events, which transport pathogen indicator bacteria from land to water. Health risks for swimmers are normally higher during and after rain events.

2.1 Conclusions from previous state of the environment analyses

The River Environment Classification (REC) (Snelder et. al. 2003) was used extensively as an analytical framework for the 2005 SoE report (Horrox 2005), and patterns between different types of West Coast waterways were established. In 2008 statistical comparisons were made between catchments with predominantly indigenous vegetation and those with various anthropogenic activities, like agriculture and urban land use. These analyses have not been repeated for this report. The general relationships from these analyses are likely to remain consistent, and these relationships are summarised in Section 2.1.1 and 2.1.2.

2.1.1 REC analysis

The 2005 Regional Council SoE report covered Regional Council data records up until 2004–2005, conducting analysis under the framework of the River Environment Classification (REC). The REC was used to group sites by climate, source of flow, geology, land cover, and stream order. Refer to Section 5.4 for a detailed description of the REC. Relationships between these REC classes and water quality were investigated.

Many significant differences in physical, chemical, and biological water quality attributes were observed between the REC classes of: source of flow, geology, land cover, and stream order. Patterns observed for these attributes amongst REC classes suggested that streams could be characterised as:

- Streams with a hill source of flow; hard sedimentary or plutonic geology; often incorporating larger rivers; with higher, less variable water quality; brown trout more abundant.

- Lowland streams (low elevation source of flow); higher turbidity, nutrients, and temperature (which may not solely have been a response of human activity); smaller, more variable and susceptible to impact; potentially higher fish and invertebrate diversity.

- Streams draining predominantly agricultural catchments (sub-set of lowland streams); comparatively poorer water quality with fewer sensitive macroinvertebrate taxa.

- Stream catchments with soft sedimentary geology; higher turbidity; distinctive physically and chemically from other geology classes; smaller size; lower source of flow.

2.1.2 Effect of land use on water quality

In 2008 monitoring program sites were separated into either predominantly Pasture or Indigenous Forest catchment types, according to the REC. Concentrations of nutrients (dissolved reactive phosphorus and all nitrogen species), levels of faecal indicator bacteria, levels of suspendable fine sediments, conductivity, and most biological indices (Taxa richness, %EPT (Ephemeroptera, Plecoptera, Trichoptera), the MCI (Macroinvertebrate Community Index) and the SQMCI (Semi-Quantitative Macroinvertebrate Community Index), differed significantly between REC Pasture and Indigenous Forest catchment types.

The percentage of ‘natural’ land cover (LCDB2, MfE 2008a) in the catchment of individual monitoring program sites was correlated significantly with improved levels of faecal indicator bacteria, nitrogen and phosphorus concentrations, and invertebrate communities requiring higher water quality (MCI & %EPT). This was consistent with relationships observed across NZ (MfE 2008b).

2.2 Comparison of Regional Council monitoring program sites to water quality guidelines

Sites in the following percentage bar graphs are ordered according to their median value, for each particular water quality attribute. Data was drawn from 2004 to early 2014. For all attributes, sites go from a desirable condition to an undesirable one, from left to right, respectively. So medians go either from low to high or vice versa depending on whether a high value is good or bad. For example, higher clarity is good but higher turbidity isn’t. Further information on the origin, meaning and rationale behind criteria used for categories is presented in Section 5.3. A model of one of these percentage bar graphs is provided in Section 5.5 to aid with interpretation. For more detailed information on data ranges for each water quality attribute, per site, the reader is directed to box and whisker plots in Section 5.6.

Some attributes are not described by percentage bar graphs. These are instead covered by tables that have scores derived through the National Objectives Framework (NOF) methodology. The NOF framework is part of the National Policy Statement for Freshwater Management (NPS-FM 2014). There are four scores in the NOF framework: A, B, C, and D. The NPS-FM states that values below C are considered by to be below the national bottom line. River attributes where the NOF system has been applied include: nitrate, total ammonia, and *E. coli*. NOF scores are calculated from a five year block of data. Up to five years of NOF scores have been provided for comparison, but trends are better evaluated with the techniques used in Section 3.

No data for pH has been presented in this section. There are a variety of drivers that influence pH on the West Coast, and a low or high pH could be either good or bad depending on what is driving it. For example, there are several sites that have pH levels around pH 4, for example Page Stream and Okutua Stream. Low pH at the former site is caused by historic mining, and in combination with dissolved metal toxicity and precipitates that smother the bed, aquatic biodiversity is low. In contrast Okutua Stream is pristine and the dissolved organic acids reducing the pH do not have a significant effect on stream biota.

2.2.1 Temperature

Few sites had high temperature i.e. above 20°C, when sampled (Figure 11). Twenty degrees is restrictive for temperature sensitive species e.g. trout, certain stoneflies, and some native fish. Sites that had temperatures exceeding 20°C varied regarding their catchment type and physical characteristics. The Arnold River @ Kotuku Fishing Access has high water quality and is close to the outlet of Lake Brunner.

Warm summer surface layers in the lake are likely to elevate river temperatures, which decrease downstream with additions from cooler tributaries. Generally, sites with a lack of riparian shading and/or small flows had high temperatures in warm, sunny weather. Ten sites recorded temperatures over 20°C, with Bradshaws Ck @ Bradshaws Rd recording a temperature of 24.2°C (Figure 31). It should be noted that temperatures used in this analysis are collected over the entire year, and are based on single spot samples. Summer medians will be higher. Also, maximum values at these sites will be higher than what is reported here. This would be apparent if continuous temperature monitoring was utilised.

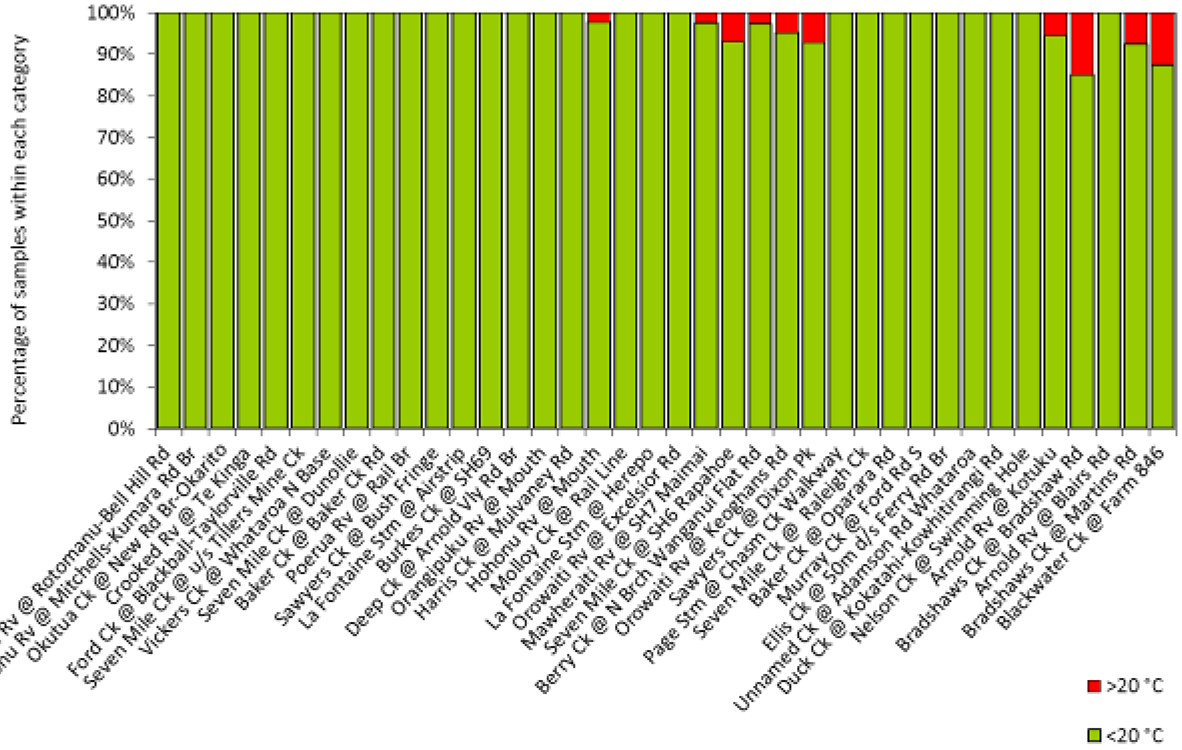


Figure 11 Percentage of samples in respective water temperature categories for individual Regional Council monitoring program sites 2004 – 2014.

2.2.2 Turbidity

Two sites had median turbidity over 5.6 NTU (Blackwater Ck and Ford Ck) (Figure 12). These sites have different reasons for higher turbidity. Erodible sedimentary geology is a common reason, usually combined with varying degrees of human disturbance. Sediment contributions from current and historic mining related activities are a feature in the Ford and Seven Mile Creek, and Page Stream catchments, with urban activity a feature in Seven Mile and Sawyers Creeks. In general, agricultural land use within a catchment leads to increased downstream turbidity. It is worth noting the influence of geology: For example, reference sites on Sawyers and Baker Creeks – both draining catchments with predominantly soft sedimentary geology – have higher median turbidity compared with the Orangipuku River. Much of the Orangipuku River drains intensive agricultural land, but it is spring-fed, with hard plutonic geology, thus yields water with relatively low turbidity.

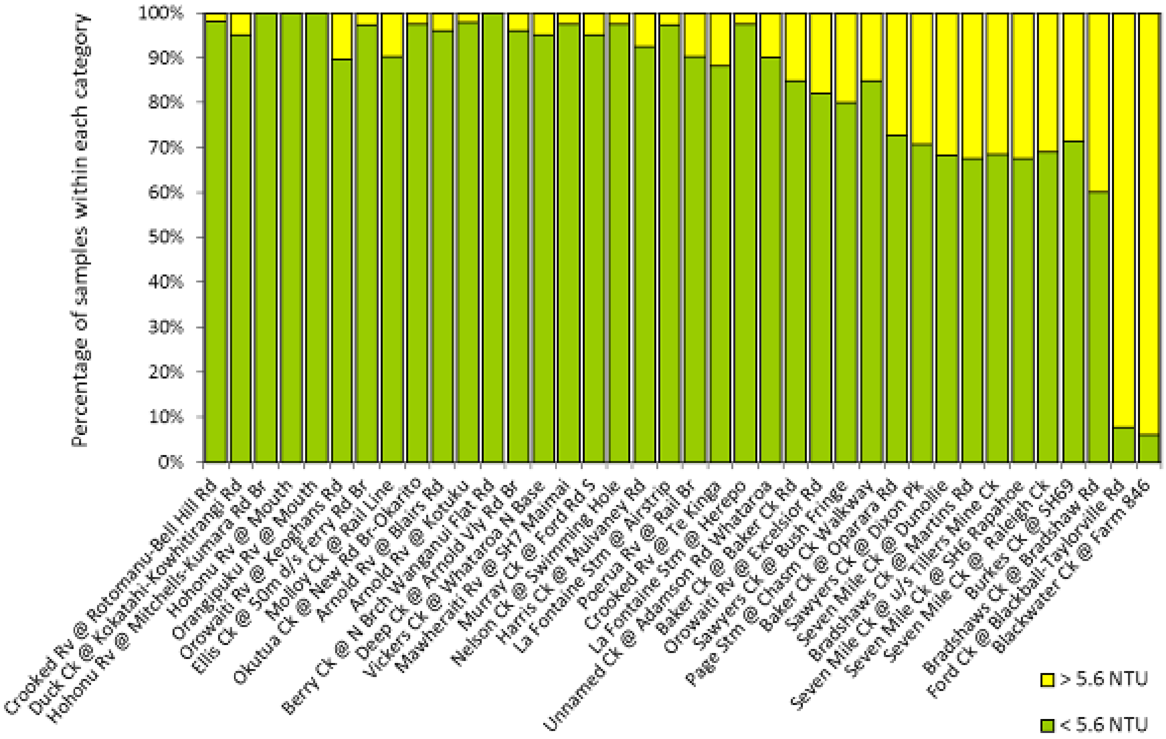


Figure 12 Percentage of samples in respective turbidity categories for individual Regional Council monitoring program sites 2004 – 2014.

2.2.3 Clarity

Patterns in clarity among sites were similar to those observed for turbidity, and the causes of poor clarity are similar to those that increase turbidity (Figure 13). Horizontal clarity, measured with a black disk, is a more sensitive measure of suspended material than turbidity in clear waters that have low coloured dissolved organic matter (CDOM). CDOM is the brown 'tea' staining colour found in many West Coast streams. It is a natural feature that can significantly reduce water clarity. This is the reason for the relatively low clarity observed in the Okutua Stream, which is a pristine site in Okarito Forest. Median clarity for this site was in the middle of the field compared to other sites, yet the quantity of sediment deposits, and suspended sediment (as indicated by turbidity) was low. Median clarity at Okutua Stream has never failed the 1.6 m contact recreation guideline.

Under the Land and Water Plan (2014) all water bodies are to be managed for aquatic ecology, to which the 0.8 m clarity threshold applies. Ninety seven percent of sites had a median clarity above 0.8 m. The 1.6 m level has been used as a visibility threshold for swimming suitability. Comparison to this guideline is most relevant for sites that are managed for swimming, as stipulated in the Proposed Land and Water Plan.

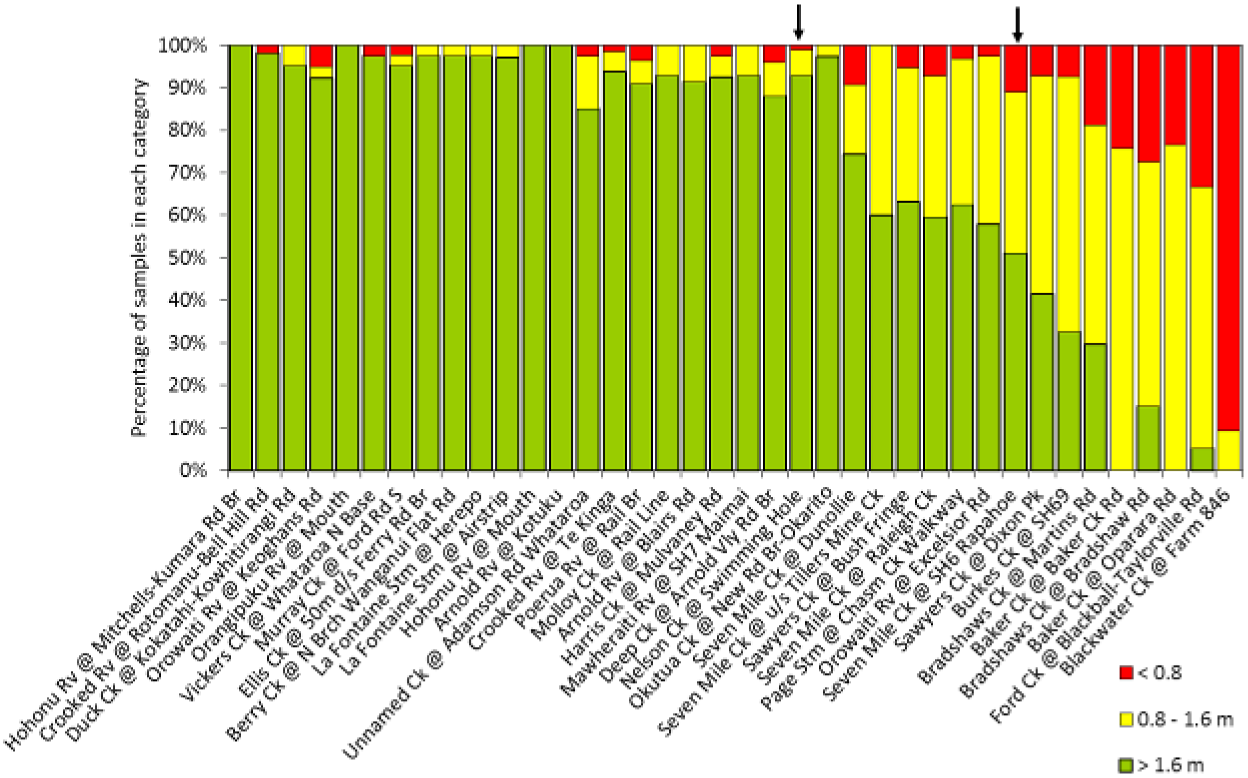


Figure 13 Percentage of samples in respective clarity categories for individual Regional Council monitoring program sites 2004 - 2014.

2.2.4 Ammonia

The term ammonia in this report refers to total ammonia-N (NH_3 + NH_4^-). The NOF has attribute states for ammonia based on two numeric methods – a median and maximum. Ammonia toxicity varies with pH so ammonia states incorporate pH correction (Section 5.2.2). This means that high total ammonia may not be as toxic if the pH is low (Section 5.3.1). The overall NOF score has been allocated based on the worst out of the median and maximum.

Ammonia toxicity risk is determined by the 2013 state (calculated from 2009 to 2013 data). There were 82% of sites in the A state (Table 1), where there should be no observable effect on species. Ammonia levels in the B state are considered to be suitable for 95% of species, with occasional impact on the 5% most sensitive species. Seven sites (16%) scored a B. One site, Un- named southern trib @ Lake Haupiri, scored a C. This state is supposed to signify levels where there are regular impacts and reduced survival for the 20% most sensitive species. The C was derived from a high maximum ammonia result, but it should be noted that median ammonia at this site was not high (0.027 mg/L, uncorrected).

Blackwater Ck @ Farm 846 and Seven Mile Ck @ 300m d/s Raleigh Ck had medians below A, indicating that ammonia toxicity was consistently higher than other B sites (Table 1). The remainder of B and C sites achieved their overall score due to spikes rather than consistently high ammonia.

Blackwater Ck @ Farm 846 had much higher ammonia levels than other streams (Figure 36) but toxicity was contained to a B state due to slightly acidic pH's. Nitrate is commonly associated with agricultural run-off yet Blackwater Ck nitrate was similar to other streams (Figure 35). Therefore unique stream and catchment characteristics are the most likely driver of high ammonia. Blackwater Ck is a slow flowing, soft bottomed stream with low dissolved oxygen (Figure 32). The catchment is low lying with wet, peaty soils. Abundant ammonia can be generated in these conditions, and oxidation of ammonia to nitrate inhibited. Total nitrogen was high (Figure 37), which will associate with high particulate loads (Figure 34, Figure 33), rather than an abundance of dissolved nitrogen.

The source of ammonia for Seven Mile Ck @ 300m d/s Raleigh Ck is an outfall from a municipal sewerage oxidation pond.

2.2.5 Nitrate-N

The term nitrate in this report refers to nitrate-N (NO_3-N). The NOF attribute states for nitrate are based on two numeric methods – a median and 95th percentile. Nitrate was adopted across sites in 2008 so analysis cannot go back beyond 2012.

Nitrate toxicity risk is determined by the 2013 state (calculated from 2009 to 2013 data). Most sites (95%) were in the A state (Table 2), where it is unlikely there will be effects even on sensitive species. Nitrate levels in the B state are considered to have some growth effect on 5% of species. Two sites (5%) scored a B. This was due to high 95th percentiles.

Table 1 Ammonical nitrogen NOF grades for Regional Council monitoring program sites. Calculated as 5 yearly rolling medians and maximums.

Ammonia-N	**2009**		**2010**		**2011**		**2012**		**2013**	
	Med	Max	Med	Max	Med	Max	Med	Max	Med	Max
Arnold Rv @ Blairs Rd No. 2 Br	A	A	A	B	A	B	A	B	A	B
Arnold Rv @ Kotuku Fishing Access	A	A	A	A	A	A	A	A	A	A
Baker Ck @ Baker Ck Rd	A	A	A	A	A	A	A	A	A	A
Baker Ck @ Oparara Rd	A	A	A	A	A	A	A	B	A	B
Berry Ck @ N Brch Wanganui Flat Rd	A	A	A	A	A	A	A	A	A	A
Blackwater Ck @ Farm 846	B	B	B	B	B	B	B	B	B	B
Bradshaws Ck @ Bradshaw Rd	B	B	A	B	A	A	A	A	A	A
Bradshaws Ck @ Martins Rd	A	A	A	A	A	A	A	A	A	A
Burkes Ck @ SH69	A	A	A	A	A	A	A	A	A	A
Buller Rv @ Longford	A	A	A	A	A	A	A	A	A	A
Buller Rv @ Te Kuha	A	A	A	A	A	A	A	A	A	A
Crooked Rv @ Rotomanu-Bell Hill Rd	A	A	A	A	A	A	A	A	A	A
Crooked Rv @ Te Kinga	A	A	A	A	A	A	A	A	A	A
Deep Ck @ Arnold Vly Rd Br	A	B	A	B	A	B	A	B	A	B
Duck Ck @ Kokatahi-Kowhitirangi Rd Br	A	A	A	A	A	A	A	A	A	A
Ellis Ck @ 50m d/s Ferry Rd Br	A	A	A	A	A	A	A	A	A	A
Ford Ck @ Blackball-Taylorville Rd	A	A	A	A	A	A	A	A	A	A
Grey Rv @ Dobson	A	A	A	A	A	A	A	A	A	A
Grey Rv @ Waipuna	A	A	A	A	A	A	A	A	A	A
Haast Rv @ Roaring Billy	A	A	A	A	A	A	A	A	A	A
Harris Ck @ Mulvaney Rd	A	A	A	A	A	A	A	A	A	A
Hohonu Rv @ Mitchells-Kumara Rd Br	A	A	A	A	A	A	A	A	A	A
Hohonu Rv @ Mouth	A	A	A	A	A	A	A	A	A	A
La Fontaine Stm @ Airstrip Fishing Access	A	A	A	A	A	A	A	A	A	A
La Fontaine Stm @ Herepo Fishing Access	A	A	A	A	A	A	A	A	A	A
Mawheraiti Rv @ SH7 Maimai	A	A	A	A	A	A	A	A	A	A
Molloy Ck @ Rail Line	A	A	A	A	A	A	A	A	A	A
Murray Ck @ Ford Rd S	A	A	A	A	A	A	A	A	A	A
Nelson Ck @ Swimming Hole Reserve	A	A	A	A	A	A	A	A	A	A
Okutua Ck @ New Rd Br-Okarito Forest	A	A	A	A	A	A	A	A	A	A
Orangipuku Rv @ Mouth	A	A	A	A	A	A	A	A	A	A
Orowaiti Rv @ Excelsior Rd	A	B	A	B	A	A	A	A	A	A
Orowaiti Rv @ Keoghans Rd	A	A	A	A	A	A	A	A	A	A
Page Stm @ Chasm Ck Walkway	A	A	A	A	A	A	A	A	A	A
Poerua Rv @ Rail Br	A	A	A	A	A	A	A	A	A	A
Sawyers Ck @ Bush Fringe	A	A	A	A	A	A	A	A	A	A
Sawyers Ck @ Dixon Pk	A	B	A	B	A	B	A	B	A	B
Seven Mile Ck @ 300m d/s Raleigh Ck	B	B	B	B	B	B	B	B	B	B
Seven Mile Ck @ Dunollie 400m u/s Ox Pd	A	B	A	B	A	B	A	A	A	A
Seven Mile Ck @ SH6 Rapahoe	A	B	A	B	A	B	A	B	A	B
Seven Mile Ck @ u/s Tillers Mine Ck	A	A	A	A	A	A	A	A	A	A
Unnamed Ck @ Adamson Rd Whataroa	A	B	A	B	A	B	A	B	A	A
Unnamed southern trib @ Lake Haupiri									A	C
Vickers Ck @ Whataroa N Base	A	A	A	A	A	A	A	A	A	A

Table 2 Nitrate NOF grades for individual Regional Council monitoring program sites, calculated as a 5 yearly median and 95th percentile. Nitrate was only widely adopted in 2008 so analysis can't go back any further than 2012.

Nitrate	**2012**	**2012**	**2013**	**2013**
	Median	95th percentile	Median	95th percentile
Arnold Rv @ Blairs Rd No. 2 Br	A	A	A	A
Arnold Rv @ Kotuku Fishing Access	A	A	A	A
Baker Ck @ Baker Ck Rd	A	A	A	A
Baker Ck @ Oparara Rd	A	A	A	A
Berry Ck @ N Brch Wanganui Flat Rd	A	A	A	A
Blackwater Ck @ Farm 846	A	A	A	A
Bradshaws Ck @ Bradshaw Rd	A	C	A	B
Bradshaws Ck @ Martins Rd	A	A	A	A
Buller Rv @ Longford	A	A	A	A
Buller Rv @ Te Kuha	A	A	A	A
Burkes Ck @ SH69	A	A	A	A
Crooked Rv @ Rotomanu-Bell Hill Rd	A	A	A	A
Crooked Rv @ Te Kinga	A	A	A	A
Deep Ck @ Arnold Vly Rd Br	A	A	A	A
Duck Ck @ Kokatahi-Kowhitirangi Rd Br	A	A	A	A
Ellis Ck @ 50m d/s Ferry Rd Br	A	A	A	A
Ford Ck @ Blackball-Taylorville Rd	A	A	A	A
Grey Rv @ Dobson	A	A	A	A
Grey Rv @ Waipuna	A	A	A	A
Haast Rv @ Roaring Billy	A	A	A	A
Harris Ck @ Mulvaney Rd	A	A	A	A
Hohonu Rv @ Mitchells-Kumara Rd Br	A	A	A	A
Hohonu Rv @ Mouth	A	A	A	A
La Fontaine Stm @ Airstrip Fishing Access	A	A	A	A
La Fontaine Stm @ Herepo Fishing Access	A	A	A	A
Mawheraiti Rv @ SH7 Maimai	A	A	A	A
Molloy Ck @ Rail Line	A	A	A	A
Murray Ck @ Ford Rd S	A	A	A	A
Nelson Ck @ Swimming Hole Reserve	A	A	A	A
Okutua Ck @ New Rd Br-Okarito Forest	A	A	A	A
Orangipuku Rv @ Mouth	A	A	A	A
Orowaiti Rv @ Excelsior Rd	A	A	A	A
Orowaiti Rv @ Keoghans Rd	A	A	A	A
Page Stm @ Chasm Ck Walkway	A	A	A	A
Poerua Rv @ Rail Br	A	A	A	A
Sawyers Ck @ Bush Fringe	A	A	A	A
Sawyers Ck @ Dixon Pk	A	A	A	A
Seven Mile Ck @ 300m d/s Raleigh Ck	A	A	A	A
Seven Mile Ck @ Dunollie 400m u/s Ox Pd	A	A	A	A
Seven Mile Ck @ SH6 Rapahoe	A	A	A	A
Seven Mile Ck @ u/s Tillers Mine Ck	A	A	A	A
Unnamed Ck @ Adamson Rd Whataroa	A	A	A	B
Unnamed south trib @ Lake Haupiri			A	A
Vickers Ck @ Whataroa N Base	A	A	A	A

2.2.6 Dissolved reactive phosphorus

The benchmark of 0.03 mg/L chosen for dissolved reactive phosphorus (DRP) is the upper limit of a guideline (MfE 1992) designed to indicate a threshold where nuisance algal growths are more likely. For nuisance algal growth to occur other factors such as warm temperatures and stable flows are also required, and these are often lacking despite adequate bioavailable phosphorus forms such as DRP. Dissolved reactive phosphorus levels have in most cases been low and rarely exceeded the threshold likely to contribute to nuisance algal growth (Figure 14). It is likely to be the limiting nutrient in most West Coast streams: that is, phosphorus is the nutrient that is required for more in-stream plant and algal growth. Harris Ck @ Mulvaney Rd and Blackwater Ck @ Farm 846 had the highest DRP (Figure 38), both exceeding 0.03 mg/L for 20 % of the time.

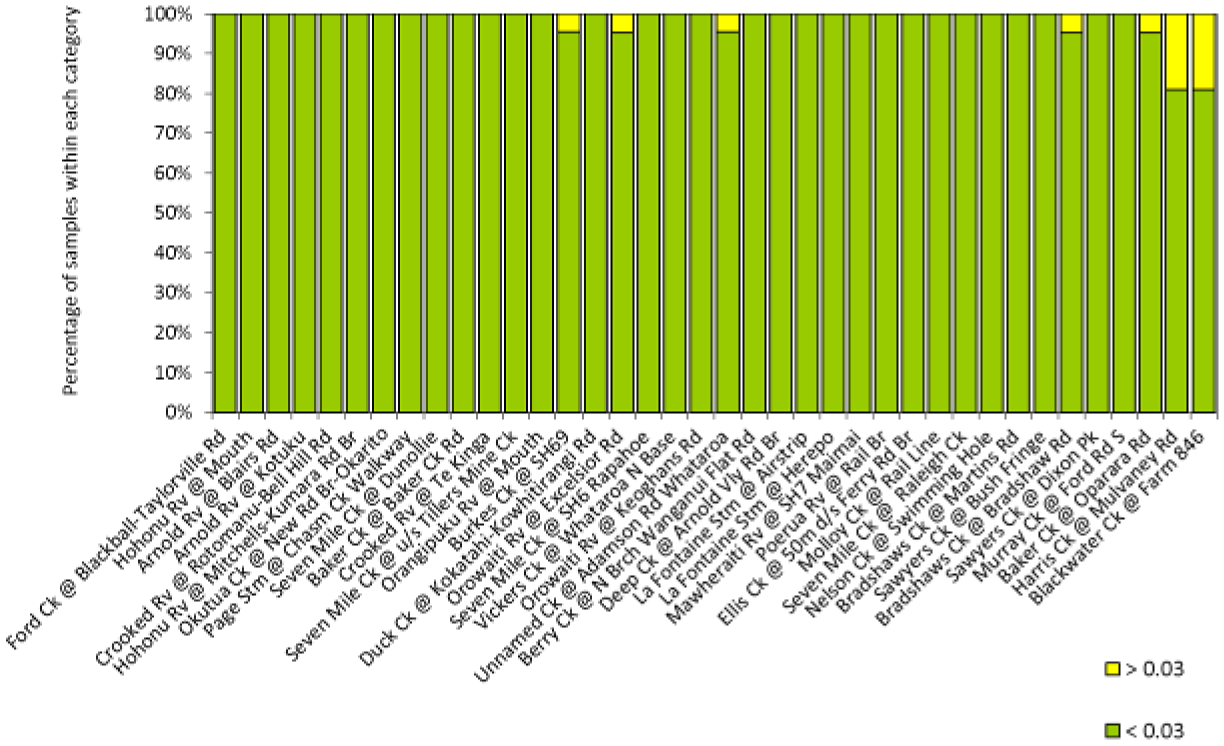


Figure 14 Percentage of samples in respective dissolved reactive phosphorus categories for individual Regional Council monitoring program sites.

2.2.7 *E. coli*

The faecal coliform Escherichia coli is an indicator of faecal contamination in water, which can create a pathogen hazard for humans and stock, but is not harmful to aquatic organisms. *E. coli* is a useful indicator of faecal source contamination from warm-blooded animals such as people, livestock, and birds.

E. coli risk is determined by the 2013 state (calculated from 2009 to 2013 data). The NOF attribute states for *E. coli* are based on two numeric methods – a median and 95th percentile. The median relates to pathogen risks to people engaging in activities that involve occasional immersion such as wading and boating. The 95th percentile relates to pathogen risks to people engaging in activities that involve complete immersion e.g. swimming. Only the median risk threshold states for occasional immersion have been applied as only two sites in Table 3 are managed for swimming in the Water Plan. Assessment of swimming suitability on the West Coast is covered in section 2.4.

89% of sites scored an A (Table 3). An A represents a very low risk of infection (less than 0.1% risk) from contact with water during activities with occasional immersion and some ingestion of water (such as wading and boating). The B state represents a low risk of infection (also less than 1% risk). Three sites (6%) scored a B.

Blackwater Ck @ Farm 846 scored a C. People are exposed to a moderate risk of infection (less than 5% risk) from contact with this water during activities with occasional immersion and some ingestion of water (such as wading and boating).

Sawyers Ck @ Dixon Park scored a D in 2013 and has done so consistently in the past (Table 3). People are exposed to a high risk of infection (greater than 5% risk) from contact with water at this site.

2.2.8 Macroinvertebrates

The Macroinvertebrate Community Index (MCI) and Semi-Quantitative Macroinvertebrate Community Index (SQMCI) evaluate water quality based on the types and tolerances of macroinvertebrates found at a site (Figure 15 and Figure 16). The four categories relate to water quality classes going from poor (<80) to excellent (>120) (refer Section 5.3.10). The rank of sites based on medians for MCI and SQMCI differ. The SQMCI takes into account the relative abundance of each type of macroinvertebrate collected, whereas the MCI works only on presence/absence. There was a close relationship between MCI and SQMCI (R=0.98) when tested with linear regression, so sites with good MCI scores also had comparative SQMCI ranking.

A range of environmental factors influence macroinvertebrate community composition. Chemical and physical properties of water are the most obvious. Habitat type is also very important. Some habitat degradation can result from anthropogenic activity e.g. poorly managed land development can lead to excessive sediment suspended in the water, and deposited on the stream bed (refer Appendix 5.3.4 for more information on sediment effects). Intrinsic habitat characteristics can also play a significant role in influencing macroinvertebrate communities. They may have a compounding effect with anthropogenic stressors, or be the main drivers of macroinvertebrate community shape. Bradshaws Ck @ Martin Rd Bridge is an example of this; where tides influence flow and sediment movements to the detriment of sensitive macroinvertebrate species. The Arnold River @ Kotuku is an example where water quality is high but stable flows, resulting from close proximity to a lake outlet, give rise to abundant algal growth, which suits pollution tolerant species. For these reasons both these sites have been omitted from MCI and SQMCI analysis.

Overall, approximately half of the sites had MCI and SQMCI scores indicative of un-impacted to slightly impacted water quality, with the bottom quarter consistently having macroinvertebrate communities typical of moderate to poor water quality.

Table 3 *E. coli* 5 yearly median NOF grades for individual Regional Council monitoring program sites 2004 - 2014.

E. coli	**2009**	**2010**	**2011**	**2012**	**2013**
Arnold Rv @ Blairs Rd No. 2 Br	A	A	A	A	A
Arnold Rv @ Kotuku Fishing Access	A	A	A	A	A
Baker Ck @ Baker Ck Rd	A	A	A	A	A
Baker Ck @ Oparara Rd	B	B	B	B	B
Berry Ck @ N Brch Wanganui Flat Rd	A	A	A	A	A
Blackwater Ck @ Farm 846	B	B	C	D	C
Bradshaws Ck @ Bradshaw Rd	A	A	A	A	B
Bradshaws Ck @ Martins Rd	A	A	A	A	A
Burkes Ck @ SH69	A	A	A	A	A
Buller Rv @ Longford	A	A	A	A	A
Buller Rv @ Te Kuha	A	A	A	A	A
Crooked Rv @ Rotomanu-Bell Hill Rd	A	A	A	A	A
Crooked Rv @ Te Kinga	A	A	A	A	A
Deep Ck @ Arnold Vly Rd Br	A	A	A	A	A
Duck Ck @ Kokatahi-Kowhitirangi Rd Br	A	A	A	A	A
Ellis Ck @ 50m d/s Ferry Rd Br	A	A	A	A	A
Ford Ck @ Blackball-Taylorville Rd	A	A	A	A	A
Grey Rv @ Dobson	A	A	A	A	A
Grey Rv @ Waipuna	A	A	A	A	A
Haast Rv @ Roaring Billy	A	A	A	A	A
Harris Ck @ Mulvaney Rd	A	A	A	A	A
Hohonu Rv @ Mitchells-Kumara Rd Br	A	A	A	A	A
Hohonu Rv @ Mouth	A	A	A	A	A
La Fontaine Stm @ Airstrip Fishing Access	A	A	A	A	A
La Fontaine Stm @ Herepo Fishing Access	A	A	A	A	A
Mawheraiti Rv @ SH7 Maimai	A	A	A	A	A
Molloy Ck @ Rail Line	A	A	A	A	A
Murray Ck @ Ford Rd S	A	A	A	A	A
Nelson Ck @ Swimming Hole Reserve	A	A	A	A	A
Okutua Ck @ New Rd Br-Okarito Forest	A	A	A	A	A
Orangipuku Rv @ Mouth	A	A	A	A	A
Orowaiti Rv @ Excelsior Rd	B	B	B	B	B
Orowaiti Rv @ Keoghans Rd	A	A	A	A	A
Page Stm @ Chasm Ck Walkway	A	A	A	A	A
Poerua Rv @ Rail Br	A	A	A	A	A
Sawyers Ck @ Bush Fringe	A	A	A	A	A
Sawyers Ck @ Dixon Pk	D	D	D	D	D
Seven Mile Ck @ 300m d/s Raleigh Ck	A	A	A	A	A
Seven Mile Ck @ Dunollie 400m u/s Ox Pd	A	A	A	A	A
Seven Mile Ck @ SH6 Rapahoe	A	A	A	A	A
Seven Mile Ck @ u/s Tillers Mine Ck	A	A	A	A	A
Unnamed Ck @ Adamson Rd Whataroa	A	A	A	A	A
Unnamed south trib @ Lake Haupiri					A
Vickers Ck @ Whataroa N Base	A	A	A	A	A

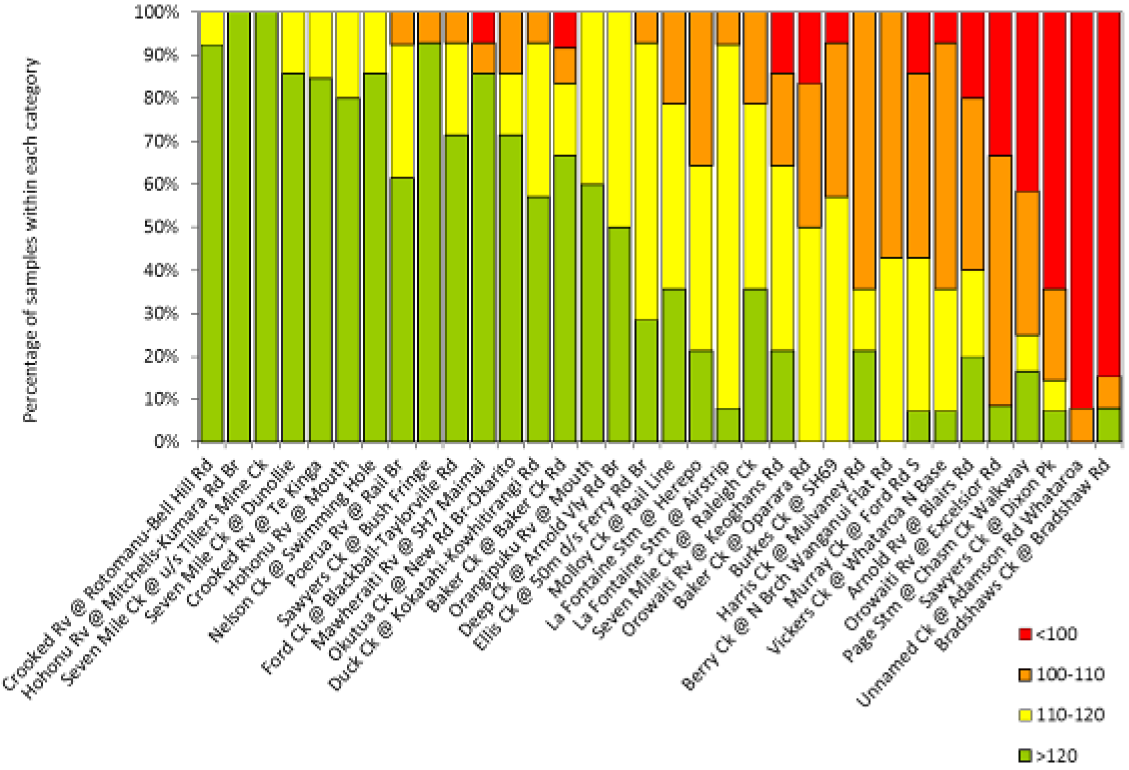


Figure 15 Percentage of samples in respective MCI categories for individual Regional Council monitoring program sites.

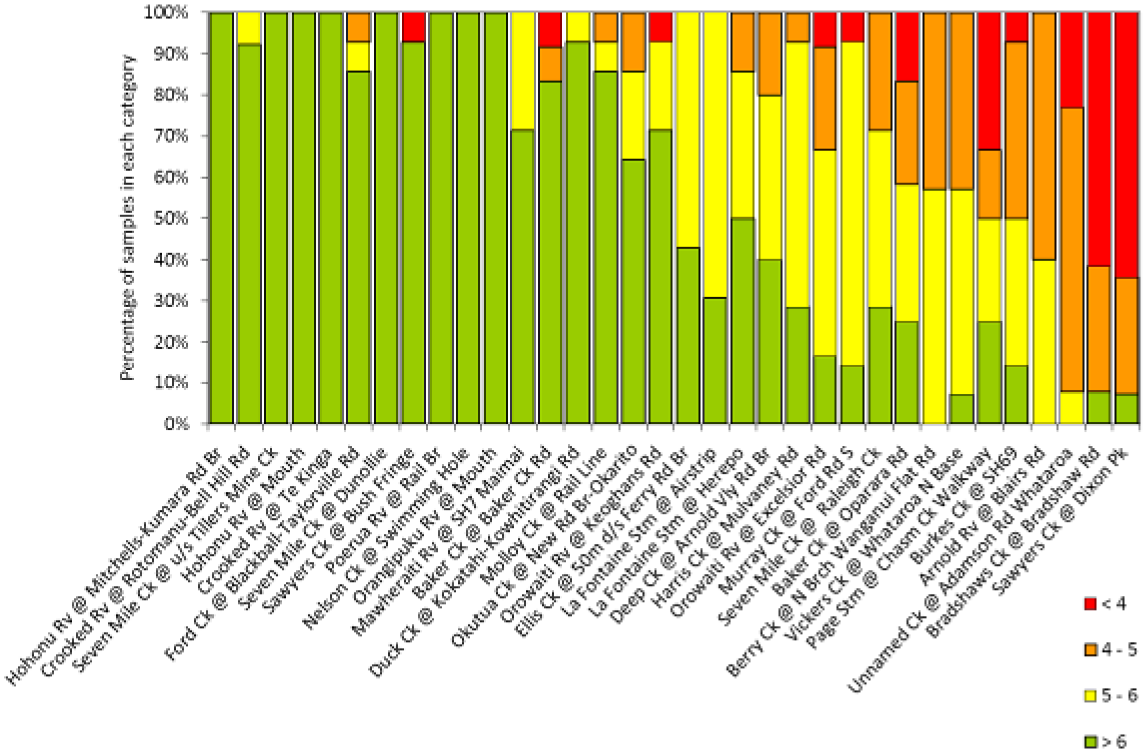


Figure 16 Percentage of samples in respective SQMCI categories for individual Regional Council monitoring program sites.

2.2.9 Periphyton

Figure 17 indicates the percentage of periphyton surveys for each site that generated an enrichment score of five or less – a threshold that is indicative of nuisance periphyton growth (refer to section 5.3.9 for an explanation of how this was derived). As well as nutrient levels, other environmental conditions can be required for large algal proliferations. These include: adequate light, warmth, and stable conditions. Such conditions can occur simultaneously during summer low flows, and high algal biomass during these periods may relate more with climatic regimes than nutrient concentrations. High nutrient levels will not cause nuisance periphyton growth if, for example, flow stability and light are not adequate for major growth to occur and build up.

Levels of anthropogenic impact varied among sites that had nuisance biological growths suggesting the role of climatic regime was often more important than nutrient concentrations. Nuisance biological growths occurred in intensively farmed catchments and those with major upstream nutrient sources e.g. sewerage treatment ponds. But they also occurred in streams where major anthropogenic sources of nutrient were unlikely. Suitable climatic regimes can promote occasional periphyton blooms in West Coast streams irrespective of land use, and did not relate to median periphyton enrichments scores (Figure 17). Median periphyton enrichment is a better indicator of typical enrichment status (

Figure 44).

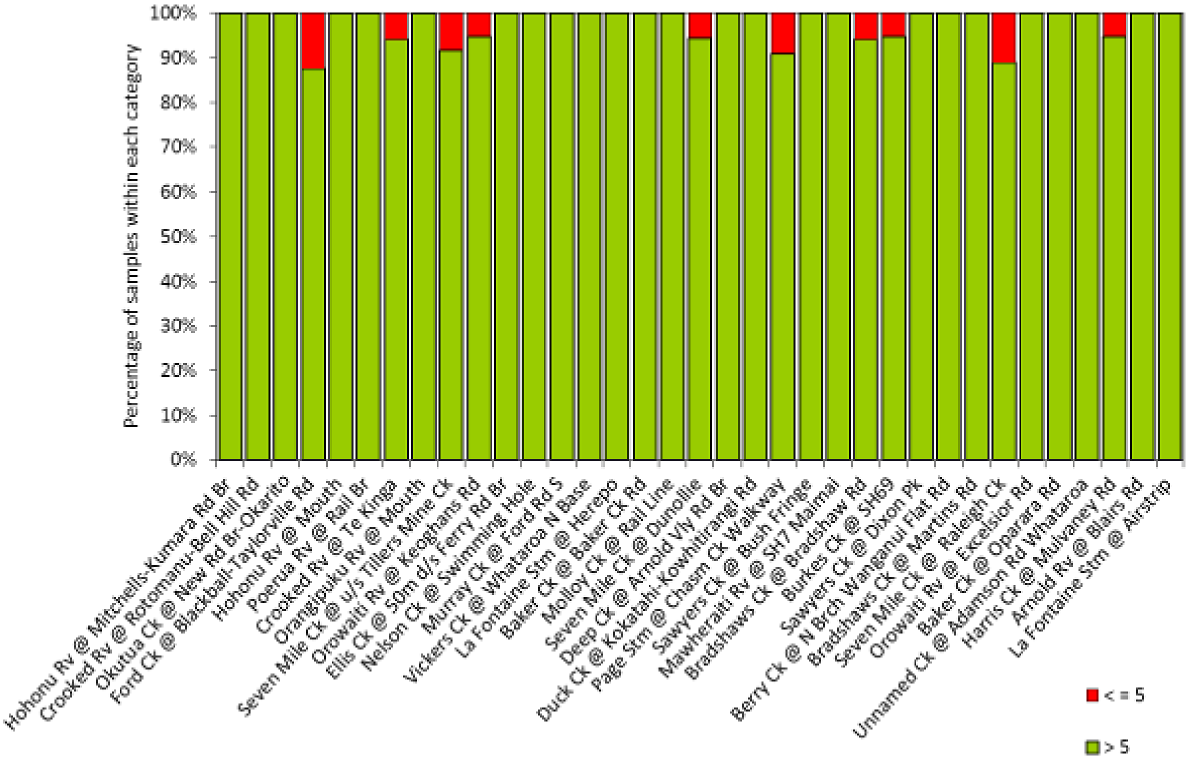


Figure 17 Percentage of samples with periphyton enrichment scores equal or less than 5, for individual Regional Council monitoring program sites. Note that lower enrichment scores indicate more periphyton and greater enrichment, which includes the sites moving to the right hand side.

2.3 Differences in water quality between paired upstream and downstream sites

Many sites that are part of the Regional Council monitoring program are located on the same waterway, within suitable proximity of each other to allow for upstream to downstream water quality comparisons. The difference between the upstream and downstream site was calculated by subtracting upstream from downstream, for same day measurements (Figure 50 to Figure 54). Analysis was conducted to determine whether the difference between sites increased over time (see 3.2.2).

Negative differences occur when the upstream value is higher than the lower. This is favorable for some attributes and not others. A negative difference for faecal coliforms means the upstream site had higher levels and water quality has improved downstream (we'd normally expect the faecal coliform difference to be positive downstream i.e. increasing). A negative clarity difference would indicate deterioration in downstream water quality.

There may be a trade-off between additions of a substance, say nitrate, and additions of water that provide dilution. Therefore loadings will increase, but concentrations may not. Reporting in this document is based primarily on concentrations.

It should be noted that most reference sites have, to varying degrees, current or historic anthropogenic influences upstream of them. Regional Council monitoring program reference sites have fewer potential sources of pollution upstream of them compared with their downstream partners.

Faecal coliforms levels were often lower downstream in Bradshaws Ck, but for most sites it was only on rare occasions that downstream levels were lower. Particle settling due to lower velocity, and tidal flushing, may assist in reducing faecal coliform levels at the lower Bradshaws site. Excluding Bradshaws Ck, faecal coliforms were consistently higher downstream, particularly in Sawyers and Baker Creeks (Figure 53).

Specific conductivity (referred to henceforth as conductivity) increased downstream in all streams except Sawyers Creek (Figure 52). Limestone contributes to high conductivity and pH in the headwaters, but in-stream processes and dilution from other sources reduce pH and conductivity downstream.

Ammoniacal nitrogen and dissolved reactive phosphorus increased downstream for all sites excluding Bradshaws Creek (Figure 50). While ammonia improved downstream at Bradshaws, median nitrate increased by 0.1 mg/L (Figure 51). The opposite was observed at Baker Creek, Seven Mile Creek and Orowaiti River: these sites had the smallest nitrate increases but the largest increases in ammonia.

Median turbidity and clarity deteriorated downstream except at Bradshaws Creek, but median turbidity increases were not large (Figure 52).

Unlike turbidity, clarity is reduced by coloured dissolved organic carbon (CDOM). The lower Crooked and Hohonu Rivers have higher CDOM, from natural sources, which will have a major impact on clarity (Figure 52). This is also true for the Orowaiti River, but increased suspended sediment, inferred from higher turbidity, is also likely to be a contributing factor.

Overall, periphyton increased downstream as indicated by median levels (a higher periphyton score indicates less periphyton)(Figure 53). Macroinvertebrate communities indicative of higher water quality occurred at upstream sites (Figure 53). Taxonomic richness - a measure of species diversity - increased downstream at some sites but the additional species were those more tolerant of pollution as indicated by a drop in pollution sensitive EPT taxa (Figure 54).

2.4 Suitability for contact recreation

This section discusses data collected at the Regional Council's contact recreation monitoring sites. These sites are located among a range of environments including: freshwater lakes and rivers, tidal and brackish estuaries and lagoons, and coastal beaches. Faecal coliforms and *E. coli* were measured at sites that have fresh or brackish waters, while Enterrococci was measured in marine environments. These are indicators of pathogen risk.

Current sites have been sampled twice monthly (10 times per season) since 2011. All sites currently have either Enterrococci (salt), or faecal coliforms and *E. coli* (fresh) measured.

The Ministry for the Environment (MfE 2003) provides guidelines for bathing suitability based on single samples of *E. coli* and Enterrococci. These categories are:

- Low Health Risk (<260 *E. coli*/100ml or <140 Enterococci/100ml);
- Moderate Risk, increased health risk but still within an acceptable range (260-550 *E. coli*/100ml or 140-280 Enterococci/100ml);
- High Risk, the water poses an unacceptable health risk (>550 *E. coli*/100ml or >280 Enterococci/100ml).

These criteria have been used to evaluate individual sites and the results for these are located in Section 5.8.

In the past coastal beach monitoring sites have proven cleaner than river counterparts. It has been found nationally that coastal beaches have better water quality than inland waters (MfE 2010), due to the increased dilution typically occurring in marine waters. During the 2011 - 2014 period 5 out of 7 coastal sites had results under 280 Enterococci/100 ml all the time. One notable exception was Hokitika Beach with two exceedances in 2012 – 2013, and five in 2013 – 2014 (Figure 59).

Lakes had the best water quality for swimming. Both Lake Mahinapua and Lake Brunner have had good swimming water quality. From 2011 – 2014 Lake Mahinapua was in the very low risk category (<260 cfu/100 ml) for 97% of the time (Figure 69). Since 2011, sites at Lake Brunner, including Iveagh Bay (Figure 67), Cashmere Bay (Figure 66), and Moana (Figure 68), have had results within the very low risk category (<260 cfu/100 ml) for 93%, 100%, and 97% of the time, respectively.

From 2011 to 2014, 2 out of 6 river sites (Kaniere Rv @ Kaniere – Kokatahi Rd and Nelson Ck @ Swimming Hole Reserve) had results less than 550 cfu/ *E. coli* for all sampling occasions. The Buller River (Figure 61 & Figure 62) and Seven Mile Ck (Figure 60) had several exceedances - these sites are below municipal sewerage systems discharges. There are other potential sources of *E. coli* including stormwater outlets, agricultural run-off, and aquatic birds. Although many sites had single high risk sample results in recent sampling seasons, the majority of these exceedances may result from run-off associated with recent rainfall.

3 Trends

Summary of surface water quality trends on the West Coast

Attributes important to aquatic ecosystems (turbidity, clarity, ammonia), and human health (*E. coli*) improved at many Council monitoring sites. These attributes are often typical of point source pollution and poor land management. A reduction in ammonia was also evident over the last 10 years at the NIWA monitoring sites.

Four out of five NIWA sites had deteriorating trends for turbidity, assumed to be driven by an increase in suspended material. NIWA sites are on much larger rivers than those monitored by Council. They encompass much larger catchments and a greater number of anthropogenic activities.

Nitrates have increased at many NIWA and Council sites indicating an intensification in agricultural land use. Several sites had improving attributes e.g. turbidity, and declining ones e.g. nitrate, at the same time. Aspects of macroinvertebrate community quality improved at Grey River @ Dobson.

3.1 Trends: NIWA sites

3.1.1 Water quality trends at NIWA sites

Trends were investigated for attributes measured at NIWA's National River Water Quality Network sites. These five sites have a large dataset highly suitable for individual analysis of trends. These five sites included two upstream/downstream pairs on the Buller and Grey Rivers. Buller @ Longford (Tasman District) and the Grey @ Waipuna are the upstream sites for these two rivers. Haast (at Roaring Billy) is a single site in the Haast catchment. The analysis determined either positive, negative, or no trends for all attributes at each site. We define a trend as 'important' if it had statistical significance i.e. $p < 0.05$, and has an annual rate of change of more than 1%. A 'slight' trend is defined as one where $p < 0.05$, but the annual rate of change is <1% of the median. Refer to Vant (2013) for a description of this rationale. Important trends are the main focus of following discussion. Any increases and decreases discussed in this section refer to important trends. Slight trends are specified as slight.

Table 4) and the other from 2004-2014 (Table 5). All results for these analyses are presented in Table 19 and

Table 20.

Over the last 25 years clarity improved at Buller River @ Longford and the Grey River @ Waipuna. Clarity is affected by coloured dissolved substances as well as suspended material. The main coloured substance in West Coast rivers is CDOM (coloured dissolved organic matter), which is monitored by measuring absorption (g340). There have been no trends in g340. For the last 10 years there was no trend in clarity at any site.

Turbidity increased in the Haast River from 1989 (25 years), with no other sites displaying turbidity trends over this time period. In the last ten year period Haast River, the Grey River sites, and the Buller River @ Te Kuha had increasing turbidity.

Ammonia is a form of nitrogen associated with raw effluent and anaerobic decomposition. It is toxic in high concentrations but quickly oxidises to nitrate in a normal stream environment. Over the last 25 years ammonia decreased (improved) at all NIWA sites. An improving trend in ammonia remained for Buller River @ Longford, over the last 10 years.

Since 1989 nitrate increased at Buller River @ Te Kuha and Grey River @ Dobson. This continued to be the case from 2004 onward, also including Buller River @ Longford. From 1989 onward total nitrogen increased at all sites except the Haast River.

Phosphorus levels are determined by measurement of DRP and TP. There were no changes in TP levels over the long term but Buller River @ Te Kuha increased from 2004 onward.

Over 25 years DRP increased in the Grey River @ Dobson, with slight increases at Buller River @ Longford and Haast River. DRP increased in the last ten years for all but Grey River @ Dobson.

From 2004 onward *E. coli* improved at Grey River @ Waipuna and Haast River. *E. coli* was very low at Haast River (median 2 cfu/100 ml), therefore only a small change, relative to other sites, is required to generate an important trend.

Table 4 Summary of Seasonal Kendall trend test for **25 years** of data collected at West Coast NIWA water quality sites. Important trends are in red (undesirable) and blue (good). Slight trends are in pink (undesirable) and light blue (good). PAC = percent annual change of the median.

Variable	Site	Samples	Median	P	PAC
Clarity	**Buller at Longford**	304	3.705	0	2.0
Clarity	**Grey at Waipuna**	303	3.2	0.001	1.0
Clarity	Grey at Dobson	300	1.69	0.002	0.9
Conductivity (uS/cm)	Buller at Te Kuha	305	66.5	0	0.2
Conductivity (uS/cm)	Buller at Longford	305	56	0	0.2
Conductivity (uS/cm)	Grey at Dobson	305	56.4	0	0.3
Conductivity (uS/cm)	Grey at Waipuna	305	52.5	0	0.4
DRP (µg/L)	Buller at Longford	304	1	0	0.8
DRP (µg/L)	**Grey at Dobson**	302	2	0.001	1.1
DRP (µg/L)	Haast at Roaring Billy	299	1	0.033	0.4
Ammonia-N (µg/L)	**Haast at Roaring Billy**	287	2	0	-7.4
Ammonia-N (µg/L)	**Buller at Longford**	291	3	0	-4.8
Ammonia-N (µg/L)	**Buller at Te Kuha**	291	4	0	-4.3
Ammonia-N (µg/L)	**Grey at Waipuna**	290	4	0	-3.6
Ammonia-N (µg/L)	**Grey at Dobson**	291	6	0	-1.3
Nitrate-N (µg/L)	**Grey at Waipuna**	302	27	0	3.1
Nitrate-N (µg/L)	**Buller at Te Kuha**	303	48	0	3.9
Nitrate-N (µg/L)	**Grey at Dobson**	303	88	0	4.5
Total nitrogen (µg/L)	**Haast at Roaring Billy**	285	56	0	-1.1
Total nitrogen (µg/L)	**Buller at Longford**	291	84	0	1.2
Total nitrogen (µg/L)	**Grey at Waipuna**	290	103	0	1.5
Total nitrogen (µg/L)	**Buller at Te Kuha**	291	143	0	1.7
Total nitrogen (µg/L)	**Grey at Dobson**	289	206	0	2.6
Turbidity (NTU)	**Haast at Roaring Billy**	299	1.5	0.044	1.4

Table 5 Summary of Seasonal Kendall trend test for **10 years** of data collected at West Coast NIWA water quality sites. Important trends are in red (undesirable) and blue (good). Slight trends are in pink (undesirable) and light blue (good). PAC = percent annual change of the median.

Variable	Site	Samples	Median	P	PAC
Conductivity (uS/cm)	Grey at Dobson	119	58.3	0	0.91
Conductivity (uS/cm)	Haast at Roaring Billy	121	82.9	0	1
Conductivity (uS/cm)	Buller at Te Kuha	119	68.9	0.003	0.52
DRP (µg/L)	**Grey at Waipuna**	119	2	0	4.97
DRP (µg/L)	**Buller at Te Kuha**	119	2	0.002	2.74
DRP (µg/L)	**Haast at Roaring Billy**	121	1	0.031	1.74
DRP (µg/L)	**Buller at Longford**	114	1	0.038	2.95
E. coli (MPN/100 ml)	**Grey at Waipuna**	112	8.6	0.041	-8.5
E. coli (MPN/100 ml)	**Haast at Roaring Billy**	113	2	0.044	-11
Ammonia-N (µg/L)	**Buller at Longford**	114	2	0.003	3.46
Nitrate-N (µg/L)	**Grey at Dobson**	119	125	0	6.04
Nitrate-N (µg/L)	**Buller at Te Kuha**	119	66	0	7.07
Nitrate-N (µg/L)	**Buller at Longford**	114	28	0.001	6.81
Total nitrogen (µg/L)	**Grey at Dobson**	118	244.5	0	2.31
Total nitrogen (µg/L)	**Haast at Roaring Billy**	120	50.5	0.018	-1.7
Total nitrogen (µg/L)	**Buller at Longford**	114	94.5	0.038	2.05
Total phosphorus (µg/L) (µg/L)	**Buller at Te Kuha**	118	7.5	0.042	2.84
Turbidity (NTU)	**Buller at Te Kuha**	119	1.48	0	9.27
Turbidity (NTU)	**Grey at Waipuna**	119	0.76	0	10.8
Turbidity (NTU)	**Grey at Dobson**	119	1.69	0.002	6.96
Turbidity (NTU)	**Haast at Roaring Billy**	121	1.3	0.021	5.77

3.1.2 Algae and macroinvertebrate trends at NIWA sites

Every month at each NIWA site the percentage of riverbed (0.5 m^2) covered with filamentous algae and algal mats is assessed. Ten replicates are assessed for both. Trends have been assessed from 1990 to 2014, and 2004 to 2014.

Low algal cover is frequent at all sites so median cover is low (Table *6*). Trend analysis detected many significant trends but the rate of change proportional to the median was so small that it was difficult to determine whether the changes were important. One important trend was detected for the Grey River @ Dobson, where filamentous cover decreased in the last ten years (Table *6*).

Visual inspection of algal cover data from 1989 to 2014, in the form of box plots, is also informative for evaluating cover over time and between seasons. Despite overall low algal cover, moderate levels did occur periodically. This differed between years and seasons.

Filamentous algal cover was rarely above 5% at Buller River @ Longford and Haast River @ Roaring Billy (Figure 71). Filamentous algae was highest in summer and autumn at Buller River @ Te Kuha and Grey River @ Waipuna, but consistent across seasons at Grey River @ Dobson (Figure 71). No distinct pattern in filamentous algal cover is discernable over time at any site, with some years having greater cover than others (Figure 70).

Formation of algal mats was also more common in summer/autumn. This seasonal pattern was strongest for Buller River @ Longford (Figure 73). Algal mat cover varied between years (Figure 72). It does appear that algal mat cover increased substantially from 2003 onward in the Buller River, particularly at Buller River @ Longford (Figure 72).

The New Zealand Periphyton Guidelines (Biggs 2000) suggest a threshold of <30% cover of long filamentous algae to preserve aesthetic value and ecology. These same guidelines suggest a threshold of <60% cover of algae mats over 3 mm in thickness to preserve aesthetic value. Over the 25 years of algal cover assessment at these NIWA sites, levels of cover over 30% did not occur for filamentous algae. Algal mats over 60% were not common, the most frequent occurrence being at Buller River @ Longford (Table 7). Algal mats over 60% were more common from 2004 to 2014, particularly for Buller River @ Longford (Table 7). While not high, nutrients that promote algal growth have increased in the last ten years. Another possibility for increased cover of algal mats in the Buller River is the invasive algae Didymosphenia germinata (Didymo).

Three NIWA sites showed trends in certain macroinvertebrate attributes from 1990 to 2014. Macroinvertebrate community quality decreased for Buller River @ Longford, as indicated by a reduction in the proportion of pollution sensitive macroinvertebrate species. Grey River @ Dobson macroinvertebrate communities improved with a greater number of pollution sensitive species and diversity.

The Haast River @ Roaring Billy declined in terms of the proportion of pollution sensitive macroinvertebrate species, but improved in overall diversity. The proportion of catchment in the Haast River that is affected by human activity is minimal, therefore it seems unlikely that urban or agricultural land use is responsible for this change. Didymo is another possibility but there has been no measurable change in algal cover at this site (Table 7).

Table 6 Seasonal Kendall trend analysis on median percentage periphyton cover over time. NIWA sites 1990 to 2014 & 2004 to 2014. Important trends are in red (undesirable) and blue (good). PAC = percent annual change of the median.

Attribute	**Site**	**Samples**	**10 years**	**Median**	**P**	**PAC**
Filamentous cover	Buller at Longford	107	11/2/04-14/5/14	<0.001	0.359	<0.001
Filamentous cover	Buller at Te Kuha	89	9/3/04-14/6/14	<0.001	0.001	<0.001
Filamentous cover	**Grey at Dobson**	81	9/3/04-13/5/14	2.200	0.019	-10.830
Filamentous cover	Grey at Waipuna	109	11/2/04-10/6/14	<0.001	0.589	<0.001
Filamentous cover	Haast at Roaring Billy	114	25/2/04-18/6/14	<0.001	0.521	<0.001
Mat cover	Buller at Longford	107	11/2/04-14/5/14	2.500	0.156	<0.001
Mat cover	Buller at Te Kuha	87	9/3/04-14/6/14	<0.001	0.074	<0.001
Mat cover	Grey at Dobson	81	9/3/04-13/5/14	<0.001	0.319	<0.001
Mat cover	Grey at Waipuna	109	11/2/04-10/6/14	<0.001	0.227	<0.001
Mat cover	Haast at Roaring Billy	113	25/2/04-18/6/14	<0.001	0.228	<0.001
Attribute	**Site**	**Samples**	**25 years**	**Median**	**P**	**PAC**
Filamentous cover	Buller at Longford	252	26/4/89-14/5/14	<0.001	0.002	<0.001
Filamentous cover	Buller at Te Kuha	199	15/8/89-14/6/14	<0.001	0.362	<0.001
Filamentous cover	Grey at Dobson	197	15/8/89-13/5/14	1.5	0.375	<0.001
Filamentous cover	Grey at Waipuna	249	15/8/89-10/6/14	<0.001	0.085	<0.001
Filamentous cover	Haast at Roaring Billy	230	4/5/89-18/6/14	<0.001	0.038	<0.001
Mat cover	Buller at Longford	252	26/4/89-14/5/14	<0.001	<0.001	<0.001
Mat cover	Buller at Te Kuha	196	15/8/89-14/6/14	<0.001	0.007	<0.001
Mat cover	Grey at Dobson	195	15/8/89-13/5/14	<0.001	<0.001	<0.001
Mat cover	Grey at Waipuna	249	15/8/89-10/6/14	<0.001	<0.001	<0.001
Mat cover	Haast at Roaring Billy	227	4/5/89-18/6/14	<0.001	<0.001	<0.001

Table 7 Percentage of samples at NIWA sites that have more than 30% algal cover.

25 years	**Percent samples >30% filamentous algal cover**	**Percent samples >60% algal mat cover**
Buller Rv @ Longford	0.8	2.3
Buller Rv @ Te Kuha	0.0	1.6
Grey Rv @ Dobson	4.6	1.0
Grey Rv @ Waipuna	1.6	0.0
Haast River @ Roaring Billy	0.9	0.4
10 years		
Buller Rv @ Longford	0.9	5.6
Buller Rv @ Te Kuha	0.0	3.4
Grey Rv @ Dobson	2.4	2.4
Grey Rv @ Waipuna	0.9	0.0
Haast River @ Roaring Billy	0.9	0.9

Table 8 Seasonal Kendall trend analysis for NIWA macroinvertebrate data 1990 – 2014. Important trends are in red (undesirable) and blue (good). Slight trends are in pink (undesirable) and light blue (good). PAC = percent annual change of the median.

Attribute	**Site**	**Samples**	**Sampling period**	**Median**	**P**	**PAC**
MCI	Buller Rv @ Longford	24	22/3/90-13/2/13	123.675	0.002	-0.611
%EPT	**Buller Rv @ Longford**	24	22/3/90-13/2/13	67.521	0.04	-2.591
QMCI	**Buller Rv @ Longford**	24	22/3/90-13/2/13	5.333	0.04	-1.225
EPT taxa richness	**Grey Rv @ Dobson**	23	28/3/90-27/3/14	13	0.018	1.532
Taxa richness	**Grey Rv @ Dobson**	23	28/3/90-27/3/14	24	0.035	1.315
%EPT	**Haast Rv @ Roaring Billy**	21	20/3/91-17/2/14	62.563	0.01	-2.738
QMCI	**Haast Rv @ Roaring Billy**	21	20/3/91-17/2/14	5.986	0.017	-1.507
Taxa richness	**Haast Rv @ Roaring Billy**	21	20/3/91-17/2/14	11	0.02	1.986

3.2 Long-term trends: Regional Council sites

3.2.1 Trends in water quality attributes: individual sites

Statistically significant trends were only reported if there was a minimum of twenty samples in the analysis. Most sites had this many samples so trend analysis was possible for the majority of attributes at most sites. A summary of trend analyses for WCRC sites is presented in Table 9, with a full description of all WCRC site trend analyses in Table 21. A graphical summary is presented in Figure 18 and Figure 19. These figures include all NIWA sites and WCRC sites, combined.

Conductivity indicates the concentration of dissolved (ionic) solids in solution that have the ability to carry an electric current. Many substances can contribute to conductivity, often which are harmless, so conductivity is not a contaminant per se. Increases in conductivity within a catchment over time are often attributed to human influence. These might be associated with land intensification and discharges. Over the last ten years conductivity increased at approximately 40% of sites.

Nitrate has deteriorated at a quarter of sites yet ammonia has improved at even more (40%). Intensified land use, in particular agriculture, is a likely source of nitrate. If these same factors are managed more carefully (e.g. improving point source discharges), they can also lead to lower ammonia. Ammonia is often associated with poorly treated discharges of organic waste.

Better management of land and point source discharges high in suspended material may have led to better clarity and turbidity (20% and 40% of sites improved, respectively).

Fewer sites (<10%) had trends for phosphorus (DRP and TP), or *E. coli*. Of the trends for these attributes, some were improving and some declining.

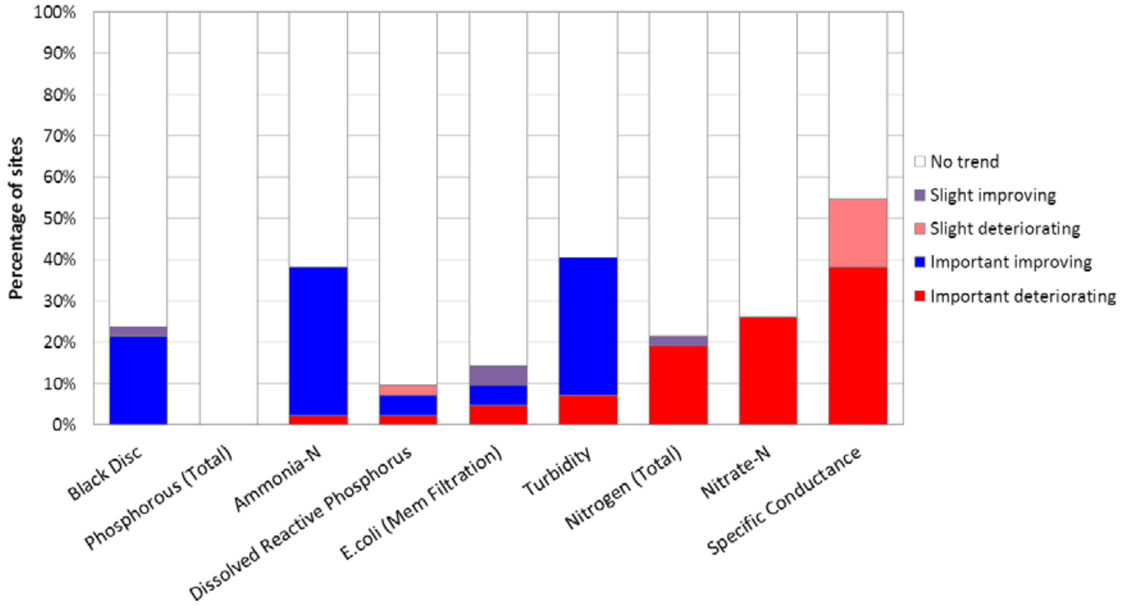


Figure 18 Proportion of sites that have important and slight trends, from 2004 to 2014.

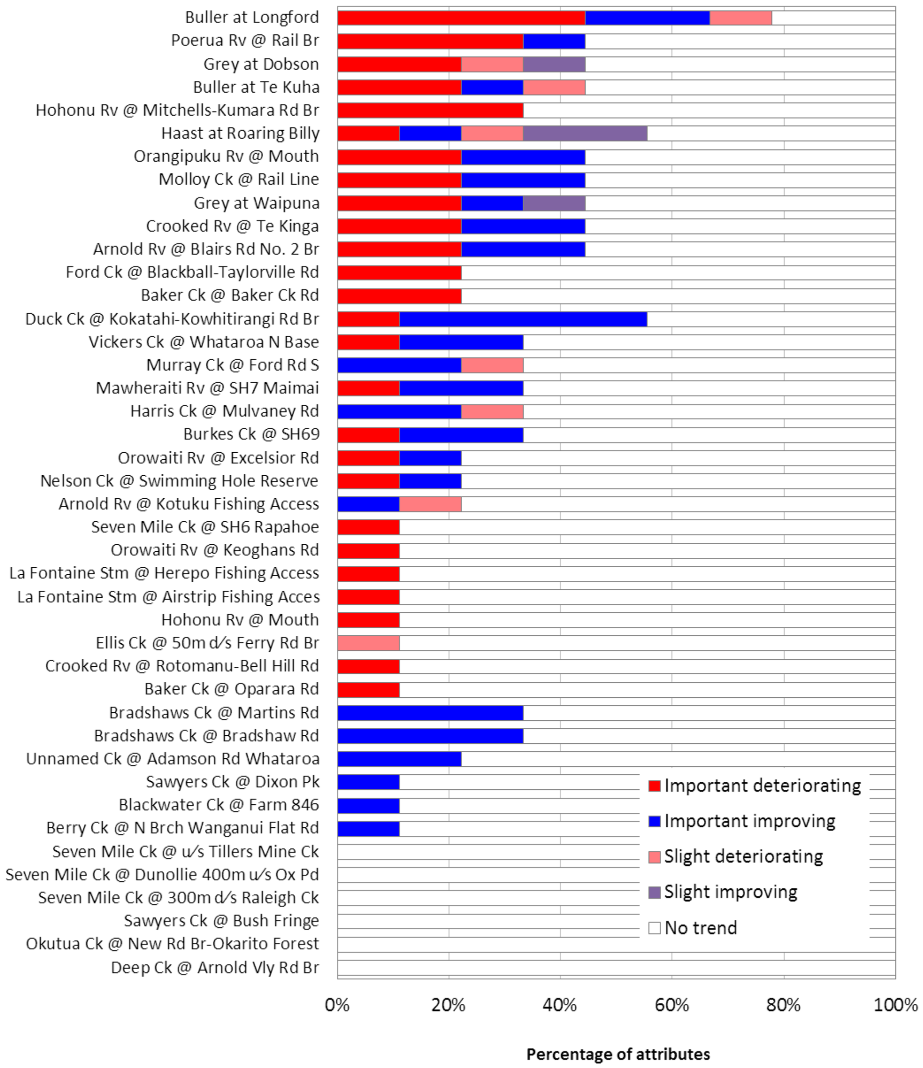


Figure 19 Proportion of trends per site from 2004 to 2014.

3.2.2 Trends in water quality attributes: differences between paired sites

There were not many important trends for changes between reference and impact sites over time. The difference in ammonia between Orowaiti River sites decreased over time, driven by improvement at the lower site (Table 21). Clarity has improved at both sites in Bradshaws Creek (Table 22), but more so at the lower site. This indicates that impacts on water clarity occurring between sites have lessened.

There have been many trends observed for individual paired sites. It might be assumed that the downstream site is more likely to change due to more influence from anthropogenic activity. If the difference between paired sites doesn't change over time it might suggest that both sites within a pair are changing simultaneously. Non-anthropogenic influences like climate are a possible driver of change within a catchment. However, few of the upstream sites could be considered pristine. The Hohonu River @ Mitchells-Kumara Rd Br would be the only site in this category. The next best would be the Crooked River @ Rotomanu-Bell Hill Rd, and Sawyers Creek @ Bush Fringe, which have some low intensity grazing upstream. A higher proportion of low intensity grazing occurs upstream of Baker Creek @ Baker Ck Rd, and urban and/or agricultural activity occurs upstream at the remain of reference sites.

Table 9 Summary of Seasonal Kendall trend test for 10 years of data collected at West Coast Regional Council water quality sites. The data period is from January 2004 to May 2014. Important trends are in red (undesirable) and blue (good). Slight trends are in pink (undesirable) and light blue (good). PAC = percent annual. DRP=Dissolved reactive phosphorus, EC25=specific conductivity.

Variable	Site	Samples	Sampling period	Median	P	PAC
Ammonia-N (mg/L)	Orowaiti Rv @ Excelsior Rd	40	6/7/04-11/4/14	0.042	0.000	-8.5
Ammonia-N (mg/L)	Duck Ck @ Kokatahi-Kowhitirangi Rd Br	40	8/7/04-7/4/14	0.007	0.000	-11.9
Ammonia-N (mg/L)	Berry Ck @ N Brch Wanganui Flat Rd	38	15/10/04-14/5/14	0.010	0.000	-27.5
Ammonia-N (mg/L)	Ford Ck @ Blackball-Taylorville Rd	31	6/1/05-13/5/14	0.039	0.001	5.2
Ammonia-N (mg/L)	Poerua Rv @ Rail Br	48	7/7/04-29/4/14	0.013	0.006	-10.2
Ammonia-N (mg/L)	Harris Ck @ Mulvaney Rd	40	8/7/04-7/4/14	0.014	0.006	-11.1
Ammonia-N (mg/L)	Molloy Ck @ Rail Line	39	7/7/04-3/4/14	0.006	0.007	-7.2
Ammonia-N (mg/L)	Crooked Rv @ Te Kinga	43	7/7/04-30/4/14	0.008	0.008	-5.7
Ammonia-N (mg/L)	Burkes Ck @ SH69	41	5/7/04-13/5/14	0.014	0.008	-11.3
Ammonia-N (mg/L)	Orangipuku Rv @ Mouth	45	15/9/04-30/4/14	0.015	0.010	-6.7
Ammonia-N (mg/L)	Murray Ck @ Ford Rd S	40	8/7/04-7/4/14	0.015	0.011	-8.2
Ammonia-N (mg/L)	Bradshaws Ck @ Bradshaw Rd	39	8/10/04-11/4/14	0.052	0.017	-9.6
Ammonia-N (mg/L)	Bradshaws Ck @ Martins Rd	38	7/1/05-11/4/14	0.025	0.023	-8.2
Black Disc (m)	Bradshaws Ck @ Martins Rd	36	6/7/04-11/4/14	1.245	0.001	9.0
Black Disc (m)	Arnold Rv @ Blairs Rd No. 2 Br	57	11/10/04-29/4/14	3.500	0.002	4.4
Black Disc (m)	Arnold Rv @ Kotuku Fishing Access	62	7/7/04-29/4/14	4.175	0.009	3.3
Black Disc (m)	Bradshaws Ck @ Bradshaw Rd	38	6/7/04-11/4/14	1.030	0.011	4.7
Black Disc (m)	Duck Ck @ Kokatahi-Kowhitirangi Rd Br	40	8/7/04-7/4/14	7.560	0.011	3.5
Black Disc (m)	Unnamed Ck @ Adamson Rd Whataroa	40	9/7/04-14/5/14	3.950	0.044	4.6
Black Disc (m)	Mawheraiti Rv @ SH7 Maimai	40	5/7/04-13/5/14	3.025	0.044	2.8
DRP (mg/L)	Crooked Rv @ Te Kinga	41	7/7/04-30/4/14	0.004	0.013	-4.4
DRP (mg/L)	Duck Ck @ Kokatahi-Kowhitirangi Rd Br	22	8/4/08-7/4/14	0.005	0.015	-7.3
E.coli /100 ml	Vickers Ck @ Whataroa N Base	39	9/7/04-14/5/14	100.000	0.012	-11.0
E.coli /100 ml	Hohonu Rv @ Mitchells-Kumara Rd Br	38	18/2/08-30/4/14	5.000	0.016	19.0
E.coli /100 ml	Arnold Rv @ Blairs Rd No. 2 Br	71	7/7/04-29/4/14	40.000	0.018	-16.2
E.coli /100 ml	Baker Ck @ Baker Ck Rd	31	18/7/06-10/4/14	40.000	0.033	18.5
Nitrate-N (mg/L)	Arnold Rv @ Blairs Rd No. 2 Br	40	7/7/04-29/4/14	0.115	0.000	5.3
Nitrate-N (mg/L)	Molloy Ck @ Rail Line	24	5/4/05-3/4/14	0.380	0.001	5.4
Nitrate-N (mg/L)	Poerua Rv @ Rail Br	46	23/5/05-29/4/14	0.151	0.001	4.9
Nitrate-N (mg/L)	Orangipuku Rv @ Mouth	45	15/9/04-30/4/14	0.350	0.001	4.0
Nitrate-N (mg/L)	Duck Ck @ Kokatahi-Kowhitirangi Rd Br	22	8/4/08-7/4/14	0.835	0.027	4.1
Nitrate-N (mg/L)	Hohonu Rv @ Mouth	35	28/8/08-30/4/14	0.039	0.043	8.3
Nitrate-N (mg/L)	Crooked Rv @ Te Kinga	40	7/7/04-30/4/14	0.116	0.046	2.7
Total nitrogen (mg/L)	Molloy Ck @ Rail Line	23	5/4/05-3/4/14	0.450	0.008	4.6
Total nitrogen (mg/L)	Vickers Ck @ Whataroa N Base	22	9/4/08-14/5/14	0.470	0.024	4.4
Total nitrogen (mg/L)	Orangipuku Rv @ Mouth	44	15/9/04-30/4/14	0.420	0.027	2.9
Total nitrogen (mg/L)	Poerua Rv @ Rail Br	46	23/5/05-29/4/14	0.260	0.038	1.7

Table 9 Summary of Seasonal Kendall trend test for 10 years of data collected at West Coast Regional Council water quality sites. The data period is from January 2004 to May 2014. Important trends are in red (undesirable) and blue (good). Slight trends are in pink (undesirable) and light blue (good). PAC = percent annual. DRP=Dissolved reactive phosphorus, EC25=specific conductivity.

Variable	Site	Samples	Sampling period	Median	P	PAC
EC25 (uS/cm)	**Ford Ck @ Blackball-Taylorville Rd**	39	5/7/04-13/5/14	200.000	0.000	2.6
EC25 (uS/cm)	**Hohonu Rv @ Mitchells-Kumara Rd Br**	37	18/2/08-30/4/14	49.000	0.000	2.3
EC25 (uS/cm)	**Burkes Ck @ SH69**	40	5/7/04-13/5/14	94.000	0.000	2.1
EC25 (uS/cm)	**Nelson Ck @ Swimming Hole Reserve**	45	5/7/04-13/5/14	45.000	0.000	2.1
EC25 (uS/cm)	**Crooked Rv @ Te Kinga**	54	7/7/04-30/4/14	64.000	0.000	1.7
EC25 (uS/cm)	**La Fontaine Stm @ Herepo Fishing Access**	40	9/7/04-14/5/14	123.500	0.001	1.1
EC25 (uS/cm)	**Orowaiti Rv @ Excelsior Rd**	39	8/10/04-11/4/14	72.000	0.002	2.1
EC25 (uS/cm)	**Mawheraiti Rv @ SH7 Maimai**	40	5/7/04-13/5/14	35.000	0.003	2.0
EC25 (uS/cm)	**La Fontaine Stm @ Airstrip Fishing Access**	36	9/7/04-14/5/14	127.000	0.003	1.7
EC25 (uS/cm)	**Orowaiti Rv @ Keoghans Rd**	40	6/7/04-11/4/14	67.500	0.006	1.3
EC25 (uS/cm)	**Crooked Rv @ Rotomanu-Bell Hill Rd**	51	7/7/04-30/4/14	60.000	0.008	1.2
EC25 (uS/cm)	**Baker Ck @ Baker Ck Rd**	33	18/7/06-10/4/14	91.000	0.011	3.5
EC25 (uS/cm)	Ellis Ck @ 50m d/s Ferry Rd Br	38	9/7/04-14/5/14	111.000	0.014	0.8
EC25 (uS/cm)	**Arnold Rv @ Blairs Rd No. 2 Br**	53	11/10/04-29/4/14	57.000	0.019	2.3
EC25 (uS/cm)	**Baker Ck @ Oparara Rd**	33	18/7/06-10/4/14	92.000	0.025	1.7
EC25 (uS/cm)	Arnold Rv @ Kotuku Fishing Access	55	7/7/04-29/4/14	49.000	0.030	0.7
EC25 (uS/cm)	Harris Ck @ Mulvaney Rd	40	8/7/04-7/4/14	98.500	0.036	0.7
EC25 (uS/cm)	Murray Ck @ Ford Rd S	40	8/7/04-7/4/14	100.000	0.036	0.6
EC25 (uS/cm)	**Poerua Rv @ Rail Br**	51	7/7/04-29/4/14	73.000	0.040	1.1
EC25 (uS/cm)	**Seven Mile Ck @ SH6 Rapahoe**	39	12/7/04-22/5/14	180.000	0.047	6.1
Turbidity (NTU)	**Bradshaws Ck @ Bradshaw Rd**	40	8/10/04-11/4/14	4.750	0.000	-7.7
Turbidity (NTU)	**Mawheraiti Rv @ SH7 Maimai**	39	5/7/04-13/5/14	0.500	0.000	-35.4
Turbidity (NTU)	**Harris Ck @ Mulvaney Rd**	39	8/7/04-7/4/14	0.600	0.000	-50.0
Turbidity (NTU)	**Murray Ck @ Ford Rd S**	39	8/7/04-7/4/14	0.200	0.000	-97.8
Turbidity (NTU)	**Duck Ck @ Kokatahi-Kowhitirangi Rd Br**	40	8/7/04-7/4/14	0.100	0.001	-148.3
Turbidity (NTU)	**Bradshaws Ck @ Martins Rd**	40	6/7/04-11/4/14	3.550	0.003	-10.5
Turbidity (NTU)	**Nelson Ck @ Swimming Hole Reserve**	39	5/7/04-13/5/14	0.600	0.003	-25.8
Turbidity (NTU)	**Orangipuku Rv @ Mouth**	46	15/9/04-30/4/14	0.100	0.007	-64.3
Turbidity (NTU)	**Molloy Ck @ Rail Line**	40	7/7/04-3/4/14	0.250	0.007	-73.0
Turbidity (NTU)	**Sawyers Ck @ Dixon Pk**	40	8/7/04-30/5/14	3.400	0.014	-8.1
Turbidity (NTU)	**Blackwater Ck @ Farm 846**	33	18/7/06-10/4/14	19.900	0.025	-11.5
Turbidity (NTU)	**Burkes Ck @ SH69**	40	5/7/04-13/5/14	4.250	0.028	-6.6
Turbidity (NTU)	**Unnamed Ck @ Adamson Rd Whataroa**	39	15/10/04-14/5/14	0.800	0.033	-25.3
Turbidity (NTU)	**Vickers Ck @ Whataroa N Base**	40	9/7/04-14/5/14	0.300	0.036	-24.6
Turbidity (NTU)	**Hohonu Rv @ Mitchells-Kumara Rd Br**	38	18/2/08-30/4/14	0.100	0.000	30.6

4 Lake Brunner water quality

Lake Brunner water quality summary

Lake Brunner is a large (41 km^2), deep lake (max. depth 109 m), inland from Greymouth on the West Coast. The lake currently remains in an oligotrophic (low nutrient) state, safe for swimming and other recreational activities.

In the past when data from the entire record (1992-2014) has been analysed, there have been important deteriorating trends for a number of parameters.

From 2001 onward, only nitrate and total nitrogen were increasing. An increase in total nitrogen was driven by increasing nitrate. Nitrate levels have also increased in the tributaries. Increasing nitrate is most likely a result of agricultural activity. Nitrogen is high in proportion to other attributes like phosphorus and chlorophyll a. Dissolved nitrogen is easily leached and nitrogen from all sources is likely to leach in abundance given the catchments wet climate.

Lake Brunner is phosphorus limited. An increase in nitrate is unlikely to affect lake biology without an accompanying increase in phosphorus.

Cashmere Bay water quality is poorer than that in the open lake due to a different suite of physical features. Nitrate has increased but clarity has improved. Despite increasingly long periods of low oxygen at the bottom, phosphorus and subsequent plankton proliferations were not observed.

4.1 Lake processes

Lake Brunner is oligotrophic (low nutrient) and algal productivity is very strongly limited by the availability of phosphorus, throughout the year, as indicated by nutrient (molar) ratios of nitrogen and phosphorus. The average total nitrogen to total phosphorus ratio is approximately 69:1, with the ratio of nitrate to dissolved reactive phosphorus much higher (~200:1). The Redfield ratio of 16:1 is considered the approximate ratio required by lake phytoplankton and plants, so phytoplankton growth is clearly limited by the amount of phosphorus. Dissolved reactive phosphorus (DRP) is almost absent as it is consumed immediately when it becomes available. There has been no apparent change in the level of phosphorus limitation since 1992. The lake retains 50 to 55% of phosphorus transported from the catchment by burial in the sediment, and 30% of nitrogen is retained by burial or removed by denitrification.

The lake has a long residence time (1.14 years) which enhances the retention of nutrients by the lake. Because of an enhanced capacity for nutrient storage by burial in the sediment, lakes with long residence times are less sensitive to phosphorus loading and are more resilient than lakes that are flushed faster. But, this is on the condition that primary productivity does not exceed a level that could result in anoxia (no oxygen) at the sediment/water interface, on the bottom of the lake. This happens when enough organic matter decomposes at the bottom of the lake, which uses up all the oxygen. With no oxygen, different chemical and biological processes occur, and phosphorus stored in the sediment can be released. This then adds to the phosphorus already coming from tributaries. More phosphorus increases algal growth, leading to more decomposing organic matter, causing less oxygen etc. Thus begins a vicious cycle which is very hard to stop, and lake water quality deteriorates.

4.1.1 Central lake

Central lake monitoring represents the overall health of Lake Brunner. Council monitor's vertical oxygen and temperature profiles monthly throughout the year. Currently, oxygen at the bottom of the lake stays high enough to avoid undesirable cycles of phosphorus release from the lake bed. When phosphorus inputs are contrasted against anticipated outputs, no obvious phosphorus recycling is apparent. This is also supported through an absence of surface phosphorus increases in winter, when deep water that has been trapped at the bottom of the lake over summer by a warm surface layer is able to be mixed once the surface cools. When this warm surface layer forms a barrier to mixing the lake is said to be stratified. Oxygen levels at the bottom of the lake are usually lowest in June, which is consistent most years. Temperature stratification was gone by July 2014 and oxygenated water from the surface reached deeper waters.

The bottom section of the lake during stratification is called the hypolimnion and oxygen can't reach the hypolimnion from the epilimnion when the lake is stratified. In the last six years dissolved oxygen in the hypolimnion has reached lower levels compared with levels in the 1990's (Figure 20). However, oxygen levels are currently still well above what would cause nutrient release from the sediments.

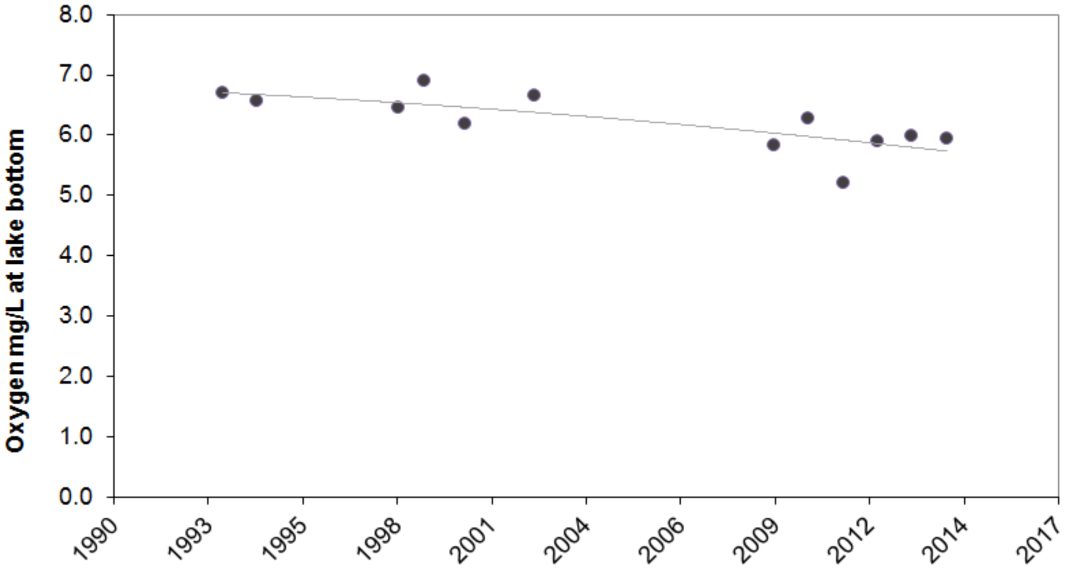


Figure 20 Minimum dissolved oxygen levels measured in autumn/winter prior to mixing. All measurements are from the lake bottom at ~ 100 m depth, central Lake Brunner.

Hypolimnetic oxygen troughs and depletion rates have varied between years with oxygen depletion strongest nearest the lake bottom (Figure 21). Different climatic regimes are likely to have some influence on this. An increase in hypolimnetic oxygen consumption at the lake bed, from 1992-2014, is a sign that eutrophication has increased. This was supported by increasing total phosphorus and total nitrogen concentrations, over this time period (Table 10). However, the trends in oxygen depletion rates were not significant at any depth during either 1998-2014, or 1992-2014.

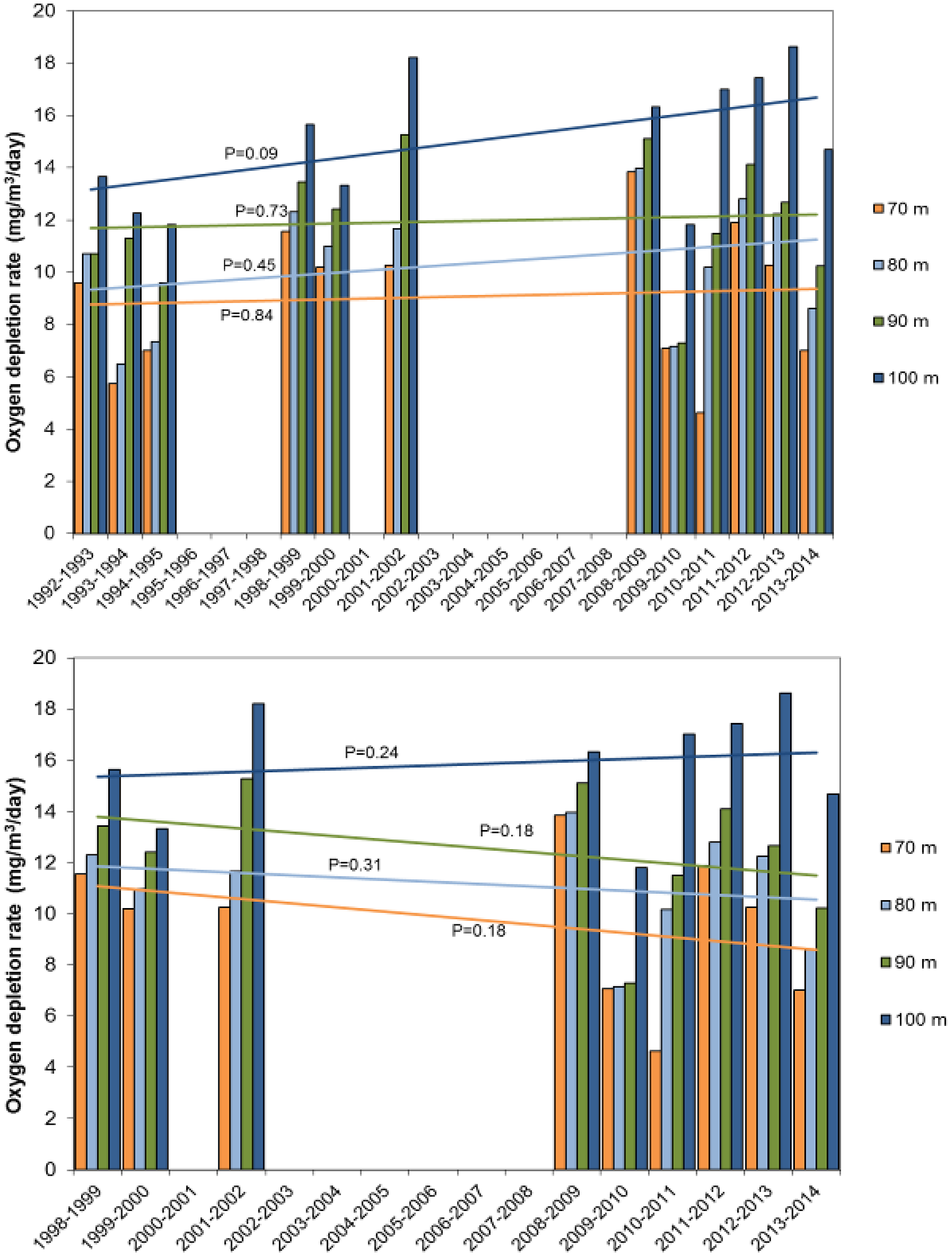


Figure 21 Hypolimnetic oxygen depletion rates in Lake Brunner 1992 to 2014, and 1998 to 2014. The P values represent the level of significance of the trend in depletion rates over time, as determined by the Mann-Kendall trend test.

As data are continually collected, water quality trends can be re-assessed. Trends have been evaluated using the “Seasonal Kendall trend test” and “Seasonal Kendall slope estimator” (SKSE) in Time Trends v5.0. The SKSE measures the magnitude of the trend and can be used to determine the rate of change. The seasonal Kendall trend test determines whether the trend is statistically significant. Statistically significant trends where the rate of change is larger than ± 1% per year are described as being “important”, while those where the rate of change is smaller than this are described as being “slight” (Vant 2013).

Earlier analysis incorporating the data record from 1992 indicated that chlorophyll a (a measure of algal biomass) and nutrient concentrations had increased, and Secchi depth (a vertical measure of water clarity) had decreased. This suggested that agricultural intensification led to a deterioration in lake water quality over this period. Important trends, using the present updated data record, remained for total nitrogen (TN), nitrate, and DRP (Table 10). A slight trend was apparent for the TLI. The TLI incorporates TN, total phosphorus (TP), clarity (vertical Secchi), and chlorophyll a levels, to form one score indicative of a lakes overall nutrient status (Burns et al. 2000).

Over a shorter time period (2001-2014), the trend in TN and nitrate remained important (Table 1, Figure 4a). However, TLI and DRP showed no significant change from 2001 to 2014 (Table 10).

Nitrate increased substantially, which drove the rise in total nitrogen. Other nitrogen forms either have not changed, or, in the case of particulate nitrogen, have actually improved (Table 10). It should be noted that particulate nitrogen accounts for only 11% of all nitrogen. For the forms of dissolved nitrogen, 2% was ammonia, and 50% was nitrate, thus 52% was dissolved inorganic nitrogen (DIN). Dissolved organic nitrogen (DON) was 37%. DON is the dominant form of dissolved nitrogen coming from forested catchments, compared with nitrate. Nitrate dominates in Lake Brunner’s pasture catchments (Rutherford et al. 2008; Verburg 2009). Intensification of farming will have contributed to this increase in nitrate. Nitrate is easily leached, particularly in wet places such as the Lake Brunner catchment.

Seasonality has a major role in creating variation over time for many of the parameters measured in the lake (Figure 22, Figure 23, and Figure 24). In some cases the linear trends maybe complex and head either up or down depending on the timeframe analyzed. This is why we use statistical tests that factor in seasonality of the data.

The NOF attribute states for the central lake site were “A’’ for TP, ammonia, and chlorophyll a. An “A” indicates ‘ecological communities that are healthy and resilient, similar to natural reference conditions’ (Table 10). Total nitrogen was a “B”, which indicates that ‘ecological communities are slightly impacted by additional algal and plant growth arising from nutrient levels that are elevated above natural reference conditions’ (MfE 2014). A wet environment will also assist leaching of dissolved nitrogen. Higher nitrogen in Brunner (primarily in dissolved forms), relative to phosphorus and chlorophyll levels, might be due to the cool, wet environment.

Ten year water quality trends for the main tributaries were investigated using the Seasonal Kendal trend test. Like the lake, there were important increasing nitrate trends in all tributaries. This was accompanied by an increase in dissolved solids, and in some cases total nitrogen, which was probably driven by nitrate. Other important trends were an improvement in DRP and ammonia in the Crooked River (at the Te Kinga bridge), and a turbidity improvement in the Orangipuku River.

Table 10 Seasonal Kendall trend analysis for water quality data collected at central Lake Brunner. Analysis is current to September 2014. Important trends are in red (undesirable) and blue (good). Pink indicates a slight undesirable trend.

Attribute	**Samples**	**Sampling period**	**Median**	**P**	**PAC**
Nitrate – N (µg/L)	147	10/1/92-24/9/14	94.0	0.00	2.1
Dissolved reactive phosphorus (µg/L)	147	10/1/92-24/9/14	0.5	0.00	2.8
Chlorophyll *a* (µg/L)	136	10/1/92-24/9/14	1.1	0.52	0.4
Clarity m (secchi vertical)	141	10/1/92-24/9/14	6.0	0.49	-0.2
Total nitrogen (µg/L)	132	10/1/92-24/9/14	203.0	0.00	1.7
Total phosphorus (µg/L)	140	10/1/92-24/9/14	5.9	0.08	0.6
Trophic level index (TLI)	141	10/1/92-24/9/14	2.7	0.00	0.5
Attribute	**Samples used**	**Sampling period**	**Median**	**P**	**PAC**
Nitrate – N (µg/L)	115	5/1/01-24/9/14	106.7	0.00	1.2
Ammonia – N (µg/L)$^{¥}$	107	19/7/01-24/9/14	5	0.97	0.0
Particulate nitrogen mg/m^{3}	74	29/9/03-24/9/14	22.0	0.00	-6.9
Turbidity NTU	89	29/9/03-24/9/14	0.8	0.4	2
Dissolved reactive phosphorus (µg/L)	115	5/1/01-24/9/14	0.5	0.27	0.0
Chlorophyll *a* (µg/L)	108	19/7/01-24/9/14	1.1	0.21	-1.7
Total suspended solids (µg/L)	90	29/9/03-24/9/14	1.0	0.98	0.0
CDOM (Absorbance g340)	86	29/9/03-24/9/14	5.7	0.86	0.0
CDOM (Absorbance g440)	86	29/9/03-24/9/14	1.2	0.74	0.0
Clarity m (secchi vertical)	107	19/7/01-24/9/14	5.8	0.05	1.7
Total nitrogen (µg/L)	108	19/7/01-24/9/14	207.6	0.00	1.3
Total phosphorus (µg/L)	108	19/7/01-24/9/14	6.0	0.45	-0.2
Trophic level index (TLI)	107	19/7/01-24/9/14	2.8	0.47	-0.3
Dissolved organic nitrogen (µg/L)	74	29/9/03-24/9/14	75.5	0.30	1.1

Table 11 NPS-FM NOF attribute states for Lake Brunner at the middle lake site, composite 1-25 m depth sample. States are calculated for both maximum and medians for ammonia and chlorophyll a. A five year block of data is used to calculate states – the final year is the year stated in the table.

Mid Lake - 0-25 m tube	**2009**		**2010**		**2011**		**2012**		**2013**	
	Med	Max	Med	Max	Med	Max	Med	Max	Med	Max
Ammonia	A	A	A	A	A	A	A	A	A	A
Chlorophyll a	A	A	A	A	A	A	A	A	A	A
Total nitrogen	B		B		B		B		B	
Total phosphorus	A		A		A		A		A	

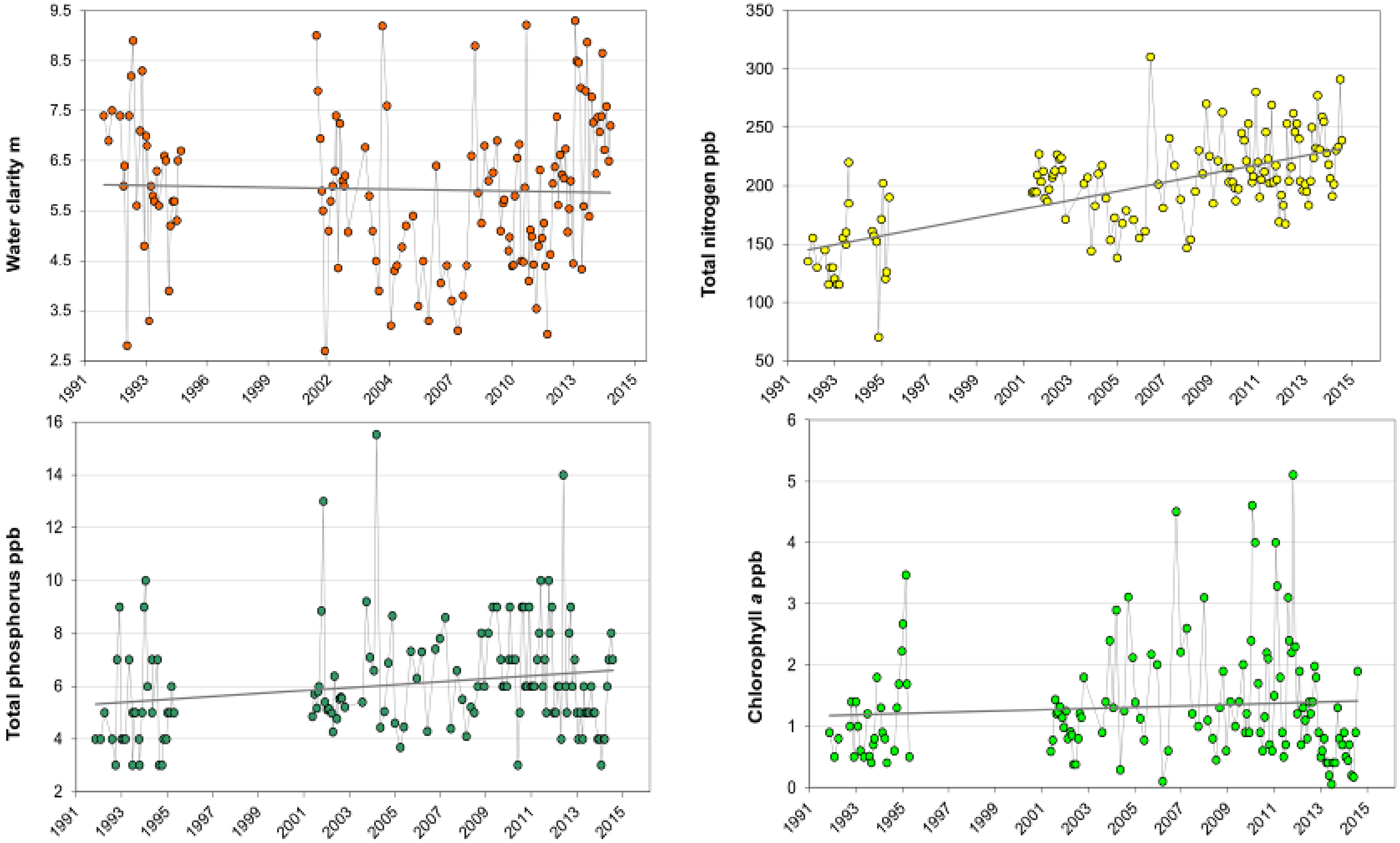


Figure 22 Full data record for water clarity (vertical secchi), total nitrogen, total phosphorus, and phytoplankton abundance (as indicated by levels of chlorophyll a). Linear regression lines are overlaid in grey.

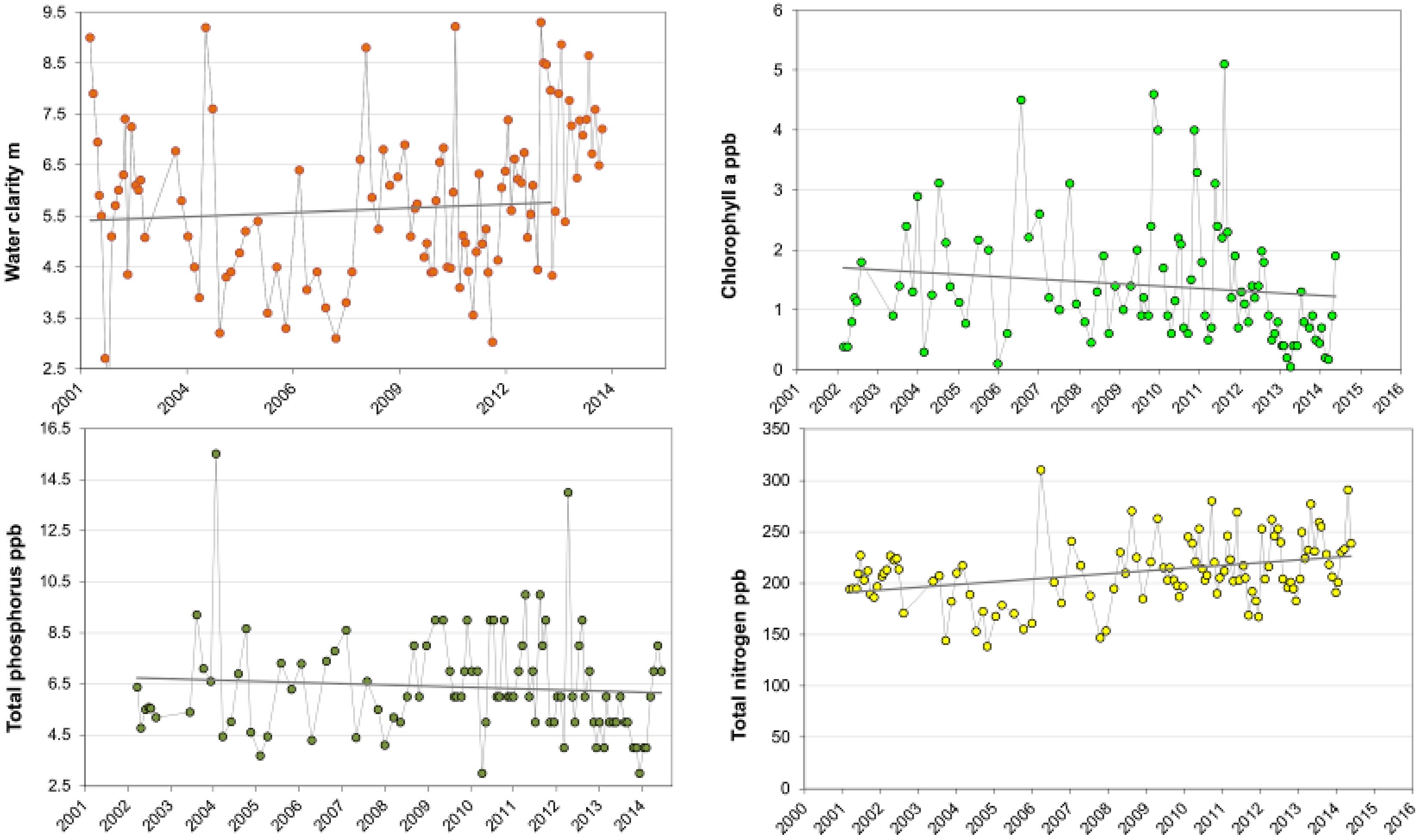


Figure 23 Recent data record for water clarity (secchi vertical), total nitrogen, total phosphorus, and phytoplanktonic algal abundance (as indicated by levels of chlorophyll a). Linear regression lines are overlaid in grey.

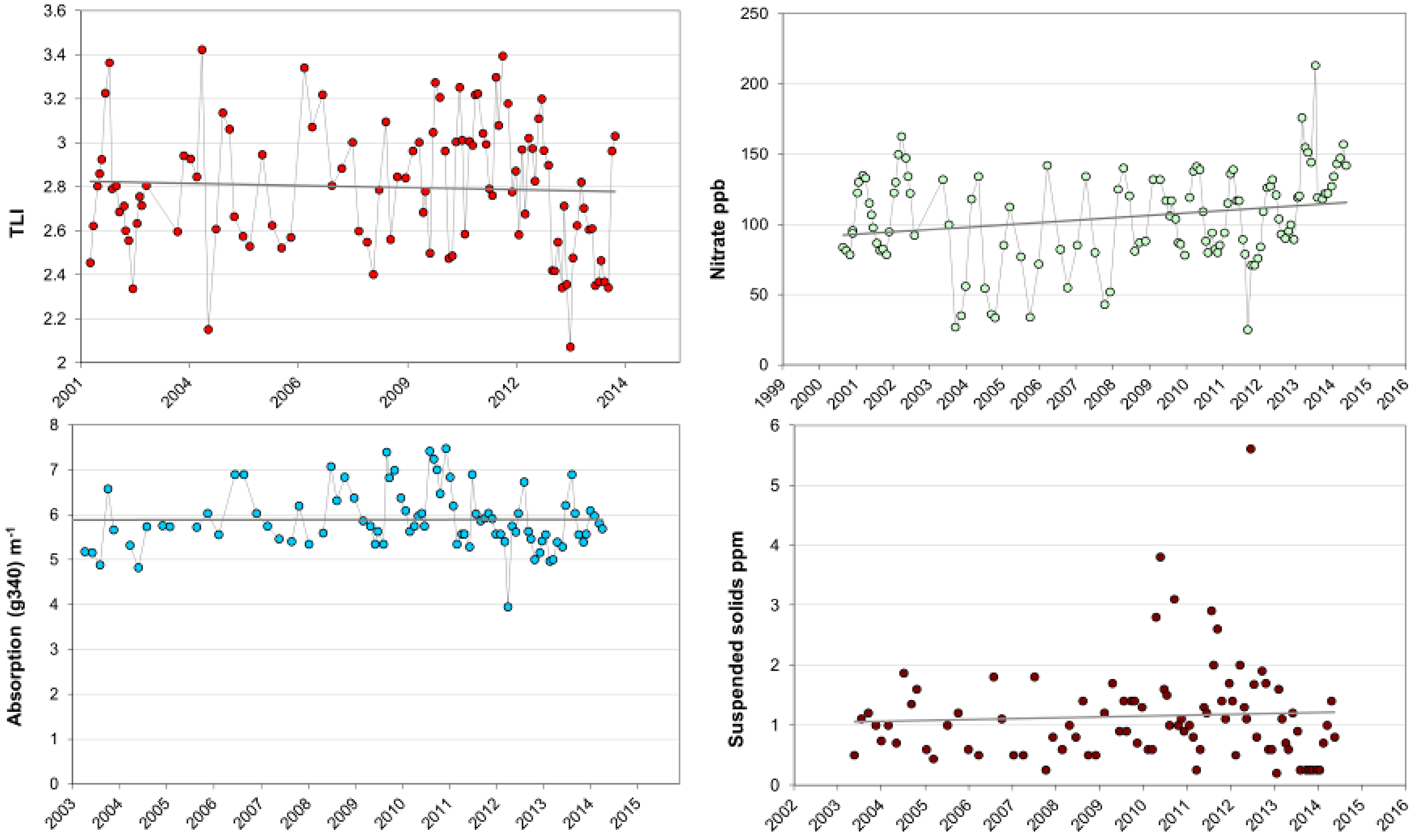


Figure 24 Recent data record for TLI, nitrate, absorption, and suspended solids. Linear regression lines are overlaid in grey.

4.1.2 Cashmere Bay

Cashmere Bay is a small bay in the far eastern corner of Lake Brunner. Its size is small compared to the rest of the lake, and it is confined by a narrow channel that links it to larger Iveagh Bay. Changes in Cashmere Bay water quality won't significantly affect, or be related, to changes in the main body of the lake.

Cashmere Bay is not deep, but it does have sufficient depth for thermal stratification, which occurs annually in summer/autumn. Vertical mixing of water stops once stratification has occurred. During stratification, oxygen is progressively used up at the bottom until it's gone. At this point, different biological and chemical processes can occur.

The duration of low oxygen at the bottom of Cashmere Bay has increased since 2009 (Table 12,

Figure 25). This suggests that oxygen depletion rates have increased at this site. We could expect this to lead to an increase in bottom water phosphorus and ammonia, but neither has occurred (Table 12). We might also expect phosphorus to be higher on the bottom due to release from sediments, but phosphorus medians are similar at both depths, suggesting no significant internal recycling of phosphorus. On average (median) ammonia is three times higher on the bottom of the bay, but during peak stratification ammonia can be 30-40 times higher on the bottom. Higher DIN (ammonia + nitrate) on the bottom during anoxia suggests some release of nitrate from bottom sediments during these periods.

Nitrate has increased since 2003, with a likely cause being changes in Cashmere Bay's catchment. As phytoplankton growth is phosphorus limited, more nitrate isn't likely to affect phytoplankton without an increase in phosphorus.

Clarity has improved (Table 12). As chlorophyll a levels have not changed, a reduction in suspended solids (SS) or a reduction in CDOM more likely explain improved clarity than dropping phytoplankton levels. Unfortunately neither SS nor CDOM have been consistently measured.

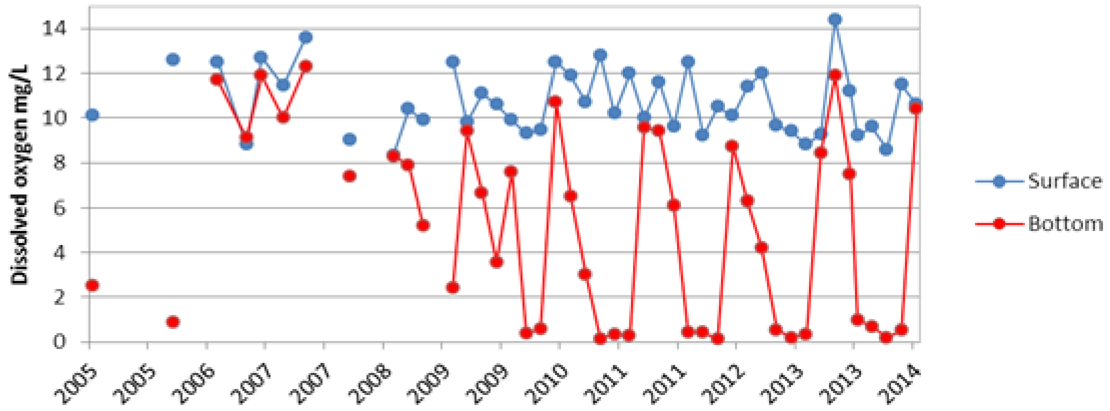


Figure 25 Dissolved oxygen levels at the surface and the bottom of Cashmere Bay, Lake Brunner.

The NOF attribute states for surface water in Cashmere Bay were A for ammonia and total phosphorus.

Seasonal spikes of ammonia during stratification meant bottom waters were both "A" and "B" depending on whether the median or maximum was used as criteria. Total nitrogen was consistently "B" at all depths.

Median chlorophyll a levels were “B”, but an absence of spikes put it in “A” under the maximum criteria. Given that a median is driven by more consistent data, designating “B” for chlorophyll would be appropriate.

Table 12 Seasonal Kendall trend analysis for water quality data collected at Cashmere Bay, Lake Brunner. Important trends are in red (undesirable) and blue (good). PAC=percent annual change.

Depth	Attribute	Samples	Sampling period	Median	P	PAC
4	Ammonia (µg/L)	61	29/9/03-23/7/14	11	0.7	-0.71
4	**Nitrate (µg/L)**	61	29/9/03-23/7/14	70	0.00	5.908
4	Dissolved reactive phosphorus (µg/L)	61	29/9/03-23/7/14	0.93	0.03	0
4	Dissolved nitrogen (µg/L)	47	29/9/03-23/7/14	157	0.2	1.466
4	Total dissolved phosphorus (µg/L)	47	29/9/03-23/7/14	4	0.4	0
4	Dissolved organic nitrogen (µg/L)	47	29/9/03-23/7/14	88	0.77	-0.93
4	Dissolved organic phosphorus (µg/L)	47	29/9/03-23/7/14	3	0.61	0
4	Chlorophyll a (µg/L)	62	29/9/03-23/7/14	2.3	0.92	0.157
4	Particulate P (µg/L)	47	29/9/03-23/7/14	5.6	0.07	-2.53
4	Particulate N (µg/L)	47	29/9/03-23/7/14	44.7	0.12	-2.22
4	**Clarity (black disk) m**	58	29/9/03-28/8/14	3.075	0.00	6.705
4	**Clarity (secchi) m**	78	29/9/03-28/8/14	4.42	0.00	5.261
4	Total nitrogen (µg/L)	62	29/9/03-23/7/14	210.65	0.89	0.121
4	Total phosphorus (µg/L)	62	29/9/03-23/7/14	9	0.12	-1.79
4	Total organic nitrogen (µg/L)	16	26/11/03-14/8/07	94.765	0.61	2.772
Surface	Dissolved oxygen mg/L	44	2/3/05-23/7/14	10.45	0.5	-1.31
Bottom	**Dissolved oxygen mg/L**	44	2/3/05-23/7/14	5.65	0.00	-4.55
10	Ammonia (µg/L)x	61	29/9/03-23/7/14	30	0.08	4.121
10	Nitrate (µg/L)	61	29/9/03-23/7/14	88.45	0.19	0.86
10	Dissolved reactive phosphorus (µg/L)	61	29/9/03-23/7/14	1	0.08	0
10	Dissolved nitrogen (µg/L)	47	29/9/03-23/7/14	243	0.3	1.162
10	Total dissolved phosphorus (µg/L)	47	29/9/03-23/7/14	5	0.07	4.142
10	Dissolved organic nitrogen (µg/L)	47	29/9/03-23/7/14	96.71	0.8	-0.51
10	Dissolved organic phosphorus (µg/L)	47	29/9/03-23/7/14	4	0.17	3.093
10	**Chlorophyll a (µg/L)**	60	29/9/03-23/7/14	0.8	0.04	-7.45
10	Particulate P (µg/L)	46	29/9/03-23/7/14	5.7	0.8	-0.49
10	Particulate N (µg/L)	46	29/9/03-23/7/14	41.702	0.92	0.428
10	Total nitrogen (µg/L)	61	29/9/03-23/7/14	285.45	0.68	0.457
10	Total phosphorus (µg/L)	61	29/9/03-23/7/14	10.3	0.62	0
10	Total organic nitrogen (µg/L)	16	26/11/03-14/8/07	100.5	0.61	3.046

Table 13 NPS-FM NOF attribute states for Lake Brunner at Cashmere Bay, for 4 m and 10 m depths. States are calculated for both maximum and medians for ammonia and chlorophyll a.

Cashmere Bay	**2009**		**2010**		**2011**		**2012**		**2013**	
	Med	Max	Med	Max	Med	Max	Med	Max	Med	Max
Ammonia @ 4 m	A	A	A	A	A	A	A	A	A	A
Ammonia @ 10 m	A	B	A	B	A	B	A	B	A	B
Chlorophyll a @ 4 m	B	A	B	A	B	A	B	A	B	A
Chlorophyll a @ 10 m	A	A	A	A	A	A	A	B	A	A
Total nitrogen @ 4 m	B		B		B		B		B	
Total nitrogen @ 10 m	B		B		B		B		B	
Total phosphorus @ 4 m	A		A		A		A		A	
Total phosphorus @ 10 m	B		B		A		A		A	

4.2 Suitability for swimming in the lake

Faecal pathogen indicators (*E. coli* and faecal coliforms) are monitored each year between November and March at Iveagh Bay (Figure 67), Cashmere Bay (Figure 66), and the Moana boat ramp (Figure 68). Occasional spikes in these indicators have occurred over time. This can be caused by water fowl activity in the area where samples are collected (based on records of water fowl numbers concurrent with each *E. coli* sample), or significant rainfall events that wash off bacteria from the surrounding land (refer to graphs in the appendix 5.8).

5 Appendices

5.1 List of sites, attributes, and sampling frequencies

West Coast Regional Council State of the Environment monitoring program for surface water quality

Nov-14

Area		Site	Grid Ref		Continuous	Gauge	Freq.	Summer			Autumn			Winter			Spring		
					flow	per visit													
			Easting	Northing		by WCRC		Peri	Macr	Extra	Peri	Macro	Extra	Peri	Macro	Extra	Peri	Macro	Extra
Grey Valley		Deep Ck@ Arnold Valley Rd Br	1473170	5287717	no	surrogate	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Grey Valley		Molloy Ck@ Rail line	1473620	5287356	no	yes	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Grey Valley		Nelson Ck@Swimming hole	1478202	5304248	no	yes	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Grey Valley		Ford Ck @ Blackball - Taylorville Rd	1469307	5306976	no	yes	1/4	-	-	SO4 (f/c & Nutrients) & other	4x5	Yes	SO4 (f/c & Nutrients) & othe	-	-	SO4 (f/c & Nutrients) & other	4x5	Yes	SO4 (f/c & Nutrients) & other
Reefton		Burkes Ck @ SH69 Reefton	1504696	5339809	no	yes	1/4	-	-	SO4 (f/c & Nutrients) & other	4x5	Yes	SO4 (f/c & Nutrients) & othe	-	-	SO4 (f/c & Nutrients) & other	4x5	Yes	SO4 (f/c & Nutrients) & other
Reefton		Mawheraiti Rv @ SH7 Maimai	1497321	5332529	no	yes	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & E. coli & F/C	-	-	Nutrients & E. coli & F/C	4x5	Yes	Nutrients & E. coli & F/C
Greymouth		Sawyers Ck @ Dixon Park	1452464	5297885	no	yes	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Greymouth		Sawyers Ck@Bush Fringe	1453257	5294215	no	surrogate	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Greymouth		Seven Mile Ck @ 400m u/s Dunollie ox ponc	1456421	5305492	no	surrogate	1/4	-	-	Nutrients & F/C & SO4 & other	4x5	Yes	Nutrients & F/C & SO4 & oth	-	-	Nutrients & F/C & SO4 & other	4x5	Yes	Nutrients & F/C & SO4 & other
Greymouth		Seven Mile Ck @ d/s Raleigh Ck	1456056	5305759	no	yes	1/4	-	-	Nutrients & F/C & SO4 & other	4x5	Yes	Nutrients & F/C & SO4 & oth	-	-	Nutrients & F/C & SO4 & other	4x5	Yes	Nutrients & F/C & SO4 & other
Greymouth		Seven Mile Ck @ u/s Tillers	1458749	5305858	no	surrogate	1/2	-	-	Solid Energy data	4x5	Yes	SO4 (f/c & Nutrients) & othe	-	-	SENZ data	4x5	Yes	SO4 (f/c & Nutrients) & other
Greymouth		Seven Mile Ck @ SH6 Rapahoe	1455300	5306936	no	surrogate	1/4	-	-	Nutrients & F/C & SO4 & other	4x5	Yes	Nutrients & F/C & SO4 & oth	-	-	Nutrients & F/C & SO4 & other	4x5	Yes	Nutrients & F/C & SO4 & other
Hokitika		Duck Ck @ Kokatahi-Kowhitirangi Rd	1439192	5255878	no	yes	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Hokitika		Harris Ck @ Mulvaney Rd	1437645	5253807	no	surrogate	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Hokitika		Murray Ck @ Ford Rd South	1439079	5252920	no	surrogate	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Westport		Bradshaws Ck @ Bradshaws Rd	1479072	5375830	no	yes	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Westport		Bradshaws @ Martins Rd	1482190	5376517	no	surrogate	1/4	-	-	Nutrients & F/C & other			Nutrients & F/C & other	-	-	Nutrients & F/C & other			Nutrients & F/C & other
Westport		Orowaiti Rv @ Excelsior Rd	1485712	5374719	no	surrogate	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Westport		Orowaiti Rv @ Keoghans Rd	1579154	4813662	no	yes	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Waitaha		Ellis Ck@Ferry Rd Bridge	1412781	5238086	no	yes	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Whanganui		Berry Ck@N Branch (Wanganui flat Rd)	1401991	5226975	no	surrogate	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Whanganui		La Fontaine @ Airstrip	1398082	5228598	no	yes	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Whanganui		La Fontaine @ Heropo fishing access	1401990	5223689	no	surrogate	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Whataroa		Okutua Rv @ Rd Br N Okarito forest	1377933	5213209	no	surrogate	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Whataroa		Un-named Ck @ Adamson Rd	1386925	5216568	no	surrogate	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Whataroa		Vickers Ck @ North Base Rd (Whataroa Bas	1387444	5215699	no	yes	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
North Buller		Baker Ck @ Baker Ck Rd	1528554	5433892	no	surrogate	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
North Buller		Baker Ck @ Oparara Rd	1527107	5433583	no	yes	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
North Buller		Page Stm @ Chasm Ck walkway	1514839	5400156	no	surrogate	1/4	-	-	SO4	4x5	Yes	SO4	-	-	SO4	4x5	Yes	SO4
North Buller		Blackwater Ck @ Farm 846	1524426	5426752	no	surrogate	1/4	-	-	Nutrients & F/C & other			Nutrients & F/C & other	-	-	Nutrients & F/C & other			Nutrients & F/C & other
Grey Valley	NIWA	Grey Rv @ Dobson NIWA	1460140	5298565	yes	no	1/12	-	-	Flow, DO%, temp, clarity, BOD, colour (340&440 nm), NO3, NHx, TN, DRP, TP, *E. coli*						Macro's once a year	All data collected by NIWA		
Grey Valley	NIWA	Grey Rv @ SH7 Ikamatua NIWA	1495184	5314254	yes	no	1/12	-	-	Flow, DO%, temp, clarity, BOD, colour (340&440 nm), NO3, NHx, TN, DRP, TP, *E. coli*						Macro's once a year	All data collected by NIWA		
Haast	NIWA	Haast Rv @ Roaring Billy NIWA	1302916	5127972	yes	no	1/12	-	-	Flow, DO%, temp, clarity, BOD, colour (340&440 nm), NO3, NHx, TN, DRP, TP, *E. coli*						Macro's once a year	All data collected by NIWA		
Buller	NIWA	Buller @ Te Kuha NIWA	1488438	5368188	yes	no	1/12	-	-	Flow, DO%, temp, clarity, BOD, colour (340&440 nm), NO3, NHx, TN, DRP, TP, *E. coli*						Macro's once a year	All data collected by NIWA		
Buller	NIWA	Buller @ Longford NIWA	1549087	5376174	yes	no	1/12	-	-	Flow, DO%, temp, clarity, BOD, colour (340&440 nm), NO3, NHx, TN, DRP, TP, *E. coli*						Macro's once a year	All data collected by NIWA		
		Site	Grid Ref		Continuous	Gauge	Freq.		Feb		April		June	August		October	December		
					flow	per visit		Peri		Extra									
Brunner		Arnold Rv @ Blairs Rd	1466541	5295450	no	no	1/6	no		Nuts & F/C & other	As for Feb + macro's & pe		As for Feb	As for Feb		As for Feb + macro's & peri	As for Feb		
Brunner		Arnold Rv @ Kotuku Fish Access	1473618	5287233	yes	no	1/6	no		Nuts & F/C & other	As for Feb + macro's & pe		As for Feb	As for Feb		As for Feb + macro's & peri	As for Feb		
Brunner		Crooked Rv @ Rotomanu-Bell Hill Rd	1484902	5279302	no	no	1/6	4x5		Nuts & F/C & other	As for Feb + macro's & pe		As for Feb	As for Feb		As for Feb + macro's & peri	As for Feb		
Brunner		Crooked Rv @ Te Kinga / mouth	1477727	5281988	no	yes	1/6	4x5		Nuts & F/C & other	As for Feb + macro's & pe		As for Feb	As for Feb		As for Feb + macro's & peri	As for Feb		
Brunner		Hohonu Rv @ Mouth	1469854	5281097	no	yes	1/6	4x5		Nuts & F/C & other	As for Feb + macro's & pe		As for Feb	As for Feb		As for Feb + macro's & peri	As for Feb		
Brunner		Hohonu Rv @ Mitchells - Kumara Rd Br	1464991	5277313	no	no	1/6	4x5		Nuts & F/C & other	As for Feb + macro's & pe		As for Feb	As for Feb		As for Feb + macro's & peri	As for Feb		
Brunner		Orangipuku Rv @ Mouth	1472080	5275934	no	yes	1/6	4x5		Nuts & F/C & other	As for Feb + macro's & pe		As for Feb	As for Feb		As for Feb + macro's & peri	As for Feb		
Brunner		Poerua River @ Rail Bridge	1478832	5278133	no	yes	1/6	4x5		Nuts & F/C & other	As for Feb + macro's & pe		As for Feb	As for Feb		As for Feb + macro's & peri	As for Feb		

Continuous flow:	The presence of a flow recording station that continuously records flow data for that particular river
Gauge per visit:	Whether water flow is gauged during a water quality site visit. Flow rate influences many water quality variables and this information is used for calibration. Surrogate means that no guaging is conducted, but a nearby gauging is used as a surrogate.
Frequency:	How many times a year the site is monitored. 1/4 means four times; once normally at the start of each season.

Measurements of water quality:

Periphyton (= Peri): This is the slime that covers rocks and is made up algae, cyanobacteria and diatoms. Four transects, each collecting five random stones across the channel, are collected. Percentage cover of different types of periphyton are assessed

Macroinvertebrates (= macro): Like periphyton, macroinvertebrates can be indicative of longer term water and habitat quality regimes, even though they are measured at a single point in time. Numbers and types of bugs say a lot about conditions in the stream.

Other: electrical conductivity, pH, turbidity, temperature, and dissolved oxygen. Collected everytime, everywhere, normally using the sonde. Also clarity, and qualitative assessment of deposited and re-suspendable sediment, riparian condition. Refer to field sheets.

NHx = ammoniacal nitrogen (NH3 + NH4+); **E. coli** = a common faecal coliform; **F/C** = total faecal coliforms; **SO4** = sulphate. Associated with acid mine drainage.

Nuts = Total nutrients. This is: TP, TN, NO, NH, DRP

Lake Brunner monitoring - Monthly schedule

	Profiles measured using YSI Data sonde														
Site	pH	Conductivity	Temperature	DO	Turbidity	Flow gauging	Secchi disk	Horizontal black disk	E coli and FC	Nutrients *[1]	Chlorophyll a	TSS	Turbidity (lab)	Colour *[2]	Light profile
Lake															
Cashmere Bay	0 - 12 m						✓	✓		Van Dorn 4 m & 10 m	✓				
Centre of Lake	0 - 100 m						✓	✓		Tube *[3]	✓	✓	✓	✓	✓
Centre of Lake - Apr/Oct	0 - 100 m						✓	✓		Van Dorn *[4]	✓	✓	✓	✓	✓
Tributaries															
Crooked R @ Bell Hill Rd	✓	✓	✓	✓	✓			✓	✓	✓					
Crooked R @ Mouth	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓		✓	
Poerua R @ Rail Bridge	✓	✓	✓	✓	✓	✓		✓	✓	✓					
Orangipuku R @ Mouth	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓		✓	
Hohonu R @ Mitchells - Kumara Rd Br	✓	✓	✓	✓	✓			✓	✓	✓					
Hohonu R @ Mouth	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓		✓	
Arnold R @ Blairs Rd	✓	✓	✓	✓	✓			✓	✓	✓					
Arnold R @ Kotuku Fishing Access	✓	✓	✓	✓	✓			✓	✓	✓					

*[1] All nutrients for lake samples are = TN, TP, DRP, NO_3, NH_4, TDP, TDN

*[2] Colour 340 nm, 440 nm, 555 nm, 740 nm

*[3] Monthly tube sample: 25 m long 20 mm diameter plastic weighted tube, lowered through the water column, then sealed and retrieved, collecting a 0 - 25 m deep composite water sample

*[4] Van Dorn samples taken at 10, 20, 40, 70 , and 95 metres - preferably in April and October.

5.2 Data analytical methods

5.2.1 Relationships between water quality and land use

Two techniques were used to estimate land use in the catchment above each monitoring site. The first used REC land use categories that designate land use according to which land use is dominant in the catchment (refer to Section 5.4 for more details on REC). Indigenous forest (IF) and pasture (P) were the two main land use categories for monitoring program sites. The other technique, LCDB2 (Land Cover Database 2), determines the proportion of land use types in a catchment. REC categories were used extensively in the earlier Regional Council Surface Water Quality report (Horrox 2005). Summaries of analyses conducted in 2008 are presented in this report and for details on these refer to the 2008 SoE report (Horrox 2008).

5.2.2 Comparison to water quality guidelines

Percentage bar graphs have been used to illustrate how some of the key attributes measured at Regional Council monitoring program sites compared to the respective guidelines for those attributes. A guide to the interpretation of these figures is provided in Section 5.5 with more detail on these guidelines provided in Section 5.3.

Some attributes are not described by percentage bar graphs. These are instead covered by tables that have scores derived through the National Objectives Framework (NOF) methodology. The NOF framework is part of the National Policy Statement for Freshwater Management (2014). River attributes where the NOF system has been applied include: nitrate, total ammonia, and *E. coli*. These NOF scores have been calculated using a five year block of data. Where these NOF scores have been applied they have been used instead of other guidelines values for these attributes.

We have calculated NOF scores using 5 year blocks of data. Individual NOF scores have been calculated in this way for the last five years e.g. 2013 nitrate is based on 2009-2013 data, and 2012 nitrate is based on 2008-2012 data, etc. As a lot of the same data is involved in computing rolling percentiles from neighboring years, attribute scores often don’t change much between years. While it is of interest to compare attribute states from previous years, the ‘trend’ aspect of this should be ignored as it is superseded by better forms of statistical trend analysis. As we didn’t have a full 2014 dataset at the time of analysis, the data was analysed up until December 2013.

The NOF has attribute states for ammonia based on two numeric methods – a median and maximum. The same numeric thresholds are used for lakes and waterways. Ammonia attribute states need to be adjusted for pH. We have used the following calculation for adjusting chronic ammonia toxicity thresholds, taken from ‘1999 Update of Ambient Water Quality Criteria for Ammonia’ (USEPA, December 1999). This is the calculation that was used for correcting the ANZECC 2000 chronic toxicity thresholds.

$$CV_t = \left(CV_{t,8}\right)\left(\frac{0.0676}{1 + 10^{7.688-pH}} + \frac{2.91}{1 + 10^{pH-7.688}}\right)$$

Maximum and median ammonia values were calculated from 5 years of data – normally amounting to 20 data values. Median pH from the same time period was used to correct ammonia.

The NOF has attribute states for nitrate are based on two numeric methods – a median and 95th percentile. Nitrate was sampled at WCRC sites from 2008 onwards so NOF scores for nitrate go as far back as 2008-2012. The NIWA sites (Buller, Grey, Haast Rivers) go back further.

We have applied the NOF secondary contact recreation criteria to all waterway sites. *E. coli* for primary contact recreation has not been calculated for any waterway sites using the NOF framework as most of these sites are not managed for contact recreation (i.e. swimming). Suitability for primary contact recreation is evaluated through the WCRC summer contact recreation monitoring program.

5.2.3 Impact/reference sites: Longitudinal patterns over time

A number of rivers in the region are sampled at two or more locations. This consists of an upstream ‘reference site’ and downstream site impacted to a greater extent by one or more anthropogenic pressures. The difference between the upstream and downstream site was calculated by subtracting the value for an attribute at the upstream site from that of the downstream site, from the same day. The median, quartiles and maximums for these differences are shown in Figure 50 - Figure 54.

5.2.4 Contact recreation

Contact Recreation suitability is currently based on faecal indicator bacterial information collected at a range of sites located between Hokitika and Westport that include marine, estuarine and fresh waters. Results from all samples collected in a year were combined and analysed according to single sample guidelines for bathing suitability. The sampling season runs from the beginning of November through to the end of March. For most sites, monitoring began in the summer of 1999 – 2000.

5.2.5 Trend analysis: Regional Council and NIWA sites

All trend analyses in this report were done using the trend analysis software package (Time Trends) developed by NIWA (Ian Jowett). Investigation of trends in water quality attributes for Regional Council sites was conducted using three techniques:

The second used Seasonal Kendall tests carried out on individual Regional Council sites for the 2000-2010 period. For a trend to be significant it required a p value of <0.05. We defined a trend as ‘meaningful’ if it had statistical significance i.e. p <0.05, *and* had an annual rate of change of more than 1%. Refer to Vant (2007). It was also desired that at least 40 data points were utilised in the analysis (i.e., quarterly samples over 10 years) as per Scarsbrook (2008).

The third technique used the Mann-Kendall trend test on differences between paired reference/impact sites. Paired site data has been collected on the same day. Differences were determined by subtracted the value at the top site from the lower site.

Monthly water quality data from five NIWA National River Water Quality Network (NRWQN) sites in the West Coast region were analysed for trends in individual attributes using Seasonal Kendall tests on raw and flow-adjusted data. Flow adjustment was carried out using the log-log covariate adjustment method. The Sen Slope Estimator (SSE) was used to represent the magnitude and direction of trends in data. Seasonal Kendall tests for NIWA data trends were carried out on two datasets: the first being 1990-2010, and the second from 2000-2010.

5.2.6 Lake Brunner catchment

As previously stated, all Seasonal Kendall trend analyses in this report were done using the Time Trends software package. Diagnostic assessment on the workings of the Seasonal Kendall trend test using the Lake Brunner data determined that a one monthly step using individual values was the most appropriate form of seasonal grouping for central lake data (Vant pers. comm. 2010). Other methods relevant to Section 4 are detailed in Verburg (2009, 2011), Rutherford *et al.* (2008), and Spigel (2008).

5.3 Physical, chemical, and biological qualities

5.3.1 pH

At a given temperature, the intensity of the acidic or basic character of a solution is indicated by the pH or hydrogen ion activity (APHA 1992). Most natural waters fall within the pH range of 6.5 to 8.0 (ANZECC 2000), and in the absence of contaminants, most waters maintain a pH value that varies only a few tenths of a pH unit. Recommended trigger limits for pH of New Zealand upland and lowland rivers are in the pH range of 7.2 to 8.0. A more appropriate means of setting pH limits involves using the 20th and 80th percentiles, calculated from seasonal medians in a reference site (ANZECC 2000). It is recommended that changes of more than 0.5 units from the natural seasonal maximum and minimum be investigated (ANZECC 1992). However, there are many streams and rivers on the West Coast that have naturally low pH (as low as pH 4), which may originate from humic acids or come from young sedimentary geologies with a pyrite component.

Some plants and animals are adapted to naturally lower pH (refer Collier et al. 1990). The key difference between streams with naturally low pH and those that are such as a result of acid rock drainage are the nature of compounds causing the acidity and the typically higher concentrations of metals found in the latter. The toxicity alone of these metals may prove detrimental to a streams ecological health and be exacerbated further when combined with low pH, but evidence of increased toxicity is not conclusive from New Zealand studies. As well as toxicity, high concentrations of metal can give rise to precipitates that negatively affect macroinvertebrate habitat and food quality, and subsequently, food webs.

Overall, it seems clear that invertebrate diversity is negatively impacted by pH and elevated metal concentrations below pH 4.5. We have chosen a minimum level of pH 5.5, based on studies of West Coast streams (e.g. Collier et al. 1990; Rowe 1991), as a general criterion for measuring exceedances in section 3.2, applicable to sites with anthropogenic acid generation, as a buffer to allow for more sensitive taxa and potential chronic effects of metal toxicity on certain species. It also considers that while many West Coast streams have lower pH, many others are within the range specified by ANZECC (2000) guidelines. Higher than ‘average’ pH can occur where a catchment contains limestone geology, although not common, parts of the West Coast have elevated pH for this reason. These higher pH’s are not toxic, although higher pH will increase the ratio of toxic un-ionised to ionised ammonium ions. Two pH ranges are used as a reference in this report: 6.5 – 8.0 (ANZECC 2000), and 5.0 – 9.0 (CCREM 1987).

Daily pH levels can be influenced by photosynthesis and respiration, particularly where plant and algae are abundant. A small amount of CO_2 in water is hydrated to form carbonic acid. This can lead to a lowering of the pH in waters that have low buffering capacity. Therefore, when ample light is present and photosynthesis is consuming large amounts of CO_2, the pH can increase. This obviously coincides with an increase in dissolved oxygen, often to supersaturated levels, i.e. >100%. In the same plant-filled streams, during early morning when it is still dark, plant respiration has consumed much of the dissolved oxygen, creating an abundance of CO_2 and lower pH relative to mid-day levels.

5.3.2 Temperature

Temperature is fundamental to the rate of biological and chemical processes in a water body. For many micro-organisms, metabolism doubles with each rise of 10 °C, but tolerance of temperature extremes for different species is generally quite specific.

Aquatic biota are strongly influenced by water temperature in terms of their growth, reproduction, and survival. The biota of Westland streams and rivers contain elements that are valued for their recreational opportunities (brown trout, whitebait) and national endemism (various native fish). Increased water temperatures may affect these taxa directly, for example via oxygen removal, and indirectly via aquatic food chains. The key components of river ecosystems (algae, plant, macroinvertebrates and fish) are all affected by temperature. Introduced sport fish (trout and salmon species) are very susceptible to high temperatures and their success in New Zealand has largely been attributed to cool summer water temperatures, and winter temperatures generally high enough to allow for some food (i.e. invertebrate prey) production (Viner 1987).

As temperature varies widely both spatially and temporally in aquatic systems, it is difficult to assign low risk trigger values for temperature. It is, however, recommended that temperatures should not be varied beyond the 20th and 80th percentiles of natural ecosystem temperature distribution (ANZECC 2000).

Algae and plant growth in New Zealand rivers are most strongly affected by a combination of nutrient supply and disturbance regime, however temperature has also been identified as an important factor in determining periphyton biomass and community structure. Higher temperatures favour high biomass accrual and the dominance of erect, stalked and filamentous algae (often synonymous with nuisance algal growths). Such effects are also strongly influenced by disturbance (i.e., floods), with low disturbance favouring increased biomass of algae and plants.

In general, algae and plants are much more resilient to high temperatures than invertebrates and some elements of the algal community exhibit high growth rates at temperatures as high as 45 °C. Lethal temperatures for algae and plants are likely to be much higher than would occur in lowland rivers. The effects of increases in water temperature on algae and plant growth are likely to be predominantly positive, presuming that nutrients are not limiting and the system is not subject to major disturbance. Therefore, no standards are recommended for protecting plants and algae.

There is relatively detailed information available on the effects of water temperature on aquatic macroinvertebrates. Water temperature can affect abundance, growth, metabolism, reproduction, and activity levels of aquatic insects. A detailed analysis of 88 New Zealand rivers (Quinn and Hickey 1990) identified water temperature as one of the important attributes affecting species distribution. Stoneflies (Plecoptera) were largely confined to rivers between 13 and 19 °C, and mayflies (Ephemeroptera) were less common in rivers with maximum temperatures of > 21.5 °C (Quinn and Hickey 1990).

Laboratory studies of the effects of water temperature on invertebrate taxa have also identified mayflies (Ephemeroptera) and especially stoneflies (Plecoptera) as being particularly sensitive to high water temperatures. The common mayfly (*Deleatidium* spp.) is a common invertebrate species in many West Coast Rivers with a LT_{50} (the temperature at which 50 % of individuals will die) of 22.6 °C. There is the potential at high temperatures for *Deleatidium* to be replaced by the grazing snail *Potamopyrgus antipodarum*, which has a much higher LT_{50} (31.0 °C). *Potamopyrgus* can be considered a less desirable taxon, as it is a less attractive prey item for trout and native fish. Some recent research has suggested that *Deleatidium* may be able to survive short periods of high temperatures, providing they have experienced a summer acclimation period (Cox and Rutherford 2000).

Fish are often strongly affected by temperature, with effects of temperature on mortality, growth and reproductive behavior all described from New Zealand or elsewhere. Some of these effects are direct, with water temperature affecting behavior, egg maturation, growth and mortality. Other effects are more subtle; increased water temperatures can increase rates of disease, reduce resistance to pollutants, and reduce competitive abilities. Approximate preferred temperatures of some main New Zealand fish groups include: just above 25°C for short fin eels and just below 25°C for longfins; around 20°C for many bully species; and below 20°C for trout and galaxid species. Greater detail is provided in Richardson et al. (1994).

5.3.3 Biochemical oxygen demand and dissolved oxygen

In order to characterise the potential for a body of water to lose oxygen, Biochemical Oxygen Demand (BOD) is often measured. The BOD of water may be defined as the amount of oxygen required for aerobic microorganisms to oxidise organic matter to a stable inorganic form.

Unpolluted waters typically have BOD5 (5 day biochemical oxygen demand) values of 2 mg/L or less, whereas receiving waters of waste may have values up to 10 mg/L or more, particularly near a point of a wastewater discharge. Raw sewage has a BOD_5 of about 600 mg/L, whereas treated sewage effluents have BOD_5 values ranging from 20 to 100 mg/L depending on the level of treatment applied.

Aquatic heterotrophic bacteria and fungi (the main components of undesirable feathery, cotton-wool-like growths commonly referred to as “sewage fungus”) grow in response to readily degradable organic compounds, such as short-chain organic acids, sugars, and alcohol, which are sometimes found in wastewater discharges (e.g., dairy shed, piggery, meat works, and cheese factory effluents). In doing so, they consume oxygen from the water and can detract from the aesthetic appeal of a water. Sewage fungus should not be visible to the naked eye as obvious plumes or mats. The MfE (1992) guideline suggests BOD_5 of <5 mg/L to avoid growth of nuisance bacterial slime.

An adequate supply of dissolved oxygen (DO) is essential to the metabolism of all aerobic organisms and for the maintenance of purification processes in aquatic systems. DO levels are most often reduced in aquatic ecosystems directly by the addition of organic material and indirectly through the addition of plant nutrients (ANZECC 2000).

The total amount of oxygen that can be dissolved in a water body is dependent upon temperature and salinity. By measuring the DO content, the effects of oxidisable wastes (e.g., human and animal faeces, dead algae) on receiving waters may be assessed. DO levels also indicate the capacity of a natural body of water for maintaining aquatic life. The DO depletion in nutrient enriched waters may be offset during the day by algal photosynthesis. As photosynthesis requires light, a high DO concentration may build up during the day but depletion will occur during the night due to respiration of the aquatic plants.

Low concentrations of dissolved oxygen adversely affect the functioning and survival of biological communities and below 2 mg/L may lead to the death of most fish.

Water quality criteria for dissolved oxygen generally state that DO concentrations should not be permitted to fall below 80% saturation for water quality classes AE (aquatic ecosystems), F (fisheries), FS (fish spawning), and SG (gathering or cultivation of shellfish for human consumption), as specified in the Third Schedule of the RMA 1991. The West Coast Water Management Plan classifies all freshwater bodies as AE (Aquatic Ecosystem) except those identified for bathing. ANZECC (1992) guidelines suggest a DO threshold of >6.5 mg/L, or a reduction to no more than 80% saturation.

5.3.4 Suspended sediment, turbidity & clarity

Sediments suspended in the water column are often referred to as suspended solids. “Turbidity” is an optical property of water where suspended and some dissolved materials cause light to be scattered and absorbed rather than be transmitted in straight lines. Clarity refers to the “transparency” of water.

Turbidity and suspended solid sampling have been used traditionally as methods for determining the degree of impact and sediment loading in waters. Assessing ‘visual water clarity’, measured using either ‘Secchi’ (for vertical water clarity) or ‘black’ disks (for horizontal water clarity) is recommended for determining the visual and ecological effects of turbidity (MfE 1994). The greater the viewing distance, the greater the water clarity. For most rivers, concentration of suspended solids is positively correlated with turbidity, and both suspended solids and turbidity are inversely correlated with visual clarity. In other words, as the visual clarity decreases, suspended solid concentration and associated turbidity increase.

In rivers, excessive concentrations of suspended sediment can affect chemical and physical water characteristics, plants, algae, invertebrates, and fish, as well as human aesthetic, recreational, and spiritual values, as described below. Sediment influxes can physically alter rivers and lakes by creating excessive turbidity and changing the nature of the bed. Coarser graded particles fill in the interstices between stones and cobbles, while finer graded particles smother or “blanket” the bed.

Sediment-laden water affects benthic macroinvertebrates by five primary mechanisms. These are:

- reduction of light penetration;
- abrasion;
- absorbed toxicants;
- changes in substrate character; and
- reduction in food quality.

Increased water turbidity, caused by suspended sediments, can affect benthic algae and macrophyte growth by reducing light penetration through the water column. This can reduce the “euphotic depth” of water (the depth at which irradiance, the penetration of diffuse light from the sun into water, is reduced to 1 % of the surface value, a point below which most aquatic plants cannot grow for the lack of light). Altering the natural euphotic depth of a river or lake can result in a shift in plant and algal communities that in turn, can affect the composition of the benthic invertebrate and fish communities. As well as reducing algal growth by reducing light penetration, fine sediments can smother algae and plants when they settle out.

Reduction of light penetration reduces periphyton production, which may result in a limiting food supply for the invertebrates (as stated above). Abrasion can act directly on benthic invertebrates by physical contact and, indirectly, by abrading periphyton.

Elevated levels of sediment in rivers and lakes affect fish, both directly and indirectly. Direct effects usually occur when concentrations of suspended solids are high. These include avoidance of turbid water by some fish, lower growth rates, impairment of growth in fish that use vision during feeding, and clogging of gills resulting in death. Indirect effects include reduction in the invertebrate food source (by mechanisms discussed above), avoidance by adult fish of silted gravels for spawning, and high egg mortality due to reduced oxygen levels in gravel fouled by silt deposition.

Turbidity, caused by suspended solids affecting the colour and clarity of water, may also have special significance to humans. Under New Zealand law, discharges of contaminants to water are not supposed to cause conspicuous changes in water colour and clarity (Resource Management Act 1991, Section 70). Most people accept that the visual clarity of running water decreases as the flow increases (Davis-Colley 1990). However, increases in turbidity that occur during low or normal flows are generally regarded as unacceptable.

As discussed above, decreased water quality, due to increased concentrations of suspended solids, can affect freshwater aquatic organisms and human values in a number of ways. In order to protect these attributes, guidelines have been developed by the Ministry for the Environment (MfE 1994). These numerical guidelines were developed to aid the interpretation of the narrative guideline found within the RMA (1991) that implies that discharges should not cause conspicuous changes in colour or clarity (Section 107). MfE guidelines of relevance to water clarity are:

Visual clarity change

For Class A waters where visual clarity is an important characteristic of the water body, the visual clarity should not be changed by more than 20 % (visual clarity is measured with a black disk). For more general waters the visual clarity should not be changed by more than 33 % to 50 % depending on the site conditions.

Significant adverse effects on aquatic life

The protection of visual clarity (as recommended above) will usually also protect aquatic life. Settlement of solids onto the beds of water bodies should be minimised, but guidelines for this have not been recommended. For lowland New Zealand Rivers ANZECC (2000) recommends a clarity trigger level of 0.8 m, and a turbidity level of 5.6 NTU.

Water managed for contact recreation.

Visual clarity affects bather preferences. Potential hazards should be visible in bathing waters and thus it is recommended that in such waters the horizontal sighting range of a 200 mm black disk should exceed 1.6 m (MfE 1994). Smith et al. (1991) recommend that total suspended solids should not exceed 4 mg/L, and turbidity should not exceed 2 NTU, and should be applied to base flow samples only. This also applies to the ANZECC (2000) default trigger value for lowland river water clarity of 0.8 m, which is referenced from unmodified or slightly disturbed ecosystems. Some Regional Council samples were collected during periods when flows may have been insufficiently low for effective use of these latter guidelines i.e. higher flows normally correspond with increased mobilisation of suspended sediment and a subsequent decrease in visual clarity.

5.3.5 Conductivity

Also known as electrical conductivity. All data in this report deals with conductivity standardized to 25^{o}C, known as specific conductivity, or EC25. The concentration of dissolved solids in solution is generally determined by salinity or conductivity measurements. Conductivity is a numerical expression of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions, their total concentration, mobility, valence, and relative concentrations, and on the temperature during measurement (APHA 1992).

Anions (including bicarbonates, carbonates, chlorides, sulphates, phosphates, and often nitrates) occur in combination with such metallic cations as calcium, sodium, potassium, magnesium, and iron, to form ionisable salts. Because of the high availability and solubility of carbon dioxide, carbonates are usually the most abundant salts in fresh water.

Total dissolved solids (in mg/l) may be obtained by multiplying the conductance (in m*S*/m) by a factor, which is commonly between 0.55 and 0.75. The lower these measurement are, the more pure the water.

Certain dissolved mineral salts serve as nutrients for plants, whereas other salts may limit metabolism through osmotic effects. The conductivity of a liquid increases in relation to the concentration of dissolved ionised substances and, therefore, provides an indirect measure of the concentration of dissolved salts in a water sample. Conductivity monitoring is often used as a surrogate measure of nutrient enrichment in rivers.

Conductivity can be greatly affected by geology with streams in limestone catchments often having conductivities > 300 µS/cm. There are no guidelines for conductivity levels in water (ANZECC 2000) but it is suggested that guidelines for south-eastern Australian coastal rivers may be applicable where geology is not a significant factor (i.e. 125-300 µ*S*/cm).

5.3.6 Nutrients: nitrogen and phosphorus

Nutrient monitoring in relation to nuisance aquatic plant and algal growths usually focuses on nitrogen and phosphorus. Dissolved inorganic nutrient concentrations are most relevant for predicting periphyton and macrophyte biomass in flowing waters. However, total nutrient concentrations are also relevant in rivers because particulate material can settle out in calm areas and become biologically available to plants via mineralisation (MfE 1992).

Aquatic plant and algal growths are important in rivers and streams as they provide food for both invertebrate and vertebrate life forms that live in, or are associated with, the water. However, if algal growth becomes excessive, due to an oversupply of nutrients (particularly nitrogen and phosphorus), the quality of the river or lake ecosystem deteriorates.

In most catchments where human impacts have been minimised, phosphorus and sometimes nitrogen are generally in short supply. As human activities intensify, the supply of both elements increases, leading to over-enrichment with the associated threat of eutrophication. The severity of eutrophication in a water body is also strongly controlled by the flushing rate. Rapidly flushed areas can tolerate higher levels of nutrient inflows than stagnant areas. Careful monitoring of phosphorus and nitrogen levels, along with flushing rates will, therefore, give a good indication of the susceptibility to eutrophication of a particular water body.

In some circumstances it may be more useful to consider dissolved inorganic nitrogen (DIN) and dissolved reactive phosphorus (DRP), as these are the forms that are readily assimilated by living organisms. DIN is made up of a combination of soluble oxides of nitrogen (nitrites/nitrates (NO_x) and ammonia (NH_x-N). The upper limit for DIN, for avoiding nuisance algal growth (MfE 1992) is 0.10 mg/L. The ANZECC (2000) guidelines suggest a value for nitrate of 0.7 mg/L to provide moderate protection for 95% of aquatic creatures.

For New Zealand lowland rivers the trigger value for total nitrogen (TN) is 0.614 mg/L, and for total phosphorus (TP) 0.033 mg/L (ANZECC 2000). Trigger values for NO_x are 0.444 mg/L, and 0.010 mg/L for DRP (ANZECC 2000). These trigger values are not national standards and are not based of toxicological studies. This and other trigger values have been devised to assess the levels of physical and chemical stressors which might have ecological or biological effects. Levels beyond them do not imply that there will be ecological and biological effects caused by increased levels of physical and chemical stressors. Rather, exceedances of trigger levels indicate cause for further consideration of water quality issues. Where trigger levels are not breached we can have reasonable confidence that water quality is sufficient to support ecological values.

5.3.7 Ammoniacal nitrogen, ammonia, and ammonium

Ammonia is a common constituent of aquatic environments. It is present both as a natural breakdown product of nitrogenous organic matter and as a contaminant from wastewater discharges and run-off. Ammoniacal nitrogen is the combination of ammonium ions (or ionised ammonia) (NH_4^+), and [un-ionised] ammonia (NH_3). The prevalence of these two forms is dependent on the pH, temperature, and salinity of the water. Concentrations are usually expressed either as total ammonia (or ammonia, the sum of NH_3 and NH_4^+), or as concentration of the un-ionised NH_3 only. NH_3 is the main poisonous component for aquatic organisms, so when ammonia is quoted, the pH and temperature are also relevant in determining toxicity (Figure 26).

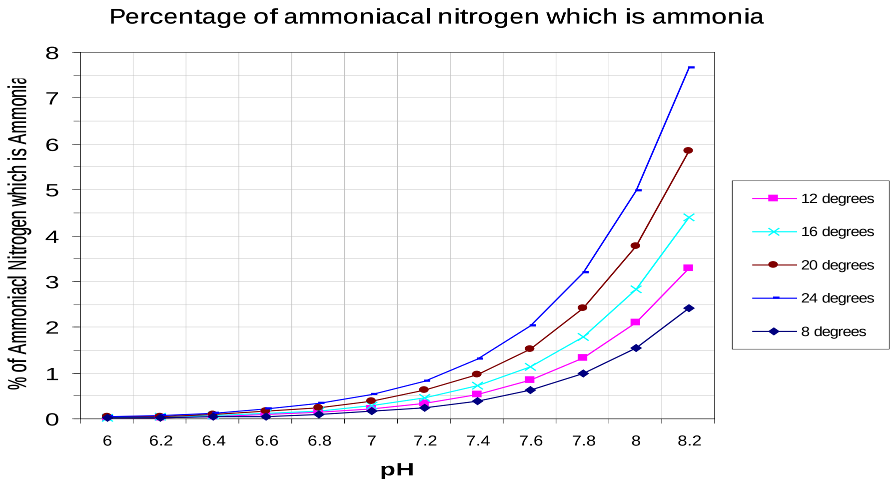


Figure 26 Percentage of ammonia which is ammonia depending on the water pH and temperature.

Most of the trigger values for toxicants in the 2000 ANZECC guidelines have been derived using data from single-species toxicity tests on a range of test species, because these formed the bulk of the concentration–response information. ‘High reliability’ trigger values were calculated from chronic ‘no observable effect concentration’ (NOEC) data. However the majority of trigger values were ‘moderate reliability’ trigger values, derived from short-term acute toxicity data (from tests ≤ 96 hour duration) by applying acute-to-chronic conversion factors.

An ammonia value of 0.9 mg/L (at pH 8, 20 °C), has been suggested as a high reliability (95%) trigger value for freshwater (ANZECC 2000). This trigger value varies with pH and temperature (Table 14). It is rare for waterways on the West Coast to go above pH 8.5, although it has occurred occasionally at a few sites (Figure 36). Based on an upper limit of pH 8.5, an ammonia guideline of 0.4 mg/L has been selected as a benchmark for analysis in this report (Table 14).

Table 14 2000 ANZECC freshwater trigger values for ammonia at different pH (temperature not taken into account).

pH	Freshwater trigger value (mg/L ammonia-N)	pH	Freshwater trigger value (mg/L ammonia-N)
6.5	2.46	7.8	1.18
6.6	2.43	7.9	1.03
6.7	2.38	8.0	0.90
6.8	2.33	8.1	0.78
6.9	2.26	8.2	0.66
7.0	2.18	8.3	0.56
7.1	2.09	8.4	0.48
7.2	1.99	8.5	0.40
7.3	1.88	8.6	0.34
7.4	1.75	8.7	0.29
7.5	1.61	8.8	0.24
7.6	1.47	8.9	0.21
7.7	1.32	9.0	0.18

5.3.8 Faecal microbiological indicators

Microbiological criteria are important because humans (particularly children) can contact various diseases from microbes in water: from drinking it, swimming in it, or eating shellfish harvested from it. The categories of microbes that can cause disease (pathogens) are well documented (e.g. McNeill 1985). Examples of water-borne diseases include: salmonella, gastroenteritis, hepatitis, and giardia.

To contain the risk of contracting such water-borne diseases various criteria have been derived from studies in which the density of suitable “indicator” organisms is correlated with disease risk. An acceptable value of this risk is then selected. Unfortunately, the relationship of the disease risk to the density of the “indicator” organisms is not clear.

Numerical standards are applied to New Zealand waters to protect them for recreational water use and for the gathering of shellfish for consumption. Typically, faecal coliforms and Enterococci are the groups of bacteria used as indicators of public health concern.

The main water quality attributes used for monitoring Regional Council sites are faecal coliforms/*Escherichia coli* and Enterococci. The latter is used only at sites that have tidal influence or are located in marine waters*.* Individual values have been plotted for *E. coli* with values separated by the following criteria: circle = acceptable (< 260 *E. coli*/100 ml), triangle = alert (260 – 550 *E. coli* 100 ml), and square = action (> 550 *E. coli*) values in accordance with MfE (2003) contact recreation guidelines for individual values (Appendix 5.2.4).

The older MfE (1999) secondary contact guideline was used as a benchmark for comparing faecal coliforms among SOE monitoring sites (1000 cfu/100 ml median from a minimum of five samples taken at regular intervals not exceeding one month has been used). This was easier to apply to the SOE monitoring site data than the 2003 MfE contact recreation guidelines, and was the same figure as that used for 1999 ANZECC stock drinking water quality guidelines also applied here. The ANZECC 1992 guidelines specify for stock drinking a faecal coliform limit of 1000 cfu/100 ml, where as the limit for stock drinking in the ANZECC 2000 guidelines is 100 cfu/100 ml.

Guidelines for shellfish gathering recommend that the mean faecal coliform content shall not exceed 14 cfu/100 ml and not more than 10 % should exceed 43 cfu/100 ml (MfE 2003).

5.3.9 Periphyton

Periphyton is the slime coating stones, wood, weeds or any other stable surface in streams and rivers. The community is composed predominantly of algae, cyanobacteria (formerly “blue-green algae”) and diatoms (Biggs 2000). Periphyton occurs in a variety of thicknesses and forms depending on conditions.

Periphyton is the “foodstuff” of aquatic grazing animals, mainly macroinvertebrates, which are, in turn, fed upon by fish. Without periphyton many waterways would be barren of life. Periphyton also plays a role in the maintenance of water quality, the community removing nitrogen, phosphorous and unwanted organic contaminants (Biggs 2000). During periods of low flows and high nutrient levels, however, periphyton communities may proliferate to the extent that aesthetics, biodiversity and other in stream attributes are compromised.

Periphyton is assessed by the Regional Council once during autumn and once during spring using an approach similar to the Rapid Assessment Method 2 (RAM 2) (Biggs & Kilroy 2000). Four transects across the stream are used, each with five points where a stone is selected and the percentage cover of each category of periphyton is visually estimated for each stone. Categories are differentiated by colour and thickness, and are likely to represent certain groups of periphyton. Categories have an assigned score, and the combination of these can be used to calculate an enrichment indicator. A *low* score indicates *high* periphyton abundance. The New Zealand periphyton guideline (Biggs 2000) suggests biomass limits of 60 % cover of >3 mm thick diatoms/cyanobacteria and 30 % cover of >2 cm filamentous algae, to maintain contact recreation and aesthetic values. The same standard of 30 % cover of >2 cm filamentous algae is also promoted to maintain trout habitat and angling values. When computed into a RAM2 enrichment score, these thresholds equate to a score of between four and six. For analysis in this report a threshold of five has been chosen. Thus, enrichment scores of five or less are deemed likely to indicate periphyton biomass beyond that recommended by the guideline.

5.3.10 Macroinvertebrates

Freshwater benthic macroinvertebrates are bottom-dwelling animals that have no backbone and are, simply speaking, large enough to be seen with the naked eye. In the case of macroinvertebrates collected by the Regional Council for monitoring, they are of a size at least as large as 500 microns (0.5 mm) as this is the mesh size of the net used to collect them. Macroinvertebrates include insect larvae (e.g. caddisflies, mayflies, and stoneflies), aquatic worms (oligochaetes), aquatic snails, and crustaceans (e.g., amphipods, isopods and freshwater crayfish). Macroinvertebrates utilise a variety of food sources depending on the species.

Numbers of individual macroinvertebrate taxa collected in samples are enumerated according to categories (Table 15)

Table 15 Values used for conversion of ranked abundances to numeric abundances for macroinvertebrate data. Ranks based on Stark (1998).

Rank class	Abundance range	Value used
Rare (R)	1-5	1
Common (C)	5-19	5
Abundant (A)	20-99	20
Very abundant (VA)	100-499	100
Very very abundant (VVA)	> 500	500

Aquatic macroinvertebrates are good indicators of ecological change in freshwater environments. Changes in density (numbers) can indicate changes in productivity of algae (e.g. periphyton), which may suggest increased nutrient inflows. Because different macroinvertebrate species have different tolerances to environmental factors, such as dissolved oxygen, chemical pollutants and fine sediment, the presence or absence of different species can also indicate changes in water quality.

Taxonomic richness (number of different types of animals); Ephemeroptera, Plecoptera, Trichoptera (EPT) number and percentage (Lenat 1988); the Macroinvertebrate Community Index (MCI) (Stark 1985); and the Quantitative Macroinvertebrate Community Index (QMCI) (Stark 1993), are typical indices that are used to assess macroinvertebrate community health. The MCI uses the occurrence of specific macroinvertebrate taxa to determine the level of organic enrichment in a stream, using the following formula:

$$\mathrm{MCI} = \left(\frac{\sum \text{of taxa scores}}{\text{Number of scoring taxa}} \right) \mathrm{X}\ 20$$

Taxa are scored between 1 and 10, with low scores indicating high tolerance to organic pollution and high scores indicating taxa that will only be found in “pristine rivers” (Stark 1985). A site score is obtained by summing the scores of individual taxa and dividing this total by the number of taxa present at the site, then multiplying by 20. Scores can range from 0 (no species present) to 200, with different scores indicating different pollution status (Table 16).

The SQMCI (Stark 1993) uses the same approach as the MCI but weights each taxa score on the abundance of the taxa within the community. As for MCI, QMCI scores can be interpreted in the context of national guidelines (Table 16).

$$\mathrm{QMCI} = \sum \frac{\text{Taxa Score X No. present in that taxa}}{\text{Total No. present}}$$

Table 16 Interpretation of Macroinvertebrate Community Index values from stony riffles (after Boothroyd & Stark 2000).

Interpretation	MCI	SQMCI
Clean water	>120	>6.00
Doubtful quality	100-119	5.00-5.99
Probable moderate pollution	80-99	4.00-4.99
Poor water quality	<80	<4

MCI and QMCI scores may be affected by a number of factors other than pollution (e.g. bed stability, recent flow conditions and regimes, water temperature, habitat type). Consequently, a useful approach is to compare MCI and QMCI scores upstream and downstream of an impact. In such a situation the differences between scores for the index are much more important than the actual scores.

5.4 What is REC?

The River Environment Classification

Water quality patterns in the West Coast Region were investigated using the framework of the River Environment Classification (REC) (Snelder et al. 2003).

The REC characterises river environments at six hierarchical levels, each corresponding to a controlling environmental factor. The factors, in order from largest spatial scale to smallest, are climate, source-of-flow, geology, land cover, network position and valley landform. Each factor is associated with a suite of physical processes that influence water quality, and vary at approximately the same scale. For example, the climate level of the REC is associated with precipitation and thermal regimes that vary at scales of 10^3 – 10^4 km2. Each REC factor is composed of 4 – 8 categories that differentiate all New Zealand rivers. Categories at each classification level and their abbreviations [relevant to the West Coast] are shown in Table 17. The number of possible classes at any level is equal to the number of categories at that level multiplied by the number of classes at the preceding level. For example, the source of flow level has 24 possible classes (6 climate classes × 4 source-of-flow classes). At the geology level there are 144 possible classes, and 1152 at the land-cover level (from Larned et al. 2005).

Typical use of the REC involves grouping REC classes from each level e.g. climate/source-of-flow/geology/land-cover/network position/valley landform. However, Regional Council sites were analysed mainly via individual controlling environmental factors because there was not in most cases sufficient replication for sites to be compared based on combined REC levels. Not all classes occurring in New Zealand are represented in the West Coast Regional Council dataset, and those that are, are listed in Table 17. Map distributions of source of flow, geology, and land cover are shown in Figure 27 to Figure 29

Table 17 REC classes found in the West Coast region. Classes are hierarchical starting at the top in order of: climate/source-of-flow/geology/land-cover/network position/valley landform. Those in bold are represented in the Regional Council SOE dataset.

Class	Definition
Climate:	
CX	Cool, extremely wet (mean annual temp. < 12, rainfall > 1000mm)
CW	Cool, wet (mean annual temp. < 12, rainfall > 500, < 1000 mm)
CD	Cool, dry (mean annual temp. < 12, rainfall < 500mm)
WW	Warm, wet (mean annual temp. > 12, rainfall > 500, < 1000 mm)
Source of flow:	
L	Low elevation (> 50 % of annual precipitation occurs < 400m ASL)
H	Hill (> 50 % of annual precipitation occurs between 400 and 1000m ASL)
M	Mountain (> 50 % of annual precipitation occurs > 1000m ASL)
Lk	Lake sourced
S	Spring
Gl	Glacial
Geology:	
Al	Alluvial and sand
HS	Hard sedimentary
SS	Soft sedimentary
Pl	Plutonic
St	Schist
M	Miscellaneous
Landcover	
IF	Indigenous forest
P	Pastoral
T	Tussock
S	Scrub
EF	Exotic forest
W	Wetland
U	Urban
Stream order:	
HO	High order (> 4)
MO	Mid order (3-4)
LO	Low Order (< 3)
Valley landform:	
HG	High gradient (slope > 0.04)
MG	Medium gradient (slope 0.02-0.04)
LG	Low gradient (slope < 0.02)

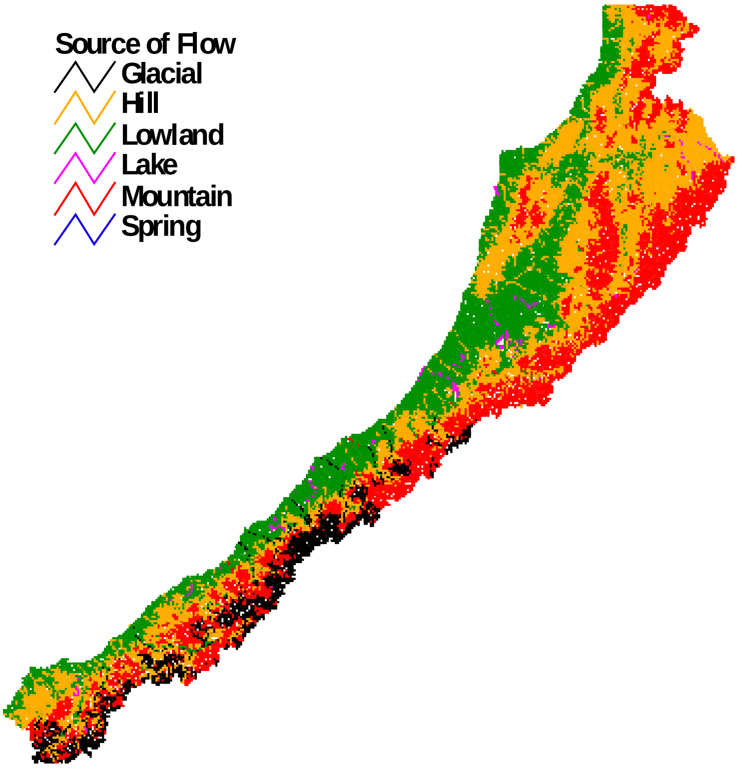


Figure 27 Map of the West Coast region showing source of flow according to REC.

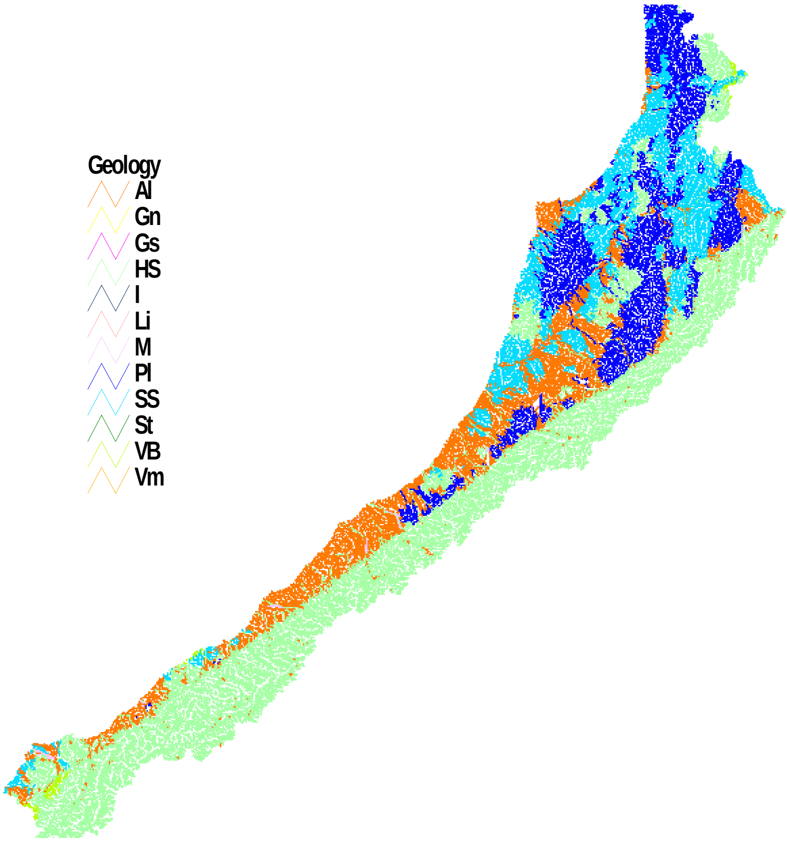


Figure 28 Map of the West Coast region showing geology class according to REC. From the key, only Al (alluvial), HS (hard sedimentary), M (metamorphic), Pl (plutonic), and SS (soft sedimentary), are present on the map.

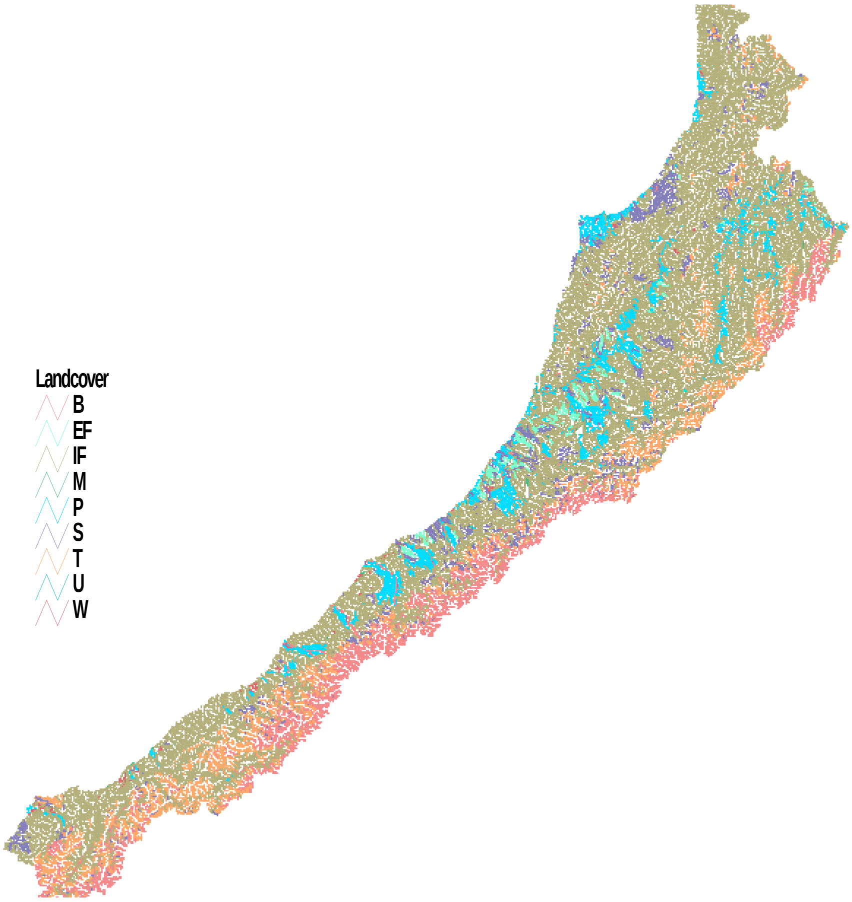


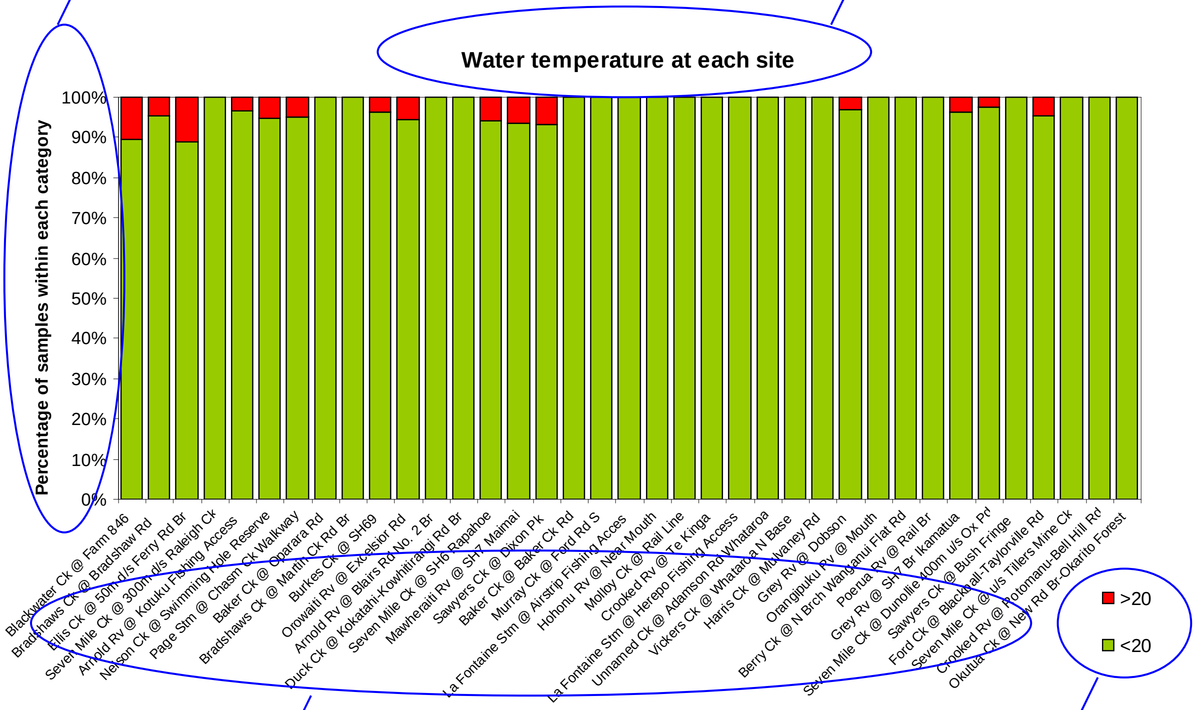
Figure 29 Map of the West Coast region showing land cover type according to REC.

5.5 Percentage bar graphs: How they work

These are located in Section 2.2. Below is an example with some additional information to assist with their interpretation.

This indicates the percentage of samples that are within the categories indicated in the legend at the bottom right of each graph.
Note that the number of samples making up the 100% may differ between sites.

States the variable measured (in this case water temperature), a bar is presented for each site.
Note that data from the past 10 years has been used for each site.



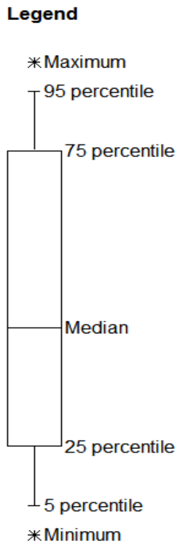
The bottom X axis shows what site each bar represents.
All data recorded for each site from 2004 - 2014 has been incorporated into each bar, and the amount of data might vary between sites. This is why a proportion has been used to standardise sites and make comparison easier. Sites are ordered left to right based on lowest to highest site median for that variable.

The legend indicates what the categories are for that variable, and what colour they are. Categories have been selected according to relevant guidelines for that variable.

We know from this graph, representing temperature, that Blackwater Ck @ Farm 846 had the highest median temperature, and Okutua Stream @ Okarito Forest the lowest median temperature. At Blackwater Ck @ Farm 846, 10% of all samples taken there were above 20 °C, hence 90% of all samples collected there were below 20 °C. This temperature (20 °C) is a common threshold considered relevant for many fish species intolerant of higher temperatures. Note that it is possible for a site to have a higher occurrence of samples over 20 °C (e.g. Seven Mile Creek @ Rapahoe), but have a lower median temperature than its neighbor to the left that will always have a higher median (e.g. Duck Creek @ Kokatahi – Kowhitirangi Road).

5.6 Box and whisker plots - Regional Council sites

In each of the following box and whisker graphs sites are listed in alphabetical order along the X axis so comparison can be made between multiple sites on the same river.



Box and whisker plots illustrate how data are distributed around a central, or median, value. The 'box' represents the range of the central 50% of values around the median. The median is the line through the box. Values that are beyond the box account for the other 50% of values (25% at the top and bottom). These values are represented by the 'whiskers' and asterisk points. The 'whiskers' terminate at the 5th and 95th percentiles and the asterisk points show the maximum and minimum values. 20% of values fall between the 'whiskers' and the box at each end with 5% then falling between the end of the 'whiskers' and the asterisk points.

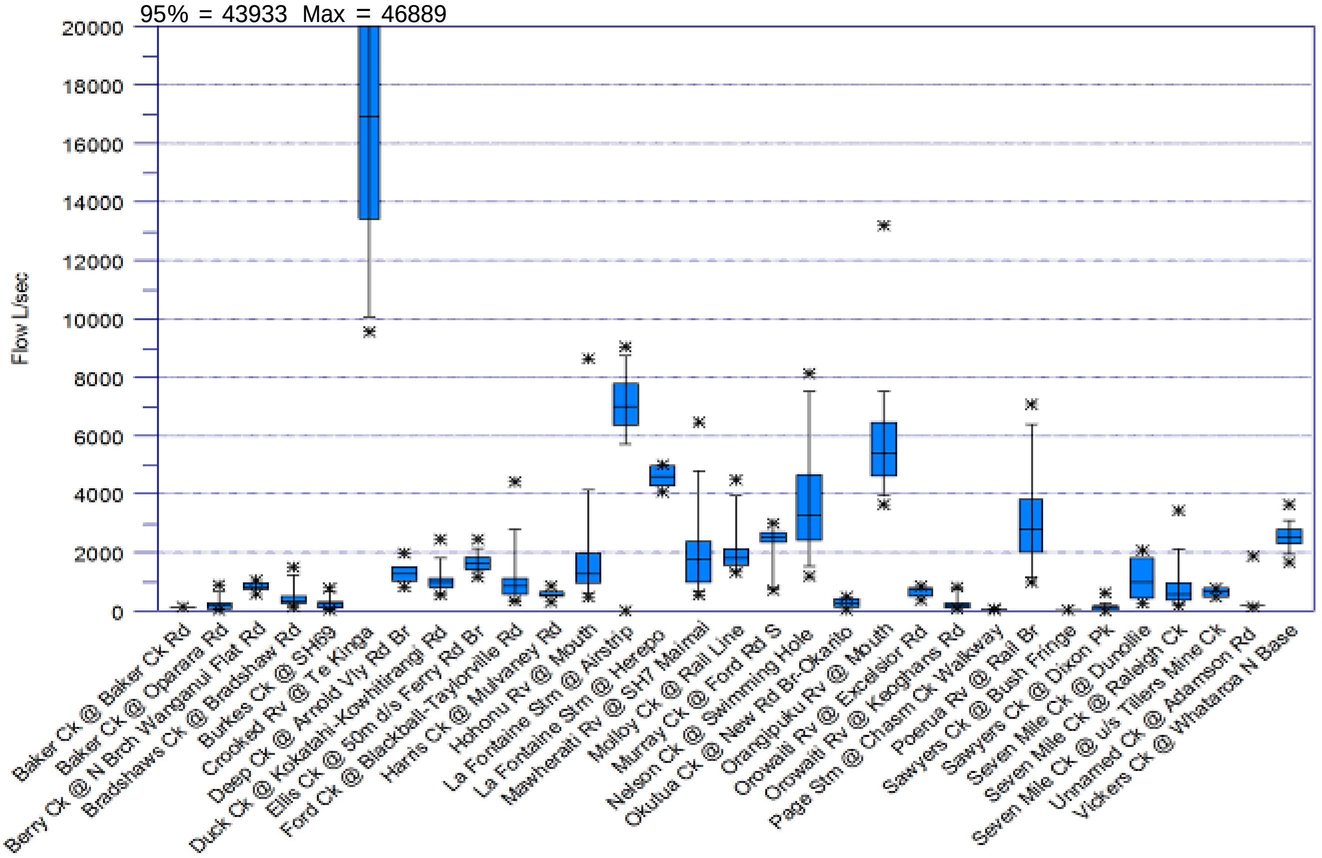


Figure 30 Box and whisker plot: Flow.

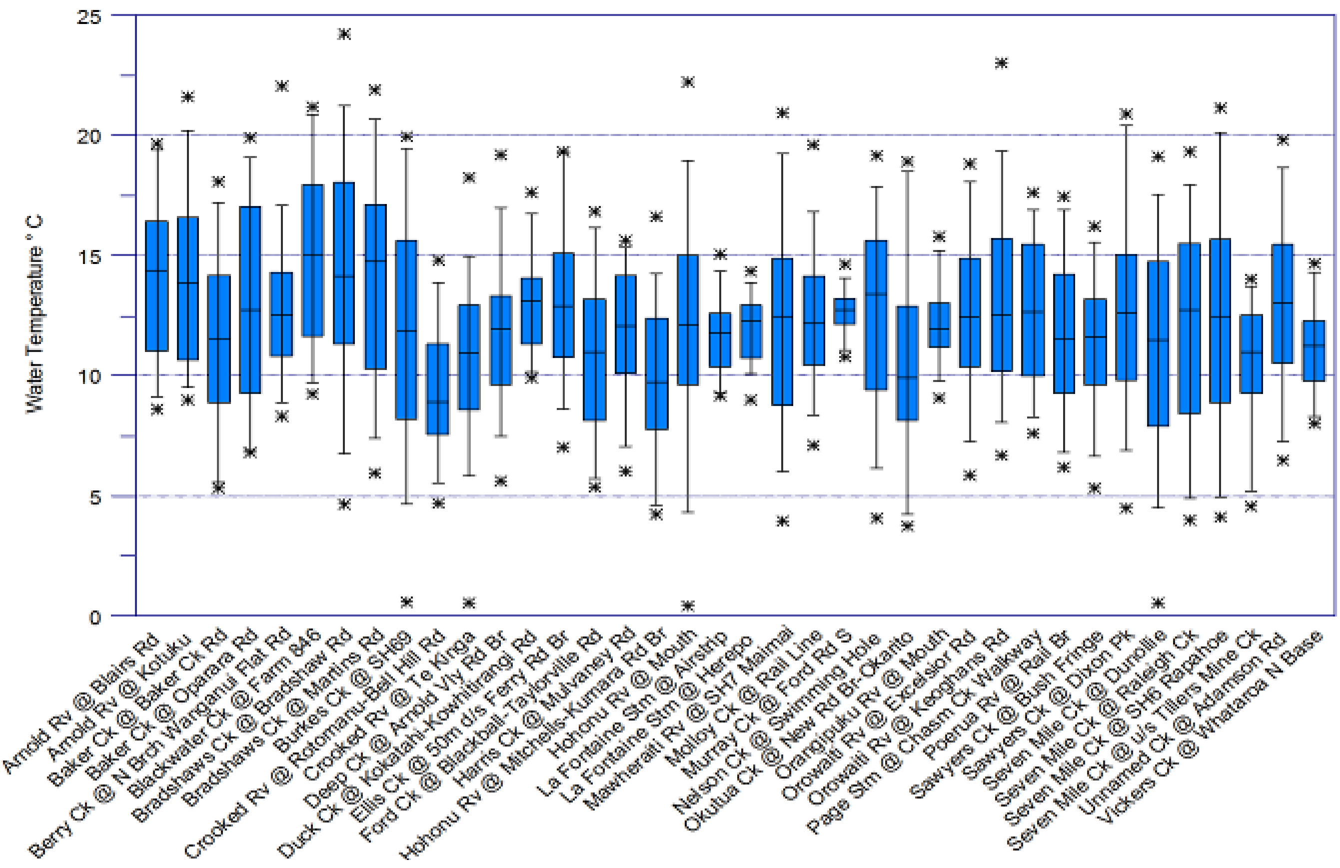


Figure 31 Box and whisker plot: Temperature

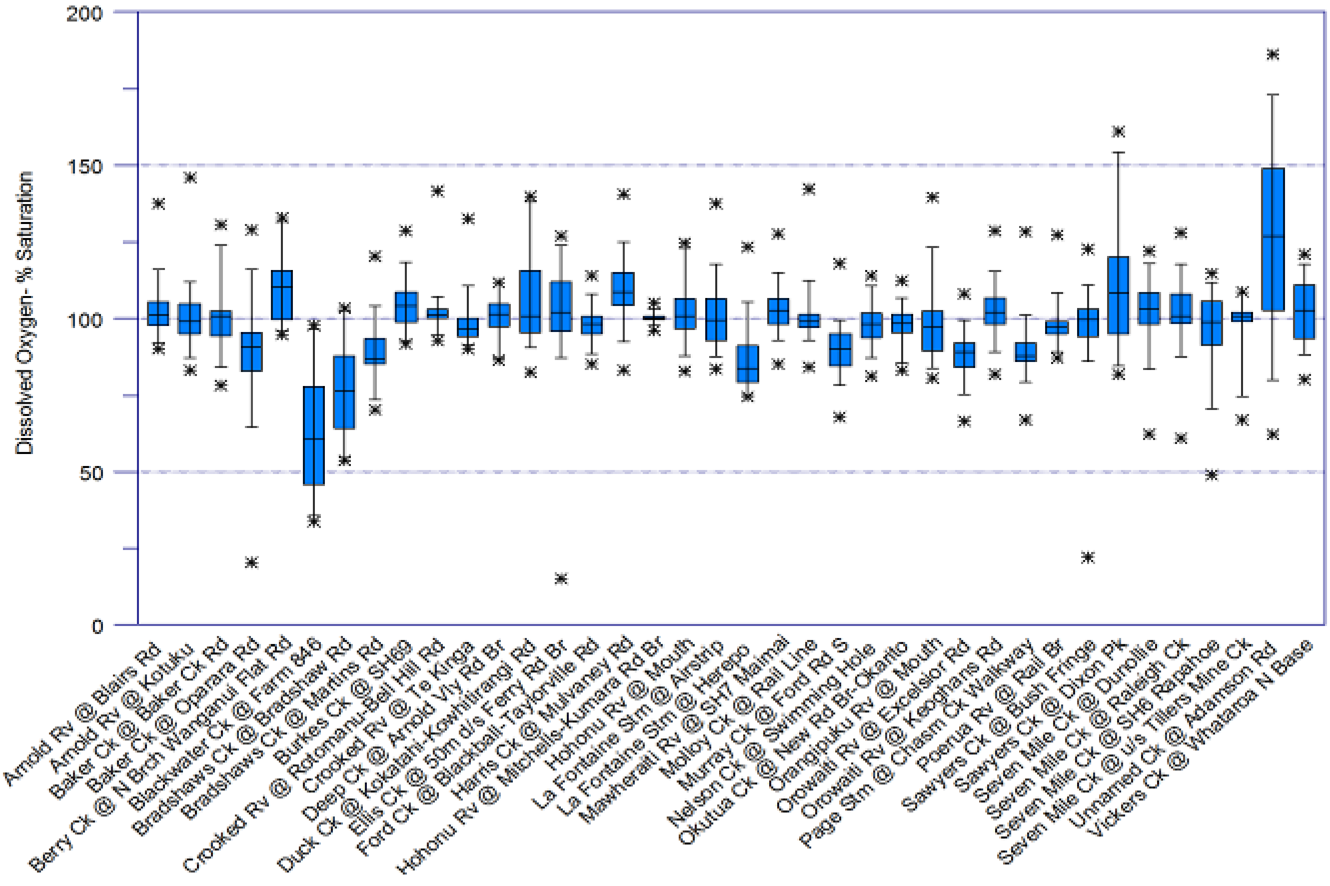


Figure 32 Box and whisker plot: Dissolved oxygen (% saturation).

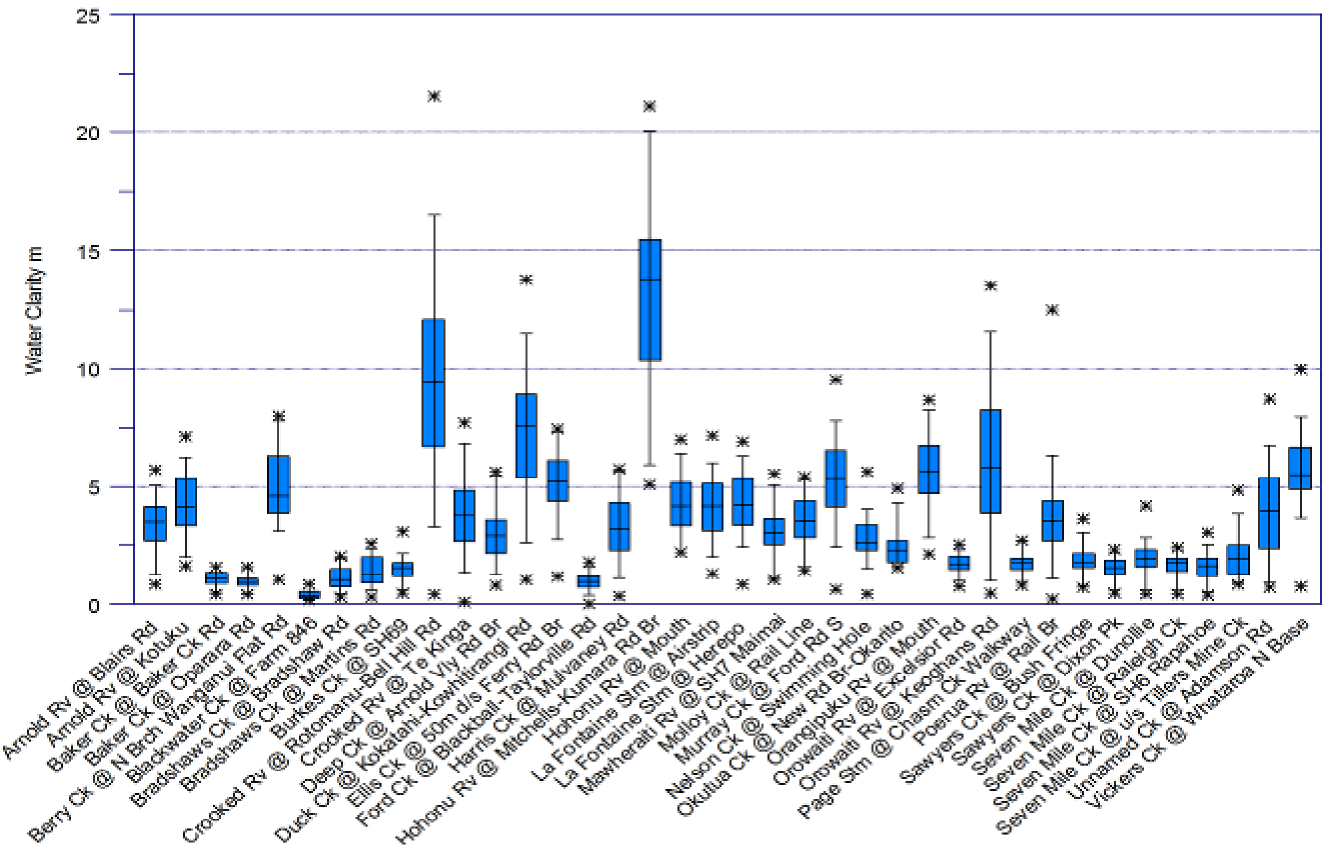


Figure 33 Box and whisker plot: Clarity.

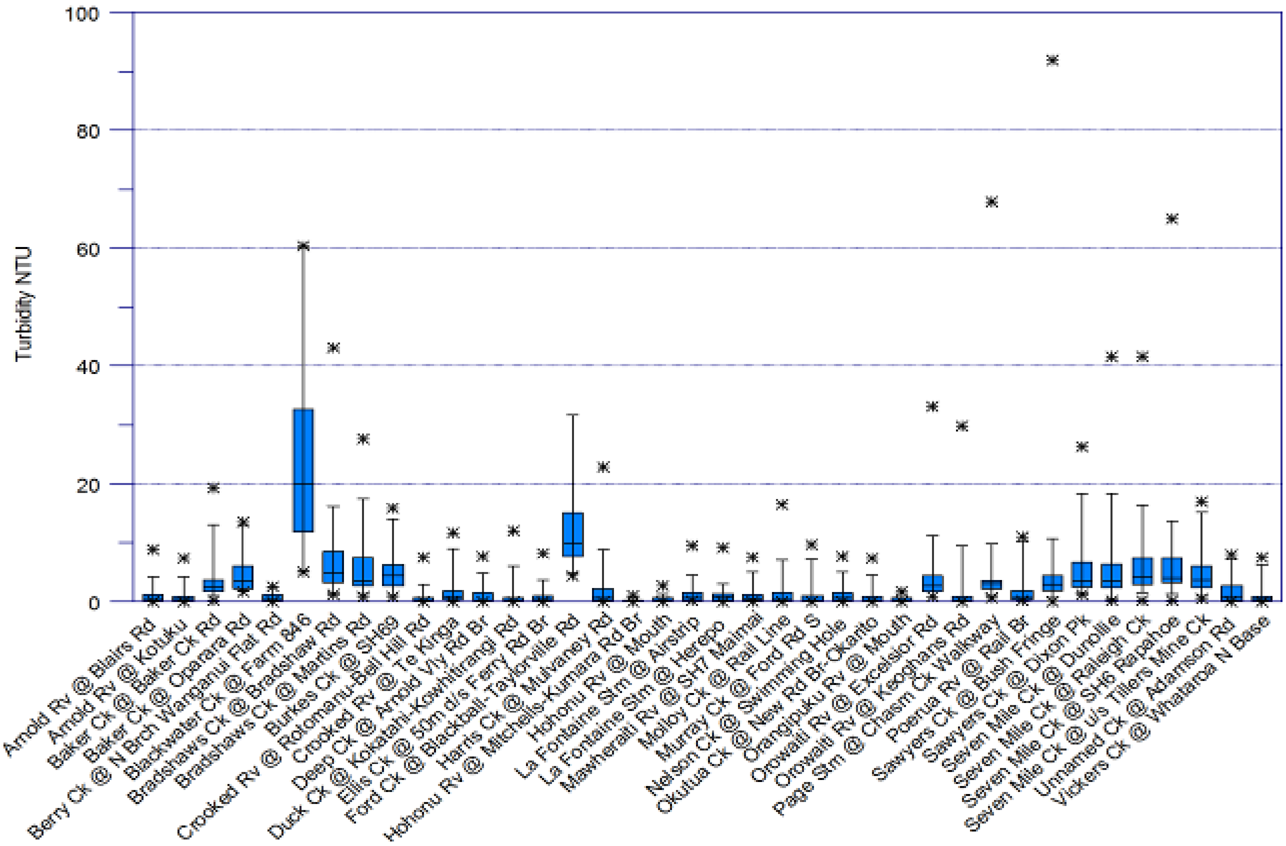


Figure 34 Box and whisker plot: Turbidity

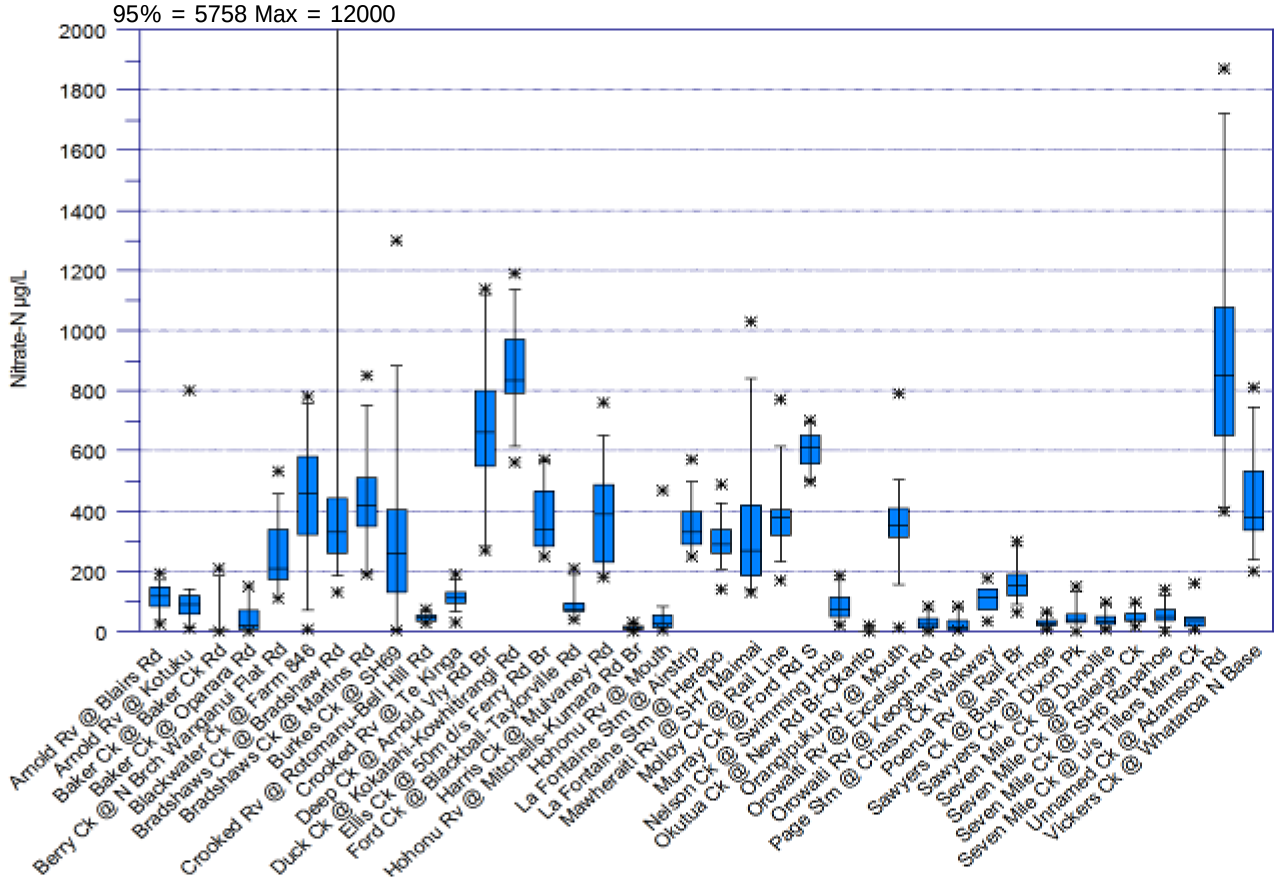


Figure 35 Box and whisker plot: Nitrate (NOx-N)

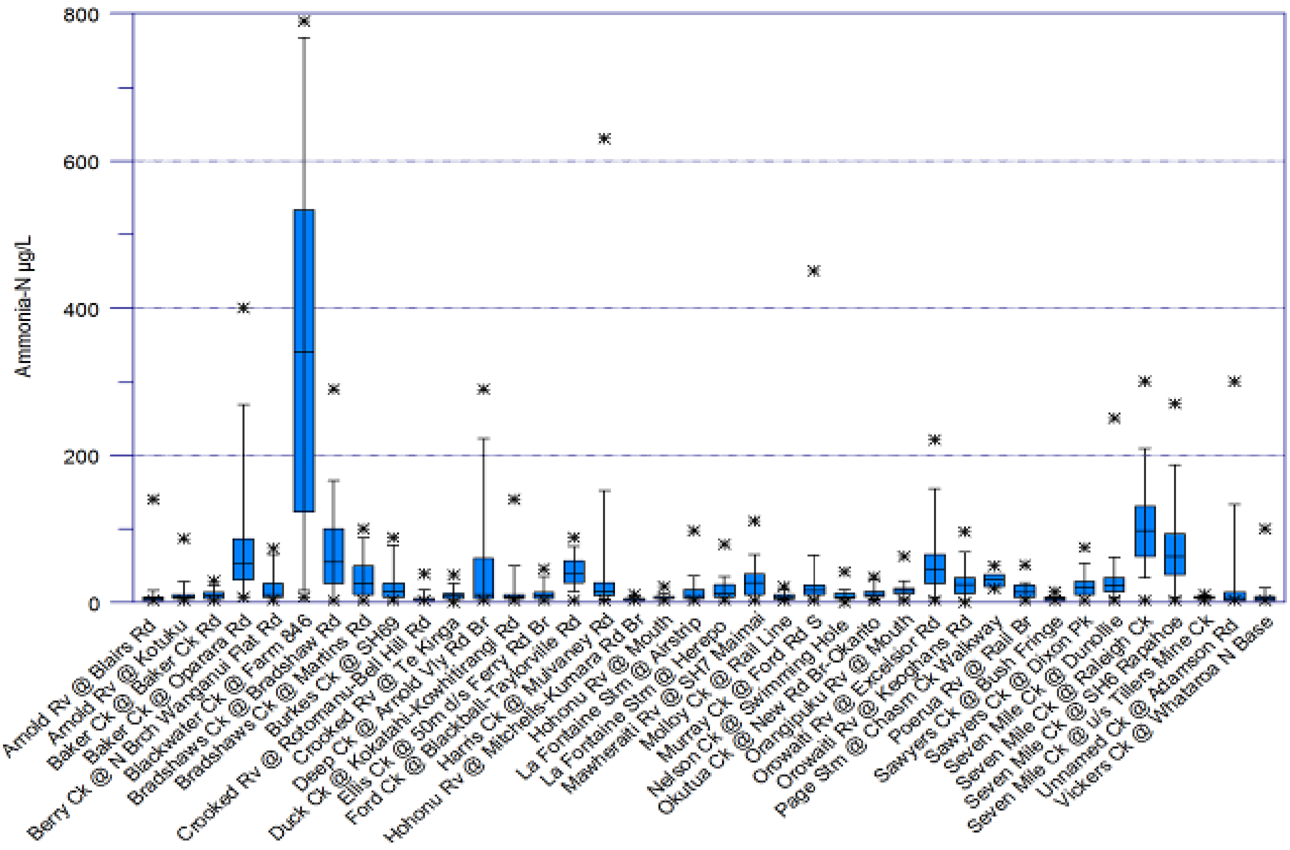


Figure 36 Box and whisker plot: Ammoniacal nitrogen (NH4-N)

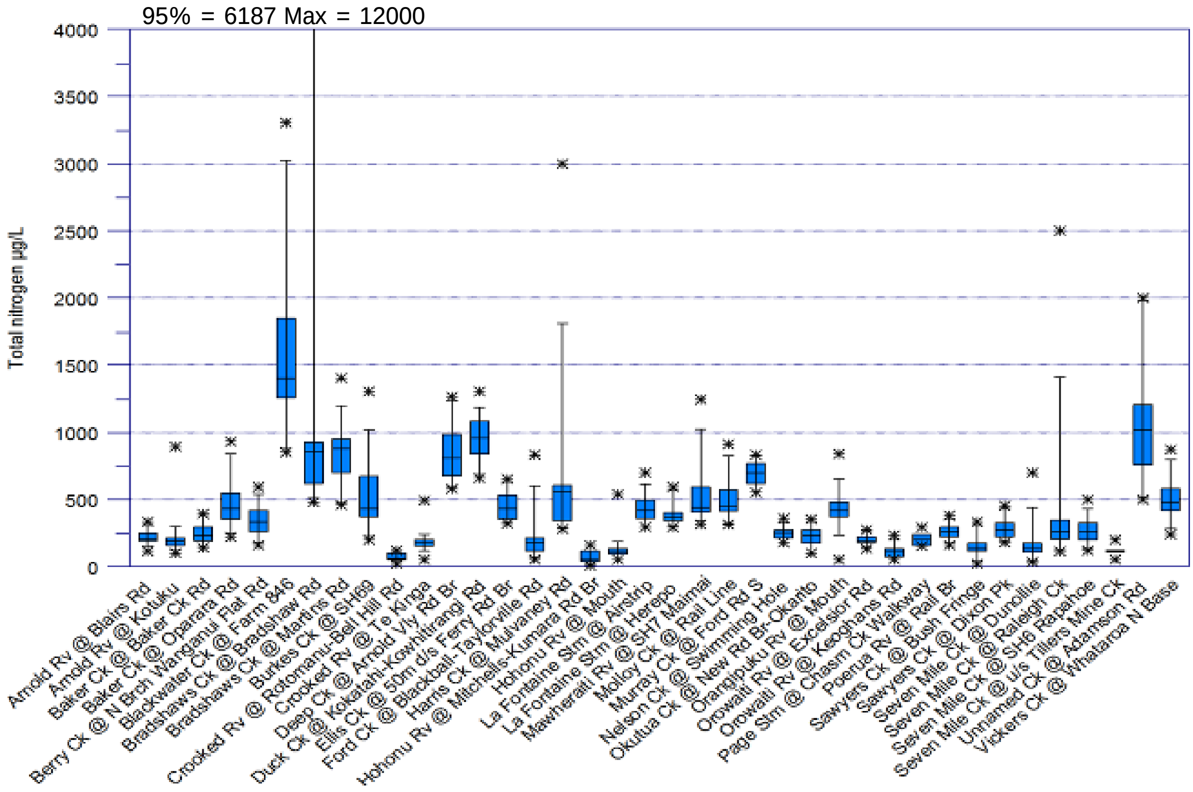


Figure 37 Box and whisker plot: Total nitrogen (TN).

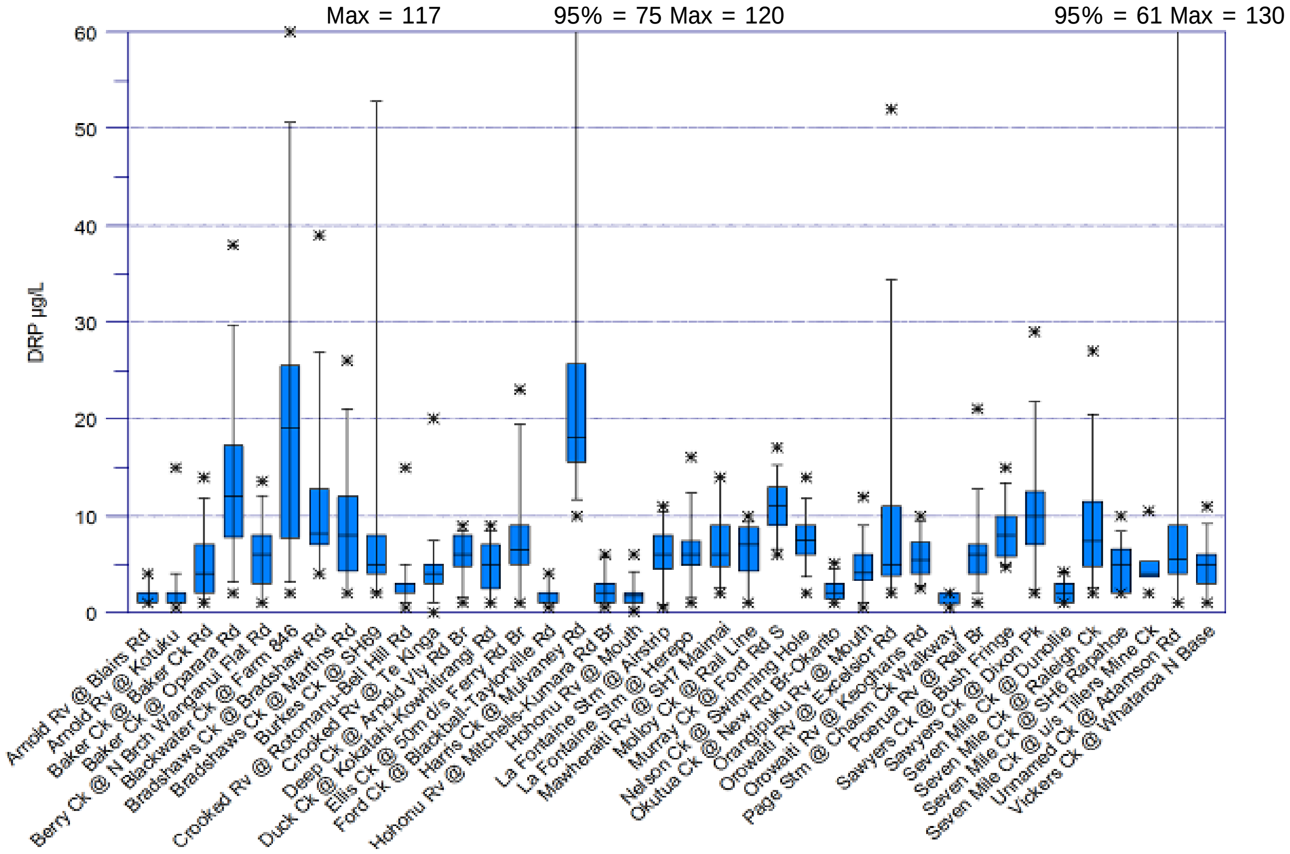


Figure 38 Box and whisker plot: Dissolved reactive phosphorus (DRP).

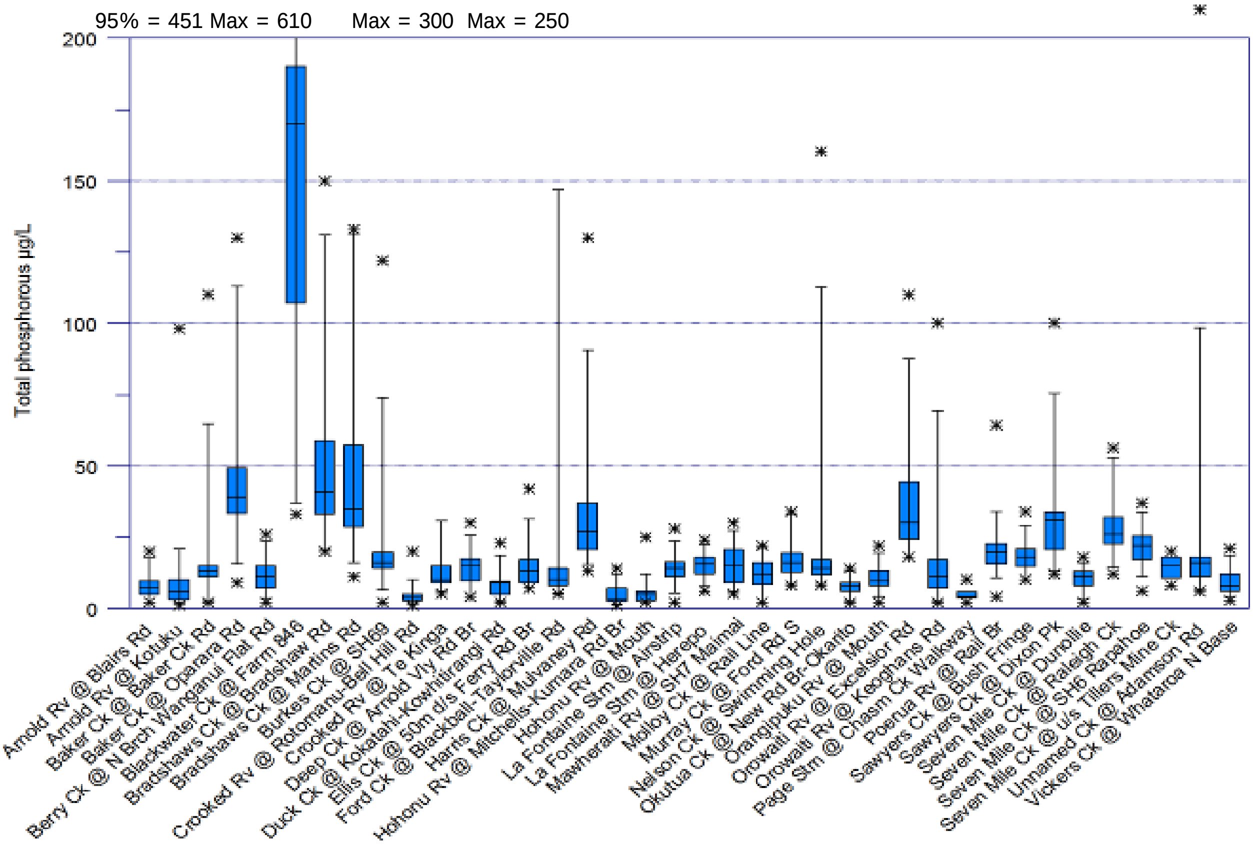


Figure 39 Box and whisker plot: Total phosphorus (TP).

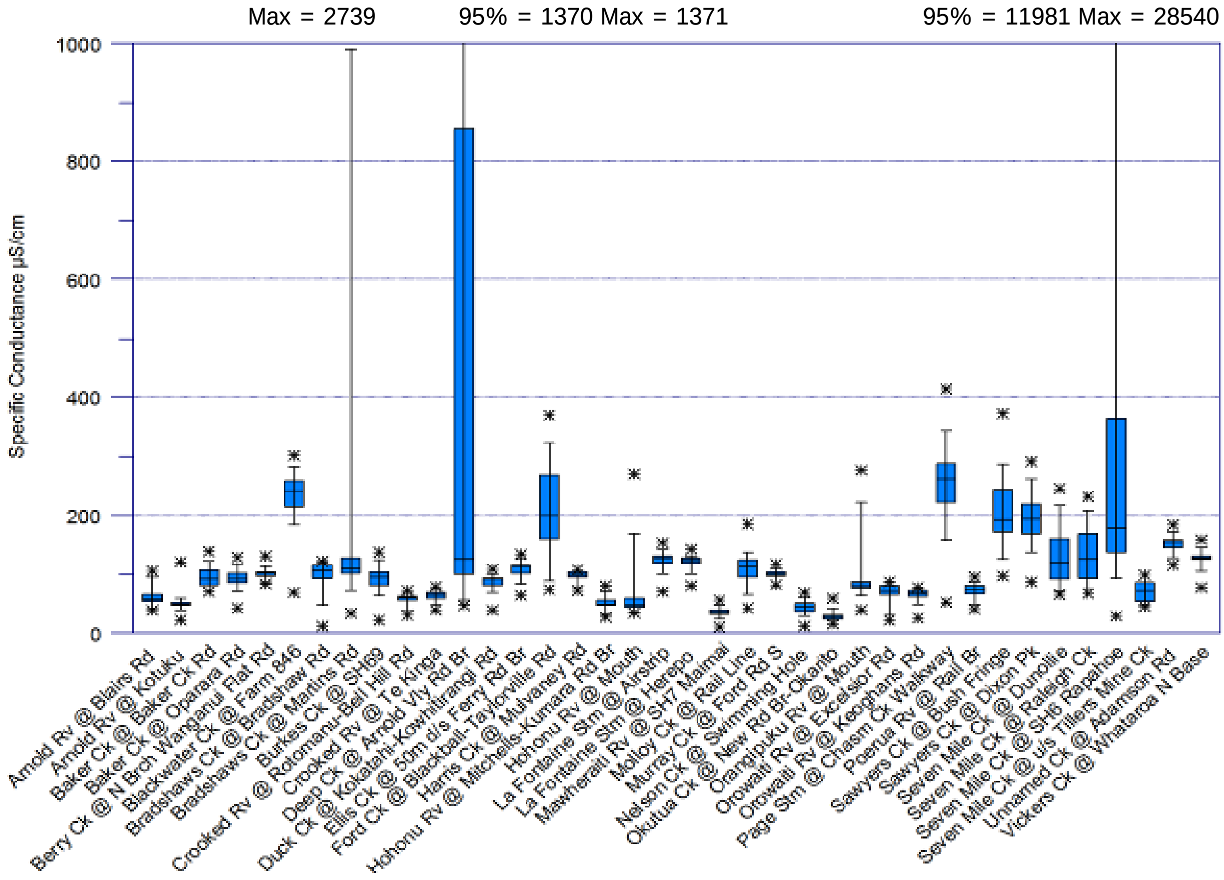


Figure 40 Box and whisker plot: Conductivity.

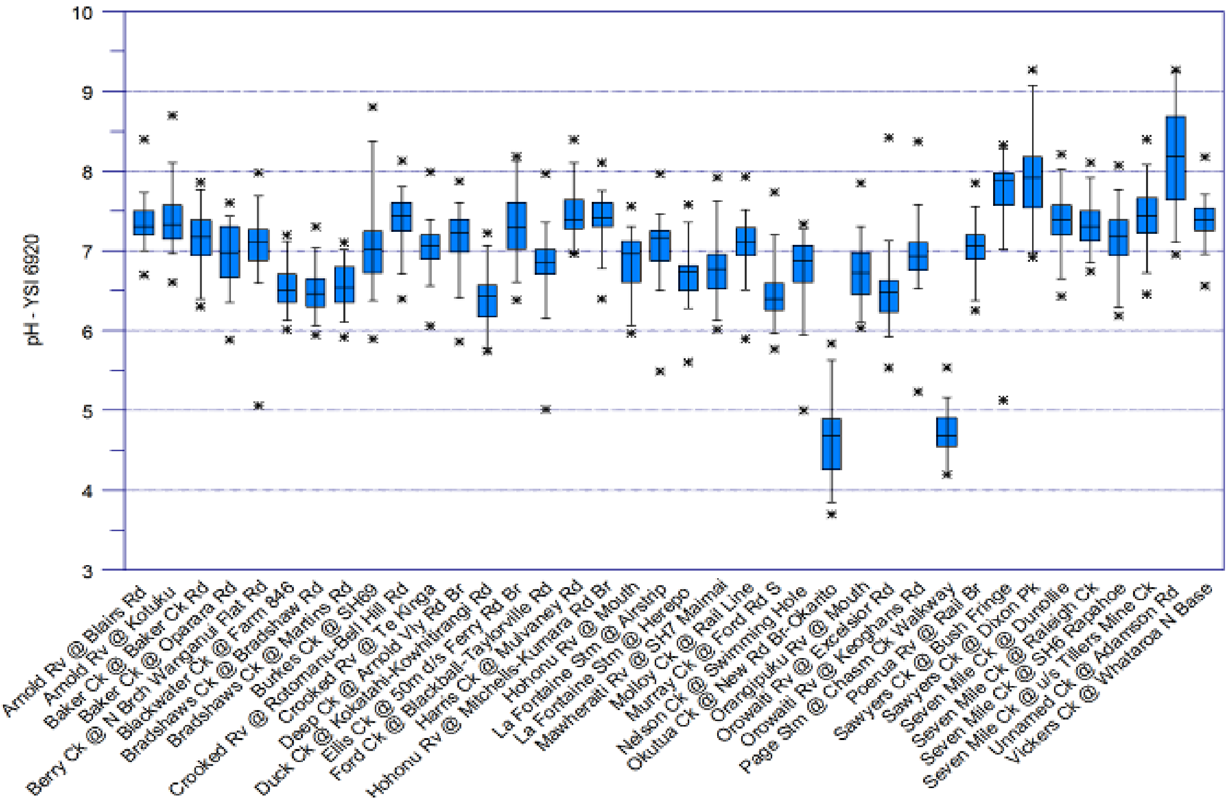


Figure 41 Box and whisker plot: pH.

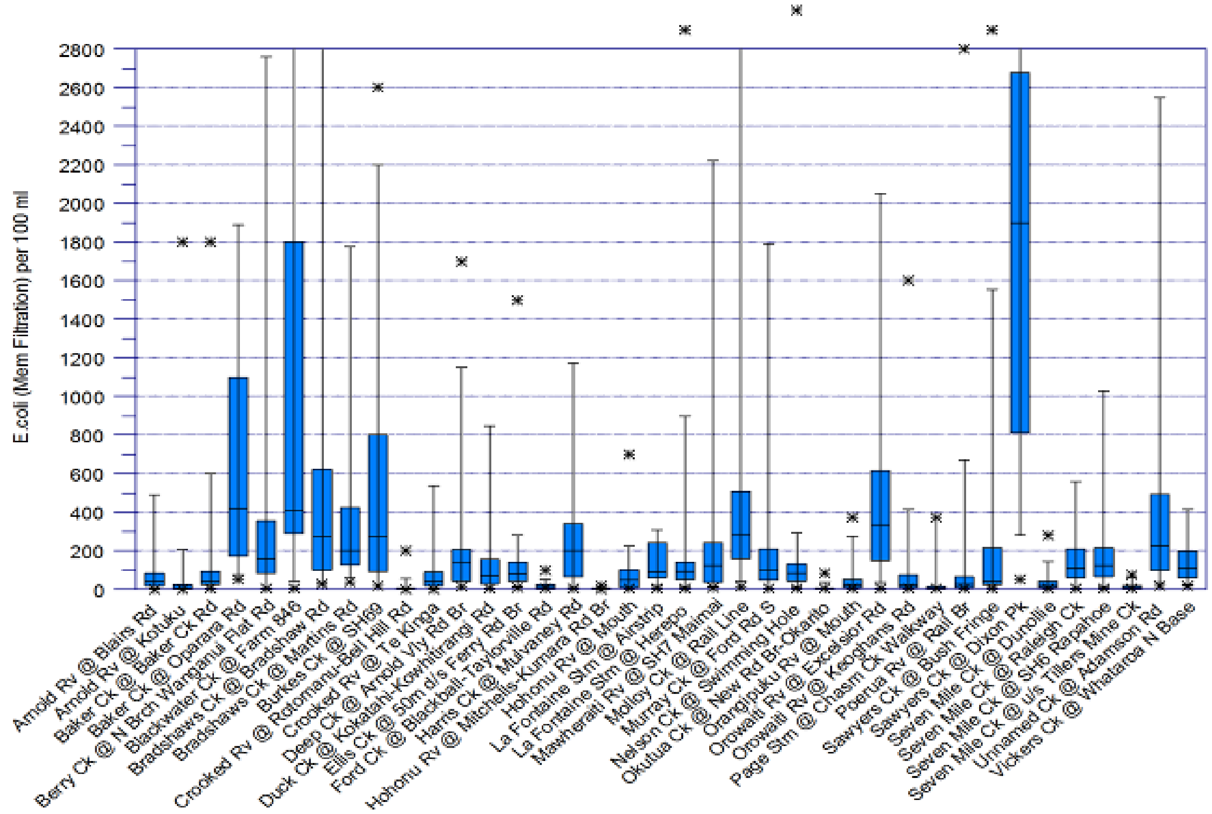


Figure 42 Box and whisker plot: E. coli - without maximum values shown.

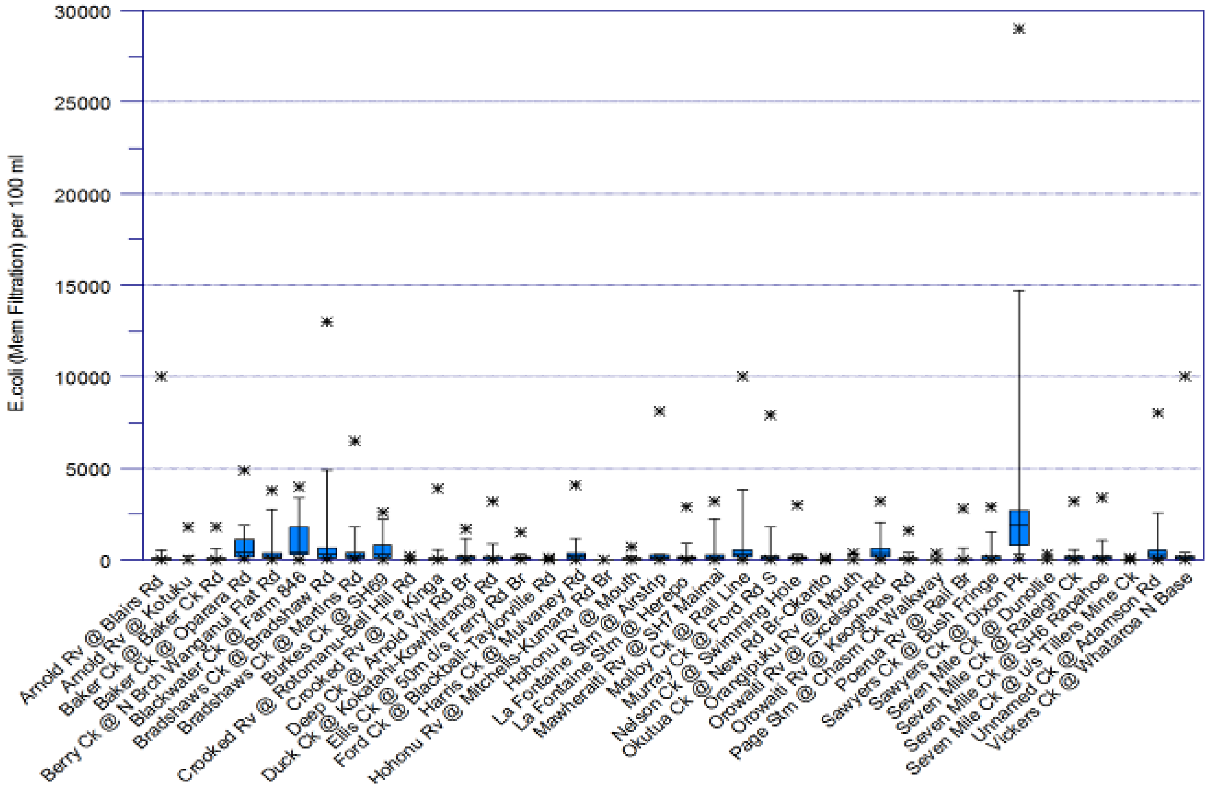


Figure 43 Box and whisker plot: E. coli – with maximum values shown.

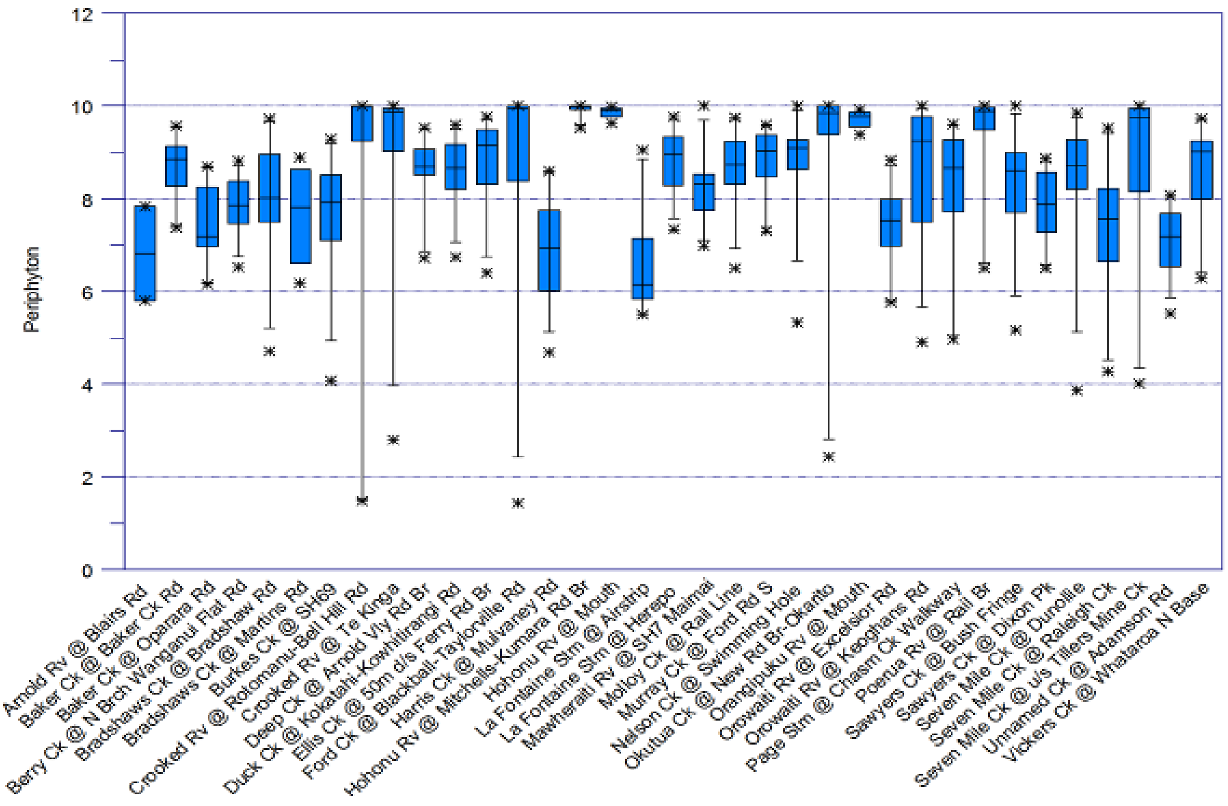


Figure 44 Box and whisker plot: Periphyton.

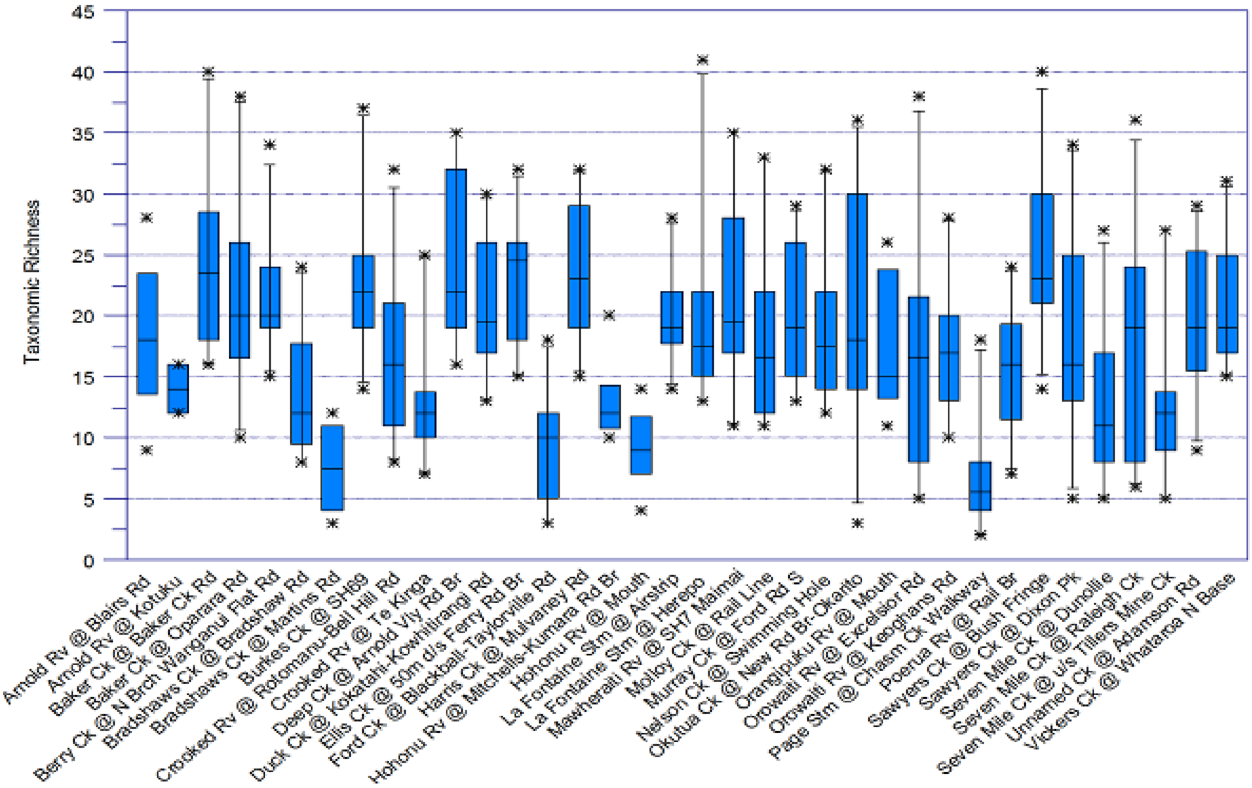


Figure 45 Box and whisker plot: Invertebrate taxonomic richness.

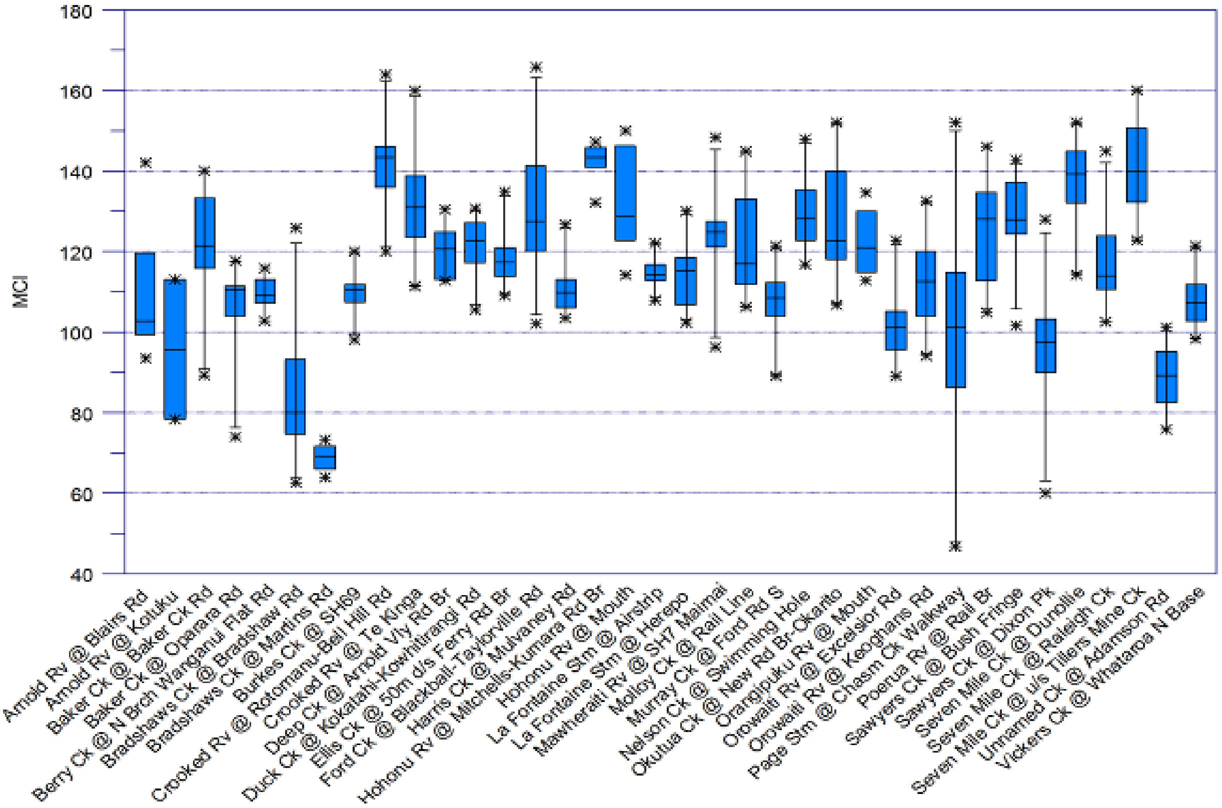


Figure 46 Box and whisker plot: Macroinvertebrate Community Index (MCI).

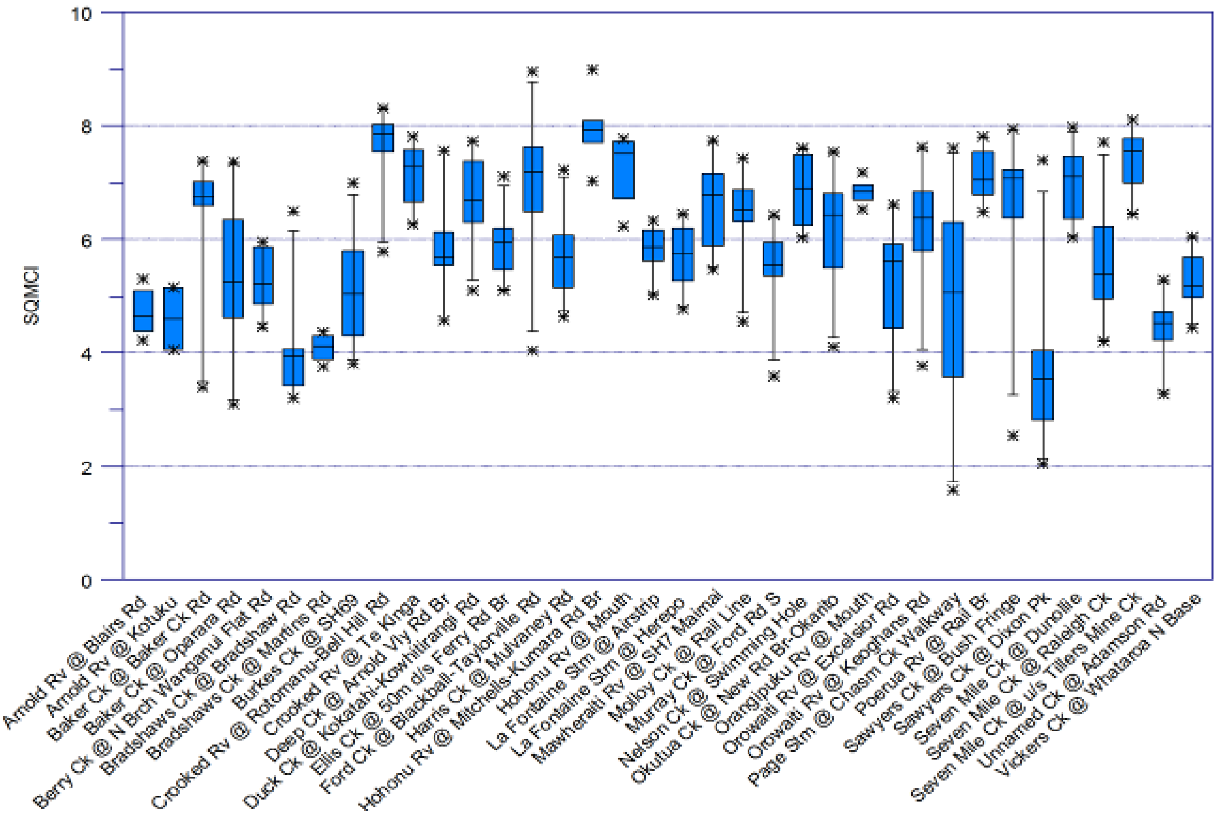


Figure 47 Box and whisker plot: Semi-Quantitative Macroinvertebrate Community Index (SQMCI).

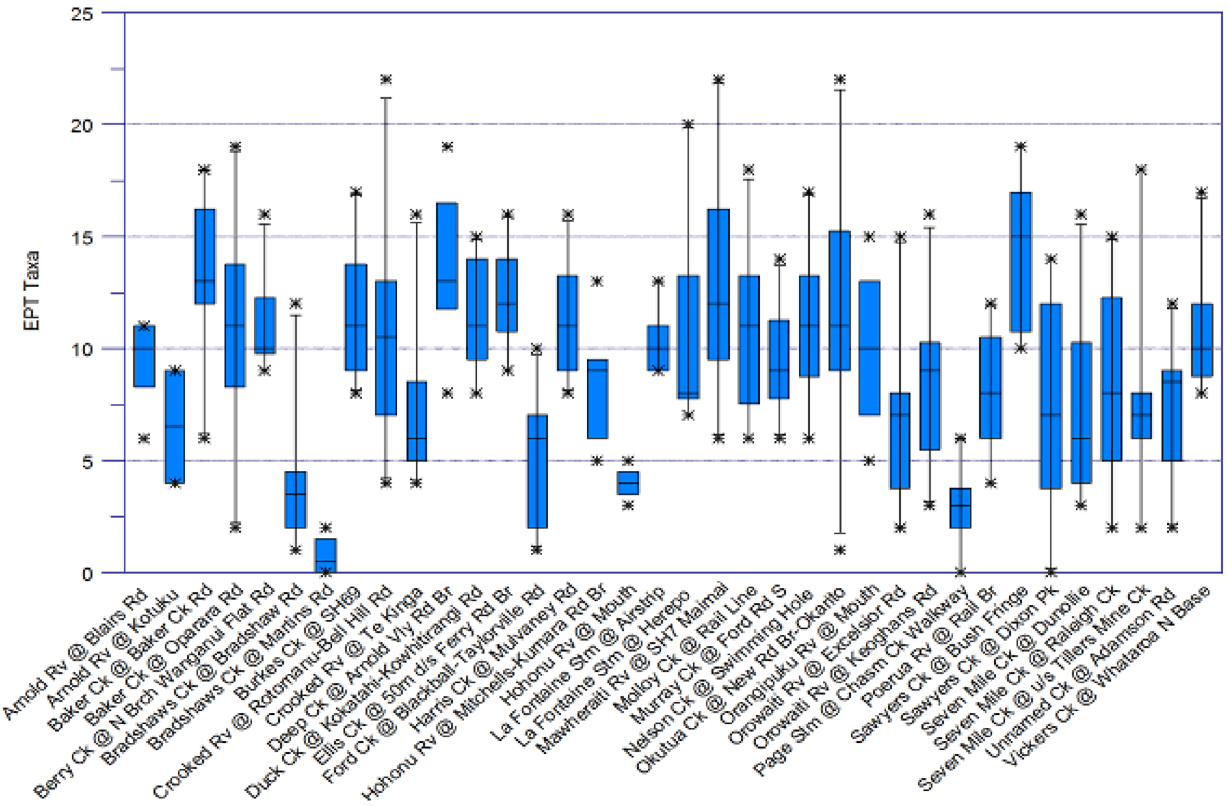


Figure 48 Box and whisker plot: EPT taxa.

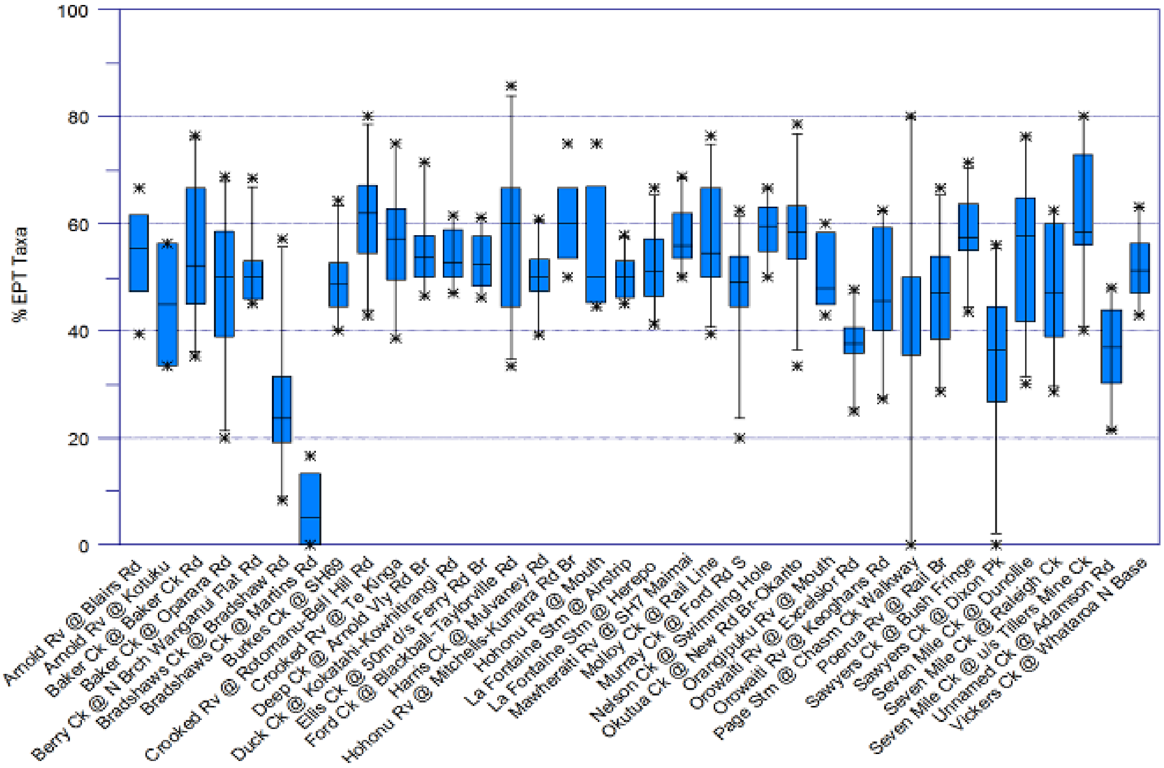
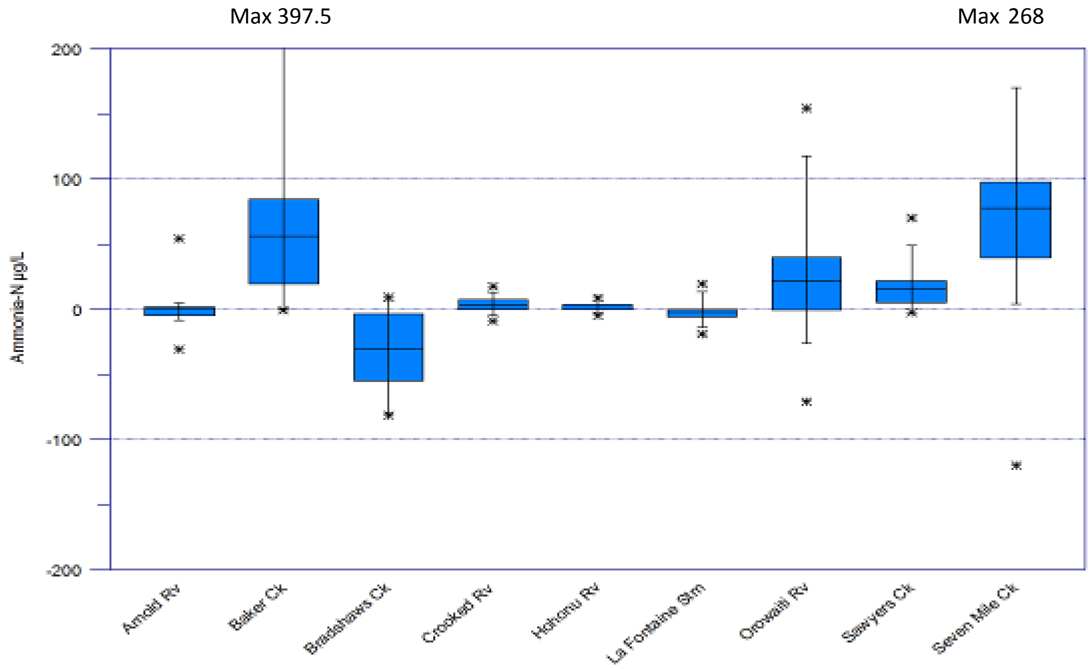


Figure 49 Box and whisker plot: % EPT.

5.7 Differences in water quality between paired upstream and downstream sites



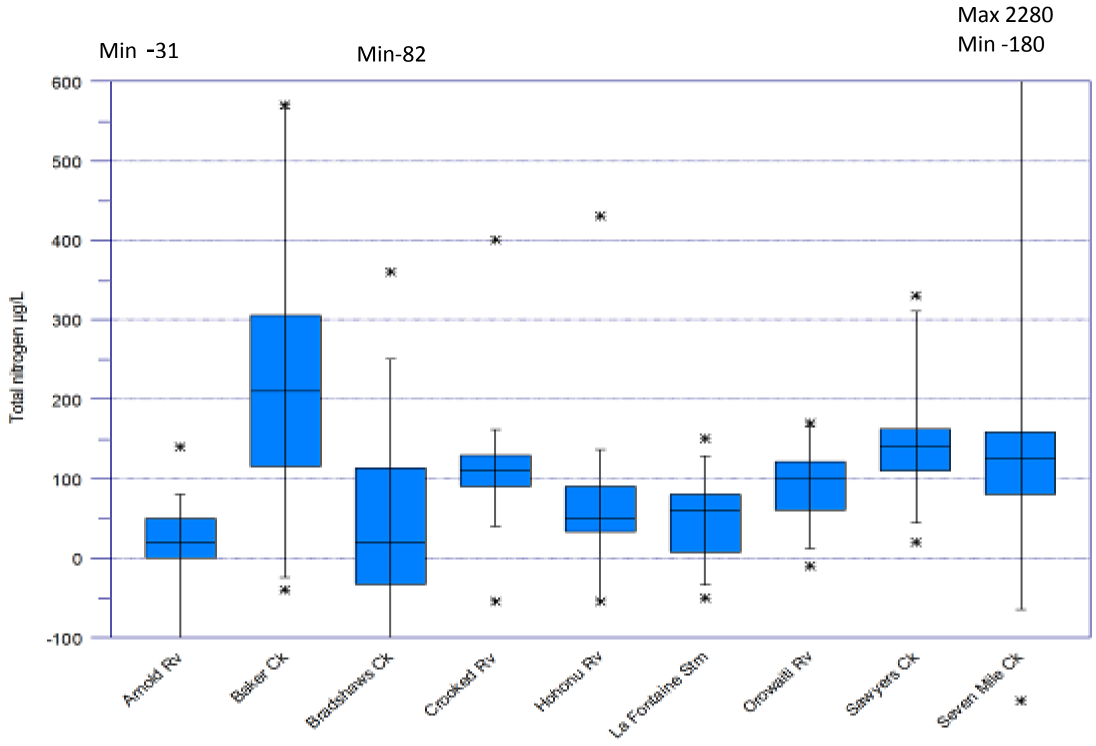


Figure 50 Differences between paired sites (downstream minus upstream values). Ammonia and total nitrogen,

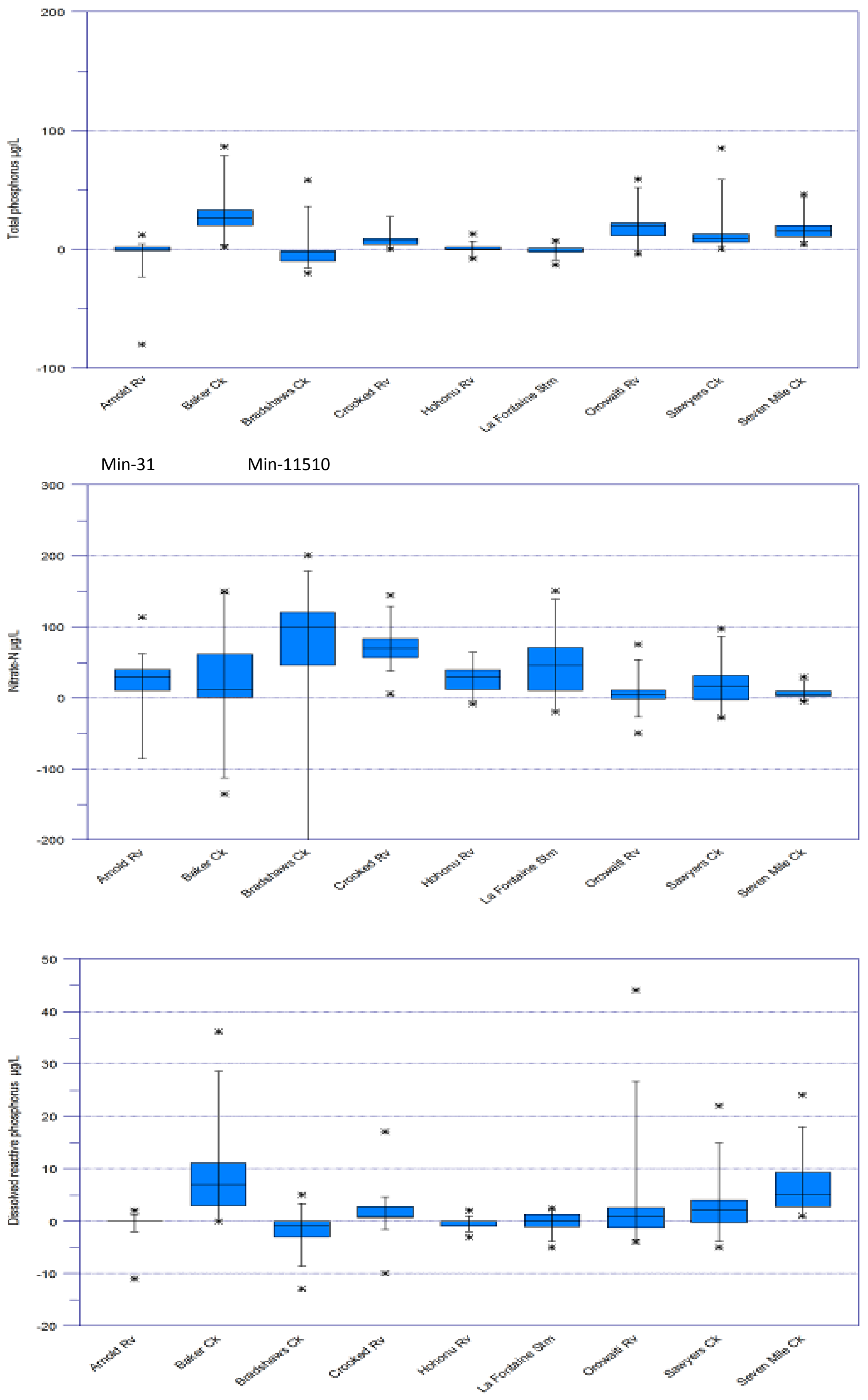


Figure 51 Differences between paired sites (downstream minus upstream values). Total phosphorus, nitrate and dissolved reactive phosphorus.

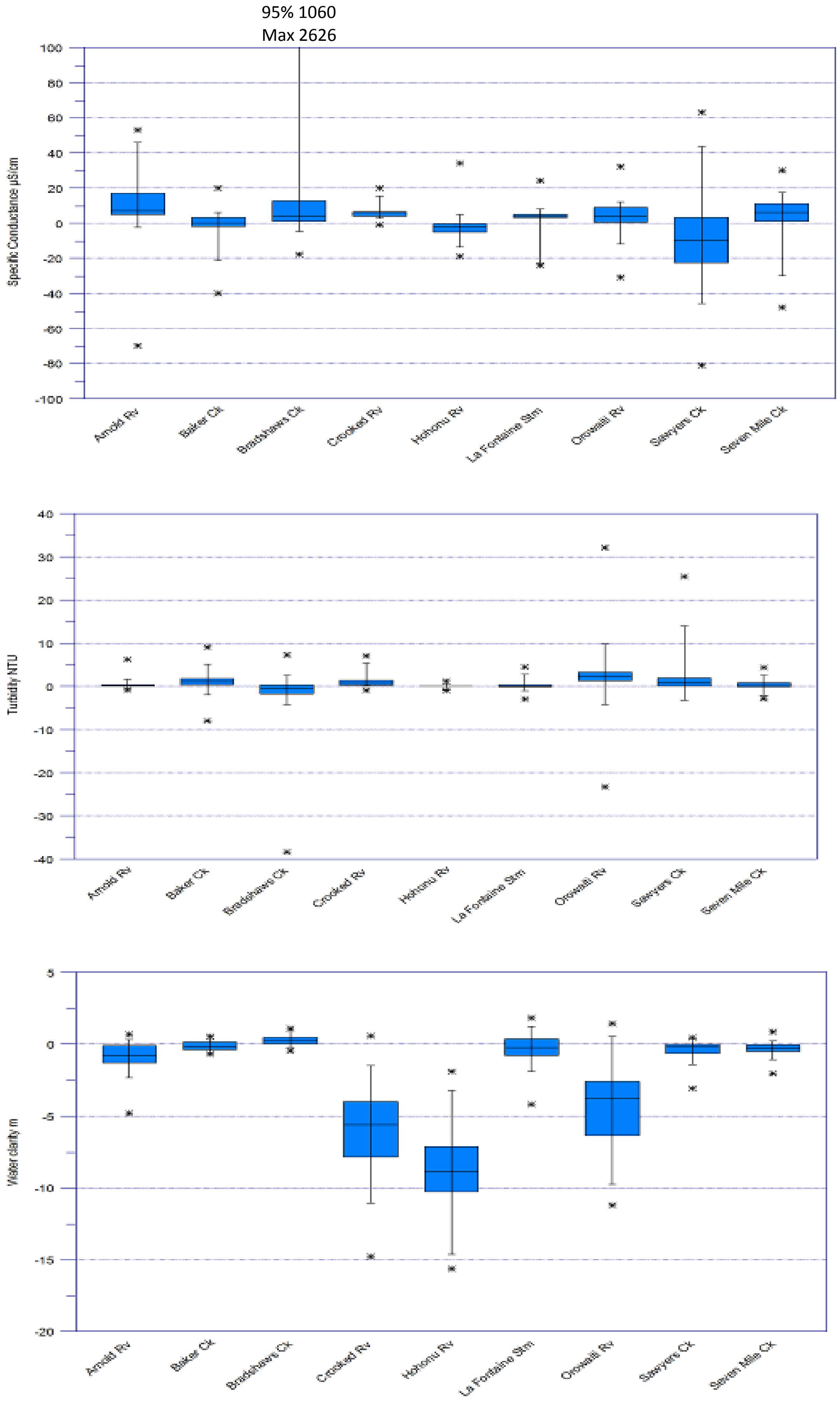


Figure 52 Differences between paired sites (downstream minus upstream values). Specific conductivity, turbidity and water clarity

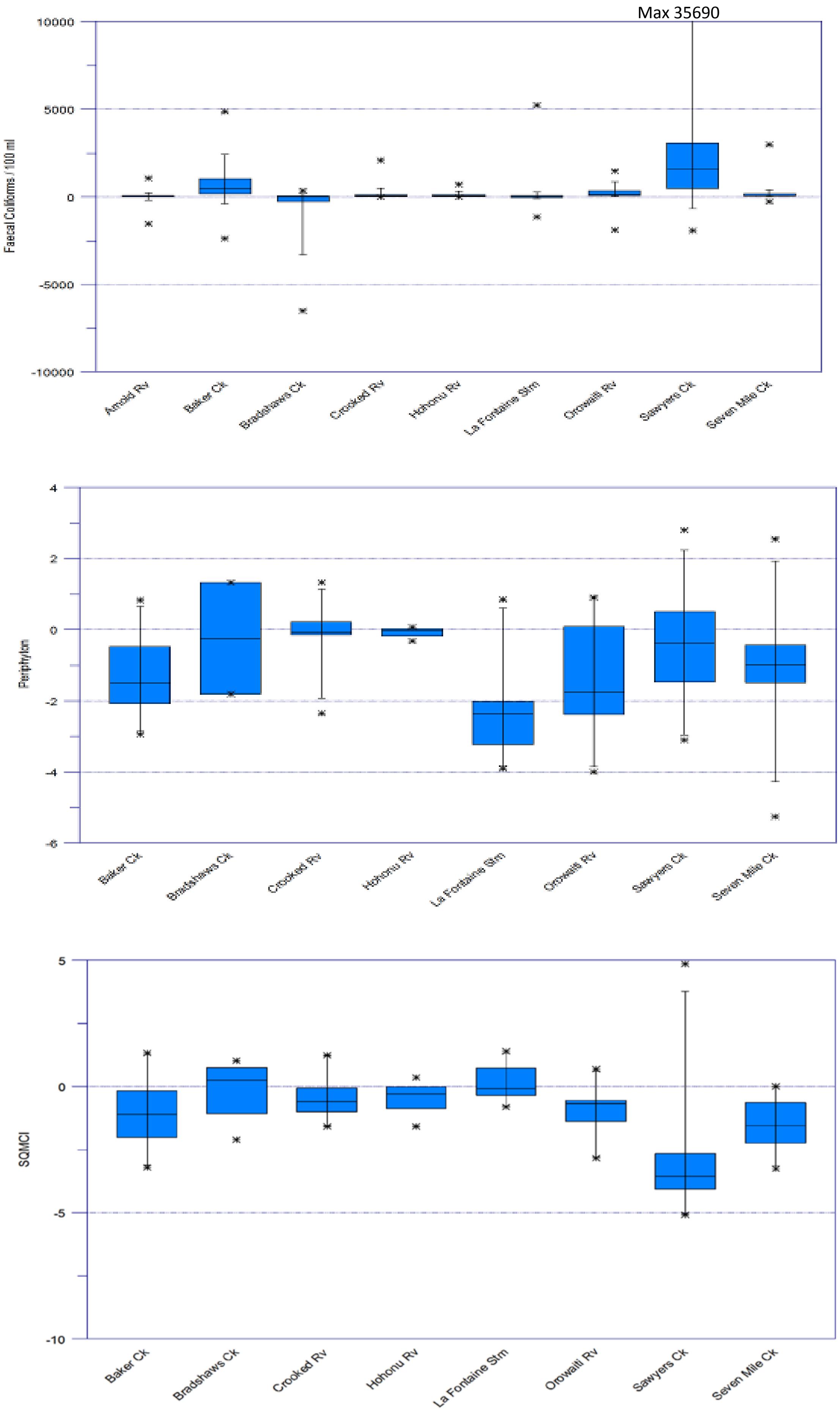


Figure 53 Differences between paired sites (downstream minus upstream values). Faecal coliforms, periphyton and SQMCI.

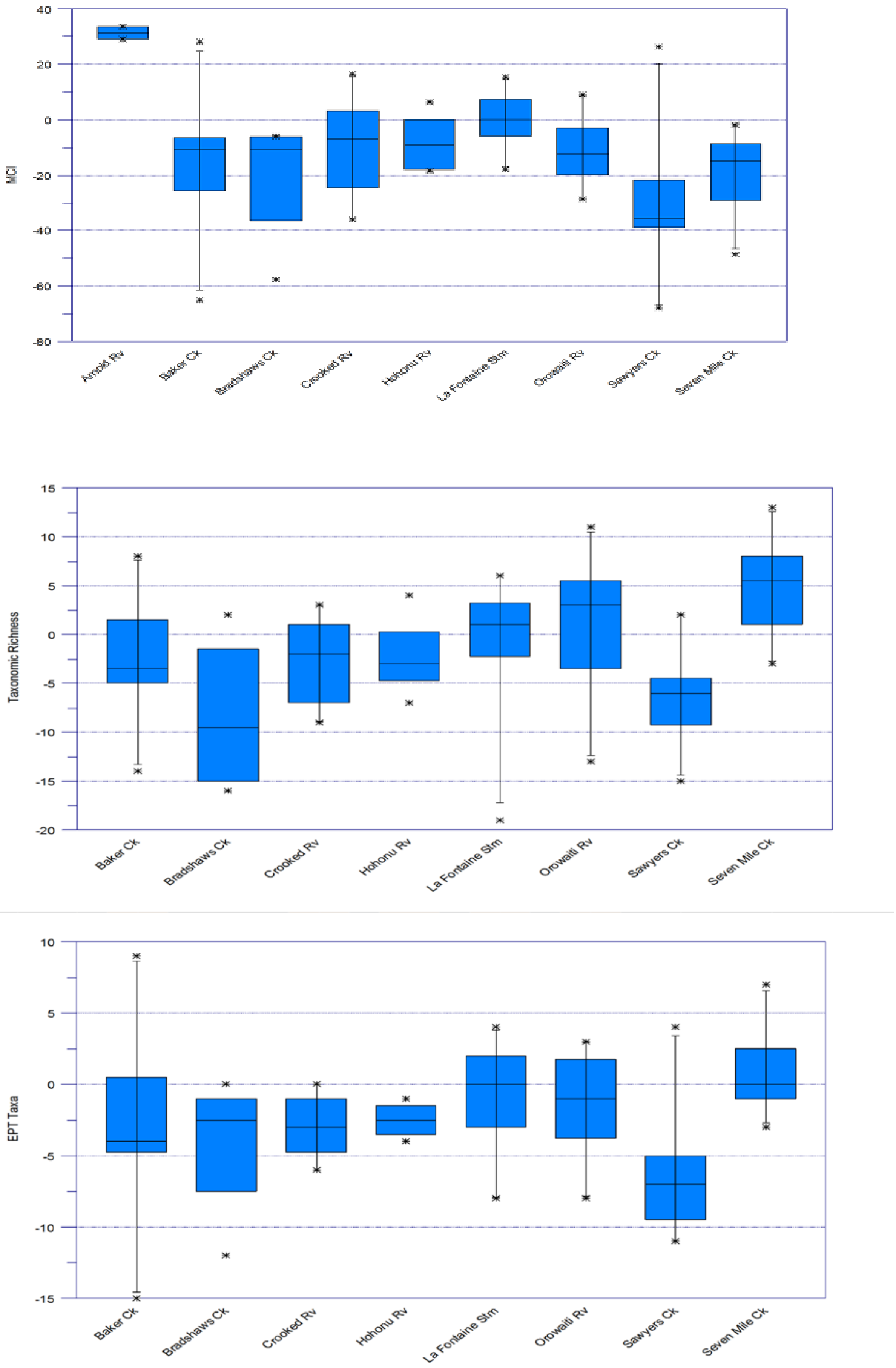


Figure 54 Differences between paired sites (downstream minus upstream values). MCI, SQMCI, EPT taxa and taxonomic richness.

5.8 Individual contact recreation sites

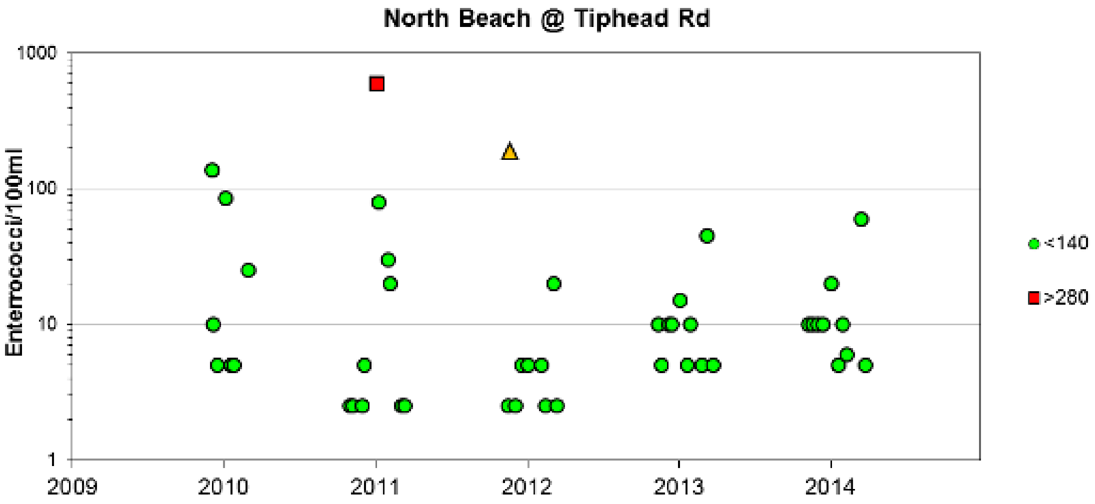


Figure 55 Single sample Enterococci levels for North Beach @ Tiphead Rd.

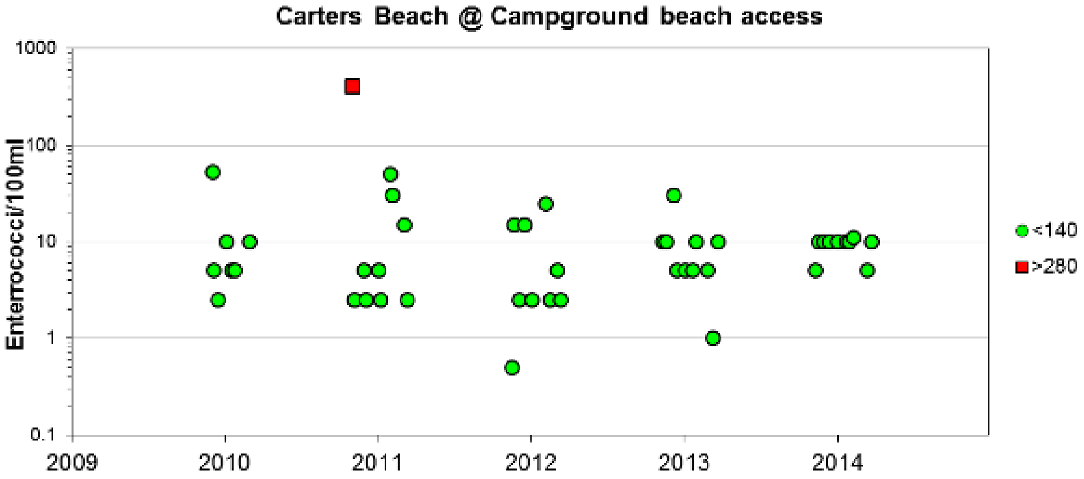


Figure 56 Single sample Enterococci levels for Carters Beach @ Campground beach access.

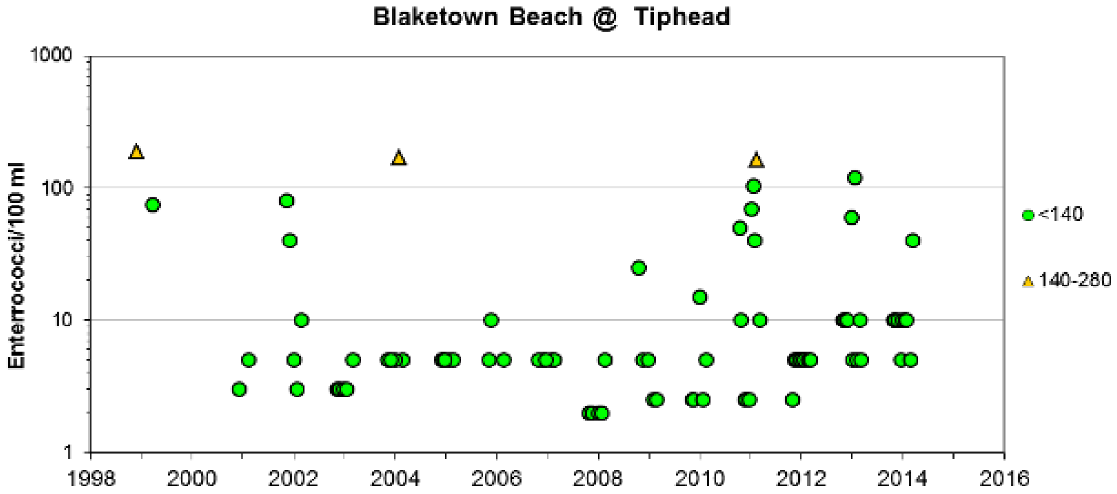


Figure 57 Single sample Enterococci levels for Blaketown Beach @ Tiphead.

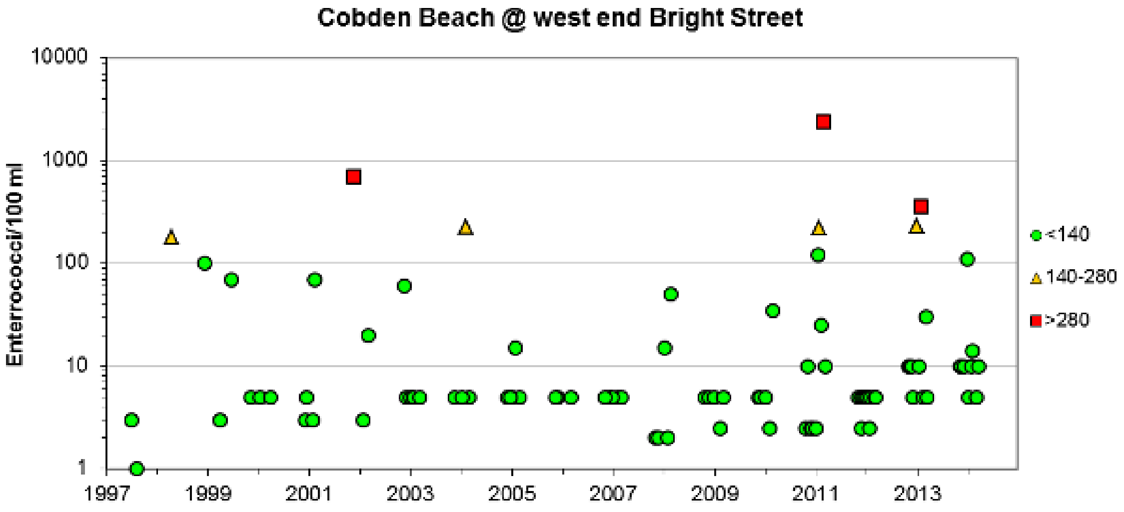


Figure 58 Single sample Enterococci levels for Cobden Beach @ west end Bright Street.

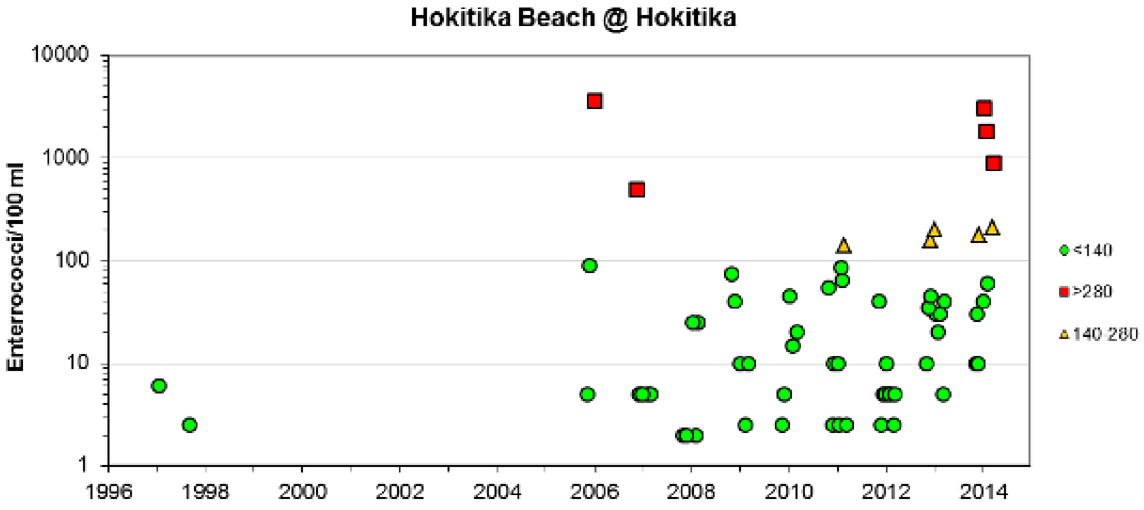


Figure 59 Single sample Enterococci levels for Hokitika Beach @ Hokitika.

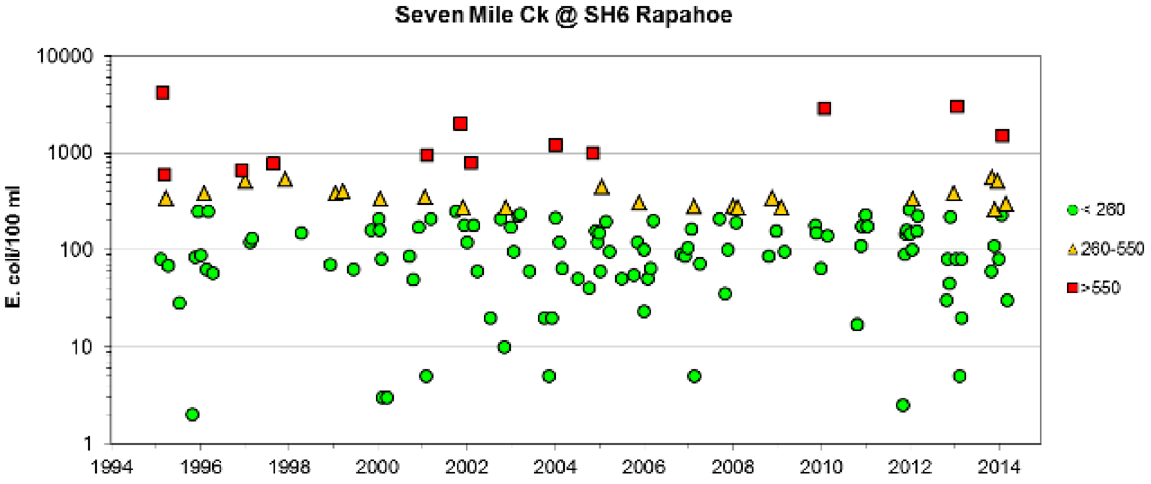


Figure 60 Single sample E. coli levels for Seven Mile Creek @ SH6 Rapahoe.

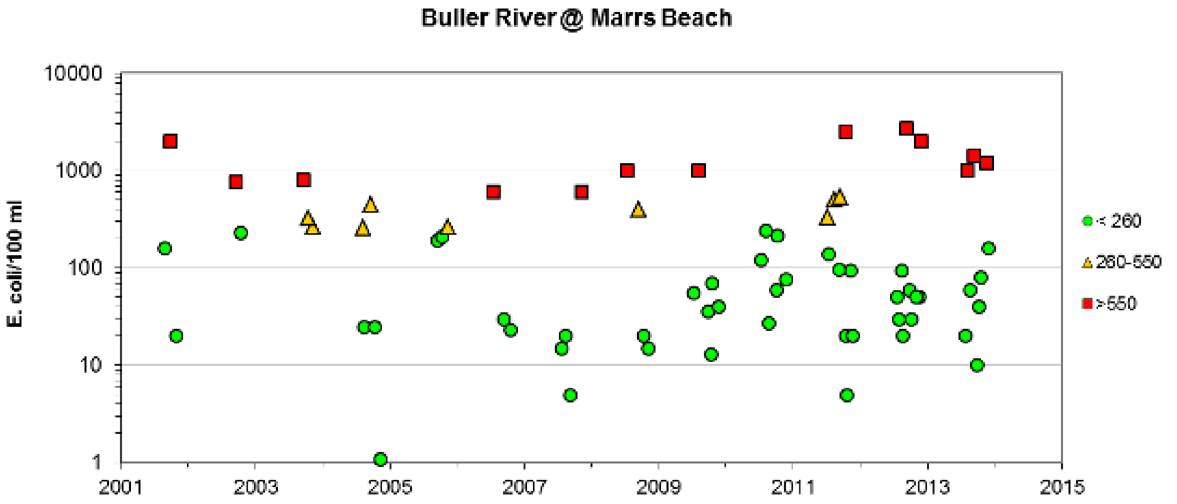


Figure 61 Single sample E. coli levels for Buller River @ Marrs Beach.

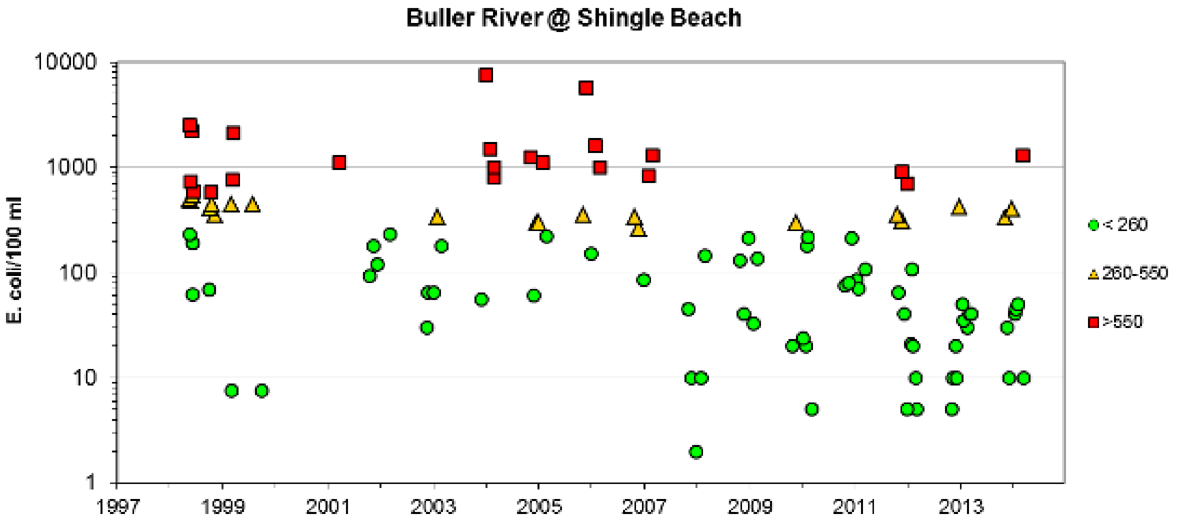


Figure 62 Single sample E. coli levels for Buller River @ Shingle Beach.

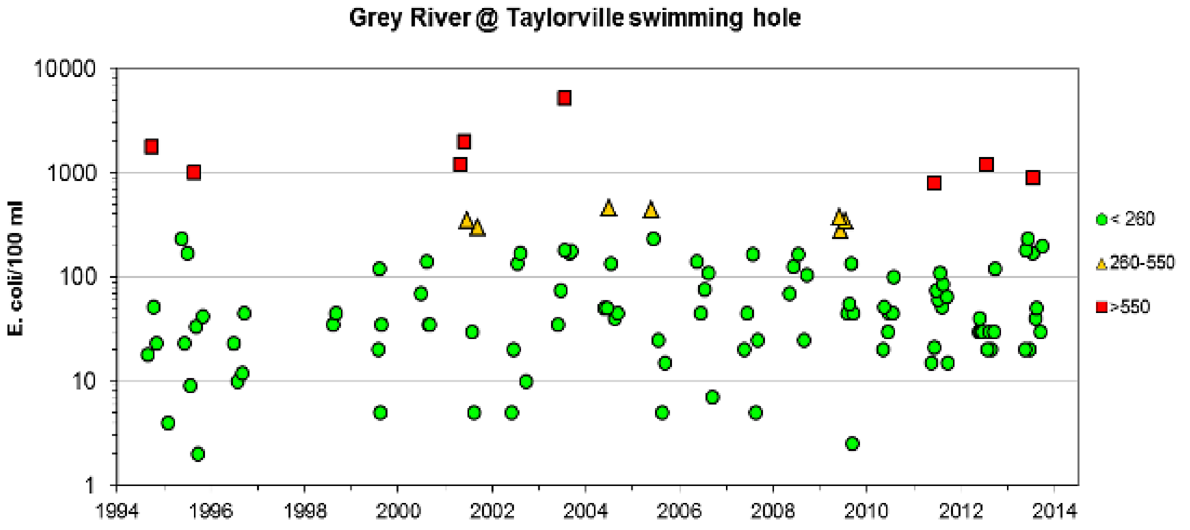


Figure 63 Single sample E. coli levels for Grey River @ Taylorville swimming hole.

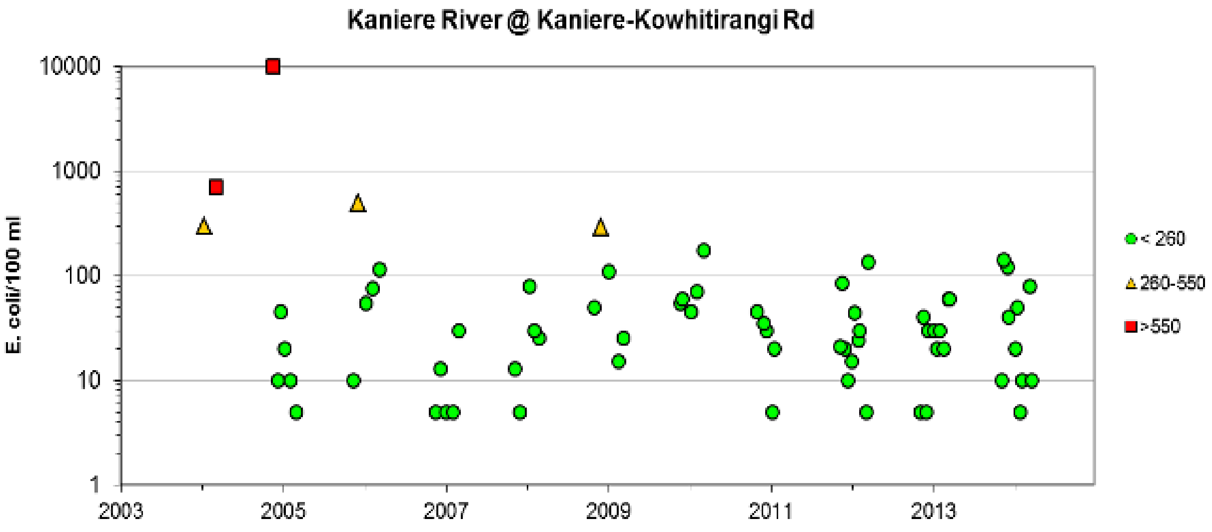


Figure 64 Single sample E. coli levels for Kaniere River @ Kaniere – Kowhitirangi Road.

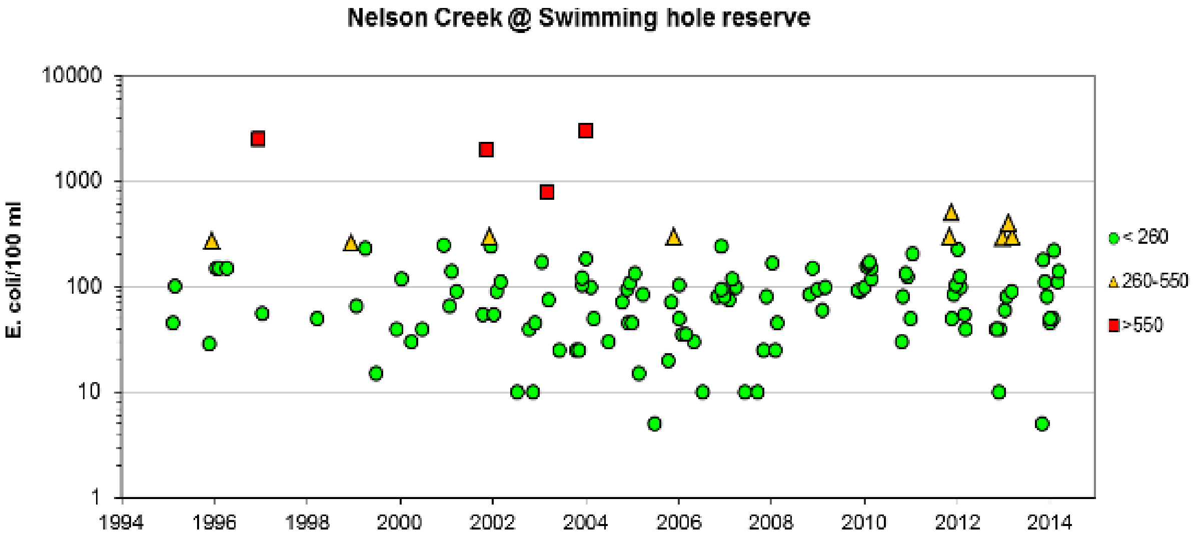


Figure 65 Single sample E. coli levels for Nelson Creek @ Swimming hole reserve.

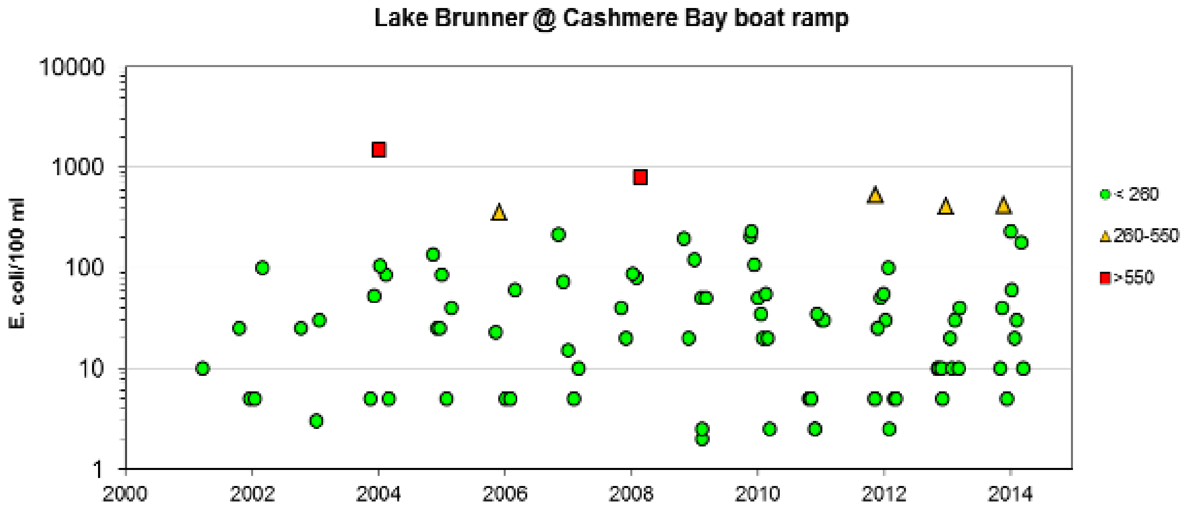


Figure 66 Single sample E. coli levels for Lake Brunner @ Cashmere Bay boat ramp.

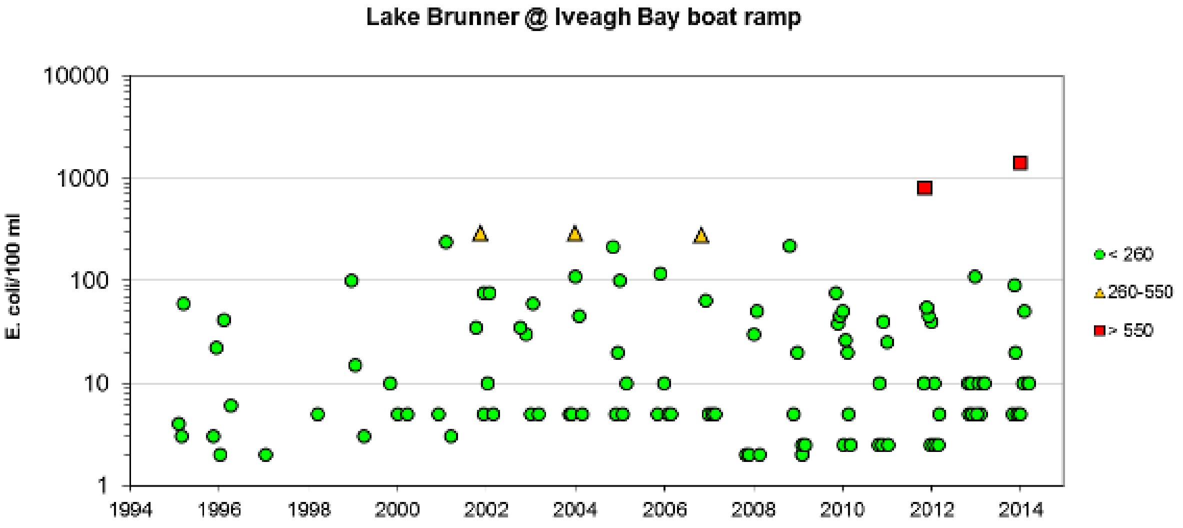


Figure 67 Single sample E. coli levels for Lake Brunner @ Iveagh Bay boat ramp.

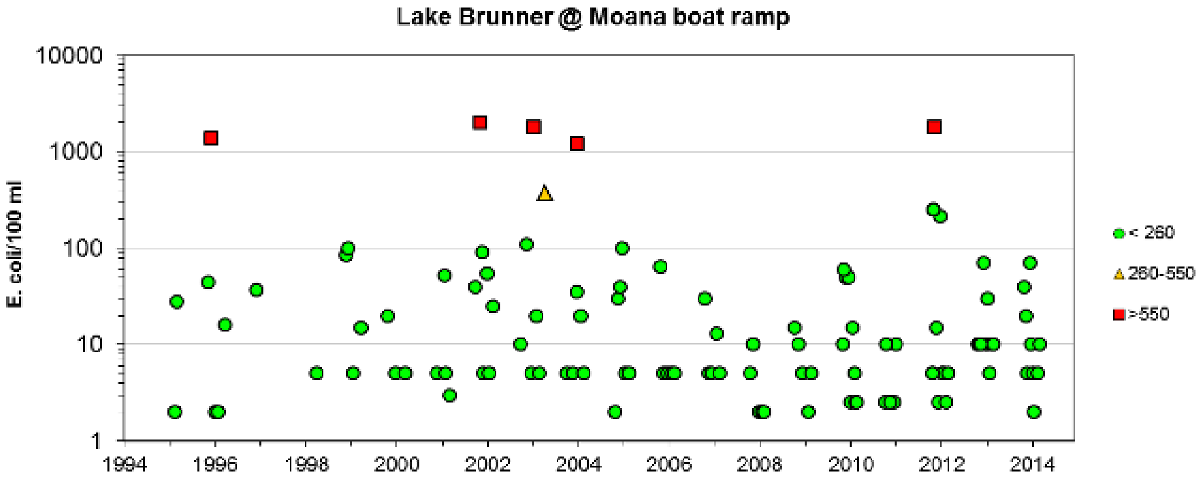


Figure 68 Single sample E. coli levels for Lake Brunner @ Moana boat ramp.

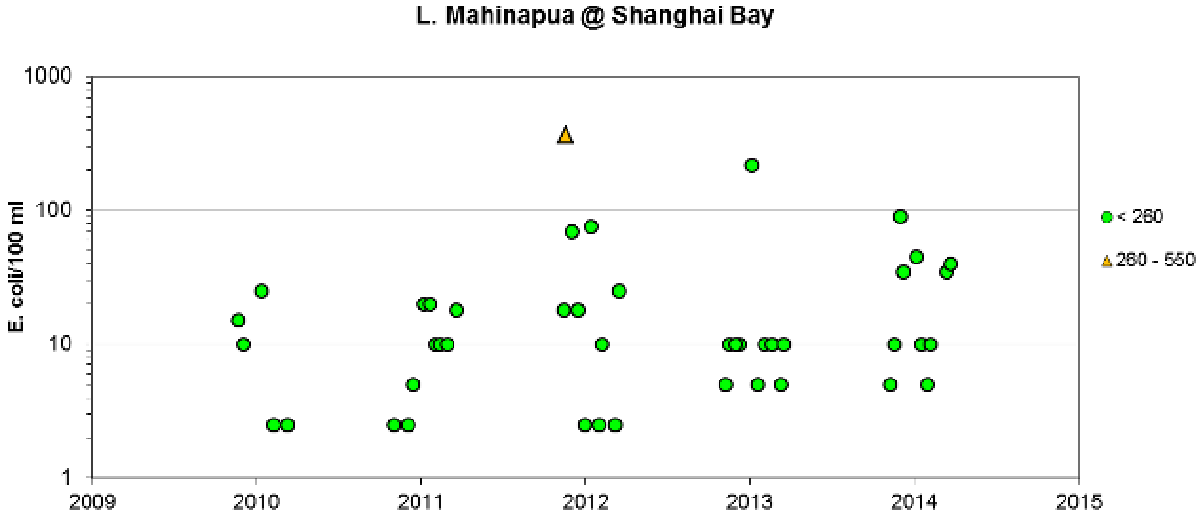


Figure 69 Single sample E. coli levels for Lake Mahinapua @ Shanghai Bay boat ramp.

5.9 Water quality trends at NIWA sites

Table 18 Seasonal Kendall trend test for **ten years** of data collected at West Coast NIWA water quality sites. Important trends are in red (undesirable) and blue (good). Slight trends are in pink (undesirable) and light blue (good). PAC = percent annual change of the median. DRP= dissolved reactive phosphorus.

Variable	Site	Samples used	Sampling period	Median	P	PAC
Clarity (m)	Buller at Longford	113	7/7/04-4/12/13	4.88	0.188	-0.829
Clarity (m)	Buller at Te Kuha	117	12/7/04-14/6/14	1.85	0.669	-0.466
Clarity (m)	Grey at Dobson	117	12/7/04-10/6/14	2	1	0.01
Clarity (m)	Grey at Waipuna	119	12/7/04-10/6/14	3.7	0.531	0.732
Clarity (m)	Haast at Roaring Billy	120	22/6/04-18/6/14	2.555	0.719	-0.924
Conductivity (25°C uS/cm)	Buller at Longford	114	7/7/04-4/12/13	57.9	0.233	0.198
Conductivity (25°C uS/cm)	Buller at Te Kuha	119	12/7/04-14/6/14	68.9	0.003	0.518
Conductivity (25°C uS/cm)	Grey at Dobson	119	12/7/04-10/6/14	58.3	0	0.91
Conductivity (25°C uS/cm)	Grey at Waipuna	119	12/7/04-10/6/14	53.8	1	0.016
Conductivity (25°C uS/cm)	Haast at Roaring Billy	121	22/6/04-18/6/14	82.9	0	0.997
DRP (µg/L)	**Buller at Longford**	114	7/7/04-4/12/13	1	0.038	2.95
DRP (µg/L)	**Buller at Te Kuha**	119	12/7/04-14/6/14	2	0.002	2.74
DRP (µg/L)	Grey at Dobson	118	12/7/04-10/6/14	3	0.162	1.658
DRP (µg/L)	**Grey at Waipuna**	119	12/7/04-10/6/14	2	0	4.973
DRP (µg/L)	**Haast at Roaring Billy**	121	22/6/04-18/6/14	1	0.031	1.741
E. coli (MPN/100 ml)	Buller at Longford	102	10/2/05-4/12/13	25.25	0.516	-2.274
E. coli (MPN/100 ml)	Buller at Te Kuha	111	8/2/05-14/6/14	18.3	0.062	-7.405
E. coli (MPN/100 ml)	Grey at Dobson	112	8/2/05-10/6/14	34.95	0.126	-4.751
E. coli (MPN/100 ml)	**Grey at Waipuna**	112	8/2/05-10/6/14	8.6	0.041	-8.488
E. coli (MPN/100 ml)	**Haast at Roaring Billy**	113	23/2/05-18/6/14	2	0.044	-11.27
g340	Buller at Longford	114	7/7/04-4/12/13	2.345	0.28	1.573
g340	Buller at Te Kuha	119	12/7/04-14/6/14	5.123	0.144	-2.164
g340	Grey at Dobson	119	12/7/04-10/6/14	7.233	0.076	-2.023
g340	Grey at Waipuna	119	12/7/04-10/6/14	6.159	0.566	-1.253
g340	Haast at Roaring Billy	121	22/6/04-18/6/14	0.66	0.109	-3.595
Ammonia – N (µg/L)	**Buller at Longford**	114	7/7/04-4/12/13	2	0.003	3.458
Ammonia – N (µg/L)	Buller at Te Kuha	119	12/7/04-14/6/14	3	0.296	-1.162
Ammonia – N (µg/L)	Grey at Dobson	119	12/7/04-10/6/14	5	0.076	2.423
Ammonia – N (µg/L)	Grey at Waipuna	119	12/7/04-10/6/14	3	0.117	1.606
Ammonia – N (µg/L)	Haast at Roaring Billy	121	22/6/04-18/6/14	1	0.593	-0.674
Nitrate - N (µg/L)	**Buller at Longford**	114	7/7/04-4/12/13	28	0.001	6.807
Nitrate - N (µg/L)	**Buller at Te Kuha**	119	12/7/04-14/6/14	66	0	7.071
Nitrate - N (µg/L)	**Grey at Dobson**	119	12/7/04-10/6/14	125	0	6.036
Nitrate - N (µg/L)	Grey at Waipuna	119	12/7/04-10/6/14	39	0.068	5.217
Nitrate - N (µg/L)	Haast at Roaring Billy	121	22/6/04-18/6/14	33	0.133	1.299
Total nitrogen (µg/L)	**Buller at Longford**	114	7/7/04-4/12/13	94.5	0.038	2.05
Total nitrogen (µg/L)	Buller at Te Kuha	119	12/7/04-14/6/14	154	0.085	1.171
Total nitrogen (µg/L)	**Grey at Dobson**	118	12/7/04-10/6/14	244.5	0	2.305
Total nitrogen (µg/L)	Grey at Waipuna	119	12/7/04-10/6/14	118	0.876	0.086
Total nitrogen (µg/L)	**Haast at Roaring Billy**	120	22/6/04-18/6/14	50.5	0.018	-1.732
Total phosphorus (µg/L)	Buller at Longford	114	7/7/04-4/12/13	5	0.081	-2.444
Total phosphorus (µg/L)	**Buller at Te Kuha**	118	12/7/04-14/6/14	7.5	0.042	2.839
Total phosphorus (µg/L)	Grey at Dobson	116	12/7/04-10/6/14	9	0.372	-1.104
Total phosphorus (µg/L)	Grey at Waipuna	119	12/7/04-10/6/14	5	0.876	-0.232
Total phosphorus (µg/L)	Haast at Roaring Billy	120	22/6/04-18/6/14	4	0.355	-2.118
Turbidity (NTU)	Buller at Longford	114	7/7/04-4/12/13	0.875	0.212	2.918
Turbidity (NTU)	**Buller at Te Kuha**	119	12/7/04-14/6/14	1.48	0	9.266
Turbidity (NTU)	**Grey at Dobson**	119	12/7/04-10/6/14	1.69	0.002	6.956
Turbidity (NTU)	**Grey at Waipuna**	119	12/7/04-10/6/14	0.76	0	10.794
Turbidity (NTU)	**Haast at Roaring Billy**	121	22/6/04-18/6/14	1.3	0.021	5.768

Table 19 Seasonal Kendall trend test for **25 years** of data collected at West Coast NIWA water quality sites. Important trends are in red (undesirable) and blue (good). Slight trends are in pink (undesirable) and light blue (good). PAC = percent annual change of the median

Variable	Site	Samples	Sampling period	Median	P	PAC
Clarity	**Buller at Longford**	304	23/1/89-4/12/13	3.705	0	2.0
Clarity	Buller at Te Kuha	301	25/1/89-14/6/14	1.85	0.743	-0.1
Clarity	Grey at Dobson	300	25/1/89-10/6/14	1.69	0.002	0.9
Clarity	**Grey at Waipuna**	303	25/1/89-10/6/14	3.2	0.001	1.0
Clarity	Haast at Roaring Billy	298	4/5/89-18/6/14	2.25	0.881	0.1
Conductivity (25°C uS/cm)	Haast at Roaring Billy	299	4/5/89-18/6/14	81.5	0.695	0.0
Conductivity (25°C uS/cm)	Grey at Waipuna	305	25/1/89-10/6/14	52.5	0	0.4
Conductivity (25°C uS/cm)	Grey at Dobson	305	25/1/89-10/6/14	56.4	0	0.3
Conductivity (25°C uS/cm)	Buller at Longford	305	23/1/89-4/12/13	56	0	0.2
Conductivity (25°C uS/cm)	Buller at Te Kuha	305	25/1/89-14/6/14	66.5	0	0.2
DRP (µg/L)	Buller at Longford	304	23/1/89-4/12/13	1	0	0.8
DRP (µg/L)	Buller at Te Kuha	303	25/1/89-14/6/14	2	0.76	-0.1
DRP (µg/L)	**Grey at Dobson**	302	25/1/89-10/6/14	2	0.001	1.1
DRP (µg/L)	Grey at Waipuna	302	25/1/89-10/6/14	2	0.057	0.4
DRP (µg/L)	Haast at Roaring Billy	299	4/5/89-18/6/14	1	0.033	0.4
g340	Buller at Longford	305	23/1/89-4/12/13	2.397	0.524	0.2
g340	Buller at Te Kuha	305	25/1/89-14/6/14	5.123	0.43	0.3
g340	Grey at Dobson	305	25/1/89-10/6/14	7.521	0.937	0.0
g340	Grey at Waipuna	305	25/1/89-10/6/14	6.159	0.979	0.0
g340	Haast at Roaring Billy	300	4/5/89-18/6/14	0.691	0.882	-0.1
Ammonia - N (µg/L)	**Grey at Dobson**	291	25/1/89-10/6/14	6	0	-1.3
Ammonia - N (µg/L)	**Grey at Waipuna**	290	25/1/89-10/6/14	4	0	-3.6
Ammonia - N (µg/L)	**Buller at Te Kuha**	291	25/1/89-14/6/14	4	0	-4.3
Ammonia - N (µg/L)	**Buller at Longford**	291	23/1/89-4/12/13	3	0	-4.8
Ammonia - N (µg/L)	**Haast at Roaring Billy**	287	4/5/89-18/6/14	2	0	-7.4
Nitrate - N (µg/L)	Buller at Longford	304	23/1/89-4/12/13	24.5	0.074	0.8
Nitrate - N (µg/L)	**Buller at Te Kuha**	303	25/1/89-14/6/14	48	0	3.9
Nitrate - N (µg/L)	**Grey at Dobson**	303	25/1/89-10/6/14	88	0	4.5
Nitrate - N (µg/L)	**Grey at Waipuna**	302	25/1/89-10/6/14	27	0	3.1
Nitrate - N (µg/L)	Haast at Roaring Billy	299	4/5/89-18/6/14	32	0.957	0.0
Total nitrogen (µg/L)	**Grey at Dobson**	289	25/1/89-10/6/14	206	0	2.6
Total nitrogen (µg/L)	**Buller at Te Kuha**	291	25/1/89-14/6/14	143	0	1.7
Total nitrogen (µg/L)	**Grey at Waipuna**	290	25/1/89-10/6/14	103	0	1.5
Total nitrogen (µg/L)	**Buller at Longford**	291	23/1/89-4/12/13	84	0	1.2
Total nitrogen (µg/L)	**Haast at Roaring Billy**	285	4/5/89-18/6/14	56	0	-1.1
Total phosphorus (µg/L)	Buller at Longford	304	23/1/89-4/12/13	5	0.557	-0.2
Total phosphorus (µg/L)	Buller at Te Kuha	301	25/1/89-14/6/14	8	0.303	0.4
Total phosphorus (µg/L)	Grey at Dobson	300	25/1/89-10/6/14	9	0.936	-0.1
Total phosphorus (µg/L)	Grey at Waipuna	302	25/1/89-10/6/14	5	0.92	0.0
Total phosphorus (µg/L)	Haast at Roaring Billy	298	4/5/89-18/6/14	4	0.311	-0.7
Turbidity (NTU)	Buller at Longford	305	23/1/89-4/12/13	0.85	0.058	0.9
Turbidity (NTU)	Buller at Te Kuha	304	25/1/89-14/6/14	1.775	0.074	0.9
Turbidity (NTU)	Grey at Dobson	305	25/1/89-10/6/14	2.1	0.207	-0.5
Turbidity (NTU)	Grey at Waipuna	304	25/1/89-10/6/14	0.9	0.332	0.4
Turbidity (NTU)	**Haast at Roaring Billy**	299	4/5/89-18/6/14	1.5	0.044	1.4

5.10 Algal cover and macroinvertebrate indices over time – NIWA sites

Table 20 Mann-Kendall trend test for ten years of data collected at West Coast NIWA water quality sites. Important trends are in red (undesirable) and blue (good). Slight trends are in pink (undesirable) and light blue (good). PAC = percent annual change of the median.

Attribute	Site	Samples	Sampling period	Median	P	PAC
%EPT	**Buller Rv @ Longford**	24	22/3/90-13/2/13	67.521	0.04	-2.591
%EPT	Buller Rv @ Te Kuha	18	27/3/90-27/3/14	13.829	0.762	-1.172
%EPT	Grey Rv @ Dobson	23	28/3/90-27/3/14	15.374	0.751	-0.888
%EPT	Grey Rv @ Waipuna	22	27/3/90-28/3/14	29.354	0.573	1.828
%EPT	**Haast Rv @ Roaring Billy**	21	20/3/91-17/2/14	62.563	0.01	-2.738
EPT taxa richness	Buller Rv @ Longford	24	22/3/90-13/2/13	13.5	0.239	-0.928
EPT taxa richness	Buller Rv @ Te Kuha	18	27/3/90-27/3/14	9	0.541	0.652
EPT taxa richness	**Grey Rv @ Dobson**	23	28/3/90-27/3/14	13	0.018	1.532
EPT taxa richness	Grey Rv @ Waipuna	22	27/3/90-28/3/14	14	0.689	0
EPT taxa richness	Haast Rv @ Roaring Billy	21	20/3/91-17/2/14	6	0.084	1.848
EPT total	Buller Rv @ Longford	24	22/3/90-13/2/13	1086.5	0.107	-2.118
EPT total	Buller Rv @ Te Kuha	18	27/3/90-27/3/14	156.5	0.495	-1.931
EPT total	Grey Rv @ Dobson	23	28/3/90-27/3/14	400	0.46	1.433
EPT total	Grey Rv @ Waipuna	22	27/3/90-28/3/14	639.5	0.778	0.722
EPT total	Haast Rv @ Roaring Billy	21	20/3/91-17/2/14	203	0.763	1.284
MCI	Buller Rv @ Longford	24	22/3/90-13/2/13	123.675	0.002	-0.611
MCI	Buller Rv @ Te Kuha	18	27/3/90-27/3/14	108.83	0.069	-0.489
MCI	Grey Rv @ Dobson	23	28/3/90-27/3/14	118.75	0.792	-0.04
MCI	Grey Rv @ Waipuna	22	27/3/90-28/3/14	125.982	0.756	-0.059
MCI	Haast Rv @ Roaring Billy	21	20/3/91-17/2/14	120.909	0.976	-0.053
QMCI	**Buller Rv @ Longford**	24	22/3/90-13/2/13	5.333	0.04	-1.225
QMCI	Buller Rv @ Te Kuha	18	27/3/90-27/3/14	2.879	1	0.138
QMCI	Grey Rv @ Dobson	23	28/3/90-27/3/14	3.324	0.398	-0.222
QMCI	Grey Rv @ Waipuna	22	27/3/90-28/3/14	4.424	0.367	1.1
QMCI	**Haast Rv @ Roaring Billy**	21	20/3/91-17/2/14	5.986	0.017	-1.507
Taxa richness	Buller Rv @ Longford	24	22/3/90-13/2/13	23.5	0.862	0
Taxa richness	Buller Rv @ Te Kuha	18	27/3/90-27/3/14	18.5	0.095	1.65
Taxa richness	**Grey Rv @ Dobson**	23	28/3/90-27/3/14	24	0.035	1.315
Taxa richness	Grey Rv @ Waipuna	22	27/3/90-28/3/14	24	0.931	0
Taxa richness	**Haast Rv @ Roaring Billy**	21	20/3/91-17/2/14	11	0.02	1.986

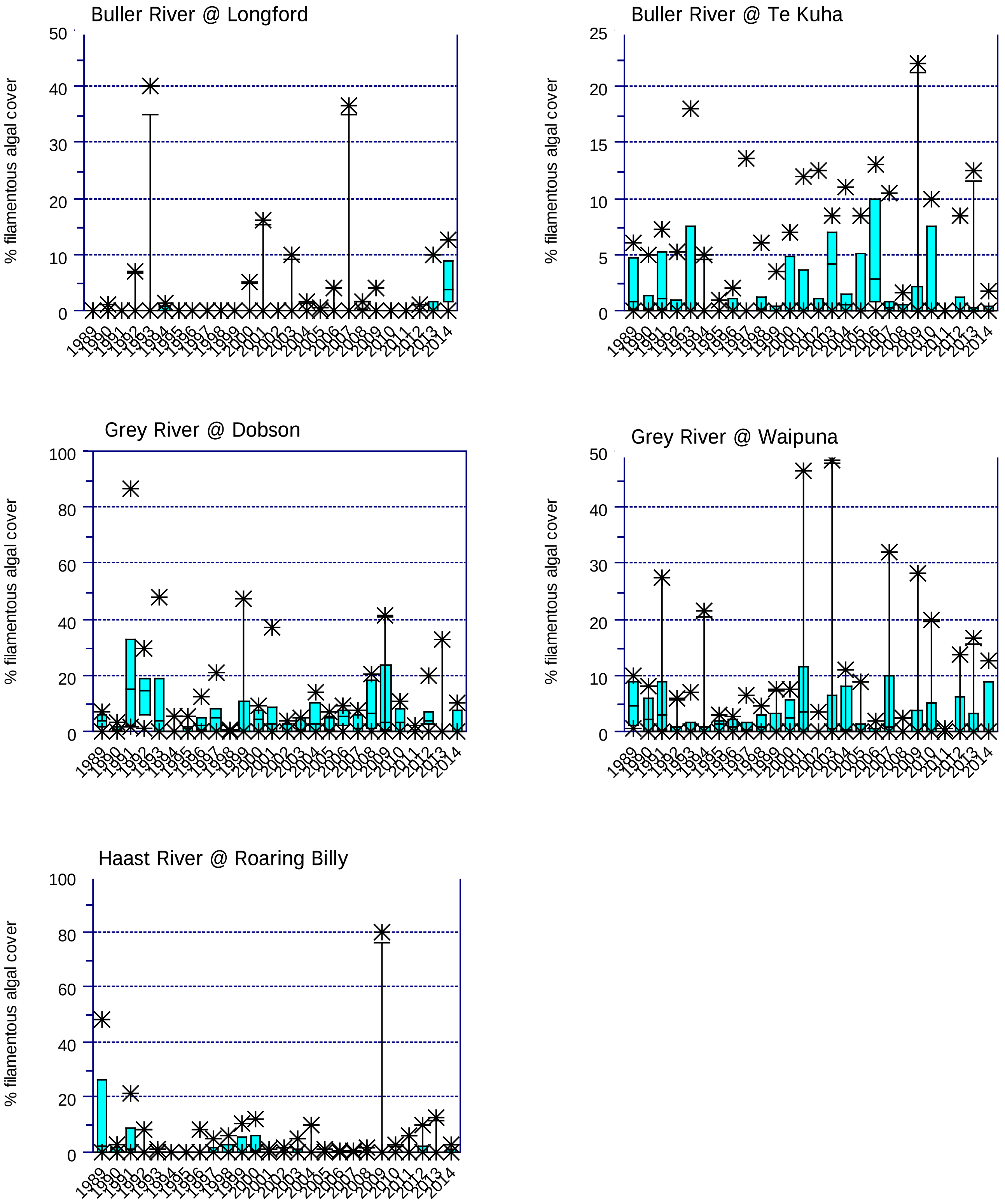


Figure 70 Percentage filamentous algal cover at NIWA sites by year.

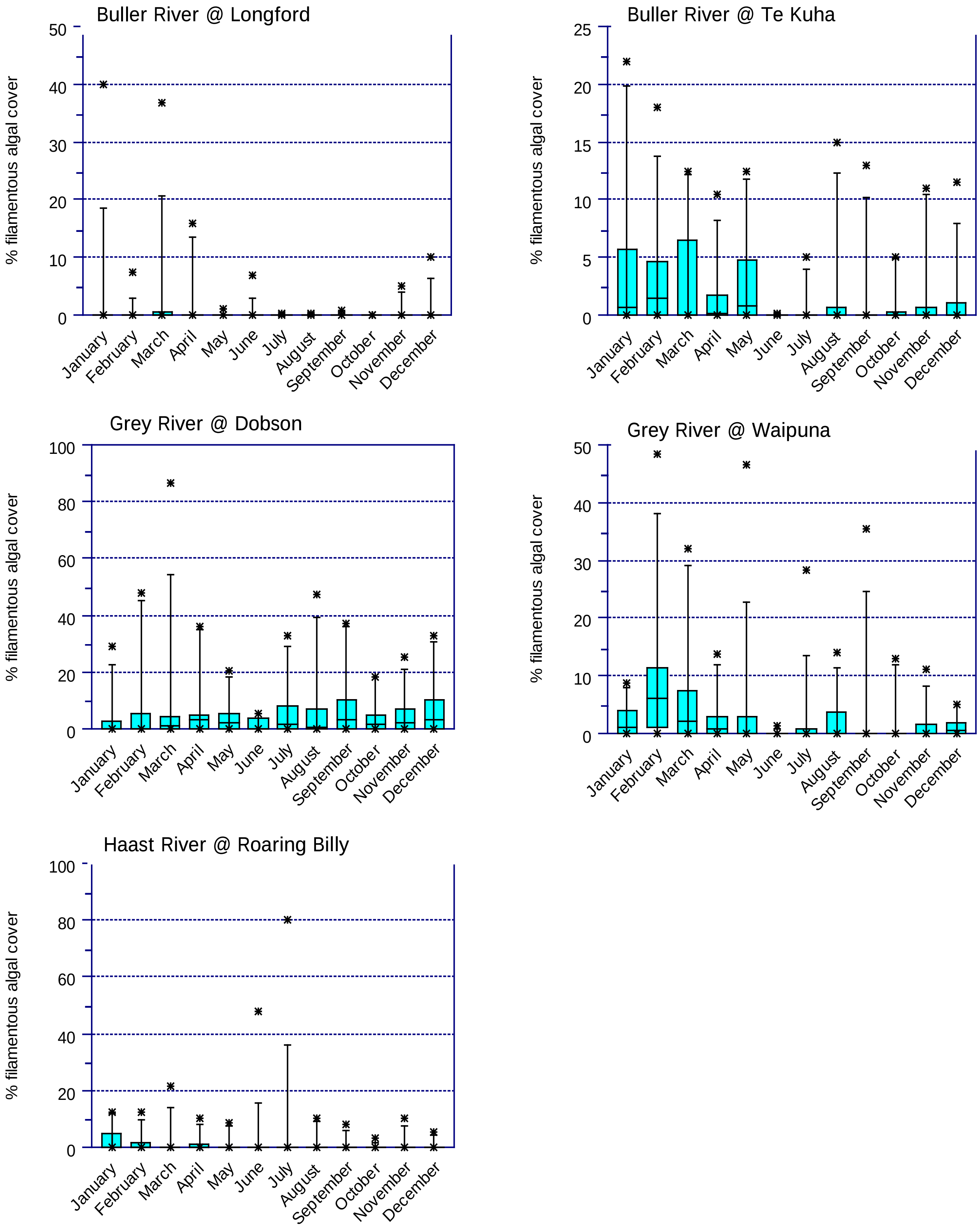


Figure 71 Percentage filamentous algal cover at NIWA sites by season. Data spans from 1998 to 2014.

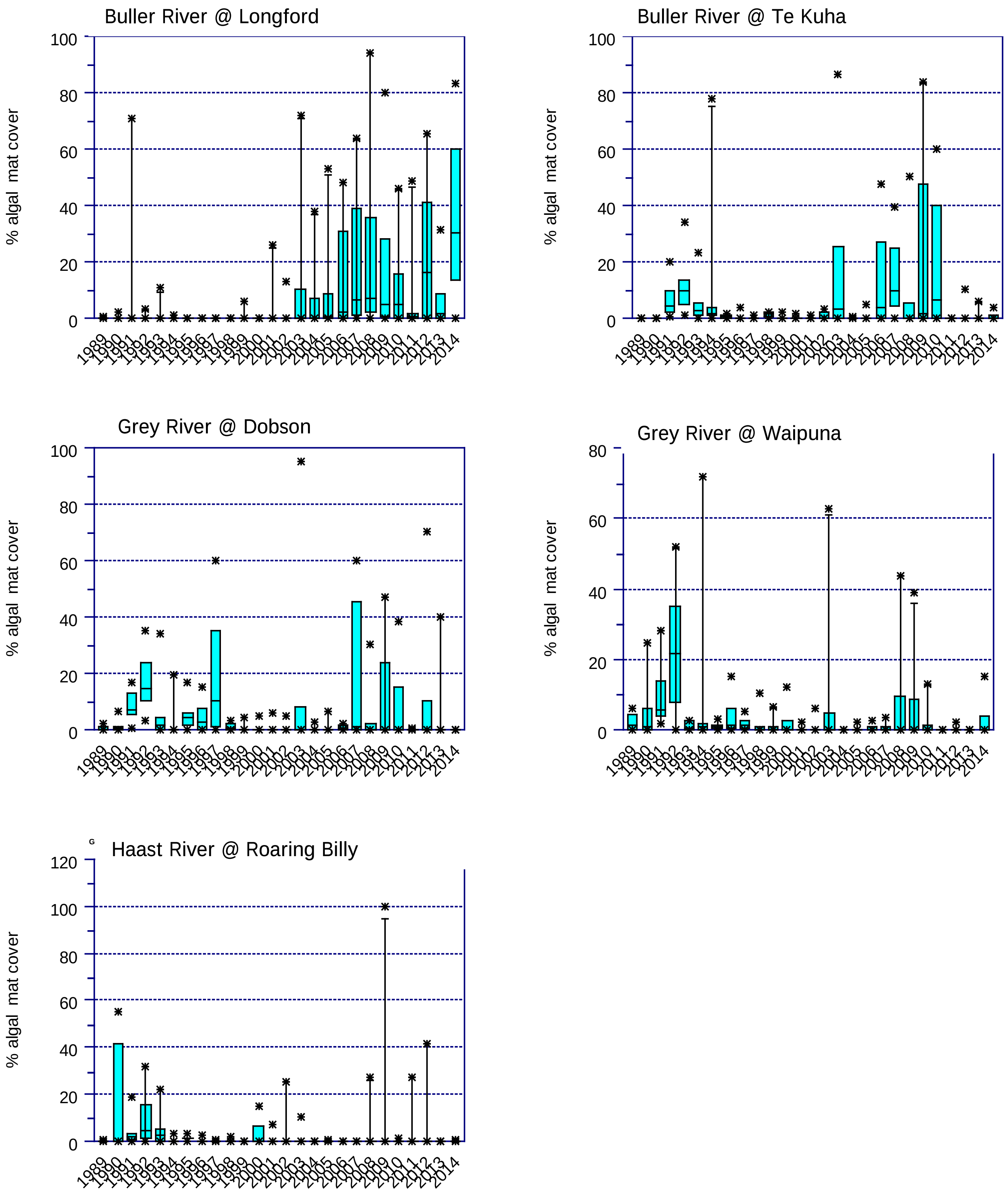


Figure 72 Percentage algal mat cover at NIWA sites by year.

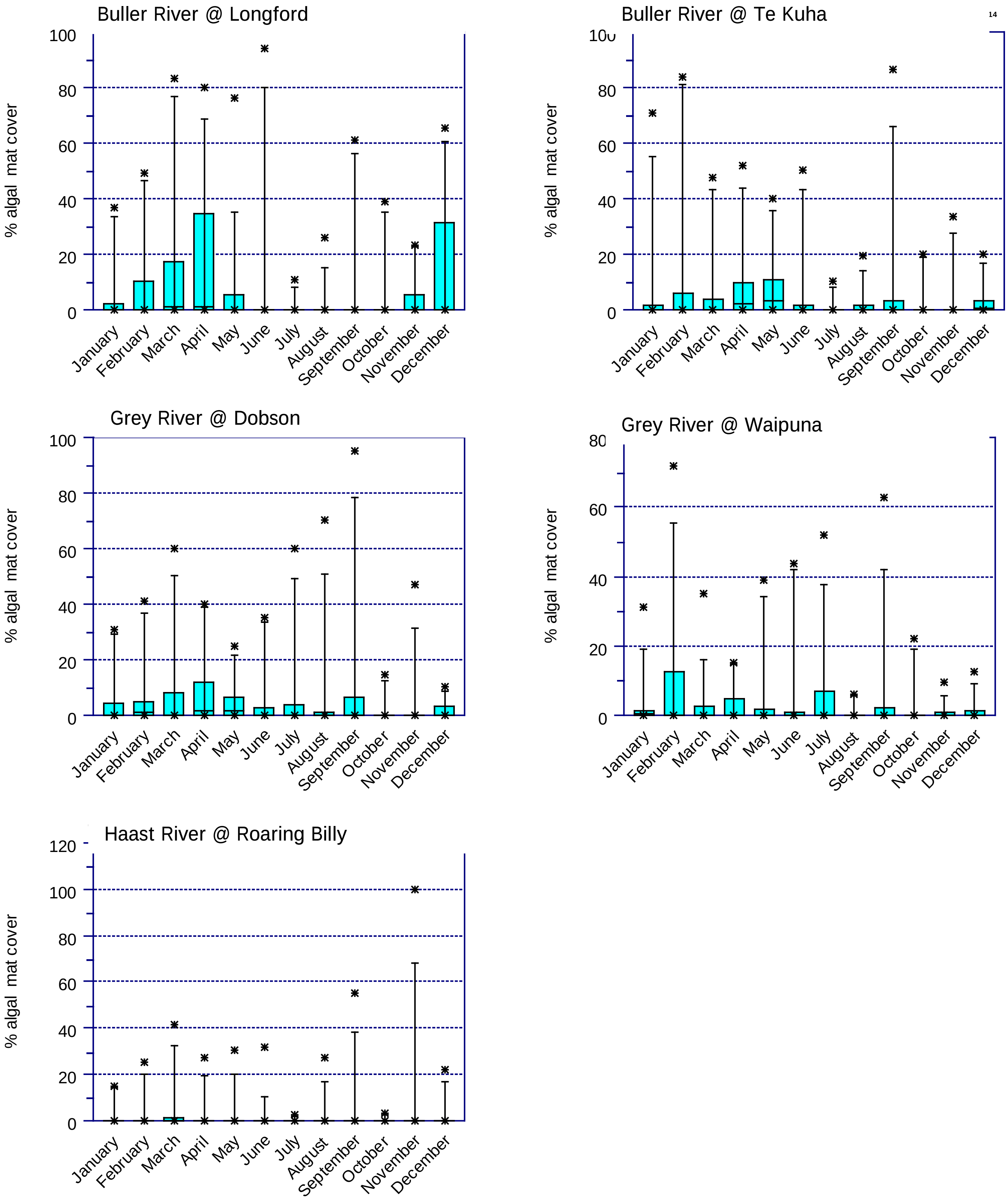


Figure 73 Percentage algal mat cover at NIWA sites by season. Data spans from 1998 to 2014.

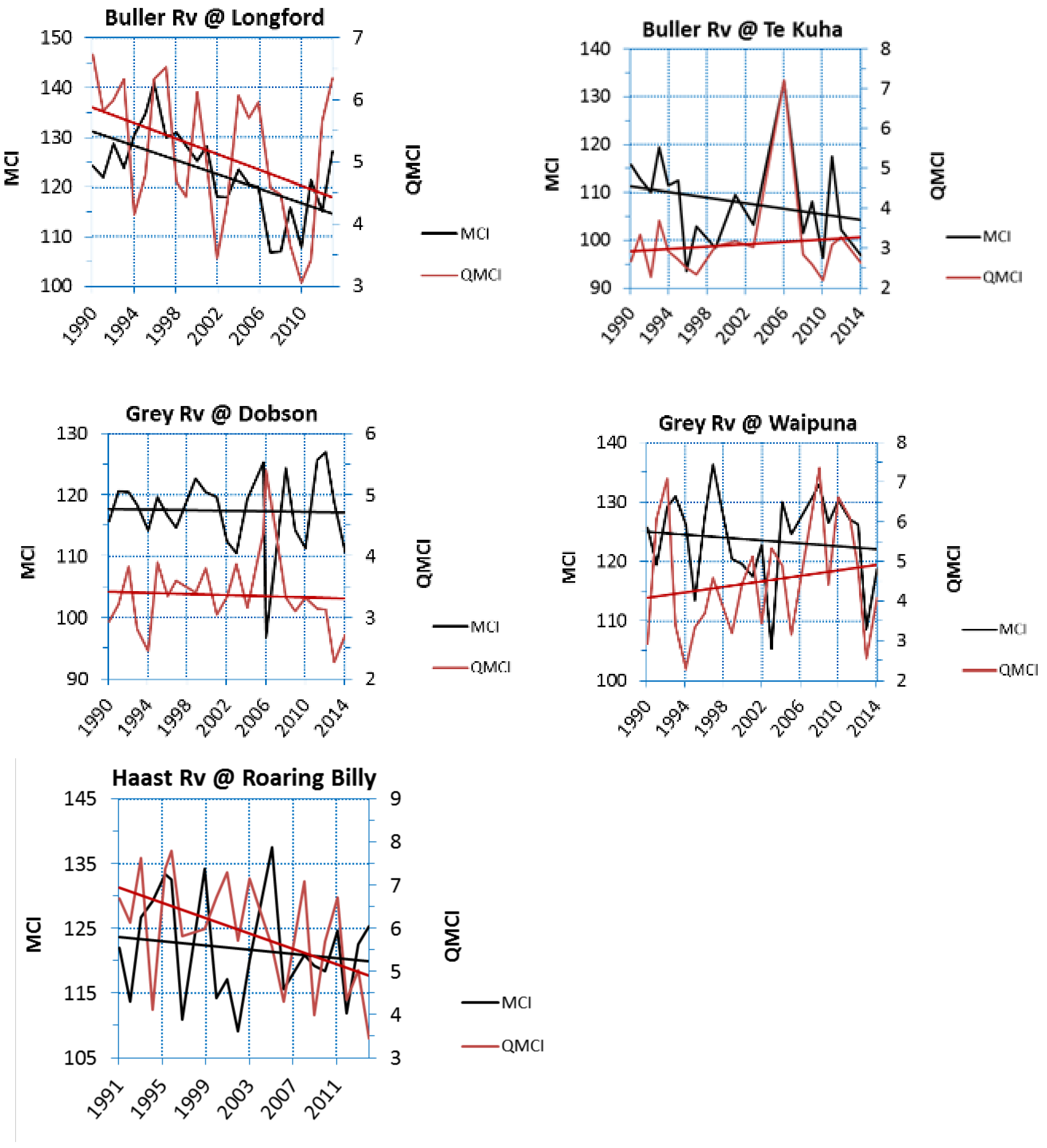


Figure 74 These plots show annual values for MCI (macroinvertebrate community index) and QMCI (quantitative macroinvertebrate community index) from 1990 to 2014. Linear regression lines are shown for both MCI and QMCI on each graph.

5.11 Water quality trends at Regional Council sites

Table 21 Seasonal Kendall trend test for Regional Council monitoring program sites. Ten year data span. Important trends are in red (undesirable) and blue (good). Slight trends are in pink (undesirable) and light blue (good). PAC = percent annual change of the median. 20 or more samples are required before a trend will be considered eligible.

Variable	Site	Samples	Median mg/L	P	PAC
Ammonia-N	Arnold Rv @ Blairs Rd No. 2 Br TN (µg/L)	39	0.005	0.230	3.1
Ammonia-N	Arnold Rv @ Kotuku Fishing Access	50	0.007	1.000	0.2
Ammonia-N	Baker Ck @ Baker Ck Rd	33	0.009	0.442	-4.3
Ammonia-N	Baker Ck @ Oparara Rd	34	0.052	0.539	1.3
Ammonia-N	**Berry Ck @ N Brch Wanganui Flat Rd**	38	0.010	0.000	-27.5
Ammonia-N	Blackwater Ck @ Farm 846	33	0.340	0.345	-3.9
Ammonia-N	**Bradshaws Ck @ Bradshaw Rd**	39	0.052	0.017	-9.6
Ammonia-N	**Bradshaws Ck @ Martins Rd**	38	0.025	0.023	-8.2
Ammonia-N	**Burkes Ck @ SH69**	41	0.014	0.008	-11.3
Ammonia-N	Crooked Rv @ Rotomanu-Bell Hill Rd	51	0.005	0.218	1.1
Ammonia-N	**Crooked Rv @ Te Kinga**	43	0.008	0.008	-5.7
Ammonia-N	Deep Ck @ Arnold Vly Rd Br	23	0.010	0.771	11.7
Ammonia-N	**Duck Ck @ Kokatahi-Kowhitirangi Rd Br**	40	0.007	0.000	-11.9
Ammonia-N	Ellis Ck @ 50m d/s Ferry Rd Br	39	0.009	0.079	-4.8
Ammonia-N	**Ford Ck @ Blackball-Taylorville Rd**	31	0.039	0.001	5.2
Ammonia-N	**Harris Ck @ Mulvaney Rd**	40	0.014	0.006	-11.1
Ammonia-N	Hohonu Rv @ Mitchells-Kumara Rd Br	37	0.005	0.312	3.5
Ammonia-N	Hohonu Rv @ Mouth	35	0.005	0.130	4.9
Ammonia-N	La Fontaine Stm @ Airstrip Fishing Access	35	0.008	0.264	-7.1
Ammonia-N	La Fontaine Stm @ Herepo Fishing Access	39	0.012	0.229	-2.9
Ammonia-N	Mawheraiti Rv @ SH7 Maimai	40	0.026	0.893	-0.6
Ammonia-N	**Molloy Ck @ Rail Line**	39	0.006	0.007	-7.2
Ammonia-N	**Murray Ck @ Ford Rd S**	40	0.015	0.011	-8.2
Ammonia-N	Nelson Ck @ Swimming Hole Reserve	38	0.007	0.137	-5.9
Ammonia-N	Okutua Ck @ New Rd Br-Okarito Forest	37	0.011	0.254	-3.3
Ammonia-N	**Orangipuku Rv @ Mouth**	45	0.015	0.010	-6.7
Ammonia-N	**Orowaiti Rv @ Excelsior Rd**	40	0.042	0.000	-8.5
Ammonia-N	Orowaiti Rv @ Keoghans Rd	40	0.023	0.166	4.0
Ammonia-N	**Poerua Rv @ Rail Br**	48	0.013	0.006	-10.2
Ammonia-N	Sawyers Ck @ Bush Fringe	36	0.005	0.876	-0.3
Ammonia-N	Sawyers Ck @ Dixon Pk	39	0.020	0.405	-2.6
Ammonia-N	Seven Mile Ck @ 300m d/s Raleigh Ck	40	0.097	0.447	1.2
Ammonia-N	Seven Mile Ck @ Dunollie 400m u/s Ox Pd	39	0.022	0.459	-2.6
Ammonia-N	Seven Mile Ck @ SH6 Rapahoe	32	0.061	0.541	3.0
Ammonia-N	Seven Mile Ck @ u/s Tillers Mine Ck	13	0.007	0.485	0.8
Ammonia-N	Unnamed Ck @ Adamson Rd Whataroa	39	0.005	0.459	-6.2
Ammonia-N	Vickers Ck @ Whataroa N Base	39	0.005	0.165	-4.7

Table 21 Seasonal Kendall trend test for Regional Council monitoring program sites. Ten year data span. Important trends are in red (undesirable) and blue (good). Slight trends are in pink (undesirable) and light blue (good). PAC = percent annual change of the median. 20 or more samples are required before a trend will be considered eligible.

Variable	**Site**	**Samples used**	**Median mg/L**	**P**	**PAC**
Nitrate-N	**Arnold Rv @ Blairs Rd No. 2 Br**	40	0.115	0.000	5.3
Nitrate-N	Arnold Rv @ Kotuku Fishing Access	51	0.089	0.117	1.6
Nitrate-N	Baker Ck @ Baker Ck Rd	21	0.002	0.306	10.7
Nitrate-N	Baker Ck @ Oparara Rd	21	0.020	0.366	30.1
Nitrate-N	Berry Ck @ N Brch Wanganui Flat Rd	23	0.210	0.642	-0.6
Nitrate-N	Blackwater Ck @ Farm 846	21	0.460	0.071	4.1
Nitrate-N	Bradshaws Ck @ Bradshaw Rd	21	0.330	0.259	-3.0
Nitrate-N	Bradshaws Ck @ Martins Rd	21	0.420	0.114	-3.8
Nitrate-N	Burkes Ck @ SH69	23	0.260	0.382	-4.6
Nitrate-N	Crooked Rv @ Rotomanu-Bell Hill Rd	50	0.046	0.328	0.7
Nitrate-N	**Crooked Rv @ Te Kinga**	40	0.116	0.046	2.7
Nitrate-N	Deep Ck @ Arnold Vly Rd Br	21	0.660	0.740	2.6
Nitrate-N	**Duck Ck @ Kokatahi-Kowhitirangi Rd Br**	22	0.835	0.027	4.1
Nitrate-N	Ellis Ck @ 50m d/s Ferry Rd Br	23	0.340	0.051	4.6
Nitrate-N	Ford Ck @ Blackball-Taylorville Rd	19	0.074	0.618	2.7
Nitrate-N	Harris Ck @ Mulvaney Rd	21	0.390	1.000	-1.0
Nitrate-N	Hohonu Rv @ Mitchells-Kumara Rd Br	37	0.011	0.316	3.7
Nitrate-N	**Hohonu Rv @ Mouth**	35	0.039	0.043	8.3
Nitrate-N	La Fontaine Stm @ Airstrip Fishing Access	22	0.330	0.385	1.2
Nitrate-N	La Fontaine Stm @ Herepo Fishing Access	23	0.290	0.162	1.1
Nitrate-N	Mawheraiti Rv @ SH7 Maimai	23	0.270	0.923	0.9
Nitrate-N	**Molloy Ck @ Rail Line**	24	0.380	0.001	5.4
Nitrate-N	Murray Ck @ Ford Rd S	21	0.610	0.498	1.2
Nitrate-N	Nelson Ck @ Swimming Hole Reserve	23	0.073	0.113	6.0
Nitrate-N	Okutua Ck @ New Rd Br-Okarito Forest	23	0.001	0.400	4.7
Nitrate-N	**Orangipuku Rv @ Mouth**	45	0.350	0.001	4.0
Nitrate-N	Orowaiti Rv @ Excelsior Rd	21	0.023	0.259	4.8
Nitrate-N	Orowaiti Rv @ Keoghans Rd	21	0.012	0.259	4.8
Nitrate-N	**Poerua Rv @ Rail Br**	46	0.151	0.001	4.9
Nitrate-N	Sawyers Ck @ Bush Fringe	21	0.025	0.651	1.1
Nitrate-N	Sawyers Ck @ Dixon Pk	21	0.038	1.000	0.0
Nitrate-N	Seven Mile Ck @ 300m d/s Raleigh Ck	21	0.037	0.651	-1.5
Nitrate-N	Seven Mile Ck @ Dunollie 400m u/s Ox Pd	21	0.032	0.821	-3.9
Nitrate-N	Seven Mile Ck @ SH6 Rapahoe	21	0.049	0.821	-4.5
Nitrate-N	Seven Mile Ck @ u/s Tillers Mine Ck	9	0.037	1.000	0.0
Nitrate-N	Unnamed Ck @ Adamson Rd Whataroa	23	0.850	0.162	6.5
Nitrate-N	Vickers Ck @ Whataroa N Base	23	0.380	0.077	4.5

Table 21 Seasonal Kendall trend test for Regional Council monitoring program sites. Ten year data span. Important trends are in red (undesirable) and blue (good). Slight trends are in pink (undesirable) and light blue (good). PAC = percent annual change of the median. 20 or more samples are required before a trend will be considered eligible.

Variable	**Site**	**Samples used**	**Median m**	**P**	**PAC**
Clarity	**Arnold Rv @ Blairs Rd No. 2 Br**	57	3.500	0.002	4.4
Clarity	**Arnold Rv @ Kotuku Fishing Access**	62	4.175	0.009	3.3
Clarity	Baker Ck @ Baker Ck Rd	33	1.060	0.236	1.7
Clarity	Baker Ck @ Oparara Rd	34	0.960	0.402	-2.0
Clarity	Berry Ck @ N Brch Wanganui Flat Rd	39	4.550	0.309	-1.9
Clarity	Blackwater Ck @ Farm 846	16	0.300	0.721	0.4
Clarity	**Bradshaws Ck @ Bradshaw Rd**	38	1.030	0.011	4.7
Clarity	**Bradshaws Ck @ Martins Rd**	36	1.245	0.001	9.0
Clarity	Burkes Ck @ SH69	38	1.535	0.885	-0.2
Clarity	Crooked Rv @ Rotomanu-Bell Hill Rd	51	9.600	0.442	1.8
Clarity	Crooked Rv @ Te Kinga	62	3.755	0.087	-1.8
Clarity	Deep Ck @ Arnold Vly Rd Br	25	2.920	0.099	-4.3
Clarity	**Duck Ck @ Kokatahi-Kowhitirangi Rd Br**	40	7.560	0.011	3.5
Clarity	Ellis Ck @ 50m d/s Ferry Rd Br	40	5.200	0.754	0.3
Clarity	Ford Ck @ Blackball-Taylorville Rd	38	0.950	0.055	-4.0
Clarity	Harris Ck @ Mulvaney Rd	39	3.270	0.165	3.3
Clarity	Hohonu Rv @ Mitchells-Kumara Rd Br	37	13.800	0.136	3.1
Clarity	Hohonu Rv @ Mouth	33	4.500	0.051	5.1
Clarity	La Fontaine Stm @ Airstrip Fishing Access	35	4.170	0.068	-2.2
Clarity	La Fontaine Stm @ Herepo Fishing Access	40	4.175	0.964	0.0
Clarity	**Mawheraiti Rv @ SH7 Maimai**	40	3.025	0.044	2.8
Clarity	Molloy Ck @ Rail Line	41	3.620	0.217	2.7
Clarity	Murray Ck @ Ford Rd S	40	5.375	0.098	1.5
Clarity	Nelson Ck @ Swimming Hole Reserve	96	2.600	0.432	-0.6
Clarity	Okutua Ck @ New Rd Br-Okarito Forest	38	2.275	0.962	0.0
Clarity	Orangipuku Rv @ Mouth	39	5.630	0.750	0.5
Clarity	Orowaiti Rv @ Excelsior Rd	37	1.640	0.231	2.5
Clarity	Orowaiti Rv @ Keoghans Rd	38	5.840	0.666	-1.5
Clarity	Poerua Rv @ Rail Br	53	3.610	0.251	1.1
Clarity	Sawyers Ck @ Bush Fringe	38	1.790	1.000	0.0
Clarity	Sawyers Ck @ Dixon Pk	40	1.515	0.304	1.9
Clarity	Seven Mile Ck @ 300m d/s Raleigh Ck	40	1.800	0.266	1.5
Clarity	Seven Mile Ck @ Dunollie 400m u/s Ox Pd	40	2.010	0.068	2.5
Clarity	Seven Mile Ck @ SH6 Rapahoe	88	1.635	0.875	0.5
Clarity	Seven Mile Ck @ u/s Tillers Mine Ck	15	1.820	1.000	0.0
Clarity	**Unnamed Ck @ Adamson Rd Whataroa**	40	3.950	0.044	4.6
Clarity	Vickers Ck @ Whataroa N Base	39	5.500	0.116	-1.9

Table 21 Seasonal Kendall trend test for Regional Council monitoring program sites. Ten year data span. Important trends are in red (undesirable) and blue (good). Slight trends are in pink (undesirable) and light blue (good). PAC = percent annual change of the median. 20 or more samples are required before a trend will be considered eligible.

Variable	**Site**	**Samples used**	**Median mg/L**	**P**	**PAC**
Total nitrogen	Arnold Rv @ Blairs Rd No. 2 Br	40	0.205	1.000	0.0
Total nitrogen	Arnold Rv @ Kotuku Fishing Access	50	0.190	0.301	0.9
Total nitrogen	Baker Ck @ Baker Ck Rd	21	0.230	0.426	-2.2
Total nitrogen	Baker Ck @ Oparara Rd	21	0.430	1.000	-0.1
Total nitrogen	Berry Ck @ N Brch Wanganui Flat Rd	22	0.330	0.837	0.7
Total nitrogen	Blackwater Ck @ Farm 846	21	1.400	0.175	-3.0
Total nitrogen	Bradshaws Ck @ Bradshaw Rd	21	0.860	1.000	0.3
Total nitrogen	Bradshaws Ck @ Martins Rd	21	0.880	0.498	-1.4
Total nitrogen	Burkes Ck @ SH69	21	0.430	0.651	-2.3
Total nitrogen	Crooked Rv @ Rotomanu-Bell Hill Rd	52	0.060	0.551	2.8
Total nitrogen	Crooked Rv @ Te Kinga	41	0.170	0.107	1.9
Total nitrogen	Deep Ck @ Arnold Vly Rd Br	21	0.810	0.740	0.9
Total nitrogen	Duck Ck @ Kokatahi-Kowhitirangi Rd Br	22	0.960	0.461	1.4
Total nitrogen	Ellis Ck @ 50m d/s Ferry Rd Br	22	0.435	0.217	2.7
Total nitrogen	Ford Ck @ Blackball-Taylorville Rd	19	0.180	0.454	3.3
Total nitrogen	Harris Ck @ Mulvaney Rd	21	0.560	0.175	6.3
Total nitrogen	Hohonu Rv @ Mitchells-Kumara Rd Br	37	0.050	0.095	11.9
Total nitrogen	Hohonu Rv @ Mouth	35	0.110	0.312	2.3
Total nitrogen	La Fontaine Stm @ Airstrip Fishing Access	21	0.420	0.282	2.4
Total nitrogen	La Fontaine Stm @ Herepo Fishing Access	22	0.365	0.410	0.7
Total nitrogen	Mawheraiti Rv @ SH7 Maimai	21	0.440	0.651	1.9
Total nitrogen	**Molloy Ck @ Rail Line**	23	0.450	0.008	4.6
Total nitrogen	Murray Ck @ Ford Rd S	21	0.700	0.651	0.5
Total nitrogen	Nelson Ck @ Swimming Hole Reserve	21	0.250	0.053	2.8
Total nitrogen	Okutua Ck @ New Rd Br-Okarito Forest	22	0.235	0.303	5.5
Total nitrogen	**Orangipuku Rv @ Mouth**	44	0.420	0.027	2.9
Total nitrogen	Orowaiti Rv @ Excelsior Rd	21	0.190	0.821	1.8
Total nitrogen	Orowaiti Rv @ Keoghans Rd	21	0.110	0.366	7.6
Total nitrogen	**Poerua Rv @ Rail Br**	46	0.260	0.038	1.7
Total nitrogen	Sawyers Ck @ Bush Fringe	21	0.130	0.366	2.4
Total nitrogen	Sawyers Ck @ Dixon Pk	20	0.270	1.000	-0.1
Total nitrogen	Seven Mile Ck @ 300m d/s Raleigh Ck	21	0.260	0.651	2.1
Total nitrogen	Seven Mile Ck @ Dunollie 400m u/s Ox Pd	21	0.130	1.000	0.7
Total nitrogen	Seven Mile Ck @ SH6 Rapahoe	21	0.260	0.821	-0.5
Total nitrogen	Seven Mile Ck @ u/s Tillers Mine Ck	9	0.110	1.000	0.0
Total nitrogen	Unnamed Ck @ Adamson Rd Whataroa	22	1.015	0.149	5.3
Total nitrogen	**Vickers Ck @ Whataroa N Base**	22	0.470	0.024	4.4

Table 21 Seasonal Kendall trend test for Regional Council monitoring program sites. Ten year data span. Important trends are in red (undesirable) and blue (good). Slight trends are in pink (undesirable) and light blue (good). PAC = percent annual change of the median. 20 or more samples are required before a trend will be considered eligible.

Variable	Site	Samples used	Median mg/L	P	PAC
Dissolved reactive phosphorus	Arnold Rv @ Blairs Rd No. 2 Br	40	0.002	0.554	1.1
Dissolved reactive phosphorus	Arnold Rv @ Kotuku Fishing Access	50	0.002	0.222	3.1
Dissolved reactive phosphorus	Baker Ck @ Baker Ck Rd	21	0.004	0.139	-11.7
Dissolved reactive phosphorus	Baker Ck @ Oparara Rd	21	0.012	1.000	-0.3
Dissolved reactive phosphorus	Berry Ck @ N Brch Wanganui Flat Rd	22	0.006	0.410	-4.4
Dissolved reactive phosphorus	Blackwater Ck @ Farm 846	21	0.019	0.821	0.9
Dissolved reactive phosphorus	Bradshaws Ck @ Bradshaw Rd	21	0.008	1.000	1.7
Dissolved reactive phosphorus	Bradshaws Ck @ Martins Rd	21	0.008	1.000	0.5
Dissolved reactive phosphorus	Burkes Ck @ SH69	22	0.005	0.829	0.0
Dissolved reactive phosphorus	Crooked Rv @ Rotomanu-Bell Hill Rd	51	0.002	0.977	0.3
Dissolved reactive phosphorus	**Crooked Rv @ Te Kinga**	41	0.004	0.013	-4.4
Dissolved reactive phosphorus	Deep Ck @ Arnold Vly Rd Br	21	0.006	0.060	-6.1
Dissolved reactive phosphorus	**Duck Ck @ Kokatahi-Kowhitirangi Rd Br**	22	0.005	0.015	-7.3
Dissolved reactive phosphorus	Ellis Ck @ 50m d/s Ferry Rd Br	22	0.007	0.680	-2.0
Dissolved reactive phosphorus	Ford Ck @ Blackball-Taylorville Rd	19	0.001	0.803	3.4
Dissolved reactive phosphorus	Harris Ck @ Mulvaney Rd	21	0.018	0.821	0.3
Dissolved reactive phosphorus	Hohonu Rv @ Mitchells-Kumara Rd Br	37	0.002	0.811	-1.3
Dissolved reactive phosphorus	Hohonu Rv @ Mouth	34	0.002	0.286	-8.3
Dissolved reactive phosphorus	La Fontaine Stm @ Airstrip Fishing Access	21	0.006	0.830	-3.7
Dissolved reactive phosphorus	La Fontaine Stm @ Herepo Fishing Access	22	0.006	0.217	-5.5
Dissolved reactive phosphorus	Mawheraiti Rv @ SH7 Maimai	21	0.006	1.000	-4.2
Dissolved reactive phosphorus	Molloy Ck @ Rail Line	23	0.007	0.127	-6.2
Dissolved reactive phosphorus	Murray Ck @ Ford Rd S	21	0.011	0.821	0.5
Dissolved reactive phosphorus	Nelson Ck @ Swimming Hole Reserve	21	0.007	0.389	1.5
Dissolved reactive phosphorus	Okutua Ck @ New Rd Br-Okarito Forest	22	0.002	1.000	0.4
Dissolved reactive phosphorus	Orangipuku Rv @ Mouth	45	0.004	0.474	-2.3
Dissolved reactive phosphorus	Orowaiti Rv @ Excelsior Rd	21	0.005	0.821	1.4
Dissolved reactive phosphorus	Orowaiti Rv @ Keoghans Rd	21	0.005	0.175	4.3
Dissolved reactive phosphorus	Poerua Rv @ Rail Br	46	0.005	0.563	0.9
Dissolved reactive phosphorus	Sawyers Ck @ Bush Fringe	21	0.008	0.071	-5.8
Dissolved reactive phosphorus	Sawyers Ck @ Dixon Pk	21	0.010	0.366	-2.4
Dissolved reactive phosphorus	Seven Mile Ck @ 300m d/s Raleigh Ck	21	0.007	0.651	5.0
Dissolved reactive phosphorus	Seven Mile Ck @ Dunollie 400m u/s Ox Pd	21	0.002	1.000	-0.1
Dissolved reactive phosphorus	Seven Mile Ck @ SH6 Rapahoe	21	0.005	0.821	-2.4
Dissolved reactive phosphorus	Seven Mile Ck @ u/s Tillers Mine Ck	9	0.004	1.000	0.0
Dissolved reactive phosphorus	Unnamed Ck @ Adamson Rd Whataroa	22	0.005	1.000	-0.5
Dissolved reactive phosphorus	Vickers Ck @ Whataroa N Base	22	0.005	0.303	-4.2

Table 21 Seasonal Kendall trend test for Regional Council monitoring program sites. Ten year data span. Important trends are in red (undesirable) and blue (good). Slight trends are in pink (undesirable) and light blue (good). PAC = percent annual change of the median. 20 or more samples are required before a trend will be considered eligible.

Variable	Site	Samples used	Median mg/L	P	PAC
Total phosphorus	Arnold Rv @ Blairs Rd No. 2 Br	40	0.007	0.353	-3.4
Total phosphorus	Arnold Rv @ Kotuku Fishing Access	50	0.006	0.433	-2.2
Total phosphorus	Baker Ck @ Baker Ck Rd	21	0.013	0.139	-6.5
Total phosphorus	Baker Ck @ Oparara Rd	21	0.039	0.259	-3.3
Total phosphorus	Berry Ck @ N Brch Wanganui Flat Rd	22	0.011	0.303	-6.7
Total phosphorus	Blackwater Ck @ Farm 846	21	0.170	0.366	-2.7
Total phosphorus	Bradshaws Ck @ Bradshaw Rd	21	0.041	0.366	-5.8
Total phosphorus	Bradshaws Ck @ Martins Rd	21	0.035	0.366	-6.6
Total phosphorus	Burkes Ck @ SH69	21	0.016	0.651	6.1
Total phosphorus	Crooked Rv @ Rotomanu-Bell Hill Rd	51	0.003	0.373	2.2
Total phosphorus	Crooked Rv @ Te Kinga	42	0.010	0.081	-3.0
Total phosphorus	Deep Ck @ Arnold Vly Rd Br	21	0.015	0.740	2.6
Total phosphorus	Duck Ck @ Kokatahi-Kowhitirangi Rd Br	21	0.009	0.175	-9.4
Total phosphorus	Ellis Ck @ 50m d/s Ferry Rd Br	22	0.013	0.680	-1.2
Total phosphorus	Ford Ck @ Blackball-Taylorville Rd	19	0.010	0.135	-12.5
Total phosphorus	Harris Ck @ Mulvaney Rd	21	0.027	0.821	0.5
Total phosphorus	Hohonu Rv @ Mitchells-Kumara Rd Br	37	0.003	0.198	7.4
Total phosphorus	Hohonu Rv @ Mouth	35	0.005	0.419	2.2
Total phosphorus	La Fontaine Stm @ Airstrip Fishing Access	21	0.014	0.667	-4.9
Total phosphorus	La Fontaine Stm @ Herepo Fishing Access	22	0.015	0.149	-7.1
Total phosphorus	Mawheraiti Rv @ SH7 Maimai	21	0.015	0.259	-5.0
Total phosphorus	Molloy Ck @ Rail Line	23	0.012	1.000	0.0
Total phosphorus	Murray Ck @ Ford Rd S	21	0.016	0.259	-10.1
Total phosphorus	Nelson Ck @ Swimming Hole Reserve	21	0.014	0.667	2.4
Total phosphorus	Okutua Ck @ New Rd Br-Okarito Forest	22	0.007	0.149	5.9
Total phosphorus	Orangipuku Rv @ Mouth	44	0.009	0.575	-1.1
Total phosphorus	Orowaiti Rv @ Excelsior Rd	21	0.030	0.821	-1.8
Total phosphorus	Orowaiti Rv @ Keoghans Rd	21	0.011	0.175	5.9
Total phosphorus	Poerua Rv @ Rail Br	46	0.018	0.234	-2.1
Total phosphorus	Sawyers Ck @ Bush Fringe	21	0.018	0.651	-1.5
Total phosphorus	Sawyers Ck @ Dixon Pk	21	0.031	0.114	-3.6
Total phosphorus	Seven Mile Ck @ 300m d/s Raleigh Ck	21	0.026	0.114	-5.5
Total phosphorus	Seven Mile Ck @ Dunollie 400m u/s Ox Pd	21	0.011	0.175	2.2
Total phosphorus	Seven Mile Ck @ SH6 Rapahoe	21	0.022	0.259	-2.5
Total phosphorus	Seven Mile Ck @ u/s Tillers Mine Ck	9	0.015	1.000	0.0
Total phosphorus	Unnamed Ck @ Adamson Rd Whataroa	22	0.016	0.537	-3.4
Total phosphorus	Vickers Ck @ Whataroa N Base	22	0.008	0.064	-9.2

Table 21 Seasonal Kendall trend test for Regional Council monitoring program sites. Ten year data span. Important trends are in red (undesirable) and blue (good). Slight trends are in pink (undesirable) and light blue (good). PAC = percent annual change of the median. 20 or more samples are required before a trend will be considered eligible.

Variable	**Site**	**Samples used**	**Median E.coli/ 100 ml**	**P**	**PAC**
E.coli	**Arnold Rv @ Blairs Rd No. 2 Br**	71	40.000	0.018	-16.2
E.coli	Arnold Rv @ Kotuku Fishing Access	69	5.000	0.331	-13.6
E.coli	**Baker Ck @ Baker Ck Rd**	31	40.000	0.033	18.5
E.coli	Baker Ck @ Oparara Rd	32	417.500	0.951	0.3
E.coli	Berry Ck @ N Brch Wanganui Flat Rd	38	160.000	0.810	4.1
E.coli	Blackwater Ck @ Farm 846	30	410.000	0.789	5.3
E.coli	Bradshaws Ck @ Bradshaw Rd	40	287.500	0.450	6.6
E.coli	Bradshaws Ck @ Martins Rd	40	230.000	0.625	-1.8
E.coli	Burkes Ck @ SH69	38	246.500	0.063	-9.7
E.coli	Crooked Rv @ Rotomanu-Bell Hill Rd	51	5.000	0.955	-2.4
E.coli	Crooked Rv @ Te Kinga	70	39.000	0.437	4.6
E.coli	Deep Ck @ Arnold Vly Rd Br	21	140.000	0.224	25.9
E.coli	Duck Ck @ Kokatahi-Kowhitirangi Rd Br	40	67.500	0.264	4.4
E.coli	Ellis Ck @ 50m d/s Ferry Rd Br	39	80.000	0.644	-1.8
E.coli	Ford Ck @ Blackball-Taylorville Rd	29	10.000	0.261	5.8
E.coli	Harris Ck @ Mulvaney Rd	40	190.000	0.823	-0.3
E.coli	**Hohonu Rv @ Mitchells-Kumara Rd Br**	38	5.000	0.016	19.0
E.coli	Hohonu Rv @ Mouth	32	47.500	1.000	0.1
E.coli	La Fontaine Stm @ Airstrip Fishing Access	35	90.000	0.830	-1.6
E.coli	La Fontaine Stm @ Herepo Fishing Access	39	95.000	0.711	1.2
E.coli	Mawheraiti Rv @ SH7 Maimai	38	110.000	0.230	-2.5
E.coli	Molloy Ck @ Rail Line	38	266.000	0.320	-4.4
E.coli	Murray Ck @ Ford Rd S	39	100.000	0.853	0.7
E.coli	Nelson Ck @ Swimming Hole Reserve	106	85.000	0.556	1.5
E.coli	Okutua Ck @ New Rd Br-Okarito Forest	38	5.000	0.362	4.5
E.coli	Orangipuku Rv @ Mouth	32	22.500	0.733	4.5
E.coli	Orowaiti Rv @ Excelsior Rd	68	337.500	0.371	4.8
E.coli	Orowaiti Rv @ Keoghans Rd	39	25.000	0.079	19.3
E.coli	Poerua Rv @ Rail Br	51	30.000	0.061	-20.0
E.coli	Sawyers Ck @ Bush Fringe	39	40.000	1.000	-0.4
E.coli	Sawyers Ck @ Dixon Pk	41	2000.000	0.168	5.1
E.coli	Seven Mile Ck @ 300m d/s Raleigh Ck	41	105.000	0.228	-4.4
E.coli	Seven Mile Ck @ Dunollie 400m u/s Ox Pd	40	22.500	0.965	-0.4
E.coli	Seven Mile Ck @ SH6 Rapahoe	102	120.000	0.732	1.3
E.coli	Seven Mile Ck @ u/s Tillers Mine Ck	13	10.000	0.161	-0.8
E.coli	Unnamed Ck @ Adamson Rd Whataroa	39	225.000	1.000	0.6
E.coli	**Vickers Ck @ Whataroa N Base**	39	100.000	0.012	-11.0

Table 21 Seasonal Kendall trend test for Regional Council monitoring program sites. Ten year data span. Important trends are in red (undesirable) and blue (good). Slight trends are in pink (undesirable) and light blue (good). PAC = percent annual change of the median. 20 or more samples are required before a trend will be considered eligible.

Variable	Site	Samples used	Median µScm	P	PAC
EC25	**Arnold Rv @ Blairs Rd No. 2 Br**	53	57.000	0.019	2.3
EC25	Arnold Rv @ Kotuku Fishing Access	55	49.000	0.030	0.7
EC25	**Baker Ck @ Baker Ck Rd**	33	91.000	0.011	3.5
EC25	**Baker Ck @ Oparara Rd**	33	92.000	0.025	1.7
EC25	Berry Ck @ N Brch Wanganui Flat Rd	39	101.000	0.052	0.9
EC25	Blackwater Ck @ Farm 846	33	241.000	1.000	0.1
EC25	Bradshaws Ck @ Bradshaw Rd	40	107.000	0.114	1.0
EC25	Bradshaws Ck @ Martins Rd	38	110.000	0.163	0.9
EC25	**Burkes Ck @ SH69**	40	94.000	0.000	2.1
EC25	**Crooked Rv @ Rotomanu-Bell Hill Rd**	51	60.000	0.008	1.2
EC25	**Crooked Rv @ Te Kinga**	54	64.000	0.000	1.7
EC25	Deep Ck @ Arnold Vly Rd Br	26	124.500	0.621	-11.3
EC25	Duck Ck @ Kokatahi-Kowhitirangi Rd Br	40	91.000	0.081	0.9
EC25	Ellis Ck @ 50m d/s Ferry Rd Br	38	111.000	0.014	0.8
EC25	**Ford Ck @ Blackball-Taylorville Rd**	39	200.000	0.000	2.6
EC25	Harris Ck @ Mulvaney Rd	40	98.500	0.036	0.7
EC25	**Hohonu Rv @ Mitchells-Kumara Rd Br**	37	49.000	0.000	2.3
EC25	Hohonu Rv @ Mouth	34	48.500	0.365	1.0
EC25	**La Fontaine Stm @ Airstrip Fishing Access**	36	127.000	0.003	1.7
EC25	**La Fontaine Stm @ Herepo Fishing Access**	40	123.500	0.001	1.1
EC25	**Mawheraiti Rv @ SH7 Maimai**	40	35.000	0.003	2.0
EC25	Molloy Ck @ Rail Line	42	111.500	0.145	1.4
EC25	Murray Ck @ Ford Rd S	40	100.000	0.036	0.6
EC25	**Nelson Ck @ Swimming Hole Reserve**	45	45.000	0.000	2.1
EC25	Okutua Ck @ New Rd Br-Okarito Forest	40	26.500	0.195	1.0
EC25	Orangipuku Rv @ Mouth	34	81.000	0.079	2.2
EC25	**Orowaiti Rv @ Excelsior Rd**	39	72.000	0.002	2.1
EC25	**Orowaiti Rv @ Keoghans Rd**	40	67.500	0.006	1.3
EC25	**Poerua Rv @ Rail Br**	51	73.000	0.040	1.1
EC25	Sawyers Ck @ Bush Fringe	39	192.000	0.459	0.9
EC25	Sawyers Ck @ Dixon Pk	40	193.000	0.227	1.4
EC25	Seven Mile Ck @ 300m d/s Raleigh Ck	41	127.000	0.102	1.7
EC25	Seven Mile Ck @ Dunollie 400m u/s Ox Pd	41	118.000	0.343	1.5
EC25	**Seven Mile Ck @ SH6 Rapahoe**	39	180.000	0.047	6.1
EC25	Seven Mile Ck @ u/s Tillers Mine Ck	15	73.000	0.314	0.6
EC25	Unnamed Ck @ Adamson Rd Whataroa	39	153.000	0.116	0.6
EC25	Vickers Ck @ Whataroa N Base	40	127.000	0.098	0.5

Table 21 Seasonal Kendall trend test for Regional Council monitoring program sites. Ten year data span. Important trends are in red (undesirable) and blue (good). Slight trends are in pink (undesirable) and light blue (good). PAC = percent annual change of the median. 20 or more samples are required before a trend will be considered eligible.

Variable	Site	Samples used	Median NTU	P	PAC
Turbidity	Arnold Rv @ Blairs Rd No. 2 Br	48	0.450	0.474	-7.3
Turbidity	Arnold Rv @ Kotuku Fishing Access	49	0.400	0.052	-20.2
Turbidity	Baker Ck @ Baker Ck Rd	33	2.500	0.953	-0.5
Turbidity	Baker Ck @ Oparara Rd	33	3.500	1.000	-0.3
Turbidity	Berry Ck @ N Brch Wanganui Flat Rd	37	0.400	0.457	-14.7
Turbidity	**Blackwater Ck @ Farm 846**	33	19.900	0.025	-11.5
Turbidity	**Bradshaws Ck @ Bradshaw Rd**	40	4.750	0.000	-7.7
Turbidity	**Bradshaws Ck @ Martins Rd**	40	3.550	0.003	-10.5
Turbidity	**Burkes Ck @ SH69**	40	4.250	0.028	-6.6
Turbidity	Crooked Rv @ Rotomanu-Bell Hill Rd	49	0.100	0.717	-12.1
Turbidity	Crooked Rv @ Te Kinga	50	0.750	0.429	9.6
Turbidity	Deep Ck @ Arnold Vly Rd Br	25	0.200	0.795	11.9
Turbidity	**Duck Ck @ Kokatahi-Kowhitirangi Rd Br**	40	0.100	0.001	-148.3
Turbidity	Ellis Ck @ 50m d/s Ferry Rd Br	38	0.275	0.195	-11.5
Turbidity	Ford Ck @ Blackball-Taylorville Rd	38	9.700	0.336	3.0
Turbidity	**Harris Ck @ Mulvaney Rd**	39	0.600	0.000	-50.0
Turbidity	**Hohonu Rv @ Mitchells-Kumara Rd Br**	38	0.100	0.000	30.6
Turbidity	Hohonu Rv @ Mouth	35	0.100	0.363	4.4
Turbidity	La Fontaine Stm @ Airstrip Fishing Access	35	0.700	0.108	-10.6
Turbidity	La Fontaine Stm @ Herepo Fishing Access	39	0.800	0.309	-11.1
Turbidity	**Mawheraiti Rv @ SH7 Maimai**	39	0.500	0.000	-35.4
Turbidity	**Molloy Ck @ Rail Line**	40	0.250	0.007	-73.0
Turbidity	**Murray Ck @ Ford Rd S**	39	0.200	0.000	-97.8
Turbidity	**Nelson Ck @ Swimming Hole Reserve**	39	0.600	0.003	-25.8
Turbidity	Okutua Ck @ New Rd Br-Okarito Forest	39	0.100	0.139	-66.3
Turbidity	**Orangipuku Rv @ Mouth**	46	0.100	0.007	-64.3
Turbidity	Orowaiti Rv @ Excelsior Rd	38	2.750	0.164	-9.4
Turbidity	Orowaiti Rv @ Keoghans Rd	39	0.200	0.309	-19.6
Turbidity	Poerua Rv @ Rail Br	50	0.700	0.977	-0.6
Turbidity	Sawyers Ck @ Bush Fringe	39	2.700	0.079	-7.7
Turbidity	**Sawyers Ck @ Dixon Pk**	40	3.400	0.014	-8.1
Turbidity	Seven Mile Ck @ 300m d/s Raleigh Ck	41	4.200	0.058	-11.5
Turbidity	Seven Mile Ck @ Dunollie 400m u/s Ox Pd	41	3.500	0.085	-12.7
Turbidity	Seven Mile Ck @ SH6 Rapahoe	39	3.900	0.059	-6.7
Turbidity	Seven Mile Ck @ u/s Tillers Mine Ck	14	3.750	0.027	-15.1
Turbidity	**Unnamed Ck @ Adamson Rd Whataroa**	39	0.800	0.033	-25.3
Turbidity	**Vickers Ck @ Whataroa N Base**	40	0.300	0.036	-24.6

Table 22 Seasonal Kendall trend test for degree of difference between paired impact-reference sites. Important trends are in red (undesirable) and blue (good). Slight trends are in pink (undesirable) and light blue (good). Ten year data span. PAC = percent annual change of the median.

Attribute	Site	Samples	Sampling period	Median	P	PAC
Faecal coliforms/100 ml	Arnold Rv	66	12/1/04-29/4/14	17.500	0.209	14.2
Faecal coliforms/100 ml	Baker Ck	28	18/7/06-10/4/14	447.500	0.386	-4.9
Faecal coliforms/100 ml	Bradshaws Ck	41	3/3/04-11/4/14	-15.000	0.285	0.0
Faecal coliforms/100 ml	Crooked Rv	49	5/3/04-30/4/14	36.000	0.651	-4.8
Faecal coliforms/100 ml	Hohonu Rv	32	28/8/08-30/4/14	47.500	0.905	1.8
Faecal coliforms/100 ml	La Fontaine Stm	34	9/7/04-14/5/14	7.500	0.543	-18.4
Faecal coliforms/100 ml	Orowaiti Rv	40	3/3/04-11/4/14	140.000	0.594	-5.0
Faecal coliforms/100 ml	Sawyers Ck	38	13/10/04-30/5/14	1602.500	0.446	7.6
Faecal coliforms/100 ml	Seven Mile Ck	43	12/1/04-22/5/14	80.000	0.299	-3.8
Ammonia-N (mg/L)	Arnold Rv	36	11/10/04-29/4/14	0.000	1.000	0.0
Ammonia-N (mg/L)	Baker Ck	31	18/7/06-10/4/14	56.000	0.561	2.9
Ammonia-N (mg/L)	Bradshaws Ck	38	7/1/05-11/4/14	-31.000	0.014	0.0
Ammonia-N (mg/L)	Crooked Rv	45	9/1/04-30/4/14	3.000	0.060	-13.6
Ammonia-N (mg/L)	Hohonu Rv	33	18/12/08-30/4/14	0.000	0.704	0.0
Ammonia-N (mg/L)	La Fontaine Stm	34	9/7/04-14/5/14	-2.250	0.868	0.0
Ammonia-N (mg/L)	**Orowaiti Rv**	40	3/3/04-11/4/14	21.500	0.001	-27.0
Ammonia-N (mg/L)	Sawyers Ck	36	13/10/04-30/5/14	15.000	0.193	-4.3
Ammonia-N (mg/L)	Seven Mile Ck	40	4/3/04-22/5/14	77.500	0.304	1.8
Clarity (m)	Arnold Rv	54	5/3/04-29/4/14	-0.825	0.624	0.0
Clarity (m)	Baker Ck	31	18/7/06-10/4/14	-0.160	0.219	0.0
Clarity (m)	**Bradshaws Ck**	37	3/3/04-11/4/14	0.200	0.016	19.3
Clarity (m)	Crooked Rv	51	9/1/04-30/4/14	-5.650	0.027	0.0
Clarity (m)	Hohonu Rv	32	28/8/08-30/4/14	-8.835	0.200	0.0
Clarity (m)	La Fontaine Stm	34	9/7/04-14/5/14	-0.235	0.293	0.0
Clarity (m)	Orowaiti Rv	37	3/3/04-11/4/14	-3.800	0.162	0.0
Clarity (m)	Sawyers Ck	38	13/10/04-30/5/14	-0.225	0.962	0.0
Clarity (m)	Seven Mile Ck	41	12/1/04-22/5/14	-0.270	1.000	0.0
Turbidity (NTU)	Arnold Rv	44	5/4/05-29/4/14	0.100	0.734	8.7
Turbidity (NTU)	Baker Ck	31	18/7/06-10/4/14	1.100	0.219	9.3
Turbidity (NTU)	Bradshaws Ck	39	8/10/04-11/4/14	-0.500	0.312	0.0
Turbidity (NTU)	Crooked Rv	46	5/3/04-30/4/14	0.750	0.393	2.7
Turbidity (NTU)	Hohonu Rv	35	28/8/08-30/4/14	0.000	0.015	0.0
Turbidity (NTU)	La Fontaine Stm	34	9/7/04-14/5/14	0.050	0.219	40.9
Turbidity (NTU)	Orowaiti Rv	38	7/1/05-11/4/14	2.200	0.472	-3.7
Turbidity (NTU)	Sawyers Ck	40	4/3/04-30/5/14	0.900	1.000	0.1
Turbidity (NTU)	Seven Mile Ck	41	12/7/04-22/5/14	0.400	0.931	0.7
Conductivity (25°C µScm)	**Arnold Rv**	50	11/10/04-29/4/14	7.000	0.011	13.5
Conductivity (25°C µScm)	Baker Ck	31	18/7/06-10/4/14	0.000	0.092	0.0
Conductivity (25°C µScm)	Bradshaws Ck	37	8/10/04-11/4/14	-4.000	0.764	0.0
Conductivity (25°C µScm)	Crooked Rv	49	5/3/04-30/4/14	6.000	0.555	-1.0
Conductivity (25°C µScm)	Hohonu Rv	33	28/8/08-30/4/14	-2.000	0.955	0.0
Conductivity (25°C µScm)	**La Fontaine Stm**	40	9/7/04-14/5/14	4.000	0.023	2.9
Conductivity (25°C µScm)	**Orowaiti Rv**	40	3/3/04-11/4/14	4.000	0.006	17.9
Conductivity (25°C µScm)	Sawyers Ck	40	4/3/04-30/5/14	-10.000	0.477	0.0
Conductivity (25°C µScm)	Seven Mile Ck	41	12/7/04-22/5/14	6.000	0.301	7.1

5.12 Limnology of Lake Brunner

Seasonal mixing processes in large lakes are extremely important for the ecology of the lake, and are driven mainly by patterns in solar exposure, wind, and river inflows (Figure 75). Lake stratification and mixing is dependent on the interactions of the sun's energy and wind energy and on the net effect of heating and cooling. The sun tends to heat the lake and increase stratification, the wind tends to mix the lake and break down stratification (courtesy of Kelly and Howard-Williams, 2003).In lakes with very long residence times (several years) these exchanges dominate the thermal regime of the lake and control patterns of mixing and stratification. In such lakes inflows and outflows generally play a minor role in determining temperature structure in the lake. In contrast, in lakes with very short residence times (weeks), inflows and outflows dominate the thermal regime and control mixing and stratification, with climate factors playing a secondary role. With a residence time of approximately 1.2 years, Lake Brunner falls in neither of these categories. Although it is a deep lake of reasonable size, inflows and outflows are also reasonably large. Hence, one can expect that both climate factors and inflows will play important roles in controlling the lake's thermal regime (Spigel 2008).

Lake Brunner, like most large New Zealand Lakes, is a deep monomictic lake, meaning the lake mixes from top to bottom only once per year. For the rest of the year the lake is thermally stratified, being warmer at the surface and cooler at depth. Mixing from top to bottom (also called turnover) usually occurs during mid-winter (typically May-June) when inputs of solar energy are lowest and winter storms allow for deep wind-driven mixing of lake surface waters. The lake will remain largely un-stratified (or isothermal, i.e., the same temperature from top to bottom) over the winter (Figure 76). During spring, surface waters of the lake are then heated by the sun, thereby thermally stratifying the lake forming a thermocline (a decrease in temperature with depth). In early spring the thermocline is shallower, but by mid-summer the thermocline usually extends to 40 m depth in Lake Brunner.

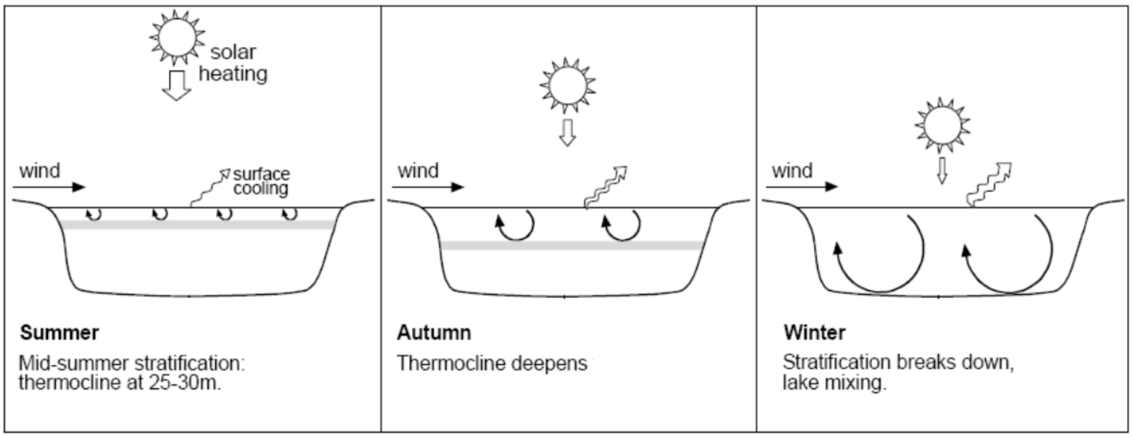


Figure 75 Lake stratification and mixing is dependent on the interactions of the sun's energy and wind energy and on the net effect of heating and cooling.

This pattern of stratification and mixing has important implications for water quality in lakes, predominantly because the thermocline prevents mixing of near surface waters (called the epilimnion) with deep bottom waters (called the hypolimnion). Because of this, waters below the thermocline are essentially isolated from the surface of the lake, where gas exchange with the atmosphere and oxygen-generating processes such as photosynthesis occur. This means that oxygen consuming processes that occur in the bottom-waters of the lake are isolated from oxygen being supplied to the lake at its surface, and can only utilise the available oxygen that was recirculated to the hypolimnion at the time of the last winter turnover. Organic matter such as phytoplankton and river inputs generally sink through the water column into the hypolimnion, where it is decomposed by bacteria and other microbes, thereby consuming oxygen in the hypolimnion. If, on an annual basis, the amount of oxygen consumed by microbes in the hypolimnion exceeds the initial supply at spring turnover, oxygen could be depleted to levels unfit for sensitive aquatic life such as trout. If oxygen is further depleted to near zero at the lake bottom (called anoxia), chemical transformations at the sediment-water interface can result in the liberation of sediment-bound nutrients into the water column, a process known as “internal loading”. In the Rotorua Lakes, anoxic conditions have resulted in the equivalent of the annual nutrient loadings from all river inflows being internally loaded from sediments in a matter of a few days. Furthermore, once these processes begin in a lake, positive feedback mechanisms tend to accelerate them, either perpetuating or worsening the water quality in the lake.

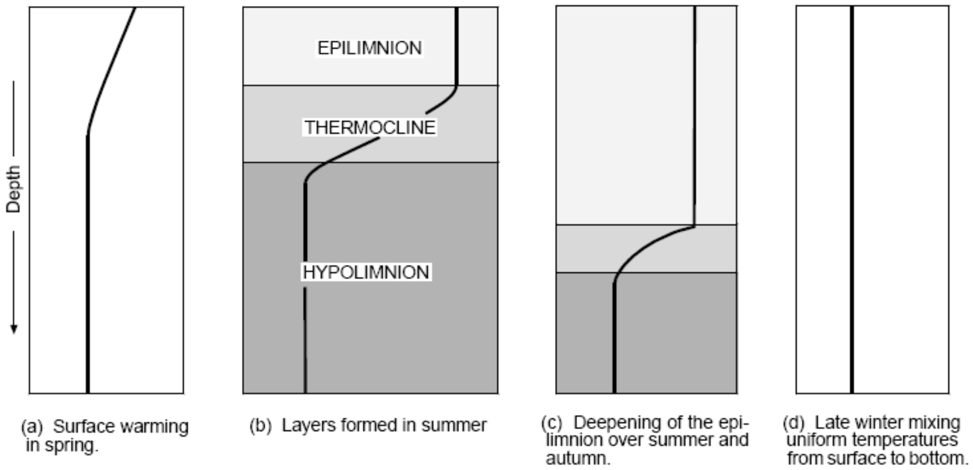


Figure 76 The mixing cycle of the water of Lake Brunner. Each panel represents water temperature with depth in the lake for a particular season: (a) spring, (b) summer, (c) late summer/autumn, (d) late winter. Water temperature is represented by the thick black line in each panel with temperature increasing from left to right in each panel (courtesy of Kelly and Howard-Williams, 2003).

It is predicted that phosphorus is the most important nutrient (or limiting nutrient) in the lake based on TN:TP ratios >20:1. The median TN:TP ratio was ~ 34:1 in both the 1990’s and 2000’s. TN:TP ratios differed between seasons, being highest in winter and lowest in summer, with similar ratios in autumn and spring. Ratios Most aquatic plants such as phytoplankton maintain TN:TP ratios of roughly 16:1, or what is termed the Redfield ratio, and as this ratio changes the nutrient in lower supply (in this case P) becomes limiting to phytoplankton growth. While faecal coliforms and sediment have short term and localised effects on lake water quality, nutrients entering the lake from tributaries are the major concern.

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